Duncan Dam Project Water Use Plan

Lower Duncan River Riparian Cottonwood Monitoring

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Year 3 Report

Study Period: April 2012 – January 2013

Vast Resource Solutions Inc.
Cranbrook, B.C.

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DDMMON#8-1 Lower Duncan River Riparian Cottonwood Monitoring
Year 3 Annual Report (2012)

Final Report

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Cover photo

Lower Duncan River, section of Segment 3 when the river discharge was 369 m^3/s, June 25, 2012. Cover photo © Jamie Heath, Terrasaurus Aerial Photography Ltd.

EXECUTIVE SUMMARY

A ten-year riparian vegetation monitoring program along the lower Duncan River was initiated in 2009 as part of the implementation of the Duncan Dam Project Water Use Plan (WUP) that was recommended by the WUP Consultative Committee. This study is intended to evaluate the impacts of operating Alternative S73 (Alt S73) on black cottonwoods (*Populus trichocarpa*) and other riparian vegetation along the lower Duncan River. The study provides site-specific data to guide the river flow regulation and to improve the understanding of the relationships between flow regime, physical environmental conditions, and riparian vegetation. This report describes Year 4 (2012) of the monitoring project for the study area, which includes the lower Duncan River and the adjacent free-flowing lower Lardeau River that serves as a comparative reference reach.

To address management questions and associated hypotheses (table following), the floodplain zones, riparian vegetation, and black cottonwood recruitment are being assessed. The performance of Alt S73 on the lower Duncan River riparian community combines all years of the study and this 2012 report represents some combined data from 2009, 2010, and 2012.

Vegetation monitoring comparisons showed similar spatial patterns for Year 1 (2009) versus Year 4. There was a trend for increasing cover by vegetation and continuing growth of the woody vegetation. At this time, no impact was detected that was interpreted to be directly related to the new Alt S73 flow regime.

The cottonwood seedling establishment and recruitment had greatly reduced density and spatial patterns as compared to results in Years 1 and 2. The high river stage through the growing season, along with extensive deposition, effectively eliminated seedling recruitment for the Duncan Reach in 2012. Cottonwood establishment and recruitment patterns deviated from the pattern that was emerging following the 2010 assessments. Conversely, the 2012 data adds a flood response dimension to the data set. The combined data from Years 1, 2, and 4, along with further monitoring in subsequent years should enable the development of a quantitative model that will characterize colonization requirements for cottonwoods.

Mapping of the two reaches using orthorectified air photos showed changes due to channel migration. Following above-average stage for two consecutive years along the lower Duncan River and two consecutive flood events (Q_5 and Q_{10}) along the lower Lardeau River, changes to vegetation community size, channel position, and width were detected for both rivers. The Lardeau River had the largest magnitude of channel migration compared to the lower Duncan River. This resulted in erosion of some vegetation communities adjacent to the channel edge, including the erosion of some mature riparian forest along the Lardeau River.

It is too early to formally assess the performance of Alt S73. However, important factors and trends are emerging. Years 1 and 2 indicated that the colonization requirements appeared to be tied particularly to elevational position with reference to stream stage pattern, geomorphic context, sediment substrate, longitudinal position (upstream-to-downstream), influences of tributary inflows, channel morphology, inundation duration and timing, and sediment deposition and scour. The greatly reduced seedling establishment and recruitment in Year 4 confirms the importance of inundation duration and timing, and sediment deposition and scour, as two main factors affecting seedling recruitment. These two factors obscured all other factors in 2012. We anticipate that continued monitoring of cottonwood seedlings, and full vegetation monitoring and mapping in years 2015 and 2018 will provide important data for hypothesis testing and addressing the management questions.

Keywords – lower Duncan River, black cottonwood (*Populus trichocarpa*), seedling recruitment, riparian vegetation monitoring, flow regime

DDMMON#8-1 Status of Objectives, Management Questions and Hypotheses after Year 4

Objectives	Management Questions	Management Hypotheses	Year 4 (2012) Status
1) To assess the performance of Alt S73 on the lower Duncan River riparian community and specifically black cottonwoods, through comparisons of field-based performance measures.	1) Will the implementation of Alt S73 result in neutral, positive, or negative changes for black cottonwoods and riparian habitat diversity along the lower Duncan River as compared to past-regulated regimes?	H_{01}: There is no change in black cottonwood establishment or survival resulting from the implementation of Alt S73.	Based on three years of assessments, the performance of Alt S73 can not yet be fully assessed. Because of different flow regimes implemented during Alt S73 in 2009 and 2010, compared to 2011 and 212, H_{01} can not yet be resolved.
2) To quantify the relationships between abiotic influences and biological responses based on analyses of field data.	2) What are the key drivers of cottonwood recruitment success along the lower Duncan River floodplain? How are these drivers influenced by river regulation?	H_{02}: Black cottonwood establishment and survival along the lower Duncan River are not affected by the river flow regime.	Key factors influencing cottonwood recruitment appear to be water inundation duration and timing, sediment deposition and scour, and elevation. All of these factors are influenced by river regulation. Other factors appear to be longitudinal location, tributary influences, and channel morphology.
3) To utilize the derived relationships in conceptual models for predicting the long-term response of black cottonwood and other riparian plant communities to a variety of flow regimes		H_{03}: The river flow regime is not the primary driver of black cottonwood establishment survival along the lower Duncan River.	Year 4 analyses during and following the high stage along the Duncan Reach indicated that the river flow regime is the primary driver of black cottonwood establishment and survival along the lower Duncan River. It is too early to formally address H_{03} with only one year of seedling data during an extreme high flow year, and two years at the Alt S73 flow regime.

ACKNOWLEDGEMENTS

Sincere thanks goes to the 2012 field data collection team: Brenda Herbison, Ben Meunier, Tanya Foster, Aden Stewart, and James Boldt. They endured mosquito swarms during the August field visits that challenged field work. The experience and knowledge of Brenda Herbison and Aden Stewart from the start of the project enabled efficient and time saving sampling this season. A special thank you for Aden Stewart and Ben Meunier for their expertise in the navigation and operation of the canoe that allowed sampling of transects not accessible by land while keeping costs within the available budget. Funding for the project was provided by BC Hydro Columbia Water License Requirements and in kind contribution of time and resources from the University of Lethbridge.

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1 INTRODUCTION

1.1 Overview

The Duncan Dam is owned and operated by the British Columbia Hydro and Power Authority (BC Hydro) under the Columbia River Treaty of 1961. It functions as a storage dam to improve hydroelectric capacity and flood control of downstream reaches of the Kootenay and Columbia river systems (BC Hydro 2005). In 2001, BC Hydro initiated the Water Use Planning (WUP) process for the Duncan Dam in southeastern British Columbia. As a multi-stakeholder consultative process, the WUP sought to refine the operations of BC Hydro's Duncan Dam, with consideration of regulatory, stakeholder, and First Nations interests that had not been sufficiently considered at the time of the original dam construction. By 2005, the consultative process had produced the Duncan Dam Water Use Plan (DDM WUP), which recommended a dam operating regime identified as Alternative S73 (Alt S73). Alt S73 became operational in 2008 and the associated cottonwood monitoring study was designated as DDMMON#8-1.

Past research has demonstrated strong links between cottonwood recruitment, and river flow (Mahoney and Rood 1998), especially below dams (Polzin 1998, Polzin and Rood 2000). Studies have also revealed the links between cottonwoods, wildlife habitat and overall ecosystem function (Naiman et al 2005). Accordingly, black cottonwood (*Populus trichocarpa*) was identified by the WUP as the indicator species for monitoring the effects of Alt S73 on riparian biological diversity for the lower Duncan River. A more detailed description of the background to this project is provided in the initial Year 1 report (Polzin et al. 2010a).

Two key management questions were developed by BC Hydro (2009) to help address uncertainty associated with cottonwood hydrograph performance measures:

1) Will the implementation of Alt S73 result in neutral, positive, or negative changes for black cottonwood and riparian habitat diversity along the lower Duncan River, as compared to past-regulated regimes?
2) What are the key drivers of successful black cottonwood recruitment along the lower Duncan River floodplain and how are these drivers influenced by river regulation?

There have been numerous reports of declines in cottonwood populations downstream from dams along other river systems (Rood and Mahoney 1990, Polzin and Rood 2000, Merritt and Cooper 2000). However, each river system has a unique geomorphic setting, climate, and multiple cottonwood species (Williams and Wolman 1984, Polzin 1998). The lower Duncan River differs from most other dammed systems studied because 50 to 60 per cent of the flow below the dam comes from unregulated stream sources. The main free-flowing source is the Lardeau River, which joins the lower Duncan River immediately below the dam. The inputs from the Lardeau and other free-flowing tributaries result in sediment and woody debris contributions below the dam, where as sediment and woody debris deficiencies normally occur on other dammed systems (Williams and Wolman 1984, Dunne 1988, Debano and Schmidt 1990, Rood and Mahoney 1995, Polzin 1998). Water below dams usually has little or no suspended sediment load resulting in channel erosion or scour immediately downstream from the dam. This results in channel down-cutting and entrenchment, and a 'silt shadow' or zone of sediment depletion downstream of the dam that can occur from a few kilometres to hundreds of kilometres (Williams and Wolman 1984, Rood and Mahoney 1990).

The Duncan Dam has reduced spring peak flows since the start of operation and Alt S73 did not change this. But attenuated flow has had an opposite result compared to other dammed systems. The reduced spring peak freshet cannot move sediment and woody debris entering the system from the free-flowing tributaries, as it did before the dam was installed. This has resulted in extensive woody debris deposits along the lower Duncan River as well as sediment deposition. A second factor different from many dammed systems studied is that the lower Duncan River is situated in a humid, hydrological gaining (ground water flows into the river), mountainous region. One past study of a free-flowing system in a humid, gaining mountainous system involved black cottonwood recruitment along the Elk River, which has a similar setting but in a colder biogeoclimatic zone than the lower Duncan River (Polzin 1998). That study provides information on black cottonwood recruitment and the driving factors affecting successful recruitment along a free-flowing river in a humid, mountainous system. It was used by Polzin and Rood (2006) to characterize the hydrogeomorphic requirements of cottonwoods and illustrated the characterization of *seedling safe sites*, positions that provide optimal elevation and substrate conditions for cottonwood seedling survival.

1.2 Objectives

The objectives of the DDMMON#8-1 monitoring program are designed to be achieved over a 10-year study period (BC Hydro 2009). They are:

- To assess the performance of Alt S73 on the lower Duncan River riparian community and specifically black cottonwood (*Populus trichocarpa*) through comparison of field-based performance measures;
- To quantify the relationships between abiotic influences (e.g., river hydrology or groundwater hydrology), and biological responses (i.e., cottonwood recruitment), based on analyses of field data; and
- To utilize the above-derived relationships in conceptual models for predicting the long-term response of black cottonwoods and other riparian plant communities to a variety of flow regimes.

To meet the objectives and address the management questions BC Hydro (2009) has identified three hypotheses:

Hypothesis 1

H$_{01}$: There is no change in black cottonwood establishment or survival resulting from the implementation of Alt S73; versus

H$_{A1}$: The implementation of Alt S73 results in either (a) a positive or (b) a negative influence on black cottonwood survival.

Hypothesis 2

H$_{02}$: Black cottonwood establishment and survival along the lower Duncan River are not affected by the river flow regime; versus

H$_{A2}$: Black cottonwood establishment and survival along the lower Duncan River are affected by the river flow regime.

Hypothesis 3

H$_{03}$: The river flow regime is not the primary driver of black cottonwood establishment and survival along the lower Duncan River; versus

H$_{A3}$: The river flow regime is the primary driver of black cottonwood establishment and survival along the lower Duncan River.

Guided by the above long-term objectives and hypotheses, the primary objectives in Year 4 were to:

- Collect data on the riparian vegetation community to add to the baseline data collected in Year 1 (2009);
- Collect cottonwood seedling data to add to the baseline data and Year 2 (2010) data; and
- Map the lower Duncan and Lardeau rivers with 10 cm (pixel size) aerial photos. Undertake change detection analysis, by comparing 2009 (baseline) with 2012 for channel migration, changes in vegetation communities, and changes in recruitment area between years.

The cottonwood seedling establishment and recruitment analyses, and riparian vegetation community analyses at the transect level for Year 4 were interpreted relative to the key management questions. By addressing the second management question, the key drivers will be identified and also how these drivers are influenced by river regulation. Mapping analysis provides changes in area for both reaches. Year 4 is a summary reporting year and included some comparison analysis. Mapping compared and analyzed changes that occurred over both reaches since the spring of 2009.

2 Methods

2.1 Study Area

The lower Duncan River is located in the Columbia Mountains region in southeastern British Columbia. It flows south out of the 45 km-long Duncan Reservoir, which was impounded by the Duncan Dam in 1967. Approximately 300 m downstream from the Dam, the lower Duncan River is joined by the free-flowing Lardeau River, and the combined rivers continue south for approximately 11 km to Kootenay Lake where a broad delta is formed (Figure 2-1:). Midway along in Segment 4, the lower Duncan River channel is joined by three free-flowing tributaries: Meadow, Hamill and Cooper creeks. The Lardeau River was selected as the reference reach because of its proximity to the lower Duncan River. The Lardeau River flows out of a nearly parallel watershed with a higher gradient and lower discharge compared to the Duncan River. The Lardeau River study reach starts approximately 3 km upstream of the confluence with the lower Duncan River and is approximately 11 km long (Figure 2-2).

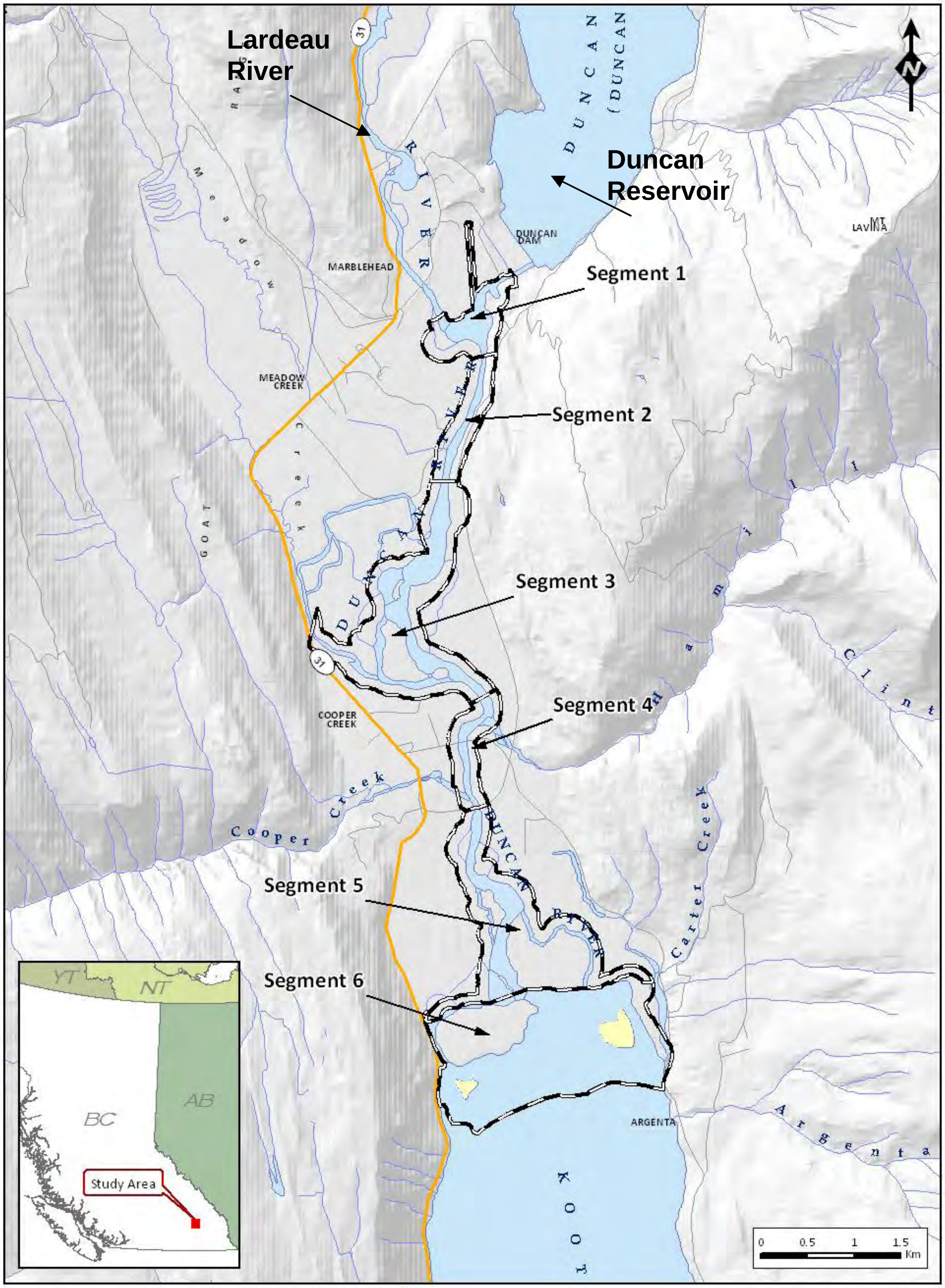


Figure 2-1: **Study area for the lower Duncan River with stratification of the river study segments.**

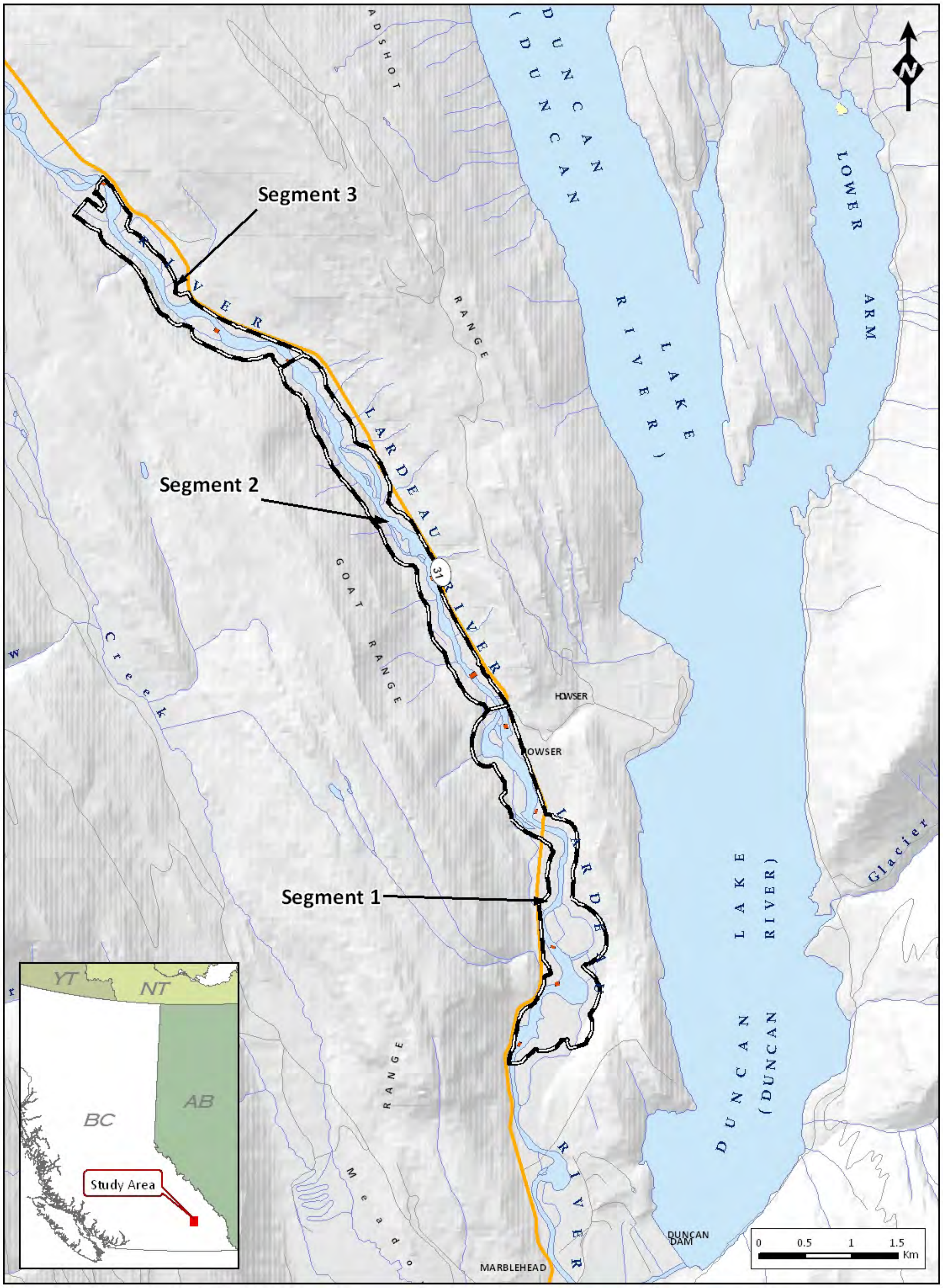


Figure 2-2: **Study area for the Lardeau River with stratification of the river study segments.**

2.2 Sampling Design

Year 4 (2012) of this study utilized the study design from Year 1 (see Polzin et al. 2010a). The sampling design incorporated a hydrogeomorphic framework, where the relationships between riparian vegetation, elevation and substrate conditions, are analyzed and modelled relative to river flow and stage patterns and groundwater (Auble et al. 1994, Mahoney and Rood 1998, and Polzin and Rood 2006). For a detailed sampling design concepts, see Polzin et al. (2010b). We implemented a composite study design within this framework, which included both temporal and spatial comparisons, as described by Braatne et al. (2008). This was required to address Hypothesis 1 and the key management question of whether Alt S73 will improve recruitment conditions for black cottonwoods and other riparian vegetation. In brief, the sampling design included the collection of the following data for 2012:

- Riparian vegetation data within quadrats along transects (including cottonwoods over two years old);
- Cottonwood germinants from 2012 and seedling information along transects for 2010 and 2011 seedlings;
- Surface substrate texture characteristics along transects and especially for the recruitment zone;
- Transect-specific stages collected at locations with gradually sloping point bars. These were collected by measuring the distance to river's edge from Point-of-Commencement (POC) along surveyed transect lines, with date and time recorded;
- Hydrometric records from Water Survey of Canada stations 08NH118, and 08NH007;
- Precipitation and temperature records (Duncan Lake Dam station at Meadow Creek station 1142574); and
- Cottonwood phenology, timing of development.

The Duncan Reach was stratified into six segments and the Lardeau Reach into three based on channel morphology (Polzin et al. 2010a). Each segment was further divided into areas where cottonwood recruitment requirements occurred (gradually sloping meander lobes, point bars, and mid-channel bars). Selection was based on areas identified in previous studies (Herbison 2003) and Google Imagery available in 2009. The identified recruitment areas had lines drawn perpendicular to the river every 10 m (representing possible transect lines locations) and labelled sequentially. A random number generator was used to randomly select transect lines for each segment for the Duncan Reach (Figure 2-3) and Lardeau Reach (Figure 2-4) (see Polzin et al. 2010a for details).

Three new transect lines were randomly selected for the Duncan Reach Segment 3 in the spring of 2012. Utilizing 2009 air photos and knowledge of the river for possible recruitment zones, candidate areas were identified, potential transect lines drawn and three randomly selected transect location coordinates were recorded. These three lines were going to replace three lines that were dropped in 2010 since they did not actually occur in cottonwood recruitment zones. However, the three new line locations no longer existed by August 2012, with randomly selected locations either in the river or on the edge of now eroding banks. Using the new 2012 air photos, potential areas will be selected and three new randomly selected transect lines will be established in 2013.

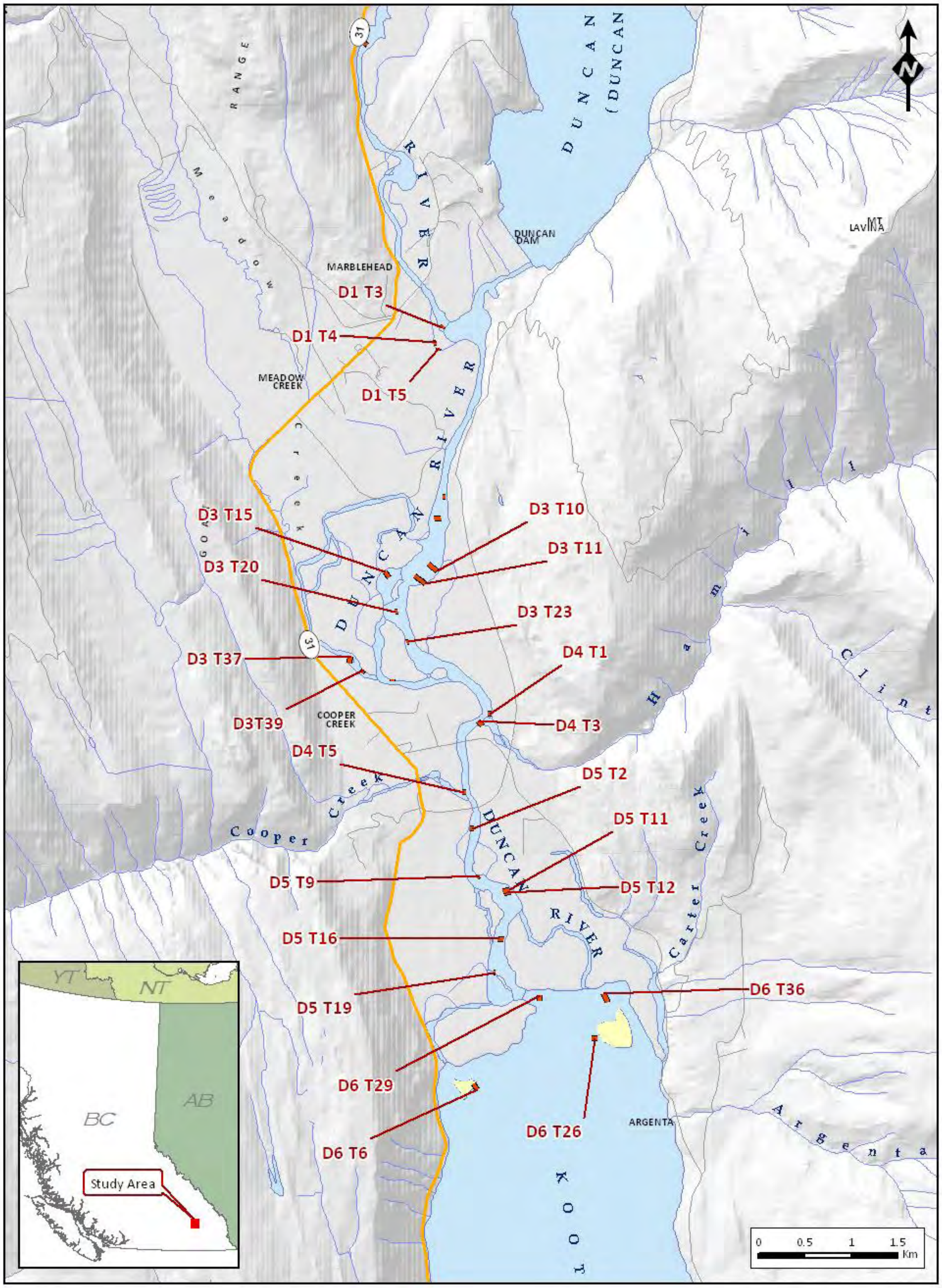


Figure 2-3: **Lower Duncan River study transects in 2012. Segments are indicated by the number following D (Duncan), and transect numbers are indicated after the T (transect).**

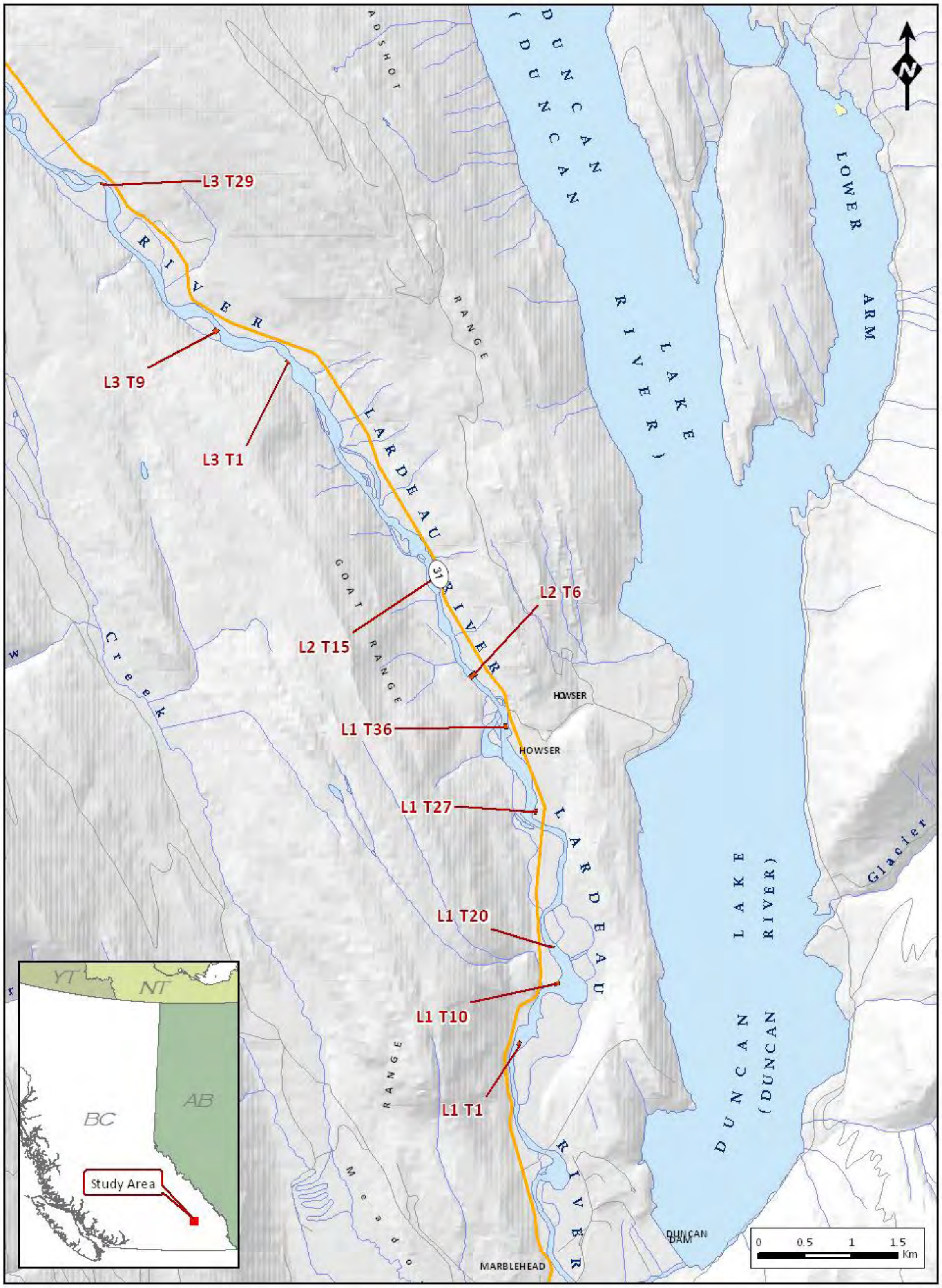


Figure 2-4: Lardeau River study transects in 2012. Segments are indicated by the number following L (Lardeau), and transect numbers are indicated after the T (transect).

