Mary River Project

October 2013

Preliminary review of Baseline Data for Freshwater Biota: Mary River Mine Site

DRAFT

North/South Consultants Inc.
Aquatic Environment Specialists

Preliminary review of Baseline Data for Freshwater Biota: Mary River Mine Site

DRAFT

October, 2013

Prepared by

North/South Consultants Inc.

For

Baffinland Iron Mines Corporation

North/South Consultants Inc.
Aquatic Environment Specialists

83 Scurfield Blvd.
Winnipeg, Manitoba, R3Y 1G4
Website: www.nscons.ca

Tel.: (204) 284-3366
Fax: (204) 477-4173
E-mail: nscons@nscons.ca

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

1.0 INTRODUCTION

This report presents the results of a desktop technical review conducted to provide a preliminary review of the adequacy of existing baseline data for the Core Receiving Environment Monitoring Program (CREMP) component of the overall Aquatic Effects Monitoring Program (AEMP) for the Mary River Project Mine site.

Biotic components reviewed included phytoplankton, benthic macroinvertebrates, and fish. The main tasks completed included:

- An inventory of sampling methods and baseline data;
- A summary of key pathways of potential effects (i.e., linkages) and development of key questions to advise on study design for CREMP;
- A review existing baseline data, including variability of the datasets and sampling design (i.e., sampling sites, frequency, and methods):
- Identification of key metrics for consideration under CREMP and for exploratory statistical analysis;
- Exploratory power analyses of baseline data for key areas and key metrics to assist with:
    - Evaluation of the power of the existing data for post-Project comparisons;
    - Preliminary identification of sample sizes for the CREMP;
    - Identification of the most sensitive metrics for CREMP;
    - Development of critical effects sizes (CESs) for the CREMP; and
    - Identifying data gaps to be addressed through additional data collection.
- Identification of issues that could affect use of data for post-Project monitoring; and
- Generation of recommendations regarding collection of additional baseline data and/or modifications to sampling design or methods.

Sampling methods and baseline data inventories were prepared for Mine Area lakes and streams. However, the detailed review of baseline data (i.e., statistical analyses) focused upon Mine Area lakes as the CREMP addresses lake monitoring and the Metal Mining Environmental Effects Monitoring (EEM) program addresses monitoring of stream/river areas (which is outside the scope of this review). The review covered available baseline data from the initiation of baseline studies (2005) through 2012.

Following completion of this baseline data review, additional baseline field sampling was conducted in the open-water season of 2013 based on the outcome of the review presented herein. Overviews of the programs conducted in 2013 are provided for phytoplankton, benthic macroinvertebrates, and Arctic Char.

2.0 PHYTOPLANKTON

The following sections provide an inventory of available baseline phytoplankton data, a description of key pathways of effect and key questions respecting the Project, a detailed examination of baseline phytoplankton data, a description of data gaps and recommendations for future sampling, and an overview of baseline field programs completed in 2013.

2.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of existing baseline data for phytoplankton in the Mine Area to assist with evaluating the existing dataset and advising on future sampling and monitoring. Specifically, the following provides:

- an overview of the sampling methods employed for collection and analysis of phytoplankton in the Mine Area waterbodies; and
- an inventory of existing baseline phytoplankton data for Mine Area waterbodies.

2.1.1 Sampling Methods

Chlorophyll *a* samples were collected using the same methods as applied for water quality sampling. Specifically, in lakes, chlorophyll *a* samples were collected approximately 1 m below the water surface (“near-surface samples”) and from approximately 1 m above the sediments (“bottom samples”) using a Kemmerer water sampler. Sample bottles provided by the analytical laboratory were then filled and the samples were submitted to EXOVA Laboratories for analysis. Replicate samples and field blanks were incorporated into the sampling program in 2007 and 2008, as a component of the Quality Assurance/Quality Control (QA/QC) program.

Samples for taxonomic identification and enumeration were collected in the 2007 and 2008 open-water seasons as depth-integrated samples of surface water collected across the euphotic zone (estimated as three times the Secchi Disk depth measured at the time of sampling, Cole 1983). A depth-integrated sample of water was collected from across the euphotic zone using a 10-m long tube sampler (up to a maximum depth of 10 m). Where the euphotic zone was calculated to exceed depth at a site, samples were collected by lowering the tube sampler to a depth 1 m from the bottom of the lake (to a maximum of 10 m).

Sample bottles provided by the analytical laboratory were then filled and a sufficient quantity of Lugol’s solution was added to render the sample “tea coloured”. The sample was then mixed and additional Lugol’s was added on site or at the end of the day as required. Samples were submitted to ALS Laboratories, Winnipeg, MB for taxonomic identification and enumeration.

2.1.2 Baseline Data Inventory

Baseline field studies included collection and analysis of surface water samples for characterization of phytoplankton in Mine Area lakes and streams. Specifically, chlorophyll *a* (sestonic) was measured at selected sites in lakes and streams and phytoplankton biomass and community composition was measured in Mine Area lakes. The following provides an inventory of baseline phytoplankton data for lakes and streams separately.

2.1.2.1 Lakes

Samples were collected for analysis of phytoplankton community composition and biomass and chlorophyll *a* from Mine Area lakes in the open-water seasons of 2007 and 2008. The sampling program was conducted in conjunction with and, therefore, at the same locations and times, as the water quality sampling program (Figure 2-1). These locations included:

- Mary Lake (BL0-01, BL0-03, BL0-04, BL0-05, and BL0-06);
- Sheardown Lake Northwest (DL0-01-1, DL0-01-2, DL0-01-4, DL0-01-5, and DL0-01-7);
- Sheardown Lake Southeast (DL0-02-1, DL0-02-3, and DL0-02-4); and
- Camp Lake (JL0-01, JL0-02, and JL0-09).

Sampling for phytoplankton was conducted twice each year:

- August 7-14, 2007 and July 29-August 6, 2008 (summer sampling); and
- September 13-20, 2007 and September 2, 2008 (fall sampling – Sheardown Lake only).

Nearshore sampling for analysis of chlorophyll *a* was also conducted at six sites in Sheardown Lake NW in 2008 in spring (June 25, 2008), summer (July 31 and August 7, 2008), and fall (September 14, 2008). In addition, chlorophyll *a* was measured at four sites in Sheardown Lake NW and one site in Sheardown Lake SE following discharge of treated sewage effluent in August 2009.

Water sampling locations where chlorophyll *a* and phytoplankton samples were collected and periods sampled for the Mine Area are presented in Tables 2-1 and 2-2, respectively. As described in Section 2.1.1, during most sampling events, chlorophyll *a* was measured in near surface (1 m below water surface) and bottom (1 m above the sediments) samples. Table 2-1 presents the total number of near-surface samples collected from lakes.

2.1.2.2 Streams

A number of streams including the Mary and Tom rivers and tributaries to Sheardown Lake and Mary Lake were sampled for analysis of chlorophyll *a* during the conduct of the water quality sampling program in 2007-2008 (Table 2-3). A total of 73 samples were collected over this period, with approximately half of them collected from the Mary River.

2.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed (or confirmed) for CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in Section 2.3. These questions and metrics focus upon key potential effects identified in the Final Environmental Impact Statement (FEIS), as well as metrics commonly applied for characterizing phytoplankton communities.

The key pathways of potential effects of the Project on phytoplankton communities include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes (primarily nutrients and total suspended solids [TSS]) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition); and
- Water quality changes due to non-point sources, such as site runoff and use of Ammonium nitrate fuel oil (ANFO) explosives (Mine Area).

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources on phytoplankton abundance in Mine Area lakes, in particular Sheardown Lake NW?

The primary issue of concern with respect to the phytoplankton community is related to nutrient enrichment and eutrophication, though effects on water clarity (e.g., changes in TSS) could also affect primary productivity. As such, the CREMP and the baseline data review focused upon waterbodies most at risk to eutrophication in relation to pathways of effect for the Project; in general, lakes (rather than streams) are most vulnerable to eutrophication in the Mine Area. Sheardown Lake NW will receive treated sewage effluent discharge during the construction phase and may also be affected by dust deposition, stream diversions, and non-point sources. Although treated sewage effluent will be discharged to the Mary River during the operation phase, Mary Lake is the ultimate receiving environment for all point sources in the Mine Area, including discharge of treated sewage effluent and is more vulnerable to effects of nutrient enrichment due to its lacustrine nature.

2.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

2.3.1 Description of Existing Data

2.3.1.1 Data Analysis

To explore the robustness of various potential metrics for phytoplankton for the CREMP, several metrics were derived as indicated in Table 2-4. A number of community metrics were calculated to describe the richness and diversity of the communities sampled. Calculations followed those in Hill (1973), Magurran (1988), and Begon et al. (1996), and included:

- Species richness (S);
- Simpson's diversity index ($D = 1-G$);
- Simpson's evenness ($E_D = 1/G \times 1/S$);
- Shannon's heterogeneity ($H = -\sum P_i \times [\ln P_i]$);
- Shannon's evenness ($E_H = H/\ln[S]$);
- Hill's effective richness (e^H); and
- Hill's evenness (e^H/S).

Where G is Simpson's diversity for sampling with no replacement ($[\sum n_i(n_i-1)]/[N(N-1)]$), P_i is the proportional contribution of species i to the total biomass, n_i is the number of individuals of the i^{th} species, and N is the total number of individuals. Diversity and evenness metrics range for 0 to 1, with values close to 0 having low diversity/evenness and values close to 1 having high diversity/evenness.

Metrics were plotted as box plots to visually assess the occurrence of extreme outliers and to provide a preliminary visual assessment of potential spatial and/or seasonal differences. However, owing to the inherently high variability of the phytoplankton dataset, no data points were removed from the analysis as outlier identification is complicated by the high natural variability.

Summary statistics (mean, median, standard error [SE], standard deviation [SD], minimum, maximum, n, coefficient of variation [COV], and 95th percentile) were derived for each lake using data from all sites sampled in that waterbody. Summary statistics were also derived for Sheardown Lake NW by sampling period and by year to examine seasonal and interannual differences. Chlorophyll *a* values reported as below the measurement detection limit (0.2 µg/L) were assigned a value equal to the detection limit. Duplicate samples were averaged and the mean was used for all data analyses.

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Correlation analyses were conducted for phytoplankton metrics, including chlorophyll *a*, biomass, and evenness and richness indices to assist with identifying the most suitable metrics for monitoring. Spearman rank correlations ($\alpha = 0.05$) were conducted for all phytoplankton data collected in all Mine Area lakes in summer and late/summer fall for the years 2007 and 2008 collectively. The broader dataset was used for this analysis to augment the number of data points.

In addition, although this report focused upon review of biological metrics, correlation and linear regression analyses were also conducted between phytoplankton metrics and total phosphorus (TP) as the primary pathway of potential effects relates to nutrient enrichment.

2.3.1.2 Results

Chlorophyll a

Chlorophyll *a* concentrations are relatively low in Mine Area lakes (Mean of 0.49 µg/L and range of <0.2 – 2.1 µg/L) and a relatively high proportion of measurements were below the analytical detection limit of 0.2 µg/L in 2007 and 2008 (Table 2-5). As a result, the data exhibit high variability and are not normally distributed. Based on a commonly applied trophic categorization scheme for lakes (Organization for Economic Cooperation and Development [OECD] 1982), chlorophyll *a* concentrations indicate oligotrophic conditions (i.e., chlorophyll *a* < 2.5 µg/L) based on mean or maximum chlorophyll *a* concentrations measured across the lakes.

Data collected from Sheardown Lake NW were examined in greater detail as this lake will be the immediate receiving environment for treated sewage effluent at the Mine Site and because the baseline dataset is largest for this lake. Considering only offshore sites, there was no seasonal (i.e., comparisons to summer and late/summer fall periods) or interannual patterns observed for this lake (Figure 2-2; Table 2-6). The COVs were similarly high when derived by sampling season or for the whole year combined, though the lowest variability was observed for the late summer/fall sampling period.

Concentrations of chlorophyll *a* measured in nearshore areas in 2008 (water depths of 1.2 m) were generally higher than offshore sites and inclusion of these data increased the overall means and maximums for the lake as a whole (Figure 2-3). In particular, higher concentrations of chlorophyll *a* were measured in nearshore areas in late summer/fall of 2008. Sampling in nearshore areas was undertaken as a component of a study examining potential effects of localized dust deposition and may not be representative of the lake as a whole. Therefore, data collected from the nearshore areas were excluded from power analyses described in Section 2.3.2.

Considering all Mine Area lakes collectively, the highest concentrations of chlorophyll *a* occurred in all lakes excepting Sheardown Lake NW in the summer of 2008 (Figure 2-4).

Phytoplankton Biomass

Phytoplankton biomass varied across sampling periods and years in Mine Area lakes and was highest in fall 2008 in lakes where sampling occurred (Figure 2-5). Open-water season means for the 2007-2008 period were highest in Sheardown Lake NW, however, Camp and Mary lakes were not sampled in fall 2008, when the biomass was highest in Sheardown Lake NW (Table 2-7, Figure 2-5). COVs for total biomass, which ranged from 60 to 89% across the Mine Area lakes, were lower than COVs observed for chlorophyll *a* (Table 2-7). This likely reflects the relatively high frequency of measurements of chlorophyll *a* below the analytical detection limit.

Within Sheardown Lake NW, biomass was significantly higher in 2008 than 2007 but no significant differences were observed between the summer and late summer/fall sampling periods (Table 2-8). COVs were greater between sampling periods than between years (Table 2-8).

Phytoplankton Taxonomic Metrics

Metrics of phytoplankton diversity and evenness were relatively similar between Camp Lake, Sheardown Lake NW, and Sheardown Lake SE (Table 2-9). These metrics were lower in Mary Lake. Species richness, Simpson's diversity indices, and Shannon's evenness indices yielded the lowest COVs for Sheardown Lake NW and for all lakes combined, all of which were less than 40%. Seasonal and interannual differences were evident for some lakes and periods (Figures 2-6 to 2-11).

Within Sheardown Lake NW, all taxonomic metrics yielded a COV of less than 40% when both years of baseline data were considered collectively (Table 2-10). The least variable metrics were species richness, Simpson's diversity index, and Shannon's evenness. All phytoplankton taxonomic metrics had lower variability (expressed as COVs) than either chlorophyll *a* or phytoplankton biomass.

All taxonomic metrics were significantly higher in 2007 than 2008 in Sheardown Lake NW. Conversely, of the phytoplankton taxonomic metrics examined, only Simpson's Evenness was significantly higher in summer relative to the fall period (Table 2-10).

Correlations and Regressions

Correlations between phytoplankton metrics were explored to assist with identifying metrics most suitable for monitoring effects of nutrient enrichment. Additionally, as noted in Section 2.3.1.1, relationships between phytoplankton metrics and TP were also explored to assist with identification of the most suitable metrics for monitoring effects of nutrient enrichment (i.e., phosphorus enrichment).

Spearman rank correlations indicated significant correlations between total biomass and a number of taxonomic parameters (Table 2-11); biomass of diatoms (r = 0.96), green algae (r = 0.46), chrysophytes (r = 0.53), cryptophytes (r = 0.32), and dinoflagellates (r = 0.30) were positively correlated to total biomass while several metrics of evenness and diversity were negatively correlated to total biomass including Simpson's diversity index (r = -0.60), Simpson's evenness (r = -0.71), Shannon's evenness (r = -0.65), Hill's effective richness (r = -0.55), and Hill's evenness (r = -0.71). Biomass was not significantly correlated to either species richness or chlorophyll *a*.

The conventional paradigm for lakes is a positive relationship between total phosphorus and chlorophyll *a* – though the relationship is not necessarily linear. As introduction of phosphorus from discharge of treated sewage effluent and subsequent eutrophication is a potential concern in the Mine Area, regression analyses were conducted between chlorophyll *a* and total phytoplankton biomass and TP measured in Mine Area lakes. Spearman correlations indicated no significant relationship between TP and total biomass but did indicate a weak but significant relationship with chlorophyll *a* (r = 0.29).

Due to the relatively low frequency of detection, chlorophyll *a* was only weakly significantly correlated with TP for all lakes combined (Figure 2-12). The relationship was even weaker for Sheardown Lake NW. However, regressions were stronger when only chlorophyll *a* measurements that exceeded the analytical detection limit were included in the analysis (Figure 2-12).

2.3.2 Power Analysis

2.3.2.1 Methods

The most robust metrics identified through review of the baseline data for further statistical exploration and consideration under CREMP were subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes (i.e., number of sites within a waterbody or area of a waterbody) required for detecting pre-defined levels of change; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of sites).

Evaluation of power of the existing baseline data for phytoplankton was conducted using data collected from Sheardown Lake NW. Sheardown Lake NW will be the immediate receiving environment for discharge of treated sewage effluent and would therefore be at greatest risk of nutrient enrichment and subsequent effects on primary production of the lakes in the Mine Area. As noted previously, this lake could also be affected by other pathways of effects including effects on water clarity (dust, sewage discharge, runoff), effects on other water quality parameters, and/or effects on hydrology.

The variability of numerous phytoplankton metrics measured during the baseline studies program was evaluated and described in Section 2.3.1 to assist with identifying the most robust metrics for further statistical exploration and consideration under CREMP. Metrics that were subject to a power analysis included:

- Total biomass;
- Chlorophyll *a*;
- Species Richness;
- Simpson's diversity index; and
- Shannon's evenness.

COVs for the taxonomic metrics were less than 20% for the whole baseline dataset (2007 and 2008 combined) in Sheardown Lake NW and were therefore identified for further analysis. COVs for chlorophyll *a* and total biomass were high but these metrics were retained as they are the most commonly used indicators for phytoplankton in lakes.

Critical effects sizes (CESs) utilized for power analysis were selected based on the Metal Mining EEM Guidance document (Environment Canada [EC] 2012), scientific literature, and other recent/current AEMPs and/or guidance documents (Azimuth 2012, INAC 2009, Munkittrick et al. 2009). Where initial power analyses indicated low power associated with the CESs identified *a priori*, larger CESs were explored.

Power analyses were conducted using all data collected in the open-water seasons of 2007 and 2008 (i.e., summer and late summer/fall sampling) in Sheardown Lake NW as well as for the fall 2007 and 2008 dataset alone. The latter was conducted to explore the additional power achieved with two sampling periods as opposed to sampling only in the fall.

Datasets were tested for normality for all phytoplankton metrics prior to the conduct of the power analyses. All metrics were normally distributed excepting chlorophyll *a*. Normally distributed datasets were analysed by parametric methods and chlorophyll *a* was analysed by non-parametric methods. Normality tests were conducted using XLSTAT Version 2011.5.01. Power analyses were run using PopTools version 3.2 (build 5) add-in for Microsoft Excel 2010.

Power analysis was conducted following general guidance provided in the EC Metal Mining EEM Guidance Document (2012), though it is noted that the EEM program does not discuss monitoring of phytoplankton. Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012).

2.3.2.2 Results

Minimum sample sizes identified through the exploratory power analyses are presented in Tables 2-12 and 2-13. As expected, power is greatest for the phytoplankton community metrics, owing to the relatively low COVs for these parameters. Power analysis indicated that a reasonably small sample size (i.e., n = 3) would be required to detect changes in phytoplankton community metrics on the order of 20-50% relative to baseline conditions, if sampling consisted of two sampling periods. A similar level of effort (i.e., n = 3-4) would be required for detecting these levels of change with sampling the fall period only.

The power associated with the total biomass dataset is lower than for the community metrics (Table 2-13). The existing baseline dataset would be sufficient to detect change on the order of 100% with a relatively small number of samples (8 samples for the entire dataset and 6 samples for the fall dataset). Smaller levels of change would require a prohibitively high number of samples to be detected. Because the fall dataset is slightly less variable than the entire dataset, there is greater power associated with the former and a slightly smaller number of samples would be required to demonstrate changes from baseline conditions.

The power associated with the chlorophyll *a* dataset is low and a sample size of 20 is estimated for detecting change on the order of 100% relative to baseline conditions (Table 2-13). As discussed in Section 2.3.1, chlorophyll *a* concentrations are relatively low in Sheardown Lake NW and other Mine Area lakes and a relatively high proportion of samples were below the analytical detection limit (50% for the summer period and 70% for the fall in Sheardown Lake NW). In addition, the variability of the data is higher for the summer sampling period than the fall. As a result, the power associated with the existing baseline chlorophyll *a* dataset to detect change is higher for the fall sampling period alone relative to the entire dataset.

2.3.3 Sampling Sites and Areas

The Project will result in introduction of nutrients to Mine Area waterbodies which may stimulate primary productivity, but may also adversely affect primary productivity through changes in water clarity and water chemistry. Given these linkages and the results of the preliminary power analyses conducted on data collected in Sheardown Lake NW in 2007 and 2008, it is recommended to conduct another year of baseline monitoring on Mine Area lakes to increase the power of the dataset for post-Project monitoring. Recommended waterbodies included Sheardown Lake NW, SE, Camp Lake, and Mary Lake.

A minimum sample size of 5 for each Mine Area lake is recommended for chlorophyll *a* in the 2013 sampling program. Though this sample size is lower than identified in the power analyses for detecting 100% change from baseline conditions, the minimum sample size identified through the power analysis (20) is prohibitively high and reflects analytical issues associated with low concentrations of chlorophyll *a*. Further, power increases most sharply with a sample size of 5 (Figure 2-13), rising slowly thereafter.

It is further recommended to collect 10 samples from each lake for biomass and taxonomy. Samples would be archived following collection. It is recommended to re-sample the same five offshore sites sampled in Sheardown Lake NW in 2007 and 2008, and to collect samples of phytoplankton for archiving at a further 5 sites. Sampling recommended in other Mine Area lakes includes the same sites sampled in 2007 and 2008, with additional sites added where required to meet the sample sizes identified above.

It is also recommended to sample for chlorophyll *a* at selected river/stream water quality sites in the open-water season.

2.3.4 Sampling Methods

Chlorophyll *a* samples have been collected from Mine Area lakes using the same methods as the water quality sampling program (i.e., samples collected with a water sampler at 1 m below the water surface and 1 m above the sediments). While this methodology ensures consistency with supporting water quality variables, notably nutrients such as TP, it may under or over represent phytoplankton density across the water column.

Conversely, samples for measurement of phytoplankton taxonomy and biomass have been collected from across the euphotic zone of lakes which generally provides a more accurate representation of phytoplankton in lacustrine environments. The depth of lake euphotic zones was estimated as 3 x the average Secchi disk depth, to a maximum of 10 m. Due to the high water clarity of Mine Area lakes, euphotic zone depths were calculated to exceed 10 m (the length of the sampling tube) in some sampling periods at some sites.

It is recommended that samples continue to be collected from across the euphotic zone depth for analysis of phytoplankton taxonomy and biomass. Euphotic zone depth should be calculated as 3 x the Secchi disk depth to be consistent with existing baseline data collection methods. Where euphotic zone depths are estimated to exceed 10 m (the maximum depth sampled in 2007 and 2008), euphotic zone samples should be collected from the calculated euphotic zone depth but split into two samples: 0-10 m depth interval; and >10 m depth interval. This will allow for comparison of phytoplankton between the depth intervals, while maintaining comparability to existing baseline data.

It is recommended that chlorophyll *a* continue to be analysed in grab samples (near surface samples) collected for water quality in the future to maintain comparability in methods with the existing datasets. Ideally, it would be useful to collect chlorophyll *a* samples from both surface grabs and from across the euphotic zone and compare results to confirm that surface grabs accurately represent phytoplankton in the water column (i.e., confirmation of sampling method).

Sampling should also include collection of duplicate or triplicate samples. Samples for taxonomy and biomass determinations can be archived.

2.3.5 Sampling Frequency

The results of the power analyses on Sheardown Lake NW phytoplankton data indicate similar levels of power for detecting changes associated with sampling during two periods as sampling only in the fall period. This suggests that one sampling period may be adequate for monitoring purposes. However, it is recommended to conduct two rounds of sampling in Mine Area lakes in the open-water season of 2013 to strengthen the baseline dataset. Following the 2013 sampling season, the baseline dataset should be revisited and, in particular, be re-evaluated for the need for two sampling periods.

Lastly, inclusion of chlorophyll *a* analysis within the water quality sampling program in winter is recommended.

2.4 SUMMARY OF DATA GAPS AND RECOMMENDATIONS

As only two years of baseline data for either chlorophyll *a* or phytoplankton taxonomy and biomass were collected to 2012, it is recommended to conduct sampling in 2013 to augment the baseline database. Following completion of the 2013 program, data and methods should be reviewed to advise on a final sampling program for post-Project monitoring. The following recommendations regarding the phytoplankton sampling program based on the review of baseline data include:

- Conduct a sampling program in the open-water season of 2013 in Mine Area lakes to augment the baseline data;
- Sampling should include measurement of chlorophyll *a* and collection of samples for phytoplankton taxonomy and biomass;
- Sampling frequency in the open-water season should continue in 2013 as done in previous years (i.e., two sampling periods) and should be conducted in conjunction with water quality sampling. Upon acquisition of 2013 baseline data, sampling frequency should be revisited to determine if a fall sampling period would be sufficient for monitoring purposes in the future;
- Analyse chlorophyll *a* in Mine Area lakes in winter, in conjunction with the water quality sampling program;
- Samples should be collected from across the euphotic zone depth for analysis of phytoplankton taxonomy and biomass. Where euphotic zone depths are estimated to exceed 10 m (the maximum depth sampled in 2007 and 2008), euphotic zone samples should be collected from the calculated euphotic zone depth but split into two samples: 0-10 m depth interval; and >10 m depth interval. This will allow for comparison of phytoplankton between the depth intervals, while maintaining comparability to existing baseline data;
- Chlorophyll *a* should continue to be measured in surface grab samples in lakes to maintain continuity with existing data;
- Sampling should include collection of duplicate or triplicate samples. Samples for taxonomy and biomass determinations can be archived;
- Chlorophyll *a* should be measured at selected river/stream water quality sites in the open-water season;
- It is recommended to sample a minimum of 5 sites in each lake in 2013 for analysis of chlorophyll *a*; and

- It is recommended to sample 10 sites in each lake in 2013 for phytoplankton taxonomy and biomass. Samples are to be archived for potential future analysis.

2.5 OVERVIEW OF 2013 SAMPLING

Sampling for analysis of chlorophyll *a* and phytoplankton taxonomy and biomass was undertaken in Mine Area lakes in the open-water season of 2013, as recommended through the baseline review. In addition, chlorophyll *a* was measured at selected stream sampling sites. Lake sampling sites are presented in Figure 2-14 and a summary of sampling completed in 2013 is provided in Table 2-14. Due to inclement weather, not all sites were resampled during each sampling period.

3.0 BENTHIC MACROINVERTEBRATES

The following sections provide an inventory of available baseline benthic invertebrate data, a description of key pathways of effect and key questions respecting the Project, a detailed examination of baseline benthic invertebrate data, a description of data gaps and recommendations for future sampling, and an overview of sampling completed in 2013.

3.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of existing baseline data (through 2012) for benthic invertebrates in the Mine Area to assist with evaluating the existing dataset and advising on future sampling and monitoring. Specifically, the following provides:

- An overview of the sampling methods employed for collection and analysis of benthic macroinvertebrates (i.e., benthos) in the Mine Area waterbodies; and
- An inventory of existing baseline benthic macroinvertebrate data for Mine Area waterbodies.

3.1.1 Sampling Methods

3.1.1.1 Lakes

Lake benthic macroinvertebrate samples were collected using either an Ekman dredge (2006) or a petit Ponar dredge (2007, 2008, and 2011) sampling device (each with a sampling area of 0.023 m^2; Table 3-1). Sample characteristics, which included substratum composition, colour, odour, sample depth, and UTM coordinates for each replicate site, were documented.

In 2006, 2007, and 2011, three replicate samples were collected at each sampling site while in 2008 three to seven replicate stations were sampled for each habitat type investigated in Sheardown Lake NW. Each replicate sample was a composite of five grabs (i.e., five sub-samples were combined per replicate site); however, at Mary Lake in 2007 each replicate sample was composed of only a single grab due to equipment malfunction and at Sheardown Lake in 2011 the three replicates were composed of one, three, and one grabs, respectively, due to poor weather conditions and time restrictions during the field program. At each sampling location, the dredge was slowly lowered until it rested on the bottom to prevent shock waves that could physically move or disturb organisms and sediment from beneath the sampler. Following completion of a grab, the dredge was slowly raised, to minimize turbulence, and the sample was immediately placed into a pail. An acceptable sample required that the jaws be completely closed upon retrieval. If the jaws were not completely closed the sample was discarded into a bucket (and disposed of once sampling was completed) and the procedure was repeated.

For each replicate collected in 2006 and 2007, five sub-samples approximately 1 m apart were collected from the same side of the boat. The three replicate samples were separated by approximately 10 m. For each habitat type sampled in 2008 and 2011, three to seven replicate stations were sampled, each resulting in a single composite sample consisting of one to five benthic macroinvertebrate field sub-samples/grabs. The geographic extent of each replicate station was at least 10m x 10m and replicate stations were separated by at least 20 m.

Samples were taken to shore and sieved through a 500 µm sieve bucket. A weed sprayer was sometimes used on a gentle setting to help break down clay. Samples were then rinsed into labelled sampling jars and fixed in 10% formalin. Sodium bicarbonate ('baking soda') was used to buffer samples where molluscs/shells were present. Sampling equipment was rinsed on shore before the next site was sampled.

Benthic macroinvertebrate samples were submitted to Zaranko Environmental Assessment Services (ZEAS) Inc. (Nobleton, ON) for processing and identification; laboratory methods were consistent over the study period.

3.1.1.2 Streams

As benthic samples were collected at or near habitat assessment sites in the Mine Area streams, site characteristics were noted extensively. Three replicate samples separated by approximately three wetted stream widths were collected at each sampling site in 2006 through 2008 and 2011; only one replicate sample was collected at each sampling site in 2005 (Table 3-2). Within each replicate site, five sub-samples were combined into one large sample. Sub-samples were collected moving in an upstream direction and, whenever possible, they were collected from representative microhabitats across the stream.

Each sub-sample was collected by placing a Surber sampler on a flat area of the streambed, facing upstream. The surface area sampled by the Surber sampler was equivalent to 0.097 m^2. Macroinvertebrates were collected over a two minute time period by rubbing the rocks and disturbing the sediment in the substrate area framed by the Surber net. All sub-samples were rinsed from the netting into a 500 µm sieve; a 250 µm mesh size was used in 2005. Forceps were used to collect any macroinvertebrates remaining on the netting after rinsing. The sample was washed, transferred into a sample jar, and fixed as soon as possible in 10% formalin.

Benthic macroinvertebrate samples were submitted to ZEAS Inc. for processing and identification; laboratory methods were consistent over the four years of investigation.

3.1.2 Baseline Data Inventory

Benthic macroinvertebrate community sampling was initiated in 2005 in the Mine Area, and initially included sampling of streams only. The program was expanded in 2006 to include lakes and additional stream sampling sites. The following sub-sections provide an inventory of baseline benthic macroinvertebrate data for lakes and streams.

3.1.2.1 Lakes

Benthic macroinvertebrate sampling in lakes was conducted in fall (August 31 and September 5, 2006; August 31 to September 20, 2007; September 8-12, 2008; September 3, 2011) from Camp (2007), Sheardown NW (2007, 2008, 2011), Sheardown SE (2007), and Mary (2006, 2007) lakes (Table 3-3). Inclement weather reduced the length of the fall sampling season in 2008, which prevented the completion of the full planned program for Sheardown Lake NW. Sampling of benthos in Sheardown NW in September, 2011was limited to a single site and was subsequent to discharge of treated sewage effluent, which began in the open-water season of 2009. Locations of benthic macroinvertebrate sampling sites and sampling dates are presented in Table 3-4 and Figure 3-1.

3.1.2.2 Streams

Benthic macroinvertebrate sampling in streams was conducted in summer 2005 (August 6-17, 2005) and fall 2006-2008 (August 23 to September 1, 2006; August 31 to September 5, 2007; September 10-11, 2008; August 28 to September 4, 2011) from the Mary (2005, 2006, 2007, 2011) and Tom (2006, 2007) rivers, and Camp Lake (2005, 2007, 2011) and Sheardown Lake (2005, 2007, 2008, 2011) tributaries (Table 3-3). Locations of benthic macroinvertebrate sampling sites and sampling dates are presented in Table 3-5 and Figure 3-2.

3.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed (or confirmed) for CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in the Section 3.3. These questions and metrics focus upon key potential effects identified in the FEIS, as well as metrics commonly applied for characterizing the benthic macroinvertebrate community.

The key pathways of potential effects of the Project on benthos include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);

- Water quality changes (primarily nutrients and TSS) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);

- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);

- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);

- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);

- Dust deposition in aquatic habitat (i.e., sedimentation); and

- Effects of the Project on primary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, aquatic habitat loss or alteration, sedimentation, and changes in primary producers on benthic macroinvertebrate abundance and community composition in Mine Area lakes?

Overall, effects on lower trophic level biota are primarily related to the introduction of dust to surface waters, discharge of treated sewage effluent to Sheardown Lake NW and the Mary River, release of wasterock and ore stockpile runoff to surface waters (Camp Lake Tributary 1, Mary River), general non-point sources in the Mine Area, and release of pit water during the post-closure phase. The benthic macroinvertebrate community will be monitored downstream of discharges of ore and waste rock stockpile runoff (i.e., Camp Lake Tributary 1 and the Mary River) under the MMER EEM program and is not considered here. The CREMP and the baseline data review focused upon waterbodies most at risk to sedimentation and eutrophication and that are not captured under the MMER EEM program: Camp Lake; Sheardown Lake NW; and Mary Lake. Dust is predicted to be deposited directly on surface waters in the Mine Area, including Sheardown and Camp lakes, portions of the Mary River, and numerous small tributaries to these waterbodies. Sheardown Lake NW will receive treated sewage effluent discharge during the construction phase and may also be affected by dust deposition, stream diversions, and non-point sources. Although treated sewage effluent will be discharged to the Mary River during the operation phase, Mary Lake is the ultimate receiving environment for all point sources in the Mine Area, including discharge of treated sewage effluent and is considered more vulnerable to effects of nutrient enrichment due to its lacustrine nature.

3.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

3.3.1 Description of Existing Data

3.3.1.1 Data Analysis

To explore the ability of various benthic macroinvertebrate community metrics to detect change as part of the CREMP, several were derived as outlined in Table 3-6. Methods for the derivation of these calculated metrics are described below.

Locations in Mine Area lakes sampled for benthic macroinvertebrates were classified according to water level and light availability, substrata type, and the presence or absence of rooted aquatic vegetation (Table 3-7).

To prepare the data for analysis, the abundance of macroinvertebrates in each replicate was converted to density (number of invertebrates per square meter [individuals/m^2]) by dividing the total number of invertebrates per sample by the bottom area of the sampling device (0.023 m^2 for Ekman and petit Ponar dredge; 0.97 m^2 for Surber sampler). Benthic invertebrate metrics were calculated for each replicate and included in statistical analyses to describe the community; these included abundance (total macroinvertebrate density [individuals/m^2±SE])), composition (Chironomidae proportion [% of total density], Shannon's Equitability [evenness], and the Simpson's Diversity Index), and richness metrics (total taxa and Hill's Effective richness, both at the genus level; Magurran 1988, 2004).

Evenness measures the similarity of population sizes of different species, with values closer to 1 indicating that invertebrates of different species are more similar in abundance and values of 0 indicating that only one species is present. A diversity index provides an estimate of the probability that two individuals in a sample belong to the same species. The higher the index (0 to 1), the less likely it is that two individuals belong to the same species (i.e., likely the higher the diversity; Magurran 1988, 2004). However, it is important to keep in mind that this index is not itself a true estimate of diversity and it is highly nonlinear. Diversity indices attempt to summarize the relative abundance of various taxa. An index may provide more succinct information about benthic macroinvertebrate communities than abundance or richness alone. Simpson's Diversity index de-emphasizes rare taxa, while highlighting common taxa and evenness among taxa (i.e., similarity of population sizes of different species; Mandaville 2002). Hill's Effective Richness provides an indication of the number of genera that contribute to the majority of the community represented in the sample collected. For example, if total richness = 28 and effective richness = 11, then of the 28 genera identified in the sample, 11 taxa are considered dominant.

