2010 SLOCAN LAKE PRELIMINARY WATER QUALITY STUDY

PREPARED FOR **SLONCAN LAKE STEWARDSHIP SOCIETY**
BY **GALENA ENVIRONMENTAL LTD**

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EXECUTIVE SUMMARY

Galena Ltd was retained by the Slocan Lake Stewardship Society (SLSS) to conduct the first part of a trend-monitoring water quality program on Slocan Lake as well as to provide recommendations for future sampling. The study was conducted in August, September and November of 2010.

The 2010 program consisted of two components: an offshore component conducted monthly, and a nearshore component conducted during a 5-week period. The offshore study analyzed water samples for five general water quality parameters (temperature, dissolved oxygen, conductivity, pH and total dissolved solids), five nutrients (nitrate as N, nitrite as N, total nitrogen, total phosphorus and chlorophyll-a, 29 total metals and zooplankton. Seven sites were sampled for total coliform analysis during the nearshore study which, since it involved bacteriological sampling, had to be completed within a 5-week period of the summer season.

Comparison, where possible, with the 2000–2001 (Pieters *et al.* 2006) and the 2008 (Galena 2008) surveys indicated little variability between those and the 2010 results. The 2000-2001 limnological survey was conducted primarily because the relatively pristine condition of the lake made it a good control for comparison purposes with the fertilization experiments on nearby Arrow Lakes and Kootenay Lake. Results from the 2008 baseline lake survey confirmed that Slocan Lake has remained oligotrophic and relatively pristine. The present 2010 trend-monitoring study will serve to assess long-term changes in water quality and will provide a basis for statistical identification of the possible causes of measured conditions or identified trends.

Total coliforms were found at each of the seven sampling sites. Of all the sites, Slocan and Hills had the most total coliforms.

Detection limits were sufficiently low to compare concentration results with the BC Water Quality Guidelines (BCWQG). General parameters, nutrients, and 28 of the 29 total metals met the BCWQG. Of all the metals, cadmium concentrations did not meet the Guidelines for the two primary uses of Slocan Lake, aquatic life and recreation. The present report describes the results of this study.

Zooplankton density and biomass were measured at a 40m depth at sites 1, 2 and 3. Two species of copepods and three species of cladocerans were found during the sampling. Copepods were the most abundant zooplankton at each sampling station. Compared to the 2000-2001 study, there was a decrease in total zooplankton biomass and biomass of other cladocerans in 2010.

CONTRIBUTORS & ACKNOWLEDGEMENTS

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- Columbia Basin Trust (CBT): Environmental Initiatives Program
- Regional District of Central Kootenay

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- Regional District of Central Kootenay: help in making copies of this report.
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- Jennifer Yeow, microbiologist (Passmore Laboratory Ltd.): professional assistance in the planning of the nearshore water quality program and preferential rates for the microbiological analyses.
- Eva Schindler, limnologist, MOE: professional assistance in the planning of the offshore water quality program.

VOLUNTEERS, FIELD WORK & EQUIPMENT

This project would not have been possible without the volunteer help and contributions of the members of the SLSS, and several non-members as well, on both the nearshore and offshore components.

- Offshore sampling program: field work planning, preparation and coordination was conducted by Luce Paquin, biologist.
- Nearshore sampling: Field work planning and preparation was conducted by Luce Paquin, biologist; field work coordination was carried out by Lane Haywood and Richard Johnson.
- Offshore sampling was conducted by Hillary Elliott, Richard Johnson, Sean Patrick Spriggs, Barb Yeomans, Jim (Pin) Hicks, Trevor Holsworth, Jonathan Sherrod, Kim Roshinsky and Luce Paquin.
- Nearshore sampling was conducted by Lane Haywood, Hank Hastings, Richard Johnson, Linda Hastings, Peter Roulston, Dick Callison, Kevin Murphy, Margaret Hartley and Jane Murphy.
- Canoes were borrowed from: Silverton Resort, Daniel Sherrod, Patrizia Menton and Clarence DenBok.

GLOSSARY OF TERMS

Algae: primitive chlorophyll-containing mainly aquatic eukaryotic organisms lacking true stems and roots and leaves.

Alkalinity: capacity of a lake to neutralize acid.

Aphotic zone: the portion of a lake that is not exposed to sunlight (deep, and close to the hypolimnion layer).

Aquatic macrophytes: aquatic plants that are large enough to be apparent to the naked eye and larger than most algae.

Epilimnion: most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and less-dense water.

Euphotic zone: the upper layer of water that receives light, and thus photothensythesis is possible.

Eutrophic lake: a nutrient-rich lake – usually shallow, "green" and with limited oxygen in the bottom layer of water.

Fall turnover: cooling surface waters, activated by wind action, sink to mix with lower levels of water. As in spring turnover, all water is now at the same temperature.

Freshets: a flood resulting from heavy rain or a spring thaw. Whereas heavy rain often causes a flash flood, a spring thaw event is generally a more incremental process, depending upon local climate and topography.

Hypolimnion: the bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

Isothermal lake: a lake without water stratification and with the same water temperatures along the water column.

Macrophytes: aquatic plants growing in a lake, river or wetland**.**

Metalimnion: The middle layer in a thermally stratified lake. Also called 'thermocline'.

Oligotrophic lake: a relatively nutrient-poor lake, it is clear and deep with bottom waters high in dissolved oxygen.

Phytoplankton: the algae or plant-like component of the plankton that drifts in the water column.

Photosynthesis: the process of green plants and certain other organisms by which carbohydrates are synthetized from carbon dioxide and water using light as an energy source. Most forms of photosynthesis release oxygen as a byproduct.

Thermal stratification: the vertical variation of temperature in a lake, in which water temperatures decrease with depth, and is most pronounced during the summer.

Thermocline: during summertime, the middle layer of lake water. Lying below the epilimnion, temperatures decrease rapidly with depth in this layer.

Water Quality Guidelines: provincially determined safe levels of substances for the protection of a given water use, including drinking water, aquatic life, recreation, irrigation and agricultural uses.

Zooplankton: small floating or weakly swimming animals that drift with water currents and, with phytoplankton, make up the planktonic food supply on which almost all aquatic organisms ultimately depend. Included are many animals, from single-celled radiolarians to the eggs or larvae of herrings, crabs, and lobsters. Permanent plankton, such as Protozoans and Copepods, spend their lives as plankton. Temporary plankton, such as young shellfish, worms, and other bottom-dwelling animals, live and feed as plankton until they become adults.

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1 INTRODUCTION

Over the last years, Slocan Lake has witnessed a considerable increase in recreational use and development pressures. Consequently, the residents around Slocan Lake have expressed concern for the lake's water quality. Water quality is the basic gauge for measuring environmental health and ecosystem integrity.

But Slocan Lake is one of the few remaining large lakes in British Columbia for which very little scientific information has been gathered to date (Pieters *et al.* 2006). Water quality samples were first collected in Slocan Lake in 2000-2001 by the Ministry of Environment and University of British Columbia (Pieters *et al.* 2006). During that study, two offshore sites were chosen to test ambient (entire lake) water quality rather than nearshore site-specific water quality. No further sampling was conducted until 2008 when the Slocan Lake Stewardship Society (SLSS) collected sufficient public funding to undertake the study. The 2008 water quality sampling program was one of the components of the Slocan Lake Baseline Study (Galena 2008). The objective of the baseline study was to gather information necessary for the future development of a comprehensive lake management plan for Slocan Lake. The 2008 Slocan Lake sampling program was a Survey Monitoring Program (Inventory) conducted during a 30-day period, measuring the average condition of the water. The goal of the study was to establish natural water quality conditions and to characterize them over a specified geographic area. This type of sampling is usually conducted within watersheds where there has been no previous sampling or where little information exists on the state of the water.

Lakes are less likely to exhibit the same degree of short-term variations as rivers and are more suited to long-term trend assessments. Trend-monitoring extends studies over a relatively long period (i.e., usually 3 years or more) with the objective of detecting true trends. In 2010, the SLSS began a trend-monitoring water study with the hope of maintaining funding for a 3-year period. The program was designed based on the established Resource Inventory Standards Committee (RISC) standards which are presented in *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia* (Cavanagh *et al.* 2004). The study focused on two main components: water quality monitoring in the offshore and nearshore zones. The present report describes the preliminary results of the 2010 water quality sampling program on Slocan Lake.

2 STUDY AREA

Slocan Lake is located in the West Kootenay Region in the southern interior of British Columbia. The lake follows Highway 6 and is positioned on a north-south axis between the Selkirk and the Valhalla mountain ranges (Figure 1). The lake drains south into its only outlet, the Slocan River, which flows into the Kootenay River, which in turn flows into the Columbia River at Castlegar, BC. The lake is located at an elevation of 541 m, within the ICHmw2 (Interior Cedar Hemlock, moist, warm) biogeoclimatic zone. The upland ecosystem is characterized as being in the ESSF (Engelmann Spruce-Subalpine Fir) and the AT (Alpine Tundra) biogeoclimatic zones containing pockets of open forest.

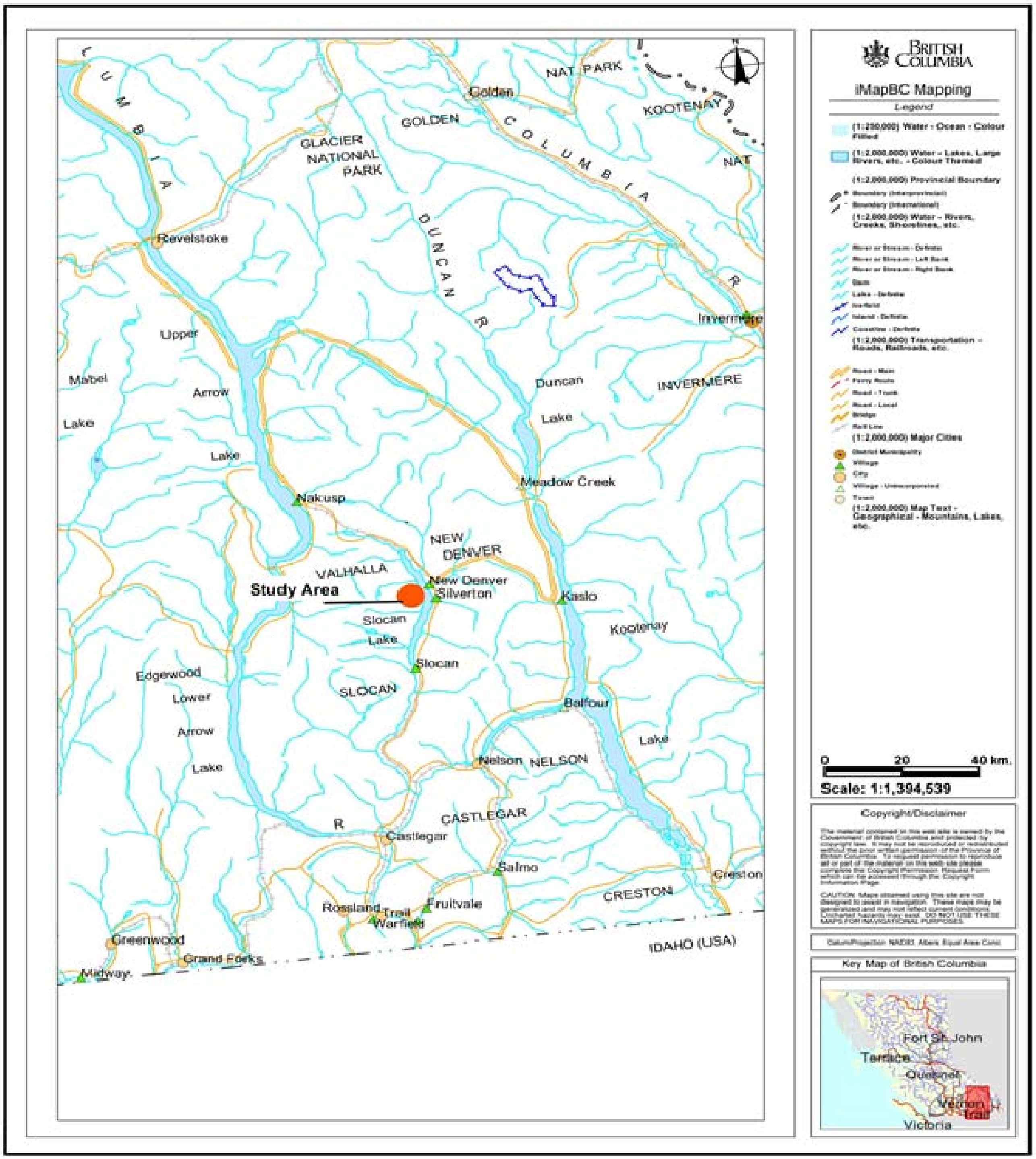


Figure 1: Location of Slocan Lake

3 METHODOLOGY

In 2009, local funding programs began showing interest in funding water quality projects extending over a 3-year period. After consultations with a local Ministry of Environment limnologist (Schindler, pers.com. June 2010), a trend-monitoring program, tailored to Slocan Lake, was designed to monitor the lake's water quality. Trend-monitoring aims at detecting subtle changes over time that may result in potential long-term problems. Measurements are made at regular time intervals to determine if there is evidence of long-term trends in particular variables.

The 2010 Trend-Monitoring Program had two separate components: nearshore and offshore. The former was sampled for bacteriological parameters and the latter for general chemistry, nutrients, total metals and zooplankton. Figure 2 shows the locations of the seven sampling sites for the nearshore component and the four sampling sites for the offshore component.

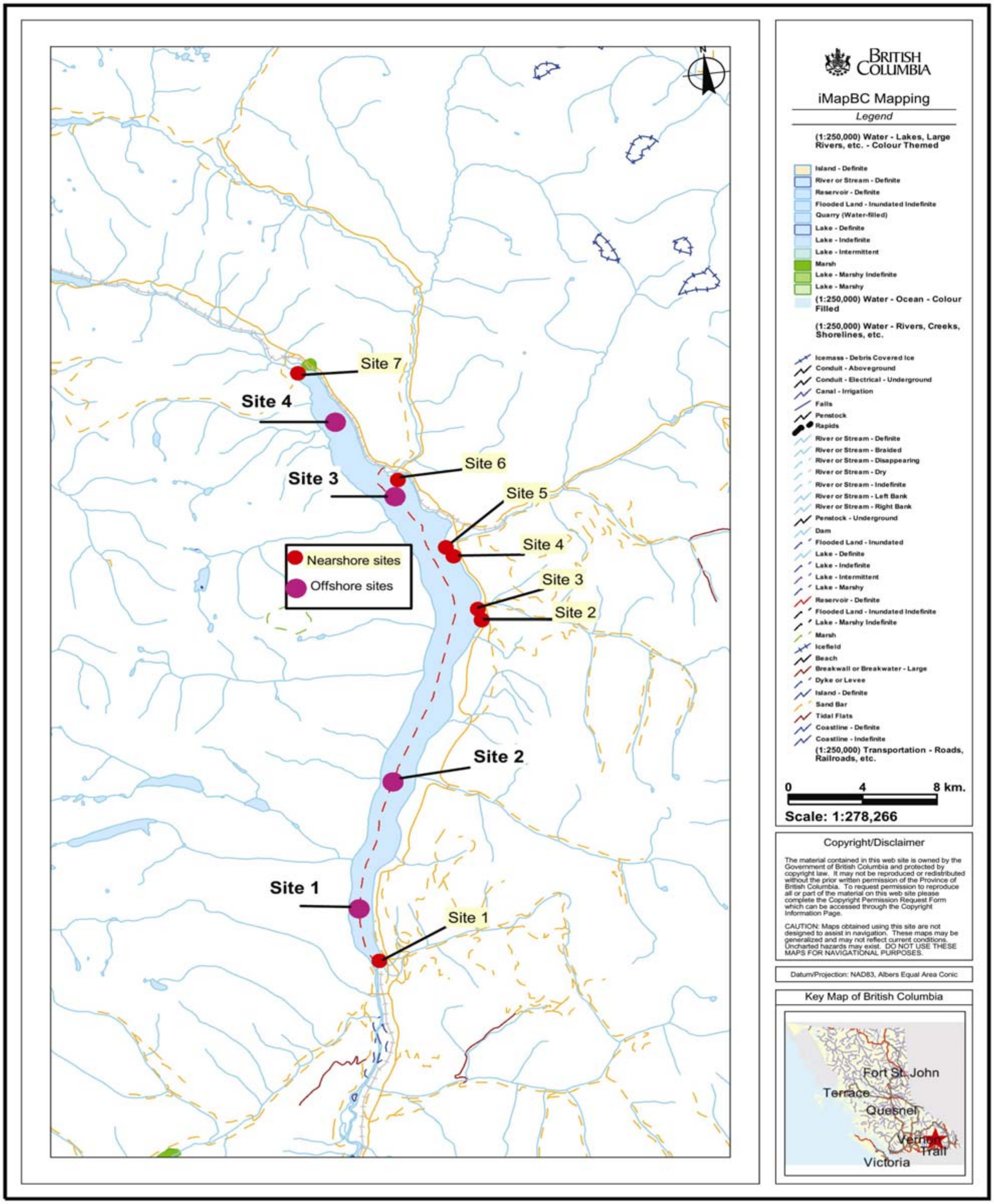


Figure 2: Slocan Lake and the nearshore and offshore sampling sites

3.1 Nearshore Sampling Program protocol

Microbiological monitoring evaluates the degree of contamination from human and animal waste, and wastewater. In 2008, the water samples were analyzed for the presence of fecal coliforms. In the 2010, the nearshore study analyzed total coliforms as well as fecal coliforms.

Site Selection

The same seven sites selected for the 2008 nearshore study were used for the 2010 study (Figure 2). Three criteria were used to select the nearshore sampling sites: their strategic location in front of high population zones (e.g. villages), areas downstream of creek outlets, and sites with high concentrations of macrophyte growth. The main goal of the microbiological water sampling program was to determine the presence of bacteria within the Slocan Lake watershed originating from private septic systems. Defective septic systems or "slow processing" septic systems will leach into groundwater, and bacteria will subsequently be transported into an adjacent creek or lake. According to microbiologist Yeow (pers.comm., 2010), coliforms from leaching septic systems often appear in adjacent surface waters after a heavy rain event. Along with fecal coliforms, leachate from septic systems often releases nutrients into adjacent surface water. Nutrients transported into a stream or a lake can either be assimilated by free-floating plants, stimulating their growth in the water column, or they can settle on the bottom and accelerate the growth of macrophyte roots (Wetzel 1985). Since the Slocan Lake macrophyte population is relatively low, areas that exhibited substantial (that is, higher than normal) aquatic plant growth were chosen as sites for coliform testing, as they suggested the potential presence of leachate.