2.3 Seasonal Weather

Daily precipitation and temperature data were downloaded from Environment Canada's website for the Duncan Lake Dam station at Meadow Creek, climate ID: 1142574:

http://www.climate.weatheroffice.ec.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=CA&StationID=1115&Year=2012&Month=6&Day=12

Data were for the years 2010, 2011, and 2012 from January to December except for 2012 as the accessed record ended October 31. Historical averages for precipitation were also downloaded.

2.4 Hydrology

The 2012 river discharge (*Q*) and stage data were downloaded from Environment Canada's Water Survey website[1] for the lower Duncan hydrometric station. The Lardeau River provisional discharge data were provided by special request from Environment Canada's water office. Hydrometric data were from the following stations:

1) Station 08NH118: located on the lower Duncan River, below the dam and below the confluence of Lardeau River (downstream (d/s) station), the 2012 data are provisional; and
2) Station 08NH007: Lardeau River at Marblehead located approximately 700 m upstream of the confluence with the lower Duncan River (2012 data are provisional).

The real-time Water Survey website data had missing data during peak flow days in June and July. Through a special request from Environment Canada's water office, provisional daily average discharges were supplied for the missing days but not the hourly discharges and stage data that were available for the majority of the data.

2.5 Cottonwood Phenology

We documented cottonwood phenology, the seasonal timing of developmental and reproductive events. This was through visual observations from a fixed vantage point that provides an excellent overview of the lower Duncan floodplain. Dispersing cottonwood seed release dates were recorded as well as the apparent rate of the dispersal (low, medium, or high quantity of seed).

2.6 Seedling Establishment and Recruitment

Belt transects were randomly located within pre-stratified segments and pre-identified recruitment areas as described in the Study Design section 2.2. Data from 2010, 2011, and 2012 cottonwood seedlings were collected. Cottonwood seedling data included density and heights (10 seedling heights recorded when greater than 10 seedlings occurred within a quadrat, for average height calculations) for each year class. Surface substrate textures were recorded within the cottonwood recruitment zones.

Initially, transect lines were scheduled to be resurveyed from POC to rivers edge in early spring for Year 4. For cost efficiency resurveys were to start from the last surveyed point (bench mark) in 2009 on the vegetated terrace above the river interface zone where recruitment occurs. The assumption was that the terrace zone had not been inundated

[1]http://www.wateroffice.ec.gc.ca/graph/graph_e.html?mode=text&stn=08NH118&prm1=3&prm2=-1&syr=2010&smo=1&sday=1&eyr=2010&emo=11&eday=21&y1min=&y1max=&y2min=&y2max=&max=0&min=0&mean=0&median=0&upper=0&lower=0&max2=0&min2=0&mean2=0&median2=0&upper2=0&lower2=0

by flood since it was surveyed and there was thus no change to the elevation profile from the bench mark to the POC. Because the Duncan Reach is below the Dam this was a reasonable assumption and it was the case at the time this decision was made in early 2011. This procedure ensured important information needed to quantify the amount of scour and deposition within the recruitment zone while reducing the cost as only a short section at the end of each transect line needed to be resurveyed. The extent of scour and deposition is important information for addressing the three hypotheses for this project and observations over previous sampling years noted deposition and scour occurring within the recruitment zones. Accurate survey profiles in the recruitment zone are also essential for accurate transect-specific stage/discharge calculations.

Two field visits occurred: August 7 to 11; and October 1 to 4, 2012. The first 2012 field visits occurred after flood water receded from some of the floodplain zones. All recruitment zones were still under high water and deposition on the floodplain occurred up to and past many of the POC's, resulting in no bench marks to use and no recruitment zones to resurvey. Due to substantial flooding complete transect lines will have to be resurveyed so scour and deposition can be determined and accurate transect-stage calculations can continue.

Data for riparian vegetation and cottonwood establishment for 2012 germinants, and for continuing 2011 and 2010 recruitment, and survival were collected during both field visits. The field data collected were tied to distances along the surveyed transect lines which provide surveyed elevation points from 2009. The link to transect distances will facilitate comparisons over time, by enabling assessment of sediment deposition and erosion, as well as revealing changes in vegetation patterns, including cottonwood colonization and survival.

Seedling occurrences were recorded within 1 m^2 quadrats on the downstream side of the transect lines. Seedling data collected included: heights of 10 representative seedlings (if 10 or more seedlings occurred), the number of seedlings for each year of seedling establishment, 2010, 2011, and 2012.

There was a change in seedling sampling methodology in 2012 which will be continued to the completion of DDMMON#8-1. This will streamline sampling in large patches of seedlings. Seedling quadrats were completed where ever seedling establishment occurred along transect lines as it was assessed in Years 1 and 2. However, in Years 1 and 2 we sampled every metre through the establishment band. Year 4, and all subsequent years, are sampled at the start, mid-point, and end point of each band of seedlings. Wide bands or large patches had start and mid-section sampled every 5 m to 10 m (large patches), and end points sampled. However, 2012 seedling establishment and survival was so low along the Duncan Reach that seedlings were sampled sequentially when there was establishment or recruitment greater than 1 m width.

The term "recruitment" is used to represent the successful contribution to the floodplain forest population (Rood et al. 2007). Recruitment is the result of two sequential but somewhat independent processes, establishment (or colonization), and survival:

Recruitment = Establishment (colonization) + Survival

The seedlings established in 2010 that survived to the October 2012 field sampling were considered successful recruits and we thus shift from tracking by seedling monitoring to vegetation monitoring utilizing cover by species to track growth.

Photos taken during the 2012 field season are documented in Appendix 2 and contact sheets of photos are located in Appendix 3. Original digital images are supplied on a compact disc (CD or DVD) with the final report.

2.7 Riparian Vegetation Sampling

Riparian vegetation monitoring utilized belt transect lines with nested quadrats when woody vegetation occurred. Quadrat size was based on vegetation type occurring along the transect line. Three sizes were used:

- ‘Herb’ quadrats of 1 m x 1 m were used to sample herbaceous vegetation and woody vegetation under 0.5 m in height;
- ‘Shrub’ quadrats of 2 m x 4 m were used to sample woody vegetation >0.5 m and <2.0 m in height; and
- ‘Tree’ quadrats of 5 m x 10 m were used to sample woody vegetation >2.0 m in height.

The labels Herb, Shrub, and Tree do not refer to the species recorded within them (i.e. ‘shrub’ species greater than 2 m in height are sampled in a Tree quadrat). When Shrub and Tree quadrats were used, the smaller size quadrats were nested within the top corner next to the transect line. This resulted in all Shrub quadrats having a Herb quadrat nested and all Tree quadrats having Shrub and Herb quadrats nested (Figure 2-5). Total species richness at each sampling point was used for the statistical comparison between years. This is not the simple addition from each quadrat since the same species can occur in multiple quadrat sizes depending on growth stage of the woody species.

Per cent cover for each species, vigour, average height, stem counts, within Shrub and Tree quadrats and wildlife utilization (browse) were recorded for vegetation within a quadrat. A modified Daubenmire (1959) per cent cover sampling method was used with an additional code bracket added for trace cover as shown in Table 2-1. Utilization and vigour were recorded using codes from Luttmerding et al. (1998) and heights were measured.

Table 2-1: The per cent cover, wildlife utilization ratings, and vigour codes with descriptions of the codes that were used for Herb, Shrub, and Tree quadrats.

Vegetation % Cover Codes			Utilization Ratings			Coding for Vigour	
	Per cent Coverage		*Code*	*% Utilization*	*Description*	*Code*	*Description*
Code	*Range*	*Mid-point*	0	0	Nil	0	Dead
1	0.1-1	0.1	1	1-5	Slight	1	Poor
2	>1 - 5	2.5	2	16-36	Light	2	Fair
3	>5 -25	15	3	36-65	Moderate	3	Good
4	>25 -50	37.5	4	66-80	Heavy	4	Excellent
5	>50 -75	62.5	5	>80	Extreme		
6	>75 -95	85					
7	>95 -100	97.5					

Belt-transects captured the elevational profiles and ensured comprehensive analyses of the riparian vegetation and the seedling recruitment zones. This same design was used along the Kootenay and Yakima rivers (Jamieson and Braatne 2001, Braatne et al. 2008), and is being continued along the Kootenay River, following recent changes in flow operations of Libby Dam (Burke et al. 2009). For additional information about belt transect line sampling used for this study see Polzin et al. (2010a and 2010b). Changes to the riparian vegetation sampling design were initiated in 2012 to improve the study and address weaknesses identified in the 2010 report.

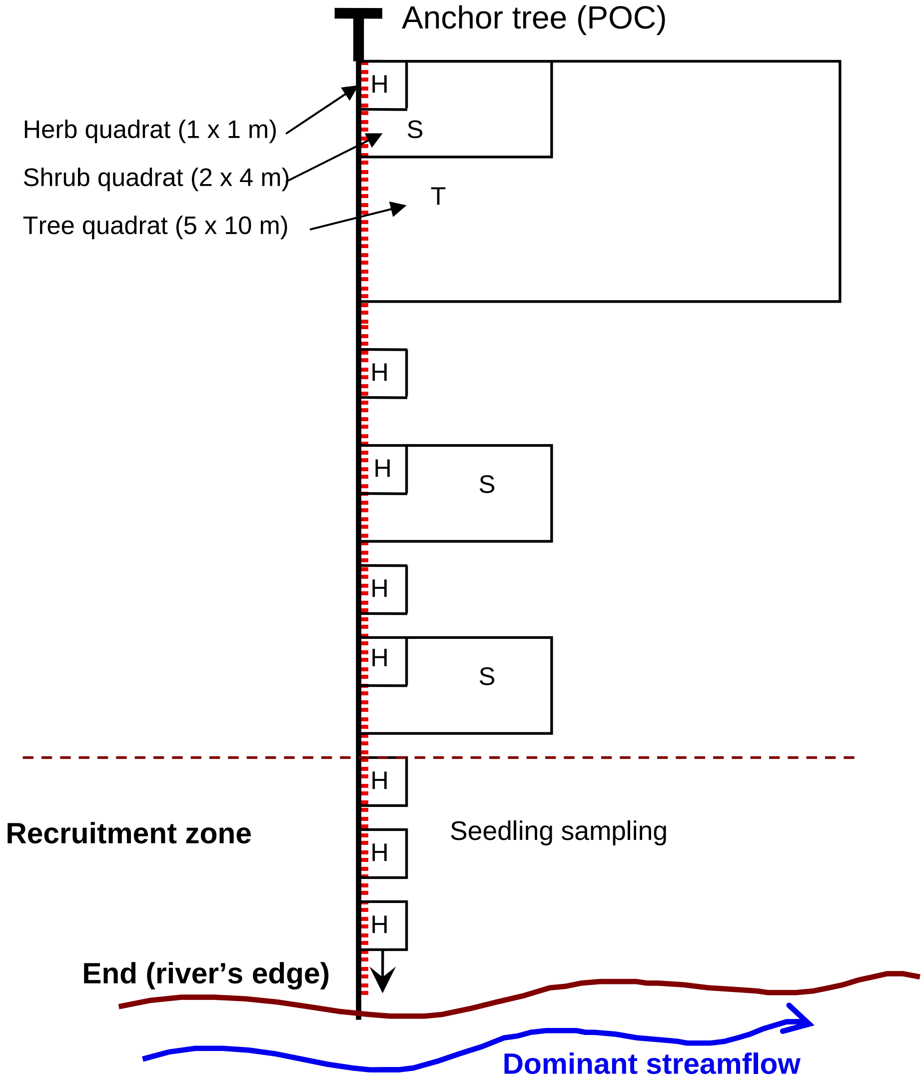


Figure 2-5: Belt transect with nested quadrats.

In 2009, sequential nested quadrats along each transect line were used. However, sequential quadrat placements are not independent and consequently autocorrelation can confound statistical analysis. Additionally, sequential nested quadrat sampling was very time-consuming. To streamline sampling and address non-independent sampling, we revised the quadratic sampling, to match an efficient design that has been used by others (e.g. Stromberg et al. 2009).

The majority of POC's occurred in woody vegetation greater than 2 m in height. As such, nested Tree quadrats started at the POC, duplicating 2009 sampling. If the 2009 data had three sequential tree plots then two were completed in 2012, at the start, and 15 m down the transect line. If the tree community was larger, quadrats were placed with a 5 m gape (one tree quadrat width) between them cutting sampling points in half while preserving the start of each nested tree quadrat to occur at the same metre mark as in 2009. This same process was used for nested Shrub quadrats, with the length of shrub community dictating how many Shrub quadrats were sampled between the start and end quadrats, always preserving the start of each quadrat at the same metre mark as in 2009. Spacing of the quadrats were 2 m increments (one shrub quadrat width) to preserve the same sampling pattern as 2009 so paired comparisons could be made between 2009 and 2012 data. If the shrub community did not start at the same point then Herb quadrats would be sampled to pair with the herb quadrat that would have been nested with-in the Shrub quadrat in 2009.

2.8 Groundwater Monitoring

Groundwater monitoring in the first two years of the study (2009 and 2010) used Solinst 3001 LT Leveloggers. These were installed in the groundwater wells established in 2009 and a Solinst 3001 LT barologger provided barometric data for correction. The results revealed an almost complete correspondence in the water table elevation across the individual piezometers for both years. Groundwater table elevation also corresponded tightly with river stage at the gauging station 08NH118. This indicated that the alluvial groundwater table is recharged by water freely infiltrating horizontally from the river. Following the confirmation in the second year groundwater monitoring was reduced to every second or third year. There will also be fewer wells since repetitive monitoring would be subsequently redundant and time consuming. Thus, groundwater monitoring was dropped from the 2012 sampling year which had a reduced budget that required streamlining of the field work. Due to the close association of groundwater to river stage recorded in 2009 and 2010 results have demonstrated that the regulation of river stage by the dam will have a direct influence on the alluvial groundwater elevation, and the subsequent water availability for colonization by cottonwoods and other riparian vegetation. Some groundwater monitoring will occur in 2013 with pressure transducer installation occurring during the spring re-survey of the transect line profiles.

2.9 Transect-Specific Stage/Discharge Relationships

Stage data collection involved measuring river distances from the POC for each transect and recording date and time of the measurements, as described in Polzin et al. 2010a. One stage measurements occurred for all transect lines corresponding to the October field visits along the Duncan Reach. The Duncan Reach had 10 stage measurements completed in August with the remaining lines inaccessible because of high water at the time of the field visit. The Lardeau had stage measurements completed for both field visits in 2012. However, no additional analysis was completed as there was no update to the survey elevation of the lines since 2009. These data points will be added to the 2013 data and analysis for the transect-specific stage discharge relationships will be updated. For this report, 2009 profiles and the transect-specific stages calculated in 2010 from combined 2009 and 2010 data were used in the analysis of transect line inundation levels corresponding to river stage levels in 2012.

2.10 Aerial Photography and Riparian Community Monitoring

The lower Duncan and Lardeau rivers were flown for photo analysis on October 15, 2012 to acquire 10 cm (pixel size) aerial photos. This component was subcontracted to Terrasaurus Aerial Photography Ltd., who also completed the subsequent orthorectification, colour balancing, image sharpening and mosaic compilation. Refer to Polzin et al. (2010a) for methodology used for the baseline mapping.

Year 4 (2012) was the first year when aerial photo interpretation was used to assess changes occurring within the study segments for both the Lardeau and lower Duncan rivers. In 2012, the rivers were flown when the Duncan River stage was at 1.62 m and just before increasing discharge from the Duncan Reservoir began. The photos were interpreted to:

1) quantify changes in area of each riparian vegetative class, as per Table 2-2, within 100 m of the active channel edge; and
2) quantify changes in major recruitment sites (present and potential future).

The baseline photos (2009) where taken April 30 at the Duncan River stage level of 1.63 m and prior to bud flushing of perennial deciduous plants and prior to the growth of annuals. Consequently, the images were not ideal for characterizing some aspects of vegetation, and especially delineation between some vegetation communities. Initially, the 2012 flight was scheduled to occur during early senescence, when the different deciduous shrubs and trees would be better discriminated. However, with the unexpected high water all summer the highest priority for the fall flight was to capture the reaches at low stage to assess changes that occurred during the summer high water.

There was a narrow window in October when the stage was similar to spring 2009 levels and the weather was good for photo acquisition (October 2 – 14). Water levels started to rise, with large fluctuations the evening of October 14 from 1.63 m to 1.66 m so the flight occurred October 15. Postponing the flight until early senescence may have resulted in stage levels above 1.7 m and/or a change in weather, thus not permitting a flight until stage levels were once again too high. Unfortunately, early senescence did not start until October 23 with average stage level at 1.8 m for the day. The 2012 Duncan River photos were taken approximately at 1.62 m stage if the photos were taken mid-day with levels rising to 1.72 m by the evening.

The resulting orthorectified photos allowed for a more accurate delineation of vegetation Community Types 1, 2, and 3 but more detailed information of species composition was not possible without senescence. The October imagery also allowed for identification of horsetail-dominated marsh areas and sedge-dominated areas that could not be previously identified because the April 2009 photos were taken before perennial species growth started for the season. Some of the 2009 Community Type 1, cottonwood and willow shrubs, under 2 m tall were missed in 2009 as they did not show up in the photo’s. These small areas were corrected for the 2009 delineation before comparing areas between 2009 and 2012.

Table 2-2: Plant community types interpreted from the aerial photographs and mapped using GIS.

Type	Description
0	active river channel
1	<2 m tall cottonwood and willow
2	<5 m tall cottonwood, willow, deciduous and conifer
3	<5 m tall willows (occasional cottonwood, alder)
4	cottonwood and cottonwood mix* - early seral
5	cottonwood and cottonwood mix* - late seral
6	very old (>200 yr) cottonwood
7	mature conifer (cedar, hemlock, fir, larch, pine)
8	logged/regenerating
9	anthro (agriculture, buildings, roadways, industry, etc.)
10	marsh (horsetail dominated)
11	recruitment zones (present and potential)
12	sedges/grasses

* Mix includes deciduous and coniferous species.

The change detection analysis started with the 2009 community layer projected onto the 2012 ortho's. Vegetation community polygons and the active channel edge that had changed since 2009 were modified to delineate the new boundaries on the 2012 community layer. The resulting areas for each vegetation community by segment were compared between years to quantify changes in area for each vegetation community and the river channel. Potential and existing recruitment areas were compared between years by segments for both the lower Duncan River and the Lardeau River reference reach.

Additionally, meander lobe areas were assessed for changes in vegetation communities' size from 2009 to 2012. Meander lobes associated with transect lines were selected for this analysis. Meander lobes starting at the upstream end of each reach were labelled consecutively resulting in labels DM1 to DM17 for the lower Duncan River and LM1 to LM9 for the Lardeau River. Meander lobe labels and the associated segments and transects are listed in Table 2-3.

Table 2-3: The Duncan and Lardeau Meander lobe labels and the corresponding segment and transects associated with the areas.

Duncan Reach (#)	Segment (D) & Transect (T)	Lardeau Reach (#)	Segment (L) & Transect (T)
DM1	D1T3, T4, & T5	LM1	L3T29
DM 2	D3T10 & T11	LM2	L3T9
DM 3	D3T15	LM3	L3T1
DM 4	D3T20	LM4	L2T15
DM 5	D3T23	LM5	L2T6
DM 6	D3T37 & T39	LM6	L1T36
DM 7	D4T1 & T3	LM7	L1T27
DM 8	D4T5	LM8	L1T10 & T20
DM 9	D5T2	LM9	L1T1
DM 10	D5T9		
DM 11	D5T11 & T12		
DM 12	D5T16		
DM 13	D5T19		
DM 14	D6T29		
DM 15	D6T36		
DM 16	D6T26		
DM 17	D6T6		

2.11 GIS Data

GIS submission requirements and file geodatabase are provided in digital form in Appendix 5.

2.12 Data Analyses

Data analyses focused on addressing the key management questions for three main objectives for 2012. To address the first objective, re-sampling of the broader riparian vegetation for vegetation cover and species richness occurred along transect lines for the lower Duncan and Lardeau rivers. The second objective concentrated on cottonwood seedling establishment and recruitment. This involved comparisons between seedling establishment and recruitment across the 2009, 2010, and 2012 data sets. The third objective involved mapping change which involved comparison analysis between 2009 and 2012 for the complete Duncan and Lardeau reaches utilizing orthophotos and GIS for delineation of the different vegetation community types identified in 2009.

Statistical analyses were conducted using SPSS 12.0 (SPSS Inc., Chicago) and all tests were interpreted with an alpha of 0.05. Descriptive statistics were used with Explore in SPSS as well as correlation tests. ANOVA Paired-Samples T-Tests were used to compare 2009 versus 2012 vegetation cover (per cent cover) and species richness (number of species). Comparison testing involved comparing quadrat locations in 2012 to the same quadrat locations in 2009. The different quadrats were always compared with like sizes and no combining of different sized quadrats occurred. Species richness count data were transformed using square root transformation but graphed using count data. Analysis of Covariance (ANCOVA) was used to compare the relationship between the lower Duncan and Lardeau rivers. Linear regressions were used for analyses of the relationship between cover and richness for each river. Comparison analysis for change in plant community and channel areas used Paired-Sampling T-Tests between 2009 (baseline) and 2012 polygon areas derived from mapping utilizing GIS. Meander lobes where transect lines occurred had the area from 2009 compared to the area in 2012. Statistical outputs related to results are provided in Appendix 4.

3 RESULTS

3.1 Weather

The weather patterns for the first two years of sampling (2009, 2010) were generally similar, with some seasonal variations in mean temperature and total precipitation (Figure 3-1). The past sampling year (2012) experienced similar mean temperatures through to October 20 compared to the previous sampling years. However, 2012 monthly total precipitation was not typical. March total precipitation was higher than sampling years 2009 and 2010 and over double the historical average total precipitation (Figure 3-2). The month of June total precipitation was just under triple the historic average. This was followed by lower than average precipitation for July, August, and September. The month of June had three days with precipitation exceeding 20 mm for each day, thus contributing to the high total precipitation (Figure 3-3).

The mean daily temperature was very similar for 2012 compared to 2009 (but 2009 was missing March and May data) and similar to 2010. The 2012 season had a mean monthly temperature from January to end of September of 8.9 ^{o}C compared to 9.2 ^{o}C in 2010 for the same period.

Both the Duncan and Lardeau rivers are snowmelt-dominated systems. As such, seasonal snow pack levels play a role in the extent of freshet flooding. The winter 2011/12 snow pack for the West Kootenay Basin was 110 to 125 per cent of normal, relative to the water equivalent. Snow pack plays a role in freshet peak flows but weather determines the rate of snow melt and whether or not flood conditions occur. Extreme precipitation and particularly rain in June 2012 during the freshet period resulted in freshet flooding for both the lower Duncan and Lardeau rivers.

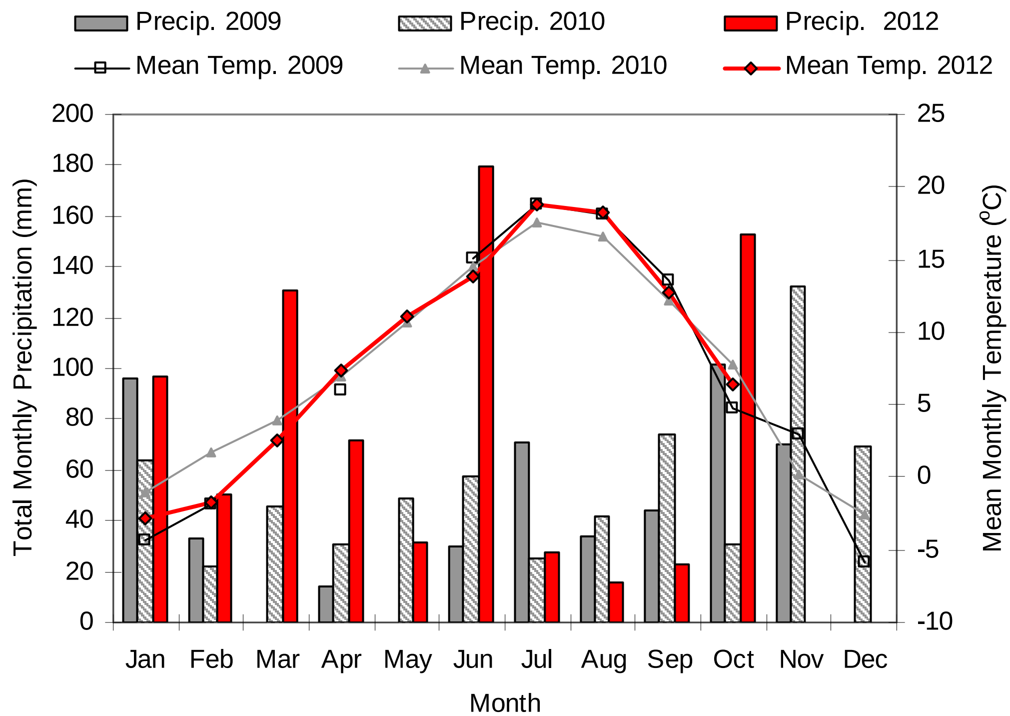


Figure 3-1: **Duncan Lake Dam weather station at Meadow Creek monthly mean temperature and monthly total precipitation for 2009, 2010, and 2012 (sampling years). Available records ended October 31, 2012.**

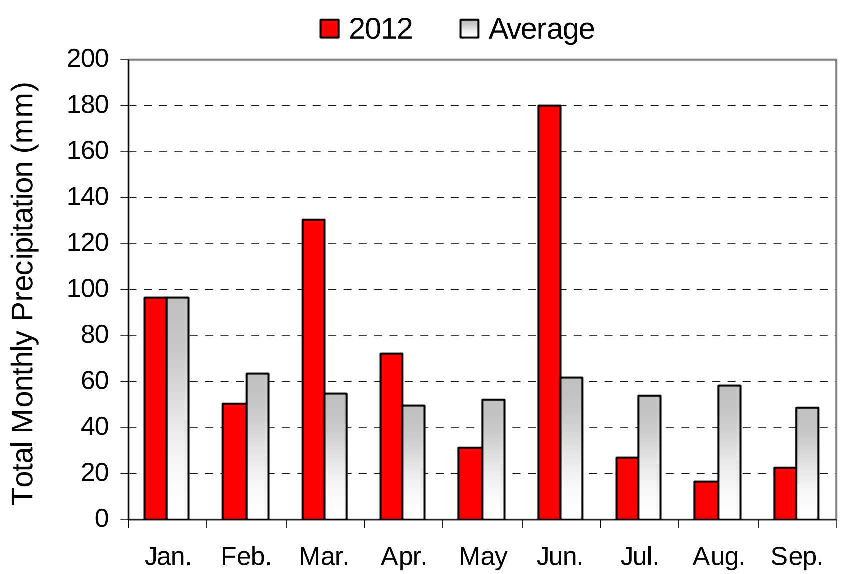


Figure 3-2: **Canadian Climate Averages (1971 – 2000) for monthly total precipitation for the Duncan Lake Dam weather station and 2012 monthly precipitation for January through September.**

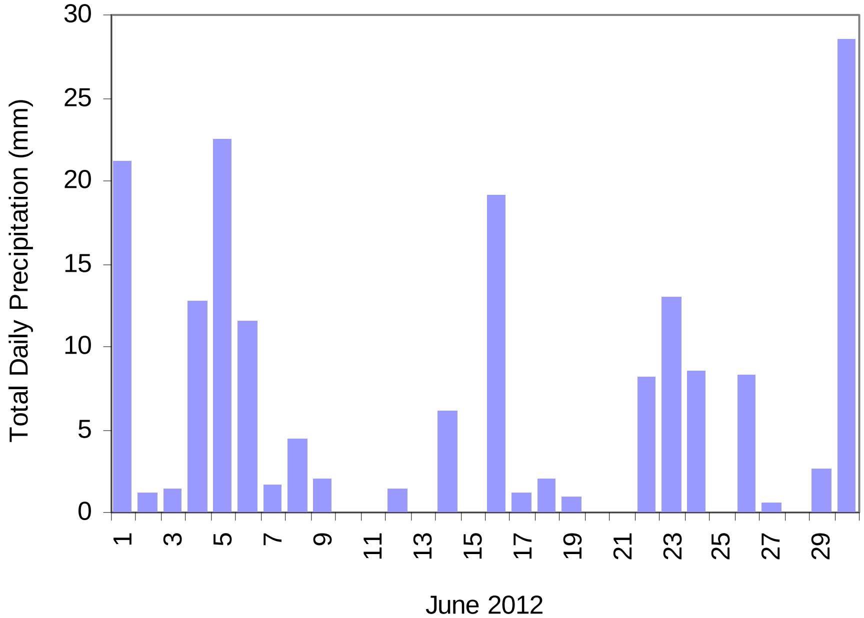


Figure 3-3: Total precipitation (mm) for the month of June 2012 at Duncan Lake Dam weather station. Total precipitation for the month of June was 179.8 mm.

