

Parameter	Unit (Dry Weight)	Guidelines		Annual Summary								
		ISQG	PEL	2016								
				Median	Mean*	Minimum	Maximum	Standard Deviation	Standard Error	Count	% Above Guideline	
											I	P
Potassium	µg/g	-	-	1,250	1,243	466	2,120	435	97	15	-	-
Selenium	µg/g	-	-	0.57	0.5	<0.2	0.94	0.23	0.052	15	-	-
Silver	µg/g	-	-	<0.1	-	<0.1	0.1	-	-	15	-	-
Sodium	µg/g	-	-	210	181	<100	260	54	12	15	-	-
Strontium	µg/g	-	-	18	16	7.7	23	4.8	1.1	15	-	-
Thallium	µg/g	-	-	0.13	0.12	<0.05	0.2	0.043	0.010	15	-	-
Tin	µg/g	-	-	<2.0	-	<2.0	<2.0	-	-	15	-	-
Titanium	µg/g	-	-	442	426	233	631	104	23	15	-	-
Uranium	µg/g	-	-	1.6	1.5	0.51	2.4	0.6	0.13	15	-	-
Vanadium	µg/g	-	-	31	29	11	47	10	2.3	15	-	-
Zinc	µg/g	123	315	45	39	13	55	13	2.8	15	-	-
Sulfur	µg/g	-	-	1,460	2,053	120	5,350	1,515	339	15	-	-
Bismuth	µg/g	-	-	<0.2	-	<0.2	<0.2	-	-	15	-	-
Particle Size And Moisture												
Grain size, 0.002-0.05 mm	%	-	-	33	31	6.3	50	15	3.3	15	-	-
Grain size, less than 0.002 mm	%	-	-	7	6	0.1	12	3.9	0.87	15	-	-
Grain size, 2-5 mm	%	-	-	62	63	41	93	18	4.1	15	-	-

Bolded values are higher than sediment quality guidelines.

(I) = value higher than the Interim Sediment Quality Guideline.

Sediment quality data shown in this table were rounded to reflect laboratory precision after comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Measured concentrations equal to the guideline values were not identified as exceedances.

- = no guideline or data.

* Means were calculated by replacing non-detect values with the detection limit. Means of parameters with > 50% non-detect values were not calculated.

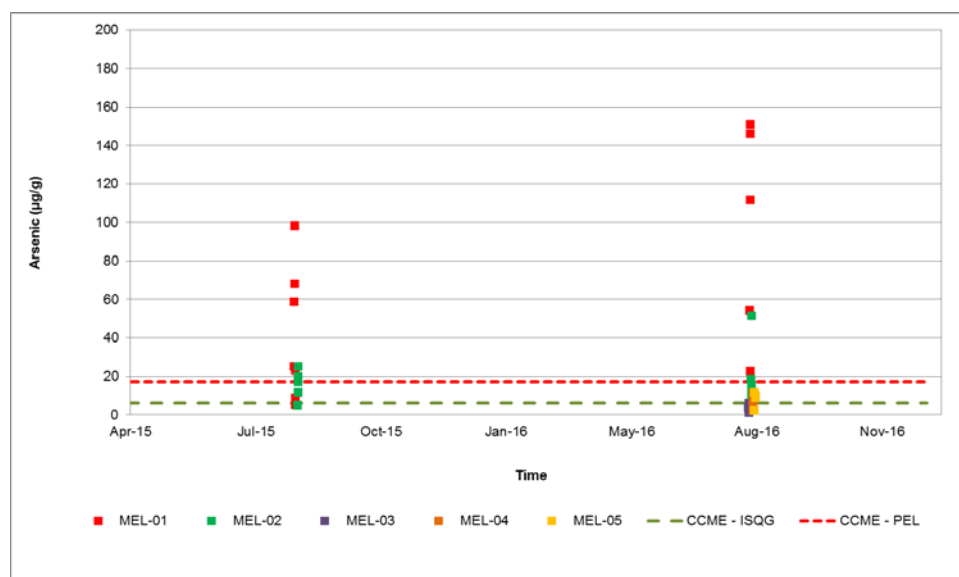


Figure 4.3-2: Arsenic in Sediment Samples from Meliadine Lake

µg/g = micrograms per gram (dry weight); ISQG = Interim Sediment Quality Guidelines; PEL = Probable Effects Level.

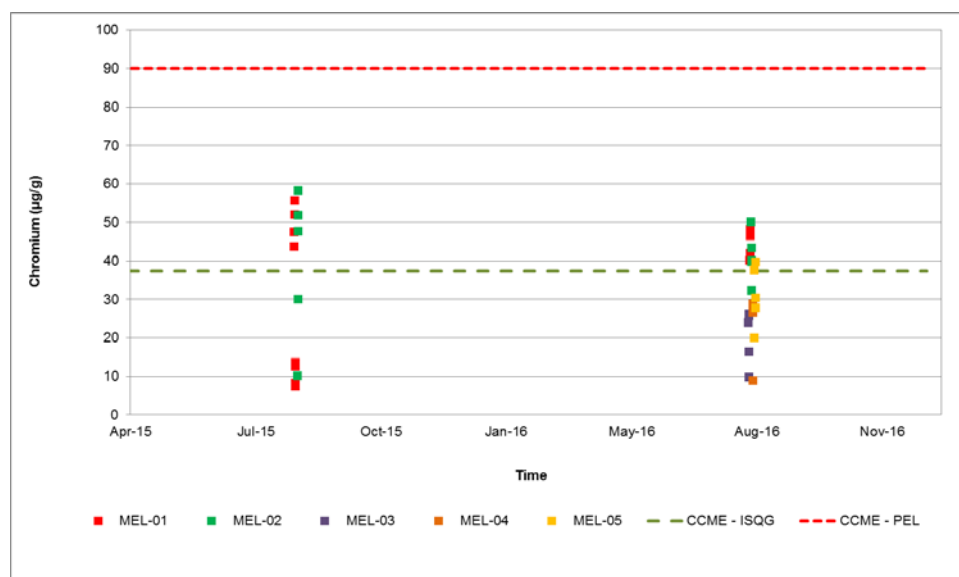


Figure 4.3-3: Chromium in Sediment Samples from Meliadine Lake

µg/g = micrograms per gram (dry weight); ISQG = Interim Sediment Quality Guidelines; PEL = Probable Effects Level.

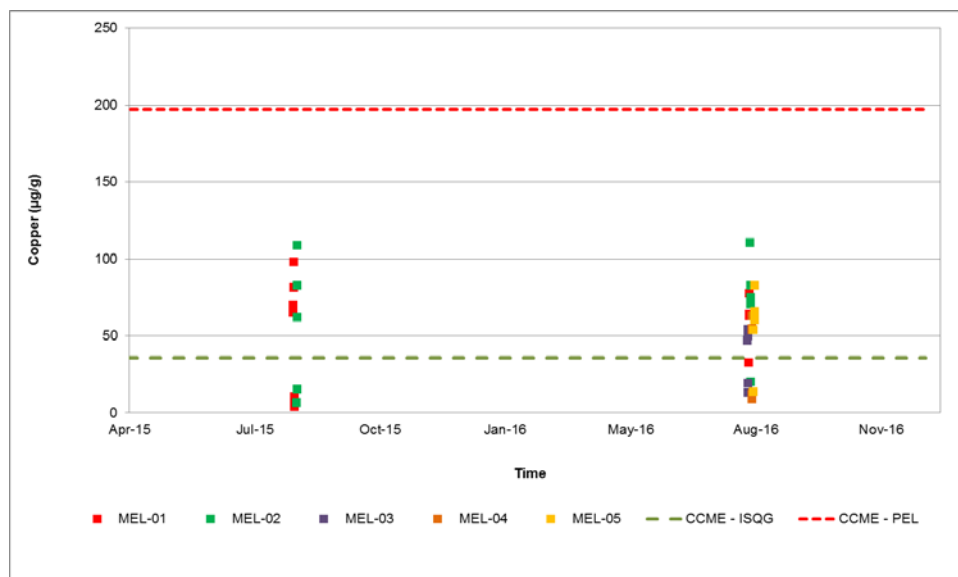


Figure 4.3-4: Copper in Sediment Samples from Meliadine Lake

µg/g = micrograms per gram (dry weight); ISQG = Interim Sediment Quality Guidelines; PEL = Probable Effects Level.

4.3.2 Between Area Comparison

In the Meliadine Lake sediment quality dataset, it was identified that there is a significant relationship between sediment grain size and concentration of total organic carbon and metals (Table 4.3-4). To reduce confounding factors of fine sediments or TOC on sediment chemistry results, sediment datasets are often normalized for a physical grain size category (Furness 1990; Bianchi et al. 1999). All subsequent statistical analyses were completed on the grain-size normalized dataset.

Table 4.3-4: Linear regression of Sediment Quality parameters to fine grained sediments in Meliadine Lake

Parameter	R-squared	P-value
Total organic carbon	0.424	<0.001
Aluminum	0.669	<0.001
Antimony	-	-
Arsenic	0.475	<0.001
Barium	0.669	<0.001
Beryllium	0.720	<0.001
Bismuth	-	-
Boron	0.316	<0.001
Cadmium	0.680	<0.001

Parameter	R-squared	P-value
Calcium	0.000	<0.001
Chromium	0.673	<0.001
Cobalt	0.759	<0.001
Copper	0.475	<0.001
Iron	0.536	<0.001
Lead	0.771	<0.001
Lithium	0.653	<0.001
Magnesium	0.640	<0.001
Manganese	0.548	<0.001
Mercury	0.651	<0.001
Molybdenum	0.619	<0.001
Nickel	0.804	<0.001
Potassium	0.748	<0.001
Selenium	0.759	<0.001
Silver	-	-
Sodium	0.818	<0.001
Strontium	0.549	<0.001
Sulfur	0.358	<0.001
Thallium	0.695	<0.001
Tin	-	-
Titanium	0.640	<0.001
Uranium	0.741	<0.001
Vanadium	0.630	<0.001
Zinc	0.614	<0.001

P-value = probability value; < = less than; - = more than 50% of data was below detection limits and data analyses were not performed.

Analyses were completed to determine if there were statistical differences between sediment chemistry (before normalization to grain size) in the Near-field versus Mid-field, Near-field versus pooled reference areas, and Mid-field versus pooled reference areas; results of these comparisons are provided in (Table 4-3.5). When data were normally distributed an ANOVA was performed; when data could not fit a normal distribution, a Kruskal-Wallis was performed. Antimony, bismuth, boron, silver and tin could not be tested due to large number of results below DLs.

Results for most parameters were significant at $p < 0.05$ (Table 4.3-5), meaning that there were significant differences between groups. Reference areas had significantly greater concentrations of sand than Near-field area, the Near-field area is significantly enriched in silt, whereas clay did not differ between the groups. Comparisons between Mid-field and reference areas for particle size parameters were not significant.

Even after normalization of sediment chemistry to fraction of fine sediments, only cadmium, copper, selenium and thallium not significantly different between areas. For arsenic, iron and mercury, concentrations were higher in the Near-field area as compared to reference area, whereas total organic carbon, calcium, strontium and sulfur were higher in the reference area as compared to Near-field after normalization. For the Mid-field area, which had mean particle-size distribution similar to the reference areas, concentrations of eight metals were still higher in the Mid-field as compared to the reference areas.

The Near-field area is enriched in some sediment chemistry parameters as compared to reference areas. Only treated sewage effluent has been indirectly discharged to Meliadine Lake (i.e., sewage is discharge to a ditch approximately 60 m upstream of Meliadine Lake; Section 2.2, Figure 1.1-2) and so these results reflect pre-existing natural differences in these areas. The use of normalized results has been able to reduce the influence of fine sediments as a confounding factor, allowing for a more robust comparison.

Table 4.3-5:Pairwise Comparisons for Statistical Analyses of Sediment Quality parameters comparing areas within Meliadine Lake

Parameter	Test Performed	Overall Test P-value	NF vs MF	NF vs REF	MF vs REF	Number of Outlier Samples
Particle Size and Moisture						
Clay (< 0.002 mm)	ANOVA / Tukey	0.211	-	-	-	-
Silt (0.002-0.05 mm)	ANOVA / Tukey	<0.001	0.003	<0.001	0.736	-
Sand (2-5 mm)	ANOVA / Tukey	0.001	0.016	0.001	0.609	-
Carbon Content ^(a)						
Total organic carbon	ANOVA / Tukey	0.029	0.131	0.025	0.832	-
Total Metals ^(a)						
Aluminum	KW / WRS	0.014	0.009	0.213	0.147	1
Antimony	-	-	-	-	-	-
Arsenic	KW / WRS	<0.001	0.015	<0.001	0.004	-
Barium	ANOVA / Tukey	0.033	0.027	0.162	0.54	1
Beryllium	KW / WRS	0.014	0.001	0.32	0.32	-
Bismuth	-	-	-	-	-	-
Boron	-	-	-	-	-	-
Cadmium	ANOVA / Tukey	0.588	-	-	-	-
Chromium	KW / WRS	0.007	0.003	0.437	0.044	1
Cobalt	KW / WRS	0.019	0.55	0.12	0.020	1
Copper	ANOVA / Tukey	0.060	-	-	-	-
Iron	KW / WRS	0.027	0.579	0.041	0.109	-
Lead	ANOVA / Tukey	0.045	0.149	0.900	0.041	-
Lithium	KW / WRS	0.01	0.003	0.112	0.285	1
Manganese	KW / WRS	0.018	0.912	0.062	0.029	-
Mercury	ANOVA / Tukey	0.018	0.927	0.029	0.071	-
Molybdenum	KW / WRS	0.027	0.189	0.338	0.025	1
Nickel	ANOVA / Tukey	0.021	0.23	0.495	0.016	1
Selenium	ANOVA / Tukey	0.409	-	-	-	-
Silver	-	-	-	-	-	-
Strontium	KW / WRS	0.003	0.003	0.009	0.567	-
Sulfur	ANOVA / Tukey	0.022	0.467	0.019	0.247	1
Thallium	KW / WRS	0.342	-	-	-	1
Tin	-	-	-	-	-	-
Titanium	KW / WRS	0.028	0.016	0.147	0.472	1
Uranium	ANOVA / Tukey	0.002	0.003	0.777	0.008	-
Vanadium	KW / WRS	0.005	0.002	0.052	0.371	1
Zinc	ANOVA / Tukey	<0.001	<0.001	0.925	0.001	1

(a) Results conducted on sediment quality normalized to fraction of fine sediments ([silt + clay]/100).
Note: **Bolded** values are significant at p <0.05.
NF = Near-field Mel-01; MF = Mid-field Mel-02; REF = Reference Areas; Tukey = Tukey’s HSD test; KW = Kruskal- Wallis test; WRS = Pairwise Wilcox Rank Sum test; < = less than; - = more than 50% of data was below detection limits and data analyses were not performed.

The presence of loamy (or fine-grained) sediments is a key factor for metal accumulation in sediments, therefore, particle size analyses and the use of normalized results to analyze differences among areas and the normal ranges of sediment quality variables are necessary for sediment chemistry assessments. The presence of a high proportion of fine sediments was likely one of the reasons why metal concentrations were higher in MEL 01-04 in 2015 and 2016. Metals also tend to bond to organic carbon present in sediment particles, nevertheless, the small variation of TOC within sediment from Meliadine Lake suggests that organic carbon will not strongly influence the concentrations of metal in the Near-field or Mid-field areas as compared to the reference areas. Based on the data collected so far, particle size appears to have a large influence on accumulation of metals in sediments in Meliadine Lake.

Arsenic is the only parameter in Meliadine Lake with concentrations above the PEL (Tables 4.3-1, 4.3-2, and 4.3-3), and is a parameter of concern within Meliadine Lake. High concentrations of arsenic in the Near-field area are elevated and significantly higher than in reference areas even after normalization. As there has been no mine effluent discharged to the lake, these represent pre-existing conditions of high spatial variability. It is common to find naturally high concentrations of arsenic associated with gold deposits (Straskraba and Moran 1990).

The presence of pre-existing elevated concentrations of parameters in the Near-field area is likely to pose some difficulty for future monitoring. The elevated results will be confounding factors that will need careful review since the Near-field area is naturally enriched in certain parameters. Hence, the use of normal ranges will be an important tool to diminish the possibility of detecting false positive effects. Assessing effects within the Mid-field area will also be key for an appropriate interpretation of mine effluent discharge.

4.3.3 Normal Range

Normal ranges were calculated following the procedure describe in Section 4.1.4 and are summarized in Table 4.3-6. To remove the confounding factor of fine grained sediments, data were normalized to the proportion of fine sediments, and data from the whole lake were included in the analyses. The widest range was for arsenic, where the upper bound was over five times greater than the lower bound. For the majority of the remaining parameters, the variation was confined to 150% to 250% between upper and lower bound.

Table 4.3-6: Normal ranges for Sediment Quality Parameters in Meliadine Lake

Parameter	Unit	Method	Lower Bound	Upper Bound	Number of Outlier Samples
Total Metals					
Aluminum	mg / kg dw Fines	logPI	13,556	27,326	1
Arsenic	mg / kg dw Fines	logPI	15.2	80.1	0
Barium	mg / kg dw Fines	PI	132	227	1
Boron	mg / kg dw Fines	logPI	6.74	18.5	1
Cadmium	mg / kg dw Fines	PI	0.32	0.74	0
Chromium	mg / kg dw Fines	logPI	53.8	102	1
Cobalt	mg / kg dw Fines	logPI	14.4	29.5	1
Copper	mg / kg dw Fines	PI	70.1	166	0
Iron	mg / kg dw Fines	logPI	27,514	76,653	0
Lead	mg / kg dw Fines	PI	11.2	22.6	0
Manganese	mg / kg dw Fines	logPI	369	986	0
Mercury	mg / kg dw Fines	PI	0.0342	0.0796	0
Molybdenum	mg / kg dw Fines	logPI	4.50	11.3	1
Nickel	mg / kg dw Fines	PI	65.9	106	1
Selenium	mg / kg dw Fines	PI	0.978	1.9	0
Strontium	mg / kg dw Fines	logPI	29.3	68.9	0
Uranium	mg / kg dw Fines	PI	3.63	6.68	0
Zinc	mg / kg dw Fines	PI	87.7	175	1

mg/kg dw = milligram per kilogram dry weight; PI = Prediction interval; logPI = log-transformed prediction interval.

5.0 BENTHIC INVERTEBRATE COMMUNITY

Benthic invertebrates (i.e., small animals with no backbones) are an integral part of Arctic ecosystem food webs, as a primary food source for fish and as secondary producers (Minshall et al 2014). They live within sediments, or on the sediment surface, for all or part of their life cycles. Benthic communities often consist of hundreds to thousands of invertebrates within a sample, and display a wide range of tolerance to contaminants, exposure conditions, and habitat types (Hauer and Lamberti 2007). The presence and abundances of specific invertebrates in the benthic invertebrate community present at a location serve as indicators of aquatic health, and can be used to evaluate effects from anthropogenic disturbances (Minshall et al 2014).

Dominant benthic invertebrates previously documented in Meliadine Lake include insects (mostly midges [Chironomidae]), mollusks (fingernail clams [Pisidiidae]), aquatic worms (Oligochaeta), and amphipods (shrimp-like crustaceans); a number of other invertebrates were also present during previous years, although less abundant (Golder 2013).

