JERICHO DIAMOND PROJECT
AQUATIC BIOTA AEMP
-2004-

Prepared for

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TABLE OF CONTENTS

Page #

LIST OF TABLES

Page #

LIST OF FIGURES

Page #

1.0 INTRODUCTION

1.1 BACKGROUND

The Jericho Diamond Project was initiated in 1995 based on the discovery of a kimberlite pipe adjacent to the southern shore of an unnamed lake (locally known as Carat Lake). The Jericho Diamond Project has undergone environmental review by the Nunavut Impact Review Board (NIRB), which recommended that the Project be approved, subject to several terms and conditions. NIRB issued a Project Certificate on 20 July 2004 after receiving approval from the Minister of Indian and Northern Affairs. The conditions include development and implementation of a comprehensive environmental monitoring program, part of which includes an Aquatic Effects Monitoring Program (AEMP). The Nunavut Water Board (NWB) issued Water License NWBJER0410 on 22 December 2004 pursuant to DIAND ministerial approval which was received on 26 January 2005. NWB adopted the NIRB recommendations regarding the AEMP. This document presents the results of the aquatic biota component of the 2004 Jericho AEMP. A detailed discussion of the rationale and design of the Jericho AEMP is presented in Mainstream and AMEC (2005).

1.2 PURPOSE AND OBJECTIVES

The purpose of an AEMP is to monitor the potential effects of the Jericho Diamond Project on the aquatic environment. The goals of the program are to:

- Protect the health and integrity of the aquatic environment.
- Confirm impact predictions.
- Ascertain whether mitigation measures are effective.
- Adjust mitigation where appropriate.

The objective of the 2004 aquatic biota component of the Jericho AEMP was to collect baseline data that describe selected components of the aquatic environment.

1.3 STUDY AREA

The ore bearing deposit and mine infrastructure will be located immediately south of Carat Lake (Figure 1.1). Potential contaminant sources that could affect aquatic biota, the mode of transport, and the receiving waterbodies are listed in Table 1.1. The modes of transport are licensed discharge, surface runoff, and airborne dust. In general the constituents of concern to the aquatic biota are nutrients, contaminants, and sediments.

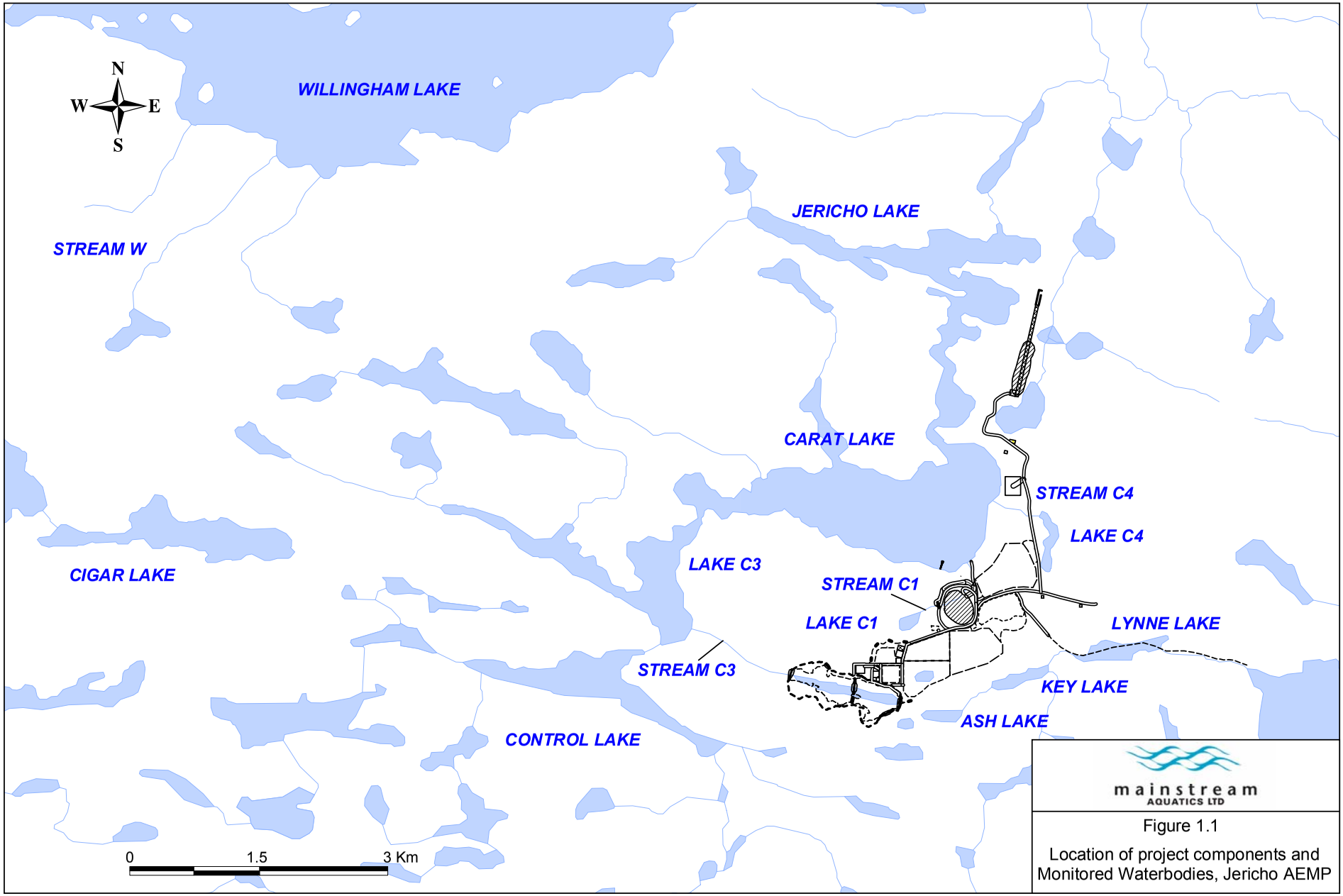

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Figure 1.1

Location of project components and Monitored Waterbodies, Jericho AEMP

Licensed discharge from the Processed Kimberlite Containment Area will be released into Lake C3 via Stream C3. Surface runoff and airborne contaminants have the potential to enter lakes and streams depending on the source.

Table 1.1 Discharge sources, potential mode of entry, and receiving waterbodies by Project phase, Jericho Diamond Project.

Phase	Source	Mode[a]	Receiving Waterbodies
Construction	• Processed Kimberlite Containment Area[b]	• Discharge	• Stream C3 and Lake C3
	• Stream C1 diversion	• Runoff	• Stream C1 and Carat Lake
	• Drainage ditch to Lake C4	• Runoff	• Lake C4, Stream C4, Carat Lake
	• Permanent	• Runoff	• Stream C4 and Carat Lake
	• Waste rock dump	• Airborne	• Lynne Lake
Operation[c]	• Discharge from PKCA	• Discharge	• Stream C3 and Lake C3
	• Stream C1 Diversion	• Runoff	• Stream C1 and Carat Lake
	• Drainage ditch to Lake C4	• Runoff	• Stream C4, Lake C4 and Carat Lake
	• Waste rock dump	• Airborne	• Lynne Lake
Post-closure	• Discharge from reclaimed PKCA	• Runoff	• Stream C3 and Lake C3
	• Mine site runoff	• Runoff	• Lake C1, Stream C1, and Carat Lake
	• Mine pit water discharge	• Runoff	• Stream C1 and Carat Lake

[a] Discharge - licensed discharge into receiving waterbodies; Runoff - unanticipated discharge; Airborne - dust.
[b] PKCA – Processed Kimberlite Containment Area
[c] Mine site runoff will be collected and directed to the PKCA for release.

Receiving waterbodies are placed into two groups based on location and flow direction. The Jericho River group is part of the Jericho River system, which flows in a northerly direction to the Kathawachaga River system situated approximately 15 km downstream of the Project. The Lynne Lake group consists of a series of small waterbodies and ephemeral watercourses situated immediately east and north of the Project, which drain into Contwoyto Lake.

Waterbodies monitored for aquatic biota include Lake C3, Carat Lake, and Jericho Lake. Two control lakes are incorporated in the AEMP to provide data from nonaffected waterbodies. These include Control Lake located immediately upstream of Lake C3 and Cigar Lake located outside the watershed, 10 km west of the Project. A control stream was added to the aquatic biota AEMP to allow collection of slimy sculpin for metal tissue contaminants. Stream W, which flows into Willingham Lake is located 5 km north of Cigar Lake.

2.0 DESIGN

2.1 STATION LOCATIONS AND INDICATORS

Station locations and the aquatic biota indicators monitored in 2004 are listed in Table 2.1 and Figures 2.1 and 2.2. Station location is based on the type of indicator monitored. Sedentary indicators are periphyton, benthic invertebrates, and slimy sculpin. Sedentary indicator stations are as follows:

1) Adjacent to source (near field)
   a) Stream C3 outlet in Lake C3 (JER-AB20)
   b) Stream C1 outlet in Carat Lake (JER-AB19)
2) Downstream and outside the immediate zone of potential effect (far field)
   a) Outlet to Carat Lake (JER-AB07)
   b) Jericho Lake (JER-AB08)
3) Outside the zone of any potential effect (control)
   a) Cigar Lake (JER-AB11)
   b) Control Lake (JER-AB10)
   c) Stream W (JER-AB23).

Nonsedentary indicators are phytoplankton, zooplankton, lake trout, and round whitefish. Nonsedentary indicator stations are as follows:

1) Waterbody adjacent to source (near field)
   a) Lake C3 (JER-AB04)
   b) Carat Lake (JER-AB06)
2) Waterbody outside the immediate zone of potential effect (far field)
   a) Jericho Lake (JER-AB08)
3) Waterbody outside the zone of any potential effect (control)
   a) Cigar Lake (JER-AB11)
   b) Control Lake (JER-AB10)

Monitoring sediment deposition and dissolved oxygen profiles are part of the Jericho AEMP (Mainstream and AMEC 2005). These two components were monitored in 2004. Stations are listed in Table 2.1 and illustrated in Figures 2.3 and 2.4.

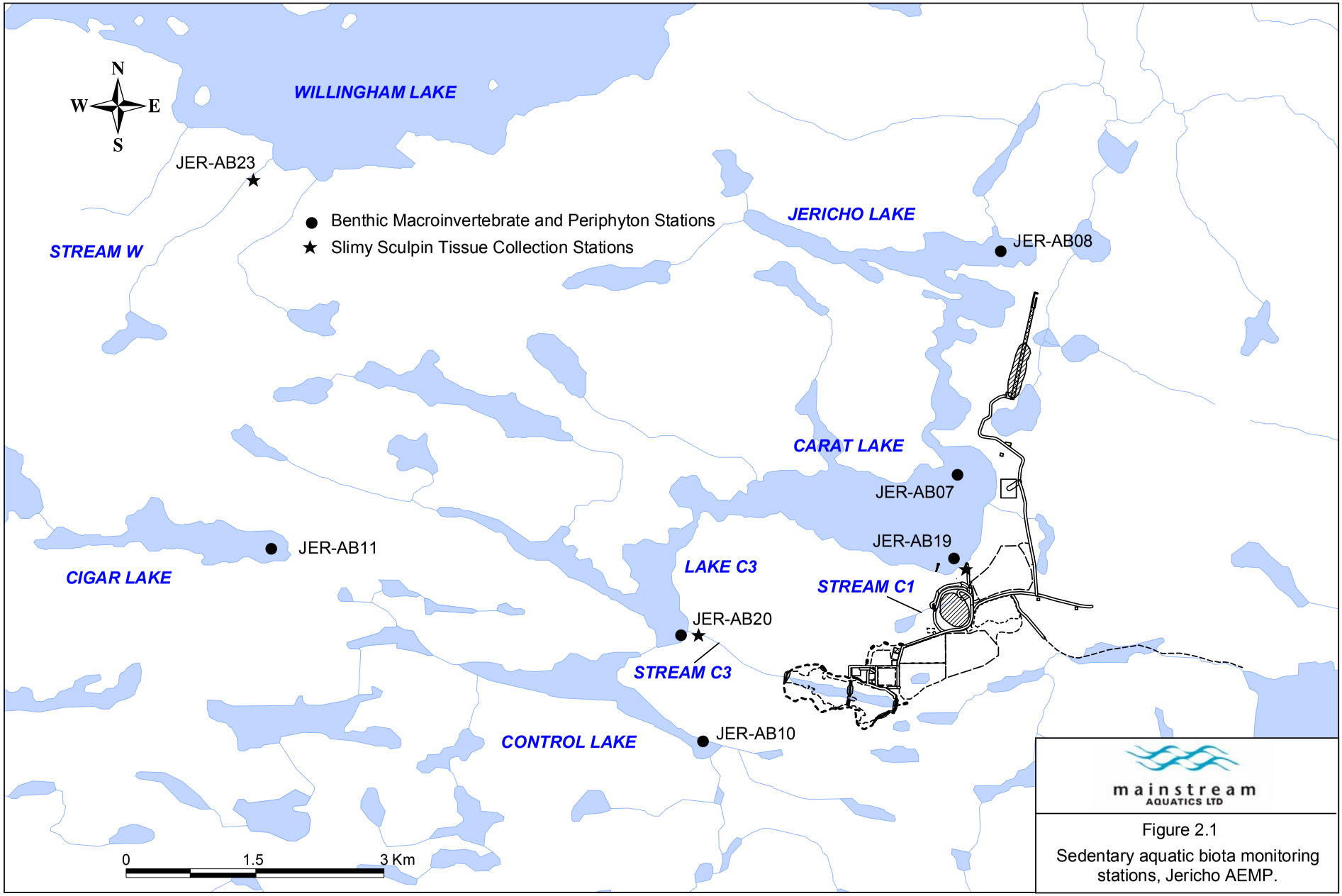

Figure 2.1

Sedentary aquatic biota monitoring stations, Jericho AEMP.