Metrics were plotted as box plots to visually assess the occurrence of extreme outliers and to provide a preliminary visual assessment of potential spatial and/or yearly differences. However, owing to the inherently high variability of the benthic macroinvertebrate dataset, no data were removed from the analysis as outlier identification is complicated by the high natural variability of biotic data.

Metrics were calculated for each replicate sample and summary statistics (n, mean, median, SD, SE, minimum, maximum, COV, and 95th percentile) were derived for each lake by aquatic habitat type to examine spatial differences. Summary statistics were also derived for Sheardown Lake NW by aquatic habitat type and by year to examine inter-annual differences. Efforts were made to include as many taxa as possible in the analysis; however, Diptera, Chironomidae and Empididae pupae were excluded from metric calculations where genus level identification was used (e.g., evenness, Simpson's Diversity Index). Taxonomic richness (i.e., the number of taxa) was determined at the genus level. If a group was identified to a higher level (e.g., class or order), then it was assumed that only one genus was represented and this likely resulted in a conservative estimate of the number of taxa; pupae were not included in the determination of richness.

Additionally, the number of field sub-samples (i.e., grabs) per replicate station that would provide an estimate with 20% precision (i.e., an acceptable level of variance) for each metric was determined for Sheardown Lake NW by aquatic habitat type and year; these results are discussed in Section 3.3.4. The number of field sub-samples was calculated as follows:

$$n = s^2 / D^2 * X^2$$

where:

X = the sample mean

n = the number of field sub-samples

s = the sample variance

D = the index of precision (i.e., 0.20)

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Detailed statistical analyses were conducted on the Sheardown Lake NW dataset as a representative lake dataset for the Mine Area. The baseline dataset is largest for this waterbody and would conceptually therefore provide the most robust pre-Project database for use in post-Project monitoring. Inter-annual differences in macroinvertebrate metrics were assessed statistically for each habitat type in Sheardown Lake NW (where multiple years of data were available). All data were tested for normality prior to statistical analysis and data that were normally distributed were assessed using parametric statistics while non-normally distributed data were analysed using non-parametric tests. Differences between years were assessed using the t-test (parametric) or Mann-Whitney U-test (non-parametric) when two years of data were available; ANOVA with Bonferroni pairwise comparison (parametric) was used when three years of data were available. All tests were assessed with significance level of 0.05; analyses were performed using XLStat Version 2007.4.

3.3.1.2 Results

Abundance

Total macroinvertebrate density was variable among Mine Area lakes and among habitat types sampled within waterbodies, ranging from a mean of 14 individuals/m^2 (Camp Lake, Habitat Type 4) to 18,562 individuals/m^2 (Sheardown Lake SE, Habitat Type 10); Table 3-8). The data exhibited relatively high variability (COVs up to 173%), but were normally distributed with the exception of Sheardown Lake NW, Habitat Type 9. COVs of samples collected were somewhat lower from deeper water depths (Profundal Zone, Habitat Type 14) in comparison to shallower water depths (particularly the Shoreline Zone, Habitat Type 4). This may reflect the more variable nature of the shallower areas of the lakes (i.e., strongly affected by water level fluctuations and wave energy, increased substrate heterogeneity, and potentially affected by anthropogenic factors).

Data from Sheardown Lake NW were further explored as this lake will be the immediate receiving environment for treated sewage effluent at the Mine Site and because the baseline data set is largest for this lake. There were notable differences in total density among habitat types and inter-annually within the same habitat type, with no clear pattern among habitat types (Figure 3-3).The COVs were somewhat higher at shallower water depths in comparison to deeper water habitat, with the lowest variability being observed in Habitat 14 in 2007 (Table 3-9). Within Habitat Type 9, total density was significantly lower in 2008 in comparison to 2007, and within Habitat Type 14, each year was significantly different from the other with total density being the lowest in 2008 and highest in 2011.

The relatively high variability of this metric and inter-annual difference(s) within habitat types highlights the importance of obtaining additional baseline data and information from appropriate reference lakes. With paired information from reference lakes, one may be able to determine whether changes over time observed at selected habitat types in affected lakes are similar to those observed at reference locations (i.e., related to Project-effects or due to natural variability).

Composition

The proportion of Chironomidae contributing to the total macroinvertebrate density was relatively similar among Mine Area lakes within the same habitat type (Table 3-10). The exception to this was Camp Lake, Habitat Type 4, where Chironomidae only made up 7% of the total in comparison to 66% in Sheardown Lake NW and 55% in Sheardown Lake SE. Differences among habitat types within a lake were evident, with the proportion of Chironomidae observed in samples increasing with water depth (Figure 3-4). The data exhibited less variability (lower COVs) in comparison to total macroinvertebrate density and were normally distributed, with the exception of Mary Lake, habitat types 9 and 14. As the proportion of Chironomidae increased with water depth, the corresponding COV declined. Within Sheardown Lake NW, COVs were less than 15% when each habitat type was considered annually, with the exception of Habitat Type 4 (28%; 2008 only), and declined with increasing water depth (Table 3-11). No significant differences were observed between years within habitat types 9 and 14.

Within a habitat type, evenness and diversity indices tended to be somewhat similar among Mine Area lakes, more so than among habitat types within a lake (Tables 3-12 and 3-13). As with the proportion of Chironomidae, differences among habitat types within a lake were evident for these two indices. Both indices decreased with increasing water depth, particularly for the Profundal Zone (Habitat Type 14; Figure 3-5 and 3-6). An exception to this was the diversity index for Camp Lake; however, the sample size for determining this metric in Habitat Type 4 was reduced to 1 due to the lack of macroinvertebrates in two of the three replicates. Data for these two indices were normally distributed, with the exception of diversity in Sheardown Lake NW, Habitat Type 9, and Mary Lake, Habitat Type 14. COVs for these two metrics were less than or equal to 40%, with the exception of diversity in Mary Lake, Habitat Type 14 (46%). Within a lake, COVs for both indices tended to increase with increasing water depth, particularly for the Profundal Zone; an exception to this was evenness in Sheardown Lake SE. Within Sheardown Lake NW, COVs ranged between 20 and 33% for evenness and 10 and 41% for diversity when each habitat type was considered annually and both were notably higher in the Profundal Zone (Tables 3-14 and 3-15). No significant differences were observed between years within habitat types 9 and 14 for either evenness or diversity indices.

Richness

Similar to evenness and diversity metrics, total and effective richness typically decreased with increasing water depth in Mine Area lakes (Tables 3-16 and 3-17); an obvious exception to this was Camp Lake. Data for these two indices were normally distributed, with the exception of total richness in Sheardown Lake NW, Habitat Type 4. COVs for these two metrics were less than 40%, with the exception of total richness in Camp Lake, Habitat Type 4 (173%), and Mary Lake, Habitat Type 14 (64%), and effective richness in Sheardown Lake SE, Habitat Type 4 (46%). Within a lake, COV for total richness increased with increasing water depth; an exception to this was Camp Lake. The pattern of COV for effective richness within a lake was inconsistent. Data from Sheardown Lake NW demonstrated that there were differences in both richness metrics among habitat types and inter-annually within the same habitat type; however, both tended to decrease with increasing water depth (Figures 3-7 and 3-8). COVs ranged between 7 and 28% for total richness and 19 and 28% for effective richness when each habitat type was considered annually (Tables 3-18 and 3-19). COVs tended to be somewhat higher for effective richness in comparison to total richness in an aquatic habitat for any given year. Within Habitat Type 9, total richness was significantly higher in 2008 in comparison to 2007. No other significant differences were observed.

3.3.2 Power Analysis

3.3.2.1 Data Analysis Methods

The most robust metrics identified through review of the baseline data for further statistical exploration and consideration under CREMP were also subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes (i.e., number of replicate stations within a waterbody or area of a waterbody) required for detecting pre-defined levels of change; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of replicate stations).

Power analysis was conducted following general guidance provided in the Environment Canada Metal Mining EEM Guidance Document (2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012); resulting power is 0.900. Evaluation of power of the existing baseline data for benthic macroinvertebrate community metrics was conducted using data collected from Sheardown Lake NW (evaluated by habitat type for pooled years of data). Sheardown Lake NW will be the immediate receiving environment for discharge of treated sewage effluent and would therefore be at greatest risk of nutrient enrichment and subsequent effects on secondary production of the lakes in the Mine Area. As noted previously, this lake could also be affected by other pathways of effects including effects on water clarity (dust, sewage discharge, and runoff), effects on other water quality parameters, and/or effects on hydrology.

The variability of numerous benthic macroinvertebrate metrics measured during the baseline studies program were evaluated and described to assist with identifying the most robust metrics for further statistical exploration and consideration under CREMP. Metrics that were subject to a power analysis included:

- Total macroinvertebrate density;
- Chironomidae proportion;
- Shannon's Equitability;
- Simpson's Diversity Index; and
- Total Taxa Richness.

COVs for the composition and richness metrics were typically less than 20% for each habitat type in Sheardown Lake NW and were therefore identified for further analysis; exceptions included Chironomidae proportion (Habitat 4), and Shannon's Equitability, Simpson's Diversity Index, and total taxa richness (Habitat 14) (Tables 3-9, 3-11, 3-14, 3-15, and 3-18). COVs for total macroinvertebrate density were high in all habitat types, but this metric was retained as it is one of the most commonly used indicators for the status of the benthic macroinvertebrate community in lakes.

CESs utilized for power analysis are summarized in Table 3-20. These CESs were selected based on the Metal Mining EEM Guidance document, scientific literature, and other recent/current AEMPs. For metrics with a non-normal distribution (total taxa richness, Habitat Type 4; total macroinvertebrate density and Simpson's Diversity Index, Habitat Type 9), all distributions were fitted to a log-normal prior to analyses; for Simpson's Diversity Index, it was truncated at 1. Analyses were run using PopTools version 3.2 (build 5) add-in for Microsoft Excel 2010.

3.3.2.2 Results

Total Macroinvertebrate Density

The power of the existing total macroinvertebrate density dataset from Sheardown Lake NW for detecting a pre-defined level of change (i.e., mean ± 50%, mean ± 25%, mean ± 20%) tends to be low for all change scenarios explored and varies depending on the aquatic habitat type (Table 3-21). The aquatic habitat type with the highest power for detecting change post-Project is Habitat Type 9, with a power of 0.807 for detecting a change in the mean of ±50%.

Sample sizes (i.e., the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change in the density metric were high for all aquatic habitat types, likely related to the high variability in the existing dataset (COVs up to 94%; Table 3-22). A total of 31, 43, and 64 replicate stations would be required in habitat types 9, 14, and 4, respectively, to detect a change in the mean of ±50% (power of 0.900).

Chironomidae Proportion

The power of the existing dataset for the Chironomidae proportion metric to be able to detect a pre-defined level of change is high for all change scenarios explored in habitat types 9 and 14 (power of 1.000), but somewhat lower for Habitat Type 4 (Table 3-21). The power in Habitat Type 4 ranges from a high of 0.957 (mean ± 50%) to a low of 0.402 (mean ± 20%).

Sample sizes required for detecting pre-defined levels of change in the Chironomidae proportion metric were notably lower than those determined for the total macroinvertebrate density metric and varied by habitat type (Table 3-22). In Habitat Type 4, sample sizes were 6, 22, and 37 to detect a change in the mean of ±50%, ±25%, and ±20%, respectively; corresponding sample sizes in Habitat Type 9 were 2, 4, and 6. Due to the low variability of this metric in Habitat 14, a sample of size of 1 would be sufficient to detect a change in the mean of ±20%.

Shannon's Equitability

The power of the existing dataset for the evenness metric to be able to detect change post-Project is high for all change scenarios in Habitat Type 9 (power of 1.000) (Table 3-21). The power is high in habitat types 4 and 14 to be able to detect a change in the mean of ±50% (power of 1.000 and 0.990, respectively), but declines for changes in the mean of ±25% and ±20%.

With respect to required sample sizes, Habitat Type 9 only requires 2, 4, and 6 replicate stations to be able to detect changes in the mean of ±50%, ±25%, and ±20%, respectively (Table 3-22). The number of replicate stations required in habitat types 4 and 14 for corresponding changes in the mean are higher, ranging between 3 and 10, and 7 and 37, respectively.

Simpson's Diversity Index

The power of the existing diversity index metric dataset to be able to detect change is high for all change scenarios in habitat types 4 and 9 (Table 3-21). The power is high in Habitat Type 14 to be able to detect a change in the mean of ±50% (power of 0.892), but declines for changes in the mean of ±25% and ±20%.

To detect a ±50% change in the mean, habitat types 4, 9, and 14 require 3, <5, and 12 replicate stations, respectively (Table 3-22). The number of replicate stations required in

Habitat Type 14 to be able to detect smaller changes in the mean increases notably in comparison to the other two habitat types.

Total Taxa Richness

The power of the existing total taxa richness dataset from Sheardown Lake NW for detecting a pre-defined level of change is high for all change scenarios and habitat types explored (Table 3-21). However, power is somewhat lower in Habitat Type 14 in comparison to the other habitat types to be able to detect a change in the mean of ±25% and ±20% (power of 0.866 and 0.712, respectively).

To detect a ±50% change in the mean, habitat types 4, 9, and 14 require <<3, 4, and 4 replicate stations, respectively (Table 3-22). The number of replicate stations required in habitat types 9 and 14 to be able to detect smaller changes in the mean increases similarly for both in comparison to Habitat Type 4.

3.3.3 Sampling Sites and Areas

3.3.3.1 Lakes

In lakes, EC (2012) recommends the spatial extent of each of the exposure and reference areas should be at least 100 m x 100 m and large enough to accommodate the required number of replicate stations, with sufficient separation. Replicate stations should encompass a minimum of a 10 m x 10 m area and be separated by at least 20 m.

Baseline sampling in the Mine Area lakes has included between three and seven replicate stations per habitat type (Table 3-1). Replicate stations were separated by approximately 10 m in 2006 and 2007, and by at least 20 m in 2008 and 2011.

3.3.3.2 Streams

In rivers and streams, EC (2012) recommends the spatial extent of each of the exposure and reference areas should be at least 100 m x 100 m and large enough to accommodate the required number of replicate stations, with sufficient separation. Replicate stations should encompass a longitudinal stretch of the river that includes one pool/riffle sequence; a river distance of six times the bankfull width should be adequate. Replicate stations should be separated by a minimum of three times the bankfull width between stations of similar habitat.

Baseline sampling in rivers/streams in the Mine Area included a minimum separation of three wetted stream widths between each replicate station (where more than one replicate station was sampled; Table 3-2).

3.3.4 Sample Size

EC (2012) recommends benthic invertebrate sampling should include at a minimum, five replicate stations, each consisting of a minimum of three sub-samples, for both the exposure and reference areas. Replicate stations should be located within the dominant habitat class to reduce variability (where possible). Actual number of samples may vary on a site-specific basis and existing data should be analysed to identify adequate sample size.

Baseline sampling has included between three and seven replicate stations within streams and lakes in the Mine Area, depending on the year and area sampled; the exception was in 2005 when only one replicate station was sampled (Table 3-2). In general, five sub-samples were collected for each replicate station (the exception was for Mary Lake in 2007 where only one sub-sample was collected for logistical reasons and at Sheardown Lake in 2011 where the three replicates were composed of one, three, and one grabs, respectively).

The power of the existing dataset in Sheardown Lake NW to be able to detect a post-Project change in the mean of ±50% is high for the majority of metrics investigated, with the exception of total macroinvertebrate density (Table 3-21). Habitat Type 9 has a power of 0.807 for detecting a ±50% change in the mean of total macroinvertebrate density; whereas habitat types 4 and 14 have power of 0.247 and 0.441, respectively. Depending on the aquatic habitat type, the power of numerous metrics remains high to be able to detect a change in the mean of ±25% and 20%, particularly in habitat types 4 and 9; existing power in Habitat Type 14 is notably lower in comparison for all metrics except Chironomidae proportion.

Sample sizes (i.e., the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change (i.e., mean ± 50%, mean ± 25%, mean ± 20%; power of 0.900) in total macroinvertebrate density in Sheardown Lake NW are high for all aquatic habitat types (minimum of 31 required to detect change in mean of ± 50%; Table 3-22). Minimum sample sizes for other metrics required to detect a change in the mean of ± 50% ranged from 1 (Chironomidae proportion, Habitat Type 14) to 12 (Simpson's Diversity Index, Habitat Type 14), with the majority being 7 or less. Depending on the aquatic habitat type, the sample size required for several metrics is 7 or less to be able to detect a change in the mean of ±25% and 20%. More sensitive metrics to change include:

- Shannon's Equitability, Simpson's Diversity Index, and total taxa richness in Habitat Type 4;
- Chironomidae proportion, Shannon's Equitability, and Simpson's Diversity Index in Habitat Type 9; and

- Chironomidae proportion in Habitat Type 14.

Depending on the CES(s) and benthic macroinvertebrate metrics ultimately chosen as part of the CREMP, 5 replicate stations per aquatic habitat type may be adequate; an increase to 7 would improve the ability of a few, more sensitive metrics to detect changes in the mean of ±25% and ±20% post-Project.

The number of field sub-samples (i.e., grabs) per replicate station was determined for Sheardown Lake NW by aquatic habitat type and year that would provide an estimate with 20% precision (i.e., an acceptable level of variance) for each metric (Tables 3-9, 3-11, 3-14, 3-15, 3-18, and 3-19). For total macroinvertebrate density, this number ranged between 1 and 22 sub-samples, depending on the habitat type and year; whereas for all other metrics the number of sub-samples ranged from 1 to 5. An assessment of the variability of sub-samples at a replicate station has not been conducted to date, as grabs were composited at each replicate station in previous years prior to identification and enumeration of macroinvertebrates. EC has recommended that sub-samples collected at replicate stations in the future be assessed separately, rather than composited as in previous years. It is recommended that 5 sub-samples be collected at each replicate station sampled in 2013 and that a further assessment of the number of field sub-samples required be undertaken once these additional data are available.

3.3.5 Sampling Methods

EC (2012) recommends the use of quantitative sampling equipment and specifically, grab samplers such as a petit Ponar or Ekman dredge for depositional habitats and stream-net samplers (e.g., Surber) for erosional habitats in freshwater systems. All baseline data collected in lakes used either an Ekman or a petit Ponar dredge and all stream sampling used a Surber sampling device. Methodologies are thus consistent with the guidance document.

EC (2012) recommends the use of a 500 µm mesh size for the freshwater environment and those samples should be preserved in 10% buffered formalin. All sampling for the Mine Area lakes and streams, with the exception of samples collected in 2005 when a mesh size of 250 µm was used, used a 500 µm mesh size and 10% buffered formalin for sample preservation.

3.3.6 Timing of Sampling

Timing of sampling should be concentrated within a single sampling season and should consider timing of previous sampling and the most ecologically relevant season. Environment Canada (2012) indicates that timing should also occur during effluent discharge but after the receiving environment has been exposed to the effluent for sufficient period during which effects would reasonably be expected to occur (i.e., generally within 3-6 months) in relation to Metal Mining EEM. Similarly, timing of sampling should consider the temporal aspects of other impact pathways being addressed through monitoring (e.g., changes in hydrology, dust deposition).

Benthic invertebrate sampling has been consistently conducted in the Mine Area in late summer/fall. This is an ecologically relevant time for sampling and would be most appropriate considering the effluent discharge regime (i.e., discharge during the open-water season only), hydrology (i.e., streams/rivers freeze solid), and dust deposition (i.e., introduction during the open-water season).

3.3.7 Taxonomy

EC (2012) recommends taxonomic identification to the family level for first and subsequent monitoring of freshwater systems but that finer taxonomic resolution may be required to detect more subtle effects.

All benthic invertebrate sorting and taxonomic identifications were conducted by the same laboratory (ZEAS Inc., Nobleton, ON), using the same laboratory methods among study years. Macroinvertebrates were identified to the lowest practical level using the most recent publications. Most taxa were identified to the level of Genus or Species, with the exception of flatworms, mites, and harpacticoid crustaceans, which were identified to Order.

3.3.8 Summary

Existing benthic macroinvertebrate community data are appropriate to use for post-Project monitoring; the robustness of these data was assessed through conduct of a power analysis (Section 3.3.2) to determine appropriate sample sizes for the recommended 2013 freshwater field program. See Section 3.4 for recommendations concerning additional baseline data collection and methodology.

3.4 SUMMARY OF DATA GAPS AND RECOMMENDATIONS

As benthic macroinvertebrate community sampling had only been conducted once at the majority of waterbodies and/or aquatic habitat types, it was recommended to conduct sampling in the fall of 2013 to augment the baseline database and improve its utility for post-Project comparisons. Following completion of the 2013 program, data and methods should be reviewed to advise on a final sampling program for post-Project monitoring.

The following recommendations regarding the benthic macroinvertebrate sampling program based on the review of baseline data include:

- Conduct a sampling program in the fall of 2013 in Mine Area lakes and candidate reference lakes to augment the baseline data;

- For Sheardown Lake NW, Sheardown Lake SE, and Camp and Mary lakes, it is recommended to sample major nearshore and offshore habitat types (anticipate 5 replicate stations per habitat type) during the fall (late August/mid-September);

- For 2013, it is recommended that 5 sub-samples be collected at each replicate station and that a further assessment of the number of field sub-samples required be undertaken once additional data are available;

- Sub-samples (i.e., grabs) collected at a replicate station in 2013 should be processed separately, rather than composited as in previous years, to allow an assessment of within-replicate station variability;

3.5 OVERVIEW OF 2013 SAMPLING

A benthic invertebrate sampling program was conducted in fall 2013 in Mine Area lakes, as recommended through the baseline data review, to augment and update the baseline database. The program focused upon sampling in key (i.e., predominant) habitat types in Camp and Sheardown lakes, as recommended in the review (Figure 3-9). Five replicate stations were sampled in each of the targeted habitat types. Five sub-samples were collected at each replicate station and preserved separately to facilitate examination of variability between sub-samples (i.e., variability within a replicate station). Due to inclement weather, sampling was not conducted in Mary Lake in 2013. A total of 11 replicate stations (five in each of two habitats, one in the third targeted habitat type) were sampled in Camp Lake, and a total of 10 (five in each of two targeted habitat types) were sampled in each of Sheardown Lake NW and Sheardown Lake SE.

4.0 ARCTIC CHAR

The following sections provide an inventory of available baseline Arctic Char (*Salvelinus alpinus*) data, a description of key pathways of effect and key questions respecting the Project, a preliminary examination of baseline Arctic Char data, a description of data gaps and recommendations for future sampling, and an overview of sampling completed in 2013.

Sampling of the fish community was initiated in 2005 in the Mine Area; Year 1 of the baseline studies was primarily a reconnaissance exercise aimed at identifying fish species present in the area and general distribution. Subsequent studies examined:

- Fish distribution across the Mine Area streams and identification of fish barriers;
- Fish movements (Arctic Char) between waterbodies;
- Fish population characteristics and condition (catch-per-unit-effort [CPUE], age structure, length/size at age, sex and sexual maturity, condition factors, deformities, erosion, lesions, and tumours, and internal and external parasites);
- Seasonal movement of Arctic Char from lakes into and out of streams/rivers;
- Anadromy;
- Seasonal use of various habitat types by different life history stages;
- Metals in liver and muscle; and
- Spawning areas/timing.

This review focused upon metrics that are currently contemplated for the CREMP (i.e., individual and population level metrics of growth, survival, condition and reproduction) and does not therefore, discuss data regarding fish movements/anadromy or metals in fish. Information on fish movements and habitat use are considered as supporting information for the review of baseline data and ultimately, recommendations for future sampling or monitoring.

This review focused upon consideration of baseline data in Mine Area lakes, as the MMER EEM program would specifically address monitoring in Mine Area streams. However, for the purposes of providing a general overview of available baseline data for Arctic Char in the Mine area, and because data collected in streams could be used to augment or support lake monitoring programs, Section 4.1 provides a brief description of baseline studies programs conducted in streams.

4.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of baseline studies for Arctic Char in the Mine Area to assist with evaluating the existing dataset (to 2012) and advising on future sampling and monitoring, in relation to metrics of growth, survival, condition, and reproduction. Specifically, the following provides:

- An overview of the sampling methods employed for collection and analysis of Arctic Char in the Mine Area waterbodies; and
- An inventory of existing baseline Arctic Char data for Mine Area waterbodies.

4.1.1 Sampling Methods

4.1.1.1 Lakes

A Smith-Root Model 11A or LR-24 backpack electrofisher was used during 2007 and 2008 to assess the use of wadeable nearshore lake habitat by small fish. During summer 2007, approximately 50-100 m long sections of shoreline with a variety of substrates (e.g., sand, cobble/boulder, gravel/cobble) were electrofished to assess habitat use by small fish in most Mine Area lakes. During spring 2008, electrofishing effort was focused on substrate types (cobble/boulder) thought to be preferred Arctic Char rearing habitat. The presence of recently hatched young-of-the-year (YOY) Arctic Char in nearshore habitat during early spring would provide some evidence of nearby fall spawning. Captured fish were sampled and released.

During the open-water seasons of 2006-2008, standard gang index gill nets were used to sample fish at sites in Camp, Sheardown, and Mary lakes. During 2006, gillnet sites were selected opportunistically. In 2007, sites were selected to achieve good spatial coverage of Camp, Sheardown, and Mary lakes. In 2008, the focus of the gillnetting program was on the identification of Arctic Char spawning habitat. Gillnet gangs consisted of six 22.9 m long by 1.8 m deep twisted nylon or monofilament panels of 1.5, 2.0, 3.0, 3.75, 4.25, and 5.0 inch (38, 51, 76, 95, 108, and 127 mm, respectively) stretched mesh. Nets were set on the bottom and left in place for short periods of time (typically less than 4 hours) to minimize fish mortality. Winter gillnetting during May 2007 used different gang arrangements and different methods and are not comparable with open water gillnetting. Therefore, winter gillnetting data were excluded from the analyses in this report. Locations of all captured fish were recorded using a hand-held GPS.

Biological data were collected for most fish captured in both gear types; however, the amount of data collected varied by gear type, and size and condition (i.e., live or mortalities) of fish. Fish were identified to species, enumerated by location, and measured for fork length (± 1 mm). For fish less than 250 mm in length, round weight was measured to an accuracy of ± 1 g, while larger fish were weighed to an accuracy of ±

25 g. When possible (i.e., during fall), live fish were examined for sex and maturity by gently massaging the abdomen and identifying any extruded gametes. Mortalities and fish in poor condition from all years were retained and examined internally to determine sex and state of sexual maturity (i.e., had never spawned, preparing to spawn in the current year, had just completed spawning in the current year, or had spawned in a previous year but would not be spawning in the current year), where possible. Ageing structures (otoliths) were collected from a length-stratified sub-sample of gillnet-caught fish from all Mine Area lakes and from a length-stratified sub-sample of electrofishing-caught fish from Mary River.

4.1.1.2 Streams

Backpack electrofishing was conducted from 2006-2008 using a Smith-Root Model 11A or LR-24 backpack electrofisher to assess the use of streams and rivers within the Mine Area by fish. Electrofishing surveys were primarily confined to reaches of streams and rivers where the results of aquatic habitat surveys suggested some potential to support fish. Stream reaches that either were ephemeral, or were cut off from lakes by impassable barriers typically were not fished. Streams and rivers electrofished in 2006 were confined to summer surveys, whereas most streams and rivers electrofished in 2007 were surveyed during spring, summer, and fall to document seasonal use of the tributaries. During 2008, several tributaries that had not been electrofished previously (particularly tributaries to Mary Lake) were fished during spring and summer.

Streams were subdivided into reaches based primarily on changes in dominant habitat types. Sections of each reach (50 m long) were isolated with barrier nets, where possible, and electrofished to estimate total fish use and compare between habitat types. Three passes were made in a downstream direction along each reach and the number of fish captured during each pass was recorded. All captured fish were released back into the reach from which they were captured at the completion of sampling.

Additional information on the fish use of selected tributaries was collected using hoop nets. Hoop nets oriented to capture fish moving downstream were installed in Camp Lake Tributary 2 (CLT2) and Sheardown Lake Tributary 1 (SDLT1) during fall 2007 to assess downstream movements of fish out of these tributaries. During 2008, hoop nets were installed during spring and fall to identify timing and magnitude of movements of fish into and out of these same two streams after spring melt and prior to freeze-up. Upstream and downstream movements were monitored in CLT2 during spring and fall and in SDLT1 during spring, 2008. Fish movements in CLT2 could not be monitored during spring 2008 due to high flows. Low water levels during fall 2008 prevented monitoring of upstream movements in SDLT1. Hoop nets were constructed of fine-mesh beach seine material, were 0.6 m in diameter, and had 5 m long wings. Each hoop net was positioned as close to the confluences as possible at sufficient depths to remain submerged. Each wing and the cod end of the net were anchored so that it remained taut and spanned the width of the stream. Wings were lengthened with rock barriers, where necessary, to achieve 100% blockage of the channel in either upstream or downstream configurations. All captured fish were released into the stream on the opposite side of the hoop net in which they were caught at the completion of sampling.

Biological data were collected for most fish captured in all gear types; however, the amount of data collected varied by gear type and size of fish. Fish were identified to species, enumerated by location, and measured for fork length (± 1 mm). For hoopnet-caught fish, only the first 50 fish captured each day were measured for fork length. For fish less than 250 mm in length, round weight was measured to an accuracy of ± 1 g, while larger fish were weighed to an accuracy of ± 25 g. Fish longer than 250 mm, and in good condition, were marked with individually numbered Floy® FD-94 tags inserted at the base of the dorsal fin.

4.1.2 Baseline Data Inventory

4.1.2.1 Lakes

Fish were sampled in lakes in the Mine Area using angling, minnow traps, backpack electrofishing, and standard gang index gill nets during the open-water periods of 2005 to 2008 and 2010 and using gill nets deployed under the ice in May 2007 (Figure 4-1, Table 4-1). However, only backpack electrofishing and open-water gillnetting data from 2006-2008 are considered for detailed analyses herein. Sampled lakes included Camp, Sheardown (northwest and southeast basins), and Mary (north and south basins) lakes.

4.1.2.2 Streams

Fish were sampled in streams within the Mine Area using angling, minnow traps, backpack electrofishing, and hoop nets during the open-water periods of 2005 to 2008 (Figure 4-2, Table 4-1). Sampled streams and rivers included inflows to Camp Lake, Sheardown Lake (northwest and southeast basins), and Mary Lake (north and south basins), as well as the Mary and Tom rivers. Only hoopnetting data are considered for detailed analyses herein. The hoopnet datasets are large and sampling was conducted at the confluences of tributary streams with Camp and Sheardown lakes. These data can, therefore, improve robustness of the baseline database respecting young-of-the-year (YOY) and age 1+ juvenile datasets for lakes.

4.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed (or confirmed) for CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in Section 4.3. These questions and metrics focus upon key potential effects identified in the FEIS, as well as metrics commonly applied for characterizing fish populations (growth, reproduction, condition and survival) and recommended by Environment Canada (2012).

The key pathways of potential residual effects of the Project on Arctic Char include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);
- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);
- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);
- Dust deposition (i.e., sedimentation) in Arctic Char spawning areas (habitat) and on Arctic Char eggs; and
- Effects of the Project on primary and secondary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, sedimentation, habitat loss or alteration, and changes in primary or secondary producers on Arctic Char in Mine Area lakes (Sheardown Lake NW and SE, Camp Lake, and Mary Lake)?

Arctic Char will be monitored downstream of discharges of ore and waste rock stockpile runoff (i.e., Camp Lake Tributary 1 and the Mary River) under the MMER EEM program and is not considered here. Of the remaining waterbodies, potential effects of the Project on Arctic Char populations are predicted to be greatest in the Camp Lake and Sheardown Lake drainages. It is proposed, and assumed for the purposes of evaluation of baseline data, that the CREMP may include monitoring of Arctic Char in these two lakes. Monitoring of small tributaries is not addressed here as some of the small tributaries to these lakes will be monitored under the EEM program and because these streams provide primarily juvenile rearing habitat and monitoring of Char in the downstream lakes would incorporate monitoring of various age classes.

4.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

The Mine Area streams and lakes support only two fish species: land-locked Arctic Char; and, Ninespine Stickleback (*Pungitius pungitius*). Of these, abundance of Ninespine Stickleback is relatively limited and highly localized while Arctic Char are overwhelmingly the most abundant fish species in the area. As Mine Area streams freeze solid during winter, overwintering habitat is provided exclusively by lakes.

Environment Canada (2012) recommends monitoring of sexually mature individuals of a minimum of two fish species for EEM programs and use of invasive sampling (i.e., lethal) if acceptable. Alternative study designs include non-lethal sampling methods for fish populations/communities, as well as studies of juvenile fish if appropriate and/or required.

Given that there are only two fish species present in the area, fish monitoring in the Mine Area would be limited to successful capture of sufficient numbers of both of these fish species in the exposure areas. In most lakes and streams in the exposure area, Arctic Char are sufficiently abundant that successful capture of enough fish for monitoring purposes is possible. In contrast, Ninespine Stickleback are absent or uncommon in a number of waterbodies. Similar results have been observed in most waterbodies surveyed for all components of the Mary River Project. It is unlikely, even with extensive effort, that sufficient numbers of Ninespine Stickleback could be captured for monitoring purposes from either the receiving environments or from prospective reference areas. It is therefore proposed that only a single species, Arctic Char, be used for the CREMP program.

The CREMP and MMER EEM programs have proposed the use of non-lethal sampling methods to minimize impacts of monitoring on the Arctic Char populations. The following therefore explores the existing baseline data with respect to non-lethal sampling methods for Arctic Char, focusing upon two waterbodies: Sheardown Lake NW; and Camp Lake (see Section 4.2 for discussion).

This review is not a true *a priori* statistical review of the CREMP program, as the intent and design of past studies are not entirely consistent with potential future monitoring programs. Past Arctic Char sampling programs did not employ the non-lethal study design described in Environment Canada (2012) that is being considered for CREMP. Therefore, the description and review of existing baseline data for use in future monitoring programs focused upon evaluating the overall variability of baseline data for key metrics and what analysis of existing data can advise for specific design of future monitoring and baseline data collection.

4.3.1 Description of Existing Data

4.3.1.1 Data Analysis

To explore the robustness of various potential metrics for Arctic Char for the CREMP, several metrics were derived as indicated in Table 4-2, using the datasets indicated in Table 4-3. The CREMP and MMER EEM programs have proposed the use of non-lethal sampling methods to minimize impacts of monitoring on the Arctic Char populations. Therefore the metrics identified and assessed for CREMP are those that can be measured using non-lethal sampling methods. Metric data for Arctic Char were analysed where sample sizes were $\geq$ 10, by waterbody, year, gear type (gill net and electrofishing only), and sex. When sex could not be determined for sufficient numbers of fish (e.g., electrofishing catches), data were pooled. Age data collected from a subsample of gillnetted fish in each lake were pooled to provide a sufficient sample size. Annual gillnetting data collected from 2006-2008 and shoreline electrofishing data (Sheardown Lake NW only) collected in 2007 and 2008 were analysed. Methods for the calculation of derived metrics are described below.

All fish catch and life history data were tabulated and reviewed for transcription errors as part of routine quality assurance/quality control (QA/QC) measures and, if warranted, outliers were eliminated from datasets. Fish catches were examined by lake, species, gear type, and year.