This report section provides a summary of benthic invertebrate community data collected during the 2015 and 2016 sampling programs in Meliadine Lake. Consistent with the AEMP study design for the Type A Water Licence (2AM MEL 1631, Part I, Item 3), data were collected over two years to characterize baseline (pre-discharge) conditions in exposure areas in the vicinity of the Mine and in reference areas in Meliadine Lake. The main objective of the benthic sampling programs was to collect benthic invertebrate samples to characterize pre-discharge conditions in the Near-field, Mid-field, and three reference areas in Meliadine Lake.

Specific objectives of this section are outlined below:

- assess spatial variability in 2016, by comparing benthic invertebrate communities in the Near-field and Mid-field exposure areas to the reference areas within Meliadine Lake
- evaluate temporal variability in benthic invertebrate communities sampled in the same areas in 2015 and 2016
- assess the potential influence of habitat variation within and among sampling areas, to identify potential confounding factors during future monitoring; where appropriate, consider water and sediment quality results from Sections 3 and 4 in this document
- evaluate whether it is possible to calculate representative normal ranges of variability for benthic invertebrate effect endpoints
- assess within-station variability and evaluate whether the current approach of collecting five subsamples at each station is appropriate for future monitoring
- provide recommendations for the AEMP benthic invertebrate component

5.1 Methods

5.1.1 Study Design Overview

As described by Golder (2014), the study design for monitoring benthic invertebrates in Meliadine Lake considered the requirements of MMER/EEM and alignment with other components, when possible.

The study design described by Golder (2014) included collection of composite samples at 25 stations, located in the Near-field (5 stations) and Mid-field (5 stations) exposure areas in Meliadine Lake, and in three reference areas in Meliadine Lake (Reference Areas 1, 2 and 3; 5 stations in each area) (Figure 1.1 2). The 2015 and 2016 benthic invertebrate sampling programs were harmonized with the August water and sediment sampling in Meliadine Lake. The 2015 program specifically targeted the exposure areas of Meliadine Lake, while the 2016 program was expanded to include both the exposure and reference areas of Meliadine Lake. A list of stations sampled in 2015 and 2016, and a summary of the data collected at each station are provided in Table 5.1 1.

Table 5.1-1: AEMP Baseline Benthic Invertebrate Sampling Program Summary, 2015 and 2016

Waterbody	Area	Station ID	UTM Coordinates (NAD 83, 15V)		Data Collected in 2015	Data Collected in 2016	In situ Profiles ^(a)
			Easting (m)	Northing (m)			
Meliadine Lake	Near-field Area (MEL-01)	MEL-01-01	542690	6989132	yes	yes	yes
		MEL-01-02	542665	6989282	yes	yes	yes
		MEL-01-03	542638	6988979	yes	yes	yes
		MEL-01-04	543145	6989086	yes	yes	yes
		MEL-01-05	542140	6989358	yes	yes	yes
	Mid-field Area (MEL-02)	MEL-02-01	537511	6992932	yes	yes	yes
		MEL-02-02	537093	6992642	yes	yes	yes
		MEL-02-03	537497	6992332	yes	yes	yes
		MEL-02-04	537961	6992341	yes	yes	yes
		MEL-02-05	537831	6992692	yes	yes	yes
	Reference Area 1 (MEL-03)	MEL-03-01	533317	6998541	no	yes	yes
		MEL-03-02	533256	6998671	no	yes	yes
		MEL-03-03	532962	6998844	no	yes	yes
		MEL-03-04	533628	6998672	no	yes	yes
		MEL-03-05	534001	6998272	no	yes	yes

Waterbody	Area	Station ID	UTM Coordinates (NAD 83, 15V)		Data Collected in 2015	Data Collected in 2016	In situ Profiles ^(a)
			Easting (m)	Northing (m)			
	Reference Area 2 (MEL-04)	MEL-04-01	525647	7000878	no	yes	yes
		MEL-04-02	526149	7001519	no	yes	yes
		MEL-04-03	525351	7001359	no	yes	yes
		MEL-04-04	525401	7001085	no	yes	yes
		MEL-04-05	525735	7001129	no	yes	yes
	Reference Area 3 (MEL-05)	MEL-05-01	530926	6990858	no	yes	yes
		MEL-05-02	530669	6990884	no	yes	yes
		MEL-05-03	530735	6991374	no	yes	yes
		MEL-05-04	530570	6991223	no	yes	yes
		MEL-05-05	530240	6991162	no	yes	yes

Note: No samples were collected in 2017.

a) Maximum depth, and physico chemical measurements of temperature, pH, dissolved oxygen, and specific conductivity.

b) At all of the benthic invertebrate stations in 2015 and 2016, sediment was collected for additional sediment chemistry analysis (particle size, TOC, nutrients, and metals).

UTM = Universal Transverse Mercator; NAD 83 = North American Datum 83; TOC = total organic carbon.

In both 2015 and 2016, benthic invertebrate communities were also sampled in the Peninsula Lakes to collect baseline data in these lakes; Peninsula Lake results are reported in the 2016 AEMP report (Golder 2017a) and are not summarized in this report.

5.1.2 Field Methods

Stations were selected based on similar habitat characteristics and were standardized to the extent possible by water depth (i.e., generally between 8 m and 10 m) and similar substrate characteristics (i.e., high proportion of fines) to reduce the habitat-related variability in the benthic invertebrate community data.

Benthic invertebrate samples were collected using a petite Ponar grab (15.24 × 15.24 cm; bottom sampling area of 0.0232 m²). At all stations, five subsamples were collected and sieved through a 500 µm mesh screen in the field. At the majority of the stations sampled, the five sub-samples were combined to form a composite sample from the material retained in the mesh and placed in a separate 500 mL sample bottle and preserved with 10% neutral buffered formalin. Exceptions were MEL-03-05 and MEL-05-01, in which the five individual subsamples (i.e., discrete samples) were placed in a separate 500 mL sample bottle and preserved as above. Preserved benthic invertebrate samples were shipped to Cordillera Consulting, Summerland, British Columbia, for taxonomic identification and enumeration of invertebrates.

Bottom sediment samples were taken concurrently with benthic invertebrate samples to characterize substrate composition. Environmental data and observations, such as habitat characteristics and field water quality data, were also recorded in conjunction with benthic sampling to provide supporting information. Specifically, the following information, in-situ surface water quality measurements, and habitat characteristics were recorded at each sampling station:

- sampling date
- global positioning system (GPS) coordinates, recorded as Universal Transverse Mercator (UTM)
- water depth
- presence of aquatic vegetation and algae
- field water quality measurements of water temperature, dissolved oxygen (DO), pH and specific conductivity
- photographs
- observations of the sediments for colour, consistency, and odour

At each station, three to five additional petite Ponar grab samples were collected and combined into a composite sample for sediment chemistry analysis; these samples were shipped to ALS in Edmonton, Alberta (Section 3).

5.1.3 Laboratory Methods

5.1.3.1 Benthic Invertebrate Sample Sorting, Enumeration, and Identification

Benthic invertebrate samples were initially processed to remove the preservative and remaining fine sediment. Samples with high inorganic content were elutriated to separate the organic material from the inorganic material prior to sorting. Inorganic material was checked for shelled or cased invertebrates that may have been too heavy to elutriate; this heavier material was included in the remaining sample to be sorted.

Due to the relatively low number of individuals collected during both 2015 and 2016 sampling events, subsampling was only conducted on a few samples, and the majority of samples were sorted as whole samples. Subsampling was undertaken using a Marchant box (Marchant 1989). Benthic invertebrates were identified to the genus/species level where possible. If organisms could not be identified to the species level, they were identified to the next higher taxonomic level of identification (i.e., genus, family, order, class or phylum). Further details regarding taxonomy methods are provided in the 2016 AEMP Report.

5.1.4 Data Analysis

Both field and taxonomic datasets were screened prior to analysis and adjustments were made to each dataset as described below.

- Field data were screened based on adherence to acceptability criteria for the collection of grab samples with respect to percent fullness. At three locations in 2015 (i.e., stations MEL 01 05, MEL 02 04 and MEL 02 05) there was an absence of sufficient soft, fine grained (silt and sand) depositional sediments, resulting in samples with less than 10% fullness of the petite Ponar grab. As a result, these samples were eliminated from the dataset, because they did not meet the “>60% fullness” criterion.

- Data for Nematoda and Ostracoda were removed from the data set before analysis; these are meiofauna, and are not reliably enumerated using 500 µm mesh sampling gear (Environment Canada 2012).
- Copepoda and Cladocera were excluded from the dataset before analysis because they are non benthic organisms.

5.1.4.1 *Selection of Benthic Invertebrate Summary Variables*

The following benthic invertebrate summary variables were calculated from the screened 2015 and 2016 datasets:

- total invertebrate density (number of organisms per square metre [org/m²])
- total taxonomic richness at the lowest taxonomic level (LTL) of identification and family level (number of taxa per station [taxa/station])
- Simpson's diversity index at the LTL and family level (SDI)
- Simpson's evenness index at the LTL and family level (SEI)
- Bray-Curtis Index (BCI), using the EEM method (i.e., comparisons to reference median) and the pairwise method
- community composition as percentages of major taxonomic groups
- densities of dominant invertebrates:
 - midges (Chironomidae)
 - bivalves (Pisidiidae)
 - aquatic worms (Oligochaeta)
 - gastropods (Gastropoda)
 - amphipods (Amphipoda)

Density was calculated as organisms per square metre (org/m²) for each station. This calculation was based on the bottom area of the grab sampler (0.0232 m²) multiplied by 5 (i.e., 0.116 m²) to represent the total area sampled by five grabs. Richness is the total number of taxa/station at the family level or the LTL. Richness provides an indication of the diversity of benthic invertebrates in an area; a higher richness value typically indicates a more healthy and balanced community.

For interpretation purposes, ranges in benthic invertebrate densities and LTL richness values were operationally defined as low/moderate/high based on experience with northern lakes, as documented by benthic invertebrate components of other ongoing AEMPs (i.e., 2016 Diavik AEMP Annual Report [Golder 2017b] and the 2016 DeBeers Gahcho Kue AEMP Annual Report [DeBeers 2017]. Observed density and richness values were categorized as follows:

- **low:** density less than 5,000 org/m² and LTL richness less than 10 taxa/station

- **moderate:** density ranging from 5,000 to 50,000 org/m², and LTL richness ranging from 10 to 40 taxa/station
- **high:** density greater than 50,000 org/m² and LTL richness greater than 40 taxa/station

When compared to other lake environments the range of densities described above are relatively low considering some lake environments have densities greater than 100,000 individuals per square metre (Hynes 1970; Resh and Rosenberg 1984; Rosenberg and Resh 1993).

The SDI measures the proportional distribution of organisms in the community, taking into account taxonomic richness and how evenly the total density is distributed among these taxa. Certain conditions may favour one organism over another, resulting in the community being dominated by a few taxa, which is reflected in decreased diversity (Simpson 1949). The SDI values range between zero and one, where lower values indicate a less diverse community and higher values indicate a more diverse community. The SDI was calculated using the formula provided by Krebs (Krebs 1999):

$$D = 1 - \sum_{i=1}^S (p_i)^2$$

Where:

- SDI = Simpson's diversity index
- S = the total number of taxa
- pi = the proportion of the ith taxon

The SEI is a measure of how evenly the total invertebrate density is distributed among the taxa present at the station. The SEI is included along with the SDI to provide context as to whether taxonomic richness or the distribution of total density among taxa is driving the SDI values. The SEI is also expressed as a value between one and zero, with one representing high evenness (i.e., equal numbers of all taxa present in a sample) and zero representing low evenness (i.e., a high degree of dominance by one or a few organisms). The SEI values were calculated using the following formula (Smith and Wilson 1996):

$$SEI = 1 / \sum_{i=1}^S (p_i)^2 / S$$

Where:

- SEI = Simpson's evenness index
- pi = the proportion of the ith taxon
- S = the total number of taxa

The above indices are measures of total invertebrate density and taxa richness, but they do not take into account any quantitative information of the types of organism's present. Therefore, the Bray-Curtis Index (a dissimilarity index) was calculated to compare entire communities between reference and exposure areas. The Bray-Curtis Index summarizes the overall difference in community structure between reference and exposure replicate stations (EC 2012). Bray-Curtis Index values range between 0 and 1, whereby lower values indicate that the community in the exposure area is more similar to the reference community.

As recommended by EC 2012, the Bray-Curtis Index was calculated following the method by Legendre and Legendre (1983), where the distance statistic is calculated as:

$$B - C = \frac{\sum_{i=1}^n |y_{i1} - y_{i2}|}{\sum_{i=1}^n (y_{i1} + y_{i2})}$$

Where:

- B-C = Bray-Curtis distance between sites 1 and 2
- Y_{i1} = count for taxon i at site 1
- Y_{i2} = count for taxon i at site 2
- n = total number of taxa present at the two sites

Bray Curtis index values have historically been calculated by comparing the benthic community of each station to the median reference area community (using pooled reference area data). This method (abbreviated to BCI-EEM in this document) is recommended by the technical guidance document for metal mining EEM (Environment Canada 2012). Huebert et al. (2011) pointed out that using the reference median value as the basis for calculating Bray Curtis distance values would result in frequently finding effects where none exist, referred to as a Type I error. To correctly calculate Bray Curtis distance, Huebert et al. (2011) recommended that pairwise, among area comparisons of individual reference and exposure stations be conducted to generate Bray Curtis distance values for statistical comparisons.

During the 2015 and 2016 AEMP baseline studies, Bray Curtis distance values were also calculated using the "pairwise comparisons" method (abbreviated to BCI-PW in this document), which for replicated reference areas includes comparing the each reference area station to all stations in the other two reference areas and calculating the mean BCI (to estimate background among-area variation), and comparing each exposure station to all reference stations and calculating the mean BCI. To allow results of the baseline AEMPs to be compared to future AEMP results, Bray Curtis distances for 2015 and 2016 were calculated using both the pairwise and the EEM methods.

5.1.4.2 Evaluation of the Effects of Habitat Variation

A spearman rank correlation analysis was used to test the strength of relationships between selected habitat variables and benthic invertebrate community variables. Spearman rank correlation coefficients were calculated using SYSTAT Version 13.0 (Systat Software Inc., Chicago, IL). Thresholds for statistical significance of $P < 0.05$, $P < 0.01$, and $P < 0.001$ were applied to identify significance of correlations. Results of the correlation analysis were used to evaluate whether habitat variation may have been a confounding factor, potentially influencing statistical comparisons of sampling areas.

5.1.4.3 Characterization of Within Station Variability in Benthic Community Variables

To characterize within-station variability, discrete samples were collected from station MEL-01-05 in the Near-field area and station MEL-03-01 in Reference area 1. At each of these stations, five subsamples were collected and sorted separately from one another. The percent standard error (%SE), which is the SE expressed as the percentage of the mean of the five samples was calculated for each station, for total invertebrate abundance and richness. Station data with %SE values of $< 20\%$ were considered to be typical of within-station variability in benthic invertebrate communities based on Elliott (1971).

5.1.4.4 Statistical Analysis

5.1.4.4.1 Approach

Using the 2016 data, the benthic invertebrate community variables were compared among sampling areas using statistical tests. The following is an overview of the three comparisons completed:

- 1) Near-field and Mid-field areas compared to the mean of the three reference areas (AEMP “effect” comparisons)
- 2) Pairwise comparisons of reference areas (exploratory comparisons to evaluate similarity of the three reference areas)
- 3) Comparisons of Near-field and Mid-field areas to individual reference areas (exploratory comparisons to evaluate suitability of individual reference areas)

The 2015 data for the exposure areas are presented in this report, but were not included in the statistical analysis, which focussed on spatial comparisons between exposure and reference areas, which were both sampled in 2016.

Data were analyzed using Analysis of Variance (ANOVA) or the equivalent non-parametric Kruskal-Wallis test, depending on whether the assumptions of normality and equal variances were met for parametric testing. Calculations and statistical summaries were performed using Excel 2013 for Windows. Statistical tests were performed using SYSTAT 13.1 for Windows (Systat Software 2009).

5.1.4.4.2 Testing Assumptions of Analysis of Variance

The assumptions for parametric tests were verified using the Shapiro-Wilk test for normality and Levene's test for homogeneity of variances on untransformed and log-transformed data for density variables, at $P < 0.05$. Data were transformed where significant normality or equality of variance violations were found and the effectiveness of the transformations was verified.

For most community variables, parametric test assumptions were met by untransformed data; therefore, analysis proceeded using ANOVA. Exceptions are described below.

- Lowest taxonomic level evenness, chironomid, oligochaete, and gastropod density, and lowest taxonomic level BCI were log transformed to meet the assumption of normality. For some samples, the original data had zero values, so the data were $\log(x+1)$ transformed.
- Even after transformation of the data, family level richness and amphipod density did not meet the assumptions of parametric test; therefore these variables were analyzed using the Kruskal-Wallis test.

5.1.4.4.3 Analysis of Variance (ANOVA) and Multiple Comparisons

To complete comparison 1, means of all sampling areas were initially compared to one another in an overall ANOVA. If a significant difference was found, the Near-field and Mid-field areas were compared to the reference areas within the overall ANOVA, as a priori comparisons (i.e., planned contrasts). Multiple comparison techniques that were not planned prior to undertaking the analysis (i.e., a posteriori) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear contrasts by formulating meaningful comparisons among sampling areas prior to conducting the study and outlining these in a study design. This approach was used here to test for differences between the Near-field and Mid-field areas and the mean of the three reference areas as two separate contrasts. To control the probability of Type I error during these contrasts, the Dunn-Šidák correction was applied to account for the two contrasts. Results of these comparisons were considered significant at $P < 0.1$ for the overall ANOVA, and at $P < 0.051$ for the planned contrasts.

A similar approach was used for comparison 2, intended to assess natural variability in benthic community variables among reference areas. The three reference areas sampled in 2016 were compared to one another in a pairwise manner after an overall ANOVA, using three separate contrasts. The Dunn-Šidák correction was applied to account for the three contrasts. Results of these comparisons were considered significant at $P < 0.1$ for the overall ANOVA, and at $P < 0.035$ for the planned contrasts.

The Near-field and Mid-field areas were compared to individual reference areas (comparison 3) using a pairwise comparisons approach. These comparisons were considered unplanned (i.e., a posteriori), and were exploratory in nature. The procedure used for these comparisons was an overall ANOVA with significance evaluated at $P < 0.1$, followed by Tukey's honestly significant difference (HSD) method for pairwise combinations of sampling areas. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, a P-value of 0.1 was used for these tests to evaluate significance.

5.1.4.4.4 Kruskal-Wallis Test and Multiple Comparisons

The Kruskal-Wallis test was used to test for differences among sampling areas for variables that did not meet parametric test assumptions. A similar approach was taken to that described for ANOVA. Upon finding a significant overall difference, additional Kruskal-Wallis tests were conducted to test for differences between the Near-field or Mid-field area and the pooled reference areas. Kruskal-Wallis tests were considered significant at $P < 0.1$. Where pairwise comparisons were required a posteriori, the Dwass-Steel-Critchlow-Fligner test was used. This test uses pairwise rankings and is a non-parametric alternative to Tukey's HSD test, and employs the experiment-wise error rate for the Type I error. Therefore, a P-value of 0.1 was used for these tests to evaluate significance.

