

**EXAMINATION OF SPECKLED DACE ABUNDANCE,
BIOLOGY, AND HABITAT IN THE CANADIAN RANGE**

by

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ABSTRACT

The Speckled dace, *Rhinichthys osculus*, a small cyprinid species, was listed as endangered under the Canadian Species at Risk Act (SARA) in 2009. This species exists throughout the western United States, but in Canada it lives in the Kettle, West Kettle, and Granby Rivers in southern British Columbia (BC). I conducted field work in 2008 to assess the abundance, range, biology, and habitat use of this species. I estimated that there were 940,000 mature Speckled dace (90% confidence interval 412,000 – 1,955,000) in the watershed in 2008, a much larger number than previous estimates. I found that the species is longer-lived than previously thought, up to age 7-years. I recommend that the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the BC Conservation Data Centre re-assess this species, and that a procedure for setting conservation priorities be developed within SARA, similar to the BC Conservation Framework.

Keywords: Species at Risk Act; SARA; species at risk; COSEWIC; Speckled dace; *Rhinichthys osculus*; population abundance estimate; conservation priority.

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TABLE OF CONTENTS

Approval.....	ii
Abstract.....	iii
Acknowledgements.....	iv
Table of Contents.....	v
List of Figures.....	vii
List of Tables.....	ix
Glossary.....	x
1: Introduction.....	1
1.1 Background.....	1
1.2 Federal and Provincial Conservation Programs.....	4
1.2.1 COSEWIC Designations.....	4
1.2.2 The Species at Risk Act.....	5
1.2.3 Provincial Conservation.....	8
1.3 Study Site.....	10
1.4 Speckled dace biology.....	14
1.4.1 Life History.....	14
1.4.2 Diet.....	15
1.4.3 Habitat.....	16
1.4.4 Canadian and Global Range.....	17
1.4.5 Previous Population Estimates.....	18
1.5 Research Objectives.....	19
1.5.1 Objective 1: Life History and Diet.....	19
1.5.2 Objective 2: Habitat Use.....	19
1.5.3 Objective 3: Range and Abundance.....	19
2: Methods.....	20
2.1 Data Collection and Laboratory processing.....	20
2.1.1 Data Collection.....	20
2.1.2 Laboratory Preparation.....	29
2.2 Analysis.....	30
2.2.1 Biology.....	30
2.2.2 Habitat Analysis.....	35
2.2.3 Range.....	38
2.2.4 Population Estimate.....	38
3: Results.....	42
3.1 Biology.....	42
3.1.1 Length-weight Relationship.....	42
3.1.2 Maturity-at-length.....	43

3.1.3	Age Determination.....	45
3.1.4	Diet.....	50
3.2	Habitat	53
3.3	Range and Abundance.....	58
3.3.1	Range.....	58
3.3.2	Abundance	59
4:	Discussion.....	61
4.1	Management Implications	66
4.1.1	BC Conservation Framework.....	66
4.1.2	COSEWIC and SARA.....	68
4.2	Conservation Priority Setting.....	69
4.3	Value of information	71
4.4	Conclusion	72
	<i>Appendix 1</i>	74
	<i>Appendix 2</i>	75
	<i>Appendix 3</i>	76
	<i>Appendix 4</i>	77
	<i>Appendix 5</i>	78
	<i>Appendix 6</i>	79
	<i>Appendix 7</i>	80
	References.....	81

LIST OF FIGURES

Figure 1. Map of the global distribution of Speckled dace (adapted from COSEWIC 2006a) with the recorded collections prior to 2008 shown in black dots on the detail map (inset).	2
Figure 2. Mean monthly flow from (m^3) 1917 to 2008 in the West Kettle River, measured at the Environment Canada Station 08NN003 at Westbridge, BC (location shown on Figure 6).	12
Figure 3. Mean daily flow (m^3) in the West Kettle River in 2008, measured at the Environment Canada Station 08NN003 at Westbridge, BC (location shown on Figure 6).	13
Figure 4. Map of the 28 quantitative sampling sites in black dots (left) and the sampling protocol at each site. An example of stratification of shoreline and channel is shown, with shaded areas representing sampled areas.	22
Figure 5. Example of habitat sampling locations within a site. Solid points indicate locations that are within quadrats and every 5 m along transects. Open circles indicate capture locations where habitat variables were measured.	24
Figure 6. Stable isotope collections sites (circles) and the capture-recapture study site (square). The northern stable isotope collection site is located near Beaverdell, BC on the West Kettle River, and the southern site is near Midway, BC on the Kettle River.	27
Figure 7. Capture-recapture sampling area. Speckled dace were captured and held overnight in a container (top left), and then were released into an enclosed 15-by-3 m area of shoreline.	29
Figure 8. Conceptual diagram of the bootstrapped population estimate. S is the proportion of mature fish in the population, RL is the reach length, N_{Ci} is the number of Speckled dace captured in channel quadrats at site i , N_i is the estimate of population at site i , \bar{D} is the mean linear density of Speckled dace, q is the capture efficiency from capture-recapture trials, \bar{q} is the mean of the bootstrapped capture efficiency, and N_t is the total population abundance estimate for the reach.	41
Figure 9. The length-weight relationship for Speckled dace collected in the Kettle-Granby system during July 12 – 21 and August 5 – 8, 2008 ($n = 297$). Each point represents a single fish, and the curve is the exponentiated linear regression.	43
Figure 10. Maturity ogive for Speckled dace. Each point represents an individual Speckled dace; those with a y-axis value of 1 were mature ($n = 52$)	

and those with a y-axis value of 0 were immature (n = 272). Fish were separated by sex for visual assessment, however, the regression was fit to all data.....	44
Figure 11. Images of four Speckled dace otoliths, with arrows indicating annual growth rings (photos by G. Carder).	46
Figure 12. Relationship between estimated age (years) from otolith examination and fork length (mm) for Speckled dace (n = 22).....	47
Figure 13. Gamma distributions fitted to the length-frequency of Speckled dace captured August 25 – 27, 2008. The lower three gamma distributions (red lines) represent age 1, age 2, and age 3+ fish. The upper curve (green line) represents probability of a single fish being a given fork length within the population. Triangles are the mean fork lengths for ages 1, 2, and 3+ fish from left to right.	49
Figure 14. Occurrence of food types in Speckled dace (SDC) stomachs (n = 36). Stomach contents of Speckled dace collected in both July (n = 14) and October (n = 22) are shown together. Detail on the names of food types and life stage is given in Appendix 1.....	50
Figure 15. The mean count of each food type per stomach (n = 36). Error bars shown are \pm two standard errors. Stomach contents of Speckled dace collected in both July (n = 14) and October (n = 22) are shown together. Detail on the names of food types and life stage is given in Appendix 1.....	51
Figure 16. Isotope analysis showing the mean of replicate samples from individual Speckled dace, and the mean of replicates from invertebrate and algal delta ^{15}N and delta ^{13}C signatures. Error bars shown are \pm two standard errors, and are obscured in some cases. Labels are as follows: SDC = Speckled dace, TRI = O. Trichoptera (I), PLC = O. Plecoptera (ny), EPH = O. Ephemeroptera (ny), CHR = F. Chironimidae (I), TIP = F. Tipulidae (I), ODE = O. Odenata (ny), FIL = filamentous algae, EPI = epilithic algae. The point labelled TERR is the expected delta ^{13}C signature for terrestrial sources. Detail on food type and life stage given in Appendix 1.	53
Figure 17. Proportion of habitat variable values at used locations (n = 25) and sampled-but-not-used locations (n = 411) in the channel quadrats.....	55
Figure 18. Proportion of habitat variable values at used locations (n = 204) and sampled-but-not-used locations (n = 618) in the shoreline transects.....	56
Figure 19. The location of all quantitative and exploratory sampling sites.....	59

LIST OF TABLES

Table 1. Sampling type and associated dates.	20
Table 2. Reach names and number of sites quantitatively sampled within the Kettle-Granby system.....	22
Table 3. Summary of the Wentworth Scale substrate diameter (mm) ranges and substrate type.	24
Table 4. Parameter estimates, standard errors, and P-values for the maturity ogive binomial logistic regression for Equation (2) using data for Speckled dace collected July 14 – 22, and August 4 – 8, 2008.	44
Table 5. Starting parameters for the 2-age-group and the 3-age-group length-frequency models, including mean age-group fork length (Mean FL) (mm) and standard deviation (SD), used in the model to estimate the proportion of each age-group. Starting parameters were estimated from the otolith examination results.	48
Table 6. Summary table of the age-groups from the 3-age-group length-frequency model and estimated proportion of the population within each age-group, the estimated mean fork length (Mean FL) (mm) of each age-group, and the standard deviation (SD) of each age-group.	49
Table 7. Summary of means and standard deviations (SD) for the measured habitat variables depth (m), velocity (m/s), and average substrate diameter (mm) where Speckled dace were found.	54
Table 8. Results of a Kolmogorov-Smirnov test for detecting differences between distributions of habitat variables in sampled-but-not-used locations and locations used by Speckled dace. Variables used are stream velocity (m/s), depth (cm), and estimated average substrate diameter (mm)	57
Table 9. Estimated coefficients for Equations (4) and (5), the logistic regression model for predicting the probability of presence of Speckled dace at a given location (n = 602).....	58
Table 10. Summary table of the reach lengths (km) with confirmed Speckled dace presence.	58
Table 11. The bootstrap estimate of mature virtual population (VP), mature population estimate (Pop) and associated 90% confidence intervals (CI) of mature Speckled dace for each reach of the river system.	60
Table 12. The bootstrap estimate of mature Speckled dace linear abundance (SDC/m) and associated 90% confidence intervals (CI) for each reach of the river system. Estimates are not adjusted for capture efficiency and thus are equivalent to the virtual population estimates.	60

GLOSSARY

BC	British Columbia
CBD	Convention on the Conservation of Biodiversity
CDC	Conservation Data Centre
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Department of Fisheries and Oceans
ESA	Endangered Species Act
FL	Fork length
GLM	Generalized linear model
IUCN	International Union for Conservation of Nature
KS	Kolmogorov-Smirnov
SAR	Species at Risk
SARA	Species at Risk Act
SDC	Speckled dace
SIA	Stable isotope analysis
US	United States of America

1: INTRODUCTION

1.1 Background

Canada's Species at Risk Act (SARA) provides the Federal Government with an avenue to identify and protect species from becoming extinct or extirpated from Canada. The SARA mandates the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to provide biological information on which SARA listing decisions are based (SARA 2002). In addition to the Federal conservation legislation, most provinces have a method of identifying species that are of conservation concern. British Columbia's (BC) Red and Blue lists, Conservation Data Centre (CDC) rankings, and Conservation Framework are all used to identify and set priorities for Species at Risk (SAR) for conservation actions, funding, and staff time.

The Speckled dace, *Rhinichthys osculus* (Girard, 1856), a small cyprinid species, is widespread throughout North America, but within Canada it is limited to the Kettle, West Kettle, and Granby Rivers in the Columbia watershed of southern BC (Figure 1). The species was first identified as a potential conservation concern in 1980 by COSEWIC (Hutchings and Festa-Bianchet 2009), and at that time it was designated as a species of special concern (COSEWIC 2006a). In March of 2009 the Speckled dace was listed as endangered under Schedule 1 of the SARA. Schedule 1 is a list of species in Canada that are considered to be extinct, extirpated, endangered, threatened, or

of special concern. The Speckled dace was listed under SARA due to its limited range in Canada, the paucity of information and data on the species, and concerns about decreased streamflow within the streams in its Canadian range (Government of Canada 2009a), as documented in the COSEWIC Assessment and Status Update Report (COSEWIC 2006a).

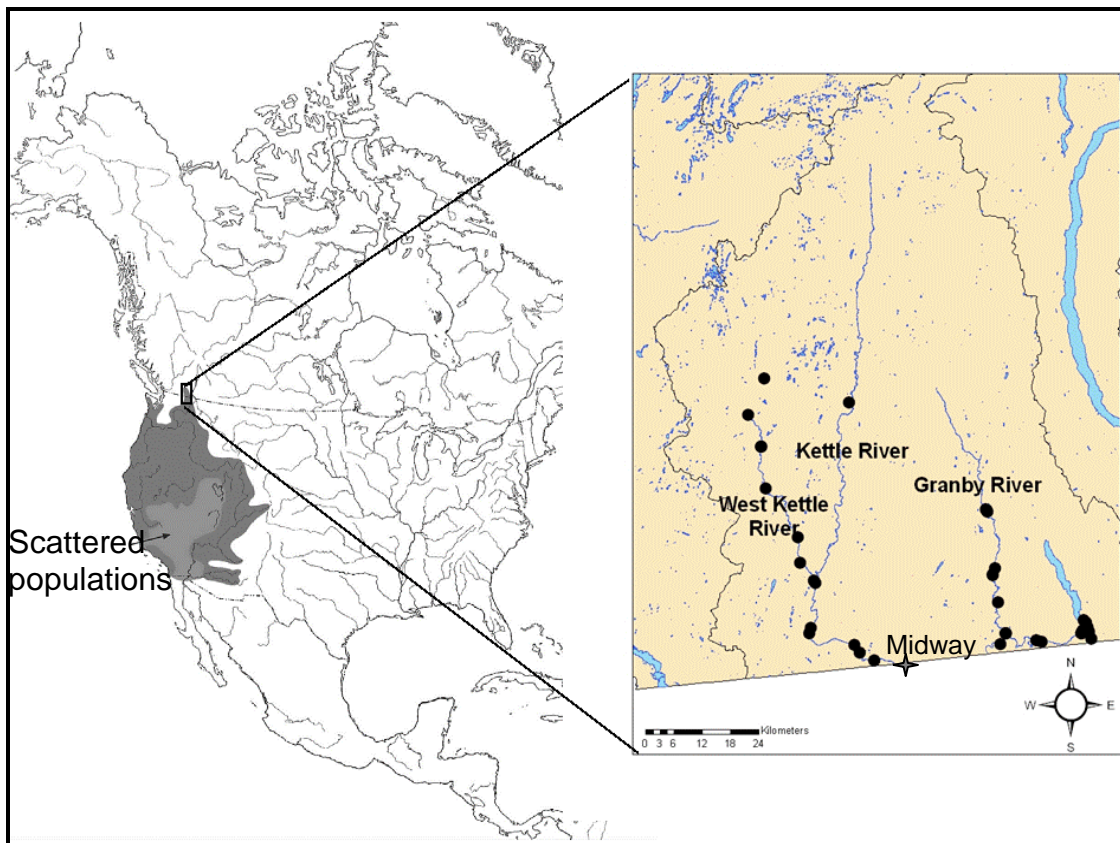


Figure 1. Map of the global distribution of Speckled dace (adapted from COSEWIC 2006a) with the recorded collections prior to 2008 shown in black dots on the detail map (inset).

In the United States of America (US), 19 subspecies of Speckled dace have been identified, and are recognized by the US Fish and Wildlife Service (US

Fish and Wildlife Service 2010). Of the 19 subspecies, 12 are listed under the US Endangered Species Act (ESA) (ESA 1973); three subspecies are endangered, one is threatened, and eight are species of concern (US Fish and Wildlife Service 2010). The definitions of subspecies vary widely in the taxonomic literature, and the term “subspecies” is not defined in the ESA either, so criteria used for classifying subspecies under the ESA vary among situations (Haig et al. 2006).

Since the recent SARA listing of Speckled dace, the need to expand the knowledge of the species in Canada has become more important because the Government is required by the SARA to develop and implement a Recovery Strategy. In support of that strategy, a number of gaps in the current knowledge of the species were highlighted in the 2006 COSEWIC Assessment (COSEWIC 2006a); those identified gaps formed the basis of my research objectives. Specifically, the COSEWIC Assessment (2006a) highlights the need for a population assessment of the Canadian population. Prior to this work, there have been no reliable estimates of abundance of Speckled dace in its Canadian range based on a combination of targeted field sampling and quantitative analysis. Also, biological characteristics of the species, such as growth, maturity, and population age-structure have not been well described (COSEWIC 2006a; Peden and Hughes 1981). Habitat use in the Kettle-Granby system has been documented to some extent, but development of the Recovery Strategy would be assisted by quantitative studies, which will likely be required for critical habitat determinations.

1.2 Federal and Provincial Conservation Programs

1.2.1 COSEWIC Designations

COSEWIC was formed in 1977 and initially produced assessments on a few bird and mammal species (Hutchings and Festa-Bianchet 2009). It has since expanded its scope to include fishes, vascular plants, reptiles, amphibians, lichens, molluscs, mosses and arthropods (Hutchings and Festa-Bianchet 2009). The committee bases its assessments on the best scientific information and aboriginal technical knowledge available at the time of the assessment (COSEWIC 2006b; Hutchings and Festa-Bianchet 2009). COSEWIC assesses the status of a species using several criteria, largely based on the International Union for Conservation of Nature (IUCN) Redlist Categories and Criteria (IUCN 2001). The main categories for the criteria are: (a) declining total population; (b) small distribution, and declining or fluctuating abundances; (c) small total population size and declining abundance; (d) very small population or restricted distribution; and (e) quantitative analysis (COSEWIC 2006b).