The sampling station in Slocan (Site 1) was located in front of the public beach, at the end of the breakwater. As the villages of Silverton and New Denver spread out along the lake shore, two sampling sites were selected near each of them; one in front of each town (sites 3 & 5, respectively), one near the mouth of Silverton Creek (Site 2), and one near the mouth of Carpenter Creek (Site 4). Silverton Creek flows through the community of Silverton, while Carpenter Creek flows through New Denver. In Rosebery, Site 6 was located near the mouth of Wilson Creek. Site 7 was located in Hills, in front of the area with the highest concentration of cottages, dwellings and macrophytes (Figure 2). Table 1 describes each of these nearshore sites.

Selection of Parameters

The total coliform group (micro-organisms) includes both fecal coliforms, common to the intestinal tract of both human and warm-blooded animals, and the non-fecal coliforms that are naturally present in soils and vegetation (RISC 1998). Escherichia coli, or E. coli, is a sub-group of fecal coliforms. Total coliforms are one of the standard "indicator" bacteria that have been measured for over 80 years when assessing water quality.

Coliform results are reported as Colony Forming Units (CFU) per 100 millilitres. In general, nearshore sampling stations serve to provide information about substances being brought into a lake from streams, groundwater and runoff, and residential and commercial drainage or sewage.

Table 1: Sampling sites for the Nearshore Program

Nearshore sampling sites	
Site 1-Slocan ☐ located approximately 10m from the shore, at the end of the public dock ☐ Lat: 49⁰ 46′ 10″ N, Lon: 117⁰ 28′ 23″ W ☐ Site is located within the town, in front of the public beach **Site 2-Silverton** ☐ located approximately 15m offshore ☐ Lat: 49⁰ 56′ 54″ N, Lon: 117⁰ 21′ 26″ W ☐ Site is located within the town, in a bay in front of the Silverton Hotel ☐ Site has abundant macrophytes **Site 3-Silverton** ☐ located approximately 20m south of Silverton Creek and approximately 20m offshore ☐ Lat: 49⁰ 57′ 06″ N, Lon: 117⁰ 21′ 44″ W ☐ Site will provide information on coliform transport from septic systems to the creek **Site 4-New Denver** ☐ located in front of the Slocan Lake hospital, approximately 20m offshore ☐ Lat: 49⁰ 58′ 59″ N, Lon: 117⁰ 22′ 31″ W ☐ Site has some macrophytes	**Site 5-New Denver** ☐ located approximately 20m south of Carpenter Creek and approximately 20m offshore ☐ Lat: 49⁰ 59′ 16″ N, Lon: 117⁰ 22′ 48″ W ☐ Site will provide information on coliform transport from septic systems to the creek **Site 6-Rosebery** ☐ located approximately 20m south of Wilson Creek and approximately 20m offshore ☐ Lat: 50⁰ 01′ 44″ N, Lon: 117⁰ 24′ 54″ W ☐ Site will provide information on coliforms transport from septic systems to the creek **Site 7-Hills** ☐ located in front of Hills public beach and cottage area at approximately 15m offshore ☐ Lat: 50⁰ 05′ 18″ N, Lon: 117⁰ 28′ 12″ W ☐ Site has abundant macrophytes

3.1.1 SAMPLING METHODOLOGY

Ideally, bacteriological parameters are measured during both the summer and the fall. Since bacterial growth is temperature dependent, higher water temperatures during the summer contribute to higher concentrations of bacteria. In addition, recreational use (another potential source of coliforms) is also highest during this time. Consequently, sampling was conducted in accordance with the 30-day provincial sampling methodology (Cavanah *et al.* 2004), on August 24th and 31st and on September 10th, 17th and 22nd. All seven sampling stations were sampled on the same day. Weather conditions were recorded in a logbook – on all sampling dates, the water was relatively calm and there was little or no rainfall. Grab samples were collected in sterilized Nasco Whirl Pak sampling bags at a uniform depth, approximately 5 to 10cm below the surface, and approximately 10 to 20m from the shore, depending on the site. A non-motorized canoe was used to collect samples. All grab samples were then shipped the same day, on ice, to an approved laboratory for analysis. Nearshore sampling was entirely conducted by volunteer members of the Slocan Lake Stewardship Society.

3.1.2 ANALYTICAL METHODS & DATA INTERPRETATION

Passmore Laboratory Ltd in Winlaw, which is certified by the Canadian Association for Laboratory Accreditation (CALA), was retained to conduct the analyses and interpretation of the water samples. Analyses were performed in accordance with methods outlined in the *Standard Methods of Examination of Water and Wastewater* (Wallace & Habou-Zamzam 1989). All tests were done using membrane filtration. Passmore Laboratory Ltd also provided the interpretation of the results (Appendix A). Due to the different sampling periods, results from the 2008 study could not be compared with the 2010 study.

3.2 Offshore Sampling Program Protocol

As previously mentioned, the program was designed based on the established Resource Inventory Standards Committee (RISC) standards which are presented in *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia* (Cavanagh *et al.* 2004).

Sampling is conducted within a 6-month period per year, from May to the end of October. Due to the timing of the funding, sampling this year could only start in August. Technical problems with the Hanna multimeter probe also caused a slight delay. Instead of sampling around the 20th of August, September and October as planned, sampling occurred on August 23rd, September 22nd and November 4th. The next portion of the 6-month sampling will be conducted around the 20th of May, June and July 2011.

Site Selection

In order to permit the comparison of data, the 2010 sampling was conducted at the same four sites used in the 2008 water study. These four sites also included the two sampling sites used in the 2000-2001 study (Pieters *et al.* 2006) (Table 2). Site 2 in this study is a duplicate of Site SL2 in the 2000-2001 study, while Site 3 is a duplicate of the 2000-2001 Site SL1. The two new sites added to the 2008 study were identified following the RISC Protocol (1998). Table 2 provides a detailed description of the four sites.

Selection of sampling depths

To allow for valid comparison of data, the same 2008 (Galena 2008) sampling depths were used in the 2010 study.

Selection of Parameters

The selection of water quality parameters for a given monitoring program is dependent on the objectives of the program, the program budget, current and proposed human activities affecting water quality, and watershed characteristics. For these reasons, the type and number of parameters included in a water quality study differ from one lake to another. Variables likely to constitute the most sensitive indicators of potential changes or trends, based on the *Guidelines for Designing and Implementing a Water Quality Program in British Columbia* (Cavanagh 2004), were selected for use in the 2010 program. These include five general chemistry parameters, five nutrients and 29 total metals. Zooplankton sampling was added to the 2010 study. Results of the offshore study were compared to the BC Water Quality Guidelines (BCWQG) for aquatic life and recreational activities. The parameters surveyed are described in Table 3. General parameters can be found in Appendix B, nutrients and total metals results, in Appendix C and zooplankton results in Appendix D.

Table 2: Offshore Sample Sites

Offshore Sample Sites
Site 1 ➢ located 5.3 km north of the town of Slocan, in front of Cape Horn & Evans Creek ➢ Lat: 49^{0} 48′ 51″ N, Lon: 117^{0} 28′ 26″ W
Site 2 ➢ located 11 km north of the lake outlet, slightly downstream of Enterprise Creek ➢ Lat: 490 51′ 46″ N, Lon: 117^{0} 26′ 17″ W ➢ Site is the same as Site # SL2 in the UBC-MOE collection of reports
Site 3 ➢ located 23.2 km north of the lake outlet, slightly upstream of Wee Sandy Creek ➢ Lat: 500 00′ 35″ N, Lon: 117^{0} 24′ 39″ W ➢ Site is the same as Site # SL1 in the UBC-MOE collection of reports
Site 4 ➢ located 27.6 km north of the lake outlet, in front of Shannon Creek ➢ Lat: 500 04′ 20″ N, Lon: 117^{0} 27′ 22″ W

Table 3: Water parameters sampled during the offshore study

General Chemistry	Nutrients	Total Metals		
Water Temperature	Nitrite as N	Aluminum	Antimony	Arsenic
Dissolved Oxygen (DO)	Nitrate as N	Barium	Beryllium	Bismuth
Conductivity	Total Nitrogen	Boron	Cadmium	Calcium
pH	Total Phosphorus	Chromium	Cobalt	Copper
Total Dissolved Solids (TDS)	Chlorophyll-a	Iron	Lead	Magnesium
		Manganese	Molybdenum	Nickel
		Potassium	Selenium	Silicon
		Silver	Sodium	Tin
		Titanium	Uranium	Vanadium
		Yttrium	Zinc	

General chemistry

Parameters described as 'General chemistry' are used as the basic indicators to gauge the quality of a lake. These include temperature, pH, dissolved oxygen, conductivity and total dissolved solids.

Nutrients

Assessing the level of nutrients is an important factor in determining lake productivity. Lake water quality is strongly influenced by the relative abundance of nutrients. A moderate amount of nutrients enhances the lake ecosystem by providing a food source for living organisms. Too few nutrients render a lake incapable of sustaining life, while an overabundance of nutrients leads to an overproduction of life forms and the suffocation of a lake.

Total Metals

Metals are naturally occurring elements found in the earth's crust and are present in ground water at different concentrations based on the geologic properties of the surrounding rocks and soils. Higher concentrations of metals in water may be due to human activities such as mining or industry. Metals are also good tracers of a wide range of industrial activities.

Zooplankton

Freshwater lakes contain a richly diverse array of microscopic and macroscopic animals existing as free-swimming or suspended forms, and collectively known as zooplankton. The most significant groups of freshwater zooplankton are the cladocerans, copepods, protozoa, and rotifers. Although they are tiny, the relative abundance and diversity of these organisms dramatically influences energy flow, nutrient cycling, and community dynamics within aquatic ecosystems. Prior to the present study, zooplankton had only been sampled once in Slocan Lake; in 200-2001 (Wilson & Dolecki 2002), in collaboration with the Pieters 2000-2001 limnology study (2006).

3.2.1 SAMPLING METHODOLOGY

The offshore sampling was conducted entirely by volunteers and members of the SLSS. The sampling crew was comprised of a boat operator and a team of two or three samplers. Three sets of samples were collected once a month during three months (Table 4). Sampling was conducted on August 23, September 22 and November 4, 2010. A motorized craft was used for transportation during the entire water sampling program. Sampling at all four sampling stations was generally completed within five hours.

General Chemistry

Monthly readings were taken for the five parameters at each of the four sites. Water temperature, dissolved oxygen, pH, conductivity and total dissolved solids were measured in the field using a Hanna HI9828 multi-meter probe equipped with a 100m cable. Readings were conducted at twelve different depths; every 5 meters from 5m to 60m at each of four sampling stations.

Nutrients

Grab samples for the five nutrients were taken monthly at each of the four sites. Sampling was conducted at two different depths: 5m and 50m. At both depths, samples were obtained using a 4.2 liter Beta bottle attached to a 60m marked cable. Water was then poured into pre-identified bottles and shipped by courier to the laboratory.

Total Metals

Grab samples for the 29 total metals were taken once, on sites 1 and 4 during the August sampling. Sampling was conducted at two depths: 5m and 50m. At both depths, samples were obtained using a 4.2 liter Beta bottle attached to a 60m marked cable. Water was then poured into pre-identified and preserved bottles and shipped by courier to the laboratory.

Zooplankton

Grab samples were collected each month at three sampling sites; sites 1, 2 and 3. Sampling was conducted using a Wisconsin Net attached to a 42m cable. The 150µm mesh Wisconsin net had a 0.5m throat diameter and a 74µm mesh window for straining water from the collection cup. Samples were hauled vertically from a depth of 40m to the surface. Each sample was placed in a 250 mL glass jar and preserved in 90% isopropanol before being sent by courier to the laboratory.

Table 4: Offshore Sampling Summary

Sampling Site	Location	Sampling Frequency	Sampling Depth	Parameters Sampled
Site #1	South of Evans Creek	Once in August, September, and November	Every 5 meters, from surface to 60m:	General chemistry: temperature, dissolved oxygen mg/L and %, pH, conductivity, total dissolved solids
		Once in August, September, and November	5 m and 50 m:	Nitrate, Nitrite, Total Nitrogen, Total Phosphorus, Chlorophyll-a
		In August only	5 m and 50 m:	Total Metals
		Once in August, September, and November	40 m:	Zooplankton collection
Site #2	Upstream (north) of Site #1, close to Enterprise Creek	Once in August, September, and November	Every 5 meters, from surface to 60m:	General chemistry: temperature, dissolved oxygen mg/L and %, pH, conductivity, total dissolved solids
		Once in August, September, and November	5 m and 50 m:	Nitrate, Nitrite, Total Nitrogen, Total Phosphorus, Chlorophyll-a
				No Total Metals sampling
		Once in August, September, and November	40 m:	Zooplankton collection
Site #3	Upstream of Site #2, close to Wee Sandy Creek	Once in August, September, and November	Every 5 meters, from surface to 60m:	General chemistry: temperature, dissolved oxygen mg/L and %, pH, conductivity, total dissolved solids
		Once in August, September, and November	5 m and 50 m:	Nitrate, Nitrite, Total Nitrogen, Total Phosphorus, Chlorophyll-a
				No Total Metals sampling
		Once in August, September, and November	40 m:	Zooplankton collection
Site #4	Upstream of Site #3, close to Wragge Creek	Once in August, September, and November	Every 5 meters, from surface to 60m:	General chemistry: temperature, dissolved oxygen mg/L and %, pH, conductivity, total dissolved solids
		Once in August, September, and November	5 m and 50 m:	Nitrate, Nitrite, Total Nitrogen, Total Phosphorus, Chlorophyll-a
		In August only	5 m and 50 m:	Total Metals
				No Zooplankton sampling

3.2.2 ANALYTICAL METHODS & DATA INTERPRETATION

Analytical Methods

Eco Tech Laboratory Ltd (Stewart Group Geochemical & Assay) from Kamloops was retained to conduct the water sampling analysis for the nutrients and total metals. The Reported Detection Limit (RDL) denotes a value below which the parameter cannot be reliably differentiated from zero, determined by the level of resolution of the method or equipment used for analysis. The detection limit for each parameter can be found in Table 5, and EcoTech results in Appendix B.

Dr Lidija Vidmanic, from LIMNO Lab. Ltd in Vancouver, conducted the analysis for the zooplankton species composition, density and biomass. Samples were re-suspended in tap water filtered through a 74 µm mesh and sub-sampled using a four-chambered Folsom-type plankton splitter. Splits were placed in gridded plastic petri dishes and stained with Rose Bengal to facilitate viewing with a Wild M3B dissecting microscope (at up to 400X magnification). Zooplankton samples were analyzed for species density and biomass (estimated from empirical length-weight regressions, McCauley 1984). For each replicate, organisms were identified to species and the organisms of the predominant species were counted (the count was discontinued once it reached 200). If 150 organisms were counted by the end of a split, a new split was not started. The lengths of 30 organisms of each species were measured for use in biomass calculations, using a mouse cursor on a live television image of each organism. Lengths were converted to biomass (µg dry-weight) using empirical length-weight regression from McCauley (1984)

Data Interpretation

Interpretation for the general chemistry, nutrients and total metals was conducted by Galena Environmental Ltd. and were compared to the *BC Water Quality Guidelines for Protection of Aquatic Life and Recreational Uses* (RICS 1998) outlined on the Ministry of Environment website. Data was also compared to the two previous 2000-2001 (Pieters *et al.* 2006) and to the 2008 (Galena 2008) Slocan Lake water studies.

Interpretation for the zooplankton results was conducted by LIMNO Lab Ltd. Zooplankton species were identified with reference to taxonomic keys (Sandercock and Scudder 1996, Pennak 1989, Wilson 1959, Brooks 1959). Zooplankton results were compared to the 200-2001 study. Results and interpretation can be found in Appendix D.

Table 5: Eco Tech Laboratory Detection Limits (D.L.) for nutrients and total metals

Nutrients			
Parameters	**D.L. (mg/L)**	**Parameters**	**D.L. (mg/L)**
Nitrate	0.003	Total Phosphorus	0.003
Nitrite	0.003	Chlorophyll-a	0.0005
Total Nitrogen	0.05		
Total Metals			
Parameters	**D. L. (mg/L)**	**Parameters**	**D. L. (mg/L)**
Aluminum	<0.001	Manganese	<0.001
Antimony	<0.001	Molybdenum	<0.001
Arsenic	<0.0002	Nickel	<0.001
Barium	<0.001	Potassium	<0.01
Beryllium	<0.0001	Selenium	<0.0001
Bismuth	<0.001	Silicon	<0.01
Boron	<0.01	Silver	<0.000005
Cadmium	<0.000001	Sodium	<0.01
Calcium	<0.01	Tin	<0.0001
Chromium	<0.0001	Titanium	<0.007
Cobalt	<0.0001	Uranium	<0.001
Copper	<0.0001	Vanadium	<0.0001
Iron	<0.000005	Yttrium	<0.001
Lead	<0.0005	Zinc	<0.0001
Magnesium	<0.0001		

3.3 Quality assurance (QA) & Quality control (QC)

Quality assurance (QA) and quality control (QC) were essential components of this water quality sampling program. The QA/QC program was used to define confidence levels in the results. The Quality Assurance (QA) is a system of activities that ensure a water study will meet defined standards of quality. Separate QA programs exist for both the field sampling procedures (collection, preservation, filtration and shipping components) and analytical procedures (laboratory component). Therefore, QA is essentially the management system that operates to ensure credible results. The quality control (QC) component of this system is a set of activities intended to control the quality of the data from collection through to analysis. It consists of day-to-day activities such as: the adherence to written protocols; up-to-date and suitable training of personnel; the use of reliable, well maintained and properly calibrated equipment; the regular use of QC samples (blanks, reference samples, spikes and replicates); and diligent record keeping. The prime objective of the field QA program was to maximize accuracy by reducing introduced variability. Imprecise data is primarily the result of inconsistent field techniques and lab analysis, and the introduction of contaminants. Therefore, the best means of ensuring high precision is to maintain consistency during the sample collection, filtration, preservation and analytical processes.

3.3.1 QUALITY ASSURANCE

Nearshore Study

Before starting the nearshore sampling, field volunteers were trained to ensure sampling uniformity and accuracy. Whirl Pak sterilized sampling bags were issued by Passmore Lab. Prior to sampling, volunteers were properly trained to handle the Whirl Pak sampling bags to avoid contaminating them, and every precaution was taken to avoid contamination of the grab samples from turbulence caused by the boat. Samples were collected at the same locations at the seven samples sites. Samples, protected in ice, were delivered to Passmore Lab the same day they were collected. The 2010 field budget did not allow for field blank samples, but the laboratory performed two Reference Samples that were used to document the bias and precision of the analytical laboratory process.