5.1.4.4.5 Multivariate Analysis

Benthic invertebrate community structure was summarized using non-metric multidimensional scaling (nMDS) (Clarke 1993). An overall one-way analysis of similarities (ANOSIM) test was carried out on the Bray-Curtis resemblance matrix to confirm interpretation of the separation of the points on the MDS ordination plot and to confirm differences in community composition observed in the nMDS ordination plots were significant. In addition, an area-level ANOSIM was carried out on the Bray-Curtis resemblance matrix to test differences between areas contrasted with differences among replicates within each area (Clarke et al. 2014). An R-statistic ranging from 0 to 1 is produced by the analysis; a strong difference in community composition is indicated by $R = 1$ and no difference between communities is indicated by $R = 0$. Significance of the R statistic was achieved when a P-value of <0.05 was observed, based on the five replicates per area. The analysis was run in PRIMER 7.0.11 (Clarke and Gorley 2016).

Lower stress values (i.e., <0.15) indicate less deviation and a greater goodness-of-fit (Clarke 1993). Points that fall close together on the nMDS ordination plot represent stations with similar community composition; points that are far apart from each other represent stations with dissimilar community composition.

5.2 Quality Assurance and Quality Control

The QA/QC practices applied during this study and detailed results of the QC analyses are provided in the 2016 AEMP Report (Golder 2017a, Appendix 4A). Quality assurance (QA) components of the program included the use of trained personnel and a recognized taxonomist; QC components included assessments of assessments of replicate samples. A summary of key QC results is provided below. QA/QC

- Key QC findings for the 2015 and 2016 benthic invertebrate monitoring programs are as follows:
- Grab fullness was evaluated and only data from the analysis of samples where grabs were at least 60% full were included in the data analysis as per Golder's internal Technical Procedures (unpublished file information).
- Sorting efficiency was considered acceptable for the three samples tested (ranged between 91% and 100%) (EC 2012).
- Subsampling efficiency for the 2016 samples was considered acceptable, because the total abundance based on the subsample was within 20% of the total organism count (EC 2012).

- Within-station variability of benthic invertebrate community variables evaluated in 2015 and 2016 for Meliadine Lake and the peninsula lakes was considered acceptable based on the results of the QC assessment (Golder 2017a). In summary, the range in %SE values for total abundance (15% to 40%) was higher than the range for richness (9% to 28%) indicating that within-station variability was greater for abundance compared to richness. However, the %SE ranges were within the range considered to be typical for benthic studies by Elliott (1971) and were indicative of reasonable precision for lakes characterized by low benthic invertebrate density and richness. Variability among benthic invertebrate subsamples and stations were explored further in Section 5.1.13.

Based on this assessment, the benthic invertebrate monitoring data are considered adequate to meet the needs of the AEMP for the Project.

5.3 Results and Discussion

5.3.1 Supporting Habitat Variables

Habitat data for all sampling stations sampled in 2015 and 2016 are summarized in Table 5.3-1 and Figure 5.3-1. Detailed habitat data and summary statistics are presented in Appendix 5A, Table 5A-1. Additional water and sediment quality data collected at these stations are provided in the Sections 2.3 and 3.3, respectively.

The following observations were made from a review of the habitat data collected in 2015 and 2016.

- Conductivity and temperature values at the time of benthic invertebrate sampling were similar among stations and between years. Slightly higher water temperatures were recorded in 2016 at stations in Reference areas 2 and 3 compared to those in Reference area 1.
- Total organic carbon (TOC) and sediment particle size distribution data collected at stations sampled for benthic invertebrates were spatially variable within and among areas, with some variability between years:
 - TOC at the Near-field stations averaged 5.2% in 2015 and 4.5 % in 2016. TOC at the Mid-field stations averaged 7.8% in 2015, and 4.6% in 2016. Mean TOC for the Reference Areas in 2016 ranged from 2.5% to 5.0% (Table 5.3-1). These ranges indicate generally low variability in TOC among areas and between years.
 - Substrates sampled in the Near-field area had a higher proportion of fine sediments (i.e., silt and clay) and less sand compared to samples taken from the 2016 Mid-field and Reference areas that were either predominantly sand or a combination of sand and silt (Figure 5.3-1). These results suggest that differences between Near-field area communities relative to other sampling areas are likely based on habitat variation alone, which may act as a confounding factor during future AEMP comparisons intended to evaluate the effects of the mine discharge.

Table 5.3-1: Summary of Mean Habitat Variables for Meliadine Lake, August 2015 and 2016

Area	Year	Station Depth	Field Water Quality ^(b)		Sediment Composition			
			Conductivity	Temperature	TOC	Sand	Silt	Clay
		(m)	(μ S/cm)	(°C)	(%)	(%)	(%)	(%)
Near-field Area (MEL-01)	2015 ^(a)	8.8	67.5	12.6	5.2	23.8	69.3	7.0
	2016	8.4	72.8	12.5	4.5	18.0	69.9	12.0
Mid-field Area (MEL-02)	2015 ^(a)	9.3	66.0	12.8	7.8	34.9	55.4	9.7
	2016	9.1	68.8	12.6	4.6	54.0	34.7	11.3
Reference Area 1 (MEL-03)	2016	8.4	65.6	12.6	3.7	62.3	32.3	5.4
Reference Area 2 (MEL-04)	2016	9.0	66.2	13.5	2.5	63.5	30.2	6.3
Reference Area 3 (MEL-05)	2016	9.0	68.0	13.5	5.0	62.6	31.1	6.4

a) Some 2015 sites were removed from the analysis due to insufficient grab volumes (<60% fullness) as described in Section 4.2.4.1.

b) Field water quality measurements represent the bottom conditions.

m = metre; μ S/cm = microSiemens per centimetre; °C = degree Celsius; % = percent; TOC = total organic carbon; = no data available.

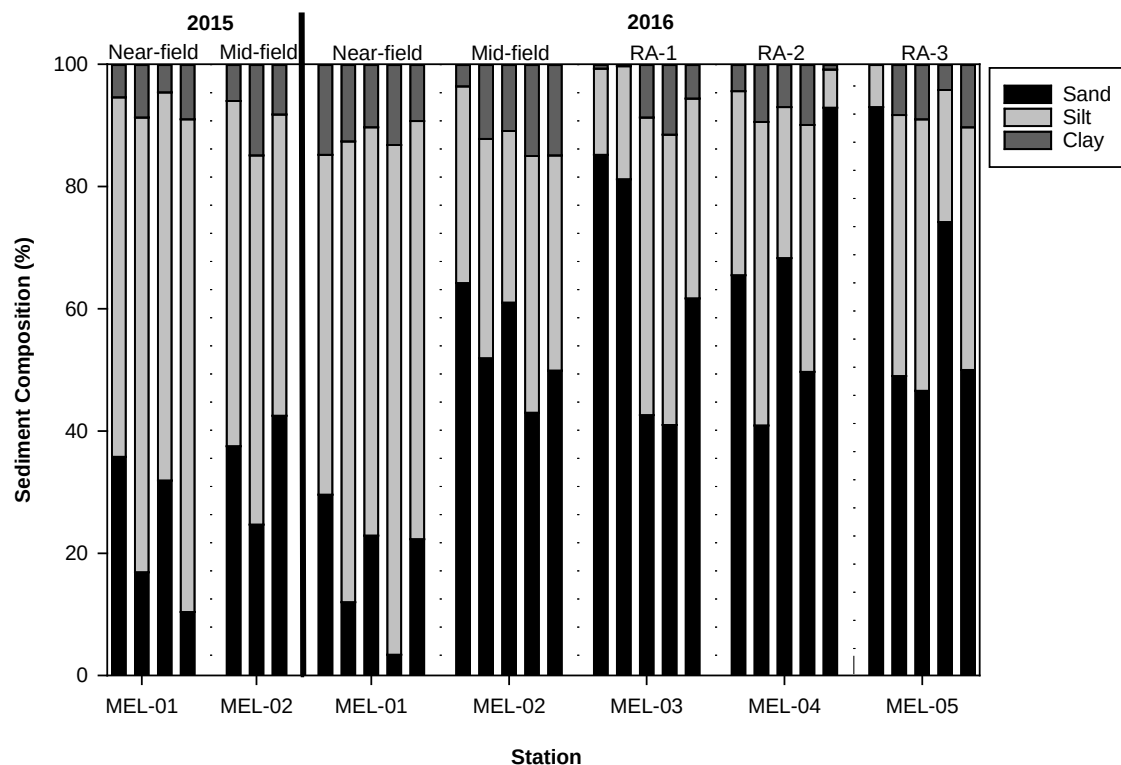


Figure 5.3-1: Sediment Particle Size Comparison for Meliadine Lake, August 2015 and 2016

5.3.2 Benthic Invertebrate Community

Raw benthic invertebrate abundance data, presence/absence data, and a summary of the benthic invertebrate community variables calculated from the raw data are presented in Appendix 5A, Tables 5A-2 to 5A-5.

Summaries of statistical comparisons for the benthic community variables between the 2016 exposure and reference areas are presented in Table 5.3 2 to Table 5.3 4 and are discussed further below.

Table 5.3-2: Results of Analysis of Variance for Benthic Invertebrate Community Variables Comparing Near-field and Mid-field Areas to Reference Areas in Meliadine Lake, August 2016

Variable	Transformation	Statistical Test	Overall Comparison	Near-field Area (MEL-01) vs. Reference Areas ^(a)	Mid-field Area (MEL-02) vs. Reference Areas
			<i>P</i>	<i>P</i>	<i>P</i>
Total Density	None	ANOVA	0.002	0.001	0.300
Richness - Family Level	None	Kruskal-Wallis	0.095	0.312	0.388
Richness - LTL	None	ANOVA	0.041	0.056	0.201
SDI - Family Level	None	ANOVA	0.038	0.377	0.644

Variable	Trans- formation	Statistical Test	Overall Comparison	Near-field Area (MEL-01) vs. Reference Areas ^(a)	Mid-field Area (MEL-02) vs. Reference Areas
			<i>P</i>	<i>P</i>	<i>P</i>
SDI - LTL	None	ANOVA	0.947	-	-
SEI - Family Level	None	ANOVA	<0.001	0.544	0.107
SEI - LTL	log(x)	ANOVA	0.102	-	-
BCI-EEM - Family Level	None	ANOVA	0.565	-	-
BCI-EEM - LTL	log(x)	ANOVA	0.026	0.008	0.333
BCI-PW - Family Level	None	ANOVA	0.843	-	-
BCI-PW - LTL	None	ANOVA	0.624	-	-
Chironomid Density	log(x)	ANOVA	0.001	0.052	0.212
Bivalve Density	None	ANOVA	0.211	-	-
Oligochaete Density	log(x+1)	ANOVA	0.131 / 0.013	- / 0.061	- / 0.006
Gastropod Density	log(x+1)	ANOVA	0.404	-	-
Amphipod Density	None	Kruskal-Wallis	0.971	-	-

LTL = lowest taxonomic level; SDI = Simpson's diversity index; SEI = Simpson's evenness index; BCI = Bray-Curtis index; BCI-EEM = BCI calculated according to EEM methods; BCI-PW= BCI calculated according to the pairwise method.

(a) Reference Areas refers to an average of MEL-03, MEL-04 and MEL-05.

Note: P-values representing significant differences are bolded (overall ANOVA comparisons: $P < 0.1$, contrasts: $P < 0.051$; overall Kruskal-Wallis comparisons and contrasts: $P < 0.1$). Multiple P-values indicate ANOVA results with / without outliers.

Table 5.3-3: Results of Analysis of Variance for Benthic Invertebrate Community Variables Comparing Reference Areas in Meliadine Lake, August 2016

Variable	Trans-formation	Statistical Test	Overall Comparison	Reference Area 1 (MEL-03) vs. Reference Area 2 (MEL-04)	Reference Area 1 (MEL-03) vs. Reference Area 3 (MEL-05)	Reference Area 2 (MEL-04) vs. Reference Area 3 (MEL-05)
			<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>
Total Density	None	ANOVA	0.039 / 0.102	0.017 / -	0.047 / -	0.587 / -
Richness - Family Level	None	ANOVA	0.029	0.009	0.147	0.147
Richness - LTL	None	ANOVA	0.159	-	-	-
SDI - Family Level	None	ANOVA	0.031	0.011	0.056	0.400
SDI - LTL	None	ANOVA	0.792	-	-	-
SEI - Family Level	None	ANOVA	0.001	<0.001	0.029	0.018
SEI - LTL	None	ANOVA	0.185	-	-	-
BCI-EEM - Family Level	None	ANOVA	0.525	-	-	-
BCI-EEM - LTL	log(x)	ANOVA	0.134	-	-	-
BCI-PW - Family Level	None	ANOVA	0.615	-	-	-
BCI-PW - LTL	None	ANOVA	0.723	-	-	-
Chironomid Density	None	ANOVA	0.022 / 0.039	0.010 / 0.014	0.031 / 0.062	0.539 / 0.387
Bivalve Density	None	ANOVA	0.343 / 0.145	-	-	-
Oligochaete Density	log(x+1)	ANOVA	0.487 / 0.124	-	-	-
Gastropod Density	log(x+1)	ANOVA	0.433 / 0.089	- / 0.450	- / 0.119	- / 0.037
Amphipod Density	None	Kruskal- Wallis	0.909	-	-	-

LTL = lowest taxonomic level; SDI = Simpson’s diversity index; SEI = Simpson’s evenness index; BCI = Bray-Curtis index; BCI-EEM = BCI calculated according to EEM methods; BCI-PW= BCI calculated according to the pairwise method.
Note: P-values representing significant differences are bolded (overall ANOVA comparisons: P<0.1, contrasts: P<0.035; overall Kruskal-Wallis comparisons and contrasts: P<0.1). Multiple P-values indicate ANOVA results with / without outliers.

Table 5.3-4: Results of Analysis of Variance and Pairwise Comparison with Tukey’s HSD of Benthic Invertebrate Community Variables in Meliadine Lake, August 2016

Variable	Trans-formation	Statistical Test	Overall Comparison	Near-field Area (MEL-01) vs Reference Area 1 (MEL-03)	Near-field Area (MEL-01) vs. Reference Area 2 (MEL-04)	Near-field Area (MEL-01) vs. Reference Area 3 (MEL-05)	Mid-field Area (MEL-02) vs. Reference Area 1 (MEL-03)	Mid-field Area (MEL-02) vs. Reference Area 2 (MEL-04)	Mid-field Area (MEL-02) vs. Reference Area 3 (MEL-05)
			<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>
Total Density	None	ANOVA /Tukey's	0.002	0.536	0.006	0.017	0.177	1	0.995
Richness - Family Level	None	KW / DSCF	0.095	0.963	0.137	0.928	0.612	1	0.942
Richness - LTL	None	ANOVA /Tukey's	0.041	0.972	0.084	0.503	0.248	1	0.798
SDI - Family Level	None	ANOVA /Tukey's	0.038	0.104	0.956	0.999	0.196	0.832	1
SDI - LTL	None	ANOVA /Tukey's	0.947	-	-	-	-	-	-
SEI - Family Level	None	ANOVA /Tukey's	<0.001	0.248	0.031	0.993	0.006	0.672	0.598
SEI - LTL	log(x)	ANOVA /Tukey's	0.102	-	-	-	-	-	-
BCI-EEM - Family Level	None	ANOVA /Tukey's	0.565	-	-	-	-	-	-
BCI-EEM - LTL	log(x)	ANOVA /Tukey's	0.026	0.666	0.255	0.013	1	0.959	0.220
BCI-PW - Family Level	None	ANOVA /Tukey's	0.843	-	-	-	-	-	-
BCI-PW - LTL	None	ANOVA /Tukey's	0.624	-	-	-	-	-	-
Chironomid Density	log(x)	ANOVA /Tukey's	0.001	1	0.009	0.113	0.021	0.999	0.858
Bivalve Density	None	ANOVA /Tukey's	0.211	-	-	-	-	-	-
Oligochaete Density	log(x+1)	ANOVA /Tukey's	0.131 / 0.013	- / 0.995	- / 0.056	- / 0.632	- / 0.697	- / 0.009	- / 0.184
Gastropod Density	log(x+1)	ANOVA /Tukey's	0.404	-	-	-	-	-	-
Amphipod Density	None	KW / DSCF	0.971	-	-	-	-	-	-

LTL = lowest taxonomic level; SDI = Simpson's diversity index; SEI = Simpson's evenness index; BCI = Bray-Curtis index; BCI-EEM = BCI calculated according to EEM methods; BCI-PW = BCI calculated according to the pairwise method; KW = Kruskal-Wallis test; DSCF= Dwass-Steel-Critchlow-Fligner test.
Note: P-values representing significant differences are bolded (P<0.1). Multiple P-values indicate ANOVA results with / without outliers.

5.3.2.1 *Total Density and Total Richness*

In 2015, total density was considered to be in the low density category described in Section 5.1.3.1, with Near-field (474 to 828 org/m²) and Mid-field values (60 to 224 org/m²) towards the lower end of that category (Figure 5.3 2). Densities in the Near-field and Mid-field areas were higher in 2016 compared to 2015; however, 2016 densities remained low (ranging from 1,172 to 3,491 org/m² in the Near-field area and from 224 to 1,672 org/m² in the Mid-field area). Lower densities were reported in the Mid-Field area compared to the Near-field area in both years (Figure 5.3 2). Low densities were also observed in all three reference areas (i.e., <3,000 org/m²).

The overall statistical comparison of the 2016 densities among the five areas found total density to be significantly different among areas (Table 5.3-2). The mean Near-field area density was significantly higher than the reference area mean density, whereas the Mid-field area density showed no significant difference from the reference area mean density (Table 5.3 2).

Although low densities were observed in the three reference areas relative to the exposure areas, there was moderate spatial variability among reference areas, with significantly higher densities reported in Reference area 1 (1,112 to 2,767 org/m²) compared to the two other areas (Reference area 2: 276 to 1,207 org/m²; Reference area 3: 500 to 1,388 org/m²) (Figure 5.3-2; Table 5.3-3). No significant difference was observed between Reference areas 2 and 3. In general, the spatial variability observed within and among the three reference areas was broadly similar to that observed for the combined 2015 and 2016 dataset for the Near-field and Mid-field exposure areas.

Tukey's pairwise comparisons for total density between the Near-field and Reference areas indicated significant differences from Reference areas 2 and 3 (Table 5.3-4). No significant differences were observed between the Mid-field area and any of the reference areas.

At the family level, total richness values reported for the two exposure areas and the three reference areas were similar (Figure 5.3 2). Apart from the 12 families present at Near-field exposure station MEL-01-03 in 2015, mean family richness was below 10 families at all stations sampled in 2015 and 2016. Family level richness was significantly different among areas overall, but no significant differences were found between the exposure areas and the mean of the reference areas (Table 5.3-2). Richness in Reference area 1 was significantly higher than in Reference area 2 (Table 5.3 3). No significant differences were observed in pairwise comparisons of reference and exposure areas (Table 5.3-4).

In both 2015 and 2016, LTL richness in the Near-field and Mid-field areas was low to moderate (Figure 5.3 2) with proportionally more Mid-field stations with low richness values (i.e., <10 taxa/station) compared to Near-field stations. In 2016, LTL richness was moderate (i.e., 10 to 40 taxa/station) at all stations, except for MEL 04 02 in Reference Area 2 (9 taxa/station). In 2016, LTL Richness was not significantly different between the Near-field area and the reference areas (Table 5.3-2), and the reference areas were also not significantly different from one another (Table 5.3-3). Pairwise comparisons detected a significant difference between the Near-field area and Reference area 2 (Table 5.3-4).

These results indicate moderate to large variation in both total invertebrate density and richness between years and among sampling areas, with the exception of family level richness. They also highlight existing significant differences between the Near-field area and the reference areas in total invertebrate density, as well as among the three reference areas.

