1.3 Stream Habitat

1.3.1 Lime Creek Watershed

1.3.1.1 General Description of Watershed

Lime Creek is a 5th order stream at its mouth and flows northwest into Alice Arm close to the Kitsault Townsite. Lime Creek drains a mountainous, 41,039 kilometres squared (km^2) watershed that ranges in elevation from 1560 metres above sea level (masl) at the top of the Mohawk Mountain to sea level at Alice Arm. The watershed is located in the Nass Ranges Ecoregion within the Meziadin Mountains Ecosection of BC. Six biogeoclimatic (BGC) units occur within the watershed, with the Mountain Hemlock Moist Maritime Leeward Variant representing the dominant BGC unit (Section 6.10). The dominant tree species in the watershed are western hemlock, mountain hemlock, western redcedar and Sitka spruce.

Lime Creek receives run-off from the lake-headed eastern portion of its watershed via Patsy Creek, a fourth order stream draining Patsy Lake at the top of the watershed, and from the non-lake-headed south-western portion of its watershed that drains the mountainous terrain to the south (Figure 1.2-1). On average, the Patsy Creek watershed provides 28% of the total annual discharge of Lime Creek at its mouth at Alice Arm; the south-western portion of the watershed provides 35%. There are also a number of smaller tributaries draining into Lime Creek downstream of the Patsy Creek confluence; these are typically small, very steep and provide <37% of the total annual discharge of Lime Creek at its mouth.

Patsy Lake is located on a plateau in the eastern portion of the Lime Creek watershed. Within its watershed, are a number of small, shallow (<2 m) ponds that drain through short (<200 m), narrow (<1 m), low gradient channels to the lake. Patsy Lake has five small inlet tributaries in total and a total watershed area of 12,208 km^2. Patsy Lake is drained by Patsy Creek.

Downstream of its confluence with Patsy Creek, Lime Creek flows through an approximately 5.4 km long bedrock canyon. This canyon has a mean gradient of approximately 7% and has numerous boulder cascades with vertical drops up to 2.5 m high. Substrates in this canyon are comprised almost exclusively of bedrock and boulders. Lime Creek exits this canyon at an 8 m high waterfall, approximately 1,600 m upstream from the creek mouth at Alice Arm, and is the upstream limit of fish distribution in the watershed (Figure 1.2-2).

Downstream of this waterfall, Lime Creek flows in a single channel which gradually loses gradient and becomes less entrenched by its bedrock banks moving downstream toward Alice Arm. Habitat in lower Lime Creek (i.e., below the waterfalls) is characterised by alternating combinations of steep cascades with large angular boulder substrates, deep (>2 m) pools with cobble / gravel substrates, turbulent riffles with boulder / cobble substrates, and fast-flowing runs. The banks of lower Lime Creek are primarily bedrock.

Below the bridge crossing, approximately 280 m upstream from Alice Arm, Lime Creek flows over an approximately 3 m high bedrock cascade (Figure 1.2-2). This is the first impediment to fish passage in Lime Creek upstream from the ocean.

Below this cascade, Lime Creek has been channelised between rip-rap banks by the builders of the Kitsault Townsite back in the 1970s. Within these banks, the lower 280 m of Lime Creek flows in a straight channel directly to the ocean. Aerial photos show that Lime Creek formerly split into numerous channels in a natural delta below this first cascade.

The Lime Creek hydrograph is dominated by surface run-off from rain events and snow melt. The hydrograph typically includes a spring freshet, starting in May and reaching a summer low flow by mid-July, and a fall high flow period, driven by rain storms, starting in mid-September and peaking in October. The daily hydrograph during the open-water period (March to November) can be relatively flashy and water levels and discharge in the creek typically reacts within 8 hours to any passing rain event over the watershed. This flashiness occurs because of the steep, bedrock terrain that dominates the watershed and the frequent rain storms events that occur between March and November along the north coast of BC.

1.3.1.2 Reach Break Analysis

For the purposes of this baseline, the 8 m high waterfall divides Lime Creek into “lower” Lime Creek (Reaches 1-4) and “upper” Lime Creek (Reaches 5-8) (Table 1.3-1). Reach 1 extends from the mouth at Alice Arm upstream approximately 150 m to the upstream limit of tidal influence. Reach 2 extends 175 m from the top of Reach 1 to the approximately 3 m high bedrock cascade, the first impediment to fish passage in the creek. Reach 3 extends from this cascade upstream 75 m to just upstream of the bridge crossing where the channel and bedrock valley begins to widen. Reach 4 extends from the top of Reach 3 upstream of the bridge crossing to approximately 350 m downstream from the base of the 8 m high waterfall.

Reach 5 is the 5.4 km long, 7% gradient canyon that extends from the waterfalls to the confluence of Patsy Creek and is the first reach in “upper” Lime Creek. The length and a description of the remaining reaches in upper Lime Creek are presented in Table 1.3-1. Reaches 6 through 8 are not discussed further as these are upstream of the proposed Project and will not be affected by it. The longitudinal gradient profile of Lime Creek from the Patsy Creek confluence to Alice Arm is shown in Figure 1.3-1

Reach 1 of Patsy Creek extends from the confluence with Lime Creek approximately 1 km upstream of the top of the old Kitsault mine pit. Banks and instream habitat in this reach of Patsy Creek are influenced by the substrates and slope grading left at the toe of the existing Kitsault mine pit. Reach 2 extends from the top of Reach 1 upstream to the beginning of the former Patsy waste rock dump. Gradient in this reach is lower than in Reach 1. Reach 3 extends from the top of Reach 2 to the upstream end of the former Patsy waste rock dump. Reach 4 extends to the outlet of Patsy Lake and is in a natural state compared to the three reaches below it. The longitudinal gradient profile of Patsy Creek is show in Figure 1.3-2.

Table 1.3-1: Reach Descriptions in Lime and Patsy Creeks

Stream	Reach #	Stream Order	Reach Length (km)	Approximate Reach Gradient (%)	Reach Description
Lime Creek	1	5	0.15	0.7	Channelised section within high tide influence
	2	5	0.18	1.4	Channel section upstream to first 3 m high cascade impediment to fish passage
	3	5	0.08	2.4	Top of cascade to bedrock constriction at bridge crossing
	4	5	1.56	3.2	Cascade dominated, step-pool habitat with bedrock banks and numerous deep (>2 m pools); ends at 8 m high waterfall
	5	5	5.40	7.0	Entrenched, steep bedrock canyon with numerous boulder cascade up to 2.5 m high
	6	5	0.30	5.2	Bedrock entrenched channel with moderate gradient extending from Patsy Creek confluence to next upstream tributary
	7	5	1.60	9.8	Bedrock entrenched canyon with steep gradient and cascade drops up to 2.5 m high
	8	5	2.80	10.5	Partially confined channel with moderate gradient and cascade-pool habitat
Patsy Creek	1	4	1.20	8.9	High gradient channel adjacent to existing open pit; bottom substrates and bank material comprised of slough material from open pit
	2	4	0.50	5.4	Moderate gradient channel adjacent to open pit
	3	4	1.35	5.5	Moderate gradient channel with bottom substrates and bank material comprised of material from former Patsy waste rock dump; abundant woody debris
	4	2	0.85	12.5	High gradient channel with riffle-pool habitat with abundant woody debris extending to Patsy Lake

Note: km - kilometre; m - metres; % - percent

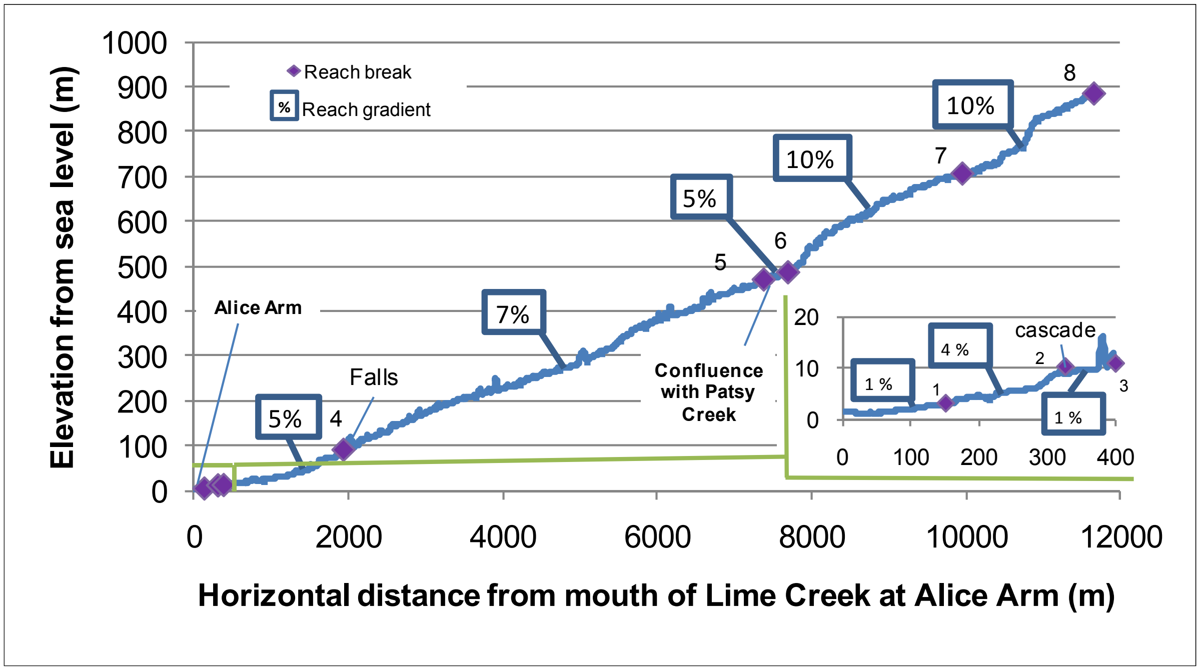


Figure 1.3-1: Stream Gradient Profile of Lime Creek

Note: Insert graph shows details of lower portion of Lime Creek

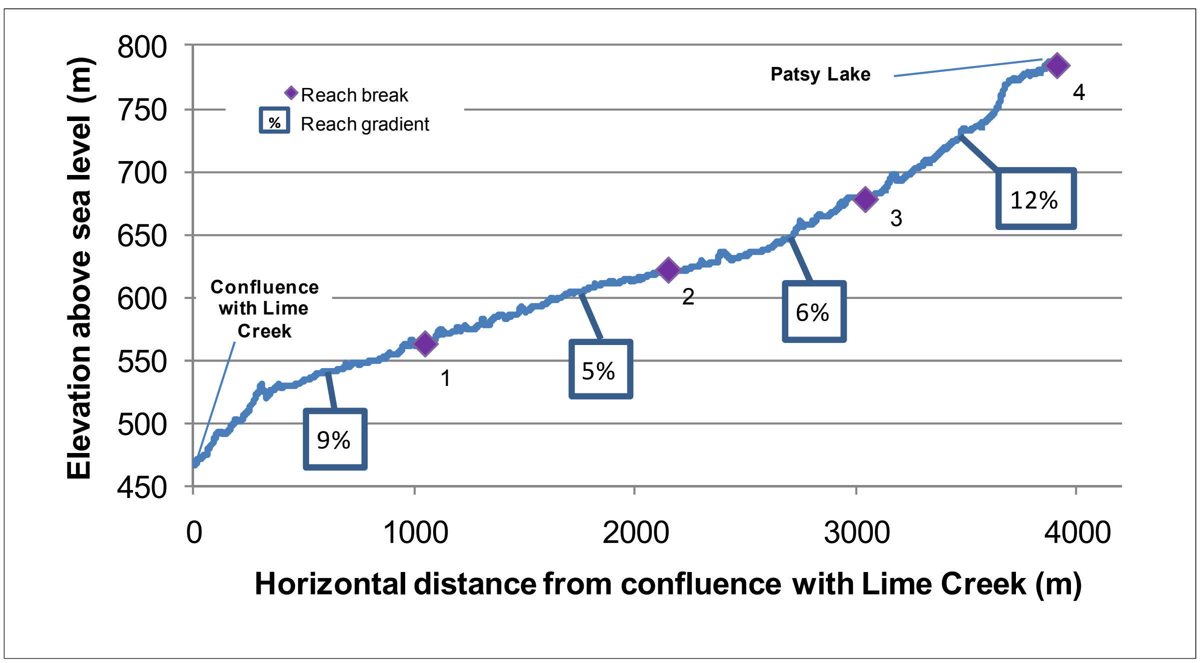


Figure 1.3-2: Stream Gradient Profile of Patsy Creek

1.3.1.3 Habitat Classification and Mapping

1.3.1.3.1 Lower Lime Creek

A map of the habitat types in lower Lime Creek below the 8 m high waterfalls is presented in Figure 1.3-3. A summary of the habitat characteristics in lower Lime Creek, by reach, is provided in Table 1.3-2. Photos of habitat in each reach of lower Lime Creek are presented in Appendix I-1. A summary of all Reconnaissance (1:20,000) site card habitat assessments conducted in Lime Creek in 2009 is provided in Appendix A-1.

Habitat in Reach 1 was entirely riffle habitat with small (65 to 128 mm diameter), angular cobbles and large gravel (16 to 64 mm diameter) substrates. Average gradient in this reach was <1% and the mean bankfull and wetted width were approximately 32 m and 10 m, respectively. Instream cover was limited to occasional boulders mid-stream or along the stream banks. Banks were largely rip-rap boulders placed during creek straightening in the 1970s. Riparian vegetation above these rip-rapped banks was predominantly willows and alder. It is unknown how many channels were present and how wide they were in this lower reach before it was straightened.

Habitat in Reach 2 was more diverse than in Reach 1 and includes riffle, cascade, glide, and pool habitat. Average gradient increased from <1% in Reach 1 to approximately 1.4% for the entire reach, but local gradients varied widely in the different habitat types. Most of the habitat in Reach 2 was riffle (39%) or cascade (32%) habitat with large (65 to 256 mm diameter) cobble substrates. There were numerous angular boulders (>256 mm diameter) throughout these habitats, which provided fish with refuge from high water velocities and were sediment traps for sand in behind them.

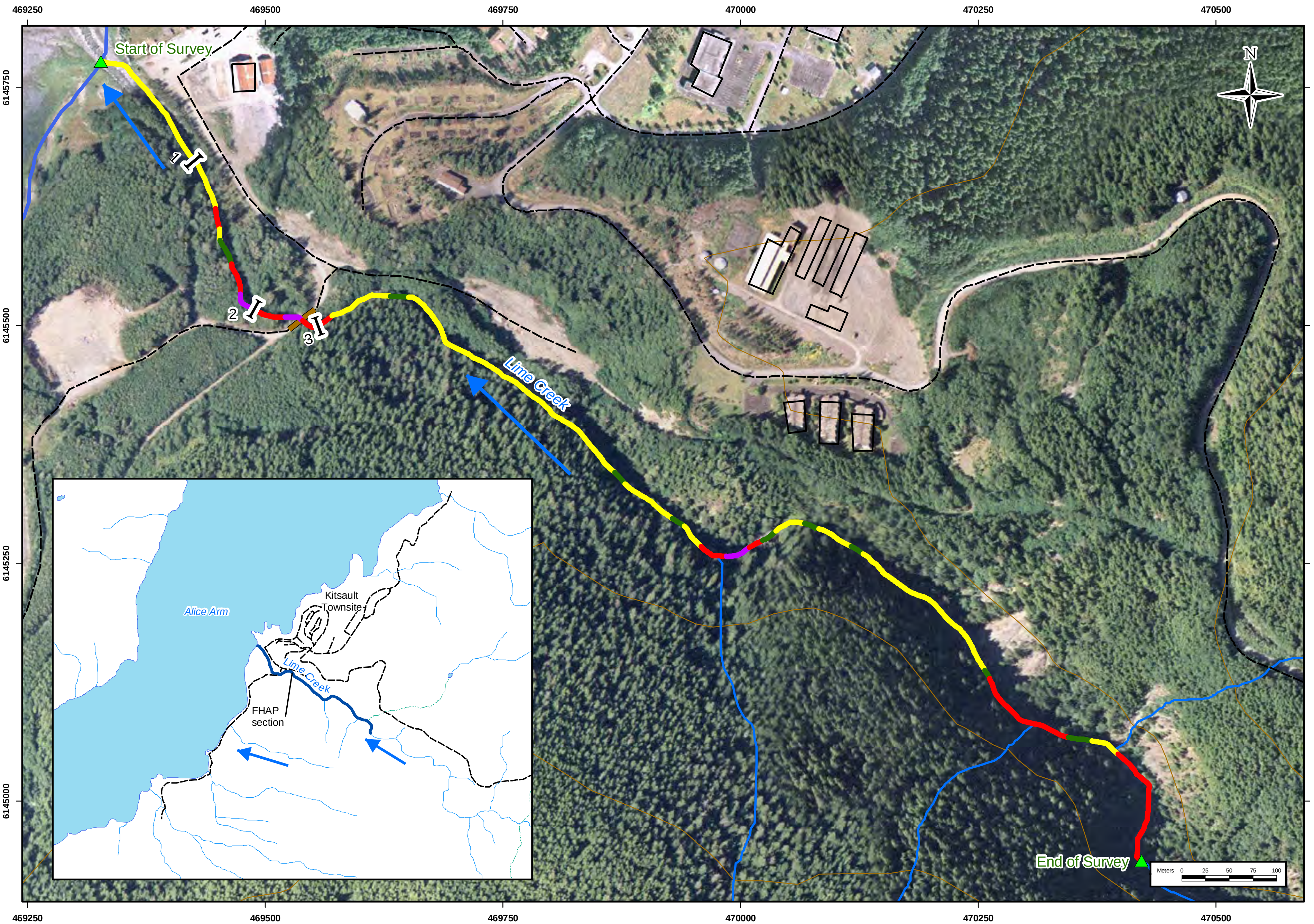
This reach ended at the approximately 3 m high cascade. Below this cascade is a large (220 m^2), deep (>3 m) pool created by the scour from the upstream cascade. This pool lies between a vertical bedrock bank on one side and a sloping bedrock bank on the other. Substrates in the bottom of this pool were comprised of small cobbles and large gravels while the pool tail-out was almost entirely comprised of smooth, small cobbles and gravels.

Reach 3 was short (75 m) and was comprised of only two habitat types: the 55 m long, approximately 3 m high bedrock, boulder cascade upstream of the pool at the top of Reach 2; and a smaller pool between the top of the cascade and the constricted bedrock and boulders at the bridge crossing. This pool was divided by natural and concrete boulders placed in the creek during bridge construction and has vertical bedrock banks on both sides. The pool tail-out was comprised entirely of smooth, small cobbles. Average gradient in this reach was approximately 2.4% and most of this slope occurs in the bedrock portion of the cascade.

Table 1.3-2: Habitat Summary, by Reach, in Lower Lime Creek

Reach	Habitat Type	Total Length (m)	Habitat Type (%)	Mean gradient (%)	Mean Depth (m)	Mean Bankfull Width (m)	Mean Wetted Width (m)	Mean Pool Residual Depth (m)	Dominant / Subdominant Substrate Type	Dominant / Subdominant Cover Type	Dominant Riparian Type
1		**150**	100	0.7		31.7	10.0				
	Riffle		100		0.12	31.7	10.0		Small Cobble/Large gravel		Shrub/herb
2		**175**	100	1.4		17.4	10.3				
	Cascade	56	32		0.37	18.3	12.8		Large Cobble/Boulder		Young Conif. Forest
	Glide	28	16		0.63	19.3	11.0		Small Cobble/Large Cobble		Young Conif. Forest
	Pool	23	13		>3	20.5	11.0	>3	Small Cobble/Large gravel	Deep Pool/Boulder	Mature Decid. Forest
	Riffle	68	39		0.51	14.7	7.1		Large Cobble/Small Cobble		Shrub/herb
3		**75**	100	2.4		17.4	9.8				
	Cascade	55	73		0.57	18.7	9.3		Large Cobble/Small Cobble	Deep Pool/Boulder	MatureDecid. Forest
	Pool	20	27		1.13	13.0	9.0	1.3	Small Cobble/Large Gravel	Deep Pool	Mature Decid. Forest
4		**1202**	100	3.2		15.4	9.2				
	Cascade	305	25	4.0	0.42	19.0	11.7		Large Cobble/Boulder	Boulder	Mature Conif. Forest
	Glide	133	11		0.56	12.5	8.0		Small Cobble/Large gravel	Boulder/Deep pool	Mature Conif. Forest
	Pool	27	2		0.87	16.5	9.0	1.1	Large Gravel/Small Cobble	Deep pool	Mature Conif. Forest
	Riffle	737	61	2.0	0.45	15.4	8.8		Large Cobble/Small Cobble	Boulder/LWD	Mature Conif. Forest

Note: For each reach, summary of total length and mean widths and gradients are presented in grey. Mean gradients for individual habitat units are provided where sufficient data exists.
Conif. - Coniferous, Decid. - Deciduous, LWD - large woody debris



Reference

Base Data
1. Land and Resource Data Warehouse 1:20,000 (TRIM)

FHAP means Fisheries Habitat Assessment Procedure

Legend

- Reach Break
- Cascade
- Glide
- Pool
- Riffle
- Flow Direction
- Stream
- Road
- Bridge
- River and Lake
- Survey Start/End Point

CLIENT: AVANTI MINING INC. Avanti Kitsault Mine Ltd.

AMEC Earth & Environmental
4445 Lougheed Highway, Burnaby, B.C., V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

amec

ANALYST:	MY
QA:	PD
DATUM:	NAD83
PROJECTION:	UTM 09
SCALE:	1:5,500

PROJECT: Kitsault Mine Project

TITLE: FHAP Habitat Units in Lime Creek 2010

REV. NO.:	A
DATE:	May 2011
PROJECT NO:	VE51988
FIGURE No.	1.3-3

Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-061.mxd

Riffle habitat comprised most (61%) of the habitat in Reach 4. Substrate in these riffles was comprised of large and small, angular cobbles. There were also numerous boulders throughout these riffles that provide most of the available cover for fish. Cascade habitat comprised 25% of the habitat in Reach 4 and most of this habitat was found in the upper half of the reach as the gradient increases and the size of the substrates increases. These cascades were primarily comprised of large angular cobbles and boulders. Water velocities in these cascades was fast, even during the summer low flow period, as water was typically constricted between adjacent boulders creating fast-flowing chutes. Drops in these cascades can be >1 m high in places, particular near the top of the reach.

There were very few deep (>2 m) pools in Reach 4 based on FHAP classification criteria and pools comprised only 2% of the total habitat in this reach. However, there were numerous deep (<2 m) glides that typically occur below cascades or riffles. These glides comprised 11% of the total habitat in Reach 4. These glides were not classified as pools because the areas of habitat below the cascades with sufficient depth to be classified as a pool were too small to meet the FHAP criteria. Tail-out areas in these glides downstream of the cascades or riffles were comprised largely of smooth, small cobbles.

In 2010, there were two large log jams located in Reach 4: one located in the second riffle, approximately 350 m upstream from the bridge along the southern bank of the creek; and one located approximately 900 m upstream from the bridge in the upstream-most riffle in the reach. This log jam was created by a bank failure at the corner of the existing mine site road nearest to the creek. In addition to trees, this bank failure has likely contributed significant sand and fine sediments to Lime Creek since it occurred. These sediments are likely carried swiftly downstream to Alice Arm during high flows as there is little evidence of channel aggradation or sedimentation in the pools anywhere in the creek.

The upper 350 m of the Reach 4 was unwalkable in 2010 due to the steep bedrock banks, and the concentrated, high velocity flow between bedrock banks and over and adjacent to the huge (>10 m diameter) boulders at the top of the reach. Habitat percentages for Reach 4 may not accurately reflect all of the available habitat as a result.

1.3.1.3.2 Upper Lime Creek

Habitat in Reach 5 of Lime Creek to the Patsy Creek confluence had a mean gradient of approximately 7% and flowed through a steep-sided bedrock canyon. Substrates in this canyon were comprised almost exclusively of bedrock and boulders. There were numerous boulder cascades with up to 2.5 m vertical drops.

Habitat in Reach 6 upstream of the Patsy Creek confluence was primarily cascades within a bedrock canyon. Boulder and bedrock substrates were dominant and there were numerous vertical drops over 1 m in height (Rescan 2010c). This reach ends at the base of a 2.5 m high vertical waterfall.

Habitat in Reach 7 could not be assessed on foot due to safety concerns in the steep canyon upstream of Reach 6. Based on helicopter surveys, habitat in Reach 7 appeared to be a steep (>7%) cascade with large boulders and bedrock vertical drops up to 2.5 m in height (Rescan 2010c).

Habitat in Reach 8 at the headwaters of the Lime Creek watershed was comprised of cascades and pools with primarily cobble and boulder substrates (Rescan 2010c). The average gradient in this headwater reach was lower than in Reach 7 downstream.

1.3.2 Patsy Creek

Habitat assessments in Patsy Creek are based on Reconnaissance (1:20,000) site cards conducted by Rescan in 2009 (Rescan 2010c). A summary of their results, by reach, is provided in Table 1.3-3 below. A summary of all Reconnaissance (1:20,000) site card habitat assessments conducted in Patsy Creek in 2009 is provided in Appendix A-1.

Habitat in Reach 1 of Patsy Creek was heavily influenced by slough and bank failures on the bank adjacent to the existing mine pit. Gradient in this reach was high (>15%) and habitat was predominantly step-pool habitat with boulder substrates. This reach had a mean channel width of approximately 15 m, a wetted width of approximately 7 m, and a bankfull depth of 1.2 m. The width of this channel precluded any canopy cover although the banks had mature conifer forest and shrubs in the form of alder bushes.

Habitat in Reach 2 of Patsy Creek was comprised of cascade-pools with cobble and boulder substrates. The average gradient in this reach is lower than in Reach 1 (5%) but there were numerous cascade drops up to 0.5 m in height in the section adjacent to the old mine pit. Bankfull width, wetted width, and bankfull depths were narrower and shallower than in Reach 1. This provided the reach with up to 40% canopy cover from the mature coniferous forest that existed along both banks.

Habitat in Reach 3 was heavily influenced by the former Patsy waste rock dump which runs adjacent to Patsy Creek over the entire length of this reach. This reach had a riffle-pool morphology with cobble and gravel substrates and mature coniferous forest on the bank opposite from the waste rock dump (Rescan 2010c). There was abundant large woody debris in this reach (Rescan 2010c).

Habitat in Reach 4 was comprised primarily of cascade-pools with cobble and boulder substrates. Gradient is approximately 5%. Mean channel and wetted widths were only 2 m and 1.5 m, respectively, and mean pool depth was only 0.2 m. Instream cover was moderate and was provided primarily from overhanging vegetation from the riparian shrubs that lined both banks. Canopy cover was up to 20% and was provided by mature coniferous forest.

Table 1.3-3: Summary of Reconnaissance (1:20,000) Site Card Habitat Assessments, by Reach, in Patsy Creek in 2009

Habitat Variable	Reach 1[a]	Reach 2[b]	Reach 4[c]
Dominant habitat type	Step-pool, boulder	Cascade-pool	Cascade-pool
Mean channel width (m)	14.7	7.3	2.0

Habitat Variable	Reach 1[a]	Reach 2[b]	Reach 4[c]
Mean wetted width (m)	7.1	3.4	1.5
Mean bankfull depth (m)	1.2	1.1	0.4
Residual pool depth (m)	0.6	0.5	0.2
Gradient (%)	15.5	5.5	5.0
Instream cover	Abundant	Abundant	Moderate
Dominant instream cover type	Boulder	Boulder	Overhanging veg.
Canopy cover (%)	0.0	20-40	1-20
Riparian cover type	Conifer forest / shrubs	Conifer forest	Shrubs
Dominant substrate type	Boulder	Cobble	Cobble
Subdominant substrate type	Cobble	Boulder	Boulder

Note: Based on Rescan reach break analysis of Patsy Creek in 2009; no habitat assessments were conducted in Reach 3 in 2009;

[a] based on data collected at Rescan site 612 (site 8 in current document; Figure 1.2-2)

[b] average of data collected at Rescan sites 111 and 112 (sites 9 and 10; Figure 1.2-2)

[c] based on data collected at Rescan site 104 (site 11; Figure 1.2-2)

Source: Rescan (2010c)

1.3.2.1.1 Patsy Lake Tributaries

Two of the Patsy Lake tributaries assessed in 2010 (sites 13 and 15 on ILPs 822 and 824, respectively) were non-classified drainages. The other three Patsy Lake tributaries were classified as either cascade-pool, step-pool or riffle-pool habitat. All three of these tributaries were rated as having none or poor overwintering habitat due to the lack of pools or the small residual pool depth (<0.3 m). Similarly, all three tributaries were rated as having poor rearing habitat due either to their small channel sizes (<1 m wide) and relative paucity of cover (<20%). None of these tributaries had spawning habitat for fish due to the lack of appropriately sized gravel substrates.

A summary of all Reconnaissance (1:20,000) site card habitat assessments conducted in the Clary Creek watershed in 2009 and 2010 is provided in Table 1.3-4. Photos of habitat in the Patsy Lake tributaries assessed in 2009 are provided in Appendix 3.2-2 of Rescan 2010c. Photos of habitat assessed in 2010 are provided in Appendix I-2.

Table 1.3-4: Summary of Habitat Characteristics for Inlet Tributaries of Patsy Lake, 2009 and 2010

Watershed Code	ILP	Reach ID	Map Site ID	Stream Order	Stream Classification	Stream Habitat	Mean Gradient	Mean BfW (m)	Mean WW (m)	Mean Res. Pool (m)	Mean BfD (m)	Stream Bed	Stream Cover	Habitat Quality[1]		
														Overwintering	Rearing	Spawning
910-929000-60300-72800		1	12	2	S4	Cascade-pool	4.7	1.3	1.0	0.15	0.47	Predominantly cobble with some fine	Cover 5-20%; Dominant - overhanging; Subdominant - boulder	P	P	N
	822	1	13	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	824	1	15	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
910-929000-60300-76100		1	16	1	S6	Step-pool	4.5	0.5	0.5	0.06	0.17	Predominantly fine with some cobble	Cover 5-20%; Dominant - undercut banks; Subdominant - overhanging	N	P	N
910-929000-60300-82400		1	14	1	S5	Riffle-pool	5.3	5.7	0.7	0.25	0.60	Predominantly fine with some cobble	Cover <5%; Dominant - instream vegetation; Subdominant - SWD	N	P	N

Note: * inferred, fish-bearing status not confirmed; m - metre; n/a - not applicable; NCD - non-continuous drainage; NVC - non-visible channel; SWD - small woody debris; LWD - large woody debris; BfW - bankfull width; WW - wetted width; Res.- residual; BfD - bankfull depth

[1] Habitat qualifiers: N - None; P - Poor; F - Fair; G - Good

1.3.2.2 Stream Temperatures

1.3.2.2.1 Upper Lime Creek

Mean, minimum, and maximum monthly water temperatures for upper Lime Creek (downstream of the Patsy Creek confluence) are provided in Table 1.3-5 and graphed in Figure 1.3-4. Mean monthly water temperatures were highest in August (10.9 degrees Celcius (°C)) and lowest in January (0.3°C). From June 2010 to May 2011, water temperatures in upper Lime Creek reached a maximum of 13.6 °C on 6 August 2010 and a minimum of 0.0°C on 19 February 2011. Mean daily water temperatures fluctuated the most in June (1.4°C) during the spring freshet and the least in December and January when the creek was almost frozen.

Table 1.3-5: Mean, Minimum, and Maximum Monthly Water Temperatures in Upper Lime Creek

Month	Minimum (°C)	Mean (°C)	Maximum (°C)	Mean Daily Fluctuation (°C)
January[1]	0.3	0.3	0.4	0.1
February[1]	0.4	0.5	0.6	0.2
March[1]	n.d.	n.d.	n.d.	n.d.
April[1]	n.d.	n.d.	n.d.	n.d.
May[1]	n.d.	n.d..	n.d.	n.d.
June[2]	5.7	6.4	7.2	1.4
July[2]	8.7	9.2	9.7	1.0
August[2]	10.7	10.9	11.2	0.5
September[2]	7.2	7.5	7.8	0.5
October[2]	4.4	4.7	4.9	0.5
November[2]	1.3	1.4	1.6	0.3
December[2]	0.6	0.6	0.7	0.1

Note: [1] Based on 2011 data
[2] Based on 2010 data
n.d. - no data; °C - degrees Celcius

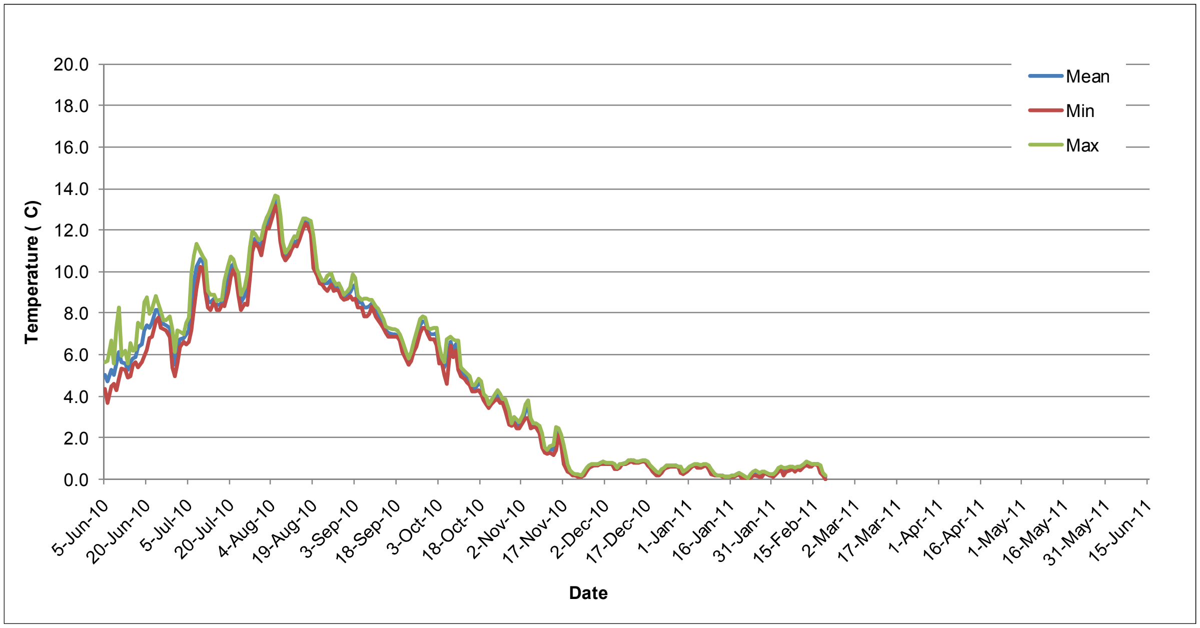


Figure 1.3-4: Water Temperature in Upper Lime Creek, 2010 / 2011

1.3.2.2.2 Patsy Creek

Mean, minimum, and maximum monthly water temperatures in Patsy Creek are provided in Table 1.3-6 and graphed in Figure 1.3-5. Mean monthly water temperatures were highest in Patsy Creek in August (9.4°C) in 2010. The temperature logger in Patsy Creek was exposed to air and frozen on 1 November and no data beyond this date was recorded. In 2010, water temperatures in Patsy Creek reached a maximum of 10.6 °C on 6 August. Water temperatures had reached 1.4°C by 31 October before the temperature logger was exposed to air. Mean daily water temperatures fluctuated the most in June (1.0°C) during the spring freshet.

The lower mean daily water temperatures in Patsy Creek compared to Upper Lime Creek indicate that Patsy Creek is cooler than Upper Lime Creek upstream of the Patsy Creek confluence. This is likely due to greater canopy cover over a longer proportion of the creek than in the headwaters of Lime Creek and the influence of Patsy Lake. Patsy Lake has a much larger thermal mass and slower thermal inertia than the headwater creeks in the southern portion of the Lime Creek watershed. Thus, water temperatures in Patsy Lake warm slower in spring, cool slower in fall, and fluctuate less daily compared to non-lake-headed, relatively open reaches of upper Lime Creek.

Table 1.3-6: Mean, Minimum, and Maximum Monthly Water Temperatures in Patsy Creek

Month	Minimum (°C)	Mean (°C)	Maximum (°C)	Mean daily fluctuation (°C)
January[1]	n.d.	n.d.	n.d.	n.d.
February[1]	n.d.	n.d.	n.d.	n.d.
March[1]	n.d.	n.d.	n.d.	n.d.
April[1]	n.d.	n.d.	n.d.	n.d.
May[1]	1.0	1.3	1.7	0.8
June[2]	6.3	6.8	7.3	1.0
July[2]	8.0	8.3	8.8	0.8
August[2]	9.1	9.4	9.7	0.6
September[2]	6.9	7.2	7.4	0.5
October[2]	4.0	4.5	4.9	0.9
November[2]	n.d.	n.d.	n.d.	n.d.
December[2]	n.d.	n.d.	n.d.	n.d.

Note: [1] Based on 2011 data
[2] Based on 2010 data
n.d. - no data; °C - degrees Celcius

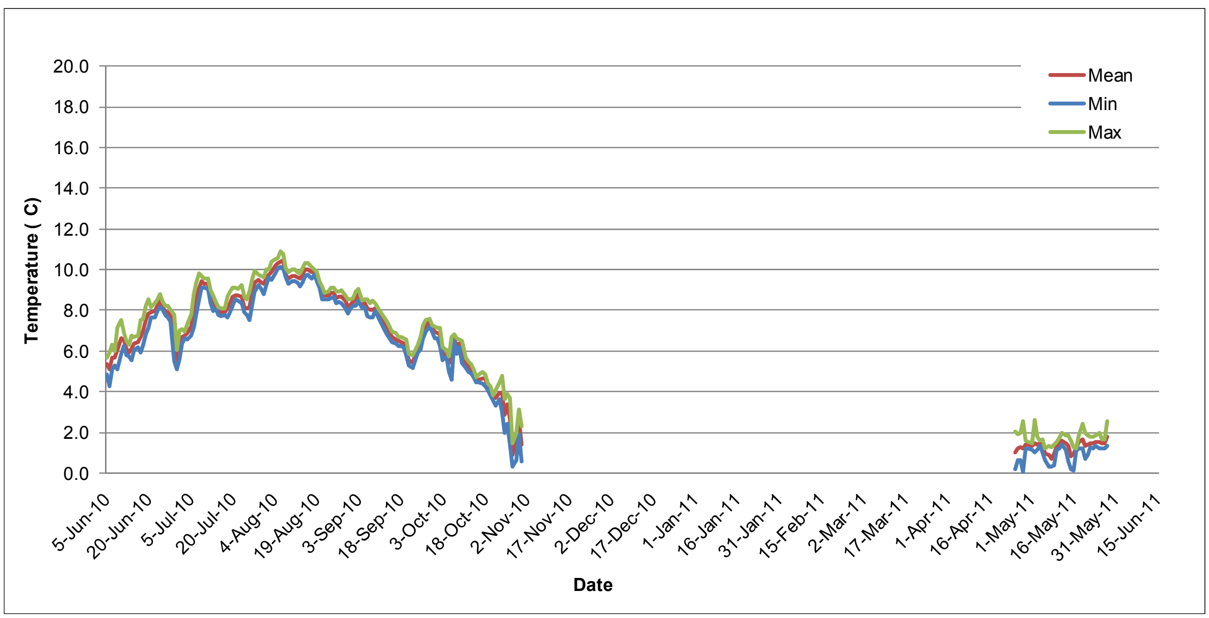


Figure 1.3-5: Water Temperatures in Patsy Creek, 2010 / 2011

1.3.2.2.3 Lower Lime Creek

Mean, minimum, and maximum monthly water temperatures in lower Lime Creek (downstream of the bridge crossing) are provided in Table 1.3-7 and graphed in Figure 1.3-6. Mean monthly water temperatures were highest in August (12.5°C) and lowest in January (0.3°C). In 2010, water temperatures in lower Lime Creek reached a maximum of 15.5 °C on 5 August. Water temperature first reached 0.0°C on 17 November 2010. Water temperature began to steadily rise on 4 March 2011. Mean daily water temperatures fluctuated the most in May and June (1.4°C) during the spring freshet and the least in January (0.2°C) when the creek was almost always near freezing. These are very low daily temperature fluctuations and indicate that fish in lower Lime Creek are exposed to relatively constant water temperatures throughout the day.

Table 1.3-7: Mean, Minimum, and Maximum Monthly Water Temperatures in Lower Lime Creek

Month	Minimum (°C)	Mean (°C)	Maximum (°C)	Mean daily fluctuation (°C)
January[1]	0.2	0.3	0.4	0.2
February[1]	0.5	0.7	0.8	0.3
March[1]	0.7	0.9	1.2	0.4
April[1]	2.2	2.7	3.1	0.9
May[1]	2.7	3.3	4.1	1.4
June[2]	7.5	8.2	8.9	1.4
July[2]	10.2	10.8	11.5	1.2
August[2]	12.0	12.5	13.0	1.0
September[2]	9.0	9.4	9.8	0.7
October[2]	5.1	5.3	5.5	0.5
November[2]	2.0	2.2	2.5	0.5
December[2]	0.5	0.7	0.8	0.3

Note: [1] Based on 2011 data
[2] Based on 2010 data
nd - no data; °C - degrees Celcius

Mean monthly water temperatures in lower Lime Creek were consistently warmer than water temperatures in Upper Lime Creek during the 2010 / 2011 season. This difference was highest in June (1.8°C difference) and September (1.9°C difference) during the spring freshet and start of fall rains, respectively. Lower Lime Creek was, on average, 1.6°C warmer in July and August than in upper Lime Creek. This gradual warming of water temperature moving downstream is typical of streams and is related to the increasing thermal input of tributaries, the greater exposure to the sun in widening downstream channels, and accumulated frictional heat. Despite this natural phenomenon, water temperatures in Lime Creek are relatively constant over the 7 km from the Patsy Creek confluence to the mouth at Alice Arm.

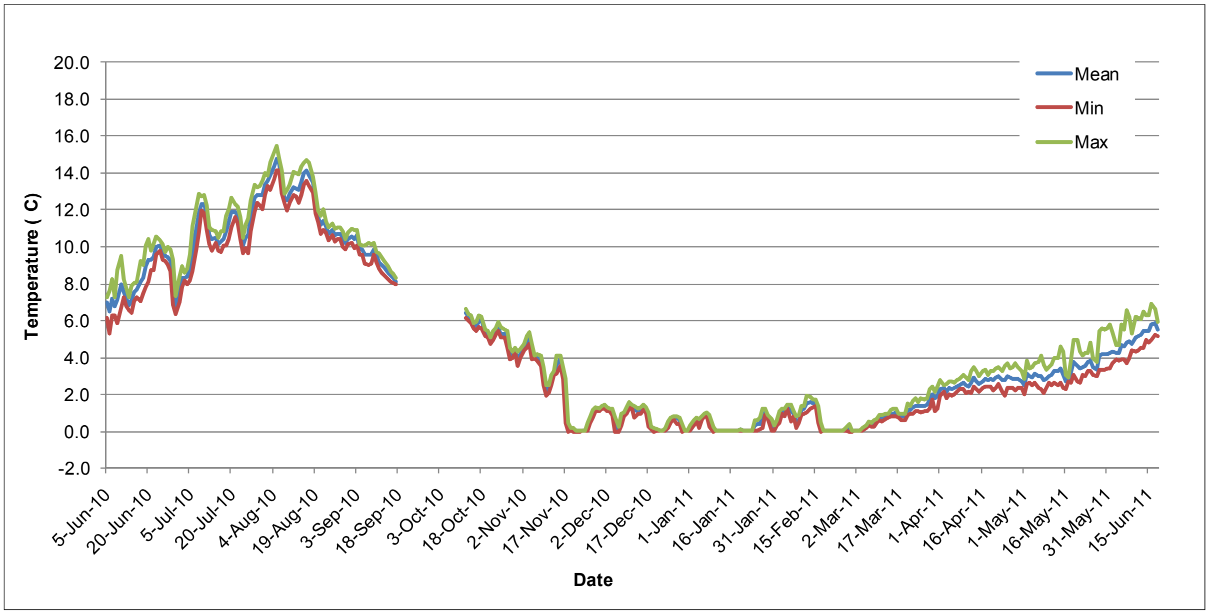


Figure 1.3-6: Water Temperature In Lower Lime Creek, 2010 / 2011

1.3.3 Clary Creek Watershed

1.3.3.1 General Description of Watershed

The Clary Creek watershed is adjacent and north of the Lime Creek watershed. Clary Creek is a tributary of the Illiance River with its confluence located approximately 1.2 km upstream from Alice Arm. Overall, the Clary Creek mainstem (WSC 910-929800-05800) is approximately 9 km long (FISS 2011) and flows in a northwest direction to the Illiance River. Elevations in the watershed range from about 1060 masl in the southern portion of the watershed to approximately 35 masl at the confluence of Clary Creek and the Illiance River (Knight Piésold 2011).

The total watershed area is approximately 33,700km^2. The watershed physiography is relatively broad and flat in the headwater plateau areas. However, the numerous headwater lakes that exist in the upper portion of the Clary Creek watershed are typically drained by high gradient channels with steep >20% bedrock cascades or >3 m high waterfalls as the water flows down off the plateaus. Many of the streams draining the headwater lakes flow through confined, bedrock canyons as they flow downstream to Clary Lake.

Clary Lake is the largest lake in the watershed, having a maximum depth of 47 m and a total surface area of 419,274 m^2. Clary Lake is the collection point for run-off from two separate headwater areas of the Clary Creek watershed. The first sub-watershed drains an area of approximately 17,092 km^2 and enters Clary Lake at its small northern basin. This sub-watershed includes numerous unnamed lakes including several with surface areas <100,000 m^2 and water depths <15 m (Rescan 2010a). The second sub-watershed drains an area of approximately 9,700 km^2 and enters Clary Lake at the southern end of its main southern basin. This tributary is actually the continuation of Clary Creek upstream of Clary Lake according to provincial 1:50,000 scale watershed coding.

This tributary (i.e., Clary Creek) drains the sub-watershed that includes Killam Lake at its headwaters and the previously unnamed lakes, Lake 493 and Lake 901, to Clary Lake. Killam Lake drains into Lake 493. The outlets of Lake 493 and Lake 901 meet downstream of the existing Alice Arm Road, approximately 1 km upstream from Clary Lake. Downstream of this confluence, Clary Creek flows through a steep (approximately 15% gradient) bedrock canyon that is likely an impediment to upstream fish migration in this sub-watershed. Downstream of this canyon, the gradient of Clary Creek decreases to approximately 8% as the creek braids into multiple boulder / cobble channels in an approximately 400 m long, 800 m wide delta.

Downstream of Clary Lake, Clary Creek flows west for approximately 5 km before turning north toward the Illiance River. There are numerous small (<3 m high) falls and cascades and the creek receives additional inflow from numerous second and third order streams in the first 4 km downstream of Clary Lake. The creek then enters an approximately 3.5 km long canyon that ends at a 35 m high waterfall approximately 250 m upstream from the confluence of Clary Creek with the Illiance River. The waterfall is the upstream limit for anadromous salmonids (e.g., steelhead, Chinook salmon, coho salmon, chum salmon, pink salmon) and Dolly Varden in the Illiance River.

1.3.3.2 Reach Break Analysis

Reach 1 of Clary Creek is the short (approximately 250 m) section between the confluence of Clary Creek and the Illiance River and the beginning of the 35 m high waterfall at the downstream end of the Clary Creek canyon. Reach 2 begins at the top of this waterfall and extends approximately 3.5 km upstream. This reach is a steep (approximately 16% mean gradient) bedrock canyon. Reach 3 extends from the top of Reach 2 to the confluence of the natural and constructed outlet channels of Clary Lake. The constructed outlet channel was made during the 1970s when Clary Lake was dammed in order to increase water levels and storage capacity for freshwater use during the first mine operation at Kitsault. This outlet drains out of the main southern basin of Clary Lake. The natural Clary Lake outlet exits Clary Lake from its smaller, northern basin. Reach 3 is approximately 3.2 km long with a mean gradient of approximately 2.4%. This is the reach that receives most of the additional run-off from the numerous smaller tributaries downstream of Clary Lake. Reach 4 is the approximately 700 m of the natural Clary Lake outlet. This reach has a lower gradient (approximately 1.7%) than all other reaches of Clary Creek downstream of Clary Lake. Clary Lake is Reach 5 in the Clary Creek watershed.

Reach break analysis upstream of Clary Lake was only conducted in the sub-watershed drained by Clary Creek (i.e., the sub-watershed that includes Killam Lake, and lakes 493 and 901). Reach 6 of Clary Creek extends from Clary Lake approximately 400 m upstream to the beginning of a steep, bedrock canyon. This reach includes just one of the multiple boulder / cobble channels that exist in the delta of Clary Creek as it exits the canyon. Reach 7 extends from the bottom of the bedrock canyon upstream to the confluence of the Lake 493 and Lake 901 outlet confluence. Reach 8 extends from this confluence upstream to the outlet of Lake 493. Reach 9 is Lake 493 while Reach 10 is the outlet of Killam Lake where it enters into Lake 493. Reach 11 is Killam Lake.

Reach 1 of the Clary Creek tributary (WSC 910-929800-05800-76800) draining Lake 901 to Clary Creek is approximately 325 m long and extends from the confluence of the Lake 901 and Lake 493 confluence upstream to Lake 901. Reach 2 of this tributary is Lake 901. Reach 3 extends from Lake 901 approximately 250 m upstream to where the mean gradient increases from approximately 3% in Reach 3 to approximately 11% in Reach 4. Reach 4 extends 270 m from the top of Reach 3 to the base of the 25 m long, 20% gradient bedrock constricted cascade. Reach 5 begins at the top of this cascade and extends approximately 1.5 km through a relatively flat (3 to 4% gradient) meadow on the plateau along the north side of Patsy Lake. Reach 6 is the short approximately 150 m) section extending from the top of Reach 5 to the top of this Clary Creek tributary. Gradient in this short reach increases to approximately 33% as the creek flows down the steep embankment to the north of Patsy Lake.

The length, mean gradient and a brief description of the reaches in Clary Creek are presented in Table 1.3-8. The longitudinal gradient profiles of Clary Creek from the waterfalls upstream of the confluence with the Illiance River to Clary Lake of and from Clary Lake to Lake 493 are shown in Figure 1.3-7and 1.3-8 respectively. The longitudinal gradient profile of the Clary Creek tributary draining Lake 901 to Clary Creek, from its confluence with the Lake 493 outlet to its headwaters is shown in Figure 1.3-9.

Table 1.3-8: Reach Descriptions in the Clary Creek Watershed

Stream	Reach #	Stream Order[1]	Reach Length (km)	Approximate Reach Gradient (%)	Reach Description
Clary Creek	1		0.25	6.7	Extends upstream from the confluence with the Illiance River to the 35 m high waterfall, the upstream limit of anadromous fish in Clary Creek
	2		3.50	15.8	Steep bedrock canyon
	3		3.20	2.4	Extends from top of canyon upstream to confluence of the two Clary Lake outlet channels
	4		0.75	1.7	The natural outlet channel of Clary Lake
	5			0.0	Clary Lake
	6		0.40	7.5	Multi-channeled delta area of Clary Creek between Clary Lake and the bedrock canyon downstream of the Lake 901 and Lake 493 outlets confluence

Stream	Reach #	Stream Order[1]	Reach Length (km)	Approximate Reach Gradient (%)	Reach Description
	7		0.51	13.0	Steep, bedrock confined canyon with cascades and numerous drops in excess of >2 m high
	8		0.34	5.0	Lake 493 outlet from Lake 493 to the confluence with the Lake 901 outlet
	9		–	0.0	Lake 493
	10		_1.28_	_4.9_	Killam Lake outlet
	11		–	0.0	Killam Lake
Clary Creek Tributary	1	3	0.35	1.3	The Lake 901 outlet extending from Lake 901 downstream to the confluence with the Lake 493 outlet
	2	3	–	0.0	Lake 901
	3	3	0.25	5.5	Inlet to Lake 901 extending from Lake 901 upstream to the gradient change
	4	3	0.26	17.1	Inlet to Lake 901 extending from the top of Reach 3 to the bottom of the 20% bedrock cascade. This cascade is the first impediment to fish passage in this tributary
	5	2	1.6	4	Extends from top of cascade through low gradient meadow on the Patsy Lake plateau; located to the north of Patsy Lake
	6	1	0.15	33	High gradient reach at the top of the tributary draining of the escarpment north of Patsy Lake onto the Patsy Lake plateau

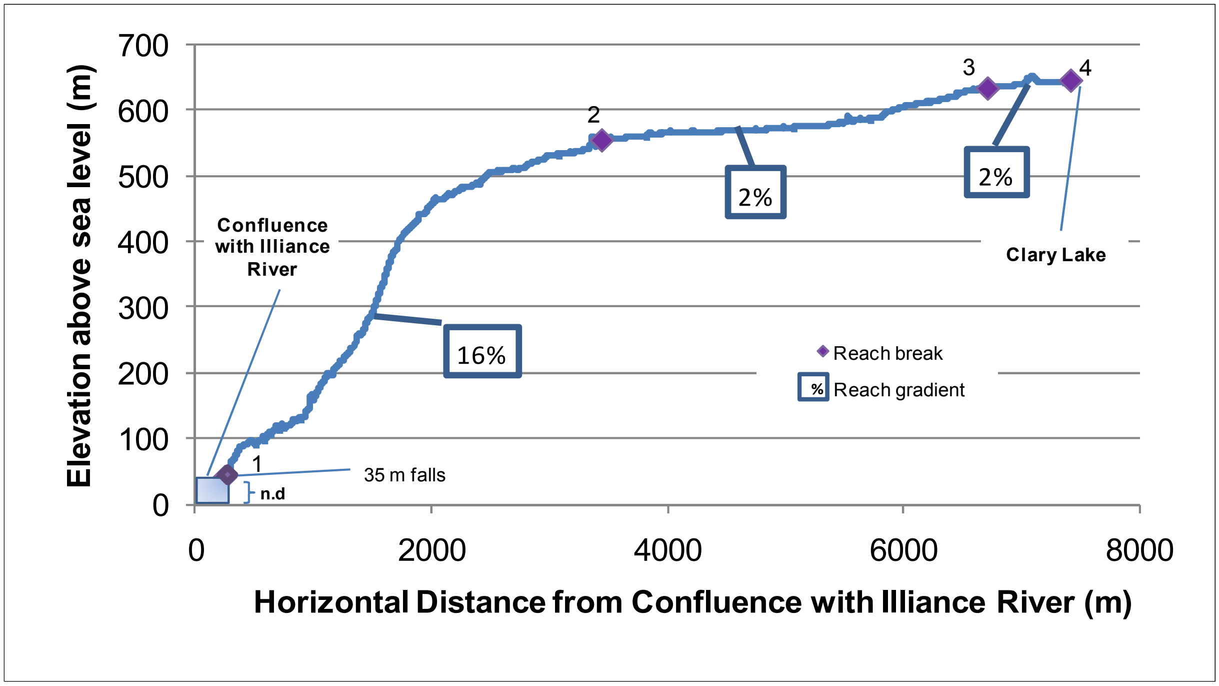


Figure 1.3-7: ***Stream Gradient Profile of Clary Creek from the Waterfalls, 250 m Upstream of the Confluence with the Illiance River, to Clary Lake***

Note: (n.d. LiDAR data not available)

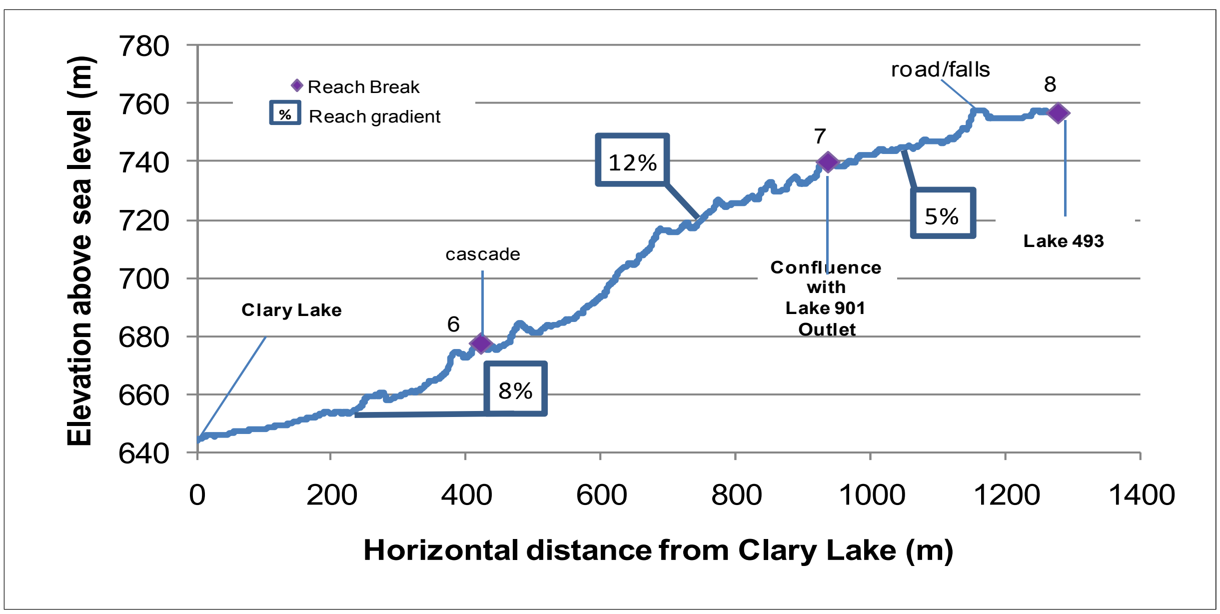


Figure 1.3-8: ***Stream Gradient Profile of Clary Creek from Clary Lake to Lake 493***

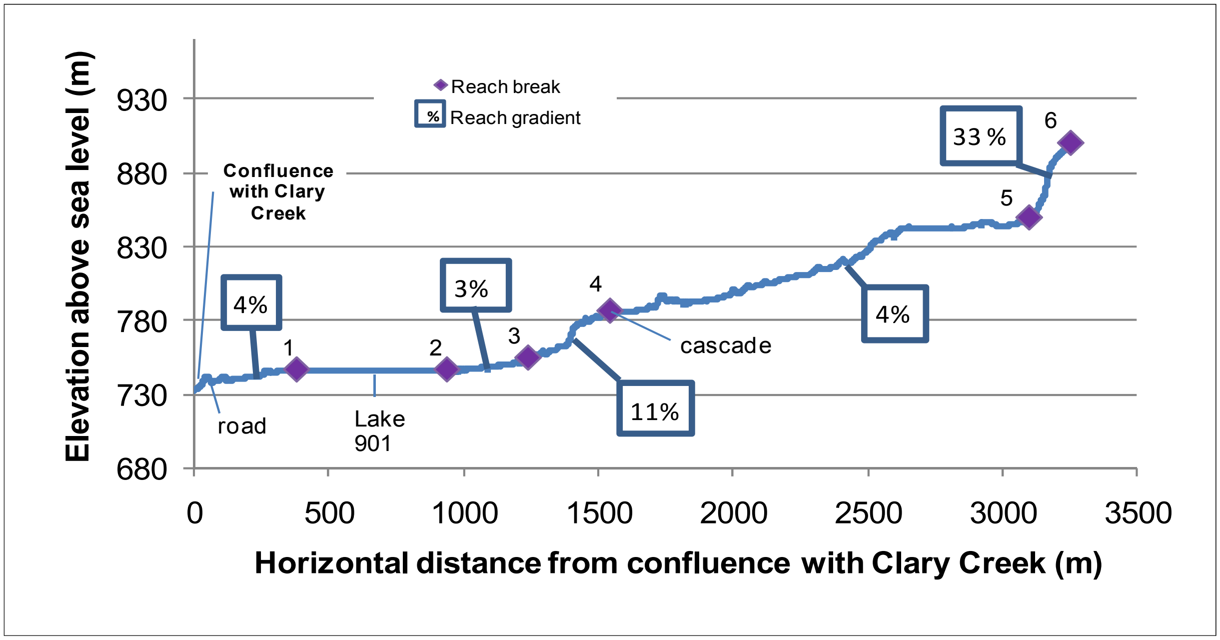


Figure 1.3-9: Stream Gradient Profile of Clary Creek Tributary (WSC 910-929800-05800-76800) from its Headwaters to its Confluence with Lake 493 Outlet

1.3.3.3 Habitat Classification and Mapping

1.3.3.3.1 Clary Creek

An FHAP habitat assessment was conducted in June 2010 in Reach 6 of Clary Creek from Clary Lake upstream to approximately 150 m into the canyon at the bottom of Reach 7. During this assessment, water levels in the channels in Reach 6 dropped quickly as water began to flow sub-surface into the course sediments of the delta at the bottom of Clary Creek as it enters into Clary Lake. It was obvious during the survey that there was considerable lateral movement of water from one channel to adjacent channels moving downstream. As a result, the original channel where the FHAP was started ran dry during the survey approximately 130 m upstream from the lake. However, the next adjacent channel had flow from this point upstream to the top of Reach 6. This second channel went dry in its lower 130 m over a 4 hour period. However, sufficient water was present in the channels during the survey to conduct the FHAP surveys in both channels.

A map of the habitat types in Reach 6 and 7 of Clary Creek upstream of Clary Lake presented in Figure 1.3-10. A summary of the habitat characteristics in Clary Creek, by reach, is provided in Table 1.3-9. Photos of habitat in these reaches of Clary Creek are presented in Appendix I-3.

Habitat in Reach 6 was comprised of cascades (33%) and riffles (45%) with angular small and large cobbles. Cover for fish in these two habitat types was provided by boulders, small and large woody debris, and some instream vegetation. There were numerous small log jams present in this reach of Clary Creek. Mean gradients in these two habitat types were

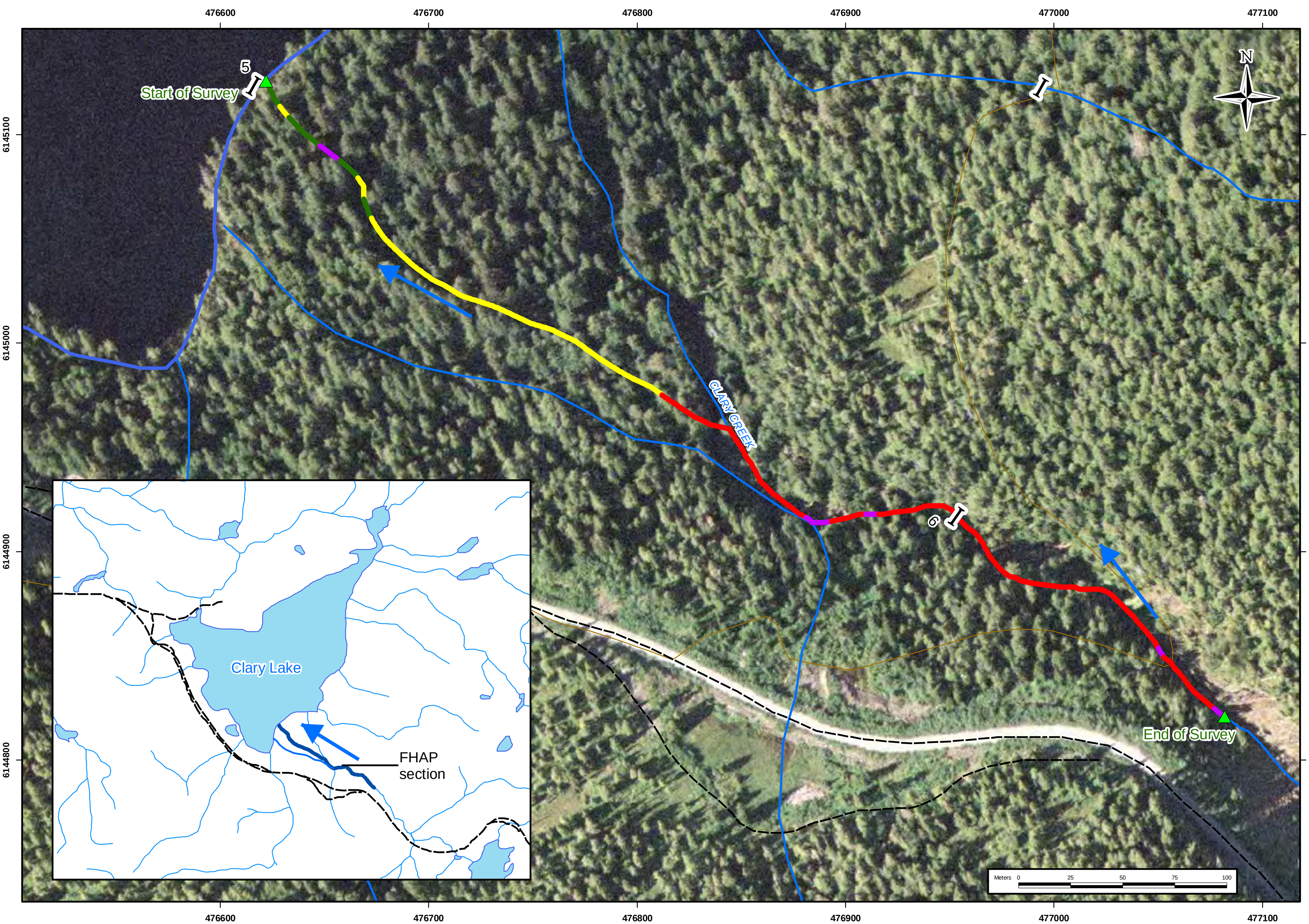
5% and 2%, respectively. Glide habitat (14%) and pool habitat (8%) were also present in Reach 6. Residual pool depths were, on average, 0.8 m deep. Substrates in the glides were comprised of fines with large gravels while substrates in the pools were comprised of large cobbles with fines. The dominant cover types in these two habitats were large woody debris, and deep pool with large woody debris, respectively.

