ASSESSMENT OF HABITAT FOR SPECKLED DACE WITHIN THE KETTLE RIVER WATERSHED

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Cover Photo: ‘Photo of the Kettle River near Midway, BC.’ Photograph taken on the 2nd of August 2011 by Greg Andrusak.

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EXECUTIVE SUMMARY

This study was undertaken in cooperation with government agencies and stakeholders to better understand habitat-flow relationships of the speckled dace (*Rhinichthys osculus*) population that inhabit the West Kettle, Kettle and Granby rivers. Habitat suitability indexes have been developed, estimates made of total available habitat and estimated weighted useable areas calculated from hydrometric transect information. This information was used to develop summer-autumn habitat-flow relationships for speckled dace within the aforementioned systems.

In Canada, speckled dace are known from only the Kettle and Granby River drainages in south-east British Columbia. The species was assessed as endangered by COSEWIC due to its very limited range and area of occupancy, existence at only three locations, perceived future loss of habitat, and lack of potential rescue above Cascade Falls. Speckled dace were federally listed in 2009. While recent work has indicated that they are considerably more abundant and well distributed within the Kettle River Basin than originally understood, continual concern over low flow conditions and potential increased water demands has highlighted the importance of developing conservation measures for all fish species and their habitats within these rivers (Epp 2012).

Based on previous work on speckled dace that identified their distribution in the Kettle and Granby rivers (Batty 2010), on the ground habitat surveys were conducted in 2011. A total of 33.1 km of the Kettle River and 8.25 km of the Granby River were surveyed by a field crew to assess habitat characteristics. Habitat features were stratified into three meso-habitat units (riffle, run and pool) and this sub-sampled information was integrated into a 1:20,000 GIS habitat layer for the Kettle and Granby rivers. The final GIS meso-habitat layer was used to calculate lineal length (km) and area of habitat (ha) within the known distribution (Batty 2010) of speckled dace for both rivers. A total of 748 ha of available habitat were estimated in the upper Kettle River upstream of Midway BC. A total of 316 ha of available habitat were estimated in the lower Kettle River downstream of Grand Forks BC. Similarly, a total of 407 ha of available habitat were estimated in the Granby River. Run habitat was the most dominate habitat unit (>50 %), while riffle habitat was prominent, accounting for > 40% and pool habitat

accounting for < 7% of all habitat on either system. No assessment of the West kettle River was conducted.

Analysis of 2010 data collected on habitat use by speckled dace (Batty 2010; Andrusak and Andrusak 2011) combined with 2011 flow monitoring data from established transects demonstrate important predictive relationships between changes in discharge and useable area within the West Kettle, Kettle and Granby rivers. In general, in all three systems the data indicates that useable widths were optimal for immature dace (< 55 mm) below a discharge of 10 m^3/s or a LTMAD of 20%. In contrast, the data for all three systems indicates that useable widths were optimal for mature speckled dace (> 55 mm) near a discharge of 5-10 m^3/s or near a LTMAD of 20%. Furthermore, data analysis indicates a substantial decline in useable width and available habitat for flows below 10% LTMAD and this was most prominent for the West Kettle River. For this river, the results suggest, using the modified Tennant method, existing low flows are a potential factor that may already limit the juvenile life stage of speckled dace.

Current work being conducted by MFLNRO is aimed at the development of a water use plan to aid in management of water use and extraction within the basin. While the ministry plan initiative is focused on salmonid recovery, the objective of the water use plan is to recommend protection measures for all fish based on critical flow thresholds. In this regard, speckled dace are more adaptive to adverse conditions and their water discharge requirements appear to be less than salmonids. Therefore base flows determined for salmonids should provide adequate protection for speckled dace.

ACKNOWLEDGEMENTS

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by

G.F. Andrusak, H Andrusak and Gary Pavan

INTRODUCTION

In recent years, Canadian speckled dace (*Rhinichthys osculus*) found only within the Kettle and Granby River drainages in south-east British Columbia have become the focus of a series of investigations into their distribution and abundance (Batty 2010; Andrusak and Andrusak 2011). Much of the impetus for these investigations is a result of this species listed as "endangered" under the Species at Risk Act (SARA) and the suspicion ~~fact~~ that their habitat within many of these drainages are being threatened.

Speckled dace were listed under the Species at Risk Act (SARA) as endangered in 2009, following species assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Despite the fact that speckled dace are abundant and distributed throughout the western United States and Mexico, the Canadian population is considered morphologically distinct and geographically isolated from the US populations (McPhail 2007; Batty 2010).

Due to the fact that speckled dace are only found within the Kettle and Granby river systems in Canada and were listed as endangered there has been concern by the Department of Fisheries and Oceans, under SARA, over cumulative impacts to these systems. Coincidentally the provincial government, the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) initiated some habitat assessments to better understand what was limiting rainbow trout within the basin. Emanating from these investigations, the MFLNRO launched a water use plan (WUP) for the watershed to identify key issues affecting fish populations with the goal of implementing conservation measures for all fish. At about the same time public concern over the state of the Kettle River led the BC Outdoor Recreation Council of British Columbia to identify this river as one of the most threatened waterways in the province in 2010.

This current study on speckled dace is complementary and supportive of the MFLNRO initiative to identify key habitat issues and develop a plan to address conservation flows for fish in these drainages. Because these waterways have endured decades of habitat degradation, the WUP process is considered long overdue and without this coordinated action by government, the threat to all fish species in the Kettle River system will only become more acute. Thus, defining the quantity of available speckled dace habitat and the relationship between discharge and habitat especially during low flows, were considered beneficial in developing the WUP.

Summary of Previous Work

The initial speckled dace work in 2010 by Andrusak and Andrusak (2011) was actually an outcome and logical extension of three years of habitat restoration work that involved construction of large woody debris (LWD) structures in a portion of the Kettle River approximately 7 km upstream of Midway BC (Andrusak 2009). This work, funded by the Habitat Conservation Trust Foundation (HCTF), was aimed at increasing overwinter habitat for resident rainbow trout. During snorkel assessments of the LWD structures observations were made that speckled dace were also present in the pool habitat formed by the structures. Concurrent with this work, the MFLNRO initiated an investigation into habitat limitations to fish species in the Kettle River. Despite this, the MFLNRO terms of reference for the WUP did not include speckled dace. Nonetheless, it became quite evident that the primary threat to fish habitat was low flows created by escalating water demand for agriculture and residential use (Epp 2012). This led to the provincial ministry initiating a three year habitat-flow relationship study in 2010.

During 2010, habitat use by immature and mature dace was defined and habitat suitability indices were developed. Immature speckled dace inhabit the periphery of the river margins and select for lower velocity sites in small gravel-sand substrate. The mature dace prefer higher velocity, deeper water associated with cobble-boulder substrate (Andrusak and Andrusak 2011). In late fall, early winter it appears all life stages move to deeper water. The 2010 survey and data generated adds to the earlier work on speckled dace by Peden (1994), Peden and Hughes (1984) and Haas (1998). Most significantly and just prior to the 2010 survey and of particular importance, Batty (2010) completed an MSc thesis that provides extensive information on speckled dace biology, including age at maturity, food habits and preferences, along with estimates of abundance and distribution.

Current study objectives

This report summarizes the second year's results that were focused on determining the amount of available habitat utilized by speckled dace under varying flow conditions. The project's objectives include:

- Conduct river habitat assessments that will define total available summer habitat and determine the impacts on speckled dace based on habitat-flow relationships within their known distribution.
- Produce a Geographic Information System (GIS) Meso-habitat map for the known speckled dace distribution.
- Conduct mapping analysis to estimate extent of available and required habitat based on use information for speckled dace.
- Assess the impact of low flow scenarios developed by MFLNRO on habitat.

Assumptions and Limitations

It is imperative to understand the assumptions and limitations when using coarse scale habitat-flow relationships for predicting the response of fish habitat to water withdrawal and climate change and how flow changes influence fish production. Most often, a number of physical and biological factors can affect fish productive capacity, making it difficult to directly detect fish-flow relationships. It is known that discharge and its inherent variability often control a suite of physical variables that in turn influence fish production through a number of direct and indirect pathways (Lewis et al. 2004). At the same time, there are a number of biological functions that also have a direct influence on fish production. Notwithstanding these controlling variables, most instream flow assessments are based on the implicit acceptance of a relationship between habitat and fish productivity (Hatfield et al. 2003).

A limitation in prediction of quantity of speckled dace habitat determined in this study, as well as in Physical Habitat Simulation System (PHABSIM) and other habitat models, is that fish habitat preference is independent of flow. By assuming this it allows use of habitat suitability index (HSI) curves to predict habitat use and preference over variable flows (see below). It is acknowledged that this assumption is debatable and arguably invalid but it is an essential underpinning and the cornerstone for making habitat use predictions. A more refined approach when using HSI curves is to define detailed critical meso-habitats that allows a more effective and efficient assessment of instream flow requirements and habitat impacts (Bradford and Higgins 2000; Hatfield et al. 2003; Lewis et al. 2004). In summary, this study uses the previously developed HSI curves (Andrusak and Andrusak 2011), in combination with hydrometric data (MFLNRO) and total available habitat data within the known distribution of speckled dace to provide a better understanding of flow limitation impacts on speckled dace habitat.

In their review of statistical methods for quantifying habitat suitability, Ahi-Nedushan et al. (2006) listed three main types of HSI: 1) those derived from professional judgment; 2) those based on habitat use; and, 3) those based on habitat preferences. The first type simply represents biological opinion about where fish are and why they are there. The second type represents the frequency with which fish are observed to utilise a range of habitats. Such curves can be constructed by tallying the characteristics of the habitats used by an unbiased sample of fish. Although relatively straightforward to understand, an implicit assumption of the HSIs developed is that they are based on habitat use and that the various habitats occur in equal abundance. This assumption is important because if it is substantially violated then it may be necessary to scale the habitat use by the habitat available in order to derive the third type of HSI, which represents preference. Failure to do so could result in the conclusion that a particular rarely used habitat is unsuitable even though the low level of use reflects the habitat's scarcity as opposed to any preference on the part of the fish. In addition to the three types discussed by Ahi-Nedushan et al. (2006), there is a fourth type of HSI that is created based on habitat requirements (Rosenfeld, 2003). Even though an HSI might accurately represent fish habitat preferences it does not necessarily follow that failure to provide a fish with its preferred habitat will have any consequences for its growth, survival or reproduction. Ultimately the purpose of any HSI is to provide a proxy for habitat requirements. Generally, a fitness-based curve can only be derived via manipulative experiments (Rosenfeld 2003). Therefore, the standard approach is to assume that a fish population's habitat preferences are likely to have evolved to approximate their habitat requirements and to use the third type of HSI as a proxy for the fourth which is the approach used in this study.

BACKGROUND

The Kettle drainage consists of three major sub-basins that include the West Kettle River, the Kettle River and the Granby River. Fish assemblage in the Kettle and Granby drainage, detailed in McPhail and Carveth (1992), indicate that twenty seven fish species have been documented as present with rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), whitefish (*Prosopium williamsoni*) and brown trout (*Salmo trutta*) being the favorite target of anglers, with rainbow trout and whitefish by far the most abundant. Primary non-game species include; sculpins (*Cottus spp*.), suckers (*Catostamus spp*.) and a variety of cyprinids (*Family Cyprinidae*). It has been well documented by McPhail and Carveth (1992), McPhail (2007) and other authors that this watershed supports the only known habitat in the province for the SARs listed speckled dace (*Rhinichthys osculus*) as well as one of the few systems that support a species of concern (chiselmouth [*Acrocheilus alutaceus*]).