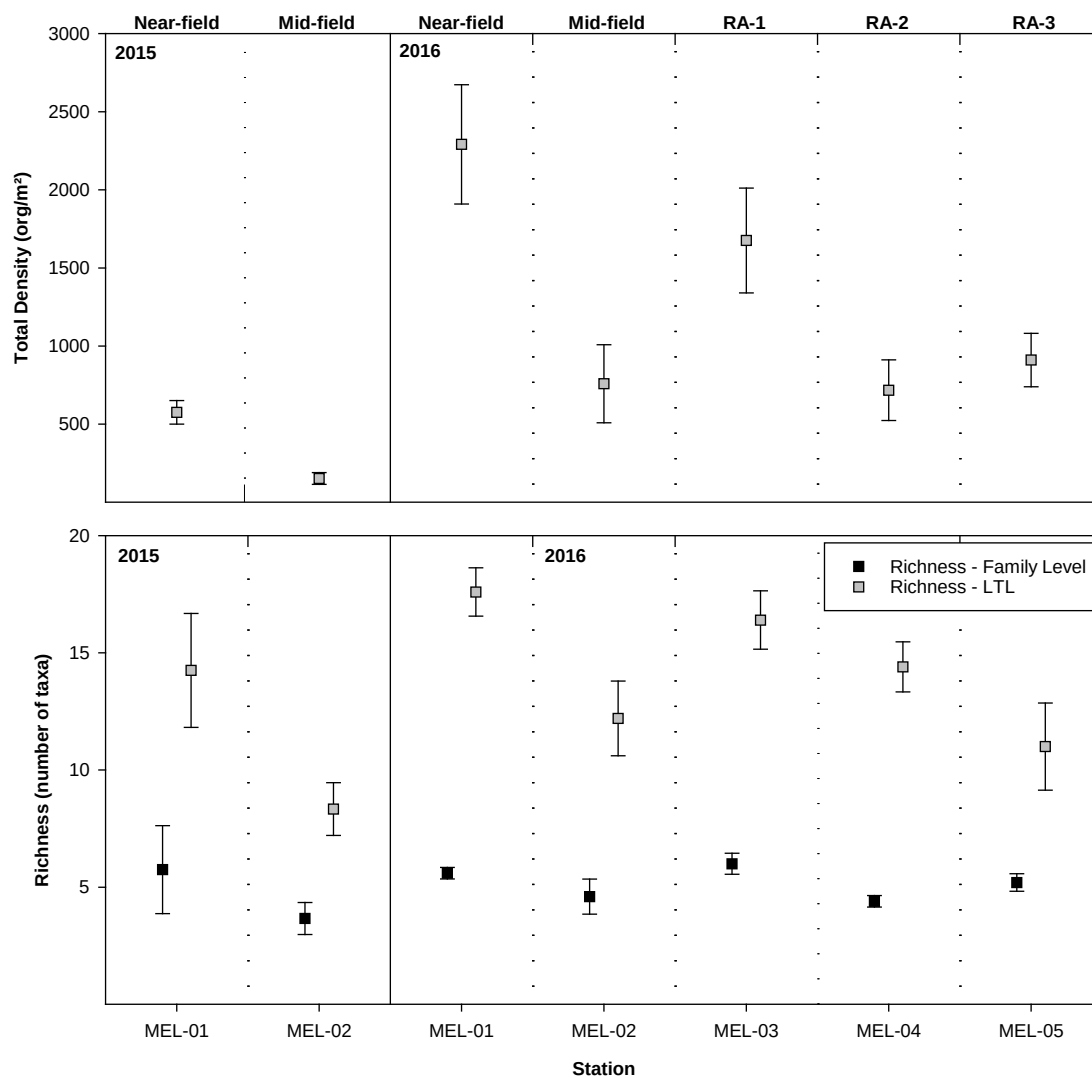


Figure 5.3-2: Mean ($\pm$ SE) Total Benthic Invertebrate Density and Richness in Meliadine Lake, August 2015 and 2016

5.3.2.2 *Simpson's Diversity and Evenness Indices*

Overall, family level and LTL SDI values suggested that exposure and reference areas had generally diverse benthic communities. The SEI calculated at the family level and LTL indicated that for the most part, few taxa in these communities accounted for the majority of the invertebrate density at each station.

Diversity and evenness in Meliadine Lake exhibited some differences among areas, but to a lesser extent than density and richness. The following specific differences were noted from the results presented in Tables 5.3-2 to 5.3-4 and Figure 5.3-3.

- At the family level, both SDI and SEI were significantly different among areas in the overall ANOVA, but not when comparing Near-field and Mid-field stations to the reference area mean (Table 5.3-2). Family level SDI and SEI were significantly different among reference areas, with SDI being significantly lower in Reference area 1 compared to Reference areas 2 and 3 (Table 5.3-3). At the family level, each reference area had a significantly different SEI than the other two (i.e., Reference Area 2 > Reference Area 3 > Reference Area 1) (Table 5.3-3).
- Relatively high SDI values were calculated for exposure areas sampled in 2015 and 2016, and reference areas sampled in 2016 (Figure 5.3-3). LTL SDI in 2016 ranged from 0.74 to 0.88 at Near-field stations, 0.79 to 0.85 at Mid-field stations, and 0.74 to 0.91 for stations in the three reference areas. These SDI values were closer to 1 than 0, indicating that communities present in both the exposure and reference areas were diverse.
- SEI was variable among the exposure area stations sampled in 2015 and 2016, but overall SEI values were low to moderate (Figure 5.3-3). As SEI is a measure of the relative densities of the different taxa at each replicate station, a lower SEI value indicates a higher degree of dominance by one or a few organisms. In the Near-field area, LTL SEI values ranged from 0.19 to 0.59 in 2016. A similar range of 0.40 to 0.58 was calculated for the Mid-field area when values observed at MEL 02 01 (0.75) in 2016 and MEL 02 02 (0.91) in 2015 were excluded. Communities at these two stations had low density and richness values and were evenly dominated by bivalves and chironomids.
- The three reference areas sampled in 2016 also had low to moderate LTL SEI values that ranged between 0.26 and 0.78, indicating that few taxa also accounted for the majority of the density at each station. The one exception was station MEL 04 05 in Reference Area 2 that had a substantially higher SEI value of 0.78. Both density and richness were low at this station and no species clearly dominated the community.
- Although SDI values were notably lower when calculated for the family level, evenness values were in similar ranges regardless of taxonomic level in the dataset used for the calculations.

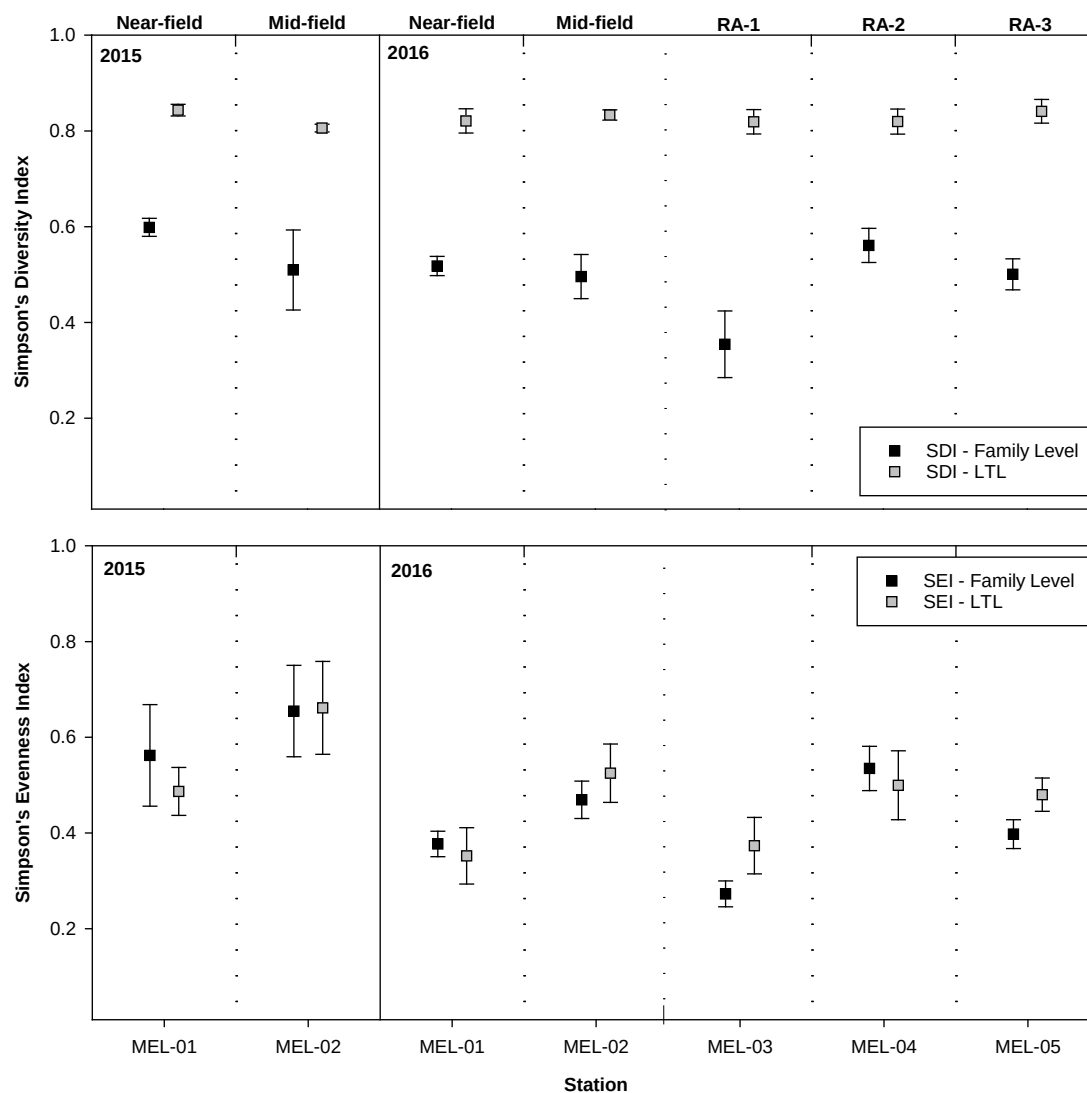


Figure 5.3-3: Mean ($\pm$ SE) Simpson's Diversity and Evenness Indices for the Benthic Invertebrate Community Collected for Meliadine Lake, August 2015 and 2016

5.3.2.3 *Bray-Curtis Index*

Bray-Curtis Index values were calculated for the 2016 data, using both family-level taxa and lowest taxonomic level data, as well as following both EEM and pairwise methods. BCI were not calculated for the 2015 data, as there were no reference area data. Meliadine Lake showed few notable differences in similarity between the sampling areas, with the Near-field area being the least similar to the Reference areas in 2016. The following specific observations were made based on the results presented in Tables 5.3-2 to 5.3-4 and Figure 5.3-4.

- Low to moderate BCI (EEM) values were observed in the family level calculations; values for individual stations were highly variable and ranged from 0.07 to 0.67. The LTL BCI (EEM) calculations had a greater variety of index values, ranging from 0.23 to 0.80, although most were moderate in value. Reference area 3 had the lowest average BCI (EEM) among areas (0.23 for family level, and 0.33 for LTL), and the Near-field area had the highest (0.40 for family level and 0.64 for LTL; Figure 5.3-4). BCI (EEM-LTL) was significantly different among areas, with the Near-field area significantly higher than the reference area mean (Table 5.3-2) and the Reference Area 3 value (Table 5.3-4). No significant differences were found in BCI (all 4 variables) among the reference areas (Table 5.3-3).
- BCI (EEM) exhibited a spatial trend among the areas sampled, whereby a slight decreasing trend was observed across the lake with increasing distance from the Near-field area.
- BCI (PW) had a narrower range of values than BCI (EEM), ranging from 0.31 to 0.65 for family-level, and 0.47 to 0.78 for LTL. As with BCI (EEM), average BCI (PW) was lowest at Reference Area 3 and highest at the Near-field area, ranging from 0.39 to 0.46 for family-level, and from 0.54 to 0.64 for LTL (Figure 5.3-4). BCI (PW) did not differ significantly among areas at either taxonomic level (Table 5.3-2).

Using both methods of calculating the BCI allows an evaluation of the suitability of this index for future monitoring data analyses. As expected, the BCI (EEM) method suggests greater existing differences in community composition between the reference areas and exposure areas, which confirms the evaluation of Huebert et al. (2011) regarding the bias in the EEM method of calculating the BCI. For future monitoring, it is recommended that greater emphasis be placed on the results obtained from analyses of BCI values calculated using the pairwise method.

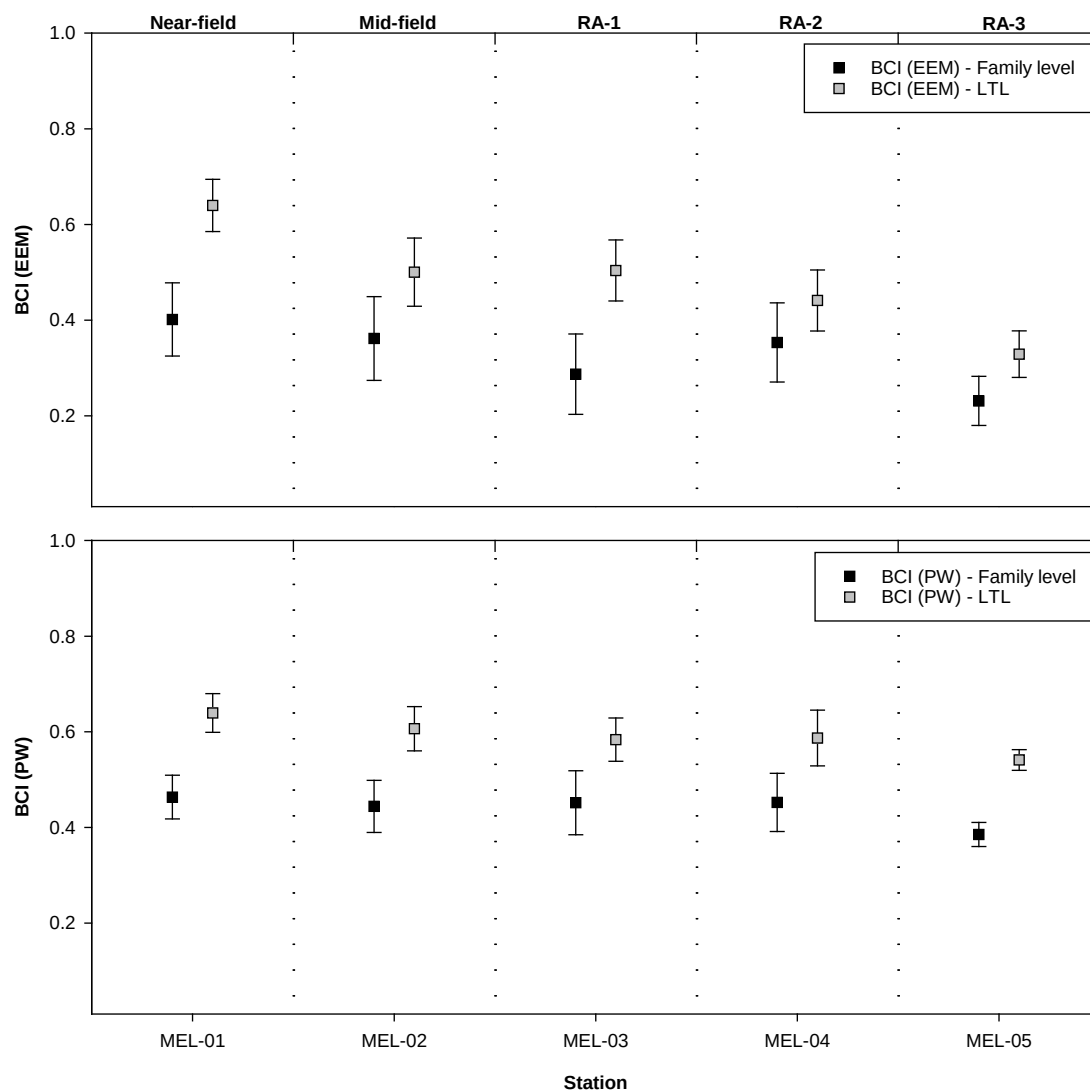


Figure 5.3-4: Mean (± SE) Bray-Curtis Index Values for the Benthic Invertebrate Community in Meliadine Lake, August 2015 and 2016

5.3.2.4 Community Composition

Overall, the composition of the benthic invertebrate community in Meliadine Lake was similar to those of other Arctic Lakes and the taxa present in 2015 and 2016 were similar to those observed during previous sampling years. As shown on Figures 5.3-5 and 5.3-6, differences in relative densities and dominant taxa were noted between areas in 2015 and 2016. These differences and the significant differences between dominant taxa shown in Tables 5.3-2 to 5.3-4 are discussed.

- Insects of the family Chironomidae (non biting midges) and bivalves of the family Pisidiidae (formerly Sphaeriidae: fingernail clams or pea clams) dominated benthic invertebrate communities in the exposure areas in 2015 and 2016. In 2015, various chironomid subfamilies and tribes collectively accounted for 44% to 80% of the total density, and bivalves accounted for 18% to 41% of the total density. A broadly similar community composition was observed in communities sampled in 2016, with chironomids accounting for 41% to 71% of the total density and bivalves accounting for between 8% and 50%. In Arctic lake ecosystems, chironomids constitute a high proportion of the benthic invertebrate communities, often accounting for more than a third of the total relative density (Namayandeh and Quinlan 2011)
- In the Near-field and Mid-field areas, the subfamily Chironominae was the dominant midge group at the majority of stations in 2015 and 2016, with a large portion of the remaining chironomid density represented by the subfamilies Orthocladiinae and Tanypodinae. Although chironomid density varied significantly among sampling areas, the Near-field area mean was not significantly different from the reference area mean (Table 5.3-2). However, pairwise comparisons showed differences between the Near-field area and Reference area 2, and between the Mid-field area and Reference area 1 (Table 5.3-4).
- Similar to the exposure areas, the reference areas were dominated by the family Chironomidae. The various chironomid subfamilies and tribes collectively accounted for 36% to 91% of the total density. Chironomidae density differed among reference area stations, and a significant difference was detected between Reference area 1, and each of Reference areas 2 and 3 (Table 5.3-3).
- Bivalves in the near-field community accounted for 11% to 57% of the total density. The density of bivalves did not differ significantly among sampling areas (Table 5.3-2).
- Oligochaetes were a minor taxon in each area. The density of this group was significantly different between the Mid-field area and the mean of the reference areas (Table 5.3-2), and in the Near-field and Mid-field areas relative to Reference areas 2 and 1 (Table 5.3-4), respectively, but did not vary significantly among the reference areas (Table 5.3-3).
- Gastropods and amphipods were also minor taxa, and their densities did not vary significantly among areas (Tables 5.3-2 to 5.3-4).
- Some differences in community composition were apparent among the three reference areas in 2016. A significantly higher density of Chironomidae was observed in Reference area 1 compared to Reference areas 2 and 3 (Table 5.3-3). Based on visual assessment (Figure 5.3-6, bottom graph), the relative density of Chironomidae was also higher in Reference area 1 compared to the other two reference areas.
- In terms of community composition as relative densities (Figure 5.3-6), none of the reference areas appeared more similar to the Near-field area than the others; however, statistical test results indicated no significant differences densities of dominant invertebrates between the Near-field area and Reference Area 1.