Habitat in Reach 7 was limited to cascades and pools. Cascades comprised over 90% of the total habitat in this reach while pools comprised the remaining 6%. Substrates in the cascades were comprised of large angular cobbles and boulders. These boulders provided most of the cover available to fish. Cover in the pools was provided by depth and boulders. The north bank of Reach 7 in the section assessed was comprised of an almost vertical bedrock face. The south bank of Reach 7 in this section was comprised of shrubs and herbs under the canopy of a mature coniferous forest. A secondary over-flow channel was present behind and adjacent to the south bank of the main channel. This channel was dry during the survey but would convey over-flow parallel to the mainstream channel during high flows and would distribute water into a myriad of rocky channels in the forested southern portion of the Clary Creek delta.

Table 1.3-9: Habitat Summary, by Reach, in Clary Creek

Reach	Habitat Type	Total Length (m)	Habitat Type (%)	Gradient (%)	Mean Depth (m)	Mean Bankfull Width (m)	Mean Wetted Width (m)	Mean Pool Residual Depth (m)	Dominant / Subdominant Substrate Type	Dominant / Subdominant Cover Type	Dominant Riparian Type
6		**406**	**100**			**17.0**	**4.0**				
	Cascade	135	33	5.0	0.23	15.0	4.3		Small Cobble / Large Cobble	Boulder / instream veg.	Mature Coniferious Forest
	Glide	56	14	1.0	0.29	8.6	3.0		Fines / Large gravel	LWD / instream veg.	Mature Coniferious Forest
	Pool	31	8	1.0	0.77	19.0	6.1	0.8	Large Cobble / Fines	Deep pool / LWD	Mature Coniferious Forest
	Riffle	184	45	2.0	0.16	40.0	2.3		Small Cobble / Large Cobble	SWD / LWD	Mature Coniferious Forest
7		**186**	**100**			**8.8**	**4.2**				
	Cascade	175	94	5.5	0.31	10.8	3.9		Large Cobble / Boulder	Boulder	Mature Coniferious Forest
	Pool	11	6	1.0	0.75	6.8	4.5	0.7	Small Cobble / Large gravel	Deep Pool	Mature Coniferious Forest

Note: For each reach, summary of total length and mean widths presented in grey
LWD - large woody debris; m - metre; % - percent; SWD - small woody debris



Reference

Base Data
1. Land and Resource Data Warehouse 1:20,000 (TRIM)]

FHAP means Fisheries Habitat Assessment Procedure

Legend
- I Reach Break
- Cascade
- Glide
- Pool
- Riffle
- Survey Start/End Point
- Flow Direction
- Road
- Stream
- River and Lake

CLIENT: Avanti Kitsault Mine Ltd.

AMEC Earth & Environmental
4445 Lougheed Highway, Burnaby, B.C., V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

ANALYST:	MY
QA:	PD
DATUM:	NAD83
PROJECTION:	UTM 09
SCALE:	1:2,500

PROJECT: Kitsault Mine Project

TITLE: FHAP Habitat Units in Clary Creek 2010

REV. NO.:	A
DATE:	May 2011
PROJECT NO:	VE51988
FIGURE No.	1.3-10

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1.3.3.3.2 Lake 901 Inlet

A map of the habitat types in Reaches 3 and 4 of the Clary Creek tributary (910-929800-05800-76800) between Lake 901 and approximately 200 m downstream of the cascade impediment to fish passage is presented in Figure 1.3-11. A longitudinal profile of this main inlet tributary of Lake 901 is provided in Figure 1.3-9. A summary of the habitat characteristics in this Lake 901 tributary, by reach, is provided in Table 1.3-10. Photos of habitat in these reaches are presented in Appendix I-4.

Habitat in Reach 3 was comprised of riffles (55%), glides (32%), and pools (14%). Riffles were, on average, 0.3 m deep and 2.5 m wide with small gravel and large gravel substrates. These riffles would provide excellent spawning habitat for rainbow trout from Lake 901. Substrates in the glides were small cobbles with large gravel. Pools were typically below riffles and, on average, had a residual pool depth of 0.6 m. Substrates in the pools were fines with small cobbles. Cover for fish in all three habitat types in Reach 3 was provided by abundant functional large woody debris and undercut banks. Riparian vegetation on both banks in Reach 3 was provided by an understory of shrubs and a mature coniferous forest.

Only the lower 175 m of habitat in Reach 4 was assessed as the channel was dry or restricted to interstitial flow between the large cobble substrates upstream of this point during the survey. Habitat in this lower section of Reach 4 was limited to riffles and pools. Riffles comprised 97% of the total habitat in this reach due to the increasing stream gradient and the armouring of the channel by small angular cobbles and large gravels. Mean gradient in the entire reach to the cascade was approximately 17% but the local gradient of the riffles in the section of habitat assessed was, on average, only 6%. Cover for fish in these riffles was provided by large angular boulders and the occasional small woody debris piece. Pools comprised only 3% of the habitat in the section of Reach 4 assessed. On average, these pools had a residual pool depth of 0.3 m and had small cobble and small gravel substrates. Cover for fish in these few pools was provided by small woody debris and undercut banks. Mature coniferous forest provided canopy cover and riparian vegetation along both banks.

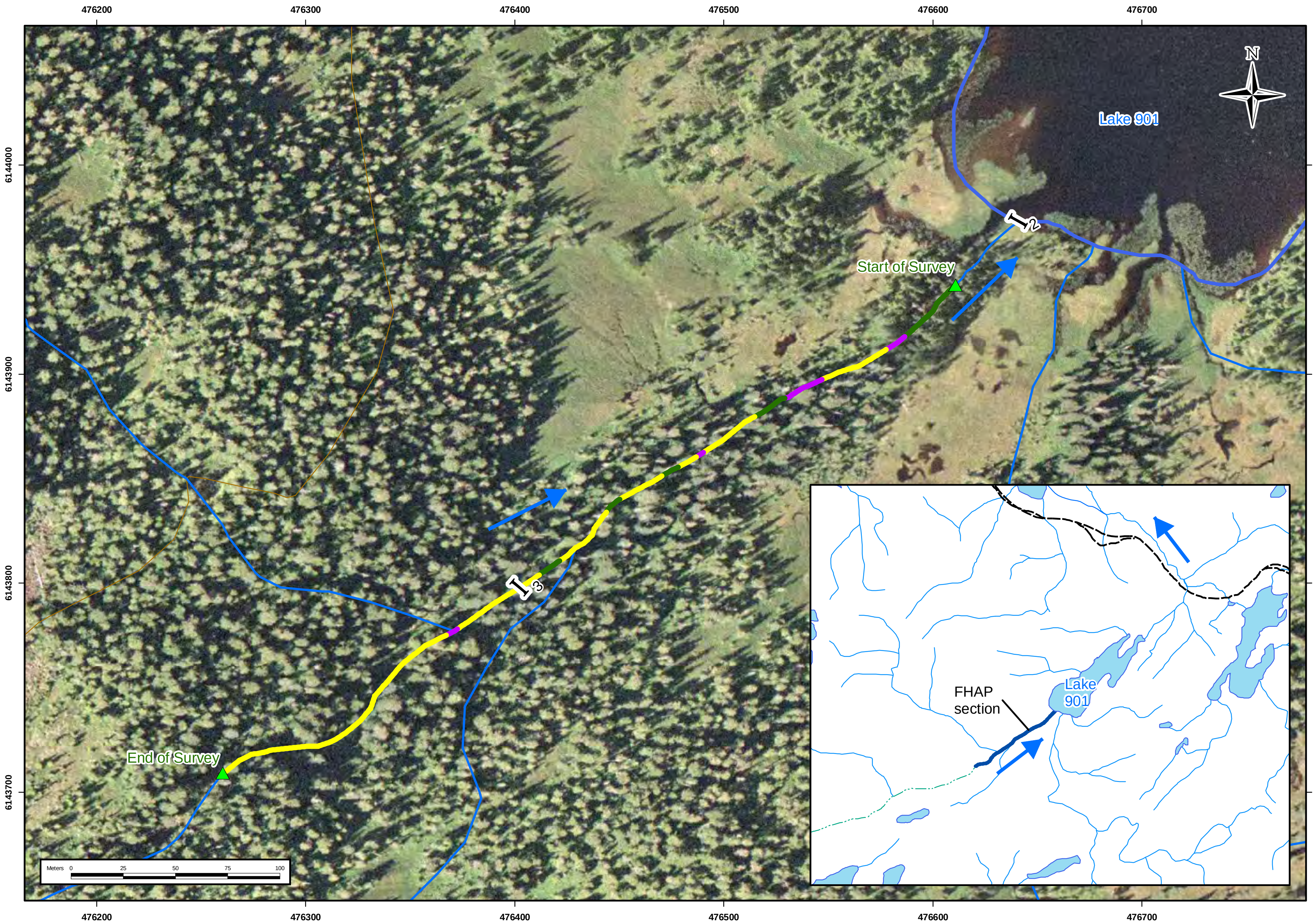
Habitat in reach 5, upstream of the cascade was comprised of riffle-pool habitat with gravels and large woody debris. In the first 150 m upstream from the cascade, the creek flowed through a low gradient meadow on the Patsy Lake plateau. The channel here was, on average, 2.4 m wide with a bankfull depth of approximately 0.3 m and a residual pool depth of approximately 0.4 m. Substrate in this lower section of the reach was comprised primarily of small gravels and cobbles. Cover was abundant (>20%) and was provided by large woody debris and undercut banks. Overwintering habitat here was poor due to shallow pool depths but the rearing habitat was good. Spawning habitat for rainbow trout was present if they were able to ascend the cascade at the top of Reach 4.

Reconnaissance (1:20,000) site cards were filled out for a site in Reach 3 of this same Lake 901 inlet downstream of the cascade (Site 19), in reach 5 upstream of the cascade (Site 20), and for a site in Reach 1 in the Lake 901 outlet (Site 18) (Table 1.3-11). Habitat at sites 19 and 18 is not discussed further because FHAP assessments were also conducted in these reaches. A summary of all Reconnaissance (1:20,000) site card habitat assessments conducted in the Clary Creek watershed in 2010 is provided in Appendix H-1.

Table 1.3-10: Habitat Summary, by Reach, in the Clary Creek Tributary (910-929800-05800-76800) Draining Into or Out of Lake 901

Reach	Habitat Type	Total Length (m)	Habitat Type (%)	Gradient (%)	Mean Depth (m)	Mean Bankfull Width (m)	Mean Wetted Width (m)	Mean Pool Residual Depth (m)	Dominant / Subdominant Substrate Type	Dominant / Subdominant Cover Type	Dominant Riparian Type
1		**326**	**100**	**1.3**		**5.9**	**2.8**				
	Glide	112	34		0.3	6.5	2.7		Small Cobble / Fines	Boulder / Overhanging veg.	Mature Coniferous Forest
	Pool	23	7		0.5	7.4	4.0	0.6	Fines / Small Cobble	Deep pool / LWD	Mature Coniferous Forest
	Riffle	191	59		0.1	4.7	2.2		Small Cobble / Large Cobble	Boulder / Overhanging veg.	Mature Coniferous Forest
3		**258**	**100**	**5.5**		**5.4**	**2.8**				
	Glide	82	32	1.8	0.3	5.7	2.6		Small Cobble / Large gravel	LWD / undercut bank	Mature Coniferous Forest
	Pool	35	14	1.5	0.5	5.9	3.8	0.6	Fines / Small Cobble	LWD / undercut bank	Mature Coniferous Forest
	Riffle	141	55	2.0	0.3	4.8	2.5		Small Gravel / Large Gravel	LWD / undercut bank	Mature Coniferous Forest
4		**174**	**100**	**17.0**		**6.4**	**2.0**				
	Pool	6	3	2.0	0.6	5.0	2.3	0.3	Small Cobble / Small gravel	SWD / undercut bank	Mature Coniferous Forest
	Riffle	168	97	5.5	0.2	7.2	1.9		Small Cobble / Large gravel	Boulder/SWD	Mature Coniferous Forest

Note: For each reach, summary of total length and mean widths and gradients are presented in grey
LWD - large woody debris; m - metre; % - percent; SWD - small woody debris



Reference

Base Data
1. Land and Resource Data Warehouse 1:20,000 (TRIM)

FHAP means Fisheries Habitat Assessment Procedure

Legend
- Reach Break
- Cascade
- Glide
- Pool
- Riffle
- Survey Start/End Point
- Flow Direction
- Road
- Stream
- River and Lake

CLIENT
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ANALYST:	MY
QA:	PD
DATUM:	NAD83
PROJECTION:	UTM 09
SCALE:	1:2,500

PROJECT
Kitsault Mine Project

TITLE
FHAP Habitat Units in Lake 901 Inlet 2010

REV. NO.:	A
DATE:	May 2011
PROJECT NO:	VE51988
FIGURE No.	1.3-11

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Table 1.3-11: Summary of Habitat Characteristics for Inlet Tributaries and Outlet of Lake 901, 2010

Watershed Code	ILP	Reach ID	Map Site ID	Stream Order	Stream Classification	Stream Habitat	Mean Gradient	Mean BfW (m)	Mean WW (m)	Mean Res. Pool (m)	Mean BfD (m)	Stream Bed	Stream Cover	Habitat Quality[1]		
														Overwintering	Rearing	Spawning
910-929800-05800-76800		1	18	4	S2	Riffle-pool	2.5	5.2	2.4	0.36	0.97	cobbles and bedrock	Cover 5-20%; Dominant - boulder; Subdominant - overhanging	P	G	P
910-929800-05800-76800		3[a]	19	3	S2	Riffle-pool with cobble / LWD	1.5	5.7	2.3	0.38	0.77	cobbles with fines	Cover >20%; Dominant - SWD; Subdominant - LWD	P	G	G
910-929800-05800-76800		5[b]	20	2	S4*	Riffle-pool with gravel / LWD	8.3	2.4	2.3	0.44	0.27	gravels with cobbles	Cover >20%; Dominant - LWD; Subdominant - undercut banks	P	G	F
	883	1	22	1	S4*	Riffle-pool with cobbles / LWD	8.5	1.7	0.8	0.29	0.60	cobbles with fines	Cover >20%; Dominant - overhanging; Subdominant - instream vegetation and LWD	N	P	P
	884	1	24	2	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	886	1	26	1	S3	Step-pool	1.5	3.5	1.2	0.41	0.97	fines with cobbles	Cover <5%; Dominant - deep pool; Subdominant – overhanging vegetation	N	P	P
	887	1	25	3	S3	Riffle-pool with cobbles / LWD	10.3	4.7	2.1	0.30	1.10	cobbles with gravels	Cover >20%; Dominant - SWD; Subdominant - LWD	P	G	G

Note: * inferred, fish-bearing status; BfD - bankfull depth; BfW - bankfull width; LWD - large woody debris; n/a - not applicable; NCD - non-continuous drainage; NVC - non-visible channel; SWD - small woody debris; WW - wetted width; Res.- residual; % - percent

[1] Habitat qualifiers: N - None; P - Poor; F - Fair; G - Good

[a] downstream of cascade impediment to fish passage

[b] upstream of cascade impediment to fish passage

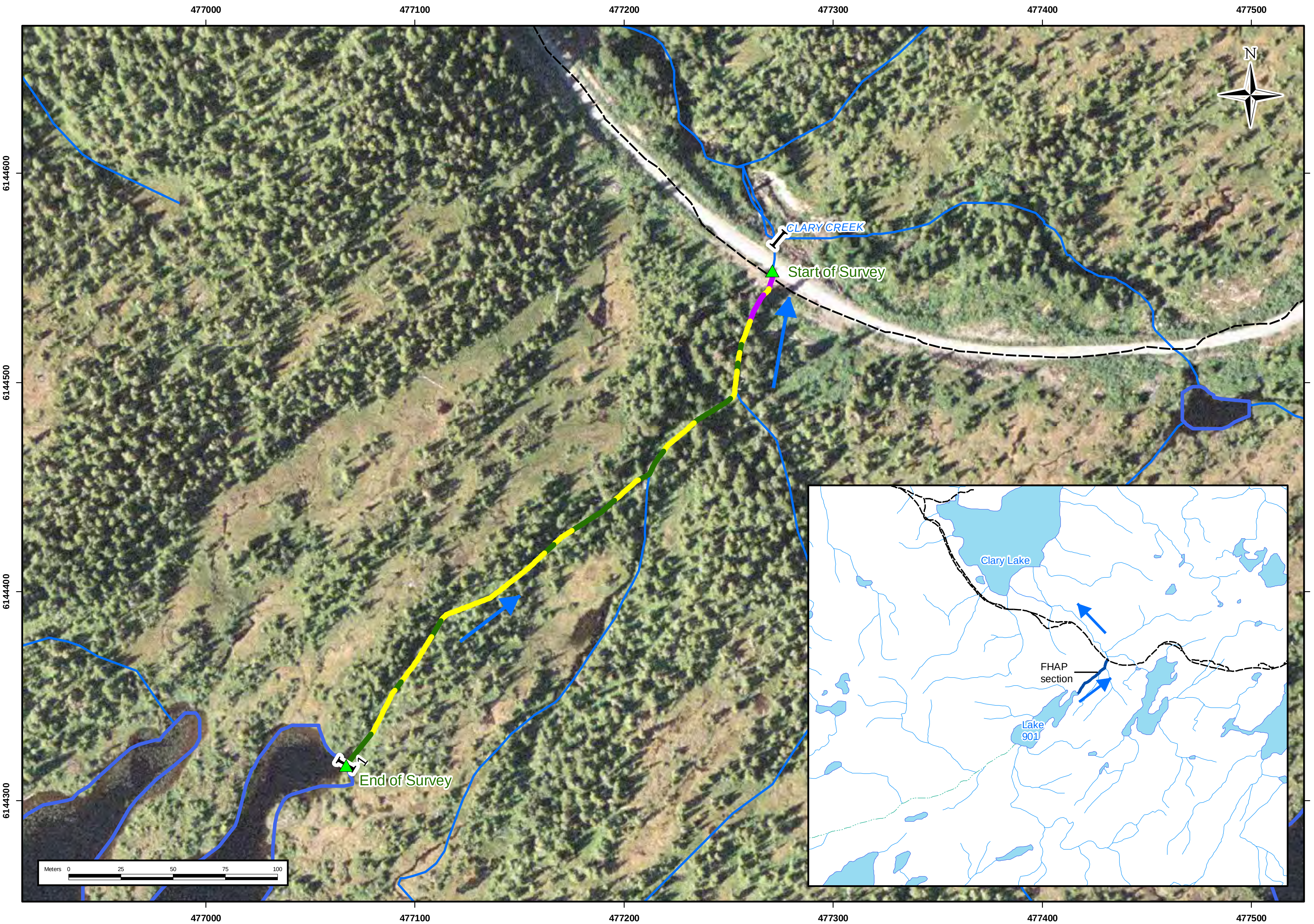
1.3.3.3.3 Lake 901 Outlet

A map of the habitat types in Reach 1 of the Clary Creek tributary (910-929800-05800-76800) between Lake 901 and the road crossing at the existing Alice Arm Road is presented in Figure 1.3-12. A summary of the habitat characteristics in the Lake 901 outlet, by reach, is provided in Table 1.3-10. Photos of habitat in these reaches are presented in Appendix I-2.

Habitat in the Lake 901 outlet was comprised of riffles (59%), glides (34%), and pools (7%). Riffles were, on average, <0.2 m deep with small and large angular cobble substrates. Glides were deeper (0.3 m on average) than riffles and had small angular cobbles with embedded fines. Cover for fish in these riffles and glides was provided behind boulders and overhanging vegetation. Pools were infrequent and small in this reach. Residual pool depths were, on average, 0.6 m deep and pool widths were, on average, 4.0 m wide. Substrates in these pools were comprised of fines with small cobbles. Cover in the pools was provided by depth and large woody debris.

While mature coniferous forest was present on both banks of the creek in this reach, these trees were often elevated above the channel due to the frequent high (>3 m) bedrock outcrops that formed the large majority of the bank types on both sides of the creek. In the few places the creek widened outside of these bedrock banks, shrubs, devil's club, skunk cabbage, and mosses dominated the riparian floodplain.

There is no spawning habitat for rainbow trout in this reach of the Clary Creek tributary (Table 1.3-11). This is because there are no gravels present anywhere in the reach, neither in the riffles or in the glides that rainbow trout would use to spawn if suitable gravels were present. The angular cobble substrates that dominate the substrates in this reach precludes rainbow trout from making the redds they need to spawn.



Reference

Base Data
1. Land and Resource Data Warehouse 1:20,000 (TRIM)

FHAP means Fisheries Habitat Assessment Procedure

Legend
- Reach Break
- Cascade
- Glide
- Pool
- Riffle
- Survey Start/End Point
- Flow Direction
- Road
- Stream
- River and Lake

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ANALYST:	MY
QA:	PD
DATUM:	NAD83
PROJECTION:	UTM 09
SCALE:	1:2,500

PROJECT
Kitsault Mine Project

TITLE
FHAP Habitat Units in Lake 901 Outlet 2010

REV. NO.:	A
DATE:	May 2011
PROJECT NO:	VE51988
FIGURE No.	1.3-12

Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-063.mxd

1.3.3.3.4 Lake 901 Tributaries

Habitat in the three smallest inlet tributaries of Lake 901 provided low habitat quality for rainbow trout (Table 1.3-11). These included sites in ILPs 883, 884, and 886. ILP 883 was a small (0.8 m mean wetted width), shallow (mean bankfull depth 0.6 m) channel incised into the erodible sediments along the northwestern shore of Lake 901. The first 10 m of ILP 883 was lake influenced but the creek then increased steeply (8.5% mean gradient) up the lake banks. There was a large tree approximately 40 m upstream from the lake that created an approximately 1.8 m high vertical drop. Above this, the creek gradient levelled as it drained a flat meadow on the north side of the lake. There was no overwintering habitat in ILP 883 and only poor rearing and spawning habitat for rainbow trout due to the paucity of suitable gravels and riffles. ILP 884 was a non-classified drainage and provided no fish habitat.

The first 30 m of ILP 886 were lake influenced and had abundant instream vegetation and erodible banks with willows. This creek then decreased in width and depth as it turned into a short (20 m) step-pool stream with cobble substrates embedded with fines. Cover for fish was provided predominantly by overhanging willows and undercut banks. The gradient of the creek then decreased as the creek meandered through a flat meadow area. Here the creek widened and deepened into a U-shaped channel with fine organic sediments. Approximately 400 m upstream from the lake, ILP 886 enters a narrow (<4 m bankfull width) V-shaped bedrock constricted channel with boulder / bedrock substrates. There is very poor spawning habitat in ILP 886 for rainbow trout due to the paucity of suitable gravels in the few riffles that exist.

ILP 887 is the second largest inlet tributary of Lake 901 (second only to the adjacent 910-929800-05800-76800 located <50 m to the west). Habitat in ILP 887 in the lower 150 m of creek is riffle-pool habitat with cobbles and abundant large woody debris. The gradient of this section of ILP 887 is approximately 4% and there are abundant riffles with gravels suitable for rainbow trout spawning. Residual pool depths are, on average 0.3 m deep, but have abundant small and large woody debris and undercut banks for cover. Gradient over the next 100 m increases substantially to approximately 18% as the creek enters a bedrock constricted cascade with step-pools up to 1.5 m high created by boulders and large woody debris. Above this cascade, the gradient levels to approximately 3% and the creek meanders through a meadow on the Patsy Lake plateau.

1.3.3.3.5 Clary Lake Tributaries

Seven of the 12 inlet tributaries of Clary Lake assessed with Reconnaissance (1:20,000) site cards were either NCD or had NVC (Table 1.3-12). All of these tributaries flowed into the main southern basin of the lake (Figure 1.2-2 and 1.2-3).

Site 41 on ILP 869 on the eastern shore, Site 43 on ILP 875 on the southern shore, and the two sites on Reaches 2 and 3 on ILP 873 (sites 48 and 49) were classified as step-pool habitat (Table 1.3-12). Channel widths at these three sites were <1.2 m wide and residual pool depths were <0.25 m deep. The gradient at Site 41 was 6% and substrates were dominated by fines although some gravels were present. Cover at this site was low (<5%) and what was present was provided by overhanging vegetation and small woody debris. The gradient at Site 43 was higher (11%) than at Site 41 and substrates were dominated by cobbles and gravels. In contrast, gradients at Sites 48 and 49 were very high (18% and 55%, respectively) and substrates were dominated by boulders. Although unproven, the high gradients at these two sites and their position upstream of the culvert and rubble apron at the existing Alice Arm Road crossing likely precludes fish from accessing habitat in the upper reaches of this tributary. None of these four sites are likely used by rainbow trout in Clary Lake for overwintering, rearing, or spawning.

Habitat at Site 52 in ILP 913, the man-made outlet channel created as a spillway for the dam used to increase lake levels on Clary Lake in the 1970s, was classified as riffle-pool habitat with gravel and large woody debris. Residual pool depths at this site were >0.4 m and overwintering habitat was rated as fair. Rearing habitat was rated as good due to the abundance of cover provided by overhanging vegetation and small woody debris. However, spawning habitat does not exist at this site because of the lack of appropriately sized gravels; the channel is comprised almost exclusively of angular cobbles.

Habitat at Site 34 in the natural Clary Lake outlet was classified as riffle-pool habitat with cobbles and large woody debris (Table 1.3-12). The channel at this site had a mean gradient of 2%, a bankfull width of 8 m, and residual pool depth of 1.2 m, and a bankfull depth of 1.6 m. Substrates were comprised of cobbles and gravels while cover was relatively abundant and comprised of boulders and overhanging vegetation. Rearing habitat in this natural outlet was rated as good while overwintering habitat and spawning habitat were rated as fair due to the infrequency of deep pools and the patchiness of the available gravels.

Habitat at Site 38 on ILP 861 was classified as riffle-pool habitat with cobbles and large woody debris. This site was rated as having good rearing habitat due to the abundance of cover (>20%) provided by deep pools and small woody debris. However, this site was rated as having poor spawning habitat because the gradient was high (5%) and the substrates were largely large cobbles.

Habitat at the two remaining sites (35 and 36) on the two inlets entering the northern basin of Clary Lake were classified as having good spawning habitat for rainbow trout. This is because both streams had abundant gravel substrates and gradients near 2%. Both sites were also rated as having good rearing habitat because of the abundant cover provided by overhanging vegetation and small and large woody debris. Site 36 is located on the main inlet tributary to Clary Lake. The channel at this site was, on average, 8 m wide, and had a bankfull depth and residual pool depth of 0.3 m.

Although spawning habitat was present at Site 35, the channel at this site was much smaller (channel width of 1.0 m, residual pool depth of 0.15 m, and bankfull depth of 0.2 m) and the total watershed area of this stream was much smaller than the main Clary Lake inlet (910-929800-05800-61400). For this reason, most of the rainbow trout in Clary Lake likely use this main inlet channel (Site 36) for spawning. The Reconnaissance (1:20,000) site card in this main inlet only extended 100 m but, based on examination of the stream to find a suitable reference site, similar high value rearing and spawning habitat for rainbow trout exists for many hundreds of metres further upstream and into the numerous tributaries of this main inlet.

Table 1.3-12: Summary of Habitat Characteristics for Inlet Tributaries and Outlet of Clary Lake, 2010

Watershed Code	ILP	Reach ID	Map Site ID	Stream Order	Stream Classification	Stream Habitat	Mean Gradient	Mean BfW (m)	Mean WW (m)	Mean Res. Pool (m)	Mean BfD (m)	Stream Bed	Stream Cover	Habitat Quality[1]		
														Overwintering	Rearing	Spawning
	860	1	37	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	864	1	39	2	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	867	1	40	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	869	1	41	1	S4*	Step-pool	6.5	0.6	0.6	0.15	0.53	Predominantly fine with some gravel	Cover <5%; Dominant - overhanging; Subdominant - SWD	n/a	n/a	n/a
	870	1	42	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	871	1	51	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	872	1	50	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	873	1	47	2	NVC	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	873	2	48	1	S4*	Step-pool	17.5	0.7	0.7	0.18	0.10	Predominantly cobble with some fine	Cover <5%; Dominant - overhanging; Subdominant - boulder	P	P	P
	873	3	49	1	S4*	Step-pool	55.0	0.9	0.9	0.09	0.10	Predominantly boulder with some fine	Cover 5-20%; Dominant - boulder; Subdominant - SWD	P	P	P
	875	1	43	2	S3	Step-pool	10.5	1.5	1.5	0.22	0.40	Predominantly cobble with some gravel	Cover >20%; Dominant - undercut banks; Subdominant - SWD	N	F	N
	913	2	52	4	S3	Riffle-pool with cobble / LWD	1.5	4.5	3.9	0.43	1.07	Predominantly cobble with some gravel	Cover >20%; Dominant - overhanging; Subdominant - SWD	F	G	N
910-929800-05800		4	34	4	S2	Riffle-pool with cobble / LWD	2.0	7.9	8.2	1.20	1.60	Predominantly cobble with some gravel	Cover 5-20%; Dominant - boulder; Subdominant - overhanging	F	G	F
910-929800-05800-61300		1	35	2	S4	Riffle-pool with gravel / LWD	1.0	1.0	1.3	0.15	0.20	Predominantly gravel with some fine	Cover >20%; Dominant - overhanging; Subdominant - SWD	P	G	G
910-929800-05800-61400		1	36	4	S2	Riffle-pool with cobble / LWD	1.5	7.9	6.8	0.27	0.30	Predominantly cobble with some gravel	Cover 5-20%; Dominant - overhanging; Subdominant - LWD	G	G	G
910-929800-05800-63400		1	38	2	S3	Riffle-pool with cobble / LWD	5.3	2.8	2.6	0.22	0.53	Predominantly cobble with some gravel	Cover >20%; Dominant - deep pool; Subdominant - SWD	P	G	P

Note: * inferred, fish-bearing status not confirmed; BfD - bankfull depth; BfW - bankfull width; LWD - large woody debris; n/a - not applicable; NCD - non-continuous drainage; NVC - non-visible channel; Res. - residual; SWD - small woody debris; WW - wetted width
[1] Habitat qualifiers: N - None; P - Poor; F - Fair; G - Good

1.3.3.4 Stream Temperature

1.3.3.4.1 Lake 901 Outlet

Mean, minimum, and maximum monthly water temperatures in Lake 901 outlet are provided in Table 1.3-13 and graphed in Figure 1.3-13. The temperature logger malfunctioned between the day it was set in June 2010 and the day it was first downloaded in September; no data are available for the three summer months of 2010. Water temperatures in the Lake 901 outlet steadily declined from October (high of 9.5°C on October 20) to December (below 0.5°C on 8 December) in 2010. Temperatures remained close to freezing through May 2011.

Table 1.3-13: Mean, Minimum, and Maximum Monthly Water Temperatures in the Lake 901 Outlet

Month	Minimum (°C)	Mean (°C)	Maximum (°C)	Mean Daily Fluctuation (°C)
January[1]	0.1	0.2	0.2	0.1
February[1]	0.2	0.4	0.5	0.3
March[1]	0.2	0.3	0.3	0.2
April[1]	0.2	0.4	0.6	0.3
May[1]	0.2	0.3	0.5	0.3
June	n.d.	n.d.	n.d.	n.d.
July	n.d.	n.d.	n.d.	n.d.
August	n.d.	n.d.	n.d.	n.d.
September[2]	8.2	8.5	8.8	0.6
October[2]	6.8	7.1	7.5	0.7
November[2]	3.0	3.3	3.5	0.5
December[2]	0.3	0.5	0.7	0.3

Note: [1] Based on 2011 data
[2] Based on 2010 data
n.d. - no data; °C - degrees Celcius

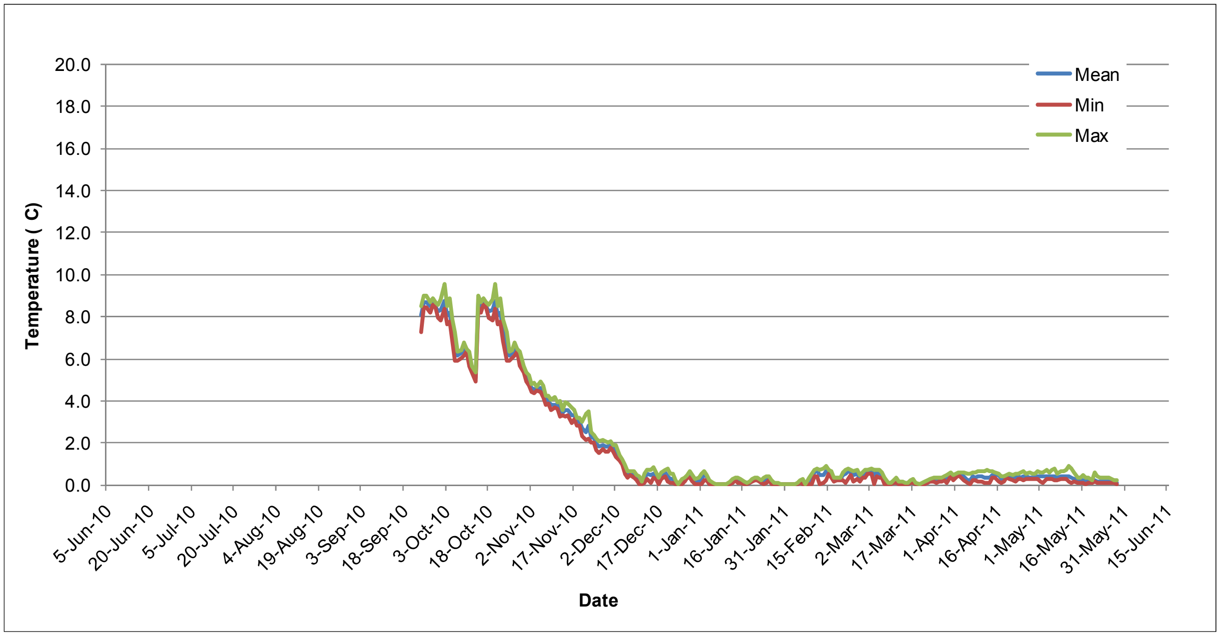


Figure 1.3-13: Water Temperature (°C) In Lake 901 Outlet, 2010

1.3.3.4.2 Clary Lake Inlet

Mean, minimum, and maximum monthly water temperatures in the main Clary Lake inlet are provided in Table 1.3-14 and graphed in Figure 1.3-14. This temperature logger was not installed until 10 July in 2010. The logger collected data for 17 days before it either malfunctioned or the battery died. This was not discovered unitl the logger was downloaded on 17 September. At this time, a new logger was installed in the stream. This incomplete data set limits knowledge about water temperatures in the Clary Lake inlet.

Mean monthly water temperatures were highest in July (13.6°C) but, given the trends in the other streams, mean water temperatures were likely higher in August. Water temperatures in the Clary Lake inlet were declining on 17 September, the day the temperature logger was re-set, and had fallen below 1.0°C by 17 November 2010.

Table 1.3-14: Mean, Minimum, and Maximum Monthly Water Temperatures in the Lake 901 Outlet

Month	Minimum (°C)	Mean (°C)	Maximum (°C)	Mean Daily Fluctuation (°C)
January[1]	0.0	0.0	0.0	0.0
February[1]	0.0	0.0	0.0	0.0
March[1]	0.0	0.1	0.1	0.1
April[1]	0.0	0.2	0.5	0.5
May[1]	0.4	0.8	1.3	0.9
June	n.d.	n.d.	n.d.	n.d.
July[2]	12.8	13.6	14.8	2.0
August[2]	n.d.	n.d.	n.d.	n.d.
September[2]	8.2	8.8	9.6	1.4
October[2]	4.7	5.1	5.5	0.8
November[2]	0.8	1.0	1.1	0.3
December[2]	0.0	0.0	0.1	0.0

Note: [1] Based on 2011 data
[2] Based on 2010 data
n.d. - no data; °C - degrees Celcius

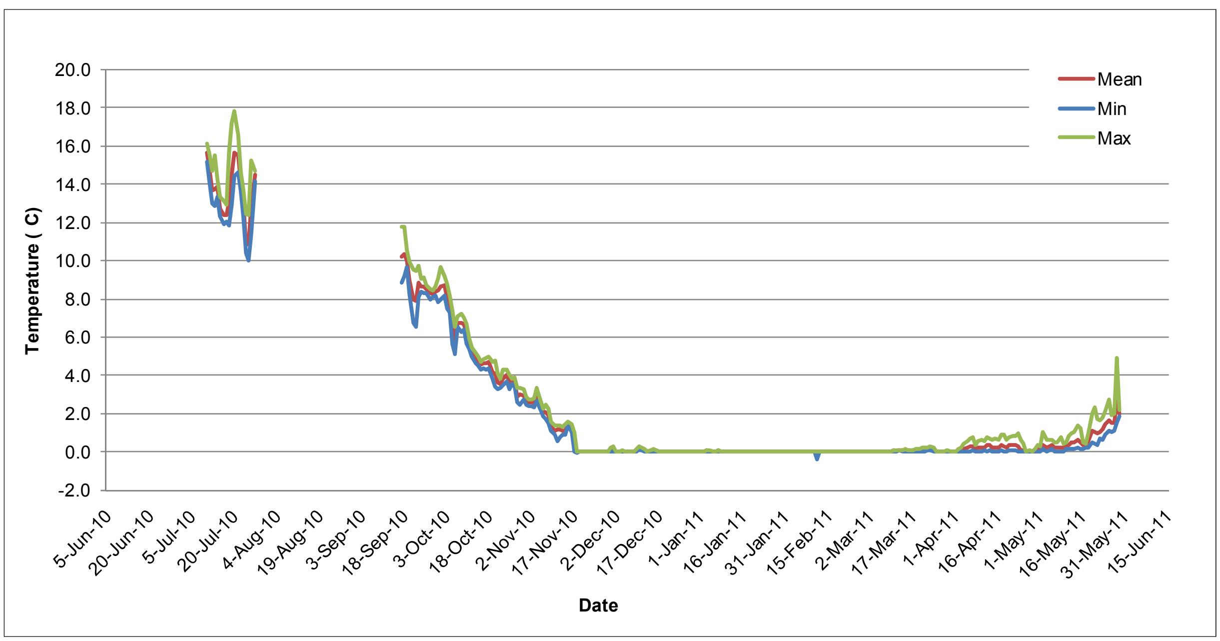


Figure 1.3-14: Water Temperature (°C) In the Clary Lake Inlet, 2010

1.3.4 Streams Along Proposed Mine Site Road

Four of the 14 stream crossing sites along the proposed new mine site road were classified as non-fish-bearing either as NCD, as NVC, or because of gradients in excess of 25% (Table 1.3-15). Two of these (sites 44 and 45) occurred on ILP 875, a first order tributary of Clary Lake upstream of the existing Alice Arm Road. Another site (Site 31) was on a first order tributary of a Lake 901 inlet along the northwest side of the lake. The last site (46) was located on a first order headwater tributary of Clary Lake where the mean gradient was approximately 47% (Figure 1.2-3).

The other 10 stream crossing sites were on inferred, fish-bearing streams (either S3 or S4). These included eight sites (21, 23, 27, 28, 29, 30, 32, and 33) on six first or second order headwater tributaries of Lake 901, and two sites (53 and 54) on a first order headwater tributary of Clary Creek downstream of Clary Lake. Gradient at these 10 sites ranged between 0% to 18%. Only one site (30 on ILP 896) had a bankfull width >1.5 m and a residual pool depth >0.4 m. Most of these sites had residual pool depths <0.25 m. Overall habitat quality at these 10 sites was none to fair for overwintering, rearing, or spawning for rainbow trout. Based on the small size of these creeks, their location upstream of existing culverts (Clary Lake and Clary Creek tributaries), their distance upstream from the lakes (most >500 m upstream), and the presence of larger, more suitable tributaries elsewhere, it is unlikely that any of the creeks at these sites are used by rainbow trout for any of these life stages.

Table 1.3-15: Summary of Stream Habitat Characteristics for Stream Potentially Crossed by New Mine Site Road

Map ID#	ILP	Reach ID	Site ID	Stream Order	Stream Classification	Mean Gradient (%)	Mean BfW (m)	Mean Residual Pool (m)	Habitat Quality[1]		
									Overwintering	Rearing	Spawning
23	883	1	1	1	S4*	8.0	1.2	0.20	N	F	P
44	875	3	1	1	NCD	n/a	n/a	n/a	n/a	n/a	n/a
45	875	4	1	1	NVC	n/a	n/a	n/a	n/a	n/a	n/a
31	897	1	1	1	NVC	n/a	n/a	n/a	n/a	n/a	n/a
27	896	1	1	2	S4*	4.0	1.1	0.40	P	F	P
30	896	2	1	2	S3*	0.0	3.3	0.53	P	F	P
28	896	2	2	1	S4*	17.7	0.8	0.13	P	P	P
29	925	1	1	1	S4*	13.0	0.8	0.21	P	F	P
54	914	4	1	1	S4*	15.0	1.0	0.19	P	F	P
53	915	1	1	1	S4*	5.7	1.0	0.15	N	F	N
32	900	2	1	1	S4*	16.7	1.2	0.16	P	F	F
21	918	6	1	1	S4*	12.0	1.5	0.32	P	P	N
33	917	1	1	1	S4*	12.5	1.1	0.24	P	F	P
46	876	2	1	1	S5	46.8	1.0	0.08	N	P	P

Note: * inferred, fish-bearing status not confirmed; ILP - Interim Locational Point; n/a - not applicable; NCD - non-continuous drainage; NVC - non-visible channel

[1] N - None; P - Poor; F - Fair; G - Good

1.4 Lake Habitat

1.4.1 Patsy Lake

1.4.1.1 Bathymetry

The bathymetry of Patsy Lake is shown in Figure 1.4-1. Patsy Lake had a maximum depth of 29 m, an average depth of 9.9 m, and a relative depth of 6.0%. Patsy Lake had a total surface area of 185,803 m^2, a shoreline perimeter of 3.6 km, and a total volume of 1,836, 480 cubic metres (m^3) (Table 1.4-1). The littoral area (i.e., <6 m) of Patsy Lake was 72, 698 m^2 and accounted for approximately 39% of the total lake surface area. Patsy Lake had a surface area to volume ratio of 0.1:1 and a shoreline development of 2.38. These two metrics indicate that Patsy Lake was deep relative to its surface area and had a littoral area potential more than twice as high as that of a circular lake.

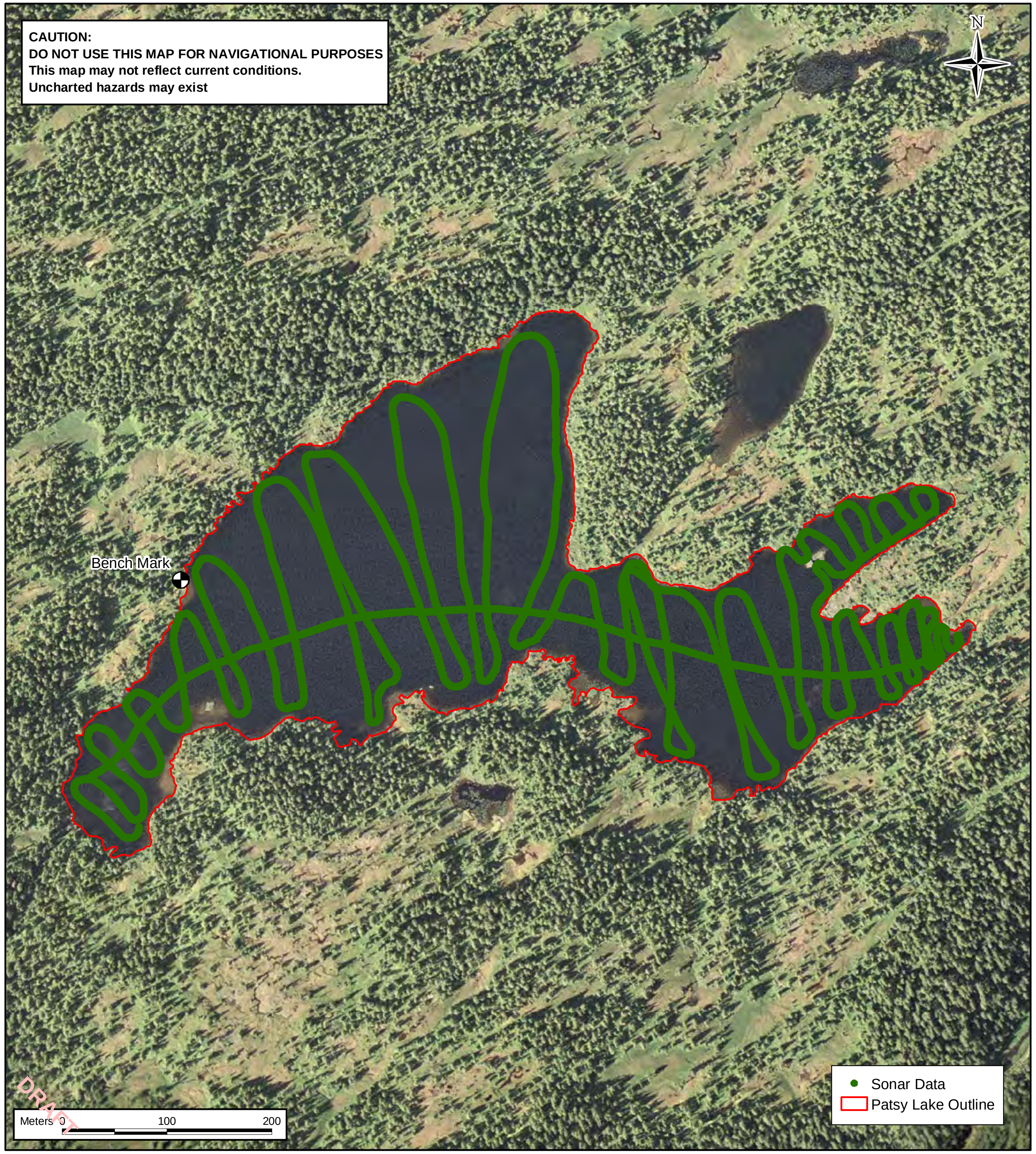
Table 1.4-1: Bathymetric Parameters of Patsy Lake, Clary Lake, and Lake 901

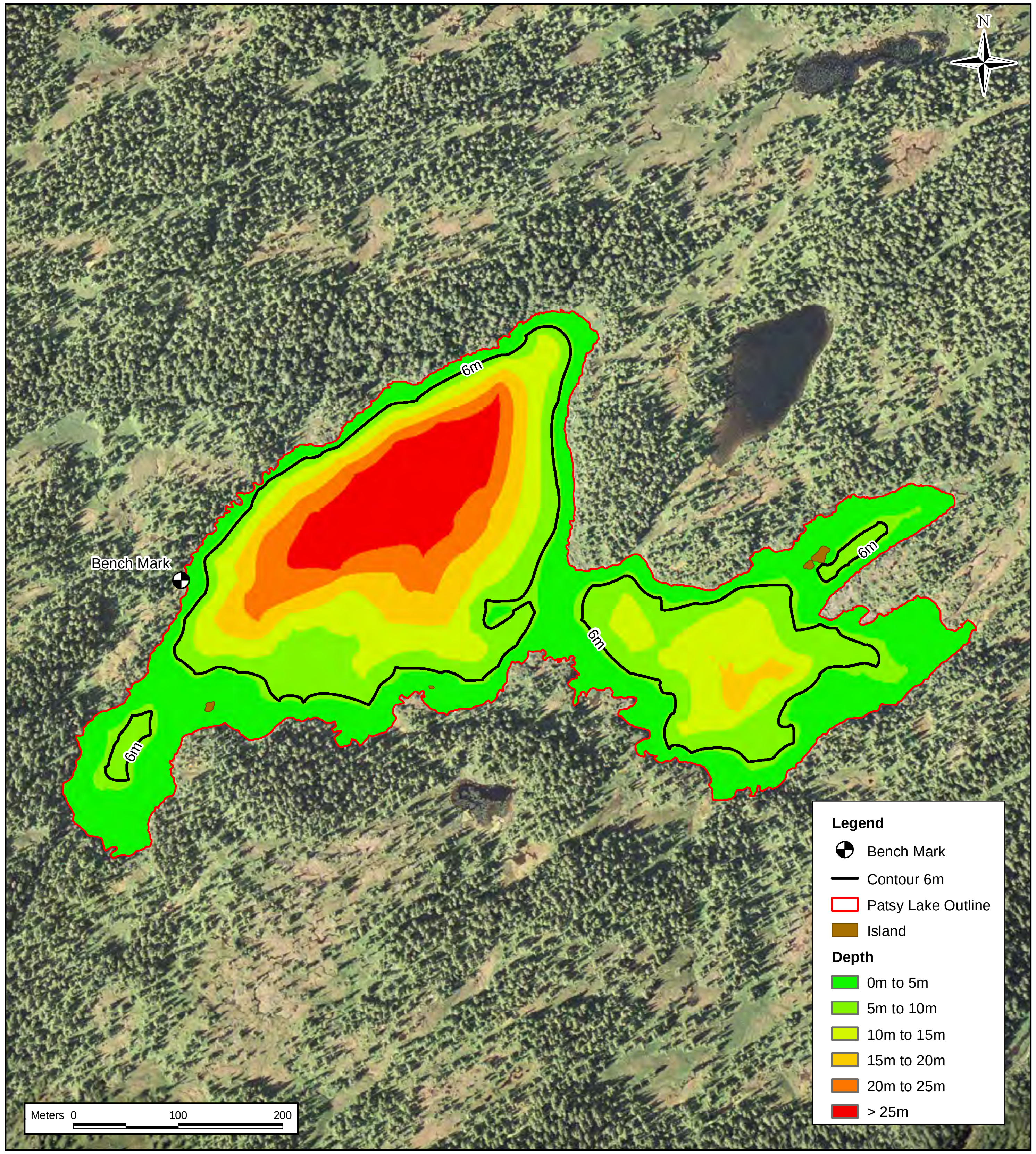
Lake	Max Depth (m)	Average depth (m)	Relative depth (%)	Shoreline length (km)	Total Surface Area (m^2)	Total Littoral Area (m^2)	Total Volume (m^3)	Shoreline Development (D_l)
Patsy[a]	29.2	9.9	6.0	3.6	185,803	72,698	1,836,480	2.38
Clary[b]	47.0	16.1	6.4	4.9	419,274	89,917	6,742,588	2.13
Lake 901[c]	5.8	2.1	2.0	2.4	61,646	61,646	126,812	2.70

Note: km - kilometre; m - metre; m^2 - metres squared; m^3 - cubic metre
[a] Watershed code (WSC) / Waterbody ID - 910-929000-60300 / 00521KSHR
[b] WSC / Waterbody ID - 910-929800-05800 / 00445KSHR
[c] WSC / Waterbody ID - 910-929800-05800-76800 / 00500KSHR

Patsy Lake had two distinct basins. The larger, western basin included the deepest portion of the lake (>25 m) and had steep sides along its western-most shoreline. The smaller, eastern basin was generally <15 m deep and had a much lower gradient littoral area over most of its shoreline length. However, there were steep bedrock cliffs flanking both sides of the peninsula that juts into this basin from the north. The lake had three small bedrock islands: two located in the western basin and a single larger island located in the eastern basin.

Patsy Lake had five inlet tributaries. The largest of these tributaries drained a small pond to the west of the lake. None of the five Patsy Lake tributaries were greater than 1 m wide and three of the five were ephemeral.





REFERENCE:
Patsy lake outline is digitize from Orthophoto and is not base on TRIM base data.

NOTES:
1 - Depths are in meters
2. Not intended for navigational use
3. Uncharted rocks shoals may exist

SURVEYED BY:	Tim Newman
SURVEYED DATE:	July 7th, 8th 2010
WATERSHED CODE:	910-925028-528913
ORTHOPHOTO:	Mcelhanney 2008
N.T.S:	103P/06

Statistics at Time of Survey

ELEVATION:	784 m	MEAN DEPTH:	6.1 m
SURFACE AREA:	185803 sq.m	MAX DEPTH:	29.2 m
AREA ABOVE 6M CONTOUR:	72698 sq.m	PERIMETER, MAIN SHORE:	3631.2 m
VOLUME:	1836108.3 cu.m	PERIMETER, ISLANDS:	130.3 m
ABOVE WATER LEVEL:	1.9 m	BENCH MARK UTM:	475299 E, 6142977 N

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amec

ANALYST:	MY
QA:	JA
DATUM:	NAD83
PROJECTION:	UTM Zone 9
SCALE:	1:5,000

PROJECT
Kitsault Mine Project

TITLE
Patsy Lake Bathymetry Map
Depth in meters

REV. NO:	A
DATE:	December 2010
PROJECT NO:	VE51988
FIGURE NO:	1.4-1

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1.4.1.2 Limnology

A summary of the limnological parameters measured in Patsy Lake in 2009 and 2010 is provided in Table 1.4-2. Raw data for both 2009 and 2010 are presented Appendix B-1.

In 2009, Patsy Lake had a D_s of 3.8 m, a 1% euphotic depth of 11.5 m, and a thermocline depth of 4.0 m. Epilimnion water temperatures and DO concentrations in August 2009 ranged between 13 and 14°C and between 8.5 and 10.5 mg/L, respectively (Figure 1.4-2). At these water temperatures, the epilimnion was near 100% saturated with oxygen. Water temperatures and DO concentrations below the thermocline ranged between 5 and 9°C and between 4 and 10 mg/L (Figure 1.4-2).

In 2010, Patsy Lake had a D_s of 6.0 m, and a 1% euphotic depth of 16.2 m (Table 1.4-2). Patsy Lake had a pH near 7 and a specific conductivity ranging from 11 microSiemens per centimetre (µS/cm) at the surface to 24 µS/cm near the bottom. Although not as pronounced as in 2009, Patsy Lake had a thermocline at approximately 5 m depth in July 2010 (Figure 1.4-3). This difference in thermocline depth between years is due to yearly differences in wind conditions and air temperatures and / or because of the month difference in sampling events between years. Epilimnion water temperatures and DO concentrations in July 2010 ranged between 10 and 18°C and between 8.0 and 9.0 mg/L, respectively (Figure 1.4-3). Water temperatures and DO concentrations below the thermocline ranged between 5 and 9°C and between 2.5 and 9 mg/L (Figure 1.4-3).

DO concentrations in the lower 4 m of the lake dropped to near anoxic levels (approximately 0 mg/L). This drop in DO near the bottom may be due to meter error if the probe became fouled by sediments or by biological oxygen demand at the water / sediment interface.

The 1% euphotic zone depth for Patsy Lake was 11.5 m in 2009 and 16.2 m in 2010. This indicated that light penetrated nearly half of the water column before the light intensity became too low for photosynthesis. Despite this relative clarity, the waters of Patsy Lake were more tannic stained than either Clary Lake or Lake 901.

Table 1.4-2: Comparison of Limnology Parameters Measured in Patsy Lake in August 2009 and in July 2010

Year	Temp. Range (°C)	DO range (mg/L)	Specific Cond. (µS/cm)	pH Range	Secchi Depth (m)	1% Euphotic Depth (m)	Thermocline Depth (m)
2009	4.4 – 15.8	2.0 – 10.4	n/a	n/a	3.8	11.5	4.0
2010	4.7 - 17.9	0.0 - 9.3	9-24-	7.3 - 7.5	6.0	16.2	5.0

Note: °C - degrees Celcius; m - metre; µS/cm - microSiemens per centimetre; mg/L -milligram per litre; % - percent; n/a - not available

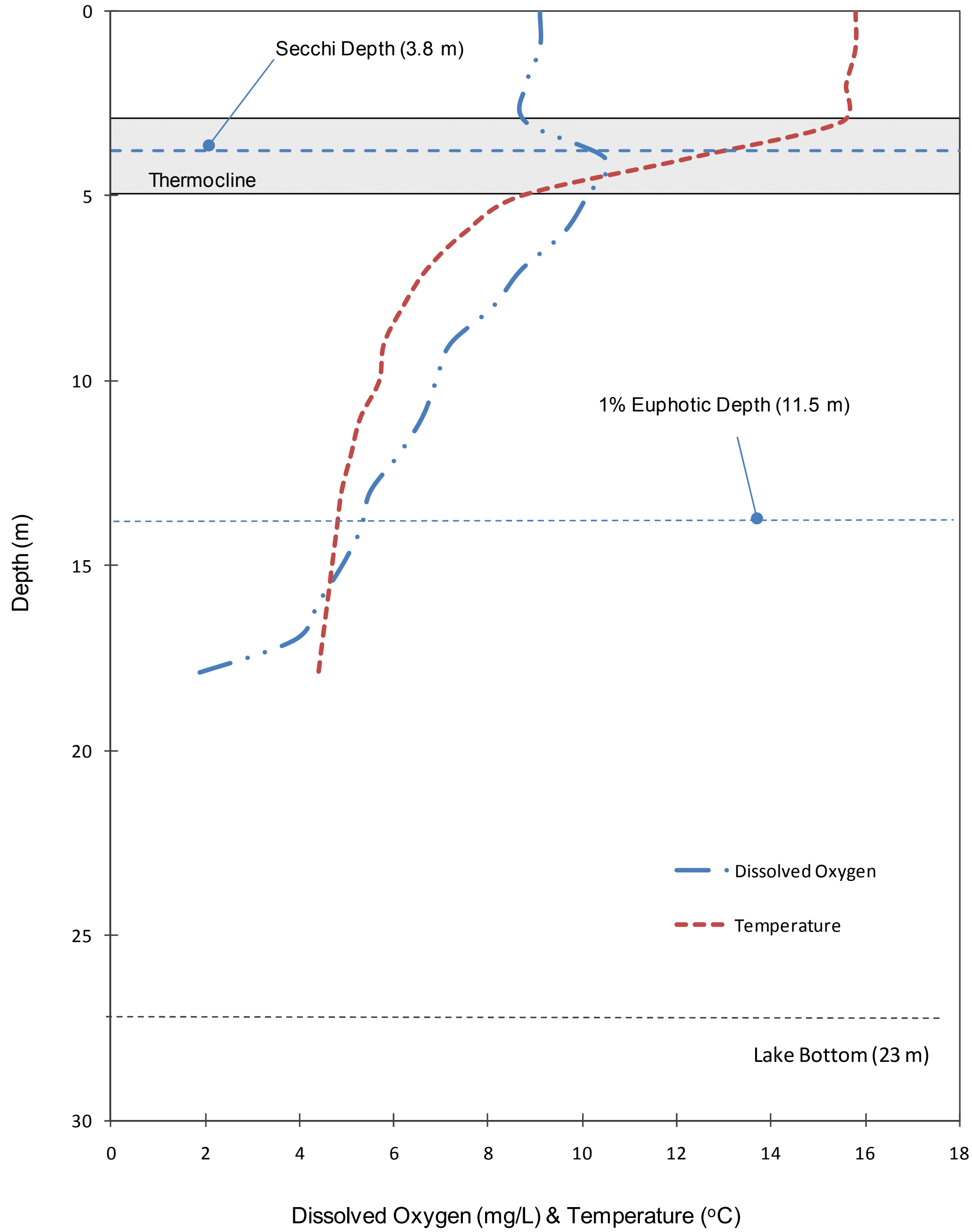


Figure 1.4-2: Dissolved Oxygen / Temperature Profile for Patsy Lake, July 2009

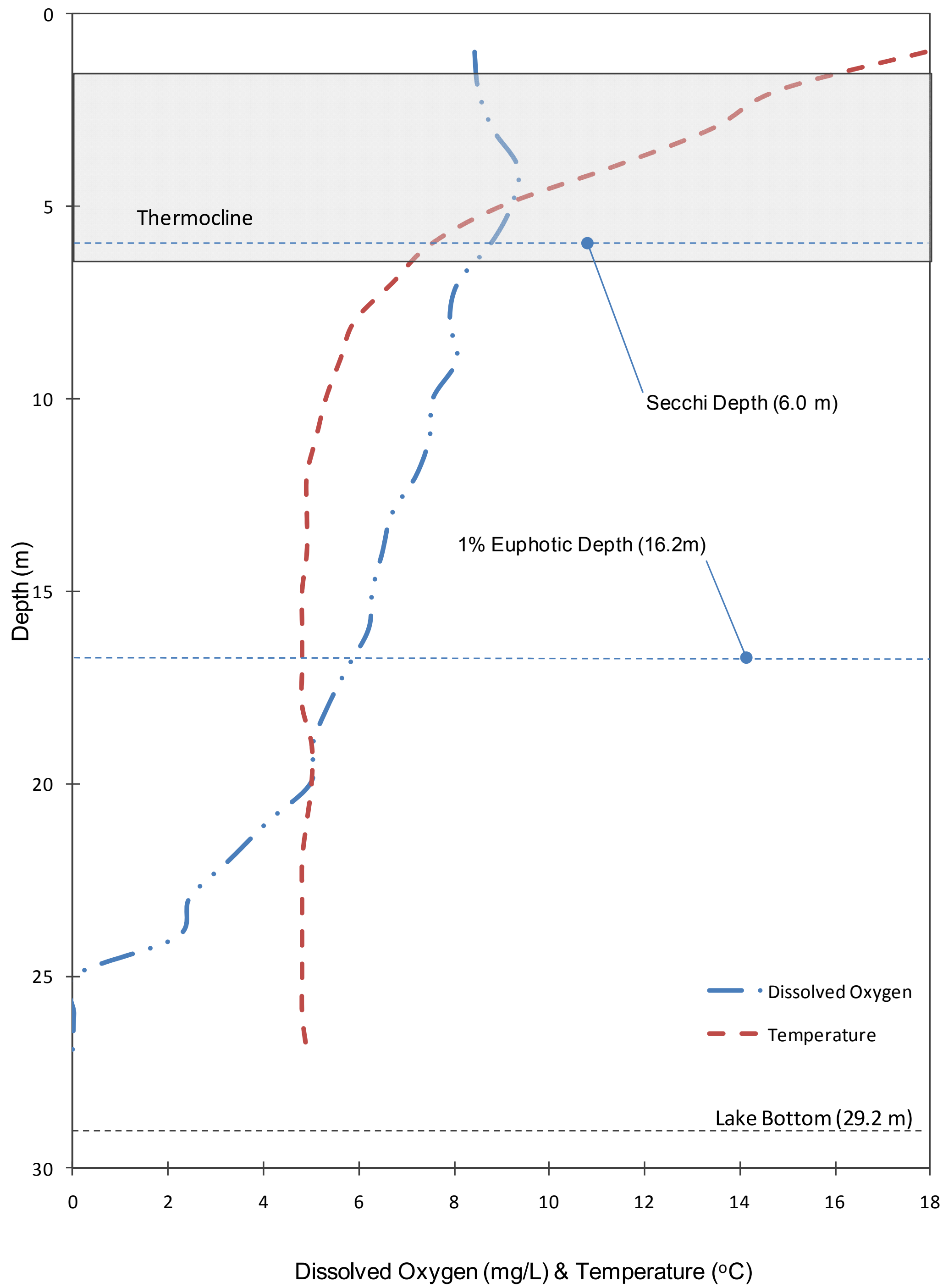


Figure 1.4-3: Dissolved Oxygen / Temperature Profile for Patsy Lake, July 2010

1.4.1.3 Habitat Classification and Mapping

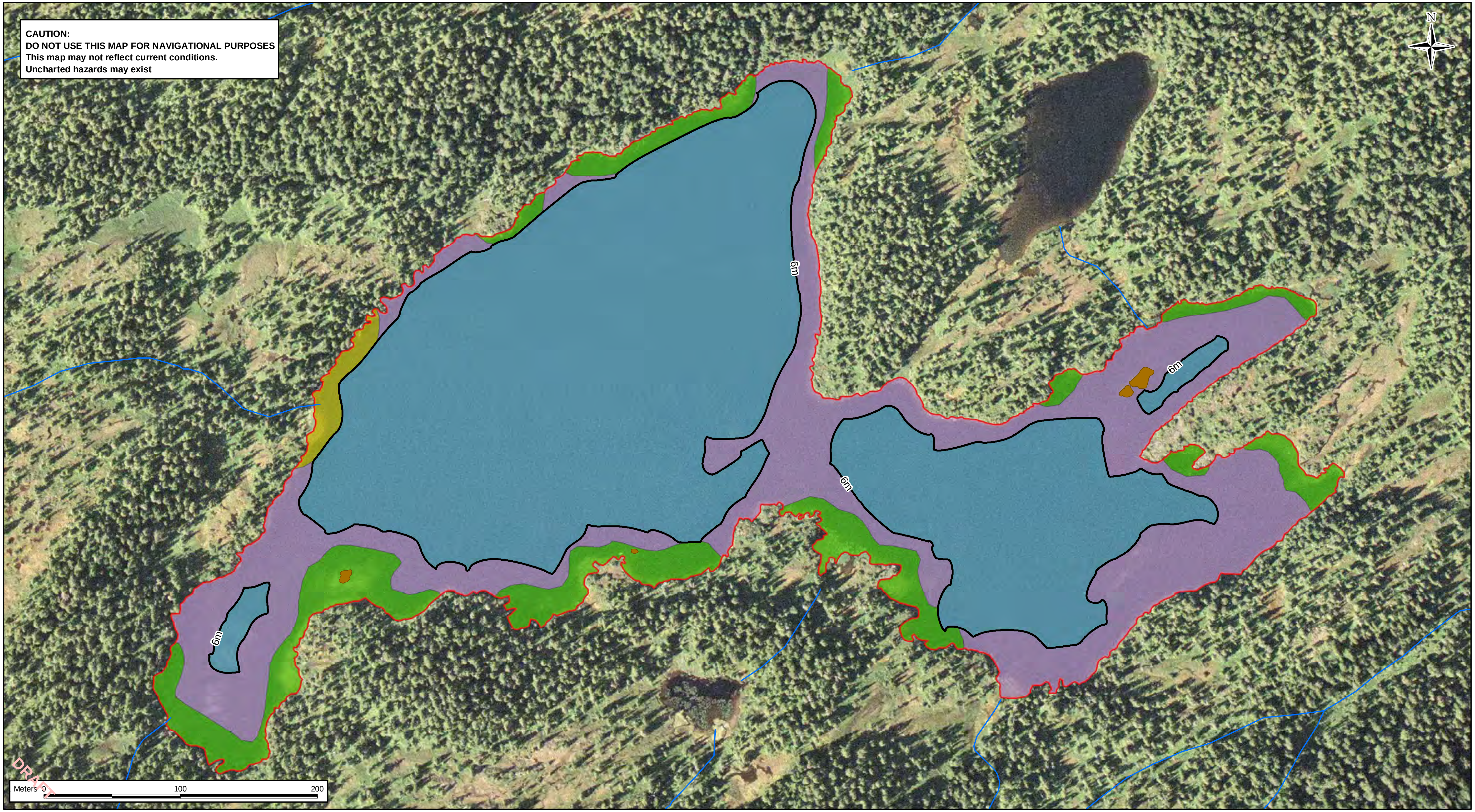
A habitat classification map of Patsy Lake is provided in Figure 1.4-4. Most of the classified littoral habitat was fine organic habitat (27%) (Table 1.4-3). This littoral habitat class included emergent aquatic vegetation species such as yellow pond lily (*Nuphar lutea*), buckbean (*Menyanthes trifoliate*) and marsh cinquefoil (*Comarum palustre*) (Rescan 2010c). The only other littoral habitat class identified in Patsy Lake was a small, discreet area of fine inorganic habitat along the western shoreline. This habitat comprised 2% of the littoral area of the lake. The remainder of the littoral habitat area of Patsy Lake (71%) was not classified. This habitat presumably included additional areas of fine organic and fine inorganic habitat classes and other littoral habitat classes (e.g., boulder / cobble habitat). This littoral area was not classified during the 2009 survey or completed during the 2010 survey because Patsy Lake is non-fish-bearing (see Section 1.7.2) and because littoral habitat will not be affected by lake level changes but will, instead, be completely lost under the TMF.