Various natural and anthropogenic factors have had profound impacts upon the abundance of rainbow trout and other species throughout much of the Kettle River Basin. As with many rivers within the Pacific Northwest, linear developments such as powerlines, pipelines and highways and resource extractions such as agriculture, logging and mining have had profound effects upon the natural river ecosystem. Specific issues such as poor water and land practices, limited pool habitat, non-native species introduction, recruitment over-fishing, low seasonal flows and high summer water temperatures have severely limited trout abundance. As a consequence, fish habitat, (especially trout habitat) in much of the Kettle River Basin, primarily in the lower reaches, is considered to be poor to fair in quality (Oliver 2001; 2002). Furthermore, the ability to mitigate many of these past disturbances is confounded by increasing changes in climate, especially acute in this very arid part of the province. Higher summer temperatures concurrent with low flows continue to impact the Kettle River basin and its fish populations. Much of the Kettle River riffle habitat in late summer is often reduced to water depths < 10 cm that is unsuitable for most fish species. The future status of viable trout populations as well as other lesser known fishes within the Kettle River system will rely on mitigating impacts of low seasonal flows and high seasonal temperatures within the mainstem of these rivers.

Historical practices of riparian logging or land clearing for agriculture have resulted in losses of woody accumulations along river banks, adversely affecting the natural morphology of the channel and its complexity (Koski 1992). Moreover, removal of riparian functions often accelerates stream bank erosion (Murphy 1995) and such activities can greatly affect natural geomorphology to the degree that there are significant losses of fish habitat (Slaney and Zaldokas 1997). Under these degraded conditions, habitat restoration is frequently needed to replace lost large wood and other natural shelter features (Slaney et al. 1997; Roni et al. 2002). Consequently, work to restore habitat has been undertaken on the West Kettle and Kettle rivers to provide an increase in over wintering habitat and critical summer low flow pool refugia for rearing juvenile and adult rainbow trout (Slaney et al. 2001; Andrusak 2009). In addition, a study by Andrusak and Andrusak (2011) in 2010 provided evidence that the LWD structures, or at least the pool habitat created by these structures, are highly important for speckled dace, especially during the winter months. An additional outcome of this study was that future river restoration work should consider boulder clusters as well as LWD structures to increase deep run and pool habitat. Speckled dace, especially mature fish, have a preference for deep, higher velocity water in association with cobble-boulder substrate.

During the latter part of the 2000s streams in the Kettle River Basin experienced a series of extreme low flows and high summer water temperatures. Flow data, collected by the United States Geological Survey (USGS) since 1929, indicate the Kettle River long term mean annual discharge (LTMAD) during the 2007-2009 period have been well below the 80 year average. In fact, the upper Kettle River annual discharge suggests flows are near the 20th percentile range during this same period. Exacerbated by extreme summer low flows, diminishing useable wetted habitat and the daily mean water temperature often exceeding 24°C by mid-July on the Kettle River at Midway were considered (Andrusak 2009). These temperature maxima would be expected to be more pronounced for the lower portion compared to the middle and upper portions of the Kettle River (Oliver 2002). While such temperatures are optimal for cyprinids prolonged exposure to these high temperatures will have a negative effect on trout resulting in higher mortality and reduced abundance (McCullough 1999, Dunham et al. 2003). Interestingly, this expectation was confirmed by a fish kill (trout and whitefish) on the lower portion of the river near Christina Lake in 2006 where maximum daily temperatures exceeded 26°C (data on file MFLNRO Penticton, BC). A second fish kill was reported in the summer, 2009.

Excessive water extraction, past development, lack of natural storage elements within the watershed, and climate change have plagued the Kettle River watershed, imperilling the aquatic habitat and species that rely on the river for their existence. Defining conservation fish flows on the West Kettle, Kettle and Granby rivers is considered a high priority by the management agencies. Regional MFLNRO (Penticton office) consider the Kettle River a high priority system because of poor habitat conditions and critical low flow issues due to over-use by the agriculture industry confounded by potential climate changes (Epp 2012).

STUDY AREA

Kettle River

The Kettle River is located in southeast British Columbia (Figure 1) and flows from north to south between the Okanagan Highlands to the West and the Monashee Mountain range to the East. Major tributaries include the West Kettle River, Kettle and Granby River. From its origin in the Monashee mountain range, Kettle River flows south ~196 km where it crosses the U.S. border at Midway, flows in a south and easterly direction ~ 46 km before it returns to Canada just west of Grand Forks, flows east 41 km before again crossing the border below Christina Lake and ultimately flowing ~53 km before converging with the Columbia River now inundated by Roosevelt Lake in Washington State. Cascade Falls (located 5 km upstream of the Washington border below Christina Lake is an impassable barrier to all fish. The Canadian portion of the watershed, excluding the Granby, extends ~237 km in length and covers an area of 8,166 km^2, including sub-basins (MFLNRO data on file). The upper Kettle River (upstream of Midway), including the West Kettle River and Kettle, has a gross drainage of 5,355 km^2 with a mean annual discharge (LTMAD) >m 40 m^3/s (MFLNRO data on file). The lower Kettle River (near Grand Forks), including the Granby River, has a gross drainage of ~2,811 km^2 with a mean annual discharge (LTMAD) > 80 m^3/s (MFLNRO data on file).

West Kettle River

The West Kettle River flows in a north-south direction between the Okanagan Highlands to the West and the Monashee mountain range to the East (Figure 1). The West Kettle River flows 113 km to it's confluence with the Kettle River near Westbridge, BC. The total watershed area for the West Kettle River is 1,898 km^2 with a mean annual discharge (LTMAD) > 14 m^3/s (Epp 2012; MFLNRO data on file).

Granby River

The Granby River flows in a southerly direction from its origin in the Monashee Mountains, to its confluence with the Kettle River at Grand Forks BC (Figure 1). The river is > 125 km in length, has a gross drainage of ~2,061 km^2, with a mean annual discharge (LTMAD) > 30 m^3/s (Epp 2012; MFLNRO data on file). At higher elevations, the river is relatively small, has many cold water sources, has a steep gradient, and substrate is dominated by cobble/boulders. At the lower elevations the river widens, is lower in gradients (often < 1%), is characterized by slow moving water, and water temperature is considerably warmer than the headwaters. Much of the lowland areas are dominated by range and forage production, although some vegetable and fruit production occurs around Grand Forks

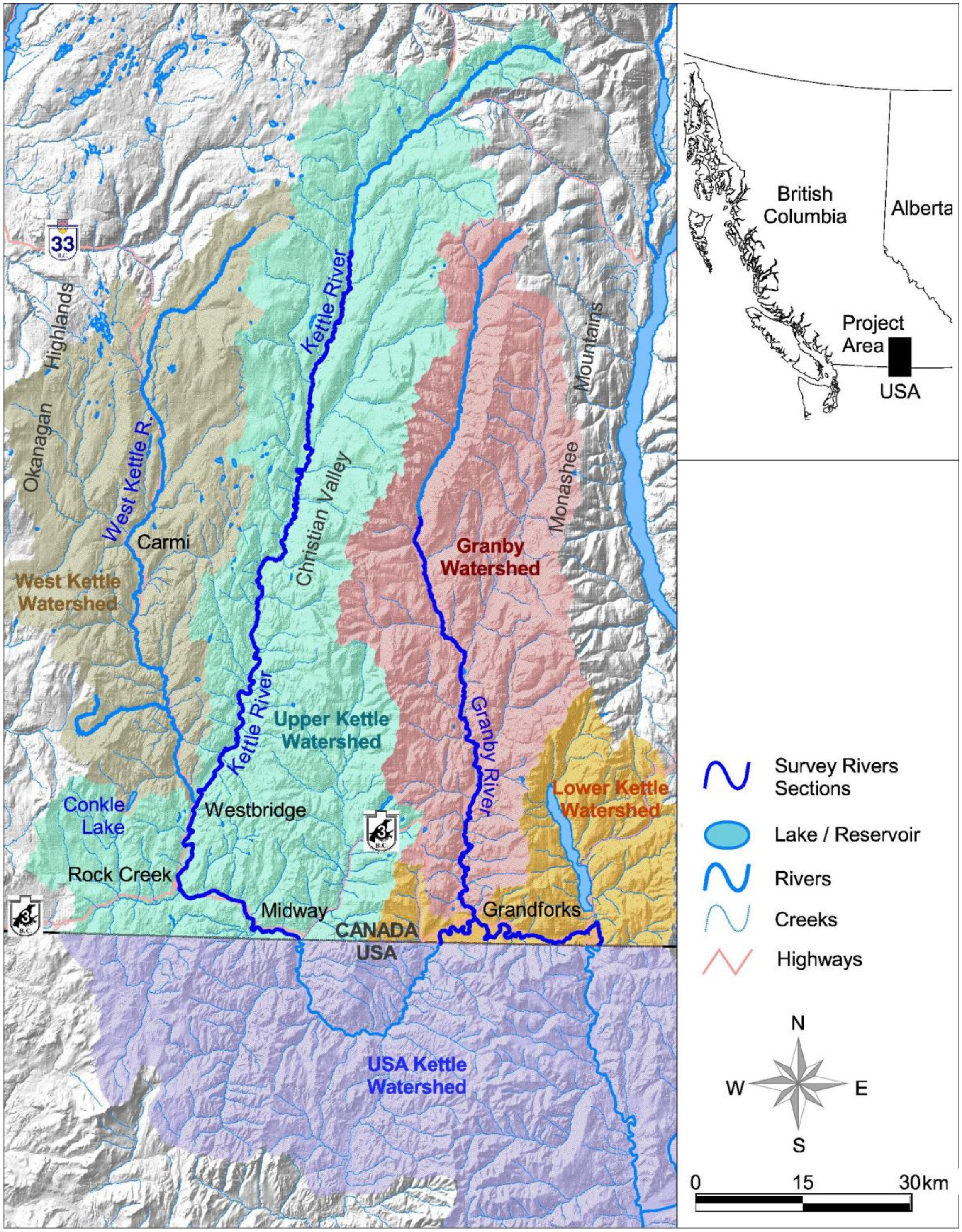

Figure 1. Kettle River (lower and upper) in Canada, West Kettle River and Granby River watersheds surveyed in 2011.

METHODS

Temperature and Discharge

Seasonal daily water temperature and discharge information on the West Kettle and Kettle rivers was provided by the monitoring programs of the Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations. This monitoring was part of a larger water use plan for the Kettle River basin and will be utilized in establishing conservation flows for fish on these systems (Tara White, Senior Biologist, MFLNRO Penticton BC, pers. comm.). A total of 7 transect stations were installed in July 2011 to monitor temperature and discharge (Figure 2). These stations were positioned to measure upper, middle and lower watershed temperatures and discharge in the West Kettle, Kettle and Granby rivers. The transects follow the instream flow incremental methodology (IFIM) detailed in Bovee et al. (1998).

