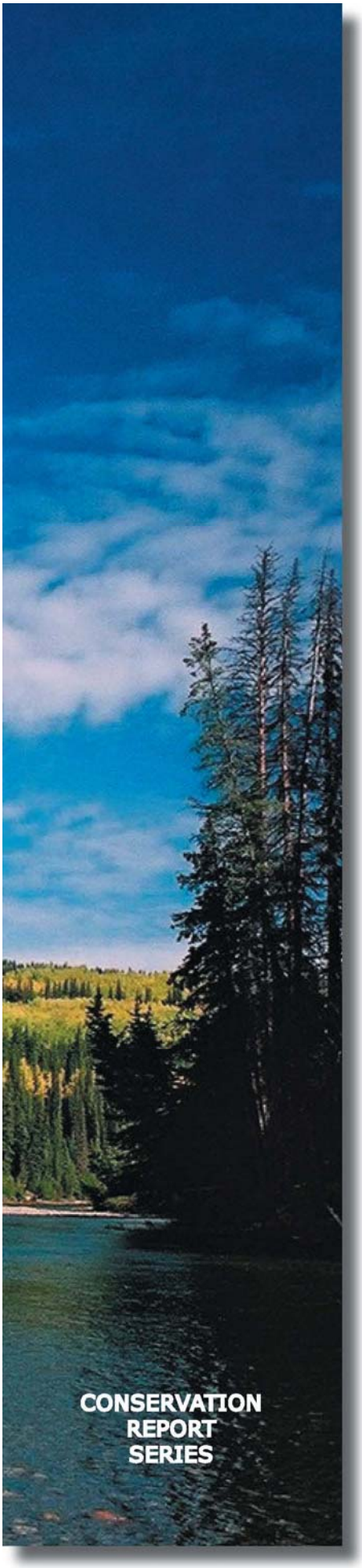


Trends in Distribution and Abundance of Westslope Cutthroat Trout and Sedimentation in the Upper Oldman River Watershed, 2015 – 2016

Alberta Conservation Association

The Alberta Conservation Association is a Delegated Administrative Organization under Alberta's Wildlife Act.

Trends in Distribution and Abundance of Westslope Cutthroat Trout and Sedimentation in the Upper Oldman River Watershed, 2015 – 2016

Jason Blackburn, Kevin Fitzsimmons, Brad Hurkett, and Logan Redman
Alberta Conservation Association
101 – 9 Chippewa Road
Sherwood Park, Alberta, Canada
T8A 6J7

Alberta Conservation Association

Report Editors
PETER AKU
Alberta Conservation Association
101 – 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7

KELLEY KISSNER
50 Tuscany Meadows Cr. NW
Calgary, AB T3L 2T9

Conservation Report Series Type
Data

ISBN: 978-0-9959984-0-7

Suggested Citation:
Blackburn, J., K. Fitzsimmons, B. Hurkett, and L. Redman. 2017. Trends in distribution and abundance of westslope cutthroat trout and sedimentation in the upper Oldman River watershed, 2015 – 2016. Data Report, produced by Alberta Conservation Association, Lethbridge, Alberta, Canada. 32 pp. + App.

Cover photo credit: David Fairless

Digital copies of conservation reports can be obtained from:
Alberta Conservation Association
101 – 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7
Toll Free: 1-877-969-9091
Tel: (780) 410-1998
Fax: (780) 464-0990
Email: info@ab-conservation.com
Website: www.ab-conservation.com

EXECUTIVE SUMMARY

Westslope cutthroat trout (WSCT) is considered *Threatened* in Alberta under Canada's *Species at Risk Act*. Long-term survival of the species requires identification, protection and restoration of strongholds where genetically *pure* populations remain. One of the last remaining strongholds for the species is in the upper Oldman River watershed, which has undergone varying intensities of landscape disturbance. Fine sediment deposition from surrounding land-use activity has been identified as a key threat and major limiting factor affecting recovery of Alberta's WSCT populations. We completed a comprehensive, two-year study to document abundance, population structure and distribution of genetically pure WSCT relative to trends in sedimentation.

We surveyed more than 25 km of stream at 73 randomly selected sampling sites along the mainstems of 18 streams, collecting fish, sediment, habitat, stream channel and pool information. We collected fish size, abundance and distribution information using backpack and totebarge electrofishing methods; measured sediment quantity and composition; and performed pool counts to determine pool frequency. We constructed generalized additive models of sediment quantity, and longitudinal WSCT abundance by maturity class, using single-pass electrofishing data corrected with capture-mark-recapture derived capture-efficiencies. In all, we captured 3,824 WSCT and collected 1,151 tissue samples for genetic (DNA) analysis.

We recorded the highest catch rates of WSCT (all fish ≥70 mm fork length; FL) in Vicary Creek (355 fish/km), juveniles (≥70 – 149 mm FL) in Pasque Creek (321 fish/km) and adults (≥150 mm) in Ridge Creek (247 fish/km). Rearing streams, where catches were dominated by juvenile fish and where fish sizes were the smallest, were Pasque (91% juveniles, 83 mm FL), Oyster (91% juveniles, 93 mm FL), Speers (84% juveniles, 110 mm FL), and Beaver (79% juveniles, 115 mm FL) creeks. Streams where catches were dominated by adult fish and median fish size was the largest were Deep (75% adults, 189 mm FL), Ridge (71% adults, 172 mm FL) and Lyall (71% adults, 160 mm FL) creeks.

Of the watersheds suitable for modelling longitudinal abundance of WSCT, the highest mainstem abundance was in Vicary Creek for both total fish (n = 20,930) and juveniles (n = 14,344), exceeding that of Racehorse, South Racehorse, North Racehorse, Dutch and Hidden creeks combined. The highest adult abundance occurred in White Creek (n = 9,012), exceeding that of Racehorse, South Racehorse, North Racehorse and Dutch creeks combined.

Streams among those with both the highest proportion of fine sediment fractions <6 and <2 mm and median sediment volumes included Pasque, Speers, Oyster, Deep and Ridge creeks. Streams among those with the lowest fine sediment proportions and volumes included Daisy, Mean, Racehorse, North Racehorse, Dutch, Beehive and Hidden creeks. Scour-pool frequency was variable relative to sediment quantity; however, it was highest in many of the streams where median sediment volume was also highest. The highest scour-pool frequencies occurred in White Creek (36 pools/km), followed by Ridge and Oyster creeks (33 pools/km) and Pasque Creek (22 pools/km), which were also some of the streams with the highest WSCT catch rates.

The relationship between sediment quantity and fish population structure within the watersheds in the study area was unclear. Pasque, Speers and Oyster creeks had both the highest proportions of fine sediment as well as juvenile fish. Conversely, Ridge and Deep creeks had the highest proportion of adult-sized fish but were still among the streams with the highest sediment levels.

Through concurrent modelling of longitudinal sediment quantity, and WSCT abundance, we revealed that watersheds with the highest catch rates had a trend of decreasing deposited sediment quantity in a downstream direction, whereas those with the lowest catch rates had a trend of increasing deposited sediment quantity in a downstream direction. Variables such as reach-scale channel morphology, stream gradient and elevation may have confounded interpretation of relationships between sediment quantity and fish abundance by differentially altering sediment transport, retention and/or settling rates. For example, deep bedrock pools and high-gradient step-pool sequences retained fish but did not create scour-pools from which to measure transported sediment.

Pool availability may also have confounded interpretation of maturity-class composition relative to sediment. Both Vicary and White creeks had similar measures of fine deposited sediment; however, White Creek, which had the most scour-pools per kilometre, had an inverse longitudinal relationship between adult and juvenile abundances, whereas Vicary Creek, which had fewer scour-pools, had a disproportionate abundance of juveniles.

Proximity of disturbances to the stream channel may be a key variable influencing WSCT longitudinal population structure, given adult abundance in South Racehorse Creek plummeted sharply where the stream closely parallels a main road and access is increased.

The interactions between fine deposited sediment, stream morphology, WSCT abundance and population structure were complex and will require considerable further analysis to better understand underlying mechanisms that impact WSCT populations in the upper Oldman River watershed.

Key words: westslope, cutthroat, sediment, disturbance, watershed, Oldman, scour-pool.

ACKNOWLEDGEMENTS

Funding for this study was provided by Alberta Conservation Association (ACA). Thank you to the ACA field crew, Jessy Dubnyk and Steven Griffeth, for your hard work, dedication and positive attitudes. Thanks to Tyler Johns (ACA), Todd Zimmerling (ACA) and Matthew Coombs (Alberta Environment and Parks; AEP) for assistance with field sampling. We are grateful to Dave Kubik (City of Lethbridge) for providing flocculant and instructions for settling stream sediments. We also thank Bryan Sundberg (AEP) for field accommodations, Mike Verhage (ACA) for GIS support and Monty Kunimoto for custom field equipment fabrication. Thank you to Shannon Frank (Oldman Watershed Council) for openly exchanging information and for providing watershed geographic information system (GIS) layers beneficial to the design of this project. Special thanks to Mike Rodtka (ACA) for providing project feedback and guidance, and for reviewing this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

Westslope cutthroat trout (WSCT; *Oncorhynchus clarki lewisi*) is considered *Threatened* in Alberta under Canada's *Species at Risk Act* (SARA; Fisheries and Oceans Canada 2014). Long-term survival of the species requires identification, protection and restoration of strongholds where genetically *pure* populations remain. The upper Oldman River watershed represents the largest remaining intact core area of *pure* WSCT within the species' historical range in Alberta. Select sub-watersheds have exhibited some of the highest WSCT densities in the province (Blackburn 2008), which feed larger downstream tributaries that contribute not only to the overall persistence and distribution of the species, but also to highly popular recreational fisheries in the upper Oldman River, Livingstone River, Dutch Creek and Racehorse Creek. The *Alberta Westslope Cutthroat Trout Recovery Plan* (The Alberta Westslope Cutthroat Trout Recovery Team 2013) highlights specific objectives to recover Alberta populations of WSCT. Recovery objectives relevant to our study included the following:

- Identify and protect critical habitat for remaining *pure* WSCT populations.
- Improve knowledge of population genetics, size, distribution and trends.
- Identify opportunities to help recover *pure* and *near-pure* populations of WSCT by restoring habitat.

One of the key threats identified in the recovery plan is the adverse effects of fine sediment deposition in stream habitat from surrounding land-use activities; this threat is classified as having "high" significance to WSCT populations and is identified as a major factor limiting the species' recovery.

In 2013, the Oldman Watershed Council and the Government of Alberta commissioned the *Oldman Watershed Headwaters Indicator Project*, which was a landscape-level assessment in which linear disturbance rankings featured prominently in overall watershed risk and integrity findings. Disturbance categories ranged from *negligible* in a few watersheds to *high* over much of the headwaters (Fiera 2014).

To help ensure that WSCT persists in the Oldman River headwaters, it is essential to identify populations, life-stage demographics and supporting habitats that are at risk from these disturbances. Similarly, an improved understanding of instream sedimentation effects on WSCT abundance and population structure at the reach and watershed scales is required.

At the watershed scale, impacts from landscape disturbance and increased sediment loading can lead to aggradation of the stream channel, degrading habitat quality. Through pool infilling, aggradation reduces overall pool habitat (i.e., size, depth and number) (Lisle 1982; Buffington et al. 2002). Aggradation similarly fragments habitat through the formation of dry riffle reaches that isolate pool habitats during low summer flows (May and Lee 2004). Pools are crucial habitat for all WSCT life stages and seasons, including spawning (Schmetterling 2000; Muhlfeld 2002), rearing (Bonneau and Scarnecchia 1998; Rosenfeld and Boss 2001) and overwintering (Heifetz et al. 1986; Harper and Farag 2004), and they also provide thermal refugia in the summer (Matthews et al. 1994; Nielsen et al. 1994).

At the reach scale, deposition of fine sediment from linear disturbance has been shown to reduce cutthroat trout abundance (Valdal and Quinn 2010) and negatively impact various salmonid life stages, including spawning success (Robertson et al. 2006), egg survival (Moring 1982), egg-fry survival (Jensen et al. 2009) and juvenile growth and survival (Harvey et al. 2009). Accumulation of fine sediment also reduces available interstitial refugia for both juvenile fish (Harvey et al. 2009) and benthic invertebrates above and below the streambed surface (Descloux et al. 2010), altering the composition of the macroinvertebrate community to a forage base less available to trout (Suttle et al. 2004). The compounding effect is increased energetic demands on fish where both food and cover are reduced (Harvey et al. 2009).

The effects of excess fine sediment in a system are most likely observed and quantified where scour-pools transition into the next immediate riffle, at the downwelling portion of the scour-pool tail-out (Lisle 1982; Kappesser 2002; Cover et al. 2008; Kusnierz et al. 2013). During flow events that are capable of transporting bed materials, sediment is scoured from pools and deposited on riffles. As flows recede, progressively finer particles are sorted out of riffle reaches and deposited into the next downstream pool (Hirsch and Abrahams 1981). When the upstream sediment load exceeds the stream's capacity to transport it, pools fill, and the downstream riffles load with the excess (Andrews 1982).

Estimates of adult and juvenile WSCT abundance, along with population structure analysis (length distribution), describe relative life-stage strengths and weakness (Neumann and Allan 2007). Abundance modelling along the course of mainstem waterbodies provides further information on juvenile and adult abundance relative to watershed position. Concurrent measurement of fine sediment deposition at the reach scale and collection of fish population data can be used to identify locations where accumulations may have impacted WSCT abundance,

population structure and habitat. Assessment across a range of linear disturbance levels can further identify habitats that support subpopulations and life stages potentially at risk, and facilitate prioritization of remediation efforts, such as road and trail decommissioning, to reduce disturbance (McCaffery et al. 2007).

Currently, the most urgent knowledge gap and data requirement identified in the Alberta WSCT recovery plan is identification of all remaining unhybridized populations in the province. Past inventories have been conducted in the Oldman River headwaters; however, significant data gaps remain with regards to genetic purity in undefined reaches of the watershed. Understanding where *pure* populations persist is crucial to establishing and connecting critical habitat areas under federal SARA legislation.

The primary objective of this study was to document trends in sedimentation relative to WSCT demographics at a landscape scale in the Oldman River headwaters. Specific objectives included the following:

- Document *pure* WSCT abundance and population structures in the upper Oldman River core area.
- Document deposited fine sediment quantity and composition relative to WSCT population structure and abundance in the upper Oldman River watershed core area.
- Collect WSCT genetic samples to improve knowledge of population genetics and help delineate additional habitat areas for protection.

2.0 STUDY AREA

The upper Oldman River watershed is the most northern of three main watersheds—which also include the Castle River and Crowsnest River watersheds—that originate in the southern Rockies of Alberta and converge at the Oldman River Dam to form the Oldman River below the reservoir. Within the Oldman River headwaters, *pure* WSCT populations are aided by the Gap falls, located at the eastern edge of the mountain front. The falls act as a significant obstacle to upstream fish migration, which limits the spread of invasive species that occur in higher numbers below the falls than above (Figure 1).

Our study area includes watersheds west of the Livingstone mountain range that have undergone varying degrees of landscape disturbance from recreational, industrial and commercial activities (Figure 1). Prominent disturbances include extensive all-terrain vehicle trail networks, widespread random camping, cattle grazing, oil and gas exploration, a long history of timber harvest, and extensive road infrastructure that connects the entire upper watershed.

Native fish species above the Gap falls include WSCT, bull trout (*Salvelinus confluentus*) and mountain whitefish (*Prosopium williamsoni*); non-native species include rainbow (*Oncorhynchus mykiss*) and cutbow trout. Tributaries within the study area that are popular with recreational anglers include the Livingstone River, the upper Oldman River, Dutch Creek and Racehorse Creek (Spiegl and Hurkett 2005). Catch-and-release angling restrictions have been in effect for WSCT since 2013, following this species' designation as *Threatened* under SARA.