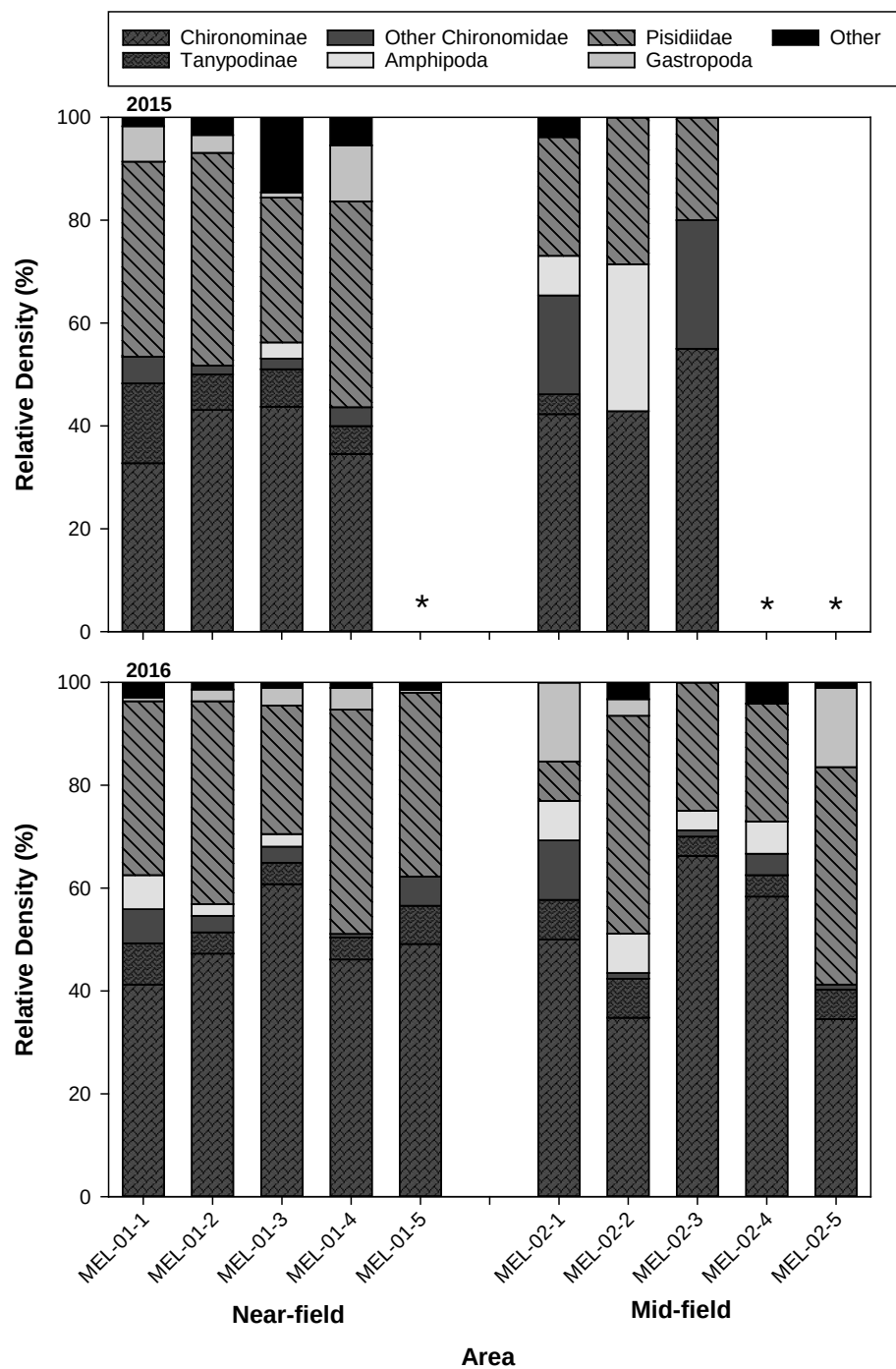


Figure 5.3-5: Relative Densities of Major Benthic Invertebrate Groups in Meliadine Lake (Exposure Areas), August 2015 and 2016

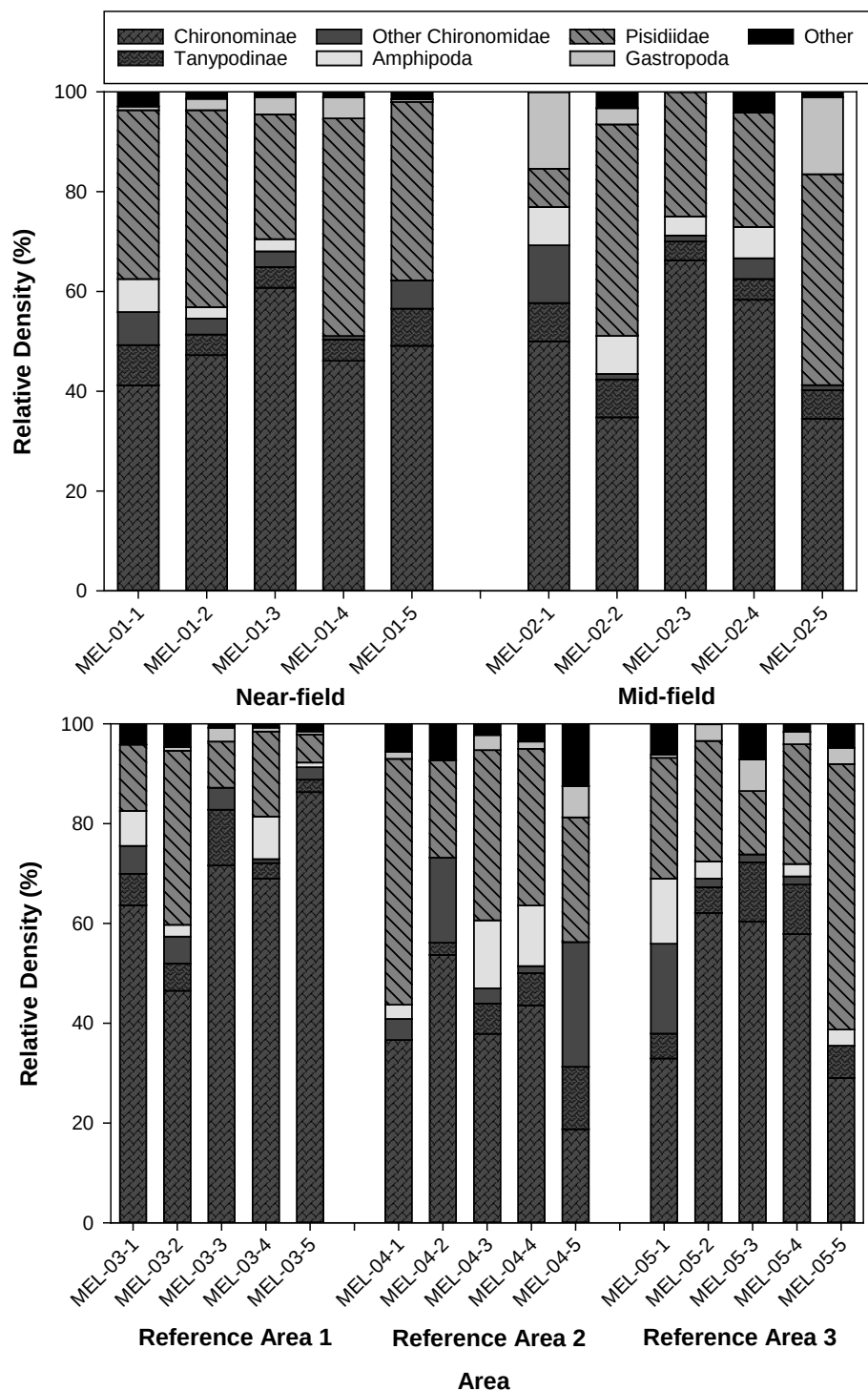


Figure 5.3-6: Relative Densities of Major Benthic Invertebrate Groups in Meliadine Lake, August 2016

5.3.2.5 Multivariate Analysis

The nMDS run on the 2016 benthic invertebrate community dataset produced a two-dimensional configuration with a stress value of 0.11, indicating a successful ordination. All areas compared were fairly similar in community structure, with a moderate to high similarity (i.e., all within the 60% similarity ellipse) as shown in Figure 5.3-7. Some separation among areas was present, consistent with the univariate analysis results. The Mid-field area and all three Reference areas were within the 70% similarity ellipse, while the Near-field area was outside this zone, indicating a greater difference between the Near-field area and other sampling areas, compared to the differences among the other sampling areas. The pairwise ANOSIM comparing all areas for 2016 indicated significant differences between the Near-field area and Reference areas 2 and 3. No other differences were observed (Table 5.3-5).

The results of this analysis suggests that in 2016, the Near-field area benthic invertebrate community was already different from Reference area communities. This is a confounding factor that will need to be addressed in subsequent studies. This finding is discussed further in Section 5.3.5.

Table 5.3-5: Benthic Invertebrate Community ANOSIM Results, 2016

Area	Near-field Area (MEL-01)	Mid-field Area (MEL-02)	Reference Area 1 (MEL-03)	Reference Area 2 (MEL-04)	Reference Area 3 (MEL-05)
Mid-field Area (MEL-02)	0.3	-	-	-	-
Reference Area 1 (MEL-03)	0.2	0.19	-	-	-
Reference Area 2 (MEL-04)	0.4	<0.1	0.13	-	-
Reference Area 3 (MEL-05)	0.4	0.2	0	<0.1	-

Significant differences are **bolded**; significance at $P < 0.05$.

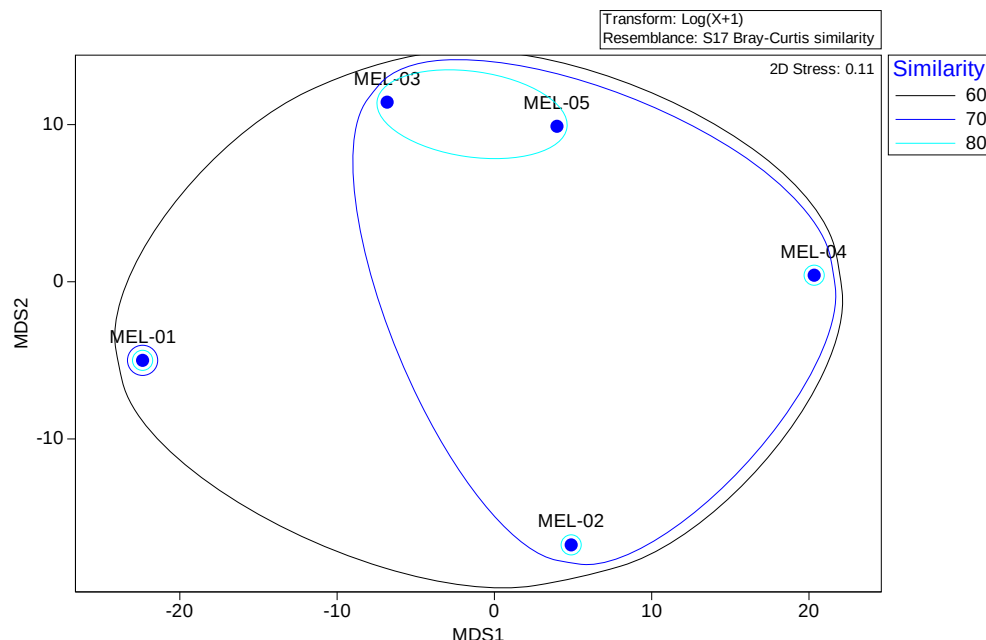


Figure 5.3-7: Ordination Plot of the Benthic Invertebrate Community for Meliadine Lake, August 2016

5.3.3 Effects of Habitat Variation on the Benthic Invertebrate Community

The potential for variation in TOC, grain size and selected sediment chemistry parameters to contribute to the spatial and temporal variability observed in community structure among stations in Meliadine Lake was evaluated. Spearman rank correlation analyses for both 2015 and 2016 (Table 5.3-7). Correlation analysis included concentrations of metals present in the Meliadine Lake sediments above CCME sediment quality guidelines (i.e., arsenic, chromium, copper), and water column concentrations of the nutrients total phosphorus and total nitrogen.

Critical values of the correlation coefficient representing significant relationships are summarized in Table 5.3-6, and the results of the Spearman correlations are provided in Table 5.3-7. TOC and grain size variables were not significantly correlated with the benthic community variables in 2015, except for oligochaete density and percent silt, where a significant positive correlation was identified. This weak correlation indicated that in 2015 the number of oligochaetes tended to increase with finer and high percentage of silt, a finding consistent with the substrate preference for oligochaetes (Thorp and Covich 2001). Positive correlations were also found between sediment arsenic concentration, and total density and bivalve density. This could be reflective of higher total invertebrate densities and specifically bivalves in finer sediments, where arsenic is preferentially partitioned, leading to higher arsenic concentrations relative to coarser sediments. With respect to nutrients in water, amphipod density was found to be significantly negatively correlated with total phosphorus in 2015. Due to the small sample sizes and large number of correlations run, it is also likely that at least some of the significant correlations are not biologically meaningful.

When the larger 2016 dataset was considered, the following significant correlations were identified (Table 5.3-7):

- Total density was significantly negatively correlated with percent sand and was significantly positively correlated with percent silt. SDI (LTL) was significantly negatively correlated with percent silt and was significantly positively correlated with percent sand. Thus, finer sediments supported more dense, but less diverse benthic invertebrate communities; a finding consistent with observed patterns in northern oligotrophic lakes such as Meliadine Lake.
- SEI (LTL) was significantly negatively correlated with TOC and percent silt, but significantly positively correlated with percent sand. This finding suggests that communities with lower densities found in sandier sediments tended to be more even with respect to the community composition.
- Bivalve density (Pisidiidae) was significantly negatively correlated with percent sand and significantly positively correlated with TOC and percent silt. Bivalves tend to inhabit sandy substrates in lakes because they are typically limited by substrate sizes above 0.18 mm (fine sand/coarse sand) (Thorp and Covich 2001). In particular, *Pisidium*, which was the dominant bivalve in Meliadine Lake, is considered to be characteristic of areas with fine sediments (Dillon 2000).
- SDI (LTL), Oligochaete density and Amphipoda density were significantly negatively correlated with sediment arsenic, indicating a decrease in density and diversity where arsenic concentrations were higher. Given that arsenic concentrations above the Predicted Effects Level (PEL) have been documented at some stations prior to the Mine discharge (likely indicative of natural metal deposits in the area; Straskraba and Moran 1990), these correlations are consistent with expectations, but are very weak, based on visual evaluation of scatter-plots.
- Gastropoda density increased with sediment arsenic concentration, which may reflect the affiliation of gastropods and arsenic with fine sediments.

- SDI was significantly positively, but weakly correlated with nitrogen; there is no clear interpretation for this relationship.
- Significant, but very weak positive correlations were observed between each of TN and TP in water and one biological variable. Given the lack of similar correlations between nutrients and other variables, these correlations are unlikely to be meaningful.
- As in the case of the correlation analysis of the 2015 dataset, due to the small sample sizes and large number of correlations run, it is also likely that at least some of the significant correlations detected are not meaningful.

Scatter-plots of habitat and community variables found to be moderately to highly significantly correlated ($P < 0.01$) are provided in Figure 5.3-8, to support interpretation of the significant correlations identified for 2015 and 2016. Examination of the scatterplots values for these correlations indicate that although significant relationships were identified between some habitat and community variables, many of these relationships were weak and unlikely to be meaningful (i.e., all for 2015), with the possible exception of those with sediment silt or sand content in 2016. The directions of relationships with sediment silt and sand content in 2016 are consistent with habitat associations and expected community changes along the gradient of increasing fine sediments, and generally support the interpretation that variation in sediment grain size accounted for at least some of the among-area variability in the benthic invertebrate community in 2016. This suggests that spatial variability observed in biological variables between the Near-field area and reference areas in 2016 was at least partly the result of habitat variation.

Treated effluent from the exploration camp sewage treatment plant was discharged into a small ditch, approximately 60 m from Meliadine Lake during 2015 and 2016 (Section 2.2). The treated effluent flowed into Meliadine Lake close to the Near-field exposure area (MEL-01) (Figure 1.1-2). The water quality of Meliadine Lake was assessed to evaluate whether differences in water quality were observed between the exposure and reference areas. The results of the analyses are provided in Section 3.3 for the 2015 and 2016 datasets and indicate typically low nutrient concentrations throughout the lake (mostly within the oligotrophic range), with instances of slightly higher concentrations of TP, dissolved phosphorus and orthophosphate in the Near-field area compared to other sampling areas during sampling events from 2015 to 2017 (time series plots are shown in Appendix 3E, Figures 3E.1-4e to 3E.1-4g). The median TP concentration in 2016 was slightly higher in the Near-field area compared to other sampling areas, and these differences were found to be statistically significant (Section 3.3.1.2). The plankton component also reported higher chlorophyll a concentration and phytoplankton biomass in the Near-field area compared other areas (Section 7.3). These results suggest a potential slight nutrient enrichment effect in the Near-field area compared to other sampling areas.

Evaluation of relationships between habitat variables and benthic community variables, combined with water quality and plankton component results, suggests that the Near-field area benthic invertebrate community may be different from communities in other sampling areas in Meliadine Lake as a result of habitat variation and potentially slight nutrient enrichment. The relative importance of these influences on the benthic invertebrate community cannot be evaluated based on available data, and should be investigated further, to allow adjustment of the AEMP sampling design to remove confounding factors from the analysis of mine-related effects during future monitoring cycles.

Table 5.3-6: Critical Values for Spearman Correlations on Benthic Invertebrate Community Variables

Year	Habitat Variables	n	Critical Value		
			<i>P</i> = 0.05	<i>P</i> = 0.01	<i>P</i> = 0.001
2015	TOC, % sand, % silt, % clay, sediment As, Cr, Cu	8	0.738	0.881	0.976
	Total phosphorus and total nitrogen in water	7	0.786	0.929	1
2016	TOC, % sand, % silt, % clay, sediment As, Cr, Cu	33	0.345	0.446	0.544
	Total phosphorus in water	25	0.460	0.584	0.712
	Total nitrogen in water	19	0.398	0.511	0.630

n = sample size; P = probability.

Note: Critical values are based on 2-tailed tests.

