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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.
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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).

<table>
<thead>
<tr>
<th>Linear disturbance category</th>
<th>Negligible (0 – 0.6 km/km²)</th>
<th>Low (&gt;0.6 – 1.2 km/km²)</th>
<th>Moderate (&gt;1.2 – 3.0 km/km²)</th>
<th>High (&gt;3.0 km/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyall Creek</td>
<td>Soda Creek</td>
<td>Hidden Creek</td>
<td>Oyster Creek</td>
<td></td>
</tr>
<tr>
<td>Beehive Creek</td>
<td>Mean Creek</td>
<td>Unnamed to Oyster</td>
<td>Dutch Creek</td>
<td></td>
</tr>
<tr>
<td>Cache Creek</td>
<td>Speers Creek</td>
<td>Straight Creek</td>
<td>North Racehorse Creek</td>
<td></td>
</tr>
<tr>
<td>Ridge Creek</td>
<td>Deep Creek</td>
<td>Pasque Creek</td>
<td>South Racehorse Creek</td>
<td></td>
</tr>
<tr>
<td>White Creek</td>
<td></td>
<td>Savanna Creek</td>
<td>Racehorse Creek</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beaver Creek</td>
<td>Vicary Creek</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daisy Creek</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Watershed area (km²)</th>
<th>Total stream length ≥ Strahler order-3 (km)</th>
<th>Mainstem stream length (km)</th>
<th>Number of sampling sites</th>
<th>Strahler stream order</th>
<th>Sampling site elevation range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch Creek</td>
<td>154.9</td>
<td>67.8</td>
<td>31.0</td>
<td>10</td>
<td>5</td>
<td>1,438 – 1,780</td>
</tr>
<tr>
<td>South Racehorse Creek</td>
<td>96.0</td>
<td>27.8</td>
<td>13.9</td>
<td>6</td>
<td>5</td>
<td>1,555 – 1,797</td>
</tr>
<tr>
<td>Hidden Creek</td>
<td>68.8</td>
<td>30.2</td>
<td>22.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10</td>
<td>5</td>
<td>1,573 – 1,855</td>
</tr>
<tr>
<td>Vicary Creek</td>
<td>66.2</td>
<td>34.1</td>
<td>16.5</td>
<td>7</td>
<td>4</td>
<td>1,472 – 1,716</td>
</tr>
<tr>
<td>Lower Racehorse Creek</td>
<td>65.6</td>
<td>39.2</td>
<td>15.1</td>
<td>5</td>
<td>5</td>
<td>1,414 – 1,498</td>
</tr>
<tr>
<td>Daisy Creek</td>
<td>63.8</td>
<td>37.7</td>
<td>18.0</td>
<td>7</td>
<td>5</td>
<td>1,465 – 1,852</td>
</tr>
<tr>
<td>White Creek</td>
<td>52.7</td>
<td>36.6</td>
<td>15.9</td>
<td>7</td>
<td>5</td>
<td>1,584 – 1,765</td>
</tr>
<tr>
<td>North Racehorse Creek</td>
<td>46.2</td>
<td>21.3</td>
<td>13.2</td>
<td>5</td>
<td>4</td>
<td>1,592 – 1,785</td>
</tr>
<tr>
<td>Deep Creek</td>
<td>23.9</td>
<td>8.6</td>
<td>8.4</td>
<td>2</td>
<td>3</td>
<td>1,649 – 1,710</td>
</tr>
<tr>
<td>Cache Creek</td>
<td>23.9</td>
<td>7.3</td>
<td>6.7</td>
<td>1</td>
<td>4</td>
<td>1,752 – 1,759</td>
</tr>
<tr>
<td>Pasque Creek</td>
<td>22.9</td>
<td>15.2</td>
<td>11.5</td>
<td>3</td>
<td>4</td>
<td>1,843 – 1,923</td>
</tr>
<tr>
<td>Ridge Creek</td>
<td>18.3</td>
<td>7.3</td>
<td>6.0</td>
<td>1</td>
<td>4</td>
<td>1,706 – 1,709</td>
</tr>
<tr>
<td>Speers Creek</td>
<td>12.8</td>
<td>10.2</td>
<td>5.8</td>
<td>1</td>
<td>4</td>
<td>1,617 – 1,620</td>
</tr>
<tr>
<td>Mean Creek</td>
<td>12.0</td>
<td>7.5</td>
<td>4.0</td>
<td>2</td>
<td>4</td>
<td>1,784 – 1,807</td>
</tr>
<tr>
<td>Lyall Creek</td>
<td>10.3</td>
<td>2.3</td>
<td>2.3</td>
<td>1</td>
<td>3</td>
<td>1,808 – 1,825</td>
</tr>
<tr>
<td>Oyster Creek polygon&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.2 (24.4)</td>
<td>12.2 (15.9)</td>
<td>4.7</td>
<td>2</td>
<td>4 (5)</td>
<td>1,906 – 1,927</td>
</tr>
<tr>
<td>Beehive Creek</td>
<td>8.3</td>
<td>5.4</td>
<td>3.1</td>
<td>2</td>
<td>2</td>
<td>1,717 – 1,879</td>
</tr>
<tr>
<td>Beaver Creek</td>
<td>7.6</td>
<td>5.9</td>
<td>2.7</td>
<td>1</td>
<td>3</td>
<td>1,685 – 1,693</td>
</tr>
</tbody>
</table>