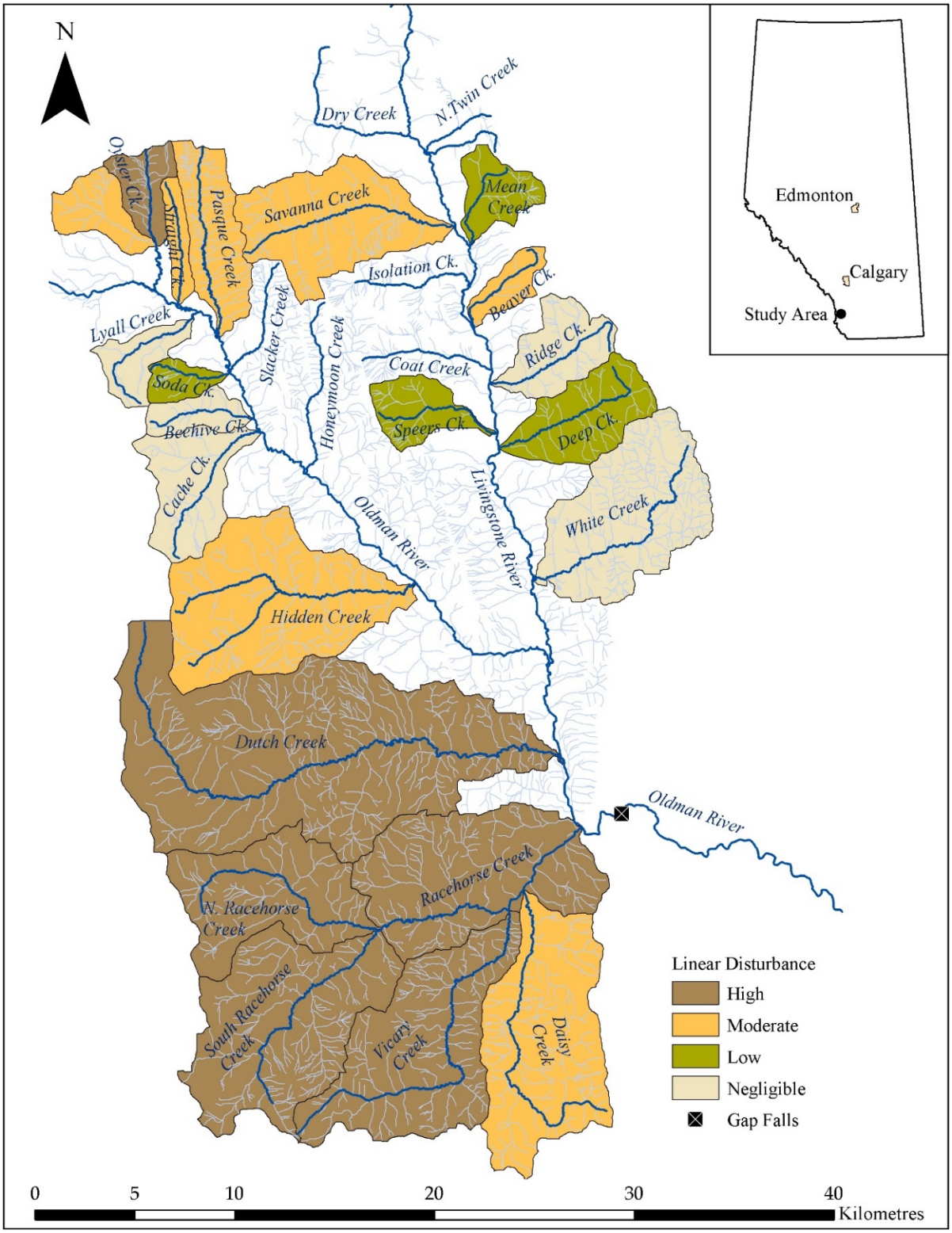


Figure 1. Upper Oldman River westslope cutthroat trout and deposited sediment study area, 2015 and 2016. Disturbances modified from Fiera (2014).

3.0 MATERIALS AND METHODS

From July through August in 2015 and 2016, we collected fish, sediment, habitat, stream channel, and pool information in key WSCT streams upstream of the Gap falls. We sampled at reaches across a range of linear disturbances (Table 1), watershed sizes and elevations (Table 2) to compare WSCT abundance and population structure at the reach and watershed scales relative to sedimentation, and to investigate the life-stage habitats supported therein.

Table 1. Watersheds included in the westslope cutthroat trout and fine deposited sediment study area, by linear disturbance, 2015 – 2016. Modified from Fiera (2014).

Linear disturbance category			
Negligible (0 – 0.6 km/km^2)	Low (>0.6 – 1.2 km/km^2)	Moderate (>1.2 – 3.0 km/km^2)	High (>3.0 km/km^2)
Lyall Creek	Soda Creek	Hidden Creek	Oyster Creek
Beehive Creek	Mean Creek	Unnamed to Oyster	Dutch Creek
Cache Creek	Speers Creek	Straight Creek	North Racehorse Creek
Ridge Creek	Deep Creek	Pasque Creek	South Racehorse Creek
White Creek		Savanna Creek	Racehorse Creek
		Beaver Creek	Vicary Creek
		Daisy Creek	

3.1 Stream network sampling eligibility

We delineated the stream network used in the study area primarily for the purposes of comparing population demographics and determining longitudinal population structure and abundance. Consequently, those stream networks considered eligible for sampling included only proven fish-bearing stream reaches typically third order (Strahler 1957) or larger to establish sufficiently robust fish-measurement datasets. We verified stream order and channel length using ArcMap 10.4 and used aerial imagery to cross-reference the longitudinal extent of stream channels. We assigned all prospective sampling points along the dominant (longest) single stream line (mainstem) per watershed that extended from a headwater source to the stream mouth.

Table 2. Description of watersheds sampled during assessment of westslope cutthroat trout and fine deposited sediment in the upper Oldman River watershed study area, 2015 and 2016.

Watershed	Watershed area (km^2)	Total stream length ≥ Strahler order-3 (km)	Mainstem stream length (km)	Number of sampling sites	Strahler stream order	Sampling site elevation range (m)
Dutch Creek	154.9	67.8	31.0	10	5	1,438 – 1,780
South Racehorse Creek	96.0	27.8	13.9	6	5	1,555 – 1,797
Hidden Creek[a]	68.8	30.2	22.5[a]	10	5	1,573 – 1,855
Vicary Creek	66.2	34.1	16.5	7	4	1,472 – 1,716
Lower Racehorse Creek	65.6	39.2	15.1	5	5	1,414 – 1,498
Daisy Creek	63.8	37.7	18.0	7	5	1,465 – 1,852
White Creek	52.7	36.6	15.9	7	5	1,584 – 1,765
North Racehorse Creek	46.2	21.3	13.2	5	4	1,592 – 1,785
Deep Creek	23.9	8.6	8.4	2	3	1,649 – 1,710
Cache Creek	23.9	7.3	6.7	1	4	1,752 – 1,759
Pasque Creek	22.9	15.2	11.5	3	4	1,843 – 1,923
Ridge Creek	18.3	7.3	6.0	1	4	1,706 – 1,709
Speers Creek	12.8	10.2	5.8	1	4	1,617 – 1,620
Mean Creek	12.0	7.5	4.0	2	4	1,784 – 1,807
Lyall Creek	10.3	2.3	2.3	1	3	1,808 – 1,825
Oyster Creek polygon[b]	10.2 (24.4)	12.2 (15.9)	4.7	2	4 (5)	1,906 – 1,927
Beehive Creek	8.3	5.4	3.1	2	2	1,717 – 1,879
Beaver Creek	7.6	5.9	2.7	1	3	1,685 – 1,693

[a]Hidden Creek stream length includes South Hidden Creek branch.

[b]Values in parentheses indicate those for the entire Oyster Creek watershed, of which only fourth-order polygons were eligible for sampling as discrete catchment areas of known disturbance level.

3.2 Sampling intensity

We used a minimum of 200 WSCT captures (Kritzer et al. 2001) per waterbody to characterize population structure, and a minimum sampling distance of 12.5% of the total mainstem, fish-bearing stream length (Fitzsimmons and Rodtka 2008) to characterize spatial distribution of abundance (Table 2). Using ArcMap 10.4, we plotted points at evenly spaced intervals along eligible watercourses, creating a pool of potential sampling locations. We spaced points at intervals twice the sampling site distance to ensure sampling independence (i.e., one site length in between eligible sampling sites). We selected sampling sites from the pool of potential locations using Generalized Random Tessellation Stratified sampling (Stevens and Olsen 2004) to achieve a spatially balanced yet randomized arrangement of sites along the mainstems, enabling both characterization of longitudinal trends in the watershed as well as unbiased comparison of population structure and abundance. No sampling sites were located within one site length of a stream mouth to maintain sampling independence between connected waterbodies, and we set a maximum one-way hiking distance of 2 km for sites that were accessible only by foot (Figure 2, Appendix 1).

Reach length for fish sampling was 40x mean wetted width or 300 m, whichever was greater (Alberta Environment and Sustainable Resource Development 2013), which also met minimum requirements for sampling stream sediment (Kusnierz et al. 2013). Consequently fish and sediment sampling site lengths were the same length, ensuring both datasets were aligned. Sampling reaches varied from 300 to 600 m in length, calculated from archival width data stored in the provincial government's (Alberta Environment and Parks; AEP) Fisheries and Wildlife Management Information System database.

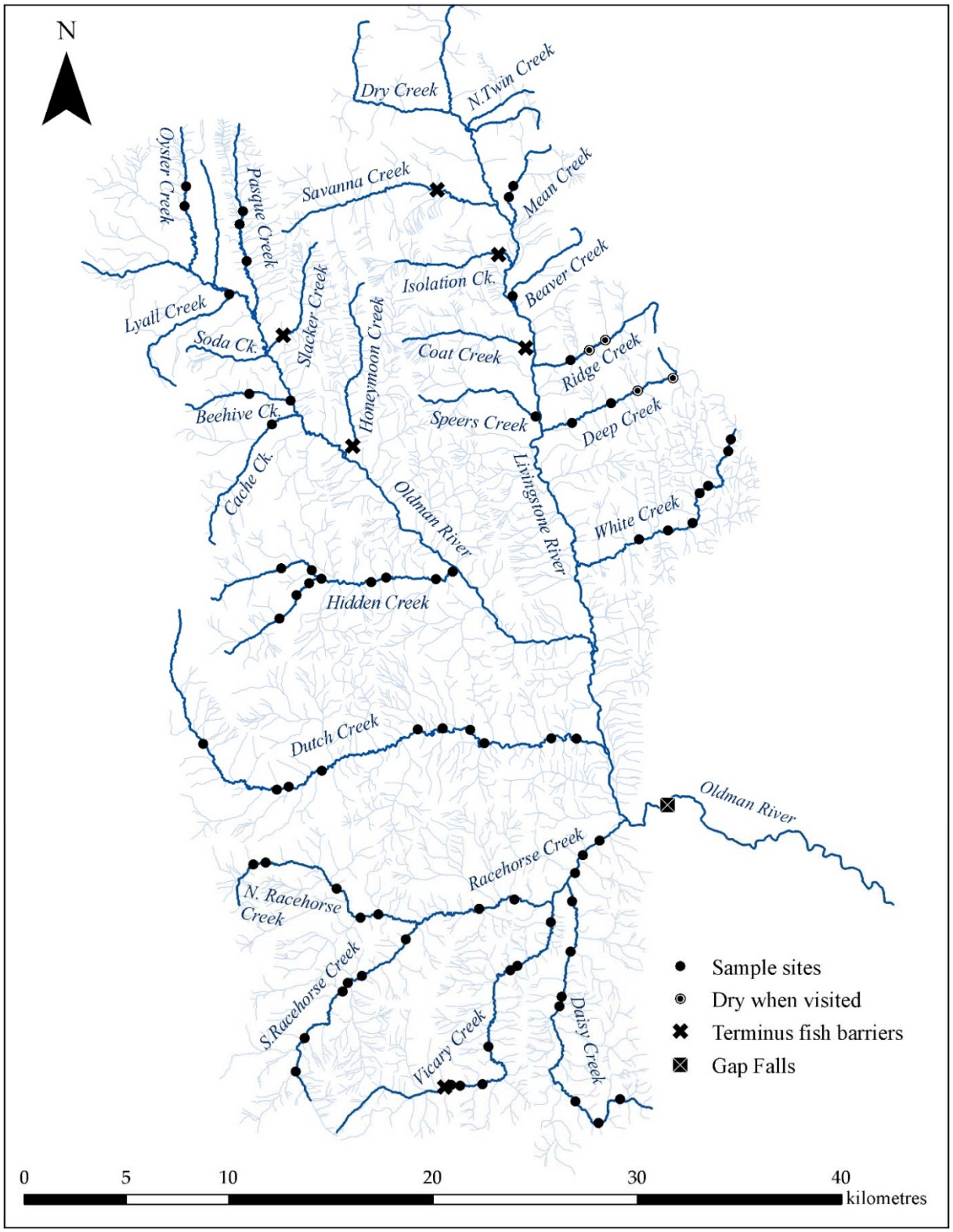


Figure 2. Sampling site locations in the upper Oldman River watershed, 2015 and 2016.

3.3 Fish data collection

We captured fish using Smith-Root backpack electrofisher types 15 and 12B for smaller streams typically <12 m wide and a Smith-Root LR-6 tote-barge with 5.0 GPP electrofisher for wider streams. We backpack electrofished in crews of two in an upstream progression at reaches ranging from 300 to 500 m in length, with one netter and one electrofisher operator. We tote-barge electrofished using a four-member crew in a downstream progression at sites ranging from 500 to 600 m in length, with one tote-barge operator, one anode operator and two netters. We collected biological data, including species, fork length (FL, mm), total length (TL, mm) and weight (g) (Appendix 2), and recorded the general condition of fish before returning them to the stream a short distance in the opposite direction of sampling. We collected tissue samples (caudal fin clip) from the first 30 black-spotted trout per sampling site in streams where genetic status was uncertain. Tissue samples were stored in 5 mL Globe Scientific mircrocentrifuge tubes immersed in a 95% denatured ethyl alcohol solution and then submitted to AEP.

Electrofishing transects were spaced at 50 m intervals for backpack reaches and 100 m intervals for totebarge reaches. Site data collected along these transects included wetted width (m), rooted width (m), mean depth (m) and total electrofishing effort in seconds (s) (Appendix 3).

3.4 Fish size categories

We summarized WSCT catch data from all electrofishing surveys into three size categories based on maturity and susceptibility to electrofishing gear. Fish <70 mm FL were not included in our analysis because they are difficult to capture with electrofishing gear and can bias abundance estimates (Peterson et al. 2004). We based life-stage categories on length-at-maturity following Downs and White (1997) and on unpublished spring sampling data for *pure* WSCT in pre-spawn condition from the headwaters of the Oldman River and Castle River watersheds collected by Alberta Conservation Association in mid-May 2009. We classified juveniles as fish ≥70 – 149 mm FL and adults as fish ≥150 mm FL.

3.5 Abundance modelling

We modelled longitudinal population abundance for all WSCT (total), juveniles and adults along the mainstems of select watersheds. We modelled cumulative sedimentation from mean scour-pool sediment quantity collected per sampling site. We performed longitudinal modelling

on mainstems with catchment areas >33 km^2 using a 27.8 km minimum stream length (i.e., ≥ third-order) as a secondary guide—that is, the requirements for a 90% chance of establishing reproducing populations of translocated cutthroat trout (Harig and Fausch 2002) and for maintaining cutthroat trout populations in small streams with low abundances (Hilderbrand and Kershner 2000), respectively (Table 2). We did not sample the Oldman and Livingstone rivers because they are not discrete catchments, but rather, are fed by numerous sub-watersheds of varying disturbance intensities and watershed condition.

We used methods described by Paul and Dormer (2005) and Fitzsimmons and Rodtka (2008) to estimate WSCT abundance and distribution. The model adjusts the observed catch data at each site by incorporating the uncertainty in capture efficiency and fish captures, given a constant capture efficiency, by using the beta and negative binomial distributions, respectively. We estimated electrofishing capture efficiency (q) from nine closed-model capture-mark-recapture (CMR) surveys on stream reaches isolated with blocking nets, with a single marking run and recapture run conducted on consecutive days (Appendix 4). To calculate q, we divided first-pass catch at a CMR reach by the Lincoln-Peterson estimate of abundance. We supplemented this dataset with q values calculated from other electrofishing CMR reaches on similar-sized streams in previous studies and watersheds (Blackburn 2008, 2010, 2011; Appendix 5). Uncertainty in estimation of q was then modelled with the beta distribution. We corrected the catch data at electrofishing sampling sites using q values picked at random from the beta distribution. The beta distribution ranges in values from zero to one, which lends itself to describing proportions, and its parameters (α and β) are defined by the mean and the standard deviation (SD) of the values of q. The parameters of the beta distribution are defined as:

$$\mu = \alpha / \alpha + \beta$$

Where μ is the mean of capture efficiencies q with an SD of

$$SD = \sqrt{\alpha\beta / (\alpha + \beta)^2 (\alpha + \beta + 1)}$$

Because capture efficiency is assumed to vary by capture technique, separate beta distributions were developed for backpack and totebarge electrofishing.

We estimated WSCT abundance at each sampling site per study stream using the observed catch at each site, a value of q drawn at random from the modelled distribution, and the negative

binomial distribution. We estimated the number of fish expected to have been missed at an inventory site while electrofishing with the previously chosen random q. Abundance of WSCT at each electrofishing site was then expressed as the observed catch plus the number of fish expected to have been missed. To accommodate sites where no fish were captured, catch was set to 0.1 fish because the binomial distribution cannot compute zero values, and trials were then conducted on the adjusted values.