Offshore Study

Before undertaking the sampling program, field volunteers were trained by a professional biologist to maintain consistency, to be diligent in collecting, preserving and shipping samples, and to ensure an accurate and uniform sampling methodology. Sampling, field measurement readings and data recording were conducted by the same five persons during the entire survey. To avoid sample contamination during the grab samples at 5 and 50m depth, the inside of the beta bottle was rinsed with distilled water before the beginning of each sampling day. Samples were sent by courier to Eco Tech Laboratory Ltd in Kamloops and to LIMNO Lab. Ltd in Vancouver, where they arrived the same day or the morning after they were collected.

Sample bottles and preservatives for the nutrients and metals were issued by Eco Tech Lab. Field blanks were submitted for nutrients and total metals. Field blanks were exposed to the sampling environment at the sample site and handled in the same manner as the real sample (e.g., preserved, filtered). Consequently, they provide information on contamination resulting from the handling technique and from exposure to the atmosphere. Field blanks are usually submitted after a certain number of samples are collected in the field. In this case, field blanks were submitted only once to the laboratory since they are usually collected every 20th sample.

Replicate samples were submitted for zooplankton. Replicate samples are often collected at one or more sites to assess precision of the entire program (field and laboratory components). The use of replicates assumes that the variability among replicates is affected by the sampling method or technician. In most cases natural variability (heterogeneity) between samples collected in close succession at a single point will be low. Replicate samples were submitted each month for the three sampling sites.

3.3.2 QUALITY CONTROL

Nearshore Study

Precautions were taken to ensure that the same 2008 sample sites were used in the 2010 study and that there was no contamination of the grab samples from turbulence caused by the canoe. Before each sampling day, laboratory personnel were notified that the samples would shortly be delivered to them. Samples were analyzed at the laboratory in conjunction with quality control measures to ensure data accuracy and quality.

Offshore Study

To ensure accurate readings of temperature, dissolved oxygen, pH, conductivity and total dissolved solids, the Hanna HI9828 multi-meter probe was recalibrated prior to each sampling field trip with calibration solution provided with the multi-meter probe kit. A professional biologist was on site two of the three sampling days. The third sampling day, a trained and experienced volunteer was in charge of the sampling. Prior to sampling, site locations were verified with a handheld GPS. Equipment was cleaned and calibrated regularly during the entire program. During the sampling period, weather conditions remained good and there was no turbulence due to wave action. Precautions were taken during deep-water sampling to ensure that there was no contamination from the boat. At the lab, samples were analyzed in conjunction with quality control samples to ensure data of high quality.

4 RESULTS & ANALYSIS

4.1 Microbiology

Coliforms are rod-shaped, non-spore forming organisms that are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. Their presence serves as an indication that other pathogenic organisms of fecal origin may be present. These include other bacteria, viruses, protozoa (Giardia, Cryptosporidium) and multicellular parasites. Total coliforms indicate contamination from plant e.g. algae, decaying leaves, vegetation and/or warm blooded animal source. Fecal coliforms indicate contamination from warm blooded animal source. The list of bacteriological parameters and the water quality guidelines for aquatic life and recreational activities are provided in Table 6 below. The Passmore Lab results can be found in Appendix A.

Table 6: Water Quality Guidelines for Microbiological Parameters (WQG)

Parameters	Aquatic Life (Lakes) Allowable Concentrations	Recreational (Lakes) Allowable Concentrations
Fecal Coliform	Not applicable	less than or equal to 200 CFU/100ml
E. coli	Not applicable	less than or equal to 77 CFU/100ml
Total Coliforms	Not applicable	less than or equal to 500 CFU/100ml

Results

Total coliforms were found at each of the seven sampling sites (Table 7). Of all the sites, Slocan and Hills had the most total coliforms: >300CFU/100ml for Slocan and 62CFU/100ml for Hills. The high coliform count in Slocan on September 10 is probably due to spoiling of the sample. On September 10, sampling in Slocan was conducted twice within the span of a few minutes due to a mechanical problem. This may explain the high coliform count that day. Two fecal coliforms were found in Slocan and one in Hills. Of the three fecal coliforms, all were identified as E.coli.

Total and fecal coliform results show higher concentrations in Slocan and Hills than at the five other sites. Figure 3 shows total coliforms, as there did seem to be some correlations between sites and counts, i. e., Slocan & Hills consistently higher.

Table 7: 2010 Nearshore Sampling Results

	Sampling Dates / Total and Fecal Coliform Results									
	August 24, 2010		August 31, 2010		September 10, 2010		September 17, 2010		September 22, 2010	
	Total	Fecal	Total	Fecal	Total	Fecal	Total	Fecal	Total	Fecal
1. Slocan	1	0	17	0	> 300	0	40	0	11	2*
2. Silverton Resort	0	0	7	0	15	0	4	0	0	0
3. Silverton Creek	0	0	5	0	5	0	4	0	0	0
4. New Denver Hospital	1	0	0	0	2	0	6	0	0	0
5.Carpenter Creek	0	0	2	0	11	0	5	0	0	0
6. Wilson Creek	0	0	3	0	8	0	16	0	2	0
7. Hills	0	0	4	0	15	0	24	0	19	1*
8. QA/QC	0	0								
Total	1	0	38	0	> 300	0	99	0	32	3

* Confirmed for positive E.coli using MUG

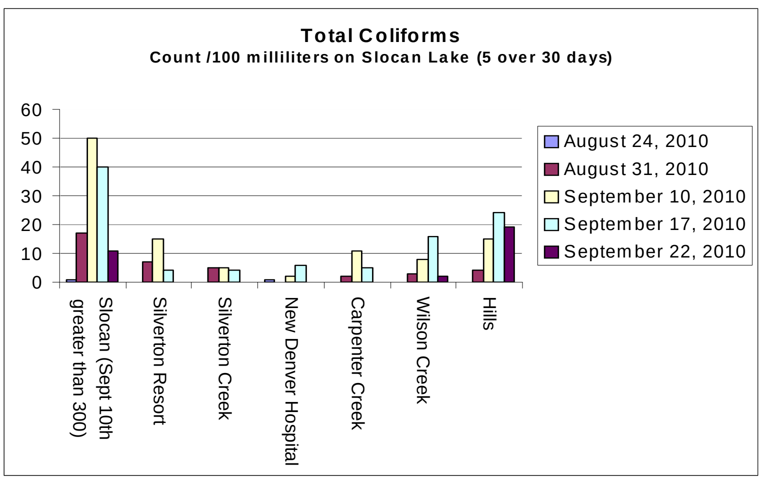


Figure 3: Total coliforms for seven sampling sites on Slocan Lake

4.2 General Chemistry

A large, deep lake such as Slocan Lake cannot be expected to be homogeneous, and it is consequently not unusual for readings of one particular parameter to differ from site to site. As long as the values are not close to or do not exceed the guidelines, there is no cause for concern. The list of general parameters, and water quality guidelines for aquatic life and recreational activities is provided in Table 8. Summary results can be found in Appendix B.

Table 8: Water Quality Guidelines for General Chemistry (WQG)

		Aquatic Life (Lakes)		Recreational (Lakes)
Parameters	**Specifications**	**Considerations**	**Allowable Concentrations**	**Allowable Concentrations**
Water Temperature	°C (Celsius)	General aquatic life	±1 degree Celsius change from natural ambient background	30^{0}C maximum
Dissolved Oxygen (DO)	Instantaneous minimum (water column mg/L)	All aquatic life stages other than buried embryo/fry	minimum 4.5	No guideline
Conductivity	µS/cm	General aquatic life	No guideline	No guideline
PH	Known pH range from 6.5 to 9 (pH units)	General aquatic life: This component of the freshwater guidelines should be used cautiously if the pH change causes the carbon dioxide concentration to decrease below a 10 µmol/L minimum or exceed a 1360 µmol/L maximum	Unrestricted change permitted within this range minimum and maximum between 6.5 to 9	6.5 to 8.5
Total Dissolved Solids (TDS)			No guideline	No guideline

4.2.1 Water Temperature

Water temperature is a critical factor for all forms of aquatic life, directly affecting the activity and physiological processes of fish and invertebrates during all of their life stages. Increases in water temperature can also encourage the replication of pathogenic organisms in both fish and humans. It also has a direct influence on the toxicity of certain chemical parameters, such as ammonia, and on the solubility of chemical compounds. In particular, dissolved oxygen (DO) and water temperature are closely related parameters. The solubility of oxygen is affected by temperature, and increases considerably in cold water. High water temperatures increase the metabolic oxygen demand which, in conjunction with reduced oxygen solubility, impacts many species (RISC 1998).

Results

Results in Figure 4 show average water temperature at the four sampling sites. Water temperatures vary from 19 to 4.25ºC in August, from 15.06 to 4.34ºC in September and from 11.35 to 4.31ºC in November. The well-established thermocline can be observed between approximately 15 and 30m in August and September. In November, the thermocline zone seeps lower down due to cooling and water layer mixing.

In August, maximum summer surface temperatures were around 19ºC (Figure 5). Slocan Lake water temperatures were generally similar for the four sites over the study period (Figure 5). Below 15m, August water temperatures were cooler at Site 1 than at the other sites, which may be due to the proximity of Evans Creek, one of Slocan Lake's major creeks located upstream of the sample site. All sites had similar water temperatures below 35m, in August and September. In November, cooler air temperatures, rain events and wind mixing resulted in different water temperatures within the metalimnion layer (thermocline), for the four sampling sites (Figure 5). Figure 5 also shows the increasing depth of the thermocline layer in November. Between depths of 20m and 40m, Site 3 was colder than the other sites. All temperatures in the hypolimnion, below 55m, were under 5ºC.

Even during the summer, water temperatures for aquatic life and recreational use were all below the provincial allowable range (Appendix B & Table 8). Summer high water surface temperatures can cause stress in fish, but the cool and well oxygenated thermocline and hypolimnion of deep lakes like Slocan Lake will compensate for that and provide refuges for fish.

Temperature readings during September and November 2010 are comparable with September and November 2008 readings and with the temperature data from for August, September and November 2000-2001 Pieters study (*et al.* 2006). All water temperatures met requirements set in the aquatic life and recreational guidelines.

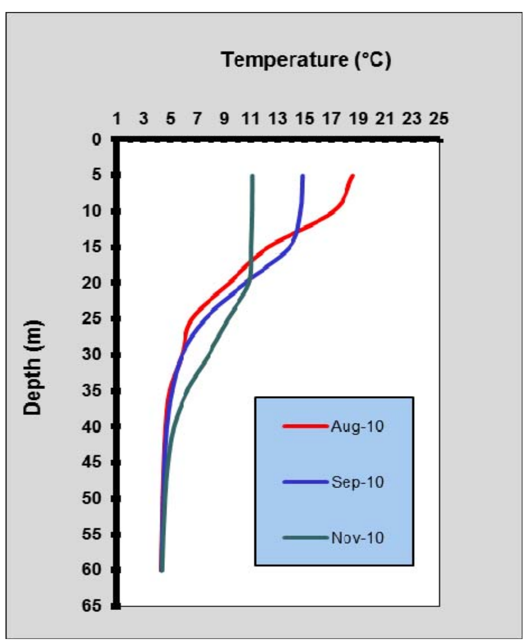


Figure 4: Average water temperature for the four sampling sites for August, September and November 2010

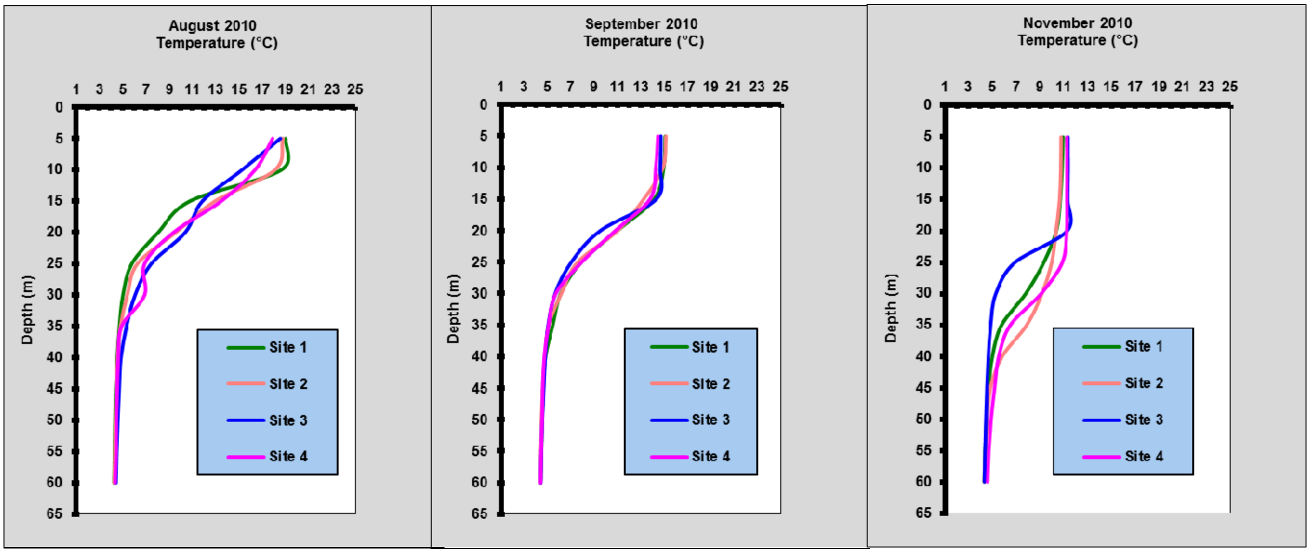
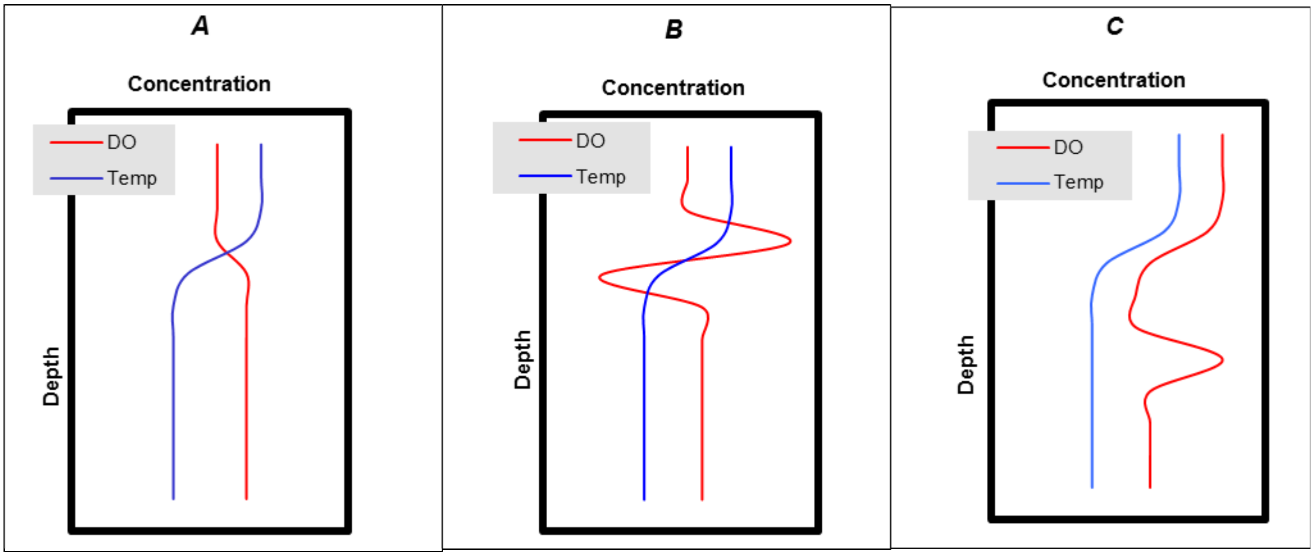


Figure 5: Water temperature profiles for each sampling site

4.2.2 DISSOLVED OXYGEN (DO)

As mentioned previously, dissolved oxygen and temperature are closely-related parameters. As temperature increases, oxygen solubility decreases. Photosynthesis and respiration are other factors that influence oxygen concentrations. Photosynthesis is the process whereby plants and algae use light energy to fix carbon. This process takes place only during the daylight hours and results in the release of oxygen. During the night, these same plants and algae consume oxygen. As a result, the levels of DO may vary over the course of a day depending on photosynthesis and respiration rates. Dissolved oxygen concentrations are also determined by the physical processes which permit gas exchange with the atmosphere. The weather can be an important factor influencing DO concentrations during sampling. Clear, calm, warm weather will result in reduced water column mixing and thus in a greater temperature gradient from surface to lake bottom and, correspondingly, greater dissolved oxygen gradients. DO is measured in mg/L and also as a percentage of saturation.

Taken from Horne and Goldman (1994), Figure 6 shows three different types of oxygen distribution with depth. The orthograde and heterograde curves in these generic oxygen patterns will help to understand the Slocan Lake patterns.



(A) Orthograde curve typical of an unproductive lake.
(B) Positive and negative heterograde curves. Photosynthesis from a layer of algae just above the thermocline raises oxygen in the upper part of the water column.
(c) Anomalous curves due to high inflow of dense, cool, oxygen-rich stream inflows.

Figure 6: Types of oxygen distribution with depth (after Horne & Goldman 1994)

Oligotrophic lakes, such as Slocan Lake, are typically nutrient poor, with dissolved oxygen concentrations near 100% saturation, indicating that those concentrations are minimally affected by biological processes, such as photosynthesis and respiration, and primarily affected by atmospheric exchange. In a lake in which water quality is declining due to an increase in nutrient loads, there are greater variations in dissolved oxygen concentrations. In an oligotrophic system, dissolved oxygen concentrations are determined by physical processes namely gas exchange with the atmosphere. As a result, warm surface water dissolved oxygen concentrations are reduced when compared to the colder water layers. Lower concentrations near the surface are a result of lower oxygen solubility associated with water with higher temperatures.

Results

Dissolved oxygen levels in Figure 7 indicate that Slocan Lake is well oxygenated throughout, consistent with an oligotrophic system. DO concentrations vary from 0 to 11.68mg/L in August, from 4.55 to 16.81mg/L in September and from 4.33 to 11.0mg/L in November. Figure 6 (graph A) demonstrates the typical orthograde curve for such a lake. In general, the DO curves at the four sites are consistent with the temperature and dissolved oxygen patterns typical of large oligotrophic lakes in summer and early fall (Figure 7).