Monthly discharge data was also available from active Environment Canada hydrometric stations on the Granby (#08NN002), West Kettle (#08NN003) and Kettle (#08NN026) rivers near Grand Forks and Westbridge BC, respectively (Table 1; Figure 2). Table 1 and Figure 2 also include additional active hydrometric stations throughout the basin, including United States Geological Survey (USGS) sites at Ferry (#08NN013) and at Laurier (#08NN012) Mean, maximum and minimum discharge on Granby, Kettle and West Kettle rivers is given (Table 1). As well, the long term mean annual discharge (LTMAD) is calculated and presented

Table 1. Kettle River Watershed Active Hydrometric Stations (Environment Canada)

River	Station ID	Length/Duration of Record
West Kettle River at Westbridge	08NN003	1914-1921, 1975-2011
West Kettle River near McCulloch	08NN015	1949-1957, 1964-2010
Kettle River near Westbridge	08NN026	1975-2011
Kettle River near Ferry (USGS)	08NN013	1928-2011
Kettle River near Laurier (USGS)	08NN012	1929-2011
Granby River at Grand Forks	08NN002	1814-1915, 1926-1931, 1966-2011
Trapping Creek near the Mouth	08NN019	1965-2010
Lost Horse Creek near Christian Valley	08NN028	1998 - 2010
Burrell Creek above Gloucester	08NN023	1973 - 2010

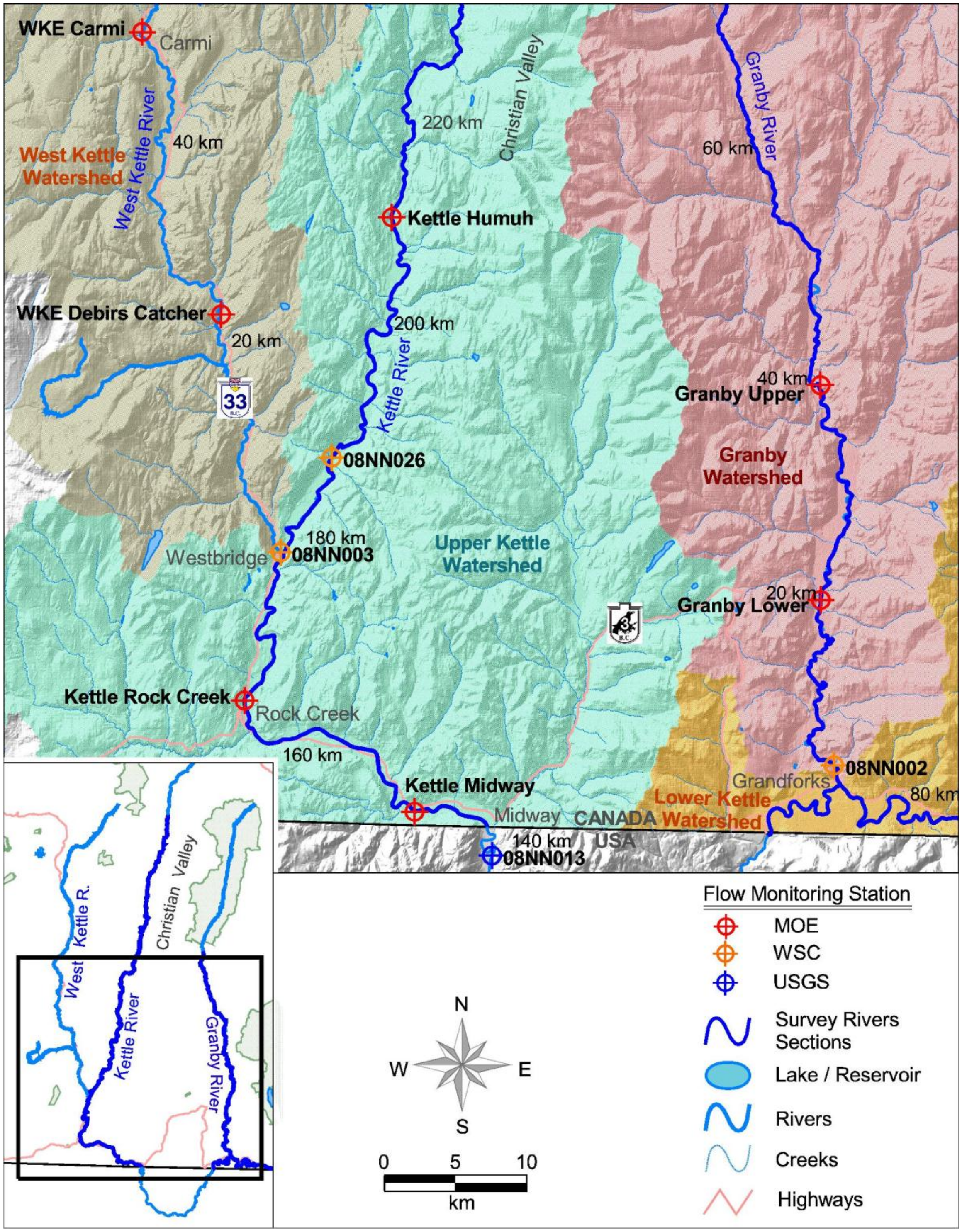

Figure 2. Flow monitoring stations from Ministry of Environment (MOE), Water Survey of Canada (WSC) and United States Geological Survey (USGS) and surveyed river sections within the Kettle River Basin in 2011.

Habitat Availability

In 2011, a field crew conducted habitat surveys to assess the total amount of habitat available on the Kettle and Granby Rivers, within the known range of speckled dace (Figure 3) based on Batty (2010). The surveys -sampled 11 randomly selected sites at each location representing >10% of the 237 km of river in the Canada portion of the Kettle Basin. On the Granby River, surveys -sampled 2 randomly selected sites representing >5% of the 125 km of river. In addition to the sites surveyed 84 habitat photo point observation sites were selected to better assess dynamic portions of both systems and help refine the GIS mapping. Habitat assessments were stratified into three meso-habitat units (riffle, run and pool), detailed in Table 2, following the level one Fish Habitat Assessment Procedure (FHAP) of the Watershed Restoration Program (WRP) (Johnston and Slaney 1996 *in* Slaney and Zaldokas 2006.) These habitat assessments build upon prior habitat use and preference information (Andrusak and Andrusak 2011).

A GIS meso-habitat layer[1] for the Kettle and Granby Rivers was developed from BC Government LRDW 1:20,000 (https://apps.gov.bc.ca/pub/geometadata/metadata). The BC Freshwater Atlas was used along with the most current (2004-2005) Orthomosacis imagery (Orthos). Linear bank boundaries and river centerline of the systems were extracted from the Freshwater Atlas layers and corrected by an experienced photo interpreter using Orthos. Delineation of meso-habitat types, detailed in Table 2, within the defined bank boundaries was then digitized to develop the initial pre-typing polygons representing the GIS habitats[1] (Figure 4). Data collect during the field surveys was used to ground truth and further refine the GIS classification producing the final GIS meso-habitat polygon layer (see next section).

Calculation of total habitat available on the Kettle and Granby rivers employed Instream Flow Incremental Methodology (IFIM) used by the MFLNRO and supported by Environment Canada hydrometric data The estimates of total available habitat for a given flow were then used was to predict the impacts of variable flows on fish and fish habitat.

[1] The entire GIS meso-habitat layer is available but too large to include in report

Table 2. Habitat stratification for used in sampling design

Meso-habitat	Depth	Depth Criteria (m)	Flow	Velocity (m/s)
Run	Deep	>0.5m	Flow	0.02-0.5
Run, riffle	Shallow	<0.5m	Flow	0.02-0.5
Pool	Deep	>0.5m	Slack	<0.02 m/s
Pool	Shallow	<0.4m	Slack	<0.02 m/s

GIS-Ground Survey Validation

It is acknowledged that there are differences in available habitat based on river discharge between survey data collected in 2011 and Ortho imagery collected in 2004-2005 that affect available habitat estimates. Moreover, it is also acknowledged that these differences may occur between years and seasonally which will also affect available habitat estimates. Despite the uncertainties, estimates are only intended to provide relative available habitat within these two river systems and assumes that the relative ratios of meso-habitat does not change significantly.

Assessments of the percent difference in GIS estimates of available habitat relative to ground survey estimates of available habitat were conducted to provide measurements of how accurate GIS estimates were. This assessment was completed for both river systems. Percent difference from the mean using information obtained from GIS compared to actual estimates derived from field surveys for full-bank width and wetted bank width was used to assess the accuracy of GIS calculations of area (ha) on both river systems. It should be noted that, observed differences and reported accuracy can be confounded by time differences between when imagery was obtained and when ground surveys were conducted.

Habitat Suitability Analysis

Fish microhabitat use is typically summarized from HSI curves. These relationships quantify the habitat suitability in particular areas via the estimated relationships (curves) between a habitat suitability index (HSI), which varies from 0 (totally unsuitable) to 1 (most suitable), and one or more quantitative habitat measures (i.e., depth, velocity or substrate etc.).

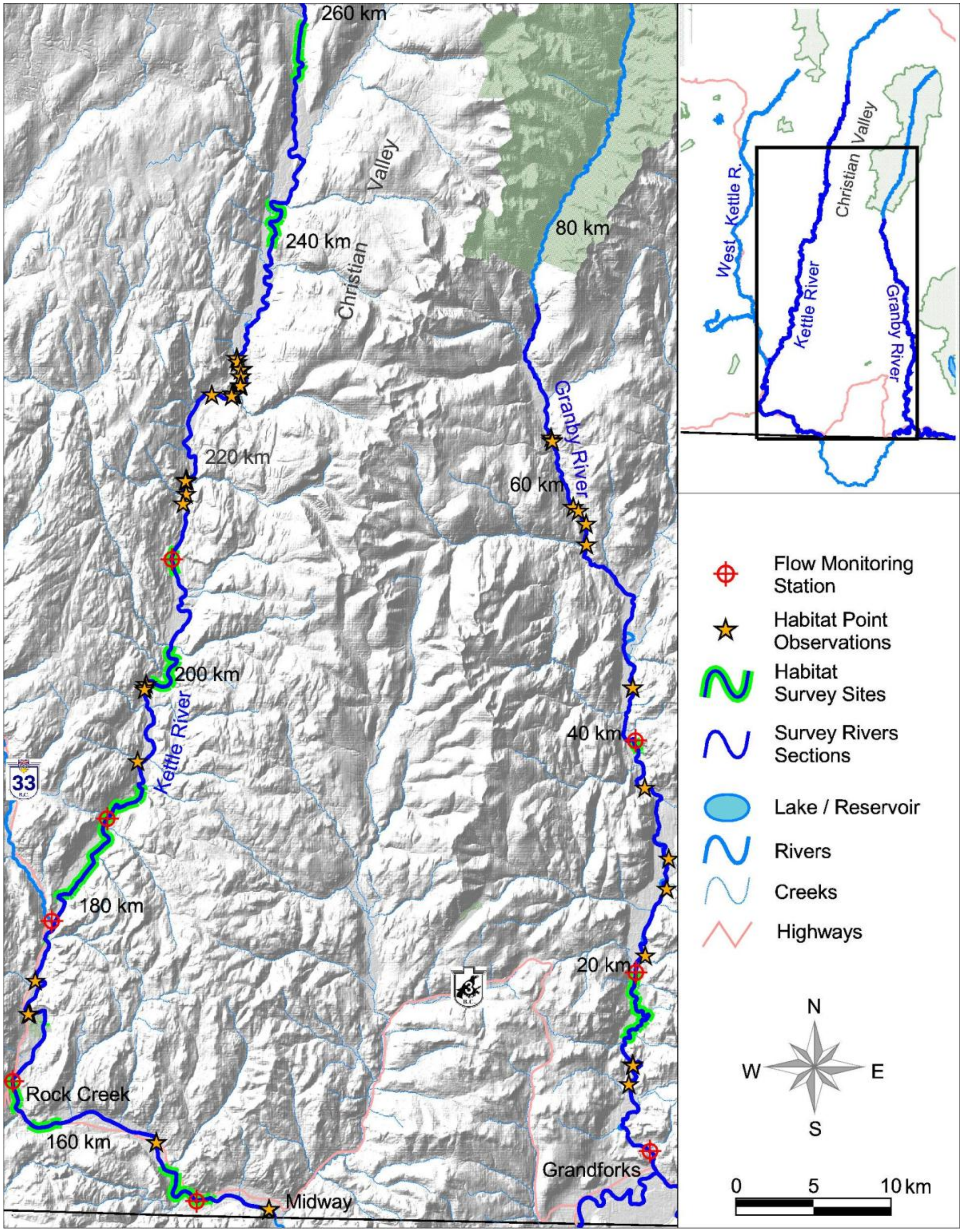

Figure 3. Habitat survey sites, habitat observation points and flow monitoring stations (MOE and WSC) in the Kettle River and Granby River watershed in 2011.