<sup>a</sup>Hidden Creek stream length includes South Hidden Creek branch.

<sup>b</sup>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 microcentrifuge 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 tote-barge 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 km² 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 ($\alpha$ and $\beta$) are defined by the mean and the standard deviation (SD) of the values of $q$. The parameters of the beta distribution are defined as:

$$\mu = \frac{\alpha}{\alpha + \beta}$$

Where $\mu$ is the mean of capture efficiencies $q$ with an SD of

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

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 $\geq$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.](image-url)
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 $\geq 150$ 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.

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Habitable mainstem (m)</th>
<th>All fish ≥70 mm</th>
<th>Juveniles ≥70 mm</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abundance</td>
<td>90% CI</td>
<td>Abundance</td>
<td>90% CI</td>
</tr>
<tr>
<td>Vicary</td>
<td>16,534</td>
<td>20,930</td>
<td>11,096 – 40,153</td>
<td>14,344</td>
</tr>
<tr>
<td>White</td>
<td>15,911</td>
<td>14,908</td>
<td>7,831 – 29,260</td>
<td>8,144</td>
</tr>
<tr>
<td>Daisy</td>
<td>18,014</td>
<td>13,155</td>
<td>6,864 – 25,839</td>
<td>7,761</td>
</tr>
<tr>
<td>RH</td>
<td>15,134</td>
<td>4,837</td>
<td>2,556 – 9,337</td>
<td>2,201</td>
</tr>
<tr>
<td>Dutch</td>
<td>30,992</td>
<td>4,173</td>
<td>2,204 – 8,114</td>
<td>2,370</td>
</tr>
<tr>
<td>NRH</td>
<td>12,262</td>
<td>3,528</td>
<td>1,867 – 6,872</td>
<td>1,803</td>
</tr>
<tr>
<td>SRH</td>
<td>12,643</td>
<td>2,661</td>
<td>1,433 – 5,038</td>
<td>887</td>
</tr>
<tr>
<td>Hidden</td>
<td>18,334</td>
<td>1,626</td>
<td>913 – 3,042</td>
<td>773</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Watershed</th>
<th>All fish ≥70 mm</th>
<th>Juveniles ≥70 mm</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abundance/km</td>
<td>90% CI</td>
<td>Abundance/km</td>
</tr>
<tr>
<td>Vicary</td>
<td>1,231</td>
<td>653 – 2,362</td>
<td>844</td>
</tr>
<tr>
<td>White</td>
<td>877</td>
<td>461 – 1,721</td>
<td>479</td>
</tr>
<tr>
<td>Daisy</td>
<td>692</td>
<td>361 – 1,360</td>
<td>408</td>
</tr>
<tr>
<td>RH</td>
<td>337</td>
<td>177 – 655</td>
<td>152</td>
</tr>
<tr>
<td>Dutch</td>
<td>130</td>
<td>69 – 254</td>
<td>74</td>
</tr>
<tr>
<td>NRH</td>
<td>301</td>
<td>159 – 586</td>
<td>151</td>
</tr>
<tr>
<td>SRH</td>
<td>213</td>
<td>115 – 401</td>
<td>76</td>
</tr>
<tr>
<td>Hidden</td>
<td>86</td>
<td>48 – 160</td>
<td>41</td>
</tr>
</tbody>
</table>
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