3.2 Hydrology

3.2.1 Duncan River

Mean monthly discharges during 2009 and 2010 were very similar in patterns, peaks, and timing (Figure 3-4). The sampling year of 2012 was an exception with the regular Alt S73 flow regime pre-empted by high rainfall in the Duncan Basin for the month of June. The combination of higher than average snowpack and higher than average rainfalls during June resulted in extremely high inflows especially in July for the lower Duncan River.

The Duncan Reservoir usually reduces spring peak flows on the lower Duncan River by filling the reservoir while major tributaries downstream of the dam result in a partial peak in June or early July. A combination of higher than average snowpack and the record rainfall in June resulted in the reservoir fill above full-pool (576.7 m) for five days, July 21 through July 25, with peak level of 576.9 m for July 23 that was intended to reduce flooding downstream through the Columbia Basin. Even with the attenuation through reservoir capture the lower Duncan River daily peak discharges exceeded 500 m^3/s through the last half of July.

The flow regime for 2012 was more consistent with post-dam, pre-Alt S73 years when releases were managed to reduce downstream flooding potential. Three such years were 1972, 1981, and 1997 and these resulted in high releases from the Duncan Dam for the month of July, similar to 2012 (Figure 3-5). The 1972 flood mitigation releases were higher for June, July and August compared to the 2012 releases. The 1997 discharge levels were similar to the 2012.

The 2012 mean daily discharge (provisional data) was compared with the two previous sampling years (Figure 3-6). The Alt S73 flow regime for 2012 was consistent with the two previous years up to April 24. The combination of snow melt and rainfall resulted in higher discharges for the lower Duncan River during the growth season from April through September, and particularly through the cottonwood establishment time period in July. The flow regime returned to levels similar to the previous two years from October through December.

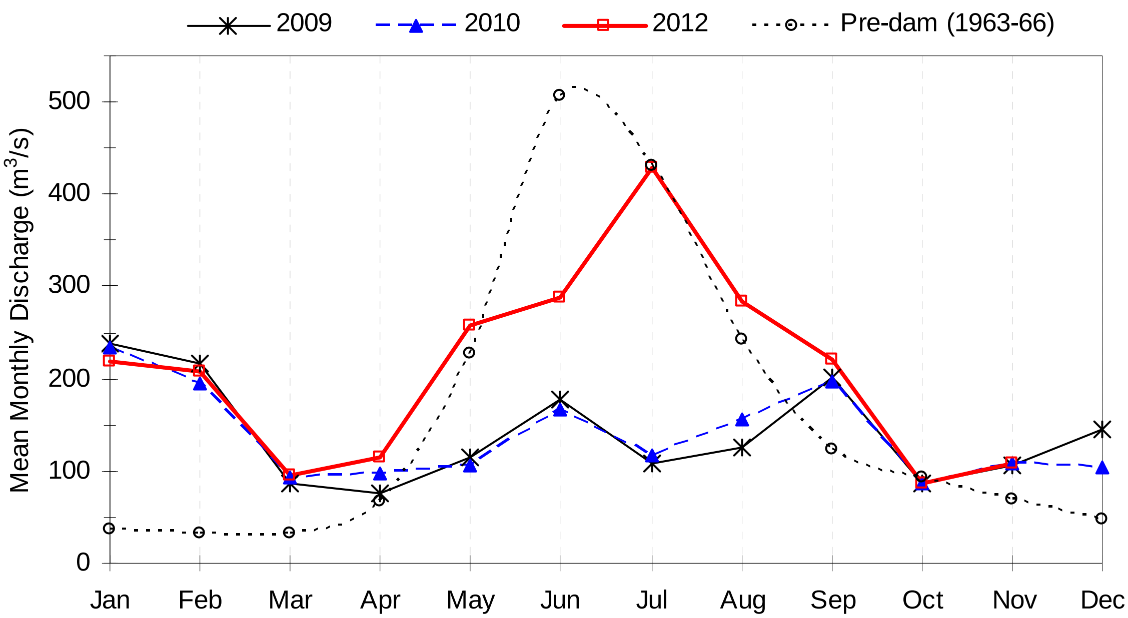


Figure 3-4: Mean monthly hydrographs for the lower Duncan River for sampling years 2009, 2010, and 2012 and pre-dam (3 years of data) mean monthly discharges plotted with a smoothed lined.

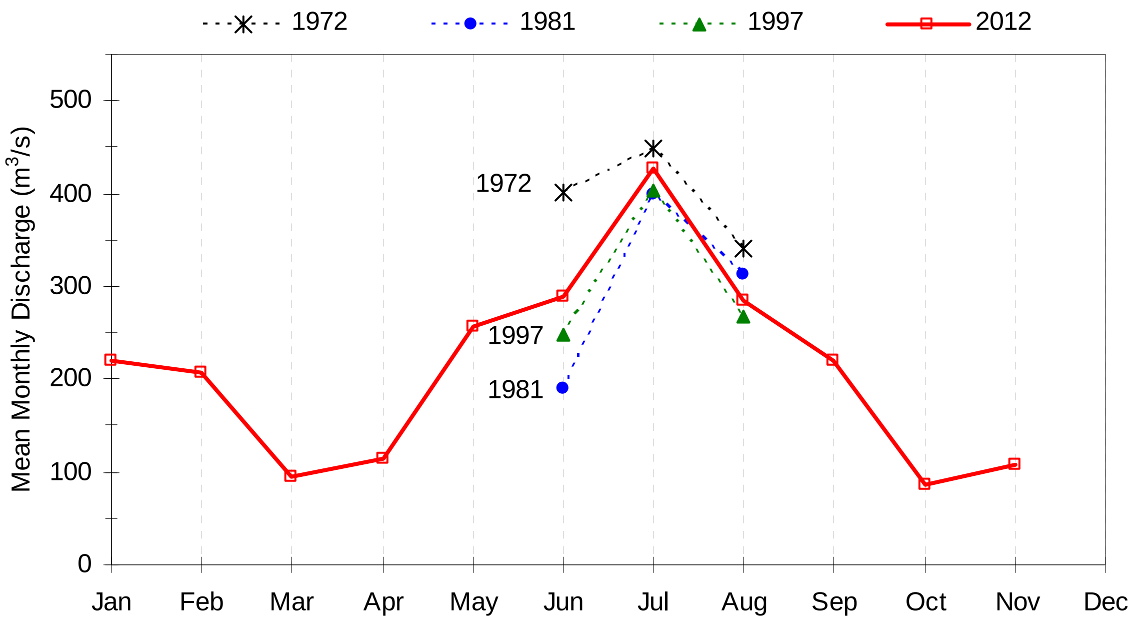


Figure 3-5: **2012 mean monthly discharge (m^3/s) compared with June, July, and August mean monthly discharge for three post-dam high flow years prior to the implementation of Alt S73.**

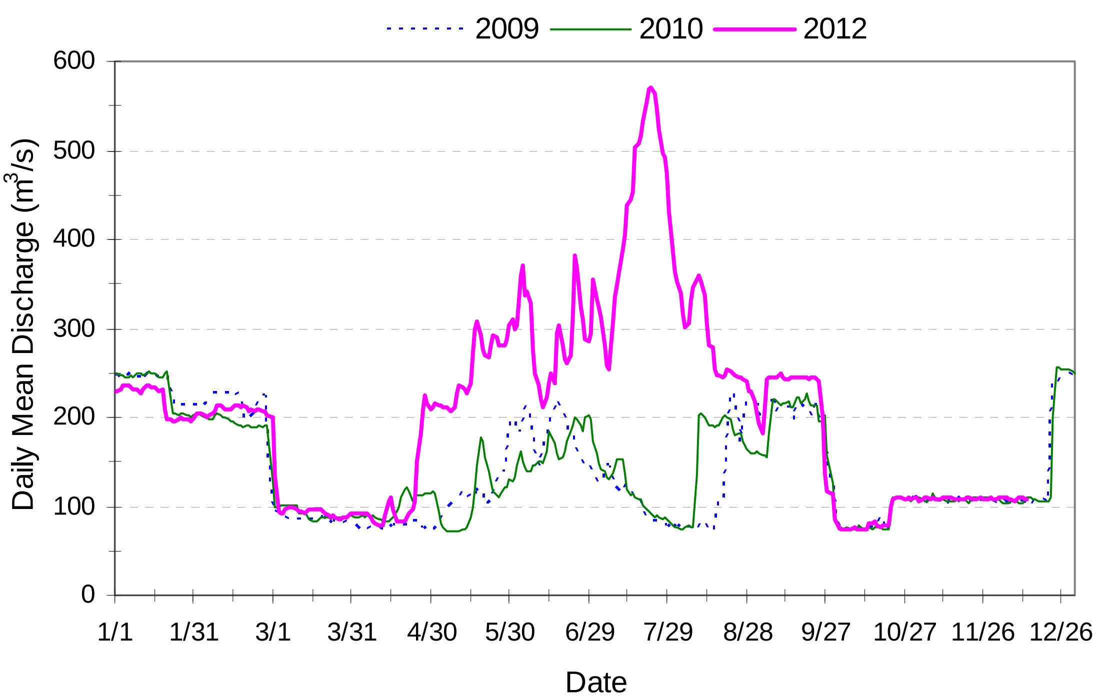


Figure 3-6: **Mean daily discharge (m^3/s) for 2009 and 2010 and 2012 (provisional) for the lower Duncan River at Station 08NH118.**

In 2012 cottonwood establishment and recruitment were tracked for a three year period: 2010 (recruitment by end of the 2012 season), 2011 (survival through the second growing season), and 2012 (establishment and survival through the first growing season). Seedlings from 2011 establishment were unknown (since 2011 was not a monitoring year), but 2011 seedlings were assessed in 2012. The 2011 hydrograph is important for our study because inundation duration and timing directly affect seedling survival and since no monitoring occurred. The 2012 peak (571 $m^{3/}$s on July 23, 2012) occurred earlier and was higher than 2011 (461 $m^{3/}$s on August 5, 2011; (Figure 3-7). The period of discharge greater than 200 m^3/s in 2012 (April 27 to September 26, 2012, 153 days) was 22.4% longer than in 2011 (May 20 to September 21, 2011, 125 days).

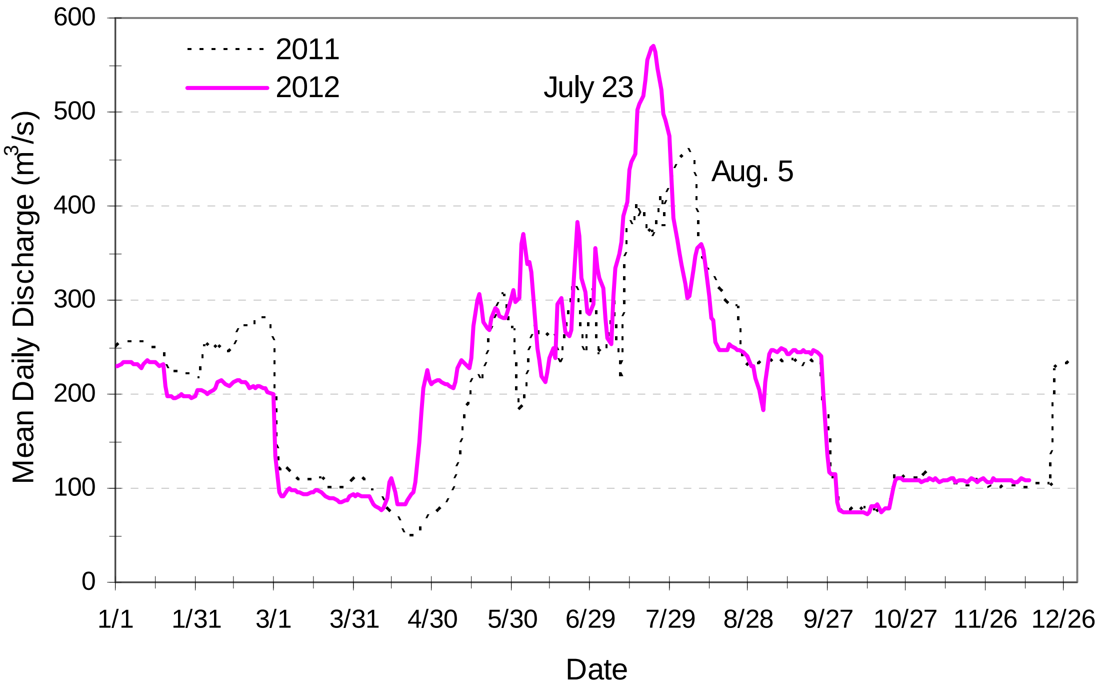


Figure 3-7: Mean daily discharge (m^3/s) for 2011 and 2012 (provisional) for the lower Duncan River at Station 08NH118.

3.2.2 Lardeau River

The Lardeau River (reference reach for the study) experienced a spring freshet flood in 2012. The flood was the result of intense rain on the watershed through the month of June, and the river peaked June 24. The 2012 Lardeau River discharge levels were similar to 2011, but the 2011 peak was lower (Figure 3-8). Because vegetation sampling was not undertaken in 2011 there is no way to resolve the influences from the 2011 versus 2012 flood flows. Therefore, only the combined effect of the two years is known.

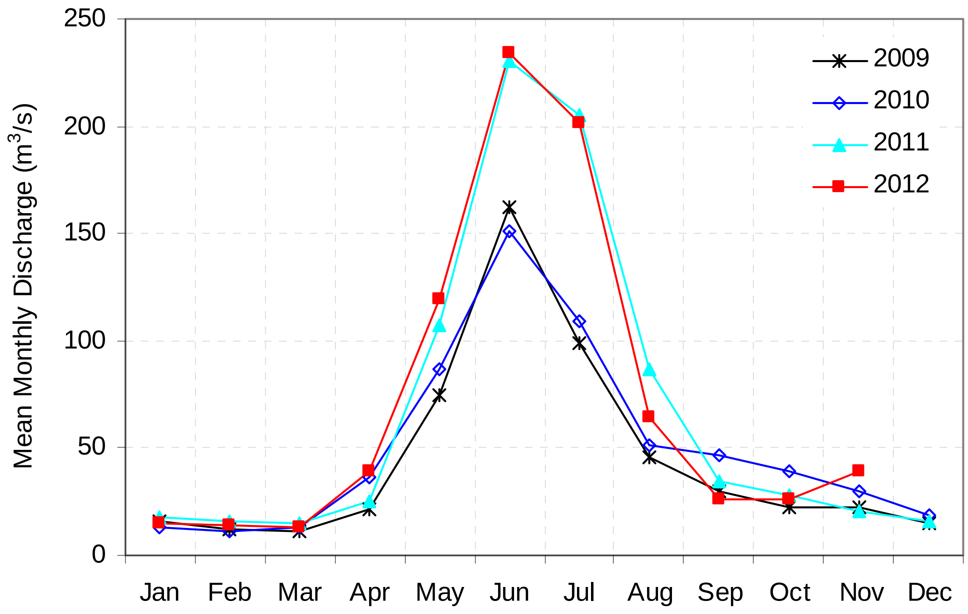


Figure 3-8: Mean monthly discharge (m^3/s) for the Lardeau River for years 2009 through 2012.

Flow records for the Lardeau River consisted of 70 years of records starting in 1917, with a period of missing records from 1920 through 1945. Flow records from two hydrometric sites were coordinated by regression analysis for the period of overlap for the missing years of 1997 through 2002 (Q_{max} at 08NH007 = Q_{max} at 08NH118 x 0.37, R^2 = 0.96, linear regression forced through origin). Recurrence analysis indicated that the 2012 flood along the Lardeau River was about a 1-in-10 year flood event (Q_{10}) (Figure 3-9, log Pearson Type III fit, Q_{10} = 349 m^3/s versus the 2012 Q_{max12} = 331 m^3/s). The 2011 flood was under a 1-in-5 year flood event (Q_5) (Q_5 = 319 m^3/s versus the Q_{max11} 297 m^3/s). The 2009 and 2010 peak flows were less than 1-in-2 year events (Q_2) (Q_2 = 269 m^3/s, Q_{max09} = 201 m^3/s and Q_{max10} = 183 m^3/s).

The 2012 peak flow occurred on June 24, which was typical timing for the Lardeau River flows. Historically, 71 per cent of annual peaks have occurred within June. Following the 2012 flood crest, the flow decreased abruptly and then more gradually through the summer (Figure 3-10). The below average precipitation for July, August, and September resulted in a steeper decline over the summer compared to 2011. The 2009 and 2010 peak flows were also similar to each other. Slight variation in the 2010 hydrograph shows a larger second peak in the autumn that followed from heavy rains.

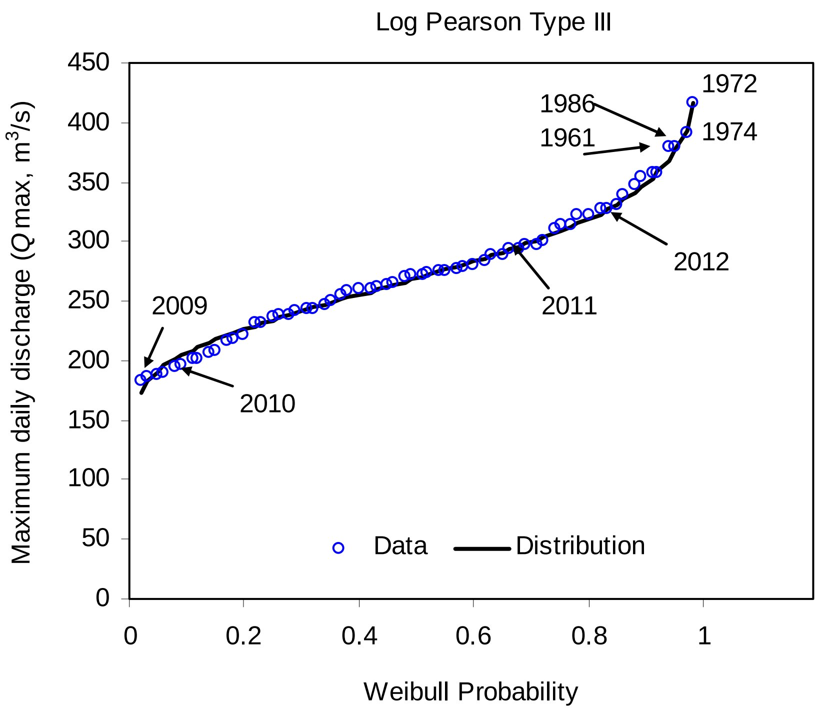


Figure 3-9: Recurrence analysis showing annual maximum daily discharge (*Qmax*) versus Weibull probability for the Lardeau River at Marblehead.

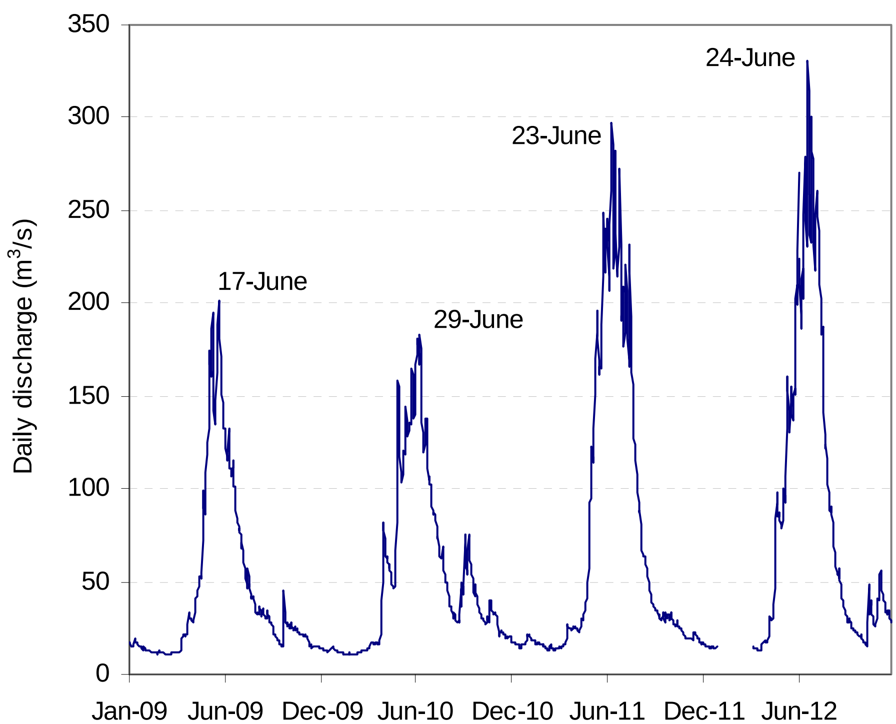


Figure 3-10: Hydrograph showing mean daily discharges for the Lardeau River at Marblehead for the years from 2009 through 2012.

3.3 Cottonwood Phenology

The main cottonwood seed dispersal events started June 19, the same as in 2010. Similar to the previous sampling years, cottonwood seed dispersal occurred sporadically over a seven-week period in 2012, between June 19 and August 12. Details on the relative abundance of seeds (low to high) in each observed dispersal event along with temperature and rainfall are reported in Table 3-1.

Table 3-1: Seed dispersal events with abundance, maximum temperature for the day, mean maximum temperature for the event and precipitation (rain). Rain events prior and post seed release events are listed under 'Comments'.

Event	Date	Seed Abundance	T_{max} (^oC)	Rain (mm)	Event T_{max}	Comments
1	Jun. 19	Medium	19	1	**22.5**	Last heavy rain event – June 16 – 19 mm
	Jun. 20	Low	21	0		
	Jun. 21	Low	26.5	0		
	Jun. 22	Medium	23.5	8.2		Rain occurred in the evening
2	Jun. 28	Low	25	0		Previous 6 days of rain – 38.7 mm total. Followed by 6 days of rain – 41.2 mm total
3	Jul. 4	Low	21	0.6	**23.5**	Last rain event – July 3 – 6.8 mm
	Jul. 5	Low	26	0		No rain for the following 15 days
4	Jul. 21	Medium	26	0	**26.7**	Last rain event – July 20 – 12 mm
	Jul. 22	Medium	27.5	0		
5	Aug. 7	High	30.5	0.5	**29.8**	Last rain event – July 20 – 12 mm
	Aug. 8	Medium	27.5	1.4		Rained in the evening
	Aug. 9	Low	28.5	0		
	Aug. 10	Low	30.5	0		
	Aug. 11	Low	30	0.2		Rained in the early morning
	Aug. 12	Low	31.5	0		

The 2012 seed release followed a possible pattern of initial seed release occurring during periods of high humidity, such as during the first warm day(s) following cool or wet weather. However, the August seed release did not show this pattern. The possible pattern associated with initial seed release during the 2010 field season was reported but the later seed release events were not analysed. Reviewing the 2010 seed release events in mid-July and August found that no pattern was consistent between years.

In 2010 a three day seed release event occurred in mid-July that did not follow a rain event or an increase in temperatures. The low seed abundance during the August event in 2010 occurred during a rain period with a maximum precipitation in one day of 10 mm and 24.2 mm of rainfall over the seed release event. It was also very cool during this seed release with an average maximum temperature of 18.6 ^oC (cooler than pervious days before seed release started). The August 2012 seed release occurred during hot dry weather with no rain event preceding it or during. There was no seed release reported for August in 2009 though seedlings from an August event were recorded in September 2009.

3.4 Cottonwood Establishment and Recruitment along the Lower Duncan and Lardeau Rivers

Following the 2012 field inventories, a total of only 12 sampling quadrats along the lower Duncan River had cottonwood seedlings, which had originated from 2010 to 2012 seedlings. This was much lower than both previous sampling years, with 272 in 2009 and 364 in 2010 (Table 3-2). There were only four transect lines with seedlings from 2010 to 2012, compared to 20 transects in 2009 and 2010 (seedlings from 2008 to 2009 were sampled in 2009, and 2008 to 2010 seedlings were sampled in 2010). The total number of 2012 germinants was also dramatically lower with only 122 germinants in 2012 compared to 22,830 germinants in 2010 and 123,956 germinants in 2009. The lower Duncan River Segment 6 had a transect line removed from sampling because of a large woody debris flow that covered the transect line reducing the sampling size by one transect compared to 2009 and 2010. However, we did visit that transect line during the October field monitoring to see if seedlings were on the point bar. There were no 2010 to 2012 seedlings in the area of the remaining section of the transect line that was not covered by woody debris.

The Lardeau River also experienced reduced seedling establishment but not as dramatic as along the lower Duncan River (Table 3-3). There were 42 sampling quadrats with germinants in 2012, compared to 73 in 2009 and 145 in 2010. The number of transect lines with seedlings did not change as much with six in 2012 and 2009, and nine transect lines in 2010. However, the total germinant counts were lower in 2012 with 3,474 germinants compared to 6,329 germinants in 2009 and 5,823 germinants in 2010. The Lardeau River Segment 3 had a transect line including the POC completely removed by river migration and a transect line in Segment 1 had most of the floodplain removed by river scour. This reduced the effective seedling recruitment sampling area by two transect lines. However, the Segment 1 transect line was an eroding bank and had lost the seedling establishment zone by 2010. It had an older recruitment zone with 2005 to 2008 seedlings which were scoured away in 2012. The overall affect from the loss of these two transect lines was minimal since no seedling establishment occurred along either transect line during the past sampling years.

Table 3-2: Comparisons of 2009, 2010, and 2012 numbers of quadrats with seedlings and number of establishment seedlings, for each transect along the Duncan River.

Duncan Segment	Transect	2009		2010		2012	
		# Quadrats	# Seedlings	# Quadrats	# Seedlings	# Quadrats	# Seedlings
D1	T3	6	18,340	15	3,197	8	52
	T4	0		0		0	
	T5	0		0		0	
D3	T10	0		5	139	0	
	T11	1	1,200	4	142	0	
	T15	63	53,190	61	7,372	1	1
	T20	11	3,220	13	784	0	
	T23	6	442	3	64	0	
	T37	2	720	1	54	0	
	T39	2	350	3	94	0	
D4	T1	3	40	20	553	2	4
	T3	2	59	31	48	1	65
	T5	3	720	32	249	0	
D5	T2	14	2,020	12	296	0	
	T9	17	8,860	20	2,276	0	
	T11	11	2,344	5	20	0	
	T12	37	12,048	34	5,260	0	
	T16	3	110	12	5	0	
	T19	8	2,115	8	614	0	
D6	T6	1	1,600	0		0	
	T26	19	2,280	14	46	0	
	T29	28	9,748	30	1,400	------	
	T36	35	4,550	41	217	0	
	Totals	**272**	**123,956**	**364**	**22,830**	**12**	**122**

Note: --- indicates transect line was buried by large woody debris, excluding sampling in 2012.

Table 3-3: Comparisons of 2009, 2010, and 2012 numbers of quadrats with seedlings and number of seedlings, for each transect along the Lardeau River.

Lardeau Segment	Transect	2009		2010		2012	
		# Quadrats	# Seedlings	# Quadrats	# Quadrats	# Seedlings	# Quadrats
L1	T1	11	730	17	143	7	2,258
	T10	20	2,820	28	3,215	18	1,145
	T20	15	1,430	22	785	11	42
	T27	3	0	0	0	----	-----
	T36	0	0	12	138	2	13
L2	T6	16	1,060	39	1,211	1	4
	T15	0	0	5	220	3	12
L3	T1	8	289	14	86	0	0
	T9	0	0	7	24	0	0
	T29	0	0	1	1	----	-----
Totals		**73**	**6,329**	**145**	**5,823**	**42**	**3,474**

Note: ---- indicates transect line and or recruitment/establishment zone removed by river scour/channel migration.