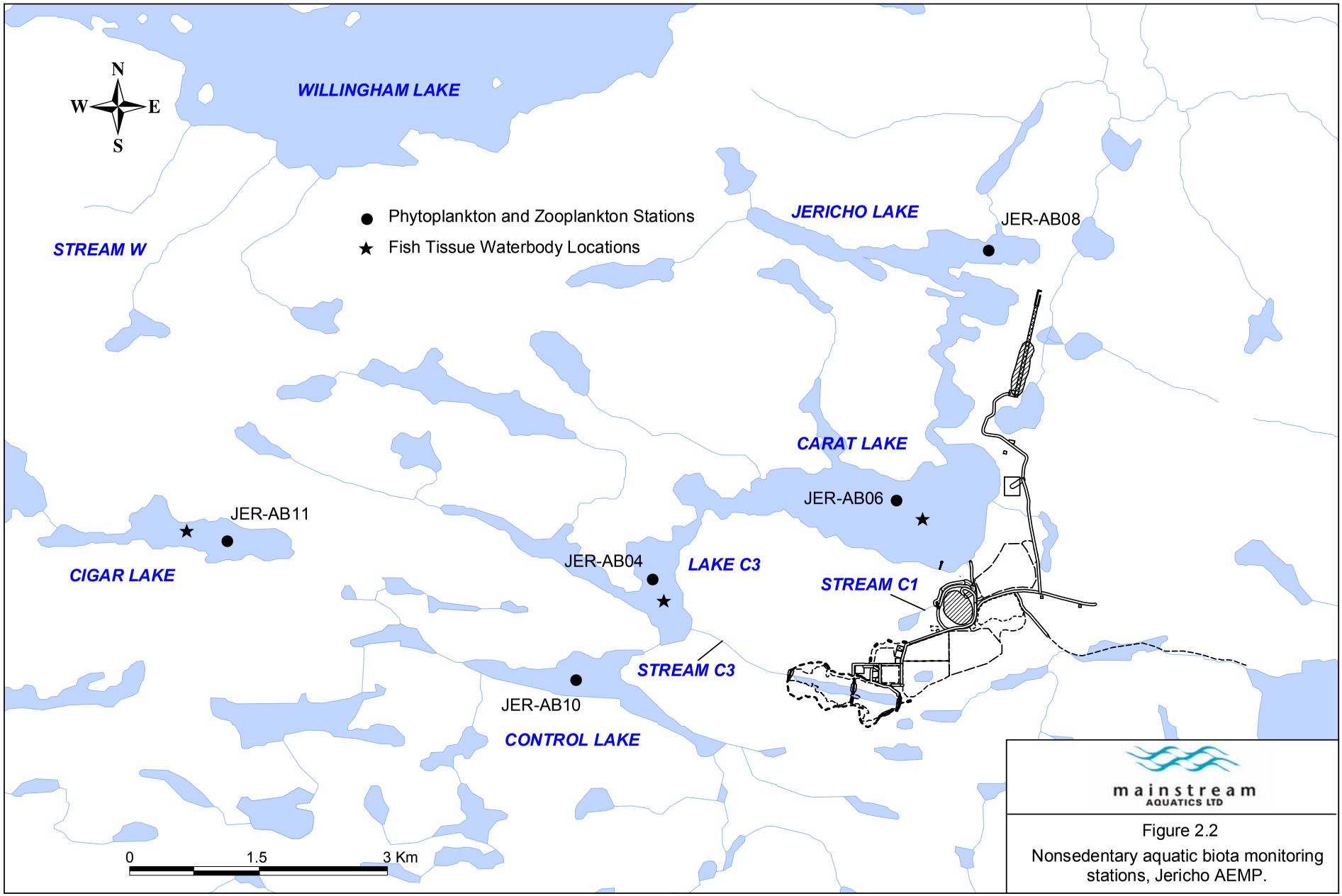

Figure 2.2

Nonsedentary aquatic biota monitoring stations, Jericho AEMP.

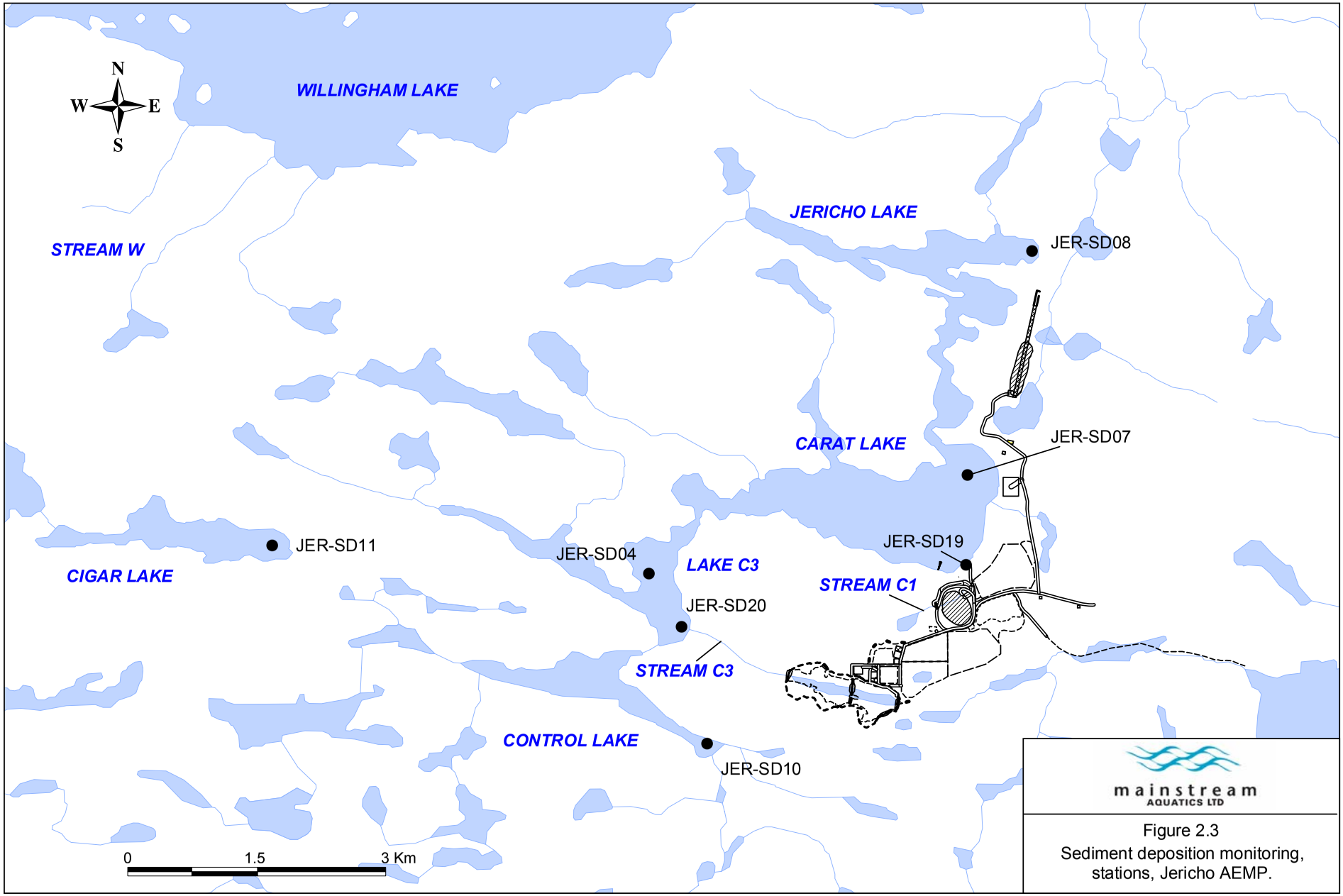

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Figure 2.3
Sediment deposition monitoring, stations, Jericho AEMP.

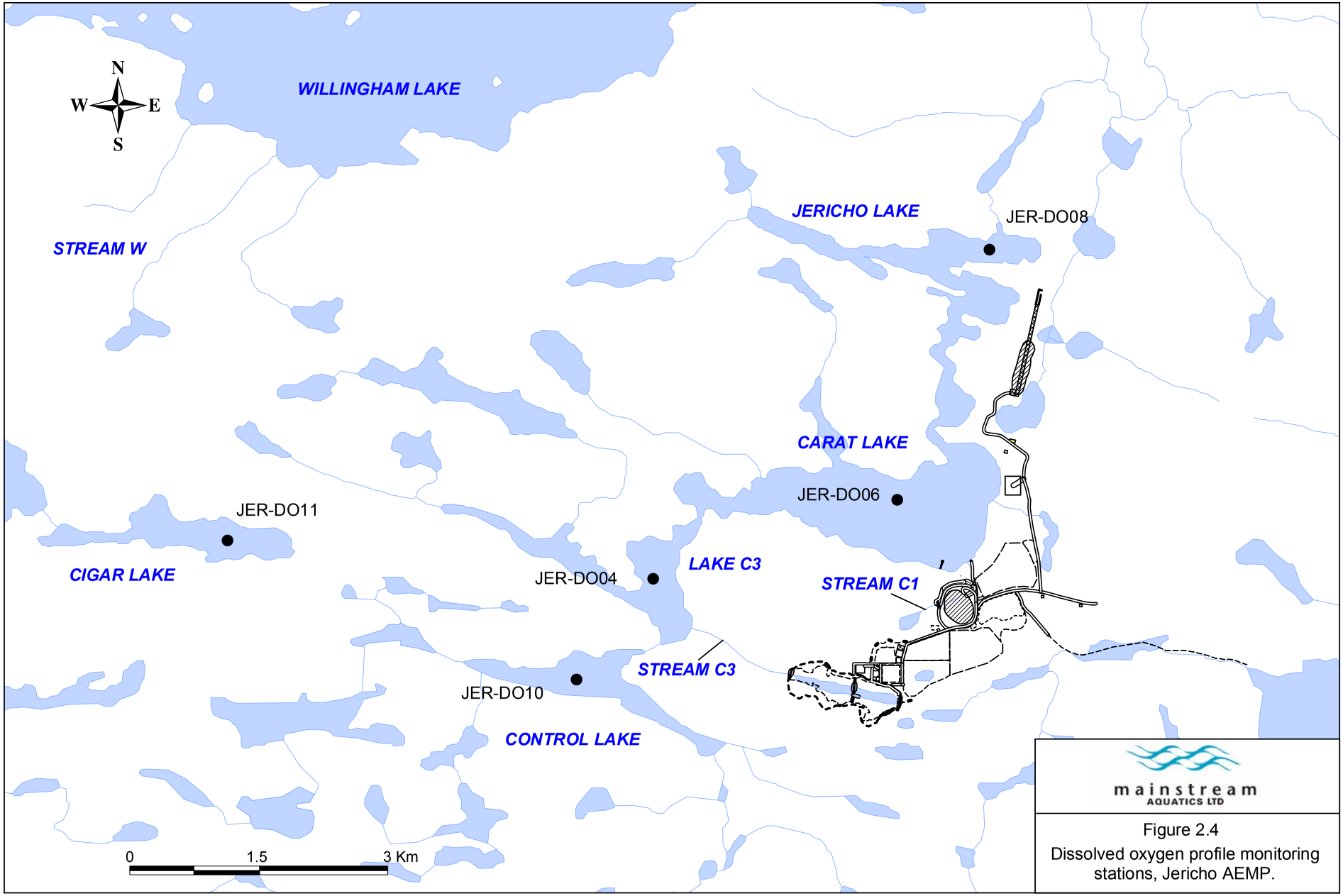

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Figure 2.4
Dissolved oxygen profile monitoring stations, Jericho AEMP.

Table 2.1 Station type, waterbody and location, and indicators monitored in 2004, Jericho AEMP.

Station	Waterbody and Location	Indicators							
		Non-sedentary			Sedentary				
		Phytoplankton	Zooplankton	Lake trout/ Round whitefish	Periphyton	Benthic Invertebrates	Slimy sculpin	Sediment Deposition	Dissolved Oxygen
JER-AB10	Control Lake	✓	✓		✓	✓		✓	✓
JER-AB11	Cigar Lake	✓	✓	✓	✓	✓		✓	✓
JER-AB23	Stream W at Willingham Lake						✓		
JER-AB04	Lake C3	✓	✓	✓					✓
JER-AB06	Carat Lake	✓	✓	✓					✓
JER-AB07	Carat Lake outlet				✓	✓		✓	
JER-AB08	Jericho Lake	✓	✓		✓	✓		✓	✓
JER-AB19	Carat Lake at Stream C1				✓	✓	✓	✓	
JER-AB20	Lake C3 at Stream C3				✓	✓	✓	✓	

2.2 PARAMETERS

For each indicator monitored parameters are listed in Tables 2.2 and 2.3.

Table 2.2 Monitored indicators and parameters in 2004, Jericho AEMP.

Indicator	Parameter
Phytoplankton	Taxa richness; taxa diversity; density; biovolume; biomass index (Chl. *a*)
Periphyton[a]	
Zooplankton	Taxa richness; taxa diversity; density; biomass
Benthic invertebrates	Taxa richness; taxa diversity; density
Sediment deposition	Sediment weight[b]
Fish	Metal contaminants • muscle and liver (lake trout and round whitefish) • whole body (slimy sculpin)

[a] Based on conditions specified in Schedule L in NWBJER0410 analyses of periphyton was omitted from the 2004 aquatic biota Jericho AEMP.

[b] To be measured in 2005.

Table 2.3 Detection limits for fish tissue metal contaminants in 2004, Jericho AEMP.

Metal	Abbreviation	Detection Limit (µg/g)	Metal	Abbreviation	Detection Limit (µg/g)
Aluminum	Al	0.2	Manganese	Mn	0.2
Antimony	Sb	0.01	Mercury	Hg	0.01
Arsenic	As	0.1	Molybdenum	Mo	0.02
Barium	Ba	0.05	Nickel	Ni	0.02
Beryllium	Be	0.005	Selenium	Se	0.1
Bismuth	Bi	0.02	Silver	Ag	0.005
Cadmium	Cd	0.0005	Strontium	Sr	0.5
Chromium	Cr	0.02	Tin	Sn	0.5
Cobalt	Co	0.005	Titanium	Ti	0.25
Copper	Cu	0.5	Uranium	U	0.025
Iron	Fe	0.5	Vanadium	V	0.05
Lead	Pb	0.05	Zinc	Zn	0.5
Lithium	Li	0.05	Moisture		0.1%

2.3 SAMPLE TIMING AND REPLICATES

The timing of sample collection and number of replicates are listed in Table 2.4.