Species can be assessed by COSEWIC, based on the above criteria, as extinct, extirpated, endangered, threatened, special concern, data deficient, or not at risk, depending on the available information. Extirpated species no longer exist in the wild in Canada, and those that are assessed as extinct no longer exist anywhere in the wild. A species may be designated as special concern if it is particularly sensitive to human activities or natural events, but it does not meet the criteria for endangered or threatened designations (COSEWIC 2006b). A species maybe designated data deficient if there are insufficient data to

determine the species' eligibility for a complete assessment (COSEWIC 2006b). After a Species Assessment and Status Report is produced and if the species meets the criteria for extinct, extirpated, endangered, threatened or special concern, then it is sent to the Government to be considered for listing under the SARA.

1.2.2 The Species at Risk Act

In 1992, Canada signed the Convention on Biological Diversity (CBD), an international agreement recognizing nations' responsibility to ensure the protection and recovery of global biota (Hutchings and Festa-Bianchet 2009). By signing the CBD, Canada committed to developing national legislation for the protection of species at risk (Hutchings and Festa-Bianchet 2009). The SARA was passed in 2002, and came into force in 2003 with the following objectives:

“... to prevent wildlife species from being extirpated or becoming extinct, to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened” (SARA 2002).

After assessment by COSEWIC, a status report is submitted to the responsible Minister for consideration. Generally, the responsible Minister is either the Minister of Fisheries and Oceans, or the Minister of Environment, depending on the species in question. The responsible Minister has 90 days to report, on the public registry, the actions that will be taken, and recommend action to the Governor in Council, which is effectively the federal cabinet. The Governor in Council has a period of nine months after receiving the Species Assessment to (1) accept the Assessment and add the species to Schedule 1,

(2) decide not to list the species and state why, or (3) refer the Assessment back to COSEWIC for further consideration and information (SARA 2002).

Mirroring the COSEWIC designations, a species can be listed on Schedule 1 as extinct, extirpated, endangered, threatened or special concern. If the species is listed as endangered or threatened, it is given protection by a number of provisions, including prohibitions on harming both individuals and their residences (i.e., habitat) (SARA 2002). In addition to providing protection, the Government must begin Recovery Planning for all species that are extirpated, endangered, or threatened (Government of Canada 2009b). Recovery Planning is a two-stage process, and involves the development of a Recovery Strategy, and one or more Action Plans. A Recovery Strategy must be created within one year of listing, and include a determination of the feasibility of recovery, population and distribution targets, and identification of critical habitat on both Federal and non-Federal lands for the species (Government of Canada 2009b).

Critical habitat is defined by SARA as:

“... the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species’ critical habitat in the recovery strategy or in an action plan for the species.” (SARA 2002)

An Action Plan is the second component to the Recovery Planning process, and must identify measures for the implementation of the Recovery Strategy (Government of Canada 2009b).

In the case of a species of special concern, the Government must create a Management Plan. A Management Plan must identify conservation measures

that will prevent a species from becoming threatened or endangered (Government of Canada 2009b).

1.2.2.1 Speckled Dace: the Road to Listing

The Government first began the formal process of SARA listing the Speckled dace in April, 2004 when it acknowledged receipt of the 2002 COSEWIC Assessment and Status Report (Government of Canada 2004a). By acknowledging receipt, the Government began the 9-month timeline for the Governor in Council to make a listing decision. In October, 2004, the Government proposed that the species be referred back to COSEWIC for further consideration (Government of Canada 2004b). In January, 2005 the Government referred the Assessment and Status Report back to COSEWIC for further information and consideration (Government of Canada 2005).

In 2006, COSEWIC released the Assessment and Update Status Report on Speckled dace (COSEWIC 2006a), and designated Speckled dace as endangered based on criterion B: Small distribution, Decline or Fluctuation¹. The explanation for the assessment was given as follows:

“The area of occupancy is 7.47 km², and exists at 3 locations with continuing decline observed or projected in the extent and quality of available habitat as a result of increases in water extraction and drought conditions.” (COSEWIC 2006a)

In June, 2008 the Government acknowledged receipt of the 2006 COSEWIC Assessment and Update Status Report (Government of Canada 2008). In March, 2009, the Government officially added Speckled dace to

¹ The full COSEWIC designation of Speckled dace was B1+2ab(iii).

Schedule 1 of the SARA, listing it as endangered (Government of Canada 2009a).

1.2.3 Provincial Conservation

The BC Ministry of Environment maintains a list of the species that it considers to be of conservation concern in the province. The Provincial Red and Blue lists identify ecological communities, indigenous species and subspecies that are extirpated, endangered, threatened, or of special concern (Ministry of Environment 2010); Red list species are of greater concern than Blue list species. The provincial Red and Blue lists have no formal protection or additional provisions for protection associated with them. Despite the lack of legal strength, the Red and Blue lists are intended to provide a list of species to be considered for formal protection (i.e., SARA listing, COSEWIC designation) and to inform conservation priority setting within British Columbia (Ministry of Environment 2010). Speckled dace are on the provincial Red list.

In addition to the BC Red and Blue list, BC has a new Conservation Framework for prioritizing SAR for conservation actions and resources such as funding, and staff time. The BC Conservation Framework is a procedure that is designed to prioritize species for conservation based on three key goals: (1) to contribute to global efforts for species and ecosystem conservation, (2) to prevent species and ecosystems from becoming at risk, and (3) to maintain the full diversity of native species within BC (Bunnell, Fraser & Harcombe 2009; Ministry of Environment 2009). Species are ranked on each goal as priority 1 through 6, with 1 being the highest priority and 6 being the lowest. The

Conservation Framework is designed to help managers set priorities for conservation actions, while being transparent and easily updated (Bunnell, Fraser & Harcombe 2009). The Conservation Framework takes into account the feasibility of maintaining the species, stewardship responsibility, range trend, population isolation, population trend, and threats to the species.

The BC Conservation Framework is based on information provided by the NatureServe North American system, and the BC Conservation Data Centre regional system. NatureServe and the CDC assign species a rank from 1 to 5, with a status of 1 being the highest risk. Globally, Speckled dace are G5, meaning “demonstrably widespread, abundant, and secure” (NatureServe 2009). The global status (G5) is assigned to all populations and subspecies of Speckled dace combined, and given the large distribution the species is considered secure. The population in BC is not recognized as a separate population or subspecies by NatureServe, but is ranked by the CDC as S1 because of the suspected small population and range in Canada. This ranking indicates that it is “critically imperilled” (Ministry of Environment 2010; BC Species and Ecosystem Explorer 2009). Speckled dace are a peripheral species to BC, meaning that they are at the very edge of their global range (Bunnell, Campbell & Squires 2004), which is likely an important factor in the difference between the NatureServe global rank and CDC local rank.

Under the BC Conservation Framework, Speckled dace have been ranked as priorities 6, 4, and 1 under goals (1), (2), and (3) respectively (Ministry of Environment 2010). Recall that the BC Conservation Framework Goals are: (1)

to contribute to global efforts for species and ecosystem conservation, (2) to prevent species and ecosystems from becoming at risk, and (3) to maintain the full diversity of native species within BC (Bunnell, Fraser & Harcombe 2009; Ministry of Environment 2009). The high priority under goal (3) is due to the S1 ranking of the BC population.

1.3 Study Site

The Kettle-Granby system is in the southern interior of BC, and is part of the Columbia Watershed. The Kettle-Granby system is comprised of the Kettle, the West Kettle, and the Granby Rivers, making up the entire known range of the Speckled dace in Canada. The species has not been found during sampling of other tributaries to this system (COSEWIC 2006).

The Kettle River begins in the Monashee Mountains and runs southward through the Christian Valley. After the confluence with the West Kettle River, near Westbridge, BC, the Kettle River winds south-east until it enters the US for about 45 km downstream of Midway, BC (Figure 1). The Kettle River then returns to Canada west of Grandforks, BC, which is the site of the confluence with the Granby River. The Kettle River runs southeast from Grandforks until it enters into the US.

The Cascade Falls, a 30.5 m series of waterfalls, are about 5 km upstream of the international border in the Kettle River. The Cascade Falls create a barrier to fish movement from downstream to upstream, and are the furthest downstream point of self-supporting Canadian Speckled dace

populations (COSEWIC 2006a; Peden and Hughes 1984). Peden and Hughes (1984) observed juvenile Speckled dace in the 5 km section downstream of the falls before the international border, but suggest that those specimens came from upstream of the falls.

In the higher elevations and northern reaches of the three rivers, the headwaters are characterized by narrow streams, with boulder and cobble substrate, and clear, cool water. The headwaters run mainly through forested riparian areas. In the lower elevation and southern areas, the rivers are wider, slow moving, and warmer. Much of the area surrounding the lower sections of the Kettle-Granby system is used for agricultural cropland, and there are fewer forested riparian areas.

The study area lies within the Southern Interior Ecoprovince (Ministry of Environment 2006), which is characterized by hot, dry summers, and is subject to frequent extreme cold weather events in the winter and spring (Ministry of the Environment 2006). Average annual snowfall for Grand Forks is 119 cm, and average annual rainfall is 391 mm (Environment Canada 2008). Peak flow in the Kettle River occurs in mid-June to mid-July. After the peak flow period in the summer, the flows begin to recede, becoming low for the winter (Figure 2Figure 3). The average annual temperature in Grand Forks is 7.7 °C, and the average temperature in August is 19.3 °C (Environment Canada 2008).

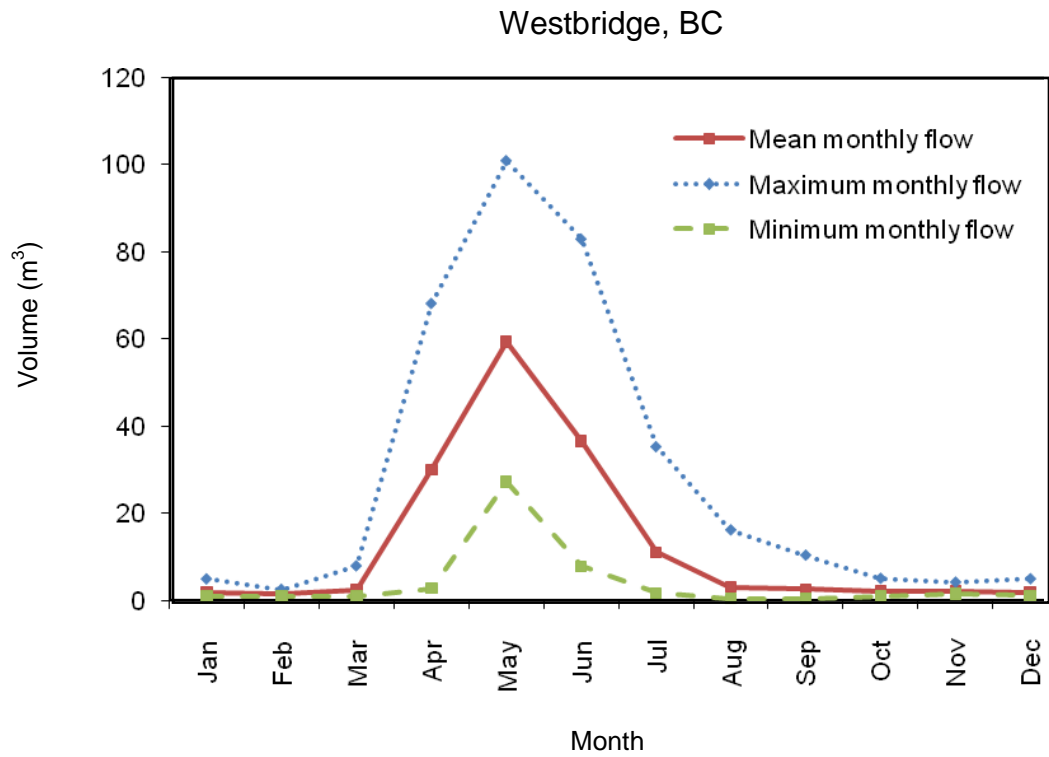


Figure 2. Mean monthly flow from (m³) 1917 to 2008 in the West Kettle River, measured at the Environment Canada Station 08NN003 at Westbridge, BC (location shown on Figure 6).

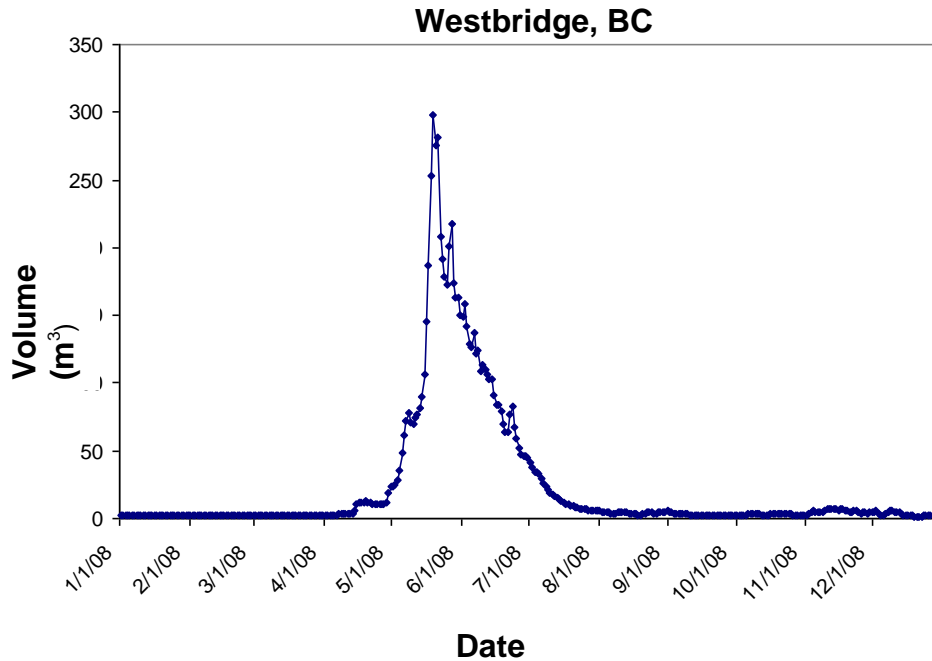


Figure 3. Mean daily flow (m³) in the West Kettle River in 2008, measured at the Environment Canada Station 08NN003 at Westbridge, BC (location shown on Figure 6).

Agriculture and ranching are the primary activities in the watershed of the Kettle River, but forestry, mining, and quarrying are also common. One main concern identified by COSEWIC is the increasing number of water withdrawals from the Kettle River for agriculture and proposed power generation (COSEWIC 2006a). Cascade Falls is the former site of a hydroelectric dam, and the proposed site of a future low-head hydroelectric dam. The Kettle and Granby Rivers are also commonly used for recreational activities such as angling and tubing, and the surrounding area is used frequently for camping.

1.4 Speckled dace biology

1.4.1 Life History

Speckled dace likely begin spawning in mid-July in the Kettle-Granby system during periods of high water levels and increasing water temperature (Peden and Hughes 1984; McPhail 2007). Spawning occurs over clean gravel (1.0 – 5.5 cm in diameter) and shallow water (2.5 – 10 cm deep) (John 1963; Mueller 1984). Kaya (1991) found that spawning can be protracted, and John (1963) found that spawning can occur in more than one peak within the spawning season. Given the above information, McPhail (2007) speculated that Speckled dace may be fractional spawners, meaning an individual fish can spawn multiple times over a spawning season.

Spawning has been documented in the wild in the US (John 1963; Mueller 1984). John (1963) found evidence of spawning site preparation by males in Arizona, whereas Mueller (1984) did not observe site preparation in New Mexico. Females enter the spawning site several times, and deposit eggs each time (John 1963; Mueller 1984). During spawning, groups of males (25 – 60 individuals) swarm the site and surround the female (John 1963; Mueller 1984).

Newly fertilized eggs observed in the laboratory are about 1.8 mm in diameter, demersal and adhesive (Haas 2001; Kaya 1991), and egg cannibalism is common (McPhail 2007). Peden and Hughes (1984) found that fecundity ranged from 450 to over 2000 eggs per female in fish collected in the Kettle River in October 1977.

Fry emerge in early August at about 9 mm in length, and by late October fry are 20 – 30 mm fork length (FL) (McPhail 2007). Males begin to spawn in their 2nd summer, (age 1+) and females begin to spawn in their 3rd summer (age 2+) (McPhail 2007). Peden and Hughes (1981, 1984) found that spawning begins when fish are 40 – 50 mm FL.

Peden and Hughes (1981, 1984) suggest that Speckled dace smaller than 40 mm in length are no more than 1½ yrs old. McPhail (2007) notes that the bulk of the population are fish < 60 mm FL, but that female fish > 90 mm FL are occasionally collected and are likely in their fourth summer (age 3+).