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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.


### APPENDICES

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

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Sampling site</th>
<th>Site ID</th>
<th>Downstream easting</th>
<th>Downstream northing</th>
<th>Upstream easting</th>
<th>Upstream northing</th>
<th>Survey date</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>MOD6</td>
<td>683224</td>
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<td>683173</td>
<td>5553102</td>
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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.

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36
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.

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<tr>
<th>Site ID</th>
<th>Mean wetted width (m) ± SD</th>
<th>n</th>
<th>Mean rooted width (m) ± SD</th>
<th>n</th>
<th>Mean depth (m) ± SD</th>
<th>n</th>
<th>Distance fished (m)</th>
<th>Electrofishing effort (s)</th>
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<td>8.2 ± 2.7</td>
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<td>0.18 ± 0.03</td>
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<tr>
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<td>8.3 ± 1.3</td>
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<td>0.31 ± 0.16</td>
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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.

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Site ID</th>
<th>Method</th>
<th>$M$</th>
<th>$C$</th>
<th>$R$</th>
<th>$E$</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>$q$</th>
<th>WW</th>
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<td>68</td>
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<td>163</td>
<td>232</td>
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<td>4.5</td>
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<td>Backpack</td>
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<td>14</td>
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<td>–</td>
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<td>235</td>
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<td>259</td>
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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.

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<th>Electrofisher</th>
<th>Stream</th>
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<th>$q$</th>
<th>Mean wetted width</th>
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</tr>
<tr>
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<td>Tributary to Racehorse</td>
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<td>0.539</td>
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Appendix 7. Summer mean, minimum and maximum water temperature and monitoring locations from the upper Oldman River watershed study area, 2015 and 2016.

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<th>Northing</th>
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<th>Elevation</th>
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<td>Summer min</td>
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<td>5531310</td>
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Appendix 8. Capture summary of westslope cutthroat trout by sampling site in the upper Oldman River watershed study area, 2015 and 2016.

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<th>Waterbody</th>
<th>Site ID</th>
<th>Number of fish captured per site</th>
<th>Fish catch-per-unit-effort per site (fish/km)</th>
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<td>Juveniles ≥70 mm</td>
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Appendix 8. Continued.

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*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.

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<td>155 ± 39</td>
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<td>53 ± 16</td>
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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.

![Graphs showing Relative abundance (%), Sediment quantity (mL), and Fork length (mm) for Speers Creek, Deep Creek, Daisy Creek, and Oyster Creek.](image)

- Speers Creek: n = 102
- Deep Creek: n = 157
- Daisy Creek: n = 608
- Oyster Creek: n = 177
Appendix 10.  Continued.

Relative abundance (%)

Beaver Creek
n = 53

North Racehorse Creek
n = 168

Lyall Creek
n = 31

Racehorse Creek
n = 292

Sediment quantity (mL)

Fork length (mm)
Appendix 10. Continued.

Relative abundance (%)

South Racehorse Creek
n = 162

Dutch Creek
n = 272

Hidden Creek
n = 113

Fork length (mm)

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

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<tr>
<th>Waterbody</th>
<th>Site ID</th>
<th>Number of pools counted</th>
<th>Number of scour-pools counted</th>
<th>% fines &lt;2 mm per scour-pool</th>
<th>% fines &lt;6 mm per scour-pool</th>
<th>Number of scour-pools sampled with DSS</th>
<th>Sediment quantity (mL)</th>
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### Appendix 11. Continued.

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