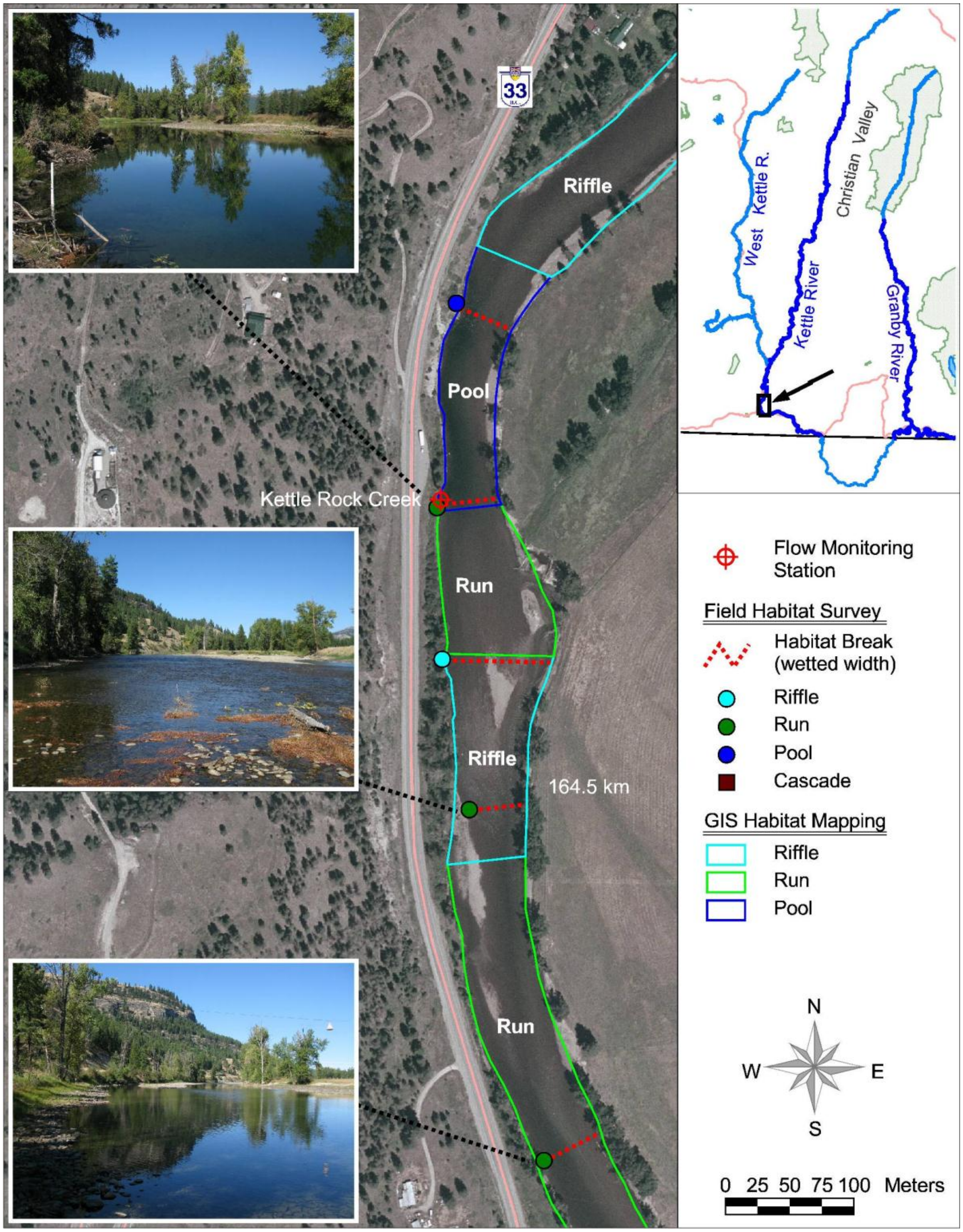

Figure 4. An example of a site used to delineate meso-habitat types within the defined bank boundaries, digitized to develop the initial pre-typing polygons representing the GIS habitats

Depth and velocity habitat suitability curves were estimated for mature and immature speckled dace. These were based on the observed patterns of habitat use obtained from 2010 electrofishing data (Andrusak and Andrusak 2011). The numbers of fish of each life stage by depth and velocity were then modelled using Generalized Linear Models (GLMs). As the response variables were fish counts, they were modelled assuming a Poisson distribution and the canonical log link function. The modeled relationship curve (the change in the counts over the range of the environmental variables) was captured using a third order polynomial. An advantage of using a polynomial over a smoother is that the relationships can be expressed algebraically [i.e., the estimated coefficients are readily interpretable] (Ntzoufras 2009). The fitted habitat use values were then transformed into habitat suitability indices by dividing by the maximum values and the resultant type three HSIs plotted (Andrusak and Andrusak 2011). Probability plots were then integrated with hydrometric information to provide information on habitat-flow relationships and useable area by speckled dace (see section below). Importantly, the analysis predicts and focuses in on the optimal criteria for the habitat use and preference and may not adequately reflect the wide range of habitat used by this species.

Weighted Useable Width

The depth and velocity data from the flow transects was used to calculate weighted useable width for juvenile (< 55 mm) and adult (> 55 mm) speckled dace for each of the measurement dates. The useable width is weighted from the probability of use in each cell based on habitat suitability indices (HSI) provided by R. Ptolemy (MOE Fisheries Biologist Victoria BC pers. comm.), multiplied by the cell widths and then summed for a total weighted useable width for that transect at that flow. The useable widths for each date were then plotted against the flows to generate a chart of how useable width varies with flow. The relationships are often complex, with a high order polynomial trend line generally providing the best fit to the data. In this case a LOESS smoother function was used to obtain the best fit.

RESULTS

Temperature and Discharge

Seasonal daily temperature data (July-October) were collected on the West Kettle, Kettle and Granby rivers in 2011 by the MFLNRO. Daily temperature profiles indicated a decline in temperatures from the summer to fall on all systems (Figure 5). In general, the Granby River average daily temperatures were cooler than both the West Kettle and Kettle rivers (5). Peak summer temperatures exceeded > 20^{o}C on all systems in 2011, with the mid-station on the West Kettle River recording a maximum temperature of 22.2 ^{o}C in late August 2011. In general, cooler water temperatures prevailed in the upper reaches of the Kettle and Granby rivers compared to mid to lower reaches throughout the seasonal monitoring period.

Annual discharge data provided by Environment Canada indicates that peak run-off occurs during the months of May and June for all systems, steadily declining over the summer.. In general, monthly discharge patterns indicate higher monthly flows on Granby River compared to the West Kettle or Kettle rivers. During the peak of run-off in May, the Granby River mean flows often exceeds 126 m^3/sec compared to 116 m^3/sec and 14.6 m^3/sec on the Kettle and West Kettle rivers, respectively (Figure 6).

Seasonal daily discharge patterns (July-October) were also collected on the West Kettle, Kettle and Granby rivers in 2011 by the MFLNRO. Daily discharge information indicated a decline in discharge from the summer to fall on all systems, with the exception of a noticeable peak in late September in 2010 (Figure 7). In general, the Granby and West Kettle rivers' average daily discharge was substantially lower compared to the Kettle River discharge (Figure 7). Following spring run-off, base flows moderated to 5 m^3/sec or less from late summer into the fall for all the systems.

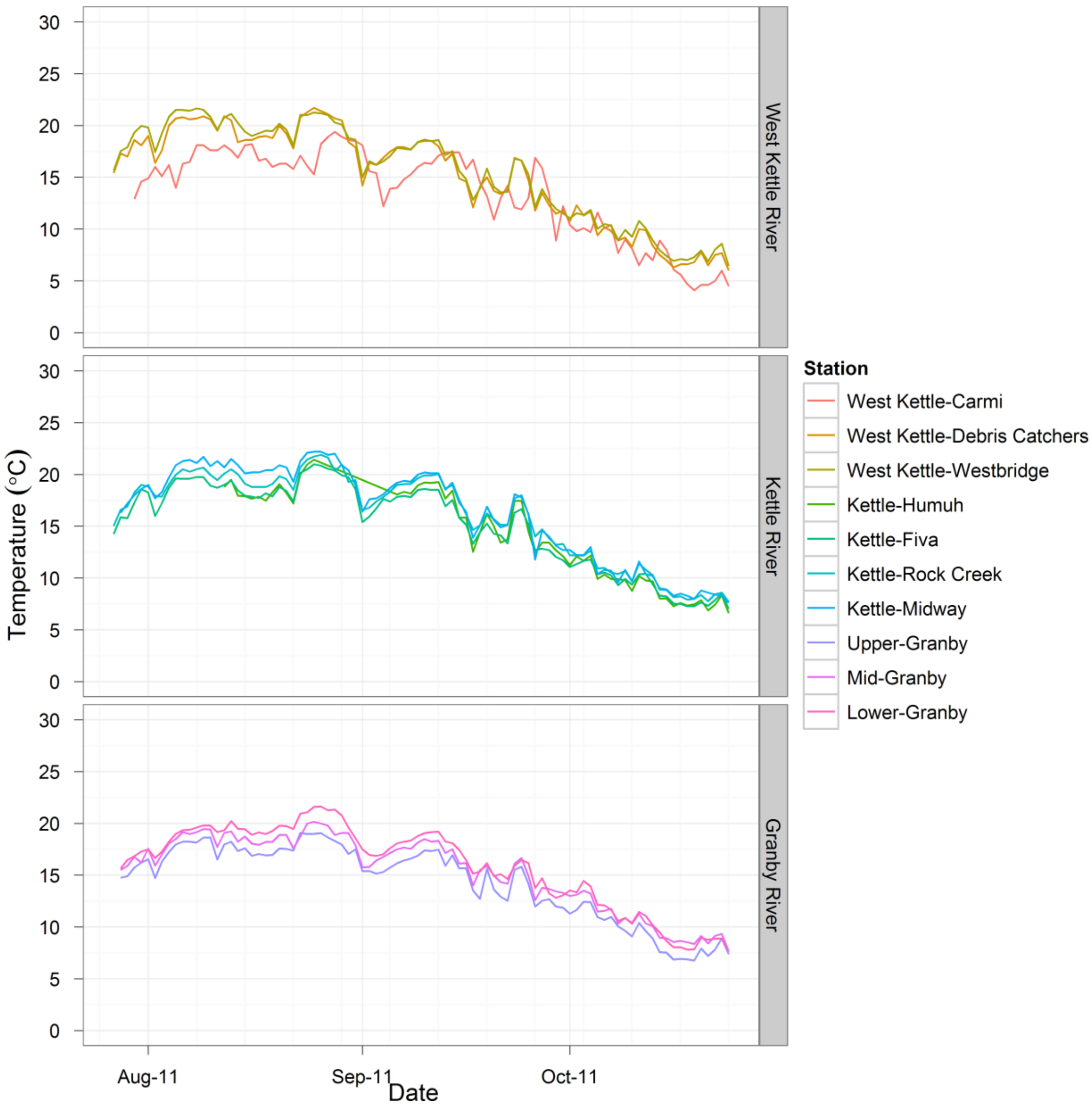

Figure 5. Temperature (°C) data from Granby, Kettle and West Kettle rivers in from Ministry of Forests, Lands and Natural Resource Operations monitoring stations from July 15-October 31, 2011.