There has not been successful determination of Speckled dace age using hard structures such as otoliths and scales in the Canadian population. Peden and Hughes (1981) report size and length data, but their attempts to age specimens using otoliths and scales were unsuccessful. Based on size-frequency histograms within Canadian populations, there are at least 3 age classes of Speckled dace (COSEWIC 2006a). Wydoski and Whitney (2003) suggest that few Speckled dace live beyond age 3-years, referring to the populations of Speckled dace within Washington. Peden and Hughes (1981) highlight the importance of investigating the population structure in more detail.

1.4.2 Diet

The diet of Speckled dace has not been rigorously studied, but Peden and Hughes (1981) and McPhail (2007) report that Speckled dace consume mainly aquatic insects such as Ephemeroptera, Hemiptera, Notonectidae, Gerridae,

Crixidae, Diptera, Coleoptera, Hydrophilidae, Coleoptera, Dryopidae, and Plecoptera. Examination of stomachs indicates that in addition to insects, the diet of adult Speckled dace includes a large amount of filamentous algae (Peden and Hughes 1981). The diet of juvenile Speckled dace consist of similar foods, but with a greater emphasis on algae and Chironomidae than the adult diet (McPhail 2007).

1.4.3 Habitat

Habitat use within the Kettle-Granby system has been documented, however, relationships between presence/absence and habitat variables have not be quantified. Peden and Hughes (1981) report finding small Speckled dace (< 40 mm) in areas with small stones (150 mm – 400 mm diameter) and moderate current (not defined). In addition, Peden and Hughes (1984) describe catching Speckled dace in clean gravel with little or no organic matter; a description that is characteristic of most of the Kettle-Granby system. McPhail (2007) describes adult habitat use in early spring to be deep areas (>1 m) in the lee of rocks, bridges, and debris; McPhail (2007) describes later summer and autumn (late July – October) habitat as being shallow depth (0.1 – 0.65 m) and currents of <0.25 m/s. McPhail (2007) also suggests that males and females occupy different habitats based on the fact that they are infrequently found together. Haas (2001) collected 60 Speckled dace in Canada and describes their habitat preferences as being in slow moving (currents ranging from 0.03 cm/s to 0.15) cm/s and in shallow water (mean depth of 30 cm).

A major factor in the assessment of the species as endangered was the suspected lack of suitable habitat (COSEWIC 2006a). However, there has been no assessment of habitat use throughout the entire Kettle-Granby system, and previous collections have been limited in scope. My research will address this need for more detailed and quantitative habitat description.

1.4.4 Canadian and Global Range

Speckled dace are the most widespread minnow species in western North America and are found in isolated populations throughout the US in Arizona, New Mexico, California, Utah, Washington and Oregon, as well as in Sonora, Mexico (McPhail 2007). Despite the large distribution in the western US, Speckled dace in Canada have been documented only in the Kettle-Granby system (COSEWIC 2006b; McPhail 2007). Speckled dace have been found in about 259 km of stream in the Canadian portion of the Kettle-Granby system above Cascade Falls (COSEWIC 2006a). In addition to being geographically isolated, the Canadian population is morphologically distinct from populations in the US, and lacks any barbels, which populations in the US are known to have (McPhail 2007).

1.4.4.1 Jurisdictional Rarity

Partly due to the limited Canadian range, the Speckled dace is of conservation concern to both Provincial and Federal agencies. Bunnell et al. (2004) define a population as a peripheral (or marginal) population in BC if the species it has <10% of its range within the province. Bunnell et al. (2004) also distinguish between continuous and disjunct (or geographically marginal)

peripheral populations; disjunct populations are separated by a large distance or barrier that isolates them from the rest of the population. Peripheral populations are of interest to conservation organizations because they are generally characterized by isolation from central populations, local rarity, low viability, erratic trend, small population size, and small ranges (Bunnell, Campbell & Squires 2004; Lesica and Allendorf 1995).

Within BC, most species on the Red and Blue lists are part of peripheral populations in the province (Bunnell, Campbell & Squires 2004). Canadian Speckled dace in the Kettle-Granby system is a disjunct peripheral species, due to the isolation of the population from US populations downstream caused by Cascade Falls.

1.4.5 Previous Population Estimates

Abundance estimates of Speckled dace within British Columbia have been based on limited information. Cannings and Ptolemy (1998) report that there are likely 3,000 – 10,000 individual Speckled dace in Canada, and that the global population is over 10,000 individuals. Harvey (2007) notes that best estimates of abundance are estimated from data collected for museum collections and an environmental impact assessment study. Based on data collected for the environmental impact assessment, between 11,546 and 23,092 mature Speckled dace were estimated to be in the Kettle-Granby system (Bradford, unpubl. cited in Harvey 2007). Harvey (2007) suggests that better census data is required for setting a target population size and determining if there is a trend in the population abundance over time. The COSEWIC Assessment and Update

Status Report on the Speckled dace (COSEWIC 2006a) also identified the need for a quantitative estimate of abundance.

1.5 Research Objectives

The objective of this research is to expand on the limited knowledge of Speckled dace within Canada, as described above. The overarching objective can be subdivided into three objectives related to life history and diet, habitat use, and Canadian abundance and range. The objectives are designed to directly address the identified knowledge gaps, and to inform future SARA-related activities, particularly in the creation of the recovery strategy.

1.5.1 Objective 1: Life History and Diet

Identify the population age structure, length at 50% maturity, and the main dietary components of the Speckled dace population in Canada.

1.5.2 Objective 2: Habitat Use

Identify Speckled dace habitat use throughout the Kettle-Granby system, and quantify the relationships between habitat variables and presence/absence.

1.5.3 Objective 3: Range and Abundance

Estimate the current range and abundance of Speckled dace, specifically the abundance of mature Speckled dace within the Canadian portion of the global range.

2: METHODS

2.1 Data Collection and Laboratory processing

2.1.1 Data Collection

2.1.1.1 Biology, Habitat, Abundance and Range Sampling

I sampled throughout the Kettle-Granby system to evaluate Speckled dace biology, habitat use, abundance and range. I sampled some sites to evaluate range (exploratory sampling), and some for quantitative abundance estimation, capture efficiency estimation, and stable isotope collection. The latter samples were also used to examine diet. The dates and sampling types are summarized in Table 1.

Table 1. Sampling type and associated dates.

Sampling Type	Dates
Preliminary sampling	July 8 – 9, 2008
Abundance and exploratory	July 14 – July 21, 2008 August 5 – August 8, 2008
Capture-recapture	August 25 – August 27, 2008
Stable isotope collection	October 2 – October 3, 2008

I used electrofishing as the primary fish sampling method because it is a widely used and effective method of capturing stream fishes. Common electrofishing techniques for estimating abundance of stream fishes include single-pass electrofishing, multiple-pass electrofishing, and depletion estimates (Dauwalter and Fisher 2007; Poos, Mandrak & McLaughlin 2007; Sály et al.

2009). Poos et al. (2007) found that electrofishing is more effective than seining when sampling SAR in wadeable streams to determine presence/absence and catch-per-unit-effort of sampling. Single-pass electrofishing, which I used, is an effective method for evaluating stream fish populations (Reid, Yunker & Jones 2009) and species assemblages (Reid, Yunker & Jones 2009; Reynolds 1996; Sály et al. 2009).

I conducted exploratory sampling to establish the range of Speckled dace in the headwaters of the Kettle-Granby system. I used single-pass electrofishing with a Smith Root model 12B backpack electrofisher, set to 300 volts for both exploratory and quantitative sampling. While conducting exploratory sampling, I electrofished at sites throughout the system using a three-person crew, one person operating the electrofisher, and two catching fish with dip-nets. In cases where I did not capture Speckled dace, I stopped electrofishing after all habitat types in the site had been sampled. I assumed that Speckled dace distribution was continuous between sites where I was able to find Speckled dace, thereby inferring the limit of the range within the watershed.

I established 28 quantitative sampling sites throughout the watershed on the July 14 – 21 and August 5 – 8, 2008 sampling trips (Figure 4). I selected sites based on accessibility from nearby roads, so site selection was not random. Site selection was opportunistic, and I assume no correlation between my ability to access a site and Speckled dace presence or abundance at a site. Sites were distributed widely throughout the river system (Figure 4). I defined 4 reaches within the system and sampled sites within each reach (Table 2).

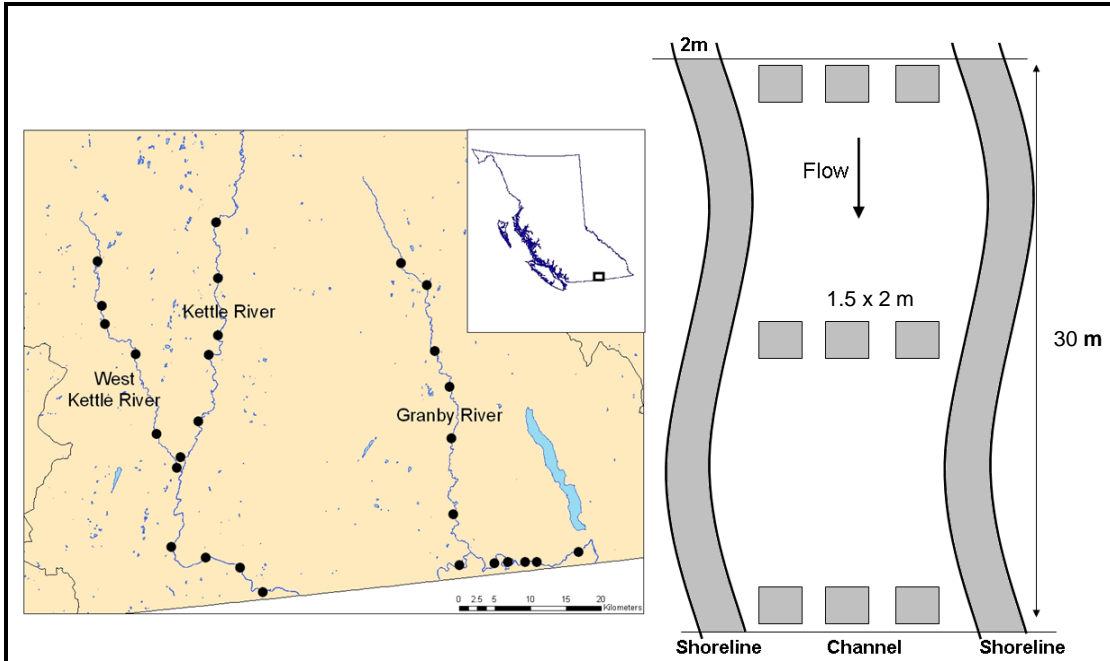


Figure 4. Map of the 28 quantitative sampling sites in black dots (left) and the sampling protocol at each site. An example of stratification of shoreline and channel is shown, with shaded areas representing sampled areas.

Table 2. Reach names and number of sites quantitatively sampled within the Kettle-Granby system.

Reach Name	Location	Sites Sampled
Mid- and Upper-Kettle River	Christian Valley and downstream of Westbridge to international border	11
West Kettle River	West Kettle upstream of Westbridge	6
Lower Kettle River	International border to Grand Forks	5
Granby River	Granby River	6

At each quantitative sampling site, I sampled a 30 m length of river. Preliminary sampling (July 8 and 9, 2008) suggested that Speckled dace were more abundant along the shoreline. Therefore, I used stratified sampling for ease of sampling and analysis. I divided the river into shoreline habitat and channel habitat areas. I define “shoreline” as the area from the wetted edges of

the river to 2 m instream; I define “channel” as the area between the shoreline areas. Within the channel, I sampled 1.5 m-by-2 m quadrats every 2 m across the channel along three transects located at 0 m, 15 m, and 30 m from the downstream end of the site (Figure 4). To sample quadrats, one person held a block net 1.5 m-wide-by-1 m high with 6 mm mesh, the second person used the electrofisher, and the third person followed behind the others and measured habitat variables in each quadrat. The electrofisher operator made one pass on each side within the quadrat, with the electrofisher moving from upstream to downstream. I sampled from upstream to downstream in the quadrats because the fast flowing water would have prevented us from being able to capture fish while sampling downstream to upstream. I sampled the entirety of each shoreline area from downstream to upstream with a single pass because water velocity was slower along the shoreline and did not pose a problem. While conducting the shoreline sampling, one person operated the electrofisher, while 2 people captured fish with dip nets, and placed them in a marked container. Netters did not capture fish that came from outside the 2 m wide shoreline area.

When a Speckled dace was captured, the location was marked with a weight and flagging tape. Each fish was stored in a marked container to identify both the specimen and the capture location. I measured habitat variables at all capture locations, channel quadrats, and every 5 m along the shoreline transect (Figure 5). At each marker, I recorded the water depth (cm), velocity (m/s), and substrate type. I measured velocity using a Swiffer Model 2100 Series Current Velocity Meter at 60% of water depth. I assessed the substrate at each location

visually according to the Wentworth Scale (Table 3). At each location, I estimated the proportion (p) of each type of substrate (boulder, cobble, gravel, sand, silt).

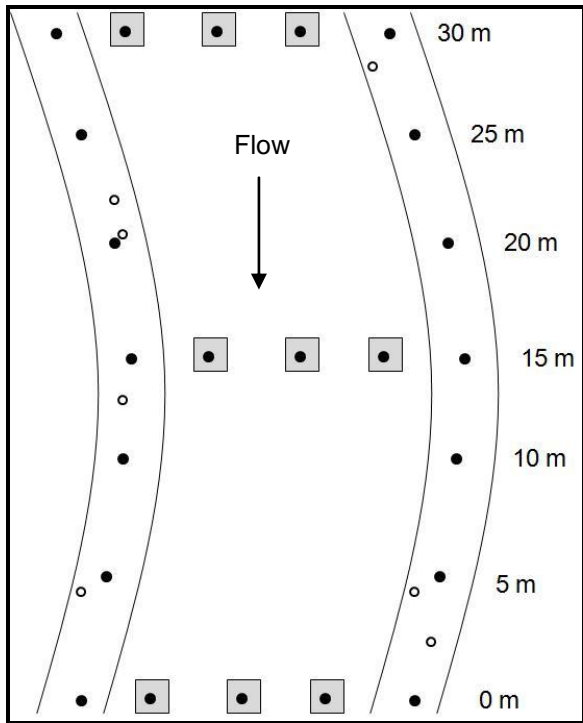


Figure 5. Example of habitat sampling locations within a site. Solid points indicate locations that are within quadrats and every 5 m along transects. Open circles indicate capture locations where habitat variables were measured.

Table 3. Summary of the Wentworth Scale substrate diameter (mm) ranges and substrate type.

Substrate Type	Diameter (mm)
Boulder	> 256
Cobbles	64 - 256
Gravel	2 - 64
Sand	2 - 1
Silt	< 1

After completing electrofishing, I anaesthetized fish by placing them in a mixture of water and a few drops of clove oil. When a fish's swimming appeared to be slowed, and it did not react to being handled, I measured fork length (mm) and weight (to nearest mg), and recorded sex (male/female/unknown) and maturity as mature (1), immature (0), or unknown. Sex and maturity were determined using the descriptions from McPhail (2007) and McPhail and Carveth (1994). In some cases, the sex could not be identified in the field due to the fact that specimens were handled live and released or due to practical logistical constraints. Also, the sex of juveniles cannot easily be determined by external characteristics. After handling, I placed fish in a recovery bucket, and once they had resumed normal swimming, I released them into a calm area of the shoreline. Other species of fish were identified and enumerated, then returned to the stream after recovery.

At each sampling site, I measured and recorded water temperature ($^{\circ}\text{C}$), water conductivity (to nearest μS), and water pH using a Condi LF 340 conductivity meter.

I euthanized 36 Speckled dace by giving them a lethal overdose of MS-222, buffered with sodium bicarbonate. After being euthanized, fish were stored in an ethanol solution for further examination in the laboratory. I assigned each of the Speckled dace a specific specimen name, and recorded the details of the capture location.

2.1.1.2 Stable Isotope Collection

I collected invertebrates, fish, and algae from two sites for stable isotope analysis (SIA) in October 2008. One site was in the West Kettle River near Beaverdell, BC and one was in the Kettle River near Midway, BC (Figure 6). At both sites, I captured 10 Speckled dace by electrofishing throughout the stream, and captured invertebrates by kick sampling and using a Hess sampler. I separated invertebrates into orders, Ephemeroptera (ny), Plecoptera (ny) Trichoptera (l) and Odenata (ny), and families Chironomidae (l), and Tipulidae (l), details of invertebrate names and life stages are given in Appendix 1. I also collected filamentous and epilithic algae for analysis. Speckled dace were euthanized using the process described in section 2.1.1.1. A small piece of tissue from each Speckled dace was removed in the field, then frozen until it could be processed further.



Figure 6. Stable isotope collections sites (circles) and the capture-recapture study site (square). The northern stable isotope collection site is located near Beaverdell, BC on the West Kettle River, and the southern site is near Midway, BC on the Kettle River.