In August, DO concentrations in the entire water column were extremely reduced at sites 1 and 2. When compared with the other sites, these results may indicate an oxygen sensor problem. In September, Site 4 also showed a different pattern from the other sites. Where decreased oxygen is evident in the hypolimnion, as at Site 4, this is primarily due to the biological oxidation of organic matter in the water and especially at the sediment-water interface, where bacterial decomposition is greater (Wetzel 1985). According to Horne and Goldman (1994), the hypolimnion layer is rarely offset by renewal mechanisms of circulation and photosynthesis that occur in the upper water layers such as the metalimnion and the epilimnion. A DO wavy pattern can be observed in the hypolimnion at all sites in September. As shown in Figure 6 (graph C), these types of anomalies, or wavy patterns, can be associated with the introduction, at intermediate depths, of inflow waters that have a different oxygen concentration in the lake.

Horizontal distribution (where the temperature line meets the oxygen line) of the oxygen profile in the hypolimnion varies slightly at the four sites during the same sampling month. Sites 2 and 4, in November, show a lower horizontal distribution of the oxygen profile. Those changes may have been affected by vertical turbulence and density currents that move along the basin sediments.

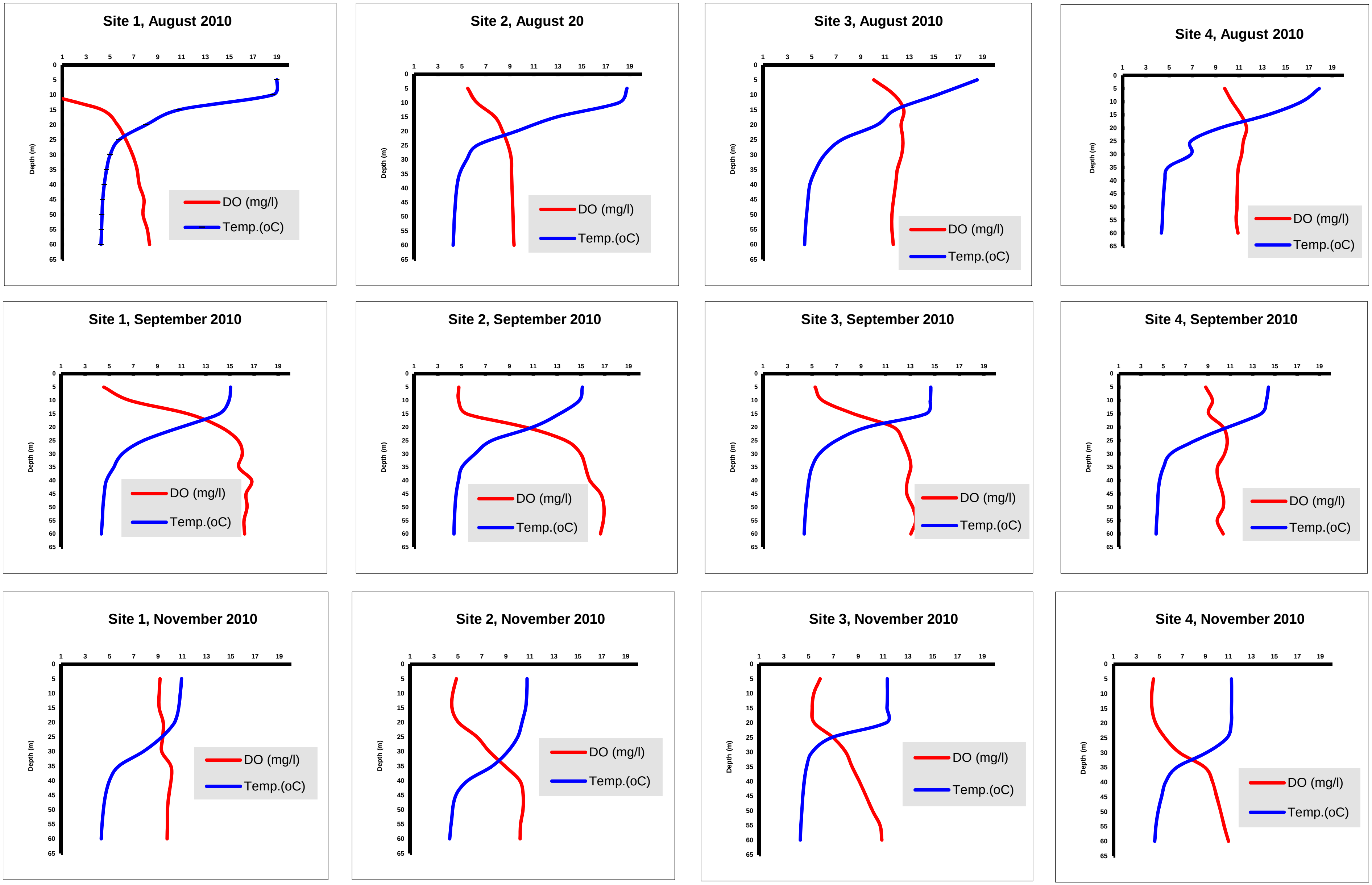


Figure 7: Temperature and dissolved oxygen profiles at four sampling sites for August, September and November 2010

As shown in Figure 8 below, results revealed high average dissolved oxygen levels in the metalimnion and hypolimnion layers, typical of an oligotrophic lake such as Slocan Lake. Average concentrations are uniformly high and exhibit a significant vertical stratification in August and September.

The DO profiles in Figure 8 demonstrate an orthograde DO curve typical of large oligotrophic lakes in the late summer, early fall. Reduced concentrations near the surface are a result of lower oxygen solubility with increased water temperature. With higher water temperatures in the upper layer (epilimnion), DO is less soluble, and with decreasing temperatures in the middle layer (metalimnion), DO solubility and concentrations increase. In the deepest layers, temperatures decreased rapidly but changes in DO concentrations were less dramatic.

DO concentrations are comparable to those registered in the 2008 (Galena 2008) and 2000-2001 (Pieters *et al.* 2006) water studies. Except for the August sampling, where DO readings were abnormally low due to a technical problem with the probe, DO readings in general were higher than the minimum DO concentrations set out by the provincial water quality guidelines for aquatic life.

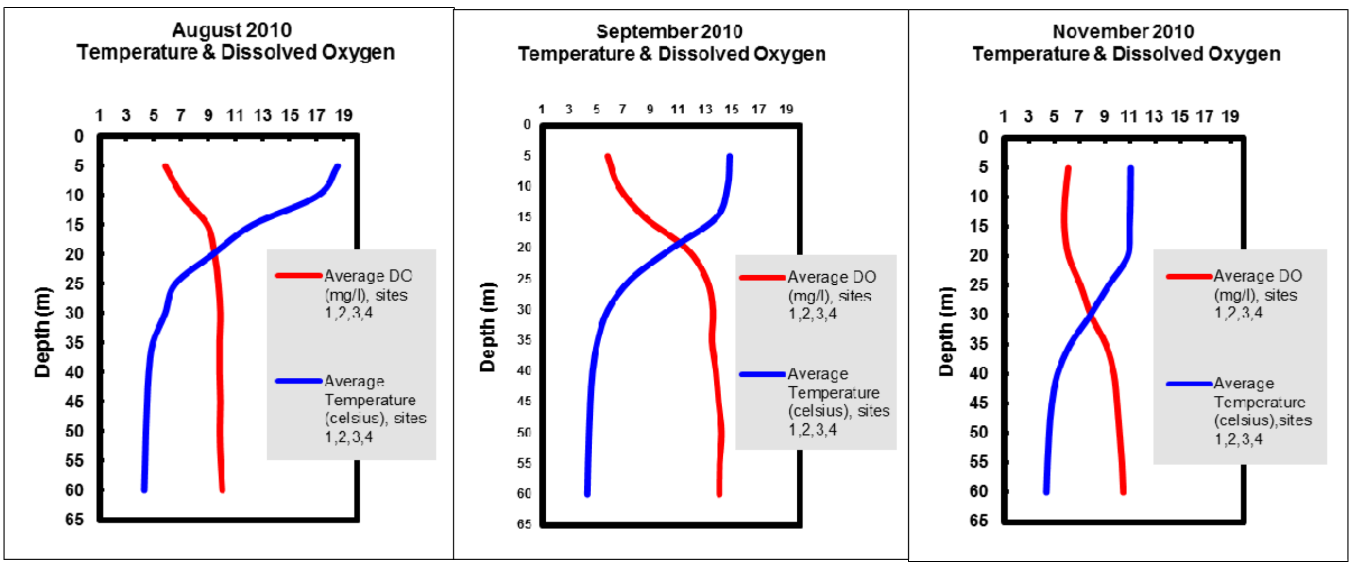


Figure 8: Average temperature and dissolved oxygen (DO) for August, September and November 2010 sampling

4.2.3 SPECIFIC CONDUCTIVITY (C25)

Conductivity, or specific conductance, is a measure of the resistance of an aqueous solution to electrical flow. Basically, the greater the ion content in the water, the higher its ability to conduct electricity. Conversely, the purer the water, the greater its resistance to electrical flow. Temperature can affect conductivity, and for this reason specific conductance (rather than simple conductance) is used, because this measurement compensates for temperature. The temperature of the electrolyte affects the ionic velocities; conductance increases about 2 per cent per ºC. Specific conductance measures the ability of water at 25ºC to conduct electricity and reflects the total concentration of dissolved ionic particles in the water. Other influences include increased flows resulting from freshets which dilute the ions and consequently decrease specific conductivity. Pollutants in the water will generally increase water conductivity.

Due to the high natural variability in conductivity, there are no set water quality guidelines to assess this parameter for recreation or aquatic life. Specific conductivity in freshwater lakes in the interior of British Columbia typically varies between 50 and 500 µs/cm (Pieters *et al.* 2006). Conductivity is measured in micro Siemens (µs/cm).

Results

From the surface to a depth of 60m, the conductivity readings averaged between 88 to 97 µs/cm in August, 59 to 73 µs/cm in September and 41 to 46 µs/cm in November (Figure 9). The August and September conductivity readings were low near the surface and increased at greater depths. The graph for August indicates that the average conductivity in the upper 25m layer likely decreases as a result of the seasonally reduced specific conductance of inflowing tributaries. During the summer, the inflow from rivers and streams is generally colder than the lake surface, descending gradually until it reaches the equivalent density layer (Pieters *et al.* 2006).

In August 2010, lake conductivity was comparable to the average conductivity readings taken during the August 2000-2001 survey (Pieters *et al.* 2006). September and November readings, however, are much lower than during the 2000-2001 study. Low conductivity readings for September and November 2010 for Slocan Lake could be associated with the unusually high levels of precipitation that the lake received (Horne & Goldman 1994). Both the September and November graphs corroborate this explanation. For both months, the conductivity curve is almost linear, indicating a high influx of fresh water into the lake.

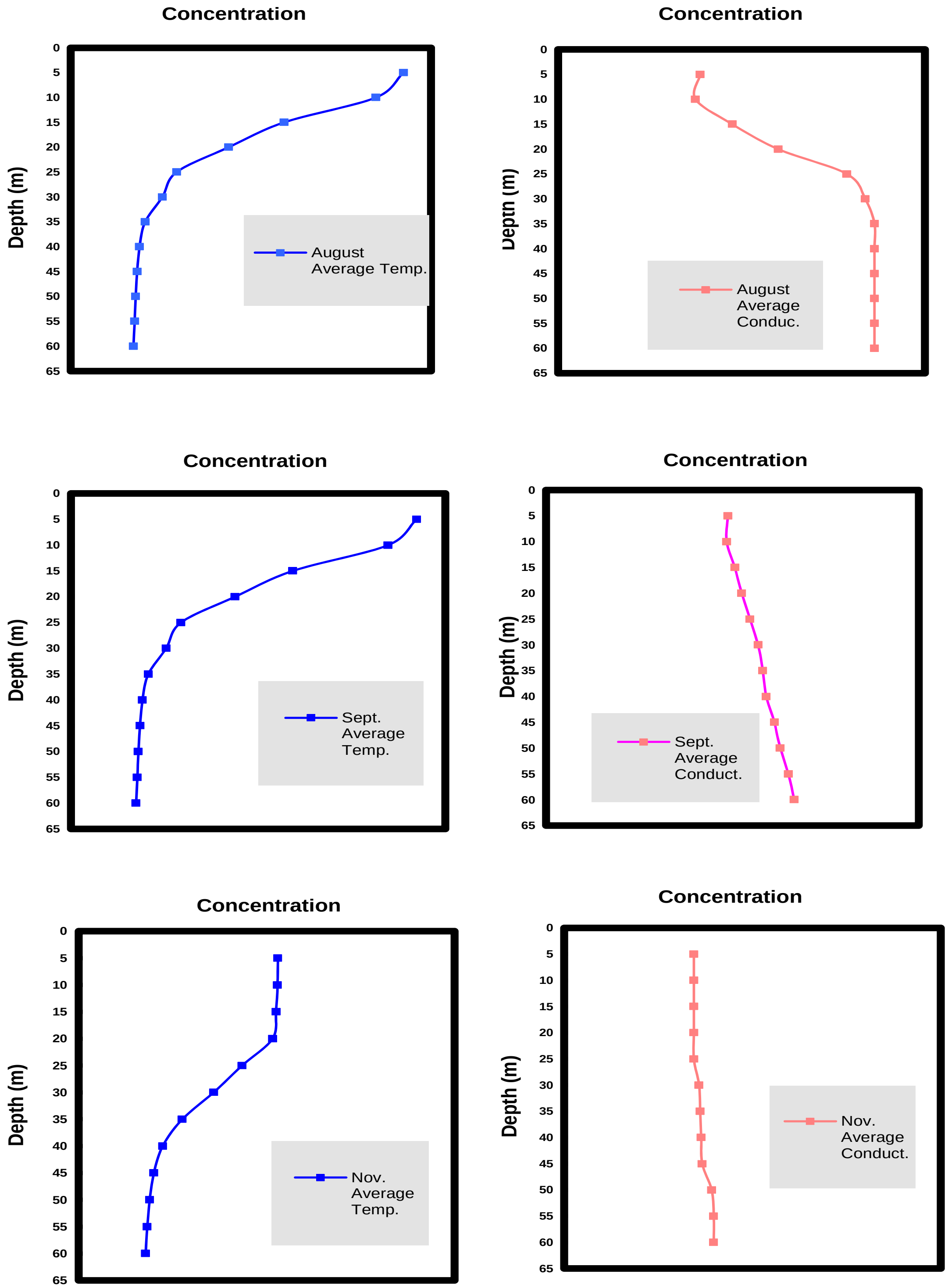


Figure 9: Average Conductivity and Temperature for August, September and November

4.2.4 pH

Natural waters exhibit wide variations in actual pH values. The pH of water determines the solubility and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients phosphorus, nitrogen, and carbon and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH may also determine whether aquatic life can use it. In the case of heavy metals, lower pH increases their solubility which, in turn, increases their toxicity. Lake water is a complex array of interacting components and contains numerous chemical "shock absorbers" that prevent major changes in pH. Small or localized changes in pH are quickly modified by various chemical reactions. This ability to resist change in pH is known as its buffering capacity.

The pH of natural waters ranges between <2 to 12. A pH of less than 7 is considered acidic, while a pH of greater than 7 is considered alkaline. Nearly all waters with pH values less than 4 occur in volcanic regions that receive strong mineral acids. Low pH values are found in natural waters rich in dissolved organic matter, especially in bogs and bog lakes. The range of pH of a majority of open lakes is between 6 and 9. Since lethal effects of most acids begin to appear near pH 4.5 and of most alkalis near pH 9.5, the buffering capacity of the lake can be of major importance in the maintenance of life.

The acidity or alkalinity of lakes is measured in units called pH, on an exponential scale of 1 to 14. The term pH is derived from the French Puissance d'Hydrogène (strength of the hydrogen) because the hydrogen ion H+ controls acidity.

Results

Data collected in 2010 were consistent with the previous studies on Slocan Lake for August, September and November. PH ranged from 7.39 to 7.92 in August, from 7.53 to 8.05 in September and 7.04 to 8.56 in November. Slocan Lake is a moderately alkaline lake with average pH varying from 7.4 to 8. The pH values demonstrated minimal vertical and seasonal stratification at all sample sites (Figure 10).

August and November pH values were slightly higher in the epilimnion than in the deeper hypolimnion layer (Appendix B). This is probably due to decomposition processes that result in increased carbon dioxide (CO2) levels in the hypolimnitic waters with a consequent decrease in pH. September pH readings indicated a different pattern, with values slightly lower in the epilimnion than in the hypolimnion. Like dissolved oxygen concentrations, pH may change according to depth, due again to changes in photosynthesis and other chemical reactions. Photosynthesis uses up dissolved carbon dioxide in the water which reduces the acidity of the water and results in higher pH. Figure 10 shows the overall low vertical variability in average pH values during the three sampling months. This low vertical variability, is often associated with oligotrophic lakes that do not contain high concentrations of bicarbonate and carbonate.

pH readings are comparable with the months of November in the 2008 (Galena 2008) water study and with the months of August, September and November in the 2000-2001 Pieters study (*et al.* 2006). The Pieters study also revealed moderately alkaline average pH levels (averaging 7.4) with little variability. pH levels met the Water Quality Guidelines for both aquatic life and recreational activities.

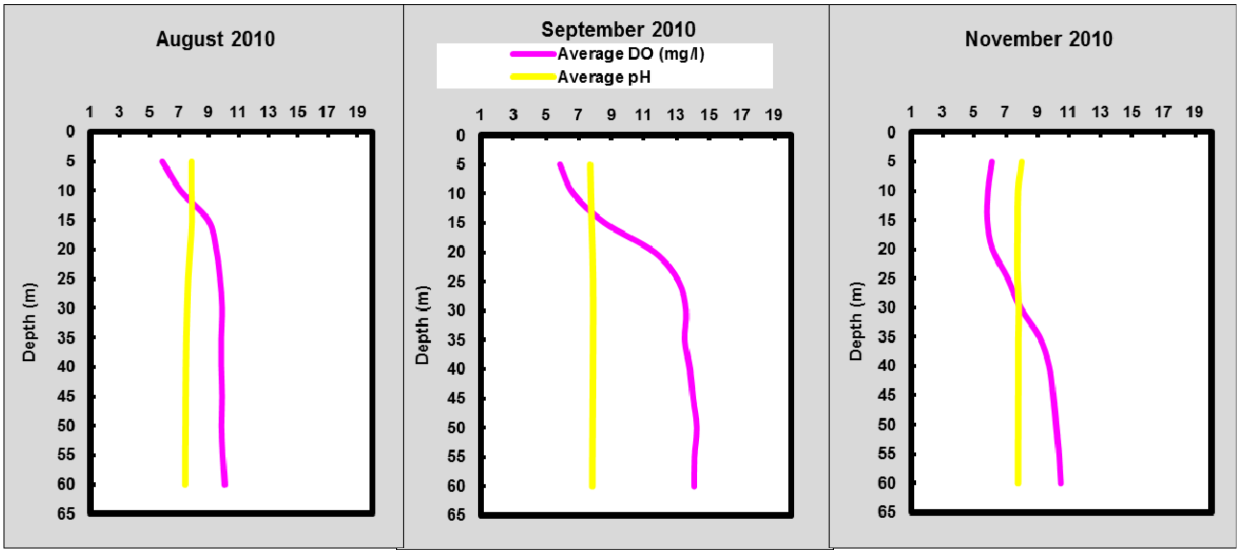


Figure 10: Average pH for August, September and November 2010

4.2.5 TOTAL DISSOLVED SOLIDS (TDS)

Total dissolved solids provide a measure of the productivity of a lake. TDS include both dissolved particles and dissolved organics. TDS are composed primarily of the various inorganic anions (Cl, SO^4,CO^3, HCO^3) and cations (Ca, Mg, Na, K) which are the primary contributors to salinity in surface waters. TDS concentrations are largely a function of watershed geology and climate. TDS is measured in mg/L.