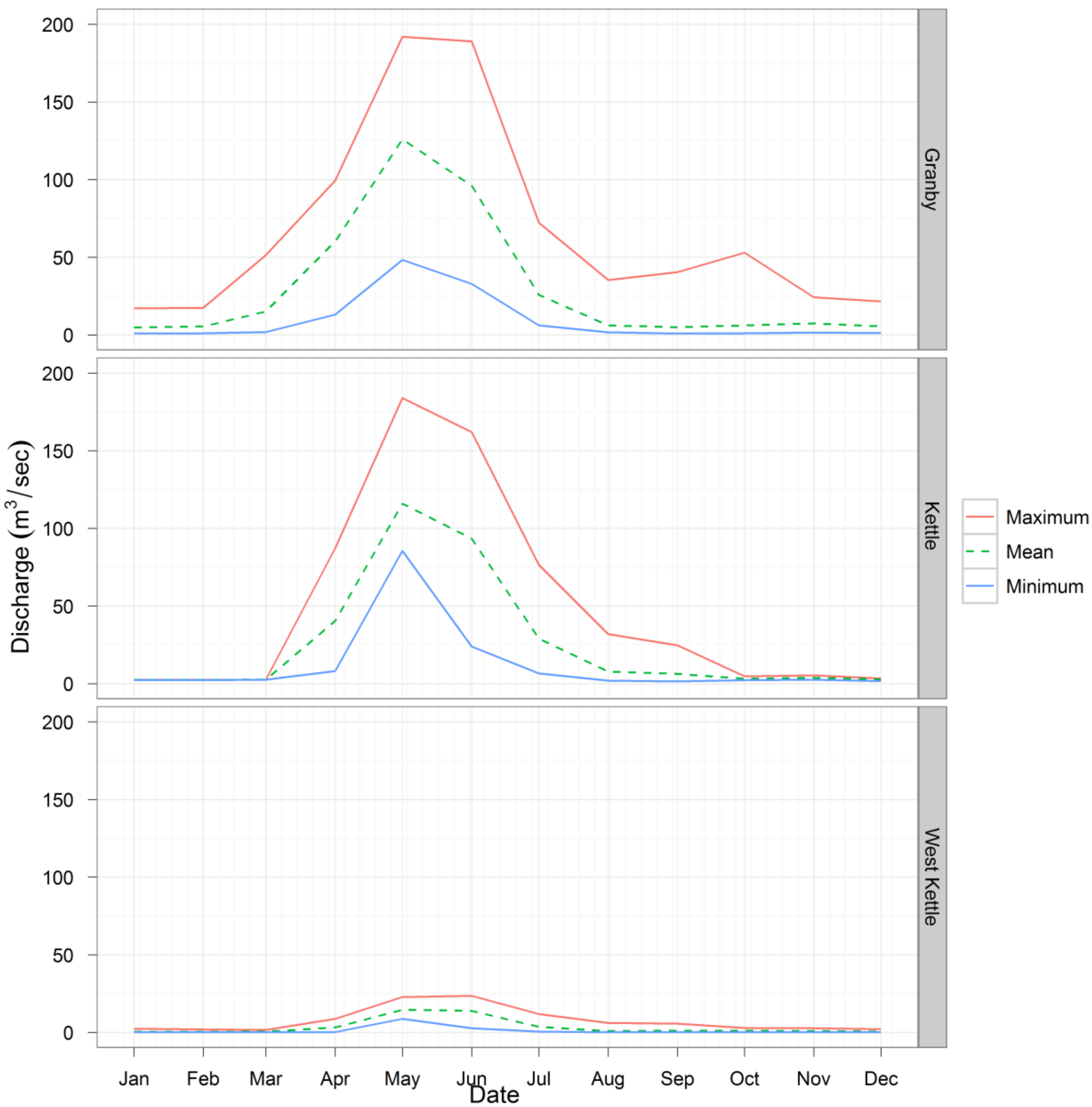

Figure 6. Mean, maximum and minimum monthly discharge (m^3/sec) data from Environment Canada hydrometric stations on the Granby (#08NN002), Kettle (#08NN026) and West Kettle rivers (#08NN003) near Grand Forks and Westbridge BC, respectively.

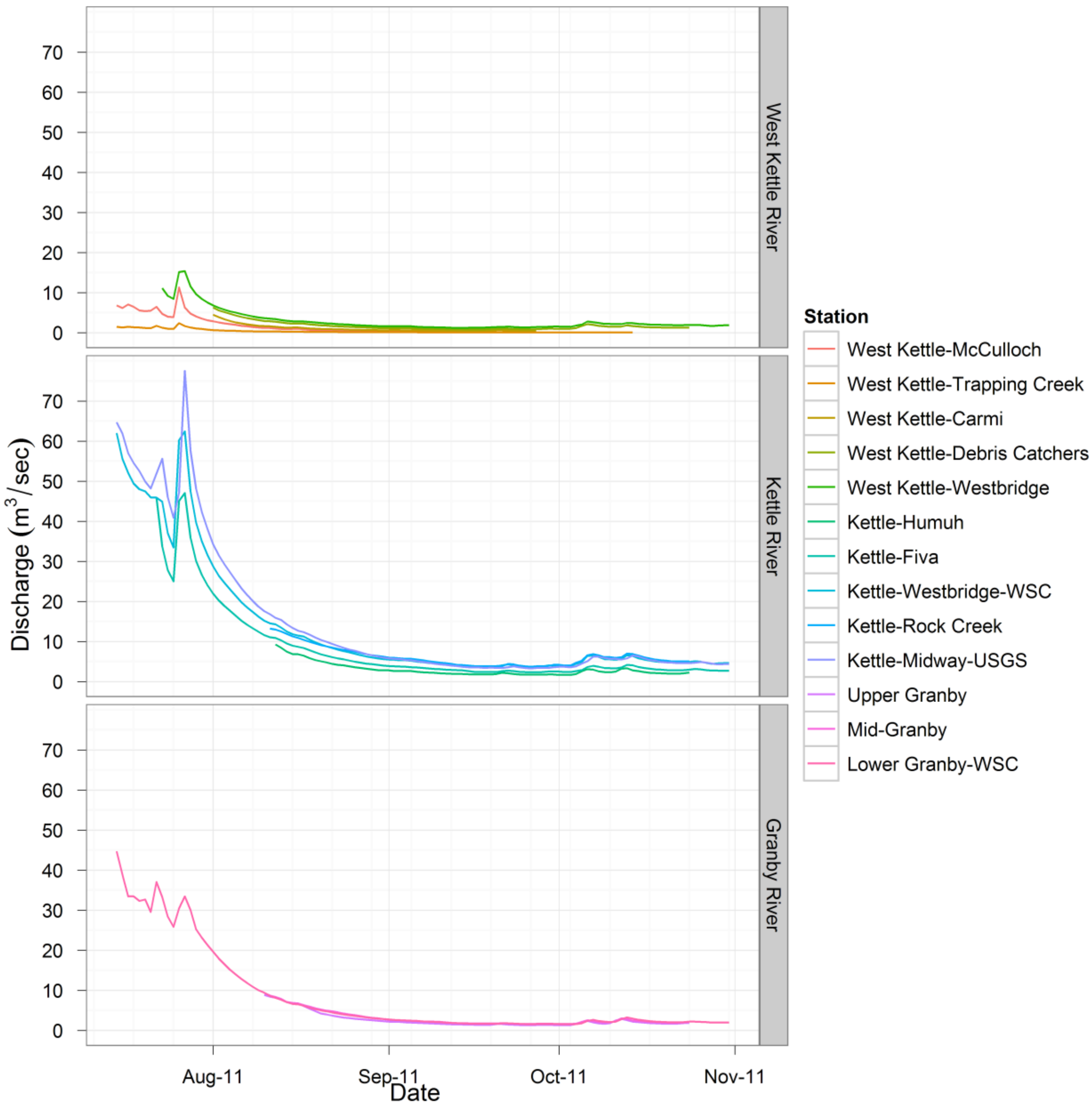

Figure 7. Discharge (m^3/s) data from Granby, Kettle and West Kettle rivers in from Ministry of Forests, Lands and Natural Resource Operations, Environment Canada (WSC) and USGS flow monitoring stations from July 15-October 31, 2011.

Habitat Availability

Kettle River

In the fall of 2011, a total of 33.1 km of habitat along the Kettle River was sampled at 11 randomly selected sites from September 26-29 (Table 3). Sites were distributed along the river from rkm 258 in the upper Christian Valley to rkm 145 near Midway BC. The sites included areas within the known distribution of speckled dace based on sampling by Batty (2010) on the Kettle River and therefore do not include the total available for the whole system. i.e. only sampled sites within the distribution range described by Batty (2010). Site lengths ranged from a minimum of 0.4 km to 11 km and were dependent upon information required to capture the dynamic nature of the system to improve the GIS derived habitat mapping (Table 3).

Table 3. Habitat surveys conducted on the Kettle and Granby rivers in 2011.

System (River)	SurveyID	Date	River km Start	River km End	Length (km)
Kettle River	1	26-Sep-2011	204.7	200.3	4.4
	2	27-Sep-2011	192.0	180.9	11.0
	3	28-Sep-2011	258.8	254.6	4.1
	4	28-Sep-2011	243.7	239.6	4.1
	5	29-Sep-2011	147.3	146.3	1.1
	6	29-Sep-2011	147.4	149.4	2.0
	7	29-Sep-2011	146.2	145.1	1.1
	8	29-Sep-2011	150.1	150.5	0.4
	9	29-Sep-2011	159.4	161.4	2.0
	10	29-Sep-2011	163.2	164.9	1.7
	11	29-Sep-2011	211.8	212.8	1.0
Granby River	12	30-Sep-2011	19.4	12.2	7.2
	13	3-Oct-2011	39.0	38.0	1.0

The total length of the Kettle River, including portions in the US, is estimated at ~336 km in length. Importantly, over 70% or 237 km of the Kettle River lies within Canada. Within Canada and within the known distribution of speckled dace (Batty 2010), available linear habitat on the Kettle River (lower and upper) was estimated to be ~179 km, translating into a total area of 1064 hectares (Table 4). Furthermore, within the known distribution of speckled dace (Batty 2010), these translate into a total area of 748 ha and 316 ha above Midway (upper Kettle) and below Grand Forks (lower Kettle), respectively.