Table 2.4 Sampling timing and replication for aquatic biota in 2004, Jericho AEMP.

Indicator	Sample Timing	No. Replicates
Phytoplankton	19 to 22 August	7
Zooplankton	20 to 22 August	7
Periphyton	27 to 29 August	7
Benthic macroinvertebrates	20 to 23 July	7
Sediment deposition (trap deployment)	27 to 30 August	1
Dissolved oxygen	19 to 22 August	1
Fish tissue metal contaminants	24 August to 1 September	10 per species

3.0 METHODS

3.1 DISSOLVED OXYGEN

Dissolved oxygen concentration (± 0.1 mg/L) and water temperature (± 0.1 C°) were measured in the field using an Oxyguard Handy Beta dissolved oxygen-temperature meter. Depth profile measurements were collected at 1.0 m intervals. Water transparency was measured using a standard 20 cm diameter Secchi disk to the nearest 0.1 m.

3.2 PHYTOPLANKTON

3.2.1 Field

Phytoplankton was collected following procedures described in Findlay and Kling (2003). Samples were collected from the water column within the euphotic zone, which was assumed to be a water depth equal to two times the Secchi depth. In lakes that were shallower than two times the Secchi depth, samples encompassed the entire water column to 1 m above the lake bottom to avoid contamination with sediment.

Each replicate consisted of a composite of five samples from the euphotic zone collected using an integrated sampler. The integrated sampler consisted of a weighted 3 cm diameter polyethylene tube. The tube was gently lowered vertically into the water column and the top capped off before being lifted out of the water and drained into a bucket. The composite sample in the bucket was thoroughly mixed and a 970 ml volume subsample collected as a replicate. The process was repeated for each replicate.

Each replicate was placed in pre-labeled 1000 ml container and preserved with a combination acid-Lugol's solution (0.5% by volume) and a formaldehyde acetic acid solution (2% by volume). All replicates were stored in the dark.

Replicates destined specifically for chlorophyll *a* analysis were collected separately. A pre-determined 300 ml volume of subsample from the mixed composite sample was filtered onto Whatman GF/C filter paper, covered with anhydrous $MgCO_3$, and frozen.

Equipment was thoroughly rinsed before and after sampling at each station to prevent contamination. All samples were labeled with the station and replicate identifier, time, date, depth, volume sampled, preservative amount, and name of the collector.

3.2.2 Laboratory

Phytoplankton samples were processed by a qualified phytoplankton taxonomist using procedures outlined in Lund et al. (1958). Prior to analyses, samples were gently inverted, and a 10 to 100 ml subsample was dispensed into sedimentation chambers (Lund et al. 1958). Subsample volume was dependant on the ability to count a minimum of 200 phytoplankton cells or units (colonies, chains or filaments). Samples were processed after a 24 h sedimentation period. A species list was developed by scanning the entire basal area of the chamber with an inverted microscope (Wild^{TM} M-40). Diatom identification was accomplished by concentrating a subsample onto a coverslip, clearing utilizing a muffle furnace and then mounting in Styrax. These were then examined under a compound microscope. Taxonomic keys used for identification included Prescott (1970), Taft and Taft (1971), and Webber (1971).

To calculate cell density (cells/ml), individual cells were enumerated within a specified area of the sedimentation chamber. This was accomplished by counting the number of cells along horizontal transects placed across the specified area. One or more transects were processed until the minimum number of 200 cells or units were counted. To calculate the cell density, the number of cells within the specified area was extrapolated to the subsample, and then to the entire sample.

Cell biovolume ($\mu m^3/m^3$) was calculated by first measuring the physical dimensions (length, width, and depth) of 10 to 30 cells of each species in the sample. Representative cell biovolume were then generated by calculating individual cell volumes for all cells measured (utilizing the nearest geometric shape(s)) and averaging these to produce an estimated cell biovolume for each species. The cell biovolume estimate for the subsample was then extrapolated to the entire sample (Note: averaging cell dimensions rather than individual cell volume estimates to produce a representative cell volume can seriously underestimate the representative cell volume used). Species that were encountered during the qualitative assessment, but not enumerated (i.e., very low numbers, nonviable, or located outside the enumeration transects) were recorded as present and included in the total taxa present for that sample.

Chlorophyll *a* analysis was conducted using the spectrophotometric-acetone extraction method described by Moss (1967a, 1967b). This method corrects for the presence of phaeophytin *a*, which may be present in decaying algal cells. This is achieved by acidification of the sample after initial measurement and referencing results to predetermined calibration curves.

3.3 ZOOPLANKTON

3.3.1 Field

Zooplankton was collected following the general procedures described in Paterson (2003). Each zooplankton sample consisted of a composite of five vertical hauls, each of which included two times the euphotic zone (i.e., four times the Secchi depth). In lakes that were shallower than four times the Secchi depth, hauls encompassed the entire water column to 1 m above the lake bottom to avoid contamination with sediment. Zooplankton were collected with a Wisconsin plankton net constructed with Nitex® mesh (net mouth diameter 130 mm; 0.064 x 0.064 mm mesh). For each haul, the net was lowered to the desired depth and then retrieved at a constant rate of 1.0 m/s. Samples were preserved immediately in 5% formaldehyde and stored in labeled 500 ml polyethylene bottles. All samples were labeled with a site identifier, time, date, depth, and name of the collector. Equipment was thoroughly rinsed before and after sampling at each site to prevent contamination.

3.3.2 Laboratory

Macrozooplankton (cladocerans and copepods) were enumerated from three 1 to 15 ml sub-samples using an automatic pipette with a dissecting microscope at magnifications of 12-50x. Subsampling was performed on samples that contained large numbers of specimens. All samples were subsampled using an automatic pipette for rotifer and copepod nauplii enumeration. Rotifers and copepod nauplii were enumerated by counting either six fields (one field = 0.02625 cm^2) or the entire counting chamber (4.907 cm^2) using a Zeiss Axiovert 40 CFL (inverted) microscope at magnifications of 200-400x. Subsamples for rotifers and nauplii were allowed to settle for 24 hours before counting. Subsample volumes depended largely on the amount of sediment in the sample. Subsamples were continually removed from the original sample until approximately 200 mature or identifiable rotifer organisms were processed. Once the numbers of organisms within each sample were established, these values were converted to densities per cubic metre. This was accomplished by dividing the number of organisms encountered in a sample by the total volume filtered (i.e., net mouth area * depth of haul * number of hauls).

Macrozooplankton were identified using keys from Brooks (1957), Edmondson (1959), Chengalath (1971), Grothe and Grothe (1977), Pennak (1978), and Clifford (1991). Microzooplankton were identified using keys from Chengalath (1971), Grothe & Grothe (1977), Stemberger (1979), Clifford (1991) and Thorp & Covich (1991).

Zooplankton biomass of major taxonomic groups was calculated based on animal lengths determined directly using a microscope with a micrometer in the ocular. Generally, lengths were measured for the first 30 individuals of each species or genus observed in each sample. Where less than 30 individuals occurred, the number measured equaled the average number counted over all sub-samples. The larger zooplankton were measured in the compound microscope at low power (40X). Smaller zooplankton, such as rotifers, were measured using an eyepiece graticule and corrected for magnification. Using length measurements from individual organisms, weights were calculated from published length-weight regressions; general equations for taxa were used where length-weight equations were not available for specific species (Table 3.1). For each sample, mean individual weights for each species were calculated by averaging estimated weights. Total biomass for each group (species or developmental stage) was calculated as the product of its density and estimated mean individual weight.

Table 3.1 Length-weight regressions used in calculating zooplankton weights.

Organism	Equation (ug=microgram)	Reference
Copepods (N I-adults)	lnW(ug) = 1.9526 + 2.399 lnL(mm)	Bottrell et al. 1976
Daphnia spp.	lnW(ug) = 1.6 + 2.84 lnL(mm)	Bottrell et al. 1976
Ceriodaphnia spp.	InW(ug) = 2.8713 + 3.079 lnL(mm)	Bottrell et al. 1976
Scapholeberis spp.	lnW(ug) = 2.5623 +3.338 lnL(mm)	Downing & Rigler 1984
Chydorus sphaericus	lnW(ug) = 4.543 + 3.6360 lnL(mm)	Downing & Rigler 1984
Other Cladocerans	lnW(ug) = 1.7512 + 2.653 lnL(mm)	Bottrell et al. 1976
Rotifers	lnW(ug) = -10.3815 + 1.574 lnL(mm)	Stemberger & Gilbert. 1987

3.4 PERIPHYTON

3.4.1 Field

The periphyton community was monitored during a 38-day period between 20 July and 27 August using artificial substrates placed on the lake bottom immediately following ice-out in July.

The artificial substrates consisted of plastic flower pots (40 mm radius x 65 mm long) having a total surface area of 165.1 cm^2. Prior to placement, the surface of each pot was roughened and the pot filled with rock substrates to add weight. Seven pots were placed on the lake bottom at depths between 2.5 and 3.1 m with 1.5 m interval between each pot. The pots were secured to a float line at the water surface connected to two buoys and anchors.

At the end of the sampling period, the pots were retrieved and processed. If a pot was not in an upright position (i.e., pot that had tipped over), the area available for periphyton growth was calculated by subtracting the portion of the pot that was submerged in the lake sediment from the total surface area.

Periphyton was removed from each artificial substrate using a tooth brush and the material rinsed with 250 ml of deionized water into a 500 ml polyethylene bottle. Samples used for algal identification and enumeration were preserved with a combination acid-Lugol's solution (1% by volume) and a formaldehyde acetic acid solution (2% by volume). All replicates were stored in the dark. Before preservation the sample was thoroughly mixed and a 20 ml subsample collected for chlorophyll *a* analysis. The subsample was filtered onto Whatman GF/C filter paper, covered with anhydrous $MgCO_3$, and frozen.

3.4.2 Laboratory

Periphyton samples were stored in the event that analyses are required in the future.

3.5 BENTHIC MACROINVERTEBRATES

3.5.1 Field

Benthic macroinvertebrates were sampled following general procedures described in Rosenberg *et al.* (2003) immediately following ice-out in July. Sampling during the early open water period is deemed appropriate for two reasons. First, it is logistically more feasible to sample during open water compared to winter when ice limits access to sites. Two, collections made during the open water period before emergence (transformation of larvae/pupae into adults), provides good representation of the benthic macroinvertebrate community.

All sites were located in water depths between 3.6 to 5.2 m. An ekman grab sampler (aperture area equal to 0.023 m^2) was used to collect seven replicates at each station. To address the issue of high within-site variation caused by clumped benthic macroinvertebrate distribution, and to increase the probability of encountering rare taxa, each replicate consisted of a composite of three ekman grabs.

The quality of the sample was examined (i.e., jaws were closed and the grab was full) before it was processed. If deemed of poor quality, the sample was rejected and the procedure repeated. Each replicate

was sieved through a 0.243 µm mesh net to remove excess sediments, placed in labelled polyethylene sample bags, and preserved in 10% formalin.

3.5.2 Laboratory

Samples were divided into two components for processing: elutriated and sediment. Invertebrates were collected by repeatedly rinsing and elutriation of the sample until invertebrates were no longer observed. The entire elutriated and sediment components of the sample were then processed.

Invertebrates were sorted by major taxonomic group and identified to the lowest practical taxonomic level (genus where possible) using a dissecting microscope (6-42x magnification). Chironomids were identified to family or tribe. Keys used for identification included Wiggins (1977), and Clifford (1991).

Once processing was complete samples were preserved in 70% ethanol.

3.6 SEDIMENT DEPOSITION

Methodology and analysis procedures will generally follow those described in DDMI (2003).

3.6.1 Field

The design of the traps was similar to those described in the CRC Handbook of Techniques for Aquatic Sediments Sampling (Mudroch and MacKnift 1991). Traps consisted of collection bottles located in PVC tubes suspended 1 m above the lake bottom and 2.5 m below the water surface (Figure 3.1). Traps were located at sites with water depths between 6.0 and 6.5 m.

3.6.2 Laboratory

Sediment deposition traps were deployed in August and will be left in place for one year before retrieval.

3.7 FISH

3.7.1 Field

Capture Methods

Variable-mesh standard gill nets sets were used to sample open water lake habitats. Each standard experimental gill net set was comprised of 15.2 x 1.8 m panels of 2.5, 3.8, 6.4, 8.9, 11.4, and 14.0 cm

mesh sizes (stretched measure). Set times were kept short (less than 2 h) to minimize capture mortality; occasionally overnight sets were employed if fish tissue quotas were not met. Shoreline areas and streams were sampled using a Smith Root Type XII high output backpack electrofisher.

All captured fish were measured for fork length (± 1 mm) and weight (± 2 g). Ageing structures and gonad weight also were collected for fish destined for tissue analyses.

Tissues Collection

Muscle and liver tissues were used to monitor tissue metal contaminants in lake trout and round whitefish, while whole fish were used for slimy sculpin.

Dorsal musculature (50 to 100 g) and livers (excluding the gall bladder) were dissected from each fish and sealed in 120 ml sterile, acid-washed specimen containers. All tissue samples were immediately frozen and kept frozen until the time of laboratory analyses.

Tissue sampling protocols followed procedures described by USAEPA (2000). Appropriate measures were taken to prevent contamination. All dissections occurred on a washable plastic surface. High-quality, corrosion-resistant stainless steel sample processing equipment was used including sterile knives with plastic handles. Utensils and containers were cleaned thoroughly with a detergent solution, rinsed with 5% HNO3, followed by an immediate rinse with distilled water. All dissecting equipment, sample containers, sample wrapping and wash equipment were shipped and stored in clean waterproof containers.

Data recorded for each fish included fork length (to the nearest 1 mm), weight (to the nearest 2 g), sex, maturity, and gonad weight. An appropriate ageing structure was also collected (otoliths) from all captured tissue fish.