Table 5.3-7: Spearman Rank Correlations between Benthic Invertebrate Community Variables and Selected Habitat Variables for Meliadine Lake, August 2015 and 2016

Benthic Community Variable	Spearman Correlation Coefficient (r_s)								
	TOC	Sand	Silt	Clay	As in Sediment	Cr in Sediment	Cu in Sediment	TP in Water	TN in Water
2015 Data									
Total density	-0.371	0.180	-0.036	-0.575	0.766*	-0.108	-0.563	0.180	0.198
Richness family level	-0.228	-0.203	0.292	-0.292	0.292	-0.203	-0.545	-0.408	0.296
Richness lowest level	-0.586	-0.122	0.293	-0.586	0.439	-0.415	-0.537	0.162	0.234
SDI LTL level	-0.571	-0.619	0.690	-0.190	0.024	-0.500	-0.024	0.036	0.250
SEI LTL level	0.143	-0.333	0.190	0.476	-0.571	0.024	0.738*	-0.071	-0.286
Chironomidae density	-0.405	0.214	-0.071	-0.619	0.714	-0.143	-0.571	0.143	0.107
Bivalvia density	-0.287	0.096	0.048	-0.467	0.838*	-0.024	-0.515	0.270	0.396
Oligochaeta density	-0.617	-0.617	0.746*	-0.257	0.591	-0.463	-0.103	0.630	0.408
Gastropoda density	-0.307	-0.393	0.442	-0.025	0.700	0.086	0.098	0.283	0.510
Amphipod density	-0.151	-0.069	0.110	-0.289	-0.316	-0.385	-0.344	-0.837*	-0.060
2016 Data									
Total density	0.323	-0.449**	0.461**	0.158	0.144	0.134	0.057	0.209	0.108
Richness family level	0.057	0.084	-0.070	0.003	-0.267	-0.159	0.013	-0.064	0.353
Richness lowest level	0.036	0.026	-0.047	0.123	-0.239	-0.027	0.125	0.208	0.268

Benthic Community Variable	Spearman Correlation Coefficient (r_s)								
	TOC	Sand	Silt	Clay	As in Sediment	Cr in Sediment	Cu in Sediment	TP in Water	TN in Water
SDI LTL level	-0.276	0.404*	-0.474**	0.099	-0.399*	-0.128	0.100	0.059	0.511**
SEI LTL level	-0.393*	0.476**	-0.506**	-0.116	-0.165	-0.143	-0.060	-0.112	0.303
Chironomidae density	0.155	-0.218	0.209	0.209	-0.105	0	0.135	0.139	0.099
Bivalvia density	0.360*	-0.477**	0.492**	0.199	0.304	0.313	0.153	0.513*	-0.061
Oligochaeta density	-0.047	0.123	-0.135	-0.074	-0.398*	-0.284	-0.017	-0.112	0.128
Gastropoda density	0.309	-0.288	0.325	0.091	0.511**	0.225	0.166	0.311	0.069
Amphipod density	-0.128	0.219	-0.275	0.137	-0.367*	-0.037	0.202	0.003	0.072

TP = total phosphorus; TN = total nitrogen.

Note: Significant correlation coefficients are **bolded**; * = $P < 0.05$, ** = $P < 0.01$.

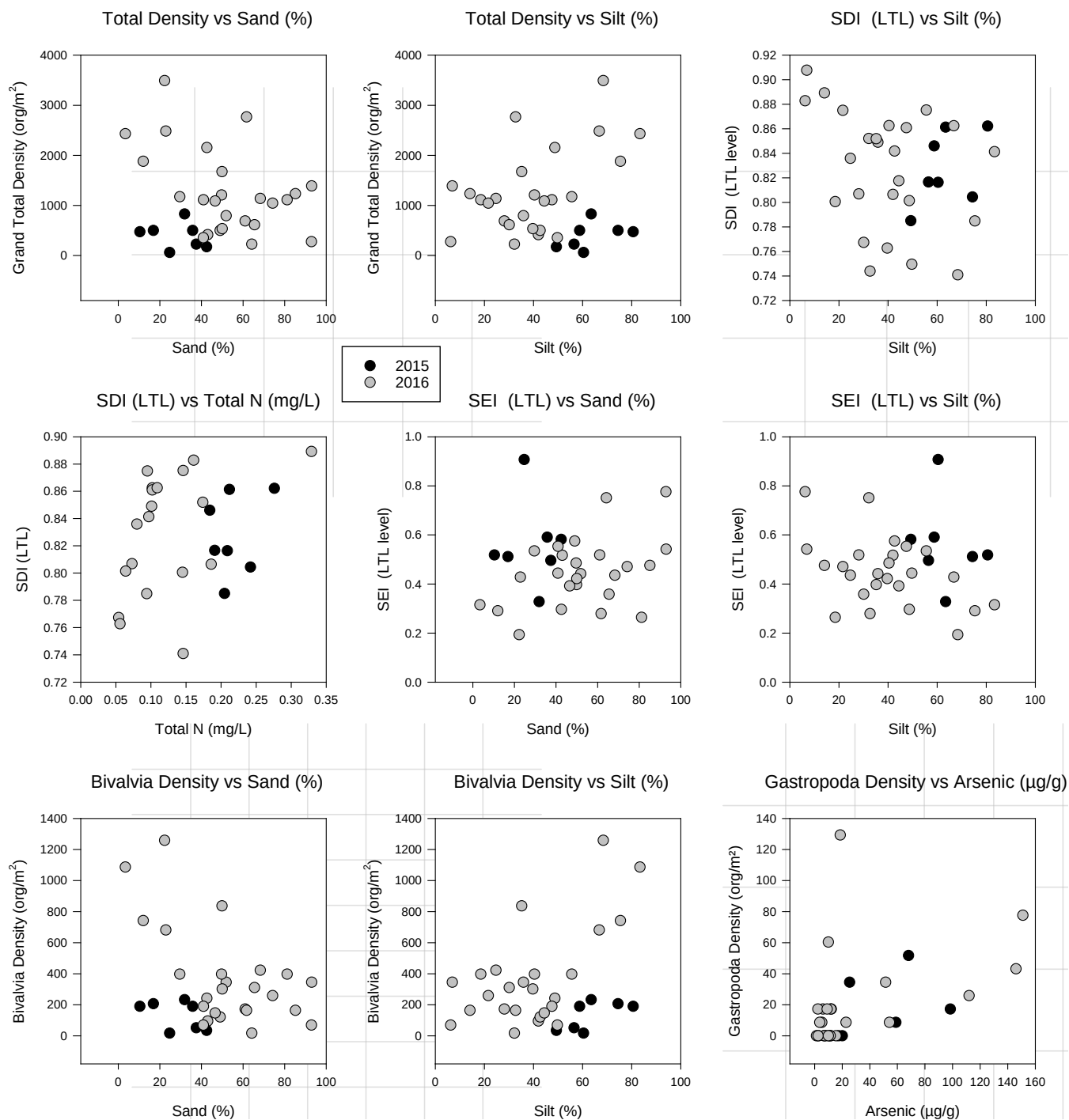


Figure 5.3-8: Scatter-Plots of Benthic Habitat Variables, Sediment Arsenic, and Total Nitrogen in water, versus Benthic Invertebrate Community Variables, August 2015 and 2016

Note: Plots representing moderately to highly significant ($P < 0.01$) Spearman rank correlations are shown.

5.3.4 Characterization of Within-Station Variability

Within-station variability was examined based on the 2016 benthic invertebrate community results. The benthic invertebrate subsamples collected at MEL-01-05 and MEL-03-01 were analyzed separately, which provided information on likely level of representativeness of composite samples taken at other stations.

Within-station estimates of variability for total invertebrate density and richness were summarized as the mean, summary statistics, and the %SE (Table 5.3-8) and the data for individual subsamples were plotted (Figure 5.3-9). The range of %SE values were 16% (MEL-01-05) to 40% (MEL-03-01) for total abundance, and 14% (MEL-01-05) to 28% (MEL-03-01) for richness. Visual evaluation of the data for individual subsamples indicate a moderate degree of within-station variation (Figure 5.3-9).

Values of the %SE greater than 20% indicate a moderate level of variation at the subsample level, and are higher than the typical range observed in benthic invertebrate data (Elliott 1971); however, these results are similar to those observed in other Arctic lakes with low invertebrate densities (e.g., Lac de Gras; Golder 2014), where similar composite sampling methods are used for the AEMP.

Table 5.3-8: Within-Station Variation in Benthic Community Variables in Meliadine Lake, 2016

Station-Replicate	Total Abundance (organisms/subsample)	Richness (no. of taxa/subsample)
MEL-01-05		
MEL-01-05-D1	102	11
MEL-01-05-D2	29	5
MEL-01-05-D3	94	13
MEL-01-05-D4	93	10
MEL-01-05-D5	87	12
Mean	81	10.2
Median	93	11
Maximum	102	13
Minimum	29	5
Standard deviation	29.6	3.1
Standard error	13.2	1.4
% Standard error	16	14

Station-Replicate	Total Abundance (organisms/subsample)	Richness (no. of taxa/subsample)
MEL-03-01		
MEL-03-01-D1	32	13
MEL-03-01-D2	26	11
MEL-03-01-D3	8	2
MEL-03-01-D4	7	4
MEL-03-01-D5	70	15
Mean	29	9
Median	26	11
Maximum	70	15
Minimum	7	2
Standard deviation	26	6
Standard error	11.5	2.5
% Standard error	40	28

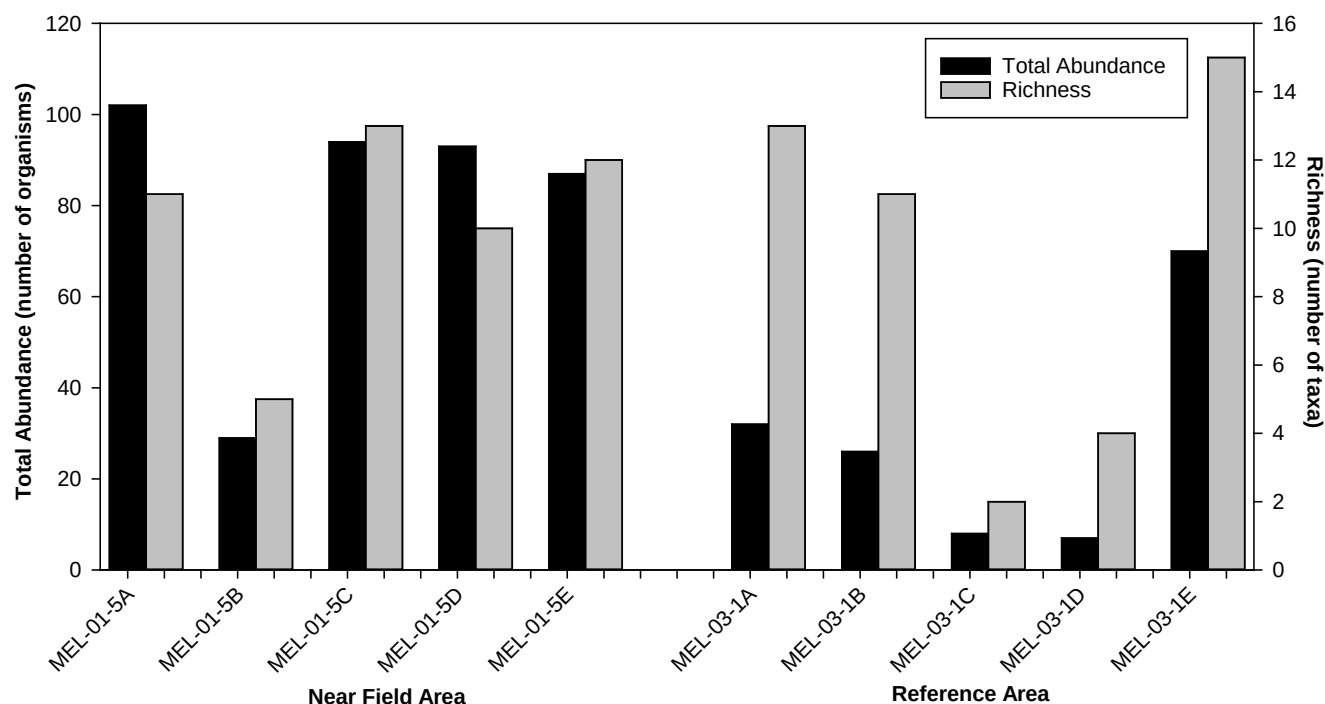


Figure 5.3-9: Within-station Variability for Abundance and Richness in Meliadine Lake, August 2016

5.3.5 Overview

Benthic invertebrate communities in Meliadine Lake were characterized by low total density and low to moderate richness, typical of subarctic lakes. In all sampling areas, invertebrate communities were dominated by chironomid midges, with fingernail clams (Pisidiidae) being the sub-dominant group. Dominance of the benthic invertebrate community by Chironomidae is common in subarctic lakes (Beaty et al. 2006; Northington et al. 2010). SDI values were moderate to high, which indicated the invertebrate communities were diverse. Evenness was more variable and ranged from low to moderate. Collectively, these two indices suggest that baseline benthic communities sampled at most stations in the reference and exposure areas had moderate to high diversity with few taxa that were overly dominant.

The benthic invertebrate community in the Near-field area was significantly different from reference area communities in terms of total density and BCI calculated using the EEM method. Further evidence of differences among sampling areas was evident in nMDS ordination plots, where the Near-field area community was shown to be dissimilar from the reference area communities and the Mid-field area community. A number of other benthic community variables were significantly different among sampling areas, but without a significant difference between the Near-field area mean and the mean of the reference areas. Pairwise comparisons of benthic community variables between the Near-field area and individual reference areas detected two or more significant differences between the Near-field area and Reference areas 2 and 3, but no significant differences between the Near-field area and Reference area 1.

Significant differences in benthic community variables were also observed among the three reference areas in Meliadine Lake, whereby Reference area 1 had greater invertebrate density and richness, lower diversity and evenness, as well as a higher proportion of Chironomidae compared to Reference areas 2 and 3. Based on visual evaluation of spatial patterns in community variables and statistical analysis results, Reference area 1 appears to be closest to the Near-field area in terms of benthic invertebrate community structure.

Habitat variation was found to act as a likely confounding factor for future AEMP monitoring. Sediments within the Near-field area differed from those in other sampling areas. A higher proportion of silt was present in Near-field area sediments, compared to sand-dominated composition observed in the Mid-field area and the reference areas. Fine sediments (silt and clay) are the preferred habitat type for the majority of invertebrates present in Meliadine Lake; therefore, a higher proportion of fine sediments is expected to contribute to higher densities in the Near-field area. The 2016 baseline results for Meliadine Lake indicate that sediment particle size differences are likely resulting in differences between Near-field and reference area benthic communities, even before mine start-up. This is a confounding factor that strongly influences the comparison of EEM BIC endpoints (e.g., density and diversity) and for the current dataset leads to a conclusion of statistically significant differences. It may be necessary to identify reference areas with similar habitat and thus remove this confounding factor from future EEM and AEMP studies.

Treated STP effluent released over land, approximately 60 m from shore, close to the Near-field area in both 2015 and 2016 had the potential to result in nutrient enrichment in part of Meliadine Lake, which may have affected the Near-field area benthic invertebrate community. An increase in nutrient loads to an oligotrophic lake such as Meliadine Lake can result in increased densities of benthic invertebrates within the area closest to the release, and associated community changes (Holopainen and Jonasson 1989; Quigley 1982). Increased nutrient concentrations can affect dominance within the community, often reducing evenness (Hillebrand 2003). However, some studies have also shown that nutrient inputs may result in no response or minimal responses during the first year of inputs, implying that low dosages may not result in sustained effects (Minshall et al 2014; Northington et al. 2010; Hershey et al 1992). At this time, the influence of indirect effluent discharge on the Near-field benthic invertebrate community is inconclusive because observed community changes are also consistent with differences in substrate composition between the Near-field area and other sampling areas.

Within-station variation in total invertebrate density and richness, based on five subsamples collected per station, was found to be generally within acceptable ranges for benthic invertebrate communities characterized by low density in oligotrophic lakes. As per the AEMP design plan (Golder 2016b), samples for BIC analysis will continue to be collected as a combination of composite samples (five grabs per station), along with individual subsamples at a subset of stations (one station per sampling area), for a reassessment of within-station variation based on a larger dataset.

Meaningful normal ranges for the benthic community, as an input to the Response Framework, could not be estimated at this time, due to variability in the available data related to substrate differences between reference and exposure areas, and a potential nutrient enrichment.

6.0 FISH HEALTH AND FISH TISSUE

The fish health and tissue chemistry components of the Aquatic Effects Monitoring Program (AEMP) evaluate potential changes in indicators of fish health (e.g., energy storage, energy usage, and survival) and tissue chemistry (e.g., metals² concentrations) in the Near-field area of Meliadine Lake, resulting from the development and operations of the Meliadine Mine Gold Project (Mine).

The objectives of the fish health component are to:

- determine whether Project effluent has an effect on the growth, reproduction, survival, condition or metals concentrations of fish in Meliadine Lake
- verify predictions made in the FEIS pertaining to fish health and fish tissue metal concentrations
- meet the requirements of Part 2, Schedule 9 (b) of the MMER regulations (Government of Canada 2012)
- recommend appropriate changes to the fish health and fish tissue chemistry program for future years
- provide data to inform adaptive management intended to reduce or eliminate Mine-related effects to fish health and fish tissue chemistry in Meliadine Lake

In 2015, baseline fish health and tissue chemistry data were collected for Threespine Stickleback and Lake Trout from the Near-field area of Meliadine Lake (Golder 2016a). Threespine Stickleback were subsequently sampled from the reference areas (i.e., Reference Area 1 and Reference Area 2) in 2017, to complete the fish health and tissue chemistry baseline dataset, and evaluate the compatibility of the Near-field and reference areas to support future sampling during the AEMP.

6.1 Methods

A fish health survey was conducted at Reference Area 1 and Reference Area 2 in August 2017 to confirm the presence and suitability of Threespine Stickleback (*Gasterosteus aculeatus*) as a sentinel species for the AEMP and complete baseline data collections initiated at the Near-field area in 2015 (Golder 2016a). Both a population (i.e., lethal and non-lethal) and a lethal survey were completed. A brief description of fish sampling methods are provided in Sections 6.1.1 to 6.1.3. A more detailed description of fish sampling methods are provided in the AEMP Design Plan, Section 5.4 (Golder 2016b). Baseline sampling for Lake Trout was completed for the Near-field area in 2015 and presented in Golder 2016a, and are not repeated herein.

² The term "metals" includes metalloids (e.g., arsenic) and non-metals (e.g., selenium).

6.1.1 Field Methods

Fish sampling was completed at Meliadine Lake from Reference Area 1 and Reference Area 2 between 9 and 18 August 2017 (Table 6.1-1). The timing of the 2017 sampling corresponded to 2015 sampling dates to minimize the impact of seasonal variability on measured endpoints. Fishing methods suitable for nearshore habitats were used to collect Threespine Stickleback during the 2015 and 2017 surveys. Fish were captured using a combination of minnow traps, seines, hoop nets, and backpack electrofishing. Sampling effort for 2015 from the Near-field area is indicated in Figure 6.1-1, sampling effort for 2017 from Reference Area 1 is indicated in Figure 6.1-2 and sampling effort for 2017 from Reference Area 2 is indicated in Figure 6.1-3. Water quality variables (i.e., water temperature, dissolved oxygen, conductivity, and pH) were measured once daily during sampling.

The target sample sizes for the lethal survey included 30 male, 30 female, and 30 juvenile Threespine Stickleback from each of the reference areas. Non-lethal data were collected from at least 100 additional Threespine Stickleback to supplement the population survey. Non-target species captured during sampling were enumerated, measured, weighed, and assessed for external abnormalities prior to release.