Based on the GIS habitat mapping, the proportion of meso-habitat can be calculated based on the ground survey data (Table 4). The upper Kettle River (138 Km) is comprised of ~ 41% or 308 ha of riffle habitat (Appendix 1,Photo 1), 54% or 402 ha of run habitat (Appendix 1, Photo 2), 5% or 35 ha of pool habitat (Appendix 1, Photo 3) and less than <1% cascade or step-pool habitat (Appendix 1, Photo 4).The lower Kettle River (41 km) is represented by 37% or 116 ha of riffle, 57% or 181 ha of run, 5% or 17 ha of pool habitat and less than <1% cascade or step-pool habitat (Table 4). These percentages approximate between a 2-1.5:1 run to riffle ratio, and a 6-8:1 riffle to pool ratio throughout both sections surveyed. Importantly, pool habitat is < 5% of the total habitat surveyed throughout all sections surveyed.

Table 4. Total available habitat (ha) within the Granby and Kettle rivers by meso-habitat type. Kettle River data is separated into three distinct river sections including; Lower Kettle River near Grand Forks, Upper Kettle River above Midway.

System (River)	River Section	Habitat Type	Total Area (ha)	Total Length (km)
Kettle River	Lower Kettle River	Riffle	116.1	12.7
		Run	181.1	25.4
		Pool	17.0	2.0
		Cascade	0.9	0.1
		StepPool	0.3	0.2
		Falls	0.9	0.4
	Total		316.3	40.8
	Upper Kettle River	Riffle	307.5	54.0
		Run	402.1	75.6
		Pool	34.6	7.1
		Cascade	3.0	0.9
		StepPool	0.2	0.1
	Total		747.4	137.7
Total			**1063.7**	**178.4**
Granby River		Riffle	129.5	19.4
		Run	228.7	40.5
		Pool	37.1	6.2
		Cascade	11.2	4.6
Total			**407**	**70.7**

West Kettle River

No habitat survey was conducted on the West Kettle River in 2011. However, habitat information can be readily obtained using relatively high resolution GIS maps and ground surveys for this system, similar to those indicated for the Kettle and Granby Rivers. Importantly, high resolution imagery is now available for over the 113 km length or 202 ha of area within the West Kettle River.

Granby River

Along the Granby River 8.25 km of habitat was surveyed at two randomly selected sites on September 30 and October 3, 2011 (Table 3). Sites were distributed along the river from river km 39 to rkm 12. These sites included river habitat within the known range of speckled (Batty 2010) and therefore does not include the total available habitat within the entire system. Site lengths were 1 km and 7.2 km and were dependent upon information required to capture the dynamic nature of the system to improve the GIS derived habitat mapping (Table 3).

Available habitat as assessed through GIS habitat mapping within the known distribution of speckled dace on the Granby River was estimated to be ~71 km in length or 407 hectares in area.. Using the GIS habitat mapping, the proportion of meso-habitat types can be calculated based from ground surveys on the river (Table 4). The Granby River (71 Km) was represented by ~ 27% or 193 ha of riffle habitat (Appendix 1, Photo 5), 57% or 229 ha of run habitat (Appendix 1, Photo 6), 9% or 37 ha of pool habitat (Appendix 1, Photo 7) and less than 7% or 11.2 ha of cascade or step-pool habitat (Appendix 1, Photo 8). These percentages approximate a 2:1 run to riffle ratio, and a 3:1 riffle to pool ratio throughout sections surveyed. Importantly, pool habitat represented ~7% of the total habitat surveyed on the Granby River, considerably higher than that observed on the Kettle River.

GIS-Ground Survey Validation

Assessment of GIS estimates relative to ground survey estimates provides a measure of how comparable estimates of available habitat are on each of the river systems. The difference in GIS information compared to ground survey information using full-bank width and wetted width is described here using the relative percent error of actual estimates compared to GIS estimates, taking into account the difference in time periods for when GIS information and when ground surveys were conducted.

Total area sampled was validated by GIS estimated full bank widths to actual full bank widths on the Kettle and Granby rivers (Table 5). In many cases, the actual estimates of full-bank width (FBW) were on average within 92% of the actual estimates, indicating only a small amount of error (~8% difference) in the calculations of area (ha) on the Kettle River. Similarly, the actual estimates of full-bank width were on average within 84% of the actual estimates on the Granby River, once again indicating calculations of area (ha) were relatively accurate (Table 5).

Table 5. GIS assessed full-bank widths (FBW) and actual full-bank widths (FBW) from ground surveys were used for validating accuracy associated with estimated area calculations on Kettle and Granby rivers in 2011.

System (River)	Habitat Type	GIS Full Bank Width	Actual Full Bank Width	FBW Range	FBW Average
Kettle River	Riffle	61.9	61.5	86% - 100%	94%
	Run	55.2	53.8	82% - 100%	93%
	Pool	64.1	58.2	80% - 99%	90%
Granby River	Riffle	71.1	61.0	84% - 87%	86%
	Run	77.8	66.3	83% - 87%	85%
	Pool	64.5	56.6	72% - 92%	82%

While GIS to ground survey comparisons indicated a close approximation using full-bank widths, wetted width information was less accurate in calculating available habitat by area using GIS based methods (Table 6). Actual estimates of wetted bank width (WBW) were on average within 75 % of the actual estimates in the calculations of area (ha) on the Kettle River (Table 6). By way of comparison, Granby River estimates of wetted bank width were on average only within 50% of the actual estimates in the calculations of area (ha), considerably less accurate than the Kettle River estimates. Despite the differences, wetted bank width is considered a better metric for estimating habitat area since it accounts for changes in habitat over variable flow conditions within both systems. Further quantification of habitat should be conducted using ground surveys over variable flows and time periods to accurately ascertain differences between GIS data and ground data.

Table 6. GIS assessed wetted bank widths (WBW) and actual wetted bank widths (WBW) from ground surveys were used for validating accuracy associated with estimated area calculations on Kettle and Granby rivers in 2011.

System (River)	Habitat Type	GIS Wetted Bank Width	Actual Wetted Bank Width	WBW Range	WBW Average
Kettle River	Riffle	59.0	56.1	46% - 93%	76%
	Run	55.2	52.7	58% - 99%	78%
	Pool	63.0	56.8	55% - 98%	81%
Granby River	Riffle	73.8	63.7	41% - 55%	48%
	Run	77.8	67.3	31% - 50%	41%
	Pool	72.6	54.8	49% - 57%	53%

Useable Area and Discharge

Analysis of data collected from habitat use on speckled dace (Andrusak and Andrusak 2011) combined with MFLNRO flow monitoring data from transects reported by Epp and Andrusak (2012), demonstrate important correlations between discharge and useable area within the West Kettle, Kettle and Granby Rivers. Although each system is different, transect data was pooled by system for comparisons with immature (< 55 mm) and mature (> 55 mm) dace. These size cohorts were used because habitat preferences for juveniles and adults were demonstrated to be different (Andrusak and Andrusak 2011).

Immature speckled dace demonstrated a narrow range (< 8 m) in useable width in relationship to discharge (m^3/s) within the West Kettle, Kettle and Granby Rivers (Figure 8). In all three systems analysis indicated that useable widths were optimal for immature dace below a discharge of 10 m^3/s. However, the useable width was much smaller on the West Kettle compared to the useable width on the Kettle and Granby Rivers. In the case of the West Kettle River useable width was optimal for immature dace when discharge was below 5m^3/s. However, useable width for juvenile speckled dace based on a discharge of <10 m^3/s was <8m. This indicated that flows near a LTMAD of 20% on all three systems were optimal for juvenile speckled dace (Figure 9). It is suspected that differences between the systems for this life stage are likely associated with habitat and river morphological processes within each system.

There is a much wider range in useable area in relation to discharge (m^3/s) for mature speckled dace than for immature dace within all three systems (Figure 10). Useable widths for mature dace are highly variable. Mature dace have a useable width up to 20 m in the Granby and Kettle rivers, while the West Kettle River data indicated substantially smaller useable widths of < 15 m. The Granby and Kettle River indicated useable widths were optimal near a discharge of 5-10 m^3/s, while the West Kettle data suggests discharges below 5 m^3/s were optimal. Nevertheless, useable width was optimal for mature dace between a LTMAD of 20-30%, demonstrating more variability in habitat use and availability under varying flows (Figure 11). Once again, differences between the systems for this life stage are likely related to habitat and river morphology processes within each system

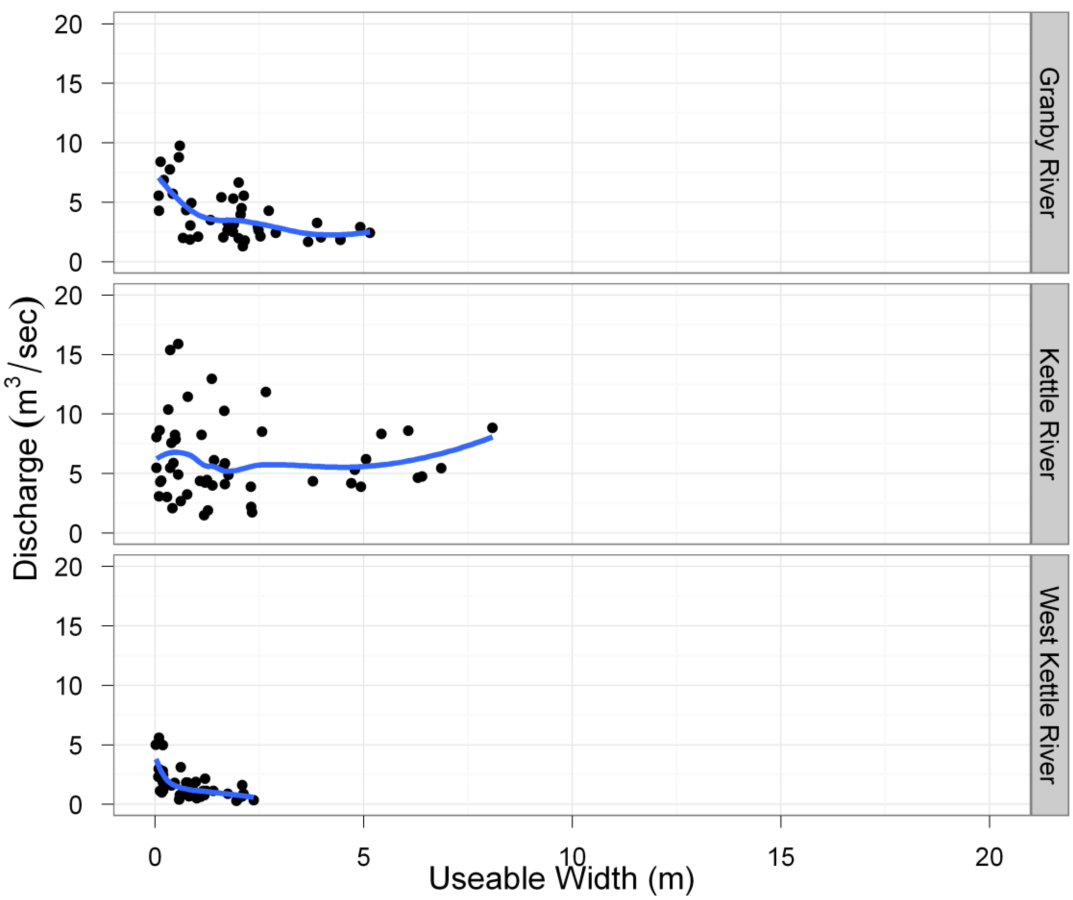

Figure 8. Immature Speckled dace (< 55 mm) useable width in relationship to discharge in the West Kettle, Kettle and Granby rivers from 2010-2011. Line represents a LOESS smoother function