Patsy Lake is the headwater lake of Lime Creek and sits on a plateau at the top of the Patsy Creek watershed. The riparian vegetation surrounding Patsy Lake was comprised of mosses, herbs and mature coniferous forests (Rescan 2010c). There was no woody debris in Patsy Lake in either 2009 or 2010.

Table 1.4-3 : Spatial Area (m^2) of Discreet Littoral and Pelagic Habitat Classes in Patsy Lake, Lake 901, and Clary Lake

	Patsy Lake		Lake 901		Clary Lake	
	Area (m^2)	**% of Littoral Area**	**Area (m^2)**	**% of Littoral Area**	**Area (m^2)**	**% of Littoral Area**
Fine Organic Habitat[1]	18,971	27	12,862	22	31,326	35
Fine inorganic Habitat	1,687	2	38,070	64		
Small Gravel Habitat					1,350	2
Large Gravel / Cobble Habitat			8,449	14	41,567	47
Boulder / Cobble Habitat					14,040	16
Boulder Habitat					729	1
Undefined Area	49,434	71				
	Area (m^2)	**% of Lake Area**	**Area (m^2)**	**% of Lake Area**	**Area (m^2)**	**% of Lake Area**
Littoral Habitat[2]	70,091	17	59,381	14	89,012	22
Pelagic Habitat[3]	110,619	27		0	323,671	78
Total Lake	**180,710**	**44**	**59,381**	**14**	**412,683**	**100**

Note: [1] emergent and / or submergent macrophytes present
[2] littoral habitat areas include all habitat to the 6 m depth contour
[3] pelagic habitat areas includes all off-shore habitat below the 6 m depth contour
m^2 - metres squared; % - percent



Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-039_v2.mxd

REFERENCE:
Patsy lake outline is digitize from Orthophoto and is not base on TRIM base data.

NOTES:
1. Not intended for navgational use
2. Uncharted rocks shoals may exist

Legend

- 6m Contour
- Stream
- Patsy Lake Outline
- Island
- Fine Organic Habitat
- Fine inorganic Habitat
- Pelagic Habitat
- Undefined Littoral Habitat

CLIENT	Avanti Kitsault Mine Ltd.
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ANALYST:	MY
QA:	JA
DATUM:	NAD83
PROJECTION:	UTM Zone 9
SCALE:	1:2,700
PROJECT	Kitsault Mine Project
TITLE	Littoral Habitat Classification of Patsy Lake
REV. NO:	A
DATE:	June 2011
PROJECT NO:	VE51988
FIGURE NO:	1.4-4

1.4.2 Clary Lake

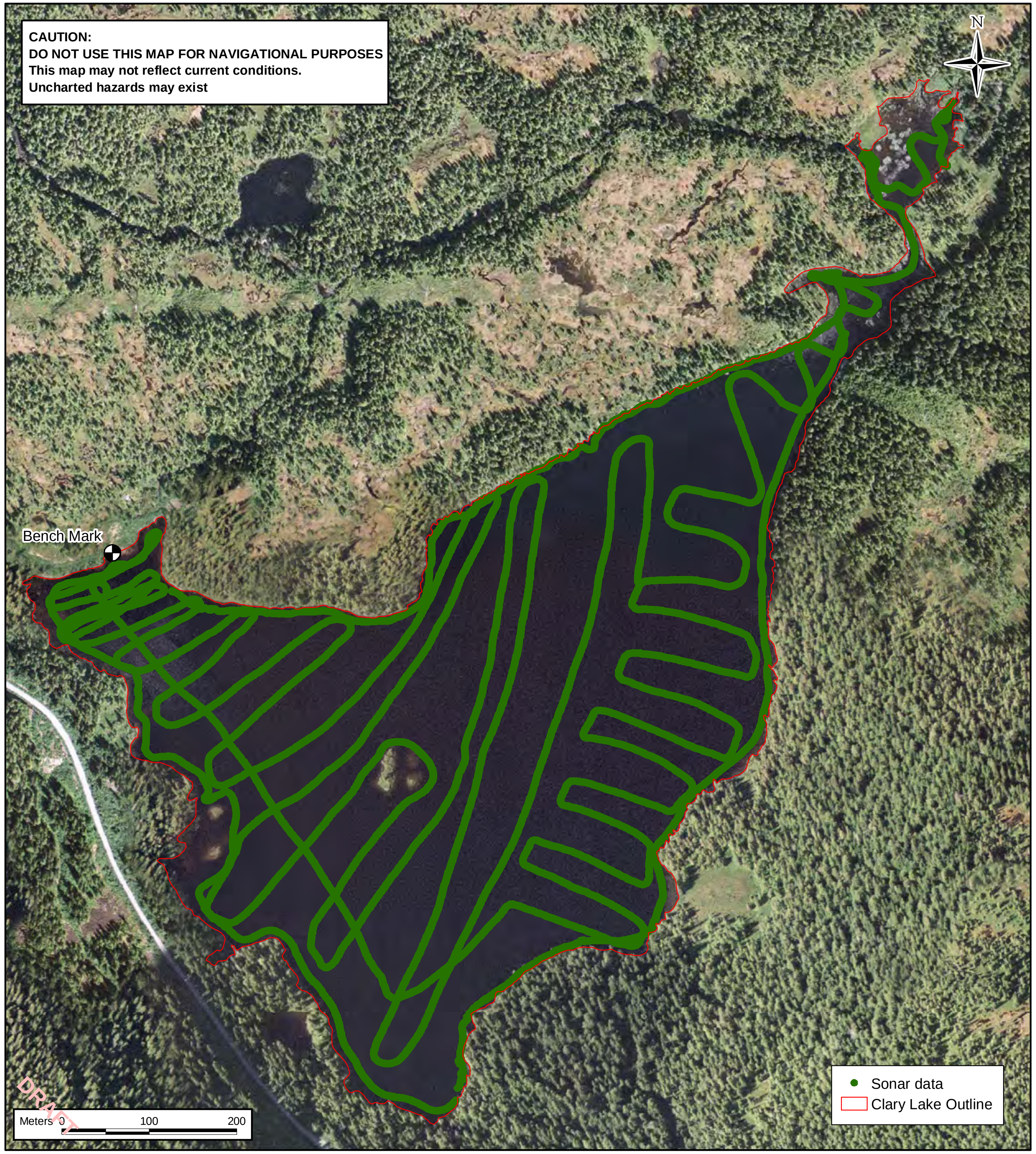
1.4.2.1 Bathymetry

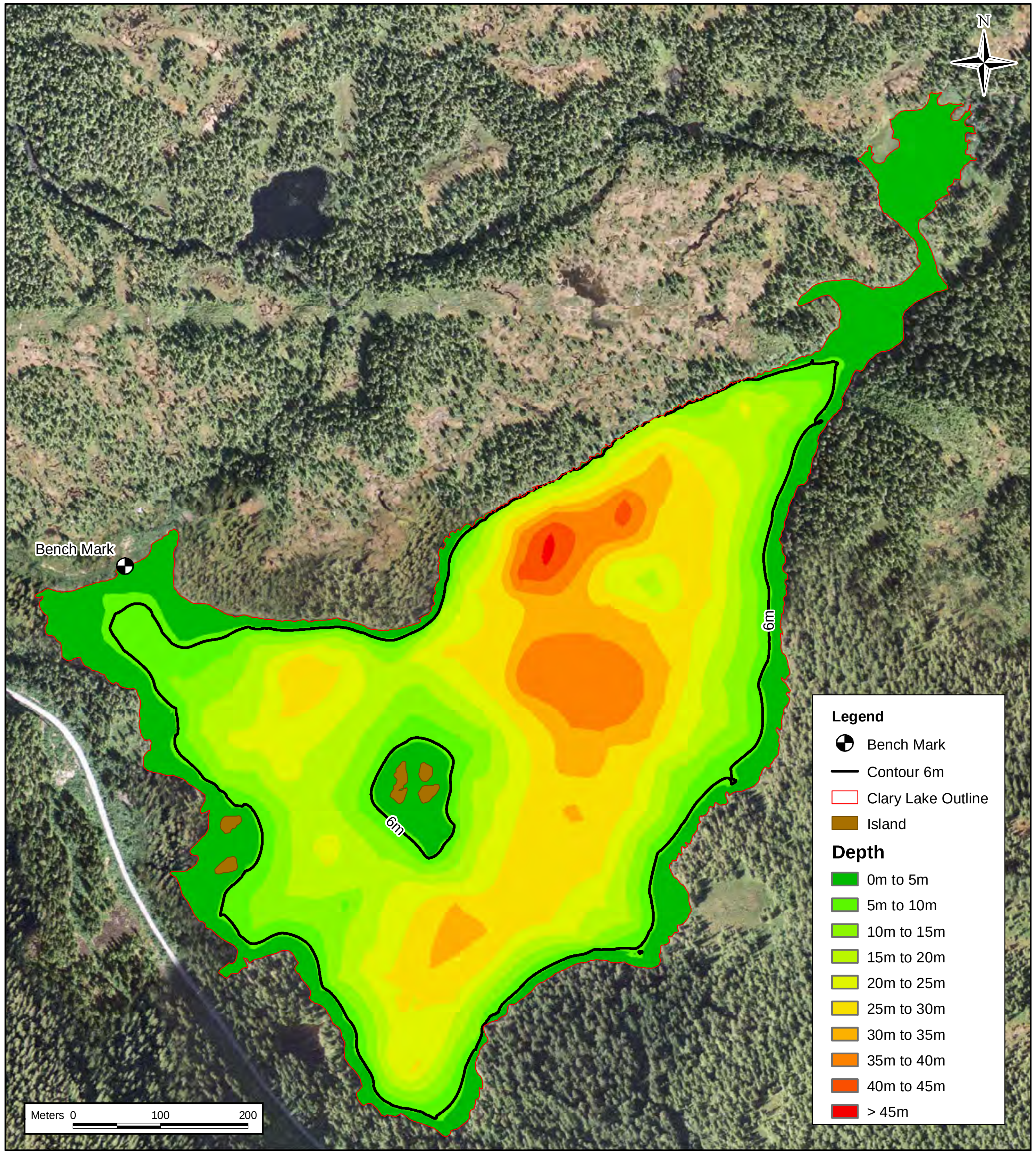
The bathymetry of Clary Lake is presented in Figure 1.4-5. Clary Lake has a maximum depth of 47 m, an average depth of 16 m, and a relative depth of 6.4% (Table 1.4-1). The larger relative depth of Clary Lake compared to Patsy Lake is indicative of its greater depth to surface area ratio. Clary Lake had a total surface area of 419,274 m^2, a shoreline perimeter of 4.9 km, and a total volume of 6,742, 588 m^3 (Table 1.4-1). The littoral area (i.e., <6 m) of Clary Lake was 89, 917 m^2 and accounted for only 21% of the total lake surface area. Clary Lake had a surface area to volume ratio of 0.06:1 and a shoreline development of 2.13. Habitat quality aside, these numbers indicated that Clary Lake was much deeper relative to its surface area than Patsy Lake and that it had a smaller potential for littoral community development and production per hectare than Patsy Lake (but still more than twice that of a perfectly circular lake).

Clary Lake had two distinct basins. The larger, southern basin was over 90% of the total lake area and included the deepest portion of the lake (>45 m). This basin had a largely steep sided littoral area. There were four islands in this basin of the lake: two vegetated islands in the middle of the basin and two bedrock islands near the western shoreline. This basin received most of its inflow from an inlet tributary (Clary Creek) entering Clary Lake near its southeastern most point. This tributary drained the portion of the Clary Creek watershed that included Lake 901, Lake 493, and Killam Lake.

There was a constructed outlet at the western end of this main basin near the old pump-house used to withdraw water from Clary Lake to meet the freshwater demands of the process plant during the previous two mining operations. This constructed outlet joined the natural outlet of the lake approximately 1 km downstream in Clary Creek. The old concrete pumphouse was still present on the shore of Clary Lake (see Appendix I-1).

The second, smaller basin of Clary Lake was at the north end of the lake and was separated from the main southern basin by a sill approximately 1.3 m below the surface (Figure 1.4-5). This basin had an average depth of approximately 1.6 m and the bottom substrates in this portion of the lake were comprised of fine organics and fine woody organic debris. This northern basin received the main inflow to Clary Lake from the inlet tributary that drained the majority of the headwater lakes, streams, and watershed area of the Clary Lake watershed. The main Clary Lake outlet drained Clary Lake less than 125 m from this main Clary Lake inlet in this same northern basin. The likely result of this unique drainage pattern and lake bathymetry was that water and nutrient turn-over rates in the main body of Clary Lake were longer than would be expected if the main inlet entered the main basin of the lake.





REFERENCE:
Clary lake outline is digitize from Orthophoto and is not base on TRIM base data.

NOTES:
1 - Depths are in meters
2. Not intended for navgational use
3. Uncharted rocks shoals may exist

SURVYED BY:	Tim Newman
SURVYED DATE:	Aug 31th, Sept 1st 2010
WATERSHED CODE:	910-925981-060157
ORTHOPHOTO:	Mcelhanney 2008
N.T.S:	103P/06

Statistics at Time of Survey

ELEVATION:	647 m	MEAN DEPTH:	16.6 m
SURFACE AREA:	419274 sq.m	MAX DEPTH:	47 m
AREA ABOVE 6M CONTOUR:	89917 sq.m	PERIMETER, MAIN SHORE:	4895.4 m
VOLUME:	6742588 cu.m	PERIMETER, ISLANDS:	416.2 m
ABOVE WATER LEVEL:	1.7 m	BENCH MARK UTM:	476193 E, 6145645 N

CLIENT
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amec

ANALYST:	MY
QA:	JA
DATUM:	NAD83
PROJECTION:	UTM Zone 9
SCALE:	1:6,000

PROJECT
Kitsault Mine Project

TITLE
Clary Lake Bathymetry Map
Depth in meters

REV. NO:	A
DATE:	December 2010
PROJECT NO:	VE51988
FIGURE NO:	1.4-5

Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-036.mxd

1.4.2.2 Limnology

A summary of the limnological parameters measured in Clary Lake in 2010 is provided in Table 1.4-4. Raw data are presented Appendix B-2.

Clary Lake had a D_s of 4.5 m, a 1% euphotic depth of 12.2 m, a pH between 7 and 8 and, a specific conductivity between 17 and 30 µS/cm on 1 September 2010 (Table 1.4-4). Clary Lake had a thermocline depth between 4 and 8 m on this same day (Figure 1.4-6). Epilimnion water temperatures and DO concentrations in Clary Lake ranged between 13 and 14°C and between 8.0 and 9.0 mg/L, respectively (Figure 1.4-6).

Table 1.4-4: Summary of Limnology Parameters Measured in Clary Lake and Lake 901 in September 2010

Lake	Temp. Range (°C)	DO Range (mg/L)	Specific Cond. (µS/cm)	pH Range	Secchi Depth (m)	1% Euphotic Depth	Thermocline Depth (m)
Clary	4.0 - 14.4	6.5 - 9.4	17 - 30	6.8 - 8.1	4.5	12.2	4.0 – 8.0
901	7.8 - 12.3	4.3 - 9.7	13 - 75	6.6 - 6.9	2.0	5.4	n/a

Note: m - metre; µS/cm - microSiemens per centimetre; mg/L - milligram per litre; n/a - not applicable; % - percent

Water temperatures and DO concentrations below the thermocline ranged between 4 and 6°C and between 6.5 and 8.5 mg/L, respectively (Figure 1.4-6). These DO concentrations were considerably higher than those in the hypolimnion of Patsy Lake in July 2010. The main basin of Clary Lake was still thermally stratified during the 1 September survey. These differences in hypolimnetic DO concentrations between the two lakes in 2010 suggests three possible theories. First, there was less biological oxygen demand in the hypolimnion of the main basin of Clary Lake than in the hypolimnion of Patsy Lake. Presumably, this would occur primarily because the unique drainage pattern and bathymetry of the lake protected the main basin of Clary Lake from accumulating the organic material carried to the lake by the main Clary Lake inlet. Second, Patsy Lake was higher in nutrients and had greater biological productivity, and hence a greater biological oxygen demand, than Clary Lake. This is a distinct possibility given Patsy Lake's greater shoreline development and greater proportion of wetland habitat in its watershed than Clary Lake. However, this theory is not supported by the lower chlorophyll *a* concentrations in Patsy Lake compared to Clary Lake in 2010 (see Section 1.5.2.2.5). Third, the main basin of Clary Lake had a higher probability of mid-season turn-over than Patsy Lake. This is the least likely scenario given the much greater average depth and much smaller shoreline development of Clary Lake compared to Patsy Lake. In addition, both lakes had a similar length fetch and were surrounded by mature forest protecting them equally from turn-over by the same force wind event.

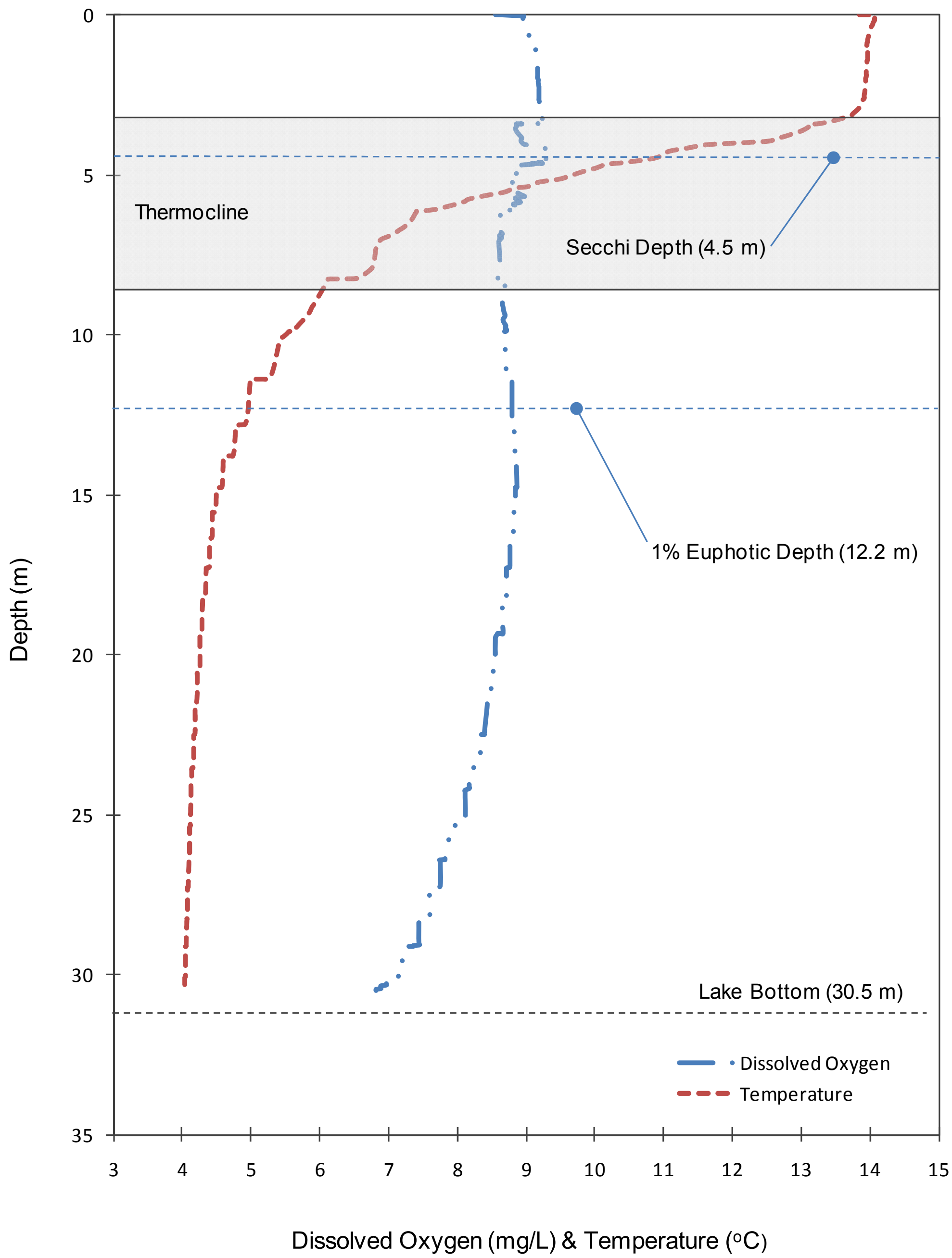


Figure 1.4-6: Dissolved Oxygen / Temperature Profile for Clary Lake, 1 September 2010

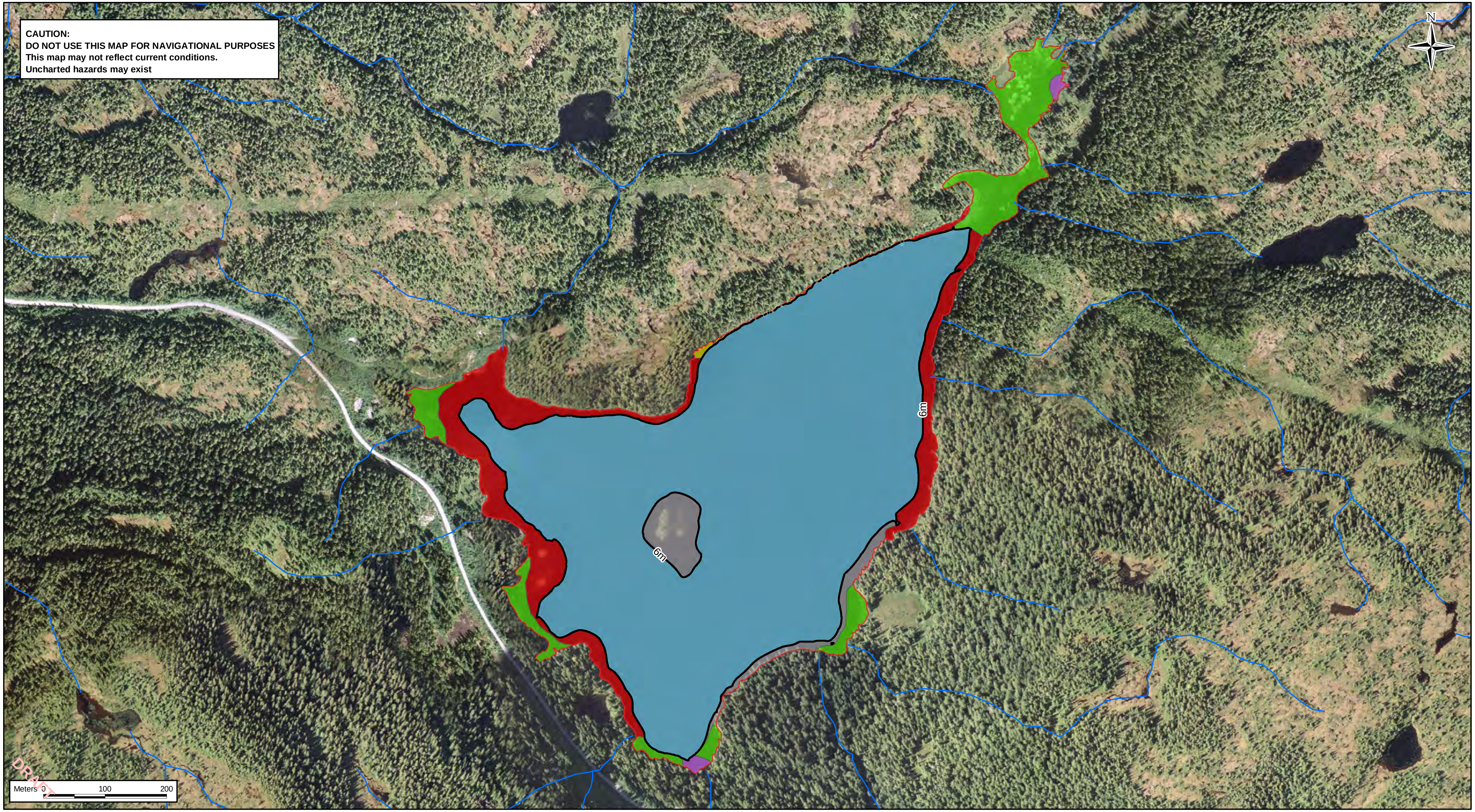
1.4.2.3 Littoral Habitat Classification and Mapping

A habitat classification map of Clary Lake is provided in Figure 1.4-7. A summary of area, volumes and % of total lake area for each of the five littoral habitat classes found in Clary Lake is provided in Table 1.4-3. The total littoral area of Clary Lake comprised only 22% of the total lake surface area. This was because most of the shoreline around the lake was very steep, resulting in a very narrow littoral area between the shore and the 6 m depth contour around most of the perimeter of the lake's southern main basin. The exception to this was in the smaller, northern basin where the shoreline gradient was low and the water depth was 1.6 m at its deepest.

Most (47%) of the littoral habitat in Clary Lake was comprised of large gravel / cobble habitat. This habitat class was found along the western, south-western, and north-eastern shorelines of the main basin (Figure 1.4-7). Fine organic habitat comprised 35% of the littoral habitat of Clary Lake. This habitat class was present in small, shallow bays around the southern main basin of the lake and, more notably, in the smaller northern basin of the lake where it was the dominant habitat class. Bottom substrates in this northern basin were a combination of fine silt, decaying organic matter, and decomposing woody debris (determined during Ekman sampling for BMI), presumably brought into the lake by the main Clary Lake inlet that entered this basin from the north. The sill separating the northern basin from the main lake basin likely prevented the majority of this organic debris from entering the southern main basin.

Other habitat classes present in the littoral zone of Clary Lake included boulder / cobble habitat (16% of total littoral area), small gravel habitat (2%), and boulder habitat (1%). Boulder / cobble habitat was found exclusively along the south-eastern shoreline and around the islands in the centre of the main basin. Small gravel habitat was found at the mouths of the two main inlets to Clary Lake: Clary Creek which drained into Clary Lake at the southern-most end of the lake in the main basin; and the main Clary Lake tributary which drained into Clary Lake at the top of the northern basin. The two islands in the middle of the larger southern basin provided extra littoral area in addition to the littoral area that existed along the lake shoreline.

The riparian vegetation surrounding Clary Lake was similar to that of Patsy Lake. This vegetation community was comprised largely of mosses, herbs and mature coniferous trees. In the lake, aquatic vegetation was moderately abundant within the littoral zone where moderate amounts of woody debris were observed.



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REFERENCE:
Clary lake outline is digitize from Orthophoto and is not base on TRIM base data.

NOTES:
1. Not intended for navgational use
2. Uncharted rocks shoals may exist

Legend

- 6m Contour
- Stream
- Clary Lake Outline
- Island
- Large Gravel/Cobble Habitat
- Fine Organic Habitat
- Small Gravel Habitat
- Boulder/Cobble Habitat
- Boulder Habitat
- Pelagic Habitat

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ANALYST:	MY
QA:	JA
DATUM:	NAD83
PROJECTION:	UTM Zone 9
SCALE:	1:6,000

PROJECT: Kitsault Mine Project

TITLE: Littoral Habitat Classification of Clary Lake

REV. NO:	A
DATE:	June 2011
PROJECT NO:	VE51988
FIGURE NO:	1.4-7

1.4.3 Lake 901

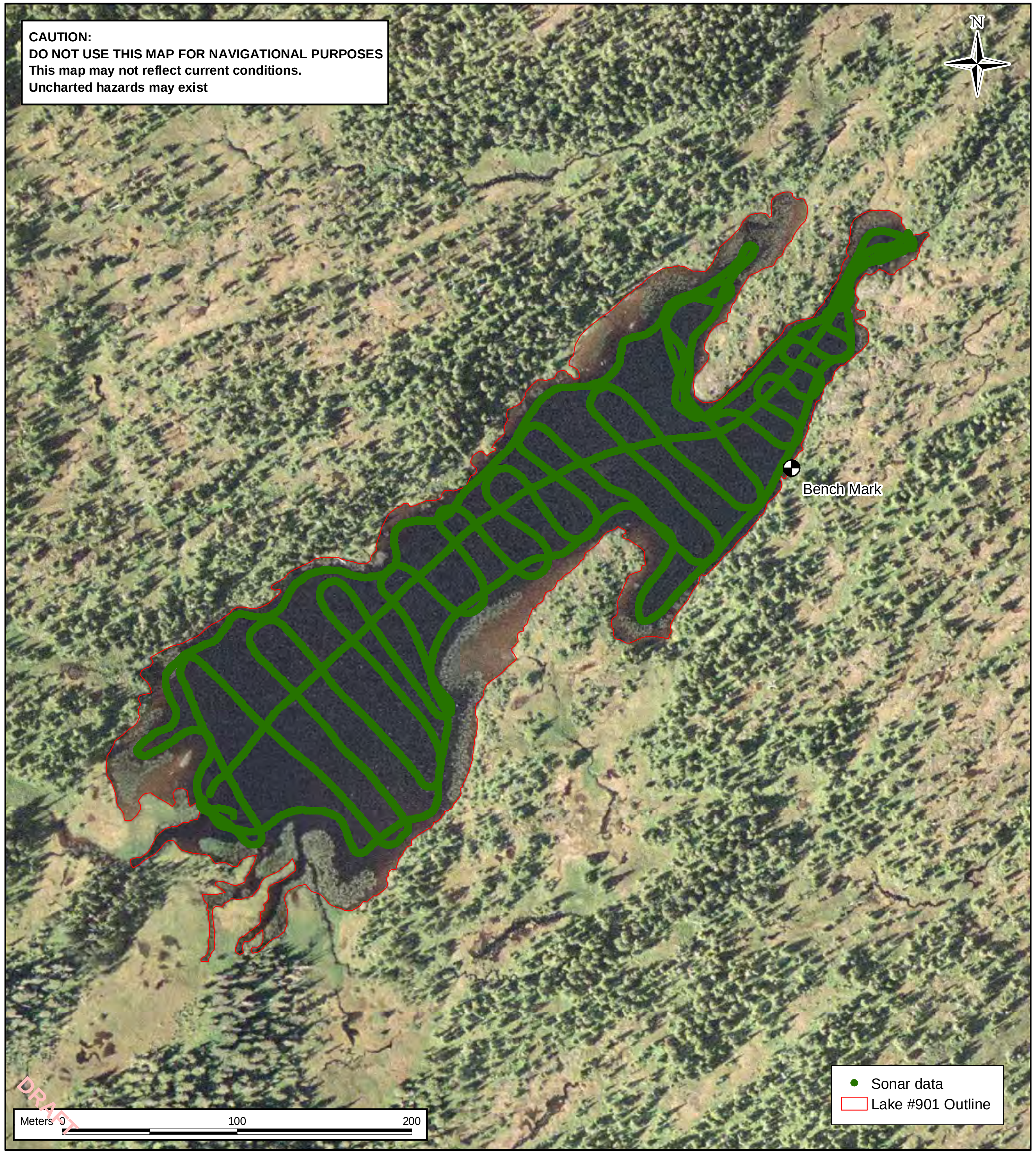
1.4.3.1 Bathymetry

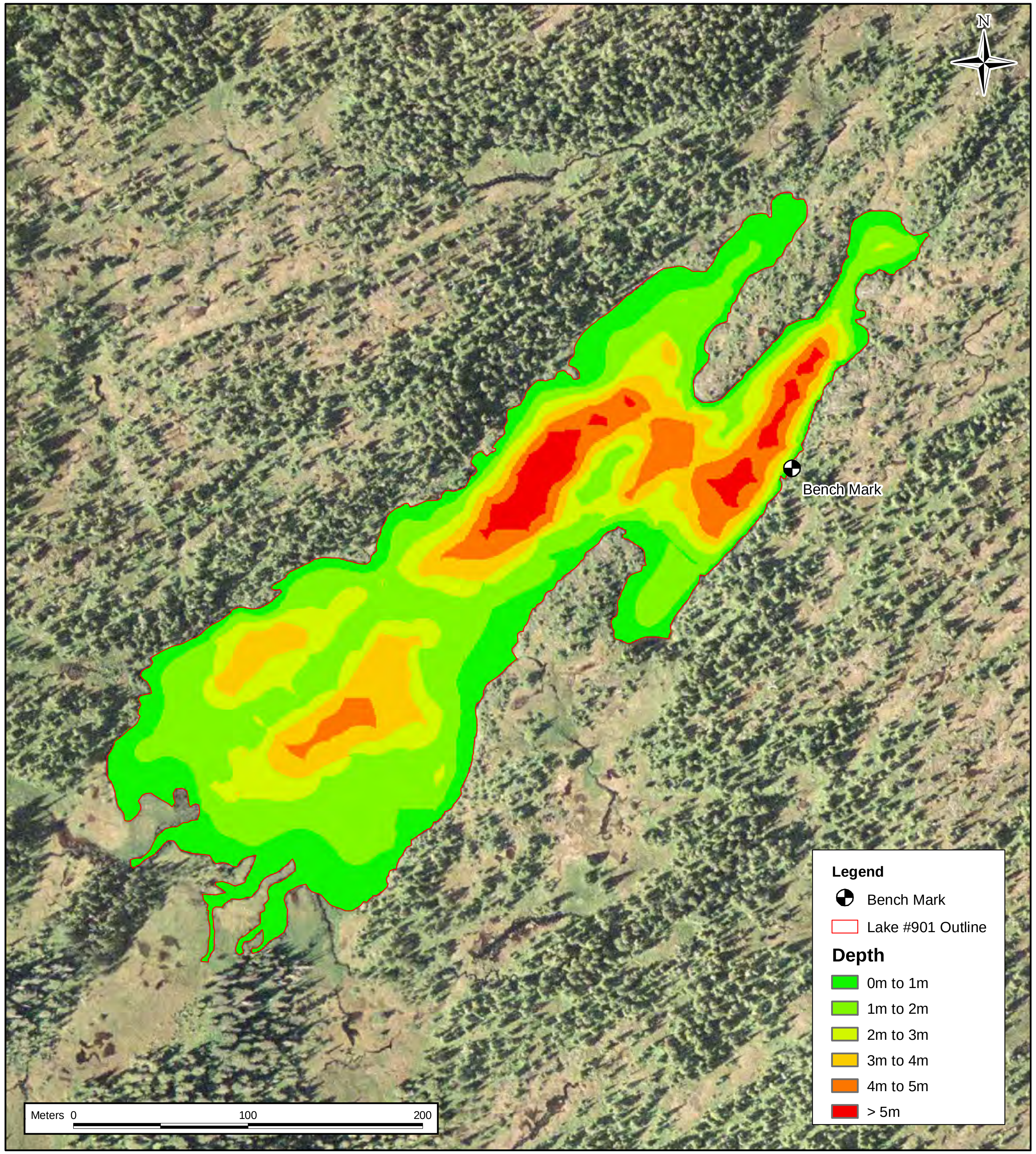
The bathymetry of Lake 901 is shown in Figure 1.4-8. Lake 901 had a maximum depth of 5.8 m, an average depth of 2.1 m, and a relative depth of 2.0% (Table 1.4-1). Lake 901 had a total surface area of 61,646 m^2, a shoreline perimeter of 2.4 km, and a total volume of 126,812 m^3. Because of its shallow depth, the entire lake surface area of Lake 901 was considered littoral habitat. Lake 901 had a surface area to volume ratio of 0.49:1 and a shoreline development of 2.70, the highest values of any of the three lakes sampled in 2010. Habitat quality aside, these numbers indicated that Lake 901 had a higher relative potential for littoral benthic invertebrate and planktonic community development and production than either Patsy or Clary lakes.

Lake 901 had one basin. The lake was generally shallower (<3 m deep) in its south-western half while the deepest part of the lake (>5 m) was found in the north-eastern half of the lake. A bedrock peninsula separated the north-eastern most portion of the lake into two bays. The bay to the northwest was shallow (<2 m deep) with extensive aquatic vegetation. The bay to the southeast was deeper (>3 m deep) and surrounded by bedrock along most of its length.

The shoreline along the western side of Lake 901 generally had a lower gradient (< 5%) than the shoreline along the eastern side of the lake (>10%). There were no islands in Lake 901.

Lake 901 received 84% of its inflow run-off from the two tributaries (Lake 901 inlet (WSC 910-929800-05800-76800) and ILP 887) at the southwestern end of the lake. Lake 901 had an additional three inlet tributaries but these were small (<0.5 m wide), shallow (<30 cm deep), and provided less than 16% of the total Lake 901 inflow per annum. As mentioned above, Lake 901 had a single outlet at the northeastern most corner of the lake.





REFERENCE:
Lake #901 outline is digitize from Orthophoto and is not base on TRIM base data.

NOTES:
1 - Depths are in meters
2. Not intended for navgational use
3. Uncharted rocks shoals may exist

SURVYED BY:	Tim Newman
SURVYED DATE:	July 8th, 9th 2010
WATERSHED CODE:	910-925981-060157-652535
ORTHOPHOTO:	Mcelhanney 2008
N.T.S:	103P/06

Statistics at Time of Survey

ELEVATION:	746 m	MEAN DEPTH:	2.0 m
SURFACE AREA:	61646 sq.m	MAX DEPTH:	5.76 m
AREA ABOVE 6M CONTOUR:	N/A	PERIMETER, MAIN SHORE:	2379.9 m
VOLUME:	126812 cu.m	PERIMETER, ISLANDS:	N/A
ABOVE WATER LEVEL:	2.0 m	BENCH MARK UTM:	476992 E, 6144189 N

CLIENT

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ANALYST:	MY
QA:	JA
DATUM:	NAD83
PROJECTION:	UTM Zone 9
SCALE:	1:3,000

PROJECT

Kitsault Mine Project

TITLE

Lake 901 Bathymetry Map

Depth in meters

REV. NO:	A
DATE:	December 2010
PROJECT NO:	VE51988
FIGURE NO:	1.4-8

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1.4.3.2 Limnology

A summary of the limnological parameters measured in Lake 901 in 2010 is provided in Table 1.4-3. Raw data are presented Appendix B-3.

Lake 901 had a D_s of 2.0 m, a 1% euphotic depth of 5.4 m, a pH between 6.6 and 6.9 and, a specific conductivity between 13 and 75 µS/cm in July 2010 (Table 1.4-4). Lake 901 was too shallow to develop a thermocline and the lake was fully mixed during the July survey (Figure 1.4-9). Water temperatures in the water column ranged from near 12°C at the surface to 8°C near the bottom. DO concentrations ranged between 8.5 and 9.5 mg/L throughout the water column. At the water temperature recorded, these DO concentrations were near full saturation.

The 1% euphotic zone depth of 5.4 m in Lake 901 placed it within 15 cm of the lake bottom. This result, combined with the high surface area to volume ratio and the high shoreline development number indicated above, further suggested that Lake 901 should have a higher potential for littoral community production per hectare than either Clary or Patsy Lake.

The pH of Lake 901 was near the lower limit specified in the guidelines for the protection of aquatic life (Canadian Council of Ministers of the Environment (CCME) 1999). However, the pH was well above the 4.5 pH threshold for lethal effects to aquatic life (RISC 1998).

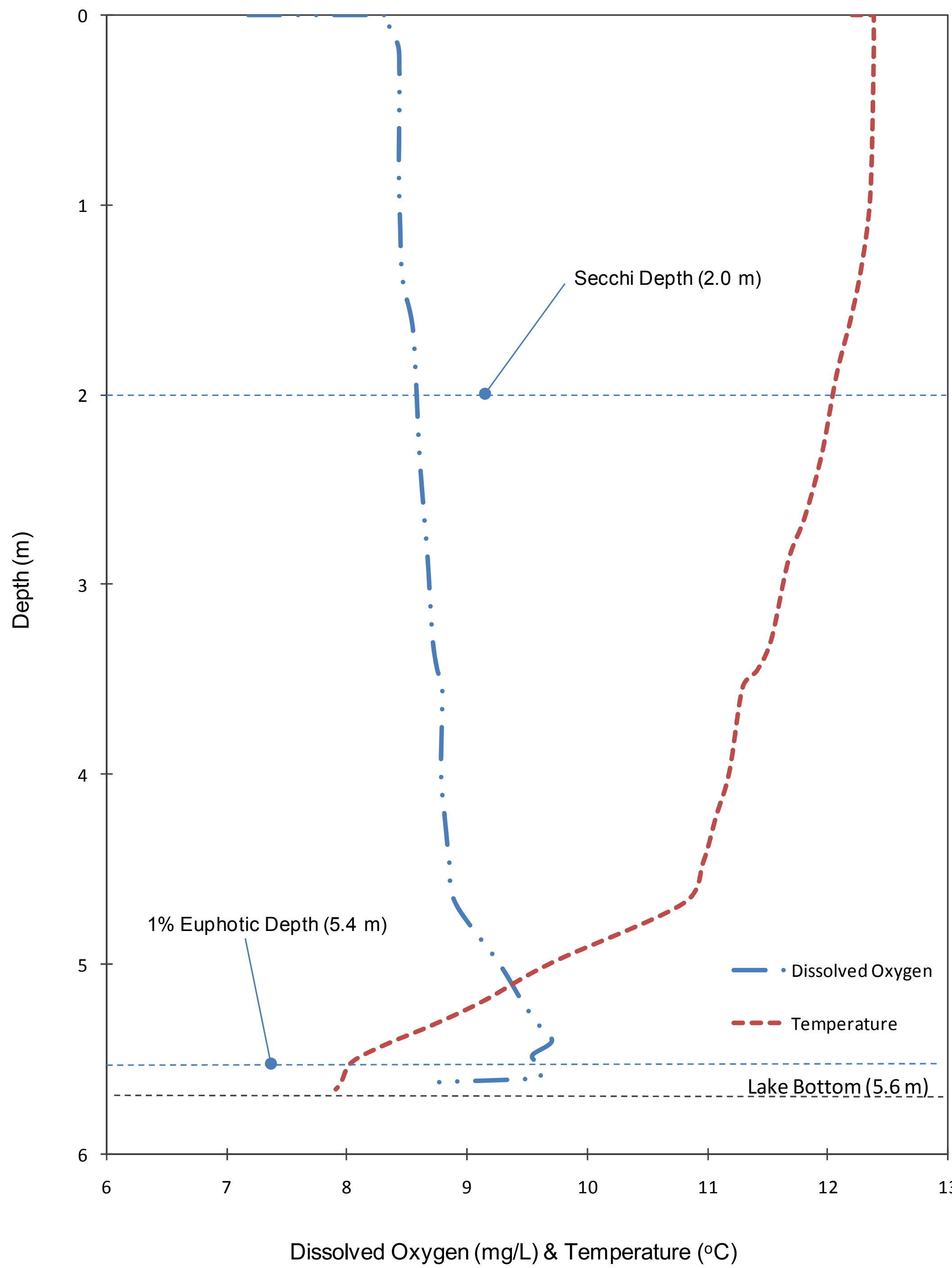


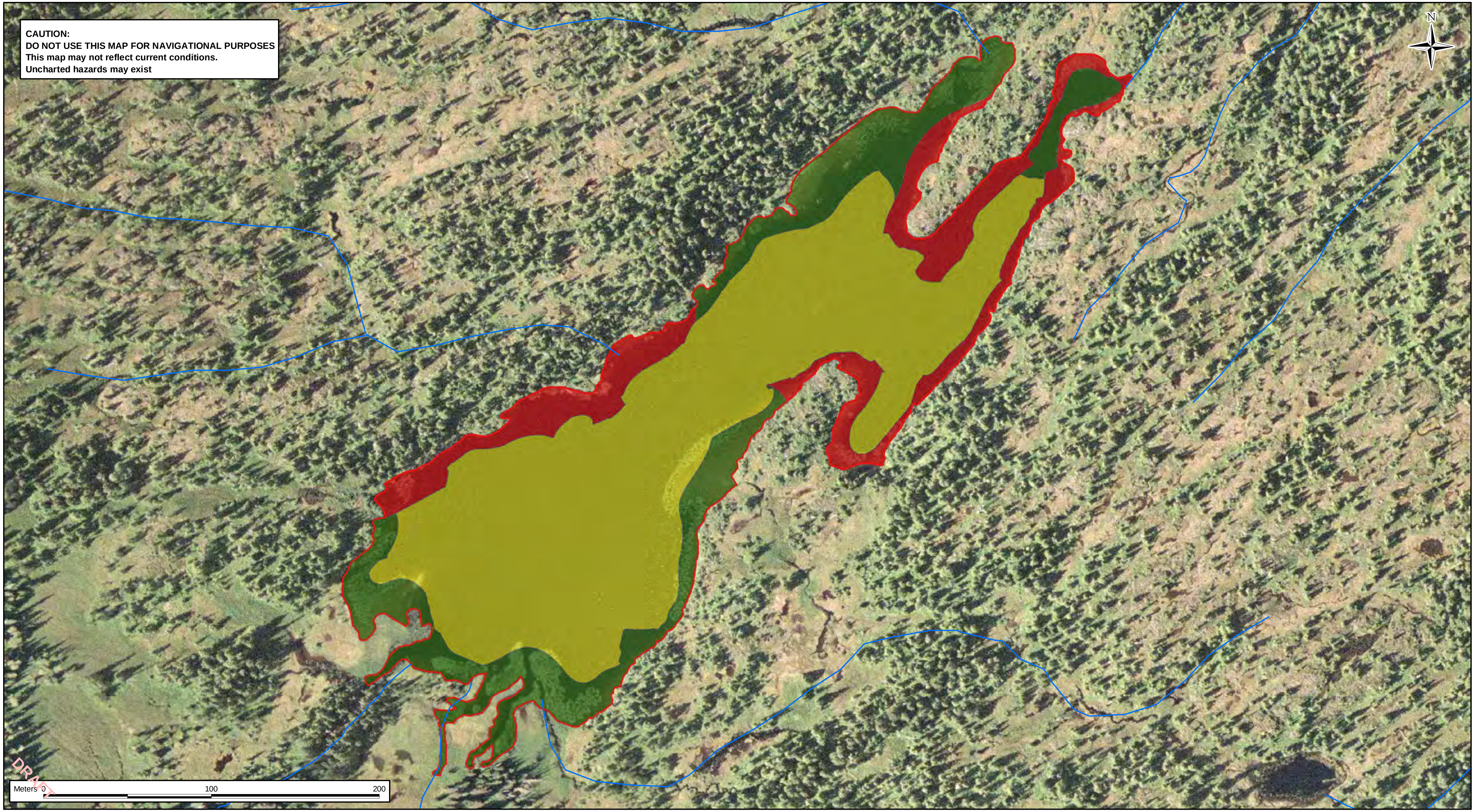
Figure 1.4-9: Dissolved Oxygen / Temperature Profile for Lake 901, September 2010

1.4.3.3 Habitat Classification and Mapping

A habitat classification map of Lake 901 is provided in Figure 1.4-10. A summary of area, volumes and % of total lake area for each of the three littoral habitat classes found in Lake 901 is provided in Table 1.4-3.

Most (64%) of the littoral habitat in Lake 901 was fine inorganic habitat. All of this habitat was located in the “off-shore” area in the middle of the lake below the 2 m depth contour. While this habitat was classed as fine inorganic habitat, it undoubtedly contained fine organic matter as well but was not classified as such because it did not have submergent or emergent macrophytes as areas closer to shore did. Presumably, because of the greater exposure to wave action and the greater depth in the middle of the lake compared to the shallower, protected bays where fine organic habitat is present. These areas with fine organic habitat with macrophytes were located at the southwestern end of the lake, along the south-eastern shoreline, and in the two bays at the northern end of the lake. In total, fine organic habitat comprised 22% of the total littoral habitat area of Lake 901. Large gravel / cobble habitat comprised the remaining 14% of the total littoral area and was found primarily along the western shoreline and along the north-eastern shoreline and the peninsula at the north end of the lake below the high (>3 m) bedrock banks.

The riparian vegetation surrounding Lake 901 was comprised of mosses, herbs and mature coniferous forests.



Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-041_v3.mxd

REFERENCE:
Lake #901 outline is digitize from Orthophoto and is not base on TRIM base data.

NOTES:
1. Not intended for navgational use
2. Uncharted rocks shoals may exist

Legend
- Stream
- Lake #901 Outline
- Large Gravel/Cobble Habitat
- Fine Organic Habitat
- Fine inorganic Habitat

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amec

ANALYST:	MY
QA:	JA
DATUM:	NAD83
PROJECTION:	UTM Zone 9
SCALE:	1:2,200

PROJECT
Kitsault Mine Project

TITLE
Littoral Habitat Classification of Lake #901

REV. NO:	A
DATE:	June 2011
PROJECT NO:	VE51988
FIGURE NO:	1.4-10

1.5 Primary Producers

1.5.1 Periphyton

1.5.1.1 2009 Results

Periphyton community taxonomic composition, abundance, and chlorophyll *a* data for 2009 are presented in Appendices C-1 and C-2.

1.5.1.1.1 Density and Biomass

Mean periphyton density in 2009 ranged from a low of 473,200 cells/cm^2 at LC3 to a high of 1,742,000 cells/cm^2 at PC2 (Table 1.5-1; Figure 1.5-1). The major taxa contributing to periphyton density at PC2 and LC0 were cyanophyte species, *Chamaesiphon* spp. and *Homoeothrix varians*, repectively. These two species were present in higher densities at these two sites compared to their densities at the other three sites.

Table 1.5-1: Periphyton Density (#Cells/cm^2) and Biomass (µg/cm^2 Chlorophyll a) at Stream Sites in 2009

	Density (cells/cm^2)			
Sampling Site	**Mean**	**SD**	**SE**	**CV**
LCO	1,545,651	264,467	458,070	30
LC1	1,022,131	104,784	181,491	18
LC3	473,170	284,501	492,771	104
PC1	1,019,814	128,089	221,857	22
PC2	1,741,865	94,717	164,055	9
	Biomass (Chl *a* µg/cm^2)			
Sampling Site	**Mean**	**SD**	**SE**	**CV**
LC0	0.298	0.051	0.088	30
LC1	0.108	0.037	0.063	59
LC3	0.005	0.002	0.003	59
PC1	0.079	0.046	0.079	101
PC2	0.436	0.105	0.183	42

Note: SD - standard deviation; SE - standard error; CV - coefficient of variation

Mean periphyton biomass (chlorophyll *a*) ranged from a low of 0.005 µg/cm^2 at LC3 to a high of 0.436 µg/cm^2 at PC2 (Figure 1.5-1). Chlorophyll *a* concentrations at sites within or downstream of the proposed Project area were all below the BC protection of aquatic life guideline (BC MOE 2007) for the maximum chlorophyll *a* concentrations in streams (10 µg/cm^2).

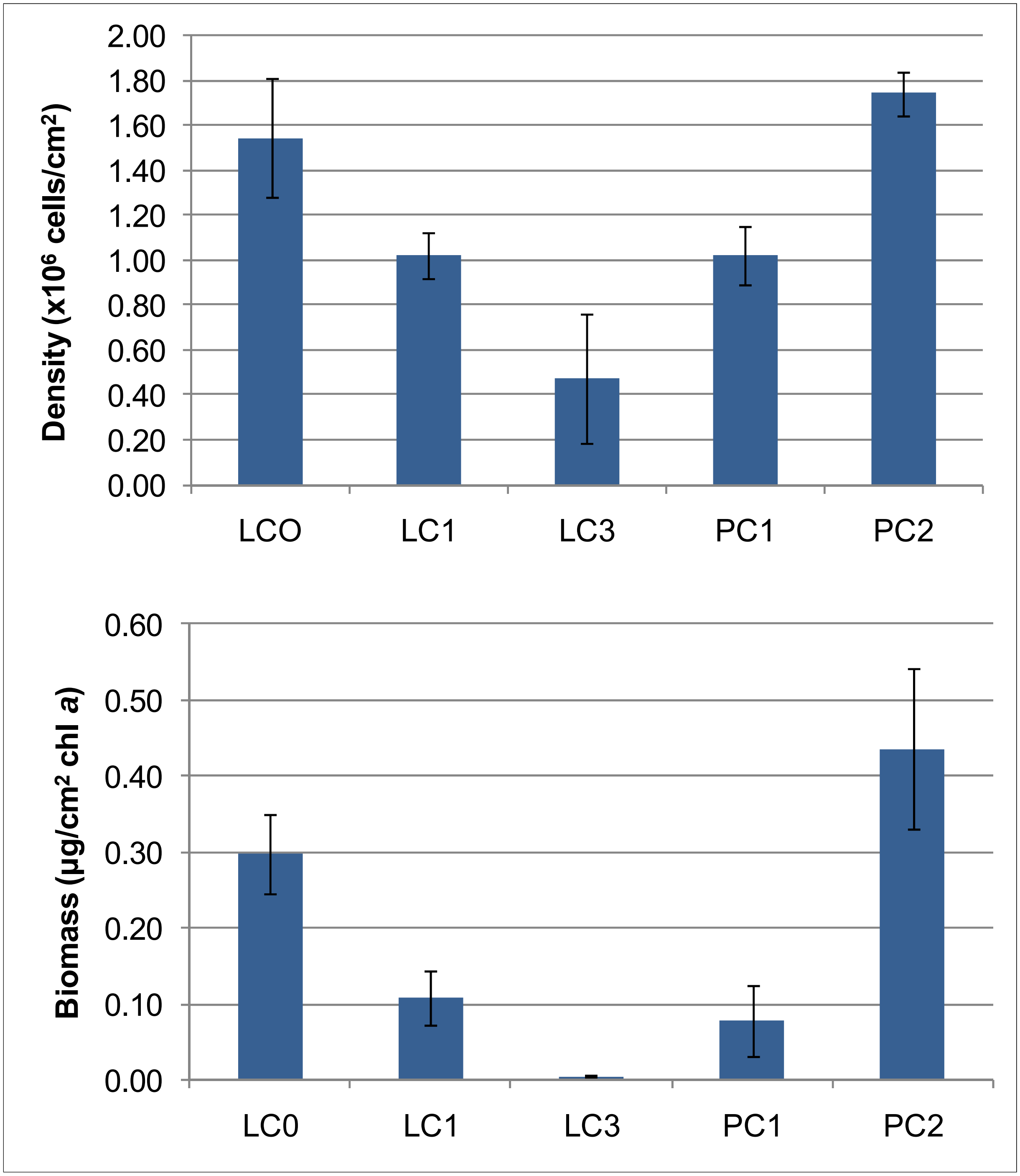


Figure 1.5-1: Periphyton Density (# cells/cm^2) and Chlorophyll a Concentrations (µg/cm^2) at Stream Sites in 2009

Note: Error Bars Represent Mean ±1 SE

1.5.1.1.2 Relative Abundance

Cyanophytes comprised between 52 to 97% of the periphyton community at the five stream sites sampled in 2009 (Table 1.5-2; Figure 1.5-2). Bacillariophytes (diatoms) (<1 to 18%) and chrysophytes (golden-brown algae) (1% to 22%) accounted for the remaining portion of the periphyton communities at these five sites. Chlorophytes (green algae) comprised 27% of the periphyton community at PC1 but <1% of the periphyton community at the other four sites. PC1 is located near the outflow of Patsy Lake, which also had high densities of chlorophytes. Proximity to the lake and the influence of lake chemistry and nutrient load at PC1 likely contributed to this difference in chlorophyte community development compared to the other four sites.

1.5.1.1.3 Richness and Diversity Indices

Mean taxa richness (*S)* values at the five sample sites in 2009 ranged between a minimum of 11 genera at LC3 and a maximum of 35 genera at PC1 (Table 1.5-3; Figure 1.5-3). Greater mean taxa richness at PC1 is likely due to the influence of Patsy Lake outflow water chemistry and nutrient loads at this site.

Mean Shannon diversity (*H')* values were relatively similar at four of the five sample sites, ranging between 0.76 at PC2 to 1.18 at LC0 (Table 1.5-3; Figure 1.5-3). The exception was at PC1 where the periphyton community was considerably more diverse than at any of the other four sites with a *H'* of 1.66.

Site PC1 had the highest Evenness index (0.47), again, likely because of the influence on Patsy Lake on the periphyton community at this site. Mean Pielou's Evenness (*J)* values for the other four sites ranged from 0.27 at PC2 to 0.43 at LC3 (Table 1.5-3; Figure 1.5-3). The periphyton community at PC1 was not only the most taxonomically diverse of the five sites but it was also the only site where bacillariophytes (diatoms), chlorophytes (green algae), and rhodophytes (red algae) contributed more than 15%, 1%, and 0.1%, respectively, to the total periphyton community abundance at a site.

Table 1.5-2: Density (#Cells/cm^2) and Relative Abundance (%) of Major Periphyton Taxa in Stream Sites Sampled in 2009

Taxonomic group	LC0		LC1		LC3		PC1		PC2	
	cells/cm^2	%	cells/cm^2	%	cells/cm^2	%	cells/cm^2	%	cells/cm^2	%
Bacillariophyceae	210,783	13.6	83,353	8.2	2,120	0.4	187,209	18.4	23,748	1.4
Chlorophyta	139	0.0	136	0.0	2	0.0	278,082	27.3	3,114	0.2
Chrysophyta	288,647	18.7	142,414	13.9	105,003	22.2	10,088	1.0	24,107	1.4
Cyanophyta	1,043,129	67.5	795,112	77.8	365,899	77.3	525,206	51.5	1,688,807	97.0
Rhodophyta	1,953	0.1	1,116	0.1	145	0.0	19,229	1.9	2,089	0.1
Total	**1,544,651**	**100.0**	**1,022,131**	**100.0**	**473,170**	**100.0**	**1,019,814**	**100.0**	**1,741,865**	**100.0**

Source: Rescan (2010b)

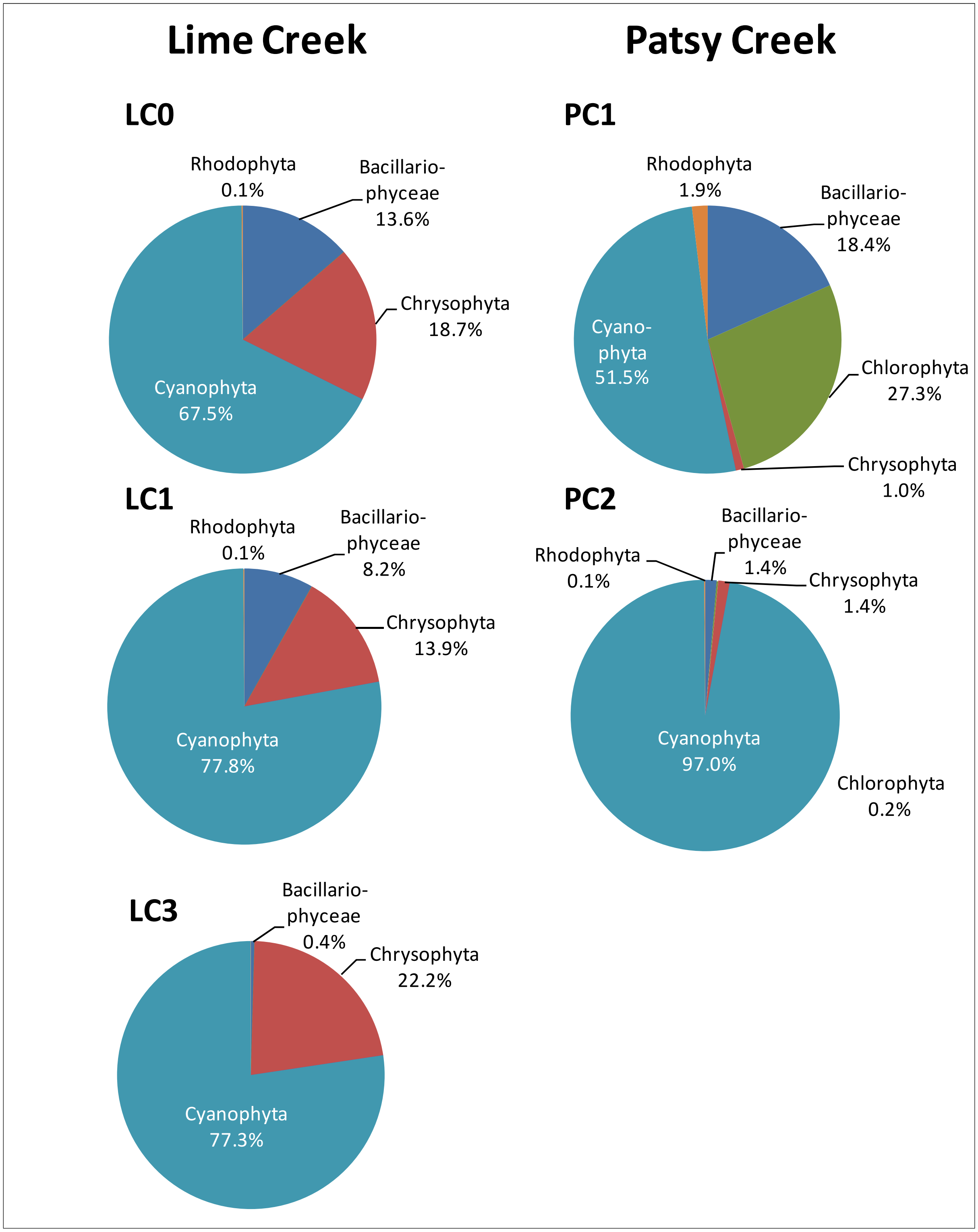


Figure 1.5-2: Relative Abundance of Periphyton Taxa at Stream Sites Sampled in 2009

Table 1.5-3: Richness, Diversity, and Evenness Metrics for Periphyton Communities in Streams Sites Sampled in 2009

Sampling Site	Richness (*S*)		Shannon's Diversity (*H'*)		Evenness (*J*)	
	Mean	SE	Mean	SE	Mean	SE
LCO	21	1	1.18	0.03	0.39	0.01
LC1	14	1	1.05	0.04	0.40	0.02
LC3	11	2	1.00	0.07	0.43	0.00
PC1	35	3	1.66	0.14	0.47	0.03
PC2	17	2	0.76	0.13	0.27	0.04

Note: SE - standard error

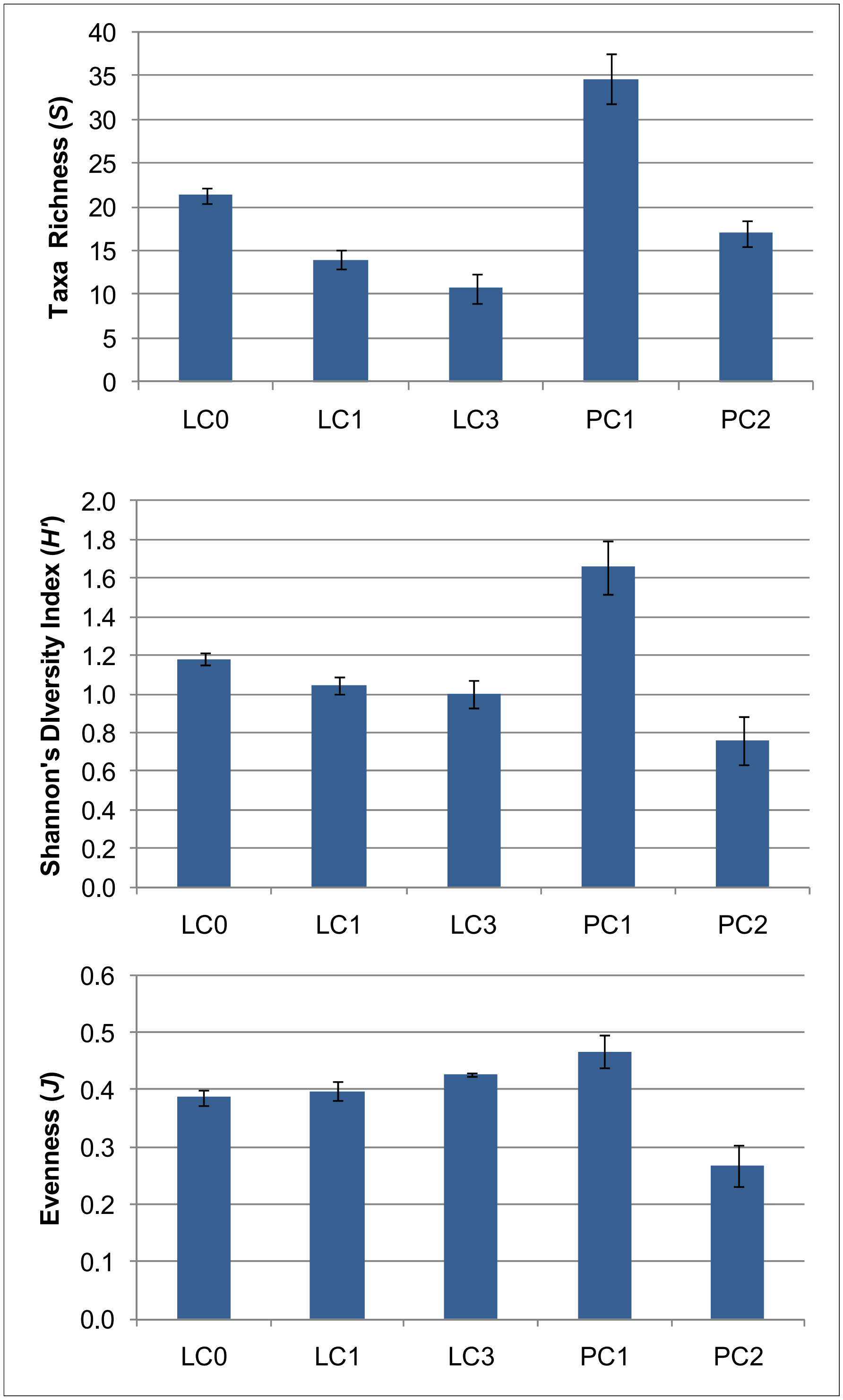


Figure 1.5-3 Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Periphyton Communities at Stream Sites Sampled in 2009

Note: Error Bars Represent Mean ±1 SE

1.5.1.2 2010 Results

Periphyton community taxonomic composition, abundance, and chlorophyll *a* data for 2010 are presented in Appendices C-3 and C-4. A summary of habitat characteristics at each periphyton site sampled in 2010 is presented in Appendix C-6.