For Arctic Char, mean length, weight, and condition factor were calculated by lake, year, gear type, and, where possible, sex. CPUE was calculated for fish captured by electrofishing (#fish/minute of electrofishing) and in gill nets (#fish/100 m of net/24 hrs). Summary statistics (mean, median, SE, SD, minimum, maximum, n, COV, and 95th percentile) for each of these metrics were derived for each year, waterbody, gear type and, where possible, sex using data from all sites sampled concurrently in that waterbody.

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Additional summary statistics were conducted on YOY and fish aged 1+, including length-frequency analyses, length-at-age and weight-at-age to provide estimates of growth and survival of these early life stages.

Some hoop net data from streams (i.e., lengths and weights for YOY and 1+ fish) were pooled with shoreline electrofishing data in Sheardown Lake NW to improve robustness of the lake dataset for analysis.

4.3.1.2 Results

Fork Length (mm)

Mean lengths of Arctic Char show variation between lake, year, and sex (Tables 4-4 to 4-6). However, there were no significant differences observed between males and females sampled within the same year in any lakes and with one exception, there were no significant differences observed between years for this metric (Table 4-7). The sole exception occurred for females captured in Camp Lake where lengths were significantly different between years.

Comparing datasets between lakes revealed that Camp Lake had the smallest mean length and highest COV while the catches from the Mary Lake basins had the highest mean length and lowest variability (Tables 4-4 and 4-6). There were no significant differences for any between-lake comparisons of datasets (Table 4-8).

Weight (g)

Mean weights of Arctic Char show even greater variation between lake, year, and sex (Tables 4-9 to 4-11) than mean fork lengths. No significant differences between sexes or years were observed for Sheardown Lake NW or Mary Lake South. Weights of females were significantly lower than males captured in 2006, 2008, and with all years combined (2006-2008) and weights of both males and females were significantly different between years in Camp Lake (Table 4-12).

Comparing datasets between lakes revealed that north basin of Mary Lake had the smallest mean weight and COV while the south basin had the highest mean weight and Camp Lake had the highest variability (Tables 4-9 to 4-11). There were no significant differences for any between-lake comparisons of datasets (Table 4-13).

Condition Factor (K)

In contrast to length and weight metrics, mean condition factor of Arctic Char showed little variation between datasets and lower COVs than fork lengths (Tables 4-14 to 4-16). Mean condition factor was similar between males and females and between years in Camp Lake with consistently low COVs (Table 4-14). Mean condition factor of Arctic Char captured in Sheardown Lake was slightly lower than for Camp Lake, but also showed consistency between sexes and across years with low COVs for the gillnetting catch (Table 4-15). CFs of fish captured by electrofishing in Sheardown Lake NW was greater than for fish captured with gill nets, however the electrofishing dataset also exhibited higher COVs. In the south basin of Mary Lake, mean condition factor was higher in 2006 than in 2007, but relatively consistent between sexes and variability was low (Table 4-16).

Non-parametric analysis revealed significant interannual differences for males captured in Sheardown Lake NW and between males and females from Sheardown Lake NW in 2006 (Table 4-17). There were no significant differences for any between-lake comparisons of condition factor datasets (Table 4-18).

Catch-Per-Unit-Effort (CPUE)

As is commonly observed, CPUE for Arctic Char showed consistently high variation among datasets (Table 4-19). The highest COV was observed in the Sheardown Lake datasets. Data for males and females were not analysed separately because sex could not be identified for all captured fish, particularly during summer sampling.

Significant interannual differences (*P* value < 0.05) were observed for gillnetting datasets for Camp Lake and Mary Lake south and for the electrofishing dataset from Sheardown Lake NW (Table 4-20). In addition, there were significant differences for all between-lake comparisons (Table 4-21).

Age

Summary statistics for age data from Arctic Char are presented in Table 4-22. Fish sampled from Sheardown and Mary lakes had the highest average age while those sampled from Mary River had the lowest. Variation is relatively low between individual lakes and high between lakes and rivers. Length and weight-at-age statistics show a general increase in size with increasing age (Table 4-23). Growth rates appear to be higher between the ages of 2 and 10 than in older fish. Analysis of covariance (ANCOVA) tests show a significant effect of age on both length and weight (Table 4-24).

4.3.2 Power Analysis

4.3.2.1 Methods

Selected Arctic Char metrics (Table 4-25) were subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes (i.e., number of sites within a waterbody or area of a waterbody) required for detecting pre-defined levels of change; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of sites).

The variability of selected Arctic Char metrics measured during the baseline studies program was evaluated and described in Section 4.3.1 to assist with identifying the most robust metrics for further statistical exploration and consideration under CREMP (Table 4-1). Metrics that were subject to a power analysis included:

- Age 0+ and 1+ Length (mm);
- Age 1+ Weight (g); and
- Age 1+ Condition Factor (K).

Condition factor and weight of Age 0+ (i.e., YOY) fish could not be subject to a power analysis due to the precision of the weight measurements for the existing baseline datasets.

Power analysis was conducted following general guidance provided in the Environment Canada Metal Mining EEM Guidance Document (2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012). Data were evaluated for assumptions of normality and equal variance and transformed where required. Baseline data on Arctic Char populations collected in Sheardown Lake NW and Camp Lake from 2006-2010 were evaluated statistically for consideration of monitoring under the CREMP. Sheardown Lake NW will be the immediate receiving environment for discharge of treated sewage effluent and would therefore be at greatest risk of nutrient enrichment and subsequent effects on Arctic Char of the lakes in the Mine Area. As noted previously, this lake could also be affected by other pathways of effects including effects on water clarity (dust, sewage discharge, runoff), effects on other water quality parameters, and/or effects on hydrology.

For non-lethal sampling, Environment Canada (2012) recommends sampling of a minimum of 100 fish older than young of the year (YOY) for each study site but also recommends retaining and measuring all YOY collected during the sampling for older fish. Where possible, fish older than YOY should represent the whole range of fish sizes and be representative of the population (mature and immature).

A Priori Power Analyses

Power analysis by simulation was implemented using PopTools (Hood 2010).Two types of power analyses were used; one based on a *t*-test (parametric) and one based on the Mann-Whitney (nonparametric) *U*-test. Figure 4-3 shows the basic analysis flow for power analysis by simulation described below.

For the parametric test, the PopTools power analysis by simulation was used to test the hypotheses that the two groups have mean differences of ± 10%, ± 20%, and ± 25%. Using the *dNormalDev*($\bar{x}$, δ) function, random data were generated for the observed baseline and hypothetical monitoring scenarios. The Excel formula for a t-test is used keeping the first row fixed. This process is iterated 1000 times by Monte Carlo simulation to determine the frequency of a realised t-probability greater than α (Type I error), this provides an estimate of β (Type II error) with the power of the test being 1 - β. Both α and β are set at 0.10 for a power of 90% following the EEM Guidelines (Environment Canada 2012).

4.3.2.2 Results

The power analyses indicated that a sample size of 100 fish is sufficient to detect changes in length of 10%, in weight of 20%, and in condition factor of 10% (Table 4-25). Weights were the most variable of these three metrics and the power associated with this metric is the lowest. The power analyses indicate that relatively small samples sizes are required to detect 10% changes in length (n = 25 YOY and n = 11 for Age 1+) and condition factor (n = 9 for Age 1+).

4.3.3 Study Design

MMER EEM programs are designed to facilitate statistical comparisons of selected biological metrics between exposure (defined in relation to mining effluent discharges) and reference areas, but may also utilize before-after comparisons in the analysis stage. The programs are specifically designed to determine if mining effluent is causing an effect on fish and fish habitat and are therefore focused upon areas affected by effluent. Further, the use of reference areas is a critical component of this approach as an effect to a biological metric is defined as a statistical difference between the reference and exposure areas. While identification of reference areas is commonly challenging, the focus of the EEM programs on areas affected by effluent discharge focuses the programs on particular habitat(s), thus more readily facilitating identification of appropriate reference areas and direct statistical comparisons.

It is currently assumed that monitoring of Arctic Char in the Mine Area under the CREMP would utilize a non-lethal sampling design. The objective of the lake monitoring programs would be to examine cumulative effects of the Project on Arctic Char populations – one of the pathways of effect being effects related to mining effluent in Mary and Camp lakes. Lakes provide critical habitat for Arctic Char, as streams freeze solid in winter and spawning and overwintering habitat is restricted to lakes. The CREMP would examine the collective Project effects through monitoring Arctic Char in Mine Area lakes as a whole.

The proposed study design is intended to meet the overall objective of monitoring effects to the Arctic Char populations. The lake-based CREMP sampling program is focused upon obtaining measures of metrics for Age 1+ fish using standardized sampling methods (i.e., standard gang index gillnetting). The monitoring program would consist of direct before-after comparisons within a lake and, depending on the suitability of the final reference lakes incorporated into the CREMP, may also include control-impact comparisons (or, ideally, before-after-control-impact comparisons).

The proposed Arctic Char monitoring program in Mine Area lakes would be habitat-based, with sampling effort weighted in accordance with the proportions of major habitat types in each of the lakes. Major habitat types are defined in terms of water depth and substrate as follows:

- Deep (> 12 m)/hard;
- Deep/soft;
- Shallow (2-12 m)/hard; and
- Shallow/soft.

Sites would be randomly selected within these habitats in each lake. Gear would be primarily standard gang index gill nets, supplemented with smaller mesh nets (i.e., Swedish nets) and/or electrofishing as required to obtain the required minimum target sample size and range of fish ages/sizes.

4.3.4 Timing of Sampling

Environment Canada (2012) indicates that timing of sampling should consider the time of year, hydrology/habitat variability, stage of reproductive development, and effluent discharge regime. Fish biology will also affect timing of sampling (e.g., seasonal use of exposure areas). Reference and exposure areas should be sampled as close in time as feasible and should consider water temperature explicitly.

For Arctic Char, the recommended sampling period is 4-6 weeks prior to first spawn (EC 2012). For non-lethal surveys that include collection of YOY, Environment Canada (2012) recommends sampling be conducted when YOY are a catchable size in the gear being used. They further recommend sampling YOY in late fall where appropriate, though timing should consider variability in YOY size distributions of the population being monitored, or ideally, at the beginning and end of the growing period. Baseline sampling programs conducted in Camp, Sheardown and Mary Lakes with standard gang index gill nets typically occurred during summer (late July/early August) and covered all habitat types throughout the lake. These data were supplemented with limited fall sampling intended to identify spawning locations. Fall gillnetting was primarily restricted to areas where preferred spawning substrates were located. Sampling in exposure area streams was conducted during spring, summer and fall in all available habitat types to document seasonal use of stream habitat by both species of fish.

It is recommended that the CREMP conduct fish sampling in fall (late August) for lake-wide monitoring. This timing would allow for sampling of Arctic Char following a prolonged period of exposure to effluent (which will be discharged in the open-water season) and other non-point sources such as dust.

4.3.5 Sampling Areas

Environment Canada (2012) provides detailed direction on identifying exposure areas for the fish monitoring component under MMER EEM. As the objective of the MMER EEM programs is to monitor for effects of metal mining effluent on fish populations, these exposure areas are intentionally selected in areas affected by effluent discharges. Reference areas are then identified with, ideally, identical features and characteristics (e.g., habitat), for comparison.

Baseline sampling of Mine Area lakes with standard gang index gill nets was designed to provide quantitative estimates of Arctic Char populations for each lake and to identify spawning areas, while backpack electrofishing in all available nearshore habitat types of the lakes was conducted to identify habitat preferences of juveniles and assist with identification of spawning areas. During 2006, gillnet sites were selected opportunistically. In 2007, sites were selected to achieve good spatial and habitat coverage of Camp, Sheardown, and Mary lakes. In 2008, the focus of the gillnetting program was on the identification of Arctic Char spawning habitat.

While the guidance and study design prescribed by Environment Canada (2012) for monitoring Arctic Char populations is considered for the CREMP, the objectives of the CREMP vary fundamentally from MMER EEM. Specifically, the CREMP would be intended to monitor the cumulative effects of the Project on Arctic Char populations in Mine Area lakes and would not be intended to focus upon mining effluent or any one particular effects pathway. As such, it is recommended that the CREMP adopt a broader spatial scope and consider monitoring/sampling on a lake-wide basis, rather than on a focused area of each lake. As previously noted, it is recommended that the CREMP be habitat-based, focusing upon the key habitat types and quantities, within each of the lakes that are monitored.

4.3.6 Sample Size

For non-lethal sampling, Environment Canada (2012) recommends sampling of a minimum of 100 fish older than YOY for each study area but also recommends retaining and measuring all YOY collected during the sampling for older fish. Where possible, fish older than YOY should represent the whole range of fish sizes and be representative of the population (mature and immature).Where YOY is "extremely high" (i.e., >80-90% of the first 100 fish captured during the program), sampling should continue until 100 non-YOY fish are captured.

Results of the power analyses conducted on the Sheardown Lake NW datasets indicates that this recommended sample size will be adequate to detect CESs between 10 and 25% on selected metrics. However, the power analyses were based on baseline data collected from a representative lake (Sheardown Lake NW) using a different study design than recommended for the CREMP. Therefore it is recommended to target a minimum of 100 individuals per lake but to review baseline data collected in 2013 using the proposed CREMP study design.

4.3.7 Metrics

Environment Canada (2012) recommends that non-lethal sampling should include fork length for fish with a forked caudal fin (± 1 mm), total body weight (± 1.0%), assessment of external condition (i.e., DELTs), external sex determination (if possible), and age (where possible; ± 1 year). They further recommend the use of a 3-decimal scale for measuring weights of small-sized fish.

Baseline studies included measurement of all of these metrics but some metrics were not measured to the recommended precision for all fish sampled. Future programs will employ the level of precision identified by Environment Canada (2012) for all fish captured.

Arctic Char were aged using otoliths - the preferred ageing structure for this species – during past baseline studies. The CREMP is anticipated to employ a non-lethal design and therefore will require use of other ageing structures (i.e., scales or pectoral fin rays) for fish that are live released. Arctic Char scales are very small, particularly on juveniles, which poses challenges for collection and ageing. It is, therefore, recommended that only otoliths and fin rays be collected from all incidental mortalities and potentially from a length-stratified sub-sample during the conduct of future studies for the purpose of cross-verification of these two ageing structures. Ageing measurements should be independently confirmed on a minimum of 10% of samples, as recommended by Environment Canada (2012).

4.3.8 Sampling Equipment

Environment Canada (2012) indicates the same gear type should be used for sampling reference and exposure areas and ideally only one gear type is used for the fish study. In nearshore areas of lakes, backpack electrofishing has been the primary method of sampling and would be used for sampling these areas during the CREMP program as needed. Standard gang index gillnetting has been used for baseline lake surveys and would continue to be used during the CREMP program as the primary sampling method. Small mesh nets may also be used to capture sufficient numbers of fish, in particular smaller size ranges. However, small mesh nets have proven relatively ineffective for capture of fish smaller than 250 mm in length and it is anticipated that backpack electrofishing will be required in future programs to obtain Arctic Char in this length range.

4.4 SUMMARY OF DATA GAPS AND RECOMMENDATIONS

The primary data gap related to baseline Arctic Char data for the Mine Area lakes relates to study design. Past programs were conducted with varying objectives and as such, the study designs are not consistent with the proposed CREMP programs for lakes. Most baseline studies were also completed prior to acquisition of habitat maps for Mine Area lakes and therefore were not designed from a habitat and habitat-use perspective.

Specific differences or gaps relate to areas or sites sampled in lakes, timing of sampling, and the level of precision for measurements of weights of small (i.e., YOY) fish. In addition, existing ageing data were based on otoliths. While otoliths are the preferred ageing structure for Arctic Char, employment of non-lethal methods in future programs will restrict ageing through the use of pectoral fin rays and/or scales. As discussed below, this may require cross-validation.

Recommendations regarding monitoring of Arctic Char under the CREMP include:

- It is recommended to conduct additional baseline data collection in 2013 to provide pre-Project data using the suggested study design and methodology. Further, baseline sampling of Arctic Char populations has not been conducted in the Mine Area since 2008 and obtaining more recent data would be advisable;
- It is proposed to use a habitat-based sampling design, with level of effort weighted in accordance with the relative abundance of four major habitat types;
- It is recommended to conduct the lake monitoring in fall;
- The sample size of 100 individuals, as advised by EC (2012) for non-lethal sampling, is recommended for each lake sampled; and
- It is recommended that otoliths and pectoral fin rays be collected from all incidental mortalities and potentially from a length-stratified sub-sample during the conduct of future studies for the purpose of cross-verification of these two ageing structures. Ageing measurements should be independently confirmed on a minimum of 10% of samples, as recommended by Environment Canada (2012).

4.5 OVERVIEW OF 2013 SAMPLING

The Arctic Char sampling program conducted in Mine Area lakes in 2013 was designed to be non-lethal and was based upon Environment Canada’s EEM survey design (EC 2012). As such, the lake-based sampling program was focused upon obtaining measures of metrics for Age 1+ fish using standardized sampling methods (i.e., standard gang index gillnetting). The program was habitat-based, with sampling effort weighted in accordance with the proportions of major habitat types in each of the lakes. Major habitat types were defined in terms of water depth and substrate as follows:

- Deep (> 12 m)/hard;
- Deep/soft;
- Shallow (2-12 m)/hard; and
- Shallow/soft.

Sites were randomly selected within these habitats in each lake. Catch rates were lower than anticipated based on gillnetting surveys conducted from 2006-2008 and sampling was enhanced by addition of random sites most likely to optimize catches (e.g., probable spawning areas). Gear included standard gang index gill nets, supplemented with smaller mesh nets (i.e., Swedish nets) and nearshore backpack electrofishing to obtain the required minimum target sample size (100 fish) and range of fish ages/sizes.

Twenty-four standard index and eleven small mesh gillnet gangs were set in Camp Lake from 27-29 August, 2013 (Figure 4-4). Twelve standard index and 6 small mesh gillnet gangs were set in Sheardown NW Lake on 30 August, 2013 (Figure 4-5). A total of 26 Arctic Char were captured in Camp Lake and 28 were captured Sheardown Lake NW with gill nets.

To supplement the small gillnetting catches, backpack electrofishing was conducted at one site in Camp Lake and two sites in Sheardown Lake NW. Fifty-seven juvenile Arctic Char were captured in Camp Lake and 183 Arctic Char and one Ninespine Stickleback were captured in Sheardown Lake NW during electrofishing surveys.

The baseline review recommended the collection of both otoliths and pectoral fin rays from incidental mortalities during the conduct of future studies for the purpose of cross-verification of these two ageing structures. Pectoral fin rays and otoliths were collected from 16 Arctic Char in 2013 to facilitate this comparison.

5.0 LITERATURE CITED

Azimuth Consulting Group. 2012. Core receiving environment monitoring program (CREMP): Design document 2012. Prepared for Agnico-Eagle Mines Ltd., Baker Lake, Nunavut. December 2012.

Begon, M., J.L. Harper, and C.R. Townsend. Ecology: individuals, populations and communities; third edition. Blackwell Science. Mississauga.

Cole, G.E. 1983. Textbook of limnology. Third Edition, Waveland Press Inc., Prospect Heights, Illinois.

Environment Canada. 2012. Metal mining technical guidance for Environmental Effects Monitoring. ISBN 978-1-100-20496-3.

Hill. M.O.. 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 54: 427-432.

Hood, G. M. 2010. PopTools version 3.2.5. Available on the internet. URL http://www.poptools.org

INAC (Indian and Northern Affairs Canada). 2009. Guidelines for designing and implementing aquatic effects monitoring programs for development projects in the Northwest Territories. Yellowknife. June 2009. Volumes 1-6.

Magurran, A.E.1988. Ecological diversity and its measurement. Princeton University Press. New Jersey.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell. Malden Massachusetts.

Mandaville, S.M. 2002. Benthic macroinvertebrates in freshwaters – taxa tolerance values, metrics, and protocols. Project H-1. Soil and Water Conservation Society of Metro Halifax. 48p. + Appendices.

Munkittrick, K., C. Arens, R. Lowell, G. Kaminski. 2009. A review of potential methods of determining critical effect size for designing environmental monitoring programs. Environmental Toxicology and Chemistry 28:1361-1371.

Organization for Economic Cooperation and Development (OECD). 1982. Eutrophication of waters: monitoring, assessment and control. Final Report. OECD cooperative programme on monitoring of inland waters (eutrophication control). Environment Directorate, OECD, Paris, France. 154 pp.

TABLES AND FIGURES

Table 2-1. Summary of number of sites sampled for analysis of chlorophyll *a* in Mine Area lakes (near surface sampling).

Sampling Period	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake
May 2007	3	2	3	4
August 2007	5	3	3	4
September 2007	5	3	3	4
June 2008	6	0	0	0
July/August 2008	22	6	3	3
September 2008	11	3	0	0
August/September 2009	4	1	0	0
Total	56	18	12	15
Total: Open-water Period	53	16	9	11

Table 2-2. Summary of number of sites sampled for analysis of phytoplankton taxonomy and biomass in Mine Area lakes.

Sampling Period	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake
August 2007	5	3	3	5
September 2007	5	3	3	5
July/August 2008	5	3	3	4
September 2008	5	3	0	0
Total	20	12	9	14

Table 2-3. Summary of number of sites sampled for analysis of chlorophyll *a* in Mine Area streams.

Sampling Period	Mary River	Tom River	Sheardown Lake Tributaries							Tributaries to Mary Lake
			SDL NW Trib 1	SDL SE Trib 9	SDL NW Trib 12	SDL NW Trib 13	Unnamed Trib A SDL NW	Unnamed Trib B SDL NW		Mary Lake Trib 2
June 2007	7	2	1		1	1				
July 2007	8	2	1		1					
September 2007	7	2	1	1	1					
June 2008	3	2	3	1	1	1	1			1
July 2008	8		3	1	1					1
September 2008	2	1	2	1	1		1	1		1
Total	35	9	11	4	6	2	2	1		3

Table 2-4. Phytoplankton metrics considered for CREMP.

Effect Indicator	Metric	Unit
Algal Abundance/Density	Chlorophyll *a*	(µg/L)
	Total Biomass	(mg/m^3)
	Biomass of Major Groups	(mg/m^3)
	Biomass of Major Groups	(% of total biomass)
Evenness	Simpson's evenness	-
	Shannon's evenness	-
	Hill's evenness	-
Taxa Richness	Total number of species	-
	Hill's effective richness	-
	Simpson's diversity index	-

Table 2-5. Summary statistics for chlorophyll *a* (µg/L) measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008. Analytical detection limit = 0.2 µg/L. Nearshore sampling sites excluded.

	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake	All Lakes: 2007 and 2008
Mean	0.33	0.63	0.40	0.75	0.49
Median	0.20	0.20	0.20	0.30	0.20
Minimum	0.20	0.20	0.20	0.20	0.20
Maximum	1.50	2.10	1.50	1.80	2.10
SD	0.31	0.69	0.42	0.67	0.53
SE	0.06	0.18	0.14	0.20	0.07
n	25	15	9	11	60
95th Percentile	0.90	2.0	1.1	1.8	1.8
% Detections	32	33	56	55	49
COV (%)	96	110	106	90	109
Mean + 2 x SD	0.96	2.00	1.25	2.09	1.55
2 x Mean	0.66	1.25	0.80	1.49	0.98
Mean + 50%	0.49	0.94	0.60	1.12	0.74
Mean + 25%	0.41	0.78	0.50	0.93	0.61
Mean + 20%	0.39	0.75	0.48	0.89	0.59

Table 2-6. Summary statistics and results of Kruskal-Wallis tests for chlorophyll *a* (µg/L) measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008. Analytical detection limit = 0.2 µg/L. Nearshore sampling sites excluded. The mean of samples collected in July and August 2008 were averaged to represent the summer sampling period.

	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.35	0.31	0.38	0.28	0.33
Median	0.20	0.20	0.20	0.20	0.20
Minimum	0.20	0.20	0.20	0.20	0.20
Maximum	0.90	0.90	0.90	0.90	0.90
SD	0.29	0.23	0.29	0.22	0.26
SE	0.09	0.07	0.09	0.07	0.06
n	10	10	10	10	20
95th Percentile	0.90	0.72	0.90	0.63	0.90
% Detections	50	30	60	20	40
COV (%)	83	74	76	79	77
Mean + 2 x SD	1	0.77	0.96	0.72	0.84
2 x Mean	0.70	0.62	0.76	0.56	0.66
Mean + 50%	0.53	0.47	0.57	0.42	0.50
Mean + 25%	0.44	0.39	0.48	0.35	0.41
Mean + 20%	0.42	0.37	0.46	0.34	0.40
P value[1]	1		0.433		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-7. Summary statistics for total phytoplankton biomass (mg/m^3) measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008.

	Phytoplankton biomass (mg/m^3)			
	Sheardown Lake NW	**Sheardown Lake SE**	**Camp Lake**	**Mary Lake**
Mean	204	125	122	149
Median	160	62	109	173
Minimum	42	43	43	28
Maximum	456	336	250	415
SD	134	111	73	106
SE	30	32	24	28
n	20	12	9	14
95th Percentile	430	312	243	298
COV	66	89	60	71
Mean + 2 x SD	471	347	268	360
2 x Mean	408	250	243	298
Mean + 50%	306	188	183	223
Mean + 25%	255	157	152	186
Mean + 20%	245	150	146	179

Table 2-8. Summary statistics and results of Kruskal-Wallis tests for total phytoplankton biomass (mg/m^3) measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008.

	Phytoplankton biomass (mg/m^3)				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	182	226	87	321	204
Median	145	208	92	302	160
Minimum	42	88	42	183	42
Maximum	429	456	137	456	456
SD	137	134	30	79	134
SE	43	42	10	25	30
n	10	10	10	10	20
95th Percentile	378	410	129	444	430
COV	75	59	35	25	66
Mean + 2 x SD	456	493	148	479	471
2 x Mean	364	451	173	642	408
Mean + 50%	273	338	130	481	306
Mean + 25%	228	282	108	401	255
Mean + 20%	218	271	104	385	245
P value[1]	0.315		<0.0001		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-9. Mean, SD, COV, and 95th percentiles for phytoplankton species diversity, evenness, and richness metrics measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008.

	MEANS					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.71	0.22	18	0.61	6.19	0.34
Sheardown Lake SE	0.71	0.29	16	0.61	6.10	0.37
Camp Lake	0.72	0.22	17	0.60	5.55	0.33
Mary Lake	0.52	0.20	15	0.47	3.84	0.28
All lakes combined	0.66	0.23	17	0.58	5.47	0.33
	SD					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.12	0.08	3	0.10	1.94	0.08
Sheardown Lake SE	0.88	0.43	20	0.77	9.31	0.54
Camp Lake	0.07	0.05	3	0.04	1.18	0.04
Mary Lake	0.19	0.15	4	0.17	2.00	0.15
All lakes combined	0.17	0.11	3	0.14	2.18	0.11
	COV					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	17	34	16	16	31	25
Sheardown Lake SE	27	42	18	26	41	34
Camp Lake	9	25	20	7	21	13
Mary Lake	36	75	28	36	52	55
All lakes combined	26	47	21	24	40	34
	95TH PERCENTILE					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.84	0.34	22	0.74	8.9	0.46
Sheardown Lake SE	0.87	0.42	19	0.76	9.2	0.51
Camp Lake	0.81	0.28	23	0.66	7.5	0.37
Mary Lake	0.84	0.52	21	0.78	7.5	0.56
All lakes combined	0.87	0.42	22	0.77	9.1	0.53

Table 2-10. Summary statistics and results of Kruskal-Wallis tests for phytoplankton taxonomy metrics measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008.

	Simpson's Diversity Index				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	0.76	0.66	0.80	0.62	0.71
Median	0.79	0.70	0.81	0.62	0.76
Minimum	0.59	0.41	0.71	0.41	0.41
Maximum	0.87	0.81	0.87	0.78	0.87
SD	0.10	0.13	0.05	0.11	0.12
SE	0.03	0.04	0.01	0.04	0.03
n	10	10	10	10	20
95th Percentile	0.86	0.80	0.86	0.77	0.84
COV	13	20	6	18	17
Mean + 2 x SD	0.95	0.93	0.89	0.85	0.96
2 x Mean	1.52	1.32	1.60	1.24	1.42
Mean + 50%	1.14	0.99	1.20	0.93	1.07
Mean + 25%	0.95	0.83	1.00	0.78	0.89
Mean + 20%	0.91	0.79	0.96	0.75	0.85
P value[1]	0.075		<0.0005		-

	Simpson's Evenness				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	0.27	0.18	0.27	0.18	0.22
Median	0.27	0.17	0.26	0.17	0.20
Minimum	0.15	0.13	0.17	0.13	0.13
Maximum	0.40	0.26	0.40	0.32	0.40
SD	0.08	0.05	0.07	0.06	0.08
SE	0.02	0.01	0.02	0.02	0.02
n	10	10	10	10	20
95th Percentile	0.37	0.25	0.37	0.28	0.34
COV	29	25	27	32	34
Mean + 2 x SD	0.42	0.27	0.41	0.30	0.38
2 x Mean	0.53	0.36	0.53	0.36	0.45
Mean + 50%	0.40	0.27	0.40	0.27	0.34
Mean + 25%	0.33	0.23	0.33	0.23	0.28
Mean + 20%	0.32	0.22	0.32	0.22	0.27
P value[1]	0.007		0.009		-

Table 2-10. - continued -

	Species Richness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	18	18	19.9	16.0	18.0
Median	17	20	20.0	15.5	18.5
Minimum	13	13	16.0	13.0	13.0
Maximum	22	22	22.0	20.0	22.0
SD	3	3	1.9	2.4	2.9
SE	1	1	0.6	0.8	0.7
n	10	10	10	10	20
95th Percentile	21	22	22.0	20.0	22.0
COV	16	17	9	15	16
Mean + 2 x SD	23	24	23.6	20.9	23.8
2 x Mean	35	37	40	32	36
Mean + 50%	26	27	30	24	27
Mean + 25%	22	23	25	20	22
Mean + 20%	21	22	24	19	22
P value[1]	0.614		0.002		-

	Shannon's Evenness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.66	0.57	0.68	0.54	0.61
Median	0.69	0.59	0.69	0.56	0.62
Minimum	0.54	0.39	0.59	0.39	0.39
Maximum	0.77	0.72	0.77	0.69	0.77
SD	0.08	0.10	0.05	0.09	0.10
SE	0.03	0.03	0.02	0.03	0.02
n	10	10	10	10	20
95th Percentile	0.75	0.69	0.75	0.65	0.74
COV	12	18	8	16	16
Mean + 2 x SD	0.82	0.78	0.79	0.72	0.81
2 x Mean	1.31	1.14	1.37	1.09	1.23
Mean + 50%	0.98	0.86	1.02	0.81	0.92
Mean + 25%	0.82	0.71	0.85	0.68	0.77
Mean + 20%	0.79	0.68	0.82	0.65	0.74
P value[1]	0.105		0.001		-

Table 2-10. - continued -

	Hill's Effective Richness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	6.8	5.6	7.7	4.6	6.2
Median	6.8	5.9	7.6	4.5	6.1
Minimum	4.4	2.8	5.9	2.8	2.8
Maximum	9.7	8.9	9.7	6.2	9.7
SD	1.8	2.0	1.1	1.2	1.9
SE	0.6	0.6	0.4	0.4	0.4
n	10	10	10	10	20
95th Percentile	9.2	8.2	9.3	6.1	8.9
COV	27	35	15	25	31
Mean + 2 x SD	10.5	9.5	10.0	6.9	10.1
2 x Mean	13.5	11.2	15.5	9.3	12.4
Mean + 50%	10.1	8.4	11.6	6.9	9.3
Mean + 25%	8.5	7.0	9.7	5.8	7.7
Mean + 20%	8.1	6.7	9.3	5.6	7.4
P value[1]	0.280		<0.0001		-

	Hill's Evenness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.38	0.30	0.39	0.29	0.34
Median	0.40	0.30	0.40	0.30	0.32
Minimum	0.28	0.21	0.30	0.21	0.21
Maximum	0.52	0.42	0.52	0.45	0.52
SD	0.08	0.07	0.07	0.07	0.08
SE	0.03	0.02	0.02	0.02	0.02
n	10	10	10	10	20
95th Percentile	0.49	0.39	0.49	0.39	0.46
COV	21	22	17	24	25
Mean + 2 x SD	0.55	0.43	0.53	0.43	0.51
2 x Mean	0.77	0.60	0.78	0.58	0.68
Mean + 50%	0.58	0.45	0.59	0.44	0.51
Mean + 25%	0.48	0.37	0.49	0.36	0.43
Mean + 20%	0.46	0.36	0.47	0.35	0.41
P value[1]	0.052		0.004		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-11. Spearman rank correlation coefficients for phytoplankton metrics and total phosphorus (TP). Values in bold indicate significant correlations at α = 0.05. Correlation analysis includes data collected from all Mine Area lakes in 2007-2008.

Variables	TP	Chlorophyll *a* (detected samples only)	Chlorophyll *a*	Total Biomass	Diatom Biomass	Green-Algae Biomass	Chrysophyte Biomass	Cryptophyte Biomass	Blue-Green Algae Biomass	Euglenoid Biomass	Dinoflagellate Biomass	Diatom Relative Abundance	Green-Algae Relative Abundance	Chrysophyte Relative Abundance	Cryptophyte Relative Abundance	Blue-Green Algae Relative Abundance	Euglenoid Relative Abundance	Dinoflagellate Relative Abundance	Maximum Species Biomass	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness
Chlorophyll *a* (detected samples only)	**0.620**																							
Chlorophyll *a*	**0.288**	**1.000**																						
Total Biomass	0.119	0.272	-0.068																					
Diatom Biomass	0.046	0.148	-0.038	**0.957**																				
Green-Algae Biomass	-0.058	0.156	-0.224	**0.462**	**0.377**																			
Chrysophyte Biomass	0.230	0.130	-0.018	**0.533**	**0.457**	**0.323**																		
Cryptophyte Biomass	0.129	0.252	0.121	**0.318**	**0.288**	0.107	0.236																	
Blue-Green Algae Biomass	0.113	0.204	0.007	0.224	0.091	0.045	0.159	0.059																
Euglenoid Biomass	-0.164	-0.231	0.123	-0.244	-0.188	-0.253	**-0.310**	0.036	-0.061															
Dinoflagellate Biomass	-0.055	0.007	-0.070	**0.303**	0.223	0.218	0.120	0.157	0.195	0.017														
Diatom Relative Abundance	-0.103	-0.194	0.165	0.035	**0.267**	**-0.431**	-0.085	-0.102	**-0.426**	0.079	**-0.398**													
Green-Algae Relative Abundance	-0.226	-0.191	-0.256	-0.095	-0.167	**0.803**	-0.018	-0.036	-0.030	-0.074	0.053	**-0.528**												
Chrysophyte Relative Abundance	0.152	0.022	0.032	0.001	-0.051	-0.003	**0.805**	0.032	0.075	-0.197	-0.098	-0.059	-0.067											
Cryptophyte Relative Abundance	0.134	0.233	0.164	-0.067	-0.083	-0.110	0.009	**0.885**	-0.024	0.176	0.018	-0.131	-0.043	0.004										
Blue-Green Algae Relative Abundance	0.111	0.183	0.028	0.140	0.000	0.028	0.096	0.032	**0.988**	-0.060	0.145	**-0.447**	0.008	0.048	-0.021									
Euglenoid Relative Abundance	-0.183	-0.258	0.112	**-0.289**	-0.237	-0.250	**-0.319**	-0.002	-0.051	**0.992**	0.026	0.048	-0.047	-0.184	0.156	-0.047								
Dinoflagellate Relative Abundance	-0.093	0.003	-0.091	0.168	0.088	0.147	0.035	0.126	0.167	0.061	**0.970**	**-0.429**	0.078	-0.122	0.041	0.126	0.079							
Maximum Species Biomass	0.142	0.193	0.012	**0.951**	**0.957**	**0.360**	**0.513**	**0.284**	0.136	-0.227	0.181	0.184	-0.189	0.018	-0.083	0.047	**-0.274**	0.047						
Simpson's Diversity Index	-0.244	-0.098	-0.183	**-0.595**	**-0.651**	-0.055	**-0.353**	-0.122	0.127	0.217	0.154	**-0.421**	**0.337**	-0.069	0.126	0.185	0.258	0.246	**-0.786**					
Simpson's Evenness	-0.084	0.073	-0.144	**-0.706**	**-0.781**	-0.094	**-0.282**	-0.156	0.010	0.062	-0.023	**-0.394**	**0.317**	0.077	0.115	0.083	0.109	0.089	**-0.858**	**0.901**				
Species Richness	**-0.434**	**-0.582**	-0.170	0.008	0.061	0.023	-0.260	-0.006	0.190	**0.429**	**0.370**	-0.058	0.111	**-0.282**	-0.003	0.176	**0.417**	**0.353**	-0.108	**0.446**	0.052			
Shannon's Evenness	-0.164	-0.008	-0.099	**-0.645**	**-0.701**	-0.049	**-0.299**	-0.105	0.079	0.198	0.101	**-0.416**	**0.348**	0.019	0.156	0.137	0.241	0.192	**-0.811**	**0.969**	**0.936**	**0.307**		
Hill's Effective Richness	**-0.282**	-0.185	-0.159	**-0.551**	**-0.588**	-0.029	**-0.314**	-0.110	0.146	**0.289**	0.214	**-0.395**	**0.346**	-0.051	0.113	0.194	**0.326**	**0.294**	**-0.733**	**0.974**	**0.826**	**0.566**	**0.946**	
Hill's Evenness	-0.084	0.062	-0.087	**-0.711**	**-0.770**	-0.089	**-0.276**	-0.137	0.021	0.123	0.017	**-0.386**	**0.318**	0.092	0.127	0.085	0.168	0.122	**-0.850**	**0.905**	**0.979**	0.103	**0.965**	**0.862**

Table 2-12. Summary of power analysis results for selected phytoplankton community metrics.