3.7.2 Laboratory

Tissues

Analyses of metal concentrations in fish tissues were conducted by Norwest Labs (Surrey, British Columbia). The following is a description of the methods and instrumentation that were used.

Tissue samples preparation was based on CFIA requirements. Samples were prepared for analyses by first homogenizing the tissue in plastic cups using a “Virtis” shearer equipped with stainless steel blades. Prior

to homogenization of each sample, the apparatus was cleaned with 18 MΩ deionized water. Approximately 1 g of homogenized tissue was then weighed into a precleaned (triple nitric acid) teflon digestion vessel. High purity "Seastar" nitric acid (4 ml) was added and the vessel was capped before being heated at 150°C. The resulting solution was made up to a volume of 25 ml with 18 ml deionized water for subsequent analyses.

The digested sample was then analyzed by ICP and ICPMS. The instrument methods are based on EPA 6010B and 6020. The minerals Ca, Mg, Na, K, Fe, P, and Si were reported from the ICP and the other metals were analyzed by ICPMS. The mercury was analyzed by cold vapor atomic absorption, based on EPA 7470.

Moisture content was measured using 1 g of homogenized tissue. The sample was weighed into a preweighed and tared 10 ml glass beaker. The beaker and sample were then dried overnight at 105°C. After cooling to room temperature, the beaker and sample were transferred to a desiccator for 2 h, after which, the beaker with the sample was re-weighed to obtain the loss in moisture.

All results were reported as micrograms per gram on a 'wet weight' basis.

Ageing

Fish ageing followed the protocol outlined in Mackay et al. (1990). Otoliths, stored dry in labelled envelopes, were first lightly ground and polished with emery cloth (400 grit) to allow sufficient light transmission. Then a binocular dissecting microscope, equipped with a transmitted light source, was used to obtain an age from each structure. Two independent readers aged each structure. When discrepancies in the assigned age occurred, the two readers conferred to arrive at a consensus.

3.8 QUALITY ASSURANCE

3.8.1 Nonvertebrate Aquatic Biota

The following QA/QC procedures were used for nonvertebrate data.

1. Strict sampling protocols were adhered to ensure consistency in technique for each parameter.
2. Consistency of identifications for each indicator was achieved by using the same person.
3. Ten percent of samples were analyzed by other qualified persons to ensure the accuracy of identifications and counts.
4. Split samples collected from 5% of the samples were submitted as blinds.

5. For benthic invertebrates the residue of the sample was examined to determine sorting efficiency. If the residue contained a number of organisms that exceeded 10% of the entire sample, the sample was re-processed.
6. All samples were archived for future reference.

3.8.2 Fish Tissues

Fish metal contaminants sampling utilized safeguards to prevent contamination as follows:

1. Use of sterile stainless steel instruments.
2. Tissue cups rinsed in 5% nitric acid solution.
3. Covering the work area in plastic.

Analytical QA/CC procedures included:

1. Use of an accredited laboratory.
2. Running certified reference materials (NBS1566A oyster tissue, DORM2, and DOLT2)
3. Split samples from 5% of the replicates were submitted for analyses.

3.8.3 Analyses

Sample precision was examined for each indicator and parameter by measuring the percent difference between the sample estimate and the quality control estimate. The accuracy and consistency of taxa identification was examined by comparing the number of unique taxa identified in the sample versus the quality control.

3.9 DATA ANALYSES

Data analyses involved generating summary metrics (mean, standard deviation, minimum, maximum) for each parameter listed in Table 2.1. This was followed by evaluation of spatial differences among stations using univariate parametric statistical tests. Prior to summaries and statistical analyses the data for each parameter were examined to ensure appropriateness for evaluation

The first step was to present the data graphically to examine gross differences among stations, to examine the distribution pattern, and to identify outliers. An individual data point was defined as an outlier if its absolute value exceeded the absolute value of the next closest data point in the entire data by a magnitude of three. Once an outlier was identified, subsequent tests were completed with and without the outlier data point.

Data were then examined to establish whether assumptions were met for parametric statistical analyses using standard procedures as follows:

1. Homogeneity of variance (Levene's test)
2. Normal distribution (G test)
3. Independence (Runs Test)

If one or more assumptions for parametric tests were violated the data were transformed to an appropriate nonlinear scale. If the assumption for homogeneous variance was not met after transformation the parametric test statistic was adjusted (i.e., *Welch* statistic used in place of *F* statistic).

Spatial difference among stations was examined using Oneway Analysis of Variance (ANOVA). If a significant difference among stations was identified a post hoc mean comparisons tests was used to identify the station(s) responsible for the difference. The Tukey's b test was employed if sample variances were homogeneous; if not the Games-Howell test was used.

A different approach was used for metal concentrations in fish tissues. First, the number of data points below the analytical detection limit was summarized. If the number below detection was >5 no further analyses were undertaken. This approach was deemed appropriate because sample sizes available for metal concentration analyses (i.e., 10 – 6 = 4) typically do not have sufficient power to identify a statistical difference if one exists assuming a size effect of 2 standard deviations (ENVCAN 2002). Samples of selected metals that met the criteria for a minimum sample size, but that contained data below analytical detection limits were adjusted. Data points below detection were assigned a value of ½ the analytical detection limit.

Second, data were examined to ascertain whether there was a relationship between metal concentration and fish length using Pearson's Correlation Coefficient. If a consistent significant trend was established a Oneway Analysis of Covariance (ANCOVA) was used to examine station effects with fish length as the covariate. If not ANOVA was used.

Prior to evaluating for differences among stations with ANCOVA, sample slopes were tested for homogeneity. If slopes were significantly different data were transformed and/or outliers removed in order to meet this assumption. If a significant difference among stations occurred the adjusted station means were examined using the Bonferroni multiple comparisons test to identify the station(s) responsible for the difference.

Statistical significance was accepted at $P \leq 0.05$. All tests followed descriptions presented in Sokal and Rolhf (1981).

4.0 RESULTS

4.1 DISSOLVED OXYGEN

Dissolved oxygen and temperature profiles were measured at five stations between 19 and 22 August 2004 (Figure 4.1). Dissolved oxygen concentrations at all stations approximated 11.0 mg/L regardless of depth. Water temperatures in most lakes ranged from 7.5^{o}C to 9.0^{o}C. At the time of measurements only one waterbody was stratified: Control Lake. The thermocline occurred at 18 m depth. Although the maximum water depths exceeded 18 m in Cigar Lake and Carat Lake, the dissolved oxygen and temperature profiles at those stations demonstrated no thermocline. Based on these data, Control Lake was the only waterbody that was stratified.

4.2 SEDIMENT DEPOSITION

Sediment deposition traps were deployed in August 2004 and will remain in place until August 2005. Therefore, there are no results for this monitoring component.

4.3 PHYTOPLANKTON

Summary information are presented in Table 4.1 and Figure 4.2.

Taxa Richness

In general, taxa richness was similar among most waterbodies with the mean number of taxa ranging from 48 to 70. The one exception was Control Lake. The mean number of taxa of 26.5 in this waterbody was significantly less than the mean number of taxa in each of the other four waterbodies.

Taxa Diversity

Taxa diversity also was generally similar among most waterbodies. The mean Simpson's D value ranged from 0.647 to 0.750. The one exception was Carat Lake. The mean Simpson's D value of 0.510 for phytoplankton sampled from this waterbody was significantly less than mean values recorded at the remaining four waterbodies.

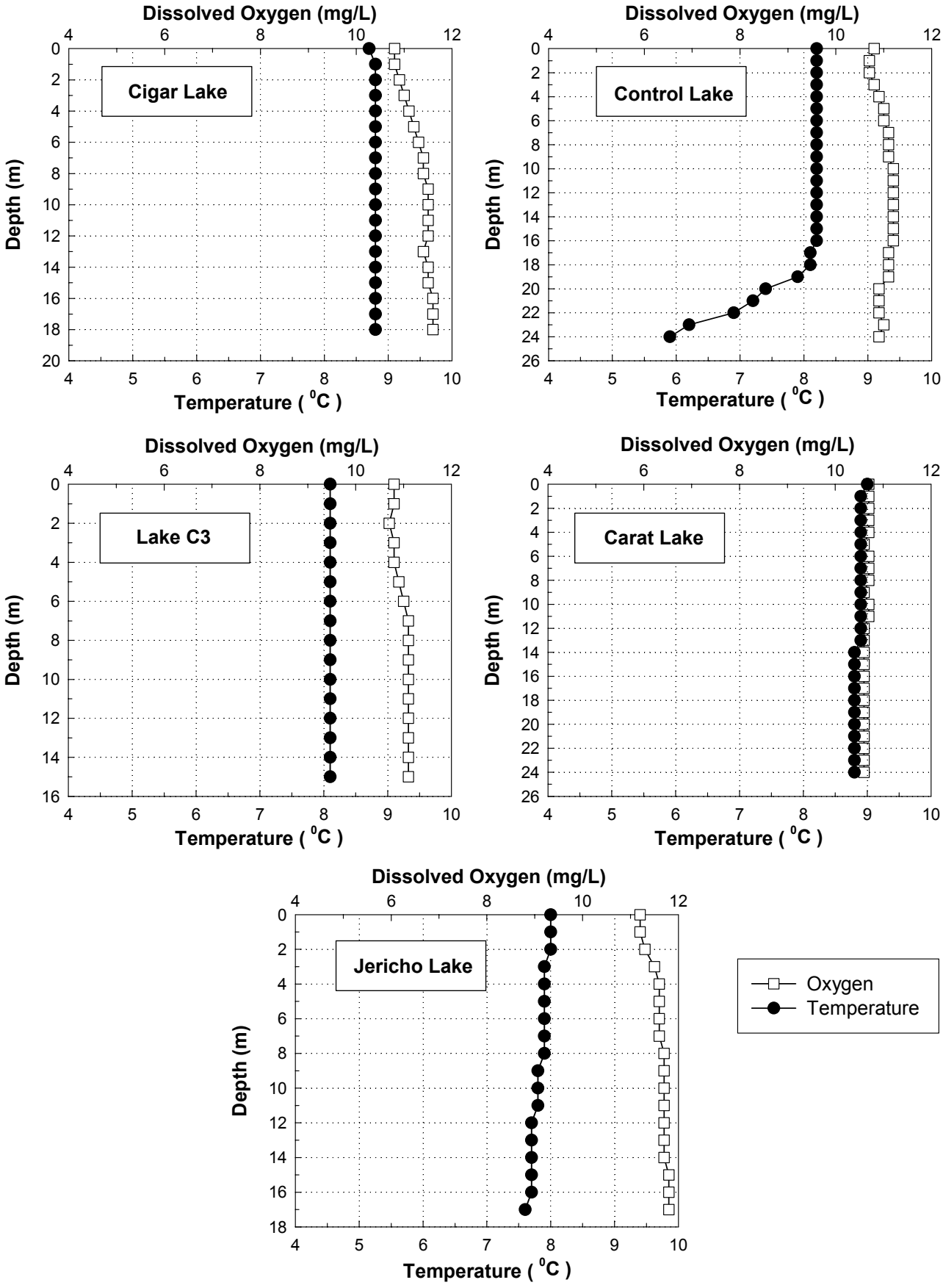

Figure 4.1 Dissolved oxygen and temperature profiles at stations monitored between 19 and 22 August 2004, Jericho AEMP.

Table 4.1 Phytoplankton parameter summary metrics at stations monitored in 2004, Jericho AEMP.

Parameter	Lake	Station	Sample Size	Mean	Standard Deviation	Minimum	Maximum	Significance[a]
Richness[b] (No. taxa)	Cigar	JER-AB11	7	55.1	1.1	48	64	B
	Control	JER-AB10	7	26.5	1.3	16	39	A
	C3	JER-AB04	7	62.4	1.1	55	70	B
	Carat	JER-AB06	7	61.6	1.1	55	67	B
	Jericho	JER-AB08	7	64.5	1.1	58	70	B
								$P = 0.000$
Diversity (Simpson's D)	Cigar	JER-AB11	7	0.731	0.113	0.58	0.89	B
	Control	JER-AB10	7	0.717	0.081	0.61	0.85	B
	C3	JER-AB04	7	0.750	0.070	0.69	0.89	B
	Carat	JER-AB06	7	0.510	0.049	0.45	0.60	A
	Jericho	JER-AB08	7	0.647	0.100	0.45	0.74	B
								$P = 0.000$
Total Density[b] (cells/ml)	Cigar	JER-AB11	7	1866.5	1.3	1110	2503	A
	Control	JER-AB10	7	3199.2	1.5	1995	5289	AB
	C3	JER-AB04	7	2676.0	1.2	2038	3324	A
	Carat	JER-AB06	7	4317.5	1.1	3842	4739	B
	Jericho	JER-AB08	7	3643.1	1.2	2592	4366	B
								$P = 0.000$
Total Biovolume[b] (μm^3/ml)	Cigar	JER-AB11	7	506,154.5	1.2	383,487	656,663	D
	Control	JER-AB10	7	408,306.2	1.2	277,306	519,036	CD
	C3	JER-AB04	7	336,287.1	1.3	242,709	514,115	BC
	Carat	JER-AB06	7	225,975.1	1.2	194,069	307,252	A
	Jericho	JER-AB08	7	296,681.4	1.3	204,482	432,354	AB
								$P = 0.000$
Chlorophyll *a*[c] (mg/m^3)	Cigar	JER-AB11	7	0.38	0.14	0.26	0.66	A
	Control	JER-AB10	7	0.70	0.21	0.35	1.05	B
	C3	JER-AB04	7	0.67	0.18	0.37	0.92	B
	Carat	JER-AB06	7	0.63	0.17	0.34	0.89	AB
	Jericho	JER-AB08	7	0.54	0.15	0.35	0.69	AB
								$P = 0.014$

[a] See Section 3.8 for description of statistical methods.
[b] Represents back-transformed log scale data.
[c] Represents back-transformed square root scale data.