The hydrology, or flow regime, of a watershed determines the amount of water in the system as well as the delivery of soluble compounds to a lake. In general, TDS peak in the late winter and early spring, before the freshet. Sudden high TDS concentrations will be observed when snowmelt runoff, loaded with road salt and sand, enters a lake. As the snowpack continues to melt, TDS input will gradually decline. High values indicate potentially richer, more productive water, whereas lower values indicate potentially cleaner, less productive water. Certain naturally occurring total dissolved solids come from the weathering and dissolution of rocks and soils. Concentrations of TDS in water vary owing to different mineral solubilities in different geological regions. Aquatic organisms require a relatively constant concentration of the major dissolved ions in the water, much as we require relatively constant concentration of certain dissolved ions in our blood and other bodily fluids. Levels too high or too low may limit survival, growth or reproduction.

Results

All readings, from the surface to the hypolimnion, at all the sites were consistently low with little variability (Appendix B & Figure 11). Total dissolved solids in Slocan Lake range from 0.055 to 0.064mg/L in August, from 0.029 to 0.039mg/L in September and from 0.049 to 0.064mg/L in November. In general, most TDS concentrations were slightly higher in the hypolimnion layer. Lower TDS concentrations were observed for September (Figure 11). September TDS results were probably affected by the occurrence of several heavy rain events prior to sampling. Heavy rain events create a decrease in TDS concentrations due to the dilution by all the rainwater.

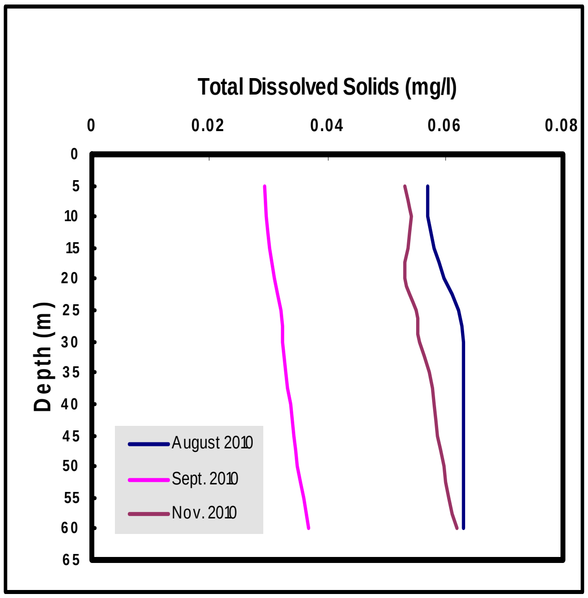


Figure 11: Average Total Dissolved Solids for August, September and November 2010

The 2010 TDS results correspond to the 2008 Slocan Lake water study results for September and November. TDS concentrations were not recorded during the 2000-2001 Slocan Lake water study (Pieters *et al.* 2006). There are no TDS provincial guidelines for aquatic life and recreational activities.

4.3 Nutrients

The term "nutrients" refers broadly to the chemical elements essential to life. Nitrogen, carbon, hydrogen and phosphorous are the major constituents of cellular protoplasm in organisms and of these, nitrogen and phosphorus are most likely to become limiting factors for growth in aquatic environments. This study has consequently focused its analyses on nitrogen and phosphorous. Dominant forms of nitrogen in fresh waters include dissolved molecular nitrogen (N_2), nitrite (NO_2) and nitrate (NO_3). Nitrite is quickly oxidized and rarely accumulates unless organic pollution is high. Nitrate is the common form of inorganic nitrogen entering fresh waters from the drainage basin in surface run-off, ground water and precipitation. It is subsequently assimilated into organic nitrogenous compounds within organisms. During normal metabolism of these organisms, and at death, their nitrogen is liberated as ammonia.

Detection limits and Water Quality Guidelines for aquatic life and recreational activities for nutrients are provided in Table 9. Summary and laboratory results can be found in Appendix C.

Table 9: Detection limits and BC Water Quality Guidelines (BCWQG) for nutrients

Nutrients				
Parameters	**D.L. (mg/L)**	**Aquatic Life (mg/L)**	**Recreational (mg/L)**	**Considerations**
Nitrate	0.003	max 31.3mg/L^{-1}	max 10mg/L	General aquatic life
Nitrite	0.003	max 0.06mg/L-1	max 1mg/L	General aquatic life
Total Nitrogen	0.05	n/a	n/a	
Total Phosphorus	0.003	in the range of 0.005 to 0.015mg/L	max ≤0.01mg/L	Salmonids are the predominant fish species
Chlorophyll-a	0.0005	n/a	n/a	

4.3.1 Nitrate ($N0_3$) & Nitrite ($N0_2$)

Nitrate and nitrite are a part of the nitrogen cycle in lakes. The major source of nitrogen in lakes is nitrate in rainfall and runoff from the watershed. Nitrate levels indicate the total amount of inorganic of nitrogen in the water. Nitrate concentrations below 0.025mg/L are considered limiting to phytoplankton (Wetzel 1985). Nitrite is generally present only in trace quantities in water exposed to oxygen because it is rapidly transformed to nitrate.

In summer, concentrations of these nutrients are often very low. Algae and aquatic plants assimilate nitrite and nitrate, often reducing concentrations to near zero. Water decomposes wastes containing organic nitrogen into ammonia, which is then oxidized into nitrite and nitrate. Because nitrite is easily oxidized into nitrate, nitrate is the compound predominantly found in surface waters (Hammer & Harmmer 2001). While nitrite can be very toxic to humans, it is an unstable form and concentrations are generally low enough to be of no concern (Nagpal *et al.* 2010). Nitrate and nitrite are measured in mg/L.

Nitrate Results

At four sites, nitrate concentrations varied from 0.033 to 0.053mg/L in the epilimnion and from 0.071 to 0.103mg/L at 50m (Table 10). During the three month sampling, nitrate levels were moderate but dropped to a low in September. Low concentrations may be attributed to biological processes that assimilate most of the nitrate nutrient.

Nitrate concentrations were slightly higher in the hypolimnion, likely due to the presence of bacteria in the aquatic sediments and a well aerated hypolimnion accelerating the nitrification process. The autumn 2010 results were generally higher than the ones in the 2008 study. It is highly probable that the higher concentrations in 2010 were due to the several rain events during the autumn. Input from precipitation and runoff will impact nitrate concentrations on a water body. Nitrate levels were slightly higher (mean 0.07mg/L) in 2000-2001 (Pieters *et al.* 2006). The 2000-2001 study also stated that the surface nitrate declines to 0.03-0.04 mg/L in the fall. These concentrations were all below the allowable maximum concentrations for aquatic life and recreation.

Nitrite Results

Nitrite concentrations were low and varied from below the detection limit (<0.003mg/L) to 0.005mg/L in the epilimnion and from below the detection limit to 0.006mg/L at 50m (Table 10). Nitrite is generally present only in trace quantities in water exposed to oxygen, where it is transformed to nitrate. Rain events are probably the cause of the higher concentrations observed in the hypolimnion during November 2010 sampling.

2010 autumn concentrations of nitrite were similar to the 2000-2001 Pieters study (*et al.* 2006) but higher than the concentrations in the 2008 study (Galena 2008). Rain events were rare during the fall of 2008 and consequently rain and runoff had almost no influence on the nitrite concentrations that year. These concentrations were also well below the allowable maximum concentrations for aquatic life and recreation.

Table 10: 2010 Nitrate and Nitrite Results at 5m and 50m

August 2010						September 2010				November 2010			
Depth (m)	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**QA/ QC**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
	Nitrate (mg/L)					Nitrate (mg/L)				Nitrate (mg/L)			
5	.053	.050	.051	.049	.050	.034	.033	.033	.036	.048	.050	.045	.046
50	.100	.102	.101	.101		.071	.074	.077	.080	.095	.097	.103	.095
	Nitrite (mg/L)					Nitrite (mg/L)				Nitrite (mg/L)			
5	.004	.003	.005	.003	.003	.003	.003	.003	<.003	.004	.003	<.003	.003
50	.003	.003	.004	.003		.003	.003	<.003	<.003	.004	.006	.003	.006

<.003 : lower than the detection limit

4.3.2 TOTAL NITROGEN

Nitrogen is an essential nutrient for aquatic plant growth. Total nitrogen is the combined measurement of various forms of nitrogen in water including nitrate, nitrite, ammonia and organic nitrogen. Such nitrogenous compounds, along with other nutrients, serve as an important nutrient base for primary productivity. The lowest total nitrogen levels are recorded in the less productive freshwater lakes.

When the concentration of these nutrients consistently exceeds natural levels, however, a nutrient imbalance is produced. This imbalance can lead to undesirable changes in the biological community and can drive an aquatic system into an accelerated rate of eutrophication. There are no baseline criteria for total nitrogen for aquatic life or recreational use. The established baseline criteria only target individual concentrations of nitrogen, nitrite (as N), nitrate (as N) and ammonia (as N). Total nitrogen is measured in mg/L.

Results

In Slocan Lake, total nitrogen concentrations ranged from <0.05 to 0.353 mg/L in the epilimnion and from 0.07 to 0.10 mg/L in the hypolimnion (Table 11). These concentrations are considered very low and were often below the detection limit in the epilimnion layer. In November, site 4 results showed higher concentrations of total nitrogen in the epilimnion. High nitrogen concentrations were probably influenced by the input of freshwater from the nearby creek (Shannon Creek) provoked by elevated rain events. Tributary inflows will often create subsurface currents and bring higher nitrogen concentrations in the epilimnion of a lake.

Table 11: 2010 Total Nitrogen Results at 5m and 50m

	August 2010					September 2010				November 2010			
Depth (m)	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**QA / QC**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
	TN mg/L					TN mg/L				TN mg/L			
5	0.05	0.05	0.05	0.05	0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.05	<0.05	0.353
50	0.10	0.10	0.10	0.10		0.07	0.07	0.08	0.08	0.10	0.10	0.10	0.10

<0.05 : lower than the detection limit

When comparing the fall data of the 2000-2001 (Pieters *et al.* 2006) and the 2008 (Galena 2008) studies with the 2010 results, the total nitrogen results seem to be lower in 2010. The 2000-2001 survey showed averages of 0.10mg/L in the epilimnion and 0.26mg/L in the hypolimnion. 2008 results revealed epilimnetic averages of 0.09 to 0.14mg/L and 0.12 to 0.14mg/L in the hypolimnion layer. High total nitrogen levels in 2008 were evident throughout the entire lake. This suggests 2008 seasonal changes were related to lake-wide influences such as photosynthetic activity, the tributaries' inflow water quality, weather or other seasonal influences. There are no water quality guidelines for total nitrogen.

4.3.3 Total Phosphorus (TP)

Total phosphorus will not be discussed in this report. Laboratory results show abnormally high concentrations for an oligotrophic lake such as Slocan Lake. High TP results are mostly found in eutrophic lakes. With such high TP concentrations, chlorophyll-a results should be much higher since both nutrients are proportionally related. These results are incorrect and due most probably to laboratory contamination of the samples.

4.3.4 Chlorophyll-a

Chlorophyll-a is a parameter generally used to measure the productivity of a water body. Chlorophyll-a is a pigment that imparts the green color to plants and algae. Algae contain two main groups of pigments; chlorophylls and carotenoids. Within the chorophylls, chlorophyll-a is the only form that can pass electrons, excited by light energy, to produce chemical energy in photosynthesis. A rough estimate of the quantity of algae present in lake water can be made by measuring the amount of chlorophyll-*a* in the water column. Monitoring the chlorophyll-a levels of a lake on a regular basis assists in determining changes in trophic status and aquatic ecosystem health.

The distribution pattern of phytoplankton biomass within a lake usually changes markedly throughout the year. Phytoplankton productivity is also very variable since it is influenced by factors that can change within a matter of minutes (e.g., light intensity). However, in spite of these differences, there are some aspects of the distribution patterns that appear to be consistent (Wetzel 1985). The vertical distribution of phytoplankton and thus chlorophyll-a vary greatly from season to season with shifts in species composition. In the seasonal depth distribution of chlorophyll-a concentrations, values are usually low in the winter, increase conspicuously in the spring and then increase in different strata during the period of summer stratification.

The trophic state of a lake is dependant on chlorophyll-a levels. Both, chlorophyll-a and phosphorus are directly proportional to each other. Ordinarily, as phosphorus inputs to a lake increase, the amount of algae will also increase. Thus, chlorophyll-a levels will increase and transparency decreases. Chlorophyll-a concentrations greater than 6 parts per billion are considered characteristic of a eutrophic condition. High chlorophyll-a concentrations are a direct result of high nutrient inputs or light inputs in streams that are usually light limited. Values below 3 µg/L are considered to indicate low water productivity characteristic of oligotrophic lakes. Values greater than 15 µg/L are generally considered to indicate high water productivity characteristic of eutrophic lakes (RISC 1998). In plankton, chlorophyll-a is found in species suspended in the water column and in species attached to the substrate (periphyton). Only the chlorophyll-a originating in free-floating plankton was analyzed during this study. Chlorophyll-a is measured as µg/L or mg/L .

Results

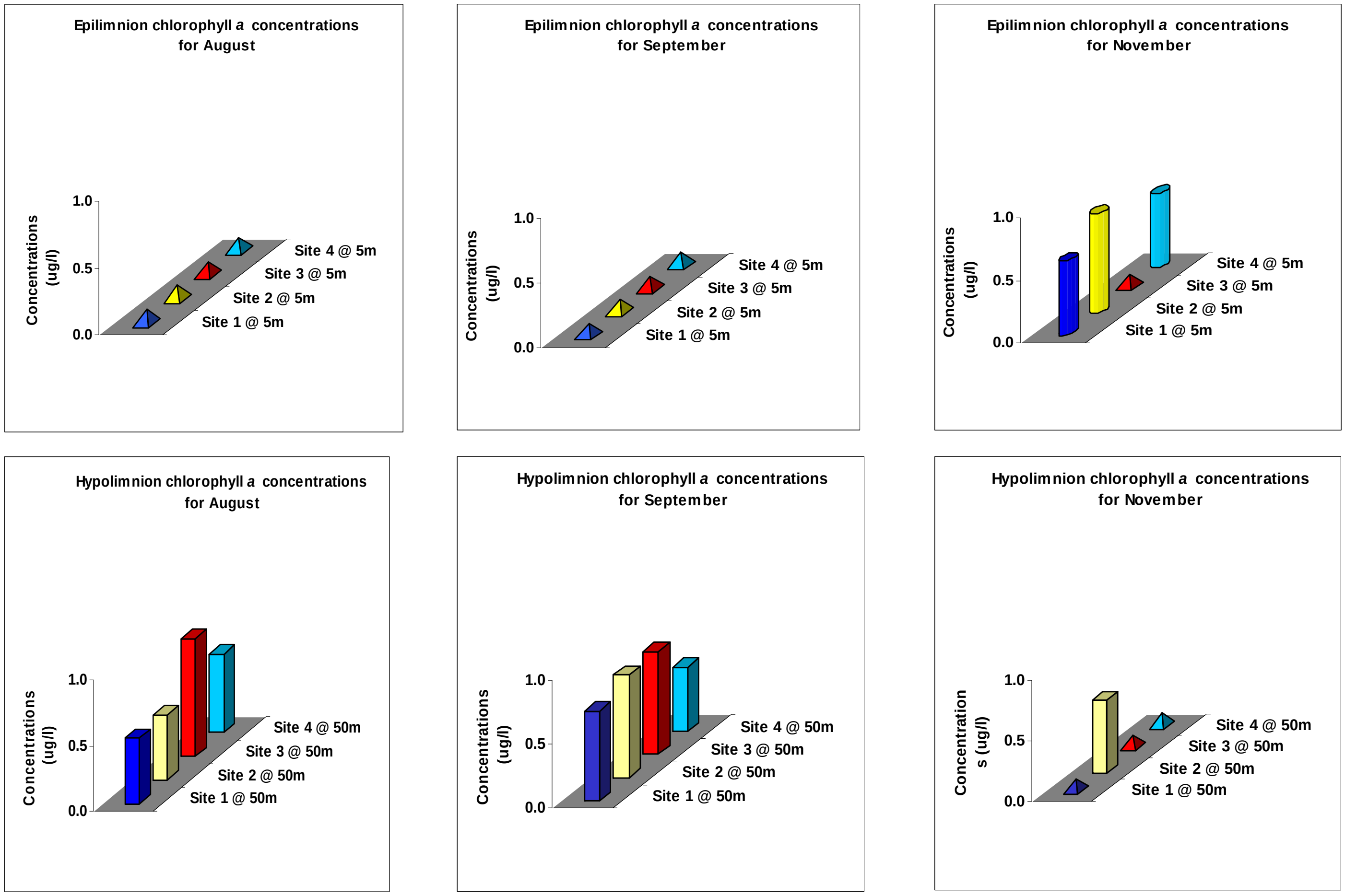
Slocan Lake water samples show low chlorophyll-a concentrations typical of an oligotrophic lake (Table 12). For the three sampling months, concentrations in the epilimnion and hypolimnion layers varied from <0.5 to 0.9 µg/L (Figure 12). Both layers had similar concentrations for August and September with higher concentrations observed in the hypolimnion. According to Wetzel (1985), high concentrations of chlorophyll-a in oligotrophic lakes are commonly found deep in the hypolimnion layer. These high concentrations are often due to algae cell sinking from the epilimnion layer. High concentrations of chlorophyll-a in the deep water column can be associated with a natural increase in nitrate with depth.

Table 12: 2010 Chlorophyll-a Results at 5m and 50m.