1.5.1.2.1 Density and Biomass

Mean periphyton densities were highly variable within and between all six stream sites sampled in 2010 (Table 1.5-4; Figure 1.5-4). Within site variability was highest at sites LC1-10 and LC3-10 in Lime Creek and at site L901-I in the Clary Creek watershed. Mean periphyton densities ranged from a low of 99, 854 cells/cm^2 at L901-O to a high of 928,266 cells/cm^2 at L901-I. With the exception of site L901-I, mean periphyton densities were higher in the Lime Creek watershed sites than in the Clary Creek watershed sites.

Mean periphyton densities in lower Lime Creek and in Patsy Creek sites (away from the influence of Patsy Lake) were higher in 2009 than in 2010. In contrast, mean periphyton density in the upper Lime Creek site was higher in 2010 than in 2009. The differences observed between year and among sites, however, were not statistically different (RM ANOVA Year effect: $F_{(1,6)}=0.699$, $p=0.435$; Site effect: $F_{(2,6)}=0.408$, $p=0.682$) due to high within site variability.

Table 1.5-4: Mean Periphyton Density (cells/cm^2) and Biomass (chl a µg/cm^2) at Stream Sites Sampled in 2010

Sampling Site	Density (cells/cm^2)			
	Mean	**SD**	**SE**	**CV**
Lime Creek watershed sites				
LC1-10	822,360	899,816	402,410	109
LC3-10	688,632	1,354,742	605,859	197
PC	302,776	520,722	232,874	172
Clary Creek watershed sites				
L901-I	928,266	696,750	311,596	75
L901-O	99,854	132,923	59,445	133
CL-O	187,772	148,017	66,195	79
Sampling Site	**Biomass (chl a µg/cm^2)**			
	Mean	**SD**	**SE**	**CV**
Lime Creek watershed sites				
LC1-10	0.41	0.42	0.19	103
LC3-10	0.11	0.10	0.04	88
PC	0.12	0.08	0.03	61
Clary Creek watershed sites				
L901-I	3.17	2.31	1.03	73
L901-O	0.64	0.63	0.20	98
CLO	2.62	2.13	0.87	81

Note: CV - coefficient of variation; SD - standard deviation; SE - standard error

Mean chlorophyll *a* concentration at stream sites sampled in 2010 ranged from a low of 0.11 µg/cm^2 at LC3-10 to a high of 3.17 µg/cm^2 at L901-I (Figure1.5-4). The three stream sites located in the Lime Creek watershed all had lower chlorophyll *a* concentrations than the three stream sites in the Clary Creek watershed (Figure 1.5-4). Chlorophyll *a* concentrations at all six sites were below the BC guideline for the protection of aquatic life in stream (BC MOE 2007) of 10 µg/cm^2.

Mean chlorophyll *a* concentrations in lower Lime Creek (LC1-10) and in upper Lime Creek (LC3-10), 0.41 and 0.10 µg/cm^2, respectively, were higher in 2010 than in 2009 (sites LC1 and LC3), 0.108 and 0.005 µg/cm^2, respectively. The opposite was true at the Patsy Creek site where mean chlorophyll *a* concentration in 2009 (0.436 µg/cm^2) was higher than in 2010 (0.12 µg/cm^2). These differences, however, were not significantly different (RM ANOVA Year effect: $F_{(1,6)}$=0.173, p=0.692; Site effect: $F_{(2,6)}$=2.50, p=0.162) due to high within site variability.

1.5.1.2.2 Richness and Diversity Indices

Mean taxa richness (*S)* at the five sample sites in 2009 ranged between a minimum of 11 genera at LC3 and a maximum of 35 genera at PC1 (Table 1.5-3; Figure 1.5-3). Greater mean *S* at PC1 is likely due to the influence of Patsy Lake outflow water chemistry and nutrient loads at this site.

Mean Shannon diversity (*H')* values were relatively similar at four of the five sample sites, ranging between 0.76 at PC2 to 1.18 at LC0 (Table 1.5-3; Figure 1.5-3). The exception was at PC1 where the periphyton community was considerably more diverse than at any of the other four sites with an *H'* of 1.66.

Site PC1 had the highest Evenness (J) index (0.47), again, likely because of the influence on Patsy Lake on the periphyton community at this site. Mean *J* for the other four sites ranged from 0.27 at PC2 to 0.43 at LC3 (Table 1.5-3; Figure 1.5-3). The periphyton community at PC1 was not only the most taxonomically diverse of the five sites but it was also the only site where bacillariophytes (diatoms), chlorophytes (green algae), and rhodophytes (red algae) contributed more than 15%, 1%, and 0.1%, respectively, to the total periphyton community abundance at a site.

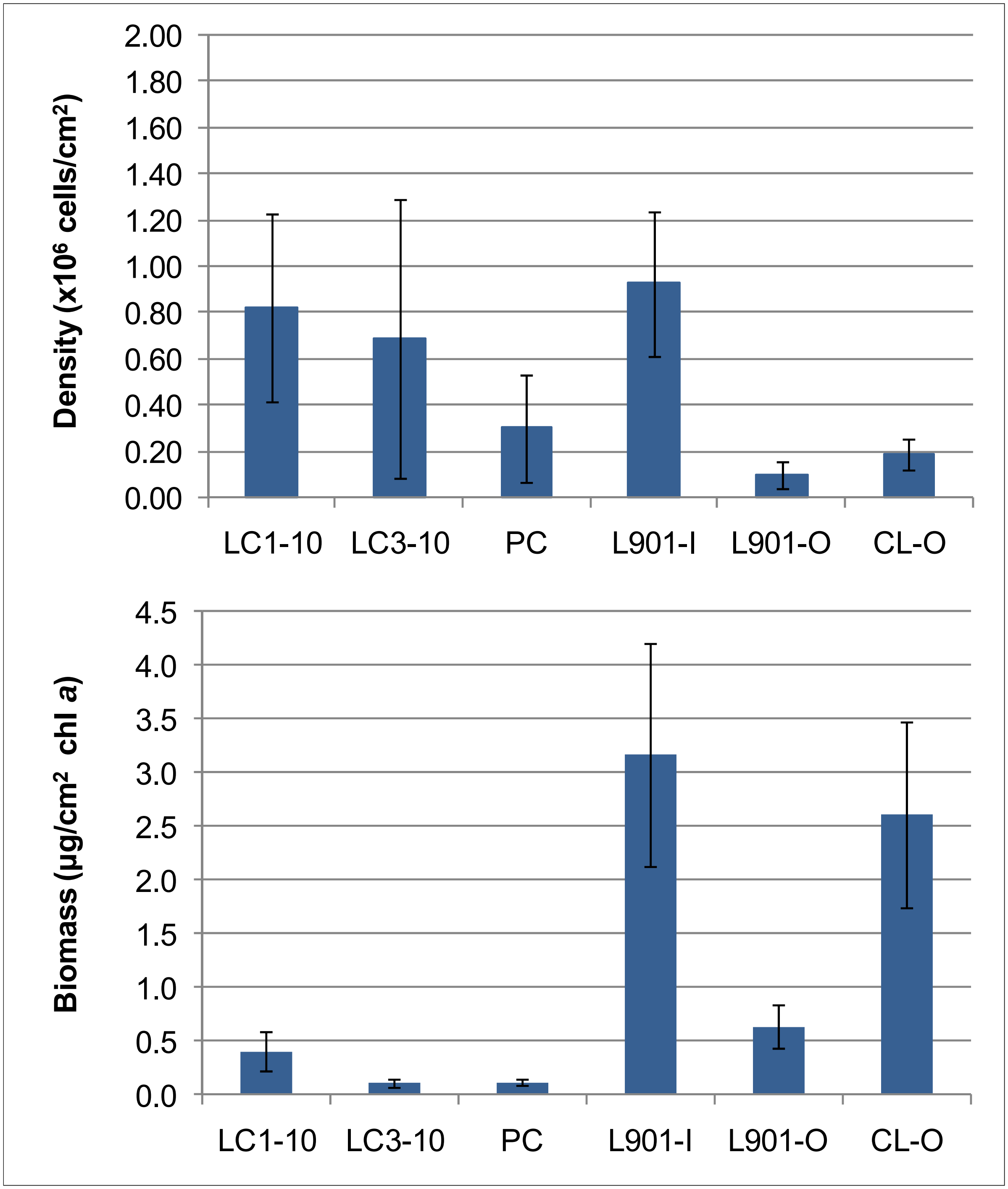


Figure 1.5-4: Periphyton Density (# cells/cm²) And Biomass (µg/cm² chl a), 2010

Note: Error Bars Represent Mean ±1 SE

1.5.1.2.3 Relative Abundance

Similar to 2009, the periphyton communities at stream sites sampled in the Lime Creek watershed in 2010 were primarily composed of cyanophytes. Cyanophytes comprised 79% to 99% of the periphyton communities at the two Lime Creek and one Patsy Creek sample sites (Table 1.5-5; Figure 1.5-5). Bacillariophytes (diatoms) comprised 20% of the total periphyton community abundance at site LC1-10 but <4% at LC3-10 and <1% at PC. Chrysophytes (golden-brown algae) and rhodophytes (red algae) comprised <2% and <1% of the periphyton communities at these three sites.

Cyanophytes were also the most abundant periphyton taxa at the three sites sampled in the Clary Creek watershed in 2010. Cyanophytes comprised over 50% of the total periphyton community abundance at all three sites (Table 1.5-5; Figure 1.5-5). However, in comparison to the three Lime Creek watershed sample sites, the relative abundance of rhodophytes and chlorophytes (green algae) were much higher at the three Clary Creek watershed sites. Rhodophtyes comprised 11%, 38%, and 3% of the periphyton communities at sites the Lake 901 inlet (L901-I), the Lake 901 outlet (L901-O) and the Clary Lake outlet (CL-O), respectively. In comparison, rhodophytes comprised <1% of the total periphyton community at the three Lime Creek watershed sites. The reason for the high relative abundance of rhodophytes at the Lake 901 outlet site is unknown but may be due to the influence of some unique habitat conditions at the site (e.g., highest % of cobble substrates than any other site; see Appendix C-6) or the influence of water quality and / or sediment quality coming out of Lake 901. Water in Lake 901 is considerably more tannic than water in Clary Lake or in Patsy Lake and these tannins may be the reason for the higher rhodophyte abundance at the Lake 901 outlet site.

Bacillariophytes (diatoms) comprised 35% of the total periphyton community at the Clary Lake outlet site (CL-O). The reason for this relative high abundance of diatoms is unknown but may be due to the influence of the water quality and sediment quality coming out of Clary Lake. There is considerable organic debris on the bottom of the small northern basin of Clary Lake and, because the Clary Lake outlet drains from this basin, water and sediment quality parameters coming out of the lake may be more suitable to diatoms than at other sites in the Clary Creek or Lime Creek watersheds. The Clary Lake outlet site also had the greatest mean depth and the largest portion of pebbles and gravel substrates of all six sample sites; this may also have contributed to the abundance of rhodophytes at this site.

Chlorophytes comprised 23%, 4% and 1.5% of the periphyton communities at L901-I, L901-O and CL-O, respectively, while chlorophytes comprised <0.1% of the three Lime Creek watershed sites. The high relative abundance of chlorophytes at the Lake 901 inlet site was the reason for the high chlorophyll *a* concentration at this site in 2010. There were unidentified pyrrophyte cells found in one of the three samples collected in the outlet of Clary Creek and likely originated from Clary Lake. Their actual relative abundance was 0.01%. These facts suggest that their presence in CL-O is likely due to Clary Lake influence and are not part of the periphyton community.

Table 1.5-5: Density (cells/cm^2) and Relative Abundance (%) of Major Periphyton Taxonomic Groups in Streams Sampled in 2010

Taxonomic group	Lime Creek Watershed					
	LC1-10		LC3-10		PC	
	#cells/cm^2	%	#cells/cm^2	%	#cells/cm^2	%
Bacillariophyceae	168,691	20.5	4,398	0.6	11,589	3.8
Chlorophyta	309	0.0	2	0.0	9	0.0
Chrysophyta	2,571	0.3	31	0.0	4,084	1.3
Cryptophyta	0.0	0.0	0	0.0	0	0.0
Cyanophyta	646,574	78.6	684,015	99.3	285,688	94.4
Pyrrhophyta	0.0	0.0	0	0.0	0	0.0
Rhodophyta	4,215	0.5	187	0.0	1,406	0.5
Total	**822,360**	**100.0**	**688,632**	**100.0**	**302,776**	**100.0**
Taxonomic group	**Clary Creek Watershed**					
	L901-I		**L901-O**		**CL-O**	
	#cells/cm^2	**%**	**#cells/cm^2**	**%**	**#cells/cm^2**	**%**
Bacillariophyceae	26,606	2.9	5,559	5.6	65,571	34.9
Chlorophyta	217,082	23.4	4,374	4.4	2,888	1.5
Chrysophyta	1,641	0.2	123	0.1	644	0.3
Cryptophyta	9	0.0	70	0.1	6	0.0
Cyanophyta	583,234	62.8	51,892	52.0	112,649	60.0
Pyrrhophyta	0	0.0	0	0.0	10	<0.1
Rhodophyta	99,694	10.7	37,837	37.9	0	0.0
Total	**928,266**	**100.0**	**99,854**	**100.0**	**187,772**	**100.0**

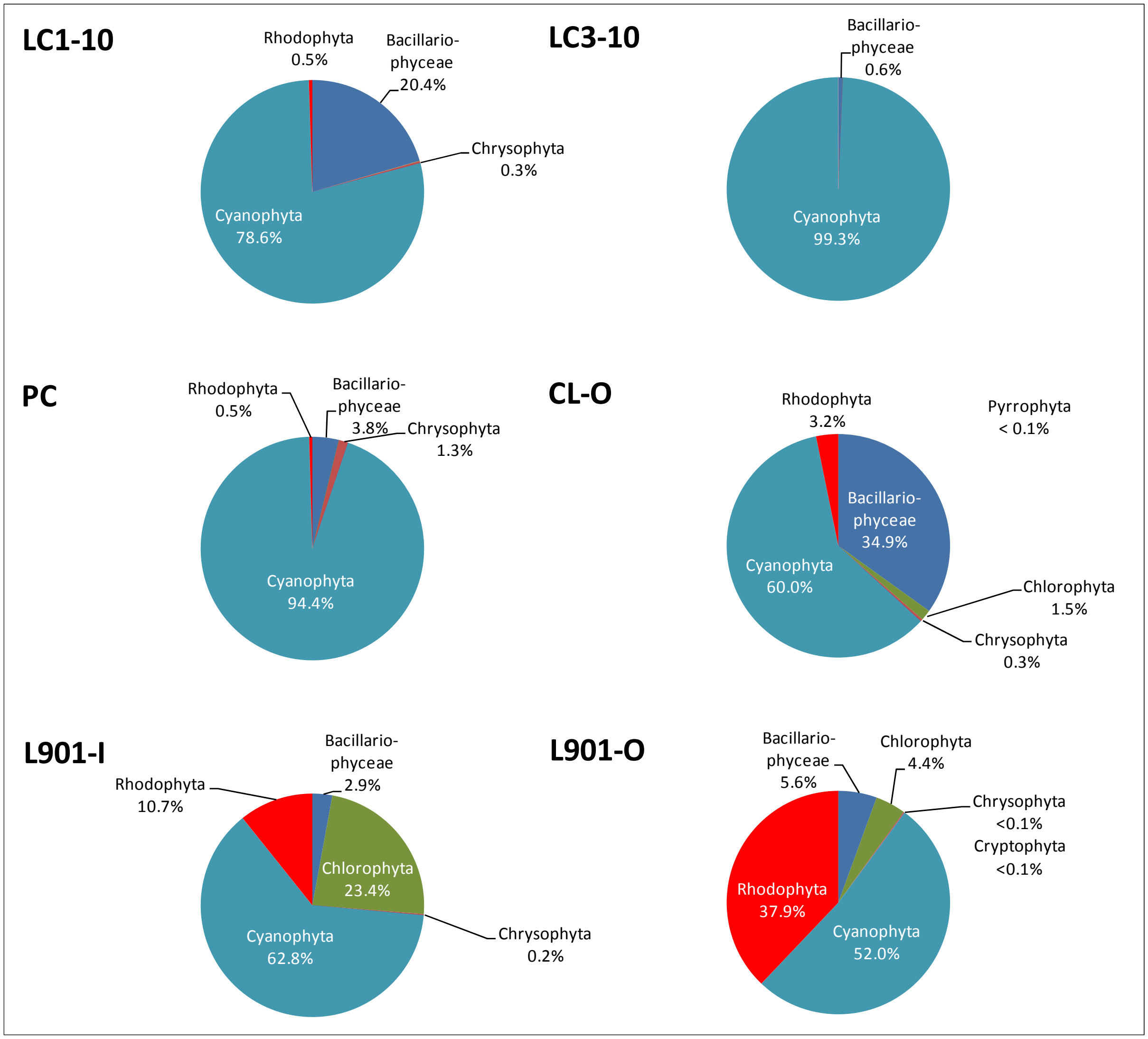


Figure 1.5-5: Relative Abundance of Periphyton Taxa at Stream Sites Sampled in 2010

The relative abundance of Bacillariophytes (diatoms) and rhodophytes at sites LC1-10, LC3-10 and PC in 2010 was similar to similar sample sites in 2009. Rhodophytes comprised <1% of the total periphyton communities at the two Lime Creek and one Patsy Creek sample sites in both years. Similarly, the relative abundance of diatoms was higher at the lower Lime Creek sample site (LC1-10) than at the upper Lime Creek (LC3-10) and Patsy Creek sites in both 2009 and 2010.

While the relative abundance of chrysophytes was similar at the Patsy Creek sample site in 2009 and 2010, 1.4% and 1.3%, respectively, the relative abundance of chrysophytes at the lower and upper Lime Creek samples sites was much higher in 2009 (14% and 22% in 2009) than in 2010 (0.3% and <0.1%), respectively.

1.5.1.2.4 Richness and Diversity Indices

Mean taxa richness (*S*) was higher at the three sites in the Clary Creek watershed than the three sites in the Lime Creek watershed. Mean *S* values ranged between a low of 11 genera at LC3-10 and a high of 17 genera at LC1-10 in the Lime Creek watershed while mean *S* values were all greater than 17 genera at the three sites in Clary Creek watershed. The site at the Lake 901 inlet (L901-I) had the highest mean *S* with an average of 29 genera per sample (Table 1.5-6; Figure 1.5-6).

Table 1.5-6: Richness, Diversity, and Evenness Metrics for Periphyton Communities in Streams Sites Sampled in 2010

Sampling Site	Richness (*S*)		Shannon's Diversity (*H'*)		Evenness (*J*)	
	Mean	SE	Mean	SE	Mean	SE
Lime Creek watershed sites						
LC1-10	17	3	1.34	0.10	0.50	0.06
LC3-10	11	1	0.57	0.11	0.24	0.04
PC	14	0	0.78	0.11	0.30	0.04
Clary Creek watershed sites						
L901-I	29	2	1.66	0.22	0.49	0.06
L901-O	18	3	1.27	0.19	0.47	0.09
CL-O	24	4	1.62	0.25	0.51	0.06

Note: SE - standard error

Similarly, mean diversity (*H'*) and evenness (*J*) values were generally higher in the Clary Creek watershed sites than in the Lime Creek watershed sites (Table 1.5-6; Figure 1.5-6). The lower Lime Creek site (LC1-10) had the highest mean diversity (1.34) and highest mean evenness (0.50) of the three sample sites in the Lime Creek watershed while the Lake 901 inlet (L901-I) and the Clary Lake outlet (CLO) sites had the highest mean diversity (1.66 and 1.62, respectively) and the highest mean evenness (0.49 and 0.51, respectively) in the Clary

Creek watershed. Sites in upper Lime Creek (LC3-10) and Patsy Creek (PC) had the lowest mean diversity and evenness values of any of the six sites sampled in 2010.

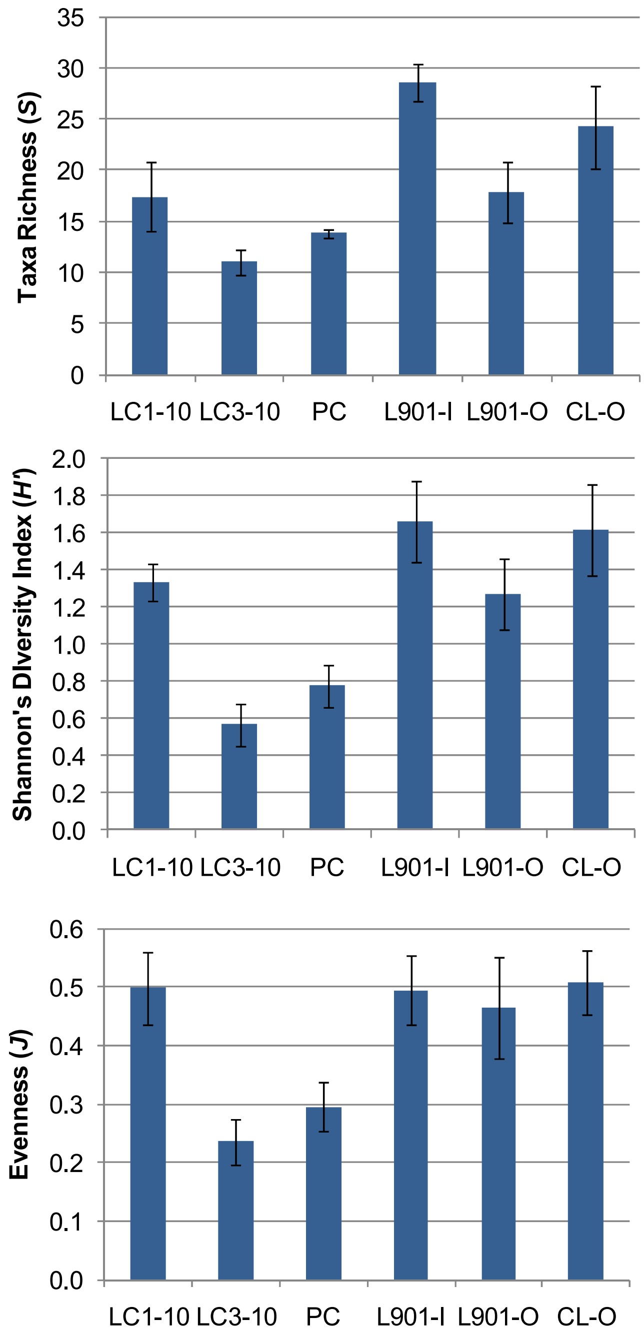


Figure 1.5-6: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Periphyton Communities at Stream Sites Sampled in 2010

Note: Error Bars Represent Mean ±1 SE

1.5.1.2.5 Comparison Between 2009 and 2010 Results

A comparison of taxonomic richness, diversity, and evenness between the three comparable sites sampled in the Lime Creek watershed in 2009 and 2010 is presented in Table 1.5-7. Mean taxa richness (*S)* was similar at all three sites between years. Mean diversity and evenness values were higher at the lower Lime Creek site (1.05 and 0.40, respectively at LC1) in 2009 than in 2010 (1.34 and 0.50, respectively, at LC1-10). The opposite was true at the upper Lime Creek site where mean diversity and mean evenness values were higher in 2009 (1.00 and 0.43, respectively, at LC3) than in 2010 (0.57 and 0.24, respectively, at LC3-10). Diversity and evenness metrics were similar at the Patsy Creek site in both years.

Table 1.5-7: Comparison of Richness, Diversity, and Evenness Metrics for Periphyton Communities in Comparable Streams Sites Sampled in 2009 and 2010

Year	Site	Richness (*S*)		Shannon's Diversity (*H'*)		Evenness (*J*)	
		Mean	SE	Mean	SE	Mean	SE
2009	LC1	14	1	1.05	0.04	0.40	0.02
2010	LC1-10	17	3	1.34	0.10	0.50	0.06
2009	LC3	11	2	1.00	0.07	0.43	0.00
2010	LC3-10	11	1	0.57	0.11	0.24	0.04
2009	PC2	17	2	0.76	0.13	0.27	0.04
2010	PC	14	0	0.78	0.11	0.30	0.04

Note: SE - standard error

1.5.2 Phytoplankton

1.5.2.1 2009 Results

1.5.2.1.1 Density and Biomass

Raw data for phytoplankton samples collected in Patsy Lake and the three wetland sites sampled in 2009 can be found in Appendices D-1 to D-3. Mean (± 1 SE) phytoplankton densities and biomass (presented as chlorophyll *a* concentrations) are presented in Table 1.5-8.

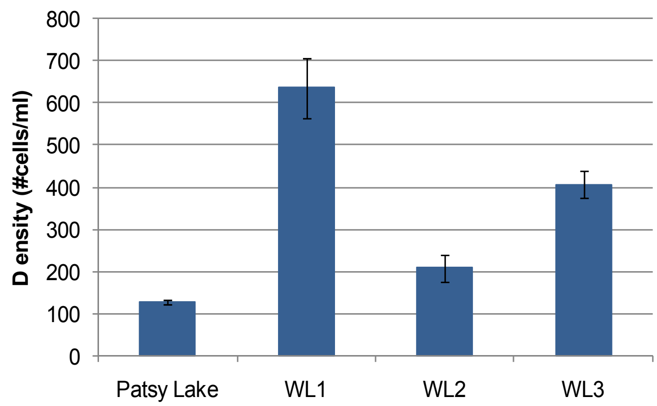
Mean phytoplankton density and biomass in Patsy Lake was 126 cells/ml and 0.35 µg/L chl *a*, respectively (Figure 1.5-7). Phytoplankton density in the wetlands varied between a low of 210 cells/ml at WL2 and a high of 635 cells/ml at WL1 (Figure 1.5-7). Phytoplankton biomass in the wetlands followed a similar pattern as phytoplankton density, ranging from a low of 0.39 µg/L of chlorophyll *a* (chl *a)* at WL2 to a high of 1.22 µg/L of chl *a* at WL1 (Figure 1.5-7). Phytoplankton density and biomass differed significantly with sites (Density: $F_{(3, 8)} = 29.17$, $p<0.001$; Biomass: $F_{(3, 8)} = 22.57$, $p<0.001$). Phytoplankton density in Patsy Lake was similar to that of WL2 ($p=0.958$) but differed significantly from that of WL1 or WL3 ($p<0.05$). The same pattern was observed for biomass.

Table 1.5-8: Phytoplankton Density (cells/ml) and Biomass (µg/L chl a) From Lakes and Wetlands Sampled in 2009

Site	Density (cells/ml)		Biomass (µg/L chl *a*)	
	Mean	SE	Mean	SE
Patsy Lake	127	6	0.35	0.05
WL1	635	71	1.22	0.15
WL2	210	32	0.39	0.09
WL3	407	31	1.10	0.06

Note: SE - standard error

Source: Rescan (2010b) data



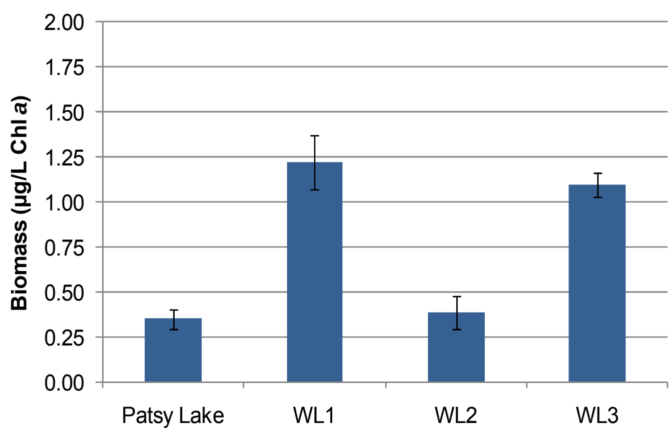


Figure 1.5-7: Density (# cells/ml) and Biomass (µg/L chl a) of Phytoplankton Communities Patsy Lake and Three Wetlands Sampled in 2009

Note: Error Bars Represent Mean ±1 SE

1.5.2.1.2 Relative Abundance

The density and relative abundance of major phytoplankton taxonomic groups present in Patsy Lake and the three wetlands sampled in 2009 are presented in Table 1.5-9 and Figure 1.5-8. A total of 40 species were identified from samples collected at Patsy Lake. Chlorophytes (green algae) were the dominant phytoplankton taxa in Patsy Lake, comprising 66% of the total phytoplankton community, by number. These were followed by cryptophytes (13%), pyrrhophytes (dinoflagellates) (6%), chrysophytes (golden-brown algae) (6%), cyanophytes (blue-green algae) (5.0%), and bacillariophyceae (diatoms) (4.1%) (Figure 1.5-8). Dominant species were the chlorophytes *Botryococcus braunii*, *Selenastrum minutum* and *Gloeocystis ampla* and the cryptophyte *Chroomonas acuta*.

The phytoplankton communities of the three wetlands were all relatively dissimilar to the phytoplankton community of Patsy Lake and to each other. None of the wetlands had phytoplankton communities dominated by chlorophytes as did Patsy Lake. The phytoplankton community in WL1 was comprised largely of cyanophytes (40%), chlorophytes (28%), and cryptophytes (18%). In contrast, the phytoplankton community of WL2 was comprised largely of chrysophytes (72%). The phytoplankton community of WL3 on the other hand, was comprised largely of cryptophytes (59%), cyanophytes (17%), and chlorophytes (10%). Euglenophytes and pyrrhophytes comprised less than 1% and less than 7%, respectively of the total phytoplankton community at all four sample sites in 2009.

Table 1.5-9: Mean Density (cells/ml) and Relative Abundance (%) of Major Phytoplankton Taxonomic Groups Present in Patsy Lake and Three Wetlands Sampled in 2009

Taxa	Patsy Lake		WL1		WL2		WL3	
	#cells/ml	%	#cells/ml	%	#cells/ml	%	#cells/ml	%
Bacillariophyceae	5	4.0	45	7.1	17	7.9	34	8.3
Chlorophyta	84	66.1	175	27.6	15	7.3	42	10.3
Chrysophyta	7	5.5	16	2.5	151	71.7	18	4.4
Cryptophyta	17	13	116	18.2	15	7.1	240	59.0
Cyanophyta	6	5.0	256	40.4	9	4.1	69	16.9
Euglenophyta	0	0.0	3	0.5	1	0.3	1	0.2
Pyrrhophyta	8	6.4	23	3.6	3	1.4	4	1.0
Total	**127**	**100.0**	**635**	**100.0**	**210**	**100.0**	**407**	**100.0**

Note: ml - millilitre; % - percent

Source: Rescan (2010b)

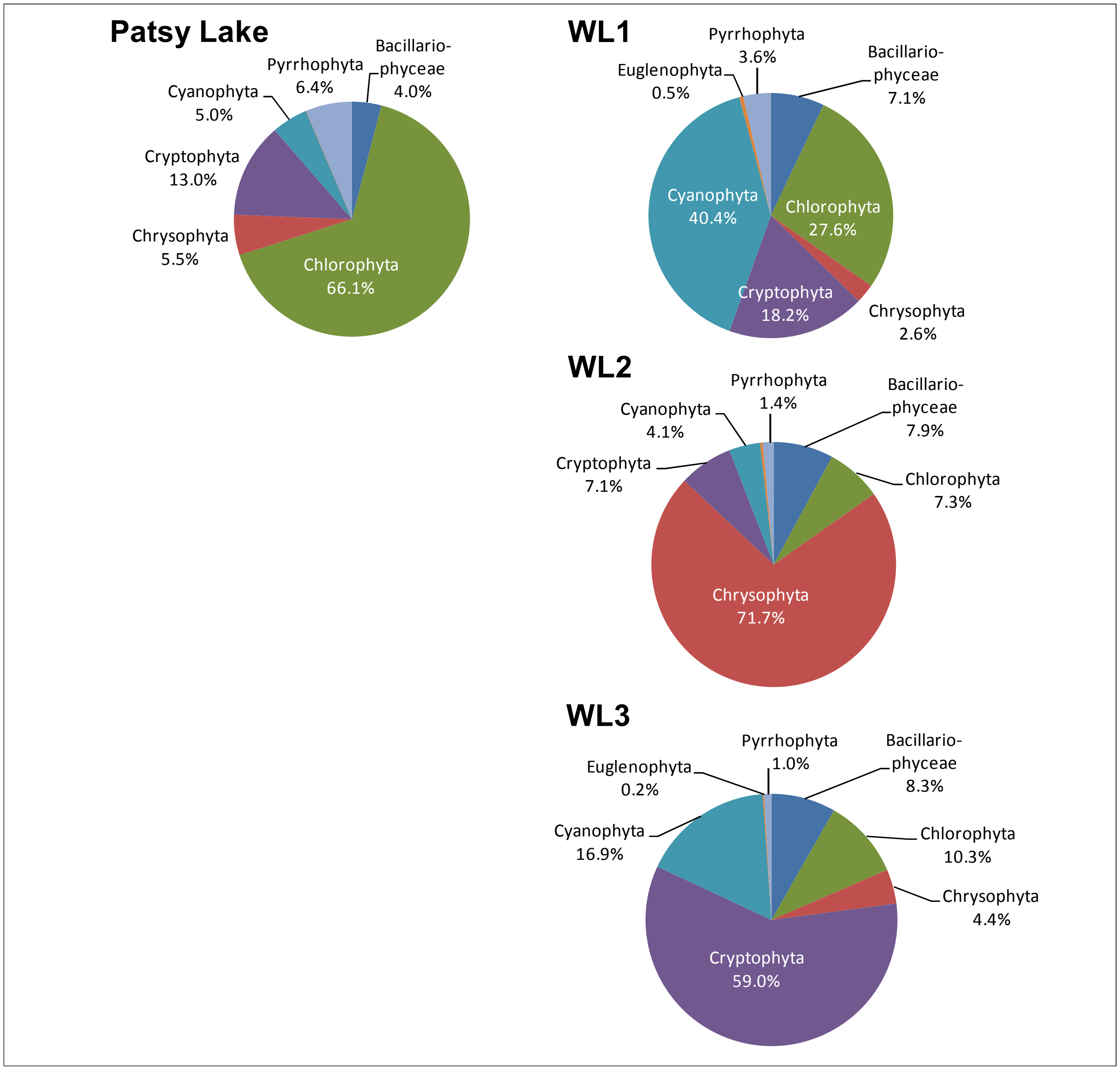


Figure 1.5-8: Relative Abundance of Major Phytoplankton Taxa in Patsy Lake and Three Wetlands Sampled in 2009

1.5.2.1.3 Richness and Diversity Indices

Mean taxa richness (*S)* in Patsy Lake was 30 genera (Table 1.5-10; Figure 1.5-9). *S* in the three wetlands was higher than Patsy Lake and ranged from 39 genera in WL1 to 48 genera in WL2.

Table 1.5-10: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Phytoplankon Communities in Patsy Lake and Three Wetlands Sampled in 2009

Lake	Depth	Richness (*S*)		Shannon's Diversity (*H'*)		Evenness (*J*)	
		Mean	SE	Mean	SE	Mean	SE
Patsy Lake	Shallow	31	3	2.43	0.17	0.71	0.03
WL1	Shallow	39	1	2.49	0.06	0.64	0.02
WL2	Shallow	48	1	1.51	0.37	0.41	0.10
WL3	Shallow	46	1	1.72	0.14	0.45	0.04

Note: SE - standard error
Source: Rescan (2010c)

Mean Shannon diversity values (*H')* in Patsy Lake was 2.42 and mean *J* was 0.71 (Table 1.5-10; Figure 1.5-9). Despite having a lower *S* than the wetlands, Patsy Lake diversity was higher than in the wetlands as a result of the greater number of identified individual taxa with a high number of individual cells. Evenness values in the three wetlands sites ranged from a low of 0.41 (WL2) to a high of 0.64 (WL1) in wetlands.

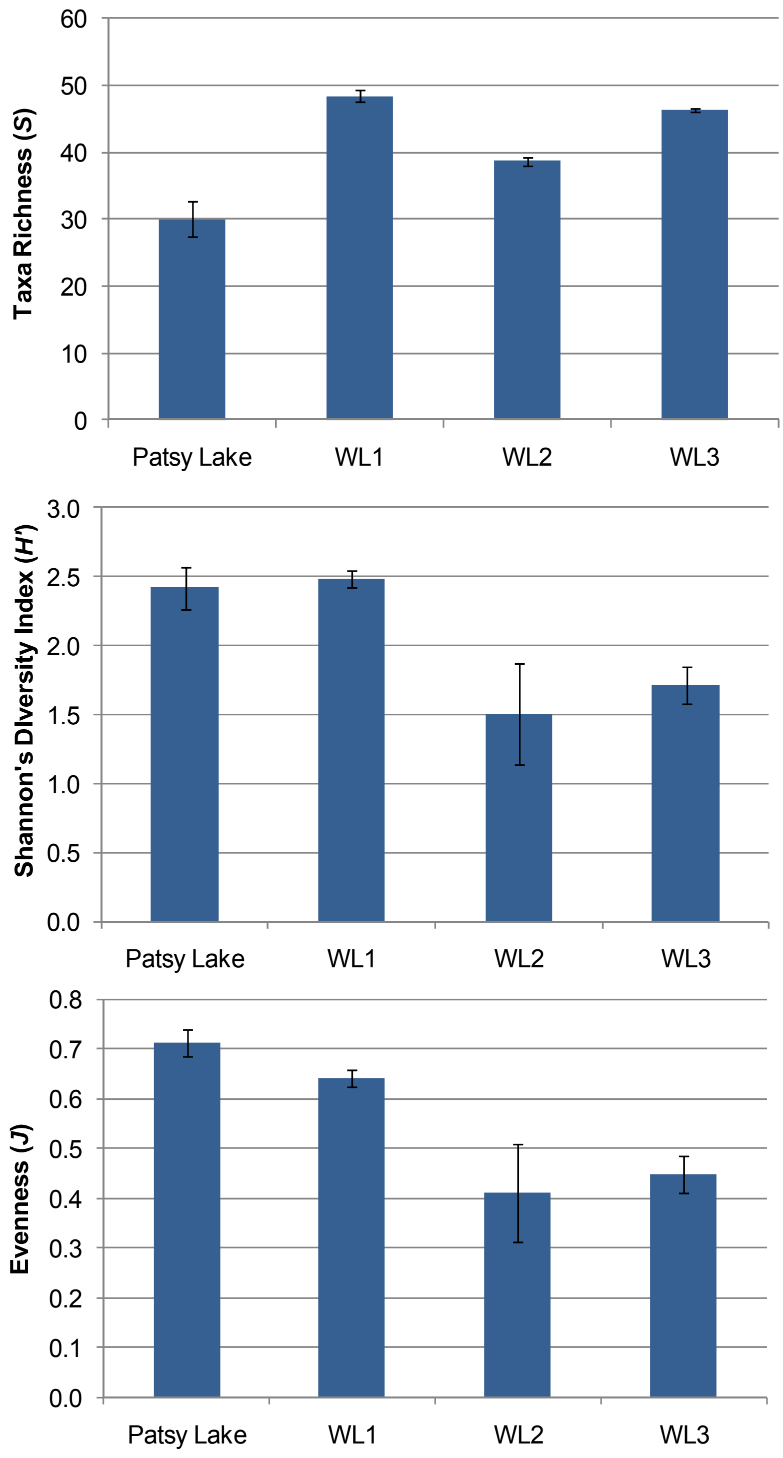


Figure 1.5-9: ***Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Phytoplankton Communities in Patsy Lake and Three Wetlands Sampled in 2009***

Note: Error Bars Represent Mean ±1 SE

1.5.2.2 2010 Results

1.5.2.2.1 Density and Biomass

Mean (± 1 SE) phytoplankton densities and biomass (presented as chlorophyll *a* concentrations) are presented in Table 1.5-11. Raw data for phytoplankton samples collected in Clary Lake and Lake 901 in 2010 can be found in Appendices D-1 to D-3.

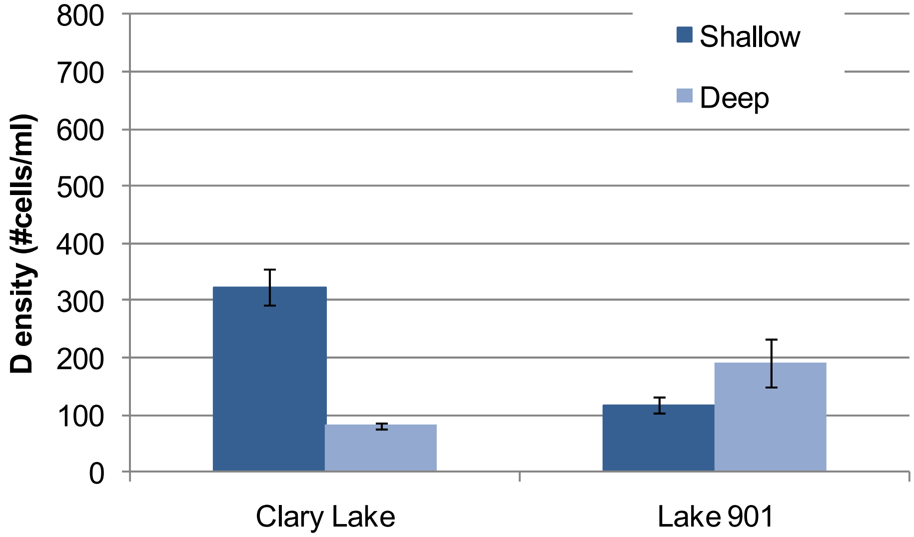
Mean phytoplankton density in the epilimnion (324 cells/ml) of Clary Lake was more than two times higher than in the hypolimnion (117 cells/ml) (Table 1.5-11). Mean phytoplankton biomass in the epilminion (1.33 µg/L chl *a*) of Clary Lake was two orders of magnitude higher than in the hypolimnion (Figure 1.5-10). These results are not unexpected given that Clary Lake is over 45 m deep and the deep water samples were collected at a depth of approximately 34 m, nearly 21.8 m below the 1% euphotic zone depth in the lake.

Table 1.5-11: Phytoplankton Density (cells/ml) and Biomass (µg/L chl a) from Shallow and Deep Locations in Clary Lake and Lake 901 in 2010

Lake	Depth	Density (cells/ml)		Biomass (µg/L chl *a*)	
		Mean	SE	Mean	SE
Clary Lake	shallow	324	32	1.33	0.07
	deep	117	13	0.04	0.01
Lake 901[a]	shallow	82	6	1.85	0.03
	deep	190	42	1.23	0.12

Note: Lake 901 was not thermally stratified in summer of 2010; SE-standard error

Mean phytoplankton densities in Lake 901 were higher at the deep sample site (190cells/ml) than at the shallow sample site (82 cells/ml) (Table 1.5-11). Mean phytoplankton biomass was similar between the two depth sample locations. These results are not unexpected as Lake 901 has a maximum depth of <6 m, does not thermally stratify in summer, and has a 1% euphotic zone depth of 5.4 m which is deeper than the depth from which samples were collected (4 m).



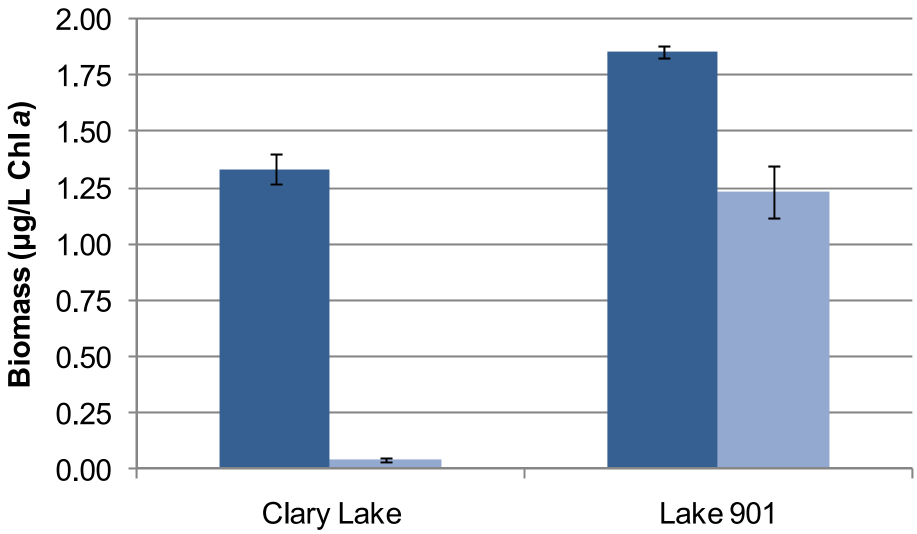


Figure 1.5-10: Mean Phytoplankton Density (# cells/ml) and Biomass (µg/L chl a) from Shallow and Deep Samples Collected in Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

Phytoplankton density differed significantly with depth (2W ANOVA depth effect: $F_{(1, 8)}$=9.51, p=0.015) but not between sites (2W ANOVA Site effect: $F_{(1, 8)}$=9.51, p=0.11). Mean phytoplankton density was higher at shallow depths in Clary Lake whereas in Lake 901 (Figure 1.5-10), phytoplankton density was higher at deeper depths (2W ANOVA Depth*Site interaction: $F_{(1, 8)}$=32.99, p<0.001). This difference in phytoplankton densities in the shallow and deep depth samples between the two lakes is due to the abundance of cyanophytes in the epilimnion of Clary Lake and the relative paucity of phytoplankton in the hypolimnion of

Clary Lake due to thermal stratification and the limits of light penetration to the depths at which deep samples from Clary Lake were taken in 2010.

Phytoplankton biomass differed significantly between Lake 901 and Clary Lake (2W ANOVA Site effect: $F_{(1, 8)}=155.43$, $p<0.001$). Lake 901 had a higher mean phytoplankton biomass at the shallow depth than Clary Lake in 2010 (Figure 1.5-10). Although phytoplankton communities can be highly variable and these data only represent one point in time, the difference in mean phytoplankton biomass between the two lakes may be due to a number of biotic and abiotic factors including, but not be limited to, differences in:

1. Nutrient availability.
2. Other water quality factors such as clarity, temperature, pH, alkalinity, and hardness.
3. Zooplankton community composition and density (i.e., predators).

Another likely reason for the difference in biomass between lakes at both depths is the greater relative size of the phytoplankton taxa that dominate the Lake 901 samples (cryptophya and chlorophyta) and compared to those that dominate Clary Lake (cyanophyta) (see Section 1.5.2.2.2 below).

1.5.2.2.2 Relative Abundance

Cyanophytes comprised the majority of the total abundance of phytoplankton at shallow (75%) and deep (74%) depths in Clary Lake (Table 1.5-12 and Figure 1.5-11). These were followed by cryptophytes which comprised 11% and 15% of the total phytoplankton abundance at shallow and deep depths, respectively. Chlorophyta comprised 10% of the phytoplankton community in the epilimnion of Clary Lake but <3% of the phytoplankton community in the hypolimnion. This is not surprising given that chlorophyta are the main photosynthetic taxa in the phytoplankton community and are generally found within the euphotic zone of lakes (Wetzel 2001). All other taxonomic groups were present in low abundance (<6%).

A total of 45 phytoplankton species were identified in Clary Lake in 2010. Dominant phytoplankton species in Clary Lake included the cyanophyte *Agmenellum tenuissima*, the cryptophytes *Chroomonas acuta* and *Cryptomonas* spp., and the chlorophytes *Crucigenia tetrapedia* and *Oocystis* spp.

The phytoplankton community of Lake 901 was markedly different than that in Clary Lake. Unlike Clary Lake, cyanophytes were found in relatively low abundance in Lake 901 at both shallow (8%) and deep (27%) depths (Table 1.5-12 and Figure 1.5-11). Instead, cryptophytes were the dominant phytoplankton taxa in both the shallow (44%) and deep (30%) depths. Chlorophytes comprised 23% and 12% of the phytoplankton community in shallow and deep samples, respectively, while diatoms (Bacillariophyceae) comprised 10% and 26% of the phytoplankton community at the shallow and deep depths.

A total of 75 phytoplankton species were identified in Lake 901 in 2010. Dominant phytoplankton species included the cryptophyte *Cryptomonas* spp., the cyanophyte *Anacystis cf. elachista*, the chlorophyte *Crucigenia tetrapedia* and the chrysophyte *Dinobryon sp*.

Table 1.5-12: Density (cells/ml) and Relative Abundance (%) of Major Phytoplankton Taxonomic Groups Present in Clary Lake and Lake 901 Sampled in 2009

Taxa	Clary Lake[1]				Lake 901[2]			
	Shallow		Deep		Shallow		Deep	
	#cells/ml	%	#cells/ml	%	#cells/ml	%	#cells/ml	%
Bacillariophyceae	4	1.2	5	6.0	13	10.8	50	26.3
Chlorophyta	32	10.0	2	2.6	27	22.9	22	11.8
Chrysophyta	13	4.0	1	0.9	11	9.8	3	1.3
Cryptophyta	36	11.2	12	14.5	52	44.2	58	30.4
Cyanophyta	229	70.5	61	74.1	9	7.8	52	27.1
Euglenophyta	0	0.1	0	0.0	2	2.0	5	2.7
Pyrrhophyta	10	2.9	2	2.0	3	2.6	0	0.1
Rhodophyta	0	0.0	0	0.0	0	0.0	0	0.2
Total	**324**	**100.0**	**82**	**100.0**	**117**	**100.0**	**190**	**100.0**

Note: [1] shallow samples taken from epilimnion at 1 m depth; deep samples taken from the hypolimnion at 34 m depth
[2] shallow samples taken from 1 m depth; deep samples taken from 4 m depth; Lake 901 did not thermally stratify in summer of 2010
% - percent

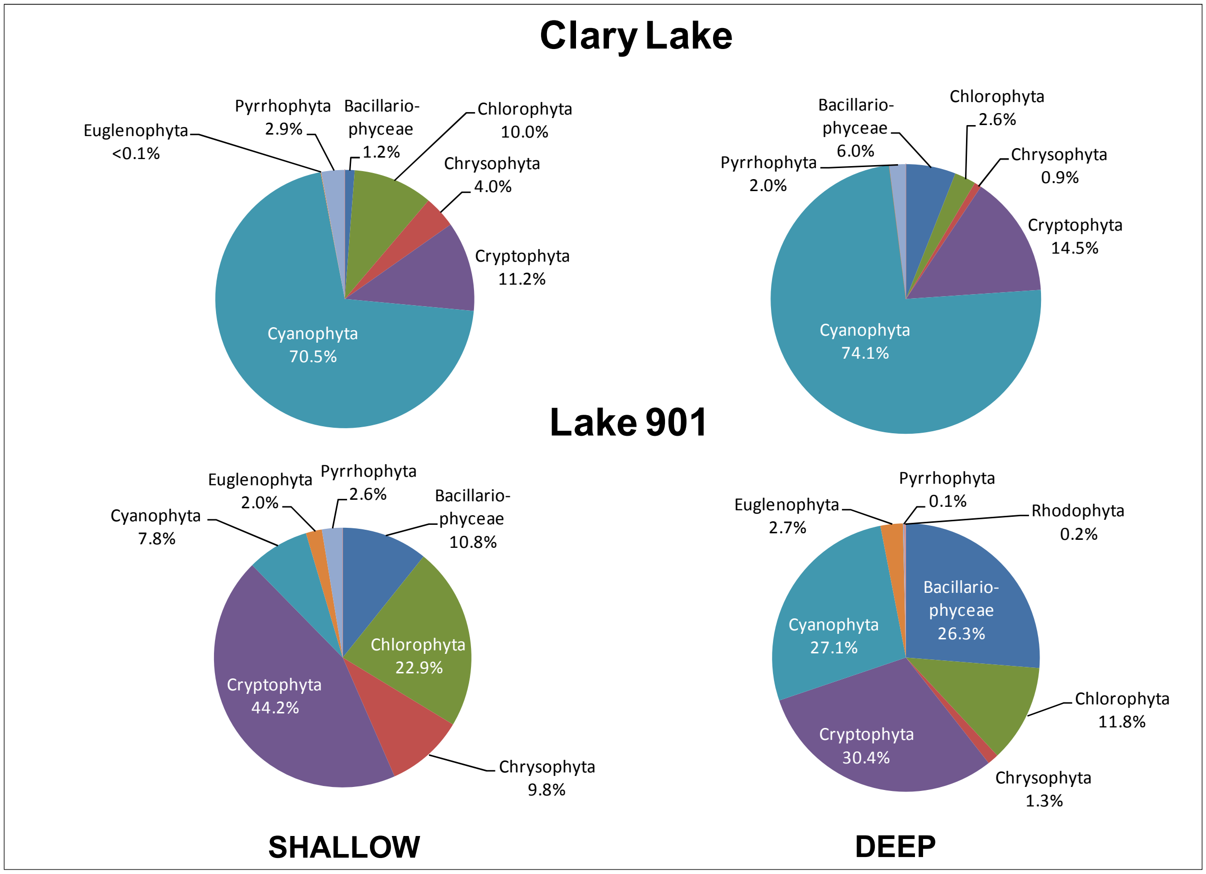


Figure 1.5-11 Relative Abundance of Major Phytoplankton Taxa in Shallow and Deep Samples Collected from Clary Lake and Lake 901 in 2010

1.5.2.2.3 Richness and Diversity

Mean taxa richness (*S*), Shannon diversity (*H'*), and Pielou's Evenness (*J*) indices were significantly higher ($p<0.001$) in Lake 901 than in Clary Lake, but did not differ across depth ($p>0.05$) (Table 1.5-13; Figure 1.5-12). Lake 901 had a mean *S* of over 40 genera at shallow and deep depths while Clary Lake had only 26 genera at shallow depth and only 14 genera at deep depth. The difference in *S* between deep depths in both lakes is likely because Clary Lake stratifies in summer and Lake 901 does not; one would expect a lower taxonomic diversity of phytoplankton in the darker, colder hypolimnion of Clary Lake than in the completely mixed Lake 901. The higher overall *S* in Lake 901 than in Clary Lake is likely due to differences in habitat (Lake 901 is composed of more fine sediment littoral habitats while Clary Lake is dominated by cobble / boulder habitat), bathymetry (Lake 901 is <6 m deep with a mean depth of 1 m while Clary Lake is steep sided, over 45 m deep, and has a mean depth of 16 m), and water quality (Lake 901 is more tannic than Clary Lake).

Table 1.5-13: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Phytoplankon Communities in Clary Lake and Lake 901 in 2010

Lake	Depth	Richness (*S*)		Shannon's Diversity (*H'*)		Evenness (*J*)	
		Mean	SE	Mean	SE	Mean	SE
Clary Lake[1]	Shallow	26	1	1.30	0.06	0.40	0.01
	Deep	14	1	1.09	0.09	0.41	0.03
Lake 901[2]	Shallow	41	1	2.49	0.08	0.67	0.01
	Deep	44	4	2.54	0.04	0.67	0.01

Note: SE-standard error

[1] shallow samples taken from epilimnion at 12 m depth; deep samples taken from the hypolimnion at 34 m depth

[2] shallow samples taken from 1 m depth; deep samples taken from 4 m depth; Lake 901 did not thermally stratify in summer of 2010

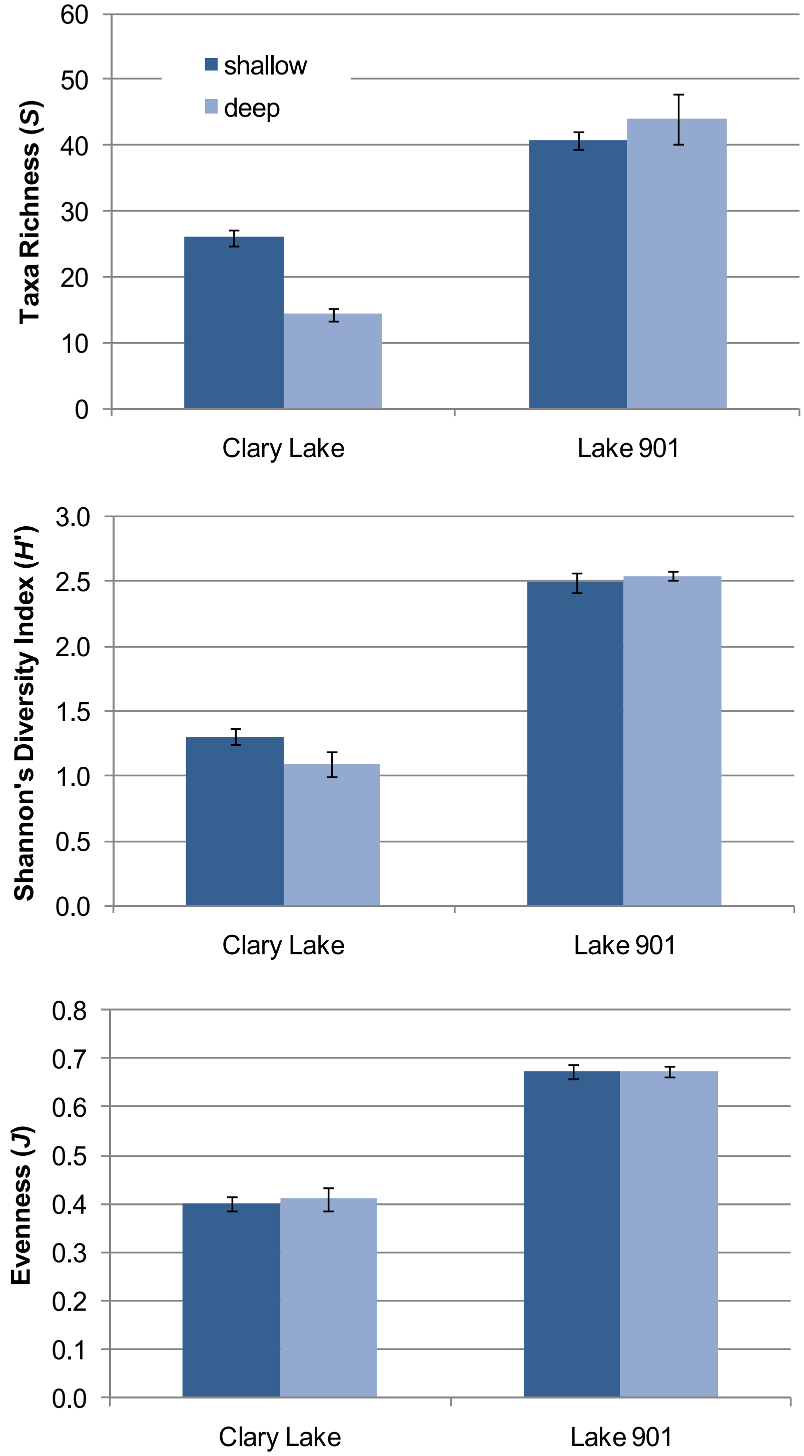


Figure 1.5-12: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Phytoplankton Communities in Clary Lake and Lake 901 at Shallow and Deep Depths in 2010

Note: Error Bars Represent Mean ±1 SE

1.5.2.2.4 Comparison Between 2009-2010

While only two of the lakes were sampled in the same year and there are many biotic and abiotic factors that affect phytoplankton community production and community composition (most principally the availability of phosphorus and nitrogen which are typically the limiting nutrients for phytoplankton production in lakes (Wetzel 1983), there are significant differences between the phytoplankton communities of Patsy Lake, Clary Lake and Lake 901 between 2009 and 2010 worth examination and discussion. As only shallow samples were collected from all three lakes, only results of the shallow depth samples are compared here.

1.5.2.2.5 Density and Biomass

Both the density and biomass of phytoplankton differed among lakes (1W ANOVA Density: $F_{(2,6)}$= 33.07, p=0.001; Biomass: $F_{(2,6)}$= 238.41, p<0.001). Mean phytoplankton density was significantly higher in Clary Lake than in either Patsy Lake or Lake 901 (p=0.001) (Figure 1.5-13). This is likely due to the relatively high abundance of cyanophytes in the Clary Lake samples. Lake 901 had a significantly higher phytoplankton biomass than Clary Lake (p=0.001) and Patsy Lake (p<0.001) while Clary Lake, in turn, had a significantly (p<0.001) higher phytoplankton biomass than Patsy Lake. This difference was likely due to the dominance of larger-sized taxa such as cryptophytes (*Cryptomonas* spp.) and chrysophytes (*Dinobryon* sp.) in Lake 901.