3.4.1 Seedling densities

There were significantly lower cottonwood establishment densities along the lower Duncan River in 2012 compared to 2009 and 2010. Box plot comparisons between establishment levels for 2009, 2010, and 2012 illustrate the magnitude of differences for the Duncan Reach between years (Figure 3-11). Data were graphed for comparison by segments as well. Only 2010 were graphed to compare to 2012. The 2009 densities were not graphed because they were very high (5,800 seedlings for Segment 1) to reduce the Y axis scale (Figure 3-12). There were two segments that had some seedling establishment in 2012, Segment 1 and 4. Segment 3 had one seedling on one transect line established from the August seed release.

The Lardeau River appeared to display a decrease in seedling densities in 2012 but this was not significantly different from 2009 or 2010 (P = 0.092 df = 141, t = 1.70 and P = 0.123 df = 141, t = 1.55 respectively). Figure 3-11 illustrates this comparison with some reduced densities for 2012 but similar mean values. Seedling density comparisons between segments shows that Segment 1 (L1) had the majority of 2012 seedling establishment. Segment 3 had reduced seedling establishment in 2010 which further decreased to zero establishment in 2012. This reflected the complete loss of the most upstream transect line due to channel migration that may have initiated scour of the floodplain during 2011 peak spring flow with further channel migration in 2012 removing the floodplain. This also removed a 114 year-old cottonwood tag tree (POC).

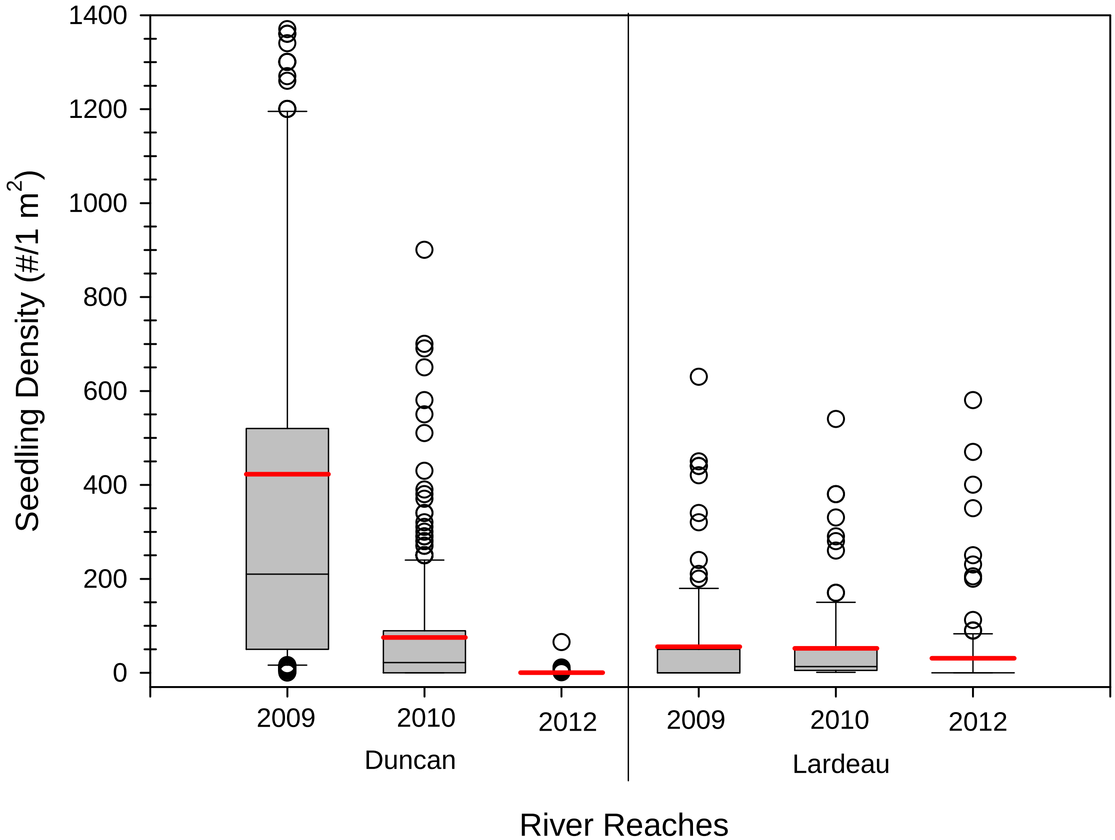


Figure 3-11: The 2009, 2010, and 2012 cottonwood germinant densities for the Duncan (left) and Lardeau (right) study reaches. The Y-axis scale extends to 1400 and some data points for Duncan seedlings (germinants) in 2009 exceeded this value with outliers from 1,650 to 4,800.

For box plots, the lower boundary of the box indicates the 25th percentile, the black line within the box marks the median, the wider red line marks the mean and the upper boundary indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. Outliers are indicated with an open circle.

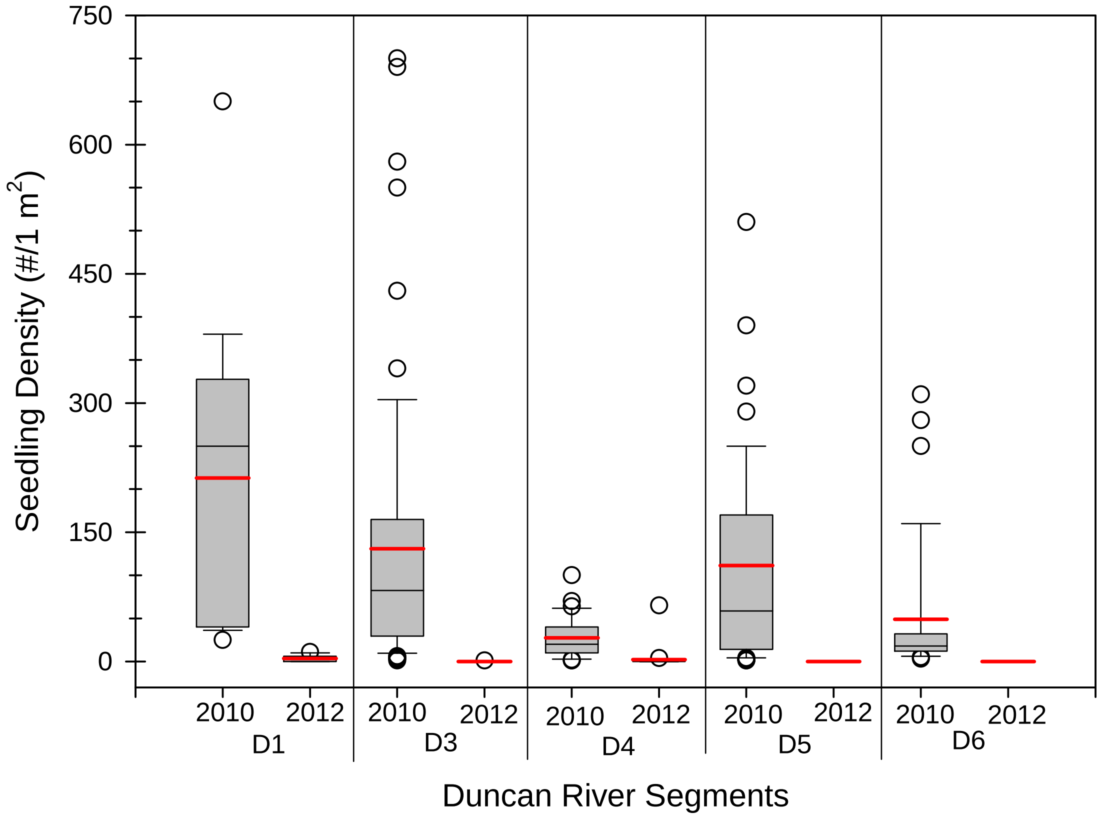


Figure 3-12: Seedling establishment densities (germinants) for 2012 compared to 2010 for each segment along the lower Duncan (D) River.

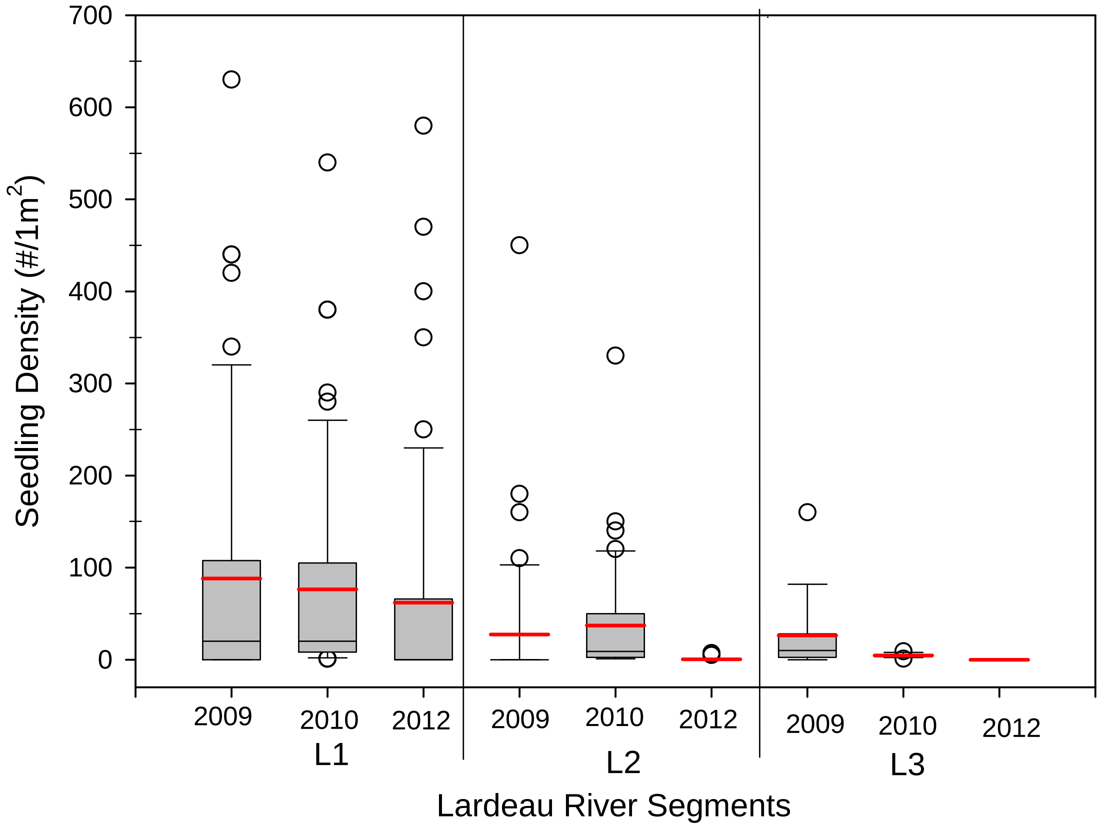


Figure 3-13: Seedling establishment densities (germinants) for 2009, 2010, and 2012 for each segment along the Lardeau (L) River.

3.4.2 Seedling survival from establishment to recruitment

In 2012, we monitored seedlings that had established in 2010, 2011, and 2012. The initial establishment and first year survival of the 2010 seedlings were assessed in 2010. The 2011 seedlings had no previous observations. Therefore, the information gathered during 2012 for the 2011 seedlings reflected survival through the first summer and the first winter. For comparisons average survival rates were calculated using available data from 2008 to 2012 seedlings.

The Lardeau and Duncan reaches had substantial decreases in seedling density by the end of the first growing season for 2009, 2010, and 2012. This is typical for cottonwood survival through the first season (Bradley and Smith 1986, Polzin 1998, Rood et al. 2007) (Table 3-4). However, initial seedling density was significantly lower in 2012 than the prior average for the Duncan Reach but not for the Lardeau Reach (Table 3-2 and Table 3-3). The seedlings from 2010 (two years old) and 2011 (one year old) had very low densities that survived to 2012 along the Duncan Reach. They were only recorded along Segment 4 and only along one transect line (Table 3-5). The 2010 seedlings had typically high establishment densities (22,830 seedlings) for the Duncan Reach in August 2010 while the establishment density of 2011 seedlings was unknown.

Seven out of the 10 observed one year old seedlings (70 per cent) survived along the Duncan Reach from August to October 2012. The total number of seedlings that survived from 2010 establishment (September 2010 density of 4,022) to August 2012 was three. The 2010 survival through the 2012 season and final number of recruitment was two (66.7 per cent) (Table 3-5).

Table 3-4: Statistical results from ANOVA Paired sample T-Test for cottonwood seedling survival rates (first summer) along the Lardeau and Duncan reaches for 2009, 2010, and 2012 germinant seedlings.

Reach	Establishment Year	*df*	*t*	*P*
Lardeau	July to Sep. 2009	141	3.75	<0.001
	Aug. to Sep 2010	141	4.84	<0.001
	Aug. to Oct. 2012	141	3.18	0.002
Duncan	July to Sep. 2009	271	10.3	<0.001
	Aug. to Sep 2010	219	9.99	<0.001
	Aug. to Oct. 2012	10	3.68	0.004

Table 3-5: The number of 2010 and 2011 germinants along the Duncan Reach in 2012.

2012 Monitoring Season – Duncan Reach				
Location	2010 (#) August 2012	2010 (#) October 2012	2011 (#) August 2012	2011 (#) October 2012
D4T1	**3**	**2**	**10**	**7**
D4T3	0	0	0	0
D4T5	0	0	0	0
Total	**3**	**2**	**10**	**7**
Survival %		**66.7**		**70.0**

The survival of the 2010 seedlings through the third summer was similar for the average survival rates (Table 3-6). However, the number that survived from the end of their first summer until August 2012 was very low. Many of the seedlings died by or in 2012. Thus, even after the first summer, seedlings are still vulnerable. The Duncan and Lardeau reaches had similar survival rates for the 2012 seedlings but lower than average (Table 3-6). This suggests that the factors affecting the survival of the few seedlings that established along the Duncan Reach were similar to the factors affecting survival along the Lardeau Reach.

Table 3-6: Average survival rates for first, second, and third summers and first and second winter survival rates for the lower Duncan River and Lardeau River (reference reach).

	Duncan Reach Average (%)	2012 (%)	Lardeau Reach Average (%)	2012 (%)
1st Summer Survival	22.2	13.0	31.0	19.0
1st Winter Survival	12.6		18.0	
2nd Summer Survival	68.9		79.2	
2nd Winter Survival	48.7*		43.5*	
3rd Summer Survival	75.0		75.9	

Note: * indicates the average is only from 2008 data, no other years had 2nd winter survival data since there was no 2011 monitoring.

The Lardeau Reach apparently had slightly higher average survival rates except for the second winter. The second winter survival calculations did not have multiple years of data to average and is the mean for 2008 seedlings survival of the second winter. Seedlings surviving the third season move into the recruitment category and are no longer tracked as seedlings the following year. The Lardeau Reach had four transect lines with 2010 and 2011 seedlings (Table 3-7) in comparison to the Duncan Reach that only had one transect line with 2010 and 2011 seedlings in 2012.

Table 3-7: The 2012 season occurrence of 2010 and 2011 seedlings recorded within quadrat sampling for the Lardeau Reach.

2012 Monitoring Season – Lardeau Reach				
Location	2010 (#) August	2010 (#) October	2011 (#) August	2011 (#) October
L1T1	13	11	11	8
L1T10	3	3	16	11
L1T20	21	21	17	17
L1T27	0	0	0	0
L1T36	0	0	0	0
L2T6	0	0	0	0
L2T15	2	2	3	3
L3T1	0	0	0	0
L3T9	0	0	0	0
L3T29	0	0	0	0
Total	**39**	**37**	**47**	**39**
Survival %		**94.9**		**83.0**

3.4.3 Longitudinal pattern of seedling establishment and survival (recruitment).

The two previous sampling years found no obvious spatial patterns that differentiated the Lardeau River from the lower Duncan River. Establishment and recruitment were greater on both reaches along wider meandering, braided segments compared to more constrained and less complex segments. The lower Duncan River 2012 flow pattern was not the regular Alt S73 flow regime. Subsequently, previously shown seedling establishment was minimal and restricted to two transect lines (Figure 3-14). Survival of 2010 seedlings (established in 2010) was also very low (Figure 3-14). The 2011 initial

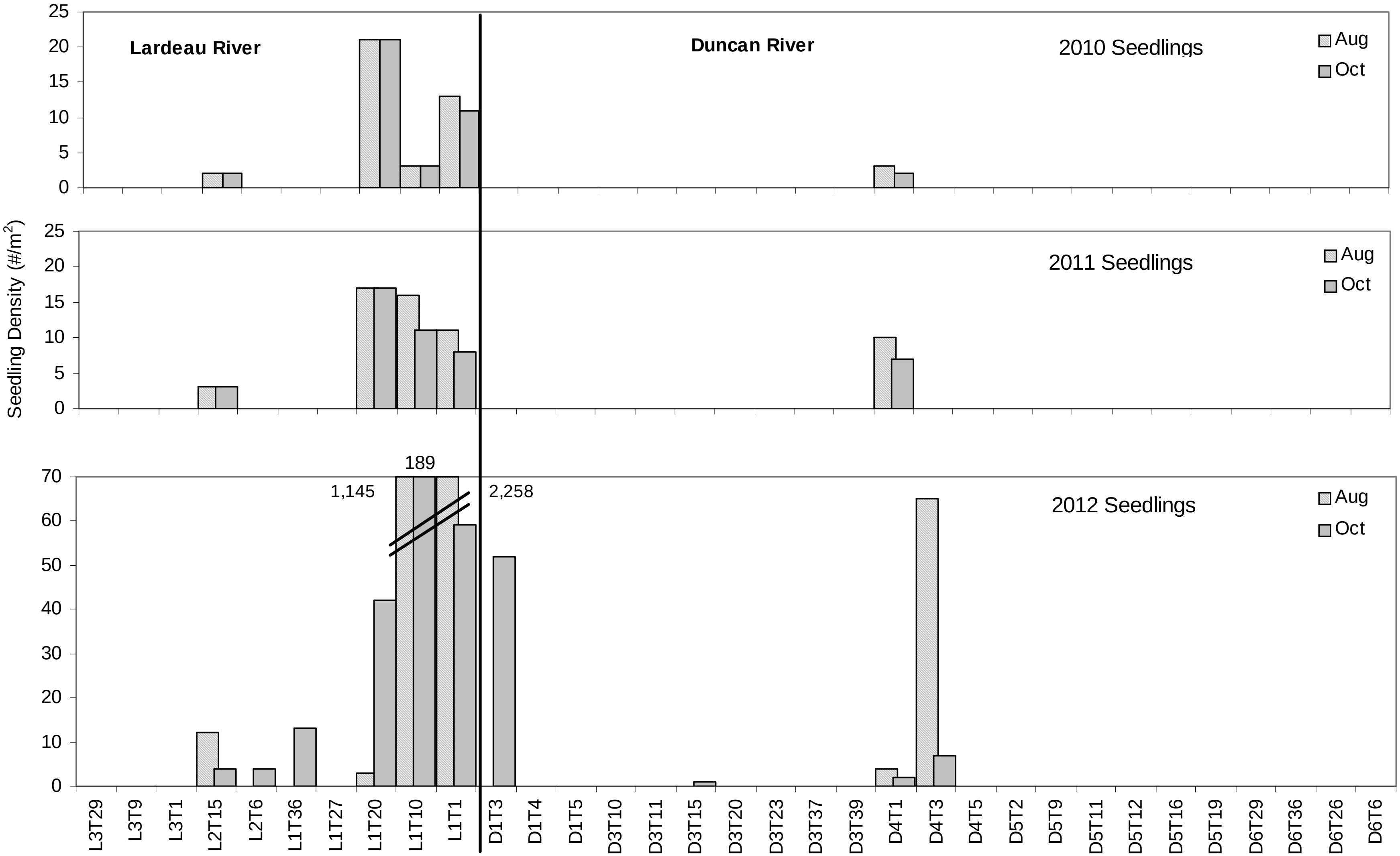


Figure 3-14: **Number of seedlings for 2010, 2011, and 2012 establishment years for the Lardeau and Duncan reaches during 2012 monitoring. Note the Y-axis scale difference for 2012 compared to 2011 and 2010. The 2012 Y axis scale was cut-off at 70 to show detail for transect lines with lower counts; the missing numbers are provided**

establishment is unknown but the density of 2011 seedlings in 2012 was apparently low for seedling densities after the first winter. There was good survival of 2009 and older seedlings along transect lines and throughout the point bars that the transect lines occurred on. These data were captured in herb quadrats that recorded the per cent cover for each species.

The Lardeau River, (reference reach) also had reduced seedlings in 2012 with four transect lines with no seedlings surviving from 2010 to 2012. Previous sampling years had two of these four transect lines with no seedlings from the three-year tracking period.

3.5 Transect Profiles and Transect-Specific Stage

Seed release occurred in June, July, and August (Section 3.3). A cross-sectional profile where the highest seedling establishment occurred in the past was selected to illustrate inundation levels and duration along transects in 2012. Transect profiles are from 2009 survey data, floodplain deposition from 2012 are not illustrated since transect re-surveys will not be completed until spring 2013 (see methods).

The mean stage level for July resulted in the river's edge 7 m from the POC for Duncan Segment 3 Transect line 15 (D3T15) (Figure 3-15A). The July mean stage was greater than 2 m above that of base discharge from July 16 through 27, with the peak level occurring from July 21 to 24. The August mean stage was 1.25 m for the transect stage level while the peak transect stage was 1.58 m August 1. The transect stage stayed at or near the peak level from August 1 to 13.

The reference Lardeau Reach experienced a 1-in-10 year flood return event June 24, 2012 with discharge of 331 m^3/s. June 25, daily mean discharge dropped to 315 m^3/s (transect stage 1.8 m) (Figure 3-16A). The June peak discharge inundated the floodplain including the transect POC. Discharge gradually increased from June 11 (186 m^3/s, 0.50 m transect stage) to the peak flow and gradually decreased after the peak. There was a one day peak on July 1, with discharge of 301 m^3/s (1.64 m transect stage). This decreased the following day and was below 200 m^3/s (0.58 m transect stage) by July 19, 2012. The spring freshet peak contrasts with the (regulated) Duncan peak which was a month later and persisted for a longer duration.

3.5.1 Transect profiles and vegetation community locations

The transect D3T15 profile is shown in Figure 3-15 and has the vegetation types delineated to illustrate inundation (Figure 3-15B). Seedling recruitment areas from 2009 and 2010 show the contrast to 2012 seedling recruitment. The seedling areas from 11 m to 26 m had no 2012 seedlings but within the herb quadrats, 2009, and older cottonwood seedlings were assessed by vegetation cover. The tree band from 26 m to 34 m was assessed as a shrub community in 2010 and by 2012 the shrubs were greater than 2 m in height and thus assessed as trees. There was still shrub communities on either side of this new tree area.

The second seedling recruitment area in 2010, from 42 m to 70 m was mainly bare ground in 2012. Vegetation ended at 26 m with a few small willows to 50 m but not along the transect line. Sediment deposition occurred throughout both zones with 2009 and 2010 seedlings. Past recruitment in this area was either scoured or buried.

Sediment deposition patches and bands occurred through the highest elevation transect zones where trees and the POC occurred. This was observed for all transects along the Duncan Reach. This indicated that as the water receded sediment deposition occurred.

The Lardeau Segment 1 and Transect line 10 (L1T10) is displayed (Figure 3-16) and was typical of that segment. It contrasts with D3T15 in that seedling recruitment occurred in the same area where 2009 and 2010 recruitment occurred. The tree band expanded from 20 m to 25 m after the 2009 sampling. The shrub band in 2009 occurred from 25 m to 41 m and this was reduced to two smaller bands 25 to 27 m and 37 to 39 m in 2012. Scour was most likely cause but alternately deposition could have been responsible for shrub toppling and burial.

Re-survey of all transect lines along the Lardeau and lower Duncan rivers in 2013, will quantify the scour and sediment deposition, key factors affecting vegetation and seedling recruitment.

The high water during 2012 resulted in one site in Segment 6 along the Duncan Reach being removed from data collection. A massive log-jam was deposited on top of the POC (the tag tree was a large willow) and covered most of the transect line. A new transect line will be surveyed in the spring of 2013 upstream from the current position. The Lardeau Reach had one transect line (T29) in Segment 3 completely scoured away, including the 114 year-old cottonwood tag tree resulting in the transect line being captured by the river channel. A new randomly selected location for another transect line will be completed and established in the spring of 2013 to replace L3T29. A second transect line (T27) in Segment 1 was almost scoured away. The transect line was 26 m long in 2009 and 6 m long in 2012. All of the recruitment zone and most of the floodplain on the river side of the POC was removed and the bank is now an eroding bank. No recruitment zone was associated with or near the transect line. A new line will also be established in 2013 to replace L1T27.

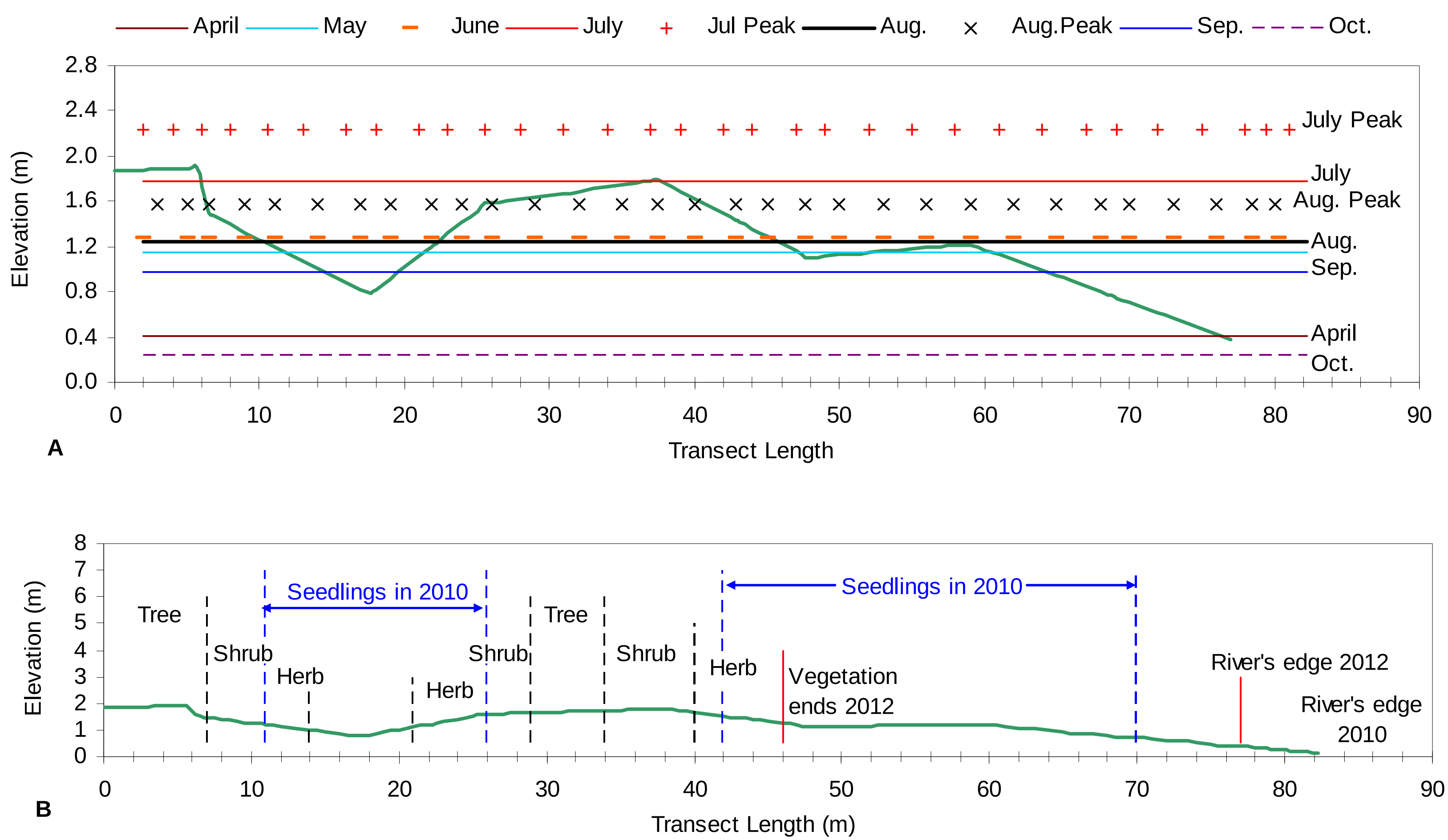
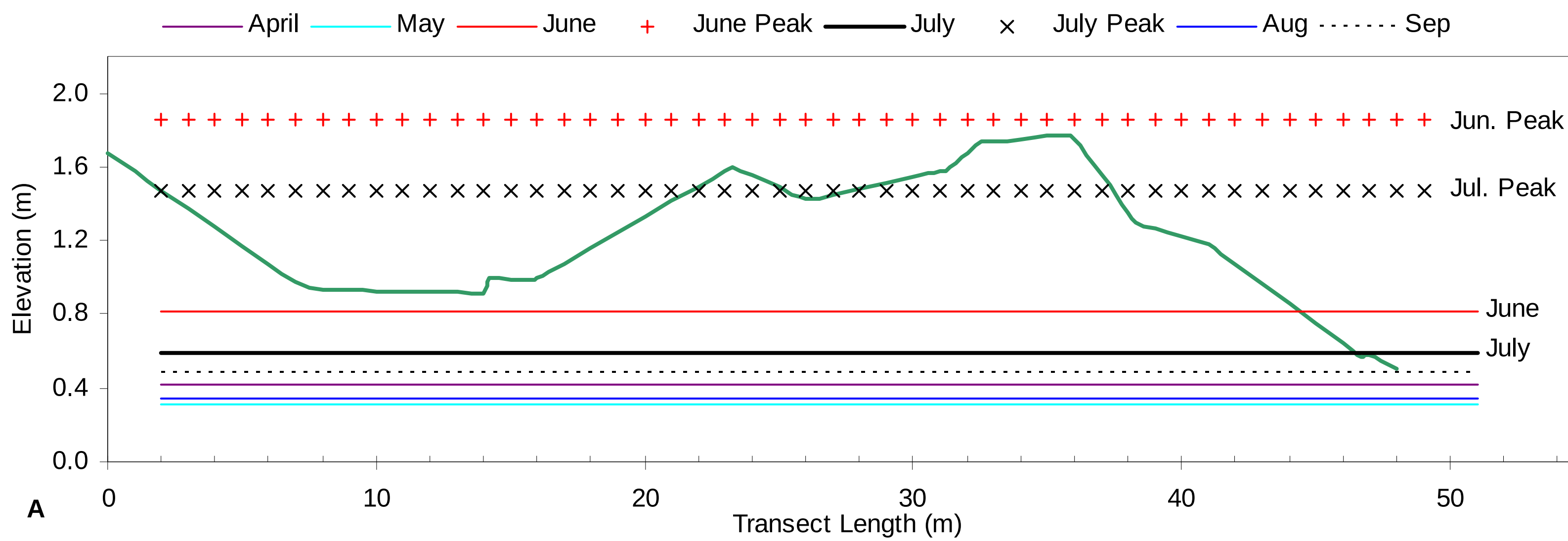


Figure 3-15: **Profile of lower Duncan Segment 3, Transect 15 (D3T15) (A) showing the transect profile (2009) and monthly mean transect stage levels during the growing season and peak stage transect levels for July and August 2012. (B) Shows the same transect line with vegetation communities along the profile, seedling zones are from 2009 and 2010 sampling years. There was only one seedling found from August seed release in October. Note the expanded Y-axis scales.**



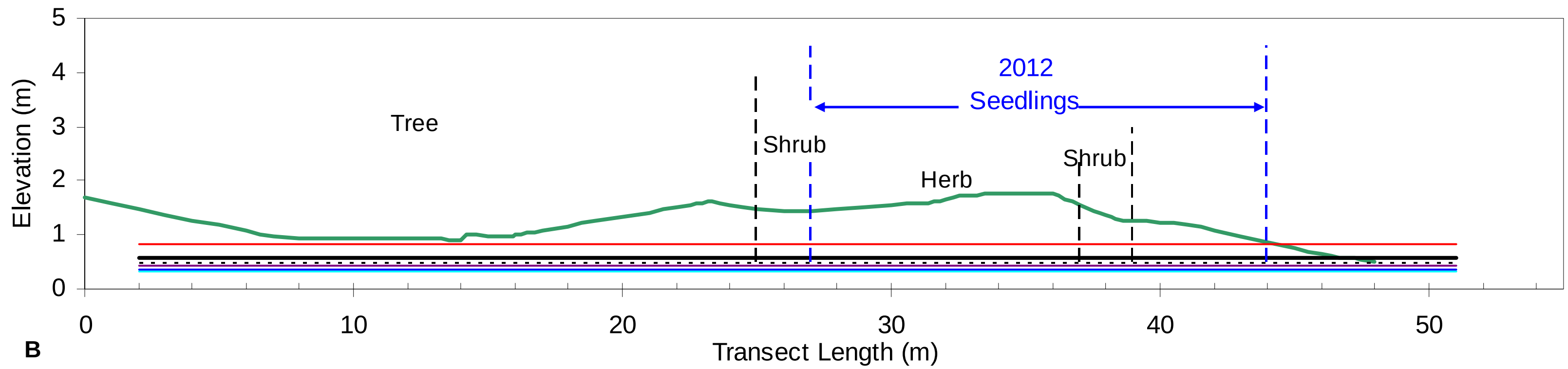


Figure 3-16: Profile of Lardeau Segment 1, Transect 10 (L1T10) (A) showing the transect profile (2009) and monthly mean transect stage levels during the growing season and peak stage levels for June 24 and July 1, 2012. (B) Shows the same transect line with vegetation communities along the profile. Note the expanded Y-axis scales.