	August 2010					September 2010				November 2010			
Depth (m)	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**QA / QC**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
	Chl µg/L					Chl µg/L				Chl µg/L			
5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	0.9	0.8	<0.5	0.6
50	0.5	0.5	0.9	0.6		0.7	0.8	0.8	0.5	<0.5	0.6	<0.5	<0.5

<0.05 : lower than the detection limit

November data revealed a different vertical pattern, with lower concentrations observed in the hypolimnion layer. November 2010 was a very windy month and according to Wetzel (1985), patchiness in phytoplankton distribution has been observed in relation to wind-induced current patterns. The onset of cooler and windier conditions in November caused stratification weakening and upwelling of nutrient-rich deeper waters.



* Pyramids: below detection limits

Figure 12: Chlorophyll-a Concentrations at 5m and 50m for August, September and November

During the 2008 Slocan Lake water study, chlorophyll-a was not analyzed. The 2000-2001 and the 2010 studies show similar chlorophyll-a levels for August, September and November. There are no aquatic life or recreational water quality guidelines for chlorophyll-a, but phosphorus criteria in lakes are designed to limit chlorophyll-a to certain levels.

4.4 Total metals

Total metals are a measurement of metals in all their forms (both dissolved and suspended). Trace quantities of many metals are important constituents of most waters, but many of these metals are also classified as priority pollutants when concentrations are too high. Some are necessary for the growth of biological life, and their absence limits the growth of certain species (Metcalf & Eddy 2003). Aquatic organisms are highly sensitive to elevated concentrations of some metals. Aquatic organisms ingest metal-laden sediments and organic material and the metals are then released in these organisms' intestinal tract and absorbed in the tissues which will then be damaged by metal toxicity. Water quality guidelines have been set for many metals in order to protect both human health and aquatic life. With the exception of dissolved aluminum, water quality guidelines are set for the total form of the metal.

Sites 1 and 4 were tested for total metals. In keeping with the purpose of this study, water samples were analyzed for a wide variety of metals in order to assure a comprehensive data-base with which to evaluate the present water quality of Slocan Lake and assess any possible future alterations in water quality. The list of metal parameters and the water quality guidelines for aquatic life and recreational activities is provided in Table 13. Results of total metals can be found in Appendix C.

Results

Of the 29 metals, 28 showed normal concentrations for Slocan Lake (Table 14). Many metals revealed concentration levels below the detection limits. Concentrations are comparable between the two sites. Little vertical stratification of total metals was detected.

Calcium levels increased slightly with depth reflecting the increase of specific conductance. Sodium (~1mg/L) and potassium (~0.4mg/L) concentrations were low and correspond to readings found in the two previous studies. Compared to the 2008 results, zinc levels were slightly lower in 2010, with concentrations of ~0.0126mg/L in the epilimnion and ~0.0155mg/L in the hypolimnion.

Table 13 shows that all cadmium readings slightly exceeded the aquatic life guidelines (BCWQG) in 2010. BCWQG for cadmium are set to 0.02-0.03µg/L (0.00002-0.00003mg/L) for a lake such as Slocan Lake with an average hardness of 42mg/L (Galena 2008). Readings varied from 0.00011 to 0.000095mg/L in the epilimnion and from 0.000113 to 0.000113 at the deeper layer. The 2010 cadmium values were comparable to those found during the 2000-2001 (Pieters *et al.* 2006) and the 2008 (Galena 2008) surveys. In higher concentrations, cadmium has a cumulative effect and has been known to be extremely toxic for trout and zooplankton. According to Nagpal (et al. 2010), cadmium is generally found in trace concentrations of less than 0.1 µg/L (0.0001mg/L). Although higher than the guidelines for aquatic life, cadmium results found in Slocan Lake are still near the trace concentration levels. As there is no evidence of past mining activities near sites 1 and 4, this is believed to be a natural condition due to the mineralization of the watershed. Slocan Lake water contains zinc and copper. Heavy metals such as zinc and copper are also known to increase cadmium's toxicity in natural environments.

Table 13: Detection Limits and BC Water Quality Guidelines (BCWQG) for Total Metals

Total Metals				
Parameters	**D. L. (mg/L)**	**Aquatic Life (mg/L)**	**Recreational (mg/L)**	**Considerations**
Aluminum	<0.001	0.1	0.2	For a pH greater than or equal to 6.5
Antimony	<0.001	0.02	n/a	
Arsenic	<0.0002	0.005	n/a	
Barium	<0.001	5	n/a	
Beryllium	<0.0001	0.0053	n/a	
Bismuth	<0.001	--	n/a	
Boron	<0.01	1.2	n/a	
Cadmium	<0.000001	0.00002 - 0.00003	n/a	
Calcium	<0.01	--	n/a	
Chromium	<0.0001	0.001	n/a	
Cobalt	<0.0001	0.004	n/a	
Copper	<0.0001	0.0024	1	When average water hardness as CaCO3 is less than or equal to 50mg/L
Iron	<0.000005	1	n/a	
Lead	<0.0005	0.004	n/a	When average water hardness as $CaCO_3$ is less than or equal to 50mg/L
Magnesium	<0.0001	--	n/a	
Manganese	<0.001	0.08-38	n/a	
Molybdenum	<0.001	≤2	n/a	
Nickel	<0.001	0.025 - 0.15	n/a	
Potassium	<0.01	---	n/a	
Selenium	<0.0001	0.002	n/a	
Silicon	<0.01	--	n/a	
Silver	<0.000005	0.0001	n/a	
Sodium	<0.01	--	n/a	
Tin	<0.0001	22	n/a	
Titanium	<0.007	46	n/a	46 median threshold level for *Daphnia*
Uranium	<0.001	0.3	n/a	
Vanadium	<0.0001	0.006	n/a	
Yttrium	<0.001	--	n/a	
Zinc	<0.0001	0.033	5mg/L	The average concentration should not exceed 0.033mg/L when water hardness is less than or equal to 90mg/L

Chromium, lead and silver levels were slightly higher at Site 4 than at Site 1. The QA/QC samples, all taken at a 5m depth at Site 4, also confirm these higher levels. Since there is no known anthropogenic source of contamination (a mine, a permitted discharge, etc) in the watershed near the area that would account for increases in any of these higher values at Site 4, it is assumed that they are a natural occurrence. A tributary carrying metal-laden water may be the cause of localized increases in some metals or it may also be attributable to natural variability in the geology. Lead, silver and zinc are naturally occurring elements widespread in the environment, but elevated concentrations of these metals are known to be toxic to aquatic life.

Table 14: Results of Total Metal Levels for Sites 1 and 4

METALS	UNITS	SITE 1 5M	SITE 1 50M	SITE 4 5M	SITE 4 50M	QA/QC
Aluminum	mg/L	0.007	0.001	0.008	0.003	0.008
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.00006	0.00009	0.00006	0.00009	0.00006
Barium	mg/L	0.19	0.23	0.24	0.23	0.23
Beryllium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	mg/L	0.000106	0.000111	0.000097	0.000113	0.000112
Calcium	mg/L	11.12	13.11	12.04	13.07	12.35
Chromium	mg/L	0.0001	0.0001	0.0001	0.0002	0.0002
Cobalt	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	mg/L	0.0002	0.0003	0.0003	0.0002	0.0002
Iron	mg/L	0.005	0.005	0.005	<0.005	0.01
Lead	mg/L	<0.0001	0.0002	0.0005	0.0002	0.0004
Magnesium	mg/L	1.61	1.94	1.73	1.96	1.75
Manganese	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Potassium	mg/L	0.43	0.47	0.42	0.45	0.43
Selenium	mg/L	0.00028	0.00042	0.00035	0.00036	0.00038
Silicon	mg/L	2.48	2.73	2.58	2.77	2.6
Silver	mg/L	<0.000005	<0.000005	0.000005	0.000005	<0.000005
Sodium	mg/L	0.85	1.02	0.86	1	0.89
Tin	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	mg/L	<0.007	<0.007	<0.007	<0.007	<0.007
Uranium	mg/L	0.00028	0.0003	0.0003	0.00032	0.0003
Vanadium	mg/L	0.0002	0.0001	0.0002	0.0002	0.0002
Yttrium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.0124	0.0158	0.0127	0.0153	0.0141

The 2008 study mentions that local prospectors and miners speak of a vein rich in metals which comes down the mountainside in an east-west direction and into the lake in the vicinity of Site 4. The 2008 sampling results also showed higher metal levels at this site. Contamination of the samples during the sampling process cannot be the cause of this increase. Iron (Fe), lead (PB) and selenium (Se) levels were also much higher in 2008 (Fe: 0.20mg/L, PB: 0.0010mg/L & Se: 0.005mg/L) than in 2010 (Fe:0.0002mg/L, PB:0.0002mg/L & Se:0.0002mg/L).

Over the years, the laboratory detection limits have changed and consequently data comparison with older water quality studies can be challenging. Detection limits in 2000-2001 were set so high that comparisons between some metals were impossible to determine. In general, concentrations were well within the established water quality guidelines for aquatic life and recreational activities.

4.5 Zooplankton

Freshwater lakes contain a richly diverse array of microscopic and macroscopic animals existing as free-swimming or suspended forms and collectively known as zooplankton. The most significant groups of freshwater zooplankton are the cladocerans, copepods, protozoa, and rotifers. Although they are tiny, the relative abundance and diversity of these organisms dramatically influences energy flow, nutrient cycling, and community dynamics within aquatic ecosystems. The growth of plankton populations is dependent on light levels and nutrient availability. The chief factor limiting growth varies from region to region.

Prior to the present study, zooplankton had only been sampled once in Slocan Lake; in 2000-2001 (Wilson & Dolecki 2002), in collaboration with the Pieters 2000-2001 limnology study (2006). LIMNO Lab results can be found in Appendix D.

4.5.1 Species Present

One calanoid copepod species was identified in the samples from Slocan Lake in 2010. *Leptodiaptomus pribilofensis* (Juday & Muttkowski) was present in samples from August to November but in low numbers, while cyclopoid copepod species *Diacyclops bicuspidatus thomasi* (Forbes) were more abundant (
Table 15). Only two species of Cladocera, *Daphnia rosea* (Sars) and *Bosmina longirostris* (O.F.Muller), were found in the Slocan Lake samples during the study period in 2010. Five genera of Rotatoria were identified: *Asplanchna, Keratella, Kellicottia, Polyarthra* and *Conochilus*.

Table 15: List of species identified during the 2010 (August to November) and 2000 – 2001 (April to November) sampling programs

SPECIES	Sampling year		
Copepoda	2000	2001	2010
CYCLOPOIDA			
Diacyclops bicuspidatus thomasi	+	+	+
CALANOIDA			
Leptodiaptomus pribilofensis	+	+	+
Leptodiaptomus ashlandi	+	+	
Cladocera			
Daphnia rosea	+	+	+
Bosmina longirostris			+
Alona sp.	+	+	
Eubosmina longispina	+	+	
Sida cristallina	+	+	
Scapholeberis kingi	+	+	

4.5.2 DENSITY AND BIOMASS

Zooplankton is measured in density and biomass. The density corresponds to the abundance of the population, and the biomass is the total weight of a species. Zooplankton density was numerically dominated by copepods, which averaged 83% of the 2010 population (Figure 13, Table 15 & Table 16) Daphnia *spp* comprised 6%, while cladocerans other than Daphnia comprised 11%. Copepods were the most abundant zooplankton at each station during the studied season (Figure 14). They dominated during the whole sampling season, with populations peaking in September. Copepods were comprised of calanoids and cyclopoids.

The seasonal average zooplankton density in 2010 (August to November) decreased to 8.99 individuals/L from 27.28 and 27.56 individuals/L in 2000 and 2001 (Figure 15) (Andrusak *et al.* 2002). The variation in abundance of the different species is showed in figures 13, 14 and 15 below.

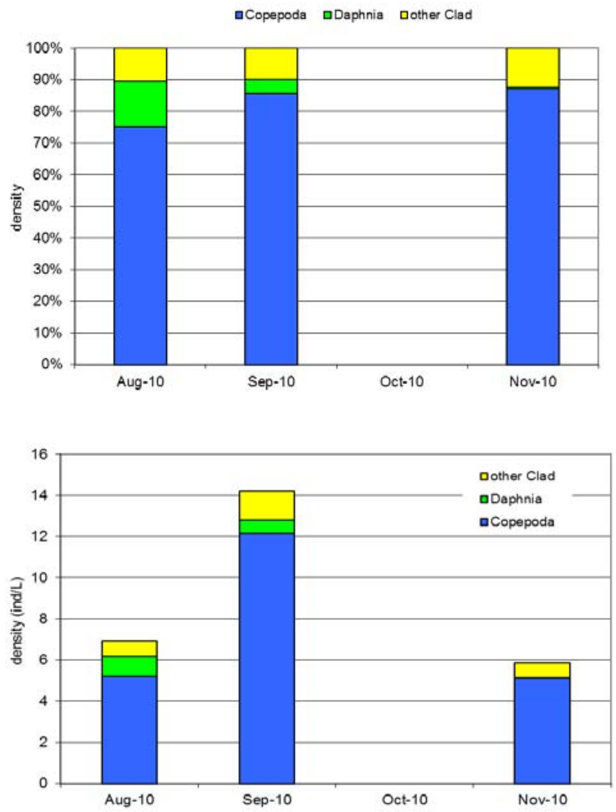


Figure 13: 2010 Seasonal average composition of zooplankton density in Slocan Lake

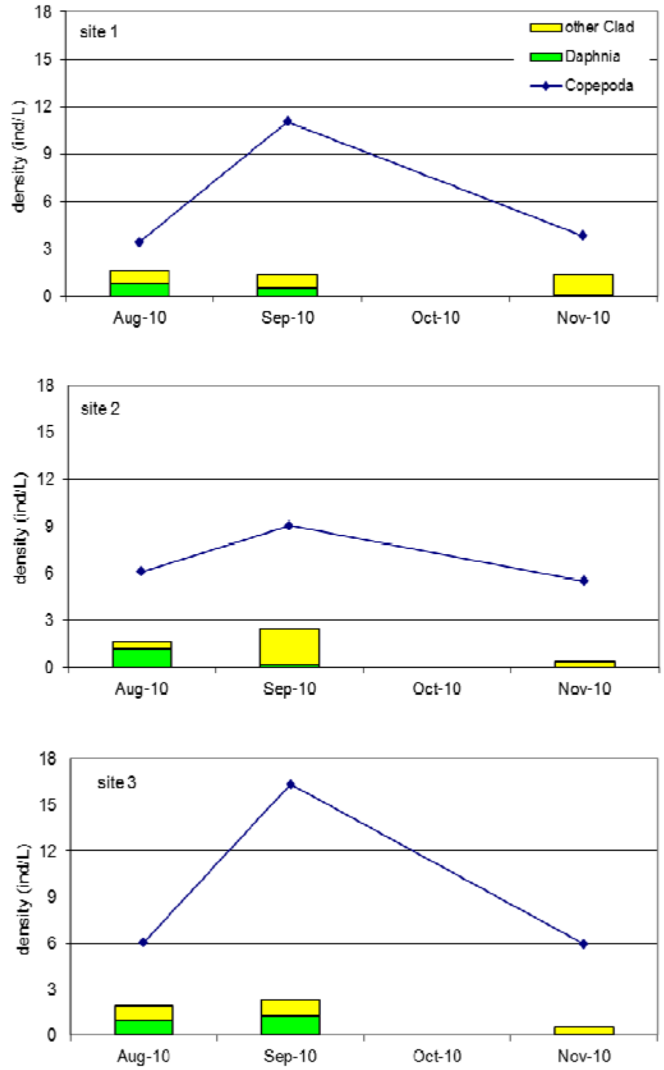


Figure 14: 2010 Zooplankton density at three sampling sites in Slocan Lake

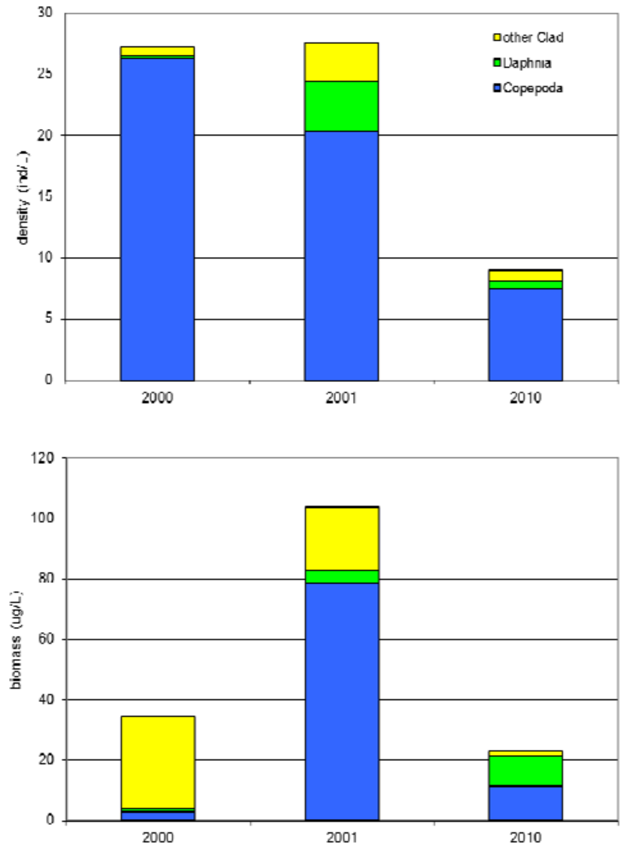


Figure 15: Seasonal average (August-November) zooplankton density and biomass in 2000, 2001 & 2010

Table 16: Seasonal average zooplankton density in 2000, 2001 (August to November) and 2010 (August to November)

Zooplankton density			
ind/L			
	2000	2001	2010
total	27.28	27.56	8.99
Copepoda	26.27	20.35	7.48
Daphnia	0.24	4.03	0.57
other Cladocera	0.77	3.17	0.95

In 2010 sampling season zooplankton biomass reached its peak in September dominated by *Daphnia* with 17.31µg/L, which made up 50% of the total biomass at that time (Figure 16). However, average for the whole study season August to November *Daphnia* comprised 44%, cladocerans other than *Daphnia* comprised 6%, while copepods made up to 50% of the total zooplankton biomass (Figure 16). However, average for the whole study season August to November *Daphnia* comprised 44%, cladocerans other than *Daphnia* comprised 6%, while copepods made up to 50% of the total zooplankton biomass (Figure 16).

Total zooplankton biomass and biomass of other cladocerans decreased in 2010 from 2000 and 2001(Table 17 & Figure 15). Biomass of copepods also decreased in comparison to 2001, but it was almost four folds higher than in 2000, while *Daphnia* biomass increased significantly to 10.11µg/L, from 0.92µg/L and 4.59µg/L in 2000 and 2001 respectively (Table 17) (Andrusak *et al.* 2002). Decrease of total zooplankton biomass was due to significant decreases in the biomass of other cladocerans and copepods. *Daphnia spp.* made up 3%, 4% and 44% of the total zooplankton biomass in 2000, 2001 and 2010 respectively.