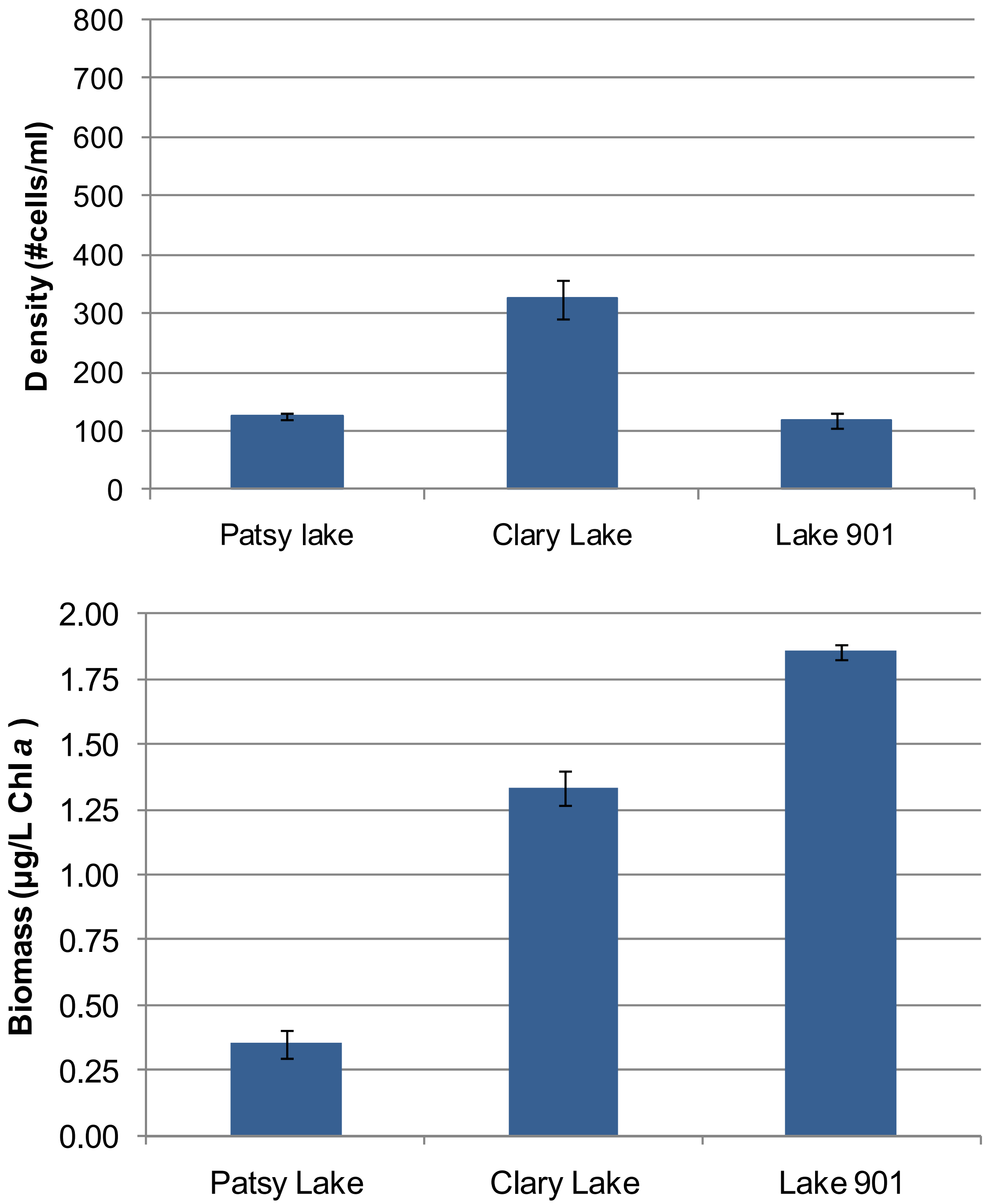


Figure 1.5-13: Comparsion of Mean Phytoplankton Density (# cells/ml) and Biomass (µg/L chl a) from Shallow Depth Samples Collected in Patsy Lake in 2009 and Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

1.5.2.2.6 Relative Abundance

Phytoplankton communities in the three lakes were remarkably different. The phytoplankton community in Patsy Lake was dominated by chlorophytes (66%) while the phytoplankton communities of Clary Lake and Lake 901 were dominated by cyanophytes (75%) and cryptophytes (44%), (Figure 1.5-14). By comparison, chlorophytes comprised only 10% and 23% of the phytoplankton communities of Clary Lake and Lake 901, respectively, in 2010. While the potential abiotic and biotic factors that may be the cause of these differences have been discussed above, a major factor in the difference between the phytoplankton community in Patsy Lake compared to the other two lakes is likely that Patsy Lake doesn't have any fish. Patsy Lake is at the top of the Lime Creek watershed, high above impassable waterfalls that exist in Lime Creek approximately 1.6 km from its mouth at Alice Arm. The top predators in Patsy Lake are benthic and pelagic invertebrates such as predaceous diving beetles and dragonfly nymphs. In contrast, Clary Lake and Lake 901 contain rainbow trout. Although there are differences in opinion in the literature which has more influence on aquatic community ecosystems, “top-down” or “bottom-up” control, this major difference in predator-prey relationships is likely to, at least partially, explain some of the differences observed in phytoplankton community composition in the observed between Patsy Lake and the other two lakes.

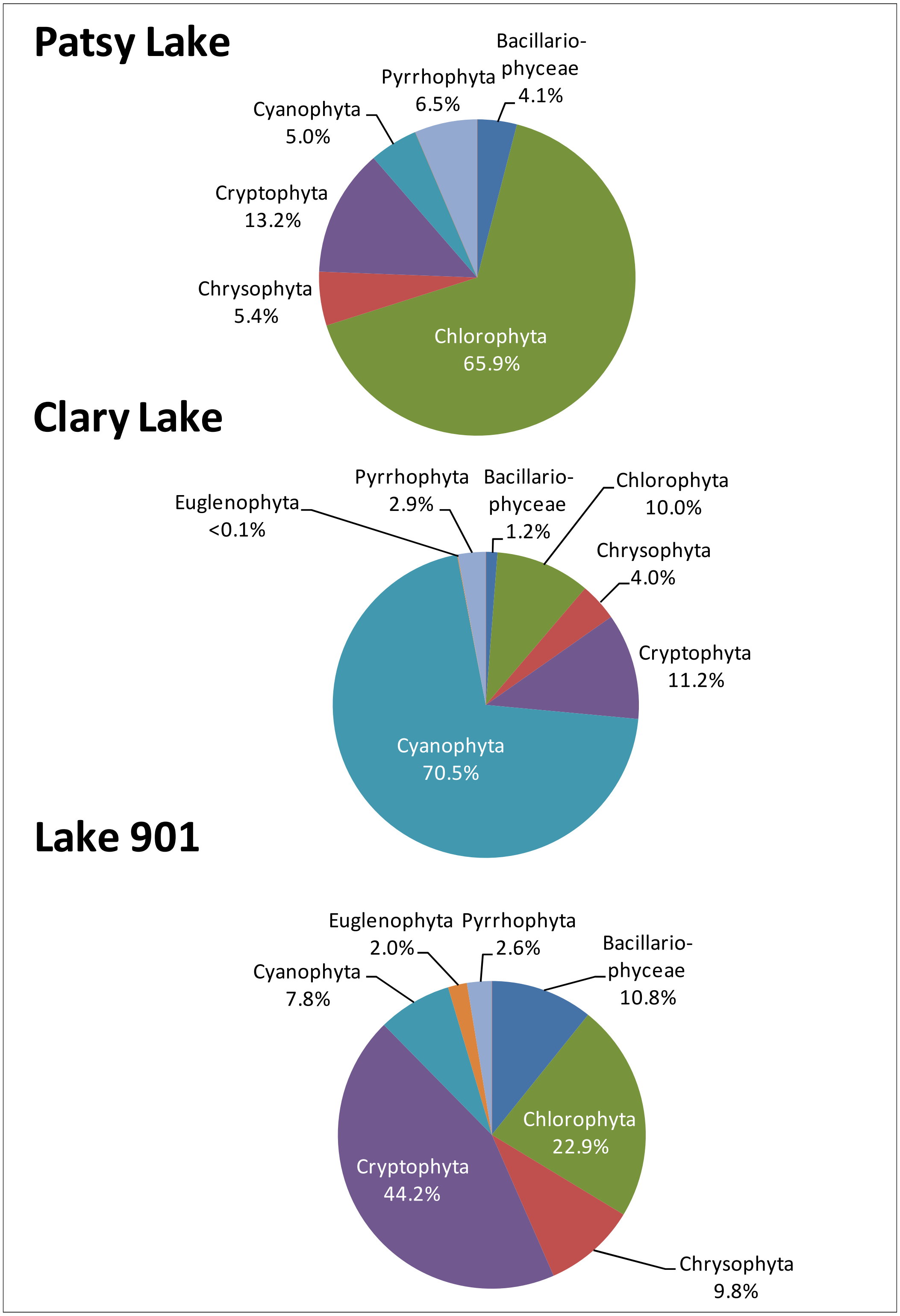


Figure 1.5-14: Relative Abundance of Major Phytoplankton Taxa in Shallow Samples Collected from Patsy Lake in 2009 and Clary Lake and Lake 901 in 2010

1.5.2.2.7 Richness, Diversity, and Evenness

Clary Lake had the lowest taxonomic richness (26 genera), Shannon's diversity (1.30), and Evenness index (0.40) than either Lake 901 or Patsy Lake (Figure 1.5-15). Again, this is likely because of the numerical dominance of cyanophytes and the relative paucity of other taxa in the Clary Lake phytoplankton community. By comparison, Lake 901 had the highest taxonomic richness (41 genera) of any of the three lakes. Patsy Lake was intermediate between the other two lakes with 31 genera. Even though comprised of largely different taxa, Lake 901 and Patsy Lake had similar Shannon's diversity and Evenness indices. This speaks to the fact that both lakes had similar taxonomic richness but that no one taxon particularly dominated the phytoplankton communities of the two lakes.

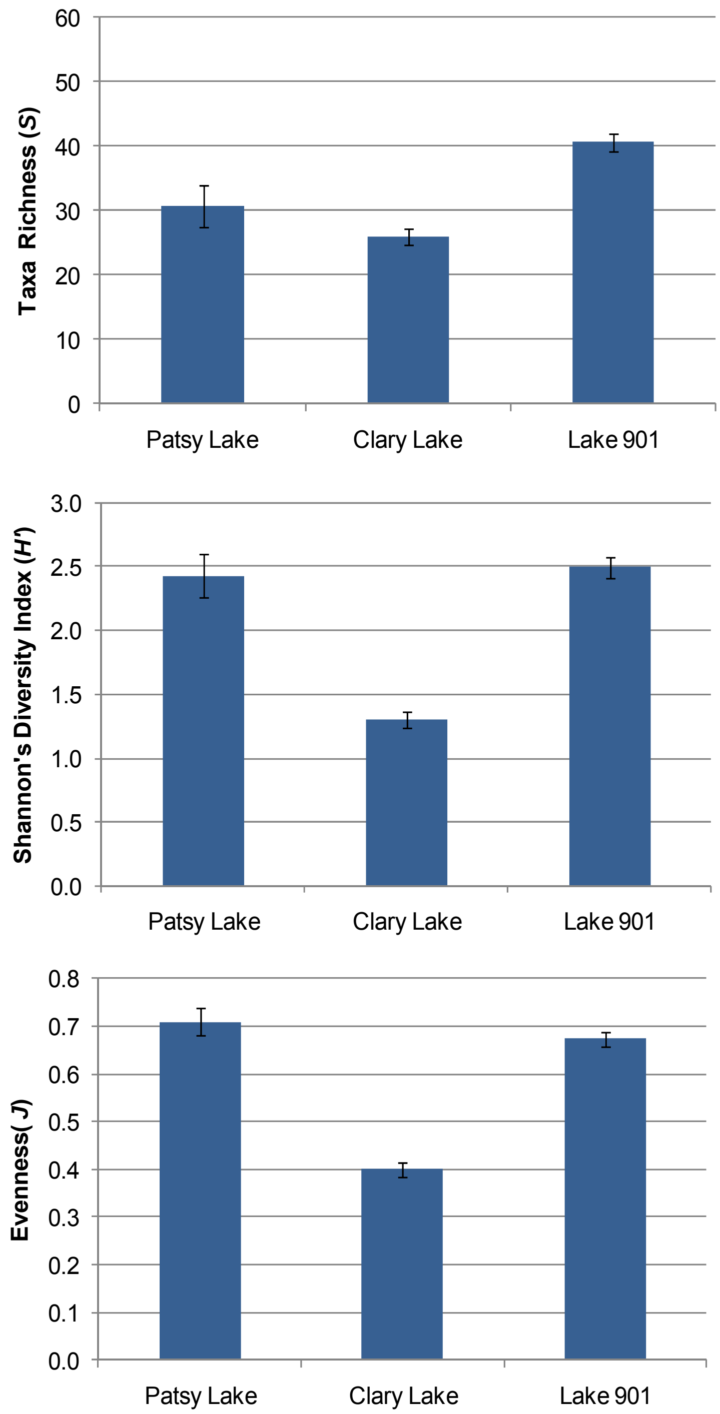


Figure 1.5-15: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Phytoplankton Communities in Shallow Depth Samples from Patsy Lake in 2009 and from Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

1.6 Secondary Producers

1.6.1 Zooplankton

1.6.1.1 2009 Results

Nine different zooplankton species were identified from samples collected in Patsy Lake in 2009. These included three species of cladocerans (water fleas), two species of calanoid copepods, one cyclopoid copepod species, two species of rotifers, and one species of aquatic insect larvae. Raw data for zooplankton samples collected from Patsy Lake in 2009 are provided in Appendix F-1 and F-2.

1.6.1.1.1 Density and Relative Abundance

Mean density of zooplankton in Patsy Lake was 19,775 organisms/m^3 (Table 1.6-1). The majority of the zooplankton community in Patsy Lake was comprised of rotifers (80%) and calanoid and cyclopoid copepod nauplii (16%) (Figure 1.6-1). Cladocerans (3%), adult calanoid (0.9%) and cyclopoid (0.1%) copepods, and *Chaoborus sp.* (0.5%), phantom midge larvae from the insect order Diptera, made up the remainder of the zooplankton community of Patsy Lake in 2009. The rotifer species *Kellicottia longispina* was the dominant zooplankton species sampled in 2009, accounting for 97% of the total number of organisms sampled.

Table 1.6-1: Mean Density and Relative Abundance of Major Zooplankton Taxa in Patsy Lake in 2009

Order/Class	Sub-Order	Patsy Lake	
		Density (#/m^3)	Relative Abundance (%)
Rotifera		15,715	79.5
Branchiopoda	Cladocera	550	2.8
Copepoda	Calanoida	180	0.9
	Cyclopoida	28	0.1
	Calanoida/Cyclopoida Nauplii	3,212	16.2
Insecta	Diptera	90	0.5
Total		**19,775**	**100.0**

Note: % - percent

Source: Rescan (2010b)

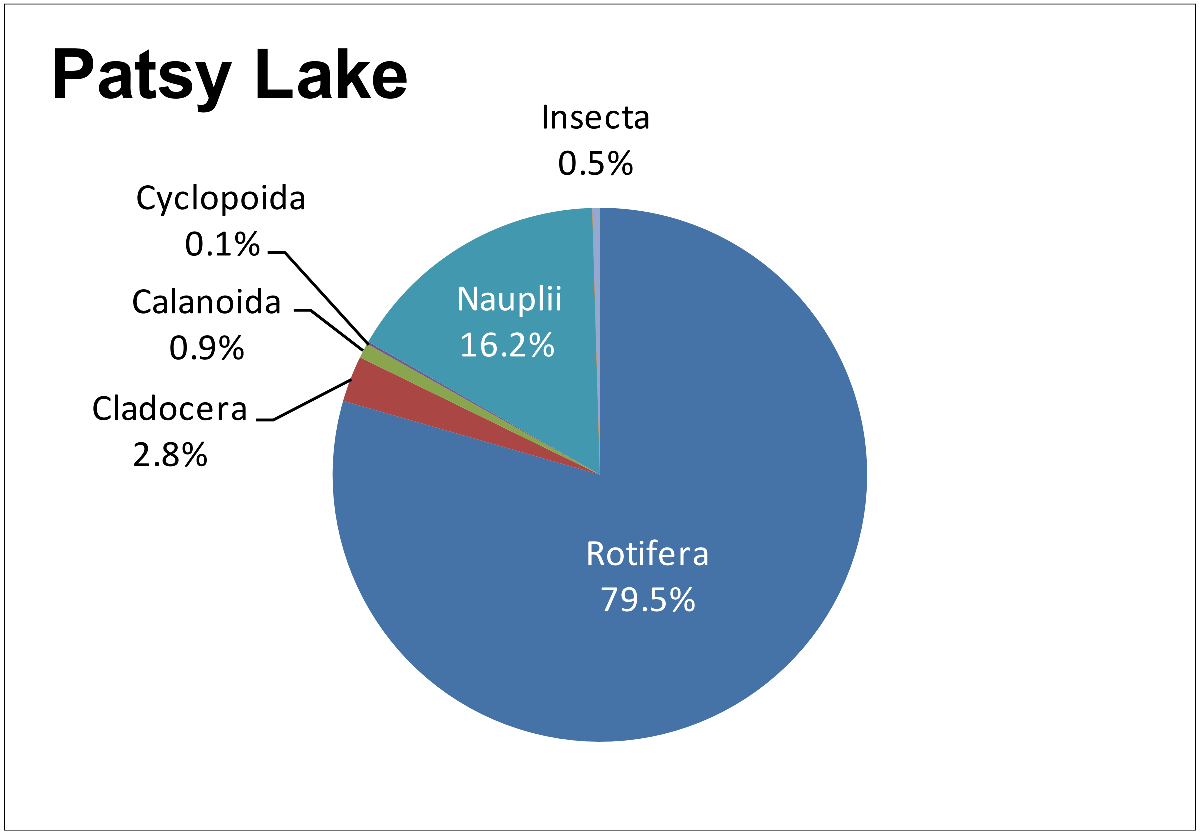


Figure 1.6-1: Relative Abundance of Major Zooplankton Taxa in Patsy Lake in 2009

1.6.1.2 Richness, Diversity and Evenness

Mean taxa richness (*S*) in Patsy Lake was nine genera in 2009 (Table 1.6-2). Shannon diversity (*H'*) and Pielou's Evenness (*J*) *values* were low (0.88 and 0.27, respectively) (Table 1.6-2).

Table 1.6-2: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for the Zooplankton Community in Patsy Lake in 2009

Community Metric	Mean	SE
Taxa Richness (*S*)	9	0.3
Shannon's Diversity (*H'*)	0.88	0.16
Evenness (*J*)	0.27	0.05

Note: SE - standard error
Source: Rescan (2010b)

1.6.1.3 2010 Results

Sixteen different zooplankton species were identified from samples collected in Clary Lake and Lake 901 in 2010. These taxa included nine species of rotifers, four species of cladocerans, two species of calanoid copepods, and one cyclopoid copepod species. Of these sixteen species, eight were common to both lakes. Raw data for zooplankton samples collected from Clary Lake and Lake 901 in 2010 are provided in Appendix F-1 and F-2.

1.6.1.3.1 Density, Biomass, and Relative Abundance

Mean density of zooplankton were five times greater in Lake 901 (25,214 organisms/m^3) than in Clary Lake (5,236 organisms/m^3) (Table 1.6-3 and Figure 1.6-2). This was due to the overwhelming abundance of rotifers in Lake 901 in comparison to Clary Lake; rotifers comprised 92% of the zooplankton community in Lake 901 and only 34% of the zooplankton community in Clary Lake (Figure 1.6-2). The rotifer species *Kellicottia longispina* was the dominant zooplankton species present in Lake 901 in 2010, accounting for 78% of the total number of organism sampled.

Cladocerans comprised 8% of the total number of organisms enumerated in Lake 901 and the other three zooplankton taxa present in the lake comprised <1% of the total. These included adult calanoid and cyclopoid copepods which comprised <0.5% of the total zooplankton organisms enumerated.

Table 1.6-3: Mean Density, Relative Abundance, and Mean Biomass of Major Zooplankton Taxa in Clary Lake and Lake 901 in 2010

Class	Order	Clary Lake		Lake 901	
		Density (#/m^3)	**Relative Abundance (%)**	**Density (#/m^3)**	**Relative Abundance (%)**
Rotifera		1,777	33.9	23,151	91.8
Branchiopoda	Cladocera	54	1.0	1,989	7.9
Copepoda	Calanoida	10	0.2	65	0.26
	Cyclopoida	1,104	21.1	8	<0.03
	Calanoida / Cyclopoida Nauplii	2,291	43.8	2	<0.01
Insecta	Diptera	0	0	0	0
Total		**5,236**	**100.0**	**25,214**	**100.0**
Class	**Order**	**Clary Lake**		**Lake 901**	
		Biomass (mg/m^3)	**Relative Biomass (%)**	**Biomass (mg/m^3)**	**Relative Biomass (%)**
Branchiopoda	Cladocera	0.522	8.0	4.814	76.8
Copepoda	Calanoida	0.670	10.3	1.431	22.8
	Cyclopoida	3.066	47.1	0.026	0.4
	Calanoida/Cyclopoida Nauplii	2.247	34.5	0.002	<0.1
Total		**6.505**	**100.0**	**6.273**	**100.0**

Note: Rotiferan biomass was not calculated because of inaccuracies measuring lengths of these small organisms; % - percent

The dominance structure of the zooplankton community in Clary Lake differed from that in Lake 901. The most abundant taxa enumerated in Clary Lake were calanoid and cyclopoid copepod nauplii (44%). Rotifers (34%) and adult cyclopoid copepods (21%) comprised most of the remaining community by numbers (Figure 1.6-3). Cladocerans and calanoid copepods were present in low numbers, accounting for 1% and 0.2% of the total zooplankton enumerated, respectively. Excluding copepod nauplii which could not be identified to species, the adult cyclopoid copepod *Orthrocyclops sp* was the dominant zooplankton species present in Clary Lake in 2010, accounting for 21% of the total number of organisms sampled. Like Lake 901, the rotifer *Kellicottia longispina* was the most abundant rotifer species present in Clary Lake.

Zooplankton community biomass was similar between Clary Lake (6.505 mg/m^3) and Lake 901 (6.273 mg/m^3) (Table 1.6-3; Figure 1.6-3). However, this is not a completely fair comparison because rotifer biomass was not calculated or included for either lake and rotifers were by far the most abundant zooplankton in Lake 901. Excluding rotifers, cyclopoid copepods (47%) and copepod nauplii (35%) comprised the largest portion of the total zooplankton community biomass in Clary Lake. Calanoid copepods and cladocerans accounted for only 10.3% and 8.0% of the total biomass in Clary Lake, respectively.

By comparison, and again excluding rotifers, cladocerans (77%) comprised the largest portion of the total zooplankton community biomass in Lake 901. Calanoid copepods (23%) comprised the remainder of the biomass present in Lake 901 (Figure 1.6-3). Cyclopoid copepods and copepod nauplii comprised <0.5% of the total Lake 901 zooplankton community biomass.

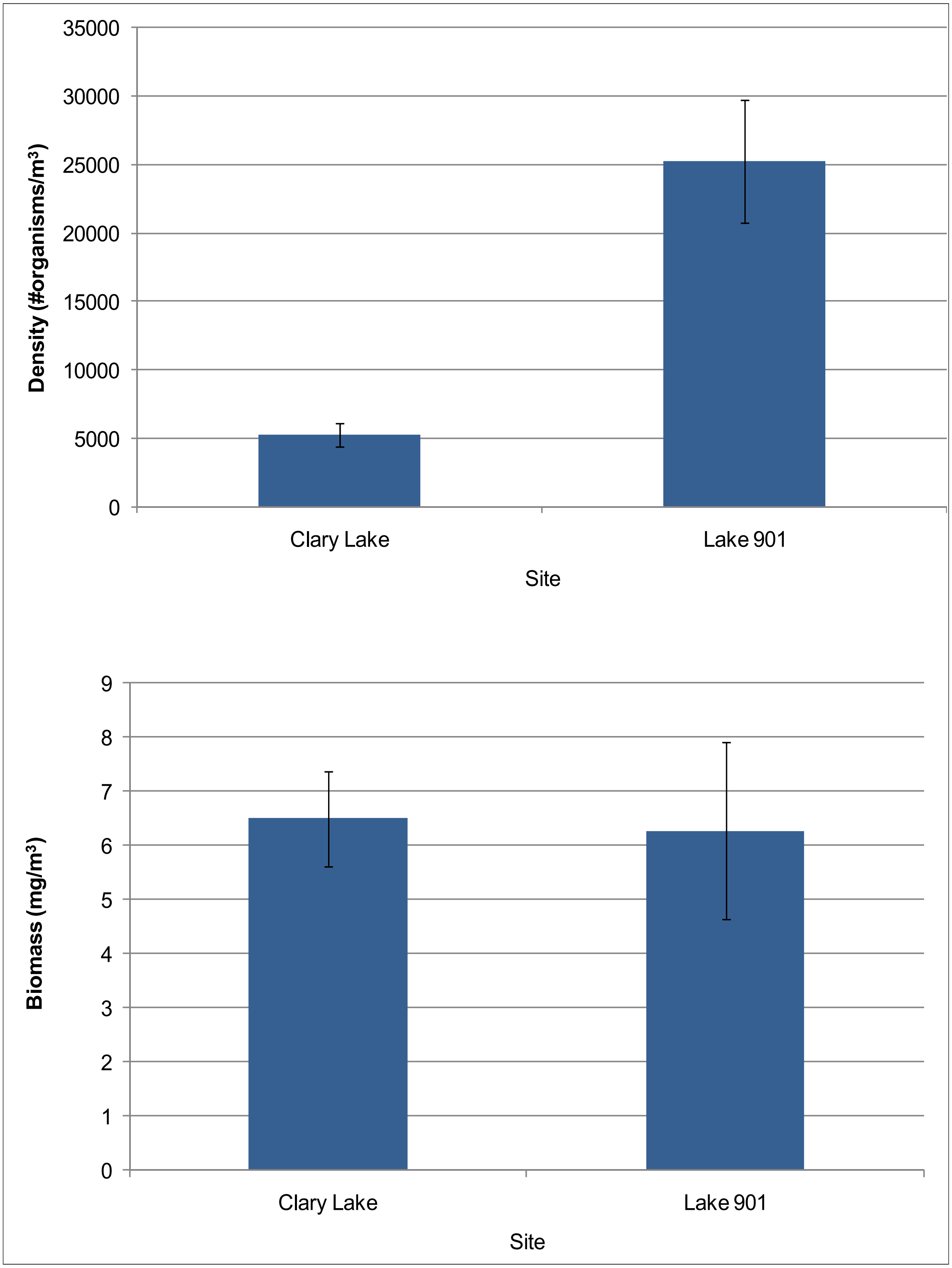


Figure 1.6-2: Mean Zooplankton Density (organisms/m^3) and Biomass (mg/m^3) in Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

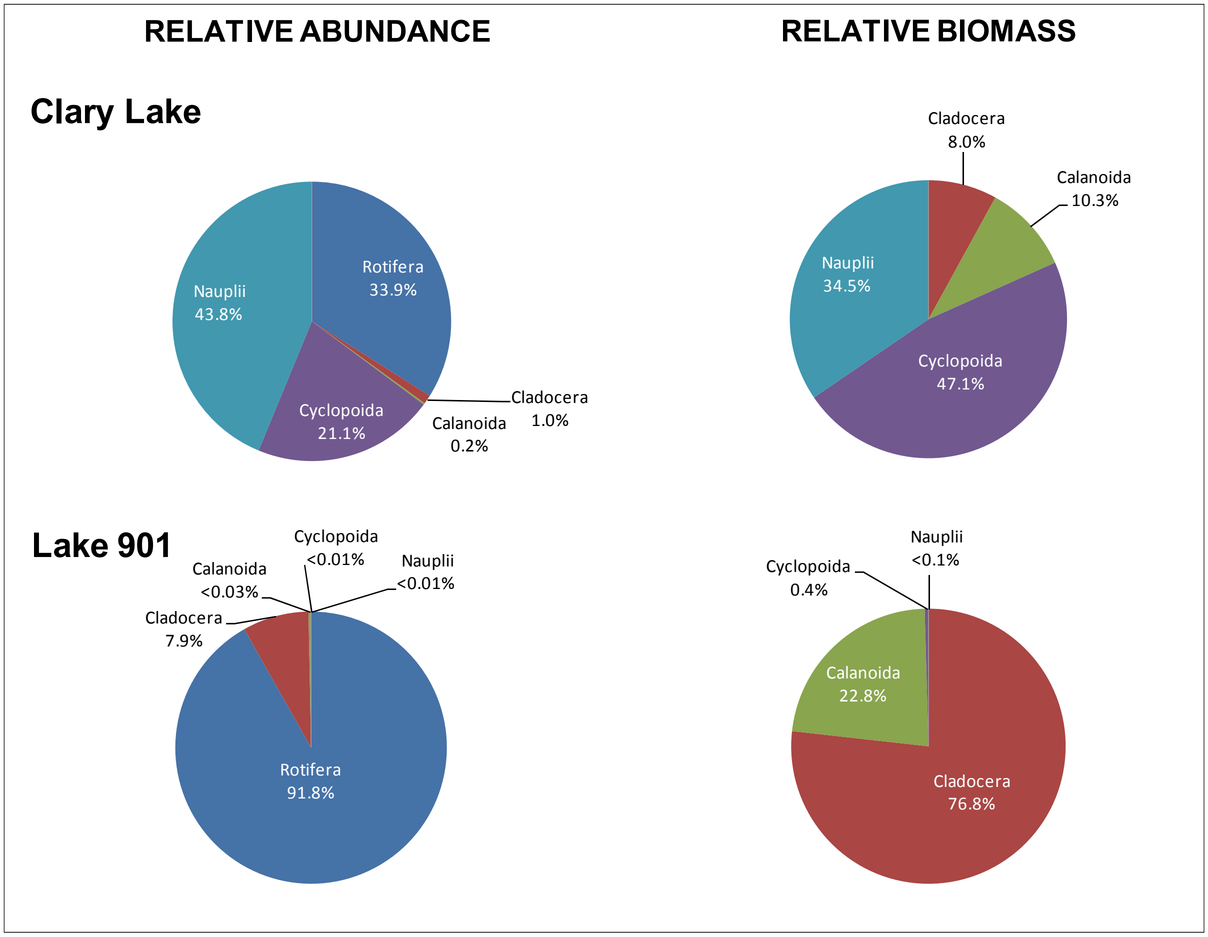


Figure 1.6-3: Relative Abundance and Relative Biomass of Major Zooplankton Taxonomic Groups in Clary Lake and Lake 901 in 2010

1.6.1.3.2 Richness, Diversity and Evenness

Clary Lake had a greater mean taxa richness (*S)* (11 genera) and a mean Shannon diversity (*H')* (1.49) value more than three times greater than that of Lake 901 (9 genera and 0.44, respectively) (Table 1.6-4; Figure 1.6-4). The distribution of individuals across identified species was also significantly more even in Clary Lake (*J*=0.40) than in Lake 901 (*J*=0.19) (Figure 1.6-4). This reflects the observed differences in the abundance of organisms between the different taxa present in each lake.

Table 1.6-4: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for the Zooplankton Community in Clary Lake and Lake 901 in 2010

Lake	Taxa Richness (*S*)		Shannon's Diversity (*H'*)		Evenness (*J*)	
	Mean	SE	Mean	SE	Mean	SE
Clary Lake	11	0.4	1.49	0.02	0.40	0.02
Lake 901	9	0.8	0.44	0.07	0.19	0.02

Note: SE - standard error

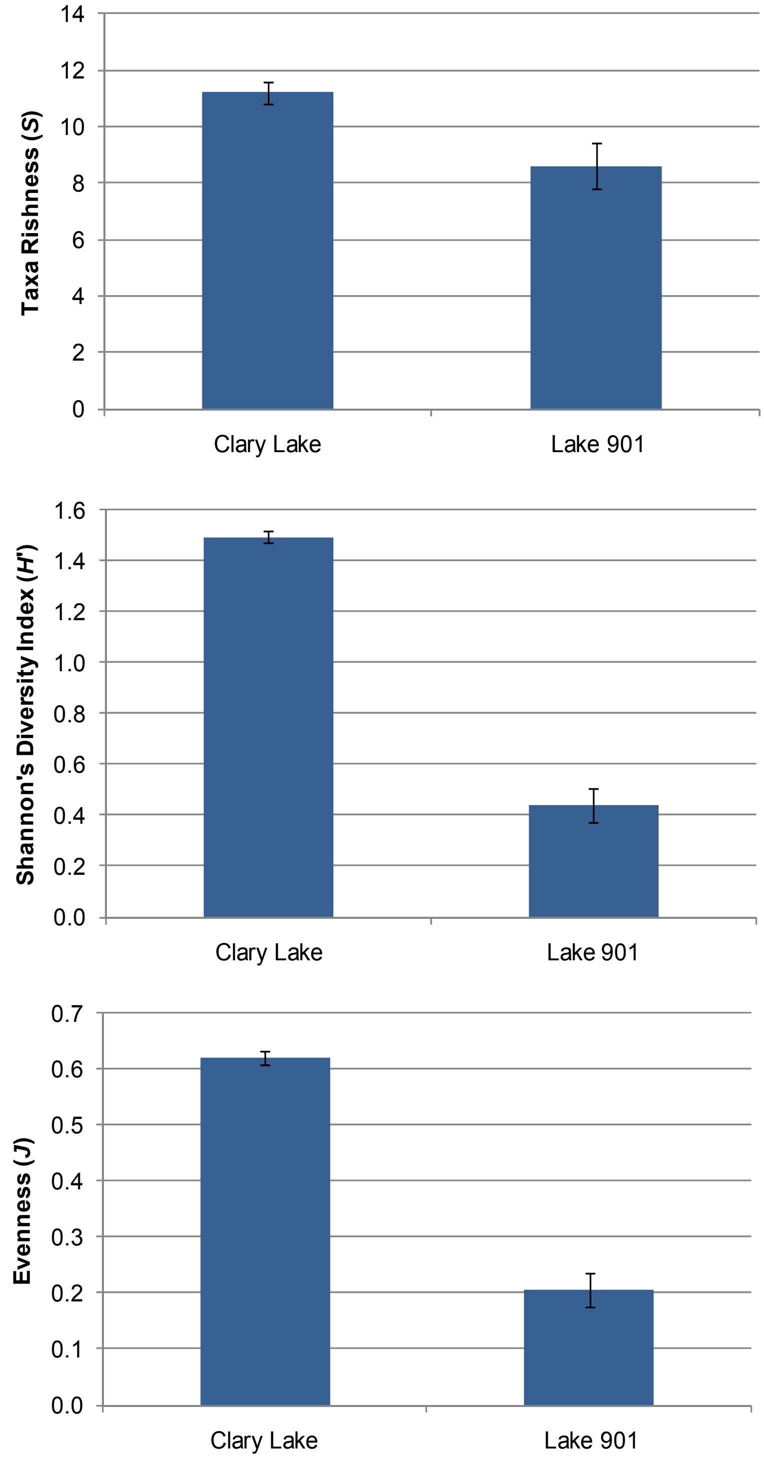


Figure 1.6-4: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Zooplankton Communities in Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

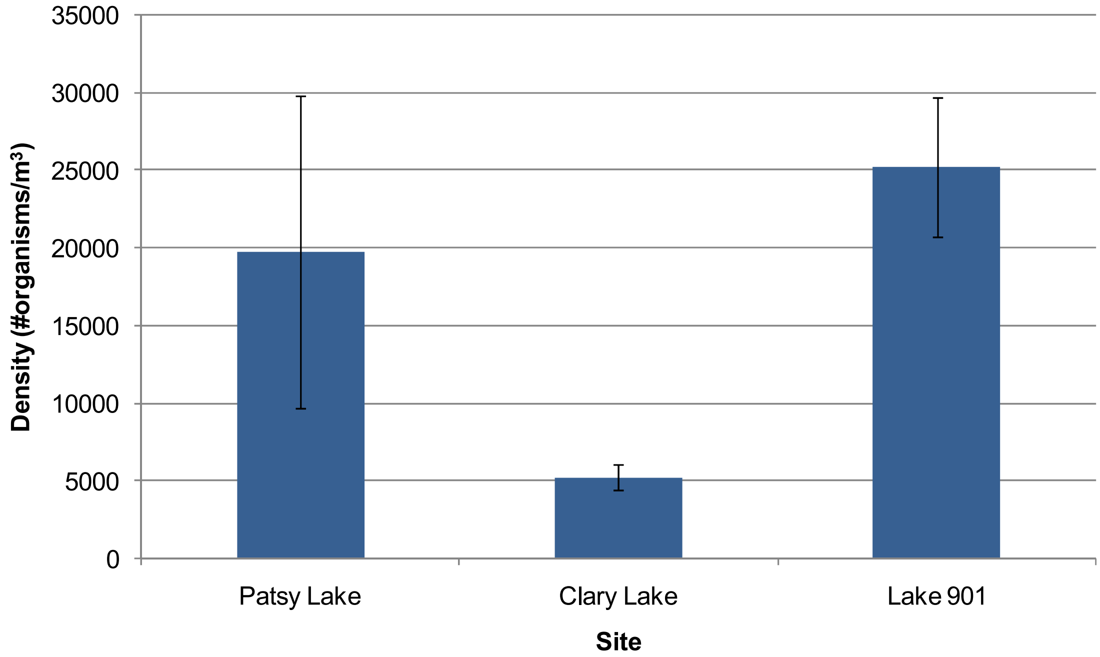
1.6.1.3.3 Comparison Between 2009 and 2010

Similar to the limitations of comparisons of phytoplankton communities between lakes, comparison of zooplankton communities between Patsy Lake, Clary Lake, and Lake 901 are difficult to draw definitive conclusions because of high natural variability typically observed in plankton communities; differences in the years and dates the lakes were sampled and the slight but potentially significant difference in mesh sizes used in Patsy Lake (118 µm) in 2009 and in Clary Lake and Lake 901 (80 µm) in 2010. However, similar to the phytoplankton communities, there are some substantial differences between the zooplankton communities in the three lakes that make such comparisions worth exploration and discussion of potential biotic or abiotic contributing factors.

1.6.1.3.3.1 Density and Relative Abundance

Zooplankton density differed among lakes sampled (1W ANOVA $F_{(2,10)}$=6.12, p=0.018). Mean zooplankton densities were lower in Clary Lake than in Patsy Lake or Lake 901, however, only differences between Clary Lake and Lake 901 densities were significant (p=0.009) (Figure 1.6-5). An overhelming abundance of rotifers in Patsy Lake and in Lake 901 in comparison to Clary Lake likely drives the observed differences in zooplankton densities (Figure 1.6-6). It is also due, at least partially, to the much greater depth that samples were towed through the hypolimnion in Clary Lake (31 m) compared to Patsy Lake (13.5 m) and Lake 901 (0 m). Even though the zooplankton are known to make vertical migrations between the hypolimnion and epilimion to lower predation risk during the day (Sekino et al. 1999), the hypolimnion is much colder, and darker than the epilimnion and one would expect a much lower zooplankton density in lake where the hypolimnion comprised a greater proportion of the total water column depth.

The relative abundance of copepod nauplii and cyclopoid copepods was much higher in Clary Lake than in Patsy Lake and Lake 901 where rotifers were the overwhelmingly most abundant zooplankton taxon present (Figure 1.6-6). The reasons for the differences in zooplankton community structure in the three lakes are likely similar to the reasons why the phytoplankton communities in the three lakes are so different. These include abiotic factors such as differences in water chemistry, water temperature and thermal stratification, and littoral and pelgic habitat. They also likely include the significant difference in trophic community structure between lakes as Patsy Lake is non-fish-bearing and Clary Lake and Lake 901 are known to contain rainbow trout. As mentioned previously, this difference in top-down control has likely contributed to the observed differences in zooplankton community structure in Patsy Lake compared to the other two lakes, similar to that observed in the phytoplankton communities. The difference in zooplankton community structure between Clary Lake and Lake 901 is more likely due to differences in physical habitat (e.g., littoral habitat composition and quantity, depth, water temperature, water clarity) and water chemistry (e.g., pH), and their resulting affect to the phytoplankton communities upon which the zooplankton communities feed, than to differences in trophic structure as both lakes contain rainbow trout.



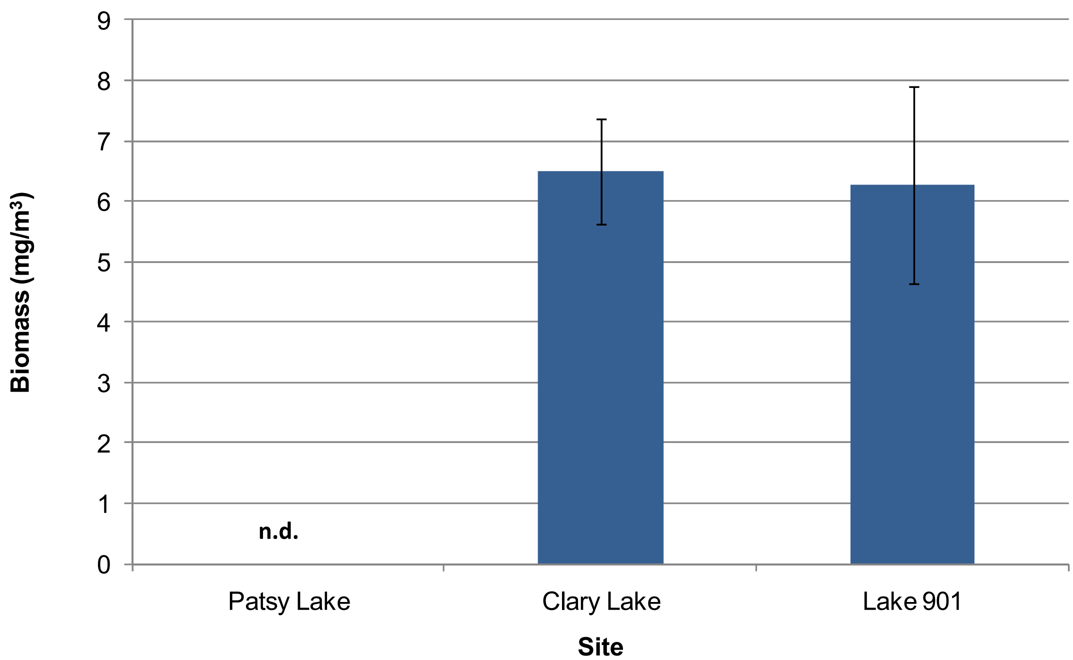


Figure 1.6-5: Mean Zooplankton Density (organisms/m^3) In Patsy Lake in 2009 and in Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

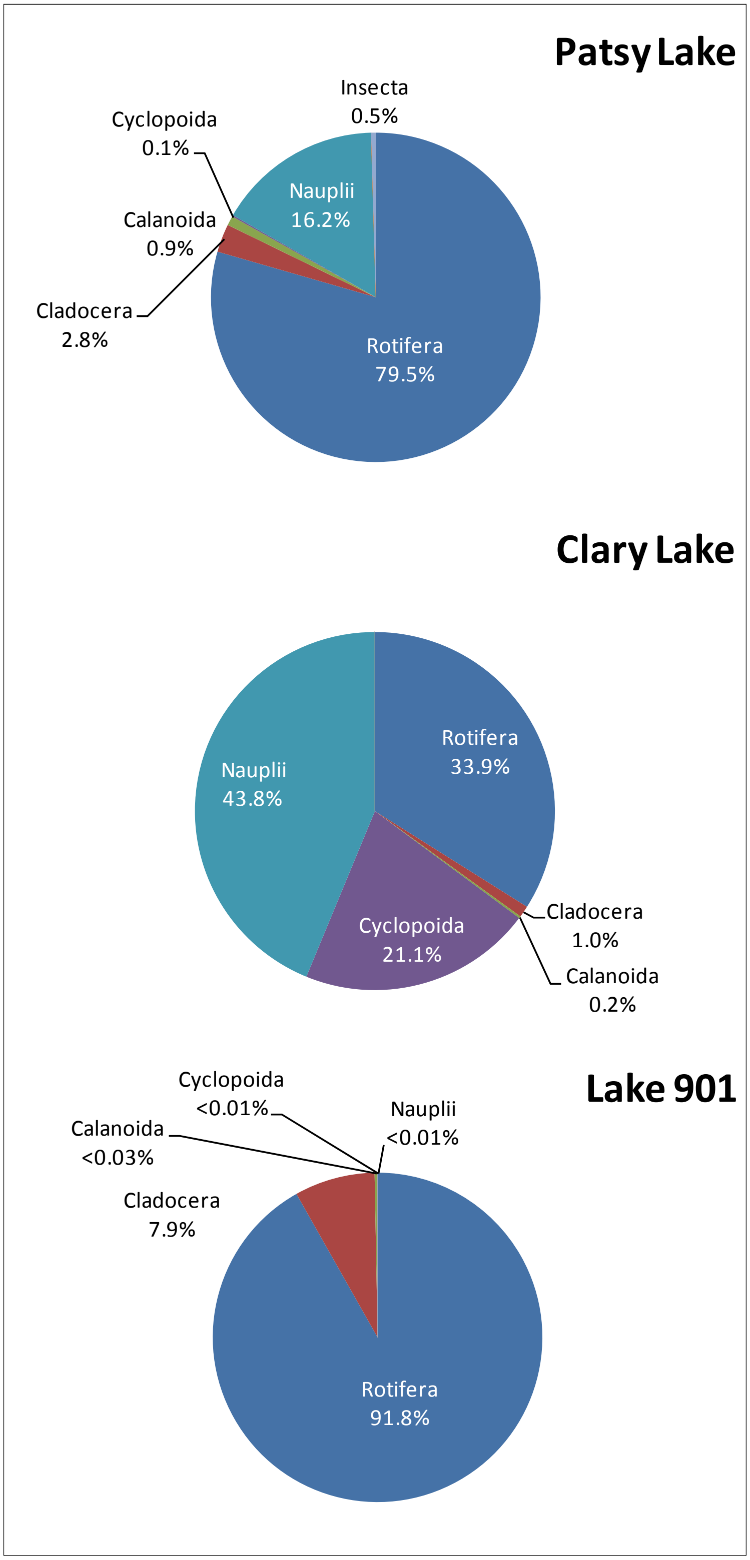


Figure 1.6-6: Comparison of Relative Abundance of Major Zooplankton Taxa in Patsy Lake in 2009 and in Clary Lake and Lake 901 in 2010

1.6.1.3.3.2 Taxonomic Richness, Diversity, and Evenness

Mean taxonomic richness of the zooplankton communities was higher in Clary Lake than in Patsy Lake or Lake 901 (Figure 1.6-7). This is due to the lower dominance of rotifers in Clary Lake compared to the other two lakes. The greater number of taxa and the greater representation of individual organisms in these taxa is the reason why Clary Lake had a higher *H'* (1.49) and *S* (0.40) than in Patsy Lake (0.88 and 0.27, respectively) and in Lake 901 (0.44 and 0.19, respectively).

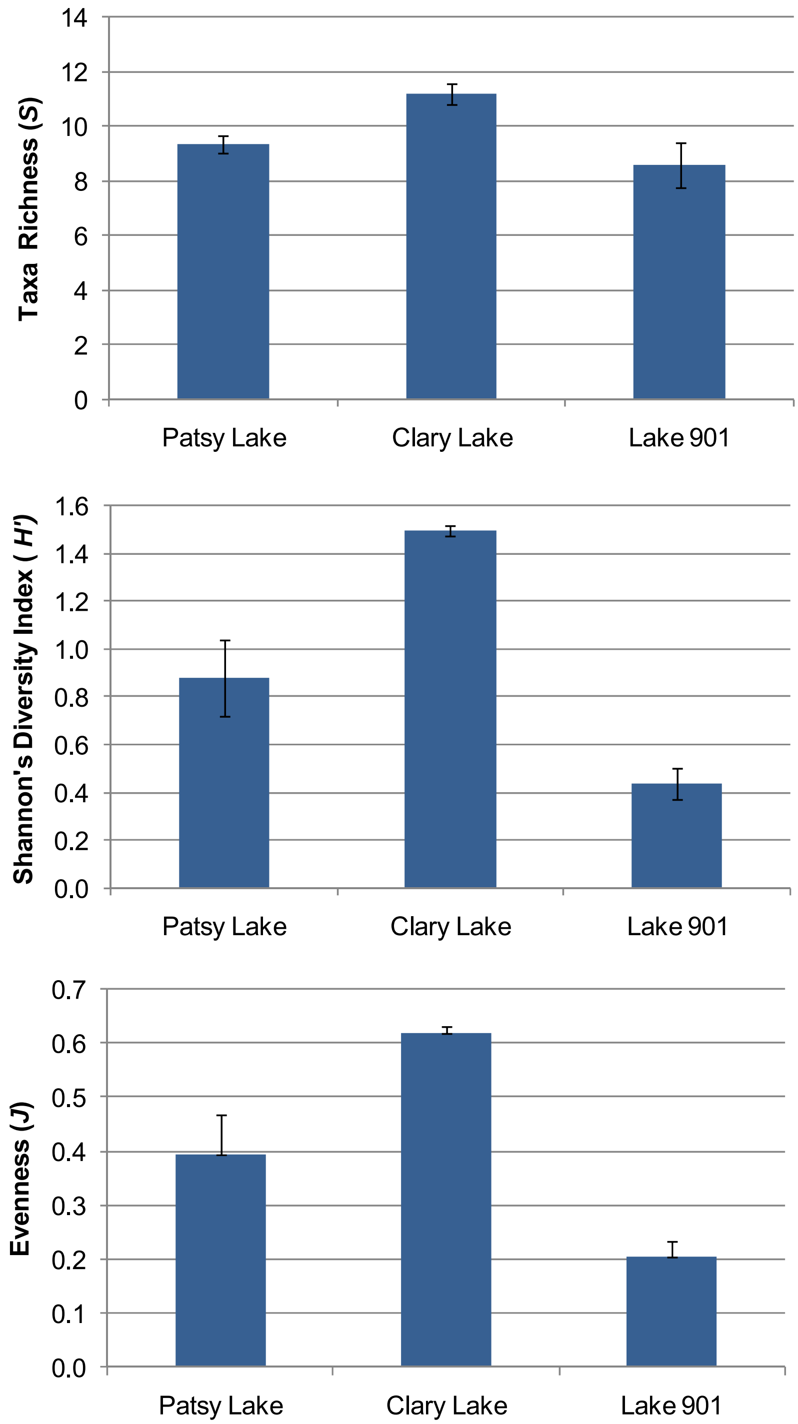


Figure 1.6-7: Mean Taxa Richness, Shannon's Diversity Index (H'), and Evenness (J) Metrics for Zooplankton Communities in Patsy Lake in 2009 and from Clary Lake and Lake 901 in 2010

Note: Error Bars Represent Mean ±1 SE

1.6.2 Benthic Macro-Invertebrates in Streams

1.6.2.1 2009 Studies

Raw taxonomical and abundance data for BMI samples collected in 2009 are provided in Appendix E-1.

1.6.2.1.1 Sorting Efficiency and Sampling Precision

Sorting efficiency exceeded 97 % in all re-sorts with a mean sorting efficiency of 99% (Table 1.6-5). Sampling precision from the replicates in each of the stream sites had a D_p value equalling or less than 0.20. The exception was at LC3 where the D_p value was 0.31 (Table 1.6-6). With the exception of LC3, these results meet the requirements of the CABIN protocol (McDermott et al. 2010) and indicate that results for mean densities, relative abundance and the various community metrics presented below are a reliable representation of the benthic macro-invertebrate (BMI) communities present at these sites. Results for LC3 in 2009 may not accurately represent the BMI community present and should be viewed with caution. This lower sampling precision is likely due to the difficulty finding similar locations for the replicates suitable for sampling with the Hess sampler. This site is dominated by large boulder / cobble substrates typically unsuitable for Hess sampling.

Table 1.6-5: Sorting Efficiency for Stream BMI Sample Sites in 2009

Site Code	Original Count	QA Count	Difference	Sorting Efficiency (%)
LC0-3	131	134	3	97.8
WL1-3	33	33	0	100
			Mean sorting efficiency	**99.2**

Note: BMI - benthic macro-invertebrate; QA - quality assurance; % - percent

Table 1.6-6: Sampling Precision, Mean Density, and Community Metrics for Stream BMI Sites Sampled in the Lime Creek Watershed in 2009

Community Metric	Statistic	LC0	LC1	LC3	PC2
Sampling Precision	D_p	0.20	0.18	0.31	0.16
Density (organisms/m^2)	Mean	586	445	803	3,910
	Median	503	458	618	4,292
	SD	266	215	565	1,427
	SE	119	81	252	638
	Min	403	118	424	1,719
	Max	1,056	747	1,788	5,188
Family richness	Total	21	23	21	28
EPT (%)	Mean	63.27	85.40	86.95	75.49
Pielou's Evenness (*J*)	Mean	0.69	0.72	0.68	0.74
	Median	0.73	0.75	0.69	0.72
	SD	0.66	0.13	0.44	0.33
	SE	0.30	0.05	0.20	0.15
	Min	0.54	0.54	0.61	0.70

Community Metric	Statistic	LC0	LC1	LC3	PC2
	Max	0.75	0.89	0.74	0.79
Simpson's Diversity (*D*)	Mean	0.74	0.75	0.74	0.83
	Median	0.77	0.73	0.75	0.83
	SD	0.10	0.09	0.07	0.03
	SE	0.05	0.03	0.03	0.01
	Min	0.56	0.61	0.67	0.80
	Max	0.82	0.87	0.83	0.87
Shannon's Diversity(*H'*)	Mean	1.75	1.76	1.75	2.14
	Median	1.80	1.73	1.66	2.10
	SD	0.25	0.28	0.22	0.10
	SE	0.11	0.11	0.10	0.04
	Min	1.38	1.38	1.56	2.04
	Max	2.06	2.20	2.13	2.28

Note: EPT - Ephemeroptera, Plecoptera, and Trichoptera; SD - standard deviation; SE - standard error
Source: Rescan (2010a)

1.6.2.1.2 Density and Relative Abundance

Mean BMI density was highest at the Patsy Creek (PC2) site (3,910 individuals/m^2). Mean BMI densities in upper Lime Creek (LC3) and in the two lower Lime Creek sites (LC0 and LC1) were lower (803, 586 and 445 individuals/m^2, respectively) than in Patsy Creek (Figure 1.6-8). The dense riparian vegetation and the large amount of woody debris at PC2 likely contributed to the higher BMI densities at this site compared to the Lime Creek sites (Rescan 2010b).

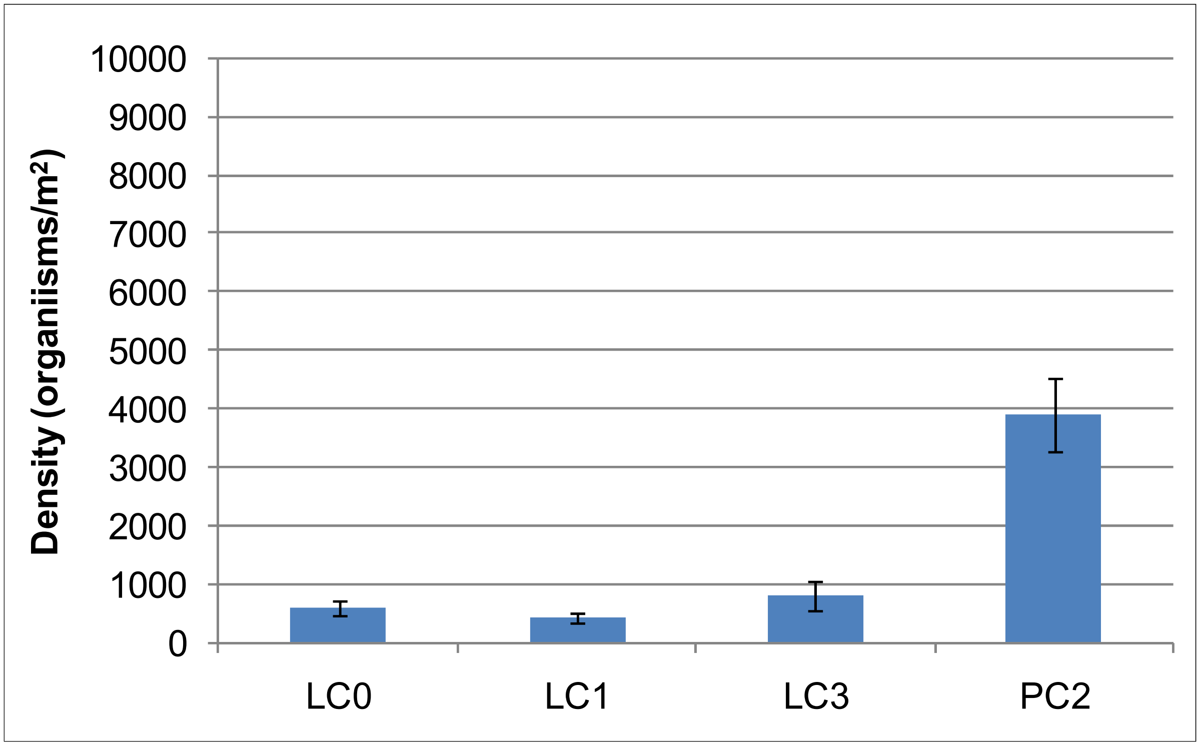


Figure 1.6-8: Mean BMI Density in Stream Sites Sampled in the Lime Creek and Clary Creek Watersheds, 2009

Plecoptera (stoneflies) and ephemeroptera (mayflies) larvae comprised between 63% and 84% of the total BMI present at all four sites sampled in 2009 (Figure 1.6-9). Plecopteran families Chloroperlidae, Leuctridae, Nemouridae and Taeniopterygidae, and Ephemeropteran families Baetidae and Heptageniidae were abundant across all sites. Even though Tricoptera (caddisfly) larvae contributed <5% to the total BMI communities at these four sites, pollution sensitive EPT taxa comprised between 63 and 87% of the total BMI organisms present at these four sites (Table 1.6-6 and Figure 1.6-9).

Diptera (true flies and midges) larvae comprised 23% and 34% of the BMI communities at the Patsy Creek site (PC2) and at the lowest Lime Creek site downstream of the Kitsault Townsite (LC0), respectively (Figure 1.6-9). Dipteran larvae comprised only 12% and 8% of the BMI communities at the upper Lime Creek site (LC3) and the lower Lime Creek site above the Kitsault Townsite (LC1). Chironomidae was the most abundant dipteran family present. Together, stoneflies, mayflies, and dipteran larvae comprised over 90% of all organisms present in the samples.

Combined, all other BMI taxonomic groups comprised <7% of the total BMI communities at these four sites in 2009 (Table 1.6-6 and Figure 1.6-9). Other BMI taxa included Acariformes (water mites), Turbellaria (flatworms), Nematoda (roundworms), Oligochaeta (worms), Ostracoda (seed shrimps), Lepidoptera (moths and butterflies), and Collembola (springtails).

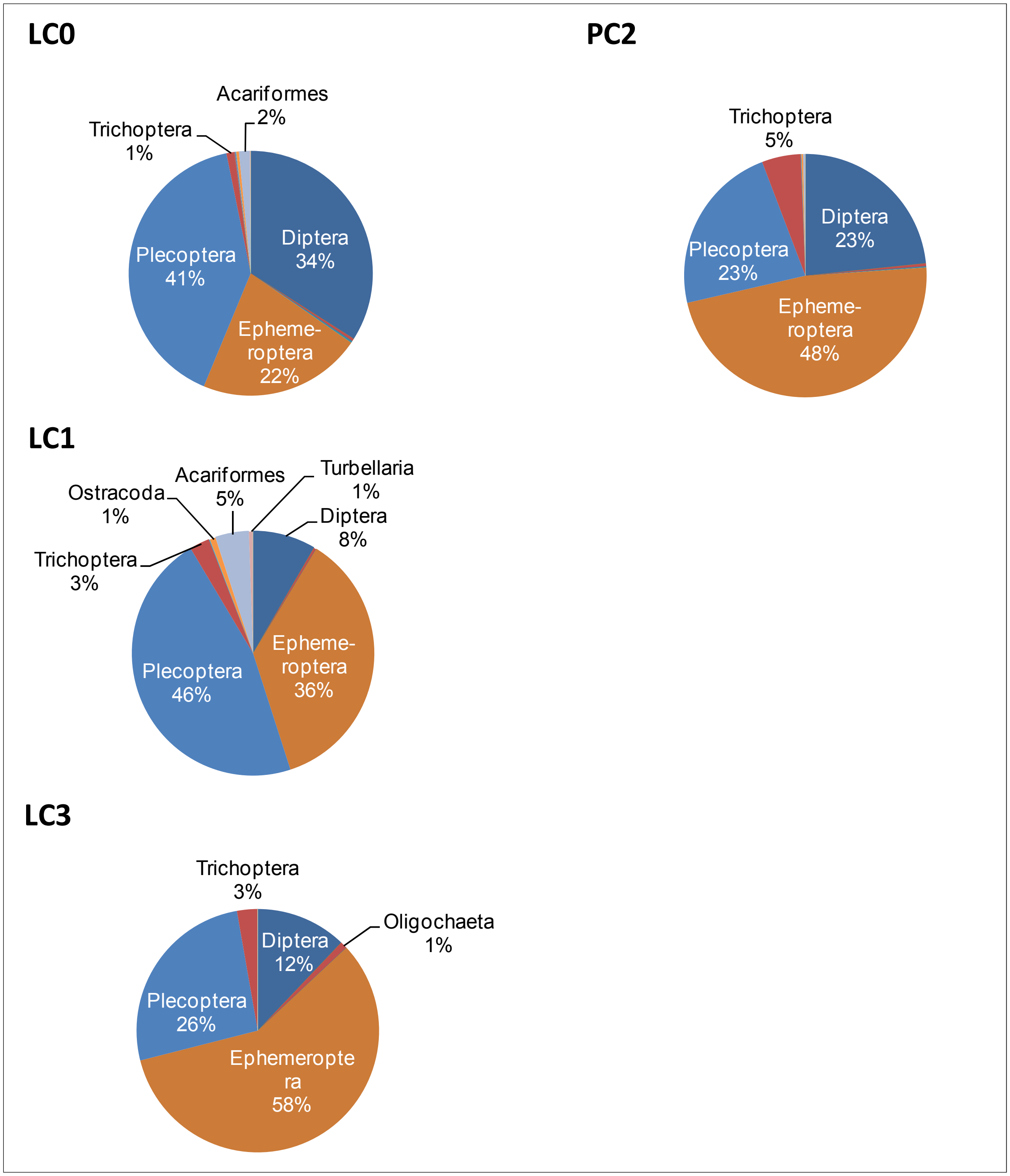


Figure 1.6-9: Relative Abundance of Major BMI Taxonomic Groups in Stream Sites Sampled in 2009

1.6.2.1.3 Richness, Diversity, and Similarity Indices

Family richness ranged from 21 at LC0 to 28 at PC2 (Table 1.6-6). The higher taxonomic richness at the Patsy Creek site is likely due to the same reasons as the higher BMI density at this site compared to the Lime Creek sites; this site had the densest riparian vegetation and most woody debris of any of the four sites (Rescan 2010b).

In addition to having the most dense and most taxonomically rich BMI community, the Patsy Creek site had the most even distribution of organisms among families present and was the most taxonomically diverse of the sites sampled in 2009. The Patsy Creek site had a higher mean *D* (0.83), *H'* (2.14), and *J* (0.74) metrics than the three Lime Creek sites. Each of these metrics was similar for the upper and lower Lime Creek sites but lower than the Patsy Creek site (Table 1.6-6 and Figure 1.6-10).

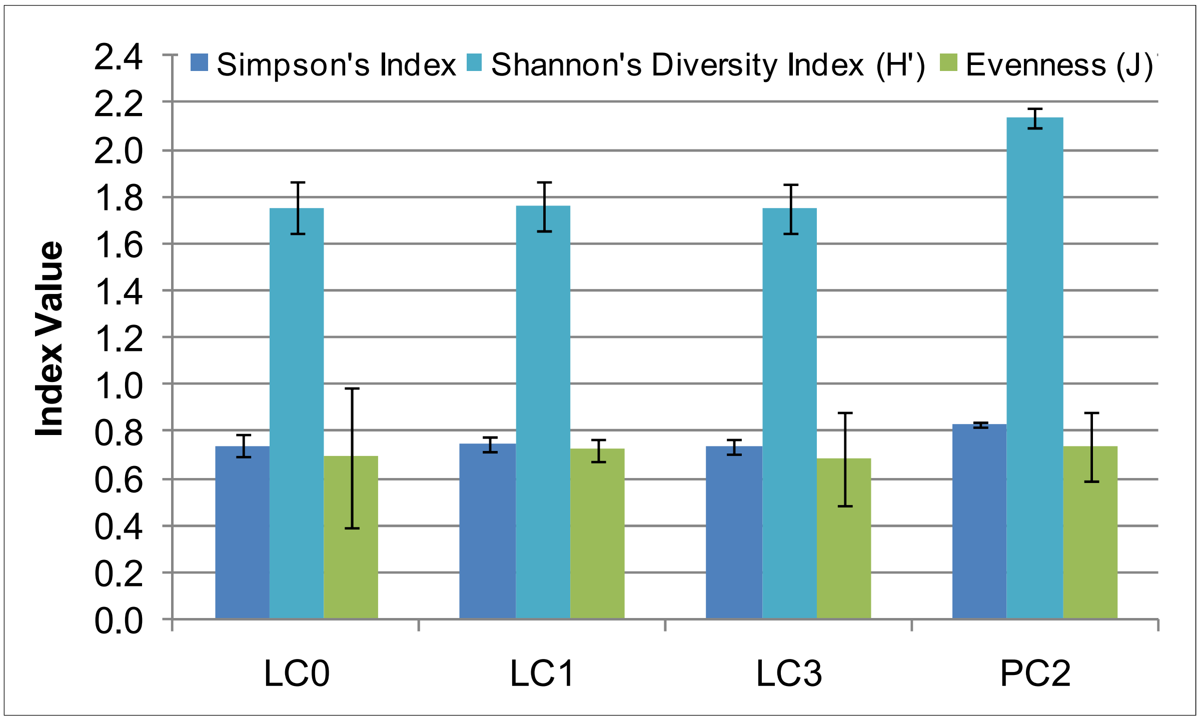


Figure 1.6-10: BMI Community Metrics in Stream Sites Sampled in the Lime Creek Watershed, 2009

There was no significant difference (p=0.17) in Bray-Curtis Dissimilarity indices between LC3 and LC1 (Table 1.6-7). The mean Bray Curtis distance from the reference median at LC1 was 0.39 and 0.26 at LC3. The reference median in 2009 was determined from the five replicates collected at LC3.

Table 1.6-7: Bray-Curtis Distance From Reference Median for Upper and Lower Lime Creek (LC3 and LC1) Sampled in 2009

Sample Site Replicates	∑y1-y2	∑y1+y2	Bray-Curtis Distance from Median	Mean Distance from Median	SE
LC3	25	337	0.07	0.26	0.12
LC3	63	385	0.16		
LC3	307	657	0.47		
LC3	123	305	0.40		
LC3	64	296	0.22		
LC1	66	241	0.27	0.39	0.15
LC1	146	321	0.45		
LC1	128	303	0.42		
LC1	32	207	0.15		
LC1	113	288	0.39		
LC1	177	352	0.50		
LC1	214	389	0.55		

Note: SE - standard error

1.6.2.2 2010 Studies

Raw taxonomical and abundance data for BMI samples collected in 2009 are provided in Appendix E-1 and E-2.