2.1.1.3 Capture Efficiency

Capture efficiency is the proportion or percentage of fishes captured during sampling, and is generally low in wadeable streams (Price and Peterson 2010). To estimate population abundance, an estimate of the capture efficiency of the sampling gear is required to account for bias created by the sampling method, species, and stream conditions (Williams, Nichols & Conroy 2002; Price and Peterson 2010). I estimated the capture efficiency of single-pass

electrofishing for Speckled dace by conducting a capture-recapture study on August 25 – 27, 2008 at a site downstream of Rock Creek, BC (Figure 6).

To conduct the capture-recapture study, I electrofished throughout the stream to capture 26 to 30 Speckled dace for each trial. Each fish was anaesthetized, measured for fork length (mm) and weight (to nearest mg) and marked by taking a small clip from one pectoral fin. I then placed the fish in a perforated container and kept the container within the stream overnight (Figure 7). Temple and Pearsons (2006) found no difference in the probability of recapture of rainbow trout after being held for either a three- or a 24-hour recovery period. Therefore, I assumed that allowing Speckled dace to recover overnight would be adequate so as to not affect future capture efficiency.

The day following the initial capture, I released the marked Speckled dace into a 15 m-long-by-3 m-wide enclosed area along a shoreline. I used a 6 mm mesh block net, and covered the base of the net with rocks from the site to minimize escapes (Figure 7). After releasing marked fish into the netted area, I waited an additional three hours to allow the fish more time to recover and disperse throughout the enclosed area. I then electrofished using the same single-pass, three-person shoreline sampling technique, as described above, within the netted area to recapture Speckled dace. I examined fish that were captured within the netted area for fin clips, indicating a recaptured specimen, and recorded the number of recaptured Speckled dace. I repeated the capture-recapture procedure at seven locations within the same site.



Figure 7. Capture-recapture sampling area. Speckled dace were captured and held overnight in a container (top left), and then were released into an enclosed 15-by-3 m area of shoreline.

2.1.2 Laboratory Preparation

In the laboratory, I dissected several preserved Speckled dace specimens for examination of aging structures, examination of stomach content, and analysis of stable isotope signatures to be used for diet analysis.

I removed at least one otolith from 22 preserved Speckled dace for aging. Gary Carder, an experienced otolith reader from Salmon Arm, B.C., aged the otoliths by examining the annual growth rings under microscope. Each specimen was aged once, and I did not validate ages by any other means. Aged

specimens were collected in both the summer collection period (July 14 – 21 and August 5 – 8, 2008) and the October stable isotope analysis (SIA) sampling period (October 2 and 3, 2008).

To examine the diet of Speckled dace, I sent 36 preserved Speckled dace to Shirley Fuchs, from the Department of Fisheries and Oceans (DFO) for examination of stomach contents. The stomachs were removed and the number of observations of each food type (Appendix 1) per stomach was recorded. Specimens that were examined for stomach contents were collected in both the summer collection period and October collection period.

To prepare samples for SIA, I thawed the frozen samples, and heated them at 60 °C for 24 hours, until fully desiccated. I combined several specimens of each type of invertebrate to get the appropriate amount of material for analysis. I ground the desiccated samples into a fine powder using mortar and pestle, then measured each sample type into the appropriate sample weights (plant 2 – 3 mg, fish and invertebrate ~1 mg), and then produced three replicates from each sample. I sent the samples to UC Davis Stable Isotope Facility for analysis of delta ^{15}N and delta ^{13}C signatures.

2.2 Analysis

2.2.1 Biology

2.2.1.1 Length-weight Relationship

The relationship between fork length and weight of fish is a widely used metric to describe a species. The equation used to describe a species' body

shape is $W = aL^b$ (Froese 2006); a b value <3 indicates that the fish is elongated, whereas a b value of >3 indicates that the fish is generally short and robust (Froese 2006). Equation (1) represents the linear form of the relationship that I used to estimate the model parameters using linear regression.

$$(1) \quad \ln(W) = \ln(a) + b \ln(L)$$

2.2.1.2 Length at Maturity

A maturity ogive can be used to estimate the probability that a fish is mature at a given length. One of the most common methods of estimating maturity is the use of a binomial GLM with a logit link (ICES 2008) or binomial logistic regression. In the data-collection phase, I recorded Speckled dace as mature (1), immature (0), or unknown. I conducted binomial logistic regression on the fork length and maturity data to identify the probability of maturity at a given fork length, and the length of 50% maturity. The probability of maturity at a given fork length is given by:

$$(2) \quad P(L) = \frac{1}{1 - \exp(-(\beta_0 + \beta_1 L))}$$

where $P(L)$ is the probability of being mature at a given length, L is the fork length (mm), β_0 and β_1 are parameters.

As sexual dimorphism occurs in this species (McPhail 2007), I compared the logistic model using data for all specimens to sex-specific models. All models

used the same data for immature fish in the analysis. I found no statistically significant difference between the sex-specific models, and therefore used a sex-combined model for analysis. Ultimately, I describe one logistic regression function, treating data for male, female and unknown fish equally, and using the data for all juvenile fish to conduct the regression.

2.2.1.3 Aging

Otolith Examination

Using the estimated age and associated fork length data from otolith examination, I calculated the mean fork length and standard deviation for each age-group. Speckled dace otoliths are very small and difficult to handle, and as a result, despite collecting 36 specimens only 22 otoliths were removed and aged. Due to the small sample size ($n = 22$), the data provide only a rough estimate of the average length at a given age, and not all age-groups are included.

Length-frequency Analysis

Examination of length data can expose patterns in the population's age-structure and the proportion of each age-group within the overall population. The distribution of lengths within an age-group usually approximates a normal distribution, resulting in discontinuities in the length-frequency of a population (Macdonald and Pitcher 1979). By creating a length-frequency plot, it is possible to visually examine the graph for age-groups; visual examination has been used to explore the relationships between length-frequency and age-group for Speckled dace (COSEWIC 2006a).

Statistical analysis of length-frequency is a more reliable method than visual examination. MacDonald and Pitcher (1979) developed a method that uses maximum likelihood estimation to identify distributions of age-groups from length-frequency data. The method was later developed into a package for the statistical software program R, called `mixdist` (MacDonald 2008). I conducted analyses using R-2.9.1 (R Development Core Team 2009), and used the `mixdist` (MacDonald 2008) and `mix` (Schafer 2007) packages.

It is often difficult to distinguish age-groups from length data beyond the first few age-groups due to decreased growth with increased age and natural variability in growth rate (Isley and Grabowski 2007). By using length-at-age data from aged fish as inputs to the `mixdist` function, the parameter estimates are more accurate than when such inputs are not used (Macdonald and Green 1988). I used the mean and standard deviation of fork lengths for each age-group from aged fish as inputs. For age-groups that had a single aged fish, I used the fork length as the parameter input, and assumed a standard deviation equal to that of the age-group one year older.

As noted, lengths within an age-group are usually normally distributed, however, I used a gamma distribution to approximate a normal distribution. The gamma distribution is more flexible than a normal distribution, and allows for multiple-age groups to be combined.

In addition to providing the estimated average length of a fish at a given age, the `mixdist` function estimates the proportion of the population in each age-group, which I used in estimating abundance (section 2.2.4).

2.2.1.4 Diet

Stomach Content Analysis

Stomach content analysis is a common practice in fisheries for examination of diet, and there is a wide variety of simple methods (Hyslop 1980). I used both the occurrence and numerical methods (Hyslop 1980). For the occurrence method the percentage of specimens' stomachs that contain at least one observation of each food type is calculated (Hyslop 1980). The numerical method uses the mean number of each food type to estimate the average diet across all Speckled dace examined.

Stable Isotope Analysis

Analysis of delta ^{15}N and delta ^{13}C stable isotope ratios of organisms can be used to estimate the long-term average of dietary components, and to trace the flow of organic matter through an ecosystem (Fry and Sherr 1984; Peterson and Fry 1987). Stable isotope analysis uses both carbon and nitrogen signatures; the nitrogen signature of a consumer is enriched by 3 – 4‰ $\delta^{15}\text{N}$ compared to its dietary nitrogen (Deniro and Epstein 1981; Peterson and Fry 1987), and can therefore be used to determine trophic level of a consumer within an ecosystem (Peterson and Fry 1987; Rounick and Winterbourn 1986). In contrast, only small changes in delta ^{13}C are expected between trophic levels (Peterson and Fry 1987; Rounick and Winterbourn 1986); on average the carbon signatures in freshwater systems fractionate by 0.2‰ $\delta^{13}\text{C}$ per trophic level (France and Peters 1997). Because of this small fractionation, carbon is used to indicate food sources of consumers in ecosystems (Peterson and Fry 1987). Terrestrial delta ^{13}C signatures are approximately -28‰ $\delta^{13}\text{C}$ and the signatures

of aquatic plant material vary widely among streams, depending on the geochemistry of the catchment area (France 1995). Given the predictable movement and concentration of ^{15}N and ^{13}C isotopes within the food web, examination of stable isotopes can identify the food sources and trophic level of an organism.

I calculated the mean delta ^{15}N and delta ^{13}C for the replicates within each food type and plotted the results for each site. I examined the graphs for patterns that reveal the food source and trophic level of Speckled dace.

2.2.2 Habitat Analysis

Preliminary field work suggested that Speckled dace may be more prevalent in shoreline habitat than in channel habitat. Therefore, I used a two-sided Student's paired t-test to compare the density of Speckled dace in the shoreline and channel areas. I used the null hypotheses that there is no difference between density of Speckled dace in channel and shoreline habitats.

To determine Speckled dace use of individual habitat variables, I converted the visual observations of substrate to weighted average substrate diameter (\bar{S}) at each location using the proportion (p) and the average diameter (mm) of each substrate type (Table 3), using Equation (3).

$$(3) \quad \bar{S} = (p_{\text{boulder}} * 256) + (p_{\text{cobble}} * 160) + (p_{\text{gravel}} * 33) + (p_{\text{sand}} * 1.5) + (p_{\text{silt}} * 1).$$

I then calculated the mean and standard deviation for each habitat variable at the locations where I captured Speckled dace. I define "sampling site" as the area of

the river that I sampled, and “location” as a specific spot within a sampling site. I measured temperature only once at each sampling site, rather than at every capture location. I identified each location where I measured habitat variables as either “sampled-but-not-used” by Speckled dace or “used” by Speckled dace. The data set for each location sampled includes presence/absence, depth, velocity, and average substrate diameter.

I used a Kolmogorov-Smirnov (KS) test to test for differences between distributions of sampled-but-not-used and used habitat variable measurements. I conducted a KS test on channel and shoreline data separately for each of the three habitat variables. The null hypothesis for each test was that the distribution of the sampled-but-not-used location data is not significantly different from the distribution of the data for locations used by Speckle dace. Results of no significant difference would suggest that Speckled dace are selecting habitat in the same proportion that it is available (i.e., randomly using the habitat). A significant difference between distributions of habitat variable measurements for sampled-but-not-used and used data would suggest that Speckled dace are selecting certain habitat variables in greater proportion than they are available.

Due to large amount of habitat data and relatively similar habitat throughout the watershed, many of the values for habitat variables were repeated in the complete data set (e.g., several locations with a depth of 60 cm). To deal with repeated values in the data set, I used the `ks.boot` function from the R package `Matching` (Sekhon 2009). The `ks.boot` function is able to deal with repeated values by bootstrap sampling a data set.

I fit a generalized linear model (GLM) to the Speckled dace presence/absence and habitat data for the channel quadrat samples. Due to the sampling methods used, I was not able to use the shoreline habitat data in a GLM. The GLM analysis requires discrete units, and the shoreline was sampled using continuous transects, so a GLM cannot be used here. The GLM provides estimates of the effect size of each habitat variable on the presence or absence of Speckled dace. I used a quasi-binomial logistic model because the data for presence/absence is binomial, and there is overdispersion in the data, meaning that the variance among data for some variables is larger than the mean of that variable. The output of a GLM is similar to the maturity ogive in that it produces parameter estimates (β_i) for the equation:

$$(4) \quad P(\textit{presence}) = \frac{1}{1 + e^{-z}},$$

where $P(\textit{presence})$ is the probability of capturing at least one Speckled dace and where

$$(5) \quad z = \beta_0 + \beta_{\textit{Depth}} X_{\textit{Depth}} + \beta_{\textit{Velocity}} X_{\textit{Velocity}} + \beta_{\textit{AveSubs}} X_{\textit{AveSubs}},$$

where $X_{\textit{Depth}}$ is the stream depth (m), $X_{\textit{Velocity}}$ is the water velocity (m/s), and $X_{\textit{AveSubs}}$ is the average substrate diameter (mm) at a given location. I excluded from the analysis any location for which I did not have data for all variables (presence/absence, depth, average substrate diameter, and water velocity).

2.2.3 Range

I estimated the total kilometres of river where Speckled dace are present using the sampling sites' GPS locations and capture data. At each sampling site, I used a Garmin GPSMAP 76 GPS unit to mark the site. I later identified each sample site according to whether I caught Speckled dace or not. I measured the river length (km) between the furthest downstream capture site, and the furthest upstream capture sites in the West Kettle, Kettle, and Granby Rivers using GoogleEarth. I assumed a continuous distribution of Speckled dace between upstream and downstream sites where I captured Speckled dace.

2.2.4 Population Estimate

I estimated the abundance of Speckled dace in the entire Kettle-Granby system, and also in each of the four reaches. I estimated the number of Speckled dace that potentially could have been caught at each site (N_i) by

$$(6) \quad N_i = N_{Si} + (\bar{N}_{Ci} * M_i),$$

where N_{Si} is the number of Speckled dace caught in both shoreline transects in site i , \bar{N}_{Ci} is the mean number of Speckled dace caught per quadrat in site i , and M_i is the possible number of channel quadrats that could have been sampled in site i . I then calculated the number of Speckled dace (\bar{N}) across all sites in the reach using:

(7)
$$\bar{N} = \sum_i^I N_i / n ,$$

where n is the total number of sites actually sampled within the reach. In order to estimate the abundance of Speckled dace per linear metre of river (\bar{D}), I used:

(8)
$$\bar{D} = \bar{N} / 30$$

because each sampling site was 30 m in length.

I estimated the total abundance of mature Speckled dace using:

(9)
$$N_t = (\bar{D} / \bar{q}) * S * RL ,$$

where N_t is the total number of mature Speckled dace, \bar{q} is the mean capture efficiency, S is the estimated proportion of Speckled dace in the population that are mature, and RL is the reach length (m). I assumed that the samples provide a randomized, unbiased sample of abundance. Therefore, multiplying the average density by the total reach length provides an unbiased estimate of abundance. I also assumed that sampled sites were representative of unsampled sites, in that unsampled sites had the same physical and biological attributes as sampled sites.

S in Equation (9) is the estimated proportion of the population that is mature. S is derived from the length-frequency analysis and the maturity ogive. I used the maturity ogive to estimate the length of 50% maturity for Speckled dace,

and the length-frequency analysis to estimate the proportion of the population that is larger than the length of 50% maturity. I assumed that all fish larger than the length of 50% maturity are mature, and that they are evenly distributed above and below the 50th percentile.

I used Equations 5 through 8 and bootstrap resampling of channel quadrat count and capture efficiency data (Efron 1979) to estimate the uncertainty around the population abundance estimates (Figure 8). Bootstrapping resamples the data with replacement multiple times to estimate the uncertainty in parameters (Manly 2002; Bolk 2008). I resampled channel quadrats with replacement for each site i and estimated N_i . I also resampled the capture efficiency (q) with replacement within each bootstrap loop and calculated \bar{q} . I repeated this process 5000 times to create a distribution of possible reach estimates. The final result is an estimated mean and 90% confidence interval (CI) for a given reach of the river system. Confidence intervals are the 5th and 95th percentile of the distribution of all 5000 population estimates. I also estimated the mean virtual population and 90% CI, by excluding the adjustment for capture efficiency in Equation (9) (i.e., $q = 1$). The virtual population is the abundance estimate based on only those specimens that were actually handled (Fry 1949) and represents the minimum population abundance estimate. Finally, I estimated the mean and 90% CIs of the linear density of mature Speckled dace (SDC/m) for each reach.