Total Density

Total density varied among waterbodies. Mean values ranged from a low of 1866.5 cells/ml to 4317.5 cells/ml. Total densities in Cigar Lake and Lake C3 were significantly less than mean total densities in Carat Lake and Jericho Lake.

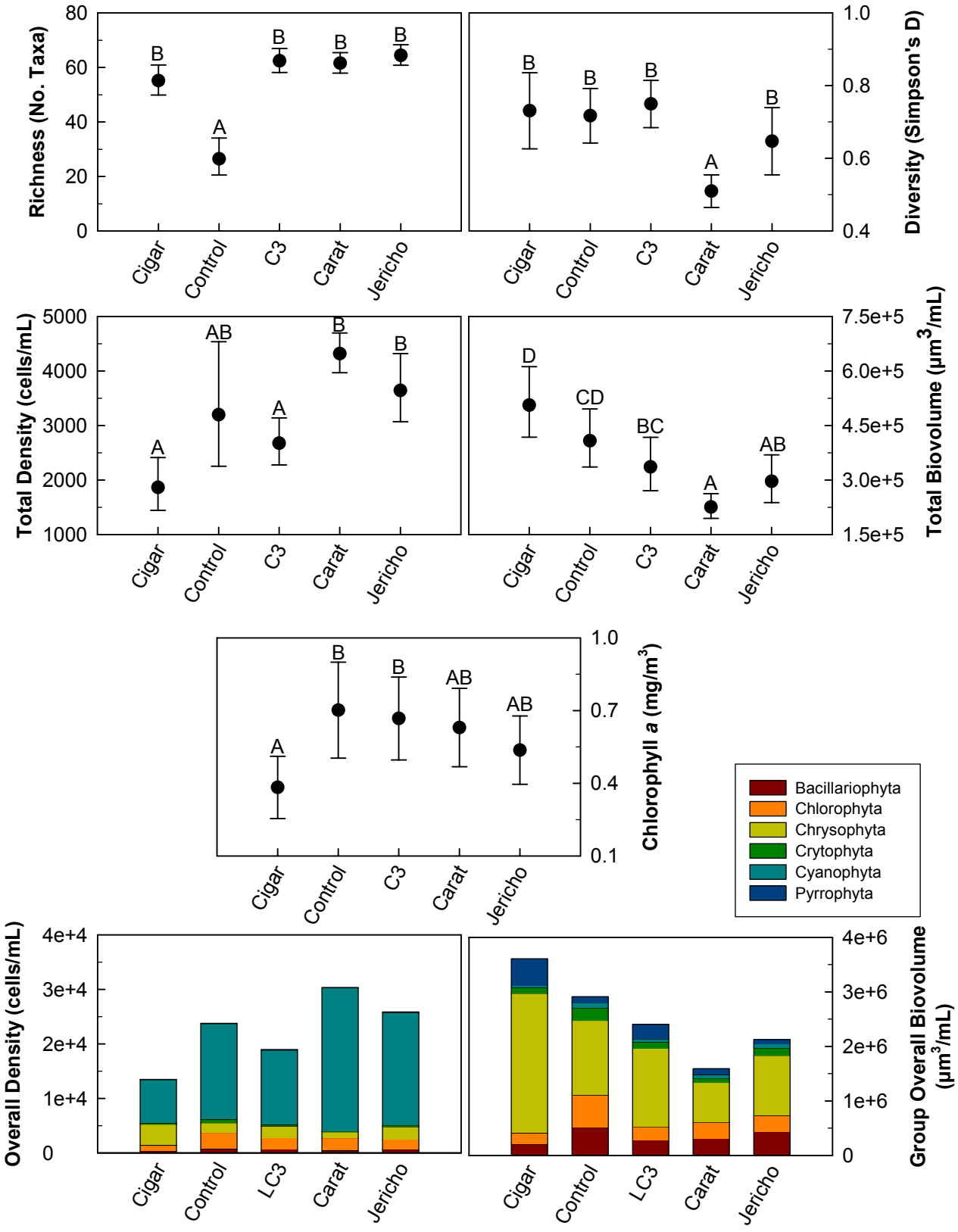

Figure 4.2 Phytoplankton parameter summary metrics ($\bar{x} \pm$ 95% CI) monitored in 2004, Jericho AEMP (Letter designates statistical differences; see section 3.8 for methods).

Total Biovolume

Total biovolume varied among waterbodies. In general, there was a trend towards lower total biovolume from upstream to downstream. The highest mean value was recorded in Cigar Lake (506,154.5 μm^3/ml) and the lowest was recorded in Carat Lake (225,975.1 μm^3/ml). This pattern resulted in four significant groupings along this spatial gradient.

Chlorophyll *a*

Chlorophyll *a* varied among waterbodies. Mean values ranged from 0.38 mg/m^3 in Cigar Lake to 0.70 mg/m^3 in Control Lake. Based on these data chlorophyll *a* in Cigar Lake was significantly less than in Control Lake and Lake C3.

Major Taxa

The phytoplankton data (density and biovolume) were summarized by major taxonomic group and presented in Figure 4.2. In terms of density, the dominant group in all waterbodies was Cyanophyta. Chlorophyta was the dominant group in all waterbodies based on biovolume.

Quality Control

Four samples sent to an outside taxonomist and two split samples were evaluated for quality control (Table 4.2). Average percent difference exceeded 20% for most parameters for samples submitted to an external reviewer. Differences recorded using split samples were slightly better with average values ranging from 17.5% for taxa richness to 33.2% total density. There were large differences in the number of unique taxa identified in the quality control versus the processed samples (i.e., taxa recorded in one sample but not in the other). Differences were documented in the split samples but they were not as large. The reasons for the large number of unique taxa included differences in identification at the species (11 taxa) and the genus (2 taxa) levels and the presence of a large number of rare taxa.

Table 4.2 Percent difference in phytoplankton summary metrics and numbers of unique taxa between processed and quality control samples, Jericho AEMP.

Type	Station	Percent Difference					Unique Taxa (No.)	
		Replicate	Total Density	Total Biovolume	Richness	Diversity	Sample	QAQC
External	JER-AB10	CN0101	50.6	-15.4	10.3	-36.1	27	23
	JER-AB04	C30101	-2.1	-4.3	60.0	-10.4	70	29
	JER-AB06	CA0101	58.1	-34.0	58.7	-78.3	52	20
	JER-AB08	JE0101	67.9	-16.9	48.3	-22.9	48	19
		Average	**48.9**	**-15.8**	**50.0**	**-32.3**	**49.3**	**22.8**
Split	JER-AB10	CN0104	73.7	45.1	20.5	-25.8	21	13
	JER-AB08	JE0101	-10.8	-2.3	15.5	58.6	34	25
		Average	**33.2**	**32.5**	**17.5**	**17.6**	**27.5**	**19.0**

4.4 ZOOPLANKTON

Summary information are presented in Table 4.3 and Figure 4.3.

Taxa Richness

Zooplankton taxa richness varied among waterbodies. Mean number of taxa ranged from 10.1 in Cigar Lake to 12.4 in Control Lake. There were two distinct groupings based on significant differences in mean values as follows: Cigar Lake and Carat Lake (lowest) and Control Lake (highest).

Taxa Diversity

Taxa diversity was generally similar among most waterbodies. The mean Simpson's D value in most waterbodies ranged from 0.703 to 0.776. The one exception was Cigar Lake. The mean Simpson's D value of 0.596 was significantly less than mean values recorded for the remaining four waterbodies.

Total Density

Total density of zooplankton was similar among waterbodies. Mean values ranged from a low of 15,338.8 organisms/m^3 to 22,647.5 organisms/m^3. There were no significant differences in mean total density.

Total Biomass

Total biomass was generally similar among most waterbodies. Mean values ranged from 32,230.7 $\mu g/m^3$ to 56,560.7 $\mu g/m^3$. The single exception was Cigar Lake. The mean total biomass was significantly less than mean values recorded at all other waterbodies.

Cladocera Density

Unlike total density, there were differences in cladocera density among waterbodies. Mean values ranged from 80.8 organisms/m^3 in Lake C3 to 415.9 organisms/m^3 in Carat Lake. The difference between the mean values of these two waterbodies was significant.

Table 4.3 Zooplankton parameter summary metrics at stations monitored in 2004, Jericho AEMP.

Parameter	Lake	Station	Sample Size	Mean	Standard Deviation	Minimum	Maximum	Significance[a]
Richness (No. taxa)	Cigar	JER-AB11	7	10.1	1.2	8	11	A
	Control	JER-AB10	7	12.4	1.7	10	15	B
	C3	JER-AB04	7	11.9	1.1	11	14	AB
	Carat	JER-AB06	7	10.3	0.8	9	11	A
	Jericho	JER-AB08	7	11.1	1.1	10	13	AB
								$P = 0.005$
Diversity (Simpson's D)	Cigar	JER-AB11	7	0.596	0.049	0.55	0.68	A
	Control	JER-AB10	7	0.703	0.053	0.64	0.76	B
	C3	JER-AB04	7	0.736	0.035	0.69	0.78	B
	Carat	JER-AB06	7	0.776	0.020	0.75	0.80	B
	Jericho	JER-AB08	7	0.750	0.019	0.72	0.77	B
								$P = 0.000$
Total Density[b] ($No./m^3$)	Cigar	JER-AB11	7	18,432.2	1.1	16,151	23,735	-
	Control	JER-AB10	7	22,647.5	1.5	10,840	38,019	-
	C3	JER-AB04	7	19,697.3	1.2	13,506	24,262	-
	Carat	JER-AB06	7	15,338.8	1.1	12,069	16,927	-
	Jericho	JER-AB08	7	21,260.4	1.3	12,157	27,271	-
								$P = 0.052$
Total Biomass[b] ($\mu g/m^3$)	Cigar	JER-AB11	7	32,230.7	1.2	26,828	44,093	A
	Control	JER-AB10	7	42,656.7	1.4	24,421	65,043	B
	C3	JER-AB04	7	56,560.7	1.2	45,081	72,391	B
	Carat	JER-AB06	7	47,378.8	1.1	40,460	54,665	B
	Jericho	JER-AB08	7	50,957.7	1.2	32,582	62,370	B
								$P = 0.000$
Cladocera Density[b] ($No./m^3$)	Cigar	JER-AB11	7	174.8	1.6	76	281	AB
	Control	JER-AB10	7	168.7	1.3	116	256	AB
	C3	JER-AB04	7	80.8	1.5	39	122	A
	Carat	JER-AB06	7	415.9	1.3	277	646	B
	Jericho	JER-AB08	7	191.1	1.4	114	289	AB
								$P = 0.000$
Cladocera Biomass[b] ($\mu g/m^3$)	Cigar	JER-AB11	7	26.9	8.7	13	40	A
	Control	JER-AB10	7	54.7	7.8	45	66	BC
	C3	JER-AB04	7	43.6	7.3	34	52	B
	Carat	JER-AB06	7	66.2	7.9	55	79	C
	Jericho	JER-AB08	7	60.2	11.2	46	77	BC
								$P = 0.000$

[a] See Section 3.8 for description of statistical methods.
[b] Represents back-transformed log scale data.

Cladocera Biomass

Cladocera biomass also varied among monitored waterbodies. Mean values ranged from 26.9 $\mu g/m^3$ to 66.2 $\mu g/m^3$. There were three groups based on significant differences in mean cladocera biomass. These were Cigar Lake, Lake C3, and Carat Lake. This pattern suggested a spatial gradient from upstream to downstream.

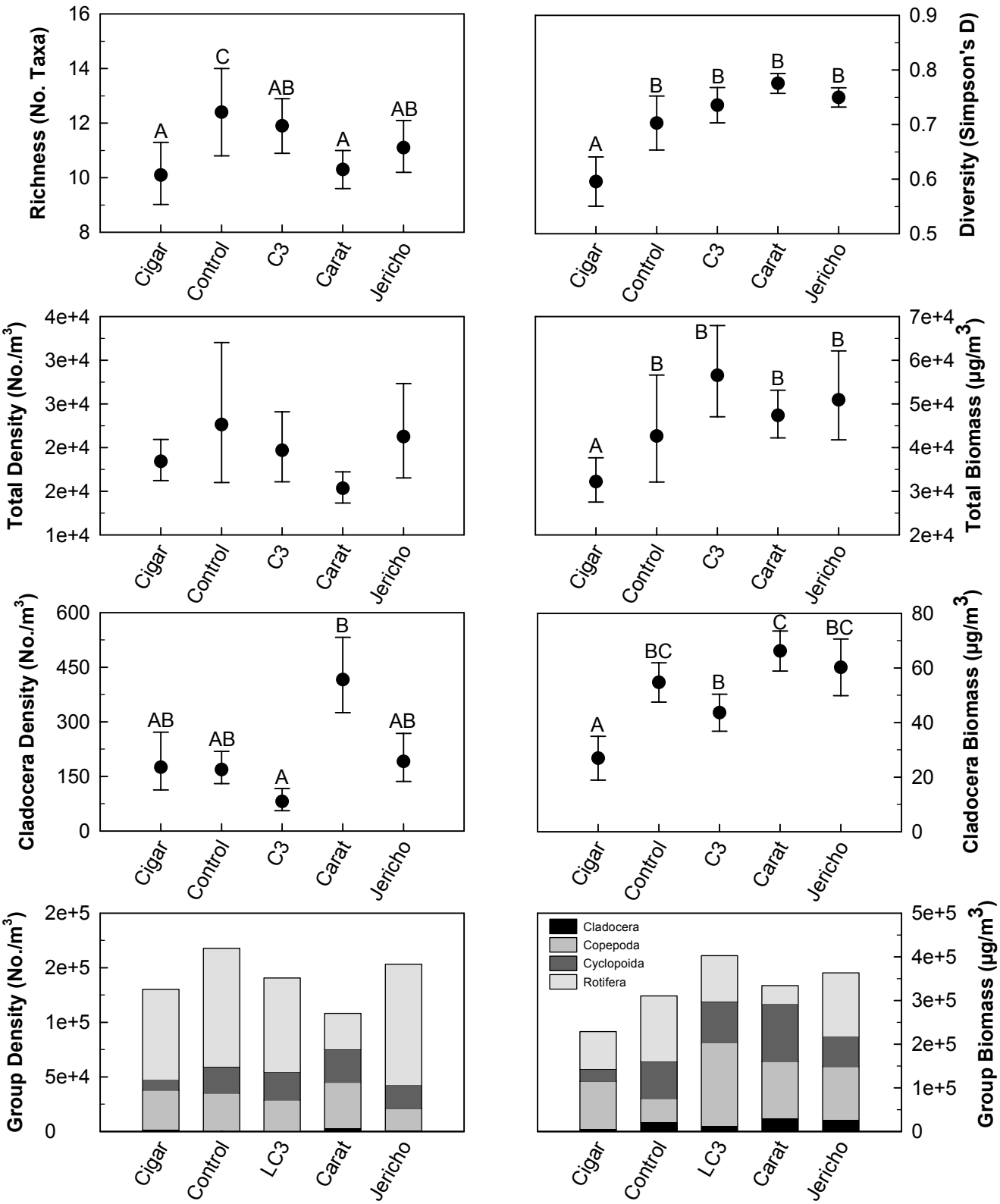

Figure 4.3 Zooplankton parameter summary metrics ($\bar{x} \pm$ 95% CI) monitored in 2004, Jericho AEMP (Letter designates statistical differences; see section 3.8 for methods).