Finally, fish abundance over the entire length of each study stream was estimated using a nonparametric generalized additive model with estimated fish abundance from each electrofishing site and each site's distance upstream as model input data. This model estimated fish abundance in 1,000 m increments along a given study stream, and integrating this function provided a single estimate of fish abundance over the entire stream. We performed 5,000 replicates for each 1,000 m estimate, and the results were stored in a data matrix where each row was one model replicate (estimate of fish abundance per 1,000 m) and each column was a 1,000 m stream increment. Summing the rows of the matrix gave 5,000 estimates of fish abundance for the entire stream. We then calculated mean fish abundance and 90% confidence limits from the 5,000 abundance estimates stored in the matrix. Modelling was performed using the software program R (R Development Core Team 2008).

3.6 Pool and sediment measurements

We collected pool information along the length of every electrofishing reach and defined pools based on Kusnierz et al. (2013). Criteria used to define a pool included connectivity to the thalweg and a maximum depth ≥1.5 times the pool tail-out depth (i.e., riffle-crest depth). We defined *scour*-pools as those formed by unimpeded scouring action of water and not from logs, ledges or the damming of the downstream end of the pool. We included only scour-pools >50% the wetted channel width for analysis of sediment deposition.

We used two methods to measure deposited sediment at electrofishing sampling sites: (1) Turner-Hillis deposited sediment sampler (DSS) (Turner et al. 2012) and (2) grid-toss methods (Kusnierz et al. 2013). We conducted sediment surveys where the effects of excess fine sediment were most likely to be observed, at the downwelling tail-out portions of scour-pools as defined by Kusnierz et al. 2013. We sampled sediment at the left, centre and right sections of scour-pool tail-outs (i.e., at 25%, 50% and 75% the distance across the wetted channel [Appendix 6]) and averaged results per scour-pool, and eventually by sampling site and waterbody.

3.6.1 Deposited sediment sampler

We measured sediment volume by collecting three sediment slurries per pool using the DSS and allowing them to settle in 1.5 L graduated Imhoff cones, following Meral et al. (2010). We accelerated settling rates of slurries using the flocculent Isofloc 251 (a polydiallyldimethylammonium chloride [pDADMAC] compound used for treating municipal drinking water) to consolidate sediments. Onsite calibration of the flocculent solution revealed optimal settling rates of about 15 minutes with the use of 5 mL of a 30 mg/L concentration of Isofloc 251 per cone. We measured sediment samples from up to 15 pools per site and used DSS calibration criteria based on depth and dominant substrate type, following Turner et al. (2012), to determine average fine sediment deposition quantity per pool. We collected three slurries per pool unless wetted channel width would not permit three independent samples, in which case we collected either two or one slurry as determined by the wetted width.

3.6.2 Grid-toss surveys

While DSS samples settled out of suspension, we conducted substrate composition assessments, following Hedrick et al. 2013, using grid-toss methods to quantify the proportion of surface substrate per scour-pool tail-out that was composed of the two fine sediment fractions of <2 and <6 mm diameter. We used a 35.5 x 35.5 cm steel grid to tally the underlying bed material at 50 intersections on the grid. We determined the proportion of sediments per pool as the total number of intersections underlain by each of the substrate size categories, out of a maximum total of 150 intersections per pool. We performed three tosses per pool unless wetted width was less than the equivalent of three grids across, in which case we performed either two or one grid-toss depending on the width capacity of the wetted channel.

3.7 Temperature monitoring

We deployed 27 temperature loggers throughout the core area at lower, mid and upper reaches of all watersheds for which abundance models were performed, and on a representative subset of smaller watersheds across a range of disturbances to document thermal habitat across the WSCT core area. We collected daily mean, maximum and minimum stream temperatures from June through August using Hobo Pendant loggers at 1.0 h intervals (Appendix 7).

4.0 RESULTS

We sampled 73 reaches on 18 waterbodies, totaling 25.2 km of stream. We captured 3,824 WSCT ≥70 mm FL and collected 1,151 tissue samples from 15 waterbodies for genetic analysis. We counted a total of 1,032 pools, of which 419 were scour-pools in which we performed a total of 1,129 grid-tosses and measured sediment volume of 458 DSS samples. We observed dry channels at four sampling sites and omitted another site based on insufficient flows.

4.1 Mean catch-per-unit-effort by waterbody

The highest catch-per-unit-effort (CPUE) of total WSCT (exceeding 300 fish/km) occurred in four waterbodies: Vicary Creek (355 fish/km), Pasque Creek (354 fish/km), Ridge Creek (350 fish/km) and White Creek (335 fish/km; Figure 3). The lowest CPUE occurred in Cache Creek (17 fish/km), Beehive Creek (8 fish/km) and Mean Creek (2 fish/km; Figure 3).

Juvenile CPUE was highest in Pasque Creek (321 fish/km), followed by Speers Creek (220 fish/km) and Vicary Creek (213 fish/km), and lowest in Beehive Creek (2 fish/km), Mean Creek (2 fish/km) and Cache Creek (0 fish/km; Figure 3). Adult CPUE was highest in Ridge Creek (247 fish/km), followed by Deep Creek (198 fish/km) and White Creek (155 fish/km), and lowest in Beehive Creek (7 fish/km) and Mean Creek (0 fish/km; Figure 3).

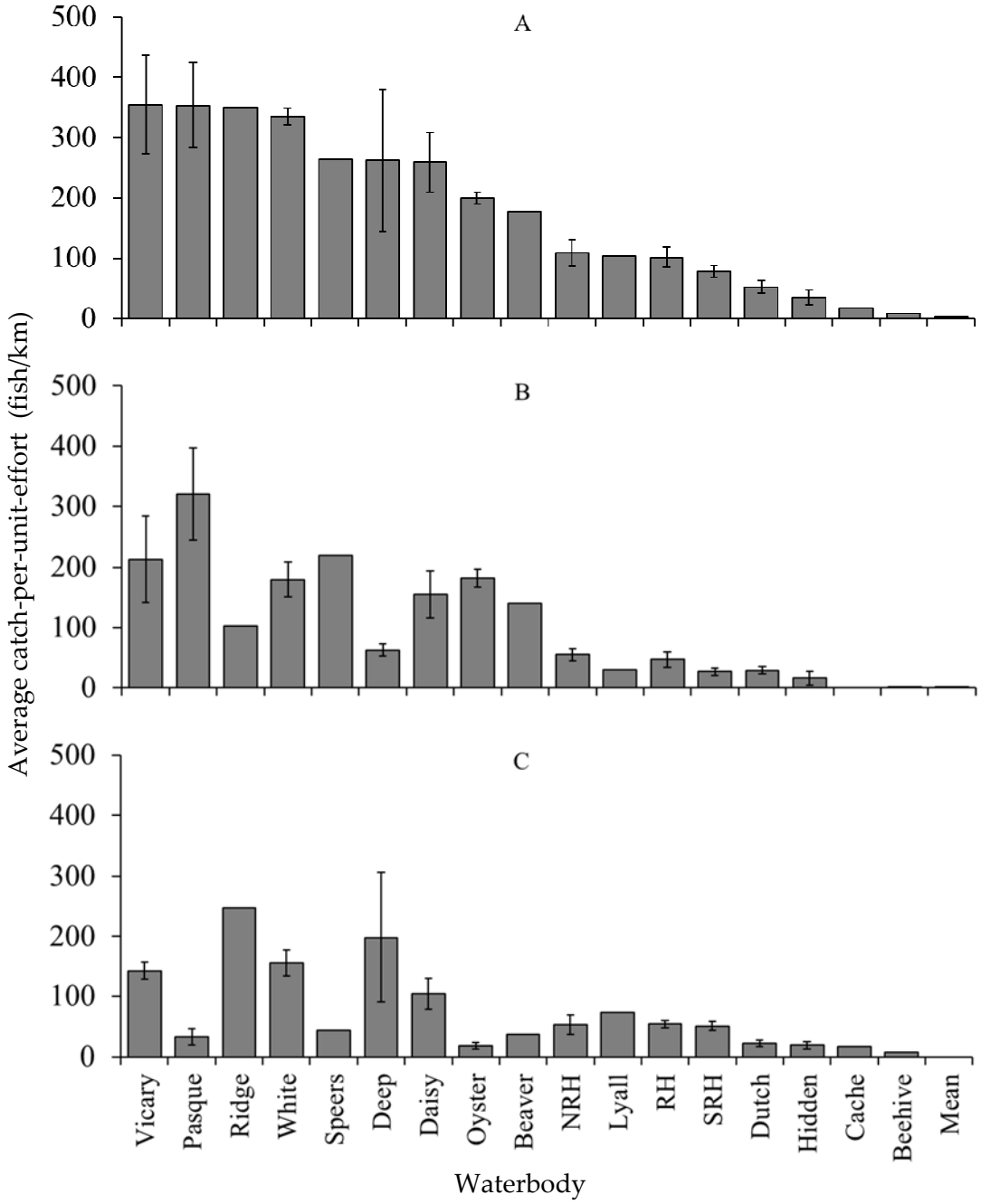


Figure 3. Mean catch-per-unit-effort (± standard error) of westslope cutthroat trout, by size class and waterbody, in the upper Oldman River study area, 2015 and 2016. Graphs shown are for A) all fish, B) juveniles and C) adults.

Juveniles represented most of the electrofishing catch in 10 of 18 watersheds. The highest proportion of juveniles occurred in Mean Creek (100%), where only a single fish was captured, followed by Oyster and Pasque (91%), Speers (84%), Beaver (79%), Vicary (60%), Daisy (60%) and Dutch (56%) creeks (Figure 4, Appendices 8 and 9). Streams where the proportion of adults and juveniles were nearly equal (i.e., within 5%) included White, North Racehorse, Hidden and Racehorse creeks (Figure 4, Appendices 8 and 9).

The proportion of adults exceeded that of juveniles in the electrofishing catches of eight waterbodies. The highest proportion of adults occurred in Cache (100%) and Beehive (88%) creeks, both of which had small capture totals of only five fish. Waterbodies where the proportion of adults exceeded that of juveniles, and where we had robust capture totals with high adult proportions, included Deep (75%), Lyall (71%), Ridge (71%) and South Racehorse (65%) creeks (Figure 4, Appendices 8 and 9).

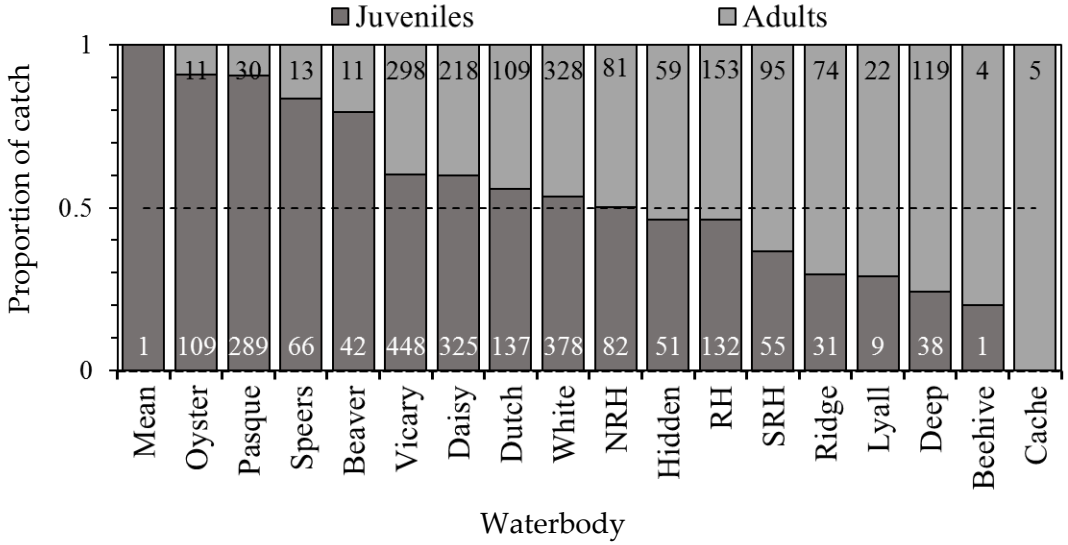


Figure 4. Proportion of adults and juveniles with respective capture totals by maturity-class per waterbody in the upper Oldman River study area, 2015 and 2016. NRH = North Racehorse, RH = Racehorse, SRH = South Racehorse. Dashed line indicates 50% of the catch.

4.2 Fish size composition by waterbody

Median WSCT size (FL) was <150 mm (juvenile) in 10 of 18 waterbodies and ≥150 mm (adult) in 8 of 18 waterbodies (Figure 5). Streams with length frequency distributions dominated by adult-sized fish included Ridge, Deep and Lyall creeks, whereas those dominated by juvenile-sized fish included Pasque, Speers, Oyster and Beaver creeks (Appendix 10). The largest median WSCT sizes occurred in Beehive Creek (246 mm), followed by Cache (218 mm), Deep (189 mm), South Racehorse (180 mm) and Ridge (172 mm) creeks (Figure 5). The smallest median WSCT size occurred in Beaver (115 mm), Speers (110 mm), Oyster (93 mm) and Pasque (83 mm) creeks.

We captured the largest WSCT (maximum FL) in Racehorse Creek (419 mm), followed by Dutch (375 mm), Daisy (367 mm), South Racehorse (355 mm), Hidden (324 mm), Cache (320 mm), North Racehorse (315 mm) and Deep (299 mm) creeks (Figure 5). We captured the smallest fish (at or near the 70 mm size limit) in 14 of the 18 streams sampled; however, minimum sizes (FL) in Cache (193 mm), Mean (148 mm), Beehive (135 mm) and Lyall (124) creeks were considerably larger than those from the remaining 14 streams (Figure 5).

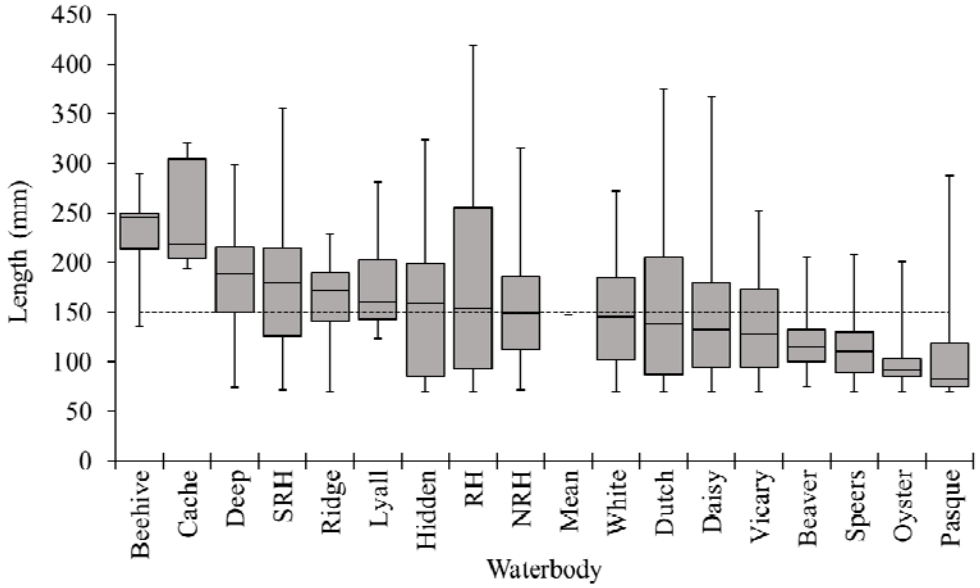


Figure 5. Box-plot diagram of westslope cutthroat trout length by waterbody in the upper Oldman River study area, 2015 and 2016, showing median (mid-line), upper and lower quartiles (boxes), minimum and maximum values (whiskers), and juvenile (below dashed line) and adult (above dashed line) values. Note: the Mean Creek value is plotted as a single whisker because of low captures.

4.3 Estimated abundance by waterbody

Vicary, White and Daisy creeks are vital streams for WSCT in the upper Oldman River watershed, with the highest abundances of total, juvenile and adult fish. Vicary Creek is the most prominent rearing stream, with the highest abundances of total WSCT (n = 20,930) and juveniles (n = 14,344), exceeding those of Racehorse, South Racehorse, North Racehorse, Dutch and Hidden creeks combined (combined total = 16,825, combined juveniles = 8,034; Table 3). The second-highest total and juvenile abundances occurred in White Creek (n = 14,908 and 8,144, respectively) and Daisy Creek (n = 13,155 and 7,761, respectively; Table 3).