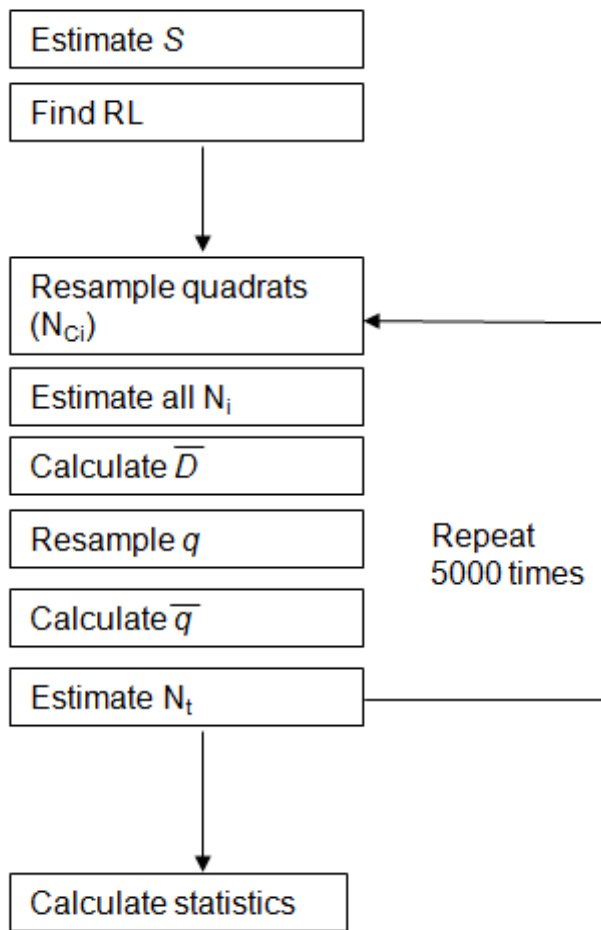


Figure 8. Conceptual diagram of the bootstrapped population estimate. S is the proportion of mature fish in the population, RL is the reach length, N_{Ci} is the number of Speckled dace captured in channel quadrats at site i , N_i is the estimate of population at site i , \bar{D} is the mean linear density of Speckled dace, q is the capture efficiency from capture-recapture trials, \bar{q} is the mean of the bootstrapped capture efficiency, and N_t is the total population abundance estimate for the reach.

3: RESULTS

3.1 Biology

3.1.1 Length-weight Relationship

I conducted linear regression on data from all fish collected during the July 14 – 22, and August 4 – 8, 2008 surveys, including males, females, and fish for which sex could not be determined. The equation for estimating the weight (W) (g) of a Speckled dace at a given FL (L) (mm) is:

$$W = 1.52 \times 10^{-5} * L^{2.93}$$

($r^2 = 0.94$, $p < 0.001$, $N = 297$) (Figure 9). The 95% CIs for a and b in Equation (1) are 1.45×10^{-6} to 1.60×10^{-4} , and 2.84 to 3.01, respectively. Alternatively, the equation in linear form is:

$$\ln(W) = \ln(-11.09) + 2.93 * \ln(L).$$

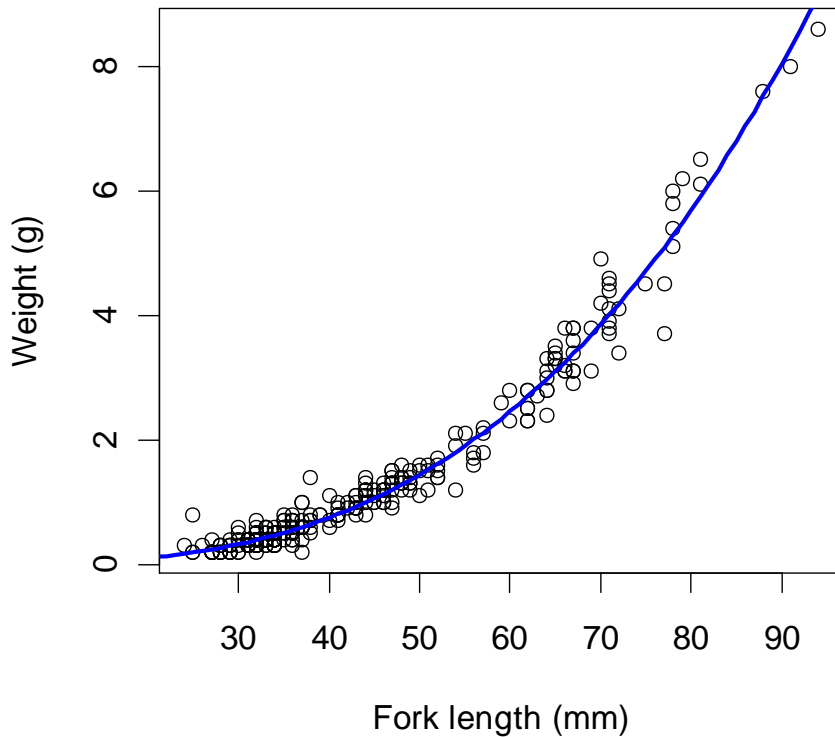


Figure 9. The length-weight relationship for Speckled dace collected in the Kettle-Granby system during July 12 – 21 and August 5 – 8, 2008 (n = 297). Each point represents a single fish, and the curve is the exponentiated linear regression.

3.1.2 Maturity-at-length

I fit one maturity ogive to data for males, females, and fish for which sex could not be determined caught July 14 – 22, and August 4 – 8, 2008 (Figure 10, Table 4). The point of 50% maturity is at a fork length of 55.8 mm. The probability of a Speckled dace being mature at a given fork length (L) (mm) is:

$$P(L) = \frac{1}{1 + \exp(-(-13.09 + 0.23 * L))}$$

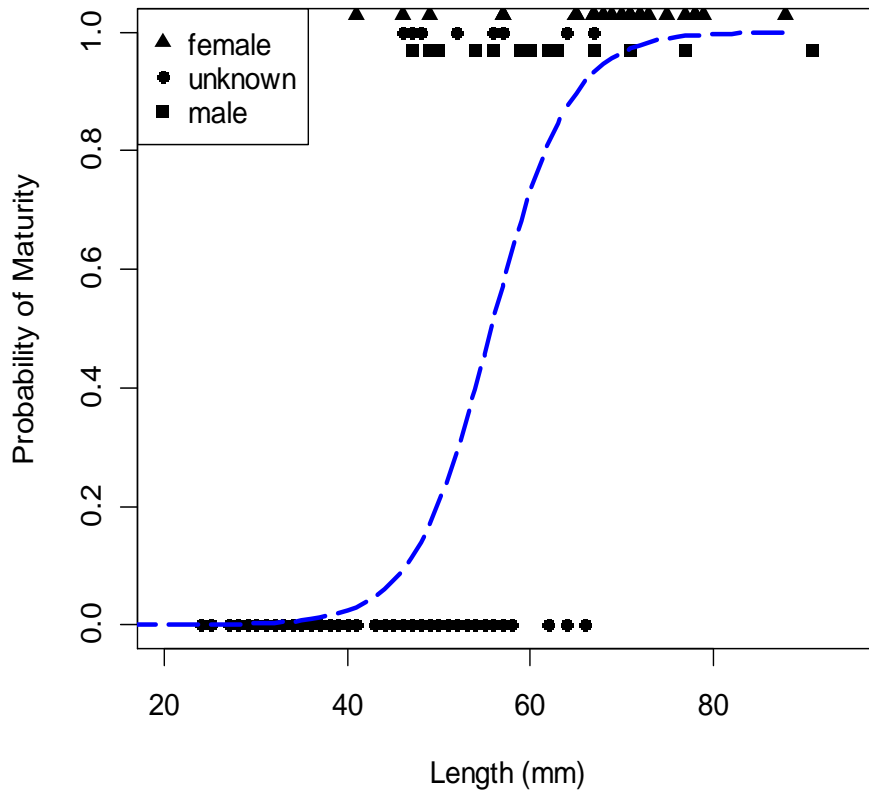


Figure 10. Maturity ogive for Speckled dace. Each point represents an individual Speckled dace; those with a y-axis value of 1 were mature (n = 52) and those with a y-axis value of 0 were immature (n = 272). Fish were separated by sex for visual assessment, however, the regression was fit to all data.

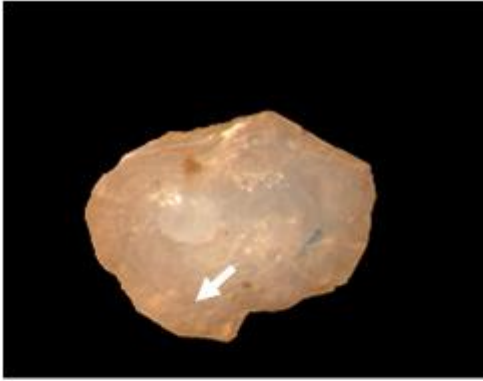
Table 4. Parameter estimates, standard errors, and P-values for the maturity ogive binomial logistic regression for Equation (2) using data for Speckled dace collected July 14 – 22, and August 4 – 8, 2008.

Parameter	Estimate	Standard Error	P-value
β_0	-13.09	1.74	P < 0.0001
β_1	0.235	0.033	P < 0.0001

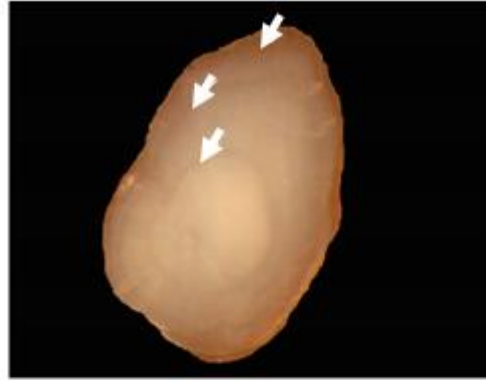
3.1.3 Age Determination

3.1.3.1 Otolith Aging Structures

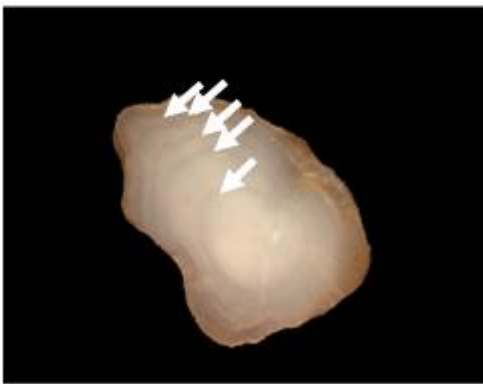
Examination of 22 otoliths showed that the examined specimens ranged from ages 1 to 7 years (Appendix 2). One fish was aged at 7+ (Figure 11), and six were age 4+. The length of specimens within a given age-group was highly variable, and there was overlap of the distributions of fork lengths of the age-groups (Figure 12). The mean and standard deviation of length of each age-group is found in Appendix 3.



SDC 25 – age 1



SDC 17 – age 3



SDC 10 – age 5



SDC 7 – age 7

Figure 11. Images of four Speckled dace otoliths, with arrows indicating annual growth rings (photos by G. Carder).

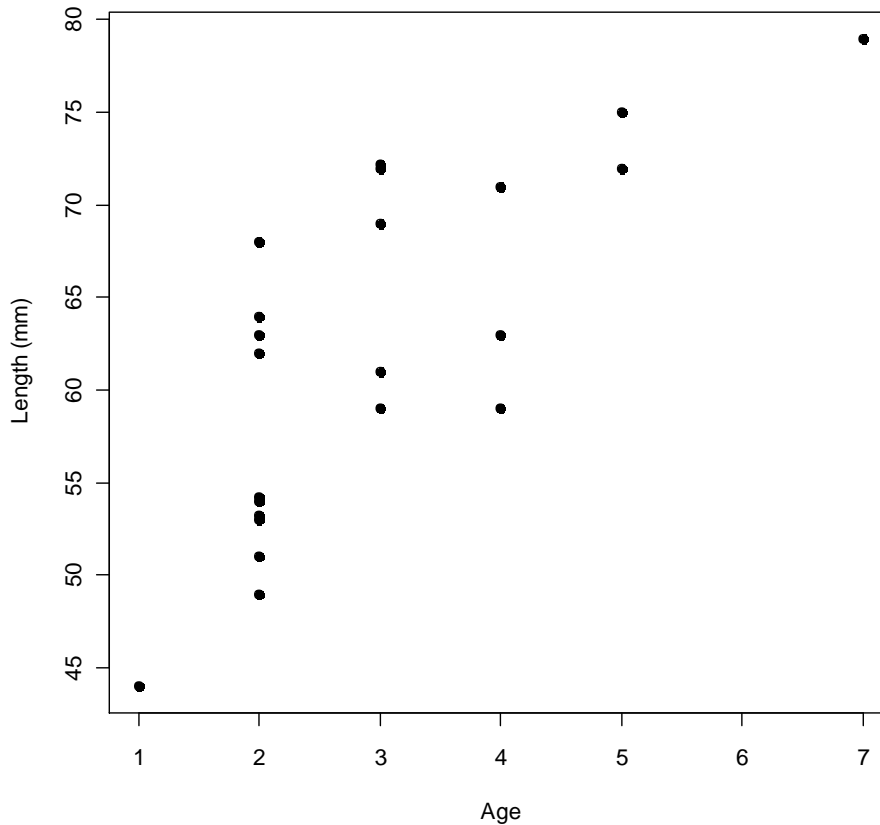


Figure 12. Relationship between estimated age (years) from otolith examination and fork length (mm) for Speckled dace (n = 22).

3.1.3.2 Length-frequency Analysis

I used results from the otolith aging procedure in combination with length-frequency analysis to further elucidate the age-structure of the population. I used the lengths and ages from the otolith aging results (Table 5) to set the starting parameters for the length-frequency model to estimate the proportion of the population in each age-group. As there was only one age-1 specimen, I used the same standard deviation as the age-2 group for the starting parameters. The

mixdist package (MacDonald 2008) allows the user to set constraints on the model. I constrained the model to use a gamma distribution for each age-group, to estimate the mean fork length for each age-group along a von Bertalanffy growth curve for the model with 3 age-groups, and to have a constant coefficient of variation.

I used the length-frequency data that I collected during the capture-recapture survey August 25 – 27, 2008. I fit the model to an increasing number of age-groups starting with a 2-age-group model. The model fit was significant with both 2 age-groups (χ^2 (6, n = 202) = 23.2, p < 0.05) and 3 age-groups (χ^2 (2, n = 202) = 10.2, p < 0.05). The function was unable to fit models with more than 3 age-groups. Given that both models were significant, and that the otolith aging results indicated up to 7 age-groups, I used the 3-age-group model in the next stages of analysis.

Table 5. Starting parameters for the 2-age-group and the 3-age-group length-frequency models, including mean age-group fork length (Mean FL) (mm) and standard deviation (SD), used in the model to estimate the proportion of each age-group. Starting parameters were estimated from the otolith examination results.

	Age Class	Mean FL	SD
2-age group	1	44	6
	2 +	62	10
3-age group	1	44	6
	2	57	6
	3 +	68	7

In the 3-age-group model, all fish age 3+ are classified as one group, because yearly growth decreases with age and older age-groups are difficult to

differentiate from one another. The mean fork length of age 2 fish is 56 mm, which coincides with the fork length of 50% maturity from the maturity ogive (55.8 mm). Therefore, I assumed that the total proportion of the population that is mature (S) is half of the age 2 fish (those larger than 56 mm), and all of the age 3+ group, or a total of 0.32 of the population (Figure 13, Table 6).

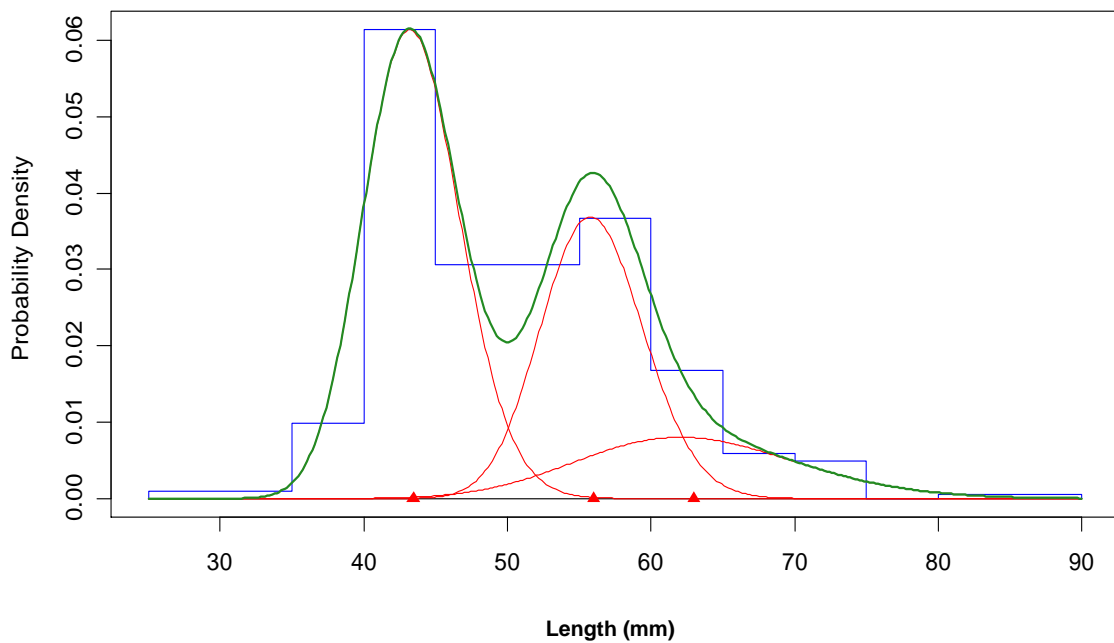


Figure 13. Gamma distributions fitted to the length-frequency of Speckled dace captured August 25 – 27, 2008. The lower three gamma distributions (red lines) represent age 1, age 2, and age 3+ fish. The upper curve (green line) represents probability of a single fish being a given fork length within the population. Triangles are the mean fork lengths for ages 1, 2, and 3+ fish from left to right.