The following information was recorded for each sampling effort:

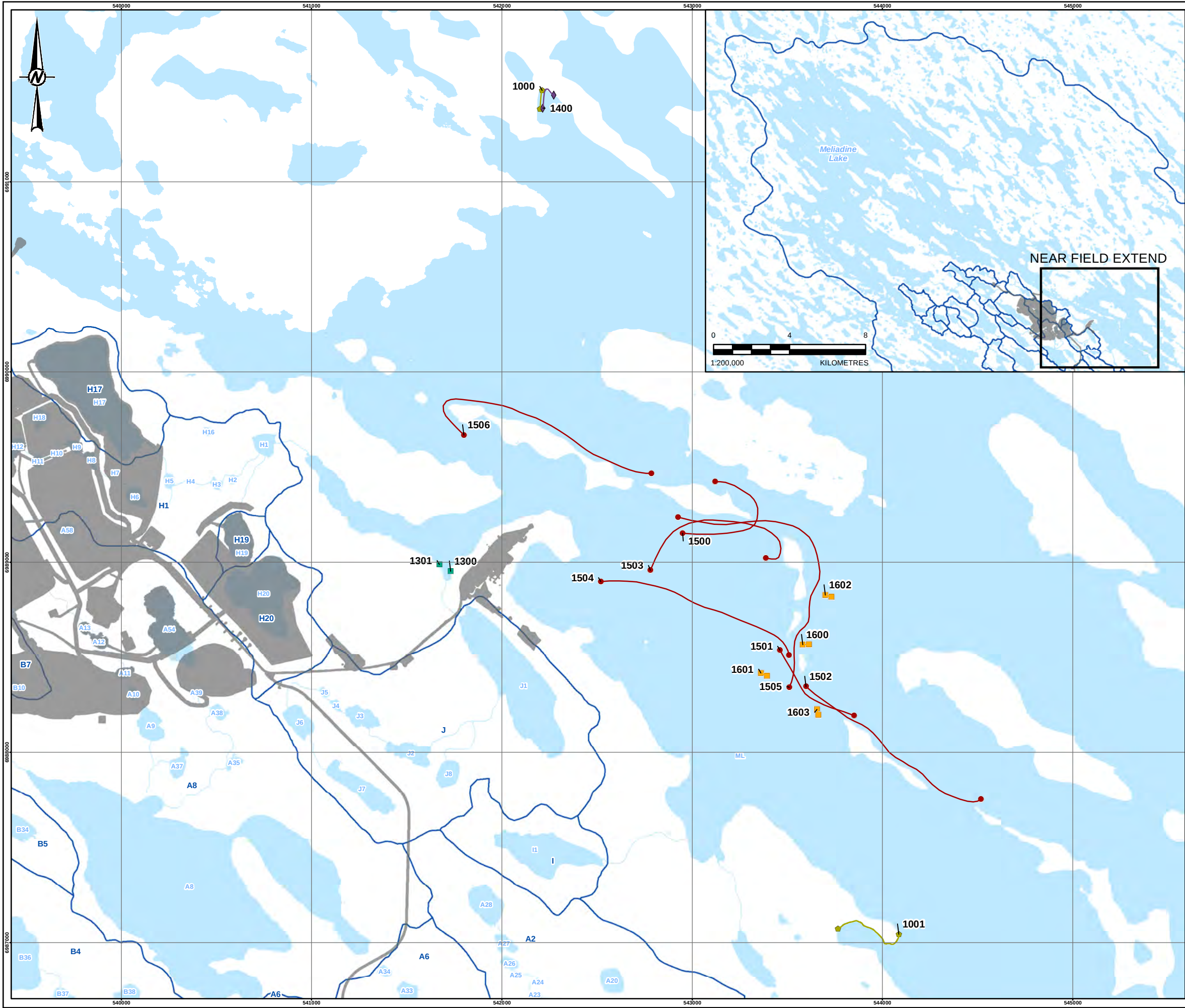
- effort number (i.e., a unique identification number assigned to each fishing effort)
- gear type (i.e., minnow traps, hoop nets, seines, or electrofishing)
- sampling effort (e.g., set duration for minnow traps, area covered for seine nets)
- sampling coordinates (UTM)
- water depth (m)
- substrate type (e.g., silt, sand, cobble)
- number and species of fish captured

Table 6.1-1: Sampling Dates for Threespine Stickleback Baseline Collections from Meliadine Lake, 2015 and 2017

Meliadine Lake Sampling Area	2015		2017	
	Start Date	Finish Date	Start Date	Finish Date
Near-field Area	14 August 2015	17 August 2015	-	-
Reference Area 1	-	-	9 August 2017	13 August 2017
Reference Area 2	-	-	14 August 2017	18 August 2017

- = not applicable.

\\G:\Users\jgolder\golder\work\17876102_PRODUCT\17876102_0000\17876102_0000_2060_Figure_1_Fish_Health_Sampling_Stations.mxd PRINTED ON: 2018/03/23 AT: 4:18:36 PM



LEGEND

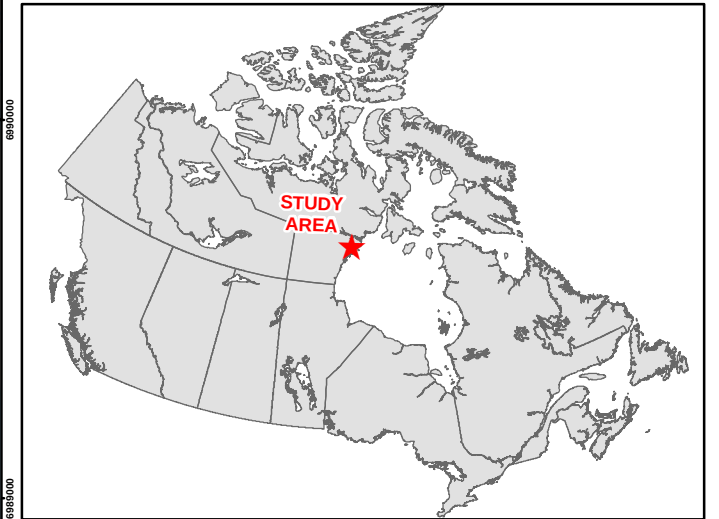
FISH HEALTH SAMPLING STATION*

- ANGLING
- ◆ BACKPACK ELECTROFISHING
- GILL NETTING
- MINNOW TRAPS
- ◆ SEINE NETTING

PATH OF TRAVEL

- ANGLING
- BACKPACK ELECTROFISHING
- GILL NETTING
- SEINE NETTING
- MINE FOOTPRINT
- SUB-WATERSHED BOUNDARY
- WATERCOURSE
- WATERBODY

*FISHING EFFORT NUMBER INDICATES START LOCATION



REFERENCE(S)

1. BASE DATA OBTAINED FROM AGNICO EAGLE MINES LIMITED.
2. DATUM: NAD83 PROJECTION UTM ZONE 15

CLIENT



AGNICO EAGLE MINES LIMITED

AGNICO EAGLE

PROJECT
MELIADINE GOLD PROJECT
NUNAVUT

TITLE

MELIADINE LAKE FISH HEALTH SAMPLING STATIONS - NEAR FIELD

CONSULTANT



YYYY-MM-DD	2018-03-23
DESIGNED	CA
PREPARED	MH
REVIEWED	RS
APPROVED	RS

PROJECT NO.
1787610

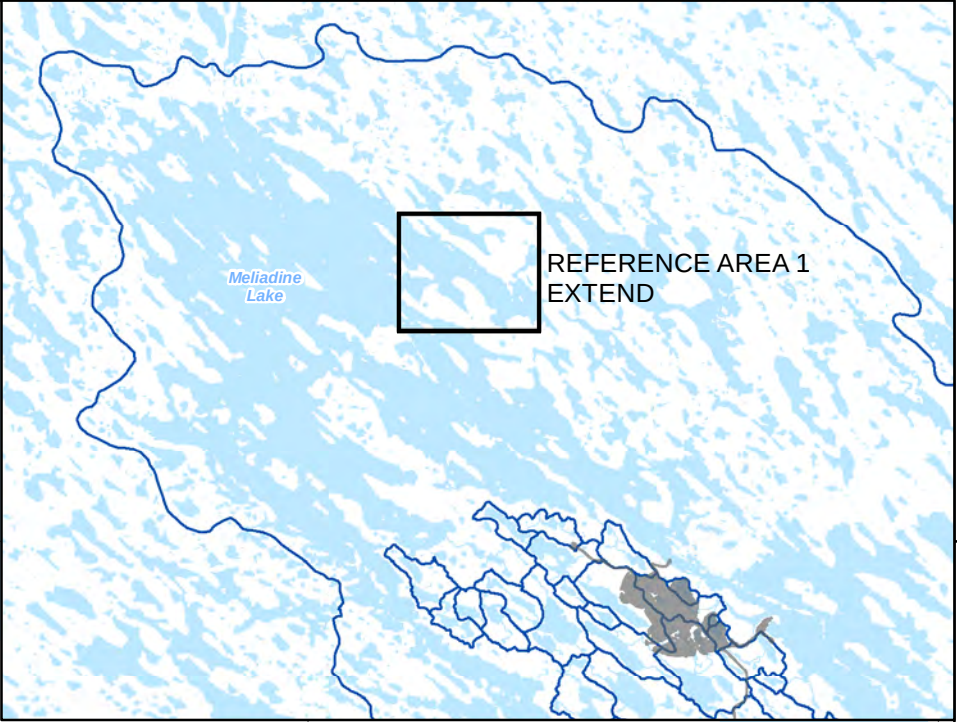
CONTROL
2000/2060

REV.
0

FIGURE
6.1-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

PATH: \\goldcorp\goldcorp\shared\GIS\client\agnico_eagle_mines\ltd\meliadine_gold_project\08_production\2000\NAD\Report1787610_2000_2060_Figure_2_Fish_Health_Sampling_Stations_REF1.mxd PRINTED ON: 2018/03/23 AT: 4:22:50 PM



LEGEND

FISH HEALTH SAMPLING STATION*

- BACKPACK ELECTROFISHING
- HOOP NET
- MINNOW TRAP
- SEINE NETTING

PATH OF TRAVEL

- BACKPACK ELETROFISHING
- MINNOW TRAP
- SEINE NETTING

- MINE FOOTPRINT
- SUB-WATERSHED BOUNDARY
- WATERBODY

*FISHING EFFORT NUMBER INDICATES START LOCATION



REFERENCE(S)

1. BASE DATA OBTAINED FROM AGNICO EAGLE MINES LIMITED.
2. DATUM: NAD83 PROJECTION UTM ZONE 15

CLIENT



AGNICO EAGLE MINES LIMITED

AGNICO EAGLE

PROJECT
MELIADINE GOLD PROJECT
NUNAVUT

TITLE

**MELIADINE LAKE FISH HEALTH SAMPLING STATIONS -
REFERENCE AREA 1**

CONSULTANT



YYYY-MM-DD 2018-03-23

DESIGNED CA

PREPARED MH

REVIEWED RS

APPROVED RS

PROJECT NO.
1787610

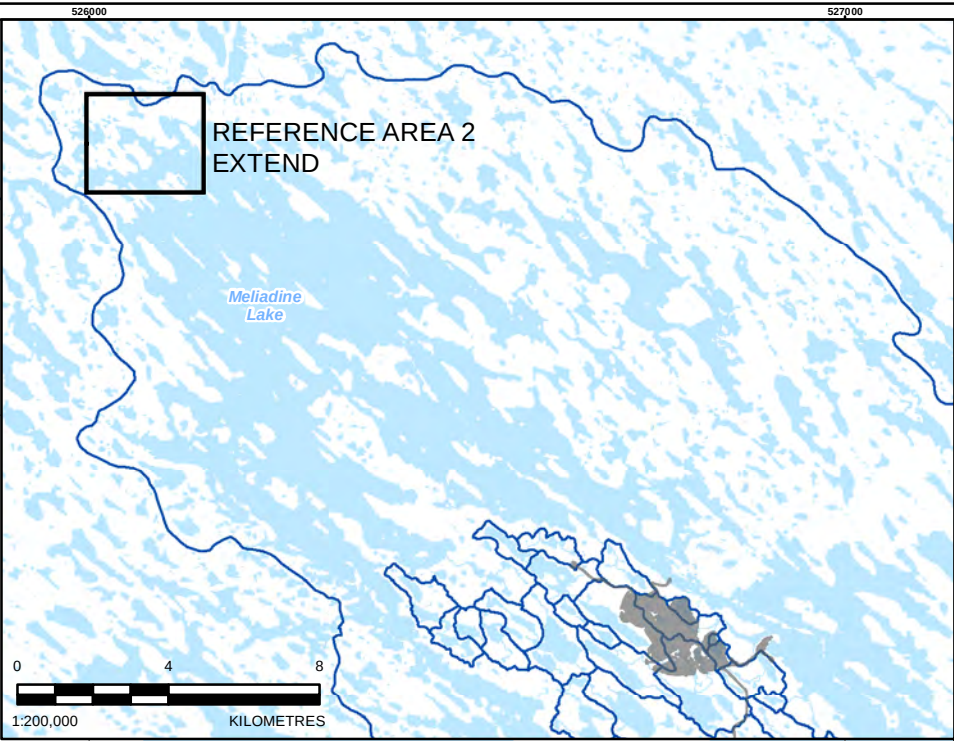
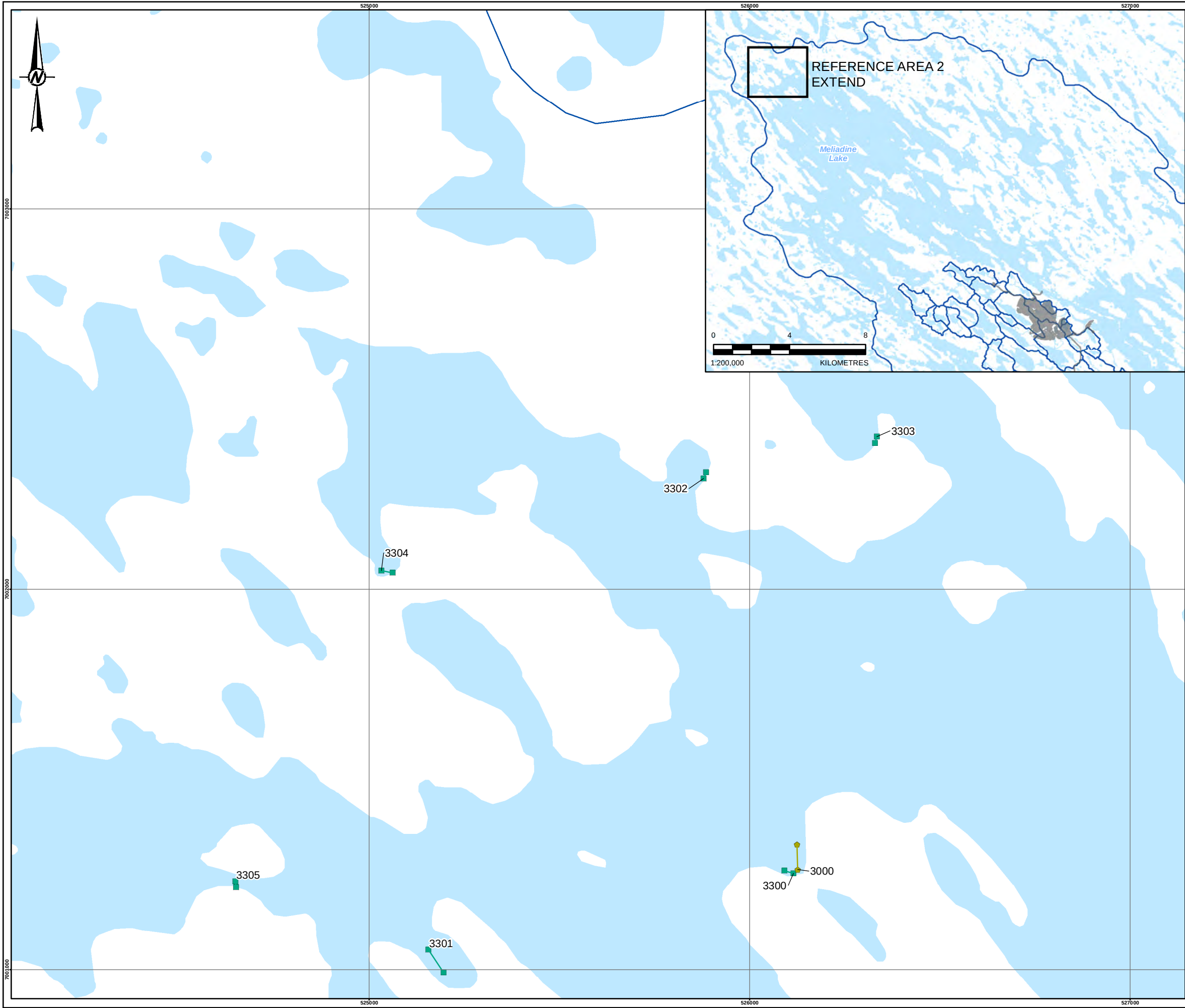
CONTROL
2000/2060

REV.
0

FIGURE
6.1-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B 25mm

\\path\lgolder\gold\geomatica\cad-gis\client\agnico_eagle_mines_lda\Meliadine_Gold_Project\089_PROJECT\SIT\787610\2_PRODUCTION\2000\NXC\Report\1787610_2000_2060_Figure_3_Fish_Health_Sampling_Stations_REF2.mxd PRINTED ON: 2018/03/23 AT: 4:28:17 PM



LEGEND
FISH HEALTH SAMPLING STATION*

- BACKPACK ELECTROFISHING
- MINNOW TRAP

PATH OF TRAVEL

- BACKPACK ELETROFISHING
- MINNOW TRAP

MINE FOOTPRINT

- MINE FOOTPRINT

SUB-WATERSHED BOUNDARY

- SUB-WATERSHED BOUNDARY

WATERBODY

- WATERBODY

*FISHING EFFORT NUMBER INDICATES START LOCATION

STUDY AREA

0 120 240

1:10,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM AGNICO EAGLE MINES LIMITED.
2. DATUM: NAD83 PROJECTION UTM ZONE 15

CLIENT

AGNICO EAGLE

PROJECT
MELIADINE GOLD PROJECT
NUNAVUT

TITLE
**MELIADINE LAKE FISH HEALTH SAMPLING STATIONS -
REFERENCE AREA 2**

CONSULTANT	YYYY-MM-DD	2018-03-23
DESIGNED	CA	
PREPARED	MH	
REVIEWED	RS	
APPROVED	RS	

PROJECT NO.	CONTROL	REV.	FIGURE
1787610	2000/2060	0	6.1-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B 25mm

6.1.2 Population Survey

Threespine Stickleback included in the population survey were sampled using a combination of lethal and non-lethal methods. All fish included in the population survey underwent an external examination and total length (± 1 mm) and total body weight (± 0.001 g) were recorded. Any features that did not appear normal (i.e., deformities, erosions, lesions, tumours, or external parasites) were documented. Fish that were sampled using non-lethal methods were released near the capture location after processing.

6.1.3 Lethal Surveys

Fish processed during the lethal survey underwent an external examination as described in the Environmental Effects Monitoring (EEM) technical guidance document (2012). Features of the fish that did not appear normal were documented (e.g., occurrence of deformities, erosion, lesions, tumours, or external parasites). Total length (± 0.1 mm) and total body weight (± 0.001 g) were recorded. Following the external examination, fish were sacrificed by a concussive blow to the head followed by cervical dislocation (i.e., cutting the spinal cord immediately behind the head). The condition of the internal organs were immediately assessed and any abnormalities in size, shape or colouration were documented. The liver and gonads were removed and weighed (± 0.001 g). Sex and reproductive stage were assigned for each fish based on a visual examination of the gonads at the time of sampling using macroscopic features described in Table 6.1-2. Tissue samples, including gonads and carcasses (i.e., the body of the fish with internal organs [viscera] removed), were labelled with an identification number and preserved for laboratory analysis. Histology and fecundity samples were preserved using 10% neutral buffered formalin and carcass samples were frozen at -20°C .

6.1.3.1 Histology

Gonad samples from Threespine Stickleback were submitted to Dr. Dave Groman at the University of Prince Edward Island, Atlantic Veterinary College (AVC) to confirm sex and maturity of lethally sampled fish. Sex and maturity were determined based on a histological assessment of gonad tissues with the aid of a light microscope, as per histological features listed in Table 6.1-2. Prior to interpretation, samples were prepared for histology by fixation, dehydration, clearing, embedding, sectioning, and staining. To verify that data quality objectives were met, histology results were cross-referenced with field designated sex and maturity stages, external and internal photographs, as well as biological data. Any discrepancies were reviewed by a second qualified biologist.