White Creek is the most crucial stream for WSCT adults, with the highest abundance of fish ≥150 mm (n = 9,012), followed by Vicary Creek (n = 6,573) and Daisy Creek (n = 5,284; Table 3). Adult abundance in White Creek was greater than that in Racehorse, South Racehorse, North Racehorse and Dutch creeks combined (n = 8,791 combined). Similarly, adult abundance in Vicary Creek was greater than that in Racehorse, South Racehorse and North Racehorse creeks combined (n = 6,079 combined; Table 3). Although mean CPUE was higher for juveniles than adults in White Creek, the modelled adult abundance was higher than for juveniles as a result of the capture pattern along the waterbody. Adult abundances in North and South Racehorse creeks were comparable; however, total WSCT abundance was greater in North Racehorse Creek primarily because the juvenile population was more than double that of South Racehorse Creek.

Density (i.e., estimated abundance per kilometre) of total WSCT and juveniles was also highest in Vicary Creek (1,231 fish/km), followed by White Creek (877 fish/km) and Daisy Creek (692 fish/km; Table 4). Total WSCT and juvenile densities were lowest in Dutch Creek (130 fish/km and 74 fish/km, respectively) and Hidden Creek (86 fish/km and 41 fish/km, respectively). Adult densities were highest in White Creek (530 fish/km), followed by Vicary Creek (405 fish/km) and Daisy Creek (278 fish/km; Table 4). The lowest adult densities were estimated for Dutch Creek (55 fish/km) and Hidden Creek (50 fish/km). Both abundance and density estimates for total and both maturity classes of WSCT were consistently lowest in Hidden Creek (Table 4).

Table 3. Estimates of westslope cutthroat trout abundance, by mainstem, in waterbodies of the upper Oldman River watershed study area, 2015 and 2016.

Waterbody	Habitable mainstem (m)	All fish ≥70 mm		Juveniles ≥70 mm		Adults	
		Abundance	90% CI	Abundance	90% CI	Abundance	90% CI
Vicary	16,534	20,930	11,096 – 40,153	14,344	7,593 – 28,461	6,573	3,498 – 12,796
White	15,911	14,908	7,831 – 29,260	8,144	4,235 – 15,990	9,012	4,723 – 17,845
Daisy	18,014	13,155	6,864 – 25,839	7,761	4,126 – 15,199	5,284	2,783 – 10,111
RH	15,134	4,837	2,556 – 9,337	2,201	1,133 – 4,326	2,595	1,354 – 4,971
Dutch	30,992	4,173	2,204 – 8,114	2,370	1,244 – 4,642	1,755	920 – 3,497
NRH	12,262	3,528	1,867 – 6,872	1,803	952 – 3,399	1,739	912 – 3,422
SRH	12,643	2,661	1,433 – 5,038	887	466 – 1,717	1,745	920 – 3,480
Hidden	18,334	1,626	913 – 3,042	773	412 – 1,487	957	538 – 1,766

Table 4. Estimates of westslope cutthroat trout density, by mainstem, in waterbodies of the upper Oldman River watershed study area, 2015 and 2016.

Watershed	All fish ≥70 mm		Juveniles ≥70 mm		Adults	
	Abundance/km	90% CI	Abundance/km	90% CI	Abundance/km	90% CI
Vicary	1,231	653 – 2,362	844	447 – 1,674	405	215 – 786
White	877	461 – 1,721	479	249 – 941	530	278 – 1,050
Daisy	692	361 – 1,360	408	217 – 800	278	146 – 532
RH	337	177 – 655	152	78 – 298	183	94 – 350
Dutch	130	69 – 254	74	39 – 145	55	29 – 109
NRH	301	159 – 586	151	79 – 282	150	79 – 295
SRH	213	115 – 401	76	40 – 146	138	73 – 275
Hidden	86	48 – 160	41	22 – 78	50	28 – 93

4.4 Pool and sediment quantity by waterbody

4.4.1 Sediment volume

The highest sediment volumes (median) per stream occurred in Ridge Creek (130 mL), followed by Pasque (102 mL), Deep (101 mL), Beaver (95 mL) and Oyster (83 mL) creeks (Figure 6A). There were considerable sediment levels in Vicary (75 mL), White (64 mL) and Speers (49 mL) creeks. Median sediment volume was lower (i.e., <30 mL) for the remaining waterbodies, including South Racehorse (29 mL), Daisy (27 mL), Dutch and Mean (26 mL), Beehive and North Racehorse (25 mL), and Racehorse (21 mL) creeks, and Hidden Creek (15 mL) had the least fine deposited sediment. Lyall and Cache creeks had no scour-pools from which to collect sediment (Appendix 11).

4.4.2 Sediment fraction composition

Streams with the highest mean proportion of fine sediments <6 mm and <2 mm, which were also among those with the highest median sediment volumes, included Pasque (60% and 54%, respectively), Speers (53% and 43%, respectively), Oyster (43% and 28%, respectively), Deep (36% and 24%, respectively) and Ridge (28% and 16%, respectively) creeks (Figure 6A–6C). Similarly, streams that had both the lowest fine sediment proportions and median sediment volumes included Daisy and Mean (both 13% and 6%, respectively), Racehorse (10% and 5%, respectively), North Racehorse (10% and 3%, respectively), Dutch (8% and 3%, respectively), Beehive (7% and 1%, respectively) and Hidden (6% and <1%, respectively) creeks.

4.4.3 Scour-pool frequency

Scour-pool frequency was variable relative to sediment quantity; however, it was highest in many of the streams where median DSS sediment volume was highest (Figure 6D). The highest scour-pool frequency was in White Creek (36 pools/km), followed by Ridge and Oyster creeks (33 pools/km) and Pasque Creek (22 pools/km); these were also some of the streams with the highest WSCT catch rates. Frequency of scour-pools was comparable between Daisy (20 pools/km), Deep and Beehive (18 pools/km), and North Racehorse (17 pools/km) creeks (Figure 6, Appendix 11). Several streams with few scour-pools had high stream gradients, including Speers (10 pools/km), Mean (8 pools/km) and Cache and Lyall (0 pools/km) creeks.

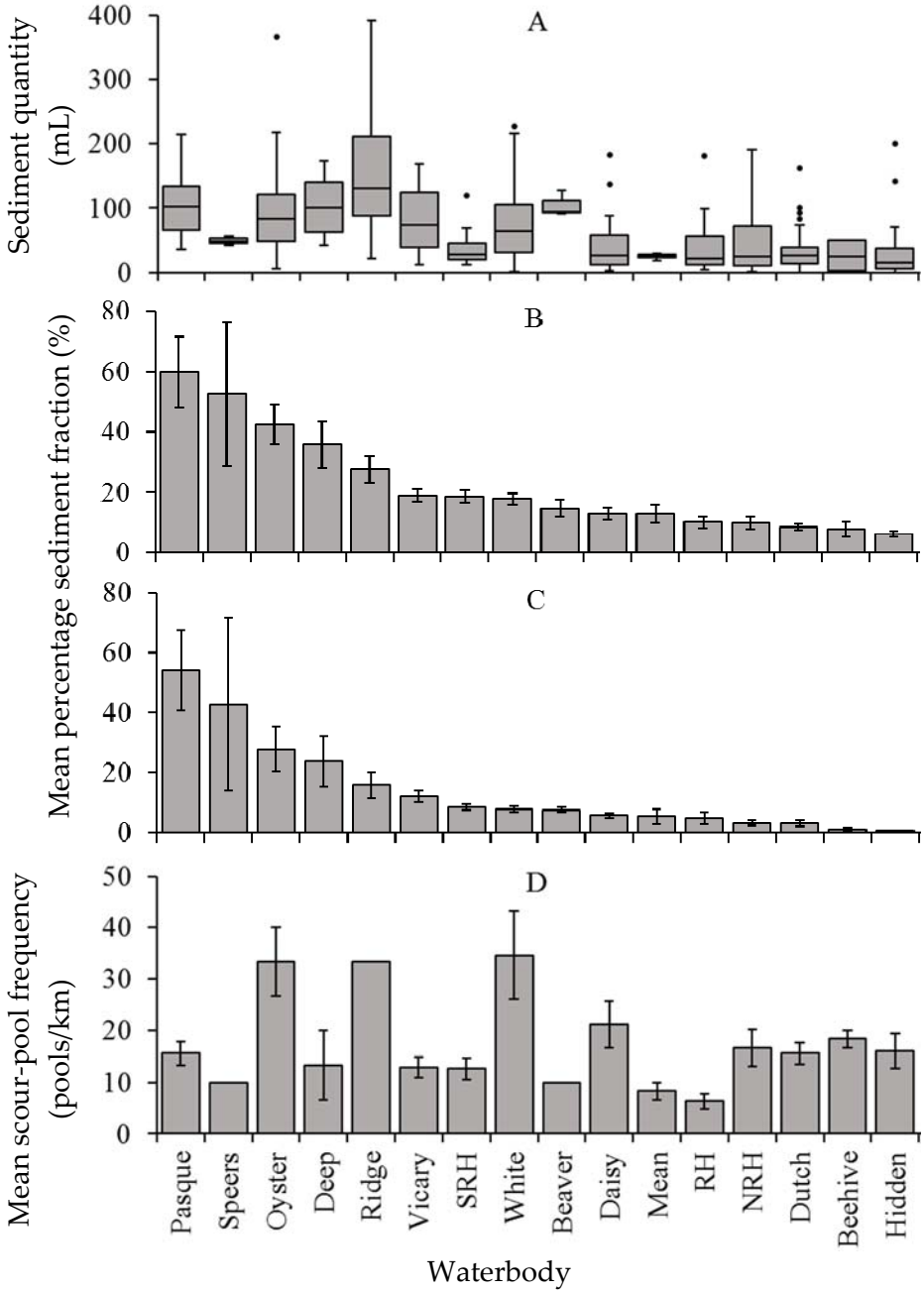


Figure 6. Sediment and pool measurement summary by waterbody for the upper Oldman River watershed study area, 2015 and 2016, showing A) box-plot diagram of sediment quantity (volume) with median (mid-line), upper and lower quartiles (boxes), minimum and maximum sediment volumes (mL) (whiskers), and interquartile outliers (points) (Note that outliers beyond the chart area include volumes of 611 mL and 420 mL on Ridge and South Racehorse creeks, respectively); mean percentage of sediment at scour-pool tail-outs of B) <6 mm diameter and C) <2 mm diameter; and D) mean scour-pool frequency (pools/km). Error bars on panels B, C and D indicate standard error. NRH = North Racehorse, RH = Racehorse, SRH = South Racehorse.

4.5 Sediment quantity relative to fish population structure

We found no clear relationship between sediment quantity and fish population structure. Pasque, Speers and Oyster creeks had both the highest proportion of fine sediments as well as juvenile fish (and smallest median FL). However, Ridge and Deep creeks were also among the streams with the highest sediment levels (the highest and third-highest sediment volumes, respectively, and the fourth- and fifth-highest proportion of fines, respectively), yet they had the highest proportion of adult fish.

4.6 Distribution of fish abundance and sediment

Overall, we observed complex interactions between longitudinal fish abundance, sediment quantity and WSCT maturity-class by waterbody. There was a trend of increasing sediment quantity with distance from the stream mouth in Vicary, White, Daisy and North Racehorse creeks, which were the streams with the highest catch rates (Figure 7). Conversely, sediment quantity decreased with distance from the mouth in Dutch, Hidden and South Racehorse creeks, which were the streams with the lowest catch rates. There was no clear trend in sediment quantity relative to distance from the mouth in Racehorse Creek; however, there was an inverse relationship between sediment quantity and fish abundance for both size categories of fish in Racehorse Creek and for adults in South Racehorse Creek (Figure 7), potentially related to reaches of bedrock pools where little sediment was retained but deep-water WSCT habitat was available.

Similarly, adult WSCT abundances peaked in mid-watershed in Daisy, South Racehorse and Dutch creeks (less so for the latter two creeks) (Figure 7), which also may be a result of more frequent and/or deeper holding pools, as was observed on Dutch Creek near kilometre-11, where lower stream gradient and a wider valley bottom contributed to frequent stream meanders and pools.

Overall, adult and juvenile abundances followed similar trends along the mainstems of Racehorse, North Racehorse, Dutch and Hidden creeks (Figure 7), potentially signifying limited availability of preferred habitat and more shared habitats between maturity classes. Conversely, the inverse relationship between adult and juvenile abundances observed on White Creek could indicate a greater availability of preferred habitat resulting in competitive segregation of fish by size and maturity class, as scour-pool frequency was highest on White Creek. No clear relationship existed between juvenile and adult abundances on Vicary, Daisy and South

Racehorse creeks; however, the obvious difference in longitudinal trends by maturity class further suggests differential use and/or availability of habitats along the mainstems.

Juvenile WSCT abundances in North and South Racehorse creeks generally increased in an upstream direction, in accordance with the trend observed in Racehorse Creek (lower) to which they are connected (Figure 7). The abundance of adults observed in North Racehorse Creek continued the trend of increasing abundance observed in Racehorse Creek; however, adult abundance in South Racehorse Creek plummeted sharply for about the last eight kilometres of the mainstem, coinciding approximately with the portion of upper South Racehorse Creek that closely parallels a main truck-accessible road (Atlas Road) and where many side roads occur in headwater source areas of the watershed. Reduced adult abundance may be a result of increased human activity occurring in or near the mainstem as a result of easier access (e.g., increased angling pressure).

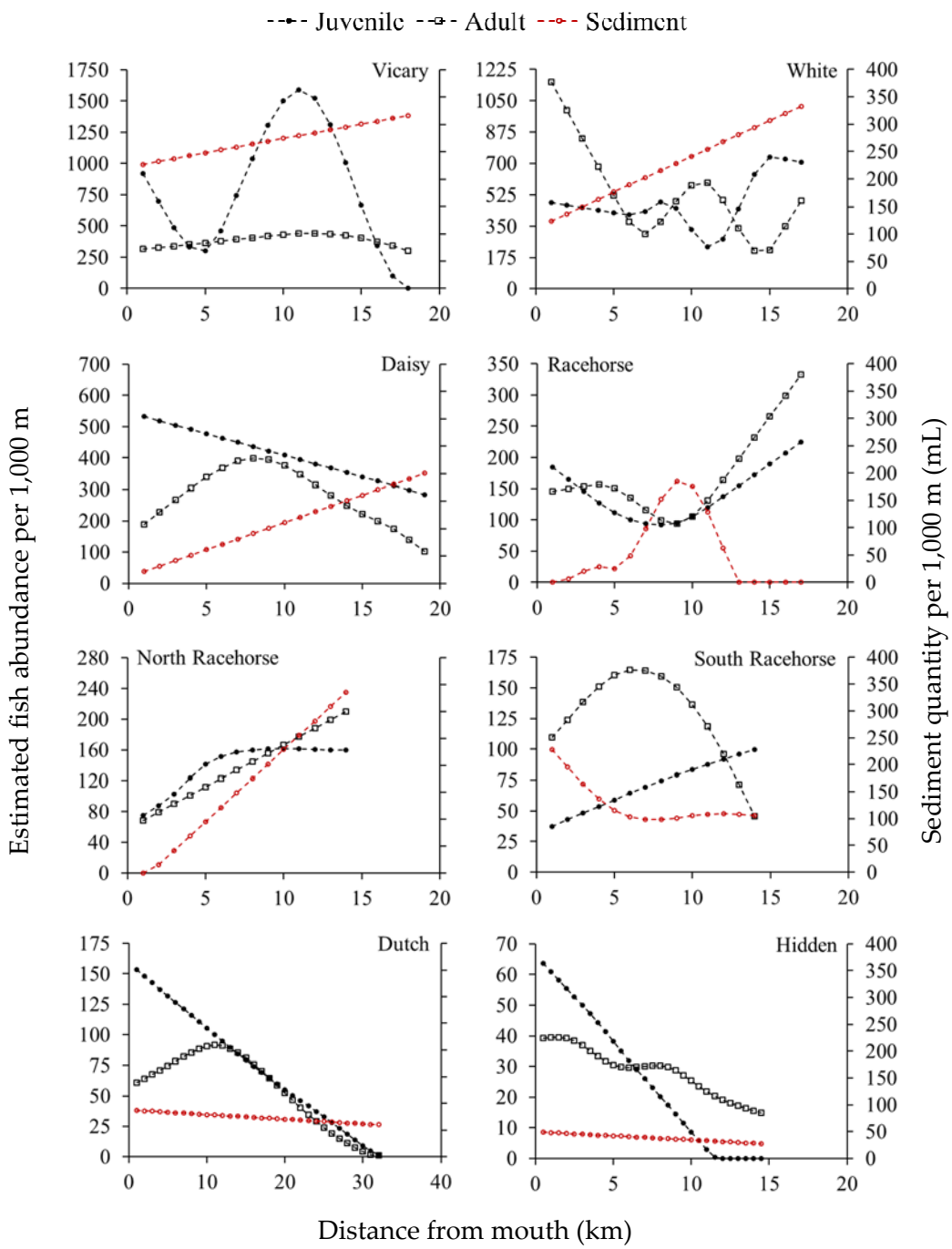


Figure 7. Mean scour-pool sediment quantity and estimated abundance of juvenile and adult westslope cutthroat trout per kilometre, by watershed. Shown are sediment estimates from mean dissolved sediment sampler volume (mL) collected per site, and mean fish abundance estimates derived from single-pass electrofishing capture data and corrected using capture-mark-recapture derived capture efficiencies (5,000 model runs). Note: the y-axis scale varies among waterbodies and the x-axis varies for Dutch Creek. Hidden Creek cutthroat trout abundances were calculated at 500 m intervals.