Metric	Minimum Sample Size						
	All data 2007-2008				Fall data 2007-2008		
	CES				CES		
	50%	25%	20%		50%	25%	20%
Simpson's Diversity Index	3	8	12		4	11	16
Species Richness	3	7	11		3	8	12
Shannon's Evenness	3	8	11		3	9	13

Table 2-13. Summary of power analysis results for phytoplankton total biomass and chlorophyll *a*.

Metric	Minimum Sample Size						
	All data 2007-2008				Fall data 2007-2008		
	CES				CES		
	100%	50%	25%		100%	50%	25%
Chlorophyll *a*	20	>50	>50		17	>50	>50
Total Biomass	8	27	99		6	22	86

Table 2-14. Overview of phytoplankton sampling conducted in Mine Area waterbodies: 2013.

Waterbody	Site ID	Summer 2013		Fall 2013	
		Chlorophyll *a*	Biomass and Taxonomy	Chlorophyll *a*	Biomass and Taxonomy
Camp Lake					
	JL0-01	x	x		
	JL0-02	x	x		
	JL0-09	x	x	x	x
	JL0-10	x	x	x	x
	JL0-11	x	x	x	x
	JL0-phyto1		x		x
	JL0-phyto2		x		x
	JL0-phyto3		x		x
	JL0-phyto4		x		x
	JL0-phyto5		x		x
Sheardown Lake Northwest Basin					
	DL0-01-1	x	x	x	x
	DL0-01-2	x	x	x	x
	DL0-01-3				
	DL0-01-4	x	x	x	x
	DL0-01-5	x	x	x	x
	DL0-01-7	x	x	x	x
	DL0-01-phyto1	x	x		
	DL0-01-phyto2	x	x		
	DL0-01-phyto3	x	x		
	DL0-01-phyto4	x	x		
	DL0-01-phyto5	x	x		
Sheardown Lake Southeast Basin					
	DL0-02-1	x	x		
	DL0-02-3	x	x		
	DL0-02-3b				
	DL0-02-4	x	x		
	DL0-02-6		x		
	DL0-02-7	x	x		
	DL0-02-8	x	x		
	DL0-02-phyto1				
	DL0-02-phyto2				
	DL0-02-phyto3				
	DL0-02-phyto4				

Table 3-14. - continued –

Waterbody	Site ID	Summer 2013		Fall 2013	
		Chlorophyll *a*	Biomass and Taxonomy	Chlorophyll *a*	Biomass and Taxonomy
Mary Lake					
	BL0-01	x	x		
	BL0-03	x	x	x	
	BL0-04	x	x	x	
	BL0-05	x	x	x	
	BL0-06	x	x	x	
	BL0-07	x	x		
	BL0-phyto1		x		
	BL0-phyto2		x		
	BL0-phyto3		x		
	BL0-phyto4		x		
-	BL0-phyto5		x		

Table 3-1. Summary of benthic invertebrate sampling methods for Mine Area lakes (2006-2011).

Year	Equipment	Mesh Size (µm)	Replicate Stations per Site or Habitat Type	Sub-samples per Replicate Station	Taxonomy	Description/Comments
2006	Ekman Dredge (sampling area of 0.023 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates approx. 10 m apart
2007	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3	5 [1]	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates approx. 10 m apart
2008	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3-7	5	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates min. of 20 m apart
2009	-	-	-	-	-	-
2010	-	-	-	-	-	-
2011	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3	1, 3, 1 [2]	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates min. of 20 m apart

[1] excepting Mary Lake where only 1 sub-sample/replicate was collected

[2] sampling occurred at one site in Sheardown Lake NW only

Table 3-2. Summary of benthic invertebrate sampling methods for Mine Area streams (2005-2011).

Year	Equipment	Mesh Size (µm)	Replicate Stations per Site or Habitat Type	Sub-samples per Replicate Station	Taxonomy	Description/Comments
2005	Surber sampler (sampling area of 0.097 m^2)	250	1	5	Genus level by qualified taxonomist (ZEAS Inc.)	-
2006	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2007	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2008	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2009	-	-	-	-	-	-
2010	-	-	-	-	-	-
2011	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths

Table 3-3. Summary of benthic macroinvertebrate sampling periods in Mine Area lakes and streams (2005-2011).

Waterbody	Sampling Period						
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Lakes							
Mary Lake	-	Aug. 31-Sept.5	Aug. 31-Sept. 20	-	-	-	-
Camp Lake	-	-	Aug. 31-Sept. 20	-	-	-	-
Sheardown Lake NW	-	-	Aug. 31-Sept. 20	Sept. 8-12	-	-	Sept. 3
Sheardown Lake SE	-	-	Aug. 31-Sept. 20	-	-	-	-
Streams							
Mary River	Aug. 6-17	Aug. 23-Sept. 1	Aug. 31-Sept. 5	-	-	-	Aug. 28-29
Tom River	-	Aug. 23-Sept. 1	Aug. 31-Sept. 5	-	-	-	-
Camp Lake Tributaries	Aug. 6-17	-	Aug. 31-Sept. 5	-	-	-	-
Sheardown Lake Tributaries	Aug. 6-17	-	Aug. 31-Sept. 5	Sept. 10-11	-	-	Sept. 4

Table 3-4. Locations of benthic macroinvertebrate lake sampling sites in the Mine Area (2006-2011).

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Camp Lake	JLO-10-B1	4	17W	556085	7913755	2-Sep-07
	JLO-10-B2	4	17W	556085	7913753	2-Sep-07
	JLO-10-B3	4	17W	556087	7913757	2-Sep-07
	JLO-01-B1	14	17W	557099	7914360	1-Sep-07
	JLO-01-B2	14	17W	557105	7914375	1-Sep-07
	JLO-01-B3	14	17W	557104	7914374	1-Sep-07
	JLO-02-B1	14	17W	557617	7914749	31-Aug-07
	JLO-02-B2	14	17W	557621	7914750	31-Aug-07
	JLO-02-B3	14	17W	557624	7914747	31-Aug-07
	JLO-07-B1	14	17W	556705	7914182	2-Sep-07
	JLO-07-B2	14	17W	556715	7914157	2-Sep-07
	JLO-07-B3	14	17W	556719	7914170	2-Sep-07
	JLO-09-B1	14	17W	556332	7913948	2-Sep-07
	JLO-09-B2	14	17W	556342	7913946	2-Sep-07
	JLO-09-B3	14	17W	556324	7913946	2-Sep-07
Sheardown Lake NW	SDL-Hab4-Stn1	4	17W	560401	7912573	8-Sep-08
	SDL-Hab4-Stn2	4	17W	560503	7912526	8-Sep-08
	SDL-Hab4-Stn3	4	17W	560605	7912654	8-Sep-08
	SDL-Hab4-Stn4	4	17W	560582	7912730	8-Sep-08
	SDL-Hab4-Stn5	4	17W	560561	7912801	8-Sep-08
	DD-Hab4-Stn-1	4	17W	560420	7913355	12-Sep-08
	DD-Hab4-Stn-2	4	17W	560374	7913391	12-Sep-08
	DD-Hab4-Stn-3	4	17W	560351	7913426	12-Sep-08
	DD-Hab9-Stn-1	9	17W	560259	7913455	12-Sep-08
	DD-Hab9-Stn-2	9	17W	560323	7913402	12-Sep-08
	DD-Hab9-Stn-3	9	17W	560354	7913358	12-Sep-08
	DLO-01-3-B1	9	17W	560466	7912837	15-Sep-07
	DLO-01-3-B2	9	17W	560485	7912833	15-Sep-07
	DLO-01-3-B3	9	17W	560496	7912815	15-Sep-07
	DLO-01-3-B1	9	17W	560474	7912833	12-Sep-08
	DLO-01-4-B1	9	17W	560690	7913045	7-Sep-07
	DLO-01-4-B2	9	17W	560678	7913055	7-Sep-07
	DLO-01-4-B3	9	17W	560683	7913060	7-Sep-07
	DLO-01-4-B1	9	17W	560695	7913043	9-Sep-08
	DLO-01-4-B2	9	17W	560775	7913069	9-Sep-08
	DLO-01-6-B1	9	17W	559705	7913525	14-Sep-07
	DLO-01-6-B2	9	17W	559721	7913526	14-Sep-07
	DLO-01-6-B3	9	17W	559705	7913506	14-Sep-07

Table 3-4. - continued -

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Sheardown Lake NW continued	DLO-01-6-B1	9	17W	559685	7913509	11-Sep-08
	DLO-01-6-B2	9	17W	559680	7913564	11-Sep-08
	DLO-01-7-B1	9	17W	560520	7912616	7-Sep-07
	DLO-01-7-B2	9	17W	560509	7912603	7-Sep-07
	DLO-01-7-B3	9	17W	560481	7912619	7-Sep-07
	DLO-01-7-B1	9	17W	560525	7912609	9-Sep-08
	DLO-01-7-B2	9	17W	560572	7912619	9-Sep-08
	DLO-01-2-B1	14	17W	560337	7912913	15-Sep-07
	DLO-01-2-B2	14	17W	560342	7912915	15-Sep-07
	DLO-01-2-B3	14	17W	560357	7912917	15-Sep-07
	DLO-01-2-B1	14	17W	560353	7912924	12-Sep-08
	DLO-01-2-B2	14	17W	560326	7912854	12-Sep-08
	DLO-01-5-B1	14	17W	559775	7913350	15-Sep-07
	DLO-01-5-B2	14	17W	559788	7913335	15-Sep-07
	DLO-01-5-B3	14	17W	559800	7913340	15-Sep-07
	DLO-01-5-B1	14	17W	559798	7913356	9-Sep-08
	DLO-01-5-B1	14	17W	559800	7913325	3-Sep-11
	DLO-01-5-B2	14	17W	559867	7913325	3-Sep-11
	DLO-01-5-B3	14	17W	559847	7913310	3-Sep-11
Sheardown Lake SE	DLO-02-3-B1	4	17W	560950	7911919	4-Sep-07
	DLO-02-3-B2	4	17W	560947	7911926	4-Sep-07
	DLO-02-3-B3	4	17W	560958	7911925	4-Sep-07
	DLO-02-4-B1	10	17W	561127	7911708	4-Sep-07
	DLO-02-4-B2	10	17W	561133	7911717	4-Sep-07
	DLO-02-4-B3	10	17W	561145	7911699	4-Sep-07
	DLO-02-1-B1	14	17W	560816	7912124	6-Sep-07
	DLO-02-1-B2	14	17W	560824	7912125	6-Sep-07
	DLO-02-1-B3	14	17W	560818	7912111	6-Sep-07
	DLO-02-2-B1	14	17W	561161	7911866	6-Sep-07
	DLO-02-2-B2	14	17W	561170	7911872	6-Sep-07
	DLO-02-2-B3	14	17W	561164	7911864	6-Sep-07
Mary Lake	BLO-01 -B1	9	17W	554695	7913212	19-Sep-07
	BLO-01 -B2	9	17W	554695	7913212	19-Sep-07
	BLO-01 -B3	9	17W	554695	7913212	19-Sep-07
	BLO-05-B1	9	17W	554780	7906047	20-Sep-07
	BLO-05-B2	9	17W	554769	7906066	20-Sep-07
	BLO-05-B3	9	17W	554785	7906078	20-Sep-07
	BLO-06-B1	9	17W	555912	7903757	20-Sep-07
	BLO-06-B2	9	17W	555913	7903734	20-Sep-07

Table 3-4. - continued -

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Mary Lake	BLO-06-B3	9	17W	555890	7903721	20-Sep-07
	BLO-01 -B1	14	17W	554695	7913212	31-Aug-06
	BLO-01-B2	14	17W	554695	7913212	31-Aug-06
	BLO-01- B3	14	17W	554695	7913212	31-Aug-06
	BLO-05-B1	14	17W	554771	7906033	31-Aug-06
	BLO-05-B2	14	17W	554771	7906033	31-Aug-06
	BLO-05-B3	14	17W	554771	7906033	31-Aug-06
	BLO-03-B1	14	17W	552387	7906645	20-Sep-07
	BLO-03-B2	14	17W	552360	7906630	20-Sep-07
	BLO-03-B3	14	17W	552356	7906635	20-Sep-07
	BLO-04-B1	14	17W	553799	7904897	20-Sep-07
	BLO-04-B3	14	17W	553824	7904871	20-Sep-07

Table 3-5. Locations of benthic macroinvertebrate stream sampling sites in the Mine Area (2005-2011).

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Mary River	AO-01	17W	559019	7900094	1-Aug-05
	CO-01	17W	556305	7906894	1-Aug-05
	DO-01	17W	560765	7911692	1-Aug-05
	DO-01	17W	560765	7911692	28-Aug-11
	EO-01a (E2-01)	17W	562348	7911310	1-Aug-05
	EO-01a (E0-03)	17W	562974	7912472	1-Aug-05
	HO-01	17W	571409	7917611	1-Aug-05
	AO-01 B1	17W	559034	7900064	5-Sep-07
	AO-01 B2	17W	558997	7900112	5-Sep-07
	AO-01 B3	17W	558994	7900151	5-Sep-07
	CO-01 B1	17W	556291	7906919	3-Sep-07
	CO-01 B2	17W	-	-	3-Sep-07
	CO-01 B3	17W	556323	7906925	3-Sep-07
	CO-05 B1	17W	558364	7909231	3-Sep-07
	CO-05 B2	17W	558389	7909248	3-Sep-07
	CO-05 B3	17W	558411	7909298	3-Sep-07
	CO-05 B1	17W	-	-	28-Aug-11
	CO-05 B2	17W	558352	7909170	28-Aug-11
	CO-05 B3	17W	-	-	28-Aug-11
	CO-10 B1	17W	560490	7911370	30-Aug-06
	CO-10 B2	17W	560490	7911370	30-Aug-06
	CO-10 B3	17W	560490	7911370	30-Aug-06
	CO-10 B1	17W	560616	7911666	4-Sep-07
	CO-10 B2	17W	560661	7911687	4-Sep-07
	CO-10 B3	17W	560708	7911701	4-Sep-07
	EO-20 B1	17W	561688	7911724	29-Aug-11
	EO-20 B2	17W	561680	7911258	29-Aug-11
	EO-20 B3	17W	561649	7911241	29-Aug-11
	EO-01 B1	17W	560926	7911488	4-Sep-07
	EO-01 B2	17W	560940	7911429	4-Sep-07
	EO-01 B3	17W	560906	7911533	4-Sep-07
	GO-03 B1	17W	567194	7912596	5-Sep-07
	GO-03 B2	17W	567220	7912598	5-Sep-07
	GO-03 B3	17W	567247	7912602	5-Sep-07
	GO-09 B1	17W	571665	7916111	1-Sep-06
	GO-09 B2	17W	571665	7916111	1-Sep-06

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Mary River	GO-09 B3	17W	571665	7916111	1-Sep-06
	GO-09 B1	17W	571572	7916367	5-Sep-07
	GO-09 B2	17W	571577	7916330	5-Sep-07
	GO-09 B3	17W	571566	7916302	5-Sep-07
Tom River	IO-01 B1	17W	555441	7914175	25-Aug-06
	IO-01 B2	17W	555441	7914175	25-Aug-06
	IO-01 B3	17W	555441	7914175	25-Aug-06
	IO-01 B1	17W	555407	7914291	5-Sep-07
	IO-01 B2	17W	555449	7914160	5-Sep-07
	IO-01 B3	17W	555496	7914154	5-Sep-07
	IO-04 B1	17W	557136	7918889	23-Aug-06
	IO-04 B2	17W	557136	7918889	23-Aug-06
	IO-04 B3	17W	557136	7918889	23-Aug-06
	IO-04 B1	17W	557132	7918928	5-Sep-07
	IO-04 B2	17W	557153	7918972	5-Sep-07
	IO-04 B3	17W	557155	7918994	5-Sep-07
Camp Lake Tributaries	FS-01 (Trib.1, Reach 1)	17W	558264	7914877	Aug-05
	KO-01 (Trib.2, Reach 2)	17W	557390	7915030	Aug-05
	JO-01 (lake outlet stream)	17W	555701	7913773	Aug-05
	CLT-1 DS B1	17W	557641	7914880	2-Sep-07
	CLT-1 DS B2	17W	557648	7914888	2-Sep-07
	CLT-1 DS B3	17W	557653	7914898	2-Sep-07
	CLT-1 US B1	17W	558515	7915032	4-Sep-07
	CLT-1 US B2	17W	558509	7915020	4-Sep-07
	CLT-1 US B3	17W	558497	7914999	4-Sep-07
	L1-09	17W	558407	7914890	1-Sep-11
	L1-09	17W	558393	7914889	1-Sep-11
	L1-09	17W	558407	7914882	1-Sep-11
	L1-08	17W	558513	7914893	1-Sep-11
	L1-08	17W	558507	7914907	1-Sep-11
	L1-08	17W	558494	7914919	1-Sep-11
	L2-03	17W	558593	7914797	1-Sep-11
	L2-03	17W	558605	7914784	1-Sep-11
	L2-03	17W	554641	7914753	1-Sep-11
	CLT-2 DS B1	17W	557466	7914969	2-Sep-07
	CLT-2 DS B2	17W	557465	7914977	2-Sep-07
	CLT-2 DS B3	17W	557449	7914956	2-Sep-07

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Camp Lake Tributaries	CLT-2 US B1	17W	557448	7915324	2-Sep-07
	CLT-2 US B2	17W	557450	7915287	2-Sep-07
	CLT-2 US B3	17W	557464	7915251	2-Sep-07
Sheardown Lake Tributary 1	SDLT-1 Reach 2a	17W	560753	7913507	Aug-05
	SDLT-1 Reach 1 B1	17W	560320	7913504	10-Sep-08
	SDLT-1 Reach 1 B2	17W	560337	7913512	10-Sep-08
	SDLT-1 Reach 1 B3	17W	560346	7913525	10-Sep-08
	SDLT-1 DS Reach 2 B1	17W	560710	7913504	31-Aug-07
	SDLT-1 DS Reach 2 B2	17W	560716	7913506	31-Aug-07
	SDLT-1 DS Reach 2 B3	17W	560722	7913504	31-Aug-07
	SDLT-1 Reach 2 B1	17W	560739	7913502	10-Sep-08
	SDLT-1 Reach 2 B2	17W	560756	7913502	10-Sep-08
	SDLT-1 Reach 2 B3	17W	560774	7913598	10-Sep-08
	SDLT-1 US Reach 4 B1	17W	561503	7913541	31-Aug-07
	SDLT-1 US Reach 4 B2	17W	-	-	31-Aug-07
	SDLT-1 US Reach 4 B3	17W	561521	7913524	31-Aug-07
	SDLT-1 Reach 4 B1	17W	561490	7913533	11-Sep-08
	SDLT-1 Reach 4 B2	17W	561506	7913538	11-Sep-08
	SDLT-1 Reach 4 B3	17W	561511	7913536	11-Sep-08
	SDLT-1 Reach 4 B1	17W	561476	7913550	4-Sep-11
	SDLT-1 Reach 4 B2	17W	561483	7913546	4-Sep-11
	SDLT-1 Reach 4 B3	17W	561490	7913533	4-Sep-11
Sheardown Lake Tributary 9	SDLT-9 US B1	17W	561771	7911813	1-Sep-07
	SDLT-9 US B2	17W	561774	7911814	1-Sep-07
	SDLT-9 US B3	17W	561784	7911819	1-Sep-07
Sheardown Lake Tributary 12	SDLT-12 DS B1	17W	561000	7942973	1-Sep-07
	SDLT-12 DS B2	17W	561011	7912970	1-Sep-07
	SDLT-12 DS B3	17W	561027	7912966	1-Sep-07
	SDLT-12 US B1	17W	561091	7912833	1-Sep-07
	SDLT-12 US B2	17W	561092	7912848	1-Sep-07
	SDLT-12 US B3	17W	561097	7912837	1-Sep-07

Table 3-6. Benthic macroinvertebrate metrics considered for CREMP.

Effect Indicator	Metric	Unit
Abundance/Density	Total Macroinvertebrate Density	(individuals/m^2)
Composition	Chironomidae Proportion	(% of total density)
	Shannon's Equitability (evenness)	-
	Simpson's Diversity Index	-
Richness	Total Taxa Richness	genus-level
	Hill's Effective Richness	genus-level

Table 3-7. Classification of lacustrine habitats in the Mine Area.

Zone	Substrata Type/ Aquatic Macrophytes		Habitat Type
Shoreline Zone (≤ 2 m water depth)	Cobble/Boulder		**1**
	Gravel/Pebble		**2**
	Sand		**3**
	Fine Sand, Silt/Clay	Macrophytes Absent	**4**
		Macrophytes Present	**5**
Littoral/Euphotic Zone (> 2-12 m water depth)	Cobble/Boulder		**6**
	Gravel/Pebble		**7**
	Sand		**8**
	Fine Sand, Silt/Clay	Macrophytes Absent	**9**
		Macrophytes Present	**10**
Profundal Zone (> 12 m water depth)	Cobble/Boulder		**11**
	Gravel/Pebble		**12**
	Sand		**13**
	Fine Sand, Silt/Clay	Macrophytes Absent	**14**

Table 3-8. Summary statistics for total macroinvertebrate density: all Mine Area lakes by aquatic habitat type.

Metric	**Total Macroinvertebrate Density (individuals/m²)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	14	829	4270	4005	3658	18562	2649	2668	1588	5042
Median	0	507	1026	3957	2165	15235	1978	2670	1665	4674
SD	25.10	782.76	6137.08	2879.22	3428.83	11312.34	1496.51	2057.11	1233.42	1350.49
SE	14.49	276.75	3543.24	959.74	731.03	6531.18	432.01	620.24	356.06	551.34
Min	0	162	435	783	250	9287	730	609	102	3548
Max	43	2129	11348	8870	10470	31165	6226	7017	4652	6730
Sub-samples (20% precision)	75	22	52	13	22	9	8	15	15	2
95th Percentile	39.1	2022.8	10315.7	8243.5	10027.8	29572.2	5250.4	5917.0	3384.8	6700.0
COV (%)	173	94	144	72	94	61	57	77	78	27
Mean + 2 x SD	64.70	2394.87	16543.73	9763.27	10515.84	41187.00	5641.58	6782.20	4054.50	7743.01
2 x Mean	28.99	1658.70	8539.14	8009.66	7316.36	37124.64	5297.10	5335.96	3175.32	10084.06
Mean +50%	21.74	1244.03	6404.36	6007.25	5487.27	27843.48	3972.83	4001.97	2381.49	7563.05
Mean -50%	7.25	414.68	2134.79	2002.42	1829.09	9281.16	1324.28	1333.99	793.83	2521.02
Mean +25%	18.12	1036.69	5336.96	5006.04	4572.73	23202.90	3310.69	3334.98	1984.58	6302.54
Mean -25%	10.87	622.01	3202.18	3003.62	2743.64	13921.74	1986.41	2000.99	1190.75	3781.52
Mean +20%	17.39	995.22	5123.48	4805.80	4389.82	22274.78	3178.26	3201.58	1905.19	6050.44
Mean -20%	11.59	663.48	3415.66	3203.86	2926.54	14849.86	2118.84	2134.38	1270.13	4033.62
Data Normally Distributed	- [1]	Yes	- [1]	Yes	No	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-9. Summary statistics for total macroinvertebrate density: Sheardown Lake NW by aquatic habitat type and year.

Metric	Total Macroinvertebrate Density (individuals/m²)					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	829	6026	817	1577	149	3048
Median	507	5887	798	1665	158	2348
SD	782.76	2970.50	448.25	218.79	42.98	1392.69
SE	276.75	857.51	141.75	89.32	24.81	804.07
Min	162	2026	250	1226	102	2145
Max	2129	10470	1677	1783	186	4652
Sub-samples (20% precision)	22	6	8	0.5	2	5
95th Percentile	2022.8	10259.1	1516.9	1769.6	183.3	4421.7
COV (%)	94	49	55	14	29	46
Mean + 2 x SD	2394.87	11967.09	1713.20	2014.39	234.66	5833.68
2 x Mean	1658.70	12052.18	1633.40	3153.62	297.40	6096.62
Mean +50%	1244.03	9039.14	1225.05	2365.22	223.05	4572.46
Mean -50%	414.68	3013.05	408.35	788.41	74.35	1524.15
Mean +25%	1036.69	7532.61	1020.88	1971.01	185.88	3810.39
Mean -25%	622.01	4519.57	612.53	1182.61	111.53	2286.23
Mean +20%	995.22	7231.31	980.04	1892.17	178.44	3657.97
Mean -20%	663.48	4820.87	653.36	1261.45	118.96	2438.65
Data Normally Distributed	Yes	No		Yes		
Significant Inter-annual Difference	-	Yes [1]		Yes - all years [2]		

[1] p-value <0.0001 (Mann-Whitney U-test)

[2] p-value 2007 vs 2008 0.015; 2007 vs 2011 0.013; 2008 vs 2011 0.001 (ANOVA with Bonferroni pairwise comparison)

Table 3-10. Summary statistics for Chironomidae proportion: all Mine Area lakes by aquatic habitat type.

Metric	**Chironomidae Proportion (% of total density)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	7	66	55	90	83	73	95	96	94	97
Median	0	64	56	96	86	68	96	99	95	98
SD	11.55	18.28	41.93	10.47	9.05	13.05	4.32	4.54	2.55	2.85
SE	6.67	6.46	24.21	3.49	1.93	7.54	1.25	1.37	0.74	1.16
Min	0	40	13	70	67	62	88	89	88	92
Max	20	88	97	99	98	87	100	100	97	100
Sub-samples (20% precision)	75	2	14	0.3	0.3	1	0.1	0.1	0.02	0.02
95th Percentile	18.0	87.7	92.5	98.8	95.3	85.3	100.0	100.0	96.6	99.7
COV (%)	173	28	76	12	11	18	5	5	3	3
Mean + 2 x SD	29.76	102.33	138.95	111.05	101.48	98.66	103.57	105.52	99.28	102.71
2 x Mean	13.33	131.54	110.18	180.22	166.76	145.12	189.87	192.88	188.36	194.02
Mean +50%	10.00	98.66	82.64	135.17	125.07	108.84	142.40	144.66	141.27	145.52
Mean -50%	3.33	32.89	27.55	45.06	41.69	36.28	47.47	48.22	47.09	48.51
Mean +25%	8.33	82.21	68.86	112.64	104.23	90.70	118.67	120.55	117.73	121.26
Mean -25%	5.00	49.33	41.32	67.58	62.54	54.42	71.20	72.33	70.64	72.76
Mean +20%	8.00	78.92	66.11	108.13	100.06	87.07	113.92	115.73	113.02	116.41
Mean -20%	5.33	52.62	44.07	72.09	66.70	58.05	75.95	77.15	75.34	77.61
Data Normally Distributed	- [1]	Yes	- [1]	No	Yes	- [1]	Yes	No	Yes	Yes

[1] insufficient data points to determine

Table 3-11. Summary statistics for Chironomidae proportion: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Chironomidae Proportion (% of total density)**					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	66	83	84	95	93	93
Median	64	87	85	96	95	93
SD	18.28	10.67	7.17	1.58	4.08	1.91
SE	6.46	3.08	2.27	0.64	2.36	1.10
Min	40	67	75	92	88	91
Max	88	98	95	97	96	94
Sub-samples (20% precision)	2	0.4	0.2	0.01	0.05	0.01
95th Percentile	87.7	96.5	94.4	96.7	95.7	94.3
COV (%)	28	13	9	2	4	2
Mean + 2 x SD	102.33	104.34	98.19	98.58	101.33	96.55
2 x Mean	131.54	166.00	167.70	190.84	186.34	185.46
Mean +50%	98.66	124.50	125.78	143.13	139.76	139.10
Mean -50%	32.89	41.50	41.93	47.71	46.59	46.37
Mean +25%	82.21	103.75	104.81	119.28	116.46	115.91
Mean -25%	49.33	62.25	62.89	71.57	69.88	69.55
Mean +20%	78.92	99.60	100.62	114.50	111.80	111.28
Mean -20%	52.62	66.40	67.08	76.34	74.54	74.18
Data Normally Distributed	Yes	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.833 (t-test)

[2] p-value 2007 vs 2008 0.224; 2007 vs 2011 0.152; 2008 vs 2011 0.828 (ANOVA with Bonferroni pairwise comparison)

Table 3-12. Summary statistics for Shannon's Equitability: all Mine Area lakes by aquatic habitat type.

Metric	**Shannon's Equitability (evenness)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	0.72	0.65	0.67	0.70	0.72	0.65	0.56	0.52	0.40	0.59
Median	-	0.64	0.61	0.76	0.74	0.69	0.57	0.56	0.41	0.59
SD	-	0.10	0.16	0.16	0.08	0.09	0.13	0.21	0.11	0.09
SE	-	0.03	0.09	0.05	0.02	0.05	0.04	0.06	0.03	0.04
Min	-	0.49	0.56	0.37	0.56	0.54	0.33	0.00	0.23	0.46
Max	-	0.79	0.86	0.86	0.84	0.71	0.82	0.81	0.57	0.68
Sub-samples (20% precision)	-	1	1	1	0.3	0	1	4	2	1
95th Percentile	0.72	0.77	0.83	0.84	0.83	0.71	0.75	0.73	0.56	0.68
COV (%)	0	15	24	22	11	14	24	40	28	15
Mean + 2 x SD	0.72	0.84	1.00	1.01	0.87	0.82	0.83	0.94	0.63	0.76
2 x Mean	1.44	1.29	1.35	1.39	1.43	1.29	1.12	1.04	0.81	1.17
Mean +50%	1.08	0.97	1.01	1.04	1.07	0.97	0.84	0.78	0.61	0.88
Mean -50%	0.36	0.32	0.34	0.35	0.36	0.32	0.28	0.26	0.20	0.29
Mean +25%	0.90	0.81	0.84	0.87	0.89	0.81	0.70	0.65	0.50	0.73
Mean -25%	0.54	0.48	0.51	0.52	0.54	0.48	0.42	0.39	0.30	0.44
Mean +20%	0.86	0.77	0.81	0.84	0.86	0.78	0.67	0.62	0.48	0.70
Mean -20%	0.58	0.52	0.54	0.56	0.57	0.52	0.45	0.42	0.32	0.47
Data Normally Distributed	- [1]	Yes	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-13. Summary statistics for Simpson's Diversity Index: all Mine Area lakes by aquatic habitat type.

Metric	Simpson's Diversity Index									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	0.33	0.73	0.73	0.67	0.76	0.71	0.60	0.50	0.37	0.61
Median	-	0.72	0.67	0.73	0.79	0.77	0.61	0.58	0.37	0.65
SD	-	0.09	0.12	0.12	0.08	0.12	0.12	0.23	0.14	0.15
SE	-	0.03	0.07	0.04	0.02	0.07	0.03	0.07	0.04	0.06
Min	-	0.57	0.66	0.43	0.56	0.57	0.39	0.00	0.15	0.35
Max	-	0.83	0.87	0.77	0.86	0.78	0.76	0.69	0.58	0.75
Sub-samples (20% precision)	-	0.4	1	1	0.3	1	1	5	4	1
95th Percentile	0.33	0.83	0.85	0.77	0.86	0.78	0.76	0.68	0.56	0.74
COV (%)	0	13	16	17	10	17	19	46	39	24
Mean + 2 x SD	0.33	0.91	0.97	0.90	0.92	0.95	0.83	0.96	0.65	0.90
2 x Mean	0.66	1.46	1.47	1.34	1.53	1.42	1.20	1.00	0.73	1.22
Mean +50%	0.50	1.09	1.10	1.01	1.15	1.06	0.90	0.75	0.55	0.91
Mean -50%	0.17	0.36	0.37	0.34	0.38	0.35	0.30	0.25	0.18	0.30
Mean +25%	0.41	0.91	0.92	0.84	0.96	0.89	0.75	0.63	0.46	0.76
Mean -25%	0.25	0.55	0.55	0.50	0.57	0.53	0.45	0.38	0.27	0.46
Mean +20%	0.40	0.88	0.88	0.80	0.92	0.85	0.72	0.60	0.44	0.73
Mean -20%	0.26	0.58	0.59	0.54	0.61	0.57	0.48	0.40	0.29	0.49
Data Normally Distributed	-[1]	Yes	-[1]	Yes	No	-[1]	Yes	No	Yes	Yes

[1] insufficient data points to determine

Table 3-14. Summary statistics for Shannon's Equitability: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Shannon's Equitability (evenness)**							
Habitat Type	**4**		**9**			**14**		
Year	**2008**		**2007**	**2008**		**2007**	**2008**	**2011**
n (rep. stn.)	8		12	10		6	3	3
Mean	0.65		0.73	0.70		0.36	0.52	0.39
Median	0.64		0.75	0.72		0.39	0.56	0.33
SD	0.10		0.08	0.08		0.10	0.08	0.13
SE	0.03		0.02	0.03		0.04	0.05	0.07
Min	0.49		0.57	0.56		0.23	0.42	0.30
Max	0.79		0.84	0.83		0.45	0.57	0.54
Sub-samples (20% precision)	1		0.3	0.3		2	1	3
95th Percentile	0.77		0.81	0.81		0.45	0.57	0.51
COV (%)	15		10	12		27	16	33
Mean + 2 x SD	0.84		0.88	0.86		0.55	0.68	0.64
2 x Mean	1.29		1.46	1.40		0.71	1.03	0.78
Mean +50%	0.97		1.09	1.05		0.53	0.77	0.58
Mean -50%	0.32		0.36	0.35		0.18	0.26	0.19
Mean +25%	0.81		0.91	0.88		0.44	0.65	0.49
Mean -25%	0.48		0.55	0.53		0.27	0.39	0.29
Mean +20%	0.77		0.87	0.84		0.43	0.62	0.47
Mean -20%	0.52		0.58	0.56		0.28	0.41	0.31
Data Normally Distributed	Yes		Yes			Yes		
Significant Inter-annual Difference	-		No [1]			No - all years [2]		

[1] p-value 0.416 (t-test)

[2] p-value 2007 vs 2008 0.051; 2007 vs 2011 0.659; 2008 vs 2011 0.155 (ANOVA with Bonferroni pairwise comparison)

Table 3-15. Summary statistics for Simpson's Diversity Index: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Simpson's Diversity Index**							
Habitat Type	**4**		**9**			**14**		
Year	**2008**		**2007**	**2008**		**2007**	**2008**	**2011**
n (rep. stn.)	8		12	10		6	3	3
Mean	0.73		0.77	0.76		0.32	0.49	0.32
Median	0.72		0.79	0.78		0.35	0.55	0.24
SD	0.09		0.07	0.09		0.13	0.12	0.15
SE	0.03		0.02	0.03		0.05	0.07	0.09
Min	0.57		0.59	0.56		0.15	0.36	0.22
Max	0.83		0.86	0.86		0.47	0.58	0.49
Sub-samples (20% precision)	0.4		0.2	0.3		4	1	5
95th Percentile	0.83		0.85	0.85		0.46	0.57	0.47
COV (%)	13		10	12		41	24	47
Mean + 2 x SD	0.91		0.92	0.94		0.59	0.73	0.62
2 x Mean	1.46		1.54	1.52		0.65	0.99	0.64
Mean +50%	1.09		1.15	1.14		0.49	0.74	0.48
Mean -50%	0.36		0.38	0.38		0.16	0.25	0.16
Mean +25%	0.91		0.96	0.95		0.40	0.62	0.40
Mean -25%	0.55		0.58	0.57		0.24	0.37	0.24
Mean +20%	0.88		0.92	0.91		0.39	0.59	0.38
Mean -20%	0.58		0.61	0.61		0.26	0.40	0.25
Data Normally Distributed	Yes		No			Yes		
Significant Inter-annual Difference	-		No [1]			No - all years [2]		

[1] p-value 0.974 (Mann-Whitney U-test)

[2] p-value 2007 vs 2008 0.103; 2007 vs 2011 0.961; 2008 vs 2011 0.140 (ANOVA with Bonferroni pairwise comparison)

Table 3-16. Summary statistics for total taxa richness: all Mine Area lakes by aquatic habitat type.