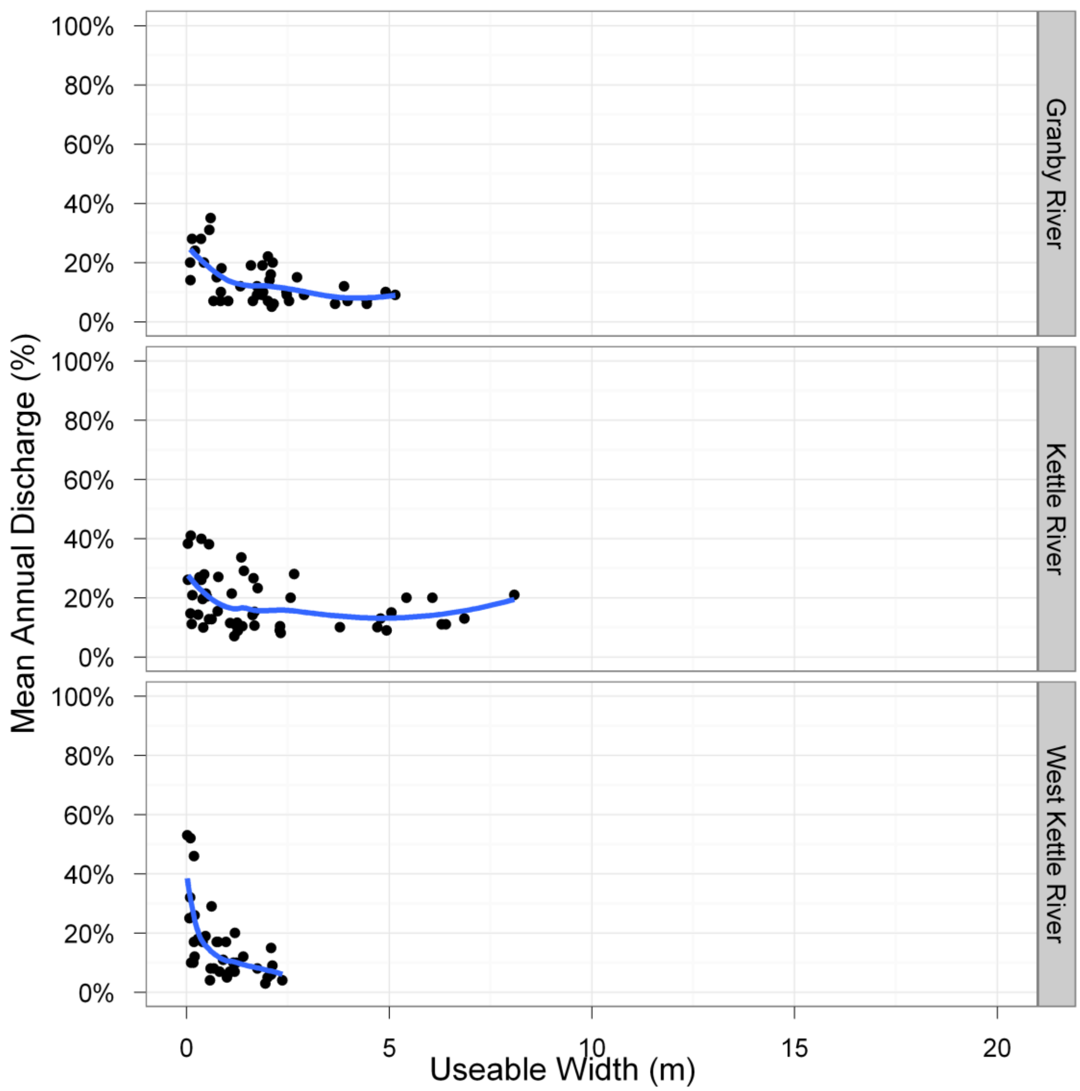

Figure 9. Immature Speckled dace (< 55 mm) useable width in relationship to %LTMAD in the West Kettle, Kettle and Granby rivers 2010-2011. Line represents a LOESS smoother function.

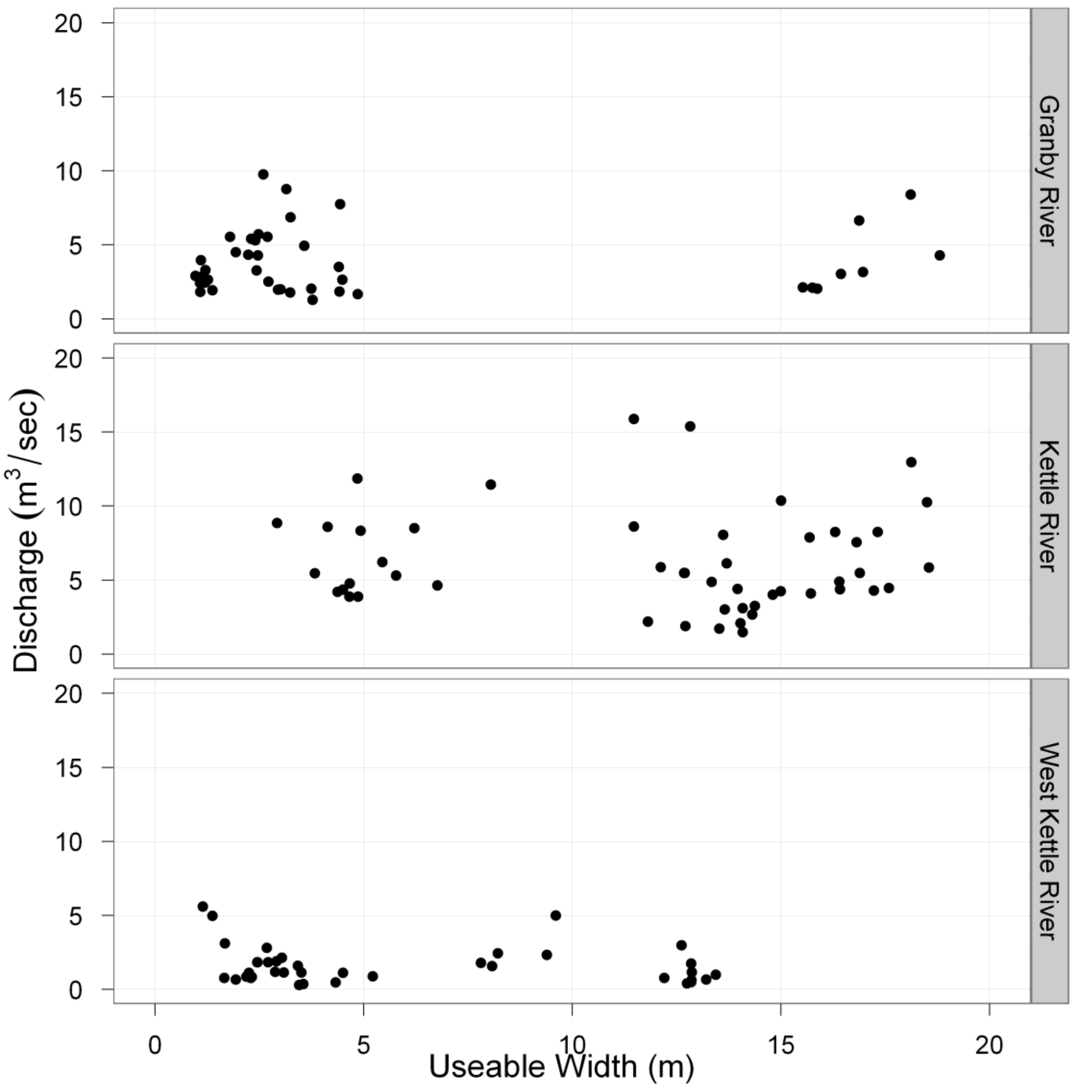

Figure 10. Mature Speckled dace (> 55 mm) useable width in relationship to discharge in the West Kettle, Kettle and Granby rivers 2010-2011.

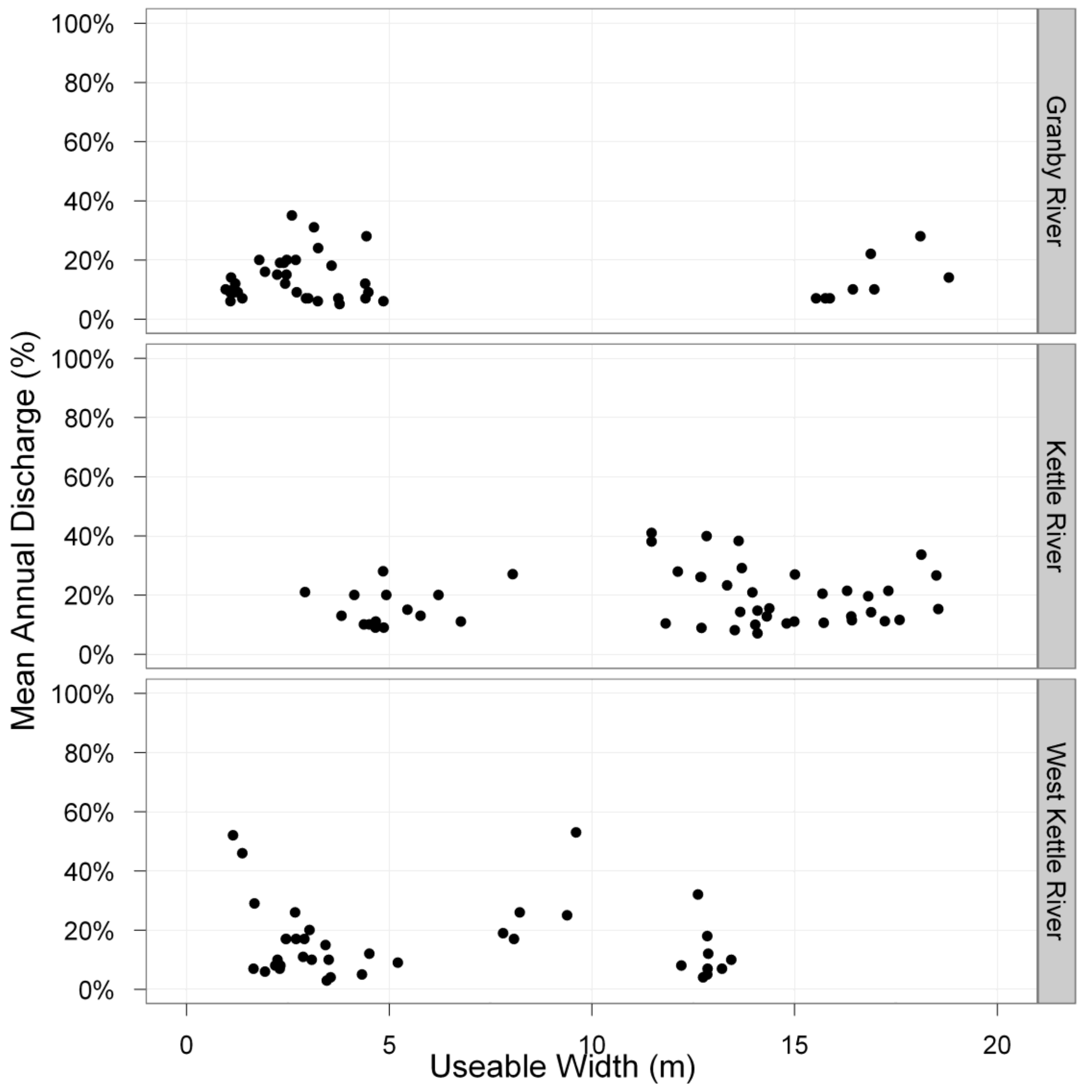

Figure 11. Mature Speckled dace (> 55 mm) useable width in relationship to %LTMAD in the West Kettle, Kettle and Granby rivers 2010-2011.