3.6 Riparian Vegetation

Two composite measures were calculated for the extent of vegetation along the Lardeau and lower Duncan rivers. Per cent shoot covers were estimated for the individual plant species and these were combined to provide the total per cent shoot cover within each quadrat. Because multiple shoot layers are possible, total cover can exceed 100 per cent. This total cover provides an integrative measure of the abundance or amount of vegetation. The second aggregate measure represented biodiversity and particularly, species richness, the number of different plant species that occurred in each quadrat. These measures were calculated for each quadrat and averaged for each transect, but it should be recognized that these are not uniform along the transect lines.

The comparison of vegetation cover versus species richness revealed 71 per cent association in 2012 for the Lardeau River. In contrast, the lower Duncan River had a weak association of 17 per cent correspondence but this was still highly significant (P<0.001) (Figure 3-17). Analysis of Covariance (ANCOVA) to contrast the two rivers (Table 3-8) indicated a significant association between cover and richness (the covariate). The influence of river was not significant. The weaker correspondence between vegetation cover and richness along the Duncan River contrasts with the baseline data in 2009 that had a stronger correspondence between vegetation cover and richness.

Table 3-8: Analysis of Covariance for mean cover (dependent variable) versus richness (covariate) across the two rivers (independent, fixed factor).

Dependent Variable: Mean Cover

Source	**SS**	***df***	**Mean Square**	***F***	***P***
Corrected Model	63574(a)	2	31787	23.3	.000
Intercept	52.4	1	52.4	.038	.845
Mean Richness (covariate)	52988	1	52988	38.8	.000
River (fixed factor)	1446	1	1446	1.06	.304
Error	398621	292	1365		
Total	1094372	295			
Corrected Total	462196	294			

a R Squared = .126 (Adjusted R Squared = .120)

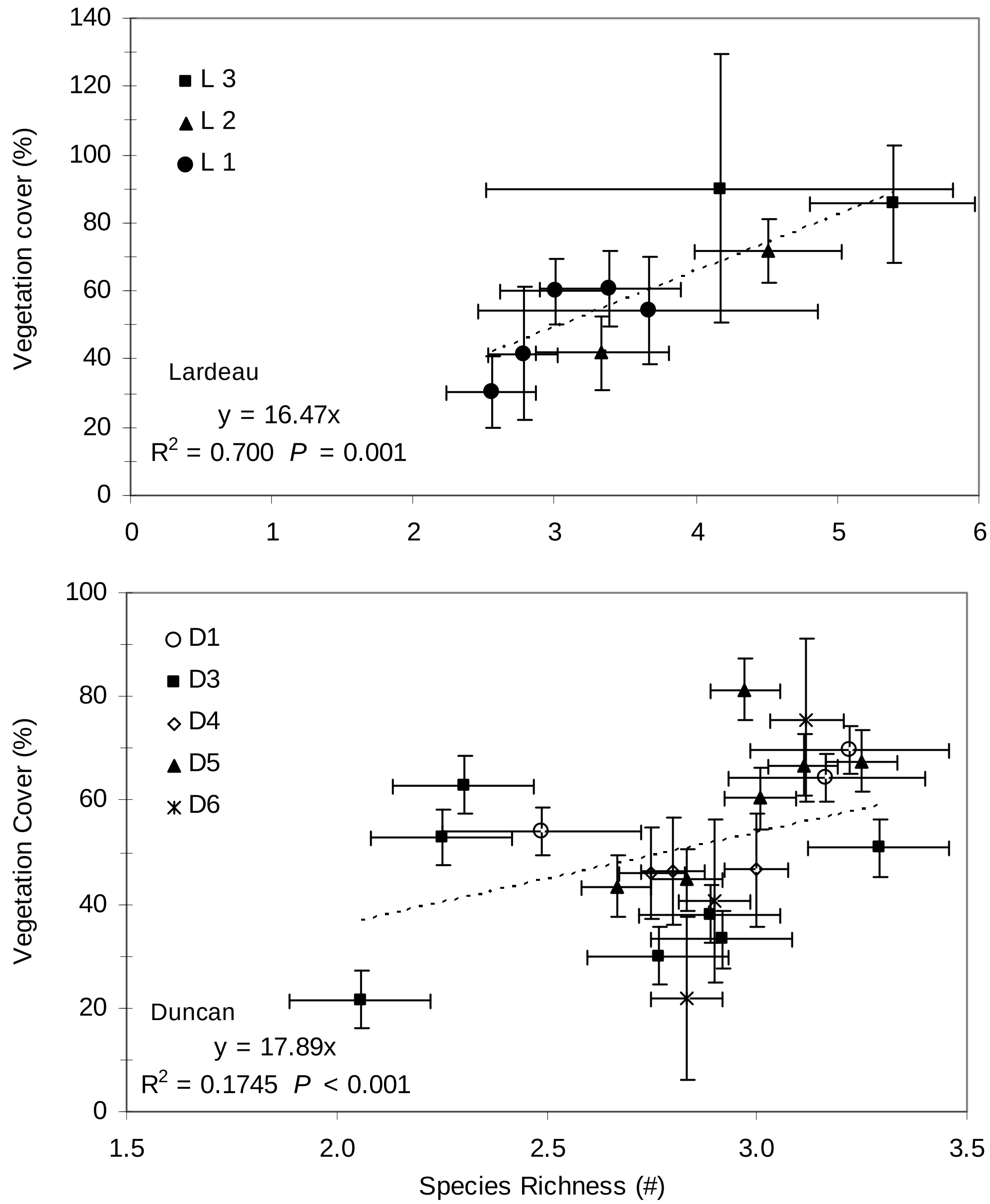


Figure 3-17: Mean (± s.e.) vegetation cover versus mean (± s.e.) species richness for transects along the Lardeau (L, top n=9) and lower Duncan (D, bottom, n=22) rivers. Linear regression displays the relationship between cover and richness for each river. Note the different X axis scales

We subsequently investigated the possible variation of cover or species richness between 2009 and the 2012 condition. The Lardeau Reach had no significant difference in vegetation cover across the three sizes of quadrats, statistical results are in Appendix 4 (Figure 3-18).

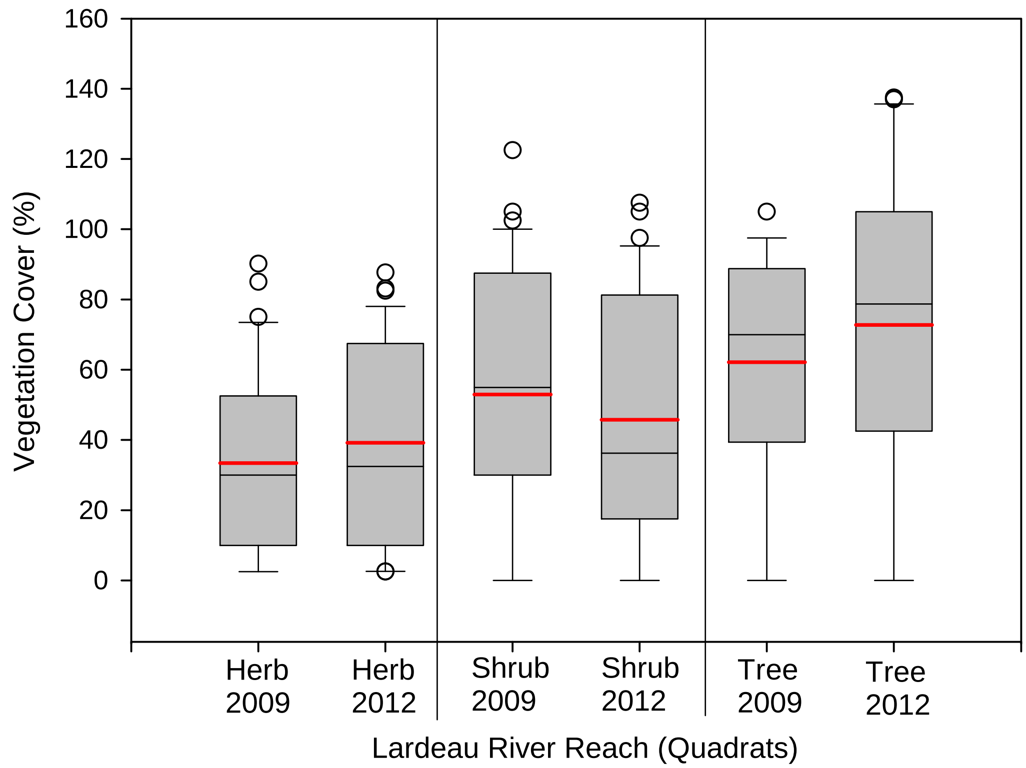


Figure 3-18: Vegetation per cent cover for the Lardeau Reach for each size of quadrat, comparing 2009 versus 2012.

There were significant differences for the Lardeau Reach in species richness between years (P=0.015, t = -2.52, df = 44 square root transformation for the count data). Significant differences occurred between Herb ($P < 0.001$, t = 5.58, df = 22) and Shrub (P = 0.001, t = 3.81, df = 21) quadrats with increased richness in 2012 (Figure 3-19 graphed using number of species).

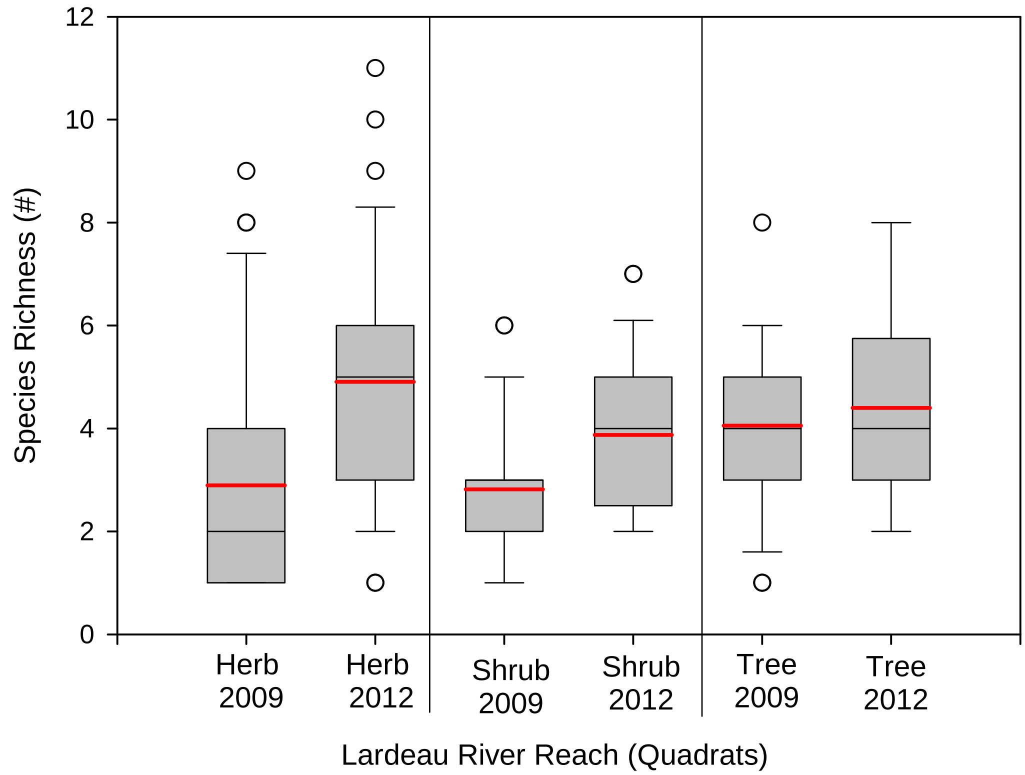


Figure 3-19: **Species richness (number of species) for the Lardeau Reach for each size of quadrat for 2009 versus 2012.**

Per cent cover vegetation for the Duncan Reach was similar between 2009 and 2012 with no significant difference (Figure 3-20). There was also no significant difference between years for species richness. Richness within each size of quadrat was very similar between Shrub and Tree quadrats and an apparent slight increase within the Herb quadrats but this was not statistically significant (Figure 3-21).

The lower Duncan River had 90 species recorded in 2012 and 85 species occurred in 2009. There was no significant difference when compared between years with the number of species per quadrat along the transect lines. The Lardeau River had 57 species recorded in 2012 and 57 species in 2009 when the transect line removed by the river in 2012 was removed from the 2009 data set. However, there was a significant difference found between years for the mean number of species within quadrats. The significant difference was between the number of species per quadrat and not the actual number of species for the Lardeau River Reach.

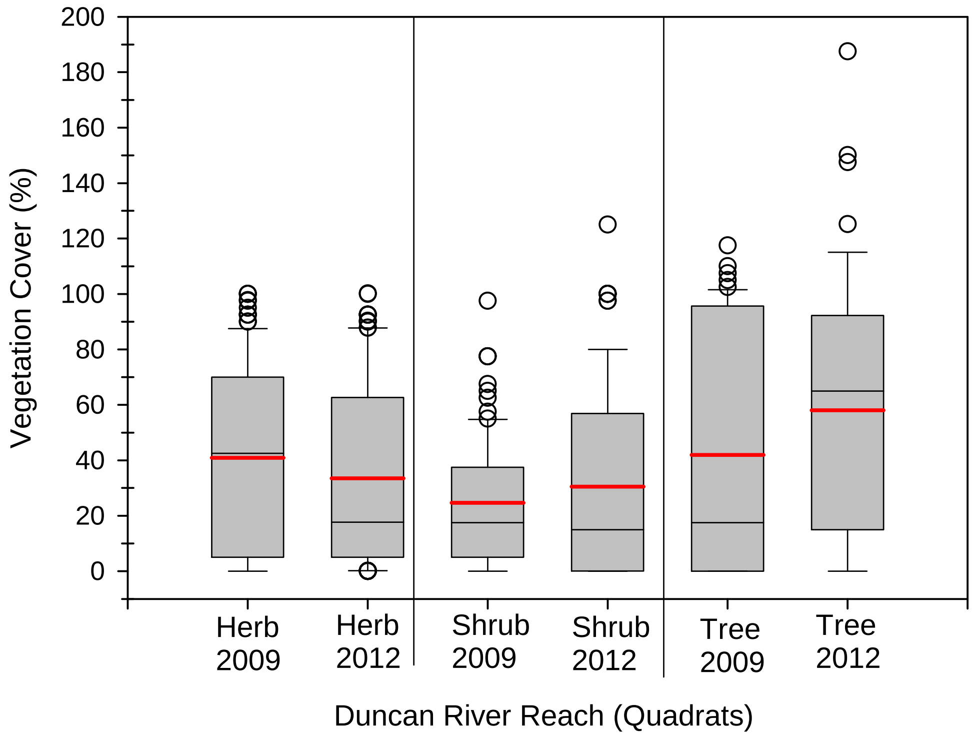


Figure 3-20: **Vegetation per cent cover for the Duncan River for each size of quadrat comparing 2009 versus 2012. Vegetation cover can be greater than 100 per cent when multiple layers of vegetation occurs.**

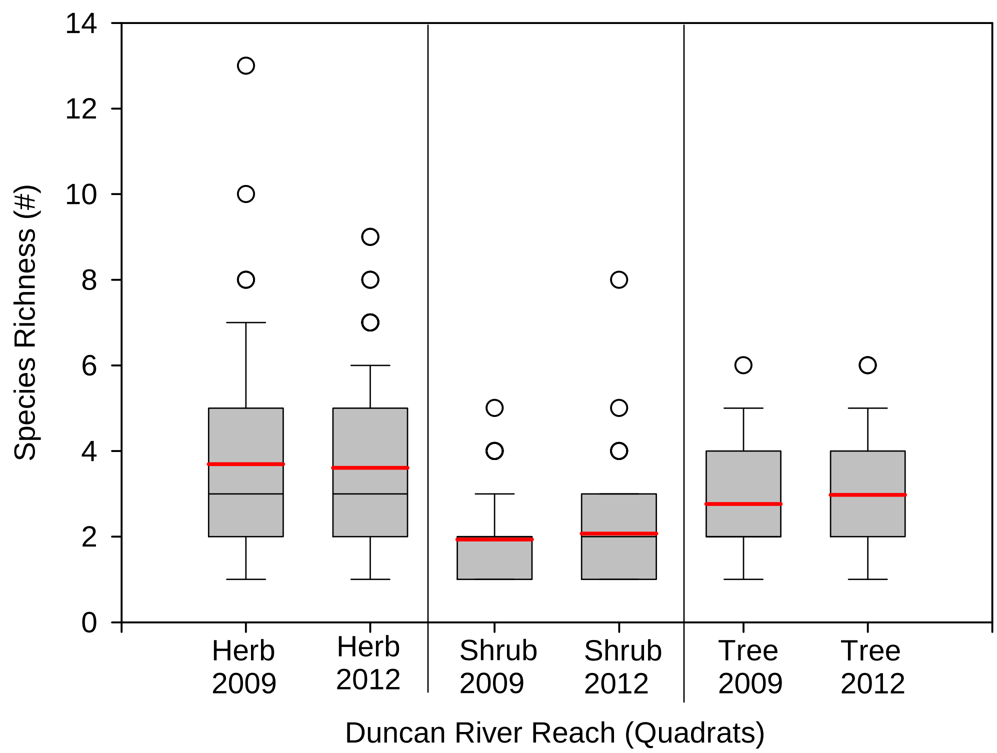


Figure 3-21: **Species richness (number of species) for the Duncan River for each size of quadrat for 2009 versus 2012.**

3.7 Riparian Community Monitoring

Ten plant community types were delineated in 2009 (Table 2-2). Two additional Community Types were added in 2012. These occurred in 2009 but could not be identified from the spring growth stage at that time. These areas were added to the 2009 delineations before comparison between the two years. Community change was recorded by area (ha) for each polygon and compared by segments for the Duncan and Lardeau reaches. The data summaries of the mapped vegetation communities using the orthorectified aerial photographs are listed in Table 3-9. The total area for each community type (1 to 12) and the active channel (0) for 2009 are listed on the row below the totals for 2012 for comparison. There were no significant differences for the vegetated area and active channel area for the lower Duncan (vegetated P = 0.785, t = 0.279, df = 11 vegetated and channel P = 0.856, t = 0.185, df = 12) or the Lardeau rivers (vegetated P = 0.516, t = 0.68, df = 8 vegetated and channel P = 0.998, t = 0.003, df = 9) between 2009 and 2012 (Figure 3-22).

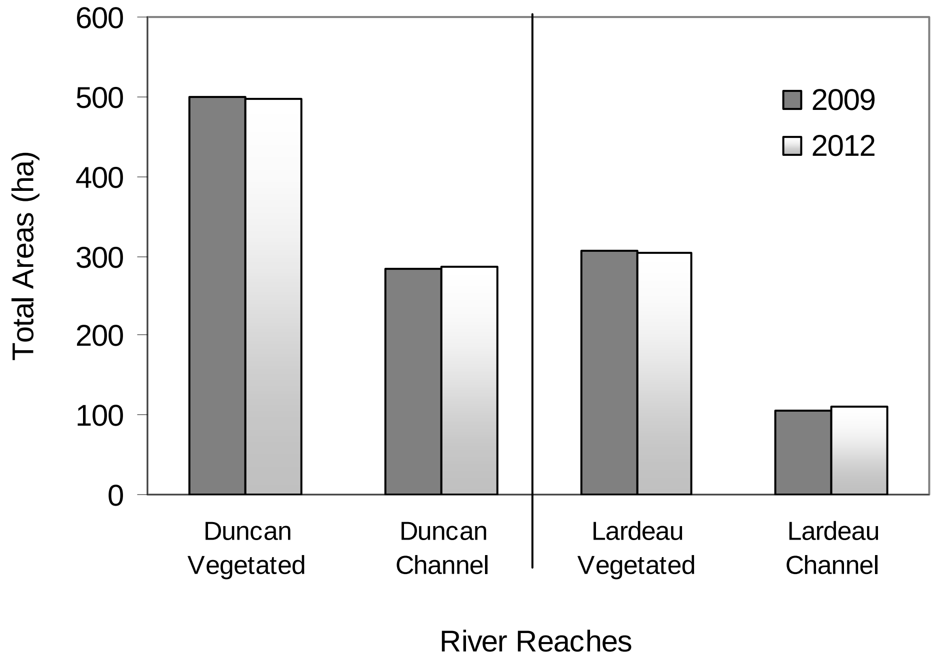


Figure 3-22: Total vegetated and active channel areas (ha) for the Duncan and Lardeau reaches in 2009 versus 2012.

Table 3-9: Summary of area (ha) occupied by the 12 vegetation communities for the lower Duncan and Lardeau rivers and active channel area. Total areas for each Community Type for 2009 are supplied below the totals for 2012. Community Type codes are listed below table.

Summary of Community Types for the Lower Duncan River (D) 2012															
Segment #	0	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total (ha)	Vegetated Total (ha)
1	25.42	1.51	1.17		5.34	8.83		8.96	0.05	0.50		0.31		52.10	26.68
2	12.83	0.08	1.69		6.93	9.13		9.45	0.25	1.45				41.81	28.98
3	57.17	6.05	11.78	0.38	20.18	53.23		2.94	0.62	33.62		1.17	0.18	187.31	130.15
4	12.95	0.33	0.97		1.11	6.13		4.07		14.17		0.33	0.02	40.10	27.14
5	38.62	13.94	16.58		16.29	78.16	3.28		0.28	8.81		0.71		176.67	138.05
6	140.33	64.30	25.36	10.99	3.03	25.62		0.98			6.36	10.09		287.06	146.73
Total (ha)	**287.31**	**86.21**	**57.55**	**11.37**	**52.87**	**181.10**	**3.28**	**26.41**	**1.20**	**58.55**	**6.36**	**12.61**	**0.20**	**785.04**	**497.73**
2009 (ha)	**282.87**	**88.95**	**58.90**	**10.84**	**52.64**	**179.13**	**3.28**	**26.41**	**1.20**	**58.80**	**6.36**	**20.12**	**0.20**	**783.13**	**500.26**
Summary of Communities Types for the Lardeau River (L) 2012															
1	47.53	6.48	11.73	0.31	32.24	72.48	0	7.76	4.27	1.92		1.54		186.27	138.74
2	38.17	2.61	14.02		8.13	44.98	0	26.68	0.00			2.75		137.34	99.18
3	24.20	2.69	6.30		10.05	16.65	0	28.57	0.21			0.74		89.41	65.21
Total (ha)	**109.90**	**11.79**	**32.06**	**0.31**	**50.41**	**134.11**	**0**	**63.01**	**4.48**	**1.92**		**5.03**		**413.02**	**303.13**
2009 (ha)	**105.83**	**10.48**	**31.4**	**0.31**	**50.96**	**138.48**	**0**	**61.16**	**4.52**	**1.92**		**7.95**		**413.00**	**307.17**

Note: column codes are:

0 – active river channel;
1 – <2 m tall cottonwood and willow;
2 – <5 m tall cottonwood, willow, deciduous and conifer;
3 – <5 m tall willows (occasional cottonwood, alder);
4 – cottonwood and cottonwood mix - early seral;
5 – cottonwood and cottonwood mix - late seral;
6 – very old (>200 yr) cottonwood;
7 – mature conifer (cedar, hemlock, fir, larch, pine);
8 – logged/regenerating;
9 – anthro (agriculture, buildings, roadways, industry, etc.);
10 – marsh (horsetail dominated);
11 – recruitment zones (present and potential); and
12 – sedges/grasses

3.7.1 Lower Duncan and Lardeau rivers analyses by segments

The lower Duncan River Reach showed similar area for vegetated area and channel area by river segments (Figure 3-23). Additionally, Community Type areas for 2009 versus 2012 were similar in total areas. The Community Type 11, recruitment zones present and potential, showed the greatest difference (Figure 3-24).

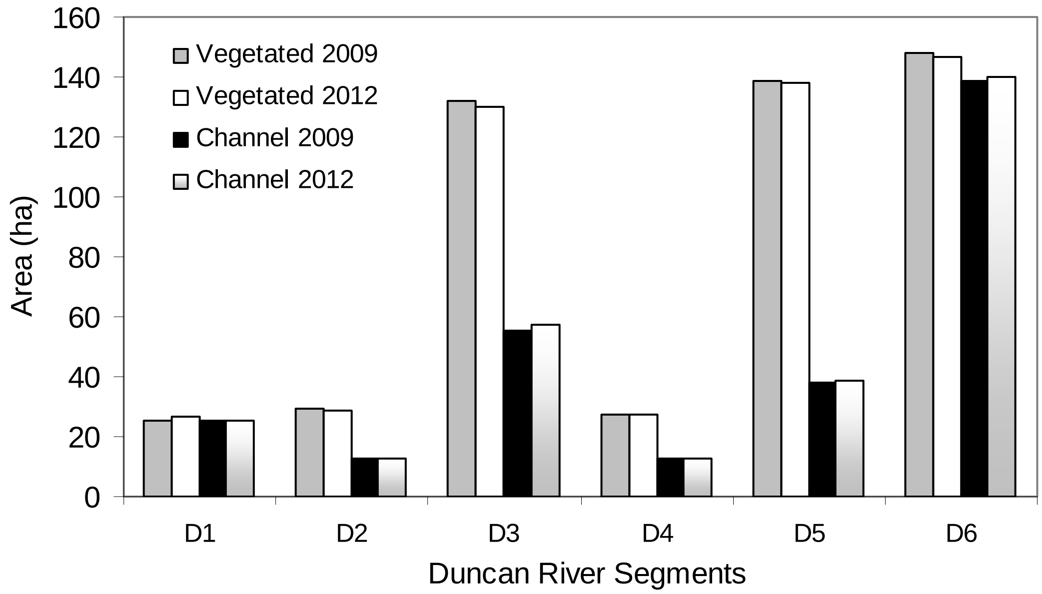


Figure 3-23: Total community type areas and active channel areas for 2009 versus 2012 along the Duncan River segments.