Table 6. Summary table of the age-groups from the 3-age-group length-frequency model and estimated proportion of the population within each age-group, the estimated mean fork length (Mean FL) (mm) of each age-group, and the standard deviation (SD) of each age-group.

Age-group	Proportion	Mean FL	SD
1	0.52	43.5	3.34
2	0.33	56.0	3.57
3 +	0.15	63.0	7.66

3.1.4 Diet

Stomach contents

I combined stomach content data from all collections for the analysis. *O. Ephemeroptera* (ny), *F. Chironomidae* (I), *O. Trichoptera* (I), and *O. Plecoptera* (ny) were the most common type of invertebrates within the examined Speckled dace stomachs (Appendix 4, Figure 14). Algae and plant material were also observed in 25 and 12 of the 36 examined stomachs, respectively.

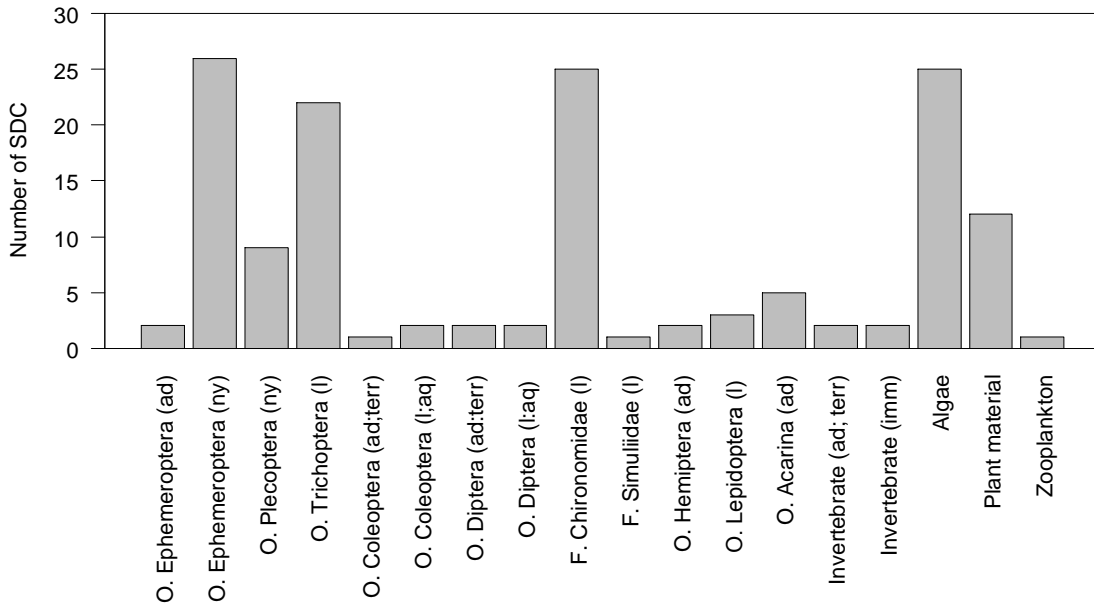


Figure 14. Occurrence of food types in Speckled dace (SDC) stomachs (n = 36). Stomach contents of Speckled dace collected in both July (n = 14) and October (n = 22) are shown together. Detail on the names of food types and life stage is given in Appendix 1.

I calculated the average number of each type of invertebrate found within Speckled dace stomachs. Again, *O. Ephemeroptera* (ny), *F. Chironomidae* (I), *O. Trichoptera* (I), and *O. Plecoptera* (ny) were the most abundant food types (Appendix 5, Figure 15).

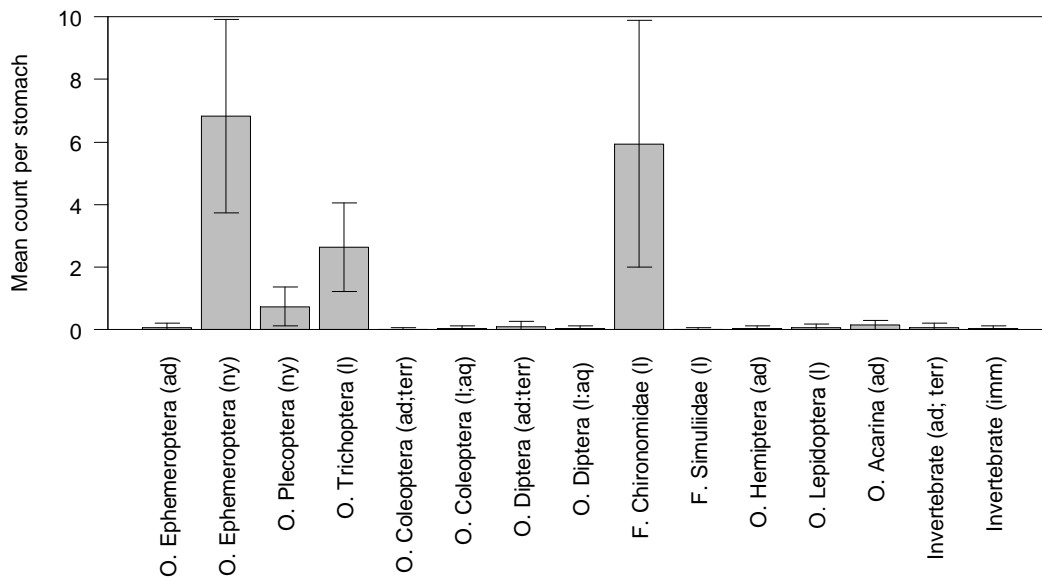


Figure 15. The mean count of each food type per stomach (n = 36). Error bars shown are \pm two standard errors. Stomach contents of Speckled dace collected in both July (n = 14) and October (n = 22) are shown together. Detail on the names of food types and life stage is given in Appendix 1.

Stable Isotope Analysis

The delta ^{15}N signatures indicate that Speckled dace are at a higher trophic level than invertebrates and plant material at both sites. At the Beaverdell site, Speckled dace delta ^{15}N signatures were enriched by 4.17 to 6.02‰ $\delta^{15}\text{N}$ above invertebrates' signatures (Appendix 6, Figure 16). Specifically, Speckled dace delta ^{15}N signatures indicate that both F. Chironomidae (l) and O. Plecoptera (ny) may be influential in the diet, because Speckled dace delta ^{15}N signatures are about 4‰ $\delta^{15}\text{N}$ enriched from both food types, which is the level of enrichment normal observed when moving up one trophic level.

At the Midway site, Speckled dace signatures are enriched by 1.86 to 4.75‰ $\delta^{15}\text{N}$ above those of the invertebrates (Appendix 6, Figure 16). Most

notably, Speckled dace are 4‰ $\delta^{15}\text{N}$ enriched above O. Trichoptera (I). Generally, consumers' $\delta^{15}\text{N}$ values are 4‰ $\delta^{15}\text{N}$ enriched above those of their dietary components. Food sources other than O. Trichoptera (I) appear to contribute to the diet, however, given the overlap of $\delta^{15}\text{N}$ signatures, it is not possible to determine the other sources from which Speckled dace gain nitrogen.

The $\delta^{13}\text{C}$ signatures of Speckled dace collected at the Beaverdell site (-26.21‰ $\delta^{13}\text{C}$) are less negative than the filamentous algae signature (-32.88‰ $\delta^{13}\text{C}$), but more negative than epilithic algae (-24.69‰ $\delta^{13}\text{C}$) (Appendix 6, Figure 16). Generally, in freshwater ecosystems, the $\delta^{13}\text{C}$ signatures of consumers are enriched by 0.2‰ $\delta^{13}\text{C}$ above those of their dietary components. Given the combination of $\delta^{13}\text{C}$ values from filamentous algae, epilithic algae and terrestrial plants (usually -28‰ $\delta^{13}\text{C}$), it is not possible to distinguish what the main source of carbon is in the system.

At the Midway site, the $\delta^{13}\text{C}$ signatures of Speckled dace (-24.91‰ $\delta^{13}\text{C}$) are close to the filamentous algal signatures (-24.24‰ $\delta^{13}\text{C}$) at the site. Fractionation is usually about 0.2‰ $\delta^{13}\text{C}$ between trophic levels in freshwater ecosystems. Given that the $\delta^{13}\text{C}$ values of Speckled dace and filamentous algae are roughly equal, and that insects are dominant in the stomach of Speckled dace, filamentous algae is likely an influential food in the diet of insects that Speckled dace feed on.

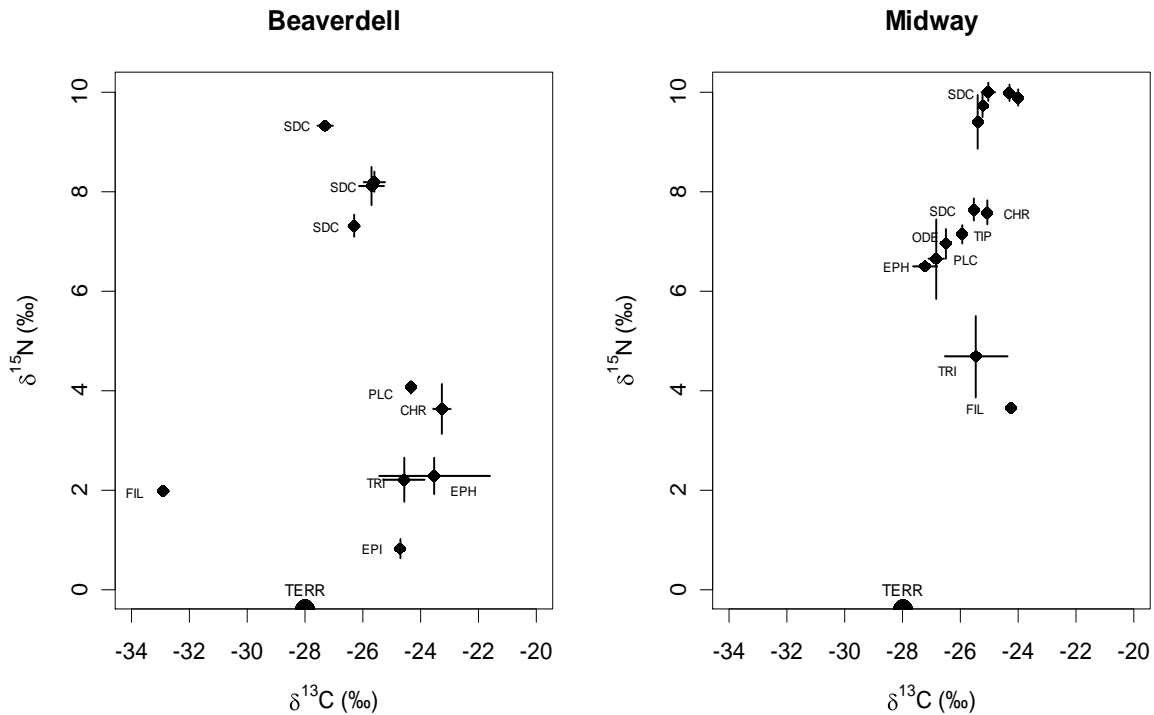


Figure 16. Isotope analysis showing the mean of replicate samples from individual Speckled dace, and the mean of replicates from invertebrate and algal delta ^{15}N and delta ^{13}C signatures. Error bars shown are \pm two standard errors, and are obscured in some cases. Labels are as follows: SDC = Speckled dace, TRI = *O. Trichoptera* (I), PLC = *O. Plecoptera* (ny), EPH = *O. Ephemeroptera* (ny), CHR = *F. Chironimidae* (I), TIP = *F. Tipulidae* (I), ODE = *O. Odenata* (ny), FIL = filamentous algae, EPI = epilithic algae. The point labelled TERR is the expected delta ^{13}C signature for terrestrial sources. Detail on food type and life stage given in Appendix 1.

3.2 Habitat

The mean density of Speckled dace in the shoreline areas across all sites (0.146 SDC/m², SD 0.201) was significantly greater than the density of Speckled dace in the channel area (0.016 SDC/m², SD 0.024; $t = -3.43$, $df = 27$, $p = 0.002$, $N = 28$). My results suggest that Speckled dace select shoreline habitat over channel habitat.

Speckled dace use a wide range of habitat conditions; I found Speckled dace in water depths from 0.01 – 1.55 m, stream velocities from 0 – 1.08 m/s, and in the presence of substrate ranging from gravel to boulder. Water temperature at the sites where Speckled dace were captured ranged from 12.7 – 22.6 °C, with a mean water temperature of 17.8 °C. To discern patterns within the data, I plotted the frequency of each habitat variable found in the habitat assessments (Figure 17, Figure 18). I also calculated the mean and standard deviation for variables where Speckled dace were found in channel and shoreline habitat (Table 7).

Table 7. Summary of means and standard deviations (SD) for the measured habitat variables depth (m), velocity (m/s), and average substrate diameter (mm) where Speckled dace were found.

		Depth	Velocity	Average Substrate Diameter
Channel	Mean	0.34	0.28	120
	SD	0.19	0.22	46
Shoreline	Mean	0.16	0.09	120
	SD	0.13	0.16	62

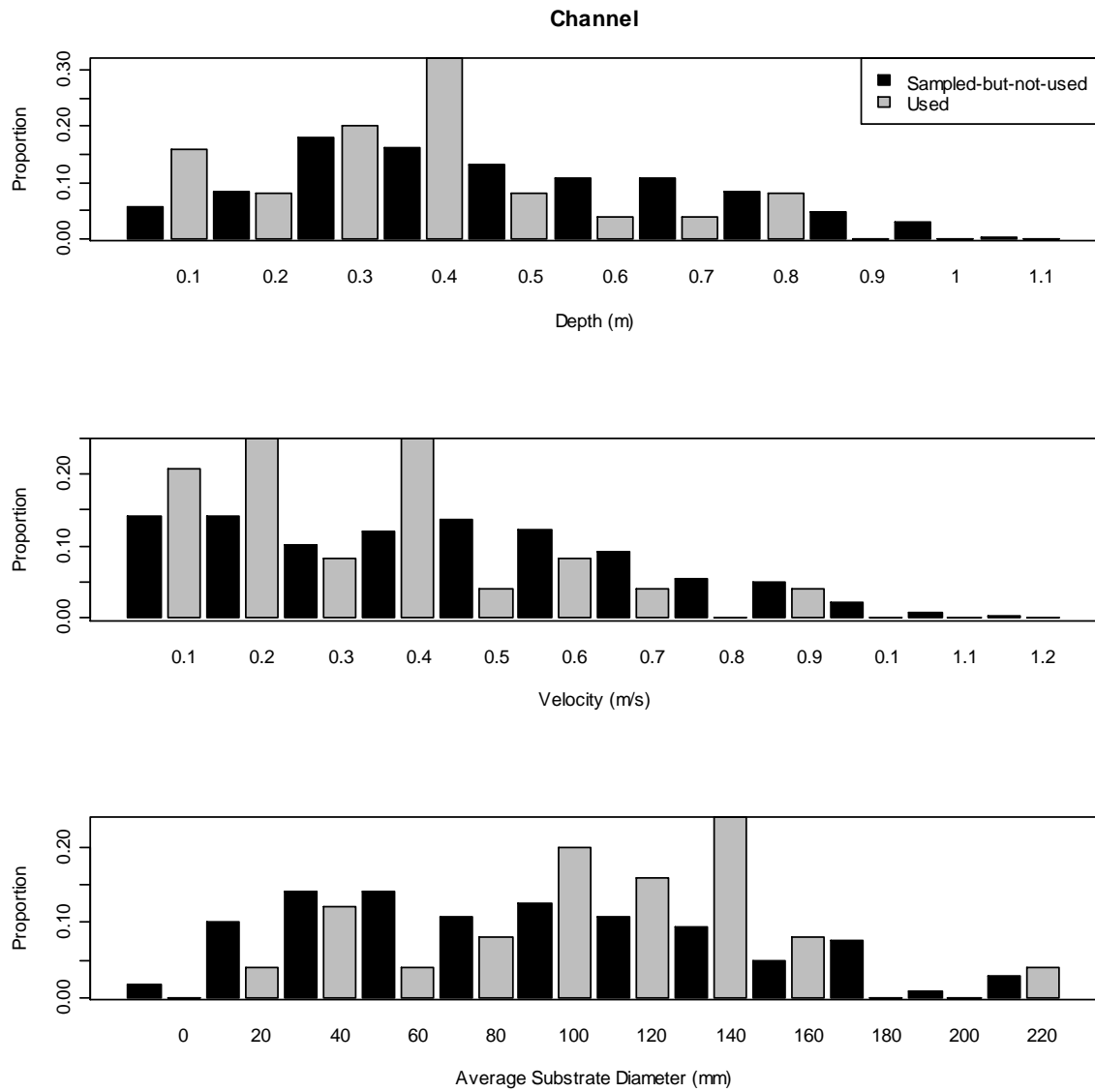


Figure 17. Proportion of habitat variable values at used locations (n = 25) and sampled-but-not-used locations (n = 411) in the channel quadrats.