5.0 SUMMARY

We recorded the highest CPUE of WSCT in Vicary, Pasque, Ridge and White creeks. Similarly, juvenile catch rates were also highest in Pasque, Speers and Vicary creeks; Speers Creek was also a key rearing waterbody with the second-highest juvenile CPUE. Adult catch rates were highest in Ridge, Deep and White creeks. Streams where the population structure was almost entirely composed of juveniles included Pasque, Oyster, Speers and Beaver creeks. Conversely streams where adult-sized fish dominated the population structure included Deep, Ridge and Lyall creeks.

The highest mainstem abundances were in Vicary Creek, for both total WSCT and juveniles, exceeding that of Racehorse, South Racehorse, North Racehorse, Dutch and Hidden creeks combined. The highest adult WSCT abundance occurred in White Creek, which exceeded that of Racehorse, South Racehorse, North Racehorse and Dutch Creeks combined.

Streams among those with both the highest proportion of fine sediment fractions and high sediment volumes included Pasque, Speers, Oyster, Deep and Ridge creeks. The highest scour-pool frequencies occurred in White Creek (also the highest adult WSCT abundance), followed by Oyster, Ridge and Pasque creeks (the latter two were among the streams with the highest catch rates).

There was considerable variability in sediment quantity relative to WSCT abundance and population structure. Pasque, Speers and Oyster creeks, which had the highest proportions of fine sediment fractions, also had the highest proportions of juvenile fish. However, Ridge and Deep creeks were also among the streams with the highest sediment quantities but had the highest proportions of adult fish.

Interactions between longitudinal fish abundance and sediment quantity were complex. In watersheds with the highest catch rates (i.e., Vicary, White and Daisy creeks), there was a trend of increasing sediment quantity with upstream distance from the mouth, whereas there was an opposite trend for streams with the lowest capture rates (i.e., Hidden, Dutch and South Racehorse creeks). Variables such as reach-scale channel morphology, stream gradient and elevation may have confounded interpretation of the relationships between sediment quantity/quality and fish demographics by differentially altering sediment transport, retention and/or settling rate. For example, deep bedrock pools (e.g., Racehorse Creek) or high-gradient step-pool sequences

(e.g., Lyall Creek) retained fish but did not create scour-pools from which to measure transported sediment.

Pool availability may have had a similar confounding effect on interpreting differences in maturity-class composition by waterbody relative to sediment. For example, Vicary and White creeks had very similar measures of fine deposited sediment. White Creek had the most scour-pools per kilometre and an inverse, somewhat even, relationship between adult and juvenile longitudinal abundances, potentially indicating competitive segregation of fish by size. Conversely, Vicary Creek, which had fewer scour-pools, had a disproportionate abundance of juvenile fish, potentially indicating less available habitat suitable for adults.

Finally, proximity of disturbances to the stream channel may be a key variable influencing longitudinal population structure. The population of adults in North Racehorse Creek continued a trend of increasing abundance originating in lower Racehorse Creek; however, adult abundance in South Racehorse Creek plummeted sharply where the creek closely parallels a main road and where access is increased. The resulting decrease in adults may be a result of increased angling pressure or other human activities occurring near the stream channel.

The interactions between fine deposited sediment, stream morphology, WSCT abundance and population structure are complex in nature and will require considerable further analysis to better understand underlying mechanisms that impact WSCT populations in the upper Oldman River watershed.

6.0 LITERATURE CITED

Alberta Environment and Sustainable Resource Development. 2013. Standard for sampling of small streams in Alberta (Public version). Available online at: http://aep.alberta.ca/fish-wildlife/fish-research-licence/documents/Standard-SamplingSmallStreams-May2013.pdf [Accessed 13 January 2015].

Andrews, E.D. 1982. Bank stability and channel width adjustment, East Fork River, Wyoming. Water Resources Research 18(4): 1184–1192.

Archer, E.K., R.A. Scully, R. Henderson, B.P. Roper, and J.D. Heitke. 2012. Effectiveness monitoring for streams and riparian areas: sampling protocol for stream channel attributes. Unpublished paper. Available online at: http://www.fs.fed.us/biology/fishecology/new.html#pibo_reports. [Accessed 13 January 2015].

Blackburn, J. 2008. Population abundance and stock assessment of westslope cutthroat trout in the upper Oldman River watershed. Data Report, D-2008-009, produced by the Alberta Conservation Association, Lethbridge, Alberta, Canada. 38 pp + App.

Blackburn, J. 2010. Abundance and distribution of westslope cutthroat trout in the Castle River Drainage, Alberta, 2008 – 2009. Technical Report, T-2010-002, produced by the Alberta Conservation Association, Lethbridge, Alberta, Canada. 39 pp + App.

Blackburn, J. 2011. Crowsnest River drainage sport fish population assessment, 2010. Technical Report, T-2011-001, produced by the Alberta Conservation Association, Lethbridge, Alberta, Canada. 27 pp + App.

Bonneau, J.L., and D.L Scarnecchia. 1998. Seasonal and diel changes in habitat use by juvenile bull trout (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus clarki*) in a mountain stream. Canadian Journal of Zoology 76(5): 783–790.

Buffington, J., T. Lisle, R. Woodsmith, and S. Hilton. 2002. Control on the size and occurrence of pools in coarse-grained forest rivers. River Research and Applications 18: 507–531.

Cover, M.R., C.L. May, W.E. Dietrich, and V.H. Resh. 2008. Quantitative linkages among sediment supply, streambed fine sediment, and benthic macroinvertebrates in northern California streams. Journal of the North American Benthological Society 27: 135–145.

Descloux, S., T. Datry, M. Philippe, and P. Marmonier. 2010. Comparison of different techniques to assess surface and subsurface streambed colmation with fine sediments. International Review of Hydrobiology 95(6): 520–540.

Downs C., and R. White. 1997. Age at sexual maturity, sex ratio, fecundity, and longevity of isolated headwater populations of westslope cutthroat trout. North American Journal of Fisheries Management 17: 85–92.

Fiera Biological Consulting Ltd (Fiera). 2014. Oldman Watershed Headwaters Indicator Project – final report (Version 2014.1). Edmonton, Alberta. Fiera Biological Consulting Report #1346.

Fisheries and Oceans Canada. 2014. Recovery strategy for the Alberta populations of westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) in Canada [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, Canada. 28 pp.

Fitzsimmons, K., and M. Rodtka. 2008. Assessment of reach length for backpack electrofishing in wadeable streams - discussion paper. Alberta Conservation Association. Rocky Mountain House, Alberta, Canada. 38 pp.

Harig, A.L., and K.D. Fausch. 2002. Minimum habitat requirements for establishing translocated cutthroat trout populations. Ecological Applications 12(2): 535–551.

Harper, D., and A.M. Farag. 2004. Winter habitat use by cutthroat trout in the Snake River near Jackson, Wyoming. Transactions of the American Fisheries Society 133: 15–25.

Harvey, B.C., J.L. White, and R.J. Nakamoto. 2009. The effect of deposited fine sediment on summer survival and growth of rainbow trout in riffles of a small stream. North American Journal of Fisheries Management 29(2): 434–440.

Hedrick, L.B., J.T. Anderson, S.A. Welsh, and L.S. Lin. 2013. Sedimentation in mountain streams: a review of methods of measurement. Natural Resources 2013(4): 92–104.

Heifetz, J., M.L. Murphy, and K.V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. North American Journal of Fisheries Management 6: 52–58.

Hilderbrand, R.H., and J.L. Kershner. 2000. Conserving inland cutthroat trout in small streams: how much stream is enough? North American Journal of Fisheries Management 20(2): 513–520.

Hirsch, P.J., and A.D. Abrahams. 1981. The properties of bed sediments in pools and riffles. Journal of Sedimentary Petrology 51(3): 757–760.

Jensen, D.W., E.A. Steel, A.H. Fullerton and G.R. Pess. 2009. Impact of fine sediment on egg-to-fry survival of pacific salmon: a meta-analysis of published studies. Reviews in Fisheries Science 17 (3): 348–359.

Kappesser, G.B. 2002. A riffle stability index to evaluate sediment loading to streams. Journal of the American Water Resources Association 38(4): 1069–1081.

Kritzer, J.P., C.R. Davies, and B.D. Mapstone. 2001. Characterizing fish populations: effects of sample size and population structure on the precision of demographic parameter estimates. Canadian Journal of Fisheries and Aquatic Sciences 58(8): 1557–1568.

Kusnierz, P., A. Welch, and D. Kron. 2013. The Montana Department of Environmental Quality western Montana sediment assessment method: considerations, physical and biological parameter Ks, and decision making. Draft Report, Quality Planning Bureau, Montana Department of Environmental Quality, Helena, Montana, U.S.A. 59 pp + App.

Lisle, E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California. Water Resources Research 18: 1643–1651.

Matthews, K., N. Berg, D. Azuma, and T. Lambert. 1994. Cool water formation and trout habitat use in a deep pool in the Sierra Nevada, California. Transactions of the American Fisheries Society 123: 549–564.

May, C.L., and D.C. Lee. 2004. The relationships among in-channel sediment storage, pool depth, and summer survival of juvenile salmonids in Oregon Coast Range streams. North American Journal of Fisheries Management 24 (3): 761–774.

McCaffery, M., T.A. Switalski, and L. Eby. 2007. Effects of road decommissioning on stream habitat characteristics in the South Fork Flathead River, Montana. Transactions of the American Fisheries Society 136(3): 553–561.

Meral, R., E. Dogan, and Y. Demir. 2010. Turbidity measurements and modified Imhoff cone method for estimation of suspended sediment concentration. Fresenius Environmental Bulletin 19: 3066–3072.

Moring, J.R. 1982. Decrease in stream gravel permeability after clear-cut logging: an indication of intragravel conditions for developing salmonid eggs and alevis. Hydrobioligia Journal 88(3): 295–298.

Muhlfeld, C. 2002. Spawning characteristics of redband trout in a headwater stream in Montana. North American Journal of Fisheries Management 22(4): 1314–1320.

Neumann R., and M. Allen. 2007. Size structure. Pages 375–421. *In:* C.S. Guy and M.L. Brown (editors). Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland, U.S.A.

Nielsen, J., E.L. Thomas, and V. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Transactions of the American Fisheries Society 123: 613–626.

Paul, A., and C. Dormer. 2005. Silvester Creek fisheries study. Ecology Division, University of Calgary, Calgary, Alberta, Canada.

Peterson, J.T., R.F. Thurow, and J. W. Guzevich. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. Transactions of the American Fisheries Society 133: 462–475.

R Development Core Team. 2008. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online at: www.r-project.org. [Accessed 19 December 2016].

Robertson, M.J., D.A. Scruton, R.S. Gregory, and K.D. Clarke. 2006. Effect of suspended sediment on freshwater fish and fish habitat. Canadian Technical Report of Fisheries and Aquatic Sciences 2544: v + 37 pp.

Rosenfeld, J. S., and S. Boss. 2001. Fitness consequences of habitat use for juvenile cutthroat trout: energetic costs and benefits in pools and riffles. Canadian Journal of Fisheries and Aquatic Sciences 58(3): 585–593.

Schmetterling, D.A. 2000. Redd characteristics of fluvial westslope cutthroat trout in four tributaries to the Blackfoot River, Montana. North American Journal of Fisheries Management 20(3): 776–783.

Spiegl, C., and B.J. Hurkett. 2005. Upper Oldman River drainage angler survey, 2004. Data Report, D-2005-036, produced by Alberta Conservation Association, Blairmore, Alberta. 24 pp.

Stevens Jr., D.L., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99(465): 262–278.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. American Geophysical Union Transactions 38: 913–920.

Suttle, K.B., M.E. Power, J.M. Levine, and C. McNeely. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications 14: 969–974.

The Alberta Westslope Cutthroat Trout Recovery Team. 2013. Alberta westslope cutthroat trout recovery plan: 2012 – 2017. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 28, Edmonton, Alberta, Canada. 77 pp.

Turner, A., J. Hillis, and C. Rabeni. 2012. A sampler for measuring deposited fine sediments in streams. Journal of the American Water Resources Association 48(2): 366–378. DOI: 10.1111/j.1752-1688.2011.00618.x.

Valdal, E.J. and M.S. Quinn. 2010. Spatial analysis of forestry related disturbance on westslope cutthroat trout (*Oncorhynchus clarkii lewisi*): implications for policy and management. ©Springer Science and Business Media B.V. 2010. Applied Spatial Analysis and Policy. DOI: 10.1007/s12061-009-9045-5.

7.0 APPENDICES

Appendix 1. Upper Oldman River watershed sampling site locations, 2015 and 2016. UTM coordinates NAD 83 Zone 11.

Waterbody	Sampling site	Site ID	Downstream easting	Downstream northing	Upstream easting	Upstream northing	Survey date
Beaver Creek	1	MOD6	683224	5552911	683173	5553102	08-Aug-16
Beehive Creek	2	NEG3	672344	5547783	672151	5547752	21-Jul-15
Beehive Creek	3	NEG6	670333	5548124	670137	5548143	21-Jul-15
Cache Creek	4	NEG2	671442	5546619	671233	5546487	17-Aug-16
Daisy Creek	5	DS1	687427	5512412	687689	5512513	09-Aug-16
Daisy Creek	6	DS2	685625	5518588	685602	5518296	28-Jun-16
Daisy Creek	7	DS3	686135	5523261	686219	5523064	28-Jul-16
Daisy Creek	8	DS4	688483	5513577	688685	5513517	14-Jul-16
Daisy Creek	9	DS5	686293	5513480	686432	5513295	25-Jul-16
Daisy Creek	10	DS6	685517	5518113	685386	5517877	28-Jun-16
Daisy Creek	11	DS7	686066	5520797	685977	5520571	11-Aug-16
Deep Creek	12	LOB1	686138	5546706	686339	5546872	11-Aug-15
Deep Creek	13	LOW3	688043	5547669	688238	5547725	11-Aug-15
Dutch Creek	14	D1	681829	5531028	681531	5531067	18-Aug-15
Dutch Creek	15	D2	678582	5531697	678188	5531453	10-Aug-15
Dutch Creek	16	D3	673882	5529672	673409	5529631	03-Jul-15
Dutch Creek	17	D4	686349	5531235	686024	5531340	23-Jul-15
Dutch Creek	18	D5	681135	5531681	680691	5531706	20-Aug-15
Dutch Creek	19	D6	679791	5531749	679464	5531722	20-Jul-15
Dutch Creek	20	D7	672265	5528897	672025	5528857	05-Aug-15
Dutch Creek	21	D8	685105	5531262	684767	5531111	16-Jul-15
Dutch Creek	22	D9	668075	5530997	667944	5531248	08-Jul-15
Dutch Creek	23	D10	671686	5528754	671459	5528768	08-Jul-15

Appendix 1. Continued.

Waterbody	Sampling site	Site ID	Downstream easting	Downstream northing	Upstream easting	Upstream northing	Survey date
Hidden Creek	24	H1	671807	5537115	671598	5536991	29-Jul-15
Hidden Creek	25	H2	680297	5539409	680152	5539367	28-Jul-15
Hidden Creek	26	H3	673392	5539491	673249	5539687	06-Jul-15
Hidden Creek	27	H4	671899	5539586	671688	5539547	07-Jul-15
Hidden Creek	28	H5	672647	5538269	672607	5538017	29-Jul-15
Hidden Creek	29	H6	676307	5538914	675930	5538872	22-Jul-15
Hidden Creek	30	H7	677028	5539123	676801	5539056	07-Jul-15
Hidden Creek	31	H8	679471	5539061	679220	5539038	20-Jul-15
Hidden Creek	32	HB1	673267	5538852	673126	5538717	04-Aug-15
Hidden Creek	33	HB2	673866	5539065	673693	5539162	03-Aug-15
Lyall Creek	34	NEG5	669352	5553000	669329	5552792	17-Aug-16
Mean Creek	35	LOW1	683251	5558296	683424	5558492	18-Aug-16
Mean Creek	36	LOW5	683035	5557754	683093	5558003	24-Aug-16
North Racehorse Creek	37	NR1	675777	5522444	675561	5522521	23-Aug-16
North Racehorse Creek	38	NR2	670530	5525050	670374	5524931	06-Jul-16
North Racehorse Creek	39	NR4	676655	5522607	676401	5522607	19-Jul-16
North Racehorse Creek	40	NR5	674611	5523878	674406	5524016	06-Jul-16
North Racehorse Creek	41	NRB1	671138	5525138	670920	5525156	16-Aug-16
Oyster Creek	42	HIGH1	667242	5558285	667194	5558472	12-Aug-15
Oyster Creek	43	HIGH2	667171	5557310	667156	5557510	12-Aug-15
Pasque Creek	44	MOD1	670015	5557060	669930	5557285	01-Sep-15
Pasque Creek	45	MOD2	670196	5554619	670117	5554881	22-Aug-16
Pasque Creek	46	MOD5	669864	5556430	669938	5556631	25-Aug-15
Racehorse Creek	47	RH1	686658	5525514	686440	5525110	23-Jun-16
Racehorse Creek	48	RH2	681580	5522885	681278	5522829	26-Jul-16

Appendix 1. Continued.