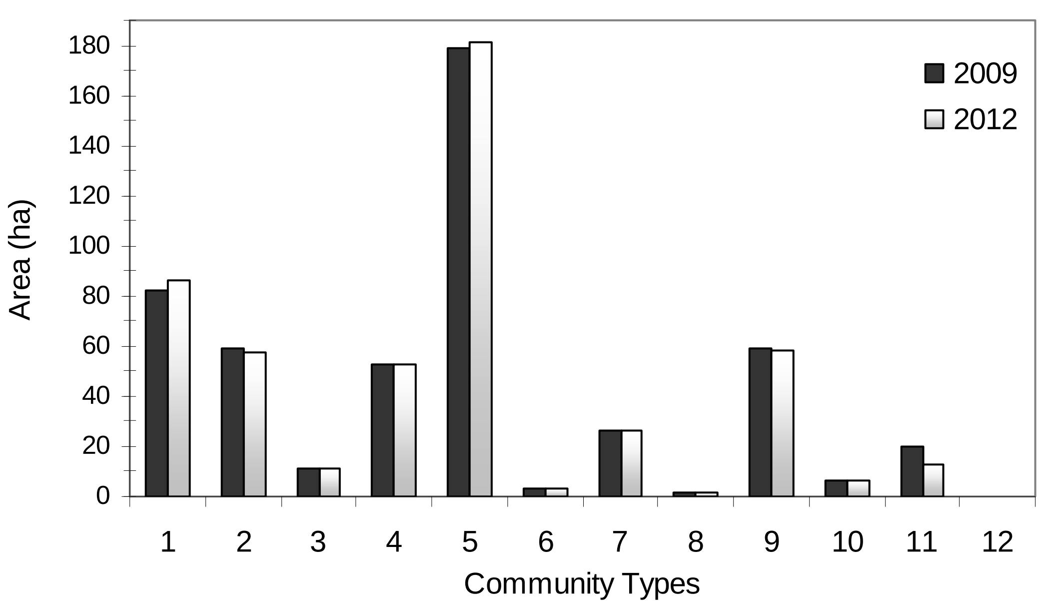


Figure 3-24: Community Type areas (ha) along the Duncan River for 2009 versus 2012.

Community types were compared between segments with no significant difference for 2009 versus 2012. However, Community Type 11, while not significant at the 0.05 alpha it showed the strongest trend of change in area since 2009 with an $R^2 = 0.96$ ($P = 0.066$, $t = 2.34$, $df = 5$). Segments 2 and 4, were similar but Segments 1, 3, 5, and 6 show a decreasing trend in recruitment area since 2009 (Figure 3-25).

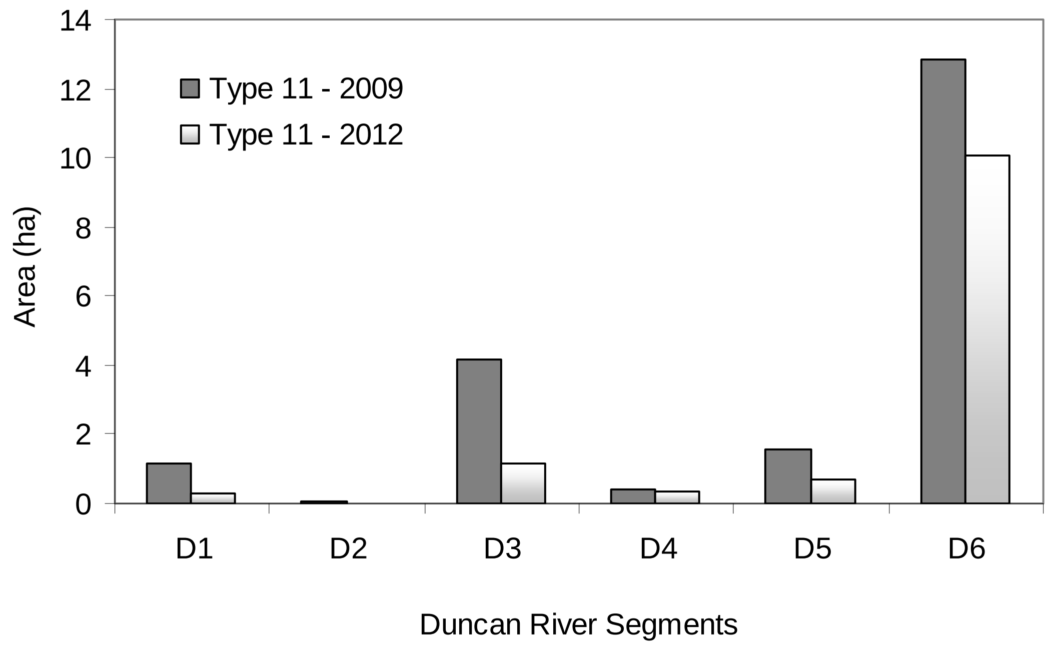


Figure 3-25: Community Type 11 area along the Duncan River segments.

The Lardeau River Reach was similar to the lower Duncan River Reach with no significant differences between vegetated areas including recruitment areas for 2009 versus 2012 by reach or by segments (Figure 3-22 and Figure 3-26 respectively). There were no significant differences between Community Types along the Lardeau River for 2009 versus 2012 (Figure 3-27). Similar to the Duncan River, Community Type 1 (cottonwood and willow less than 2 m tall) showed an increase in total area from 2009 to 2012 and Community Type 11 (recruitment zones present and potential) showed a decrease in area from 2009 to 2012 (Figure 3-28). Segment 2 showed the greatest increase in Community Type 1 area since 2009. Segments 1 and 3 showed the greatest decrease in Community Type 11 area since 2009.

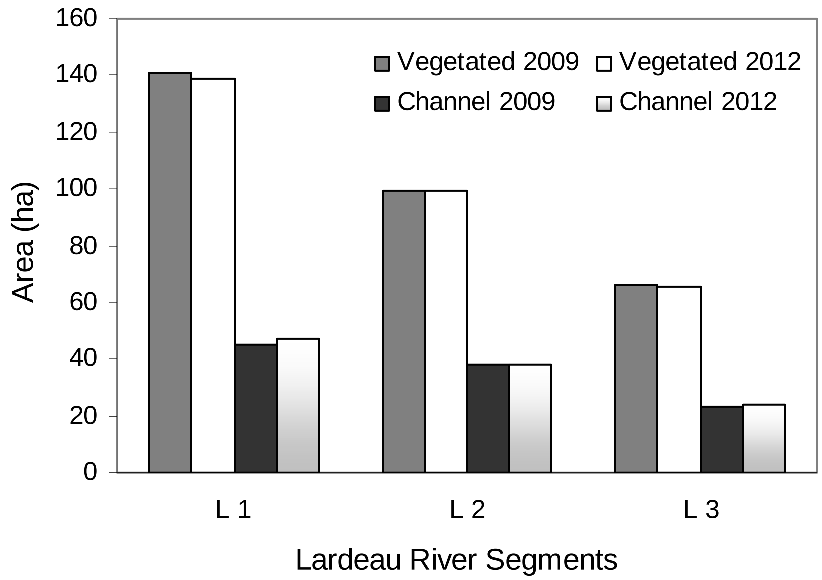


Figure 3-26: Total areas for Community Types and the active channel for 2009 versus 2012 along the Lardeau River segments.

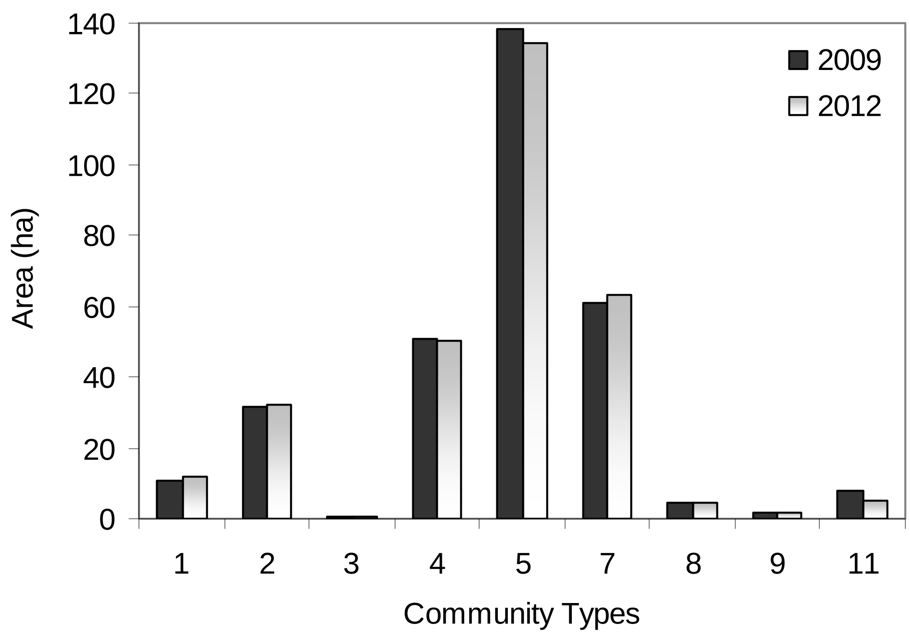


Figure 3-27: Community Type areas (ha) along the Lardeau River for 2009 versus 2012.

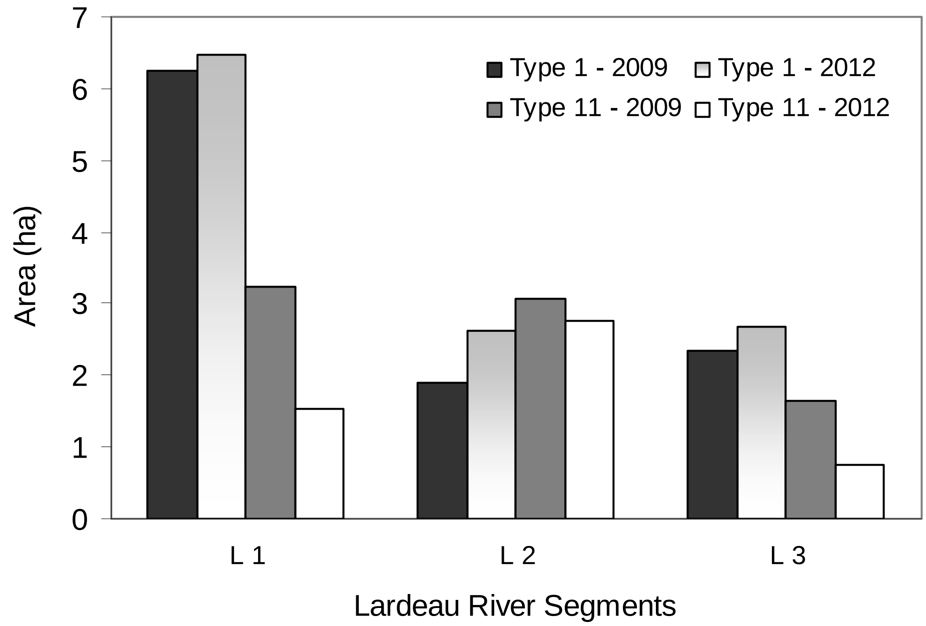


Figure 3-28: Community Types 1 and 11 area along the Lardeau River segments.

3.7.2 Lower Duncan and Lardeau rivers analyses by meander lobes

Comparison of the total lower Duncan River vegetation community types showed no significant difference (P = 0.122, t = 1.63, df = 16) in meander lobe area from 2009 to 2012 (Figure 3-29). There was a slight downstream pattern with greater variation occurring between years for DM14, 16, and 17 with slight decreases in area since 2009. Vegetation community type areas were similar in 2012 compared to 2009. Only Community Type 11 showed a significant difference in meander lobe area from 2009 to 2012 (P = 0.026, t = 2.47, df = 15, Figure 3-30). DM6 (Meander lobe 6) did not have recruitment areas in 2009 or in 2012 so it was not included in the analysis. The area of Community Type 11 decreased in 13 of the 16 Meander lobes (81 per cent), and increased in three Meander lobes (19 per cent) from 2009 to 2012. There was no clear spatial pattern for the three sites with increased area of Community Type 11: DM1 is in Segment 1, just below the dam and Lardeau River confluence, spill zone; DM13 is in Segment 5, broad alluvial (braided) zone; and DM17 is in Segment 6, the delta zone on a braided channel of the Duncan River upstream of Kootenay Lake.

The high spring freshet and flow regime of the lower Duncan River in 2012 required replacement of two transect lines from 2009. Transect line 1 in Segment 4 (D4T1) was originally established perpendicular to the Duncan River in 2009 and 2010. It now has Hamill Creek running across the recruitment zone (Figure 3-31). The second transect was impacted by a large log debris pile on top of the POC and part of the line. Sampling occurred on the downstream side of the line resulting in the top part of the line that was not covered by the logs having the sampling area covered by logs (Figure 3-32). A short section of the line does not have logs on the vegetation or on the sampling side of the line but the transect line could not be laid out accurately with no starting point (POC).

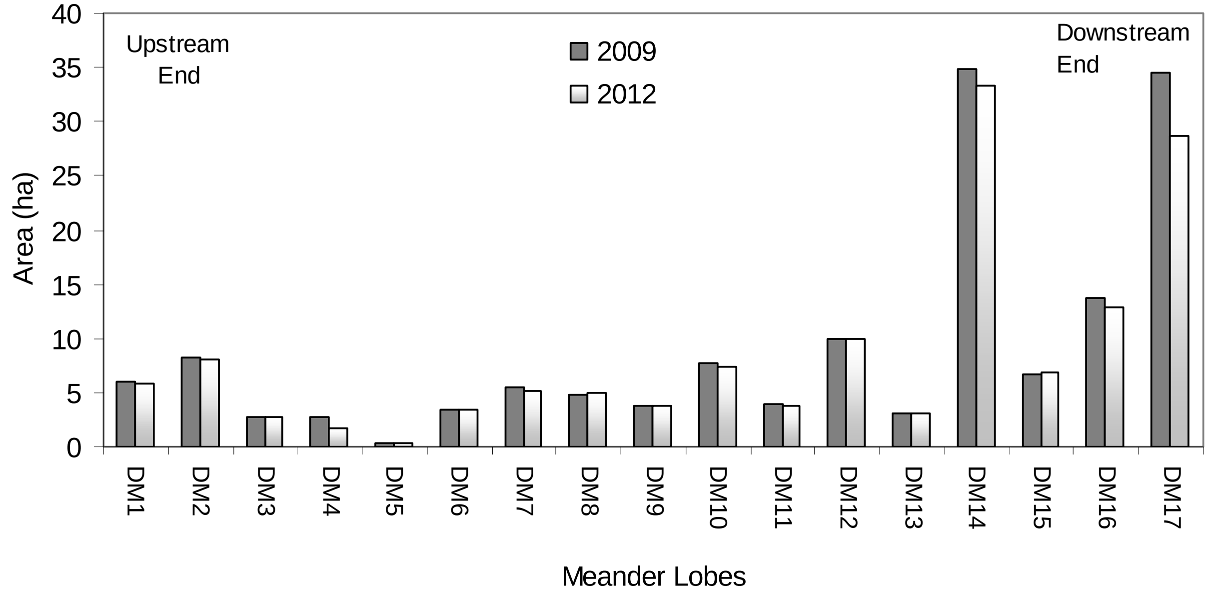


Figure 3-29: Total area for all vegetation community types along the Duncan River for 2009 versus 2012 areas (ha).

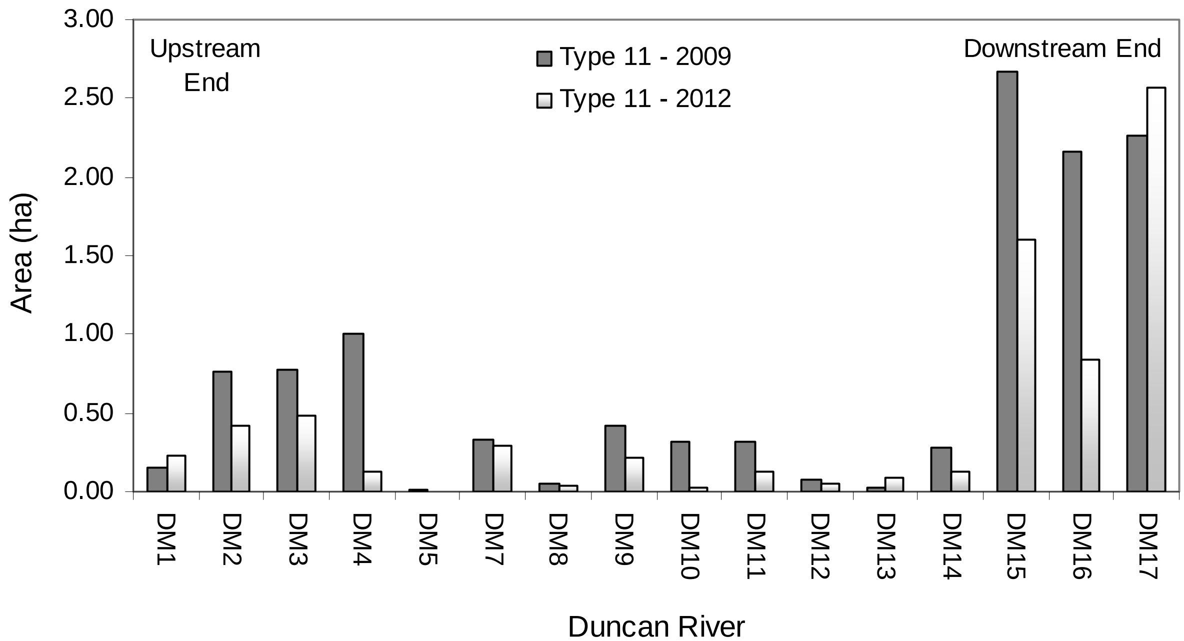


Figure 3-30: Comparison of area between meander lobes along the Duncan River for the Community Type 11 (recruitment) for 2009 versus 2012.

Figure 3-31: Air photos of Segment 4, Transect 1 (D4T1) in April 2009, June 25, 2012, and October 2012.

Figure 3-32: Air photos of Segment 6, Transect 26 (D6T26) in April 2009, June 2012, and October 2012.

There was no significant difference in meander lobe areas on Lardeau River LM1 to LM9 from 2009 to 2012 (*P* = 0.136, *t* = 1.66, *df* = 8). However, of the five community types (Community Types 1, 2, 4, 5, and 11) occurring along the meander lobes delineated areas, Community 11 had a significant difference for 2009 versus 2012 (*P* = 0.015, *t* = 3.082, *df* = 8) (Figure 3-33). Meander lobe 5 (LM5) with L2T6 had the greatest amount of the recruitment zone area scoured. Figure 3-34 shows LM5 in a series of photos of the same area in 2009, during the peak flow June 25, 2012, and October 2012. Figure 3-35 shows LM7 and the reduction in recruitment area since 2009. Some of the new area will become potential recruitment area if/when sediment deposition occurs in subsequent years resulting in 'safe' recruitment elevations.

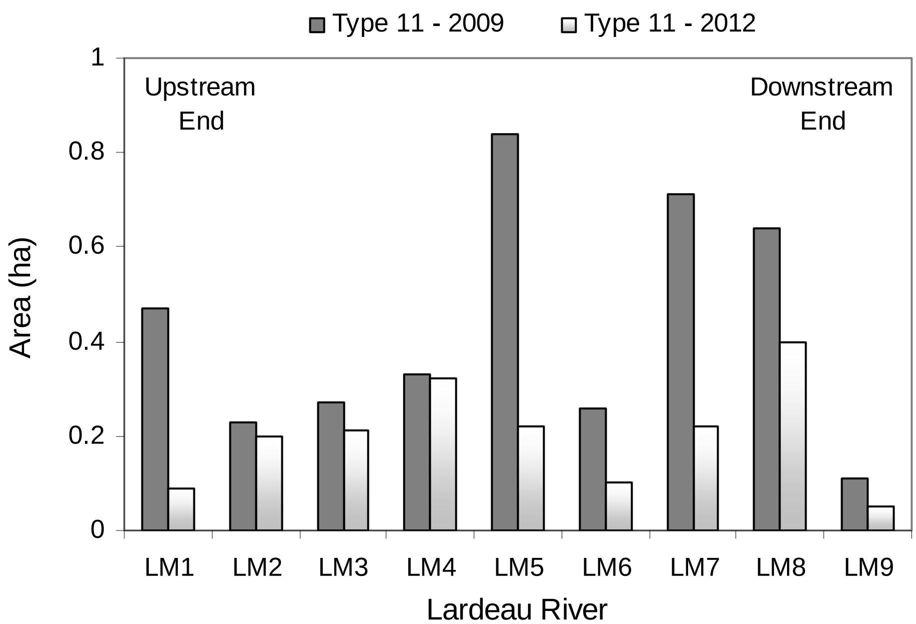


Figure 3-33: Comparison of areas for meander lobes along the Lardeau River for the Community Type 11 (recruitment) for 2009 versus 2012.

The Lardeau River experienced channel migration since 2010. Some of the scour directly impacted our study transects. LM1 at the upstream end of the study reach had the largest impact with the POC and substantial area of mature forest scoured away. This resulted in the transect POC now being located in the middle of the channel (Figure 3-36). LM7 had a substantial area of the recruitment zone scoured but most of this area did not occur along L2T6. Along the transect line (L2T6) a large area colonized by juvenile cottonwood and willows five years-old and older (Community Types 1 and 2) first recorded in 2009 was scoured away by the river after 2010. The transect line was 27 m long in 2009, 24 m long in 2010 (lost Community 11), and 6 m long in August, 2012. Community Types 11, 1 and 2 were lost from this transect (Figure 3-37).

Figure 3-34: Aerial photos of the meander area LM5 in April 2009, June 2012, and October 2012.

Figure 3-35: Aerial photos of the meander area LM7 in April 2009, June 2012, and October 2012.

Figure 3-36: **LM1 with Lardeau Segment 3, Transect 29 (L3T29), aerial photos of the meander area in April 2009, June 2012, and October 2012.**

Figure 3-37: **Part of ML7 with Lardeau Segment 2, Transect 27 (L2T27), aerial photos of the transect area in April 2009, June 2012, and October 2012.**

4 DISCUSSION

4.1 Seasonal Weather

Seasonal weather patterns during 2012 influence results for the riparian cottonwoods monitoring and the vegetation community mapping. A combination of above average snow levels, extreme precipitation levels in June, and emergency flood control measures required by the Duncan Dam operations added an important flood data set for the decade-long study. The 2012 monitoring was able to assess the affect of extended flood inundation on riparian cottonwood along the lower Duncan River, the affect of the Q_{10} flood event along the Lardeau River, and channel migration extent for both the lower Duncan and Lardeau rivers. Both the extended flood period on the lower Duncan River and the Q_{10} flood event the Lardeau River experienced in 2012, followed similar but lower magnitude flood events in 2011.

4.2 Hydrology

Interior British Columbia streams typically exhibit nival, or snowmelt-dominated hydrographs. These hydrographs display low base flow conditions throughout the winter and early spring. Subsequently, flows increase to an annual high peak in late spring or early summer during the annual freshet, and then decline towards base flow conditions by the end of summer. Both the lower Duncan River, the focus of this study, and the Lardeau River, used as a free-flowing reference, exhibited snowmelt dominated hydrographs prior to construction of the Duncan Dam (Polzin et al. 2010a).

The 2012 flow regime followed Alt S73 regime and was similar to 2009 and 2010 sampling years for the start of the year (January, February, and March). April was the start of the increase in discharge for the lower Duncan River but still within the range of Alt S73 (Figure 3-4). The above normal mean monthly discharge for May through September resulted in the lower Duncan River being in flood stage for the majority of the growing season. Daily peak flows greater than 500 m^3/s occurred from mid-July through to the end of July with a peak discharge of 571 m^3/s July 23 (Figure 3-6). Flows returned to Alt S73 levels at the beginning of October and were similar to the previous monitoring years for the remainder of the year. The combination of above average snow pack and above average precipitation in March and June was the precursor to the high discharge experienced by the lower Duncan River for most of the growing season. Flooding also occurred in 2011 but was not as extreme as in 2012. With no monitoring in 2011 the amount of channel migration, deposition and scour assessed in 2012 was attributed to the combined affect of the two flood years.

The Lardeau River is the free-flowing reference for the study and experienced under a Q_{10} flood event (Q_{10} = 349 m^3/s) with a Q_{max12} = 331 m^3/s. The peak occurred June 24; a month earlier than along the lower Duncan River because of the dam controlled releases. A flood event occurred June 23, 2011 that was under a Q_5 flood event (Q_5 = 319 m^3/s) with a Q_{max12} = 297 m^3/s. The previous two years of monitoring (2009 and 2010) did not experience flood events and had very similar hydrographs for both yeas well under a Q_2 flood event.

Periodic floods in free-flowing systems are responsible for the geomorphic transformations that occur at the riparian zone interface (Bull 1988). Following the 2012 flood major geomorphic transformations occurred along the study reach with channel shifts, erosion of floodplains and terraces, sediment depositions (the building up of floodplains, and vegetation removal and establishments that is common after a flood event (Brinson 1990, Rood and Mahoney 1990, Polzin 1998). The magnitude of channel migration recorded in 2012 may have resulted from the sequential flood years of 2011 and 2012 combined. When flooding occurs in concurrent years, the degree of change can be much greater in the following year due to the unconsolidated banks resulting from the initial flood year (Polzin 1998). The unconsolidated material requires less energy to move the substrate resulting in an increase of scour and undercutting of material compared to the initial flood water acting on consolidated banks.

The flooding of the lower Duncan River during the monitoring period provided an opportunity to assess channel change and the affect on cottonwood recruitment and riparian vegetation from this event on a controlled river. The corresponding Q_{10} event on the Lardeau River supplies a reference for a free-flowing flood event for comparison.

4.3 Cottonwood Phenology

Initial seed release events appear to be more common during periods of high humidity, such as during the first warm day(s) following cool or wet weather. This pattern was initially observed by Herbison (2005) and observed in 2009 and 2010 and reported in 2010 (Polzin et al. 2011). However, the mid-July and August seed release in 2010 did not follow this pattern nor did the August seed release in 2012. It appears from the limited data set that the initial trigger for seed release in June is not the same trigger for release in August.

The above-average rainfall in June may have contributed to the reduced seed dispersal levels during this initial seed release period. The excessive rain fall following seed dispersal greatly reduces the distance seedling “fluff” will travel and can cause large quantities of seed to drop to the ground at the parent tree which is not favourable conditions for seedling establishment (Mahoney and Rood 1998, Scott et al. 1997, Karrenberg et al. 2002). This was noted in 2010 when June precipitation levels were higher compared to 2009 levels though it was an average historical precipitation level. The extreme June rainfall in 2012 may have contributed to a reduction of seed density along the Lardeau River. We assumed the lower Duncan River experienced this as well but if there were full seed pods at the base of parent trees they were likely washed away during the July peak flows. There was no way of measuring affect of this weather factor as the main factor contributing to the low to almost no seedling establishment was the flooding of recruitment zones during seed release.

4.4 Cottonwood Establishment and Recruitment along the Lower Duncan and Lardeau Rivers

This study focuses on the long-term investigation of cottonwood recruitment trends in response to Alt S73. During the August and October 2012 field season, 2010 cottonwood seedling recruitment, 2011 cottonwood seedling survival and 2012 cottonwood seedling establishment were monitored. As previously discussed (Rood et al. 2007), the term “recruitment” is used to represent the successful contribution to the floodplain forest population; the result of two sequential processes, establishment (or colonization), and survival:

Recruitment = Establishment (colonization) + Survival (for 3 years)

Establishment primarily represents seedling establishment, although in black cottonwood, limited dispersive, clonal reproduction can also occur through the rooting of branch or stem fragments, which are sheared with beaver browsing or through physical disturbance of floods or ice scour (Rood et al. 2003). Clonal saplings are recognizable, because they grow much faster than seedlings, and their ontogenic status can be confirmed through root excavation to reveal the parental shoot fragment or root. Some propagation through branch fragments was observed along the lower Duncan and Lardeau rivers but clonal establishment through root suckering was the more common form of clonal recruitment. Anecdotal observations suggest that clonal recruitment was very low compared to seedling establishment although an extensive investigation into clonal recruitment was not part of this project.

One of the factors contributing to the success or failure of recruitment is the amount of sedimentation and scour that occurs (Polzin and Rood 2006). Increased deposition and scour as well as changes in substrate texture were observed in 2010 and 2012. Recruitment areas where 2010 seedlings were established were either bare or had seedlings from 2009 establishment or older and they were half buried by sediment. This Indicated extensive depositions in all segments along the Duncan and Lardeau reaches. Following the long duration of high water in 2012, re-surveying transect line profiles is essential for quantifying the levels of change that occurred along the lower Duncan River. Thus, allowing analyses of ‘safe’ seedling zones known to occur in humid mountainous rivers (Polzin and Rood 2006).