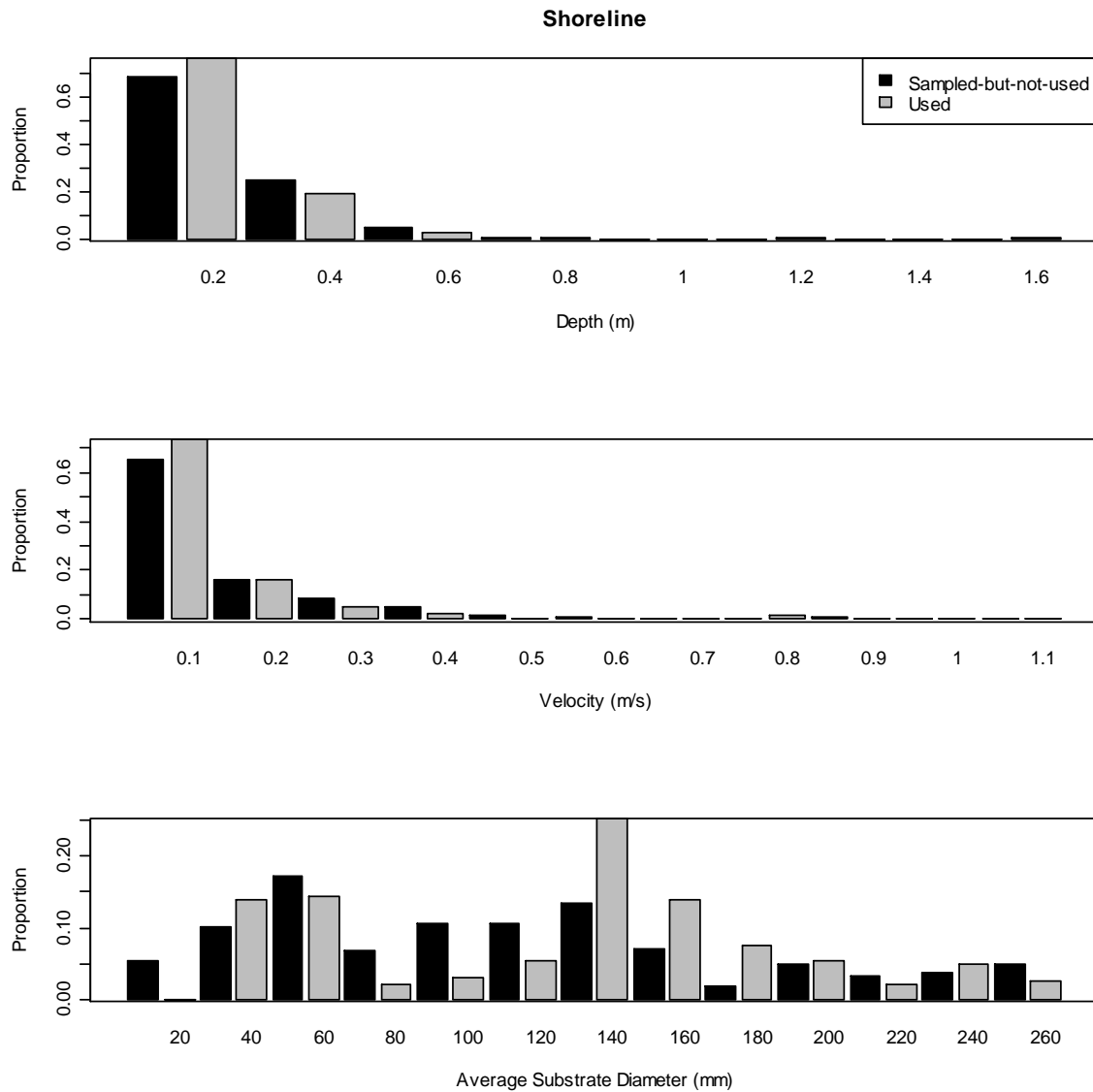


Figure 18. Proportion of habitat variable values at used locations (n = 204) and sampled-but-not-used locations (n = 618) in the shoreline transects.

Results of a KS test indicate that within the channel habitat, the distributions of habitat variable values measured at used and sampled-but-not-used locations were significantly different ($P < 0.05$) for both depth and velocity, but were not significantly different for average substrate diameter (Table 8). In

contrast, within the shoreline habitat, the distributions of variable values measured at used and sampled-but-not-used locations were significantly different for all three habitat variables.

Table 8. Results of a Kolmogorov-Smirnov test for detecting differences between distributions of habitat variables in sampled-but-not-used locations and locations used by Speckled dace. Variables used are stream velocity (m/s), depth (cm), and estimated average substrate diameter (mm)

	D-value	P-value	Bootstrapped P-value
Channel			
Velocity	0.312	0.023	0.012
Depth	0.287	0.039	0.020
Average substrate	0.247	0.107	0.069
Shoreline			
Velocity	0.111	0.093	0.032
Depth	0.114	0.061	0.038
Average substrate	0.253	<0.001	<0.001

Although a Kolmogorov-Smirnov test indicates if distributions of variables are significantly different, it does not indicate how the distributions differ, therefore it provides limited information. Results of the GLM provide more information, in that the coefficients indicate the direction of the effect on the probability of capturing a Speckled dace caused by changes in variables in the channel habitat.

The estimates of the GLM's coefficients indicate that the probability of finding a Speckled dace decreased with increasing depth and water velocity (Table 9). Increased substrate size had a positive impact on the probability of finding a Speckled dace in a given location within the channel.

Table 9. Estimated coefficients for Equations (4) and (5), the logistic regression model for predicting the probability of presence of Speckled dace at a given location (n = 602).

	Estimate	Standard Error	P-value
β_0	-2.51	0.568	< 0.0001
β_{Depth}	-2.01	0.997	0.0436
β_{Velocity}	-1.94	0.861	0.0248
β_{AveSubs}	0.00723	0.0034	0.0338

3.3 Range and Abundance

3.3.1 Range

I estimated the total range to be 275 km of river (Figure 19, Table 10). I captured Speckled dace at 29 out of the 39 sites sampled for exploratory and quantitative surveys. I assumed that Speckled dace presence was continuous from the furthest downstream capture location to the furthest upstream capture location. A large stretch of the lower Granby River was not sampled, and I did not capture Speckled dace at the furthest downstream sampling site in the river. Previous studies have shown that Speckled dace are present in this area (COSEWIC 2006a) (Figure 1), and I captured Speckled dace near the confluence with the Kettle River. Therefore, I assumed that Speckled dace presence was continuous within this reach.

Table 10. Summary table of the reach lengths (km) with confirmed Speckled dace presence.

Reach	Reach Length
Whole System	275
Mid- and Upper-Kettle	118
West Kettle	43
Lower Kettle	59
Granby	55

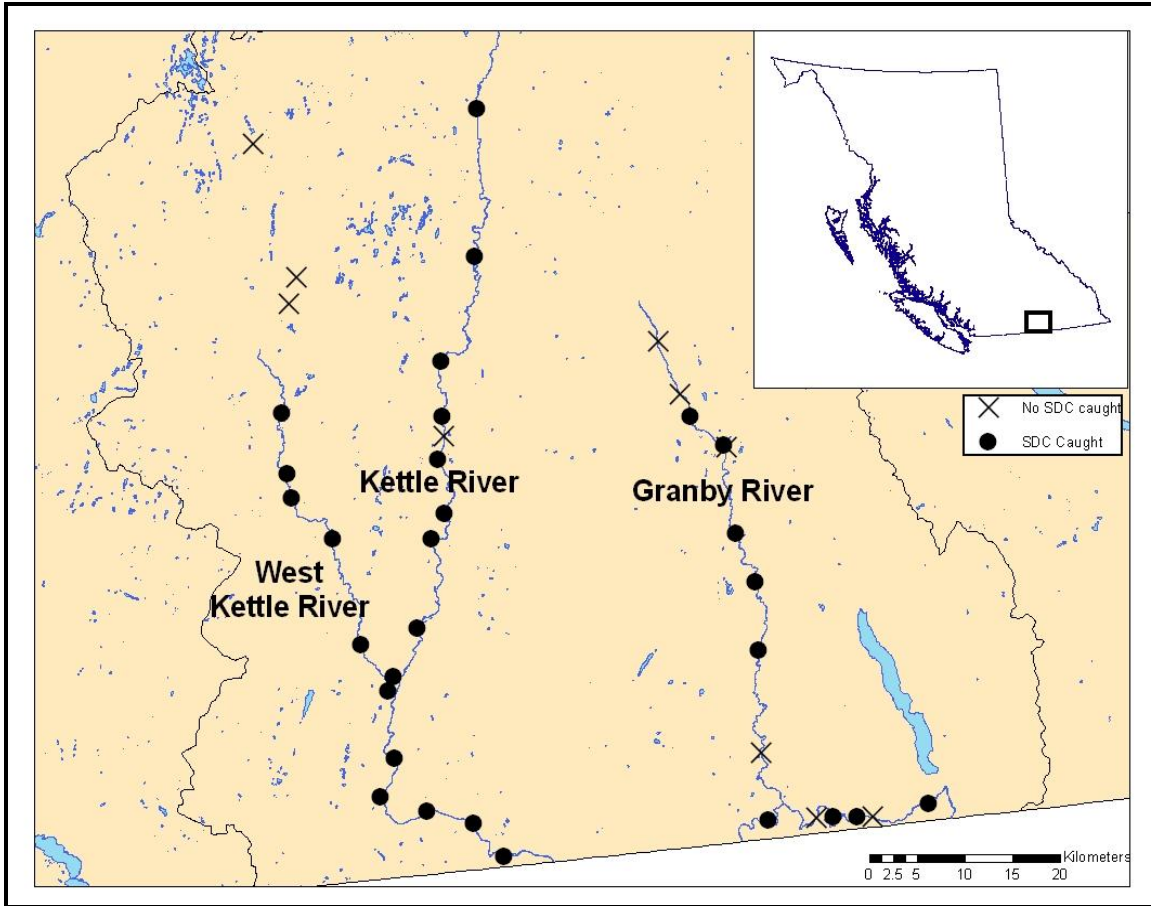


Figure 19. The location of all quantitative and exploratory sampling sites.

3.3.2 Abundance

Capture efficiency (q) was highly variable in the capture-recapture experiments, and ranged from 0 to 0.214, with a mean of 0.079 (SD 0.080) (Appendix 7).

The length of each reach that I used to estimate the population is shown in Table 10. As noted in section 3.1.3.2, I assumed that all fish larger than 56 mm were mature, resulting in a total estimated mature proportion of sampled fish (S) of 0.32. Results of the virtual population, abundance, and linear abundance

estimates and associated confidence intervals are given in Table 11 and Table 12.

Table 11. The bootstrap estimate of mature virtual population (VP), mature population estimate (Pop) and associated 90% confidence intervals (CI) of mature Speckled dace for each reach of the river system.

Reach	km	VP	VP		Pop	Pop	
			Lower CI	Upper CI		Lower CI	Upper CI
Whole River	275	63,092	39,762	91,592	939,610	412,431	1,954,522
Mid- and Upper-Kettle	118	29,388	13,296	49,723	441,184	151,053	967,120
West Kettle	43	13,416	4,611	24,602	196,929	53,119	453,518
Lower Kettle	59	11,834	2,232	25,296	172,650	29,135	428,412
Granby	55	7,582	2,243	15,851	110,627	25,736	270,859

Table 12. The bootstrap estimate of mature Speckled dace linear abundance (SDC/m) and associated 90% confidence intervals (CI) for each reach of the river system. Estimates are not adjusted for capture efficiency and thus are equivalent to the virtual population estimates.

Reach	Linear Abundance	Linear Abundance Lower CI	Linear Abundance Upper CI
Whole River	0.229	0.145	0.333
Mid- and Upper-Kettle	0.249	0.113	0.421
West Kettle	0.313	0.107	0.573
Lower Kettle	0.202	0.038	0.432
Granby	0.137	0.041	0.287

4: DISCUSSION

I found that the estimated abundance of Speckled dace is much larger than previous estimates (Harvey 2007), and the maximum age of the species may be older than estimated by Peden and Hughes (1981). My population estimate would be useful in a re-assessment of Speckled dace by COSEWIC, and subsequently may warrant a change in status under SARA. The CDC should also consider updating the status that they assign to the Speckled dace.

Speckled dace are widespread and locally abundant within the Kettle-Granby system. Previous estimates of abundance ranged from 11,546 to 23,092 Speckled dace in Canada (Harvey 2007). With a mean estimate of 939,610 (90% CI from 412,431 to 1,954,522), I found that the abundance of mature Speckled dace in the Kettle-Granby system is approximately 20 to 40 times larger than previous estimates.

Gard and Flittner (1974) use the diversion and draining method to sample and estimate that the density of Speckled dace in Sagehen Creek, California ranged from 0.15 to 0.29 SDC/m² over a ten year period. Beauchamp et al. (1994) estimate that adult Speckled dace densities range from 0 to 0.01 SDC/m² in Sagehen Creek, based on transect sampling by scuba divers. My shoreline density estimate is as large as or larger than those from other river systems (Gard and Flittner 1974; Beauchamp et al. 1994), despite being unadjusted for capture efficiency.

My estimated linear abundance of mature Speckled dace is 0.22 SDC/m in the Kettle-Granby system. In Sagehen Creek, California, the maximum linear abundance is about 0.1 SDC/m, based on samples by scuba divers (Decker and Erman 1992). My estimate is not adjusted for capture efficiency; however, results suggest that the linear density of Speckled dace in the Kettle-Granby system is at least as high as in Sagehen Creek, near the centre of the species' range. Generally, the largest population densities of species are found at the core of a species' range (Lawton 1993; Vucetich and Waite 2003), however, the Kettle-Granby population appears, in terms of linear abundance, to be in similar or better condition to other populations located more centrally within the species' range.

Using the combination of otolith examination and length-frequency analysis, I found that there may be more age groups within the population than previously thought. Using length-frequency analysis, I estimated that there were at least three age groups, which is in agreement with McPhail (2007) and Peden and Hughes (1981). However, the otolith readings suggest that Speckled dace may live to age 7+. Previous estimates of the number of age groups (Peden and Hughes 1981; McPhail 2007; COSEWIC 2006) were likely limited by the overlap in the distributions of fork length frequencies of older age groups. In the US, populations are believed to live to 3 or 4 years in most streams (Wydowski and Whitney 2003; Moyle 2002). Baker (1967) found that Lahontan Speckled dace in Lake Tahoe, California may live to 5 or 6 years.

It is possible that Speckled dace live to be older than age 7. The age 7+ fish I captured was 79 mm in length. I captured fish larger than 79 mm in all three rivers, the largest of which was 94 mm FL in the Granby River. Moyle (2002) reports that the largest Speckled dace he has found in California is 111 mm standard length (SL). Examination of larger specimens could lead to discovery of older age groups, however, such large specimens are uncommon in samples.

I estimate the current range of Speckled dace to be about 16 km or 6% larger than was estimated by COSEWIC (COSEWIC 2006a). I caught Speckled dace in areas further upstream (northward) than had previously been recorded in both the Kettle and Granby Rivers. Of the 10 sites where Speckled dace were not captured, three of the sites were in the West Kettle River upstream of the sampling site near Beaverdell, which is suspected to be near the upstream limit (COSEWIC 2006a). As well, two of the sites where I did not capture Speckled dace were in the headwaters of the Granby River, and the species may not be present there. It appears that I did not reach the upstream limit of the range in the Kettle River because I found Speckled dace at the four furthest upstream sites that I sampled.

I found Speckled dace during late July and early August in shallow, low-velocity areas, with gravel or cobble substrate. These results are consistent with previous research in Canada (Peden, Hughes 1981; Peden, Hughes 1984). Moyle and Baltz (1985) found adult Speckled dace in Deer Creek, California near the bottom of the water column in shallow (29.9 cm), low velocity (0.404 m/s)

areas. Limitations of my analysis are that I did not sample across a wide variety of river conditions, or at night. Future habitat sampling should be conducted throughout a variety of water levels and during night in order to more fully understand habitat use.

Stable isotope analysis revealed that there was a large difference in the delta ^{15}N between the Beaverdell sampling site, and the Midway sampling site. The difference in signatures is likely due to the different activities in the terrestrial areas surrounding sampling sites. The Beaverdell site is in the headwaters of the Kettle River and the most common nearby activity is forestry. In the lower reaches of the river, where the Midway site is, the Kettle River runs through agricultural croplands and is more heavily populated. McKinney et al. (2002) show that land use in nearby areas affects the delta ^{15}N of freshwater mussels. They found that smaller delta ^{15}N signatures in mussels were associated with forested riparian areas, whereas mussels with larger delta ^{15}N signatures were located in more densely populated areas. Deibel and Vander Zanden (2009) found that variance of delta ^{15}N signatures in aquatic biota is explained by the use of inorganic fertilizers in the watershed. The combination of more dense human population and agriculture likely explains the increased delta ^{15}N signatures found at the Midway site.