1.6.2.2.1 Sorting Efficiency and Sampling Precision

Sorting efficiency exceeded 98% in all re-sorts with a mean sorting efficiency of 99% (Table 1.6-8). Taxonomic identification error was less than 2.7%. This meets the requirements of the CABIN protocol for sorting efficiency and taxonomic identification (McDermott et al. 2010).

Table 1.6-8: Sorting Efficiency for Stream BMI Samples in 2010

Site Code / Replicates	Original Count	QA Count	Difference	Sorting Efficiency (%)
LC1-10[a]	319	320	4	98.8
LC3-10[a]	77	79	2	97.4
LC-10 (3)	599	611	12	98.0
L901 (replicate 5)	2	2	0	100.0
			Mean sorting efficiency	**98.6**

Note: [a] CABIN kick-net sample; BMI - benthic macro-invertebrate; % - percent; QA - quality assurance

Sampling precision for the majority of stream samples sites was equal to or less than 0.2 indicating that sampling reflects the sample mean at those sites and that statistical power is not reduced (Table 1.6-8). Sampling precision at these sites met the recommended tolerance for sampling precision (Elliott 1977; EC 2002). The exceptions were samples collected from the Lake 901 inlet and outlet where sampling precision was 0.27 to 0.30, respectively. This reduced precision was likely a result of the smaller channel widths compared to the other sites sampled in 2010 which required greater distances to be sampled longitudinally along the streams to collect the required five replicate samples in similar riffle habitats.

1.6.2.2.2 Habitat Variables

Habitat variables for BMI sample sites in 2010 are presented in Table 1.6-9. Raw data are presented in Appendix E-3. The Patsy substrate and channel morphology in Patsy Creek has been influenced by past mining activity. The substrate is sorted waste rock from the previous mining activities and has the highest percent boulder substrates (20%) and highest Wolman Pebble Count D_{50} (12.25 cm) of any of the sites in the Lime Creek watershed sampled in 2010. In addition, the PC site had the highest gradient (14%), highest maximum channel velocity (1.18 m/s), and highest conductivity (187 µS/cm) of the four Lime Creek watershed sites and has no canopy closure.

Habitat in the upper Lime Creek (LC3-10) and lower Lime Creek (LC1-10) sites was relatively similar, making LC3-10 a good candidate reference site for monitoring potential effects of the proposed Project on BMI at LC1-10. Both sites had similar gradient, substrate composition, pH, DO, conductivity, water velocity and wetted width. Both sites were confined by bedrock stream banks although LC3-10 was incised in a bedrock canyon and had no canopy cover.

Table 1.6-9: Summary of Habitat Variables from Stream BMI Sites in 2010

Habitat Variable	Units	Lime Creek Watershed			Clary Creek Watershed		
		LC1-10	LC3-10	PC	L901-I	L901-O	CLO
Stream order (1:50,000)	-	4	3	3	1	1	4
Bankfull width	m	11.6	10.4	10.4	2.3	3.0	7.2
Wetted width	m	6.9	6.1	7.7	2.2	2.2	7.4
Gradient	%	3	2	14	1	4	2
Velocity – channel average	m/s	0.52	0.60	0.58	0.13	0.28	0.44
Velocity – channel maximum	m/s	0.82	0.97	1.18	0.3	0.47	0.83
Substrate – Boulder (>26 cm)	%	15	16	20	0	9	4
Substrate – Cobble (6-26 cm)	%	63	61	73	29	75	46
Substrate – Pebble (0.4-6 cm)	%	15	20	7	57	16	35
Substrate – Gravel (2-4 mm)	%	5	1	0	12	0	15
Substrate – Sand (<2 mm)	%	2	2	0	2	0	0
Wolman D_{50} (median size)	cm	11.7	11.55	12.25	4.6	10.7	6.3
Wolman D_g (mean diameter)	cm	9.6	10	14.6	3.8	11.2	5.9
Macrophyte and bryophyte	%	< 25	0	0	51-75	51-75	51-

Habitat Variable	Units	Lime Creek Watershed			Clary Creek Watershed		
		LC1-10	LC3-10	PC	L901-I	L901-O	CLO
coverage							75
Canopy coverage	%	< 25	0	0	< 25	< 25	< 25
Conductivity	µS/cm	41	40	187	12	12	30
DO	mg/L	11.58	11.53	11.37	11.08	9.91	10.30
pH	-	7.14	7.14	7.25	7.20	6.95	7.60

Note: DO - dissolved oxygen; Wolman D_{50} - median size; Wolman D_g - mean diameter

Habitat at the Lake 901 inlet (L901-I) and outlet (L901-O) sites were substantially different than the three sites in the Lime Creek watershed. At these sites, wetted widths were <3.0 m, average water velocities were low (<0.3 m/sec), conductivities were <20 µS/cm, macrophyte and bryophyte coverages were 51 to 75%, and canopy cover was up to 25%. The Lake 901 inlet site (L901-I) differed from the Lake 901 outlet site (L901-O) in that substrates at this site were dominated by pebbles (57%) while substrates at the L901-O, similar to the substrates at the three Lime Creek watershed sites, were dominated by cobbles (75%).

1.6.2.2.3 Density and Relative Abundance

The mean density of BMIs was similar at the three sites in the Lime Creek watershed ranging from 1,388 to 1.871 organisms/m^2 (Table 1.6-10). Mean BMI densities were significantly ($p<0.001$) higher at the sites in the Clary Creek watershed than at the sites in the Lime Creek watershed. The site at the outlet of Clary Lake (CL-O) had the highest mean BMI (19,577 organisms/m^2) density of any of the sites sampled in 2010 and was significantly ($p<0.01$) higher than the density of BMIs at the Lake 901 inlet and outlet (6,698 and 9,037 organisms/m^2, respectively).

Table 1.6-10: Sampling Precision, Mean Density, and Community Metrics for Stream BMI Sites Sampled in 2010

Metric	Statistic	Lime Creek Watershed			Clary Creek Watershed		
		LC1-10	LC3-10	PC	L901-I	L901-O	CL-O
Sampling Precision	D_p	0.09	0.14	0.20	0.27	0.30	0.16
Density (organisms/m^2)	Mean	1,640	1,871	1,388	6,698	9,037	19,577
	Median	1,678	2,116	1,209	7,171	4,942	19,841
	SD	347	571	613	4,093	6,139	6,845
	SE	155	256	274	1,830	2,745	3,061
	Min	1,128	876	640	1,775	4,562	10,523
	Max	2,078	2,302	2,167	12,469	18,128	29,581
Family richness	Total	20	19	23	32	28	22
EPT (%)	Mean	98	99	91	40	45	20
Pielou's Evenness	Mean	0.38	0.55	0.62	0.69	0.63	0.55
	Median	0.37	0.54	0.66	0.67	0.63	0.50
	SD	0.38	0.15	0.26	0.58	0.41	0.20
	SE	0.17	0.07	0.11	0.26	0.19	0.09
	Min	0.30	0.49	0.54	0.59	0.59	0.38
	Max	0.45	0.61	0.68	0.79	0.69	0.78
Simpson's diversity index	Mean	0.38	0.66	0.74	0.79	0.79	0.62
	Median	0.39	0.65	0.73	0.79	0.80	0.57
	SD	0.08	0.03	0.04	0.07	0.02	0.15
	SE	0.04	0.01	0.02	0.03	0.01	0.07
	Min	0.28	0.62	0.70	0.68	0.76	0.43
	Max	0.48	0.68	0.78	0.88	0.81	0.79
Shannon's Diversity	Mean	0.92	1.41	1.67	2.10	1.87	1.47
	Median	0.96	1.39	1.63	2.14	1.90	1.35
	SD	0.18	0.11	0.10	0.24	0.10	0.34
	SE	0.08	0.05	0.05	0.11	0.05	0.15
	Min	0.71	1.29	1.56	1.74	1.69	1.06
	Max	1.18	1.57	1.81	2.40	1.95	1.87

Note: SD - standard deviation; SE - standard error; % - percent

Plecoptera and Ephemeroptera larvae comprised over 90% of the BMI communities at the three sites in the Lime Creek watershed (Figure 1.6-11). Despite the relative paucity of tricopteran larvae (1% or less), the % EPT taxa was >90% at all three sites and was as high as 98% of the BMI community at the lower Lime Creek (LC1-10) site. All other BMI taxa, including dipteran larvae, comprised <10% of the total organisms present at these three sites.

Replicates from the lower Lime Creek site (LC1-10) were dominated by plecopteran larvae from the family Taeniopterygidae (winter stoneflies). They accounted for >70 % of individuals in each replicate. Taeniopterygidae are from the "shedder" functional feeding group and are typically found in leaf packs or snags at the edges of streams. They are also indicative of well oxygenated, unpolluted waters (Hoell et al. 1998).

The BMI communities at the three sites in the Clary Creek watershed were substantially different than the BMI communities at the three sites in the Lime Creek watershed. EPT taxa comprised no more than 45% of the BMI communities at the Lake 901 inlet and outlet and only 20% at the Clary Lake outlet (Figure 1.6-11). Similar to the Lime Creek watershed sites, trichopteran larvae comprised <3% of the total BMI organisms found at these three sites. Instead of EPT taxa, dipteran larvae (predominantly chironomids [midges] and Simulidae [blackfly] larvae) were the dominant taxa at L901-I and L901-O, comprising 49% and 31% of the total BMI community at these sites (Figure 1.6-11). Bivalves comprised 21% of the BMI community at L901-O but only 1% at the L901-I.

The BMI community at the Clary Lake outlet site was the most different of the six sites sampled in 2010. Here, the BMI community was dominated by bivalves (67%). EPT taxa comprised only 20% of the total organisms present and dipteran larvae comprised only 11% of the total organisms present.

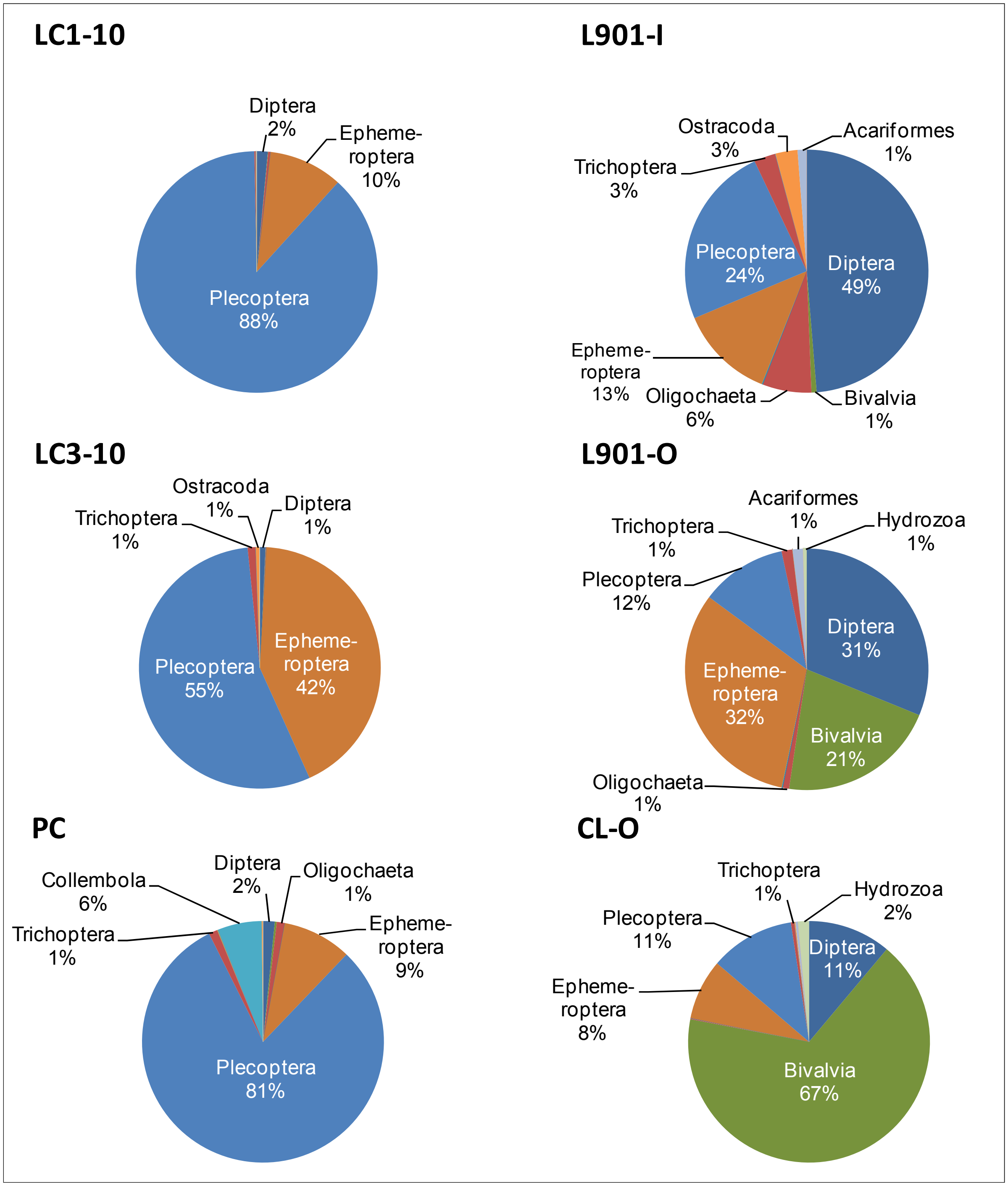


Figure 1.6-11: Relative Abundance of Major BMI Taxonomic Groups in Stream Sites in the Lime Creek and Clary Creek Watersheds, 2010

1.6.2.2.4 Richness, Diversity, and Similarity Indices

Family richness ranged from 19 families at the upper Lime Creek site (LC3-10) to 23 families at the Patsy Creek site (PC) (Table 1.6-10). Family richness was generally higher at the three Clary Creek sample sites than at the three Lime Creek sample sites. Family richness ranged from 22 families at the Clary Lake outlet (CL-O) to 32 families at the Lake 901 inlet (L901-I) site.

The Patsy Creek site (PC) had a significantly higher ($p<0.001$) *H'* value (1.67) than at the upper Lime Creek site (1.41) and the lower Lime Creek site (0.92) (Figure 1.6-12). *J* and *D* indices were significantly higher (both $p<0.001$) at the Patsy Creek site (0.62 and 0.74 respectively) and the upper Lime Creek site (0.55 and 0.66 respectively) than at the lower Lime Creek site (0.38 and 0.38 respectively; Figure 1.6-12). There was no significant difference in *J* and *D* indices between the Patsy Creek site and the upper Lime Creek site.

In the Clary Creek watershed, *D* and *H'* indices were significantly higher at the Lake 901 outlet ($p=0.03$; 0.79 and 2.10, respectively) and the Lake 901 inlet ($p=0.006$; 0.79 and 1.87, respectively) than at the Clary Lake outlet (0.62 and 1.47, respectively). *J* was higher at the Lake 901 inlet and outlet sites (0.69 and 0.63, respectively) than at the Clary Lake outlet site (0.55) but not significantly so ($p=0.138$) (Figure 1.6-12).

Family richness, *J*, and both *D* and *H'* values were highest at the Lake 901 inlet and outlet sites compared to the other four sites sampled in 2010. The higher community metric values at these two sites is likely due to the substantial differences in physical habitat and water chemistry at these two sites compared to the Clary Lake site and the three sites in the Lime Creek watershed. As mentioned above, these two sites had the lowest average water velocities (<0.3 m/sec), lowest water conductivities (<20 µS/cm), highest macrophyte and bryophyte coverage (51 to 75%), and highest canopy coverage (up to 25%) of any of the sites. The Lake 901 inlet site (L901-I) had the smallest average substrate size of the sites sampled and this physical feature, in particular, likely had the greatest influence on the BMI community present at this site. The Lake 901 outlet site (L901-O) had similar large substrates as the other sites but had a substantially lower DO concentration and pH compared to the other sites. The water quality parameters at this site are influenced by the water quality in Lake 901 where summer water temperatures are higher, water clarity is lower (i.e., high tannin content), and pH is lower than in Clary and Patsy lakes.

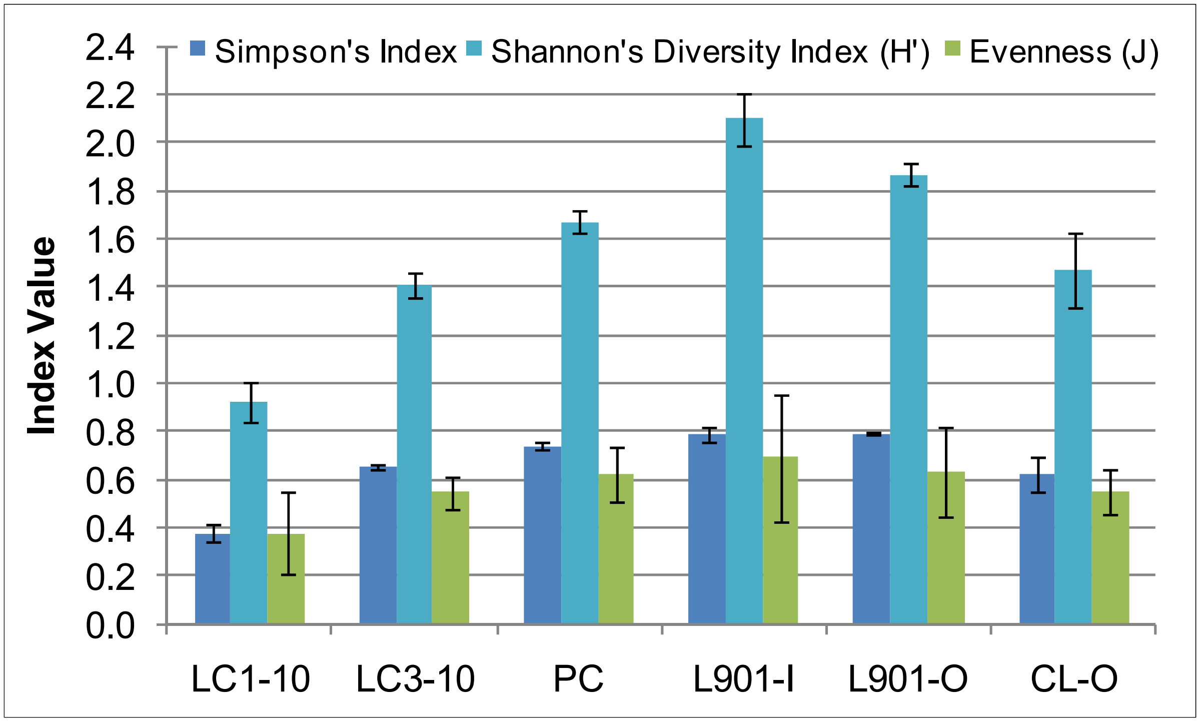


Figure 1.6-12: BMI Community Metrics in Stream Sites Sampled in the Lime Creek and Clary Creek Watersheds, 2010

The mean Bray Curtis distance at LC1-10 (0.62) which was significantly different ($p<0.001$) from that of LC3-10 (0.15) (Table 1.6-11).

Table 1.6-11: Bray-Curtis Distance from Reference Median for Upper and Lower Lime Creek (LC3-10 and LC1-10) Sampled in 2010

Sample Site	∑y1-y2	∑y1+y2	Bray-Curtis Distance from Mean	Mean Distance from Median	SE
LC3-10	1045	2781	0.38	0.15	0.06
LC3-10	345	4025	0.09		
LC3-10	589	4221	0.14		
LC3-10	114	3868	0.03		
LC3-10	386	4006	0.10		
LC1-10	1090	1929	0.57	0.62	0.06
LC1-10	1358	2010	0.68		
LC1-10	1249	2074	0.60		
LC1-10	1718	2111	0.81		
LC1-10	875	1897	0.46		

Note: SE - standard error

1.6.2.3 Comparison of Stream BMI Results Between Years

Total BMI density in upper Lime Creek in 2009 (803 organisms/m^2) was significantly lower than the total BMI density in 2010 (1,871 organisms/m^2) (Table 1.6-12). Similarly, total BMI density in lower Lime Creek in 2009 (445 organisms/m^2) was significantly lower than the total BMI density in 2010 (1,640 organisms/m^2). Although similar field and laboratory methods were used in both years, different field crews were used in 2009 and 2010 and because habitat data were not collected in 2009, it is unknown how the instream and riparian conditions at the sites had changed, if any. Additionally, potential differences in sampling locations laterally across the stream may have also contributed to these inter-annual differences in BMI densities at these sites.

Table 1.6-12: Test of Significance in Mean Community Metrics Between Upper and Lower Lime Creek Sample Sites

Community Metric	LC1 $\bar{x}_A$	LC1-10 $\bar{x}_J$	Difference	Significant?	P(T<=t) *two tail*
Density	445	1,640	1,195	Y	<0.001
Evenness	0.72	0.38	0.34	Y	<0.001
Simpson's Diversity	0.75	0.38	0.37	Y	<0.001
Community Metric	**LC3** $\bar{x}_A$	**LC3-10** $\bar{x}_J$	**Difference**	**Significant?**	**P(T<=t)** ***two tail***
Density	803	1,871	1,068	Y	<0.001
Evenness	0.68	0.55	0.13	N	
Simpson's Diversity	0.74	0.66	0.08	N	

Note: If P(T<=t) Two-Tail Is Less Than 0.05 A Significant Difference Is Indicated (5% Level)
See Appendix E.4 for detailed statistical results

Family richness was similar at these two sites between years: 21 and 19 families at the upper Lime Creek site in 2009 and 2010, respectively, and 23 and 20 families at the lower Lime Creek site in 2009 and 2010, respectively. Although both *J* and *D* were higher at the upper Lime Creek site in 2009 compared to 2010, neither were significantly higher.

J and *D* were significantly lower at the lower Lime Creek site (0.38 and 0.38, respectively) in 2010 compared to 2009 (0.72 and 0.73, respectively). The reduced diversity and evenness of the BMI community in the lower Lime Creek site in 2010 was the result of the dominance of winter stoneflies (Taneiopterygidae) in the 2010 samples which weren't nearly as abundant in the 2009 samples. This family represented 78% of the total organisms present in samples collected at LC1-10 in 2010 but only 26% of the total organisms present in sampled collected at LC1 in 2009.

As expected, BMI communities sampled within the same watersheds, within the same year were the most similar as indicated by high values of B-C Similarity Indices (Table 1.6-13). For example, LC1 was most similar to LC0 in 2009 (0.74) and LC3-10 was most similar to

LC1-10 in 2010 (0.65). The B-C indices between the BMI communities at Patsy Creek and the upper and lower Lime Creek sites were also relatively high in 2010 (0.51 and 0.50, respectively) as were the B-C values for Lake 901 inlet and outlet sites (0.52) and the Lake 901 outlet and the Clary Lake outlet sites (0.52) in 2010.

Table 1.6-13: Bray-Curtis Similarity Index for Stream Sites Sampled in 2009 and 2010

	LC0	LC1	LC1-10	LC3	LC3-10	PC	PC2	L901-I	L901-O	CL-O
LC0	1.00									
LC1	0.74	1.00								
LC1-10	0.14	0.13	1.00							
LC3	0.47	0.48	0.21	1.00						
LC3-10	0.12	0.12	0.65	0.21	1.00					
PC	0.15	0.14	0.50	0.22	0.51	1.00				
PC2	0.19	0.13	0.23	0.32	0.36	0.25	1.00			
L901-I	0.04	0.03	0.09	0.06	0.12	0.19	0.23	1.00		
L901-O	0.03	0.02	0.05	0.04	0.13	0.07	0.14	0.52	1.00	
CL-O	0.02	0.01	0.04	0.02	0.05	0.06	0.10	0.32	0.52	1.00

Note: Grey highlights indicate B-C ≥ 0.50

B-C indices were low for similar sites sampled in different years. For example, the B-C index for the upper Lime Creek site sampled in 2009 and in 2010 was only 0.21, while the B-C index for the lower Lime Creek site sampled in 2009 and 2010 was only 0.13 (Table 1.6-13). Similarly, the Bray-Curtis similarity index for the two sites sampled in Patsy Creek in 2009 and 2010 was only 0.25. Unlike the Lime Creek sites, differences in site locations and habitat conditions between the sites sampled in Patsy Creek in 2009 and 2010 are the likely reason for this dissimilarity in BMI community between years.

1.6.3 Benthic Macro-Invertebrates in Lakes and Wetlands

BMI were collected from the profundal zone of Patsy Lake and from three wetlands in 2009. In 2010, BMI from the profundal zone of Clary Lake and Lake 901 were collected. Samples were collected from the deepest part of each lake sample at 29, 47 and 5.8 m respectively for Patsy, Clary and Lake 901.

No BMI were found in any of the 15 replicate samples collected from the profundal zone of Clary Lake in 2010. Therefore, data from the lakes and wetlands where BMI were present in both years are presented together for brevity and to assist comparisons.

1.6.3.1.1 Sorting Efficiency and Sampling Precision

Sorting efficiency in replicate samples collected from Patsy Lake and the three wetlands reached 100% in all re-sorts with a mean sorting efficiency of 100% (Table 1.6-14).

Table 1.6-14: Sorting Efficiency for Lake BMI Sample Sites in 2009 and 2010

Site	Original Count	QA Count	Difference	Sorting Efficiency (%)
Patsy Lake-2	30	30	0	100.0
WL1-3	33	33	0	100.0.
L901-5	2	2	0	100.0
			Mean sorting efficiency	**100.0**

Note: % - percent; QA 0 quality assurance

Sampling precision from replicates collected in the three wetlands in 2009 ranged from a low of 0.46 in WL2 to a high of 1.09 in WL1 (Table 1.6-15). Sampling precision in Patsy Lake in 2009 and Lake 901 in 2010 was 0.77 and 0.32, respectively. These results suggest a high degree of variability in the replicate BMI communities and, therefore, a low precision in the estimates of density, relative abundance, and the different community metrics presented below.

1.6.3.1.2 Density and Relative Abundance

Mean density of BMIs in the three wetlands in 2009 ranged from 2,637 organisms/m^2 in WL1 to 4,928 organisms/m^2 in WL3 (Table 1.6-15). Mean BMI densities in the two lakes were significantly lower than in the wetlands. Mean BMI density in Patsy Lake in 2009 was 153 organisms/m^2 while mean BMI density in Lake 901 in 2010 was 95 organisms/m^2. Variability was high between replicates at all sites (Figure 1.6-13). Low BMI density in Patsy Lake and the absence of BMI in Clary Lake is likely due to the cold water temperatures and relative lack of dissolved oxygen at the bottom. Reasons for the paucity of BMI in Lake 901 compared to wetlands are unclear. It may be due, but not limited to, differences in water quality parameters, water temperature, nutrient levels, trophic structure (lack of fish predator in wetlands), depth of water column and/or bottom substrate.

Table 1.6-15: Sampling Precision, Mean Density, and Community Metrics for Lake and Wetland BMI Sites Sampled in 2009 and 2010

Community Metric	Statistic	WL1	WL2	WL3	PL	L901
Sampling precision	D_p	1.09	0.46	0.88	0.77	0.32
Density (organisms/m^2)	Mean	2,637	6,538	4,928	153	95
	Median	1,378	4,326	785	74	104
	SD	4,975	5,154	7,473	204	68
	SE	2,872	2,976	4,315	118	31
	Min	1,304	2,859	444	0	30
	Max	5,230	12,430	13,556	385	193
Family richness	Total	9	11	10	3	4
Pielou's Evenness (*J*)	Mean	0.68	0.31	0.70	0.75	0.36
	Median	0.67	0.38	0.75	0.75	0.39
	SD	0.04	0.17	0.12	0.04	0.08

Community Metric	Statistic	WL1	WL2	WL3	PL	L901
	SE	0.02	0.07	0.05	0.02	0.03
	Min	0.65	0.13	0.57	0.72	0.00
	Max	0.73	0.43	0.80	0.78	0.81
Simpson's Diversity (*D*)	Mean	0.57	0.26	0.63	0.34	0.15
	Median	0.59	0.34	0.60	0.34	0.14
	SD	0.09	0.15	0.06	0.02	0.16
	SE	0.04	0.07	0.03	0.01	0.07
	Min	0.47	0.09	0.59	0.32	0.00
	Max	0.65	0.36	0.70	0.36	0.38
Shannon's Diversity(*H'*)	Mean	1.01	0.56	1.24	0.52	0.25
	Median	1.01	0.70	1.25	0.52	0.27
	SD	0.30	0.29	0.20	0.03	0.25
	SE	0.13	0.13	0.09	0.01	0.11
	Min	0.71	0.23	1.04	0.50	0.00
	Max	1.30	0.75	1.43	0.54	0.56

Note: *Dp* - sampling precision; SD - standard deviation; SE - standard error

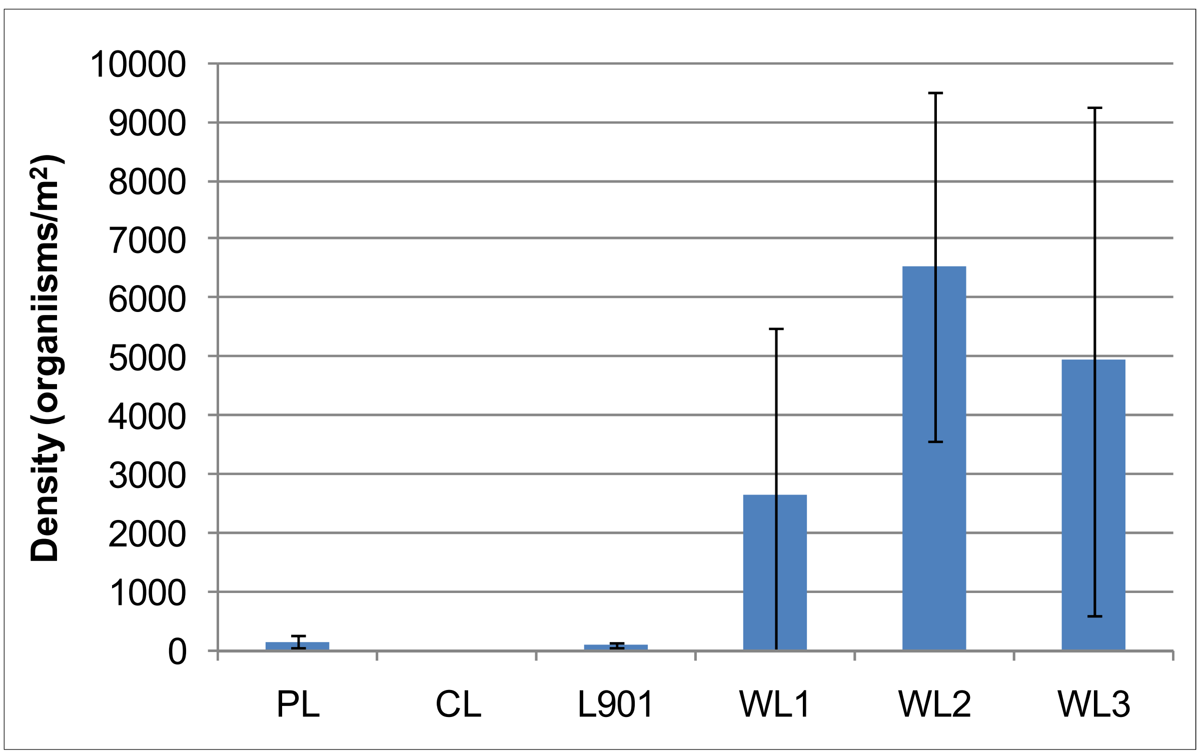


Figure 1.6-13: Mean BMI density in Lake and Wetland Sites Sampled in the Lime Creek and Clary Creek Watersheds, 2009-2010

Diptera larvae, bivalves, and oligochaetes (worms) were the dominant taxa present in all three wetlands and in Patsy Lake and Lake 901. Although the abundance of these three taxa were different between the lakes and wetlands, these three taxa comprised over 94% of all organisms found in the replicate samples collected from each waterbody in 2009 and 2010 (Figure 1.6-14). Dipterans were the dominant taxa in all five waterbodies, comprising between 48% and 91% of the total organisms present. Bivalves were the second most abundant taxa in WL1 (41%), WL2 (5%), and Patsy Lake (19%) while Oligochaetes were the second most abundant taxa in WL3 (21%) and Lake 901 (28%). Bivalvia of the family Sphaeriidae (pea clams), Oligochaeta from the family Tubificidae and Dipterans from the family Chironomidae (midges) were the dominant taxa present in these waterbodies and were present across all sites. These families were the only BMI taxa collected from Lake 901 and Patsy Lake. Amphipods, Odonata (dragonfly) larvae, Hemiptera (true bugs), Hirundinea (leeches), and Nematoda (roundworms) were also present in the wetland sites. However, these taxa contributed <6% to the total number of organisms present in any of the wetland samples combined.

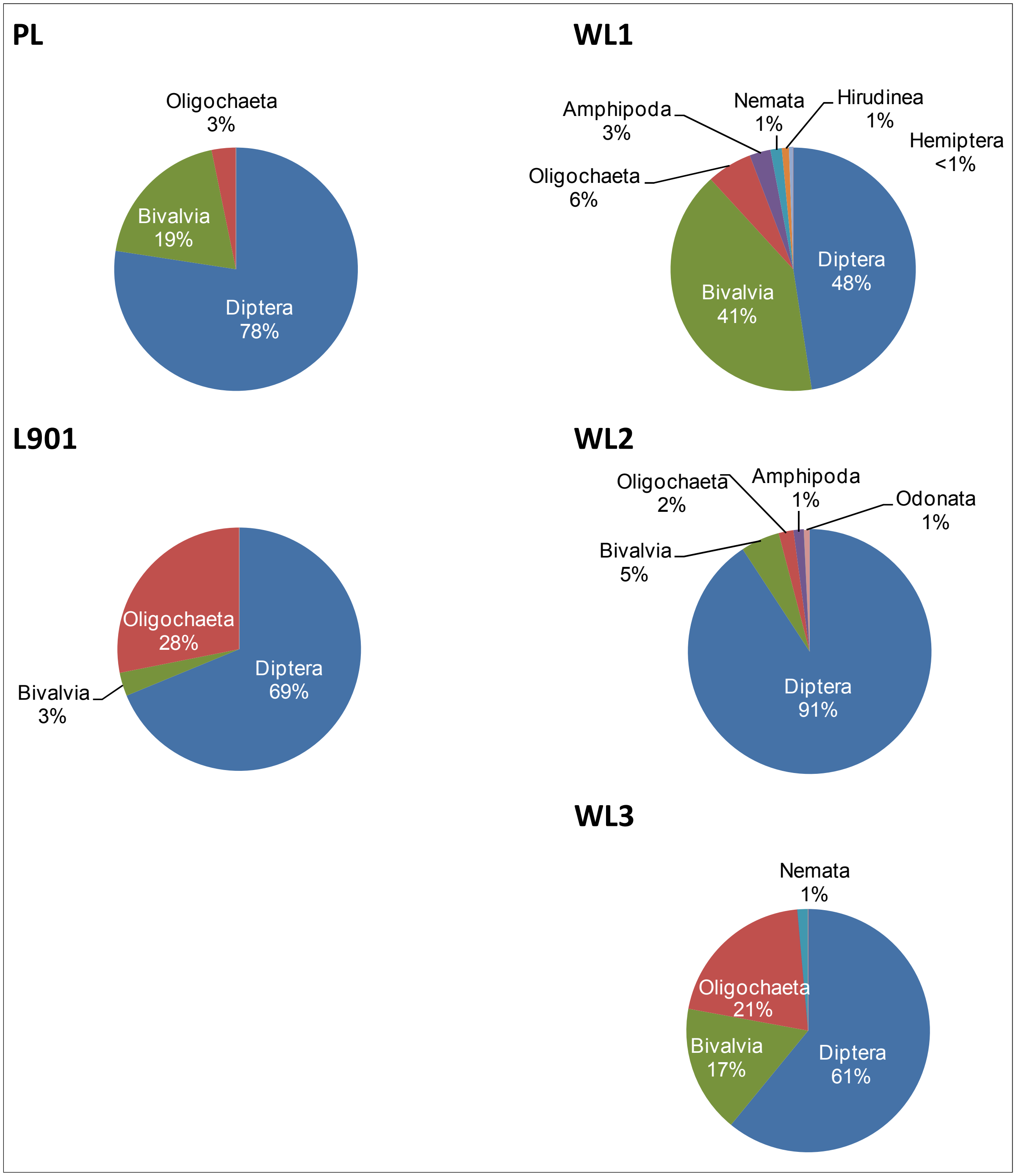


Figure 1.6-14: Relative Abundance of Major BMI Taxonomic Groups in Lake and Wetland Sites Sampled in the Lime Creek and Clary Creek Watersheds, 2009 and 2010

1.6.3.1.3 Richness, Diversity, and Similarity Indices

Family richness lower in the two lakes than in wetlands as would be expected from such low number of individuals collected in lakes (Table 1.6-15). Family richness in the wetlands ranged from 9 families in WL1 to 11 families in WL2 in 2009. Family richness was only 3 in Patsy Lake in 2009 and only 4 in Lake 901 in 2010. No BMIs were found in 15 Ekman grab samples taken from Clary Lake.

WL2 was more similar to Patsy Lake and Lake 901 than the other two wetlands sampled in 2009 in terms of Simpson's diversity (D), Shannon's diversity (*H')*, and Pielou's evenness (*J) values* (Table 1.6-15 and Figure 1.6-15). Mean *D*, *H'* and *J* were 0.26, 0.56, and 0.31, respectively, in WL2 and 0.34, 0.52, and 0.75 in Patsy Lake in 2009 and 0.15, 0.25, and 0.36 in Lake 901 in 2010. By comparison, mean *D*, *H'*, and *J* in WL1 (0.57, 1.01, and 0.68, respectively) and WL3 (0.26, 0.56, and 0.31, respectively) were substantially higher. The reason for the lower community metrics in WL2 compared to the other two wetlands was that, although 11 different families were present in the samples, 91% of the total abundance was dipteran larvae dominated by one family, Chironomidae. The two lakes had lower community metrics because they had low family richness and the BMI communities of the two lakes were dominated by only one or two families. The greater depth samples were collected in these lakes compared to the wetlands, the colder water, the homogenous fine organic sediments, and low DO concentrations make the profundal zones of these lakes a relatively inhospitable habitat for most BMI.

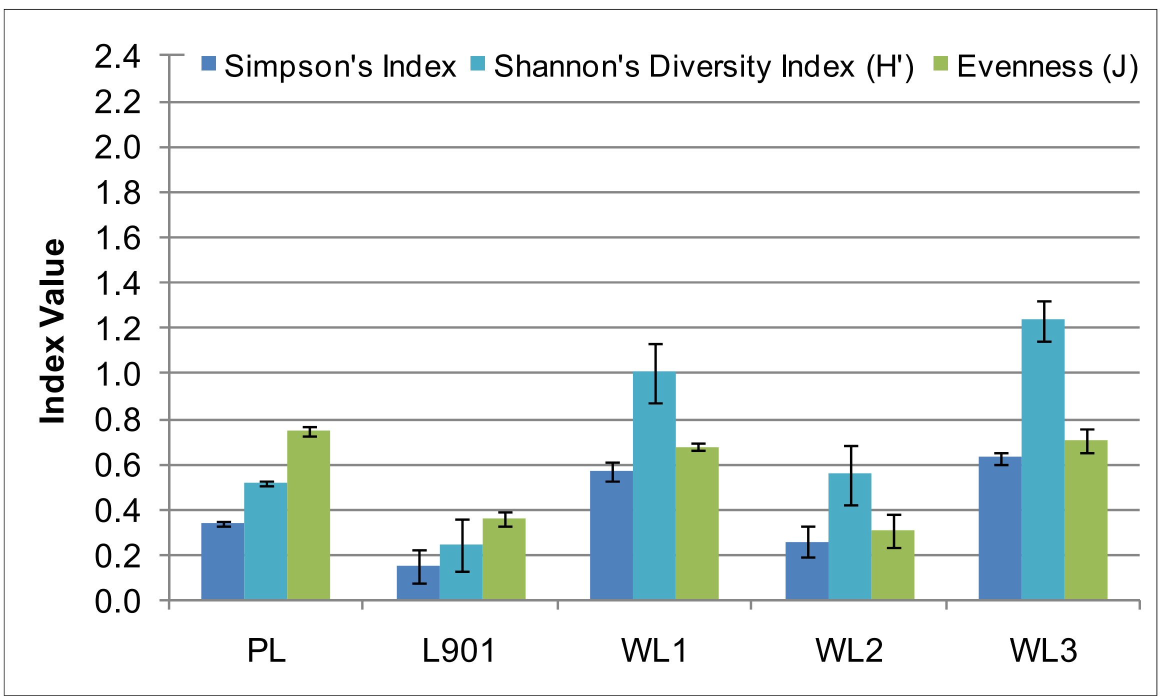


Figure 1.6-15: BMI Community Metrics in Patsy Lake and Three Wetland Sites Sampled in 2009 and Lake 901 Sampled in 2010

Table 1.6-16 presents the B-C indices for samples collected in the lakes and the three wetlands sampled in 2009 and 2010. Means were compared to aid interpretation of the data.

There was a low degree of similarity between replicates within the same waterbody and between different waterbodies in the B-C Index (Table 1.6-16). This analysis supports the low sampling precision calculated for each of the wetlands and lakes mentioned previously. It suggests that the distribution and abundance of BMI communities in the wetlands and lakes are very patchy. These results lower the confidence in making comparisons between BMI communities sampled in the five waterbodies in 2009 and 2010.

Table 1.6-16: Bray-Curtis Index for Lake and Wetland Sites Samples in 2009 and 2010

	L901	PL	CL	WL1	WL2	WL3
L901	1.00					
PL	0.10	1.00				
CL	0.00	0.00	0.00			
WL1	0.49	0.06	0.00	1.00		
WL2	0.28	0.03	0.00	0.36	1.00	
WL3	0.38	0.04	0.00	0.61	0.58	1.00

Note: Grey highlights indicate B-C ≥ 0.50

While sampling precision was low, generalisations can be made from the data. First, the absence of BMIs from the Clary Lake profundal zone and the low density and diversity of BMI in Patsy Lake suggests that BMI from these depths do not provide a significant contribution to the diet of fish in these lakes. This is supported by the relative paucity of profundal BMI taxa from the rainbow trout stomachs analysed in 2010 from Lake Clary Lake (see Section 1.7.2.4). Zooplankton and / or BMIs from the littoral areas or terrestrial insects falling into the lake from the surrounding riparian vegetation are more likely prey items for fish in these lakes. This was the case for rainbow trout diet in Clary Lake in 2010. Second, BMI communities in wetlands were denser and more diverse than BMI communities in lakes. Wetland habitats were shallower and more physically diverse than the habitats in the profundal zones of Patsy Lake, Clary Lake, and Lake 901. As a result, these wetlands had conditions more conducive to production of a greater number and greater diversity of BMI taxa than the deepest parts of the lakes. Third, although sampling the profundal zone of lakes was consistent with provincial sampling standards and guidelines (BC MOE 2009; RISC 1997) the high variability within sites and the relative paucity of BMI from deeper lakes, such as Clary Lake, suggest that continued sampling of BMI communities from the profundal zone of lakes is unlikely to be useful for monitoring potential effects of the proposed Project on the freshwater aquatic ecosystem.

1.7 Fish Community

1.7.1 Streams

1.7.1.1 Lime Creek

1.7.1.1.1 Species Composition, Relative Abundance, Distribution, and Catch-Per-Unit-Effort

A total of 25 Dolly Varden were captured in lower Lime Creek in 2009 (Table 1.7-1). Most (80%) of these fish were captured angling in the pool below the falls in late September during the Dolly Varden spawning period. Three dead Dolly Varden were observed and measured on 30 September. All of these fish were observed in Reach 4 between the bridge crossing and the falls. In addition, four Dolly Varden were captured by electrofishing in July. The identity of these fish as Dolly Varden was confirmed by genetic analysis conducted at the University of BC (E. Taylor 2010; Appendix 3.3-3 of Rescan 2010b). No other fish species was captured or observed in lower Lime Creek in 2009.

Average CPUE for Dolly Varden captured by electrofishing below the falls was 0.54 fish/100 seconds in both summer and fall sampling periods. No fish were captured in Lime Creek or in Patsy Creek upstream of the impassable falls in 2009 despite over 9,347 seconds of electrofishing effort.

Table 1.7-1: Summary of Fish Captured and Average Catch-Per-Unit-Effort, by Season and Gear Type, in Lime and Patsy Creeks in 2009

				Total Catch and CPUE		
Creek	**Season**	**Method[1]**	**Total Effort[2]**	**# of Dolly Varden**	**Average CPUE[3,4]**	**SE**
Lime Creek below falls	Summer	EF	740	4	0.54	-
	Fall	EF	186	1	0.54	-
		AG	1.0	20	20.00	-
		VO		3	-	-
Total below falls		**EF**	**926**	**5**	**0.54**	**0.00**
		AG	**1.0**	**20**	**20.00**	**-**
		VO		**3**	**-**	**-**
Lime Creek above falls	Summer	EF	1,500	0	0.00	0.00
	Fall	EF	3,250	0	0.00	0.00
Patsy Creek	Summer	EF	2,242[a]	0	0.00	0.00
	Fall	EF	2,355	0	0.00	0.00
Total above falls		**EF**	**9,347**	**0**	**0.00**	**0.00**

Note: [1] EF - backpack electrofishing; AG - angling; VO - visual observed dead on creek margin
[2] total effort for backpack electrofishing is in seconds; total effort for angling is in rod-hours
[3] average CPUE for backpack electofishing is in fish/100 seconds
[4] average CPUE for angling is in fish/rod-hour
[a] includes 438 seconds of backpack electrofishing at Site 100 on a Patsy Lake tributary
SE - standard error
Raw data can be found in Appendix G-1

Source: Rescan 2010b.

A total of 243 fish were captured in lower Lime Creek in 2010 (Table 1.7-2). These included 138 Dolly Varden (57% of total catch), 78 coastrange sculpin (32%), 18 coho salmon parr (7%), and nine prickly sculpin (4%). 96% of all Dolly Varden, 91% of all coastrange sculpin and 100% of all coho salmon and prickly sculpin were captured by backpack electrofishing. Dolly Varden were the only fish species captured by angling. Eight other Dolly Varden were visually observed in 2010. These included two Young-of-the-Year (YOY) along the stream margin on 6 June, two fish in a deep pool on 6 July, and two juveniles that escaped after being caught by electrofishing on 6 July and 8 October.

Dolly Varden was the only fish species captured or observed in Reaches 3 and 4 of Lime Creek upstream of the first bedrock cascade approximately 268 m upstream from Alice Arm. Coho salmon parr, coastrange sculpin, and prickly sculpin were only captured in Reaches 1 and 2 of Lime Creek below this 2.5 m high cascade. Coastrange sculpin were the most abundant species below this cascade, comprising 68% of the total catch. These were followed by coho salmon parr (16%), and prickly sculpin and Dolly Varden (8% each). These data suggest that both sculpin species are unable to pass upstream of this cascade and that the distribution of coastrange sculpin, prickly sculpin, and coho salmon is limited to the lower 268 m of the creek.

These data also suggest that coho salmon do not spawn upstream of this cascade. The absence of coho salmon parr upstream of this cascade in summer and the fact that adult coho salmon were not captured or observed in Lime Creek in either 2009 or 2010 suggests that the coho salmon parr found in the lower 268 m are strays from other streams along the Alice Arm coast. This phenomenon of rearing in non-natal streams has been observed for coho salmon elsewhere in BC (Levings et al. 1995; Levy and Northcote 1982), in other locations from Alaska to northern California (Koski 2009; Wallace and Allen 2009) and for other Pacific salmon species such as Chinook salmon (Murray and Rosenau 1989). Reasons for this phenomenon include physical displacement of poor swimming fry during high spring flows (Koski 2009), a behavioural response to aggression and territorial space from larger juveniles (i.e., density-dependent competition; Koski 2009), or a result of habitat limitations in the natal stream (Koski 2009). Immature coho and Chinook salmon were captured in the Lime Creek estuary in 2009 (Rescan 2010c). These fish, although not captured directly in Lime Creek, provide another year of data suggesting that some portion of coho salmon parr hatched in other streams in the Alice Arm area rear in the estuary and / or lower reaches of Lime Creek.

Coho salmon are known to inhabit Lime Creek (FISS 2011; Rolston and Proctor 1999). Coho salmon parr were also captured in the Lime Creek estuary in 2009 (Rescan 2010a). However, while a historical coho salmon spawning run in Lime Creek has been suggested by an Alice Arm resident (Littlepage 1978), the absence of coho salmon parr upstream of this first cascade (even though there is an abundance of suitable spawning and rearing habitat between this cascade and the impassable falls) suggests strongly that this spawning run no longer occurs. The cascade is not a barrier to Dolly Varden and, given their superior jumping ability, would not be a barrier to adult coho salmon either.

Table 1.7-2: Summary of Fish Captured, by Season, Reach, and Gear Type, in Lower Lime Creek in 2010

			Total Number of Fish Captured			
Season	**Reach**	**Method[1]**	**Dolly Varden**	**Coho Salmon**	**Coastrange Sculpin**	**Prickly Sculpin**
Early Summer[2]	2	EF	4	1	28	1
	3	EF	3	0	0	0
	3	MT	0	0	0	0
	4	EF	33	0	0	0
	4	MT	3	0	0	0
	4	AG	2	0	0	0
Season Total			**45**	**1**	**28**	**1**
Late Summer[2]	1,2	EF	4	17	38	8
	3	EF	5	0	0	0
	3	AG	0	0	0	0
	4	EF	72	0	0	0
	4	AG	0	0	0	0
Season Total			**81**	**17**	**38**	**8**
Early Fall[2]	1,2	EF	1	0	5	0
	1,2	MT	0	0	7	0
	4	EF	9	0	0	0
Season Total			**10**	**0**	**12**	**0**
Late Fall[2]	1,2,3	AG	0	0	0	0
	4	EF	2	0	0	0
	4	AG	0	0	0	0
Season Total			**2**	**0**	**0**	**0**
Total by reach	1,2	EF,MT,AG	**9**	**18**	**78**	**9**
	3	EF,MT,AG	**8**	**0**	**0**	**0**
	4	EF,MT,AG	**121**	**0**	**0**	**0**
Total by method	1,2,3,4	EF	**133**	**18**	**71**	**9**
	1,2,4	MT	**3**	**0**	**7**	**0**
	1,2,3,4	AG	**2**	**0**	**0**	**0**
Grand Total			**138**	**18**	**78**	**9**

Note: [1] EF - backpack electrofishing; MT - minnow trapping; AG - angling

[2] early summer is first week of July; late summer is last week of July; early fall is 1-17 September; late fall is 8-12 October

Total average electrofishing CPUE for Dolly Varden in Lime Creek over all seasons and reaches in 2010 was 0.69 fish/100 seconds (Table 1.7-3). Total average electrofishing CPUE for coastrange sculpin, coho salmon, and prickly sculpin was 0.32 fish/100 seconds, 0.11 fish/100 seconds, and 0.05 fish/100 seconds, respectively.

Average electrofishing CPUE for Dolly Varden was higher in Reach 4 (0.81 fish/100 seconds) than in Reach 3 (0.64 fish/100 seconds) or Reaches 1 and 2 combined (0.23 fish/100 seconds) (Table 1.7-3). Lower densities of Dolly Varden in Reaches 1 and 2 may be due to increased competition for space and prey from the presence of coho salmon parr, coastrange sculpin, and prickly sculpin, and by predation by large prickly sculpin. Prickly sculpin >130 mm were captured in Reaches 1 and 2 in 2010 and adult prickly sculpin of this size can be significant predators on salmonine fry (Berejikian 1995; Patten 1962; McPhail 2007).

Coastrange sculpin had the highest average electrofishing CPUE (1.85 fish/100 seconds) of all four fish species captured in Reaches 1 and 2 (Table 1.7-3); 0.61 fish/100 seconds for coho salmon parr, 0.29 fish/100 seconds for prickly sculpin, and 0.23 fish/100 seconds for Dolly Varden. The higher density of coastrange sculpin to prickly sculpin in Reaches 1 and 2 is likely due to the greater abundance of fast flowing riffle habitat preferred by coastrange sculpin and the relative paucity of the quiet water (deep pools, undercut banks, or associated with woody debris) preferred by prickly sculpin (McPhail 2007).

Average electrofishing CPUE for Dolly Varden in early (0.89 fish/100 seconds) and late (1.00 fish/100 seconds) summer was higher than in early (0.27 fish/100 seconds) or late (0.14 fish/100 seconds) fall for Reach 4 (Table 1.7-3). This difference was most likely due to the lower catchability of Dolly Varden by electrofishing in fall due to the higher water velocities and rising water levels after the increasingly frequent and intense rain events.

Average electrofishing CPUE for Dolly Varden in late July 2010 (1.00 fish/100 seconds) (Table 1.7-3) was higher than the average electrofishing CPUE for Dolly Varden in late July 2009 (0.54 fish/seconds) (Table 1.7-1). While this difference may be due to actual differences in fish densities between years, it is more likely due to the greater fishing efficiency of the three person crew used in 2010 than the two person crew used in 2009. The three person crew included two netters, one on each side of the person electrofishing. This likely reduced the number of fish missed in the fast flowing riffle sections that dominate Lime Creek habitat.

Only Dolly Varden and coastrange sculpin were caught by angling or minnow trapping (Table 1.7-2). Total average minnow trapping and angling CPUE for Dolly Varden in Lime Creek over all seasons and reaches in 2010 was 0.03 fish/trap-hour and 0.47 fish/rod-hour (Table 1.7-4). Total average minnow trapping CPUE for coastrange sculpin was 0.02 fish/trap-hour.

Table 1.7-3: Summary of Average Backpack Electrofishing Catch-Per-Unit Effort (CPUE), by Season and Reach, in Lower Lime Creek in 2010

				Average Catch-Per-Unit-Effort[1] (SE)			
Season	**Reach**	**Effort[2]**	**Sample Events (n)**	**Dolly Varden**	**Coho Salmon**	**Coastrange Sculpin**	**Prickly Sculpin**
Early Summer[3]	2	1,566	1	0.26 (-)	0.06 (-)	1.79 (-)	0.06 (-)
	3	725	1	0.41 (-)	0.00 (-)	0.00 (-)	0.00 (-)
	4	3,959	6	0.89 (0.43)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Late Summer[3]	1,2	1,389	2	0.29 (0.02)	1.21 (0.28)	2.57 (2.57)	0.55 (0.40)
	3	573	1	0.87 (-)	0.00 (-)	0.00 (-)	0.00 (-)
	4	6,718	8	1.00 (0.20)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Early Fall[3]	1,2	1,100	1	0.09 (-)	0.00 (-)	0.45 (-)	0.00 (-)
	4	3,366	1	0.27 (-)	0.00 (-)	0.00 (-)	0.00 (-)
Late Fall[3]	4	1,243	2	0.14 (0.14)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Total By Reach	**1,2**	**4,055**	**4**	**0.23 (0.05)**	**0.61 (0.36)**	**1.85 (1.16)**	**0.29 (0.22)**
	3	**1,298**	**2**	**0.64 (0.23)**	**0.00 (0.00)**	**0.00 (0.00)**	**0.00 (0.00)**
	4	**15,286**	**17**	**0.81 (0.19)**	**0.00 (0.00)**	**0.00 (0.00)**	**0.00 (0.00)**
Grand Total	**1,2,3,4**	**20,639**	**23**	**0.69 (0.15)**	**0.11 (0.07)**	**0.32 (0.23)**	**0.05 (0.04)**

Note: [1] average catch-per-unit-effort is in fish per 100 seconds of electofishing

[2] total effort is in seconds

[3] early summer is first week of July; late summer is last week of July; early fall is 1-17 September; late fall is 8-12 October.

n - number of sample events; SE - standard error

Raw data can be found in Appendix G-1

Table 1.7-4: Summary of Average Minnow Trapping and Angling Catch-Per-Unit Effort (CPUE), by Season and Reach, in Lower Lime Creek in 2010

Season	Reach	Method[2]	Effort[3]	Sample Events (n)	Average Catch-Per-Unit-Effort[1] (SE)			
					Dolly Varden	Coho Salmon	Coastrange Sculpin	Prickly Sculpin
Early Summer[4]	3	MT	46.7	1	0.00 (-)	0.00 (-)	0.00 (-)	0.00 (-)
	4	MT	118.3	1	0.03 (-)	0.00 (-)	0.00 (-)	0.00 (-)
	4	AG	0.8	3	2.33 (1.20)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Late summer[4]	3	AG	0.4	1	0.00 (-)	0.00 (-)	0.00 (-)	0.00 (-)
	4	AG	0.1	1	0.00 (-)	0.00 (-)	0.00 (-)	0.00 (-)
Early Fall[4]	1,2	MT	237.5	3	0.00 (0.00)	0.00 (0.00)	0.03 (0.01)	0.00 (0.00)
Late Fall[4]	1,2	AG	8.9	5	0.00 (0.00)	0.00 (0.00)	0.03 (0.01)	0.00 (0.00)
	4	AG	2.8	5	0.00 (0.00)	0.00 (0.00)	0.03 (0.01)	0.00 (0.00)
Total By Reach	**1,2**	**AG**	**8.9**	**5**	**0.00 (0.00)**	**0.00 (0.00)**	**0.03 (0.01)**	**0.00 (0.00)**
	3	**AG**	**0.4**	**1**	**0.00 (-)**	**0.00 (-)**	**0.00 (-)**	**0.00 (-)**
	4	**AG**	**3.7**	**3**	**0.78 (0.52)**	**0.00 (0.00)**	**0.00 (0.00)**	**0.00 (0.00)**
Total By Method	**1,2,3,4**	**MT**	**402.5**	**5**	**0.03 (0.01)**	**0.00 (0.00)**	**0.02 (0.01)**	**0.00 (0.00)**
	1,2,3,4	**AG**	**13.0**	**15**	**0.47 (0.32)**	**0.00 (0.00)**	**0.00 (0.00)**	**0.00 (0.00)**

Note: [1] average catch-per-unit-effort for minnow trapping and angling is in fish per trap-hour and fish per rod-hour, respectively
[2] MT- minnow trapping; AG - angling
[3] total effort for minnow trapping is in trap-hours; total effort for angling is in rod-hours
[4] early summer is first week of July; late summer is last week of July; early fall is 1-17 September ; late fall is 8-12 October
n - number of sample events; SE - standard error
Raw data can be found in Appendix G-1

1.7.1.1.2 Length, Weight, and Condition

Average length, weight, and condition factor of Dolly Varden, coho salmon, coastrange sculpin, and prickly sculpin captured in Lime Creek in 2009 and 2010 are provided in Table 1.7-5. Weight-length relationships for each fish species captured in Lime Creek are provided in Table 1.7-6. Raw data are tabulated in Appendix G-2.

Dolly Varden captured in 2009 were significantly (F_1=120.17, p<0.001,) larger than Dolly Varden captured in 2010. This is an artefact of the different sampling periods and gear types used between the two years. In 2009, all but five of the 25 Dolly Varden captured were caught angling in September during the Dolly Varden spawning period. In 2010, all but two of the 138 Dolly Varden captured were caught by electrofishing in July or early September before the Dolly Varden spawning period.

This difference in size of Dolly Varden captured in 2009 and 2010 is clearly shown in the length-frequency distributions (Figure 1.7-1). Dolly Varden in 2009 ranged in length between 71 and 320 mm. However, the majority (85%) of these fish were >140 mm (mean length of 222 mm (±10.1 mm)), were captured by angling in September, and were adult spawners. The four fish <120 mm in 2009 were all captured electrofishing in July (average length of 89 mm (±10.1 mm) and were juveniles. In contrast, Dolly Varden captured in 2010 ranged in length between 24 and 175 mm with the majority (85%) of fish <140 mm in length. The two fish captured in October were also smaller (<80 mm) juveniles as no adult spawning Dolly Varden were captured by electrofishing or angling during the late fall sampling period in 2010.

A distinct separation of YOY Dolly Varden from older (1+, 2+) juveniles is present in the 2010 length-frequency distribution (Figure 1.7-1). YOY Dolly Varden were <60 mm long while yearling and older juveniles were >70 mm long.

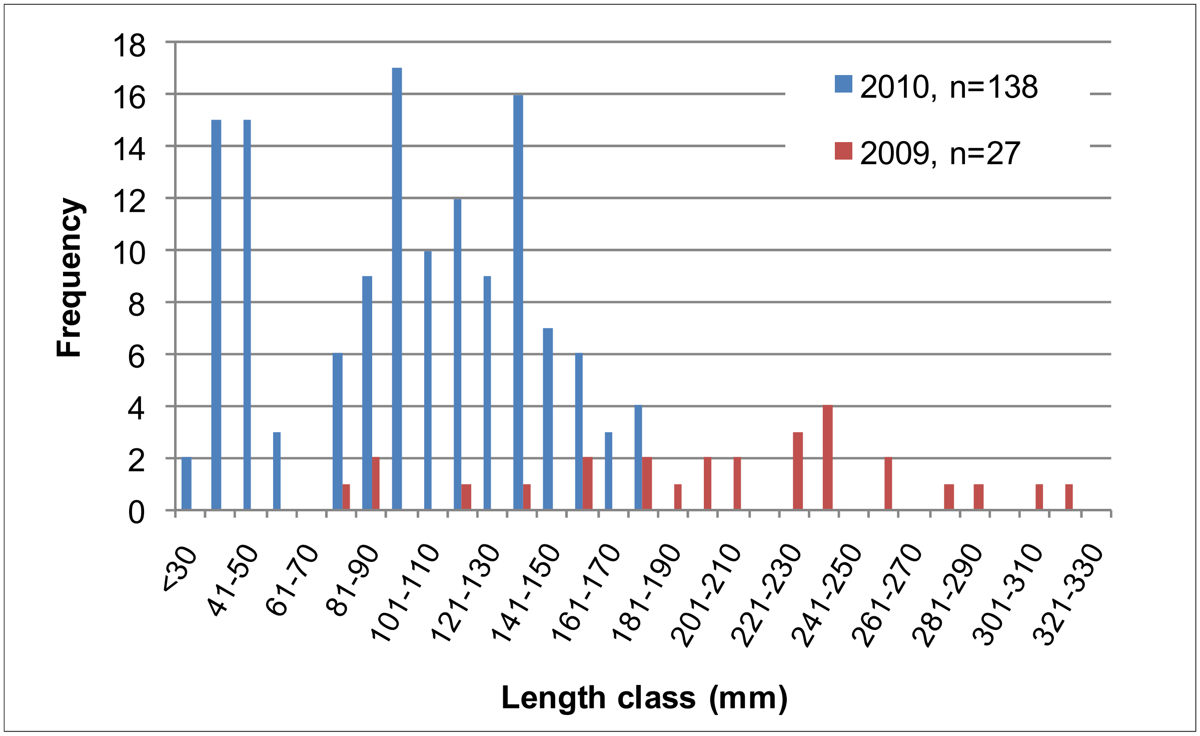


Figure 1.7-1: Length-Frequency Distribution of Dolly Varden Captured in Lower Lime Creek in 2009 and 2010

Coho salmon captured in Lime Creek in 2010 had an average length of 52 mm and an average weight of 2.8 g (Table 1.7-5). Coho salmon ranged in length between 33 and 88 mm (Figure 1.7-2). Although none of these fish were aged, coho salmon of this size on the North Coast are typically YOY (McPhail 2007).