Cottonwood seedling establishment is usually considerably greater than the subsequent survival through the first summer (Bradley and Smith 1986, Polzin 1998, Rood et al. 2007). The 2009 and 2010 monitoring seasons followed this expected trend the 2012 monitoring season was not typical. During seed release the recruitment zones were under water. The very limited seedling establishment occurred at higher elevation adjacent to creeks entering the lower Duncan River. As a result, the lower Duncan River had almost no seedling establishment in 2012. There was 69 germinants (recorded in August) compared to 22,830 germinants in 2010 and 123,956 germinants in 2009. There was an additional 53 seedlings recorded in October that established along the top edge of the recruitment zone as water levels decreased slowly in August. Survival of the 69 seedlings from August sampling was 13 per cent with nine seedlings surviving to the October field sampling period.

4.4.1 Seedling survival

Seedling survival for the first, second, and third summers, as well as survival through the first and second winters was calculated excluding 2012 establishment seedlings results. The lower Duncan seedling survival was similar to the Lardeau River but slightly lower. Survival in 2012 was lower than first summer average survival for both reaches. The low survival of the few seedlings that established initially occurred at elevations above the flood stage after the peak in July along the lower Duncan River. The summer months of July, August, and September had precipitation levels below average. The combination of these factors suggests that drought stress may have reduced 2012 seedling survival below average levels for both reaches.

We do not know the establishment densities for 2011 for either reach because no monitoring occurred in 2011. We can predict that the high water in 2011 along the Duncan Reach and the flood event along the Lardeau Reach probably had a similar affect on cottonwood establishment as recorded in 2012. This suggests that 2011 seedling establishment and spatial pattern was probably similar to the 2012 seedlings.

Deposition and scour resulted in burial or removal of 2010 seedlings resulting in low survival densities recorded in 2012. However, it is not known when this occurred only that after 2011 and the 2012 summer, there was significantly lower recruitment survival along the lower Duncan River. Many cottonwood seedlings from 2009 establishment and older recruitment survived two years of summer flooding; it was the young cottonwoods from 2010 to 2012 that were impacted by the flooding.

The Lardeau River experienced a 1-in-10 year flood event that resulted in increased levels of deposition and scour compared to 2009 and 2010 monitoring years (no flood events). Seedling densities were lower which could be attributed to the heavy rains in June during the first seed release period. However, seedling densities were not significantly different from previous years though some of the recruitment zones had been reduced in size while others had substantial deposition. The level of scour and deposition will not be known until transect lines are re-surveyed. The Lardeau River had one transect line completely removed including the 114 year old cottonwood tag tree. A second transect line had the recruitment zone and most of the riparian floodplain on the transect line removed by the river reducing the line from 26.5 m in length in 2009 to 6 m in length in 2012.

4.4.2 Longitudinal patterns of seedling establishment and recruitment

The Lardeau reach showed a pattern of increased densities progressively downstream but the downstream portion (Segment 1) was also the widest braided section of the Lardeau reach. The downstream gradient also follows channel morphology with the most constrained channel at the most upstream end and the widest braided section at the downstream end.

The Duncan Reach did not show a pattern; the majority of the reach had no seedling establishment or recruitment and, when seedlings did occur, densities were very low. The limited seedling establishment and recruitment occurred where creeks entered the Duncan Reach mainly in Segment 4 (D4T1 and D4T3). Further data collection during more typical years (similar to 2009 and 2010) may reveal a clear pattern if it exists. The 2009 and 2010 data did not show a downstream gradient pattern but did show a trend for high densities to occur in the wider braided segments.

4.4.3 Transect profiles and transect stage

The most striking difference between the profiles is the magnitude of change between the monthly average transect-stage for the Duncan meander lobe compared to the Lardeau meander lobe (Figure 3-15 and Figure 3-16). The monthly average stage along the free-flowing Lardeau River transect line had inundation near the end of the transect line, at the interface zone with the river. This zone is typically bare ground with no seedling survival even if they establish in this zone. Peak stage in June and a smaller peak in July inundated the meander lobe but for a very short period of time (days). This allowed seedling establishment to occur within the recruitment zone.

In contrast the Duncan meander lobe had monthly average transect-stage inundating the meander lobe from May through August. The peak stage in July flooded D3T15 and the sediment deposition at the POC and throughout the treed area confirms that the meander lobe was under water for a period of time. Previous seedling zones from 2008 to 2010 were inundated during seed release from June through August. A higher elevation section was not inundated during August but these higher elevations were colonized by dense willow eliminating the area as a potential seedling recruitment zone.

The seedling establishment area from previous years had cottonwood survival from 2009 recruitment and older that were sampled within Herb quadrats and survived the inundation and the observed deposition. Deposition along the recruitment zone was noted during excavation along stems to determine the age of the seedlings within sampling quadrats. Deposition is one of the potential factor for loss of seedlings along transect lines and will be quantified when transect lines are re-surveyed in 2013. Inundation during seed release is the major factor that reduced seedling establishment levels in 2012.

At this time, levels of deposition and scour can not be reported until re-surveying is completed. However, river flow regime did affect cottonwood establishment and survival levels. Following this season of monitoring, key factors influencing cottonwood recruitment during a flood year appears to be sediment deposition and scour, water inundation timing and duration, and the elevation seedlings establish at. All of these factors are driven by river discharge.

4.5 Riparian Vegetation

There were no significant changes in the riparian vegetation per cent cover, species richness, vigour, or height when comparing 2009 data with 2012 for the lower Duncan River. There was a significant difference found for species richness when using the mean count of species occurring within quadrats along transects for the Lardeau River (reference reach) but the overall number of species was the same for both years (57 species). The difference may be attributed to our use of the average count within quadrats for the analyses. The statistical analyses indicate a significant difference in the average number of species within quadrats with an increase within the Herb and Shrub quadrats, but the actual number of species for the reach remained the same between years.

Observation in the field and the resulting data for both reaches showed that woody species had increased in height and density. Some Shrub zones in 2009 had increased in height to greater than 2 m, some Herb zones with young woody species had become Shrub zones (greater than 0.5 m in height), and some seedling recruitment zones or parts of them had became Herb zones. These shifts were not statistically significant but they indicate that there is a positive trend of growth for the riparian community in relationship to the management questions and the affect of Alt S73 on the riparian community.

4.6 Riparian Community Monitoring

The lower Duncan and Lardeau rivers exhibited similar changes in land and channel areas from 2009 to 2012. That is, both areas showed a slight increase in cottonwood and willows less than 2 m tall (Community Type 1) area and a decrease in present and potential recruitment zones (Community Type 11) area. The increase in Community Type 1 was attributed to growth in previous seedling recruitment areas that achieved Community Type 1 delineation by 2012. Some of the increase was also due to young shrub zones that did not show up on the 2009 air photos as they were less than a metre tall. Some of the decrease in Community Type 11 was the result of growth from recruitment to Community Type 1 but the majority of the decrease resulted from scour of the zone since 2009.

The reduced meander lobe areas was the result of scour from high water during 2011 and 2012 for the lower Duncan River and spring freshet floods in 2011 and 2012 for the

Lardeau River. The Lardeau River had a higher magnitude of scour along some of the meander lobes compared to meander lobes along the lower Duncan River.

5 CONCLUSIONS

Year 4 data collection (third sampling year) for the 10-year monitoring program, DDMMON#8-1, occurred from August to October 2012. The purpose of Year 4 was to investigate the effects of the implementation of Alt S73 flow regime on riparian vegetation with respect to the following attributes:

- percent of vegetation cover;
- species richness;
- the expansion or reduction in vegetated area;
- the amount of cottonwood seedling establishment;
- the level of cottonwood seedling survival and recruitment; and
- the change in area covered by vegetation communities for the Duncan and Lardeau reaches.

The results in this report document changes to riparian vegetation and communities since 2009 and impacts to cottonwood establishment and recruitment since 2010 along the lower Duncan River and the reference reach, the Lardeau River.

No changes were detected for per cent cover and the number of species for the riparian vegetation when compared to the baseline data collected in 2009 for both reaches. Both reaches experienced increases in heights for woody species resulting in some shifts of open area into shrub cover and previous areas that were less than 2 m tall now being greater than 2 m in height.

We recorded low to no establishment or recruitment along a number of geomorphic segments of the lower Duncan River for the three age classes; germinants, one-year, and two-year-old seedlings monitored. The lower Duncan River had above average river stage during the growing season, effectively eliminating cottonwood seedling establishment except to very limited areas above inundation levels.

The Lardeau River experienced reduced establishment and recruitment for the three age classes of seedlings monitored. This reduction can be attributed to the two flood years (2011 and 2012), reduced seed dispersal in June because of the above average precipitation in June, and drought condition during the summer months. With three years of data involving seedlings originating in a five year period, preliminary analyses were undertaken to compare seedling recruitment, which results from the sequence of establishment and survival. Average survival rates for seedlings through their first, second, and third seasons, and first and second winters were similar between the Duncan and Lardeau reaches. As the study progresses more survival rates will be averaged with this preliminary data set following each monitoring year.

The lower Duncan River experienced higher than average stage during the 2011 and 2012 growing season. The Lardeau River experienced a Q_5 event in 2011 and a Q_{10} event in 2012. High river discharge resulted in the lower Duncan and Lardeau rivers experiencing change in area for vegetation communities adjacent to the river due to channel migration. Recruitment zones (present and potential) also experienced change in size (mainly reduction but some areas increased) and removal or creation of mid-channel bars. The Lardeau River experienced a larger magnitude of change compared to the lower Duncan River. The 2012 vegetation communities and the active channel areas were similar to the 2009 areas except for the present and potential recruitment areas that decreased since 2009.

Results from comparative analyses for 2009 and 2010 data indicated that sediment deposition and erosion, inundation duration and timing, and establishment elevation are key factors for assessing the performance of Alt S73 on black cottonwoods along the lower Duncan River. Findings in 2012 support first and second year results of key factors and the drivers affecting cottonwood recruitment. Quantifying these factors requires resurveying transect lines along the lower Duncan and Lardeau rivers. This will enable analyses of the project's two key management questions and the associated null hypotheses. Collecting data to monitor these factors will be fundamental for the quantitative analyses and associated modeling. Monitoring annual cottonwood recruitment, riparian vegetation, and vegetation communities over the next few years are therefore important to complete rigorous analyses. The results of which will be used to inform the three hypotheses, and therefore address the objectives and the two key management questions (BC Hydro TOR 2009).

The Year 4 study components largely extended and confirmed the patterns observed in Year 1 and 2. The consistency of cottonwood seedling recruitment distributions in the first two years supports a deterministic pattern, whereby establishment and survival follow from particular physical conditions and timing. Flooding dramatically lowered the sampling sizes for seedlings along the lower Duncan River. The above-average river stage and flood events along the lower Duncan and Lardeau rivers provide a pattern of establishment and recruitment during periodic flood years. This adds an additional level of information for the conceptual model and important information for the development of a predictive quantitative model. A predictive model should also be broadly applicable for other regulated rivers in British Columbia and the American Pacific Northwest.

6 RECOMMENDATIONS

6.1 Transect Line Resurveying

In order to complete the DDMMON#8-1 project, resurveying of the transect lines is essential, as described in Interior Reforestation (2009) and Polzin et al. (2010a). The study was designed for all field data to be coordinated to surveyed elevations for monitoring the positional dynamics of the system to address the management questions and for hypothesis testing. The data collected from the resurvey of transect lines allows for the quantitative analysis of sediment deposition and scour, which has been identified as one of the key factors effecting cottonwood recruitment. It also allows accurate stage-discharge calculations for each transect line that is essential for inundation analysis occurring along transect lines. The results from the 2010 stage-discharge analysis indicated that some transect lines had experienced scour and deposition within the transition zone. Following two seasons of high flows, extensive deposition and scour (observational) at the interface zone as well as deposition along vegetated zones up to and past the POC along transect lines has occurred.

The data resulting from resurveying transect lines after flood inundation will be used for addressing hypotheses testing and the identification of key drivers of cottonwood recruitment success, the second management question. Inundation of the floodplain, including the recruitment zone, has essentially reset the clock for cottonwood recruitment baseline data for the Duncan River. The seedlings established since 2010 to 2012 were probably scoured, buried, or could not establish (2012) because of the flood level and duration experienced. Resurveying will also allow for quantitative data collection on the depth of inundation that occurred associated with river discharge/stage levels, allowing accurate assessment of the fate of previous recruitment of cottonwood seedlings since Alt S73 was implemented. Resurveying of transect lines will ensure that the new baseline-data-post-flood cottonwood seedling recruitment is tied to accurate elevation profiles.

6.2 Air Photo Acquisition – Vegetation Differentiation with Autumn Senescence

We changed the flight-time for the 2012 air photo acquisition, from spring to autumn. However, the high water in 2012 required the main objective of the air photo acquisition to change from capturing of senescing (yellowing) and the different fall colors and differing phenology (seasonal timing) of the deciduous vegetation, to capturing the lower Duncan River at low flow in order to assess the full extent of channel changes. Senescing had not started when it was necessary to fly in order to have imagery at low stage. We propose to try and capture the fall colours during the next scheduled mapping in 2015.

7 CLOSURE

VAST Resource Solutions Inc., trusts that this report satisfied your present requirements. Should you have any comments, please contact us at your convenience.

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Appendix 1: Plant species list

Plant Species List: Scientific Names, Common Names and Species Codes

Vegetation Classes:
AG Annual Grass
PG Perennial Grass
AH Annual Herb
PH Perennial Herb
F Fern
WS Woody Shrub
WT Woody Tree

Vegetation Group:
UPL Obligate Upland
OBL Obligate Riparian
FAC Facultative
FACR Facultative Riparian
FACU Facultative Upland
(R) Ruderal

Status:
N Native
E Exotic
(NOX) Noxious
(W) Weed

Location:
D Duncan
L Lardeau

Vegetation Group Descriptions

NOL – Upland species that does not occur in wetlands/riparian in another region. It is not on the national list (NOL).

UPL – Obligate upland species that occurs in wetlands in another region (estimated probability greater than 99%), but almost always occurs under natural conditions in non-riparian/wetlands in the region specified.

OBL – Obligate riparian species that almost always occurs under natural conditions in riparian zones (estimated probability greater than 99%).

FAC – Facultative species that is equally likely to occur in wetlands/riparian or uplands (estimated probability 34% - 66%).

FACR – Facultative riparian species that usually occurs in riparian/wetland habitat (estimated probability 67% - 99%), but is occasionally found in non-riparian/wetland habitat.

FACU – Facultative upland species that usually occurs in uplands (estimated probability 67% - 99%), but is occasionally found in wetland/riparian habitats (estimated probability 1% - 33%).

(R) – Ruderal species are first to colonize disturbed lands.

Grasses

Species Name	Common Name	Species Code	Veg Class	Status	Veg Group	Location
Agrostis gigantea	redtop	Agro. gig.	PG	E	FAC (R)	L, D
Agropyron repens	quackgrass	Agro. rep.	PG	E (W)	FAC	D
Agrostis scabra	hair bentgrass	Agro. sca.	PG	N	FAC	L, D
Agropyron trachycaulum	slender wheat grass	Agro. tra.	PG	N	FAC	D
Bromus inermis	pumpelly brome	Brom. ine.	PG	N	UPL	D
Bromus tectorum	cheatgrass	Brom. tec.	AG	E (W)	UPL (R)	D
Calamagrostis canadensis	blue-joint	Cala. can.	PG	N	FACR (R)	L
Cinna latifolia	nodding wood-reed	Cinn. lat.	PG	N	FACR (R)	L, D
Dactylis glomerata	orchard grass	Dact. glo.	PG	E	FACU (R)	D
Elymus glaucus	blue wildrye	Elym. gla.	PG	N	FACU	L, D
Festuca campestris	rough fescue	Fest. cam.	PG	N	FAC	D
Festuca rubra	red fescue	Fest. rub.	PG	N	UPL	D
Glyceria grandis	reed mannagrass	Glyc gra	PG	N	OBL	L
Phalaris arundinacea	reed-canary grass	Phal. aru.	PG	N (W)	FACR	D
Phleum pratense	timothy	Phle. pra.	PG	E	FAC (R)	D
Poa pratensis	Kentucky bluegrass	Poa pra.	PG	E	FAC	D
Poa secunda	Sandberg bluegrass	Poa sec.	PG	N	FACU	D
Scolochloa festucacea	spangle-top	Scol. fes.	PG	N	OBL	D

Herbaceous

Species Name	Common Name	Species Code	Veg Class	Status	Veg Group	Location
Achillea millefolium	yarrow	Achi. mil.	PH	N (W)	FACU	L, D
Actaea rubra	baneberry	Acta. rub.	PH	N	FACR	L
Anaphalis margaritacea	pearly everlasting	Anap.mar.	PH	N	UPL	L
Aralia nudicaulis	wild sarsaparilla	Aral. nud.	PH	N	FACU	D
Artemisia frigida	tarragon	Arte. fri.	PH	N	UPL	D
Aruncus Sylvester	goats beard	Arun. sys.	PH	N	UPL	D
Aster ciliolatus	Lindley's aster	Aste. cil.	PH	N	NOL	L, D
Aster conspicuus	showy aster	Aste. con.	PH	N	NOL	L, D
Athyrium filix-femina	lady fern	Athy. fil.	F	N	FAC	D
Carex aperta	Columbian sedge	Care. ape.	PH	N	FACR	L, D
Carex aquatilis	water sedge	Care. aqu.	PH	N	OBL	L, D
Carex crawfordii	Crawford's sedge	Care. cra.	PH	N	FAC	D
Carex utriculata	beaked sedge	Care. utr.	PH	N	OBL	D
Carex viridula	green sedge	Care vir	PH	N	OBL	D
Castilleja miniata	common red paintbrush	Cast. min.	PH	N	FAC	L, D
Centaurea maculosa	spotted knapweed	Cent. mac.	PH	E (NOX)	UPL (R)	D
Chrysanthemum leucanthemum	oxeye daisy	Chry. leu.	PH	E (W)	NOL (R)	L, D
Cirsium arvense	Canada thistle	Cirs. arv.	PH	E (NOX)	FAC	L, D
Dryas drummondii	yellow mountain avens	Drya. dru.	PH	N	FACU	LD
Eleocharis palustris	common spike-rush	Eleo. pal.	PH	N	OBL	L
Elodea spp	water weed	Elod. spp	PH	N	OBL	D
Epilobium angustifolium	fireweed	Epil. ang.	PH	N (W)	FACU	D
Equisetum arvense	common horsetail	Equi. arv.	PH	N (W)	FAC	L, D
Equistetum hyemale	scouring-rush	Equi. hye.	PH	N	FACR	L, D
Equisetum sylvaticum	wood horsetail	Equi. syl.	PH	N	FAC	D
Galium boreale	northern bedstraw	Gali. bor.	PH	N	FACU	L, D
Galium triflorum	sweet-scented bedstraw	Gali. tri.	PH	N	FACU	L, D
Gymnocarpium dryopteris	oak fern	Gymn. dry.	F	N	FACR	L
Hieracium umbellatum	narrow-leaved hawkweed	Hier. umb.	PH	N (W)	NOL	LD
Juncus balticus	Baltic rush	Junc. bal.	PH	N	FACR	D
Juncus effuses	common rush	Junc. eff.	PH	N	OBL	D
Melilotus alba	white sweet-clover	Meli. alb.	AH	E (W)	NOL	L, D
Mentha arvensis	field mint	Ment. arv.	PH	N	FACR	L, D
Myosotis alpestris	mountain forget-me-not	Myos. alp.	PH	N	FAC	D
Oplopanax horridus	devils club	Oplo. hor.	PH	N	FAC	L
Platanthera dilattata	white bog orchid	Plat. dil.	PH	N	FACR	L
Potamogeton foliosus	leafy pond weed	Pota. fol.	PH	N	OBL	D
Prunella vulgaris	self-heal	Prun. vul.	PH	N	FACU	D
Pyrola asarifolia	pink wintergreen	Pyro. asa.	PH	N	FACU	D
Ranunculus acris	meadow buttercup	Ranu. acr.	PH	E (W)	FACR	D
Senecio streptanthifolius	rocky mountain butterweed	Sene. str.	PH	N	FACU	D
Scirpus microcarpus	small-flowered bulrush	Scir. mic.	PH	N	OBL	D
Solidago candensis	Canada goldenrod	Soli. can.	PH	N	FACU	L, D
Sonchus arvensis	perennial sow-thistle	Sonc. arv.	PH	E NOX	FACU	D

Species Name	Common Name	Species Code	Veg Class	Status	Veg Group	Location
Spiranthes romanzoffiana	lady's tresses	Spir. rom.	PH	N	FACR	L, D
Taraxacum officinale	dandelion	Tara. off.	PH	E (W)	UPL	L, D
Trifolium pratense	red clover	Trif. pra.	PH	E (W)	FAC	L
Vicia americana	American vetch	Vici. ame.	PH	N	FAC	L, D
Viola adunca	early blue violet	Viol. adu.	PH	N	FAC	L

Shrubs

Species Name	Common Name	Species Code	Veg Class	Status	Veg Group	Location
Acer glabrum	Douglas maple	Acer gla.	WS	N	FACU	L, D
Alnus incana ssp *tenuifolia*	mountain alder	Alnu. inc.	WS	N	FACR	L, D
Alnus crispa	Sitka alder	Alnu. cri.	WS	N	FACR	D
Amelanchier alnifolia	Saskatoon	Amel. aln.	WS	N	FACU	L, D
Cornus stolonifera	red-osier dogwood	Corn. sto.	WS	N	FACR	L, D
Corylus cornuta	beaked hazelnut	Cory. cor.	WS	N	FACU	L
Crataegus douglasii	black hawthorn	Crat. dou.	WS	N	FAC	D
Lonicera involucrata	black twinberry	Loni. inv.	WS	N	FAC	L
Rhamnus purshiana	cascara	Rham. pur.	WS	N	FAC	L
Rosa acicularis	prickly rose	Rosa aci.	WS	N	FACU	L
Rosa gymnocarpa	baldhip rose	Rosa gym	WS	N	FACU	L, D
Rosa nutkana	nootka rose	Rosa. nut.	WS	N	FAC	D
Rosa woodsii	prairie rose	Rosa woo.	WS	N	FACU	D
Rubus idaeus	red raspberry	Rubu. ida.	WS	N	FACU	D
Rubus parviflorus	thimbleberry	Rubu. par.	WS	N	FAC	L, D
Salix amygdaloides	peachleaf willow	Sali. amy.	WS	N	FACR	D
Salix bebbiana	Bebb's willow	Sali. beb.	WS	N	FACR	L, D
Salix boothii	Booth's willow	Sali. boo.	WS	N	FACR	D
Salix exigua	sandbar willow	Sali. exi.	WS	N	OBL	L, D
Salix lucida	pacific willow	Sali. luc.	WS	N	FACR	L, D
Salix prolixa	MacKenzie's willow	Sali. pro.	WS	N	NOL	D
Salix scouleriana	Scouler's willow	Sali. sco.	WS	N	FAC	L, D
Salix sitchensis	sitka willow	Sali. sit.	WS	N	FACR	L, D
Shepherdia canadensis	buffalo berry	Shep. can.	WS	N	UPL	D
Symphoricarpos albus	common snowberry	Symp. alb.	WS	N	FACU	L, D
Viburnum edule	high-brush cranberry	Vibu edu	WS	N	FACR	D

Trees

Species Name	Common Name	Species Code	Veg Class	Status	Veg Group	Location
Betula occidentalis	water birch	Betu. occ.	WT	N	FACR	L, D
Betula papyrifera	paper birch	Betu. pap.	WT	N	FAC	L, D
Picea glauca x *engelmannii*	hybrid white spruce	Pice. gla.x	WT	N	FAC	L, D
Pinus contorta var. *latifolia*	lodgepole pine	Pinu. con.	WT	N	FACU	D
Pinus monticola	western white pine	Pinu. mon.	WT	N	FACU	D
Populus trichocarpa	black cottonwood	Popu. tri.	WT	N	FACR	L, D
Pseudotsuga menziessii var. *glauca*	interior Douglas fir	Pseu.men.	WT	N	FACU	L, D
Thuja plicata	western redcedar	Thuj. pli.	WT	N	FAC	L, D
Tsuga heterophylla	western hemlock	Tsug. het.	WT	N	FACU	L, D

Appendix 2: Lower Duncan and Lardeau rivers photo documentation

Date: August 2012			**Environmental Crew:** Mary Louise and Ben Meunier
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
8-Aug	DSCN1756	9:07	**D3T10** POC - looking down line. Bare ground is fresh deposition from July peak high water.
8-Aug	DSCN1757	9:08	Looking down line towards EOT. Standing water and in foreground and new deposition along line from receding peak flood water.
8-Aug	DSCN1758	9:08	EOT - looking upstream. Tap measure was at river's edge when initially laid out. A new river's edge measurement with the new time recorded the change in the Duncan River discharge.
8-Aug	DSCN1759	9:08	EOT - looking downstream. Same as above after increase in discharge.
8-Aug	DSCN1760	9:51	**D3T11** 0 m - looking down line.
8-Aug	DSCN1761	9:51	EOT - looking up line.
8-Aug	DSCN1762	9:51	EOT - looking upstream.
8-Aug	DSCN1763	9:51	EOT - looking downstream.
8-Aug	DSCN1764	11:23	**D5T2** 0 m - looking down line.
8-Aug	DSCN1765	11:23	EOT - looking up line.
8-Aug	DSCN1766	11:23	EOT - looking upstream.
8-Aug	DSCN1767	11:23	EOT - looking downstream.
8-Aug	DSCN1774	16:46	**D5T9** 0 m - looking down line.
8-Aug	DSCN1775	14:47	Channel between tag tree and river's edge - channel is ~ 4-7 m wide. Pink ribbons mark the edge of a tree quadrant (10 m long).
8-Aug	DSCN1776	14:47	Looking towards POC just after crossing the channel and shrubs end.
8-Aug	DSCN1777	14:47	EOT - looking downstream. Seedling recruitment zone under water and presumed scoured away since 2009 and 2010. Seedling zone went to and included the area where dry ground and willows can be seen behind the large stump.
8-Aug	DSCN1778	14:48	EOT - looking upstream.
8-Aug	DSCN1768	14:26	**D5T16** POC (0 m) - looking down line.
8-Aug	DSCN1769	14:27	At EOT - looking up line at POC with piezometer at the 29 m mark in foreground.
8-Aug	DSCN1770	14:27	EOT - looking upstream.
8-Aug	DSCN1771	14:27	EOT - looking downstream.
8-Aug	DSCN1772	14:28	At 31 m looking at transect sampling area up to the 28 m mark. Bare ground is all fresh deposition from 2012 peak high water in July.
8-Aug	DSCN1773	14:29	At 18 m looking at the shrub quadrat 16-18 m. Pink ribbons marks one side (18 m edge) of quadrat.

Date: August 2012			**Environmental Crew:** Mary Louise and Ben Meunier
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
10-Aug	DSCN1793	11:05	**D6T6** EOT - 62.3 m - facing west. Kootenay Lake is water's edge. Power lines are along Highway 31 at the base of the mountains in photo.
10-Aug	DSCN1794	11:05	EOT - 62.3 m water's edge - facing east.
10-Aug	DSCN1795	11:05	EOT - looking up line. Sandbar willow edge along woody debris was 1 to 2 m tall in 2009 and 2010. Sandbar willow now <0.5 m tall.
10-Aug	DSCN1796	11:07	Looking down line at EOT standing about 10 m from POC.
10-Aug	DSCN1797	11:48	**D6T26** Panorama view of log jam deposited on transect line facing east. Tag tree is under log debris.
10-Aug	DSCN1798	11:51	Flattened willows from log jam.
10-Aug	DSCN1799	11:51	Tag tree would be approximately in the middle of the log jam in photo.
10-Aug	DSCN1800	11:53	Standing on log jam where the downstream side of the line would have been sampled for vegetation monitoring and seedling establishment.
10-Aug	DSCN1801	11:53	Same as above, canoed to log jam and climbed up from the canoe as transect line was under water.
10-Aug	DSCN1802	11:54	Standing on the upstream side of the transect line.
10-Aug	DSCN1803	13:18	**D6T36** Looking downstream at river's edge.
10-Aug	DSCN1804	13:18	Standing near river's edge looking upstream.
10-Aug	DSCN1805	13:18	Mid-channel bar that was normally sampled but not this time due to high waters. Transect line is inline with old snag on the far bank of main channel.
10-Aug	DSCN1806	13:18	Looking up line at POC.
10-Aug	DSCN1807	13:19	Looking up line at POC within the shrub/tree sampling zone.
10-Aug	DSCN1808	14:35	**D6T29** looking upstream of where transect line occurs about midway up edge of river from the log jam.
10-Aug	DSCN1809	14:36	Close up of approximate area of tag tree.
10-Aug	DSCN1810	14:40	Log jam that was floating and logs were moving at this point so we did not continue to cross the log jam to get to the transect line. The water that has no ripples and slightly brownish is the mid-channel bar (under water) is where past recruitment occurred.
7-Aug	IMG_5515	15:45	**D1T3** 20 m looking up line.
7-Aug	IMG_5517	15:48	Looking downstream at the line.
7-Aug	IMG_5518	15:50	5 m looking up line.
7-Aug	IMG_5516	15:48	Looking downstream at the line.