Waterbody	Sampling site	Site ID	Downstream easting	Downstream northing	Upstream easting	Upstream northing	Survey date
Racehorse Creek	49	RH3	687481	5526212	686995	5525956	24-Jun-16
Racehorse Creek	50	RH4	686274	5524635	685873	5524192	24-Jun-16
Racehorse Creek	51	RH5	683313	5523335	683003	5523463	11-Jul-16
Ridge Creek	52	NEGB1	686062	5549784	686269	5549837	19-Aug-15
South Racehorse Creek	53	SR1	675854	5519610	675739	5519551	12-Jul-16
South Racehorse Creek	54	SR2	674899	5518842	674697	5518797	10-Aug-16
South Racehorse Creek	55	SR3	672610	5514938	672814	5514574	04-Jul-16
South Racehorse Creek	56	SR4	677989	5521401	677925	5521169	13-Jul-16
South Racehorse Creek	57	SR5	673037	5516567	672892	5516399	20-Jul-16
South Racehorse Creek	58	SR6	675162	5519274	675046	5519131	13-Jul-16
Speers Creek	59	LOW6	684339	5547018	684123	5547163	24-Aug-16
Vicary Creek	60	V1	683454	5520099	683358	5519941	02-Aug-16
Vicary Creek	61	V2	680221	5514283	679926	5514193	29-Jun-16
Vicary Creek	62	V3	680659	5514238	680403	5514293	25-Aug-16
Vicary Creek	63	V4	683102	5519881	682810	5519827	18-Jul-16
Vicary Creek	64	V5	685096	5522225	685118	5521978	03-Aug-16
Vicary Creek	65	V6	682043	5516150	682102	5515937	15-Aug-16
Vicary Creek	66	V7	681740	5514321	681514	5514348	04-Aug-16
White Creek	67	W1	692037	5541810	692264	5541989	13-Aug-15
White Creek	68	W2	692375	5543265	692475	5543378	15-Jul-15
White Creek	69	W3	690836	5541434	691120	5541459	08-Jul-15
White Creek	70	W4	692802	5543626	693009	5543565	14-Jul-15
White Creek	71	W5	689415	5540997	689663	5541025	27-Jul-15
White Creek	72	W6	693912	5545891	693977	5546085	13-Jul-15
White Creek	73	W7	693769	5545319	693772	5545525	06-Aug-15

Appendix 2. Summary of westslope cutthroat trout size range and capture total by waterbody in the upper Oldman River watershed, 2015 and 2016. SD = standard deviation.

Watershed	Fork length (mm)		Weight (g)		Fish captured	Sampling sites
	Mean (± SD)	Range	Mean (± SD)	Range		
White Creek	141 ± 51	25 – 272	48 ± 45	1 – 280	751	7
Daisy Creek	136 ± 58	40 – 367	48 ± 64	1 – 542	597	7
Hidden Creek	153 ± 65	61 – 324	75 ± 88	3 – 416	113	10
Vicary Creek	144 ± 59	60 – 345	57 ± 69	1 – 452	758	7
Dutch Creek	153 ± 83	41 – 375	97 ± 141	2 – 616	267	10
Racehorse Creek	176 ± 96	54 – 419	129 ± 184	1 – 989	292	5
North Racehorse Creek	152 ± 58	44 – 315	67 ± 76	2 – 413	167	5
South Racehorse Creek	166 ± 64	43 – 355	90 ± 89	2 – 654	162	6
Ridge Creek	160 ± 39	62 – 228	58 ± 32	1 – 152	109	1
Lyall Creek	177 ± 46	124 – 281	82 ± 73	21 – 273	31	1
Cache Creek	248 ± 60	193 – 320	250 ± 202	93 – 498	5	1
Beehive Creek	227 ± 58	135 – 290	191 ± 112	29 – 306	5	2
Deep Creek	184 ± 44	74 – 299	92 ± 62	3 – 344	157	2
Speers Creek	104 ± 38	54 – 208	23 ± 24	3 – 118	98	1
Mean Creek	148 ± 0	148 – 148	39 ± 0	39 – 39	1	2
Pasque Creek	93 ± 35	55 – 287	15 ± 26	1 – 290	398	3
Beaver Creek	122 ± 31	75 – 205	24 ± 23	4 – 100	53	1
Oyster Creek	87 ± 30	31 – 201	16 ± 20	4 – 115	176	2

Appendix 3. Stream and site measurement data from the upper Oldman River watershed study area, 2015 and 2016. WW = wetted width, RW = rooted width, SD = standard deviation, s = seconds.

Site ID	Mean wetted width (m) ± SD	n	Mean rooted width (m) ± SD	n	Mean depth (m) ± SD	n	Distance fished (m)	Electrofishing effort (s)
DS1	2.5 ± 0.7	7	4.1 ± 1.6	7	0.18 ± 0.10	7	300	1,351
DS2	4.5 ± 1.6	7	8.5 ± 2.0	7	0.31 ± 0.09	7	300	1,690
DS3	6.2 ± 2.4	7	13.0 ± 3.5	7	0.75 ± 0.61	7	300	1,969
DS4	1.7 ± 0.3	7	3.0 ± 0.4	7	0.18 ± 0.07	7	300	1,079
DS5	3.3 ± 1.2	6	4.9 ± 1.3	6	0.17 ± 0.05	6	300	1,325
DS6	5.2 ± 1.4	7	6.8 ± 1.6	7	0.29 ± 0.09	7	300	1,734
DS7	5.4 ± 1.0	6	9.8 ± 1.8	6	0.61 ± 0.55	7	300	2,578
D1	9.3 ± 2.9	12	25.2 ± 19.4	12	0.42 ± 0.23	11	515	2,641
D2	8.1 ± 2.7	11	10.7 ± 2.2	11	0.45 ± 0.19	11	500	2,311
D3	8.3 ± 1.2	11	7.3 ± 1.3	11	0.43 ± 0.11	11	500	4,177
D4	10.3 ± 2.6	7	11.9 ± 2.7	7	0.49 ± 0.17	8	500	3,456
D5	8.7 ± 1.3	10	12.1 ± 2.4	10	0.35 ± 0.06	10	500	2,676
D6	9.6 ± 3.0	11	13.0 ± 5.4	11	0.36 ± 0.14	11	500	3,177
D7	6.2 ± 1.5	7	6.9 ± 1.3	7	0.32 ± 0.13	7	300	1,899
D8	10.1 ± 1.6	11	11.8 ± 1.6	11	0.68 ± 0.49	11	500	3,527
D9	4.3 ± 0.8	7	7.3 ± 1.6	7	0.30 ± 0.03	7	300	1,273
D10	5.3 ± 0.5	7	7.5 ± 1.9	7	0.41 ± 0.10	7	300	1,839
H1	3 ± 0.8	7	3.6 ± 0.9	7	0.31 ± 0.07	7	300	1,337
H2	6.2 ± 1.0	7	8.1 ± 0.8	7	0.52 ± 0.23	7	300	1,724
H3	4.8 ± 1.2	11	6.1 ± 3.9	11	0.30 ± 0.07	10	500	1,839
H4	3.8 ± 0.4	7	4.6 ± 0.7	7	0.49 ± 0.21	7	300	1,447
H5	3.1 ± 0.6	7	4.3 ± 1.0	7	0.24 ± 0.05	7	300	1,059
H6	5.5 ± 0.4	11	6.3 ± 1.4	11	0.53 ± 0.17	11	500	2,290
H7	7.2 ± 1.3	6	7.3 ± 1.5	6	0.46 ± 0.14	6	300	1,968
H8	6.2 ± 1.3	7	6.6 ± 1.5	7	0.41 ± 0.06	7	300	1,301

Appendix 3. Continued.

Site ID	Mean wetted width (m) ± SD	n	Mean rooted width (m) ± SD	n	Mean depth (m) ± SD	n	Distance fished (m)	Electrofishing effort (s)
Hb1	3.4 ± 0.6	7	4.3 ± 0.7	7	0.25 ± 0.07	7	300	1,316
Hb2	5.1 ± 1.5	7	6.5 ± 1.2	7	0.32 ± 0.07	6	300	1,064
NR1	5.4 ± 1.2	7	8.7 ± 2.0	7	0.36 ± 0.19	7	300	1,642
NR2	2.9 ± 0.6	7	4.5 ± 0.9	7	0.27 ± 0.12	7	300	1,280
NR4	6.7 ± 1.1	7	8.1 ± 1.7	7	0.42 ± 0.12	7	300	1,733
NR5	5.1 ± 1.0	7	7.7 ± 2.0	7	0.39 ± 0.12	7	300	1,564
NRB1	3.2 ± 1.0	7	4.8 ± 1.4	7	0.32 ± 0.07	7	300	1,629
RH1	19.4 ± 6.3	5	22.1 ± 4.1	5	0.46 ± 0.21	5	600	1,959
RH2	9.1 ± 2.6	11	14.9 ± 2.8	11	0.41 ± 0.22	11	500	4,021
RH3	14.4 ± 2.4	7	17.9 ± 2.4	7	0.41 ± 0.15	7	600	3,430
RH4	17.0 ± 3.2	8	19.0 ± 2.4	8	0.64 ± 0.32	8	600	4,216
RH5	9.9 ± 3.0	11	15.4 ± 3.8	11	0.48 ± 0.30	11	500	2,179
SR1	6.3 ± 2.0	7	9.6 ± 2.0	7	0.33 ± 0.18	7	300	1,583
SR2	3.3 ± 0.9	7	6.8 ± 1.4	7	0.38 ± 0.29	7	300	1,719
SR3	3.8 ± 0.7	12	5.4 ± 1.2	12	0.18 ± 0.08	12	500	1,450
SR4	7.2 ± 1.7	7	10.5 ± 2.7	7	0.55 ± 0.40	7	300	1,225
SR5	3.9 ± 1.3	7	7.8 ± 3.6	7	0.35 ± 0.17	7	300	1,628
SR6	4.3 ± 1.3	7	8.4 ± 1.7	7	0.24 ± 0.13	7	300	1,370
V1	5.8 ± 1.1	7	7.0 ± 1.0	7	0.26 ± 0.08	7	300	1,756
V2	4.1 ± 0.7	7	6.5 ± 0.9	7	0.32 ± 0.22	7	300	1,187
V3	4.5 ± 0.6	7	6.6 ± 0.8	7	0.22 ± 0.05	7	300	1,238
V4	6.7 ± 3.0	7	11.4 ± 3.6	7	0.31 ± 0.06	7	300	2,538
V5	5.2 ± 1.5	7	9.2 ± 1.9	7	0.33 ± 0.12	7	300	1,996
V6	6.7 ± 3.5	7	11.9 ± 4.3	7	0.32 ± 0.21	7	300	2,386
V7	4.2 ± 0.8	7	8.0 ± 3.4	7	0.22 ± 0.13	7	300	1,520

Appendix 3. Continued.

Site ID	Mean wetted width (m) ± SD	n	Mean rooted width (m) ± SD	n	Mean depth (m) ± SD	n	Distance fished (m)	Electrofishing effort (s)
W1	5.9 ± 2.1	7	14.0 ± 2.9	7	0.56 ± 0.57	7	300	1,461
W2	3.8 ± 2.4	5	6.2 ± 1.9	5	0.16 ± 0.06	5	300	1,819
W3	5.9 ± 1.8	7	34 ± 11.6	7	0.21 ± 0.05	7	300	1,726
W4	3.7 ± 0.8	7	9.2 ± 2.5	7	0.20 ± 0.09	7	310	1,239
W5	5.0 ± 0.8	7	10.7 ± 2.2	7	0.14 ± 0.05	7	300	1,758
W6	1.7 ± 0.7	7	2.1 ± 0.8	7	0.30 ± 0.27	7	300	1,193
W7	1.3 ± 0.4	7	2.0 ± 0.8	7	0.20 ± 0.10	7	300	1,340
MOD6	2.4 ± 1.9	7	4.0 ± 1.9	7	0.27 ± 0.11	7	300	1,650
NEG3	1.7 ± 0.2	7	2.6 ± 1.1	7	0.19 ± 0.03	7	300	1,208
NEG6	2.4 ± 0.6	7	3.4 ± 0.6	7	0.28 ± 0.10	7	300	819
NEG2	3.9 ± 0.9	7	5.3 ± 1.2	7	0.38 ± 0.12	7	300	969
LOB1	5.2 ± 2.0	6	7.6 ± 1.3	6	0.38 ± 0.12	6	300	1,323
LOW3	4.0 ± 1.2	7	6.5 ± 2.4	7	0.21 ± 0.02	7	300	1,089
NEG5	3.1 ± 0.6	7	4.8 ± 1.6	7	0.30 ± 0.06	7	300	1,341
LOW1	4.7 ± 1.4	7	9.3 ± 2.3	7	0.31 ± 0.14	7	300	1,042
LOW5	4.4 ± 1.4	7	6.7 ± 1.5	7	0.42 ± 0.12	7	300	1,392
HIGH1	2.5 ± 0.8	7	4.4 ± 2.6	7	0.22 ± 0.13	7	300	1,578
HIGH2	1.8 ± 0.8	7	4.7 ± 1.8	7	0.25 ± 0.25	7	300	1,232
MOD1	3.3 ± 1.2	7	8.2 ± 2.7	7	0.18 ± 0.03	7	300	1,225
MOD2	3.9 ± 0.8	7	8.3 ± 1.3	7	0.31 ± 0.16	7	300	1,190
MOD5	3.3 ± 0.8	7	8.5 ± 2.3	7	0.18 ± 0.04	7	300	1,869
NEGB1	2.3 ± 1.0	7	4.3 ± 2.3	7	0.18 ± 0.09	7	300	1,579
LOW6	3.8 ± 1.1	7	7.1 ± 2.4	7	0.13 ± 0.04	7	300	1,578

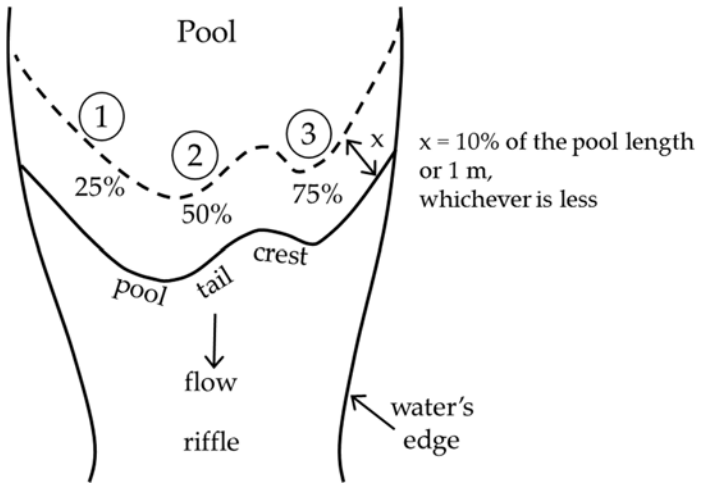
Appendix 4. Summary of capture-mark-recapture (CMR) abundance estimates and *q* values from the upper Oldman River study area, 2015 and 2016. *M* = fish marked and released on first pass, *C* = total fish captured on second pass, *R* = recaptured fish on second pass, *E* = Lincoln-Peterson population estimate, CI = confidence interval, *q* = catchability (*M*/*E*), WW = wetted width (m). Italics denote insufficient captures or recaptures for valid CMR abundance estimates.