The very negative filamentous algal delta ^{13}C signature ($-32.88\text{‰ } \delta^{13}\text{C}$) at the Beaverdell site was consistent with findings by Finlay (2001). Finlay (2001) concludes that in headwater streams, the delta ^{13}C signatures for algae are more negative than terrestrial sources by at least $4\text{‰ } \delta^{13}\text{C}$.

Results of stable isotope analysis of Speckled dace at the Midway site were consistent with the expectation that delta ^{13}C values of fish tissue (-24.91‰ $\delta^{13}\text{C}$) would be more influenced by algal sources (-24.24‰ $\delta^{13}\text{C}$) than they were in upstream areas (Finlay 2001). My results are also consistent with the River Continuum Concept (Vannote 1980), which states that non-headwater areas of streams are more influenced by algae than they are by leaf-litter from the surrounding area.

COSEWIC (2006a) suggests that the threat from the combination of drought and increased water withdrawals may have a negative impact on Speckled dace due to associated water temperature increases. I captured Speckled dace within the entire range of sampled water temperatures (12.7 – 22.6 °C), thus, temperature of the stream was not a limiting factor for Speckled dace presence. John (1964) found that increasing water temperature by 1 °C per day did not lead to mortality of Speckled dace in Arizona until about 32 °C, suggesting that Speckled dace are able to survive high water temperatures. My GLM results indicate that the probability of finding a Speckled dace decreases with increasing depth and water velocity, suggesting a preference for slow, shallow habitats. In the event that there are increased water withdrawals and drought in the future, Speckled dace may not be as negatively affected by the changes as previously thought.

The mean capture efficiency of my sampling method for Speckled dace was low and highly variable. Price and Peterson (2010) report capture efficiencies of 0.17 when using single-pass electrofishing for minnows in warm-

water wadeable streams. Speckled dace are bottom-dwelling species and hide among the substrate, which may account for the low capture efficiency in my research. In equation (9), my abundance estimate is inversely proportional to capture efficiency; therefore, small changes in capture efficiency lead to large changes in abundance. Given the highly variable and low capture efficiency of my methods, future abundance surveys for Speckled dace should focus on estimating capture efficiency with more precision, or using a sampling method that has a higher capture efficiency.

4.1 Management Implications

4.1.1 BC Conservation Framework

The BC Conservation Framework takes into account several factors when assigning conservation priority to species, including feasibility of recovery actions, global responsibility, change in known range, population isolation, population trends, and threats to the species (Bunnell, Fraser & Harcombe 2009; Ministry of Environment 2009). The situation of the Speckled dace within BC is an interesting case study within the context of the Framework because the Canadian population is isolated from other populations, but does not meet the criterion of being a “disjunct” population. Bunnell et al. (2009) define “disjunct” as being separated from other populations by 1000 km. Using the Conservation Framework criteria, species can be categorized as D1 if the population is disjunct *and* the entire disjunct population is within BC, or D2, if the population is disjunct but occurs in multiple jurisdictions (i.e., areas outside of BC). Category D1

describes Speckled dace in Canada and BC because the entire population is isolated by the Cascade Falls from downstream populations.

The Conservation Framework is a new system, so modifications might improve the methods of ranking priority for disjunct populations. One potential change would be to refine the definition of disjunct to include a specific category for fishes. Fish populations can be isolated, but separated by only a small distance, and therefore not meet the criteria for being disjunct, as in the case of Speckled dace. For example, the presence of a waterfall or other obstacle, such as a dam, can isolate a population, but does not necessarily mean that there will be a large distance between populations. In such cases, isolation can be masked during the priority ranking process by the proximity to other populations.

The BC Conservation Framework relies on NatureServe and the BC CDC species rankings for assigning priority. The Speckled dace is currently ranked by the CDC as S1 (critically imperilled). I used the NatureServe Element Rank Calculator Version 2.0 (NatureServe 2010) to determine what the CDC ranking would be if my population abundance estimate were taken into account. If the provincial ranking is changed based on my population estimate, it would be changed to S3 (special concern), assuming a “medium” threat impact. This lower rank would be due to the large increase in estimated population abundance. As a result of any changes to CDC ranking, the BC Conservation Framework priority for goal 3 (to contribute to global efforts) would be lowered from priority 1 to priority 4. The Speckled dace should be re-assessed by the CDC to ensure that

it is classified at the appropriate priority level under the Conservation Framework goals.

4.1.2 COSEWIC and SARA

4.1.2.1 Reassessment

Given the results of my research, particularly the population abundance of mature individuals, Speckled dace do not meet the COSEWIC quantitative abundance criteria for either endangered or threatened designations. It is unlikely that Speckled dace meet the COSEWIC criteria for observed population decline given that the (1) current population abundance is much larger than any previous estimates (Harvey 2007), (2) spatial range has not contracted from previous studies (COSEWIC 2006a), and (3) population densities are similar to, or larger than, those in the core of the range (Decker and Erman 1992; Beauchamp et al. 1994; Gard and Flittner 1974). If Speckled dace are reassessed by COSEWIC, changes in the designation could affect the SARA listing.

Speckled dace were assessed by COSEWIC as endangered partly because of concerns that limited habitat, increasing water withdrawals and increased frequency of drought conditions would pose a threat to the species (COSEWIC 2006a). Furthermore, in the US, some populations exist in hot dry areas, and have a tolerance for water temperatures up to 28 °C (Moyle et al. 1995). The results of my habitat analysis indicate that Speckled dace select shallow, slow-moving areas of the river over deeper, faster areas. Given the high temperature tolerance and preference for low velocity and shallow water, it is

likely that Speckled dace would be able to persist in drought conditions. My sampling was conducted 5 years after the 2003 drought, which resulted in the lowest flows on record for the Kettle River. The high abundance of Speckled dace 1 – 2 generations after a drought further supports the idea that Speckled dace are either tolerant of drought conditions or resilient to such adverse environmental events.

COSEWIC (2006a) notes the potential for a “catastrophic event” as a threat to the species, but acknowledges that a single event that could affect the entire Canadian population is unlikely. I found that each of the four reaches of the Kettle-Granby system supported at least 110,000 mature Speckled dace (Table 12), providing a potential source population for re-establishment if a catastrophic event did occur in one area of the system.

4.2 Conservation Priority Setting

Globally, many countries have methods of identifying and cataloguing species that are at risk of extirpation or extinction (de Grammont and Cuarón 2006). de Grammont and Cuarón (2006) propose that in order to be effective conservation tools, regional or national lists of species of conservation concern should include 3 main elements: (1) sound categorization, (2) priority setting, and (3) normative tools (i.e., laws). As it currently exists, the SARA has both sound categorization (based on the COSEWIC assessments) and laws, but priority setting is less well developed. Conservation priority includes extinction risk, as well as other factors such as funding, staff, legal frameworks, economics, and cultural preference for species (Gärdenfors et al. 2001).

Effectively, there is a two-stage process of evaluating conservation priority and protecting the species. The first stage of conservation priority setting occurs when the Government decides whether or not to list a species under SARA that COSEWIC has designated as endangered, threatened, or special concern. At this stage, the need to conserve the species is weighed against other factors, such as social and economic issues. In some cases, the Government decides not to list a species, as was the case for two populations of Sockeye salmon, the polar bear, and one population of grizzly bear (Government of Canada 2005). In these cases, the Government placed a higher priority on the implications of a SARA listing.

The second stage of conservation priority setting occurs when managers set priorities among listed species. Managers within the responsible departments allocate funding and staff to the many listed species for which the department is responsible. Allocation of resources between species is based on factors such as global status, threats, and likelihood of achieving recovery (Government of Canada 2009b).

Presently, many SARA listed species do not have a Recovery Strategy in place (Government of Canada 2010) and the Government is not meeting the legislated requirements to prepare Recovery Strategies (Commissioner of Environment and Sustainable Development 2008). This issue of lack of Recovery Strategies could be alleviated by assigning different levels of conservation priority to listed species, thereby focusing funds and agency staff time on the most important issues. Future amendments to SARA should include

a procedure for conservation priority setting to aid managers in balancing multiple factors, and ensure that priority setting is consistent across and within responsible departments. A priority setting procedure could include taking into account factors such as feasibility of species recovery, national responsibility for the species, proximity to the centre of the species' range, and isolation of the population from other populations of the same species. Similar to the BC Conservation Framework, a priority setting procedure could guide the allocation of resources such as funding and staff time, and would provide a transparent method of ranking priorities.

4.3 Value of information

The outcome of the SARA listing process for Speckled dace would likely have been different if research similar to mine had been conducted earlier. If a quantitative population estimate, such as the one here, had been made prior to, or as a component of, the 2002 Species Assessment, COSEWIC may not have designated the population as endangered. Without population estimates, COSEWIC assessments may lack the information necessary to correctly categorize the level of risk to the species. Targeted studies may help to prevent unnecessary expenditures and allow for re-allocation of limited funds to species that are at a high probability of extinction.

An alternative to conducting field work when a species is first considered for COSEWIC assessment is to use the data deficient designation, rather than the endangered or threatened designations in cases where there are no population abundance estimates. The COSEWIC Assessment Guidelines

(COSEWIC 2006b) state that the data deficient designation should be used when the best information available has been reviewed, yet it is insufficient to satisfy the criteria or resolve the species eligibility for assessment. Despite the rules of use outlined by COSEWIC, assessors may be reluctant to use the data deficient designation in favour of a more precautionary approach over an evidence-based approach when evidence is limited. In the case of the Speckled dace, using the data deficient designation would have allowed for research to answer key questions first, while not using the limited staff time and funding associated with SARA listing the species.

4.4 Conclusion

Further research on Speckled dace is required to determine whether there is a trend in the population abundance and threats to the population. Population surveys, similar to this study, should be conducted periodically to determine whether there is a trend in the abundance over time because population trend is one criterion for COSEWIC assessments. Future abundance estimates should focus on reducing the variability in capture efficiency across sampling trials or on using a method with a higher capture efficiency.

Given the results of my research, I recommend that COSEWIC and the BC CDC re-assess Speckled dace and update the species' designations. Changes in the designations will affect the allocation of conservation funds and staff time, and ensure that they are allocated to species that are most at risk.

The SARA should be updated so that it has effective procedures to assign conservation priority to listed species. The result will be allocation of funds and staff to species of highest conservation priority.

The fate of Speckled dace in Canada appears to be much more secure than previously thought, given my results indicating the large population abundance. Priority should be placed on maintaining the current population and preventing degradation to the Kettle-Granby system. If these conditions are met, the species is likely to be a low conservation concern under provincial and Federal conservation programs and legislation.

Appendix 1

Food types, associated life stage and common name (if applicable).

Food Type	Abbreviation	Stage	Common name
Order Ephemeroptera (ad)	O. Ephemeroptera (ad)	adult	Mayfly
Order Ephemeroptera (ny)	O. Ephemeroptera (ny)	nymph	Mayfly
Order Plecoptera (ny)	O. Plecoptera (ny)	nymph	Stonefly
Order Trichoptera (l)	O. Trichoptera (l)	larvae	Caddisfly
Order Coleoptera (ad;terr)	O. Coleoptera (ad;terr)	terrestrial adult	Beetle
Order Coleoptera (l;aq)	O. Coleoptera (l;aq)	aquatic larvae	Beetle
Order Diptera (ad;terr)	O. Diptera (ad;terr)	terrestrial adult	True fly
Order Diptera (l;aq)	O. Diptera (l;aq)	aquatic larvae	True fly
Family Chironomidae (l)	F. Chironomidae (l)	larvae	Midge
Family Simuliidae (l)	F. Simuliidae (l)	larvae	Black fly
Order Hemiptera (ad)	O. Hemiptera (ad)	adult	True bug
Order Lepidoptera (l)	O. Lepidoptera (l)	larvae	Butterfly and moth
Order Acarina (ad)	O. Acarina (ad)	adult	Mite
Family Tipulidae (l)	F. Tipulidae (l)	larvae	Cranefly
Order Odenata (ny)	O. Odenata (ny)	nymph	Dragonfly and damselfly
Invertebrate (ad; terr)		terrestrial adult	
Invertebrate (imm)		immature	
Algae			
Plant material			
Zooplankton			
Unidentified			

Appendix 2

Results from otolith age structures showing the estimated age (years) and fork length (Length) (mm) of each specimen.

Sample Number	Collection Date	Length	Estimated Age
SDC-3	2-Oct-08	68	2
SDC-5	2-Oct-08	75	5
SDC-7	2-Oct-08	79	7
SDC-10	2-Oct-08	72	5
SDC-12	3-Oct-08	69	3
SDC-13	3-Oct-08	59	4
SDC-14	3-Oct-08	63	2
SDC-15	3-Oct-08	54	2
SDC-16	3-Oct-08	64	2
SDC-17	3-Oct-08	59	3
SDC-18	3-Oct-08	72	3
SDC-20	3-Oct-08	51	2
SDC-21	9-Jul-08	49	2
SDC-24	9-Jul-08	53	2
SDC-25	9-Jul-08	44	1
SDC-27	18-Jul-08	62	2
SDC-30	18-Jul-08	71	4
SDC-32	18-Jul-08	54	2
SDC-33	18-Jul-08	63	4
SDC-34	18-Jul-08	53	2
SDC-35	2-Oct-08	61	3
SDC-37	8-Aug-08	72	3

Appendix 3

Summary of age-groups' mean fork length (Mean FL) (mm) and standard deviation (SD) from the otolith examination.

Age-group	n	Mean FL	SD
1	1	44	
2	10	57	6.5
3	5	67	6.2
4	3	64	6.1
5	2	74	2.1
7	1	79	

Appendix 4

Occurrence of each food type in all 36 stomachs examined. The occurrence is the number of stomachs that contained at least one specimen of each food type. Detail on food type and life stage given in Appendix 1.

Food Type	Occurrence
Order Ephemeroptera (ad)	2
Order Ephemeroptera (ny)	26
Order Plecoptera (ny)	9
Order Trichoptera (l)	22
Order Coleoptera (ad;terr)	1
Order Coleoptera (l;aq)	2
Order Diptera (ad;terr)	2
Order. Diptera (l;aq)	2
Family Chironomidae (l)	25
Family Simuliidae (l)	1
Order Hemiptera (ad)	2
Order Lepidoptera (l)	3
Order Acarina (ad)	5
Invertebrate (ad; terr)	2
Invertebrate (imm)	2
Algae	25
Plant material	12
Zooplankton	1

Appendix 5

The mean number observations (Mean) and standard deviation (SD) of each food type per Speckled dace stomach examined (n = 36). Detail on food type and life stage given in Appendix 1.

Food Type	Mean	SD
Order Ephemeroptera (ad)	0.08	0.37
Order Ephemeroptera (ny)	6.83	9.27
Order Plecoptera (ny)	0.75	1.83
Order Trichoptera (l)	2.64	4.26
Order Coleoptera (ad;terr)	0.03	0.17
Order Coleoptera (l;aq)	0.06	0.23
Order Diptera (ad;terr)	0.11	0.52
Order Diptera (l;aq)	0.06	0.23
F. Chironomidae (l)	5.94	11.82
F. Simuliidae (l)	0.03	0.17
Order Hemiptera (ad)	0.06	0.23
Order Lepidoptera (l)	0.08	0.28
Order Acarina (ad)	0.17	0.45
Invertebrate (ad; terr)	0.08	0.37
Invertebrate (imm)	0.06	0.23

Appendix 6

Mean delta ¹⁵N and delta ¹³C values for each analysed food type. Enrichment is the delta ¹⁵N of Speckled dace (SDC) minus the delta ¹⁵N of a given food type. The sampling site near the town of Beaverdell, BC, is in the West Kettle River in the upper reach, and the sampling site near the town of Midway, BC, is in the Kettle River, upstream of the confluence with the Granby River. Detail on invertebrate names given in Appendix 1.

Beaverdell	delta ¹⁵N	Enrichment	delta ¹³C
Speckled dace	8.23		-26.21
O. Trichoptera (I)	2.21	6.02	-24.56
O. Plecoptera (ny)	4.06	4.17	-24.32
F. Chironomidae (I)	3.63	4.6	-23.24
O. Ephemeroptera (ny)	2.28	5.95	-23.51
Epilithic algae	0.82	7.41	-24.69
Filamentous algae	1.97	6.26	-32.88
Midway			
Speckled dace	9.43		-24.91
O. Trichoptera (I)	4.68	4.75	-25.46
O. Plecoptera (ny)	6.64	2.79	-26.84
F. Chironomidae (I)	7.57	1.86	-25.08
O. Ephemeroptera (ny)	6.49	2.94	-27.23
F. Tipulidae (I)	7.14	2.29	-25.94
O. Odenata (ny)	6.95	2.48	-26.52
Filamentous algae	3.65	5.78	-24.24

Appendix 7

Capture efficiency calculated for seven capture-recapture experiments.

Trial Number	Released	Recaptured	Capture Efficiency
CR-1	28	6	0.214
CR-2	26	1	0.038
CR-3	30	0	0
CR-4	30	2	0.067
CR-5	30	1	0.033
CR-6	30	5	0.167
CR-7	29	1	0.034
		Mean	0.079
		Standard Deviation	0.08

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