Metric	**Total Taxa Richness (genus-level)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	1	15	15	8	13	13	9	9	7	9
Median	0	16	15	8	14	13	9	8	8	10
SD	1.15	1.04	1.53	1.42	2.72	1.53	2.76	5.66	1.62	2.83
SE	0.67	0.37	0.88	0.47	0.58	0.88	0.80	1.71	0.47	1.15
Min	0	13	14	5	8	12	6	1	4	4
Max	2	16	17	10	20	15	14	18	9	12
Sub-samples (20% precision)	75	0.1	0.2	1	1	0.3	2	10	1	2
95th Percentile	1.8	16.0	16.8	9.2	16.0	14.8	13.5	16.5	9.0	11.8
COV (%)	173	7	10	19	20	11	31	64	22	31
Mean + 2 x SD	2.98	17.32	18.39	10.40	18.85	16.39	14.53	20.24	10.66	14.66
2 x Mean	1.33	30.50	30.67	15.11	26.82	26.67	18.00	17.82	14.83	18.00
Mean +50%	1.00	22.88	23.00	28.50	20.11	20.00	13.50	13.36	11.13	13.50
Mean -50%	0.33	7.63	7.67	9.50	6.70	6.67	4.50	4.45	3.71	4.50
Mean +25%	0.83	19.06	19.17	23.75	16.76	16.67	11.25	11.14	9.27	11.25
Mean -25%	0.50	11.44	11.50	14.25	10.06	10.00	6.75	6.68	5.56	6.75
Mean +20%	0.80	18.30	18.40	22.80	16.09	16.00	10.80	10.69	8.90	10.80
Mean -20%	0.53	12.20	12.27	15.20	10.73	10.67	7.20	7.13	5.93	7.20
Data Normally Distributed	- [1]	No	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-17. Summary statistics for Hill's effective richness: all Mine Area lakes by aquatic habitat type.

Metric	Hill's Effective Richness (genus-level)									
Habitat Type	4			9		10	14			
Lake	Camp	SDL NW	SDL SE	Mary	SDL NW	SDL SE	Camp	Mary	SDL NW	SDL SE
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	2	6	7	4	6	5	4	3	2	4
Median	-	6	5	5	6	6	3	4	2	4
SD	-	1.63	3.06	1.05	1.47	1.23	1.24	1.31	0.66	1.15
SE	-	0.58	1.77	0.35	0.31	0.71	0.36	0.40	0.19	0.47
Min	-	4	5	2	4	4	2	1	1	2
Max	-	8	10	5	9	6	6	5	3	5
Sub-samples (20% precision)	-	2	5	2	1	1	3	4	2	2
95th Percentile	1.6	8.1	9.7	5.3	8.7	6.4	5.5	4.9	3.3	5.0
COV (%)	0	27	46	26	23	23	35	39	28	31
Mean + 2 x SD	1.65	9.25	12.78	6.21	9.40	7.89	6.03	5.96	3.65	6.01
2 x Mean	3.30	11.98	13.33	8.22	12.94	10.85	7.11	6.68	4.68	7.43
Mean +50%	2.47	8.98	10.00	6.17	9.70	8.14	5.33	5.01	3.51	5.57
Mean -50%	0.82	2.99	3.33	2.06	3.23	2.71	1.78	1.67	1.17	1.86
Mean +25%	2.06	7.49	8.33	5.14	8.09	6.78	4.44	4.18	2.92	4.65
Mean -25%	1.24	4.49	5.00	3.08	4.85	4.07	2.67	2.51	1.75	2.79
Mean +20%	1.98	7.19	8.00	4.93	7.76	6.51	4.27	4.01	2.81	4.46
Mean -20%	1.32	4.79	5.33	3.29	5.18	4.34	2.84	2.67	1.87	2.97
Data Normally Distributed	- [1]	Yes	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-18. Summary statistics for total taxa richness: Sheardown Lake NW by aquatic habitat type and year.

Metric	Total Taxa Richness (genus-level)							
Habitat Type	**4**		**9**			**14**		
Year	**2008**		**2007**	**2008**		**2007**	**2008**	**2011**
n (rep. stn.)	8		12	10		6	3	3
Mean	15		12	15		8	8	7
Median	16		13	15		9	8	6
SD	1.04		2.35	2.67		2.07	0.58	1.73
SE	0.37		0.68	0.84		0.85	0.33	1.00
Min	13		8	11		4	7	6
Max	16		15	20		9	8	9
Sub-samples (20% precision)	0.1		1	1		2	0.1	2
95th Percentile	16.0		15.0	18.2		9.0	8.0	8.7
COV (%)	7		19	18		28	8	25
Mean + 2 x SD	17.32		17.03	20.04		11.65	8.82	10.46
2 x Mean	30.50		24.67	29.40		15.00	15.33	14.00
Mean +50%	22.88		18.50	22.05		11.25	11.50	10.50
Mean -50%	7.63		6.17	7.35		3.75	3.83	3.50
Mean +25%	19.06		15.42	18.38		9.38	9.58	8.75
Mean -25%	11.44		9.25	11.03		5.63	5.75	5.25
Mean +20%	18.30		14.80	17.64		9.00	9.20	8.40
Mean -20%	12.20		9.87	11.76		6.00	6.13	5.60
Data Normally Distributed	No		Yes			Yes		
Significant Inter-annual Difference	-		Yes [1]			No - all years [2]		

[1] p-value 0.039 (t-test)

[2] p-value 2007 vs 2008 0.897; 2007 vs 2011 0.699; 2008 vs 2011 0.655 (ANOVA with Bonferroni pairwise comparison)

Table 3-19. Summary statistics for Hill's effective richness: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Hill's Effective Richness (genus-level)**							
Habitat Type	**4**		**9**			**14**		
Year	**2008**		**2007**	**2008**		**2007**	**2008**	**2011**
n (rep. stn.)	8		12	10		6	3	3
Mean	6		6	7		2	3	2
Median	6		6	7		2	3	2
SD	1.63		1.38	1.60		0.51	0.56	0.86
SE	0.58		0.40	0.51		0.21	0.32	0.49
Min	4		4	4		1	2	2
Max	8		9	9		3	3	3
Sub-samples (20% precision)	2		1	1		1	1	4
95th Percentile	8.1		8.5	9.1		2.6	3.3	3.1
COV (%)	27		22	24		24	19	38
Mean + 2 x SD	9.25		9.05	9.90		3.11	4.03	3.97
2 x Mean	11.98		12.56	13.39		4.19	5.82	4.50
Mean +50%	8.98		9.42	10.04		3.15	4.37	3.38
Mean -50%	2.99		3.14	3.35		1.05	1.46	1.13
Mean +25%	7.49		7.85	8.37		2.62	3.64	2.81
Mean -25%	4.49		4.71	5.02		1.57	2.18	1.69
Mean +20%	7.19		7.54	8.04		2.52	3.49	2.70
Mean -20%	4.79		5.02	5.36		1.68	2.33	1.80
Data Normally Distributed	No		Yes			Yes		
Significant Inter-annual Difference	-		No [1]			No - all years [2]		

[1] p-value 0.520 (t-test)

[2] p-value 2007 vs 2008 0.094; 2007 vs 2011 0.729; 2008 vs 2011 0.222 (ANOVA with Bonferroni pairwise comparison)

Table 3-20. Critical effects sizes for select benthic macroinvertebrate community metrics from Sheardown Lake NW.

Metric	Habitat Type 4 (2008; n = 8)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	1244.03	414.68	1036.69	622.01	995.22	663.48
Chironomidae proportion	98.66	32.89	82.21	49.33	78.92	52.62
Shannon's Equitability	0.97	0.32	0.81	0.48	0.77	0.52
Simpson's Diversity Index	1.09	0.36	0.91	0.55	0.88	0.58
Total taxa richness	22.88	7.63	19.06	11.44	18.30	12.20

Metric	Habitat 9 (2007 and 2008; n = 22)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	5487.27	1829.09	4572.73	2743.64	4389.82	2926.54
Chironomidae proportion	125.07	41.69	104.23	62.54	100.06	66.70
Shannon's Equitability	1.07	0.36	0.89	0.54	0.86	0.57
Simpson's Diversity Index	1.15	0.38	0.96	0.57	0.92	0.61
Total taxa richness	20.11	6.70	16.76	10.06	16.09	10.73

Metric	Habitat Type 14 (2007, 2008, 2011; n = 12)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	2381.49	793.83	1984.58	1190.75	1905.19	1270.13
Chironomidae proportion	141.27	47.09	117.73	70.64	113.02	75.34
Shannon's Equitability	0.61	0.20	0.50	0.30	0.48	0.32
Simpson's Diversity Index	0.55	0.18	0.46	0.27	0.44	0.29
Total taxa richness	11.13	3.71	9.27	5.56	8.90	5.93

Table 3-21. Power of existing benthic macroinvertebrate data to detect pre-defined levels of change.

Metric	Habitat Type 4 (2008; n = 8)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.247	0.148	0.123
Chironomidae proportion	0.957	0.536	0.402
Shannon's Equitability	1.000	0.935	0.813
Simpson's Diversity Index	1.000	0.982	0.938
Total taxa richness	1.000	1.000	1.000

Metric	Habitat 9 (2007 and 2008; n = 22)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.807	0.387	0.282
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	1.000	0.999
Simpson's Diversity Index	1.000	1.000	1.000
Total taxa richness	1.000	0.992	0.943

Metric	Habitat Type 14 (2007, 2008, 2011; n = 12)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.441	0.170	0.154
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	0.990	0.681	0.495
Simpson's Diversity Index	0.892	0.446	0.317
Total taxa richness	1.000	0.866	0.712

Table 3-22. Sample sizes (i.e., number of replicate stations) required for detecting pre-defined levels of change.

Metric	**Habitat Type 4**		
	Mean +/-50%	**Mean +/-25%**	**Mean +/-20%**
Total macroinvertebrate density	64	>180	>>180
Chironomidae proportion	6	22	37
Shannon's Equitability	3	7	10
Simpson's Diversity Index	3	5	7
Total taxa richness	<<3	<3	3

Metric	**Habitat 9**		
	Mean +/-50%	**Mean +/-25%**	**Mean +/-20%**
Total macroinvertebrate density	31	>60	>>60
Chironomidae proportion	2	4	6
Shannon's Equitability	2	4	6
Simpson's Diversity Index	<5	5	6
Total taxa richness	4	12	18

Metric	**Habitat Type 14**		
	Mean +/-50%	**Mean +/-25%**	**Mean +/-20%**
Total macroinvertebrate density	43	167	>180
Chironomidae proportion	1	1	1
Shannon's Equitability	7	22	37
Simpson's Diversity Index	12	45	70
Total taxa richness	4	13	21

Table 4-1. Summary of baseline electrofishing and gillnetting Arctic Char data collections in selected Mine Area waterbodies, 2006-2008.

Waterbody	Year	Season	Gear Type[1]	Sampling Effort[2]	Catch
Camp Lake	2006	Summer	Gill Net	2	21
	2007	Winter	Gill Net	2	3
		Summer	Gill Net	20	94
			Electrofishing	1	8
	2008	Fall	Gill Net	14	22
Camp Lake Tributary 1	2006	Summer	Electrofishing	3	8
	2007	Summer	Electrofishing	3	196
		Fall	Electrofishing	3	211
Sheardown Lake NW	2006	Summer	Gill Net	1	17
	2007	Winter	Gill Net	2	5
		Summer	Gill Net	12	92
			Electrofishing	5	220
	2008	Spring	Electrofishing	10	36
		Fall	Gill Net	4	5
Sheardown Lake SE	2007	Winter	Gill Net	2	7
		Summer	Gill Net	2	30
			Electrofishing	2	32
	2008	Spring	Electrofishing	4	4
		Fall	Gill Net	4	63

Table 4-1. Continued.

Waterbody	Year	Season	Gear Type[1]	Sampling Effort[2]	Catch
Sheardown Lake Tributary 1	2006	Summer	Electrofishing	1	5
	2007	Spring	Electrofishing	4	4
		Summer	Electrofishing	4	145
		Fall	Electrofishing	4	52
			Hoop Net	23	1240
	2008	Spring	Electrofishing	2	33
			Hoop Net[3]	18	849
		Summer	Electrofishing	2	55
		Fall	Electrofishing	2	13
			Hoop Net	17	469
Mary Lake – South	2006	Summer	Gill Net	2	62
			Electrofishing	1	
	2007	Summer	Gill Net	24	168
	2008	Spring	Electrofishing	7	2
Mary Lake – North	2007	Summer	Gill Net	8	98
	2008	Spring	Electrofishing	3	4

[1]Does not include minnow trap or angling data.

[2]Effort for gill nets described as the number of standard index gillnet gangs set in each lake; electrofishing effort is the number of 50-100 m sections of shoreline or stream sampled, and hoopnetting effort is the number of days traps were installed.

[3]Data include two hoop nets (one facing upstream and one downstream) that each fished for 18 days.

Table 4-2. Summary of fish metrics and statistical analysis methods recommended under EEM (EC 2012). Metrics indicated with an asterisk are endpoints used for determining effects under EEM, as designated by statistically significant differences between exposure and reference areas. Other endpoints may be used to support analyses.

Effect Indicators	Fish Effect Endpoint				
	Non-Lethal Survey	Statistical Test	Notes	Lethal Adult Survey	Statistical Test
Growth	*Length of YOY (age 0) at end of growth period	ANOVA		-	
	*Weight of YOY (age 0) at end of growth period	ANOVA		-	
	*Size of 1+ fish if possible	ANOVA			
	*Size-at-age (body weight at age) - if possible	ANCOVA		*Size-at-age (body weight at age)	ANCOVA
	Length-at-age	ANCOVA		Length-at-age	ANCOVA
	Body Weight	ANOVA			
	Length	ANOVA			
Reproduction	*Relative abundance of YOY (% composition of YOY)	Kolmorgorov-Smirnov test performed on length-frequency distributions with and without YOY included; OR proportions of YOY can be tested using a Chi-squared test.		-	
	OR relative age-class strength			*Gonad weight at body weight	ANCOVA
	-			Gonad weight at length	
	-			Fecundity	
Condition	*Condition Factor	ANCOVA		*Condition Factor	ANCOVA
	-			*Liver size at body weight	ANCOVA
	-			Liver weight at length	
	-			Egg weight at body weight and/or age (mature females only)	
Survival	*Length-frequency-distribution	2-sample Kolmorgorov-Smirnov test	Examine YOY alone and for both sizes combined	Length-frequency-distribution	2-sample Kolmorgorov-Smirnov test
	*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test		*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test
	YOY Survival			*Age	ANOVA

Table 4-3. Datasets analysed for Arctic Char metrics.

Waterbody	Year	Gear Type	Sex
Camp Lake	2006	Gill Net	M, F, Total
	2007	Gill Net	M, F, Total
	2008	Gill Net	M, F, Total
	All Years	Gill Net	M, F, Total
Sheardown Lake	2006	Gill Net	M, F, Total
	2007	Electrofishing	Total
		Gill Net	M, F, Total
	2008	Electrofishing	Total
		Gill Net	M, F, Total
	All Years	Electrofishing	Total
		Gill Net	M, F, Total
Mary Lake – South	2006	Gill Net	M, F, Total
	2007	Gill Net	M, F, Total
	All Years	Gill Net	M, F, Total
Mary Lake – North	2007	Gill Net	Total

Table 4-4. Summary statistics for fork lengths (mm) of Arctic Char captured in standard index gill nets deployed in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	10	21	3	3	99	9	2	22	23	15	134
Mean	335	224	282	291	329	305	465	394	401	380	267	332
Median	265	221	230	312	338	321	430	394	368	350	236	323
SD	195	39	151	38	45	117	137	100	117	171	80	114
SE	59	12	33	22	26	12	46	71	25	36	21	10
Minimum	170	175	170	247	280	40	342	323	236	170	175	170
Maximum	751	311	751	315	368	682	745	464	745	751	464	751
95th Percentile	699	286	647	315	365	542	680	457	582	735	397	578
COV (%)	58	18	54	13	14	38	29	25	29	45	30	34

Table 4-5. Summary statistics for fork lengths (mm) of Arctic Char captured during backpack electrofishing (EF) and index gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	14	252	12	15	116	39	27	8	68	291	45	25	198
Mean	313	385	346	76	367	353	372	83	402	383	387	77	381	365	375
Median	281	385	293	65	371	335	369	87	403	380	385	66	388	364	377
SD	142	142	137	29	59	69	82	28	37	18	38	29	70	63	76
SE	58	101	37	2	17	18	8	4	7	6	5	2	10	13	5
Minimum	180	284	180	33	278	240	178	26	360	364	276	26	180	240	178
Maximum	572	485	599	180	507	508	587	140	552	420	552	180	572	508	599
95th Percentile	519	475	581	139	449	497	541	127	441	410	431	138	495	491	531
COV (%)	45	37	39	38	16	20	22	34	9	5	10	37	18	17	20

Table 4-6. Summary statistics for fork lengths (mm) of Arctic Char captured in standard index gill nets deployed in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	386	370	384	383	375	383	385	372	384	379
Median	390	370	384	394	373	392	395	372	391	389
SD	132	116	133	74	43	71	114	102	92	41
SE	26	20	17	20	13	6	18	15	6	4
Minimum	165	181	165	266	266	197	165	181	165	198
Maximum	685	658	705	548	432	671	685	658	705	458
95th Percentile	594	586	648	485	424	457	573	552	559	432
COV (%)	34	31	35	19	12	18	30	27	24	11

Table 4-7. Comparison of Arctic Char length between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	0.58
	2007 GN Males	2007 GN Females	-	0.38
	2008 GN Males	2008 GN Females	-	0.37
	All Years Males	All Years Females	-	0.17
	2006 GN Males	2007 GN Males	2008 GN Males	0.11
	2006 GN Females	2007 GN Females	2008 GN Females	0.04
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.70
Sheardown Lake	2006 GN Males	2006 GN Females	-	0.11
	2007 GN Males	2007 GN Females	-	0.98
	2008 GN Males	2008 GN Females	-	0.47
	All Years GN Males	All Years GN Females	-	0.66
	2006 GN Males	2007 GN Males	2008 GN Males	0.91
	2006 GN Females	2007 GN Females	2008 GN Females	0.77
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.98
	2007 EF All Fish	2008 EF All Fish	-	0.76
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.79
	2007 GN Males	2007 GN Females	-	0.43
	All Years Males	All Years Females	-	0.72
	2006 GN Males	2007 GN Males	-	0.55
	2006 GN Females	2007 GN Females	-	0.60
	2006 GN All Fish	2007 GN All Fish	-	0.72

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-8. Inter-lake comparisons of fork lengths (mm) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	**Dataset 2**	**Dataset 3**	**Dataset 4**	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.74
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.94
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.52
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.94

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-9. Summary statistics for weights (g) of Arctic Char captured in standard index gill nets deployed in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	9	20	3	3	91	9	2	22	23	14	133
Mean	823	139	515	275	342	435	1450	625	876	997	252	520
Median	200	150	150	325	400	350	750	625	463	375	150	350
SD	1512	69	1152	109	146	509	1705	460	1181	1506	234	785
SE	456	23	258	63	85	53	568	325	252	314	62	68
Minimum	50	75	50	150	175	25	375	300	200	50	75	25
Maximum	4900	300	4900	350	450	3050	5600	950	5600	5600	950	5600
95th Percentile	3650	240	2525	348	445	1475	4320	918	2368	4650	625	1965
COV (%)	184	49	224	40	43	117	118	74	135	151	93	151

Table 4-10. Summary statistics for weights (g) of Arctic Char captured during backpack electrofishing (EF) and index gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	8	230	12	15	116	36	27	8	68	266	45	25	192
Mean	479	600	509	7	435	396	494	9	698	591	604	7	599	475	533
Median	200	600	225	4	400	350	425	8	675	575	538	4	525	425	500
SD	711	566	640	9	218	209	317	6	249	101	209	8	348	227	306
SE	290	400	226	1	63	54	29	1	48	36	25	1	52	45	22
Minimum	50	200	50	1	150	125	50	1	475	450	250	1	50	125	50
Maximum	1900	1000	1900	59	1000	950	1800	28	1750	725	1750	59	1900	1000	1900
95^{th} Percentile	1538	1900	1585	27	780	828	1119	20	948	716	850	26	998	915	1086
COV (%)	148	94	126	123	50	53	64	70	36	17	35	115	58	48	57

Table 4-11. Summary statistics for weights (g) of Arctic Char captured in standard index gill nets set in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	736	639	743	534	467	548	665	593	602	493
Median	600	525	600	513	475	525	575	450	525	500
SD	596	600	709	329	132	344	523	522	481	125
SE	117	104	90	88	38	27	83	78	32	13
Minimum	25	75	25	125	175	75	25	75	25	75
Maximum	2350	2450	3300	1425	700	3050	2350	2450	3300	850
95th Percentile	1825	2060	2348	1019	645	825	1630	1780	1590	679
COV (%)	81	94	95	62	28	63	79	88	80	25

Table 4-12. Comparison of Arctic Char weights between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at p < 0.05.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	**< 0.01**
	2007 GN Males	2007 GN Females	-	0.32
	2008 GN Males	2008 GN Females	-	**0.02**
	All Years Males	All Years Females	-	**0.01**
	2006 GN Males	2007 GN Males	2008 GN Males	**< 0.01**
	2006 GN Females	2007 GN Females	2008 GN Females	**< 0.01**
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.34
Sheardown Lake	2006 GN Males	2006 GN Females	-	0.55
	2007 GN Males	2007 GN Females	-	0.76
	2008 GN Males	2008 GN Females	-	0.29
	All Years GN Males	All Years GN Females	-	0.40
	2006 GN Males	2007 GN Males	2008 GN Males	0.42
	2006 GN Females	2007 GN Females	2008 GN Females	0.28
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.92
	2007 EF All Fish	2008 EF All Fish	-	0.77
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.95
	2007 GN Males	2007 GN Females	-	0.42
	All Years Males	All Years Females	-	0.85
	2006 GN Males	2007 GN Males	-	0.33
	2006 GN Females	2007 GN Females	-	0.12
	2006 GN All Fish	2007 GN All Fish	-	0.31

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-13. Inter-lake comparisons of weights (g) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.71
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.91
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.14
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.67

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-14. Summary statistics for condition factors (K) of Arctic Char captured in standard index gill nets set in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	9	20	3	3	91	9	2	22	23	14	133
Mean	1.00	1.10	1.04	1.06	0.91	0.96	1.03	0.92	1.02	1.02	1.03	0.99
Median	1.01	1.06	1.02	1.04	0.90	0.98	1.01	0.92	0.95	1.01	1.01	0.99
SD	0.13	0.15	0.14	0.08	0.12	0.19	0.16	0.04	0.23	0.14	0.16	0.19
SE	0.04	0.05	0.03	0.05	0.07	0.02	0.05	0.03	0.05	0.03	0.04	0.02
Minimum	0.84	0.89	0.84	1.00	0.80	0.47	0.86	0.89	0.82	0.84	0.80	0.47
Maximum	1.23	1.35	1.35	1.15	1.04	1.43	1.35	0.95	1.67	1.35	1.35	1.67
95th Percentile	1.19	1.32	1.27	1.14	1.02	1.23	1.30	0.95	1.51	1.23	1.29	1.28
COV (%)	12.77	13.39	13.69	7.62	13.11	19.45	15.93	4.66	22.03	13.28	15.00	19.25

Table 4-15. Summary statistics for condition factors (K) of Arctic Char captured during backpack electrofishing (EF) and index gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	8	230	12	15	116	36	27	8	68	266	45	25	192
Mean	0.91	0.87	0.90	0.98	0.82	0.86	0.85	1.21	1.04	1.05	1.02	1.01	0.97	0.92	0.91
Median	0.89	0.87	0.87	1.02	0.80	0.90	0.87	1.13	1.03	1.02	1.01	1.02	0.98	0.93	0.93
SD	0.08	0.00	0.07	0.24	0.07	0.11	0.13	0.29	0.09	0.11	0.13	0.26	0.13	0.13	0.15
SE	0.03	0.00	0.02	0.02	0.02	0.03	0.01	0.05	0.02	0.04	0.02	0.02	0.02	0.03	0.01
Minimum	0.83	0.87	0.83	0.44	0.70	0.59	0.54	0.72	0.86	0.93	0.49	0.44	0.70	0.59	0.49
Maximum	1.02	0.88	1.02	2.04	0.93	0.98	1.16	2.02	1.24	1.22	1.51	2.04	1.24	1.22	1.51
95^{th} Percentile	1.01	0.88	1.00	1.36	0.93	0.96	1.05	1.80	1.19	1.21	1.21	1.40	1.17	1.16	1.16
COV (%)	8.37	0.28	7.37	24.04	8.65	12.62	15.06	23.98	8.75	10.35	12.86	25.30	13.37	14.69	16.29

Table 4-16. Summary statistics for condition factors (K) of Arctic Char captured in standard index gill nets set in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin												North Basin
	2006				2007				All Years				2007
	Males	Females	All		Males	Females	All		Males	Females	All		
n	26	33	62		14	12	161		40	45	223		98
Mean	1.03	1.00	1.01		0.85	0.86	0.88		0.96	0.96	0.92		0.90
Median	1.02	0.99	0.99		0.86	0.87	0.88		0.88	0.96	0.90		0.91
SD	0.27	0.16	0.21		0.08	0.08	0.11		0.24	0.16	0.16		0.13
SE	0.05	0.03	0.03		0.02	0.02	0.01		0.04	0.02	0.01		0.01
Minimum	0.56	0.77	0.56		0.66	0.71	0.60		0.56	0.71	0.56		0.60
Maximum	1.93	1.64	1.93		1.01	0.98	1.41		1.93	1.64	1.93		1.20
95^{th} Percentile	1.46	1.23	1.39		0.97	0.97	1.04		1.41	1.21	1.15		1.11
COV (%)	26.24	16.42	20.97		9.87	9.08	12.37		24.64	16.45	16.96		14.94

Table 4-17. Comparison of Arctic Char condition factors (K) between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	0.44
	2007 GN Males	2007 GN Females	-	0.38
	2008 GN Males	2008 GN Females	-	0.29
	All Years Males	All Years Females	-	0.79
	2006 GN Males	2007 GN Males	2008 GN Males	0.86
	2006 GN Females	2007 GN Females	2008 GN Females	0.42
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.85
Sheardown Lake	2006 GN Males	2006 GN Females	-	**< 0.01**
	2007 GN Males	2007 GN Females	-	0.60
	2008 GN Males	2008 GN Females	-	0.85
	All Years GN Males	All Years GN Females	-	0.69
	2006 GN Males	2007 GN Males	2008 GN Males	**< 0.01**
	2006 GN Females	2007 GN Females	2008 GN Females	0.19
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.67
	2007 EF All Fish	2008 EF All Fish	-	0.49
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.95
	2007 GN Males	2007 GN Females	-	0.42
	All Years Males	All Years Females	-	0.85
	2006 GN Males	2007 GN Males	-	0.33
	2006 GN Females	2007 GN Females	-	0.12
	2006 GN All Fish	2007 GN All Fish	-	0.31

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-18. Inter-lake comparisons of condition factors (K) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.51
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.84
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.63
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.85

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-19. Summary statistics for catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char captured in standard index gill nets deployed in Mine Area lakes, 2006-2008.

Statistic	Camp Lake				Sheardown Lake				Mary Lake – South Basin			Mary Lake – North Basin
	2006	2007	2008	All	2006	2007	2008	All	2006	2007	All	Males
n	2	21	14	36	1	14	8	23	2	24	26	8
Mean	13.4	41.8	10.1	29.0	13.8	92.8	57.8	77.2	27.1	73.4	69.9	175.2
Median	13.4	34.9	10.0	18.0	-	55.6	41.8	53.9	27.1	66.2	64.4	169.1
SD	5.0	37.5	8.4	32.6	-	86.3	64.0	78.6	12.4	55.5	54.7	59.8
SE	3.5	8.2	2.2	5.4	-	23.1	22.6	16.4	8.7	11.3	10.7	21.1
Minimum	9.9	0.0	0.0	0.0	13.8	0.0	0.0	0.0	18.4	0.0	0.0	78.8
Maximum	16.9	157.2	22.9	157.2	13.8	314.4	189.9	314.4	35.9	216.7	216.7	286.3
95th Percentile	16.5	99.8	21.4	86.1	-	219.0	158.3	187.6	35.0	159.9	159.2	259.7
COV (%)	37.1	89.7	83.2	112.4	-	93.0	110.8	101.9	45.6	75.6	78.3	34.1

Table 4-20. Comparison of catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char between years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at p < 0.05.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	< 0.01
Sheardown Lake	2007 GN All Fish	2008 GN All Fish	-	0.23
	2007 EF All Fish	2008 EF All Fish	-	< 0.01
Mary Lake - S	2006 GN All Fish	2007 GN All Fish	-	< 0.01

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-21. Inter-lake comparisons of catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char captured during index gillnetting surveys, 2006-2008. Values in red indicate significant difference at p < 0.05.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Mary L – S 2006 GN	-	-	< 0.01
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.02
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	< 0.01
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.01

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-22. Summary statistics for age of Arctic Char captured during standard index gillnetting and backpack electrofishing surveys in selected mine area lakes and in Mary River, 2006-2008.

Statistic	Camp Lake	Sheardown Lake	Mary Lake	Mary River	All Waterbodies
n	28	35	97	29	189
Mean	9.5	13.3	13.2	2.6	11.1
Median	9	13	13	2	11
SD	3.7	4.5	3.6	0.9	5.2
SE	0.7	0.8	0.4	0.2	0.4
Minimum	4	5	7	2	2
Maximum	19	22	24	5	24
95^{th} Percentile	16.7	21	19.4	4.6	19
COV (%)	39.2	33.8	27.5	33.5	47.3

Table 4-23. Length and weight-at-age for Arctic Char pooled from all Study Area waterbodies, 2006-2008.

Age	Fork Length (mm)					Weight (g)			
	n	Mean	SD	Range		n	Mean	SD	Range
2	17	88	12	63 - 108		17	10	4	4 - 18
3	9	106	13	86 - 128		9	17	7	7 - 28
4	2	179	69	130 - 228		2	92	82	33 - 150
5	5	189	44	149 - 240		4	92	53	44 - 150
6	4	186	13	170 - 197		4	69	24	50 - 100
7	7	228	46	171 - 301		7	125	76	50 - 275
8	9	246	59	172 - 331		9	178	90	75 - 300
9	15	273	48	192 - 351		15	210	111	75 - 450
10	14	294	78	167 - 496		14	300	306	50 - 1300
11	19	337	63	181 - 465		19	400	230	75 - 1100
12	12	364	39	312 - 451		12	473	154	275 - 800
13	13	398	107	241 - 658		13	685	625	100 - 2450
14	12	404	81	315 - 615		12	756	573	325 - 2300
15	11	390	17	370 - 418		11	525	51	450 - 600
16	16	404	43	357 - 490		16	608	232	350 - 1200
17	7	488	98	354 - 647		7	1114	691	350 - 2400
18	4	385	8	373 - 391		4	494	94	375 - 600
19	5	541	143	384 - 751		5	1985	1753	525 - 4900
20	0	-	-	-		-	-	-	-
21	3	440	62	387 - 508		3	608	163	450 - 775
22	1	507	-	-		1	1000	-	-
23	3	529	93	424 - 602		3	1408	610	725 - 1900
24	1	685	-	-		1	2350	-	-
Total	189	316	136	63 - 751		188	462	570	4 - 4900

Table 4-24. Results of Analysis of Covariance (ANCOVA) tests of length and weight-at-age for Arctic Char captured in Study Area waterbodies.

Statistic	Degrees of Freedom	R^2	Sum of Squares	Mean Squares	Pr > F [a]
Length	157	0.581	1544.568	772.284	< 0.0001
Weight	156	0.351	913.208	456.604	< 0.0001

[a] Fisher's F-test significance

Table 4-25. Results of power analyses for selected Arctic Char metrics for Sheardown Lake.

Effect Indicator	Metric	Effect Size	Sample Size @ $\beta = 0.1$
Growth	Age 0+ Length	10%	25
		20%	8
		25%	6
	Age 1+ Length	10%	11
		20%	4
		25%	3
	Age 1+ Weight	10%	250
		20%	62
		25%	42
Condition	Age 1+ Condition	10%	9
		20%	3
		25%	3

.