Waterbody	Site ID	Method	*M*	*C*	*R*	*E*	Lower 95% CI	Upper 95% CI	*q*	WW
Daisy	DS2	Backpack	85	68	28	205	163	232	0.415	4.5
Dutch	*D3*	*Backpack*	*9*	*14*	*4*	*30*	*16*	*32*	*0.300*	*8.3*
Hidden	*H3*	*Backpack*	*5*	–	–	–	–	–	–	*4.8*
North Racehorse	NR2	Backpack	27	12	10	33	22	38	0.816	2.9
Racehorse	RH2	Backpack	65	59	15	248	181	284	0.263	9.1
South Racehorse	SR5	Backpack	25	21	7	72	45	81	0.350	3.9
South Racehorse	SR1	Backpack	23	19	7	60	38	68	0.383	6.3
Vicary	V5	Backpack	113	104	50	235	199	261	0.481	5.2
White	W4	Backpack	66	41	22	122	95	140	0.539	3.7
White	W5	Backpack	104	78	31	259	210	293	0.401	5.0

Appendix 5. Summary of capture probabilities (q) used for correction of capture data and subsequent mainstem abundance estimates in the upper Oldman River study area, 2015 and 2016.

Electrofisher	Stream	Year sampled	q	Mean wetted width
Backpack	Straight	2006	0.692	2.1
	Daisy	2007	0.435	6.1
	Dutch	2007	0.415	12.5
	Racehorse	2007	0.441	7.8
	Station	2007	0.378	1.8
	Tributary to Daisy	2007	0.289	1.9
	Tributary to Racehorse	2007	0.539	2.6
	Lynx	2009	0.156	10.3
	Tributary to Lost	2009	0.791	1.4
	Blairmore	2010	0.404	3.4
	Blairmore	2010	0.477	4.8
	Carbondale River	2010	0.415	6.4
	Gold	2010	0.276	5.9
	Lost	2010	0.636	6.0
	Dutch	2015	0.300	8.3
	White	2015	0.539	3.7
	White	2015	0.401	5.0
	Daisy	2016	0.415	4.5
	North Racehorse	2016	0.816	2.9
	Racehorse	2016	0.263	9.1
	South Racehorse	2016	0.350	3.9
	South Racehorse	2016	0.383	6.3
	Vicary	2016	0.481	5.2
Totebarge	Livingstone River	2006	0.500	12.1
	Oldman River	2006	0.359	14.7
	Livingstone River	2007	0.313	11.3
	Oldman River	2007	0.714	16.5
	West Castle River	2008	0.353	14.0
	West Castle River	2009	0.419	12.2

Appendix 6. Locations within scour-pools where deposited sediment and grid-toss sampling occurred along mainstems in the upper Oldman River watershed, 2015 and 2016. Adapted from Archer et al. (2012) and Kusnierz et al. (2013).



Appendix 7. Summer mean, minimum and maximum water temperature and monitoring locations from the upper Oldman River watershed study area, 2015 and 2016.

Watershed	Temp logger	Monitoring year	Easting	Northing	Stream temperature °C			Elevation
					Summer mean	Summer min	Summer max	
Dutch	T-D1	2015	670366	5528817	6.6	1.9	8.2	1,684
Dutch	T-D2	2015	677759	5531310	8.5	3.0	14.4	1,558
Dutch	T-D3	2015	685872	5531445	10.4	3.0	13.9	1,446
Daisy	T-DS1	2016	687011	5512659	8.5	5.4	10.6	1,735
Daisy	T-DS2	2016	685443	5518013	9.4	6.3	11.9	1,578
Daisy	T-DS3	2016	686001	5523908	10.8	7.5	13.2	1,447
Hidden	T-H1	2015	679040	5539135	6.3	2.3	11.7	1,607
Hidden	T-H2	2015	675214	5538875	7.3	2.7	11.1	1,711
Hidden	T-NH	2015	672308	5539801	4.7	1.5	9.1	1,799
N. Racehorse	T-NR1	2016	672132	5525189	7.7	3.8	10.5	1,738
N. Racehorse	T-NR2	2016	678399	5522293	9.5	5.4	13.0	1,543
Racehorse	T-RH1	2016	682763	5523354	10.2	6.4	13.0	1,482
Racehorse	T-RH2	2016	688401	5527017	10.2	7.2	12.5	1,400
S. Racehorse	T-SR1	2016	672838	5516387	7.0	3.9	9.0	1,708
S. Racehorse	T-SR2	2016	677803	5521137	8.7	5.1	11.7	1,586
Vicary	T-V1	2016	680371	5514303	8.0	4.6	10.9	1,704
Vicary	T-V2	2016	682309	5519246	10.6	6.5	14.3	1,546
Vicary	T-V3	2016	685139	5522717	11.9	7.5	15.7	1,462
White	T-W1	2015	692995	5543561	11.8	3.8	18.7	1,694
White	T-W2	2015	690935	5541478	11.5	4.2	19.0	1,615
White	T-W3	2015	688165	5540109	11.6	4.3	19.5	1,558
Beaver	T-BV	2016	683297	5552770	8.6	5.0	10.8	1,682
Cache	T-CH	2015	672340	5547013	5.7	2.1	10.4	1,721
Mean	T-MN	2016	683401	5556918	5.0	4.1	5.6	1,749
Oyster	T-OY	2015	667201	5558909	8.3	2.2	14.5	1,935
Ridge	T-RG	2016	684755	5549573	9.1	5.2	10.9	1,657
Straight	T-ST	2015	668720	5554798	6.5	2.8	9.8	1,875

Appendix 8. Capture summary of westslope cutthroat trout by sampling site in the upper Oldman River watershed study area, 2015 and 2016.

Waterbody	Site ID	Number of fish captured per site			Fish catch-per-unit-effort per site (fish/km)		
		All fish ≥70 mm	Juveniles ≥70 mm	Adults	All fish ≥70 mm	Juveniles ≥70 mm	Adults
Daisy	DS1	97	61	36	323	203	120
Daisy	DS2	85	31	54	283	103	180
Daisy	DS3	57	37	20	190	123	67
Daisy	DS4	22	13	9	73	43	30
Daisy	DS5	50	43	7	167	143	23
Daisy	DS6	86	31	55	287	103	183
Daisy	DS7	146	109	37	487	363	123
Dutch	D1	33	20	13	64	39	25
Dutch	D2	22	9	13	44	18	26
Dutch	D3	8	2	6	16	4	12
Dutch	D4	43	30	13	86	60	26
Dutch	D5	55	25	30	110	50	60
Dutch	D6	33	13	20	66	26	40
Dutch	D7	13	9	4	43	30	13
Dutch	D8	33	24	9	66	48	18
Dutch	D9	1	0	1	3	0	3
Dutch	D10	5	5	0	17	17	0
Hidden	H1*	no fish captured					
Hidden	H2	9	3	6	30	10	20
Hidden	H3	5	1	4	10	2	8
Hidden	H4	no fish captured					
Hidden	H5*	4	0	4	13	0	13
Hidden	H6	8	4	4	16	8	8
Hidden	H7	21	20	1	70	67	3
Hidden	H8	38	22	16	127	73	53
Hidden	Hb1*	9	0	9	30	0	30
Hidden	Hb2	16	1	15	53	3	50
N. Racehorse	NR1	41	23	18	137	77	60
N. Racehorse	NR2	27	17	10	90	57	33
N. Racehorse	NR4	11	5	6	37	17	20
N. Racehorse	NR5	32	19	13	107	63	43
N. Racehorse	NRB1	52	18	34	173	60	113
Racehorse	RH1	48	11	37	80	18	62
Racehorse	RH2	66	34	32	132	68	64
Racehorse	RH3	82	48	34	137	80	57
Racehorse	RH4	66	31	35	110	52	58
Racehorse	RH5	23	8	15	46	16	30

Appendix 8. Continued.

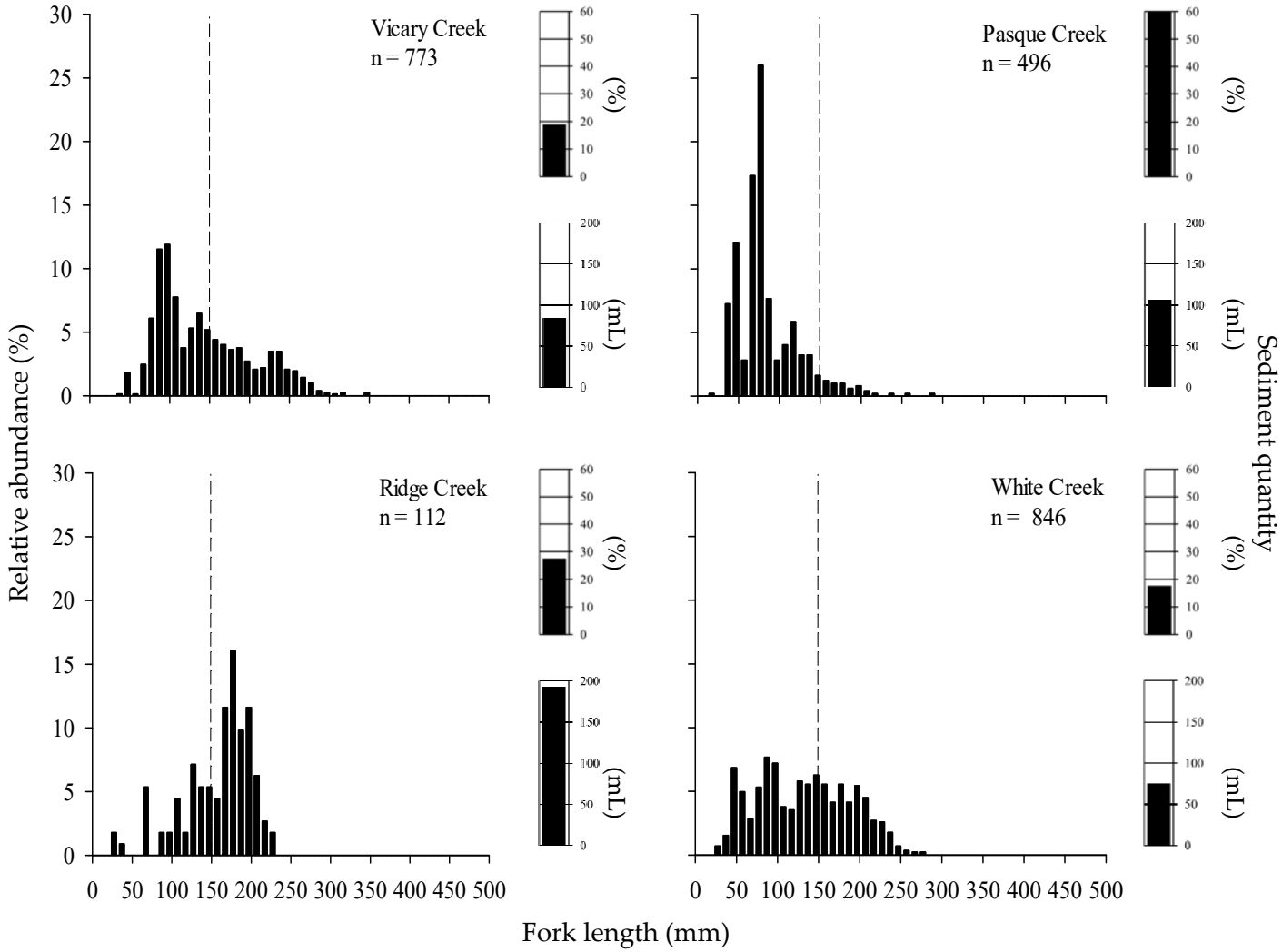
Waterbody	Site ID	Number of fish captured per site			Fish catch-per-unit-effort per site (fish/km)		
		All fish ≥70 mm	Juveniles ≥70 mm	Adults	All fish ≥70 mm	Juveniles ≥70 mm	Adults
S. Racehorse	SR1	23	2	21	77	7	70
S. Racehorse	SR2	31	10	21	103	33	70
S. Racehorse	SR3	25	15	10	50	30	20
S. Racehorse	SR4	17	4	13	57	13	43
S. Racehorse	SR5	25	11	14	83	37	47
S. Racehorse	SR6	29	13	16	97	43	53
Vicary	V1	87	45	42	290	150	140
Vicary	V2	30	8	22	100	27	73
Vicary	V3	67	18	49	223	60	163
Vicary	V4	101	60	41	337	200	137
Vicary	V5	114	77	37	380	257	123
Vicary	V6	236	180	56	787	600	187
Vicary	V7	111	60	51	370	200	170
White	W1	104	56	48	347	187	160
White	W2	99	32	67	330	107	223
White	W3	84	49	35	280	163	117
White	W4	94	26	68	303	84	219
White	W5	104	48	56	347	160	187
White	W6	116	83	33	387	277	110
White	W7	106	84	22	353	280	73
Beaver	MOD6	53	42	11	177	140	37
Beehive	NEG3	5	1	4	17	3	13
Beehive	NEG6	no fish captured					
Cache	NEG2	5	0	5	17	0	17
Deep	LOB1	43	16	27	143	53	90
Deep	LOW3	114	22	92	380	73	307
Lyall	NEG5	31	9	22	103	30	73
Mean	LOW1	no fish captured					
Mean	LOW5	1	1	0	3	3	0
Oyster	HIGH1	63	59	4	210	197	13
Oyster	HIGH2	57	50	7	190	167	23
Pasque	MOD1	81	75	6	270	250	20
Pasque	MOD2	90	72	18	300	240	60
Pasque	MOD5	148	142	6	493	473	20
Ridge	NEGB1	105	31	74	350	103	247
Speers	LOW6	79	66	13	263	220	43

*Sampling sites that occurred on South Hidden Creek.

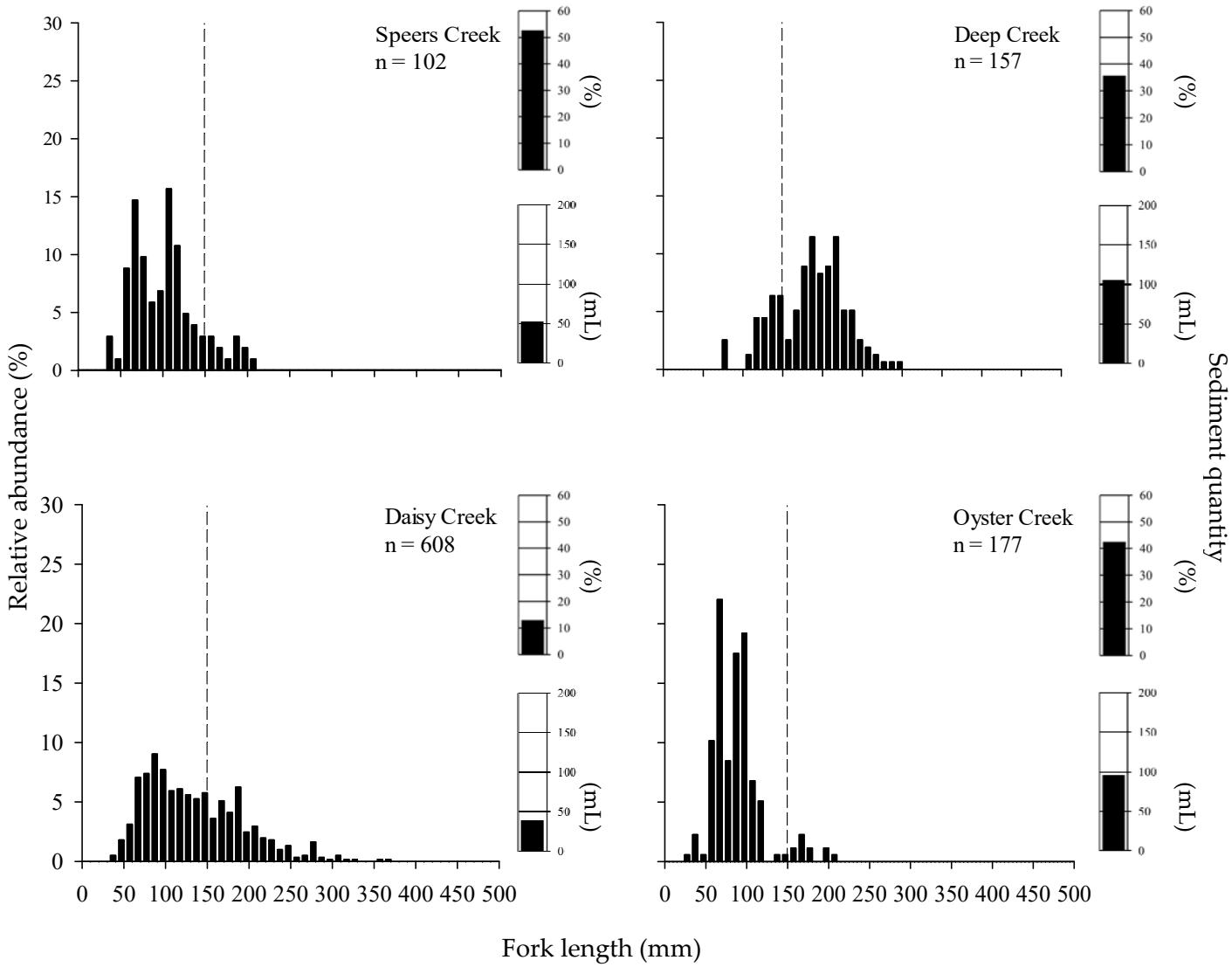
Appendix 9. Mean catch-per-unit-effort (± standard error) by waterbody in the upper Oldman River watershed study area, 2015 and 2016.