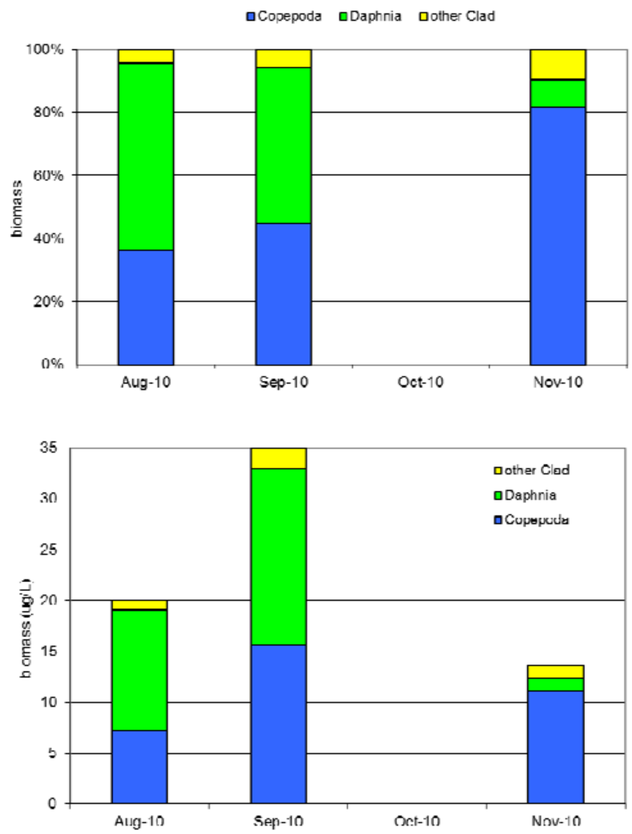


Figure 16: 2010 Monthly average composition of zooplankton biomass for Slocan Lake

Table 17: Seasonal average zooplankton biomass 2000, 2001 (August to November) and 2010 (August to November)

Zooplankton biomass			
µg/L			
	2000	2001	2010
Total	34.54	103.96	22.86
Copepoda	2.96	78.54	11.36
Daphnia	0.92	4.59	10.11
other Cladocera	30.66	20.83	1.39

The largest zooplankton population was seen in September at site 3 with 18.65 individuals/L and biomass of 50.37 µg/L (Figure 14 & Figure 17). In August and November the most numerous populations were also at site 3 with 7.98 and 6.46 individuals/L. Daphnia was present during the whole sampling season with the highest density in September at site 3 with 1.27 individuals/L and biomass 29.29 µg/L which was comprising to 58% of total biomass at that time.

Seasonal average values of zooplankton density and biomass are calculated for samples collected in August, September and November at three stations in 2010, while in 2000 and 2001 there were only two sampling stations. In 2000 and 2001 sampling season started in April and continued on the monthly basis throughout November, however due to better comparison we used only data from August to November.

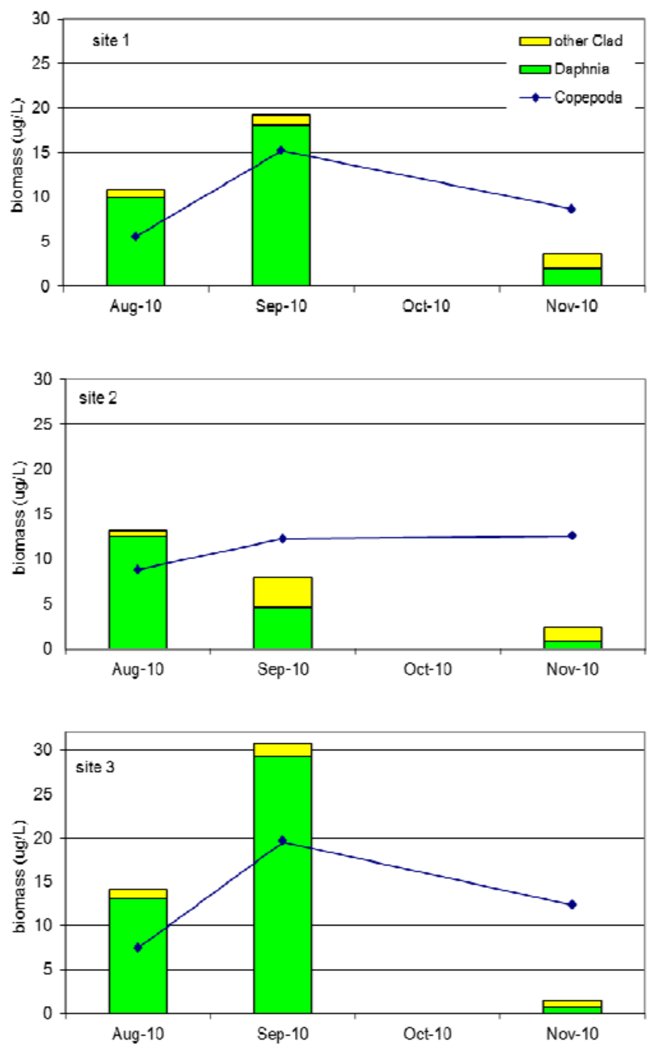


Figure 17: Zooplankton biomass at three sampling sites in 2010

5 RECOMMENDATIONS

It is recommended that the Slocan Lake sampling program continue on an annual basis for a minimum of two more years at the four established lake sites. Continued and regular monitoring of Slocan Lake is obviously the best way to maintain up-to-date records on the status of the lake and to gauge any variations due to natural causes or to developments in land use around the lake. This recommendation was echoed in the Pieters study (*et al.* 2006) and also, in the Slocan Lake FIM report (Arnett 2008), which suggested that a water monitoring program for Slocan Lake be put in place in cooperation with governing agencies and the involvement of the Slocan Lake Stewardship Society. A community based monitoring program serves both to accumulate valuable data and increase awareness within the local population of water quality and shoreline issues. Findings from these studies are important tools for land planners to use in determining future development possibilities within the area.

Recommendations for the Nearshore Sampling

- The Nearshore Program should be continued for a minimum of two more years in order to provide a better understanding of natural variability within Slocan Lake;
- Monitoring should continue to focus on septic runoff entering the lake and determine any patterns in coliform leaching. Bacterial source tracking would also differentiate between septic leaching and wildlife sources;
- Future monitoring programs should use the same sampling sites in order to maintain uniformity in the comparison of results; and
- Future monitoring should be conducted during summer and early fall.

Recommendations for the Offshore Sampling

- The Offshore Program should be continued for a minimum of two more years to help determine significant changes and trends within the watershed;
- General parameter readings should be conducted monthly over a one year period, at least;
- Zooplankton sampling should continue to be a part of future monitoring programs;
- Total metals should be tested at sites 1 and 4 twice a year;
- Future monitoring programs should use the same sampling sites in order to maintain uniformity in the comparison of results; and
- Future monitoring should be conducted during spring, summer and fall.

6 CONCLUSION

The purpose of this study was to collect comprehensive data on the present condition of Slocan Lake. The information collected in the present study is intended to help identify and evaluate any future trends or variations in water quality as development along the shores of Slocan Lake progresses, and to help establish guidelines and recommendations for such development which will serve to maintain the present status of the lake. The parameters tested proved to be well within the Provincial Water Quality Guidelines, indicating that this oligotrophic lake has maintained its pristine condition. But this study constitutes only one necessary and vital phase in what should be a multi-year trend-monitoring study. The full use and significance of its findings will only be meaningful when set within the context of the larger endeavour. Future development projects and community planning initiatives can only benefit from the availability of the most complete and comprehensive data on the present condition of Slocan Lake and the trends revealed by that data.

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APPENDICES

APPENDIX A
PASSMORE LAB
Microbiology Results & Interpretation

APPENDIX B
General parameters results

APPENDIX C
Nutrients & Total Metals results

APPENDIX D
LIMNO Lab
Zooplankton Results & Interpretation

APPENDIX A

PASSMORE LAB: Microbiology Results & Interpretation

PASSMORE
LABORATORY LTD.

4235 Upper Passmore Road
Winlaw, B.C. VOG 2JO
250 - 226 - 7339   passlab@xplornet.com

Client: Slocan Lake Stewadship Society

Email: galena@netidea.com

We have tested the samples of water submitted by you during August and September, 2010, and report as follows:

Method of Testing:

Analyses was performed in accordance with methods outlined in the "Standard Methods of Examination of Water and Wastewater", 17th edition, 1989 Published by the American Public Health Association, Specifically, Section 9222D. Microbiological tests were done using Membrane Filtration.

Results of Testing:

	8/24/2010		8/31/2010		9/10/2010		9/17/2010		9/22/2010	
	Total	Fecal	Total	Fecal	Total	Fecal	Total	Fecal	Total	Fecal
1. Slocan	1	0	17	0	Gt 300	0	40	0	11	2*
2. Silverton Resort	0	0	7	0	15	0	4	0	0	0
3. Silverton Creek	0	0	5	0	5	0	4	0	0	0
4. New Denver Hospital	1	0	0	0	2	0	6	0	0	0
5. Carpenter Creek	0	0	2	0	11	0	5	0	0	0
6. Wilson Creek	0	0	3	0	8	0	16	0	2	0
7. Hills	0	0	4	0	15	0	24	0	19	1*
8. QA/QC	0	0								

Gt = Greater than
* Confirmed for positive E.coli using MUG
Analyst:
Jennifer Yeow, Microbiologist, Passmore Laboratory Ltd.

Passmore Laboratory Ltd. complies with methods and certification through the Canadian Association for Laboratory Accreditation (CALA).

Below is information on the significance of Total Coliforms found on Websites indicated

Health Canada:
As early as the late 19th century, *E. coli* was recognized as the only species in the coliform group found exclusively in the intestinal tract of humans and other warm-blooded animals. At the time, detection methods for *E. coli* were impractical for routine monitoring. As a result, total coliforms were used as a surrogate for *E. coli* to indicate faecal contamination of drinking water supplies. It was recognized even then that total coliforms were not faecal specific; at the time, however, the majority of the total coliforms in drinking water were indeed *E. coli*.

Total coliforms continued as an indicator of faecal contamination for a large part of the 20th century. It was not until the mid-20th century that more specific methods for the thermotolerant coliforms, which include *E. coli* and members of the genera *Klebsiella*, *Enterobacter*, and *Citrobacter*, were developed. The use of the thermotolerant coliform test became widespread as a surrogate for *E. coli*, but it soon became evident that the majority of these organisms isolated from distribution systems were primarily members of the genus *Klebsiella* (Edberg *et al.*, 2000).

Total coliforms belong within the family Enterobacteriaceae and have been defined in the 20th edition of *Standard Methods for the Examination of Water and Wastewater* (APHA *et al.*, 1998) as follows:
(1) all facultative anaerobic, Gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose with gas and acid formation within 48 hours at 35°C;
(2) many facultative anaerobic, Gram-negative, non-spore-forming, rod-shaped bacteria that develop red colonies with a metallic (golden) sheen within 24 hours at 35°C on an Endo-type medium containing lactose; or
(3) all bacteria possessing the enzyme β-galactosidase, which cleaves a chromogenic substrate (e.g., *ortho*-nitrophenyl-β-D-galactopyranoside), resulting in release of a chromogen (*ortho*-nitrophenol).

Wikipedia:
Coliform is the name of a test adopted in 1914 by the Public Health Service for the Enterobacteriaceae family. It is the commonly-used bacterial indicator of sanitary quality of foods and water. They are defined as rod-shaped Gram-negative non-spore forming organisms. Some enteron forms can ferment lactose with the production of acid and gas when incubated at 35-37°C. Coliforms are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. They are easy to culture and their presence is used to indicate that other pathogenic organisms of fecal origin may be present.

Environmental Protection Agency (United States)

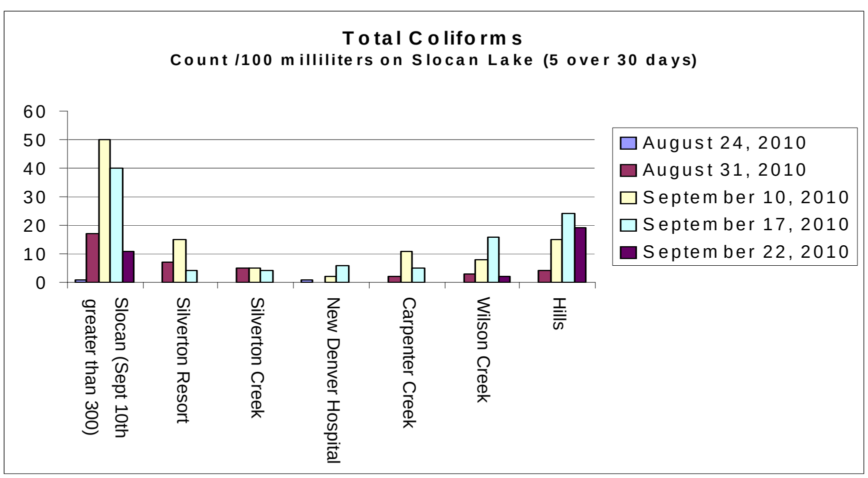
Total coliforms are considered a group of related bacteria found in the environment that generally are considered to be unharmful to human health, according to the Federal Register publication. The EPA noted that coliform bacteria are found in mammal feces, but may also be found in aquatic environments, in soil, and on vegetation.

While the agency said that total coliforms are a useful indicator and that fecal contaminants may get into drinking water distribution systems, it considers E. coli a better indicator of actual fecal contamination than fecal coliforms or total coliforms. E. coli is a restricted group of coliform bacteria that nearly always come from human or mammal guts.

Our comments:
Coliform refers to a group of bacteria that have been tested for over 90 years as indicators of human infection. They are defined as rod-shaped non-spore forming organisms. Coliforms are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. Their presence is used to indicate that other pathogenic organisms of fecal origin may be present. These include other bacteria, viruses, protozoa (Giardia, Cryptosporidium) and multicellular parasites

There are no Provincial Guideline limits for Total Coliforms drinking water.Our experience in studying Slocan Valley Creeks is that some creeks consistently show high Total Coliforms and no E.coli. People consume the water without becoming ill. Other creeks show both. When questioned about the difference we usually say: "Total coliforms indicate contamination from plant e.g. algae, decaying leaves, vegetation and/or warm blooded animal source. Fecal coliforms indicate contamination from warm blooded animal source".

Regarding Coliform test results on Slocan Lake, it is worth noting a correlation between high counts and regions where the water is likely to experience human and/or tributary creek inputs (Hills with Bonanza Creek and Slocan with Slocan City). See chart below:



As noted in the study done in 2008, low numbers of Fecal Coliform Bacteria indicate human/warm blooded animal contamination is minimal in sample site waters of Slocan Lake.

APPENDIX B

General Parameters

GENERAL PARAMETERS

Temperature												
Depth (m)	Aug 2010 Site 1	Aug 2010 Site 2	Aug 2010 Site 3	Aug 2010 Site 4	Sept 2010 Site 1	Sept 2010 Site 2	Sept 2010 Site 3	Sept 2010 Site 4	Nov 2010 Site 1	Nov 2010 Site 2	Nov 2010 Site 3	Nov 2010 Site 4
5	19	18.76	18.55	17.88	15.06	15.12	14.68	14.42	10.93	10.76	11.34	11.26
10	18.66	18.1	15.27	16.38	14.92	14.86	14.63	14.24	10.84	10.74	11.35	11.27
15	10.79	12.94	11.85	13.47	14.1	13.2	14.28	13.74	10.69	10.64	11.32	11.26
20	8.05	9.56	10.37	9.37	10.93	10.96	9.48	10.77	10.36	10.34	11.26	11.24
25	5.78	6.26	7.45	6.87	7.83	7.53	6.98	7.87	9.31	9.98	6.89	10.87
30	5.02	5.39	6.06	6.88	6.07	6.12	5.59	5.65	7.79	9.15	5.28	9.08
35	4.71	4.8	5.32	4.9	5.38	5.02	4.99	5.02	5.76	7.87	4.84	6.49
40	4.52	4.56	4.84	4.62	4.76	4.73	4.74	4.66	4.99	5.81	4.65	5.53
45	4.39	4.45	4.69	4.53	4.58	4.53	4.61	4.53	4.67	4.83	4.53	5.18
50	4.33	4.37	4.57	4.44	4.47	4.44	4.49	4.48	4.49	4.56	4.45	4.88
55	4.29	4.32	4.48	4.42	4.42	4.38	4.41	4.4	4.38	4.42	4.38	4.69
60	4.25	4.26	4.41	4.33	4.34	4.35	4.36	4.35	4.31	4.31	4.33	4.59