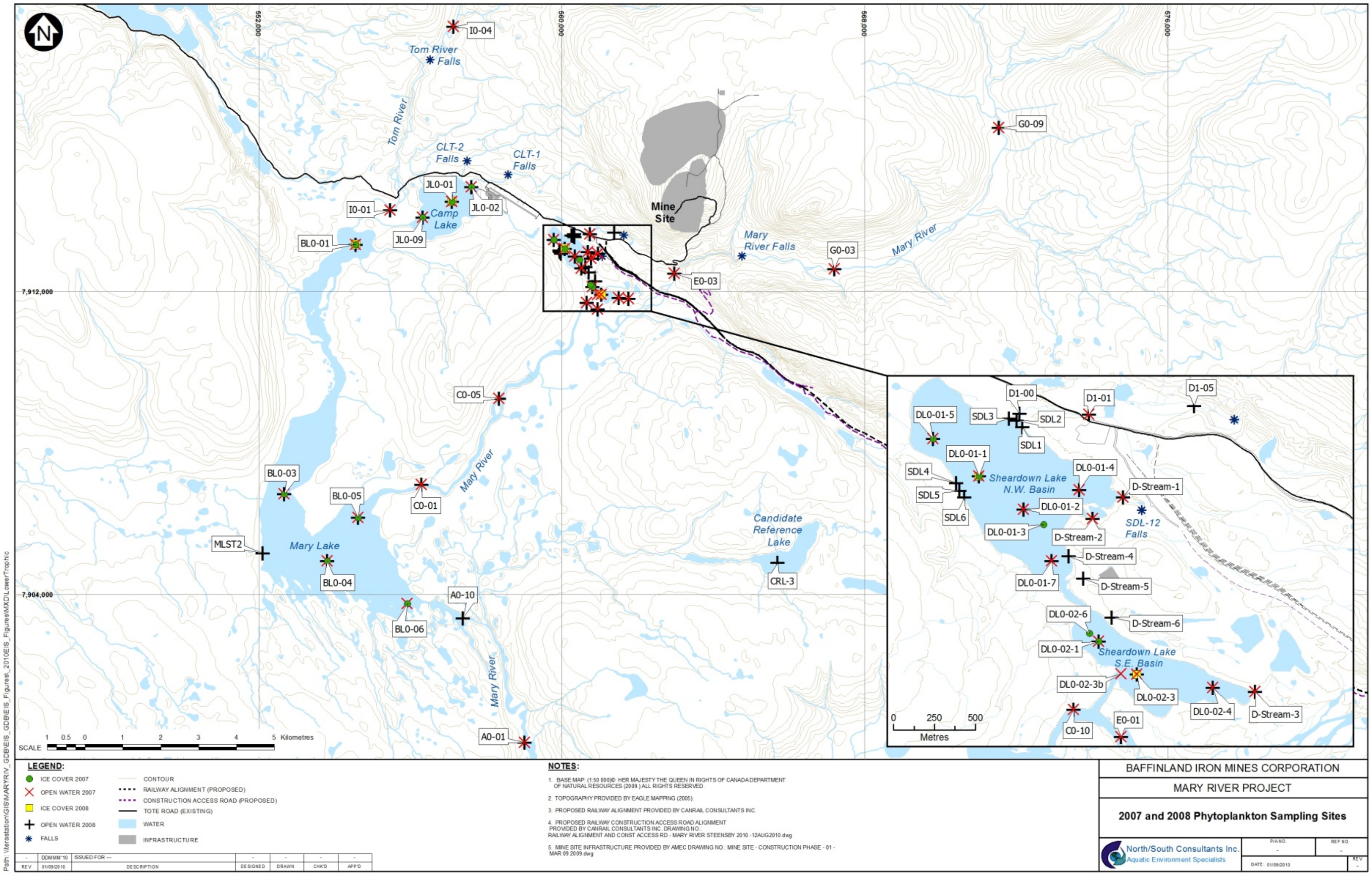


Figure 2-1. Locations of sites where phytoplankton taxonomy and biomass and/or chlorophyll *a* were measured in Mine Area lakes and streams: 2007-2008.

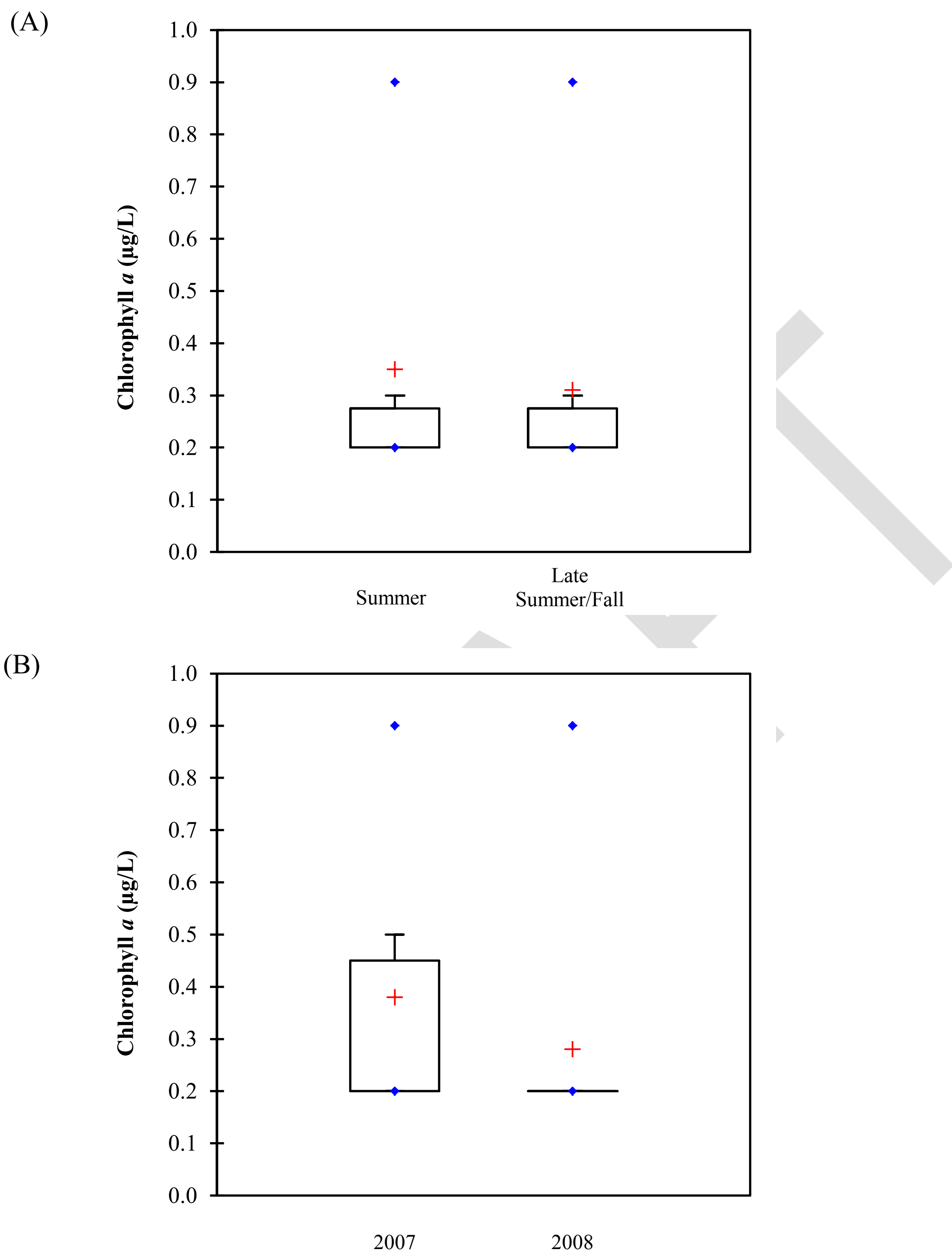


Figure 2-2. Box plots of chlorophyll *a* measured in Sheardown Lake NW by (A) sampling period and (B) sampling year. Data include offshore sampling measurements collected in summer and late summer/fall in 2007 and 2008.

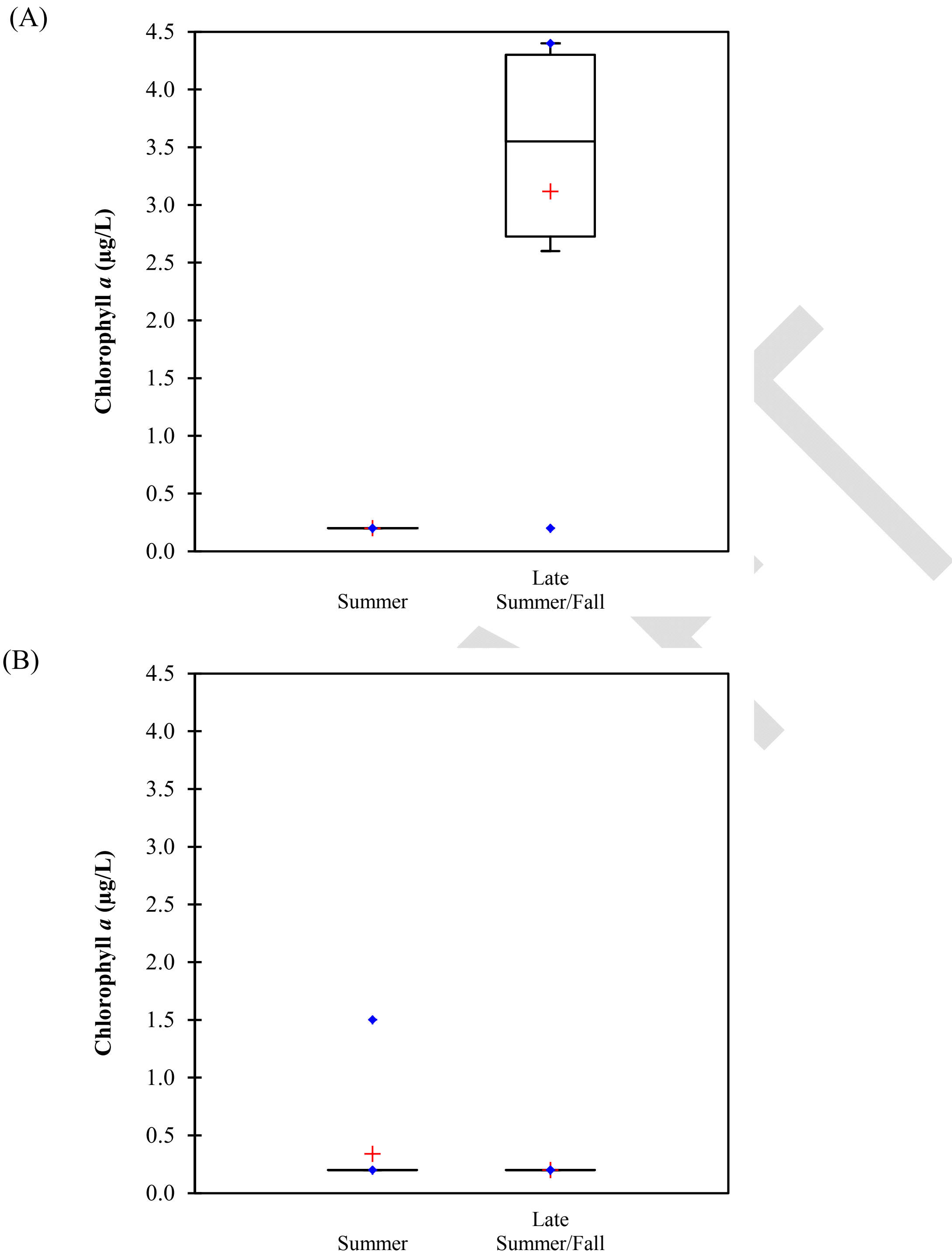


Figure 2-3. Comparisons of chlorophyll *a* measured in Sheardown Lake (A) nearshore sites and (B) offshore sites. Data include measurements collected in summer and late summer/fall in 2008.

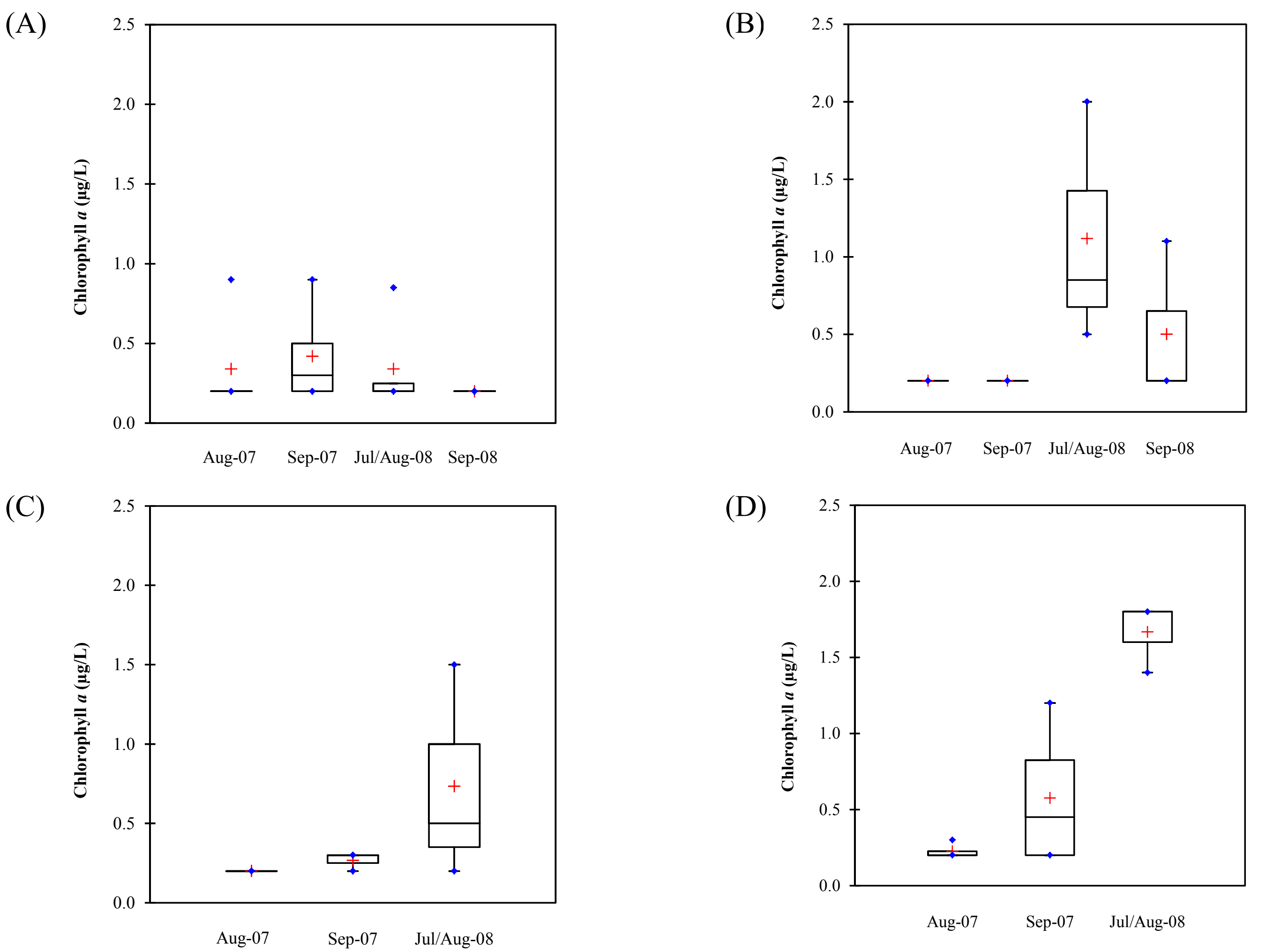


Figure 2-4. Comparisons of chlorophyll *a* measured in the open-water season of 2007 and 2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake. Where two samples were collected in summer 2008 (Sheardown Lake NW and SE), the data points were averaged to normalize sample sizes.

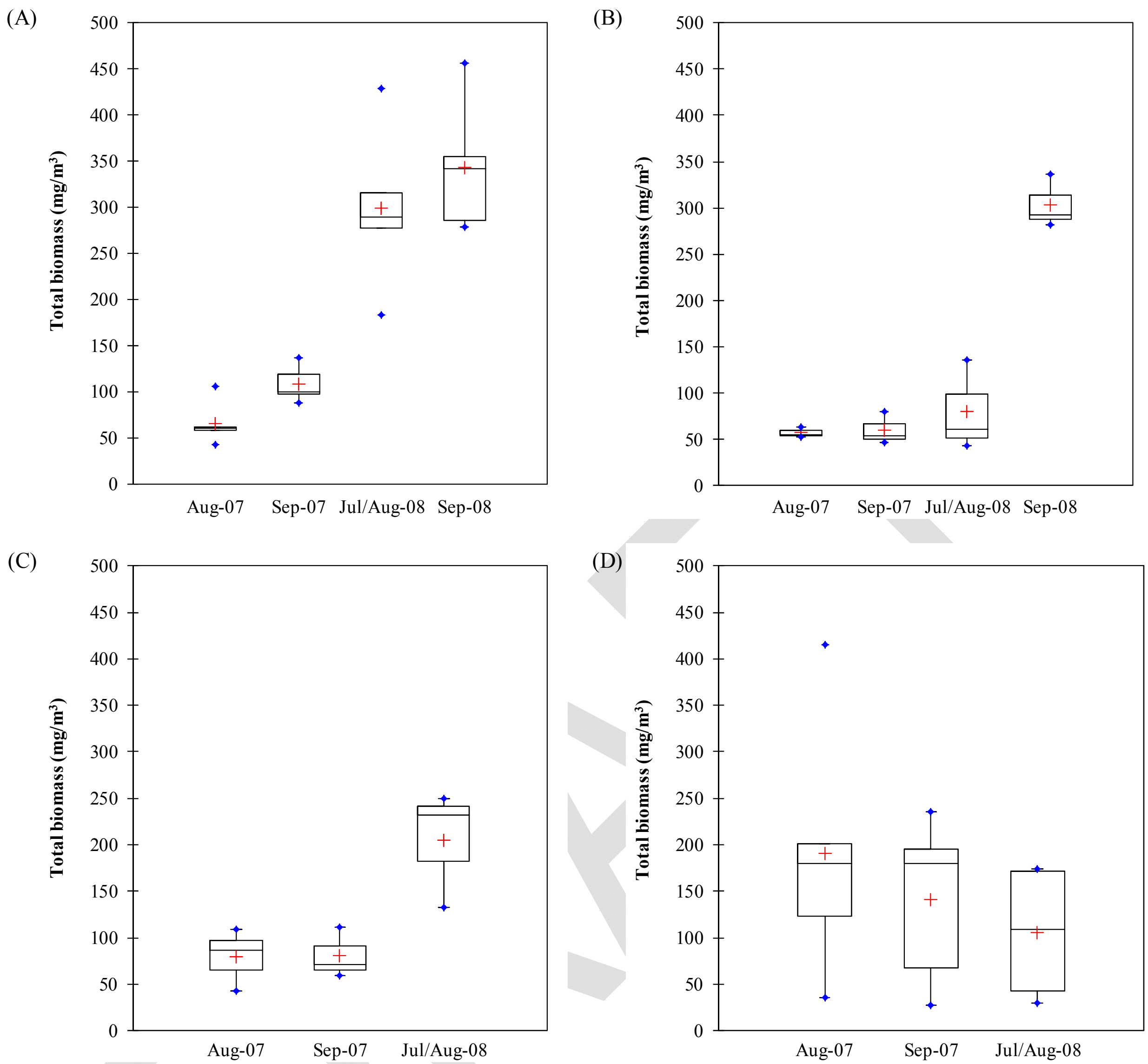


Figure 2-5. Total biomass of phytoplankton measured by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

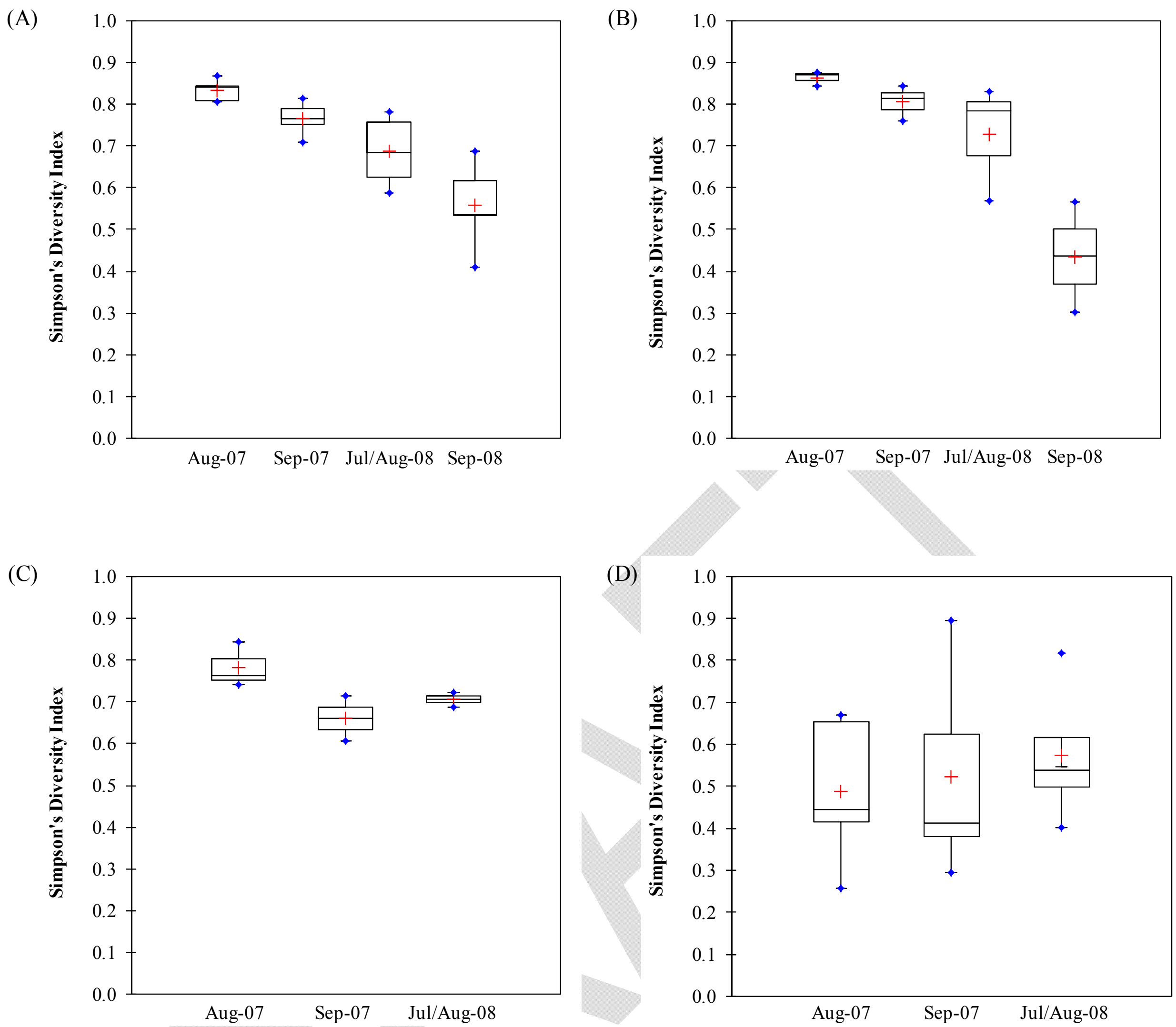


Figure 2-6. Phytoplankton Simpson's Diversity Index by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

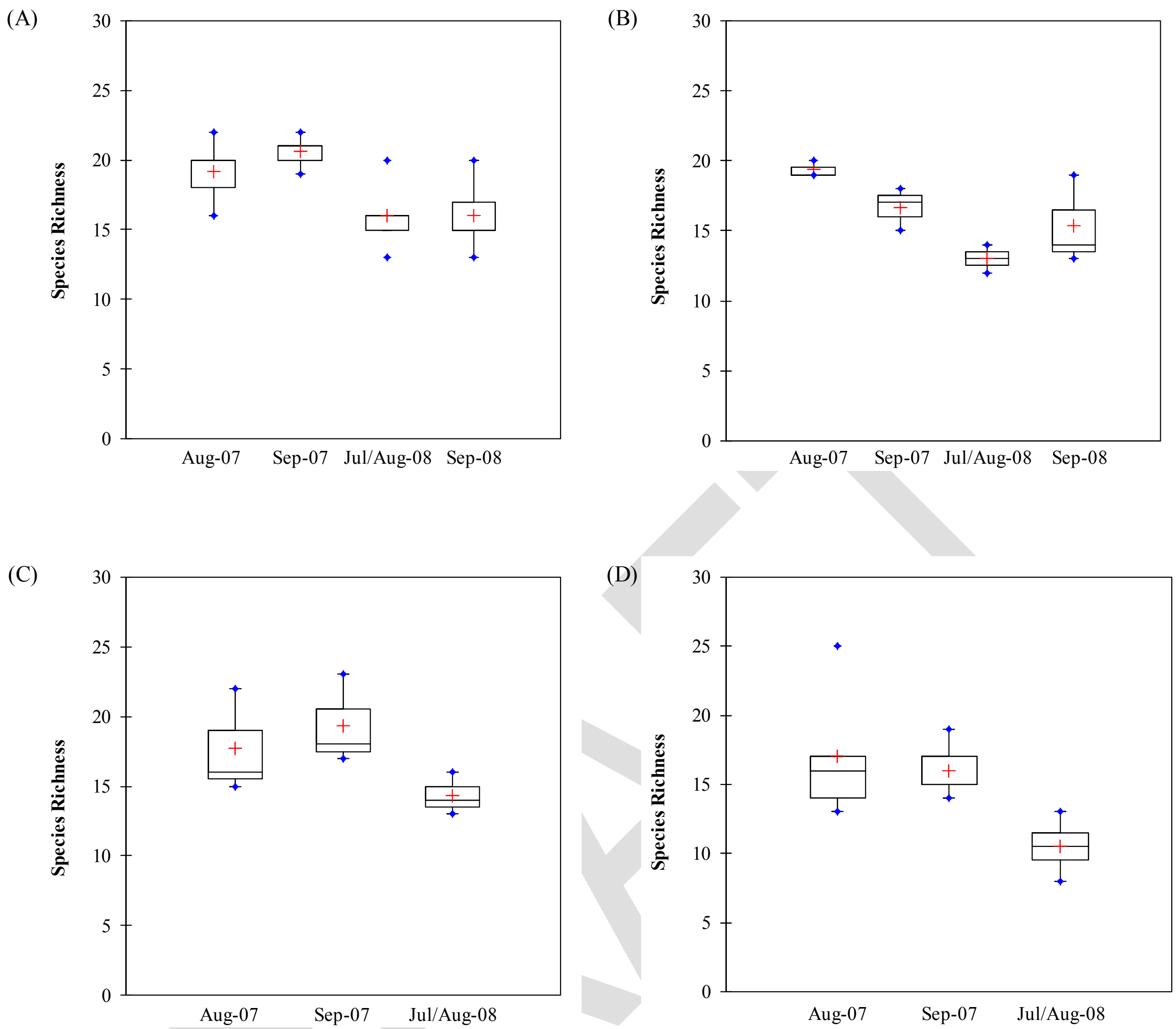


Figure 2-7. Phytoplankton species richness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

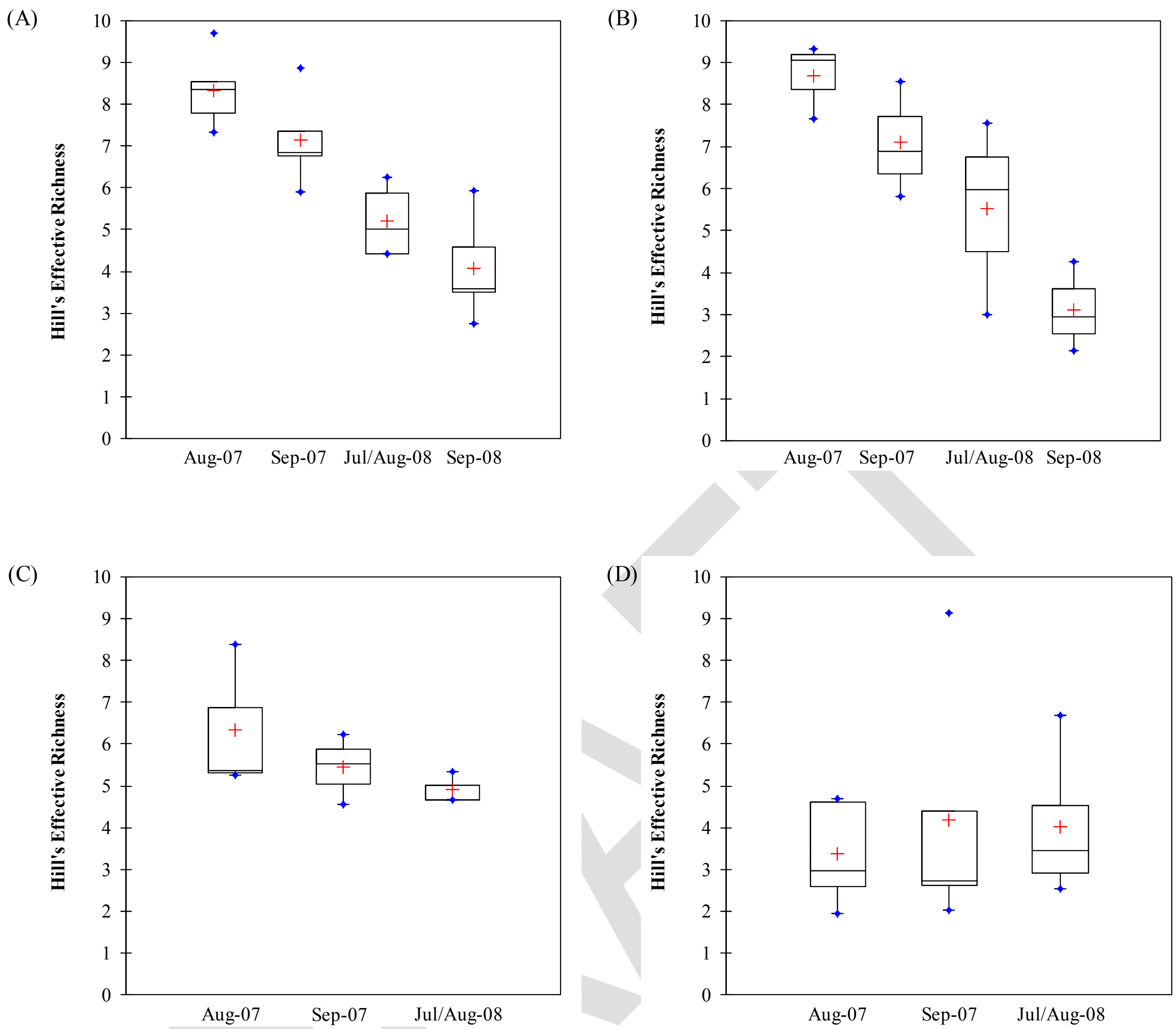


Figure 2-8. Phytoplankton species richness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

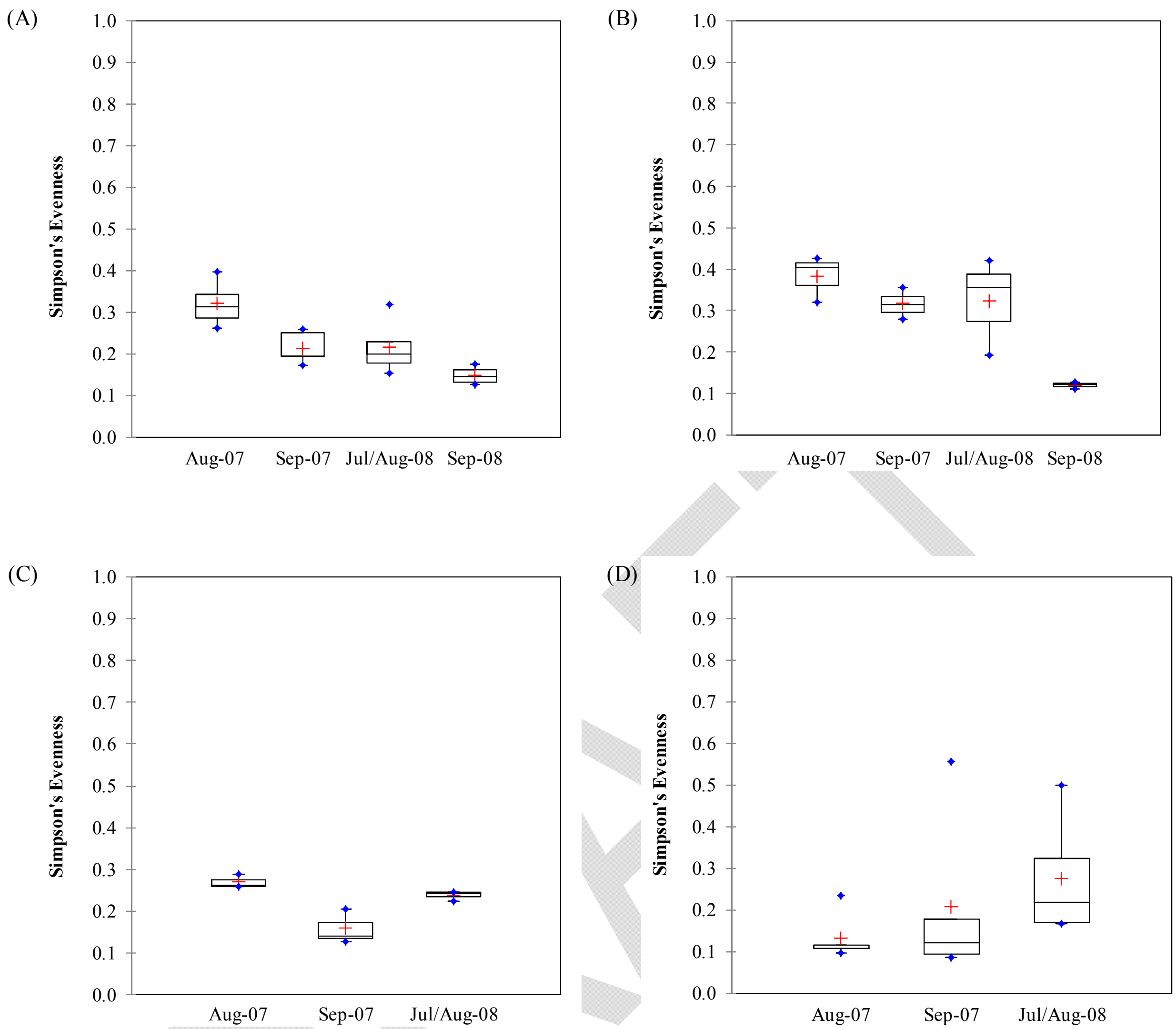


Figure 2-9. Phytoplankton Simpson’s evenness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

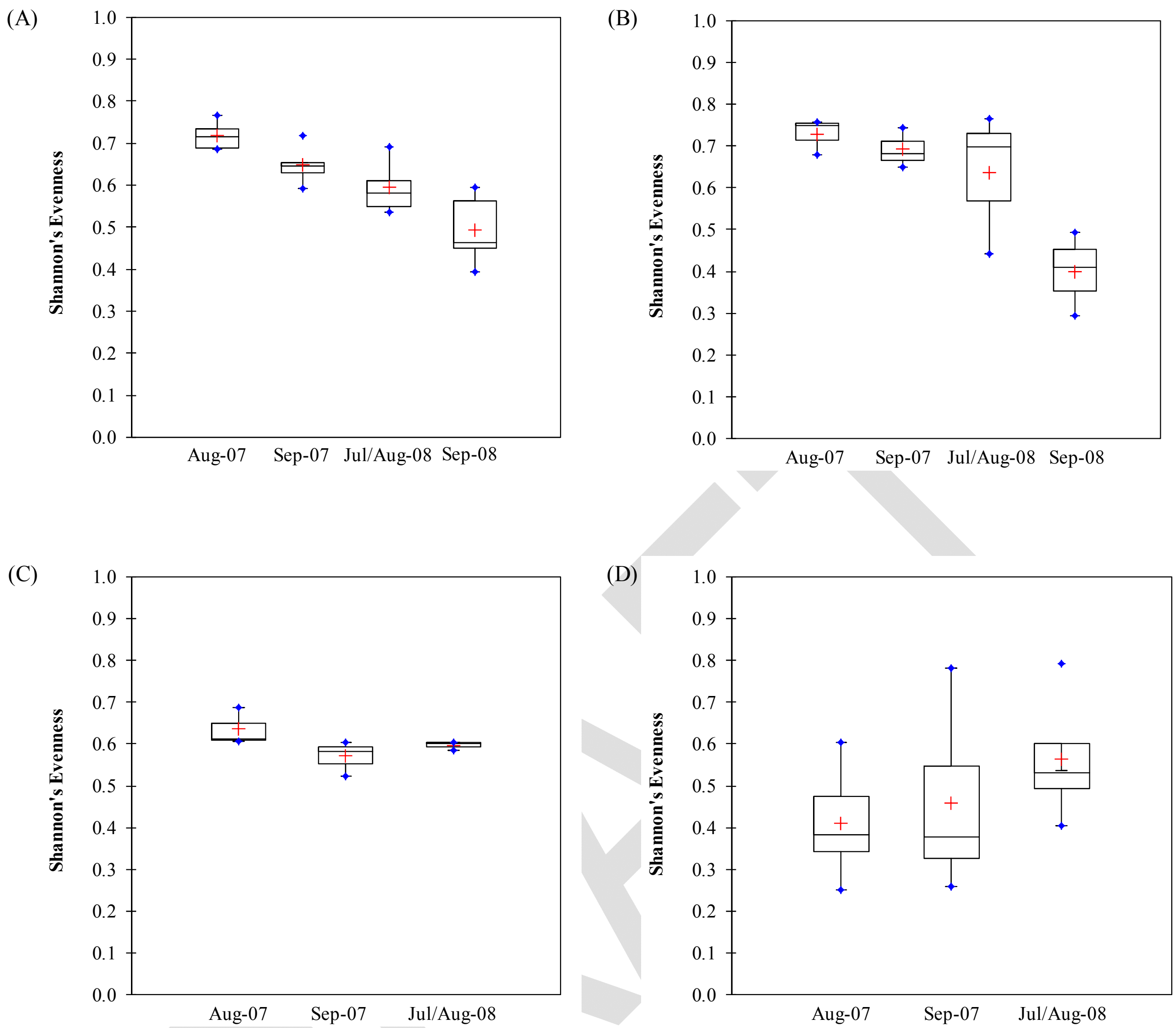


Figure 2-10. Shannon's evenness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