Date: August 2012			**Environmental Crew:** Mary Louise and Ben Meunier
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
7-Aug	IMG_5519	17:41	**D1T4** 0 m looking down line.
7-Aug	IMG_5520	17:42	5 m looking down line.
7-Aug	IMG_5521	17:42	14 m looking down line.
7-Aug	IMG_5522	17:42	22 m looking up line.
8-Aug	IMG_5527	16:47	**D4T1** 0 m looking up line.
8-Aug	IMG_5528	16:48	8 m looking up line.
8-Aug	IMG_5529	16:48	15 m looking up line.
8-Aug	IMG_5523	16:32	**D4T3** 0 m looking down line.
8-Aug	IMG_5524	16:32	9 m looking down line.
8-Aug	IMG_5525	16:34	27 m looking down line.
8-Aug	IMG_5526	16:34	33 m looking up line.
10-Aug	IMG_5558	15:43	**D4T5** 0 m looking down line.
10-Aug	IMG_5559	15:44	7 m looking up line.
10-Aug	IMG_5560	15:44	Looking downstream at the line.
10-Aug	IMG_5561	15:45	5 m looking up line.

Date: August 2012			**Environmental Crew:** Mary Louise Ben Meunier
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
9-Aug	DSCN1779	10:07	**L3T29** upstream view of the new shoreline.
9-Aug	DSCN1780	10:08	Near reference point looking at new waters edge.
9-Aug	DSCN1781	10:10	Near old trans line looking downstream of new bank.
9-Aug	DSCN1788	17:57	**L3T9** 0 m - looking down line.
9-Aug	DSCN1789	17:59	EOT - looking up line.
9-Aug	DSCN1790	18:00	EOT - looking upstream.
9-Aug	DSCN1791	18:00	EOT - looking downstream.
9-Aug	DSCN1792	18:00	Vegetation growth on roots of large cedar tree same root as in 2009/2010 pictures of this.
9-Aug	DSCN1782	16:05	**L3T1** 0 m - looking down line.
9-Aug	DSCN1783	16:05	EOT - looking up line.
9-Aug	DSCN1784	16:06	MaryLouise working.
9-Aug	DSCN1785	16:07	EOT - looking upstream.
9-Aug	DSCN1786	16:07	EOT - looking downstream.
9-Aug	DSCN1787	16:07	Deposition of recruitment zone upstream of transect line where lots of juvenile cottonwoods were recorded in 2009/2010. Still doing well even with deposition. Establishment time before Alt S73.

Date: August 2012			**Environmental Crew:** Mary Louise Ben Meunier
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Image #**
8-Aug	IMG_5530	12:04	**L2T15** 0 m looking down line.
9-Aug	IMG_5531	12:05	11 m looking down line.
9-Aug	IMG_5532	12:05	21 m looking down line.
9-Aug	IMG_5533	12:06	27 m looking down line.
9-Aug	IMG_5534	12:06	32 m looking up line.
9-Aug	IMG_5535	14:29	**L2T6** 52 m looking up line.
9-Aug	IMG_5536	14:30	40 m looking up line.
9-Aug	IMG_5537	14:31	40 m looking down line.
9-Aug	IMG_5538	14:31	24 m looking up line.
9-Aug	IMG_5539	14:33	17 m looking up line.
9-Aug	IMG_5540	14:34	0 m looking down line.
9-Aug	IMG_5541	16:36	**L1T27** 0 m looking down line.
9-Aug	IMG_5542	16:37	8 m looking up line.
9-Aug	IMG_5543	16:37	Looking upstream at line.
9-Aug	IMG_5544	16:38	Tag tree POC.
9-Aug	IMG_5545	18:23	**L1T20** 26 m looking up line.
9-Aug	IMG_5546	18:23	10 m looking up line.
9-Aug	IMG_5547	18:23	10 m looking down line.
9-Aug	IMG_5548	18:24	2 m looking down line.

Date: August 2012			**Environmental Crew:** Brenda Herbison and Tanya Foster
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
10-Aug	IMG_5549	9:08	**L1T10** 45 m looking up line.
10-Aug	IMG_5550	9:09	32 m looking up line.
10-Aug	IMG_5551	9:10	13 m looking down line.
10-Aug	IMG_5552	9:11	7 m looking up line.
10-Aug	IMG_5553	9:12	2 m looking down line.
10-Aug	IMG_5554	12:06	**L1T1** 30 m looking up line.
10-Aug	IMG_5555	12:07	17 m looking up line.
10-Aug	IMG_5556	12:08	Looking downstream at the line.
10-Aug	IMG_5557	12:09	0 m at tag tree looking down line.

Date: October 2012			**Environmental Crew:** Mary Louise and Aden Stewart
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
1-Oct	IMG_5734	14:55	**D3T10** Looking up line towards POC.
1-Oct	IMG_5735	14:55	Looking down line at POT.
1-Oct	IMG_5736	14:56	Same as above.
1-Oct	IMG_5737	19.25	**D3T15** Looking up line towards POC.
1-Oct	IMG_5738	19.25	Looking down line at rivers edge.
1-Oct	IMG_5739	19.25	Looking at shrub band through middle of line.
2-Oct	IMG_5740	11:46	**D3T20** Looking up line towards POC from 31 m mark.
2-Oct	IMG_5741	11:46	Looking down line at rivers edge.
2-Oct	IMG_5742	11:46	Looking towards POC in the tree band.
2-Oct	IMG_5743	13:18	**D3T23** looking at rivers edge from 18 m mark.
2-Oct	IMG_5744	13:18	Looking up line towards POC. Tree quadrat
2-Oct	IMG_5745	15:15	**D5T12** Looking at river.
2-Oct	IMG_5746	15:16	Looking at POC.
2-Oct	IMG_5747	15:18	Standing upstream of line looking into the sampling area.
2-Oct	IMG_5748	15:19	Rebar on transect at 57.4 m.
2-Oct	IMG_5749	17:06	**D5T11** Looking at shrub band towards POC from 70 m mark.
2-Oct	IMG_5750	17:06	Looking at river from 70 m mark.
2-Oct	IMG_5751	17:09	Middle section of willow/ cottonwood band.
2-Oct	IMG_5752	17:10	Looking at river channel.
2-Oct	IMG_5753	17:11	Looking at tree tag in Tree quadrat.
2-Oct	IMG_5754	11:18	**D5T19** Looking at rivers edge.
2-Oct	IMG_5755	11:19	Looking at POC and start of vegetation.
2-Oct	IMG_5756	11:19	Looking at POC and deposition on tree, shrub and herb quadrats.
2-Oct	IMG_5757	11:59	**D6T29** Looking down line towards rivers edge from the 14 m mark.
2-Oct	IMG_5758	11:59	Looking up line towards POC at the start of the vegetation from 13 m.
2-Oct	IMG_5759	12:00	On line looking into Tree quadrat.
2-Oct	IMG_5760	12:01	Same as above.
2-Oct	IMG_5761	12:01	Same as above.
2-Oct	IMG_5762	12:07	On line looking at tag tree.
2-Oct	IMG_5763	14:06	**D6T36** Looking at willows on point bar.
2-Oct	IMG_5764	14:09	Standing at 52 m looking at POC.
2-Oct	IMG_5765	14:09	Standing at 52 m looking at rivers edge.
2-Oct	IMG_5766	14:15	Standing up stream of transect, looking at willows.
3-Oct	IMG_5767	14:16	Standing at 73.5 m mark looking towards rivers edge.
3-Oct	IMG_5768	14:18	Standing at 73.5 m mark looking towards POC.
3-Oct	IMG_5769	14:30	Looking at ridge of deposition with Herb quadrat at 45 m.

Date: August 2012			**Environmental Crew:** Brenda Herbison and James Bolt
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
1-Oct	PA13016	15:18	**D4 T3** A large sediment deposition across the river from the transect EOT.
1-Oct	PA13017	15:18	Same as above.
1-Oct	PA13018	15:18	Looking up line towards the POC.
1-Oct	PA13019	15:18	Looking down line. The line has not been run out to the EOT yet.
1-Oct	PA13020	15:18	The 11 m mark with seedlings under leaf layer.
1-Oct	PA13021	15:18	The 11 m mark with seedlings under leaf layer.
2-Oct	PA13022	12:20	**D4T1** Looking at the EOT where it currently meets Hamill Creek.
2-Oct	PA13023	12:20	Same as above.
2-Oct	PA13024	12:22	Same as above.
2-Oct	PA13025	12:22	Same as above.
2-Oct	PA13026	12:23	Same as above.
2-Oct	PA13027	12:30	Hamill Creek.
2-Oct	PA13028	12:30	Same as above.
2-Oct	PA13029	12:31	Same as above.
2-Oct	PA13030	12:31	Same as above.
2-Oct	PA13031	12:31	Looking up line towards POC.
3-Oct	P1013040	9:15	**D3T37** Looking down line at EOT.
3-Oct	P1013041	9:15	Looking up line at willow from 83 m mark.
3-Oct	P1013042	9:15	Same as above.
3-Oct	P1013043	9:15	Looking up line towards the POC from the 33 m mark.
3-Oct	P1013044	9:15	Looking at the POC through alder.
3-Oct	P1013045	9:15	Looking down line standing at the POC.
3-Oct	P1013046	9:15	Looking down line as it is being set up crossing new sediment deposition.
3-Oct	P1013047	9:15	Same as above.
3-Oct	P1013048	9:15	Looking Down stream with D3T39 on the far bank.
3-Oct	P1013049	9:15	Looking up line towards POC as the line enters the willow band at the 79 m Mark.
3-Oct	P1013050	12:56	**D3T39** Looking Down line at EOT and new deposits along waters edge.
3-Oct	P1013051	12:56	Looking Up line towards POC from EOT
3-Oct	P1013052	12:56	Looking Up line towards POC from vegetative edge.
3-Oct	P1013053	12:58	Moose tracks in new deposition material along channels edge.
3-Oct	P1013054	12:58	Same as above.
3-Oct	P1013055	12:58	Same as above with eslon tape for size comparison.

Date: October 2012			**Environmental Crew:** Mary Louise and Aden Stewart
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
3-Oct	IMG_5770	16:39	**L3T9** Bald eagle watching us land canoe.
3-Oct	IMG_5771	16:39	Same as above.
3-Oct	IMG_5772	16:44	Looking at tag tree from 5 m mark.
3-Oct	IMG_5773	16:44	Looking down line towards rivers edge from 5 m mark.
3-Oct	IMG_5774	16:48	Standing at the 28 m mark looking up line.
3-Oct	IMG_5775	16:48	Standing at the 28 m mark looking down line at rivers edge.
3-Oct	IMG_5776	16:50	Looking at the start of sediment deposition at the 36.5 m mark.
3-Oct	IMG_5777	17:17	**L3T1** looking at the tag tree on the downstream side of the vegetation quadrats from the 4 m mark.
3-Oct	IMG_5778	17:18	Looking at the downstream side of the transect from the 10 m mark.
3-Oct	IMG_5779	17:20	Looking at the river's edge from the 15 m mark.
4-Oct	IMG_5782	10:19	**L2T6** Looking at the tag tree from rebar location.
4-Oct	IMG_5783	10:20	Looking at the rebar location from the 35 m mark.
4-Oct	IMG_5784	10:21	Looking at the rivers edge from the 35 m mark.
4-Oct	IMG_5785	11:48	**L1T10** Looking at the tag tree from the waters edge.
4-Oct	IMG_5786	11:48	Looking at the waters edge from the rebar.
3-Oct	IMG_5780	18:31	**L1T36** Looking at the POC from the 12.5 m mark.
3-Oct	IMG_5781	18:31	Looking down the line at the rivers edge from the 12.5 m mark.

Date: August 2012			**Environmental Crew:** Brenda Herbison and James Bolt
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
2-Oct	PA013034	13:36	**L1T1** Looking down line at EOT from the 18 m mark.
2-Oct	PA013035	13:36	Looking at the POC from the EOT.
2-Oct	PA013036	13:38	Looking at the POC from the 22 m mark.
2-Oct	PA013037	13:38	Looking down line at EOT
2-Oct	PA013038	13:38	Looking down line at EOT
2-Oct	PA013039	13:41	Looking up line towards the bank and POC.
3-Oct	P1013056	15:27	**L1T20** Looking towards EOT from 13.5 m.
3-Oct	P1013057	15:27	Looking towards POC.
3-Oct	P1013058	15:28	Looking towards POC.
4-Oct	P1013059	8:10	**L2T15** Looking towards POC.
4-Oct	P1013060	8:10	Looking towards EOL
4-Oct	P1013061	8:10	Looking through vegetation.
4-Oct	P1013062	8:12	Looking through vegetation.
4-Oct	P1013063	8:12	Looking through vegetation at POC.

Appendix 3: Duncan and Lardeau rivers contact sheets

Duncan River Segment 1 Transects 3 and 4 - August 2012


IMG_5515 T3


IMG_5516 T3


IMG_5517 T3


IMG_5518 T3


IMG_5519 T4


IMG_5520 T4


IMG_5521 T4


IMG_5522 T4

Duncan River Segment 3 Transects 10 and 11 - August 2012

DSCN1756 T10

DSCN1757 T10

DSCN1758 T10

DSCN1759 T10

DSCN1760 T11

DSCN1761 T11

DSCN1762T11

DSCN1763 T11

Duncan River Segment 4 Transects 1, 3 and 5 - August 2012


IMG_5527 T1

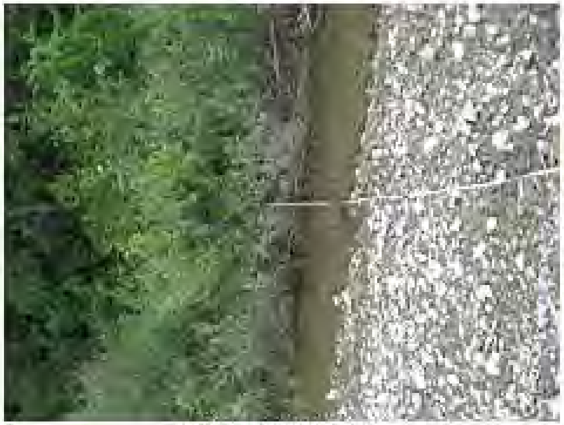

IMG_5528 T1


IMG_5529 T1


IMG_5523 T3


IMG_5524 T3


IMG_5525 T3


IMG_5526 T3


IMG_5558 T5


IMG_5559 T5

Duncan River Segment 4 Transects 1, 3 and 5 - August 2012

IMG_5560 T5

IMG_5561 T5

Duncan River Segment 5 Transects 2 , 9 and 16 - August 2012

DSCN1764 T2

DSCN1765 T2

DSCN1766 T2

DSCN1767 T2

DSCN1774 T9

DSCN1775 T9

DSCN1776 T9

DSCN1777 T9

DSCN1778 T9

Duncan River Segment 5 Transects 2 , 9 and 16 - August 2012

DSCN1768 T16

DSCN1769 T16

DSCN1770 T16

DSCN1771 T16

DSCN1772 T16

DSCN1773 T16

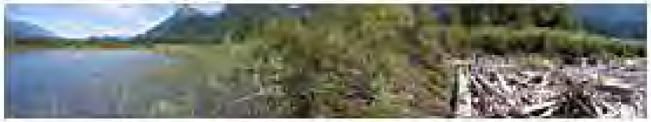
Duncan River Segment 6 Transects 6, 26, 29 and 36 - August 2012


DSCN1793 T6


DSCN1794 T6


DSCN1795 T6


DSCN1796 T6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DSCN1798 T26


DSCN1799 T26


DSCN1800 T26


DSCN1801 T26

Duncan River Segment 6 Transects 6, 26, 29 and 36 - August 2012


DSCN1802 T26


DSCN1808 T29


DSCN1809 T29


DSCN1810 T29


DSCN1803 T36


DSCN1804 T36


DSCN1805 T36


DSCN1806 T36


DSCN1807 T36

Duncan River Segment 3 Transects 10, 15, 20, 23, 37 and 39 - October 2012


IMG_5734 T10


IMG_5735 T10


IMG_5736 T10


IMG_5737 T15


IMG_5738 T15


IMG_5739 T15


IMG_5740 T20


IMG_5741 T20


IMG_5742 T20

Duncan River Segment 3 Transects 10, 15, 20, 23, 37 and 39 - October 2012


IMG_5743 T23


IMG_5744 T23


P1013040 T37


P1013041 T37


P1013042 T37


P1013043 T37


P1013044 T37


P1013045 T37

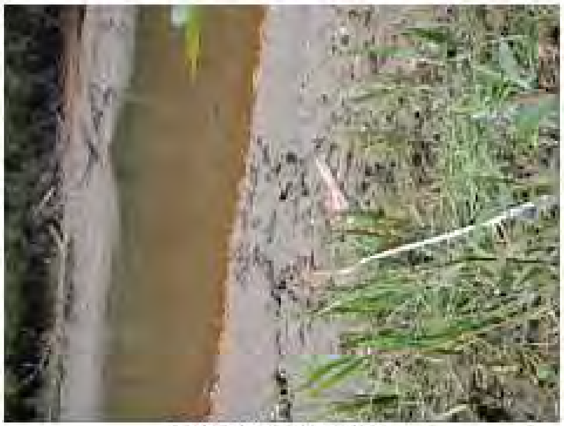

P1013046 T37

Duncan River Segment 3 Transects 10, 15, 20, 23, 37 and 39 - October 2012


P1013047 T37


P1013048 T37


P1013049 T37


P1013050 T39


P1013051 T39


P1013052 T39


P1013053 T39


P1013054 T39


P1013055 T39

Duncan River Segment 5 Transects 11, 12 and 19 - October 2012


IMG_5749 T11


IMG_5750 T11


IMG_5751 T11


IMG_5752 T11


IMG_5753 T11

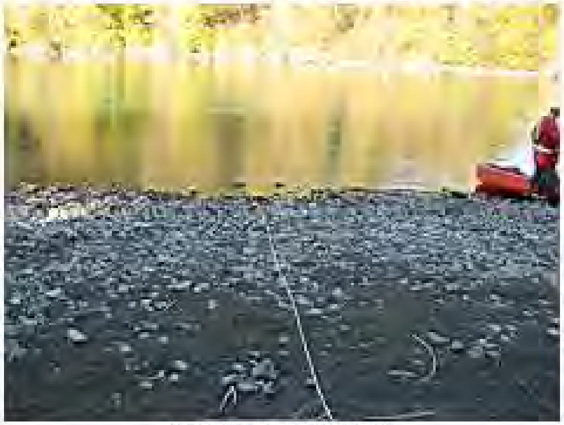

IMG_5745 T12


IMG_5746 T12


IMG_5747 T12


IMG_5748 T12

Duncan River Segment 5 Transects 11, 12 and 19 - October 2012



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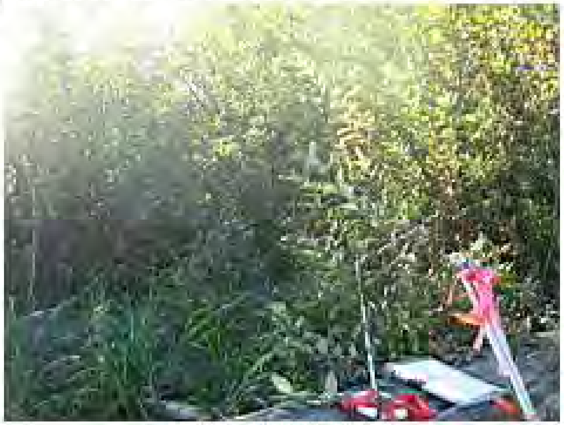
IMG_5755 T19

IMG_5756 T19

Duncan River Segment 6 Transects 29 and 36 - October 2012


IMG_5757 T29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IMG_5759 T29


IMG_5760 T29


IMG_5761 T29


IMG_5762 T29


IMG_5763 T36


IMG_5764 T36


IMG_5765 T36

Duncan River Segment 6 Transects 29 and 36 - October 2012

IMG_5766 T36

IMG_5767 T36

IMG_5768 T36

IMG_5769 T36

Lardeau River Segment 1 Transects 1, 10, 20 and 27 August 2012

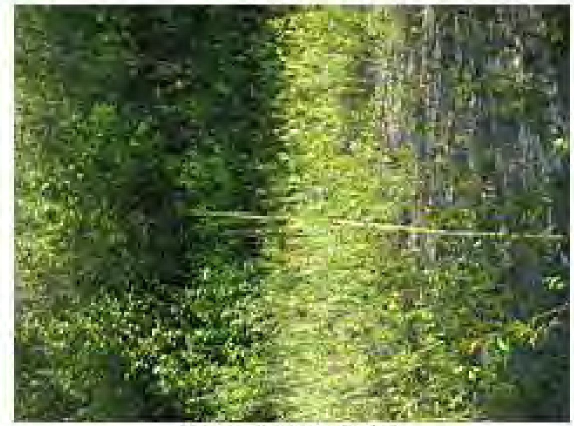

IMG_5554 T1


IMG_5555 T1


IMG_5556 T1


IMG_5557 T1


IMG_5549 T10


IMG_5550 T10


IMG_5551 T10


IMG_5552 T10


IMG_5553 T10

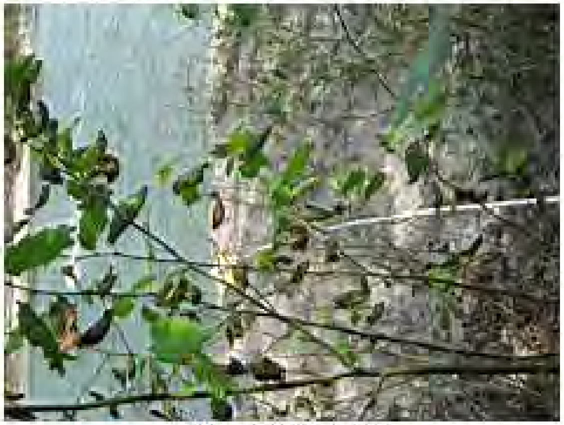
Lardeau River Segment 1 Transects 1, 10, 20 and 27 August 2012

IMG_5545 T20

IMG_5546 T20

IMG_5547 T20

IMG_5548 T20



IMG_5541 T27

IMG_5542 T27

IMG_5543 T27

IMG_5544 T27

Lardeau River Segment 2 Transects 6 and 15 August 2012

IMG_5535 T6

IMG_5536 T6

IMG_5537 T6

IMG_5538 T6

IMG_5539 T6

IMG_5540 T6

IMG_5530 T15

IMG_5531 T15

IMG_5532 T15

Lardeau River Segment 2 Transects 6 and 15 August 2012

IMG_5533 T15

IMG_5534 T15

Lardeau River Segment 3 Transects 1, 9 and 29 - August 2012


DSCN1782 T1


DSCN1783 T1


DSCN1784 T1


DSCN1785 T1


DSCN1786 T1


DSCN1787 T1


DSCN1788 T9


DSCN1789 T9

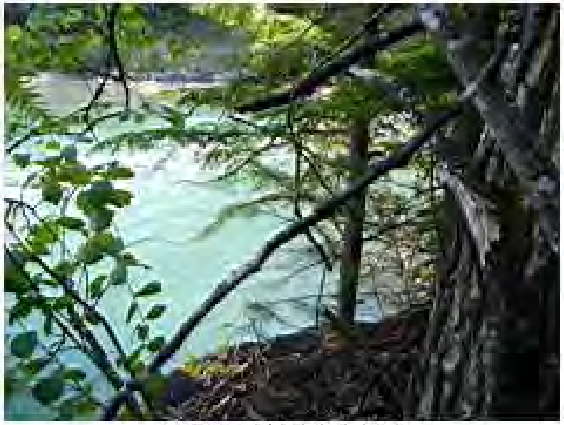

DSCN1790 T9

Lardeau River Segment 3 Transects 1, 9 and 29 - August 2012


DSCN1791 T9


DSCN1792 T9


DSCN1779 T29


DSCN1780 T29


DSCN1781 T29

Lardeau River Segment 1 Transects 1, 10, 20 and 36 - October 2012


IMG_5780 T36


IMG_5781 T36


IMG_5785 T10


IMG_5786 T10


P1013056 T20


P1013057 T20


P1013058 T20


PA013034 T1


PA013035 T1

Lardeau River Segment 1 Transects 1, 10, 20 and 36 - October 2012

PA013036 T1

PA013037 T1

PA013038 T1

PA013039 T1

Lardeau River Segment 2 Transects 6 and 15 - October 2012

IMG_5782 T6

IMG_5783 T6

IMG_5784 T6

P1013059 T15

P1013060 T15

P1013061 T15

P1013062 T15

P1013063 T15

Lardeau River Segment 3 Transects 1 and 9 - October 2012


IMG_5777 T1


IMG_5778 T1


IMG_5779 T1


IMG_5770 T9


IMG_5771 T9


IMG_5772 T9


IMG_5773 T9


IMG_5774 T9


IMG_5775 T9

Lardeau River Segment 3 Transects 1 and 9 - October 2012

IMG_5776 T9

Appendix 4: Statistical analyses

Paired-Sample T-Test for Lardeau seedling densities between 2009 and 2010. No data for 2011 as data collection was cancelled.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	July09Density2009	43.06	142	103.904	8.719
	Den12_Aug12	24.07	142	84.524	7.093
Pair 2	Aug10 Density2010	39.30	142	84.389	7.082
	Den12_Aug12	24.07	142	84.524	7.093

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	July09Density2009 - Den12_Aug12	18.986	133.298	11.186	-3.128	41.100	1.697	141	.092
Pair 2	Aug10 Density2010 - Den12_Aug12	15.225	116.891	9.809	-4.167	34.618	1.552	141	.123

Duncan Reach test for significance for first year survival between establishment densities and fall densities for 2009, 2010, 2012 (sampling years)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Jul09_Den_09	455.61	272	639.318	38.764
	Sep09_Den_09	86.58	272	181.380	10.998
Pair 2	Aug10_Den_10	102.52	220	139.827	9.427
	Sep10_Den_10	11.83	220	33.615	2.266
Pair 3	Aug12_Den_12	23.00	11	17.280	5.210
	Oct12_Den_12	5.64	11	3.107	.937

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Jul09_Den_09 - Sep09_Den_09	369.029	590.937	35.831	298.487	439.572	10.299	271	.000
Pair 2	Aug10_Den_10 - Sep10_Den_10	90.691	134.680	9.080	72.795	108.587	9.988	219	.000
Pair 3	Aug12_Den_12 - Oct12_Den_12	17.364	15.661	4.722	6.843	27.885	3.677	10	.004

Lardeau Reach test for significance for first year survival between establishment densities and fall densities for 2009, 2010, 2012 (sampling years)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	July09Density2009	43.06	142	103.904	8.719
	Sep09 Density 2009	14.99	142	42.880	3.598
Pair 2	Aug10 Density2010	39.30	142	84.389	7.082
	Sep10 Density2010	5.40	142	6.650	.558
Pair 3	Den12_Aug12	24.07	142	84.524	7.093
	Den12_Oct12	2.19	142	5.145	.432

Paired Samples Test

		Paired Differences					t	df	Sig.-
		Mean	Std. Deviation	Std. E Mean	95% Confidence Interval of the Difference				(2 tailed)
					Lower	Upper			
Pair 1	July09Density09 - Sep09 Density09	28.063	89.126	7.479	13.277	42.849	3.752	141	.000
Pair 2	Aug10 Density10 - Sep10 Density10	33.894	83.486	7.006	20.044	47.745	4.838	141	.000
Pair 3	Aug12 Density12- Oct12 Density12	21.880	81.979	6.880	8.280	35.481	3.180	141	.002

Paired-Samples T-Test for species richness for the Lardeau Reach comparing 2009 with 2012.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Rich09_SQRT	1.8133	45	1.06647	.15898
	Rich12_SQRT	2.2306	45	1.23498	.18410

Paired Samples Test

		Paired Differences					t	df	Sig.
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				(2-tailed)
					Lower	Upper			
Pair 1	Rich09_SQRT -Rich12_SQRT	-.41729	1.10942	.16538	-.75060	-.08399	-2.523	44	.015

		Paired Differences					t	df	Sig.
		Mean	Std. Deviation	Std. E. Mean	95% Confidence Interval of the Difference				(2-tailed)
					Lower	Upper			
Pair 1	Rich09_SQRT - Rich12_SQRT	-.41729	1.10942	.16538	-.75060	-.08399	-2.523	44	.015

Results of the Paired T-Test for the Lardeau Reach for vegetation cover 2009 versus 2012.

Paired Samples Test

Paired Samples Test

		Paired Differences							Sig.
		Mean	Std. Dev.	Std. E. Mean	95% Confidence Interval Difference				(2-tailed)
					Lower	Upper	*t*	*df*	*P*
Pair 1	L_Total_H_Quad_12 - L_Total_H_Quad_09	7.46	30.7	5.26	-3.24	18.2	1.42	33	.165
Pair 2	L_Total_SH_Quad_12 - L_Total_SH_Quad_09	-11.3	45.5	8.45	-28.6	6.02	-1.34	28	.193
Pair 3	L_Total_T_Quad_12 - L_Total_T_Quadrat_09	10.3	38.2	10.2	-11.7	32.4	1.01	13	.330

Appendix 5: GIS standards (digital submission)