Major Taxa

The zooplankton data (density and biomass) were summarized by major taxonomic group and presented in Figure 4.3. In terms of density, the dominant group in all waterbodies was Rotifera, followed by Copepoda. Biomass was evenly distributed among groups. In general, Copepoda, Cyclopoida, and Rotifera dominated.

Quality Control

Four samples sent to an outside taxonomist and two split samples were evaluated for quality control (Table 4.4). Average percent difference ranged from 16.8% for total density to -6.9% for species richness for samples submitted to an external reviewer. Differences recorded using split samples were similar. There were small differences in the number of unique taxa identified in the quality control versus the processed samples (i.e., taxa recorded in one sample but not in the other). Values ranged from 1 to 3. The reasons for the unique taxa numbers included differences in identification of a single taxa in each of the external samples and the presence of rare taxa.

Table 4.4 Percent difference in zooplankton summary metrics and numbers of unique taxa between processed and quality control samples, Jericho AEMP.

Type	Station	Percent Difference					Unique Taxa (No.)	
		Replicate	Total Density	Total Biomass	Richness	Diversity	Sample	QAQC
External	JER-AB11	CI0101	12.5		-15.4	0.0	1	3
	JER-AB04	C30101	28.1		0.0	5.7	3	3
	JER-AB06	CA0101	-19.2		-7.1	-7.7	1	2
	JER-AB08	JE0101	34.0		-6.7	6.9	1	2
		Average	**16.8**	**-**	**-6.9**	**1.5**	**1.5**	**2.5**
Split	JER-AB10	CN0104	-12.6	4.9	25.0	-7.4	0	3
	JER-AB08	JE0104	-14.9	5.4	-30.0	3.9	3	0
		Average	**-13.6**	**5.2**	**0.0**	**-1.4**	**-1.4**	**-1.4**

4.5 BENTHIC MACROINVERTEBRATES

Summary information are presented in Table 4.5 and Figure 4.4.

Taxa Richness

Taxa richness was similar among stations. Mean number of taxa ranged from 11.8 at near and far field stations in Carat Lake to 14.2 at the Control Lake station. There were no significant differences among benthic macroinvertebrate stations monitored in 2004.

Table 4.5 Benthic macroinvertebrate parameter summary metrics at stations in 2004, Jericho AEMP.

Parameter	Lake	Station	Sample Size	Mean	Standard Deviation	Minimum	Maximum	Significance[a]
Richness (No. taxa)	Cigar	JER-AB11	5	14.0	2.6	10	17	-
	Control	JER-AB10	5	14.2	0.8	13	15	-
	C3	JER-AB20	5	13.4	1.1	12	15	-
	Carat (near)	JER-AB19	5	11.8	1.6	10	14	-
	Carat (far)	JER-AB07	5	11.8	1.9	9	14	-
	Jericho	JER-AB08	5	13.2	2.7	11	17	-
								$P = 0.240$
Diversity (Simpson's D)	Cigar	JER-AB11	5	0.709	0.102	0.58	0.86	A
	Control	JER-AB10	5	0.824	0.024	0.79	0.86	B
	C3	JER-AB20	5	0.821	0.045	0.76	0.87	B
	Carat (near)	JER-AB19	5	0.764	0.024	0.73	0.80	AB
	Carat (far)	JER-AB07	5	0.816	0.029	0.79	0.86	B
	Jericho	JER-AB08	5	0.821	0.037	0.76	0.85	B
								$P = 0.008$
Total Density[b] ($No./m^2$)	Cigar	JER-AB11	5	10,494.4	1.9	3638	19,870	B
	Control	JER-AB10	5	5487.1	1.3	4290	7942	AB
	C3	JER-AB20	5	5007.8	1.2	3580	5957	AB
	Carat (near)	JER-AB19	5	3033.4	1.6	1565	5812	A
	Carat (far)	JER-AB07	5	4346.2	1.4	3203	7652	A
	Jericho	JER-AB08	5	6487.0	1.8	3783	14362	AB
								$P = 0.006$
Chironomid Density[b] ($No./m^2$)	Cigar	JER-AB11	5	6925.7	1.8	2884	12812	B
	Control	JER-AB10	5	2635.1	1.3	2203	3609	A
	C3	JER-AB20	5	1513.3	1.3	1000	2058	A
	Carat (near)	JER-AB19	5	1713.9	1.7	942	3768	A
	Carat (far)	JER-AB07	5	1746.3	1.4	1159	2899	A
	Jericho	JER-AB08	5	1884.8	1.7	841	3420	A
								$P = 0.000$
Oligochaete Density[b] ($No./m^2$)	Cigar	JER-AB11	5	118.7	16.7	1	1304	-
	Control	JER-AB10	5	266.0	1.4	188	406	-
	C3	JER-AB20	5	221.4	2.6	44	478	-
	Carat (near)	JER-AB19	5	69.8	2.6	15	188	-
	Carat (far)	JER-AB07	5	129.6	2.4	44	290	-
	Jericho	JER-AB08	5	25.4	7.2	1	116	-
								$P = 0.226$

[a] See Section 3.8 for description of statistical methods.
[b] Represents back-transformed log scale data.

Taxa Diversity

Taxa diversity was generally similar among most waterbodies. Mean Simpson's D values ranged from 0.764 to 0.824. The one exception was Cigar Lake. The mean Simpson's D value of 0.709 was significantly less than mean values recorded for the remaining four waterbodies. The Cigar Lake station exhibited higher range of replicate values compared to other stations, which may have influenced the mean value at this station.

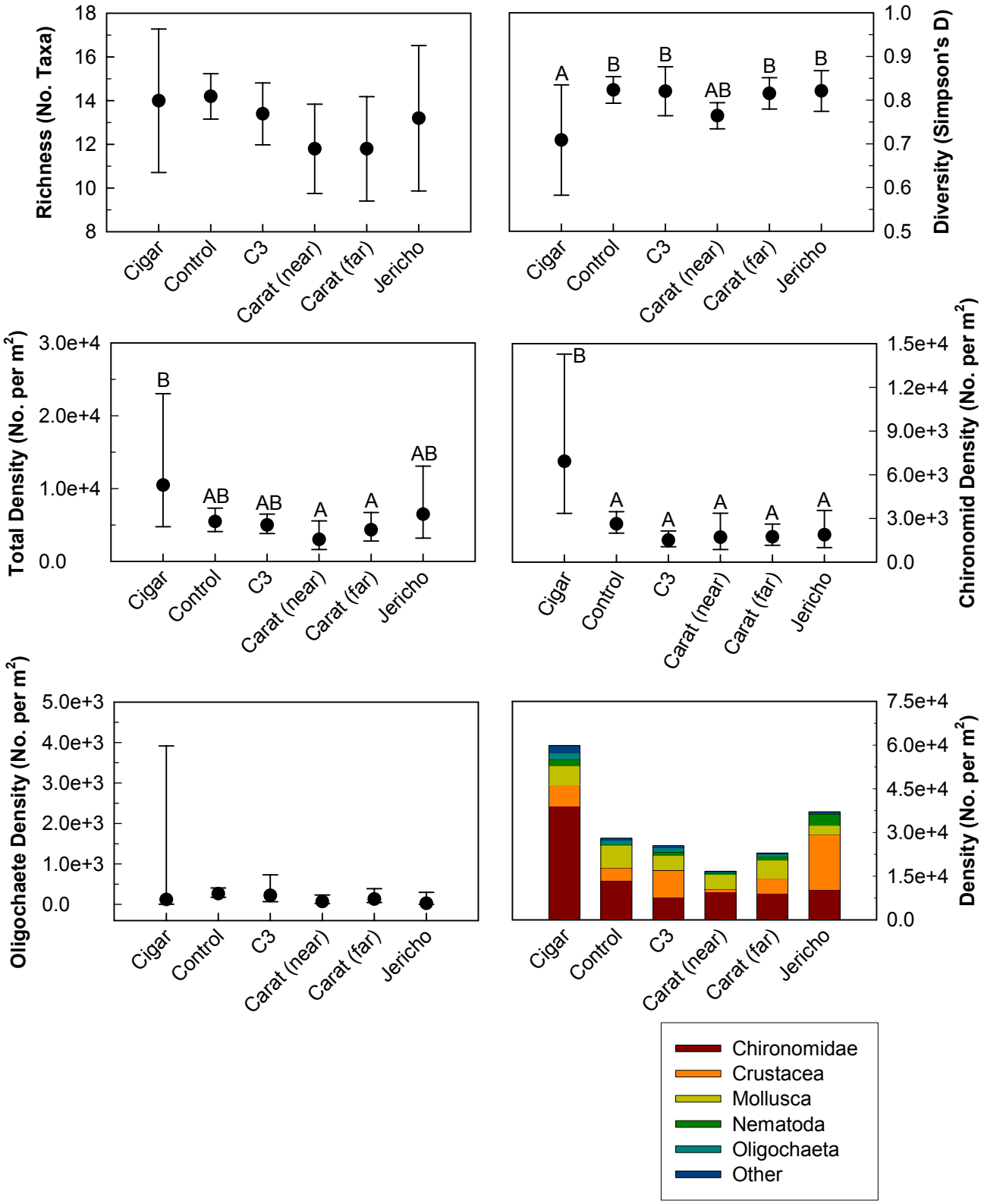

Figure 4.4 Benthic macroinvertebrate parameter summary metrics ($\bar{x} \pm$ 95% CI) monitored in 2004, Jericho AEMP (Letter designates statistical differences; see section 3.8 for methods).

Total Density

Total density of benthic macroinvertebrates varied among waterbodies. Mean values ranged from a low of 4346.2 organisms/m^2 at the Carat Lake near field station to 10,494.2 organisms/m^2 at the Cigar Lake station. Differences among the mean values were significant. Carat Lake near and far field stations were significantly less than the Cigar Lake station. The Carat Lake stations did not differ significantly from stations at Control Lake, Lake C3 and Jericho Lake. It should be noted that the Cigar Lake site exhibited high within station variation compared to other stations, which may explain the significant difference.

Chironomid Density

A similar pattern was recorded for chironomid density. The mean value recorded at the Cigar Lake station (6925.7 organisms/m^2) was approximately 2.5 times higher than the next closet mean value at the Control station (2635.1 organisms/m^2). The difference was significant.

Oligochaete Density

Oligochaete densities were similar among the monitored stations. No significant differences were recorded. As per total density and chironomid density, oligochaete density replicates at the Cigar Lake station exhibited greater within station variation when compared to other stations.

Major Taxa

Major taxonomic groups varied among monitored stations (Figure 4.4). Chironomids were the numerically dominant taxa at all stations except Jericho Lake, where Crustacea (cladocera and copepoda) were the major group. Crustacea were important at most except Carat Lake near field. These data suggest that the importance of major taxonomic groups was not consistent among stations.

Quality Control

Four samples sent to an outside taxonomist and were evaluated for quality control (Table 4.6). Average percent differences were small for the summary metrics. Average values ranged from 4.6% for total density to -3.7% for species richness for samples submitted to an external reviewer. There were small differences in the number of unique taxa identified in the quality control versus the processed samples (i.e., taxa recorded in one sample but not in the other). Values ranged from 0 to 4. The reasons for the differences did not involve misidentification of taxa, but instead were due to the presence of rare taxa.

Table 4.6 Percent difference in benthic macroinvertebrates summary metrics and numbers of unique taxa between processed and quality control samples, Jericho AEMP.

Type	Station	Percent Difference				Unique Taxa (No.)	
		Replicate	Total Density	Richness	Diversity	Sample	QAQC
External	JER-AB10	CN0102	6.1	-20.0	1.2	3	1
	JER-AB20	C30102	2.4	-15.4	0.0	2	1
	JER-AB19	CA0202	5.7	23.1	3.9	0	3
	JER-AB07	CA0102	3.4	0.0	2.5	2	4
		Average	**4.6**	**-3.7**	**1.9**	**1.8**	**2.3**

4.6 FISH TISSUE

Summary information are presented in Table 4.7 to Table 4.9

There was a wide range in fork length of lake trout and round whitefish collected for tissues (Table 4.7). The length of lake trout ranged from 218 mm to 1009 mm and the length of round whitefish ranged from 312 mm to 445. This wide range was reflected in the age distribution of samples collected from both species. Slimy sculpin collected for tissue analyses exhibited a wide range in total length. Values ranged from 49 mm to 115 mm.

Table 4.7 Summary of biological characteristics of fish collected for tissue metal contaminants in 2004, Jericho AEMP.