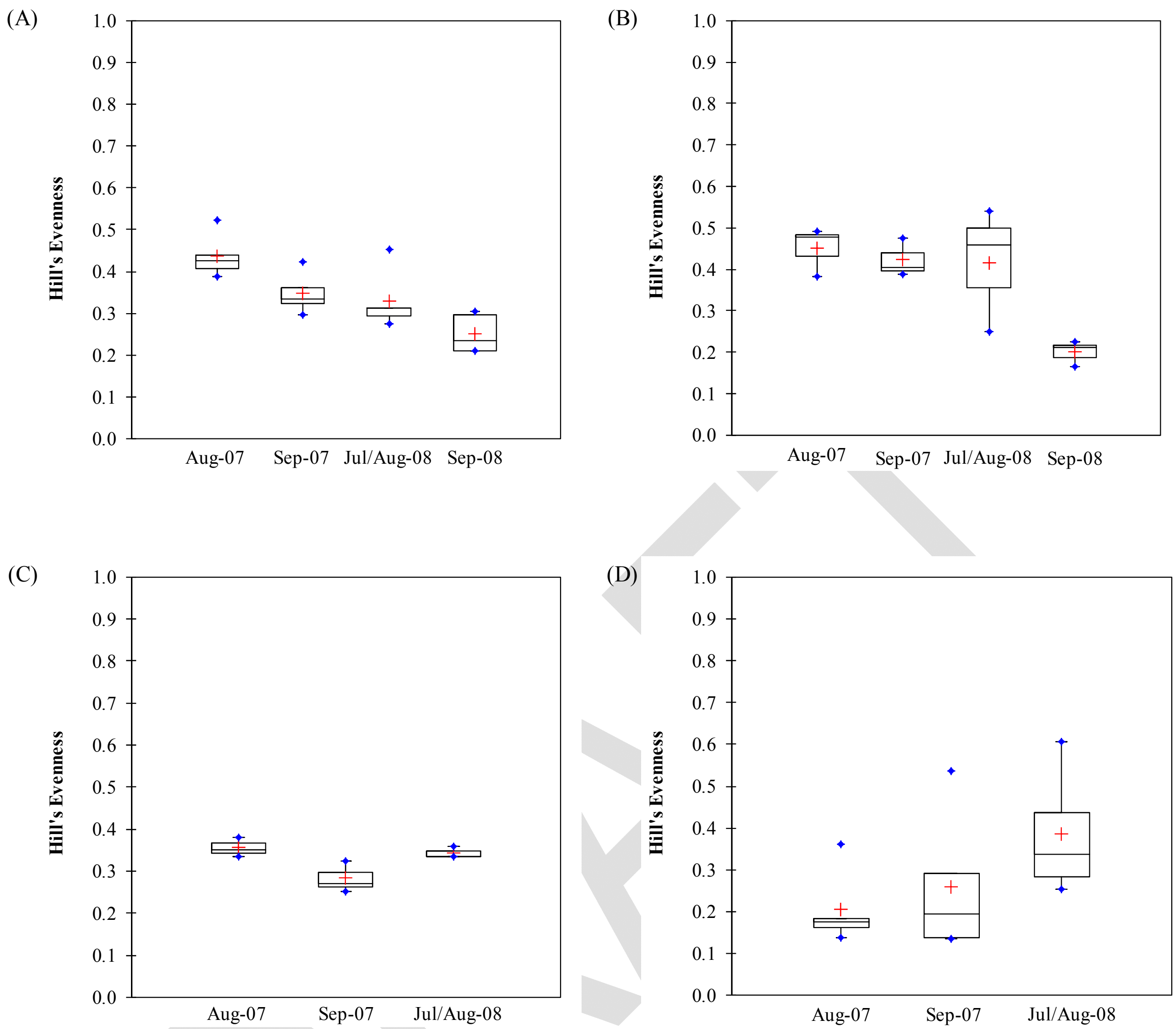


Figure 2-11. Phytoplankton Hill's evenness by sampling period in Mine Area lakes 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

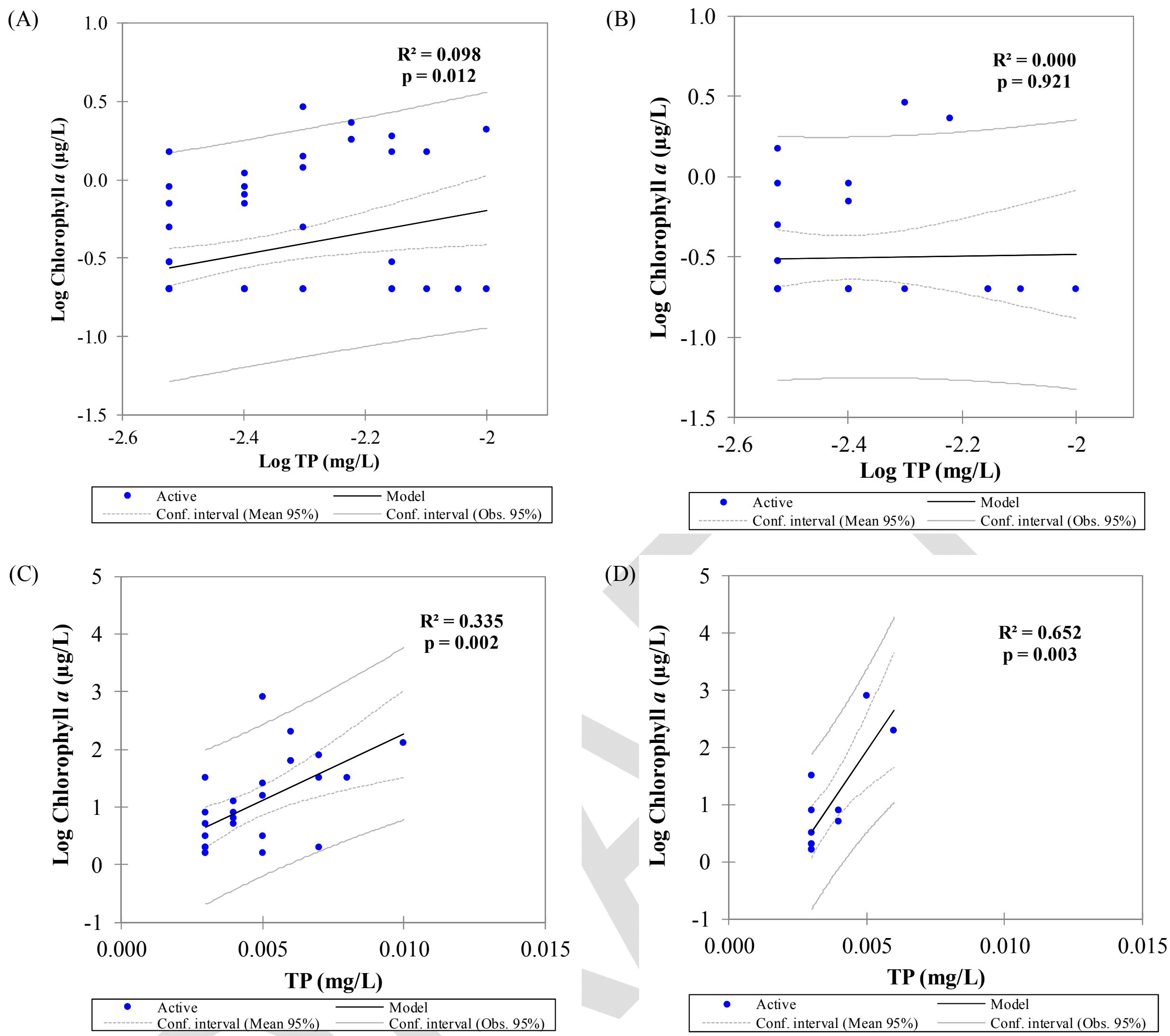
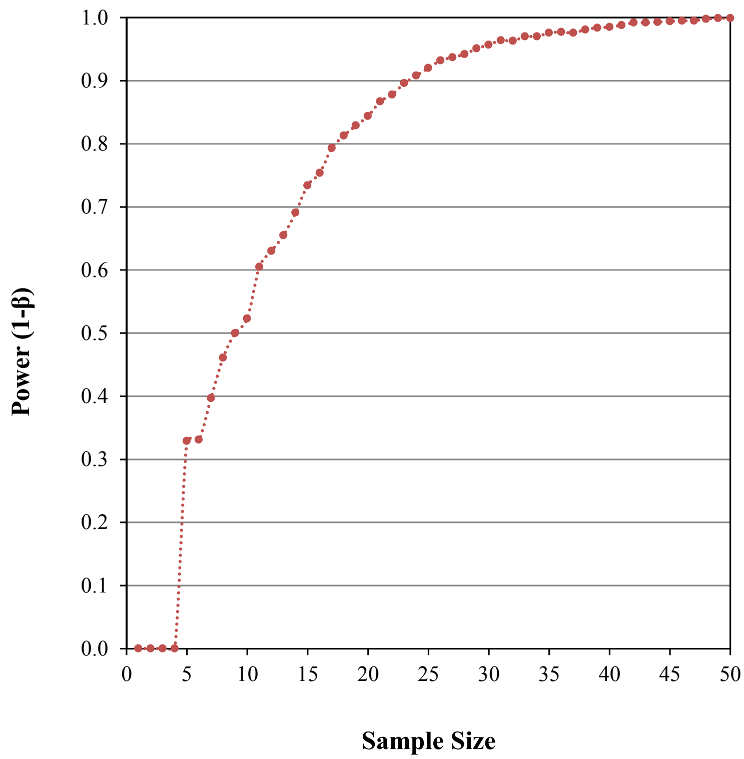


Figure 2-12. Linear regressions between total phosphorus (TP) and chlorophyll *a* (nearshore samples excluded) in Mine Area lakes. (A) and (B) present regressions for all lakes and Sheardown Lake NW, respectively, using all data points. (C) and (D) present regressions for all lakes and Sheardown Lake NW, respectively, using only chlorophyll *a* measurements that exceeded the analytical detection limits.

(A)



(B)

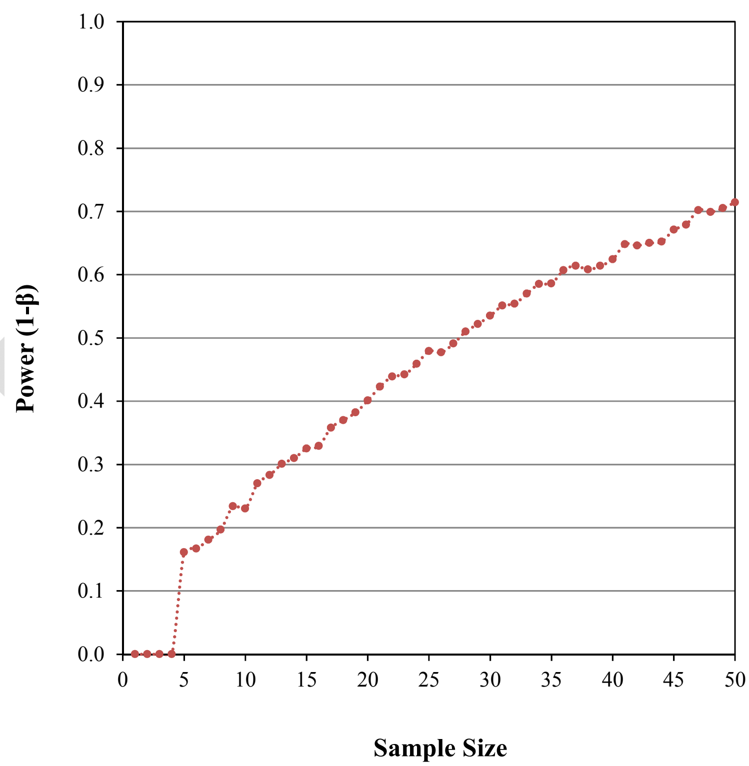


Figure 2-13. Power analysis results for chlorophyll *a* for a critical effect size of (A) 100%; and (B) 50%.

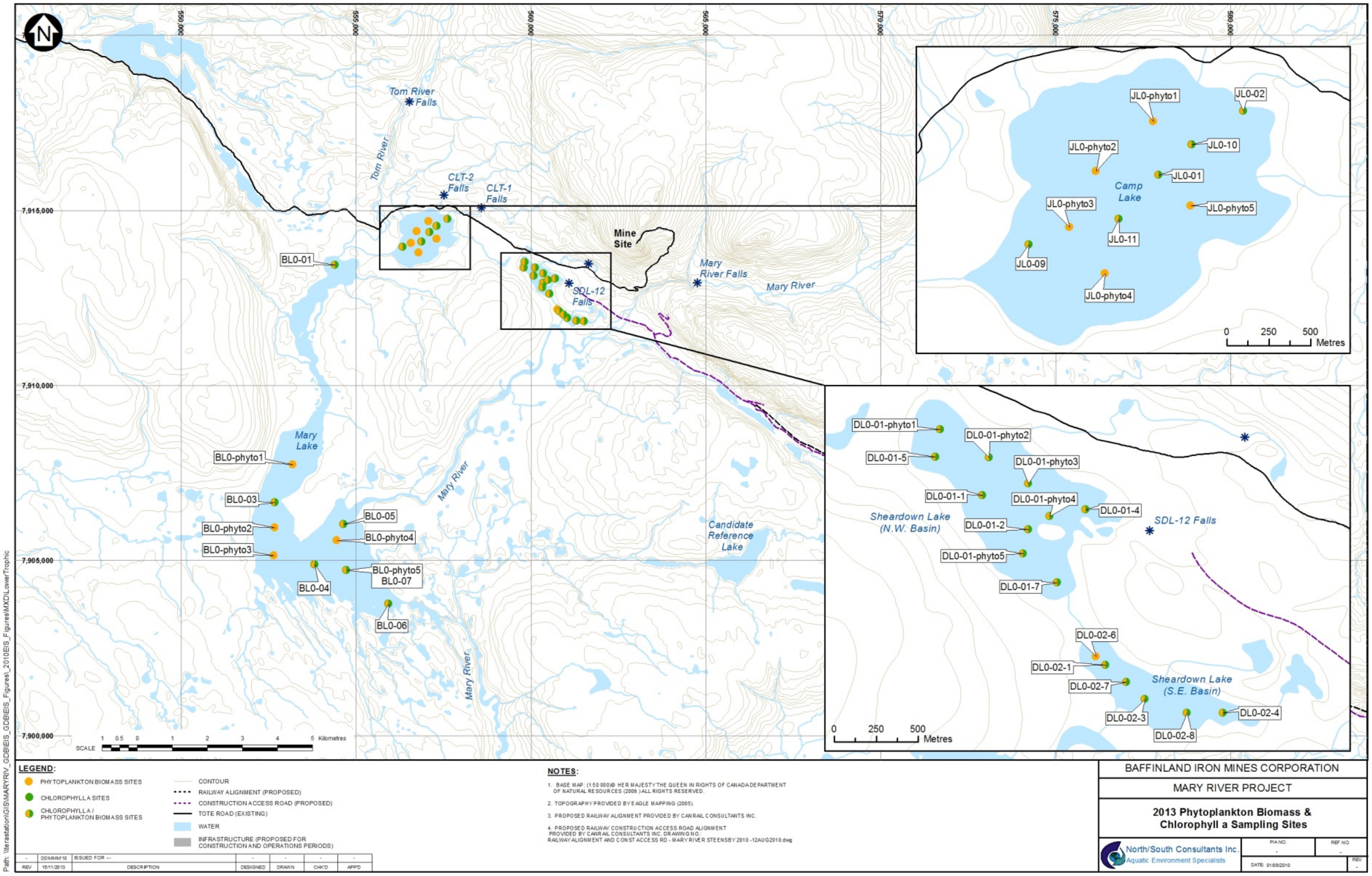


Figure 2-14. Locations of sites where phytoplankton taxonomy and biomass and/or chlorophyll *a* were measured in Mine Area lakes: 2013.

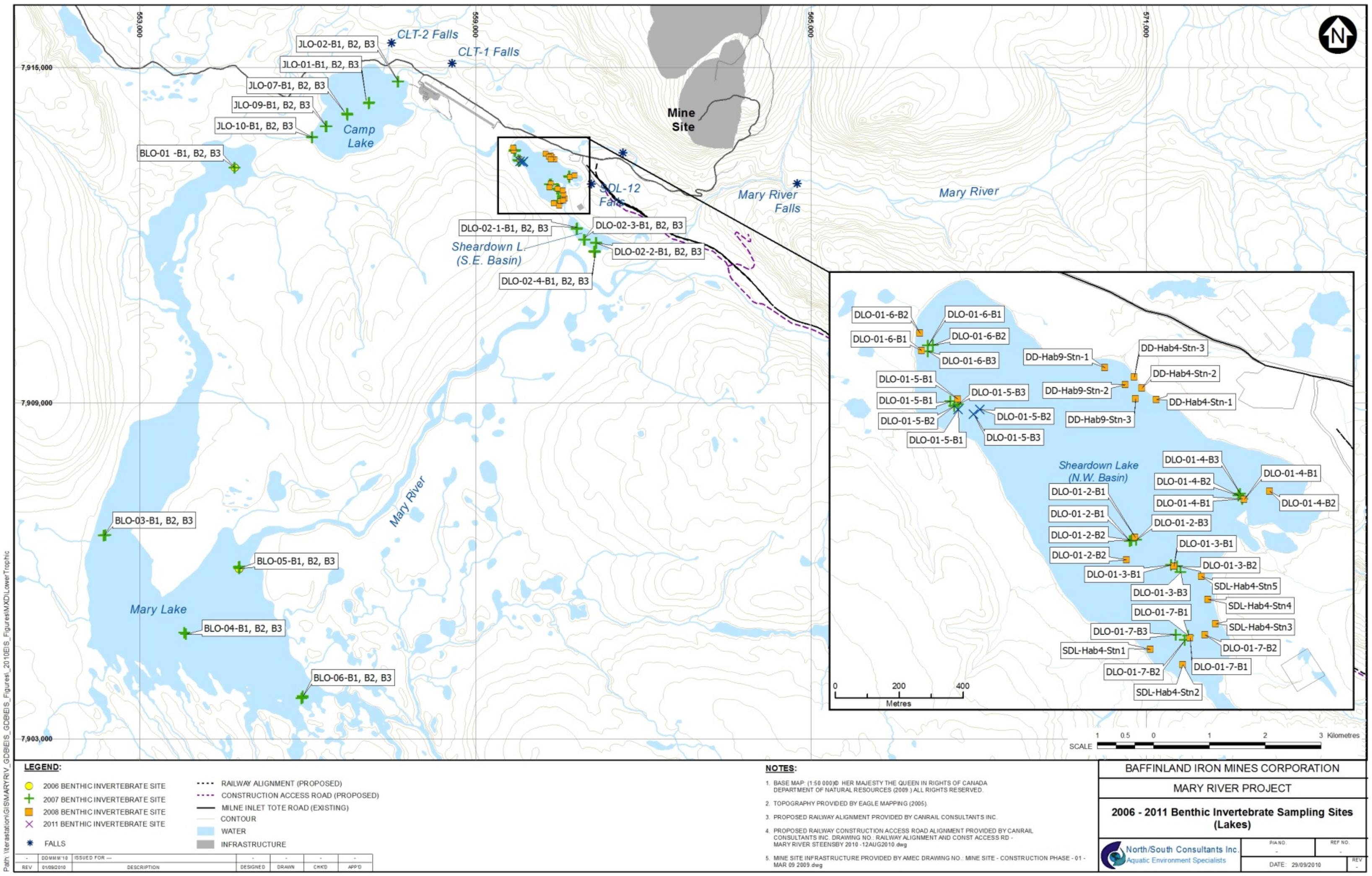


Figure 3-1. Benthic invertebrate sampling sites in Mine Area lakes.

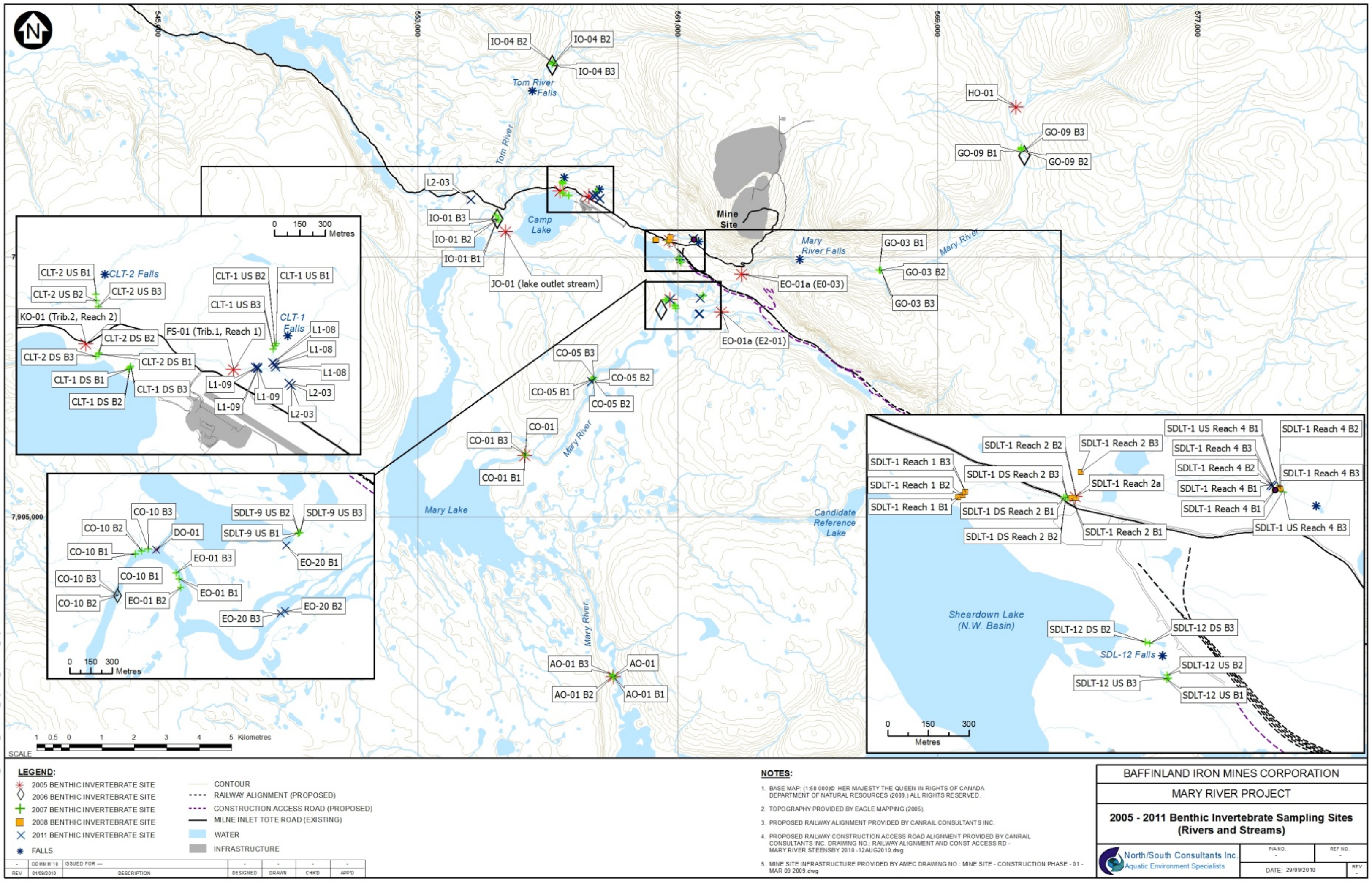


Figure 3-2. Benthic invertebrate sampling sites in Mine Area streams.

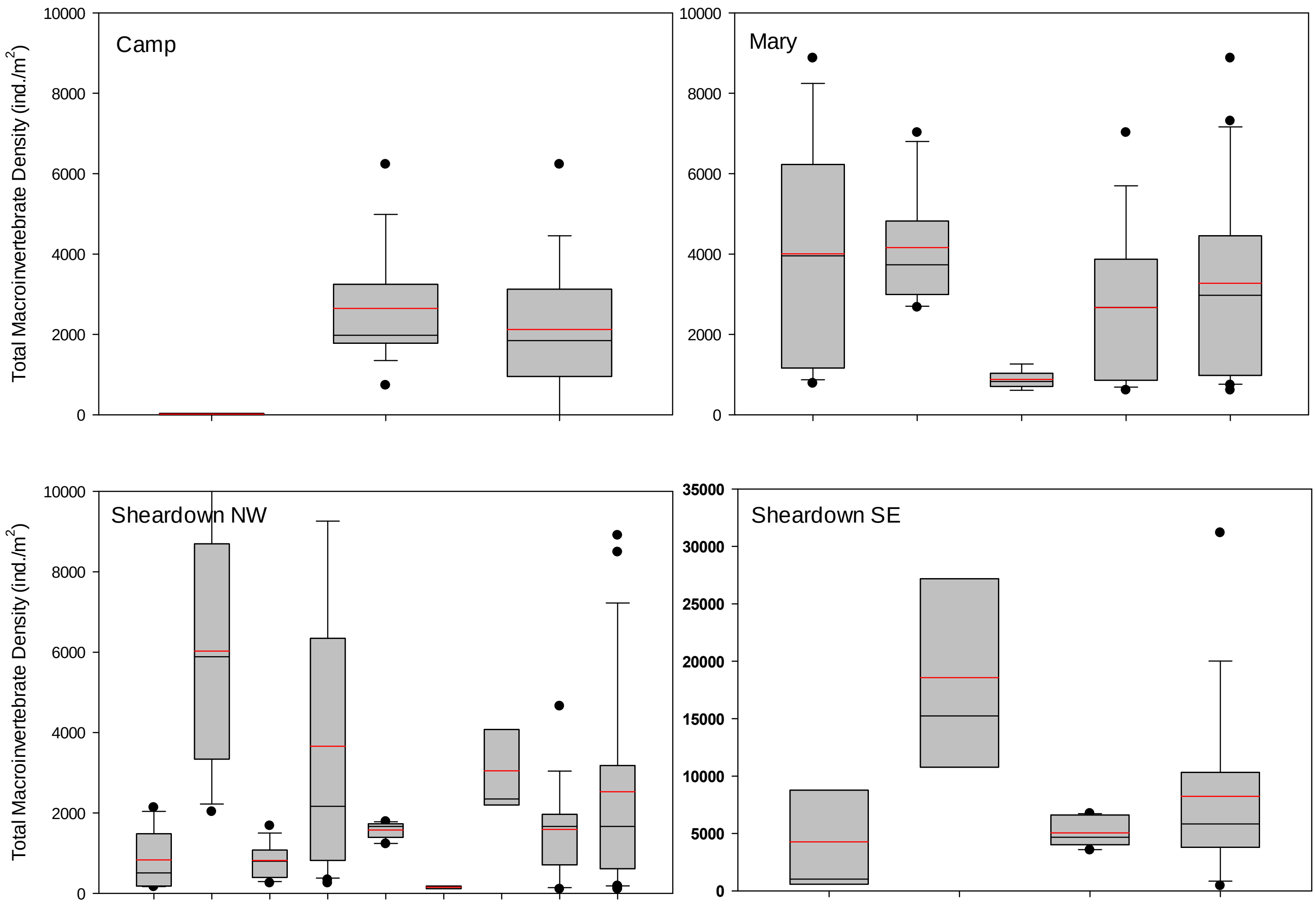


Figure 3-3. Boxplot of total macroinvertebrate density (ind./m^2) for all Mine Area lakes, by aquatic habitat type and year. Mean is represented by red line. Note different vertical scale for Sheardown SE.

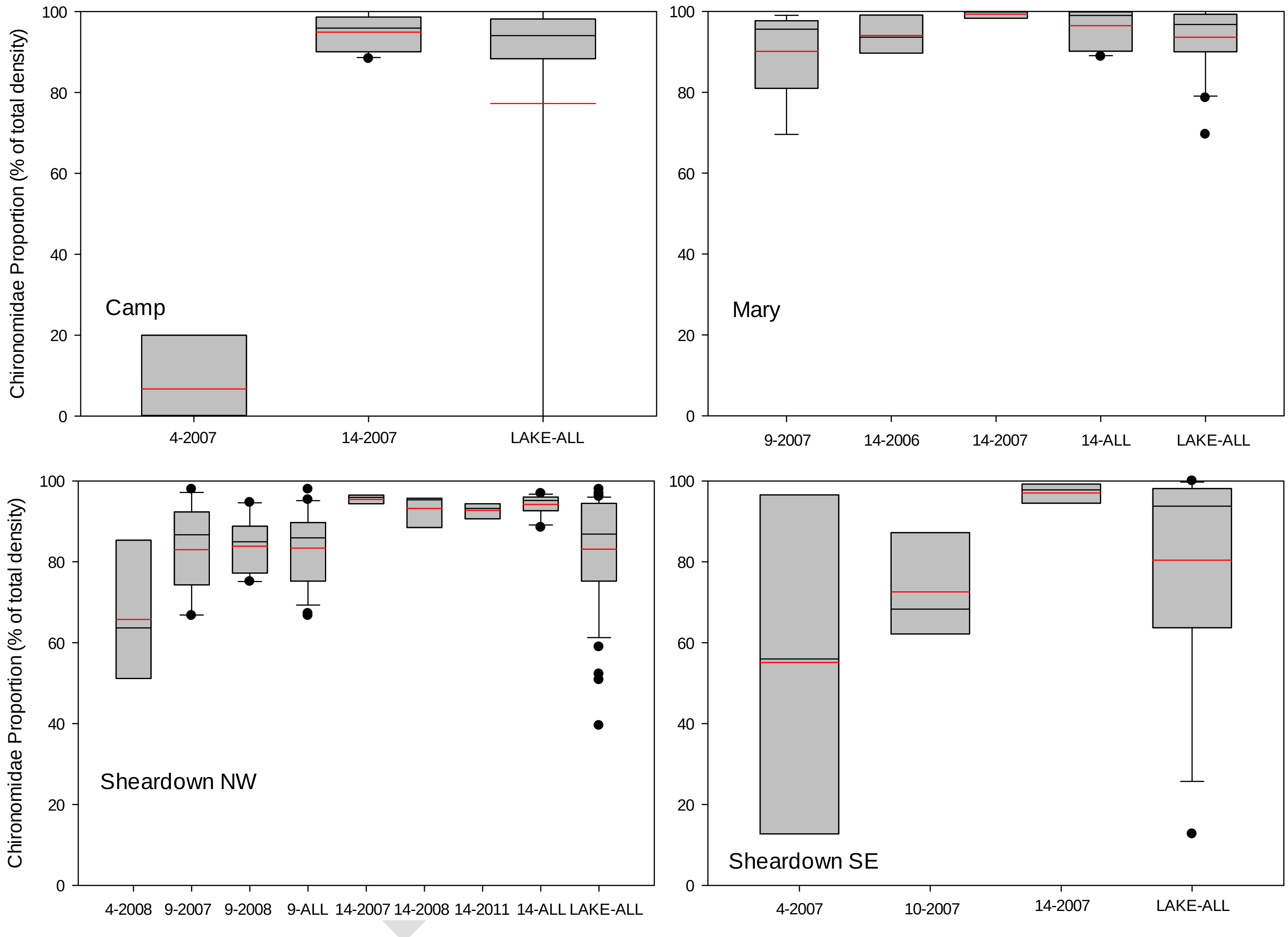


Figure 3-4. Boxplot of Chironomidae proportion (% of total density) for all Mine Area lakes, by aquatic habitat type and year.

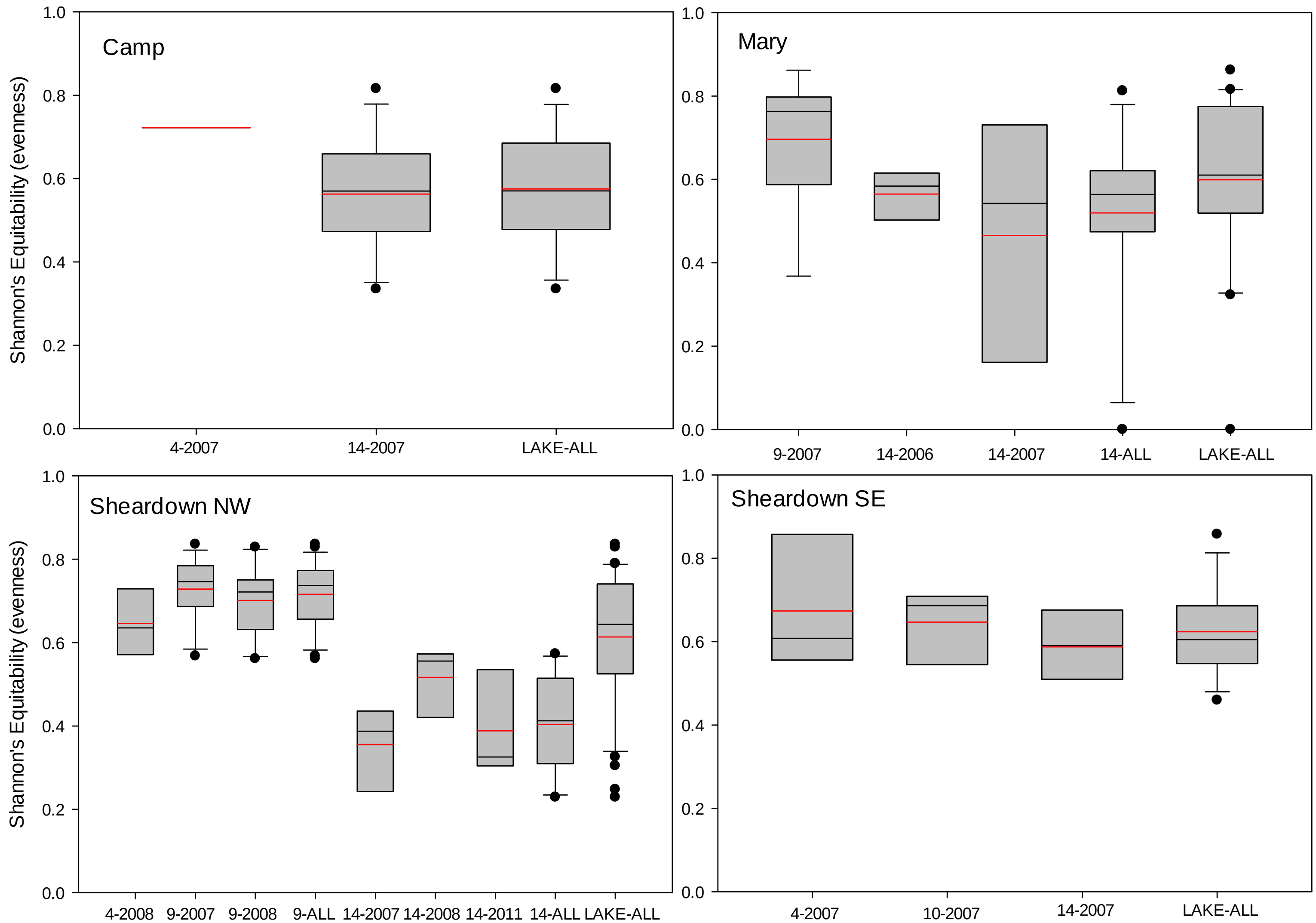


Figure 3-5. Boxplot of Shannon's Equitability (evenness) for all Mine Area lakes, by aquatic habitat type and year.