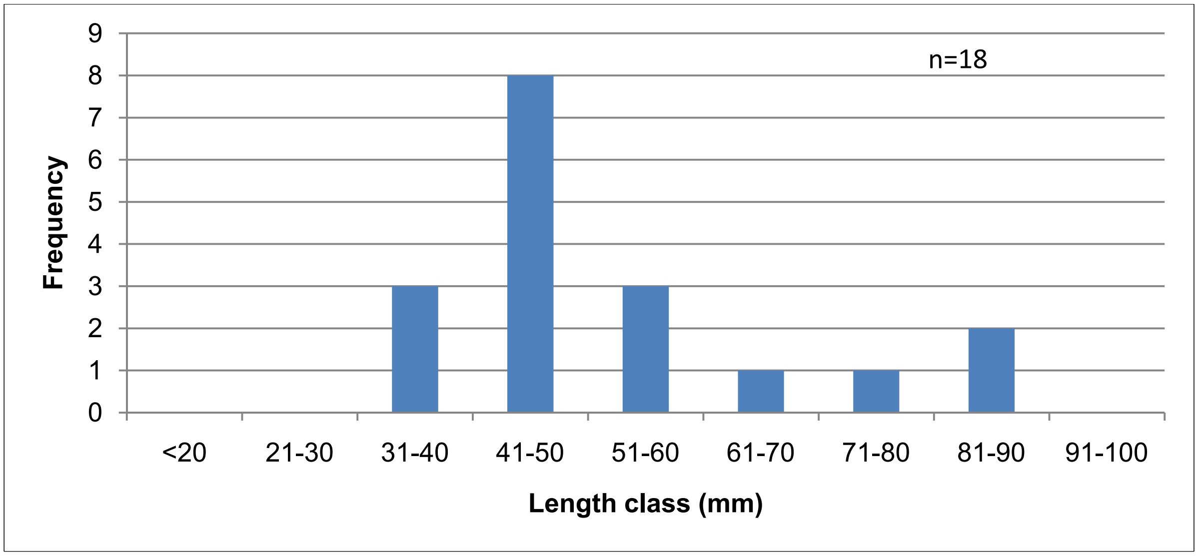


Figure 1.7-2: Length-Frequency Distribution of Coho Salmon Captured in Lower Lime Creek in 2010

Table 1.7-5: Average Length, Weight, and Condition Factor for Fish Captured in Lime Creek in 2009 and 2010

Species	Year	Length (mm)				Weight (g)				Condition			
		n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
Dolly Varden	2009	27	203	12.7	71-320	22	86.3	13.0	5.1-240	22	1.11	0.03	0.94-1.42
	2010	134	97.1	3.5	24-175	128	15.6	1.3	0.2-64.1	128	1.10	0.02	0.44-1.62
Coho Salmon	2010	18	52.1	3.9	33-88	18	2.8	0.6	0.7-9.0	18	1.65	0.07	1.25-2.39
Coastrange Sculpin	2010	78	60.6	2.1	35-102	78	3.5	0.3	0.4-10.2	78	1.37	0.04	0.61-2.43
Prickly Sculpin	2010	9	83.7	15.2	40-153	9	17.4	7.9	0.9-64.5	9	1.51	0.12	1.16-2.19

Note: g - gram; n - number of samples; SE - standard error

Table 1.7-6: Weight-Length Relationships for Fish Captured in Lime Creek in 2009 and 2010

Species	Sample Size (n)	Equation	r^2
Dolly Varden	150	$LnWt = 3.05LnLt - 11.67$	0.99
Coho Salmon	18	$LnWt = 2.61LnLt - 9.51$	0.97
Coastrange Sculpin	78	$LnWt = 2.53LnLt - 9.30$	0.94
Prickly Sculpin	9	$LnWt = 3.00LnLt - 11.11$	0.98

Note: n - number of samples; r^2 - ray of a disk squared

Coastrange sculpin had an average length of 60 mm, an average weight of 3.5 g, and an average condition factor of 1.37 (Table 1.7-5). Coastrange sculpin ranged in length from 35 mm to 102 mm with a modal length class of 41 to 50 mm (Figure 1.7-3). Although few coastrange sculpin were aged, fish <50 mm were likely less than three years old; the seven fish >70 mm long that were aged were likely between 4 and 10 years old.

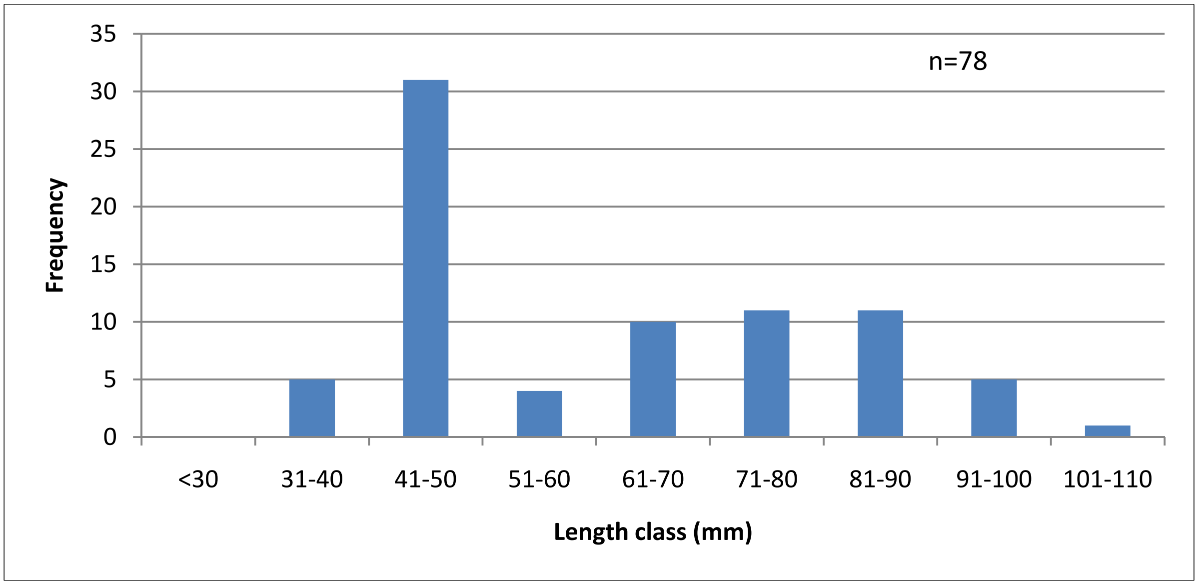


Figure 1.7-3: Length-Frequency Distribution Of Coastrange Sculpin Captured In Lower Lime Creek In 2010

1.7.1.1.3 Mark / Recapture

A total of 11 Dolly Varden were marked with pelvic and adipose fin clips and released in 2009. One of these fish was recaptured in 2010 during the early July sampling period. This fish was 120 mm long, weighed 17.2 g and was over two years old in 2010. Based on the limited number of small, clipped and released fish in 2009, this fish had grown between 39 and 49 mm and between 10 and 12 g since 2009. This fish was not re-released.

A total of 37 Dolly Varden were marked with pelvic fin clips in Lime Creek in 2010 during the early July sampling period (Table 1.7-7). None of these marked fish were recaptured during the late July sampling period. An additional 48 Dolly Varden were marked with pelvic fin clips during this second July sampling period. Although sampling effort and capture efficiency in September and October sampling periods were lower than in July (because of different sampling objectives, different gear types, restricted spatial area, and high flow conditions), none of the 10 potentially at-large fish marked in 2009 and none of the 85 marked fish potentially at-large in Lime Creek were recaptured. Because no marked fish were recaptured in either re-sampling period, a population estimate for summer resident Dolly Varden in Lime Creek was not possible in 2010.

The most likely reason for the failure of the population estimate is that not enough fish were marked in 2009 or early July 2010. Typically, at least 15% of the population needs to be marked in order to have a chance at recapturing enough fish to estimate population size (Robson and Regier 1964).

Another reason for this failure is the difficulty sampling all of the habitat potential occupied by marked Dolly Varden in Lime Creek. These include the steep, boulder cascades, the two large woody debris jams, and the numerous deep pools that exist in lower Lime Creek. While this difficulty was the virtually the same during the early and late July sampling periods, marked fish may have been more inclined to seek cover in these habitats than un-marked fish. Such behaviour would violate the Peterson mark / recapture assumption that marked and unmarked fish are completely mixed and equally susceptible to capture.

Other potential violations of assumptions of the Peterson mark / recapture estimate include emigration of marked fish out of Lime Creek in 2009 and after the early July marking period in 2010 and increased mortality of marked fish compared to un-marked fish. Both of these possibilities would reduce the number of marked fish at-large available for recapture. While the relatively short three week period between mark and recapture surveys in July 2010 would have reduced the likelihood and / or number of fish dying or leaving the creek, both scenarios could have had a significant effect on the ability to recaptured marked fish.

It is unlikely that any recaptured fish would have been missed as each fish was thoroughly searched for previous clips on all fins prior to release. It is also unlikely that many, if any, Dolly Varden immigrated into Lime Creek from other creeks between mark and recapture periods. This is because the mark and recapture periods were only three weeks apart, flow levels over the first cascade barrier in July would have precluded upstream migration of smaller Dolly Varden, and there are no other tributaries entering Lime Creek that provide fish habitat (i.e., it is reasonable to assume that the system was closed to immigration during the July mark / recapture period).

Table 1.7-7: Summary of Marked and Recaptured Dolly Varden in Lime Creek in 2009 and 2010

Year	Sampling Period	# of Fish Marked and Released	# of 2009 Marked Fish Recaptured	# of 2010 Marked Fish Recaptured
2009	July	4	-	-
	September	7	0	-
2010	Early July	37	1	-
	Late July	48	0	0
	September/October	0	0	0
Total		**96**	**1**	**0**

1.7.1.1.4 Age, Growth, and Maturity

Dolly Varden captured in Lime Creek in 2009 and 2010 ranged in age from 0+ to 4+ years (Figure 1.7-4). However, there were significant differences in the mean age of fish captured in the two years; mean age of Dolly Varden captured in 2009 was 2.8 years old while mean age of Dolly Varden captured in 2010 was 1.3 years old. For the same reason fish were larger in 2009 than in 2010, this difference in mean age was due to the different gear used and the different sampling periods sampled in 2009 and 2010.

In 2009, over 83% of all Dolly Varden captured were 3+ or 4+ years old (Figure 1.7-4). All of these older fish were captured in September 2009 and all but two of these fish were identified as mature or ripe adults preparing to spawn (Table 1.7-8). Of these 3+ and 4+ fish, 80% were >180 mm long and many of the males had pronounced kipes (Rescan 2010c). The other four 3+ year old fish were less than <180 mm but two of these fish were also identified as mature spawners. These smaller mature fish may actually be older juveniles that were preparing to spawn next year, may in fact be individuals with a “sneaker” or “jack” life history (male individuals of small body size which have reached sexual maturity and that take advantage of their small size to ‘sneak’ close to a breeding pair in order to fertilize the eggs first), or may simply be sea-run fish that matured younger than most.

In contrast, the majority (87%) of Dolly Varden captured in 2010 were less than 3+ years old (Figure 1.7-4). All of these fish were juveniles captured in July or early September; none of these fish were identified as mature or ripe fish preparing to spawn in 2010.

Average length, weight, and condition factor, at age, for Dolly Varden captured in 2009 and 2010 is presented in Table 1.7-9. On average, Dolly Varden had reached 81 mm, 103 mm, 124 mm, 184 mm, and 258 mm by their first, second, third and fourth years, respectively. Similar growth has been observed in the Keogh River on Vancouver Island (Smith and Slaney 1980). On average, Dolly Varden in the Keogh River smolt in their third summer (at about 140 mm) where upon they almost double in size before returning to the river after about 100 days in the ocean (Smith and Slaney 1980). This difference in growth rates between the stream rearing juveniles and the ocean foraging adults is the reason why a von Bertallanfy growth equation could not be fit to the length-at-age data for the Lime Creek Dolly Varden (i.e., four parameter logistic growth function was the best fit to all of the data (Figure 1.7-5)). This difference in stream and ocean growth is evident in the length-at-age data between the juvenile fish captured in 2010 and the adult fish captured in 2009 (Figure 1.7-6).

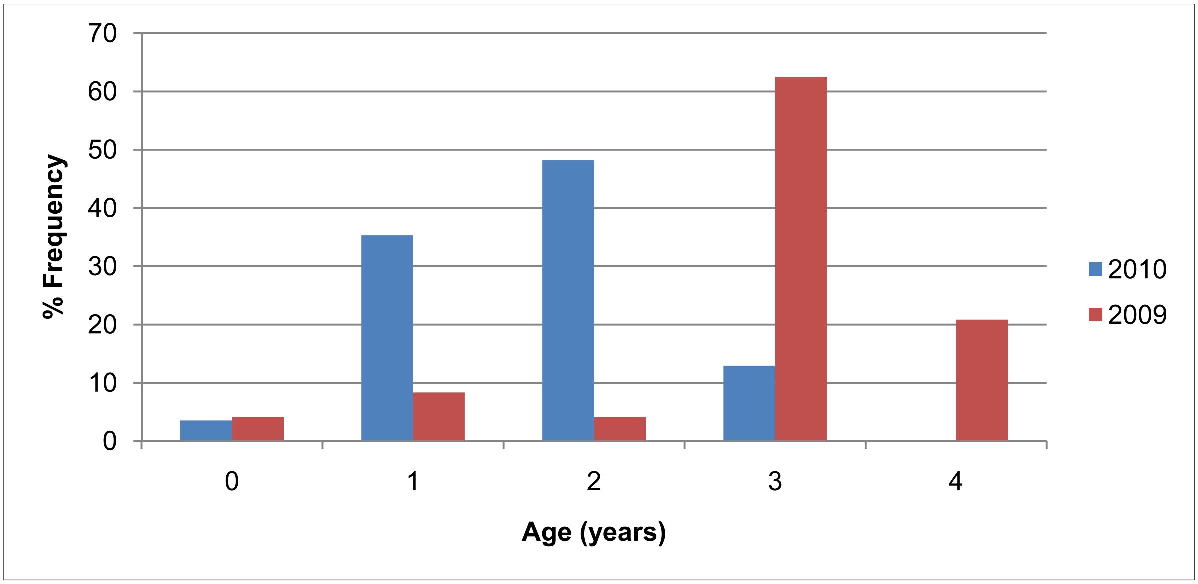


Figure 1.7-4: Age-Frequency Distributions of Dolly Varden Captured in Lower Lime Creek in 2009 and 2010

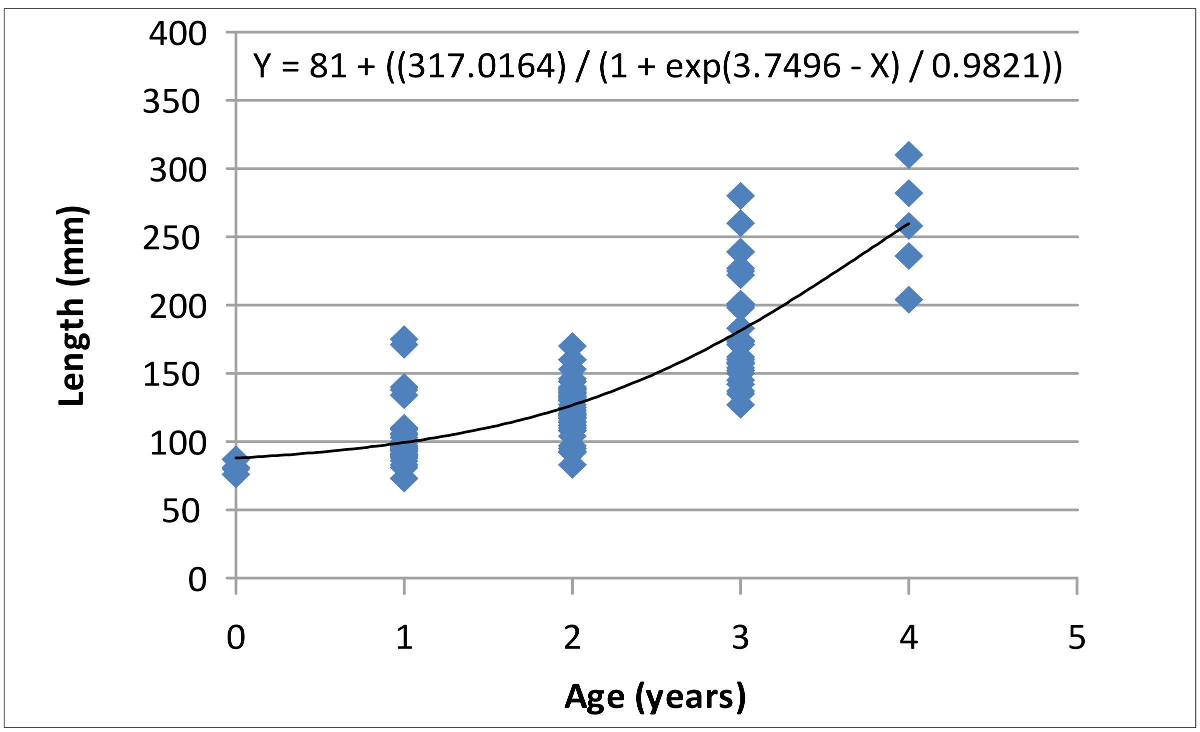


Figure 1.7-5: Growth Curve for Dolly Varden Captured in Lime Creek in 2009 and 2010

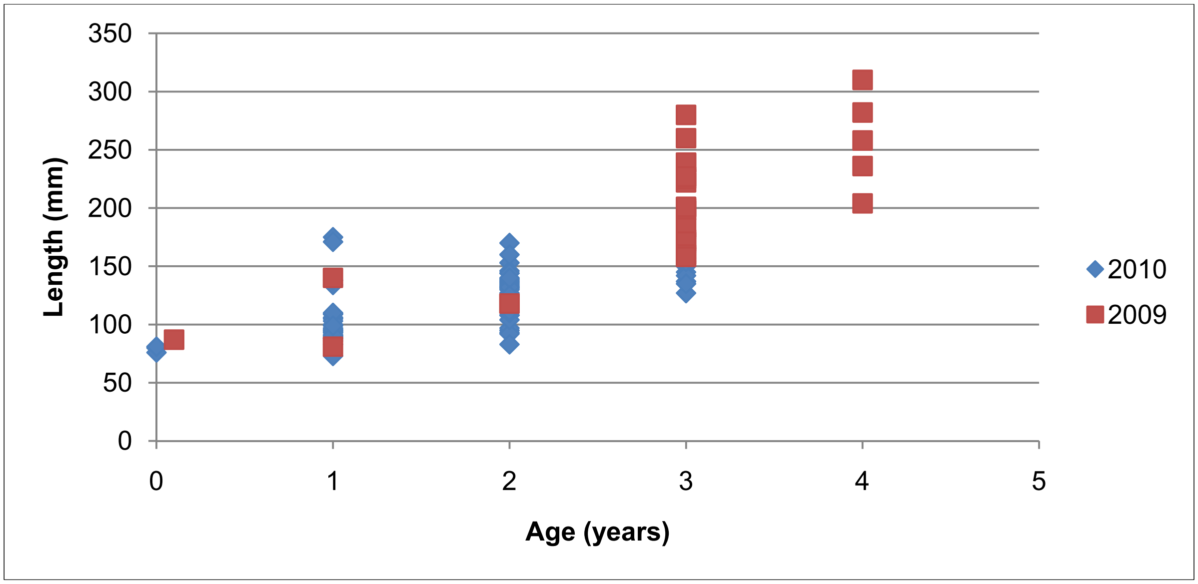


Figure 1.7-6: Length-at-Age for Dolly Varden Captured in Lime Creek in 2009 and 2010

Table 1.7-8: Percent Maturity, by Age, for Female and Male Dolly Varden Captured in Lime Creek in Fall 2009

Age	Both Sexes Combined		Females		Males	
	n	% mature	n	% mature	n	% mature
0+	0	-	0	-	0	-
1+	2	50.0	0	-	1	0.0
2+	0	-	0	-	0	-
3+	15	80.0	5	100.0	6	100.0
4+	5	100.0	1	100.0	2	100.0
Total	**22**		**6**		**9**	

Note: n - number of samples; % - percent

Table 1.7-9: Average Length, Weight, and Condition Factor at Age for Dolly Varden Captured in Lime Creek in 2009 and 2010

Age	Length (mm)				Weight (g)				Condition			
	n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
0+	4	81.0	2.3	76-87	4	6.3	0.5	5.2-7.2	4	1.18	0.05	1.09-1.32
1+	32	103.1	4.2	73-175	32	14.5	2.4	4.7-63.0	32	1.11	0.02	0.82-1.43
2+	42	124.0	2.9	83-170	40	22.5	1.5	5.8-55.5	40	1.12	0.02	0.91-1.62
3+	26	183.5	8.2	127-280	24	65.4	7.6	24.7-146.7	24	1.09	0.02	0.84-1.26
4+	5	258.0	18.3	204-310	3	161.4	41.8	97.2-240	3	1.11	0.02	1.07-1.14
Total	**109**				**103**				**103**			

Note: g - grams; mm – millimetre; n - number of samples; SE - standard error

The difference in age, length, and maturity between the fish captured in fall 2009 and in summer 2010 indicates that there is a single anadromous population of Dolly Varden in Lime Creek. Mature adults of this population enter Lime Creek from the ocean in mid to late September. Spawning likely occurs at water temperatures near 6°C (McPhail 2007). Based on observations made in the field, YOY appear to inhabit stream margins and slow moving water behind boulders. Juvenile Dolly Varden appear to remain in Lime Creek for one to three years, although the majority of juveniles appear to leave Lime Creek by their third summer. Although numbers of returning adults observed or captured in fall were limited, it appears that Dolly Varden in Lime Creek reach sexual maturity by three years of age (Table 1.7-8). Similar growth and maturity rates have been observed in Keogh River Dolly Varden on Vancouver Island (Smith and Slaney 1980).

1.7.1.1.5 Diet

Dipteran (true flies) larvae and adults comprised the largest proportion (34%) of identifiable prey items found in 12 Dolly Varden stomachs in 2009 (Figure 1.7-7). This was followed by, in order of abundance, fish eggs (20%), tricopteran (caddisflies) larvae (13%), adult and larval hymenopterans (ants, bees, and wasps) (9%), adult lepidopterans (moths and butterflies) (7%), ephemeropteran (mayflies) larvae (5%), and plecopteran (stoneflies) larvae (4%). All other prey items comprised <4% of the total prey items consumed.

Of the 339 prey items consumed, only 53% were adults or larvae of freshwater origin (i.e., insects on the bottom or drifting in Lime Creek). The other 47% were adults or larvae of terrestrial origin that were eaten when they fell into Lime Creek, presumably from the riparian vegetation and tree canopy. These included 68% of all hymenopterans, 89% of all dipterans, 93% of all coleopterans, and 100% of all lepidopterans consumed.

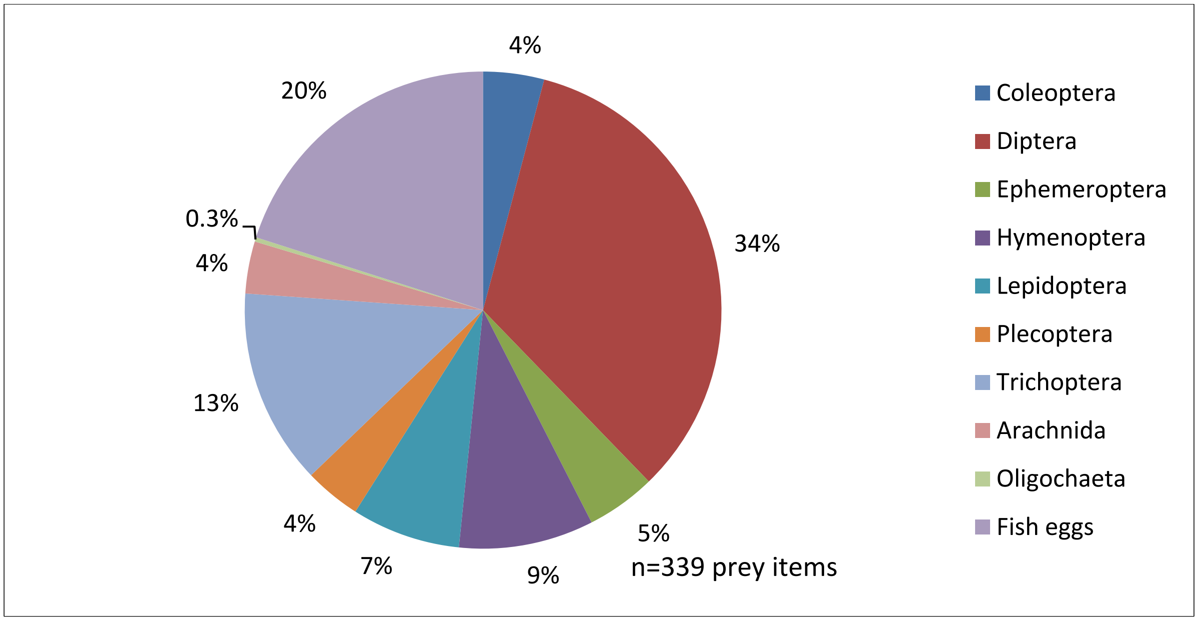


Figure 1.7-7: Relative Abundance of Prey Items in Dolly Varden Stomachs Captured in 2009

Fish eggs comprised the largest proportion (46%) of the total wet weight of prey items eaten (Figure 1.7-8). These were followed by, in order of percentage of total wet weight, trichopteran larvae (16%), unidentifiable insect parts (10%), adult lepidopterans (9%), and adult and larval dipterans (5%). All other prey taxa comprised <5% of the total wet weight of prey items consumed by Dolly Varden in 2009.

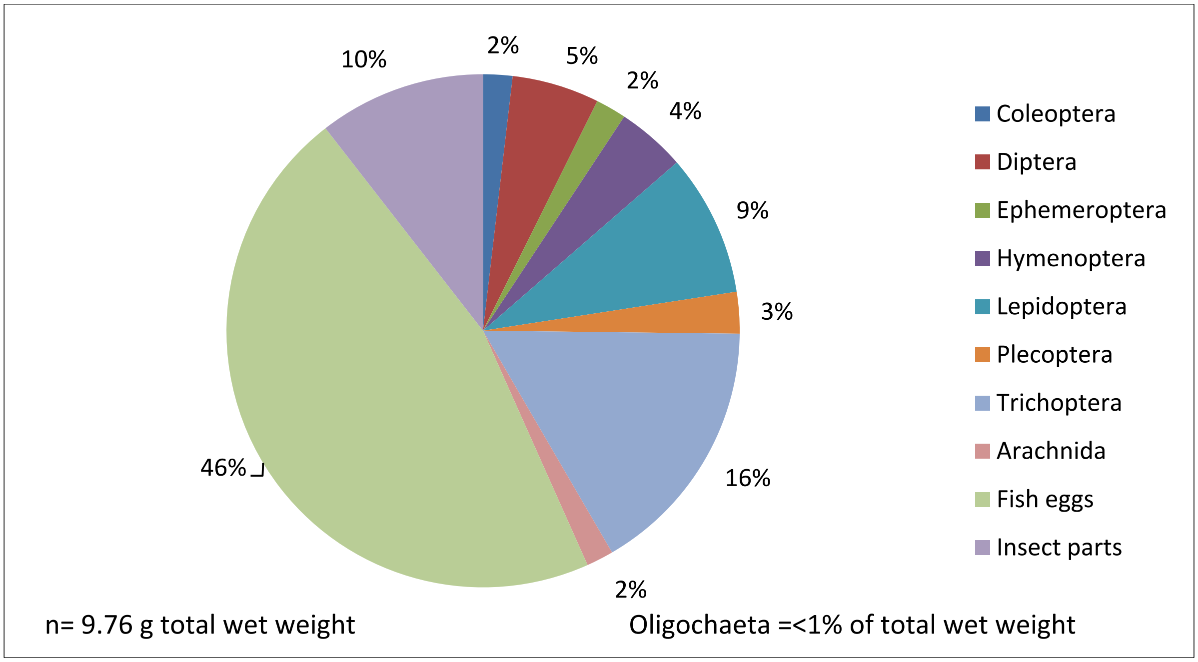


Figure 1.7-8: Relative Percentage of Total Wet Weight of Prey Items, by Taxa, in Dolly Varden Stomachs Captured in 2009

Although the sample sizes were small, there was a substantial difference in diet between Dolly Varden greater than 180 mm (n=8 fish) and Dolly Varden less than 180 mm (n=4 fish). The diet of larger fish was comprised largely of terrestrial and aquatic insects; dipterans, trichopterans, hymenopterans, lepidopterans, and plecopterans comprised 83% of total prey items consumed by these larger fish (Figure 1.7-9). These dietary items comprised 81% of the total wet weight of prey items consumed by these eight fish (Figure 1.7-10). By contrast, fish eggs were the primary food item of Dolly Varden less than 180 mm in length, comprising 32% of the total prey items consumed (Figure 1.7-11). These eggs comprised 62% of the total wet weight of prey items consumed in these smaller fish (Figure 1.7-12). Fish eggs comprised only 6% of the total wet weight of prey items consumed by the larger fish (Figure 1.7-10).

Such a difference in diet between these two size groups of Dolly Varden suggests that the smaller fish were juveniles that had not yet migrated to Alice Arm, who began opportunistically feeding on fish eggs as the adult spawners returned to Lime Creek. Three of these four fish were three year olds and would probably move to Alice Arm after the spawning periods or during the winter. The different diet, larger size and the age- and length-at-maturity data (all eight fish were 3+ or 4+ years old) suggests that the other eight fish were adults returning to Lime Creek to spawn and had likely been in the creek for only a short period.

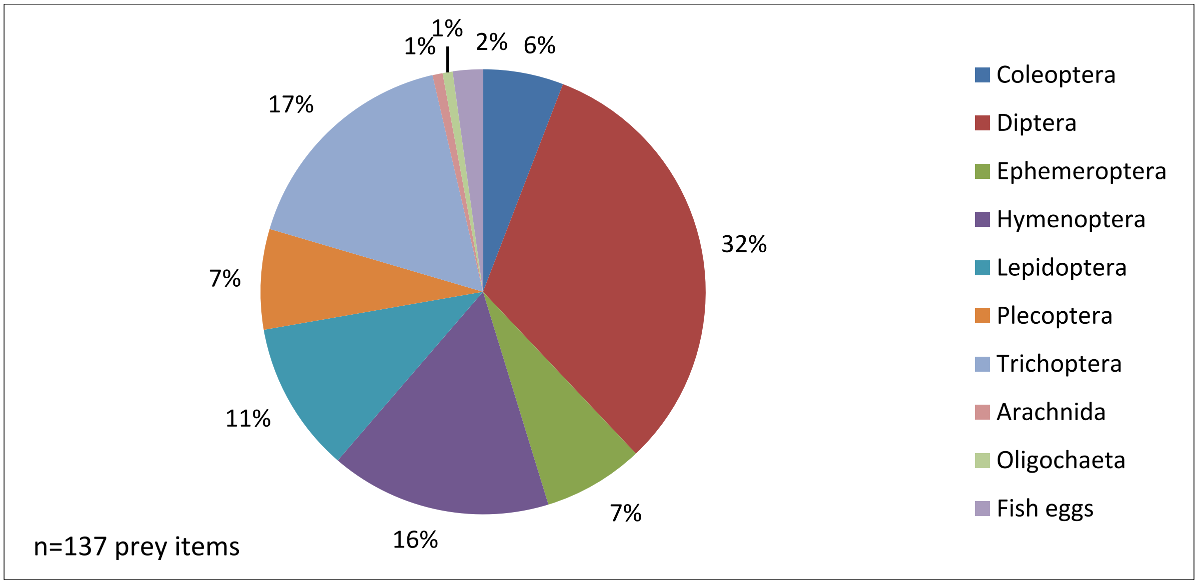


Figure 1.7-9: Relative Abundance of Prey Items in Dolly Varden (>180 mm) Stomachs Captured in 2009

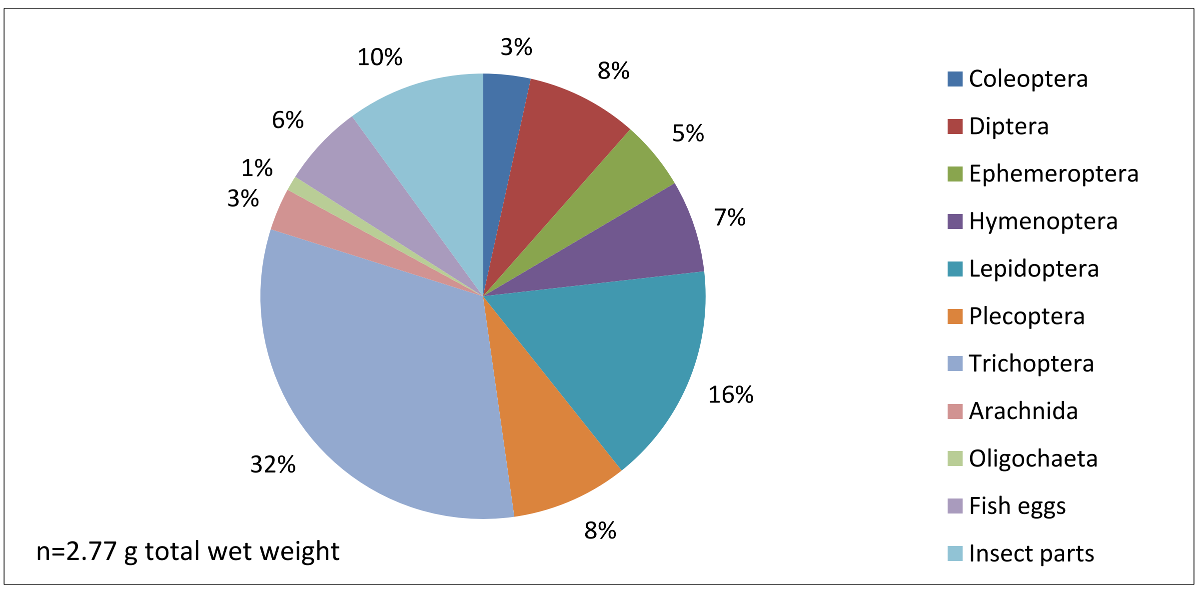


Figure 1.7-10: Relative Percentage of Total Wet Weight of Prey Items, by Taxa, in Dolly Varden (>180 mm) Stomachs Captured in 2009

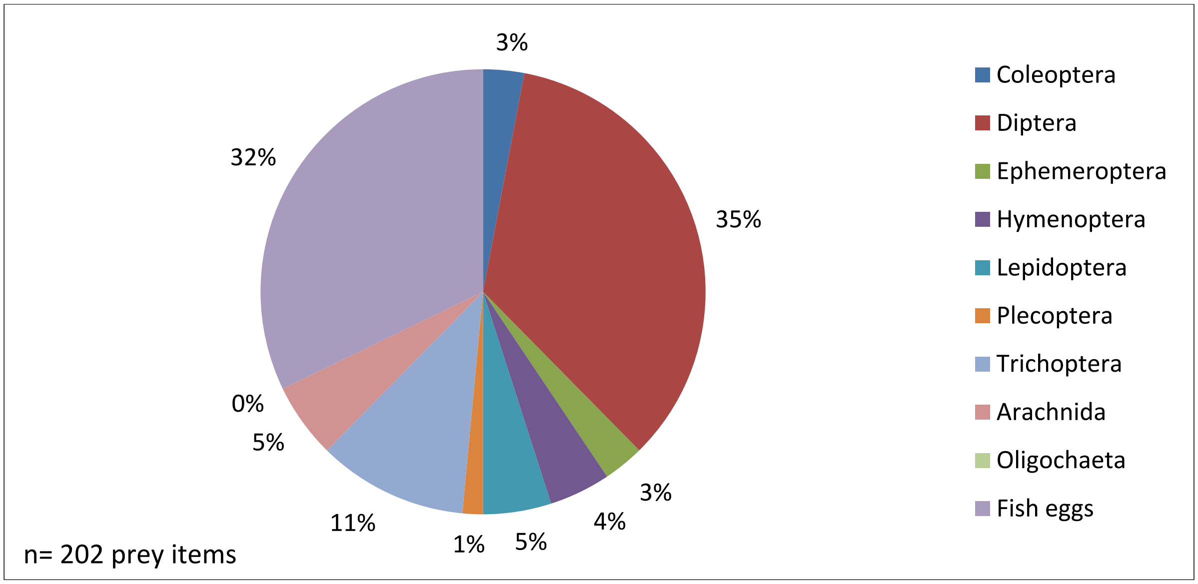


Figure 1.7-11: Relative Abundance of Prey Items in Dolly Varden (<180 mm) Stomachs Captured in 2009

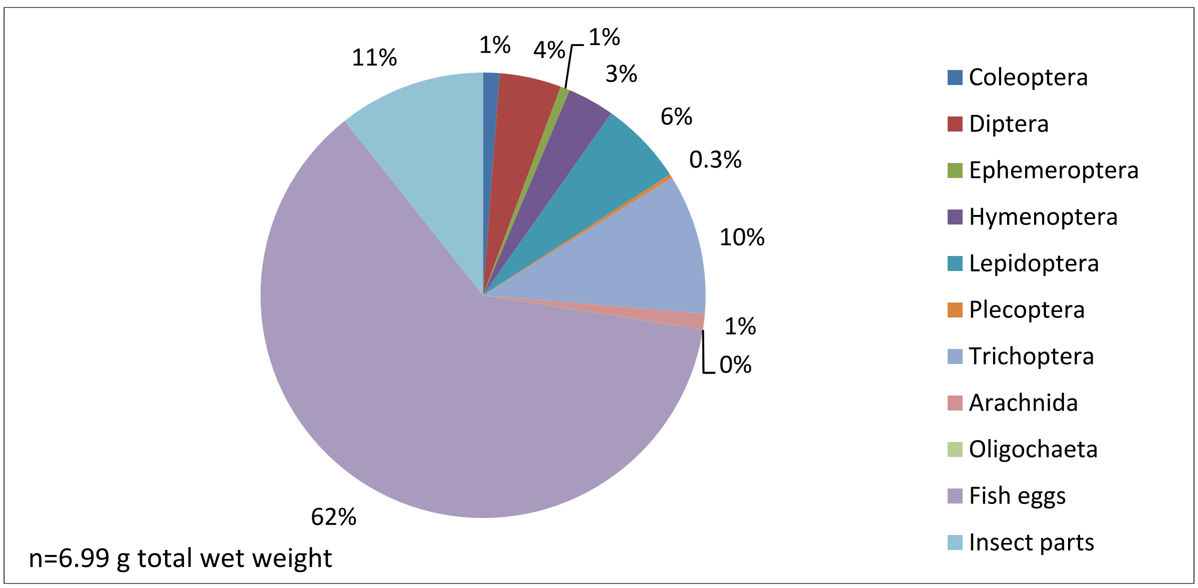


Figure 1.7-12: Relative Percentage of Total Wet Weight of Prey Items, by Taxa, in Dolly Varden (<180 mm) Stomachs Captured in 2009

1.7.1.1.6 Energy Storage and Energy Use

Dolly Varden in 2009 had a significantly ($p<0.005$) larger hepatosomatic index (HSI) than Dolly Varden captured in 2010 (Table 1.7-10). This difference was due to the significantly larger fish captured in 2009 than in 2010 and the residual correlation between HSI and fish weight even after liver weight was standardised by fish weight to calculate the HSI (Figure 1.7-13). The liver serves as a major storage site for glycogen and the HSI can, therefore, provide an indication of the nutritional state of the fish (Adams and McLean 1985). The increasing relationship between HSI and fish length indicates that liver weight increases faster than body weight as Lime Creek Dolly Varden grow and, therefore, the nutritional state of Dolly Varden increases as they grow.

Table 1.7-10: Mean Hepatosomatic Indices for Dolly Varden Captured in Lime Creek in 2009 and 2010

Year	Hepatosomatic Index		
	n	Average	SE
2009	12	1.568	0.135
2010	5	0.621	0.164

Note: n - number of samples; SE - standard error

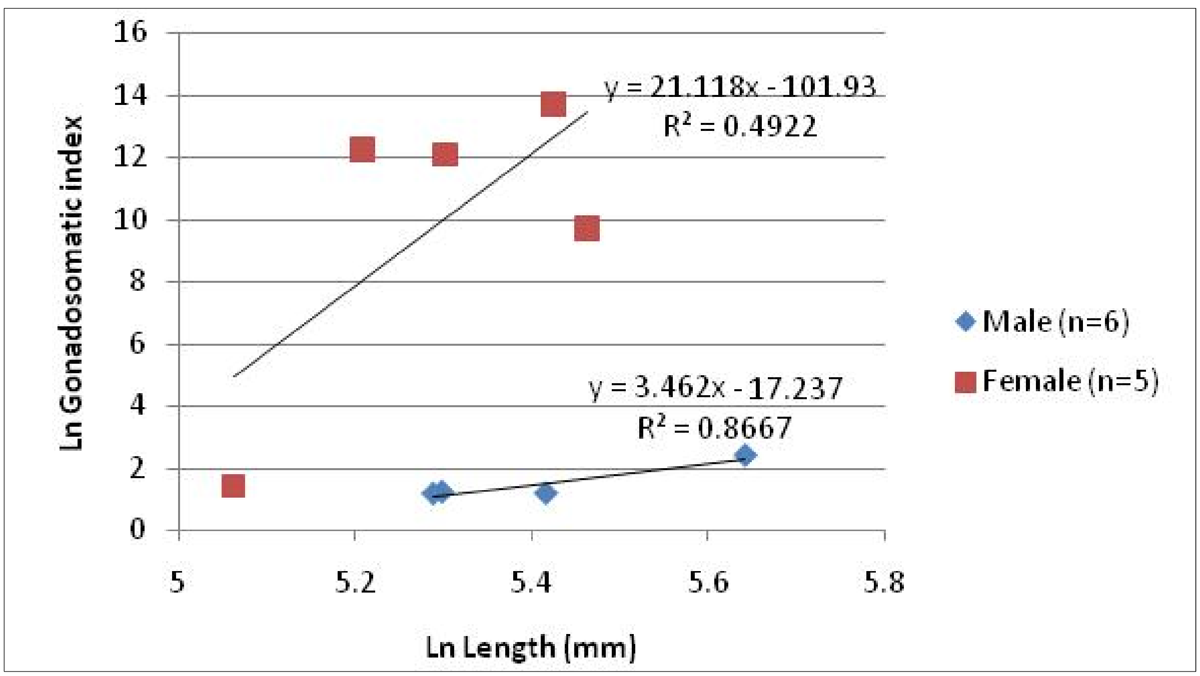


Figure 1.7-13: Relationship Between Hepatosomatic Index and Body Weight for Dolly Varden Captured in Lime Creek in 2009 and 2010

Including all five female fish captured, female Dolly Varden had a significantly ($p<0.05$) higher gonadosomatic index than male Dolly Varden in 2009 (Table 1.7-11). This difference is even more pronounced ($p<0.001$) if the one immature female Dolly Varden captured in 2009 is removed from the comparison. This difference in GSI between sexes is not unexpected given that ovaries of spawning females are typically larger and heavier than testes of spawning males. As Figure 1.7-14 shows, even when gonad weight is standardised by body weight for the GSI, gonads of female Dolly Varden increase in weight faster than body weight significantly faster than males as they grow and mature. This shows the much more significant energy input females put into reproduction than males.

Table 1.7-11: Mean Gonadosomatic Indices, by Sex, for Dolly Varden Captured in Lime Creek in 2009 and 2010

Year	Sex	Gonadosomatic Index		
		n	Average	SE
2009	Female	5[a]	9.846	2.199
	Female	4[b]	11.949	0.828
	Male	6	4.407	0.485
2010	Immature	4	3.883	1.412

Note: [a] includes one immature (140 mm) fish
[b] excludes one immature (140 mm) fish
n - number of samples; SE - standard error

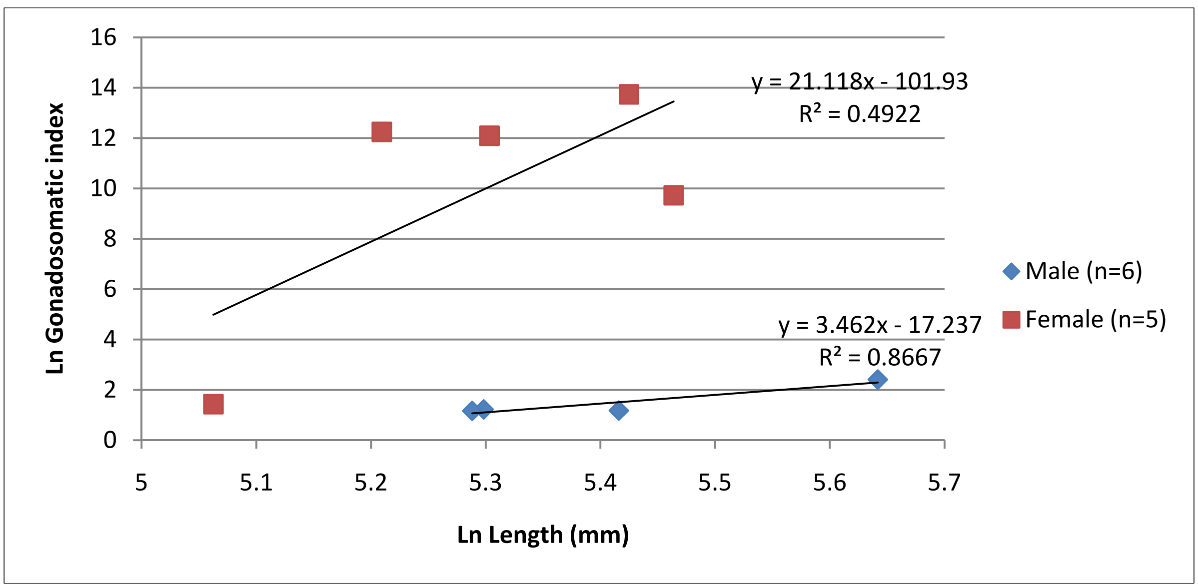


Figure 1.7-14: Relationship Between Gonadosomatic Index and Body Length (mm) of Male and Female Dolly Varden Captured in Lime Creek in 2009

There was no significant ($p>0.05$) difference in gonadosomatic indices between Dolly Varden captured in 2009 and 2010. This result is surprising given that most fish captured in fall 2009 were adult spawners while all fish captured in summer 2010 were immature juveniles. This result can likely be partially explained by the relatively small sample sizes used in the comparison but may also be partially due to a larger proportion of female Dolly Varden included in the 2010 data (75%) than in the 2009 data (45%).

1.7.1.2 Patsy Creek Watershed

No fish were captured in Patsy Creek in 2009 despite over 4,597 seconds of electrofishing effort (Table 1.7-12).

Table 1.7-12: Summary of Fish Captured and Average Catch-Per-Unit-Effort, by Season and Gear Type, in Patsy Creek in 2009

Season	Method[1]	Total Effort[2]	Total Catch and CPUE		
			# of Fish	Average CPUE[3]	SE
Summer	EF	2,242[a]	0	0.00	0.00
Fall	EF	2,355	0	0.00	0.00
Total	**EF**	**4,597**	**0**	**0.00**	**0.00**

Note: [1] EF - backpack electrofishing
[2] total effort for backpack electrofishing is in seconds
[3] average CPUE for backpack electofishing is in fish/100 seconds
[a] includes 438 seconds of backpack electrofishing at Site 100 on a Patsy Lake tributary
CPUE - Catch-Per-Unit-Effort; SE - standard error

Source: Rescan 2010b.

No fish were captured in any of the Patsy Lake tributaries sampled in 2010 (Table 1.7-13).

Table 1.7-13: Summary of Fish Sampling Effort and Catch in Patsy Lake Tributaries in 2010

ILP #	Date	Method[1]	Site Length (m)	Total Effort[2]	# of Fish Captured (CPUE)[3]
823	July 8	EF	40	150	0.0 (0.0)
906	July 31	EF	104	202	0.0 (0.0)
Total		**EF**	**144**	**352**	**0.0 (0.0)**

Note: [1] EF - backpack electrofishing
[2] total effort for backpack electrofishing is in seconds
[3] catch-per-unit-effort for backpack electrofishing is in fish/100 seconds
CPUE - Catch-Per-Unit-Effort; ILP - Interim Point; m - metre

1.7.1.3 Clary Creek Watershed

1.7.1.3.1 Spring Hoopnetting

1.7.1.3.1.1 Species Composition, Abundance, and Distribution

Twenty-four rainbow trout were captured moving downstream towards Clary Lake in the hoopnets set in two of the channels within the lower delta of Clary Creek (910-929800-05800 in spring 2010 (Figure 1.2-7 and Table 1.7-14). Most (67%) fish were captured in hoopnet #2 and average CPUE in this net over the two days of fishing was 1.3 fish / trap-hour. In comparison, average CPUE in hoopnet #1 was 0.05 fish / trap-hour. No other fish species were captured.

Table 1.7-14: Summary of Catch and Average CPUE of Rainbow Trout Captured in Hoopnets in the Clary Lake Inlet in June 2010

Date	Hoopnet #1			Hoopnet #2			Total		
	Effort[1]	# of Fish	Average CPUE[2]	Effort[1]	# of Fish	Average CPUE[2]	Effort[1]	# of Fish	Average CPUE[2]
June 3	5.0	0	0.0 (-)	4.7	8	1.71 (-)	9.7	8	0.86 (0.85)
June 4	18.8	2	0.11 (-)	17.7	14	0.79 (-)	36.5	16	0.45 (0.34)
Total	**23.8**	**2**	**0.05 (0.05)**	**22.4**	**22**	**1.3 (0.46)**	**46.2**	**24**	**0.65 (0.39)**

Note: [1] effort is in trap-hours
[2] average catch-per-unit-effort is in fish per trap-hours
Standard error for catch-per-unit-effort is presented in brackets
CPUE - Catch-Per-Unit-Effort
Raw data can be found in Appendix G-1

The difference in total fish captured and average CPUE between the two hoopnets is likely a reflection of their locations in different channels and the drastically changing water depths and discharges in these channels during the two day hoopnetting survey. Both nets were set on 3 June when water levels in the channels at both hoopnet sites were approximately equal and both channels carried approximately equal proportions of the total creek discharge. By next morning however, water levels at hoopnet #2 had dropped such that depths at the hoopnet location were only approximately 15 cm deep (down from 60 cm). This occurred despite the fact that most of the Clary Creek discharge was flowing into this channel approximately 100 m upstream of the hoopnet location. In contrast, water levels at hoopnet #1 had dropped only by half overnight but the channel approximately 100 m upstream of this hoopnet site was dry. Both channels were completely dry four hours later even though there was continuing surface flow in Clary Creek within its canyon approximately 300 m upstream from the lake. Numerous rainbow trout were found floundering in the drying pools of these lower channels throughout the day.

The rapid change in water depth and discharge in these two adjacent channels during the survey and the variability in flow between locations within the same channel indicates three things:

1. There is significant sub-surface transfer of flow between the two channels upstream of the hoopnet sites.
2. The delta area of Clary Creek between its upstream canyon and Clary Lake is comprised of highly porous substrates that create a complex pattern of surface water / groundwater interaction.
3. There is a threshold discharge in Clary Creek at which all water in the lower channels goes sub-surface.

Despite this complex hydraulic environment, rainbow trout from Clary Lake appear to use the channels in this inlet for spawning. Of the five males and three females that could be identified externally for sex, all but one of these fish were spent while one male was still ripe.

1.7.1.3.1.2 Length, Weight, and Age

The mean length, weight, and condition factor for all 24 rainbow trout captured in the two hoopnets in spring 2010 is presented in Table 1.7-15. Raw data can be found in Appendix G-2. Fish ranged in length between 115 mm and 218 mm with a modal length class of 141 to 160 mm (Figure 1.7-15).

The mean length and modal length class of rainbow trout captured in the hoopnets in spring were significantly smaller (F_1=21.84, $p<0.001$) than the average length and modal length class of rainbow trout captured in gillnets in Clary Lake in summer (see Section 1.7.2.2). Average length of rainbow trout captured in the hoopnets in spring was 149 mm (Table 1.7-15) and 71% of these fish were <160 mm long (Figure 1.7-15). In contrast, rainbow trout captured in the gillnets had an average length of 205 mm (Table 1.7-22), a modal length class of 241 mm to 260 mm and over 80% of fish captured in these nets were >160 mm (Figure 1.7-16).

Table 1.7-15: Average Length, Weight, and Condition Factor of Rainbow Trout Captured in Hoopnets in the Clary Lake Inlet in June 2010

	Length (mm)	Weight (g)[1]	Condition factor[1]
Sample size (n)	24	24	24
Average	149.0	35.5	1.00
SE	5.47	4.06	0.02
Range	115-218	16.8-95.5	0.86-1.16

Note: [1] includes at least eight post-spawned fish including three post-spawned females
g - gram; mm - millimetre; SE - standard error

This difference in size suggests that Clary Creek upstream of Clary Lake is used only by smaller rainbow trout for spawning. This creek, and in particular the multiple channels within the lower delta area, are likely too small, too ephemeral, and less suitable for spawning by the larger rainbow trout that exist in Clary Lake. These larger fish likely use the main Clary Lake inlet at the north end of the lake. This main inlet is much larger (mean channel width of 7.9 m), contributes over 50% of the total inflow to Clary Lake, and has significantly more suitable spawning habitat in the form of gravel riffles, runs, and pool tailouts than Clary Creek (see Section 1.3.3.1). These smaller rainbow trout may eventually move to the main Clary Lake inlet to spawn once they become bigger and are better able to compete for spawning sites and mates.

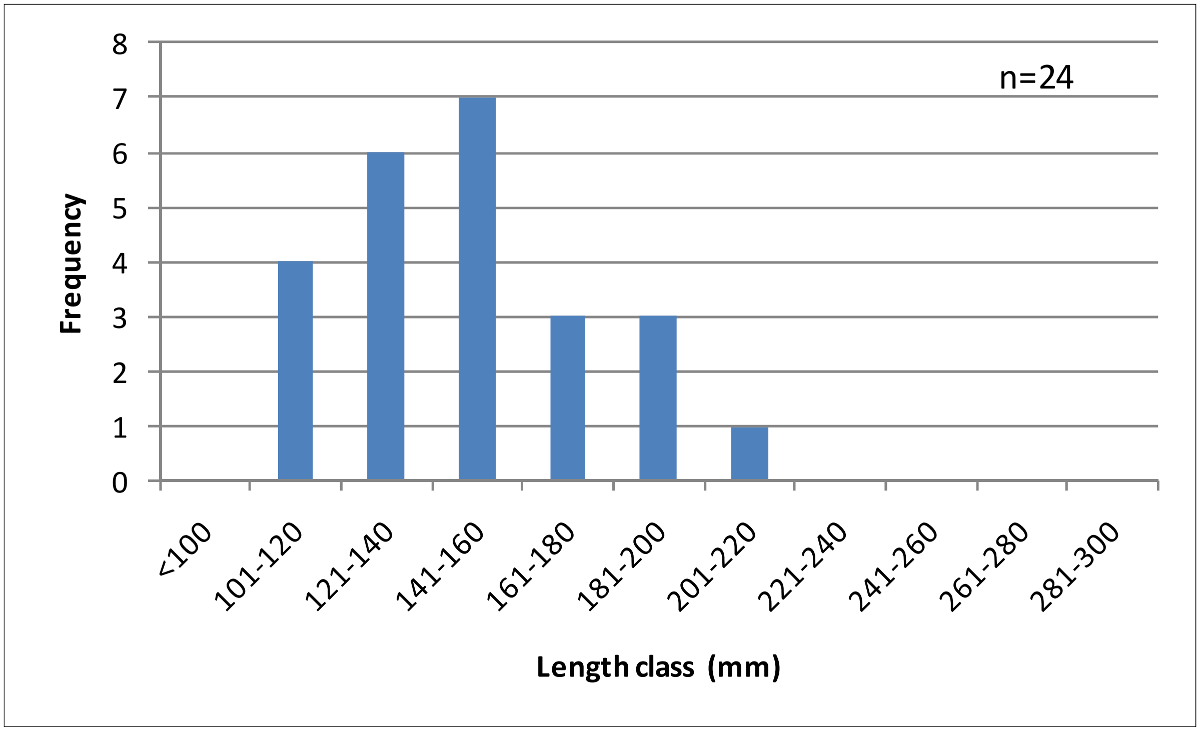


Figure 1.7-15: Length-Frequency Distribution of Rainbow Trout Captured in Clary Creek in Spring 2010

1.7.1.3.2 Summer Electrofishing

1.7.1.3.2.1 Species Composition, Relative Abundance, and Distribution

A total of 12 rainbow trout were captured in the inlet tributaries and outlet of Lake 901 in July of 2010 (Table 1.7-16). No other fish species was captured.

Table 1.7-16: Summary of Fish Captured Backpack Electrofishing in Lake 901 Tributaries in Summer, 2010

Watercourse	Watershed Code / ILP #	Reach	Total Effort[2]	# of Rainbow Trout Captured	CPUE[1]
Lake 901 Inlet	WSC-910-929800-05800-76800	5[2]	1,116	0	0.0
Lake 901 Outlet	WSC-910-929800-05800-76800	1	1,310	5	0.4
Lake 901 Inlet	WSC-910-929800-05800-76800	3	1,193	0	0.0
Lake 901 Inlet	887	1	597	7	1.2
Lake 901 Inlet	886	2	544	0	0.0
Total			**4,760**	**12**	

Note: [1] catch-per-unit-effort is in fish/100 seconds of backpack electrofishing
: [2] upstream of cascade
CPUE - Catch-Per-Unit-Effort; ILP - Interim Locational Point
Raw data can be found in Appendix G-1

No fish were captured in Reach 5 of Lake 901 inlet (WSC910-929800-05800-76800) upstream of the bedrock cascade despite 1,116 seconds of electrofishing effort in July 2010 (Table 1.7-16). These data suggest that the inlet of Lake 901 is non-fish-bearing upstream of this cascade. This bedrock cascade is approximately 15 m long and is comprised of a narrow (<7 m wide) bedrock chute with an approximately 20% slope. This geometry creates a potential velocity barrier in spring when water is sped up and concentrated between the bedrock banks. This cascade likely restricts upstream fish passage during the low flow summer period because there are no pools at the bottom or in the middle of the cascade deep enough for fish to attain the speeds necessary for jumping (e.g., <25 cm deep pool at the bottom), and flow is largely interstitial between the boulders or sheet flow over the bedrock.

In addition to the bedrock cascade, there is approximately 100 m of steep (>10% gradient), angular cobble / boulder habitat in Reach 4 immediately below the cascade. This section of habitat likely impedes the upstream passage of rainbow trout in this tributary before they reach the cascade because water velocities in this reach would be high in spring and because flow would be restricted to interstitial flow between the cobble and boulder substrates in summer (as it was in July 2010). Despite these impediments, additional sampling will be conducted in two-seasons (spring and summer) in 2011 to confirm the fish-bearing status of this tributary upstream of these impediments as per BC provincial guidelines.

No fish were captured in the lower two reaches of the main Lake 901 inlet tributary (WSC910-92900-05800-76800) in late July despite nearly 1,200 seconds of electrofishing (Table 1.7-16). However, these reaches are known to be fish-bearing because there are no barriers or impediments in these reaches upstream from the lake, Lake 901 is known to contain a population of rainbow trout (see Section 1.7.2.1.2), and 10 to 15 rainbow trout were observed in the lower 40 m of this tributary in early June. Given the high quality of gravel riffles and pools present, these fish were likely using habitat in Reach 3 of this tributary for spawning and rearing.

Seven rainbow trout were captured in the lower two reaches of ILP 887 in July 2010 (Table 1.7-16). This tributary is the second largest inlet tributary to Lake 901 and has similar high quality rainbow trout spawning and rearing habitat in its lower 200 m as in the Lake 901 main inlet tributary (WSC910-929800-05800-76800). All seven of these trout were captured in the lower 240 m of the creek below a 55 m long, up to 18% gradient, bedrock constricted, step-pool cascade. While low flows and high (>1 m) bedrock and large woody debris steps likely restrict the upstream passage of rainbow trout beyond this cascade in summer, it is currently unknown whether fish are able to pass this cascade in spring and whether habitat upstream of this cascade is fish-bearing as a result. Similar to WSC910-929800-05800-76800, additional sampling will be conducted upstream of this cascade in two-seasons (spring and summer) in 2011 to confirm the fish-bearing status of this reach as per BC provincial guidelines.

1.7.1.3.2.2 Length, Weight, and Age

Average length, weight and condition factor of the rainbow trout captured in the Lake 901 tributaries is presented in Table 1.7-17. Raw data can be found in Appendix G-2. A weight-length relationship for these 12 fish combined with the two rainbow trout captured gillnetting in Lake 901 is presented in Table 1.7-18. Length-at-age for the nine rainbow trout that were aged from those captured in Lake 901 main inlet (WSC910-929800-05800-76800) and ILP 887 is presented in Table 1.7-18. Although sample sizes are small, growth rate of rainbow trout in Lake 901 (of which the fish captured in the inlet tributaries are assumed to be apart) appears similar to that observed in Clary Lake rainbow trout. On average, 3+ year old rainbow trout in Lake 901 were 144 mm long while 3+ year old fish in Clary Lake were 133 mm long. Seven year old rainbow trout in Lake 901 were 240 mm long while similar aged rainbow trout in Clary Lake were 232 mm long (see Section 1.7.2.3 for Clary Lake data).

Table 1.7-17: Average Length, Weight, and Condition Factor of Rainbow Trout Captured in Lake 901 Inlets in July 2010

Inlet	Length (mm)				Weight (g)				Condition			
	n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
WSC 910-929800-05800-76800	5	150.0	29.6	87-240	5	49.3	22.3	6.6-118.7	5	1.06	0.06	0.86-1.18
ILP 887	7	87.1	12.9	58-153	7	11.5	5.5	2.1-42.3	7	1.19	0.04	1.05-1.40
Combined	**12**	**113.3**	**16.6**	**58-240**	**12**	**27.2**	**10.8**	**2.1-118.7**	**12**	**1.14**	**0.04**	**0.86-1.40**

Note: g - gram; mm - millimetre; n - number of samples; SE - standard error

Table 1.7-18: Average Length, Weight, and Condition Factor at Age for Rainbow Trout Captured in Lake 901 Inlets in July 2010

Age	Length (mm)				Weight (g)				Condition			
	n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
1+	2	78.5	1.5	77-80	2	5.6	0.8	4.8-6.3	2	1.14	0.09	1.05-1.23
2+	3	97.7	7.9	87-113	3	11.2	3.3	6.6-17.5	3	1.13	0.07	1.00-1.21
3+	2	144.0	9.0	135-153	2	34.7	7.7	27.0-42.3	2	1.14	0.04	1.10-1.18
4+	1	195.0	-	-	1	84.8	-	-	1	1.14	-	-
7+	1	240.0	-	-	1	118.7	-	-	1	0.86	-	-
Total	**9**				**9**				**9**			

Note: g - gram; mm - millimetre; n - number of samples; SE - standard error

1.7.2 Lakes

1.7.2.1 Species Composition, Relative Abundance, and Catch-Per-Unit-Effort

1.7.2.1.1 Patsy Lake

No fish were captured in Patsy Lake in the summer or fall of 2009 (Table 1.7-19). This lack of fish occurred despite over 103.2 hours of gillnetting, 1049 trap-hours of minnow trapping, and 0.5 rod-hours of angling in summer and 93.3 hours of gillnetting and 980 trap-hours of minnow trapping in fall (Table 1.7-19).

Table 1.7-19: Fish Sampling Methods and Effort in Patsy Lake in 2009 by Rescan

Season	Gear Type	Total Net Area or Total Trap Numbers	Set #	Total Soak Time (hr) or Rod-Hours	Fish Catch	CPUE
Summer	Sinking gillnet	225.0	1	1.8	0	0.0
	Sinking gillnet	225.0	2	49.5	0	0.0
	Floating gillnet	112.5	1	2.5	0	0.0
	Floating gillnet	112.5	2	49.4	0	0.0
	Minnow traps	20	1	1049.3	0	0.0
	Angling			0.5	0	0.0
Fall	Sinking gillnet	225.0	1	46.6	0	0.0
	Floating gillnet	112.5	1	46.7	0	0.0
	Minnow traps	20	1	980.0	0	0.0

Note: angling effort in Patsy Lake was not documented in Rescan 2010c; CPUE - Catch-Per-Unit-Effort
Source: Rescan 2010c

A total of 22.8 hours of gillnetting and 135.1 trap-hours of minnow trapping was conducted in Patsy Lake in July 2010 (Table 1.7-20). Similar to 2009, no fish were captured in either gear type in 2010. The absence of fish during two seasons of fish effort in 2009 and during a repeat of summer sampling in 2010 indicates that Patsy Lake is non-fish-bearing. The non-fish-bearing status of this lake is further supported by the capture of large invertebrates in minnow traps in both years. The presence of these large invertebrates (e.g., dragonfly nymphs and predacious diving beetles) suggests strongly that they are the top aquatic predators in the lake in the absence of fish.

Table 1.7-20: Summary of Fish Catch and Catch-Per-Unit-Effort in Patsy Lake, Clary Lake, and Lake 901 in 2010 by AMEC

Lake	Gear Type	Total Net Area or Total Trap Numbers	Set #	Total Soak Time or Total Trap Hours (hr)	Fish Catch	CPUE[a]
Patsy	Sinking gillnet	225	1	22.8	0	0.0
	Floating gillnet	225	1	22.8	0	0.0
	Minnow traps	6	1	135.1	0	0.0
Clary	Sinking gillnet	225	1	22.4	5 RNTR	2.4
	Floating gillnet	225	1	19.2	16 RNTR	8.9
	Minnow traps	7	1	201.8	0	0.0
Lake 901	Sinking gillnet	225	1	0.7	1 RNTR	16.0
	Floating gillnet	225	1	1.9	0	0.0
	Sinking gillnet	225	2	0.6	1 RNTR	18.3
	Minnow traps	6	1	110.8	0	0.0

Note: [a] CPUE for gillnetting is in # of fish/100 m^2/24 hours; CPUE for minnow trapping is in # of fish/trap-hour
CPUE - Catch-Per-Unit-Effort
Raw data can be found in Appendix G-1

1.7.2.1.2 Clary Lake and Lake 901

A total of 21 rainbow trout were captured in Clary Lake in 2010 (Table 1.7-20). All of these fish were captured in gillnets; no fish were captured in any of the minnow traps set within the littoral zone of the lake despite over 200 trap-hours of effort. CPUE for rainbow trout captured in the sinking gillnet was 2.4 fish/100 m^2/24 hours while the CPUE for rainbow trout captured in the floating gillnet was 8.9 fish/100 m^2/24 hours. The higher CPUE in the floating gillnet is likely due to the pelagic nature of adult rainbow trout (Bassista and Maiolie 2004), especially in lakes devoid of other predatory fish species.