DISCUSSION

The rivers within the Kettle Basin have endured over a century of disturbances that have had profound impacts on the natural river ecosystem. The Kettle River itself has gained the distinction of the most threatened waterway in BC by the Outdoor Recreation Council of British Columbia in 2010. Excessive water extraction, development and factors related to climate change have plagued these watersheds, thus potentially reducing their natural productivity and imperilling the aquatic habitat and species that rely on the rivers for their existence. Defining conservation fish flows on the West Kettle, Kettle and Granby rivers is considered a high priority by the government management agencies. Consequently, the MFLNRO has implemented temperature and flow monitoring as part of a larger basin wide water use plan for developing and defining conservation fish flows and critical thresholds. Defining conservation flows is essential for a number of vulnerable and threatened species such as rainbow trout and endangered speckled dace that inhabit these rivers.

While speckled dace have a limited distribution in Canada, recent work has indicated that they are considerably more abundant and more widely distributed within the Kettle River watershed than originally thought (Batty 2010). Nonetheless, the species is limited to a single watershed, which was considered threatened by low flows. The species was SARA listed. Understanding habitat-flow relationships on the Kettle River will assist in identifying imminent threats to fish habitat and may provide options for mitigation. Habitat suitability indexes (criteria II and III; Ahi-Nedushan et al. 2006) in conjunction with habitat-flow relationships provide an important information on habitat requirements of endangered fish species such as speckled dace.

Temperature information indicated that water temperatures were cooler in the West Kettle, Kettle and Granby rivers in 2011 compared to 2010 (Andrusak and Andrusak 2011). Despite this, peak summer temperatures still exceeded > 20^{o}C on all systems in 2011, once again demonstrating that temperatures often exceed the optimal growth criteria for salmonid species within these rivers, (McCullough 1999). Peak summer temperatures for these rivers have ranged from 23-26 ^{o}C during 2006-2010 (data on file MFLNRO Penticton BC), and these extreme temperature events appear to be more frequent in recent years. Oliver (2002) also demonstrated that these temperature maximums are more pronounced in the lower portion of the Kettle River compared to the middle and upper portions of the West Kettle, Kettle and Granby rivers. Nonetheless, speckled dace are believed to have a higher temperature threshold compared to salmonids (John 1964; McCullough 1999). This suggests that summer temperatures within the observed ranges on these rivers are likely not a limiting factor to this species (Batty 2010).

River flow information indicates a highly synchronized pattern within sub-basins (West Kettle, Upper Kettle, Lower Kettle and Granby), with storm events and periods of low flows well replicated throughout the watershed (Epp and Andrusak 2012). All three rivers indicated an above average flow year until early July 2011, precipitously declining to low flow stage, with about a 1 in 5 year return period, by late August (Epp and Andrusak 2012). Low flows ranged from 6 to 7% LTMAD in the West Kettle and Kettle and 9 to 10% LTMAD in the Upper Kettle and Granby rivers, respectively (Epp and Andrusak 2012). Furthermore, MFLNRO hydrometric stations show a reduction in flows at downstream sites compared to upstream sites, indicating the likelihood that downstream flows are being reduced by upstream water use.

Both the Granby and Kettle Rivers have an abundance of available habitat for speckled dace within the range delineated by Batty (2010). Use of GIS-ground survey data proved valuable in quantifying habitat type and the total area available in each system, Not surprisingly, based on the relatively low gradient, both systems were dominated by riffle and run habitats. Meanwhile, pool habitat was generally the smallest area of habitat in both systems, representing < 5% and 7% of the total available habitat in the Kettle and Granby Rivers, respectively. Such a low percentage of this habitat type is of considerable importance for overwintering salmonids, and is considered the most limiting factor for the adult rainbow trout population within the Kettle River (Oliver 2001; Oliver 2002; Andrusak 2009). Despite the use of GIS-ground survey data to provide estimates of habitat type and the total available in each system, accuracy of the data is confounded by temporal timing of ground surveys and flow conditions in relation to differential time period of when GIS imagery is obtained. In both systems, further accuracy can be obtained by increasing the sampling frequency conducted by ground surveys over variable flow conditions.

Comparison of speckled dace by life stage indicates some important attributes regarding use and preference within the rivers of the Kettle Basin (Batty 2010; Andrusak and Andrusak 2011). Juvenile dace were more closely associated with river margins, selecting for smaller substrate, lower velocity and depth; compared to adults which preferred larger substrate, higher velocity waters, and deeper water. Suitability curves for mature dace indicated maximum preference for velocities that were six times higher than that for immature dace. Nevertheless, the probability of finding a speckled dace decreases with increasing depth and water velocity, suggesting an overall preference for slow, shallow habitats. Based on their preferences and the habitat information that indicates an abundance of slow shallow habitats within both systems, primarily in the lower sections of these rivers, habitat itself would not be considered a limiting factor for this species.

Analysis of the habitat–flow relationship demonstrates important predictive relationships between changes in discharge and useable area for speckled dace within the study area. In general, useable width for juvenile dace is optimized when flows are near or slightly below 20% LTMAD within the West Kettle, Kettle and Granby rivers. In comparison, useable width for adult dace is optimized when flows are between 20-30% LTMAD within the same systems, reflecting a wider range in use and available habitat for this life stage. The useable width declines substantially at flows of <10% LTMAD, with both riffle velocities and riffle depths declining rapidly (Epp and Andrusak 2012). While not as apparent within the Granby and Kettle rivers, the substantial decline in useable width and available habitat for flows below 10% LTMAD is highly evident for the West Kettle River (Figure 8). This finding is most prominent for the juvenile life stage and provides supporting evidence of a limiting factor for speckled dace in the West Kettle River.

This study measured available dace habitat, calculated useable width habitat and analyzed these measurements with available flow data to determine whether speckled dace are impacted by variable and low flow conditions. The data suggest that recent low flows experienced on the Kettle and Granby rivers may not be impacting the speckled dace population as much as previously thought, and that the species appears well adapted to low flow conditions and warm waters evident within the basin. Batty (2010) also surmised that increased water withdrawals (Epp 2012) and drought in the future may not negatively affect speckled dace population as much as previously believed. However, this assumes that their core habitat requirements, inferred from habitat use and preference information, are not drastically affected by lower flows. The West Kettle River is believed to be the exception and provides a stark contrast to information obtained on the Granby and Kettle rivers. Low flows below 10% LTMAD within the West

Kettle River potentially have a negative effect on the speckled dace population, especially during the juvenile stage. This information should be kept in mind since a flow of 10% LTMAD has been proposed as the minimum necessary for maintenance of riffle width in B.C. streams while flows near 20% LTMAD are thought to be required to maintain riffle depth and velocity for salmonids(DFO 2008). Furthermore, it has previously documented in other streams and rivers that a 1% loss of stream flow during the low flow month, usually September, corresponds to around a 1% loss of salmonid?? fish habitat (Beecher et al. 1996). In view of these findings it is imperative for the management agencies to fully understand the impacts of water withdrawal and climate change. Water withdrawals are now complicated by a switch to considerable unregulated groundwater withdrawal as opposed to direct river withdrawals. An understanding of how groundwater withdrawal and recharge relates to discharge patterns in the rivers is important.

In summary, data from this study provides considerably more insight into the population health and status of speckled dace in the Kettle River Basin. While recent assessments have indicated the population is distributed widely and abundance is much greater (20-40 times) than previously thought, lessening the threat of extinction in the event of a catastrophic event, concern over increasing water use (Epp2012) and low flows that fall below historic levels are reasons for concern. The concern is most evident for speckled dace within West Kettle River where low flow conditions may be implicated in a possible population decline, despite having the highest densities within the Kettle River system. Further assessment and understanding of the habitat flow relationships on the dace population within the West Kettle River is warranted, especially when discharge decline below 10%LTMAD. Importantly, much of this work is currently being conducted by MFLNRO during development of a water use plan that aims to better understand and mange water use and extraction within the basin, especially during extreme low flow periods. While this ministry initiative is focused on salmonid recovery, the objective of the water use plan is to implement fish protection measures based on defensible low flow thresholds. In this regard, speckled dace requirements appear to be less rigorous than salmonids and that defining optimal flows, as detailed within this report, are inherently different than defining conservation flows for threatened fish species. Nonetheless, establishing base flows deemed suitable for salmonids should provide a measurable benefit in protecting speckled dace.

RECOMMENDATIONS

- Conduct river habitat and abundance estimates within the specific locations designated as potential critical habitat within the CSAS Working Research Document -- Brown et al. (2012 in prep)
- Conduct complete river habitat assessments that will enable estimations of total available habitat and the impacts based on habitat-flow relationships.
- Conduct mapping analysis to estimate extent of available and required habitat based on use and preference information for speckled dace.
- Assess the impact of low flow scenarios developed by MFLNRO on pool and run habitats.
- Since LWD and groins structures are important for trout and speckled dace consideration should be given to adding more structures to the West Kettle River.
- The property 7 km west of Midway BC where the LWD structures were placed should be considered for purchase for conservation purposes as it not only supports important speckled dace habitat but also supports six other red listed wildlife species.

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APPENDIX 1. Photos

Photo 1. Riffle habitat within the Kettle River above Midway in 2011.

Photo 2. Run habitat within the Kettle River above Midway in 2011.

Photo 3. Pool habitat within the Kettle River above Midway in 2011.

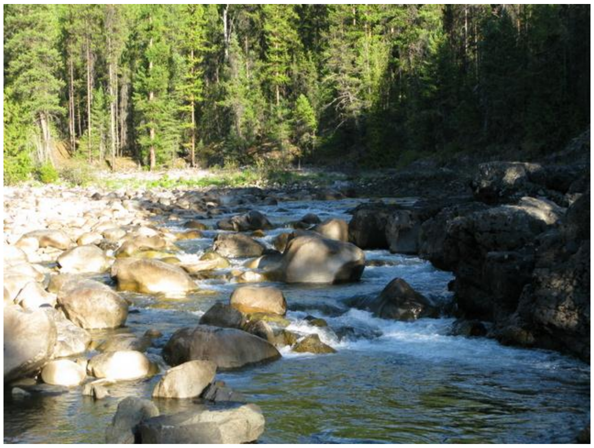

Photo 4. Cascade habitat within the Kettle River above Midway in 2011

Photo 5. Riffle habitat within the Granby River in 2011.

Photo 6. Run habitat within the Granby River above in 2011.

Photo 7. Pool habitat within the Granby River above in 2011.

Photo 8. Cascade-pool habitat within the Granby River in 2011.