Species	Lake	Sample Size	Length (mm)[a]				Age			
			Mean	Standard Deviation	Min.	Max.	Mean	Standard Deviation	Min.	Max.
Lake trout	Cigar Lake	10	409.8	33.5	352	474	15.1	3.3	10	19
	Lake C3	10	484.8	161.3	218	754	18.5	6.7	9	29
	Carat Lake	10	486.9	188.3	359	1009	16.3	9.7	11	45
Round whitefish	Cigar Lake	10	380.8	50.3	312	445	12.0	5.1	7	24
	Lake C3	10	363.1	25.7	315	395	10.2	1.6	8	13
	Carat Lake	10	389.2	24.2	346	435	9.9	1.3	8	12
Slimy sculpin	Stream W	14	83.2	16.9	58	115	-	-	-	-
	Stream C3	18	67.8	6.6	55	82	-	-	-	-
	Stream C1	19	66.2	11.1	49	84	-	-	-	-

[a] Fork length for lake trout and round whitefish; total length for slimy sculpin.

The concentrations of most metal contaminants in fish tissues were below analytical detection limits (Table 4.8). Five metals meet the criteria for minimum sample size ($n \geq 5$ above detection limit) to allow statistical comparisons of the monitored lakes as follows:

- aluminum - slimy sculpin (whole fish)
- cadmium - lake trout and round whitefish (liver); slimy sculpin (whole fish)
- copper - lake trout and round whitefish (liver); slimy sculpin (whole fish)
- mercury - lake trout and round whitefish (liver and muscle); slimy sculpin (whole fish)
- zinc - lake trout and round whitefish (liver and muscle); slimy sculpin (whole fish)

Table 4.8 Number of fish tissue samples below analytical detection limits in 2004, Jericho AEMP.

Species	Tissue	Lake	Number below detection limit										
			Al (0.2)[a]	As (0.1)	Cd (0.005)	Cr (0.25)	Cu (0.5)	Hg (0.01)	Mo (0.5)	Ni (0.05)	Pb (0.05)	U (0.025)	Zn (0.05)
Lake trout	Liver	Cigar Lake	6	5	0	10	0	0	10	10	10	10	0
		Lake C3	8	6	0	10	0	0	10	9	10	10	0
		Carat Lake	5	6	0	9	0	0	10	8	10	10	0
	Muscle	Cigar Lake	8	10	10	10	10	0	10	10	10	10	0
		Lake C3	10	10	10	10	10	0	10	10	10	10	0
		Carat Lake	10	10	9	10	10	0	10	10	7	10	0
Round whitefish	Liver	Cigar Lake	9	8	0	10	0	0	10	10	10	10	0
		Lake C3	6	6	0	10	0	0	10	10	10	10	0
		Carat Lake	4	10	0	10	0	0	10	10	10	10	0
	Muscle	Cigar Lake	10	10	10	10	10	3	10	10	10	10	0
		Lake C3	9	10	10	8	10	0	10	8	10	10	0
		Carat Lake	8	10	10	9	8	0	10	9	9	10	0
Slimy sculpin	Whole	Stream W	1[b]	10	0	10	0	0	10	10	10	10	0
		Stream C3	2	10	0	10	0	0	10	10	10	10	0
		Stream C1	3	10	0	10	0	0	10	10	10	10	0

[a] Analytical detection limit.
[b] Highlighted cells represent samples used for analyses of metal concentrations.

Summary metrics for the five metals are presented in Table 4.9.

Metal concentrations were compared to fork length of lake trout and round whitefish to establish if there were correlations (Table 4.10). Mercury concentrations were significantly correlated with fish length for both liver and muscle tissue of lake trout. Positive correlations between mercury concentration and length also were recorded for round whitefish muscle tissue and correlations were significant in two of three samples. No consistent trends between metal concentration and fish length were recorded for other metals.

Based on the results for mercury fork length was assigned as a covariate in subsequent statistical analyses for lake trout and round whitefish muscle tissue and lake trout liver tissue. Composite samples for slimy sculpin precluded comparisons of fish length to metal concentrations for this species.

Table 4.9 Metal concentrations in fish tissue summary metrics in 2004, Jericho AEMP.

Species	Tissue	Lake	Parameter	Metal Concentrations (µg/g based on wet weight)[a]				
				Al (0.2)[a]	Cd (0.005)	Cu (0.5)	Hg (0.01)	Zn (0.05)
Lake trout	Liver (n = 10)	Cigar Lake	Mean ± SD[b]		0.281±1.632	12.8±1.8	0.15[c]	37.53±1.15
			Range		0.136-0.732	6.4-35.7	0.06-0.37	29.61-45.81
		Lake C3	Mean ± SD		0.153±2.317	9.9±2.1	0.14[c]	34.01±1.30
			Range		0.027-0.508	1.8-28.7	0.07-0.57	22.55-48.13
		Carat Lake	Mean ± SD		0.190±1.716	9.0±1.6	0.26	34.40±1.17
			Range		0.097-0.542	5.7-27.1	0.09-0.56	28.58-44.69
	Muscle (n = 10)	Cigar Lake	Mean ± SD				0.10[c]	4.87±1.20
			Range				0.05-0.18	3.99-6.95
		Lake C3	Mean ± SD				0.11[c]	3.72±1.14
			Range				0.07-0.37	2.67-4.44
		Carat Lake	Mean ± SD				0.20[c]	4.03±1.14
			Range				0.10-0.30	3.41-5.26
Round whitefish	Liver (n = 10)	Cigar Lake	Mean ± SD		0.120±2.167	2.0±1.3	0.05±1.48	25.72±1.13
			Range		0.035-0.386	1.3-2.7	0.03-0.09	20.87-31.04
		Lake C3	Mean ± SD		0.069±1.594	1.9±1.2	0.05±1.36	25.55±1.05
			Range		0.021-0.116	1.5-2.8	0.03-0.08	23.05-27.81
		Carat Lake	Mean ± SD		0.096±1.574	1.7±1.2	0.04±1.51	24.87±1.08
			Range		0.036-0.177	1.3-2.1	0.03-0.11	21.81-28.24
	Muscle (n = 10)	Cigar Lake	Mean ± SD				0.02[c]	4.16±1.11
			Range				0.02-0.04	3.56-5.14
		Lake C3	Mean ± SD				0.04[c]	3.92±1.09
			Range				0.02-0.07	3.58-4.58
		Carat Lake	Mean ± SD				0.06[c]	4.05±1.08
			Range				0.04-0.07	3.53-4.56
Slimy sculpin	Whole (n = 10)	Stream W	Mean ± SD	8.57±2.36	0.027±1.368	0.9±1.1	0.08±1.41	29.90±1.20
			Range	1.25-21.46	0.016-0.048	0.8-1.2	0.05-0.15	22.66-40.30
		Stream C3	Mean ± SD	4.02±1.99	0.031-1.154	0.9±1.1	0.06±1.23	36.56±1.12
			Range	1.25-8.33	0.024-0.039	0.8-1.1	0.04-0.08	30.78-44.68
		Stream C1	Mean ± SD	4.61±2.64	0.043±1.791	0.9±1.1	0.04±1.51	35.00±1.29
			Range	1.25-15.03	0.011-0.093	0.8-1.0	0.03-0.08	23.24-51.14

[a] Represents back-transformed log scale data.
[b] Standard deviation.
[b] Adjusted mean based on ANCOVA with fork length as covariate; see Section 3.8 for description of methods.

Table 4.10 Correlations between metal concentrations in tissues and fish length in 2004, Jericho AEMP.

Species	Tissue	Lake	Pearson Correlation Coefficient				
			Al	Cd	Cu	Hg	Zn
Lake trout	Liver	Cigar Lake		+0.061	+0.515	+0.750*	+0.121
		Lake C3		-0.584	-0.345	+0.691*	-0.733*
		Carat Lake		+0.387	+0.898*	+0.987*	-0.259
	Muscle	Cigar Lake				+0.819*	-0.142
		Lake C3				+0.834*	-0.254
		Carat Lake				+0.984*	-0.014
Round whitefish	Liver	Cigar Lake		+0.867*	-0.199	+0.845*	-0.342
		Lake C3		+0.369	-0.755*	+0.168	-0.575
		Carat Lake		+0.299	-0.045	+0.620	+0.210
	Muscle	Cigar Lake				+0.963*	+0.245
		Lake C3				+0.694*	+0.169
		Carat Lake				+0.289	-0.343

[a] * Denotes statistical significance.

Mean metal concentrations for the selected metals are presented in Table 4.11 and illustrated in Figures 4.5 to 4.7. For most comparisons, metal concentrations were not significantly different between waterbodies. No significant differences were recorded for aluminum and copper. Cadmium concentration in slimy sculpin whole fish tissue was higher in Stream C1 (0.043 µg/g) compared to Stream W (0.027 µg/g). Zinc concentration in lake trout muscle tissues was significantly higher in Cigar Lake (4.87 µg/g) compared to Lake C3 and Carat Lake (≤ 4.03 µg/g). Zinc concentration in slimy sculpin whole fish tissue in Stream C3 approached but was not significantly different from zinc concentrations in whole fish samples collected from slimy sculpin in the other streams.

In general, there were waterbody differences in mean mercury concentration. Wet weight concentrations in muscle tissues ranged from 0.57 µg/g in lake trout to 0.02 µg/g in round whitefish (Table 4.9). Mean concentrations were significantly higher in tissues collected from Carat Lake compared to Cigar Lake and Lake C3 (lake trout muscle and liver) and were significantly higher in Carat Lake compared to Cigar Lake (round whitefish muscle). Mean mercury concentration in slimy sculpin whole fish sample was significantly higher in Stream W compared to Stream C1.

Table 4.11 Statistical comparisons of mean metal concentrations in fish tissues in 2004, Jericho AEMP.

Species	Tissue	Lake	Mean Metal Concentration (µg/g wet weight)[a]				
			Al	Cd	Cu	Hg	Zn
Lake trout	Liver	Cigar Lake		0.281	12.8	0.15 A	37.53
		Lake C3		0.153	9.9	0.14 A	34.01
		Carat Lake		0.190	9.0	0.26 B	34.40
	Significance[b]			$P = 0.120$	$P = 0.401$	$P = 0.027$[c]	$P = 0.470$
	Muscle	Cigar Lake				0.10 A	4.87 B
		Lake C3				0.11 A	3.72 A
		Carat Lake				0.20 B	4.03 A
						$P = 0.000$[c]	$P = 0.001$
Round whitefish	Liver	Cigar Lake		0.120	2.0	0.05	25.72
		Lake C3		0.069	1.9	0.05	25.55
		Carat Lake		0.096	1.7	0.04	24.87
	Significance			$P = 0.122$	$P = 0.162$	$P = 0.519$	$P = 0.661$
	Muscle	Cigar Lake				0.02 A	4.16
		Lake C3				0.04 B	3.92
		Carat Lake				0.06 B	4.05
	Significance					$P = 0.000$[c]	$P = 0.331$
Slimy sculpin	Whole fish	Stream W	8.6	0.027 A	0.9	0.08 B	29.90
		Stream C3	4.0	0.031 AB	0.9	0.06 AB	36.56
		Stream C1	4.6	0.043 B	0.9	0.04 A	35.00
	Significance		$P = 0.122$	$P = 0.043$	$P = 0.579$	$P = 0.002$	$P = 0.067$

[a] Represents back-transformed log scale data.
[b] Unless stated otherwise all tests based on ANOVA; different letters designate significant difference based on post-hoc means test; see Section 3.8 for description of methods.
[c] Based on ANCOVA with fork length as covariate; different letters designate significant difference based on post-hoc means test; see Section 3.8 for description of methods.

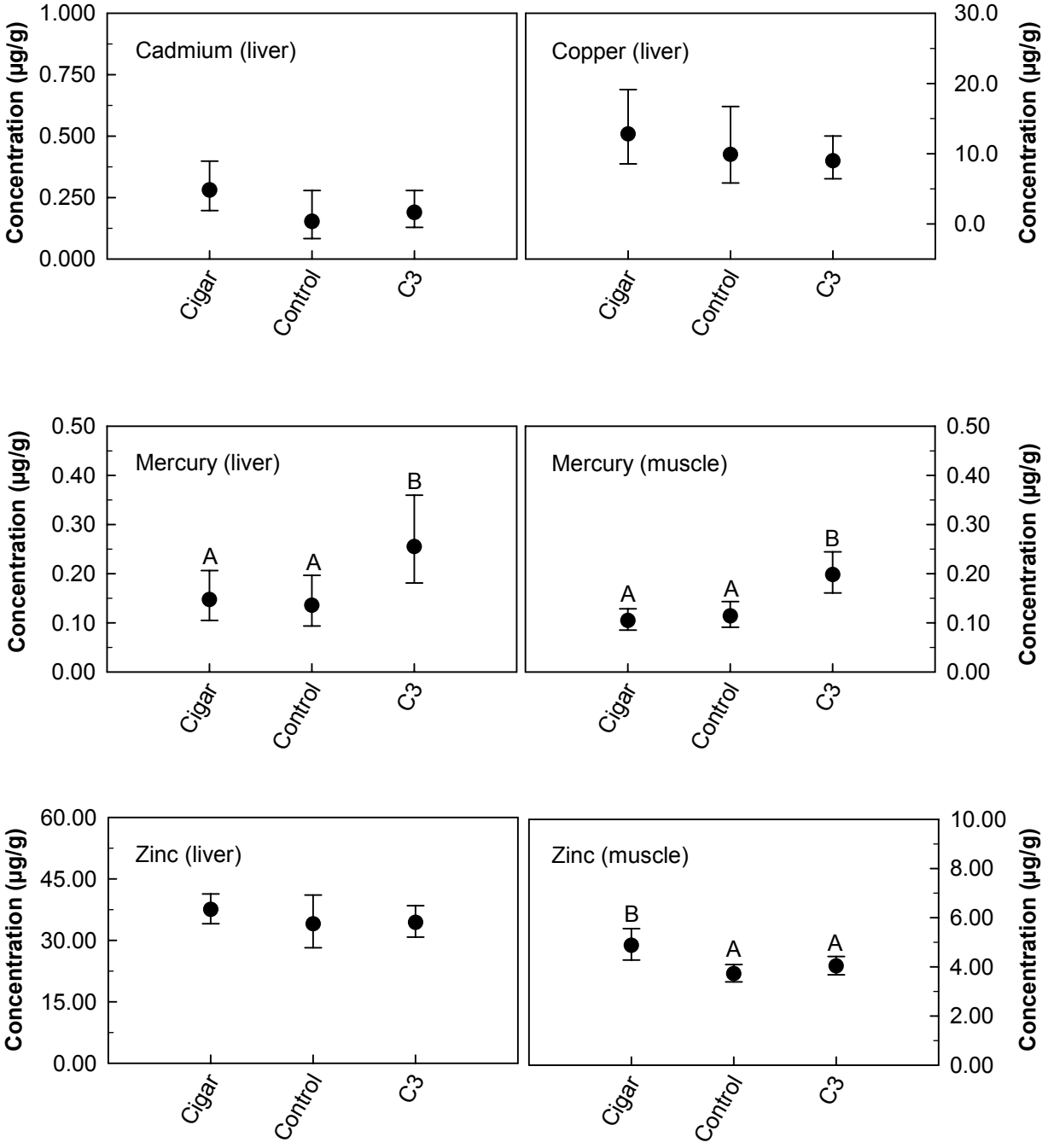

Figure 4.5 Selected metal contaminants in lake trout tissues summary metrics ($\bar{x} \pm$ 95% CI) monitored in 2004, Jericho AEMP.