DO mg/l											
Aug 2010 Site 1	Aug 2010 Site 2	Aug 2010 Site 3	Aug 2010 Site 4	Sept 2010 Site 1	Sept 2010 Site 2	Sept 2010 Site 3	Sept 2010 Site 4	Nov 2010 Site 1	Nov 2010 Site 2	Nov 2010 Site 3	Nov 2010 Site 4
-1.88	5.48	10.08	9.76	4.55	4.76	5.25	8.8	9.16	4.87	5.93	4.48
0	6.24	11.76	10.39	6.71	4.74	5.85	9.4	9.09	4.57	5.42	4.33
4.33	7.75	12.54	11.16	11.53	5.41	8.39	9.06	9.09	4.5	5.29	4.35
5.62	8.38	12.32	11.64	14.25	10.34	11.64	10.36	9.42	5.04	5.45	4.67
6.33	8.85	12.47	11.37	15.68	13.72	12.38	10.72	9.39	6.59	6.96	5.5
6.89	9.12	12.37	11.22	16.03	14.98	12.84	10.49	9.30	7.61	7.99	6.75
7.27	9.13	12.01	10.94	15.74	15.38	13.05	9.85	10.06	8.91	8.5	8.96
7.45	9.18	11.88	10.86	16.81	15.75	12.77	9.94	10.07	10.15	9.09	9.63
7.85	9.22	11.69	10.83	16.34	16.66	12.72	10.31	9.88	10.44	9.63	9.97
7.77	9.26	11.57	10.82	16.42	16.93	13.2	10.37	9.78	10.42	10.15	10.33
8.13	9.28	11.57	10.74	16.17	16.88	13.45	9.83	9.77	10.22	10.76	10.63
8.32	9.34	11.68	10.9	16.22	16.64	13.05	10.36	9.74	10.18	10.9	11

pH														
Depth (m)	Aug 2010 Site 1	Aug 2010 Site 2	Aug 2010 Site 3	Aug 2010 Site 4	Average	Sept 2010 Site 1	Sept 2010 Site 2	Sept 2010 Site 3	Sept 2010 Site 4	Average	Nov 2010 Site 1	Nov 2010 Site 2	Nov 2010 Site 3	Nov 2010 Site 4	Average
5	7.7	7.77	7.92	7.88	7.8	7.93	7.72	7.62	7.53	7.7	7.04	7.89	8.56	8.44	8.0
10	7.71	7.81	7.89	7.85	7.8	7.95	7.75	7.66	7.59	7.7	7.07	7.8	8.07	8.1	7.8
15	7.73	7.87	7.84	7.92	7.8	7.99	7.83	7.69	7.65	7.8	7.15	7.72	8.03	8.04	7.7
20	7.62	7.73	7.76	7.8	7.7	8.03	7.87	7.77	7.71	7.8	7.17	7.7	8.01	7.99	7.7
25	7.53	7.6	7.62	7.63	7.6	8.05	7.91	7.82	7.75	7.9	7.21	7.69	8.03	7.96	7.7
30	7.47	7.52	7.55	7.57	7.5	8.04	7.92	7.83	7.77	7.9	7.57	7.68	8.04	7.95	7.8
35	7.45	7.46	7.48	7.49	7.5	8.01	7.92	7.83	7.76	7.9	7.45	7.69	8.03	7.96	7.8
40	7.44	7.44	7.45	7.44	7.4	8	7.91	7.83	7.75	7.9	7.43	7.7	8.03	7.96	7.8
45	7.43	7.42	7.42	7.42	7.4	7.97	7.91	7.81	7.75	7.9	7.42	7.71	8.02	7.95	7.8
50	7.42	7.42	7.41	7.41	7.4	7.96	7.89	7.8	7.75	7.9	7.42	7.71	8.01	7.95	7.8
55	7.41	7.41	7.4	7.4	7.4	7.94	7.88	7.8	7.74	7.8	7.41	7.71	8	7.94	7.8
60	7.41	7.41	7.39	7.39	7.4	7.92	7.87	7.8	7.74	7.8	7.41	7.71	7.99	7.93	7.8

Conductivity															
Depth (m)	Aug 2010 Site 1	Aug 2010 Site 2	Aug 2010 Site 3	Aug 2010 Site 4	Average	Sept 2010 Site 1	Sept 2010 Site 2	Sept 2010 Site 3	Sept 2010 Site 4	Average	Nov 2010 Site 1	Nov 2010 Site 2	Nov 2010 Site 3	Nov 2010 Site 4	Average
5	85	85	90	91	88	58	57	60	61	59	41	41	41	41	41
10	84	85	89	92	88	57	57	60	61	59	41	41	41	41	41
15	91	88	90	89	90	60	60	60	62	61	41	41	41	41	41
20	94	91	91	92	92	61	62	62	63	62	41	41	41	41	41
25	96	96	95	96	96	63	63	65	64	64	41	41	41	41	41
30	97	96	97	97	97	65	65	66	66	66	42	42	42	43	42
35	97	97	97	98	97	66	66	67	67	67	42	43	43	42	43
40	97	97	97	98	97	67	67	68	67	67	43	43	43	42	43
45	97	97	97	98	97	69	69	70	68	69	43	43	44	42	43
50	97	97	97	98	97	70	70	71	70	70	45	43	46	47	45
55	97	97	97	98	97	72	72	72	72	72	45	43	47	48	46
60	97	97	97	98	97	72	73	74	74	73	45	43	47	48	46

TDS															
Depth (m)	Aug 2010 Site 1	Aug 2010 Site 2	Aug 2010 Site 3	Aug 2010 Site 4	Average	Sept 2010 Site 1	Sept 2010 Site 2	Sept 2010 Site 3	Sept 2010 Site 4	Average	Nov 2010 Site 1	Nov 2010 Site 2	Nov 2010 Site 3	Nov 2010 Site 4	Average
5	0.055	0.055	0.059	0.059	0.057	0.029	0.028	0.03	0.03	0.029	0.051	0.053	0.054	0.055	0.053
10	0.055	0.055	0.058	0.06	0.057	0.029	0.029	0.03	0.031	0.030	0.051	0.053	0.056	0.057	0.054
15	0.059	0.057	0.058	0.058	0.058	0.03	0.03	0.03	0.031	0.030	0.049	0.053	0.056	0.057	0.054
20	0.061	0.059	0.059	0.06	0.060	0.031	0.031	0.031	0.031	0.031	0.049	0.052	0.056	0.056	0.053
25	0.063	0.062	0.062	0.062	0.062	0.032	0.032	0.032	0.032	0.032	0.05	0.053	0.061	0.056	0.055
30	0.063	0.063	0.063	0.063	0.063	0.032	0.032	0.033	0.033	0.033	0.052	0.053	0.061	0.057	0.056
35	0.063	0.063	0.063	0.064	0.063	0.033	0.033	0.033	0.033	0.033	0.054	0.055	0.06	0.06	0.057
40	0.063	0.063	0.063	0.063	0.063	0.034	0.034	0.034	0.033	0.034	0.055	0.057	0.061	0.06	0.058
45	0.063	0.063	0.063	0.064	0.063	0.034	0.034	0.035	0.034	0.034	0.056	0.058	0.061	0.06	0.059
50	0.063	0.063	0.063	0.064	0.063	0.035	0.035	0.035	0.035	0.035	0.057	0.059	0.062	0.061	0.060
55	0.063	0.063	0.063	0.064	0.063	0.036	0.036	0.036	0.036	0.036	0.058	0.06	0.063	0.062	0.061
60	0.063	0.063	0.063	0.064	0.063	0.036	0.037	0.037	0.037	0.037	0.059	0.061	0.064	0.064	0.062

APPENDIX C

Nutrients & Total Metals Results

Eco Tech Laboratory Ltd.
2953 Shuswap Road
Kamloops, BC
V2H 1S9 Canada
Tel + 1 250 573 5700
Fax + 1 250 573 4557
Toll Free + 1 877 573 5755
www.stewartgroupglobal.com

StewartGroup
Geochemical & Assay

ANALYTICAL RESULTS - E10-2075

Galena Environmental
8075 Upper Galena Farm Rd
Silverton BC
V0G 1S0

21-Sep-10

SAMPLE IDENTIFICATION:

9 Water Samples Received:August 25, 2010
Samples Dated: August 23, 2010

Labelled #1: Site 1 @ 5m #4: Site 2 @ 50m #7: Site 4 @ 5m
#2: Site 1 @ 50m #5: Site 3 @ 5m #8: Site 4 @ 50m
#3: Site 2 @ 5m #6: Site 3 @ 50m #9: Site 4 @ 5m (QC/QA)

PARAMETERS	1	2	3	4	5	6	7	8	9
Nitrate (as N)	0.053	0.100	0.050	0.102	0.051	0.101	0.049	0.101	0.050
Nitrite (as N)	0.004	0.003	0.003	0.003	0.005	0.004	0.003	0.003	0.003
TKN	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Nitrogen	0.05	0.1	0.05	0.10	0.05	0.10	0.05	0.10	0.05
Chlorophyll A	<0.5	0.5	<0.5	0.5	<0.5	0.9	<0.5	0.6	0.5
Total Phosphate (as P)	0.031	0.031	0.038	0.032	0.034	0.039	0.033	0.033	0.032

Eco Tech Laboratory Ltd.
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Tel + 1 250 573 5700
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www.stewartgroupglobal.com

StewartGroup
Geochemical & Assay

Galena Environmental

Results Continued

21-Sep-10
E10-2075

PARAMETERS	YOUR SAMPLES									Units
TOTAL METALS:	1	2	3	4	5	6	7	8	9	
Aluminum	7	1	-	-	-	-	8	3	8	ug/L
Antimony	<1	<1	-	-	-	-	<1	<1	<1	ug/L
Arsenic	0.06	0.09	-	-	-	-	0.06	0.09	0.06	ug/L
Barium	19	23	-	-	-	-	24	24	23	ug/L
Beryllium	<0.1	<0.1	-	-	-	-	<0.1	<0.1	<0.1	ug/L
Bismuth	<1	<1	-	-	-	-	<1	<1	<1	ug/L
Boron	<0.01	<0.01	-	-	-	-	<0.01	<0.01	<0.01	mg/L
Cadmium	0.106	0.111	-	-	-	-	0.097	0.113	0.112	ug/L
Calcium	11.12	13.11	-	-	-	-	12.04	13.07	12.35	mg/L
Chromium	0.1	0.1	-	-	-	-	0.1	0.2	0.2	ug/L
Cobalt	<0.1	<0.1	-	-	-	-	<0.1	<0.1	<0.1	ug/L
Copper	0.2	0.3	-	-	-	-	0.3	0.2	0.2	ug/L
Iron	0.005	0.005	-	-	-	-	0.005	<0.005	0.01	mg/L
Lead	<0.1	0.2	-	-	-	-	0.5	0.2	0.4	ug/L
Magnesium	1.61	1.94	-	-	-	-	1.73	1.96	1.75	mg/L
Manganese	<1	<1	-	-	-	-	<1	<1	<1	ug/L
Molybdenum	<1	<1	-	-	-	-	<1	<1	<1	ug/L
Nickel	<1	<1	-	-	-	-	<1	<1	<1	ug/L
Potassium	0.43	0.47	-	-	-	-	0.42	0.45	0.43	mg/L
Selenium	0.28	0.42	-	-	-	-	0.35	0.36	0.38	ug/L
Silicon	2.48	2.73	-	-	-	-	2.58	2.77	2.6	mg/L
Silver	<0.005	<0.005	-	-	-	-	0.005	0.005	<0.005	ug/L
Sodium	0.85	1.02	-	-	-	-	0.86	1	0.89	mg/L
Tin	<0.1	<0.1	-	-	-	-	<0.1	<0.1	<0.1	ug/L
Titanium	<0.007	<0.007	-	-	-	-	<0.007	<0.007	<0.007	mg/L
Uranium	0.28	0.3	-	-	-	-	0.3	0.32	0.3	ug/L
Vanadium	0.2	0.1	-	-	-	-	0.2	0.2	0.2	ug/L
Yttrium	<1	<1	-	-	-	-	<1	<1	<1	ug/L
Zinc	12.4	15.8	-	-	-	-	12.7	15.3	14.1	ug/L

ECO TECH LABORATORY LTD.
John Andrew, BSc.
Environmental Lab Manager

JA/ap
email:luce@galenaenvironmental.ca

Eco Tech Laboratory Ltd.
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StewartGroup
Geochemical & Assay

ANALYTICAL RESULTS - E10-2374

Galena Environmental
8075 Upper Galena Farm Rd
Silverton BC
V0G 1S0

5-Oct-10

SAMPLE IDENTIFICATION:

8 Water Samples Received:September 27, 2010
Samples Dated:September 22, 2010

Labelled: #1: Site 1 @ 5m #5: Site 3 @ 5m
#2: Site 1 @ 50m #6: Site 3 @ 50m
#3: Site 2 @ 5m #7: Site 4 @ 5m
#4: Site 2 @ 50m #8: Site 4 @ 50m

PARAMETERS	1	2	3	4	5	6	7	8
Nitrate (as N)	0.034	0.071	0.033	0.074	0.033	0.077	0.036	0.080
Nitrite (as N)	0.003	0.003	0.003	0.003	0.003	<0.003	<0.003	<0.003
TKN	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Nitrogen	<0.05	0.07	<0.05	0.07	<0.05	0.08	<0.05	0.08
Chlorophyll A	<0.5	0.7	<0.5	0.8	<0.5	0.8	<0.5	0.5
Total Phosphate (as P)	0.018	0.022	0.021	0.019	0.017	0.020	0.019	0.019

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StewartGroup
Geochemical & Assay

ANALYTICAL RESULTS - E10-2805

Galena Environmental
8075 Upper Galena Farm Rd
Silverton BC
V0G 1S0

17-Nov-10

SAMPLE IDENTIFICATION:

8 Water Samples Received: November 8, 2010
Samples Dated: October 24, 2010
Labelled: #1: Site 1 @ 5m #5: Site 3 @ 5m
#2: Site 1 @ 50m #6: Site 3 @ 50m
#3: Site 2 @ 5m #7: Site 4 @ 5m
#4: Site 2 @ 50m #8: Site 4 @ 50m

PARAMETERS	1	2	3	4	5	6	7	8
Nitrate (as N)	0.048	0.095	0.05	0.097	0.045	0.103	0.046	0.095
Nitrite (as N)	0.004	0.004	0.003	0.006	<0.003	0.003	0.003	0.006
TKN	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.304	<0.05
Total Nitrogen	0.05	0.1	0.05	0.1	<0.05	0.1	0.353	0.1
Chlorophyll "a" (ug/L)	0.9	<0.5	0.8	0.6	<0.5	<0.5	0.6	<0.5
Total Phosphate (as P)	0.035	0.041	0.032	0.043	0.034	0.038	0.037	0.023

Results expressed as mg/L unless otherwise specified

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APPENDIX D

LIMNO Lab: Zooplankton Results & Interpretation

Zooplankton – Slocan Lake 2010

Methods

Samples were collected at three sampling sites in the Slocan Lake with a 153(?) µm mesh Wisconsin net (mouth diameter = 0.5 m) hauled vertically to the surface from 40 m. Duplicate samples were taken at each site of the lake. Each sample was placed in 250-mL glass jar and preserved in 90% isopropanol. Samples were re-suspended in tap water filtered through a 74 µm mesh and sub-sampled using a four-chambered Folsom-type plankton splitter. Splits were placed in gridded plastic petri dishes and stained with Rose Bengal to facilitate viewing with a Wild M3B dissecting microscope (at up to 400X magnification). Zooplankton samples were analyzed for species density and biomass (estimated from empirical length-weight regressions, McCauley 1984). For each replicate, organisms were identified to species level and counted until up to 200 organisms of the predominant species. If 150 organisms were counted by the end of a split, a new split was not started. The lengths of 30 organisms of each species were measured for use in biomass calculations, using a mouse cursor on a live television image of each organism.

Zooplankton species were identified with reference to taxonomic keys (Sandercock and Scudder 1996, Pennak 1989, Wilson 1959, Brooks 1959). Lengths were converted to biomass (µg dry-weight) using empirical length-weight regression from McCauley (1984).

Results

Species Present

One calanoid copepod species has been identified in the samples from Slocan Lake in 2010. *Leptodiaptomus pribilofensis* (Juday & Muttkowski) was present in samples during the sampling season from August to November but in considerably lower number, while cyclopoid copepod species *Diacyclops bicuspidatus thomasi* (Forbes) prevailed numerically in samples (Tab. 1).

Only two species of Cladocera *Daphnia rosea* (Sars) and *Bosmina longirostris* (O.F.Muller) were present in Slocan Lake samples during the studied period in 2010 (Tab.1).

Table 1. List of species identified in samples from Slocan Lake 2010 (August to November) and 2000 - 2001 (April to October) (Andrusak et al. 2002)

COPEPODA	2000	2001	2010
CYCLOPOIDA			
Diacyclops bicuspidatus thomasi	+	+	+
CALANOIDA			
Leptodiaptomus pribilofensis	+	+	+
Leptodiaptomus ashlandi	+	+	

CLADOCERA			
Daphnia rosea	+	+	+
Bosmina longirostris			+
Alona sp.	+	+	
Eubosmina longispina	+	+	
Sida cristallina	+	+	
Scapholeberis kingi	+	+	

Five genera of Rotatoria were identified in samples: *Asplanchna*, *Keratella*, *Kellicottia*, *Polyarthra and Conochilus*. Considering that sampling mesh size was ?? μm, captured species are just a portion of Rotatoria community in the Slocan Lake, and will not be discussed in this report.

Density and Biomass

The zooplankton density has been numerically dominated by copepods, which averaged 83% of the 2010 population (Fig. 1). *Daphnia* spp comprised 6%, while cladocerans other than *Daphnia* comprised 11%. Copepods were the most abundant zooplankton at each station during the studied season (Fig. 2). They dominated during the whole sampling season, with populations peaking in September. Copepods were comprised of calanoids and cyclopoids.

The seasonal average zooplankton density in 2010 (August to November) decreased to 8.99 individuals/L from 27.28 and 27.56 individuals/L in 2000 and 2001 (Tab.2, Fig. 3) (Andrusak et al. 2002). That was the result of Copepoda abundance decrease, while *Daphnia* spp. and other Cladocera abundance stayed at the similar level as in 2000, but significantly decreased in comparison to 2001.

Table 2. Seasonal average zooplankton density in Slocan Lake 2000, 2001 (August to October) and 2010 (August to November)

ind/L	2000	2001	2010
total	27.28	27.56	8.99
Copepoda	26.27	20.35	7.48
Daphnia	0.24	4.03	0.57
other Cladocera	0.77	3.17	0.95

In 2010 sampling season zooplankton biomass reached its peak in September dominated by *Daphnia* with 17.31μg/L, which made up 50% of the total biomass at that time (Fig. 4). However, average for the whole study season August to November *Daphnia* comprised 44%, cladocerans other than *Daphnia* comprised 6%, while copepods made up to 50% of the total zooplankton biomass (Fig. 4).

Total zooplankton biomass and biomass of other cladocerans decreased in 2010 from 2000 and 2001(Tab. 3, Fig 3). Biomass of copepods also decreased in comparison to 2001, but it was almost four folds higher than in 2000, while *Daphnia* biomass increased significantly to 10.11μg/L, from 0.92μg/L and 4.59μg/L in 2000 and 2001 respectively (Tab.3) (Andrusak et al. 2002). Decrease of total zooplankton biomass was due to significant decreases in the biomass of other cladocerans and copepods. *Daphnia* spp. made up 3%, 4% and 44% of the total zooplankton biomass in 2000, 2001 and 2010 respectively.

Table 3. Seasonal average zooplankton biomass in Slocan Lake 2000, 2001 (August to October) and 2010 (August to November)

μg/L	2000	2001	2010
total	34.54	103.96	22.86
Copepoda	2.96	78.54	11.36
Daphnia	0.92	4.59	10.11
other Cladocera	30.66	20.83	1.39

The largest zooplankton population was seen in September at site 3 with 18.65 individuals/L and biomass of 50.37 μg/L (Fig. 2, Fig. 5). In August and November the most numerous populations were also at site 3 with 7.98 and 6.46 individuals/L. *Daphnia* was present during the whole sampling season with the highest density in September at site 3 with 1.27 individuals/L and biomass 29.29 μg/L which was comprising to 58% of total biomass at that time.

Seasonal average values of zooplankton density and biomass are calculated for samples collected in August, September and November at three stations in 2010, while in 2000 and 2001 there were only two sampling stations. In 2000 and 2001 sampling season started in April and continued on the monthly basis throughout October, however due to better comparison we used only data from August to October.

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