Waterbody	Number of sampling sites	Number of fish per km		
		All fish ≥70 mm	Juveniles ≥70 mm	Adults
Vicary Creek	7	355 ± 81	213 ± 71	142 ± 14
White Creek	7	335 ± 14	180 ± 29	155 ± 22
Daisy Creek	7	259 ± 50	155 ± 39	104 ± 25
North Racehorse Creek	5	109 ± 23	55 ± 10	53 ± 16
Racehorse Creek	5	101 ± 17	47 ± 13	54 ± 6
South Racehorse Creek	6	78 ± 9	27 ± 6	51 ± 8
Dutch Creek	10	52 ± 11	29 ± 6	22 ± 5
Hidden Creek	10	35 ± 12	16 ± 11	19 ± 6
Pasque Creek	3	354 ± 70	321 ± 76	33 ± 13
Ridge Creek	1	350	103	247
Speers Creek	1	263	220	43
Deep Creek	2	262 ± 118	63 ± 10	198 ± 108
Oyster Creek	2	200 ± 10	182 ± 15	18 ± 5
Beaver Creek	1	177	140	37
Lyall Creek	1	103	30	73
Beehive Creek	2	8	2	7
Cache Creek	1	17	0	17
Mean Creek	2	2	2	0

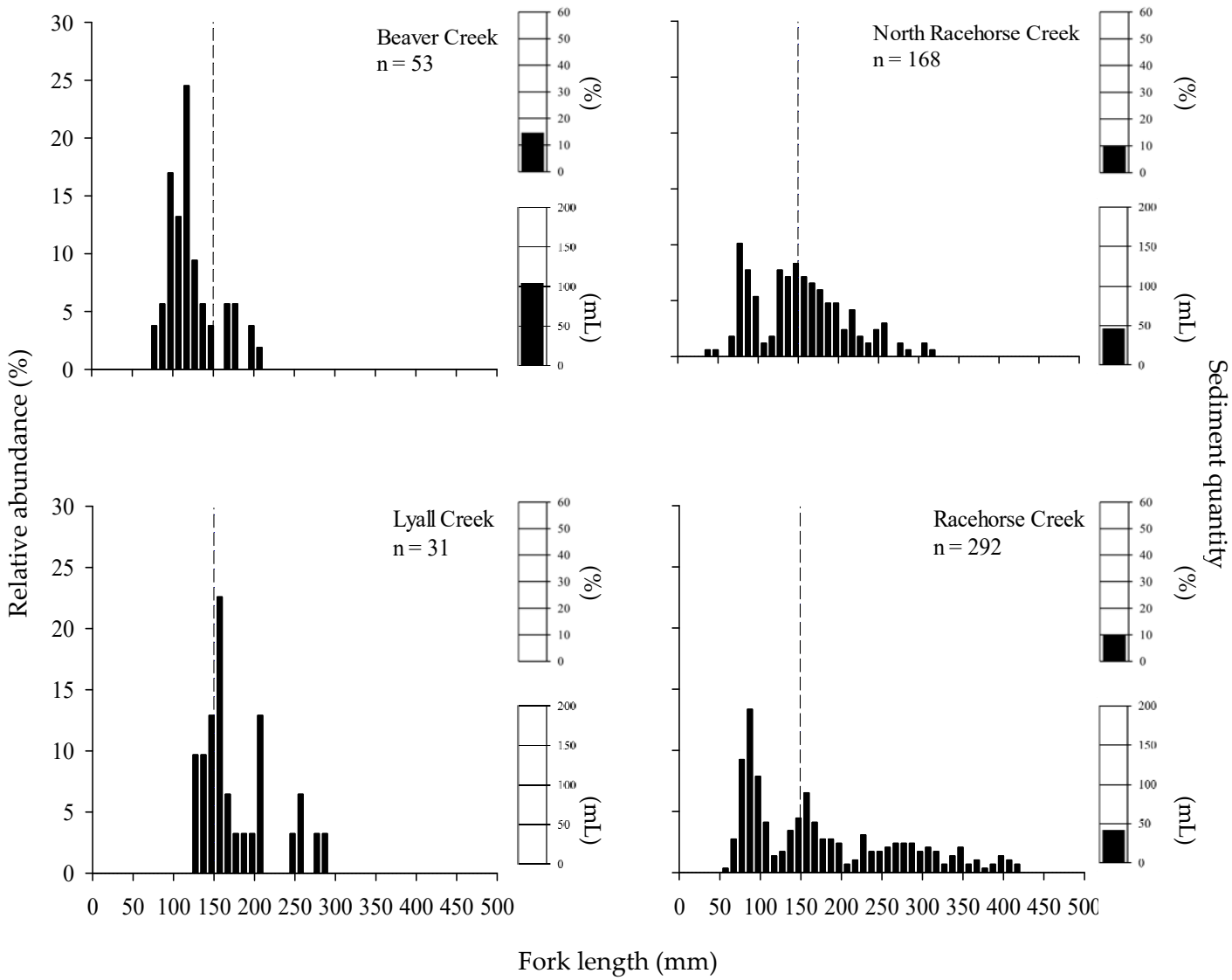
Appendix 10. Length frequency distribution of westslope cutthroat trout, median scour-pool sediment volume, and mean proportion of fine sediment by waterbody in the upper Oldman River study area, 2015 and 2016. Dashed lines delimit juvenile (<150 mm) from adult (≥150 mm) size classes.



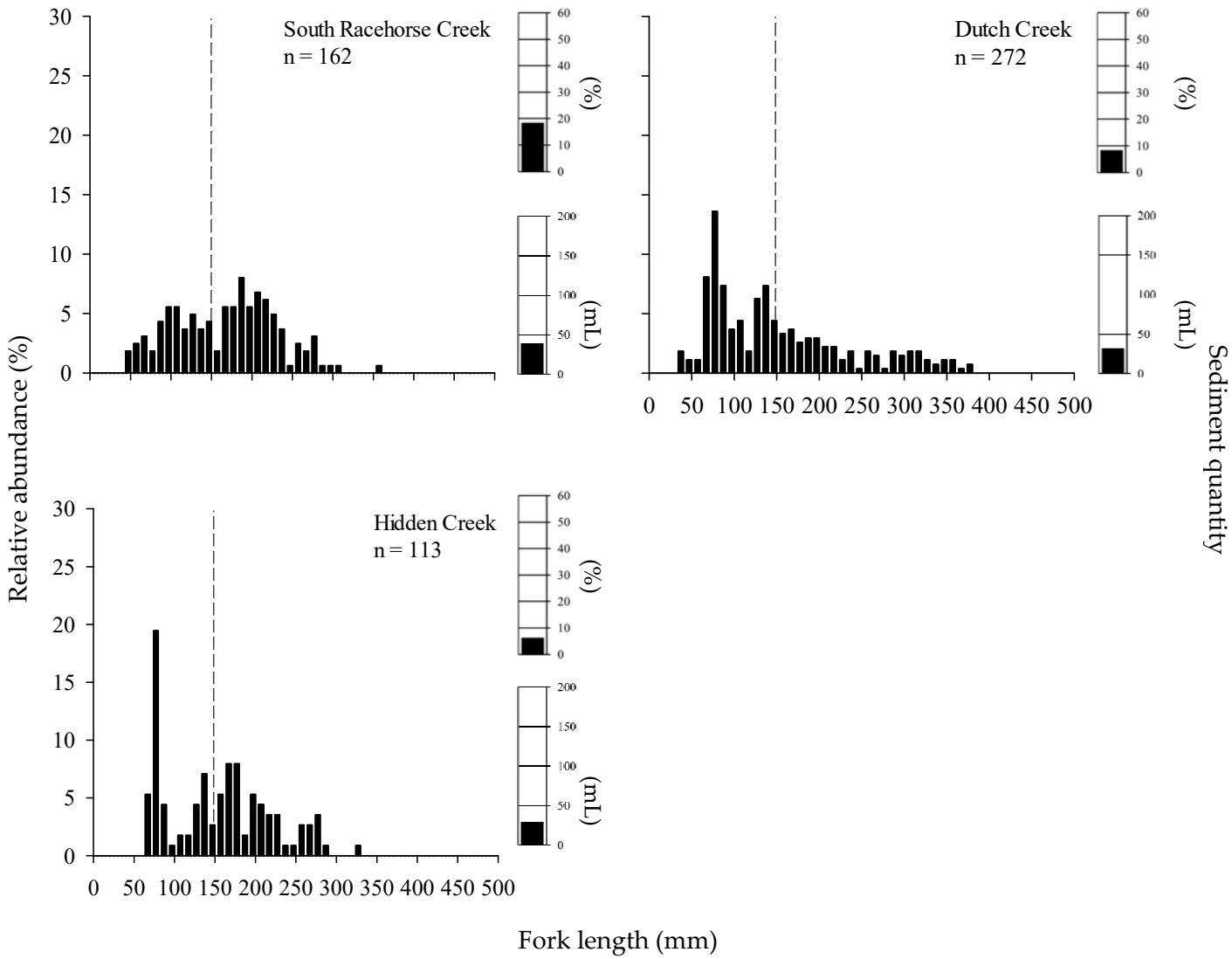
Appendix 10. Continued.



Appendix 10. Continued.



Appendix 10. Continued.



Appendix 11. Mean sediment and pool quantity (± standard deviation) in the upper Oldman River watershed study area, 2015 and 2016. Note: na = not available.

Waterbody	Site ID	Number of pools counted	Number of scour-pools counted	% fines <2 mm per scour-pool	% fines <6 mm per scour-pool	Number of scour-pools sampled with DSS	Sediment quantity (mL)
Daisy	DS1	26	4	16 ± 13	26 ± 9	4	62 ± 19
Daisy	DS2	11	4	5 ± 3	16 ± 7	4	17 ± 9
Daisy	DS3	23	3	0 ± 1	3 ± 3	3	11 ± 6
Daisy	DS4	23	10	9 ± 12	19 ± 19	10	70 ± 56
Daisy	DS5	19	11	2 ± 3	7 ± 5	10	22 ± 15
Daisy	DS6	13	5	2 ± 1	6 ± 3	5	33 ± 28
Daisy	DS7	17	5	6 ± 5	13 ± 7	5	28 ± 30
Dutch	D1	13	8	3 ± 2	8 ± 4	8	50 ± 27
Dutch	D2	6	6	3 ± 4	10 ± 7	6	30 ± 23
Dutch	D3	9	5	2 ± 2	6 ± 6	2	55 ± 28
Dutch	D4	16	7	14 ± 18	17 ± 19	7	30 ± 17
Dutch	D5	7	3	1 ± 0	8 ± 1	3	18 ± 11
Dutch	D6	9	9	1 ± 1	5 ± 4	9	20 ± 12
Dutch	D7	11	8	0 ± 0	3 ± 1	6	22 ± 10
Dutch	D8	8	6	3 ± 5	10 ± 5	5	73 ± 59
Dutch	D9	12	6	2 ± 2	10 ± 5	6	12 ± 12
Dutch	D10	9	7	1 ± 1	7 ± 3	5	25 ± 18
S. Hidden	H1	16	12	0 ± 0	4 ± 2	12	12 ± 11
Hidden	H2	11	4	1 ± 1	12 ± 6	4	25 ± 15
Hidden	H3	9	5	2 ± 1	7 ± 2	5	81 ± 57
Hidden	H4	9	4	0 ± 0	3 ± 2	4	50 ± 101
S. Hidden	H5	12	5	0 ± 0	3 ± 2	5	29 ± 27
Hidden	H6	18	5	0 ± 0	6 ± 4	5	19 ± 17
Hidden	H7	9	4	3 ± 5	9 ± 9	4	33 ± 25
Hidden	H8	8	5	1 ± 3	9 ± 4	5	34 ± 30
Hidden	HB1	14	6	1 ± 1	11 ± 6	6	22 ± 23

Appendix 11. Continued.

Waterbody	Site ID	Number of pools counted	Number of scour-pools counted	% fines <2 mm per scour-pool	% fines <6 mm per scour-pool	Number of scour-pools sampled with DSS	Sediment quantity (mL)
Hidden	HB2	8	6	0 ± 0	3 ± 2	6	22 ± 25
N. Racehorse	NR1	17	5	1 ± 1	4 ± 4	5	17 ± 14
N. Racehorse	NR2	28	10	6 ± 5	14 ± 10	10	37 ± 31
N. Racehorse	NR4	24	3	3 ± 3	14 ± 9	3	10 ± 6
N. Racehorse	NR5	9	4	2 ± 4	9 ± 6	4	57 ± 53
N. Racehorse	NRB1	21	4	3 ± 3	8 ± 8	4	129 ± 53
Racehorse	RH1	16	3	1 ± 1	3 ± 2	3	23 ± 28
Racehorse	RH2	13	5	6 ± 7	11 ± 5	5	34 ± 26
Racehorse	RH3	8	2	0 ± 0	3 ± 3	2	10 ± 5
Racehorse	RH4	9	2	1 ± 0	11 ± 0	2	10 ± 4
Racehorse	RH5	11	4	10 ± 6	17 ± 6	4	96 ± 61
S. Racehorse	SR1	9	3	11 ± 6	18 ± 5	3	30 ± 20
S. Racehorse	SR2	16	3	9 ± 8	17 ± 12	3	28 ± 16
S. Racehorse	SR3	20	4	6 ± 5	21 ± 16	4	53 ± 45
S. Racehorse	SR4	9	4	11 ± 9	22 ± 9	4	58 ± 63
S. Racehorse	SR5	27	5	9 ± 3	24 ± 8	5	34 ± 12
S. Racehorse	SR6	15	6	7 ± 6	10 ± 8	6	32 ± 23
Vicary	V1	12	3	3 ± 5	10 ± 5	3	76 ± 59
Vicary	V2	20	4	6 ± 3	16 ± 14	4	55 ± 61
Vicary	V3	7	5	8 ± 4	17 ± 10	5	133 ± 28
Vicary	V4	10	5	9 ± 6	14 ± 8	5	47 ± 17
Vicary	V5	8	3	9 ± 7	16 ± 5	3	97 ± 68
Vicary	V6	12	5	11 ± 7	18 ± 7	5	59 ± 29
Vicary	V7	11	5	30 ± 17	34 ± 16	5	118 ± 31
White	W1	11	4	16 ± 18	18 ± 18	4	103 ± 32
White	W2	15	15	11 ± 16	19 ± 16	15	90 ± 60

Appendix 11. Continued.

Waterbody	Site ID	Number of pools counted	Number of scour-pools counted	% fines <2 mm per scour-pool	% fines <6 mm per scour-pool	Number of scour-pools sampled with DSS	Sediment quantity (mL)
White	W3	6	6	4 ± 4	12 ± 7	6	54 ± 44
White	W4	13	10	7 ± 11	13 ± 10	10	71 ± 49
White	W5	8	6	4 ± 4	8 ± 6	6	31 ± 29
White	W6	13	13	10 ± 13	28 ± 23	13	112 ± 62
White	W7	23	22	6 ± 5	18 ± 11	21	58 ± 43
Beaver	MOD6	18	3	43 ± 50	53 ± 41	3	105 ± 20
Beehive	NEG3	17	6	2 ± 2	10 ± 8	5	26 ± 24
Beehive	NEG6	44	5	1 ± 1	5 ± 8	0	na
Cache	NEG2	17	0	na	na	na	na
Deep	LOB1	9	4	5 ± 4	17 ± 11	4	96 ± 52
Deep	LOW3	10	7	34 ± 31	47 ± 25	7	109 ± 50
Lyall	NEG5	23	0	na	na	na	na
Mean	LOW1	14	2	9 ± 3	12 ± 3	2	26 ± 1
Mean	LOW5	25	3	10 ± 1	17 ± 0	2	24 ± 8
Oyster	HIGH1	18	8	46 ± 39	57 ± 32	8	98 ± 62
Oyster	HIGH2	15	12	16 ± 22	33 ± 25	12	95 ± 97
Pasque	MOD2	9	7	6 ± 6	25 ± 15	7	108 ± 27
Pasque	MOD1	8	6	15 ± 22	22 ± 23	6	95 ± 37
Pasque	MOD5	14	7	27 ± 18	36 ± 19	7	111 ± 66
Ridge	NEGB1	10	10	54 ± 42	60 ± 37	10	193 ± 179
Speers	LOW6	14	3	8 ± 1	15 ± 5	3	104 ± 94

Alberta Conservation Association acknowledges the following partner for its generous support of this project:

Alberta

Alberta Conservation Association