Two rainbow trout were captured in gillnets set in Lake 901 in 2010 (Table 1.7-20). No fish were captured in the six minnow traps set in the littoral area during 110.8 trap-hours of effort. Soak times for all three gillnet sets were short (<2 hours) to minimise mortalities in this small lake. Despite the short sets, CPUE for rainbow trout captured in the sinking and floating gillnets were higher in Lake 901 (16.0 fish/100 m^2/24 hours and 18.3 fish/100 m^2/24 hours, respectively) than in similar nets set in Clary Lake. Although too few net sets were conducted in either lake to make statistically comparisons, the greater rainbow trout CPUE in Lake 901 may be due to greater catchability of rainbow trout in Lake 901 due to its shallower depth (< 6 m maximum depth) and shallower littoral gradient than in Clary Lake (the former limiting lake volume and cover from depth and the later allowing more net to be fished closer to shore near structure and cover typically preferred by fish) and / or a greater rainbow trout density in Lake 901 due to its more suitable habitat conditions for rainbow trout than in Clary Lake. This may be due to Lake 901's great habitat diversity, warmer summer water temperatures and absence of thermocline, greater proportion of littoral area to total lake area (and correspondingly higher benthic invertebrate production), and / or higher ratio of shoreline length to total lake area (and correspondingly higher terrestrial invertebrate input) than in Clary Lake. Other unknown physical, chemical, or biological factors that benefit rainbow trout production may also contribute to this difference in CPUE between lakes.

Results from studies conducted in 2009 and 2010 indicate that rainbow trout are the only fish species present in the Clary Creek watershed upstream of the waterfalls located approximately 225 m from the confluence of Clary Creek and the Illiance River. These falls are over 30 m in height and, therefore, present a barrier to upstream passage of anadromous fish from the Illiance River into Clary Creek. This conclusion is supported by a one-day survey conducted on 24 November 1979 (Fanning 1980) and a late-winter survey conducted in March 2010 (Rescan 2010c). Rainbow trout were the only fish species captured in Clary Lake in 1979 and in three unnamed headwater lakes of the Clary Creek watershed upstream of Clary Lake in March 2010.

The source of rainbow trout in the Clary Creek watershed upstream of the waterfalls is most likely from stocking. The BC MOE has stocked rainbow trout into Killam Lake, upstream of Clary Lake, on at least six occasions since 1988 (Table 1.7-21). However, the presence of rainbow trout in Clary Lake during the 1979 survey conducted by Fanning (1980) indicates that rainbow trout were stocked into the Clary Creek watershed either before the province began keeping stocking records or were stocked by someone or some other agency before the province began stocking in 1988. The road from the Kitsault Townsite to Nass Camp was not completed until 1982. This suggests that the initial stocking of rainbow trout into the Clary Creek watershed would most likely have been done from float plane or helicopter by the province or by employees of previous Kitsault mine operations after the road from Kitsault to Clary Lake was built in 1967 (Smythe, Knight Piesold pers. comm.).

Table 1.7-21: Summary of Known Rainbow Trout Stocking in Killam Lake by the BC Ministry of Environment

Date	# of Fish Released	Life Stage Released	Brood Stock	Hatchery
1 June 1988	3,300	unknown	NRT Premier	Loon Creek
16 June 1989	3,000	yearling	NRT Premier	Loon Creek
8 September 1990	3,000	Fall fry	Sheridan	Loon Creek
4 September 1996	3,000	Fall fry	NRT Premier	Loon Creek
12 September 2000	3,000	Fall fry	Badger Tunkwa	Clearwater
11 September 2003	3,000	Fall fry	Dragon	Clearwater

Source: Habitat Wizard Lake Report (waterbody identifier 00486KSHR)

1.7.2.2 Length, Weight, and Condition

Rainbow trout captured in Clary Lake in 2010 ranged in length between 112 mm and 282 mm with a modal length class of 241 mm to 260 mm (Figure 1.7-16). These 21 fish had a mean length and mean weight of 205 mm, 105 g, respectively, with a mean condition factor of 1.02 (Table 1.7-22). The weight-length relationship for Clary Lake rainbow trout is presented in Table 1.7-23. Raw data can be found in Appendix G-2 and G-3.

The two rainbow trout captured in Lake 901 were both 270 mm in length and weighed 200 g and 210 g each. These fish were 4+ and 5+ years old and had condition factors of 1.02 and 1.07, respectively.

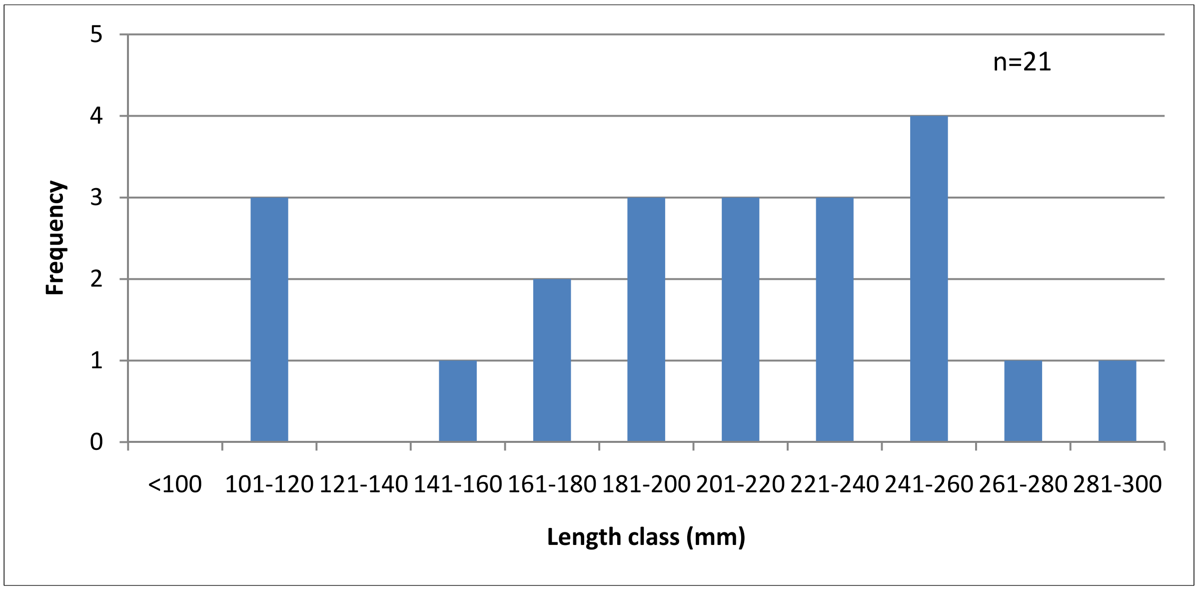


Figure 1.7-16: Length-Frequency Distribution of Rainbow Trout Captured in Clary Lake in 2010

Table 1.7-22: Average Length, Weight, and Condition Factor af Rainbow Trout Captured in Clary Lake and Lake 901 Creek in 2010

Lake	Length (mm)				Weight (g)				Condition			
	n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
Clary Lake	21	205.1	11.2	112-282	21	105.3	15.0	14.2-260	21	1.02	0.02	0.83-1.21
Lake 901	2	270.0	0.0	270-270	2	205.0	5.0	200-210	2	1.04	0.03	1.02-1.06

Note: g - gram; mm - millimetre; n - number of samples; SE - standard error

Table 1.7-23: Weight-Length Relationship for Rainbow Trout Captured in Clary Lake and Lake 901 in 2010

Lake	Sample size (n)	Equation	r^2
Clary	21	$LnWt = 3.10LnLt - 12.00$	0.99
Lake 901[a]	14	$LnWt = 2.89LnLt - 10.90$	0.99

Note: [a] includes two fish captured by gillnetting in the lake, five fish captured by electrofishing in inlet tributary 901 and seven fish captured in inlet tributary 887
n - number of samples; r^2 - ray of disk squared

1.7.2.3 Age, Growth, and Maturity

Rainbow trout captured in Clary Lake in 2010 ranged in age from 2+ to 8+ years old with a modal age class of 6+ years old (Figure 1.7-17). Mean age of these 21 rainbow trout was 5 years old and 67% of these fish were greater than 4 years old.

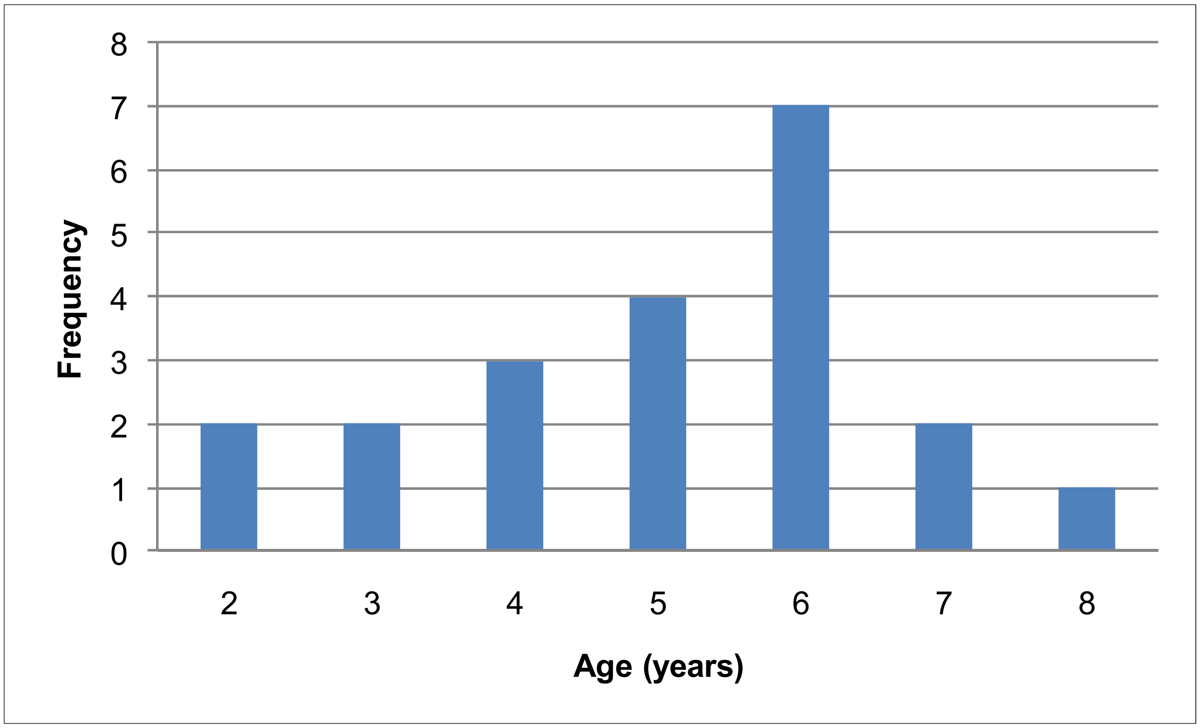


Figure 1.7-17: Age-Frequency Distribution of Rainbow Trout Captured in Clary Lake in 2010

Average length, weight, and condition factor at age for rainbow trout captured in Clary Lake in 2010 is presented in Table 1.7-25. A von Bertalanffy growth curve is fitted to the length-at-age data in Figure 1.7-18. Based on the 21 fish captured in 2010, rainbow trout in Clary Lake have a theoretical maximum length (L_∞) of 350 mm, a growth coefficient (K) of 0.1774, and an age at theoretical zero length (t_0) of -0.261 years.

Rainbow trout exhibit a high degree of variability in growth pattern (Ford et al. 1995; McPhail 2007). This growth is influenced by factors including, but not limited to, elevation, latitude, water temperature (i.e., degree days above threshold for growth), life history pattern (i.e., lacustrine, fluvial, or adfluvial), genetic strain, inter- and intra-species competition for space and food, and prey availability and their associated energy content. Lake resident rainbow trout, such as those in Clary Lake, typically grow faster and larger than stream resident rainbow trout in similar locations. This is because lake resident fish have lower energy requirements than stream resident fish that need to maintain position in flowing water. Similarly, rainbow trout eating fish or benthic or terrestrial invertebrates will grow faster than rainbow trout feeding more exclusively on zooplankton due to their higher energy content

(Siesennop 1998). Rainbow trout in Clary Lake feed primarily on zooplankton (see Section 1.7.2.4).

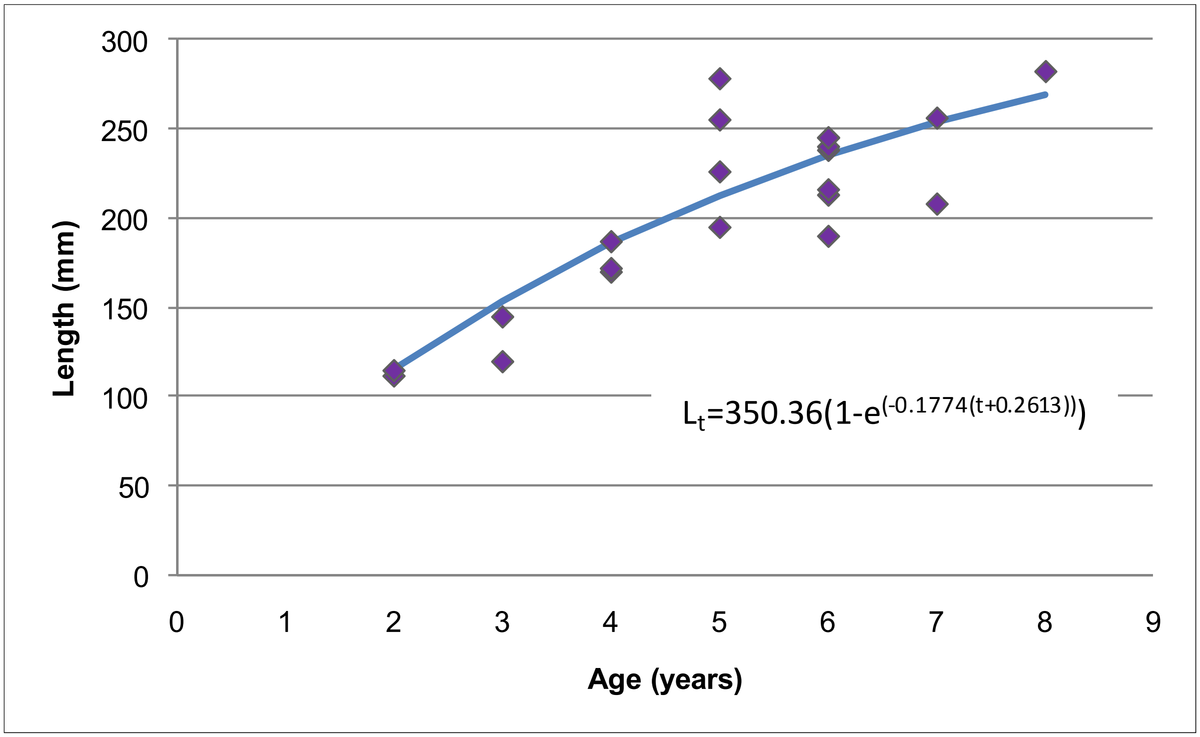


Figure 1.7-18: Von Bertallanfy Growth Curve for Rainbow Trout Captured in Clary Lake in 2010

Compared to data collected in 1979, growth rates of rainbow trout captured in Clary Lake in 2010 appear to have decreased. Only six rainbow trout were captured during the 1979 survey but the mean length of the five 3+ year old fish was 238 mm while the one 2+ year old fish was 187 mm (Table 1.7-24). On average, these 3+ year old fish were over 105 mm longer than similarly old fish captured in 2010. Similarly, the 2+ year old fish was 73 mm longer than the average length of 2+ year old fish captured in 2010. Too few fish were captured in 1979 to fit a von Bertalanffy growth curve to the data but this difference in growth rates is clearly shown in a plot of the length-at-age data in Figure 1.7-19.

While it is difficult to determine the exact reasons for this difference in growth, a number of theories exist. These include:

1. Introduction of different genetic strains of rainbow trout by the province since 1988.
2. Differences in ageing structures and methods used between years.
3. A real difference in growth rates due to changes in food availability, habitat suitability, and / or density-dependent effects.

Introduction of rainbow trout from Dragon, Tunkwa, Sheridan, and Premier Lakes into the Clary Creek system should have increased, not decreased, growth rates of Clary Lake rainbow trout from 1979 to today. This is because fish in the lakes used as brood stock since 1988 are known to produce large rainbow trout. For example, spawning rainbow trout from Dragon Lake average over 2000 g in weight (BC MOE 1980a) while three year old rainbow trout in Tunkwa Lake have an average length of approximately 450 mm (Webb 2000), three year old rainbow trout in Sheridan Lake average 384 mm (Westover and George 1987) while two and four year old Premier Lake rainbows average 340 mm and 465 mm, respectively (BC MOE 2008). While the brood stock of the rainbow trout introduced into Clary Lake in the 1970's is unknown, the lower growth rate in Clary Lake rainbow trout today would not appear to be due to genetics given the source of brood stock used by the province since 1988.

A more plausible reason for the apparent decreased growth rate in Clary Lake rainbow trout since 1979 is density effects. The density of rainbow trout in Clary Lake in 1979 may have been much lower than what currently exists in the lake as the population may not have reached carrying capacity in 1979 if they were only introduced to the lake a few years prior to the 1979 survey. This would have allowed rainbow trout present in the lake in 1979 to feed to near satiation without competition from other fish. Once a lake reaches carrying capacity, fish are rarely able to feed to satiation and their growth rate is subsequently restricted by competition for food. Given that decades have passed since the lake was originally stocked, it is reasonable to assume that the Clary Lake rainbow trout population is now at carrying capacity and that rainbow trout growth rates are stunted as a result.

Table 1.7-24: Average Length, Weight, and Condition Factor at Age for Rainbow Trout Captured in Clary Lake and the Clary Lake Outlet in 1979

Age	Length (mm)				Weight (g)				Condition			
	n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
0+	4	49.3	2.9	44-57	4	1.4	0.3	0.9-2.1	4	0.92	0.06	0.92-1.20
2+	1	187	-	-	1	49	-	-	1	0.75	-	-
3+	5	238	9.4	225-275	5	140.0	20.2	110-220	5	1.01	0.03	0.92-1.07

Note: age 0+ fish captured electrofishing in the Clary Lake outlet near the water intake structure; age 2+ and 3+ fish captured in a 63.5 mm mesh gillnet; g - gram; n - number of samples; mm - millimetre; SE - standard error

Source: Fanning (1980)

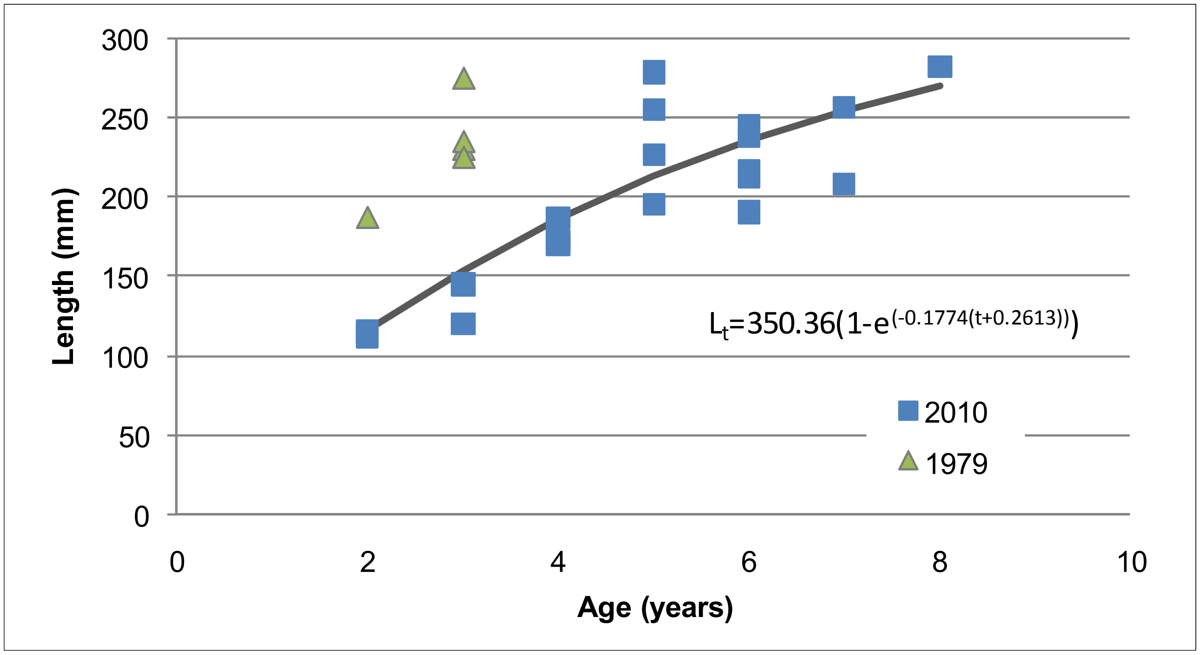


Figure 1.7-19: Comparison of Length-At-Age for Rainbow Trout Captured in Clary Lake in 1979 and 2010

State of sexual maturity of rainbow trout captured in Clary Lake could not be accurately determined due to the timing of the survey in late summer (rainbow trout are spring spawners). However, an estimate of the age and length at sexual maturity of Clary Lake rainbow trout can be approximated from the rainbow trout captured in a Clary Lake inlet tributary in spring 2010 (Table 1.7-25). From the eight rainbow trout captured in spring for which sex and maturity could be determined, it appears that males reach sexual maturity at a length of at least 118 mm and 2+ years old while females reach sexual maturity at a length of at least 135 mm and 3+ years old (Table 1.7-26). Such a difference in maturity between sexes is common and male rainbow trout usually mature at least one year before females (McPhail 2007). Although considerable variability exists between populations of rainbow trout across their distribution in BC, maturity at the ages observed in the rainbow trout captured in the Clary Lake inlet tributary are consistent with many BC lake resident populations (Giroux and Lough 2004).

Table 1.7-25: Average Length, Weight, and Condition Factor at Age for Rainbow Trout Captured in Clary Lake in 2010

Age	Length (mm)				Weight (g)				Condition			
	n	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range
2+	2	113.5	1.5	112-115	2	15.5	1.3	14.2-16.7	2	1.05	0.04	1.01-1.10
3+	2	132.5	12.5	120-145	2	21.0	5.4	15.5-26.4	2	0.88	0.02	0.87-0.90
4+	3	176.3	5.4	170-187	3	55.1	3.9	47.9-61.1	3	1.01	0.05	0.93-1.11
5+	4	238.5	18.0	195-278	4	152.9	41.9	61.6-260.0	4	1.03	0.08	0.83-1.21
6+	7	226.7	7.9	190-245	7	122.1	10.0	68.7-145.4	7	1.04	0.04	0.97-1.21
7+	2	232.0	24.0	208-256	2	141.0	43.7	97.2-184.7	2	1.09	0.01	1.08-1.10
8+	1	282.0	-	-	1	225.0	-	-	1	1.00	-	-
Total	**21**				**21**				**21**			

Note: g - gram; mm - millimetre; n - sample size; SE - standard error

Table 1.7-26: Length and Age of Mature Female and Male Rainbow Trout Captured in the Clary Lake Inlet (910-929800-05800-76800) in Spring 2010

Spent females		Spent males	
length (mm)	Estimated age[b]	Length (mm)	Estimated age[b]
135	3+	118[a]	2+
148	3+	119	2+
218	5+	152	3+
		176	4+
		194	4+

Note: [a] ripe male
[b] ages estimated from von Bertalanffy growth curve for Clary Lake rainbow trout
m - millimetre

1.7.2.4 Diet

Zooplankton comprised approximately 85% of the total wet weight of all prey items found in the 17 rainbow trout stomachs from Clary Lake with identifiable prey items (Figure 1.7-20). Aquatic dragonfly (Odonata) nymphs (12%) and terrestrial Hemipterans (3%) comprised the remainder of identifiable prey items in rainbow trout stomachs. The other four rainbow trout stomachs were either empty or contained unidentifiable material. Weight of prey items in individual rainbow trout stomachs from Clary Lake are presented in Appendix G-4.

Zooplankton were found in all 17 stomachs with identifiable prey items and 13 of these 17 rainbow trout stomachs (76%) contained zooplankton exclusively. In contrast, only three of the 17 rainbow trout (18%) have been feeding on Odonata nymphs and only one rainbow trout had been feeding on Hemipterans. Interestingly, this one fish was feeding on Hemipterans exclusively. These data suggest that although zooplankton are the primary prey item of Clary Lake rainbow trout, they feed opportunistically on aquatic insect larvae and terrestrial insects. These prey are larger and have a higher lipid content than the smaller zooplankton and, therefore, provide higher energy meals for rainbow trout, which they take advantage of when present on the water surface or in the littoral areas of the lake.

The opportunity for rainbow trout to eat these higher energy preys is likely limited in Clary Lake due to its bathymetry and shoreline characteristics. Clary Lake has a steep shoreline gradient around most of its perimeter and cobbles are the most common littoral substrate type. These two features limit the amount and suitability of Clary Lake's littoral habitat for aquatic insect production. Coupled with the absence of benthic invertebrate prey in the profundal (>20 m) areas that comprise most of the Clary Lake (see Section 1.6.3) and the absence of other prey fish species, it is not unexpected that rainbow trout in Clary Lake feed primarily on zooplankton.

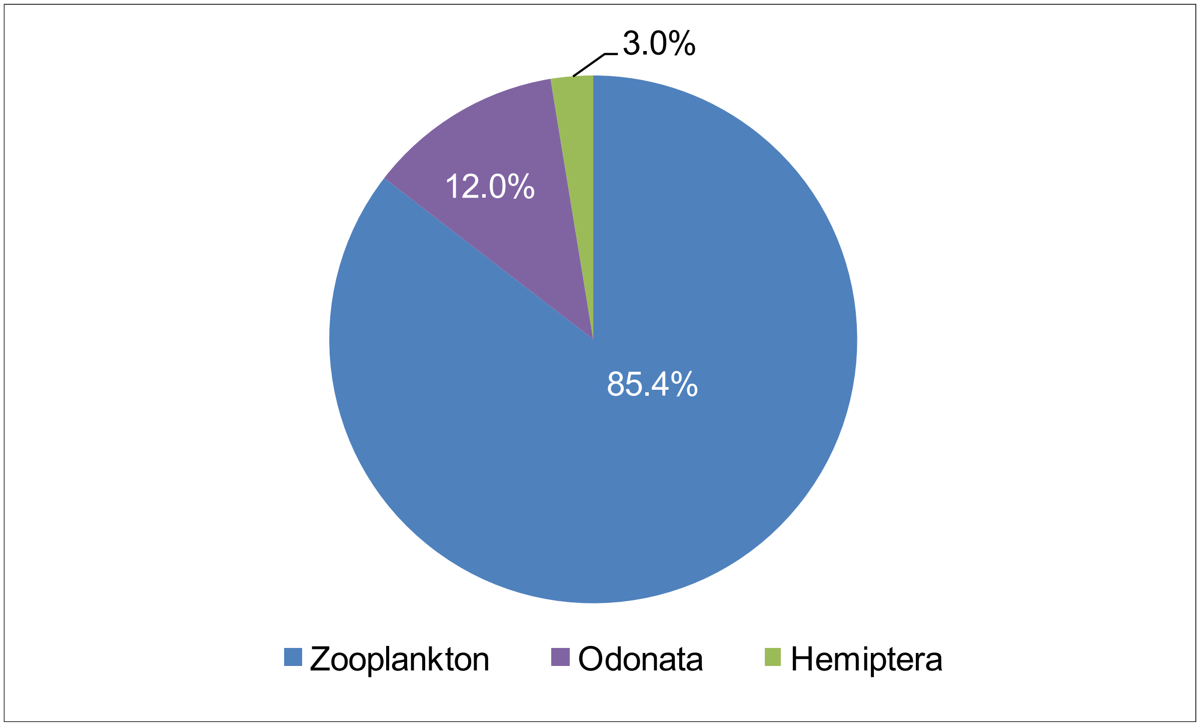


Figure 1.7-20: Stomach Contents, as Percent of Total Weight by Major Taxa, of Rainbow Trout captured in Clary Lake in 2010

1.7.2.5 Energy Storage and Energy Use

Average hepatosomatic and gonadosomatic indices for rainbow trout captured in Clary Lake in 2010 is presented in Table 1.7-27. Clary Lake rainbow trout had an average HSI of 0.37. Female rainbow trout had an average GSI of 0.7 while male rainbow trout had an average GSI of 1.6. There was no residual relationship between the HSI or GSIs for Clary Lake rainbow trout when regressed on body weight.

Table 1.7-27: Mean Hepatosomatic and Gonadosomatic Indices, by Sex, for Rainbow Trout Captured in Clary Lake in 2010

Index	Sex	n	Average	SE
Hepatosomatic	Both sexes combined	17	0.37	0.03
Gonadosomatic	Female	10	0.70	0.10
	Male	7[a]	1.60	0.29

Note: [a] exclude one outlier, a fish 56 g, 172 mm long fish with a GSI of 5.76
n - number of sample; SE - standard error

1.8 Fish Tissue Metals

1.8.1 Dolly Varden

Mean, standard error, minimum and maximum metal concentrations, and frequency of detection in juvenile (<180 mm) Dolly Varden captured in 2009 and 2010 and adult (>180 mm) Dolly Varden captured in 2009 are presented in Tables 1.8-1 and 1.8-2, respectively. Available provincial and federal fish tissue screening value guidelines are presented for comparison to mean metals concentrations for both size classes of fish. Raw data for all 22 Dolly Varden analysed in 2009 and 2010 are provided in Appendix G-5.

Mean total mercury concentration in juvenile Dolly Varden in lower Lime Creek (0.041 mg/kg) was lower than the Canadian Action Level guideline for the protection of human health (0.5 mg/kg; CFIA 2009) (Table 1.8-1). None of the fish captured had total mercury concentrations higher than this guideline. However, the mean total mercury concentration in these 14 fish was greater than the provincial and federal screening value for the protection of piscivorous wildlife (0.033 mg/kg; BC MOE 2001a; CCME 2000). Only two individual juvenile Dolly Varden had total mercury concentrations lower than this guideline.

Mean total mercury concentration in adult Dolly Varden in lower Lime Creek (0.054 mg/kg) was lower than the Canadian Action Level guideline for the protection of human health (0.5 mg/kg; CFIA 2009) (Table 1.8-2). None of the fish captured had total mercury concentrations higher than this guideline. However, the mean total mercury concentration in these eight fish was greater than the provincial screening value for the protection of piscivorous wildlife (0.033 mg/kg; BC MOE 2001a; CCME 2000). Only two individual adult Dolly Varden had total mercury concentrations lower than this guideline. Based on these data, mercury in juvenile and adult Dolly Varden in lower Lime Creek may be a chemical of concern for the health of piscivorous wildlife under current baseline conditions.

The provincial guideline for the protection of piscivorous wildlife is based on the CCME (2000) guidelines for methylmercury, the form of mercury that poses the greatest risk to aquatic biota, wildlife and human because of its tendency to bioaccumulate (US EPA 1997 a, b). Although mean, minimum and maximum total mercury concentrations are presented for the Dolly Varden captured in Lime Creek, methylmercury contributes at least 90% of the total mercury concentration values in fish tissues and other aquatic biota (Rai et al. 2002; Lasorsa and Allen-Gil 1995), so the comparison to this guideline is likely appropriate.

Table 1.8-1: Metal Concentrations in Juvenile Dolly Varden Muscle Tissue

Metal	Frequency of Detection	Mean	Standard Error	Minimum	Maximum	Screening Value for Protection of Human Health	Screening Value for Protection of Piscivorous Wildlife
Aluminum	0/14	1.0	0.0	1.0	1.0	n/a	n/a
Antimony	0/14	0.005	0.000	0.005	0.005	n/a	n/a
Arsenic	14/14	0.055	0.011	0.022	0.194	n/a	n/a
Barium	14/14	0.033	0.005	0.013	0.077	n/a	n/a
Beryllium	0/14	0.05	0.00	0.05	0.05	n/a	n/a
Bismuth	0/14	0.015	0.000	0.015	0.015	n/a	n/a
Cadmium	14/14	0.085	0.017	0.007	0.185	n/a	n/a
Calcium	14/14	290	20	150	404	n/a	n/a
Chromium	4/14	0.1	0.1	0.1	0.5	n/a	n/a
Cobalt	13/14	0.069	0.012	0.010	0.181	n/a	n/a
Copper	14/14	0.6	0.1	0.4	1.4	n/a	n/a
Iron	4/4	5.3	0.6	0.0	6.9	n/a	n/a
Lead	0/14	0.010	0.000	0.010	0.010	n/a	n/a
Lithium	0/14	0.050	0.000	0.050	0.050	n/a	n/a
Magnesium	14/14	242	13	181	320	n/a	n/a
Manganese	14/14	0.257	0.032	0.136	0.605	n/a	n/a
Mercury	14/14	0.041	0.003	0.027	0.063	0.5[c]	0.033[a]
Molybdenum	7/14	0.013	0.004	0.005	0.038	n/a	n/a
Nickel	5/14	0.106	0.039	0.050	0.270	n/a	n/a
Phosphorus	4/4	2,650	27	0	2,690	n/a	n/a
Potassium	4/4	4,518	72	0	4,660	n/a	n/a
Selenium	14/14	0.67	0.03	0.51	0.89	n/a	1.0[b]
Silver	0/14	0.005	0.000	0.005	0.005	n/a	n/a
Sodium	4/4	340	30	0	399	n/a	n/a
Strontium	14/14	0.68	0.1	0.2	1.1	n/a	n/a
Sulfur	4/4	2,258	15	0	2,300	n/a	n/a
Thallium	3/14	0.007	0.002	0.005	0.016	n/a	n/a
Tin	4/14	0.044	0.016	0.025	0.101	n/a	n/a
Titanium	0/4	0.05	0.00	0.000	0.050	n/a	n/a
Uranium	0/14	0.001	0.000	0.001	0.001	n/a	n/a
Vanadium	0/14	0.050	0.000	0.050	0.050	n/a	n/a
Zinc	14/14	12.4	1.1	6.4	18.2	n/a	n/a

Note: All metal concentrations are in milligrams of total metal per kilogram of wet weight fish tissue (mg/kg ww muscle filet); n/a - not applicable (no published Canadian screening value exists);
Descriptive statistics were calculated using metal concentration data for juvenile (<180 mm) Dolly Varden with a mean (± 1 SE) length of 128 ± 7.9 mm and mean weight of 27 ± 4.0 g;
Grey highlights represent chemical that may be of potential concern to the health of piscivorous wildlife. Refer to Section 6.12 for discussion of potential ecological health risks.
n/a - not applicable

Source: [a] BC MOE guideline for methylmercury (BC MOE 2001a, based on CCME 2000); [b] BC MOE guideline for total selenium (BC MOE 2001b), [c] Canadian Action Level for contaminants in fish and fish products (CFIA 2009)

Table 1.8-2: Metal Concentrations in Adult Dolly Varden Muscle Tissue

Metal	Frequency of Detection	Mean	Standard Error	Minimum	Maximum	Screening Value for Protection of Human Health	Screening Value for Protection of Piscivorous Wildlife
Aluminum	0/8	1	0	1	1	n/a	n/a
Antimony	1/8	0.006	0.001	0.005	0.011	n/a	n/a
Arsenic	8/8	0.073	0.024	0.037	0.242	n/a	n/a
Barium	8/8	0.058	0.025	0.024	0.234	n/a	n/a
Beryllium	0/8	0.05	0.00	0.05	0.05	n/a	n/a
Bismuth	0/8	0.015	0.00	0.015	0.015	n/a	n/a
Cadmium	6/8	0.006	0.001	0.003	0.010	n/a	n/a
Calcium	8/8	221	35	90	375	n/a	n/a
Chromium	4/8	0.28	0.18	0.05	1.55	n/a	n/a
Cobalt	4/8	0.017	0.003	0.010	0.025	n/a	n/a
Copper	8/8	0.535	0.030	0.412	0.663	n/a	n/a
Iron	8/8	6.95	0.88	4.75	12.80	n/a	n/a
Lead	0/8	0.01	0	0.01	0.01	n/a	n/a
Lithium	0/8	0.05	0.00	0.05	0.05	n/a	n/a
Magnesium	8/8	306	5	291	330	n/a	n/a
Manganese	8/8	0.191	0.012	0.141	0.242	n/a	n/a
Mercury	8/8	0.054	0.009	0.010	0.077	0.5[c]	0.033[a]
Molybdenum	2/8	0.016	0.008	0.005	0.065	n/a	n/a
Nickel	1/8	0.15	0.10	0.05	0.83	n/a	n/a
Phosphorus	8/8	2,670	42	2,510	2,890	n/a	n/a
Potassium	8/8	4,744	70	4,410	5,050	n/a	n/a
Selenium	8/8	0.723	0.070	0.410	0.905	n/a	1.0[b]
Silver	0/8	0.005	0.000	0.005	0.005	n/a	n/a
Sodium	8/8	291	13	238	341	n/a	n/a
Strontium	8/8	0.432	0.079	0.168	0.768	n/a	n/a
Sulfur	8/8	2,186	35	2,050	2,360	n/a	n/a
Thallium	6/8	0.011	0.001	0.005	0.016	n/a	n/a
Tin	0/8	0.025	0.000	0.025	0.025	n/a	n/a
Titanium	0/8	0.05	0.00	0.05	0.05	n/a	n/a
Uranium	0/8	0.001	0.000	0.001	0.001	n/a	n/a
Vanadium	0/8	0.05	0.00	0.05	0.05	n/a	n/a
Zinc	8/8	5.5	0.3	4.7	7.5	n/a	n/a

Note: All metal concentrations are in milligrams of total metal per kilogram of wet weight fish tissue (mg/kg ww muscle filet); n/a - not applicable (no published Canadian screening value exists);
Descriptive statistics were calculated using metal concentration data for adult (>180 mm) Dolly Varden with a mean (± 1 SE) length of 218 mm ± 11 mm and mean weight of 119 g ± 19 g;
Grey highlights represent chemical that may be of potential concern to the health of piscivorous wildlife. Refer to Section 6.12 for discussion of potential ecological health risks.

Source: [a] BC MOE guideline for methylmercury (BC MOE 2001a, based on CCME 2000); [b] BC MOE guideline for total selenium (BC MOE 2001b), [c] Canadian Action Level for contaminants in fish and fish products (CFIA 2009)

Mean total selenium concentration in juvenile Dolly Varden in lower Lime Creek (0.7 mg/kg) was lower than the BC MOE guideline for the protection of piscivorous wildlife (1.0 mg/kg; BC MOE 2001b) (Table 1.8-1). No individual juvenile Dolly Varden had a total selenium concentration above this guideline.

Mean total selenium concentration in adult Dolly Varden in lower Lime Creek (0.7 mg/kg) was lower than the BC MOE guideline for the protection of piscivorous wildlife (1.0 mg/kg; BC MOE 2001b). No individual adult Dolly Varden had a total selenium concentration above this guideline.

A summary of mean metal concentrations and significant differences in juvenile and adult Dolly Varden muscle tissues from Lime Creek are presented in Table 1.8-3. Metals are not listed in this table if they were not detected in at least one fish from either of the adult or juveniles size classes.

Of the ten metals with significance differences between the mean concentrations in juvenile and adult Dolly Varden, all ten were significantly higher in juvenile Dolly Varden muscle tissue than in adult Dolly Varden muscle tissue. These include significantly higher concentrations of cadmium, calcium, cobalt, copper, manganese, sodium, strontium, sulfur, tin, and zinc in juvenile Dolly Varden than in adult Dolly Varden.

Two of these results are worth further discussion. First, higher concentrations of strontium in juvenile Dolly Varden than in adult Dolly Varden is counter to what would be expected given that strontium concentrations are known to be higher in the marine environment than in freshwater (on average 8.0 mg/L in the ocean and 0.1 mg/L in freshwater; Rosenthal et al. 1970). This difference in strontium concentrations in the two different environments is so striking that researchers now use strontium concentrations found in body structures of fish (e.g., otoliths) to determine anadromy and life history characteristics of coastal fish species (Radtke 1995; Babaluk et al. 1997; Howland et al. 2001; Zimmerman 2005). Given what we know about the life history of Dolly Varden in Lime Creek, one would expect that strontium concentrations in adult Dolly Varden returning from the ocean would be higher than strontium concentrations found in juveniles. Second, there was no significant difference in mercury concentrations between adult and juvenile Dolly Varden in Lime Creek. This is surprising because mercury cannot be metabolised and, instead, is known to bioaccumulate in fish as they grow and age (Bodaly et al. 1984; Bodaly et al. 1997; Hecky et al. 1987; Hecky et al. 1991). As a result, one would expect mercury concentrations in adult Dolly Varden to be higher than mercury concentrations in juvenile Dolly Varden. This result suggests that mercury concentrations in water, sediments, and BMI prey in Lime Creek are higher than in Alice Arm and that the rate of mercury uptake in Dolly Varden decreases when they enter the marine environment.

Table 1.8-3: Test for Significance Differences in Mean Metal Concentrations Between Adult and Juvenile Dolly Varden Muscle Tissue in Lower Lime Creek

Parameter	Adult Concentrations	Juvenile Concentrations	Significance (p-value)
Arsenic	0.073	0.055	n.s.
Barium	0.058	0.033	n.s.
Cadmium	0.006	0.085	<0.001
Calcium	221	290	0.005
Chromium	0.28	0.1	n.s.
Cobalt	0.017	0.069	<0.001
Copper	0.535	0.6	0.03
Iron	6.95	5.3	n.s.
Magnesium	306	242	n.s.
Manganese	0.191	0.257	0.001
Mercury	0.054	0.041	n.s.
Molybdenum	0.016	0.013	n.s.
Nickel	0.15	0.106	n.s.
Phosphorus	2,670	2,650	n.s.
Potassium	4,744	4,518	n.s.
Selenium	0.723	0.67	n.s.
Sodium	291	340	0.04
Strontium	0.432	0.68	<0.001
Sulfur	2,186	2,258	0.004
Thallium	0.011	0.007	n.s.
Tin	0.025[a]	0.044	<0.001
Zinc	5.5	12.4	<0.001

Note: [a] Not detected in any of the eight adult Dolly Varden sampled in 2009. Mean tin concentration represents half of the laboratory detection limit

All metal concentrations are in milligrams of total metal per kilogram of wet weight fish tissue (mg/kg ww muscle filet)

Grey highlights represent significant differences; n.s. - non-significant

1.8.2 Coastrange Sculpin

Mean, standard error, and minimum and maximum total metal concentrations in the 12 coastrange sculpin analysed from lower Lime Creek are presented in Table 1.8-4. Raw data for all 12 fish are provided in Appendix G-6.

Mean total mercury concentration in coastrange sculpin in lower Lime Creek (0.060 mg/kg) was higher than the provincial or federal screening value for the protection of piscivorous wildlife from methylmercury (0.033 mg/kg; BC MOE 2001a; CCME 2000). Only two individual coastrange sculpin had total mercury concentrations lower than this guideline. Based on these data, mercury in coastrange sculpin may be a chemical of concern for the health of piscivorous wildlife under current baseline conditions.

Mean total selenium concentrations in coastrange sculpin in lower Lime Creek (0.7 mg/kg) were lower than the BC MOE guideline for the protection of piscivorous wildlife (1.0 mg/kg; BC MOE 2001b). No individual coastrange sculpin had a total selenium concentration above this guideline.

Table 1.8-4: Metal Concentrations in Coastrange Sculpin Whole-Body Tissues

Metal	Frequency of Detection	Mean	Standard Error	Minimum	Maximum	Screening Value for Protection of Human Health	Screening Value for Protection of Piscivorous Wildlife
Aluminum	12/12	175	49	16	492	n/a	n/a
Antimony	5/12	0.033	0.014	0.005	0.18	n/a	n/a
Arsenic	12/12	0.285	0.037	0.097	0.508	n/a	n/a
Barium	12/12	6.8	1.9	1.5	24.0	n/a	n/a
Beryllium	0/12	0.096	0.004	0.050	0.100	n/a	n/a
Bismuth	3/12	0.057	0.018	0.015	0.238	n/a	n/a
Cadmium	12/12	0.665	0.078	0.237	1.140	n/a	n/a
Calcium	12/12	13,258	870	6,690	18,700	n/a	n/a
Chromium	12/12	24.0	6.0	3.2	60.9	n/a	n/a
Cobalt	12/12	0.351	0.069	0.076	0.823	n/a	n/a
Copper	12/12	1.57	0.21	0.63	2.82	n/a	n/a
Lead	12/12	1.50	0.44	0.19	5.85	n/a	n/a
Lithium	4/12	0.175	0.035	0.050	0.390	n/a	n/a
Magnesium	12/12	369	29	209	602	n/a	n/a
Manganese	12/12	12.7	2.1	4.2	28.1	n/a	n/a
Mercury	12/12	0.060	0.008	0.016	0.124	0.5[c]	0.033[a]
Molybdenum	12/12	2.2	0.7	0.3	6.6	n/a	n/a
Nickel	12/12	11.6	2.9	1.6	29.3	n/a	n/a
Selenium	12/12	0.718	0.033	0.500	0.860	n/a	1.0[b]
Silver	2/12	0.024	0.010	0.005	0.124	n/a	n/a
Strontium	12/12	53	5	22	71	n/a	n/a
Thallium	0/12	0.010	0.000	0.005	0.010	n/a	n/a
Tin	9/12	0.141	0.021	0.025	0.260	n/a	n/a
Uranium	12/12	0.038	0.008	0.014	0.110	n/a	n/a
Vanadium	8/12	0.563	0.144	0.050	1.440	n/a	n/a
Zinc	12/12	38	3	23	55	n/a	n/a

Note: All metal concentrations are in milligrams of total metal per kilogram of wet weight fish tissue (mg/kg ww muscle filet); n/a - not applicable (no published Canadian screening value exists);
Descriptive statistics were calculated using data for juvenile and resident adults (n = 12) with a mean (± 1 SD) length of 88 ± 7 mm and a mean of weight 7 ± 2 g
Grey highlights represent chemical that may be of potential concern to the health of piscivorous wildlife. Refer to Section 6.12 for discussion of potential ecological health risks.

Source: [a] BC MOE guideline for methylmercury (BC MOE 2001a, based on CCME 2000); [b] BC MOE guideline for total selenium (BC MOE 2001b)

1.8.3 Rainbow Trout

Mean, standard error, and minimum and maximum total metal concentrations in the 21 rainbow trout analysed from Clary Lake are presented in Table 1.8-5. Raw data are provided in Appendix G-7.

Mean total mercury concentration in rainbow trout in Clary Lake (0.045 mg/kg) was lower than the Canadian Action Level guideline for the protection of human health (0.5 mg/kg; CFIA 2009). None of the fish captured had total mercury concentrations higher than this guideline. However, the mean total mercury concentration in these 21 fish was greater than the provincial and the federal screening value for the protection of piscivorous wildlife from methylmercury (0.033 mg/kg; BC MOE 2001a; CCME 2000). Only four individual rainbow trout had total mercury concentrations lower than this guideline. Based on these data, mercury in Clary Lake rainbow trout may be a chemical of concern for the health of piscivorous wildlife under current baseline conditions.

Mean total selenium concentration in rainbow trout in Clary Lake (0.4 mg/kg) was lower than the BC MOE guideline for the protection of piscivorous wildlife (1.0 mg/kg; BC MOE 2001b). No individual juvenile rainbow trout had a total selenium concentration above this guideline.

Table 1.8-5: Metal Concentrations in Rainbow Trout Fish Tissue

Metal	Frequency of Detection	Mean	Standard Error	Minimum	Maximum	Screening Value for Protection of Human Health	Screening Value for Protection of Piscivorous Wildlife
Aluminum	0/21	1.1	0.1	1.0	2.0	n/a	n/a
Antimony	0/21	0.005	0.000	0.005	0.010	n/a	n/a
Arsenic	17/21	0.015	0.002	0.005	0.043	n/a	n/a
Barium	15/21	0.018	0.003	0.005	0.074	n/a	n/a
Beryllium	0/21	0.055	0.003	0.050	0.100	n/a	n/a
Bismuth	0/21	0.016	0.001	0.015	0.030	n/a	n/a
Cadmium	19/21	0.013	0.001	0.003	0.028	n/a	n/a
Calcium	21/21	242	17	152	501	n/a	n/a
Chromium	7/21	0.12	0.03	0.05	0.45	n/a	n/a
Cobalt	2/21	0.01	0.00	0.01	0.04	n/a	n/a
Copper	21/21	0.302	0.009	0.238	0.409	n/a	n/a
Lead	0/21	0.01	0.00	0.01	0.02	n/a	n/a
Lithium	1/21	0.06	0.00	0.05	0.11	n/a	n/a
Magnesium	21/21	213	5	168	249	n/a	n/a
Manganese	21/21	0.358	0.074	0.132	1.650	n/a	n/a
Mercury	21/21	0.045	0.003	0.025	0.082	0.5[c]	0.033[a]
Molybdenum	3/21	0.007	0.001	0.005	0.020	n/a	n/a
Nickel	4/21	0.08	0.01	0.05	0.25	n/a	n/a
Selenium	20/21	0.45	0.03	0.20	0.76	n/a	1.0[b]
Silver	0/21	0.005	0.000	0.005	0.010	n/a	n/a
Strontium	21/21	0.262	0.022	0.148	0.556	n/a	n/a
Thallium	0/21	0.005	0.000	0.005	0.010	n/a	n/a
Tin	5/21	0.049	0.011	0.025	0.213	n/a	n/a
Uranium	0/21	0.001	0.000	0.001	0.002	n/a	n/a
Vanadium	0/21	0.05	0.00	0.05	0.10	n/a	n/a
Zinc	21/21	8.65	0.40	5.78	12.40	n/a	n/a

Note: All metal concentrations are in milligrams of total metal per kilogram of wet weight fish tissue (mg/kg ww muscle filet); n/a - not applicable (no published Canadian screening value exists);
Descriptive statistics were calculated using data for 21 rainbow trout with a mean (± 1 SD) length of 205 ± 51 mm and a mean of weight 105 ± 69 g
Grey highlights represent chemical that may be of potential concern to the health of piscivorous wildlife. Refer to Section 6.12 for discussion of potential ecological health risks.

Source: [a] BC MOE guideline for methylmercury (BC MOE 2001a, based on CCME 2000); [b] BC MOE guideline for total selenium (BC MOE 2001b), [c] Canadian Action Level for contaminants in fish and fish products (CFIA 2009)

1.8.4 Chemicals of Potential Concern

Mercury was conservatively identified as potentially being a chemical of concern to any piscivorous wildlife currently feeding on Dolly Varden and coastrange sculpin in lower Lime Creek and rainbow trout in Clary Lake. Reasons for this conservatism include:

- Mercury accumulates in fish tissue primarily as methylmercury and, although methylmercury typically comprises over 90% of the total mercury concentration in fish tissue, comparison of total mercury concentrations to a guideline based on methylmercury concentration is not entirely accurate;
- Presumably piscivorous wildlife would be exposed because mercury concentrations tend to be positively correlated with fish size and because wildlife would be expected to consume smaller fish;
- The analysis of tissues on a muscle fillet basis instead of a whole body basis overestimates the concentration of methylmercury to which piscivorous wildlife would be exposed because methylmercury preferentially accumulates in protein-rich tissues such as muscle and wildlife would be expected to consume the whole fish carcass; and
- BC MOE / CCME tissue screening guidelines are set conservatively to be protective of as many organisms and environments across Canada as possible.

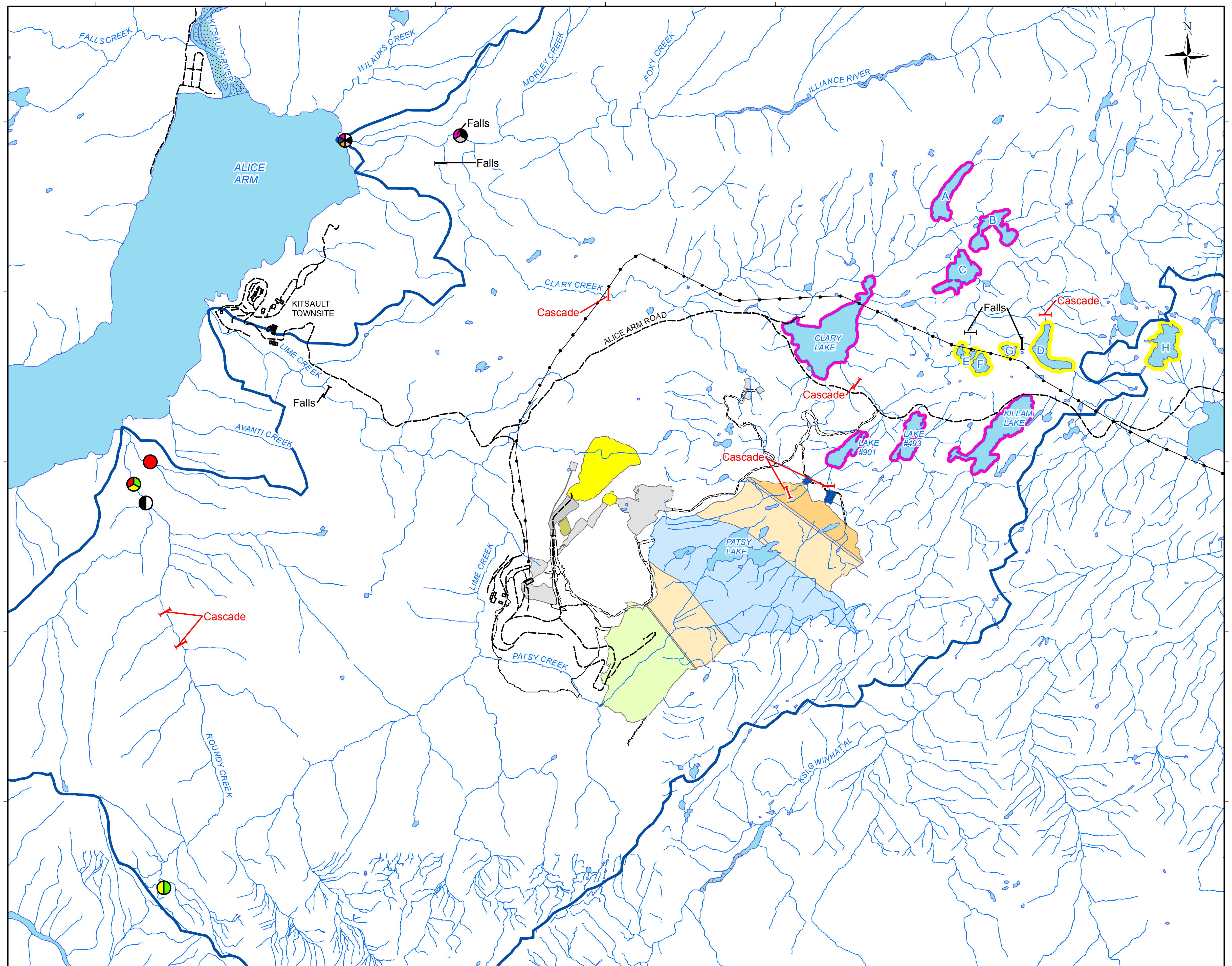
Depending on site-specific environmental chemistry, and the particular piscivorous animals near the proposed Project, the BC MOE / CCME guideline for mercury may not be relevant to the piscivorous animals in the area and thus, the risk of adverse effects would be less than guideline exceedances may suggest.

1.9 Regional Baseline Summary

1.9.1 Clary Creek Watershed

1.9.1.1 Watershed Description and Stream and Lake Habitat

A description of the Clary Creek watershed and the lake and stream habitat located within the LSA is provided in Section 1.3.3. The only other data from the lakes and streams within the Clary Creek watershed is provided by the winter survey conducted by Rescan in March 2010 (Rescan 2010e). This report indicated the location of waterfalls and potential fish impassable cascades in the watershed upstream of Clary Lake (Figure 1.9-1). The report also indicated which lakes upstream of Clary Lake in the northern portion of the watershed were fish-bearing or presumed non-fish-bearing based on winter DO profiling, results of ice-fishing, and the location of these lakes in relation to potential fish barriers.



Legend

Sampling Sites
- Primary Producers
- Secondary Producers
- Stream Habitat Assessment

Fish Distribution
- Coho
- Chum
- Dolly Varden
- Pink
- Sculpin
- Steelhead
- Cascade
- Falls
- Non-fish-bearing lakes (presumed)
- Fish-bearing lakes (known)
- Transmission Line
- Road
- Access Road
- Diversion Ditch
- Process Plant
- Open Pit
- Ore Stockpile
- Topsoil Stockpiles
- East Waste Rock Management Facility
- Northeast Embankment
- Tailings Beach
- TMF Supernatant Pond
- Regional Study Area

Scale:1:45,000
0 0.5 1 2
Kilometers

Reference
1. Base Data
Geobase 1:20,000 (TRIM)
Land and Resource Data Warehouse 1:20,000 (TRIM)
2. Project Infrastructure
Supplied by AMEC and Knight Piesold on March 2011

CLIENT: Avanti Kitsault Mine Ltd.

PROJECT: Kitsault Mine Project

Regional Baseline
Aquatics and Fisheries Resources

DATE: July 2011	ANALYST: MY	**Figure** 1.9-1
JOB No: VE51988	QA/QC: BH	PDF FILE: 10-50-077_regional_map.pdf
GIS FILE: 10-50-077.mxd		
PROJECTION: UTM Zone 9	DATUM: NAD83	

Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-077.mxd

No barriers to fish migrations were observed between Clary Lake and lakes A, B, and C upstream. A >20% cascade at the outlet of Lake D likely precludes fish from accessing habitat in this lake. Lake D had a maximum depth of 9 m and had DO concentrations sufficient to support overwintering rainbow trout (5 mg/L; Rescan 2010e). Falls at the outlets of Lakes E and G preclude upstream fish passage to these lakes and to Lake F. However, the fish-bearing status of these lakes is not currently known.

1.9.1.2 Fish Species Composition and Distribution

As indicated above, rainbow trout are the only fish species known to exist in the Clary Creek watershed upstream of the impassable waterfalls located near the confluence of the creek with the Illiance River. No other fish species have been reported in the Clary Creek watershed (FISS 2011). These trout were likely first introduced to Clary Lake in the early 1970s by the province or by employees of the first mining operation at Kitsault before the road to Kitsault was built. Subsequently, rainbow trout have been re-stocked in Killam Lake by the BC MOE between 1988 and 2003.

Stocked rainbow trout have now naturalised and created self-sustaining populations in most of the lakes and streams with the Clary Creek watershed upstream of the waterfalls. These include Clary Lake, Lake 901, Lake 493, Killam Lake and at least three unnamed lakes upstream of Clary Lake where Rescan found rainbow trout during winter investigations in March 2010 (Lakes A, B, and C; Figure 1.9-1). The upstream distribution of rainbow trout in the upper Clary Creek watershed is likely limited by the numerous natural barriers to fish passage that exist on the landscape. These include natural waterfalls, narrow canyons, and steep cascades (Figure 1.9-1).

1.9.2 Illiance River Watershed

1.9.2.1 Watershed Description

The Illiance River is located north of the proposed Project area and is the largest watercourse in the RSA. It has a mainstem length of approximately 21 km and an average width varying between 25 to 37 m (FISS 2011; BC FishWizard 2011). Like other rivers and streams in the area, the Illiance River is glacially-fed.

Elevation within the watershed ranges from approximately 1860 masl at Tchitin Peak in the northern portion of the upper watershed (Knight Piésold 2011) to sea level at the mouth of the river at Alice Arm. The Illiance River Valley is steep sloped and heavily canyonised over much of its length. The river is subject to heavy erosion and siltation and glacial debris from upper mountain slopes is commonly found in river sediments during spring run-off (Taylor 1981).

The lower portion of the valley is heavily forested, with balsam firs, hemlocks and cedars. The upper valley is more sparsely vegetated, with vegetation consisting primarily of ground juniper and swampy meadowland.

Over the last 50 years, large woody debris, log jams and bank erosion have affected up to 40% of the stream bed of the Illiance River causing significant (up to 50%) loss in spawning habitat and viable redds (Marshall 1984). Over the years, stream channelling work and restoration work have occurred along the lower reaches of the river, but with limited success (Marshall 1984).

1.9.2.2 Fish Composition and Distribution

The Illiance River is known to support anadromous runs of coho, chum and pink salmon and steelhead as well as anadromous and resident populations of Dolly Varden and resident sculpins (FISS 2011; BC FishWizard 2011; North Coast Fisheries Renewal Council (NCFRC) 2002). Based on historical escapement data, coho, chum and pink salmon stocks are considered unthreatened in this system (Gordon and Bahr 2003). Coho, chum, and pink salmon are evenly distributed along the lower reaches of the river, from the mouth of the river to a set of impassable falls approximately 1.6 km upstream from the mouth at Alice Arm (Marshall 1984) (Figure 1.9-1). No records of fishing were found for reaches upstream of these falls (FISS 2011). It is currently unknown what, if any, fish species are present upstream of these falls. Queries of HabitatWizard, Mapster and the BC CDC returned no results for the Illiance River watershed. Overall, very little work has been done on the Illiance River (L. Archibald pers. comm. 2011).

In 1999, the Illiance River was surveyed as part of the North Coast Stream Inventory Program (NSCIP) (NCFRC 2002). Fish were trapped at two sites in August using Gee traps. A total of 109 coho salmon were caught (34 at Site 1 and 75 at Site 2; Figure 1.9-1), Most of these fish were YOY (<75 mm). CPUE was 2.27 fish / trap hour for Site 1 and 5.00 fish / trap hr for Site 2. Three resident Dolly Varden and 22 sculpins were also caught during the survey.

1.9.3 Roundy Creek Watershed

In 2009, Roundy Creek was surveyed as a potential reference site for monitoring potential effects of the proposed Project in Lime Creek as part of the freshwater aquatic and fisheries baseline sampling conducted by Rescan (Rescan 2010b, c). Two stream sites (one in the Roundy Creek mainstem and one in a Roundy Creek tributary) and one wetland site (WL4) were surveyed (Figure 1.9-1). Surveys included inventory and characterisation of the fish habitat, fish community composition and Dolly Varden fish tissue metals analysis, and the lower trophic communities in streams and wetland including periphyton, phytoplankton, and BMI communities.

1.9.3.1 Watershed Description and Stream Habitat

The Roundy Creek watershed is located to the southwest of the proposed Project with its headwater located adjacent to the headwaters of Lime Creek. The creek is approximately 6.4 km long and flows northwest to Alice Arm. Elevations in the Roundy Creek watershed range from approximately 1380 masl along the Dawson Ridge (Knight Piésold 2011) to sea level at Alice Arm.

Stream morphology in Roundy Creek alternates between riffle-pool and cascade pool, with cascades up to 0.5 m in height. Habitat conditions in lower Roundy Creek include a stream bed composed of large gravel and cobble interspersed with boulders, abundant instream cover from boulders and large woody debris (where present), and low (<40%) to high (>70%) riparian cover from second-growth deciduous and coniferous trees, on the Roundy Creek mainstem and Roundy Creek tributary, respectively (Rescan 2010b).

The Roundy Creek watershed was logged decades ago which has resulted in lower riparian cover, unstable banks, sediment erosion and a considerably smaller wetted width than channel width (average channel width in reaches sampled 30.8 m). Spawning, rearing, and overwintering habitat for salmonids in Roundy Creek was classified as poor, fair, and fair, respectively (Rescan 2010b). Spawning, rearing, and overwintering habitat in the Roundy Creek tributary was classified as non-existent to fair. Presumably, habitat degradation has occurred in Roundy Creek due to past logging.

1.9.3.2 Fish Species Composition, Distribution and Metal Concentrations

A total of 26 fish were captured in Roundy Creek in 2009 (Rescan 2010b). These included 24 Dolly Varden and two coho salmon parr (<95 mm). Dolly Varden ranged in length between 37 mm and 222 mm (with a mean length of 119 mm ± 9.8 mm) and included fish ranging in age from 0+ to 3+ years old. Most (46%) of the Dolly Varden captured were 1+ and 2+ year old fish between 100 mm and 120 mm in length. The sample included four YOY Dolly Varden (<60 mm) indicating the Dolly Varden use Roundy Creek for spawning. The presence of coho salmon parr suggests that coho salmon may spawn in Roundy Creek or its tributaries. However, the degraded habitat in Roundy Creek suggests that these fish may have moved into Roundy Creek as strays, similar to the coho salmon parr found in lower Lime Creek in 2010.

The presence of two chute / cascades on the Roundy Creek mainstem suggests that the distribution of fish in Roundy Creek is limited to the lower 2.5 km of Roundy Creek (Figure 1.9-1). No fish sampling was conducted above these chute / cascades in 2009 or 2010 to confirm this however.

Tissue concentrations of copper, zinc and potassium were higher in Dolly Varden collected in Roundy Creek than in Dolly Varden collected in Lime Creek. The opposite was true for strontium and calcium (Rescan 2010b).

1.9.3.3 Lower Trophic Communities

The periphyton community of Roundy Creek was dominated numerically by cyanophytes (blue-green algae) (97%). Chrysophytes (golden-brown algae) and bacillariophytes (diatoms) comprised the remaining 3% of the total organisms enumerated. Periphyton density (1,185,614 cells/cm^2) in Roundy Creek was moderate and biomass (0.012 µg/cm^2 chl *a*) was low compared to Lime Creek in 2009 (Rescan 2010c).

Ephemeropterans (mayflies) (60%), plecopterans (stoneflies) (29%), and dipterans (true flies) (10%) comprised 99% of the total BMI community in Roundy Creek (Rescan 2010c).

Trichopterans comprised the remaining 1% of the total number of individually enumerated. Roundy Creek had an EPT index of 89%, the highest of all stream sites sampled in 2009 including upper and lower Lime Creek.

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