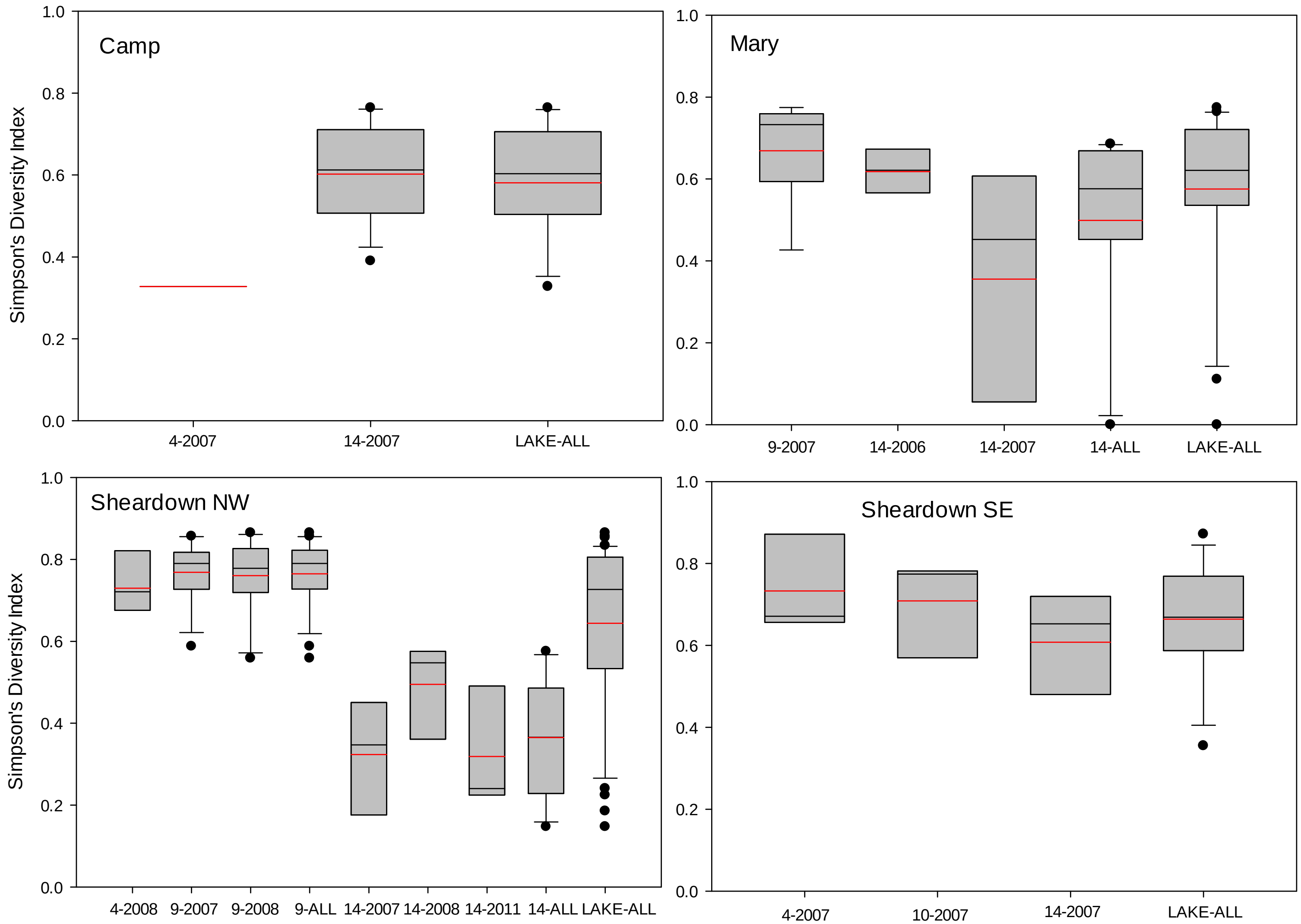


Figure 3-6. Boxplot of Simpson's Diversity Index for all Mine Area lakes, by aquatic habitat type and year.

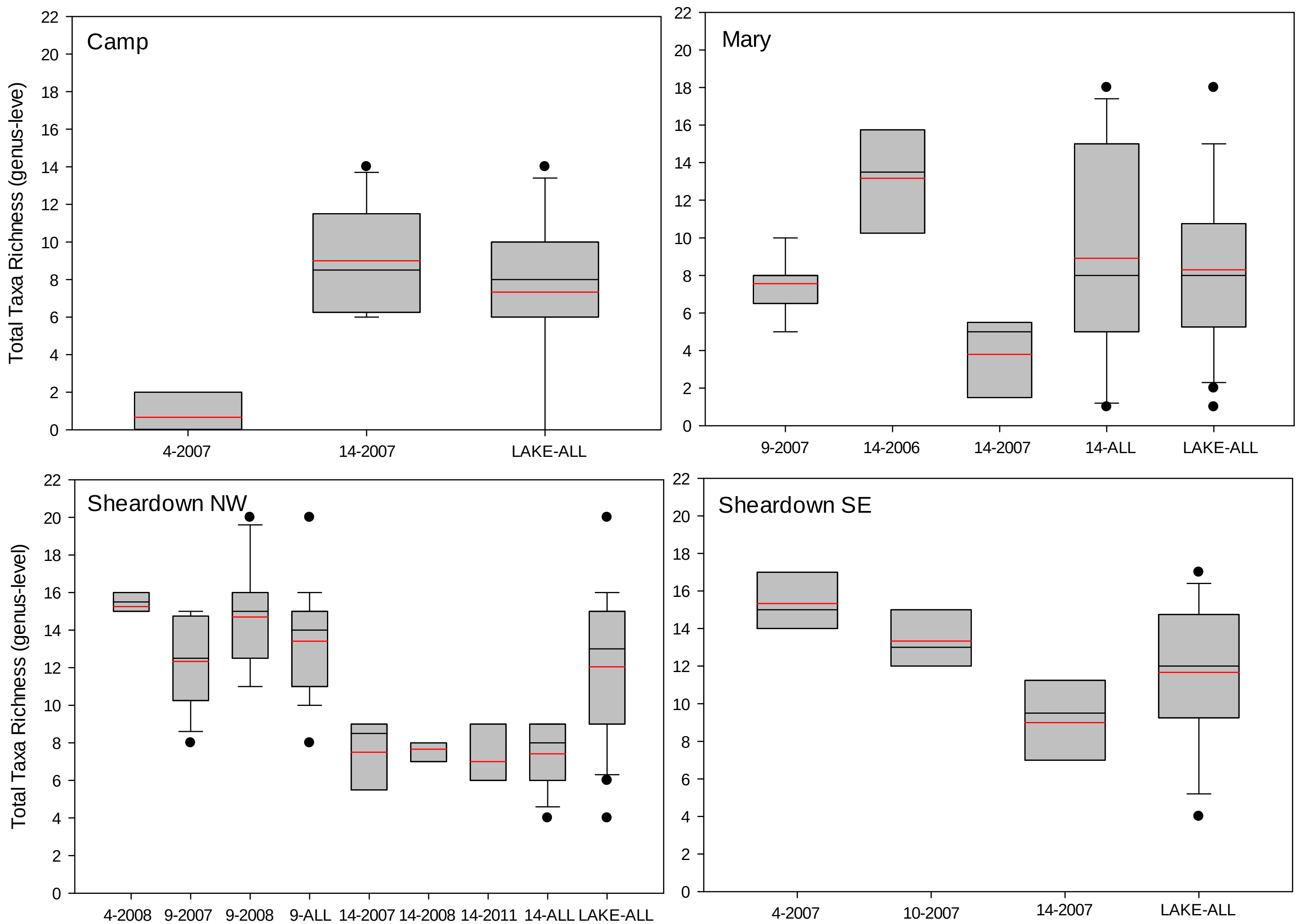


Figure 3-7. Boxplot of total taxa richness (genus-level) for all Mine Area lakes, by aquatic habitat type and year.

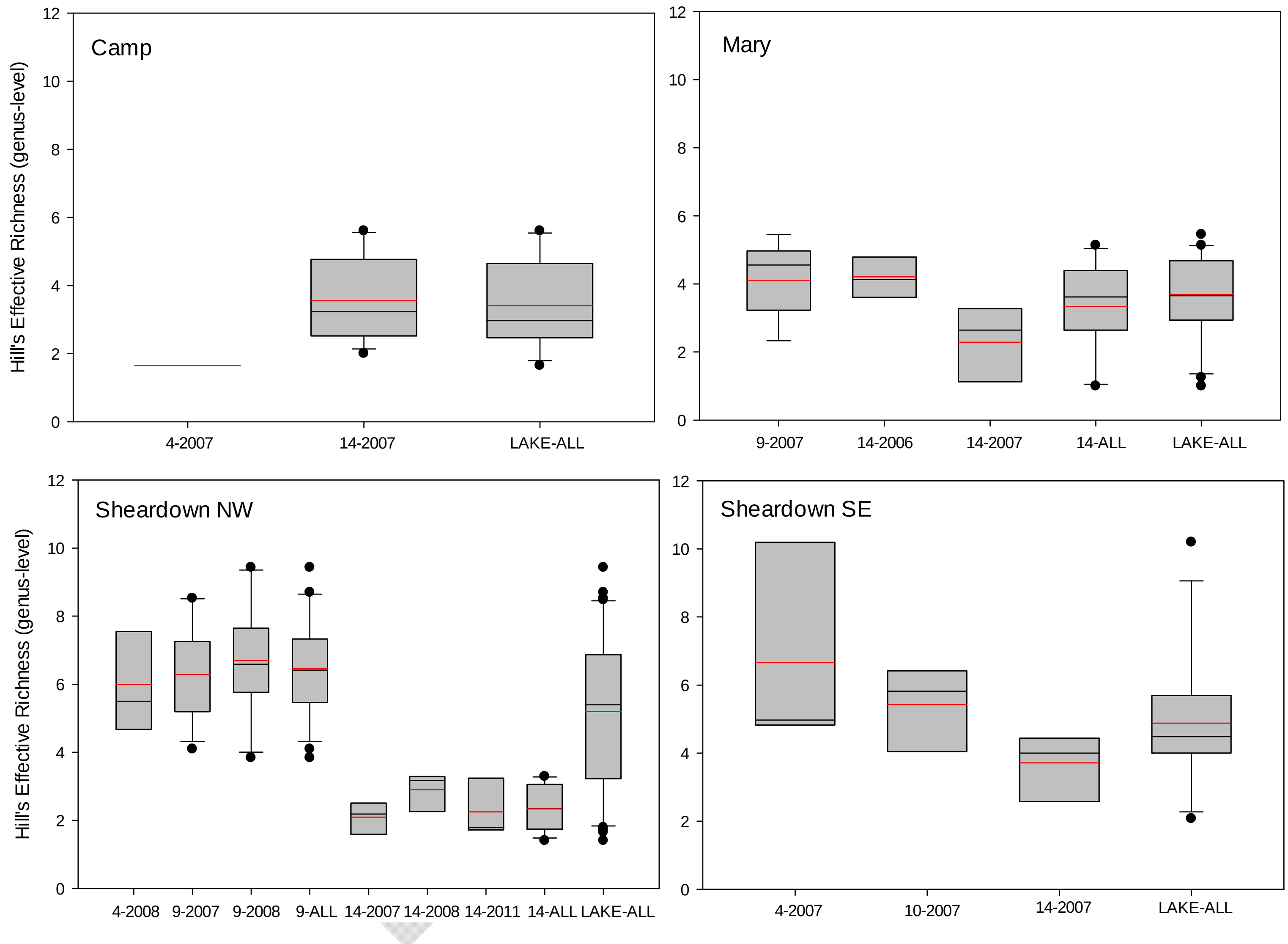


Figure 3-8. Boxplot of Hill's effective richness (genus-level) for all Mine Area lakes, by aquatic habitat type and year.

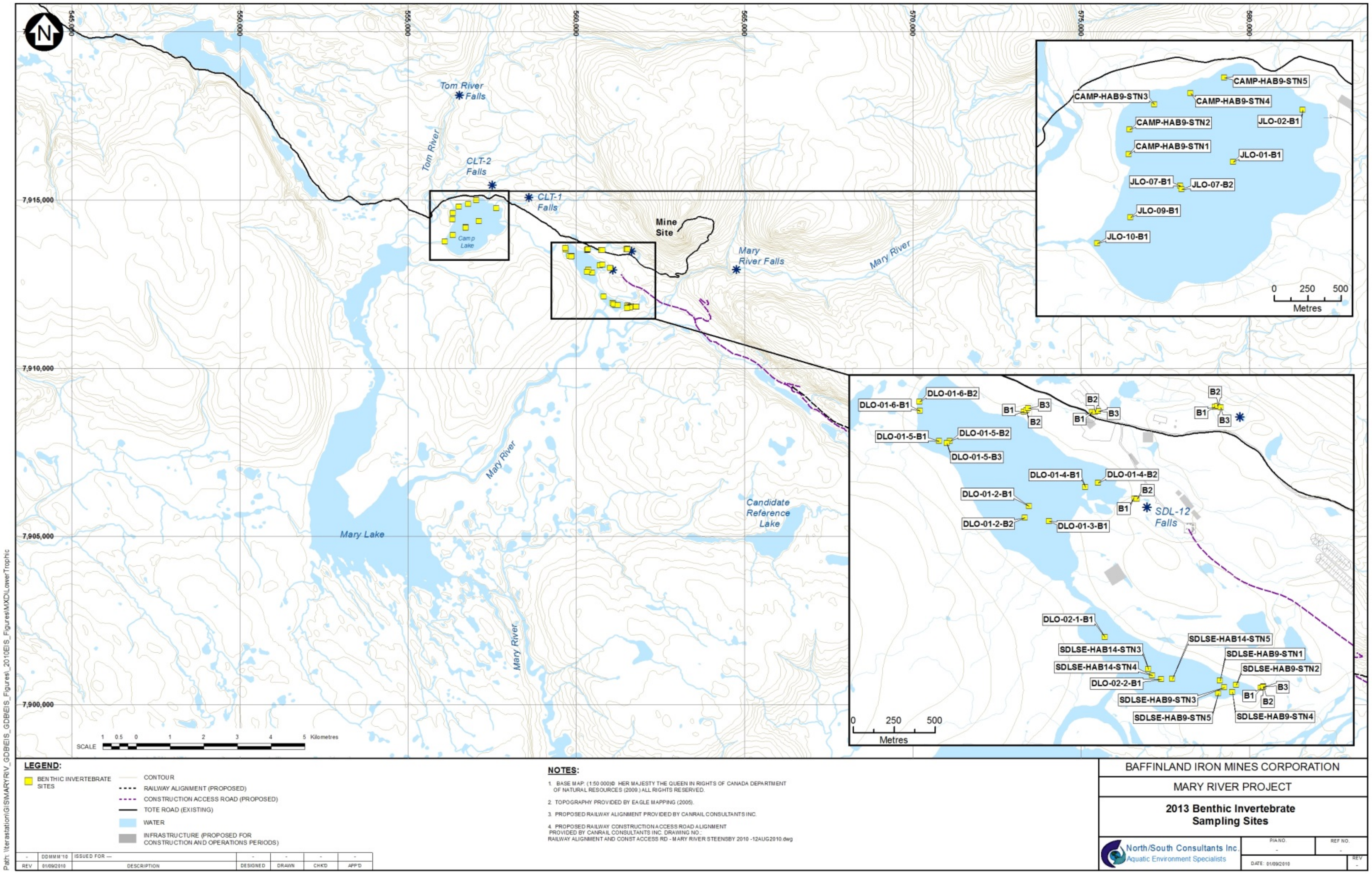


Figure 3-9. Benthic invertebrate sampling sites: 2013.

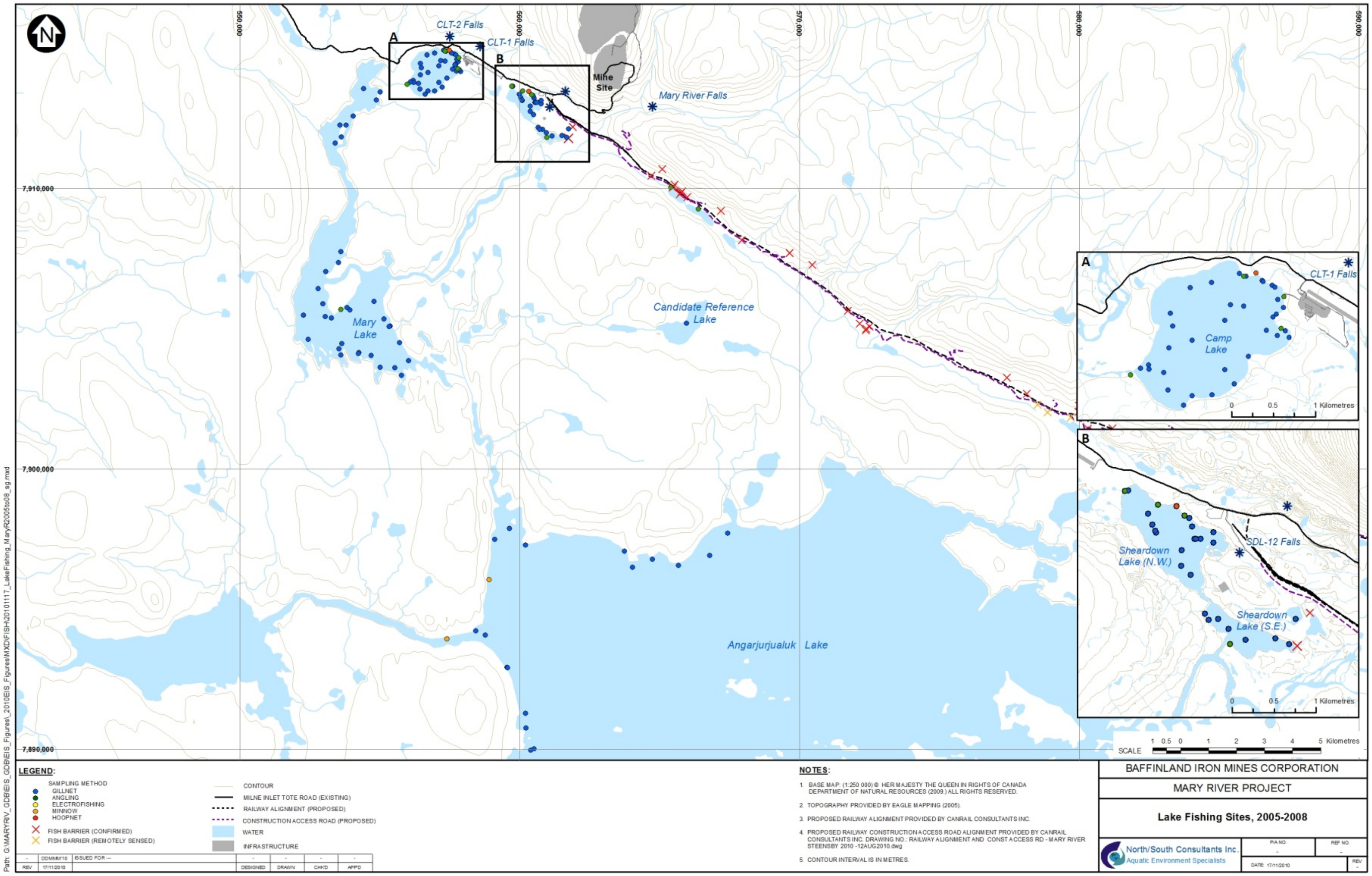


Figure 4-1. Fish sampling sites in Mine Area lakes.

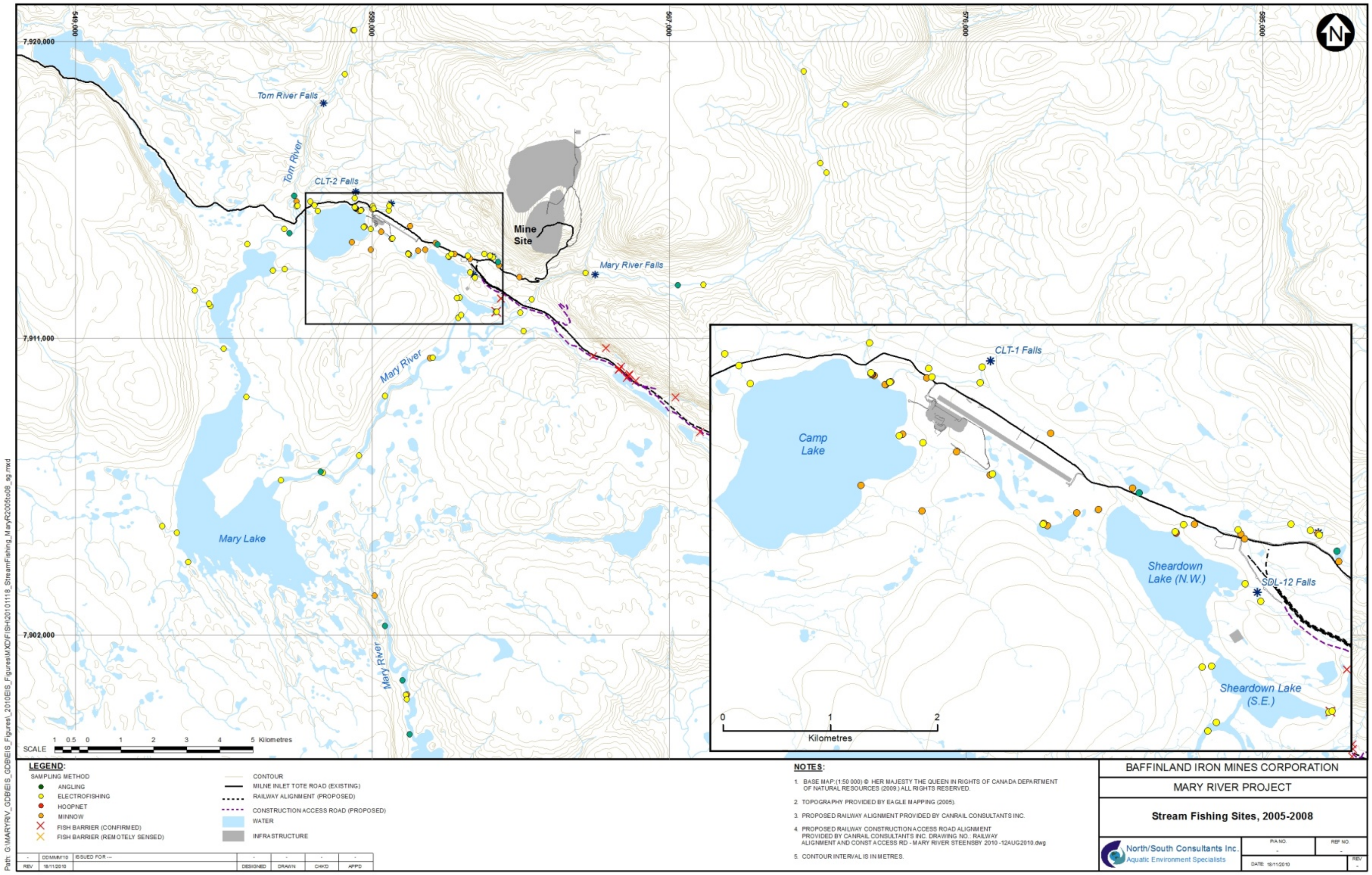


Figure 4-2. Fish sampling sites in Mine Area streams.

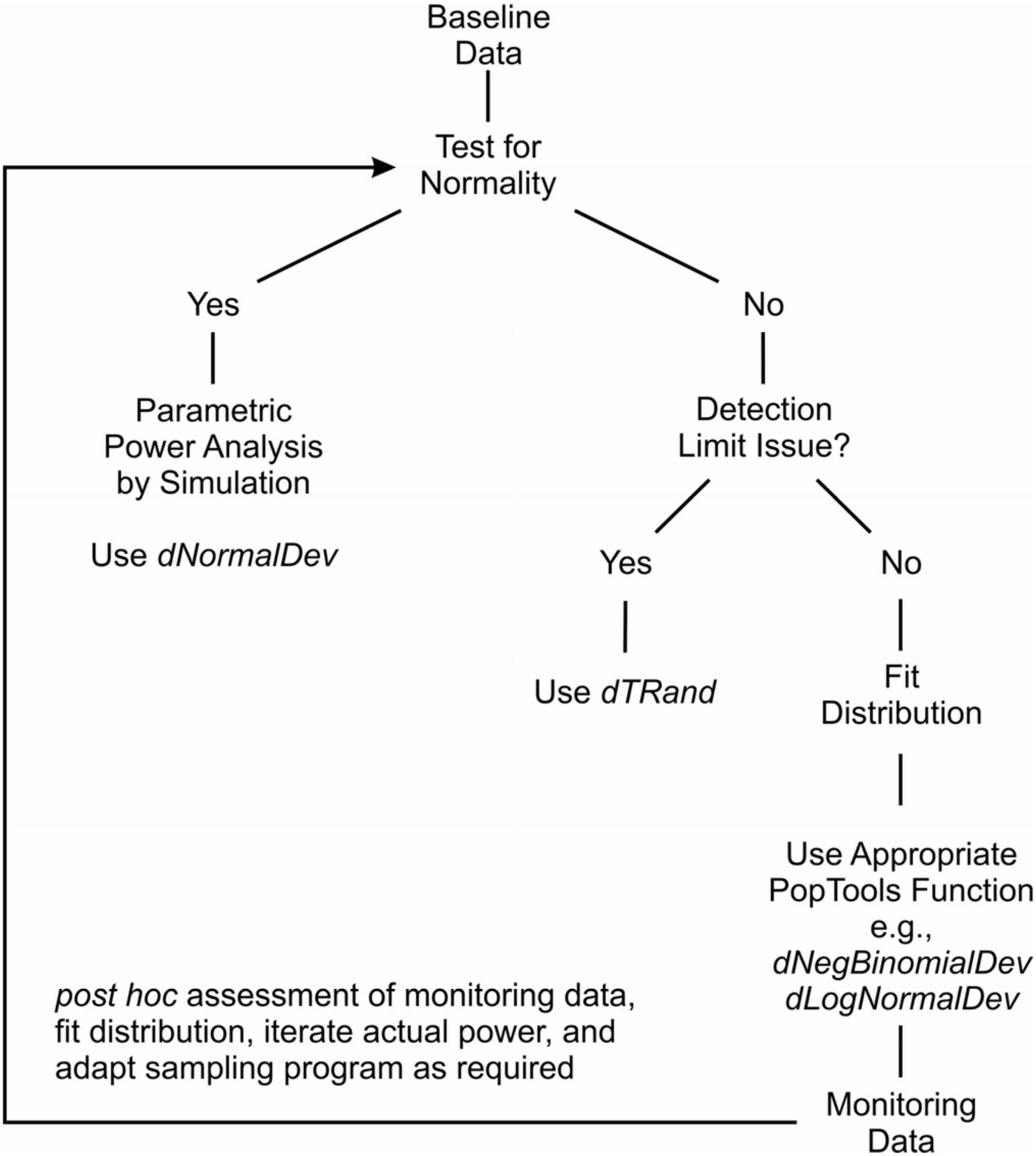


Figure 4-3. Basic treatment of baseline data for power analysis by simulation. The *post hoc* assessment of monitoring data allows for more precise assessment of power and any adaptive decisions to the sampling program that arise.

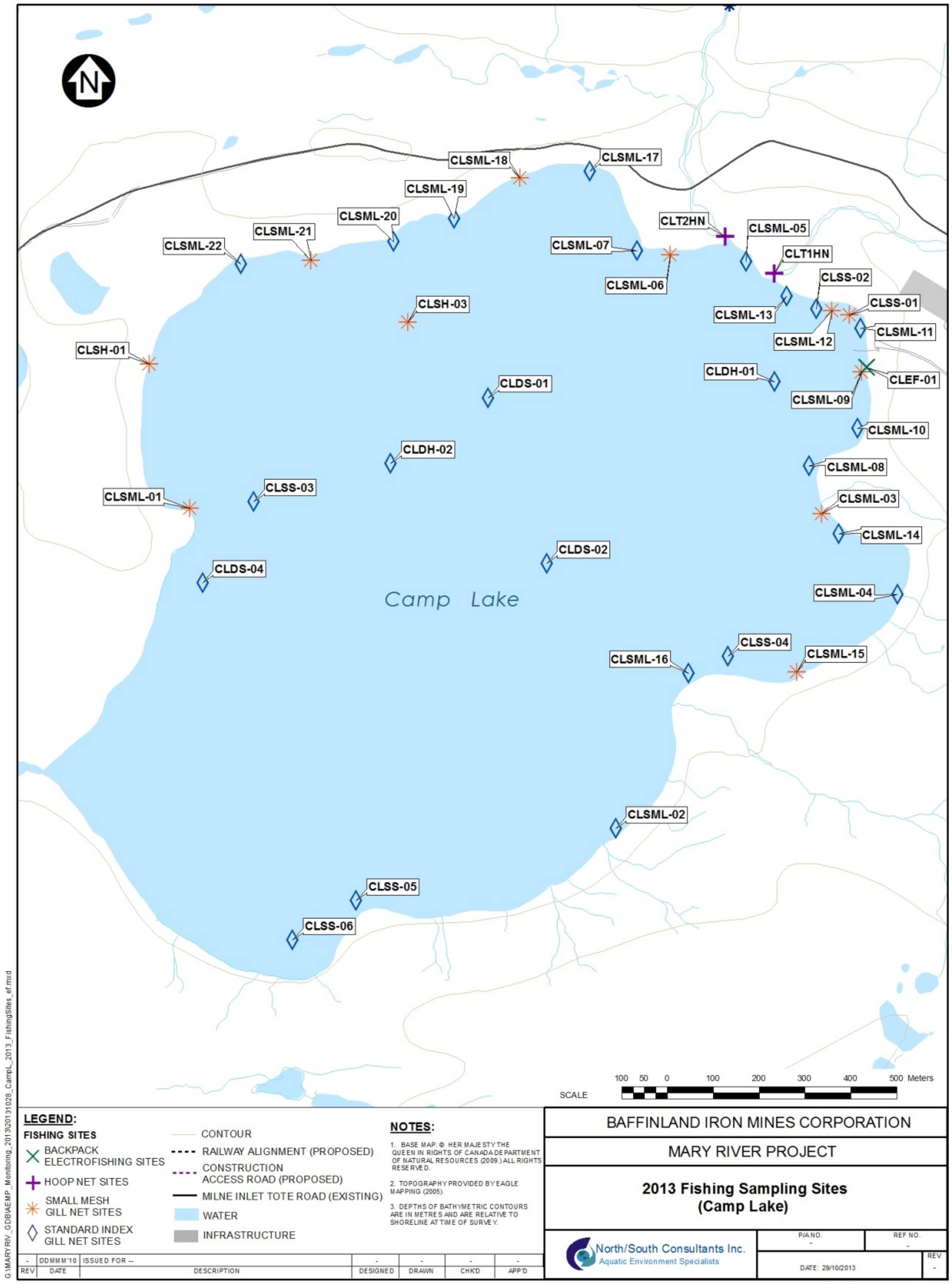


Figure 4-4. Fish sampling locations in Camp Lake: 2013.

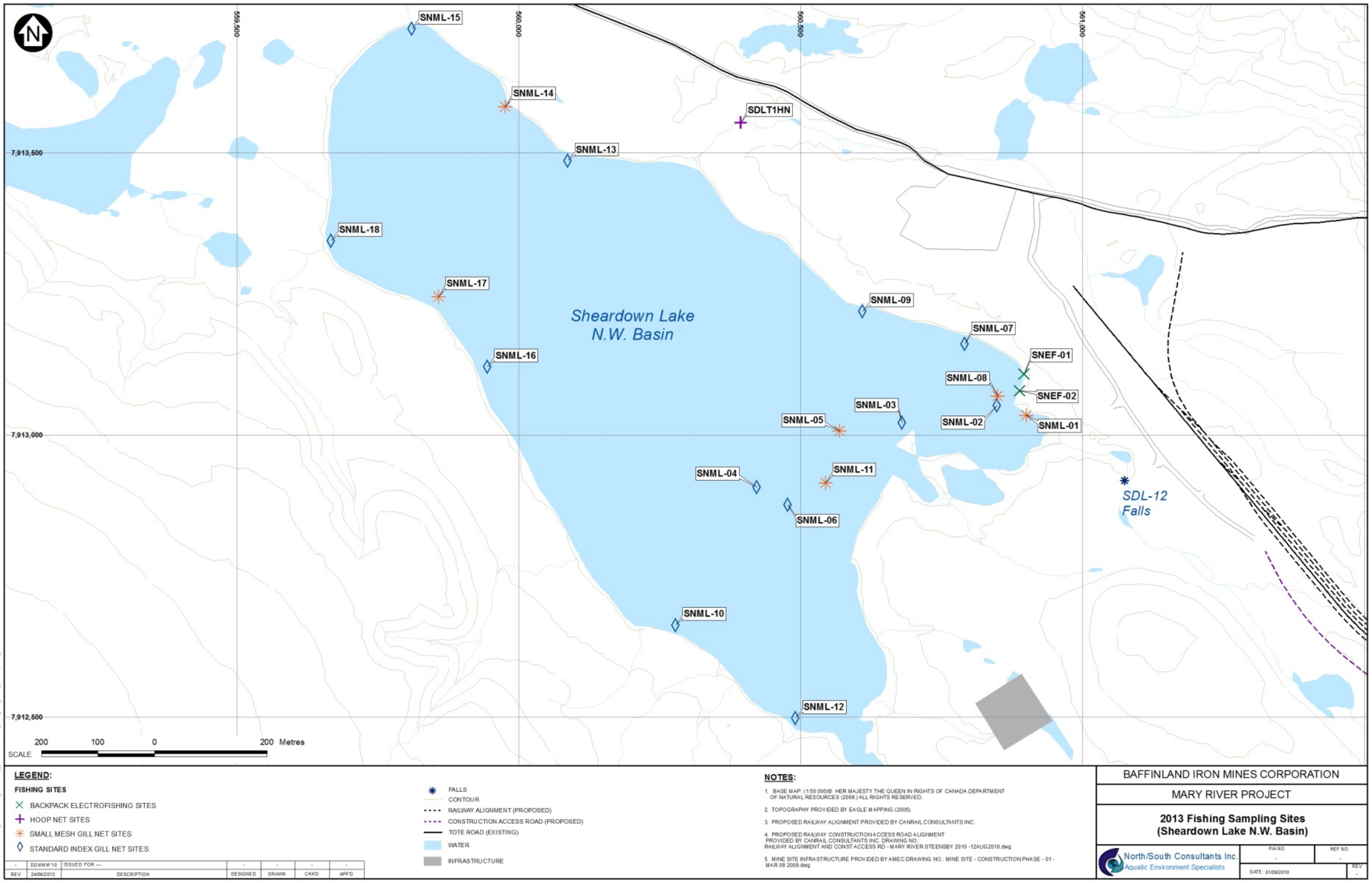


Figure 4-5. Fish sampling locations in Sheardown Lake: 2013.