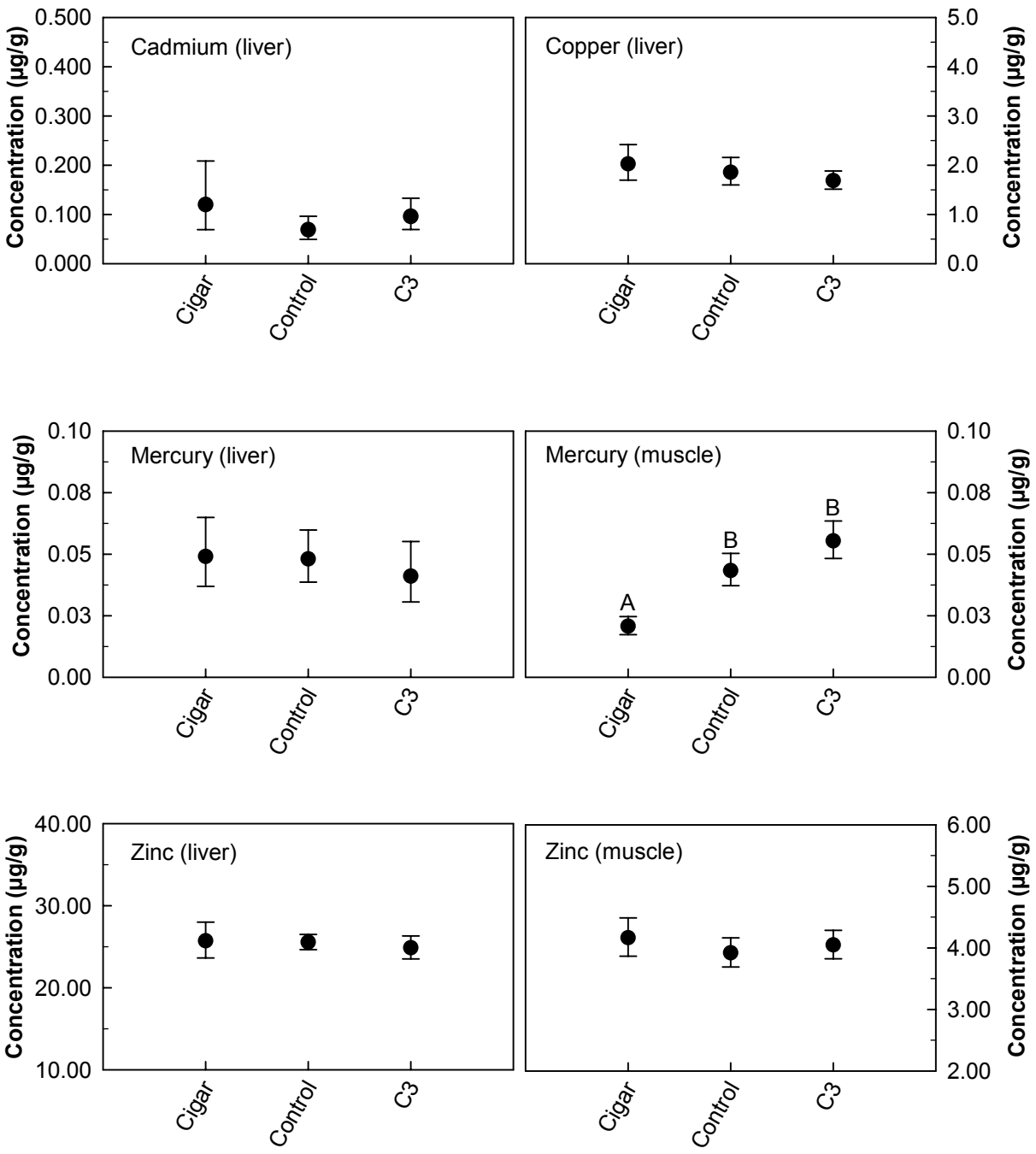

Figure 4.6 Selected metal contaminants in round whitefish tissues summary metrics ($\bar{x} \pm$ 95% CI) monitored in 2004, Jericho AEMP.

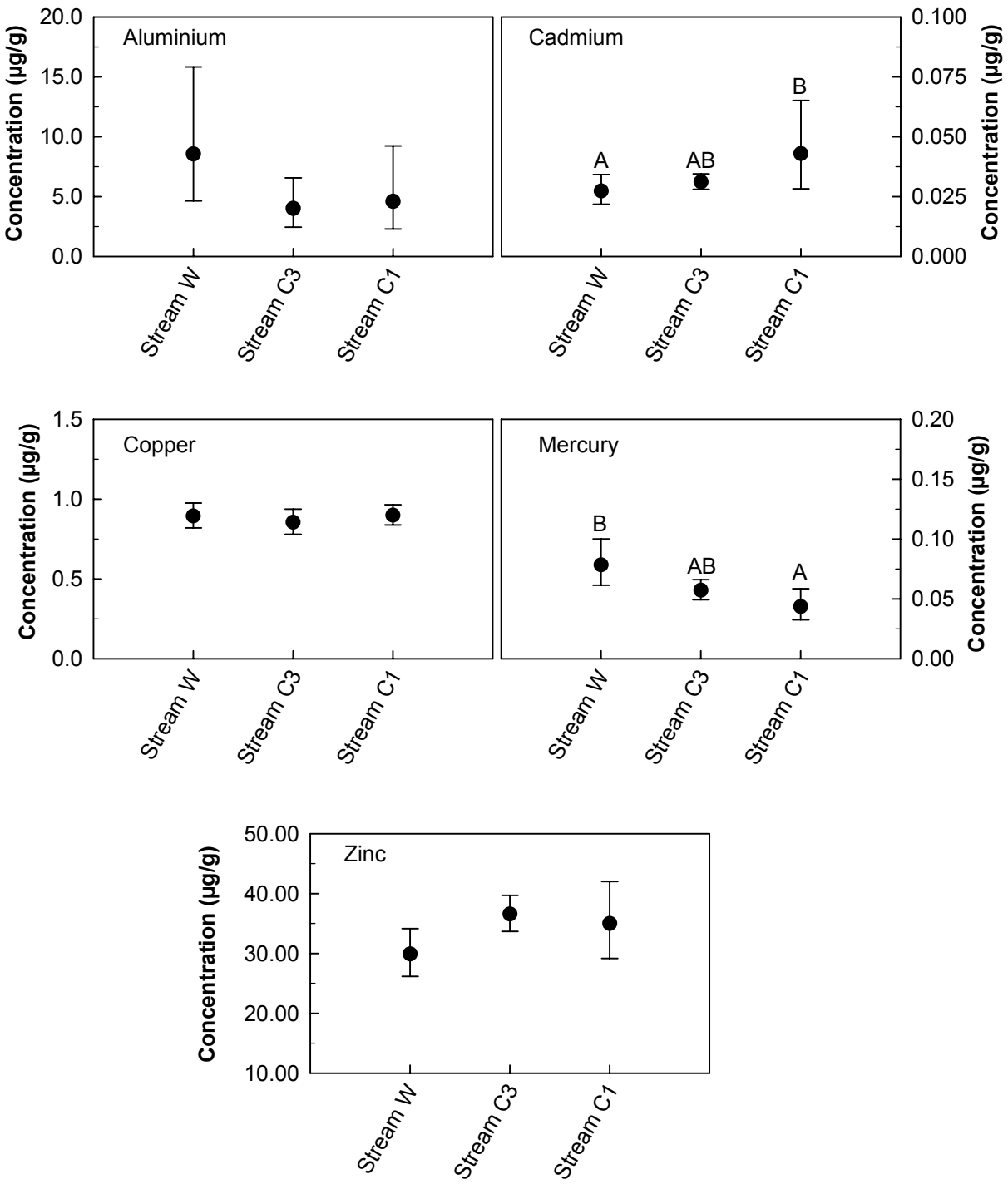

Figure 4.7 Selected metal contaminants in slimy sculpin tissues summary metrics ($\bar{x} \pm$ 95% CI) monitored in 2004, Jericho AEMP.

Quality Control

Three lake trout muscle tissue samples were submitted as split samples for quality control analyses. Table 4.12 presents a summary of comparisons between the duplicate samples for metal contaminants that were above analytical detection limits. Absolute mean differences in metal concentrations varied from 0.1% (manganese) to 10.6% (selenium). Maximum percent differences were recorded for mercury (23.0%) and selenium (-26.8%). Mean percent difference for all remaining metals did not exceed 6.1%.

Table 4.12 Percent difference in selected metal concentrations between processed and quality control samples, Jericho AEMP.

Metal	Percent Difference			
	Mean	**Number**	**Minimum**	**Maximum**
Hg	3.8	3	-7.5	23.0
K	-0.6	3	-1.1	-0.3
Mg	-2.0	3	-2.6	-1.6
Mn	-0.1	3	-0.8	0.4
Na	1.2	3	-4.0	7.1
P	-1.1	3	-3.8	3.7
Se	-10.6	2	-26.8	5.6
Si	-0.1	3	-0.8	0.4
Sn	-1.4	3	-5.8	6.6
Ti	-0.2	2	-1.6	1.2
Va	-4.6	1		
Wet	-0.9	3	-2.6	0.1
Zn	6.1	3	-3.0	18.8
Average	**-0.8**	**35**	**-26.8**	**23.0**

5.0 SUMMARY

Indicators monitored in 2004 by the aquatic biota Jericho AEMP included dissolved oxygen profiles in summer, sediment deposition, phytoplankton, zooplankton, periphyton, benthic macroinvertebrates and metal concentrations in fish tissues. Data for some indicators were not presented either because they were omitted from the program based on conditions specified in Schedule L NWBJER0410 (periphyton) or data will not be available until 2005 (sediment deposition).

5.1 INDICATORS AND PARAMETERS

The dissolved oxygen results suggested that most waterbodies were not stratified at the time of measurement. Only one waterbody was stratified: Control Lake.

Multiple parameters were measured for aquatic biota indicators phytoplankton, zooplankton, and benthic invertebrates. For each of the parameters categories measured in phytoplankton and zooplankton significant (10 comparisons) or near significant (1 comparison) differences were recorded among stations. However, there was no apparent spatial trend among the parameters either for phytoplankton or zooplankton. The results indicated that the baseline phytoplankton and zooplankton communities in monitored lakes are variable.

Significant differences were recorded for three of five comparisons of benthic macroinvertebrate parameters. The spatial difference among waterbodies was primarily related to the Cigar Lake station, which contained higher density and lower diversity of macroinvertebrates. The result for Cigar Lake may be due in part to the large within site variation.

A large portion of metal concentration in fish tissue sample was below analytical detection limits for the respective metals. Of eleven metals of interest, five contained sufficient data for statistical analyses for one or more species and tissue type. These were aluminium (slimy sculpin whole fish), cadmium and copper (lake trout and round whitefish liver; slimy sculpin whole fish), and mercury and zinc (lake trout and round whitefish muscle and liver; slimy sculpin whole fish). Metal concentrations in fish tissues were not significantly different among waterbodies for the majority of comparisons. This included all comparisons for aluminium and copper. For cadmium, the mean concentration in slimy sculpin whole fish tissue was significantly higher in Stream W compared to Streams C1 and C3. For zinc, the mean

concentration in lake trout muscle tissue was significantly higher in Cigar Lake compared to Lake C3 and Carat Lake.

Unlike other metals mercury concentrations in tissues of all three species were significantly different among waterbodies. For lake trout muscle and liver, samples collected from Carat Lake were significantly higher than Cigar Lake and Lake C3. The same pattern was recorded for round whitefish muscle tissue. These results suggested that Carat Lake fish contain higher concentrations of mercury compared to other waterbodies. These results should be interpreted with caution because fish have the potential to move between Carat Lake and Lake C3. For slimy sculpin muscle tissue, mercury concentrations were significantly higher in Stream W compared to Stream C1.

5.2 QUALITY CONTROL

Quality control assessments suggested different levels of sample precision depending on the aquatic biota indicator and parameter. Phytoplankton estimate precision rarely was below 20%, which is the suggested threshold for acceptable precision (ENVCAN 2002). This result likely reflects the standard phytoplankton laboratory sampling methodology that relies heavily on subsampling. The majority of parameters for the two remaining indicators were below the 20% threshold. Overall, benthic macroinvertebrate estimates exhibited a higher level of precision than zooplankton estimates. The accuracy of taxa identification followed the same pattern. Based on the number of unique taxa, accuracy was deemed poor for phytoplankton, but good for zooplankton and benthic macroinvertebrates. The results for phytoplankton reflect the large number of taxa at the species and subspecies level and differences in the taxonomist expertise.

Quality control evaluations of metal concentrations in fish tissue suggested that the analytical precision of the laboratory was good. Percent difference between duplicate samples for the majority of metals was $\leq 6.1\%$.

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