6.1.3.2 Fecundity

Threespine Stickleback fecundity samples were processed by qualified biologists at the Golder Saskatoon office. Fecundity (i.e., the number of ripening eggs contained within the ovaries) was estimated by counting the number of ripening eggs present in a subsample of Threespine Stickleback ovarian tissue. Fecundity was then calculated using the following formula:

$$\text{Fecundity} = \text{Subsample Egg Count} * \frac{\text{Ovary Weight (g)}}{\text{Subsample Weight (g)}}$$

Mean egg size was determined by measuring the diameter of 30 eggs. To verify that data quality objectives were met, 10% of samples were independently verified by a second qualified biologist.

Table 6.1-2: Gonad Maturity Stages Used During the Meliadine Lake Fish Health Assessment, August 2017

Sex	Stage	Code	Macroscopic Features	Histological Features
Female	Unknown stage	10	Unable to determine stage.	Unable to determine stage.
	Immature	11	Small ovaries, often clear, blood vessels indistinct.	Only oogonia and PG oocytes present. No atresia or muscle bundles. Thin ovarian wall and little space between oocytes.
	Early Stage Development	12	Enlarging ovaries, blood vessels more distinct. Granular in appearance.	PG, CA, Vtg1, and Vtg2 oocytes present. No evidence of POFs or Vtg3 oocytes. Some atresia can be present.
	Late Stage Development	13	Large ovaries filling the body cavity, prominent blood vessels. Individual oocytes visible.	Vtg3 oocytes present or POFs in batch spawners. Atresia of vitellogenic and/or hydrated oocytes may be present. Early stages of OM can be present.
	Ripe	14	Eggs released with gentle pressure on abdomen.	Oocytes undergoing late OM including GVM, GVBD and hydration, or ovulation.
	Spent	15	Deflated ovaries, blood vessels prominent.	Presence of oocyte atresia and, in some species, POFs. Few if any Vtg2 or Vtg3 oocytes.
	Reabsorbing	16	Small atretic oocytes throughout the ovaries, which are hard and white.	Advanced stage oocytes are atretic and no POFs are present.
	Resting	17	Small ovaries, blood vessels reduced but present.	Only oogonia and PG oocytes present. Muscle bundles, enlarged blood vessels, thick ovarian wall, atresia and degenerating POFs may be present.
Male	Unknown stage	20	Unable to determine stage.	Unable to determine stage.
	Immature	21	Small testes, often clear and threadlike.	Sg1 only; no lumen in lobules.
	Early Stage Development	22	Small testes, semi-translucent, but easily identified.	Spermatocysts evident along lobules. Sg2, Sc1, Sc2, St and Sz can be present in spermatocysts. Sz not present in lumen of lobules or in sperm ducts. GE continuous throughout.
	Late Stage Development	23	Testes large, firm and lobate. White to purplish in colour. Granular appearance.	Sz in lumen of lobules and/or sperm ducts. All stages of spermatogenesis (Sg2, Sc, St, Sz) can be present. Spermatocysts throughout the testis, active spermatogenesis. GE may be continuous or discontinuous.
	Ripe	24	Milt released with gentle pressure on abdomen.	Based on macroscopic observation only.
	Spent	25	Small and deflated testes. Blood vessels obvious. Violet-pink in colour.	Residual Sz present in lumen of lobules and in sperm ducts. Widely scattered spermatocysts near periphery containing Sc2, St, Sz. Little to no active spermatogenesis. Spermatogonial proliferation and regeneration of GE common in periphery of testes.
	Reabsorbing	26	Not typically observed in males.	Not typically observed in males.
	Resting	27	Small testes, often threadlike.	No spermatocysts. Lumen of lobule often nonexistent. Proliferation of spermatogonia throughout testes. GE continuous throughout. Small amount of residual Sz occasionally present in lumen of lobules and in sperm duct.

Note: Table modified from Brown-Peterson et al. (2011).

CA = cortical alveolar; GVBD = germinal vesicle breakdown, GVM = germinal vesicle migration, OM = oocyte maturation, PG = primary growth, POF = postovulatory follicle complex, Vtg1 = primary vitellogenic, Vtg2 = secondary vitellogenic, Vtg3 = tertiary vitellogenic, GE = germinal epithelium, Sc1 = primary spermatocyte, Sc2 = secondary spermatocyte, Sg1 = primary spermatogonia, Sg2 = secondary spermatogonia, St = spermatid, Sz = spermatozoa.

6.1.3.3 Tissue Chemistry

Tissue chemistry samples were analyzed by ALS Canada Ltd. (ALS; Burnaby, British Columbia) for metals listed in the AEMP Design Plan, Section 5.5.3 (Golder 2016b). Tissue samples were homogenized and sub-sampled prior to HotBlock® digestion with nitric and hydrochloric acids, in combination with hydrogen peroxide.

Instrumental analysis was completed using collision cell inductively coupled plasma - mass spectrometry. A list of metals analyzed and their respective detection limits (DL) for fish tissue are provided in Table 6.1-3. For some metals, the achieved DL differed from those defined in the AEMP Design Plan (Golder 2016b) due to low sample volumes preventing routine analyses; these samples were instead analyzed by high resolution inductively coupled plasma mass spectrometry. Data are reported in milligrams per kilogram wet weight (mg/kg ww).

Table 6.1-3: Analytical Detection Limits for Tissue Samples Processed Using Low Volume Analysis

Parameter	AEMP Design Plan DL ^(a) (mg/kg ww)	Low Volume Analysis DL (mg/kg ww)	Achieved DL (mg/kg ww)	
			2015	2017
Aluminum	0.4	1	0.4 to 1	1 to 2
Antimony	0.002	0.002	0.002	0.002 to 0.004
Arsenic	0.004	0.006	0.004 to 0.006	0.006 to 0.012
Barium	0.01	0.01	0.01	0.01 to 0.02
Beryllium	0.002	0.002	0.002	0.002 to 0.004
Bismuth	0.002	0.002	0.002	0.002 to 0.004
Boron	0.2	0.2	0.2	0.2 to 0.4
Cadmium	0.001	0.002	0.001 to 0.002	0.002 to 0.004
Calcium	4	4	4	4 to 8
Cesium	0.001	0.001	0.001	0.001 to 0.002
Chromium	0.01	0.04	0.01 to 0.04	0.04 to 0.08
Cobalt	0.004	0.004	0.004	0.004 to 0.008
Copper	0.02	0.04	0.02 to 0.04	0.04 to 0.08
Iron	0.6	1	0.6 to 1	1 to 2
Lead	0.04	0.01	0.004 to 0.01	0.01 to 0.02
Lithium	0.1	0.1	0.1	0.1 to 0.2
Magnesium	0.4	0.4	0.4	0.4 to 0.8

Parameter	AEMP Design Plan DL ^(a) (mg/kg ww)	Low Volume Analysis DL (mg/kg ww)	Achieved DL (mg/kg ww)	
			2015	2017
Manganese	0.01	0.01	0.01	0.01 to 0.02
Mercury	0.001	0.001	0.001 to 0.076	0.001 to 0.03
Molybdenum	0.004	0.008	0.004 to 0.008	0.008 to 0.016
Nickel	0.04	0.04	0.04 to 0.13	0.04 to 0.08
Phosphorus	2	2	2	2 to 4
Potassium	4	4	4	4 to 8
Rubidium	0.01	0.01	0.01	0.01 to 0.02
Selenium	0.01	0.02	0.01 to 0.02	0.02 to 0.04
Silver	0.001	0.001	0.001 to 0.002	0.001 to 0.002
Sodium	4	4	4	4 to 8
Strontium	0.01	0.02	0.01 to 0.02	0.02 to 0.04
Tellurium	0.004	0.004	0.004	0.004 to 0.008
Thallium	0.0004	0.0004	0.0004	0.0004 to 0.0008
Tin	0.02	0.02	0.02	0.02 to 0.04
Titanium	NA	0.1	0.02 to 0.1	0.1 to 0.2
Uranium	0.0004	0.0004	0.0004	0.0004 to 0.0008
Vanadium	0.02	0.02	0.02	0.02 to 0.04
Zinc	0.1	0.2	0.1 to 0.2	0.2 to 0.4
Zirconium	0.04	0.04	0.04	0.04 to 0.08
Lipid Content	NA	NA	0.5 to 1.25	0.4 to 2.1

(a) Provided in Golder (2016b).

mg/kg ww = milligrams per kilogram wet weight, DL = detection limit; NA = not applicable.

6.1.4 Data Analysis

Data collected during the fish health program were compared among sampling areas to identify and quantify potential differences in endpoints between the Near-field and reference areas. Endpoints were considered as either “effect” or “supporting” endpoints. Effect endpoints included specific parameters measured to determine whether there were any effects on indicators of survival, energy use, and energy storage among fish populations (Environment Canada 2012). Supporting endpoints included parameters measured to support the interpretation of potential effects. A list of measured effect and supporting endpoints for the population survey and the lethal survey are provided in Table 6.1-4 and Table 6.1-5, respectively. The magnitude of differences in effect endpoints were compared to critical effect sizes (CES), defined by Environment Canada in the EEM program (Environment Canada 2012), which establish effects thresholds indicative of potential risk to the environment (e.g., greater than 10% for relative body weight and greater than 25% for relative liver and gonad size).

Table 6.1-4: Statistical Procedures Used in the Population Survey

Indicator	Parameter	Endpoint	CES	Response Variable (Y)	Covariate (X)	Statistical Procedure
Survival	Length-frequency	Effect ^(a)	-	-	-	K-S test
Growth (energy use)	Length	Supporting	-	Length	-	ANOVA
	Body weight	Supporting	-	Total weight	-	ANOVA
Condition (energy storage)	Relative body weight	Effect	10%	Total weight	Length	ANCOVA

(a) Length-frequency is an effect endpoint for non-lethal sampling in the EEM program; however, because effect sizes are not expressed as a magnitude, but rather a maximum percent difference, there are no defined CES. Effects were based on the interpretation of the length-frequency distribution.

CES = critical effect size; K-S = Kolmogorov-Smirnov test; ANOVA = analysis of variance; ANCOVA = analysis of covariance; - = not applicable.

Table 6.1-5: Statistical Procedures Used in the Lethal Survey

Indicator	Parameter	Endpoint	CES	Response Variable (Y)	Covariate (X)	Statistical Procedure
Survival	Length-frequency	Supporting	-	-	-	K-S test
Growth (energy use)	Fork length	Effect ^(a)	25%	Fork length	-	ANOVA
	Body weight	Supporting	-	Total weight	-	ANOVA
	Size-at-age	Effect	25%	Total Weight	Age ^(b)	ANOVA
Reproduction (energy use)	Relative gonad size	Effect	25%	Gonad weight	Total weight	ANCOVA
	Relative fecundity	Supporting	-	# eggs	Total weight	ANCOVA
Condition (energy storage)	Relative body weight	Effect	10%	Total weight	Fork length	ANCOVA
	Relative liver size	Effect	25%	Liver weight	Total weight	ANCOVA
	Relative egg size	Supporting	-	Mean egg weight	Total weight	ANCOVA
Tissue Chemistry	Metals	Supporting	-	Metals	-	ANOVA

(a) Threespine Stickleback are short-lived in freshwater so length was used as a surrogate for age (Environment Canada 2012).

(b) Due to the short life span of Threespine Stickleback, size-at-age was examined for individuals age classes (i.e., 1+ and 2+) using an ANOVA model based on EEM technical guidance (Environment Canada 2012).

CES = critical effect size; K-S test = Kolmogorov-Smirnov test; ANOVA = analysis of variance; ANCOVA = analysis of covariance; - = not applicable.

6.1.5 Descriptive Statistics

Catch-per-unit effort (CPUE) was calculated to provide an estimate of abundance by standardizing catch data to fishing effort. The CPUE was calculated for each species captured and was summarized by sampling area and gear type. For minnow traps and hoop nets, CPUE was expressed as the number of fish captured per trap per hour. For seine nets, CPUE was expressed as the number of fish captured per m² of sampling area. For electrofishing, CPUE was expressed as the number of fish captured per 100 seconds.

Descriptive statistics were calculated for individual fish health and tissue chemistry parameters, separated by sampling area. Descriptive statistics included sample size, median, arithmetic mean, standard deviation (SD), standard error (SE), and minimum and maximum values. Fish health indices were calculated as follows:

$$\text{Condition Factor} = \left(\frac{\text{body weight}}{\text{length}^3} \right) \times 100,000$$

$$\text{Gonadosomatic index} = \left(\frac{\text{gonad weight}}{\text{body weight}} \right) \times 100$$

$$\text{Liver somatic index} = \left(\frac{\text{liver weight}}{\text{body weight}} \right) \times 100$$

Weight and length measurements were reported in units of grams (g) and millimetres (mm), respectively.

Fish health and tissue chemistry data were plotted by area using censored box plots as outlined in Barrett et al. (2014). Box plots were used to plot data when eight or more observations were above the DL, otherwise, individual concentrations were plotted. The censored boxplots were defined using the minimum values, the quartiles, and the maximum values. Values that were 1.5 times the interquartile range beyond the quartiles were considered extreme and plotted individually. When extreme values were present, the whiskers were truncated to the next value in the dataset that was within 1.5 times the interquartile range beyond the quartiles (i.e., the whiskers may not always extend to the full 1.5 times the interquartile range if the next value in the dataset is closer to the quartile than the full 1.5 times the interquartile range). The boxplots were censored (by a horizontal line) at the DL and the distribution of values below the DL were not shown. The concentrations below the DL are plotted at half of the DL as open circles.

6.1.6 Inferential Statistics

Statistical comparisons were conducted among sampling areas for fish health endpoints presented in Table 6.1-4 and Table 6.1-5, and fish tissue parameters presented in Table 6.1-3. Differences in the mean length, body weight, size-at-age, and individual metals were compared among sampling areas using analysis of variance (ANOVA). Differences in relative body weight, relative gonad weight, relative liver weight, relative fecundity, and relative egg size were compared among sampling areas using analysis of covariance (ANCOVA). Significant differences between sampling areas were determined using an α (alpha) of 0.1. As tapeworms were frequently observed in Threespine Stickleback captured from all areas of Meliadine Lake, inferential statistics were completed both with and without parasitized fish included (Golder 2016b).

The assumptions of ANOVA and ANCOVA are that the residuals of the data, after being fit to the model, are normally distributed and have equal variance between groups. The assumption of normality was assessed using the Shapiro-Wilk test, while Levene's test was used to assess equality of variances. Significant differences in assumptions were evaluated using an α of 0.05. If the assumptions of normality and equality of variance were not met, the data were $\log_{10}$ -transformed and the assumptions were re-tested. When the assumptions of ANOVA could not be met using a $\log_{10}$ transformation, the non-parametric Kruskal-Wallis (K-W) test was used. In addition to the assumptions of normality and equality of variance, ANCOVA has the additional assumption that the parameter regression slopes are parallel among sampling areas. To test this assumption, the ANCOVA was conducted by first fitting separate regression models for each sampling area using a general linear model that included an interaction term between the sampling area and covariate:

$$\text{Full ANCOVA model: } y = \beta_0 + \beta_1(x) + \beta_2(\text{Area}) + \beta_3(x) \times (\text{Area}) + \varepsilon$$

where y is the response variable, x is the covariate, Area is the sampling area indicator variable, and ε is the error term. If the coefficient β_3 of the $(x) \times (\text{Area})$ interaction term was not significant (i.e., $p > 0.05$), then the slopes were considered parallel and the ANCOVA proceeded by testing the significance of the coefficient β_2 of the (Area) term in the reduced ANCOVA model that fits separate regressions for each area, but with a common regression slope:

$$\text{Reduced ANCOVA model: } y = \beta_0 + \beta_1(x) + \beta_2(\text{Area}) + \varepsilon.$$

When a significant interaction was observed, the regression slopes were considered significantly different. When the covariate was a strong predictor of the response variable and the ANCOVA had a high coefficient of determination ($r^2 > 0.8$), the test for parallel slopes had high power to detect a difference that may not be practically significant. In this case, when the interaction term in the full ANCOVA model was significant, the slopes were fixed as parallel by fitting the reduced ANCOVA model because the reduced model explained almost as much (within 2%) of the variability in the response variable as the full model. In this case, the ANCOVA proceeded under the assumption that the regression slopes between groups were practically similar (Barrett et al. 2010).

Statistical outliers were evaluated using studentized residuals (SR) from the ANOVA and ANCOVA models. A magnitude of 3.0 for the SR was used to identify observations that were unusual. When an outlier was detected, the validity of the data point was examined. If the outlier was determined to be the result of a data entry error, it was corrected; if the outlier was not the result of data entry error and could not be resolved otherwise, the analysis was completed with and without outliers included.

When significant differences in fish health and tissue chemistry parameters were observed between sampling areas, the magnitude of difference between the Near-field area and individual reference areas were calculated by expressing the difference as a percentage of the mean as follows:

$$\text{Magnitude:} \quad \text{Magnitude} = \frac{\bar{x}_{NF} - \bar{x}_{\text{Reference Area}}}{\bar{x}_{\text{Reference Area}}} * 100$$

where $\bar{x}$ is the mean of the effect endpoint, and Reference Area refers to either Reference Area 1 or Reference Area 2.

If the statistical comparison was conducted on $\log_{10}$ -transformed data, then the magnitude was calculated using geometric means. If the statistical comparison between sampling areas was conducted using the K-W test, the data were not considered to be normally distributed and the magnitude was calculated using medians. As the K-W test is a non-parametric method for testing whether samples originate from the same distribution (i.e., it is not a comparison of sample medians), there were instances where the K-W test was significant, but no differences in medians were observed. For effect endpoints analyzed using ANCOVA, magnitudes were calculated from least squares means. When significant differences were observed among reference areas, the relative percent difference (RPD) was calculated instead, using the formula:

$$\text{Relative Percent Difference:} \quad \text{RPD} = \frac{\bar{x}_{RA1} - \bar{x}_{RA2}}{\bar{x}_{\text{Reference}}} * 100$$

where $\bar{x}_{RA1}$ and $\bar{x}_{RA2}$ are the means of the individual reference areas, and $\bar{x}_{\text{Reference}}$ is the mean of the pooled reference areas.

Length-frequency distributions were compared among sampling areas using the non-parametric, two-sample Kolmogorov-Smirnov (K-S) test. The K-S test compares the cumulative relative distributions of total length between sampling areas by comparing the maximum difference between the two cumulative relative frequency distributions to a critical value, which is determined based on sample size, to assess whether the difference is large enough to indicate that the two distributions came from different populations. Ages for individual fish were assigned based on length-frequency analyses of each sampling area using the Petersen Method (Petersen 1892, Mackay et al. 1990), with ages assigned to individual modes. Differences in the length of Threespine Stickleback were compared among gear types using the K-W test. The prevalence of abnormalities, including deformities, erosions, lesions and tumours (DELT), were compared among sampling areas using the chi-square test.

6.1.7 Power Analysis

Power analyses were performed to determine the power and sample size requirements to detect a magnitude of change that was equivalent to the CES defined in the metal mining technical guidance for Environmental Effects Monitoring (Environment Canada 2012). The CES defined for relative body weight was a 10% change in the mean relative to reference; for size-at-age, relative liver size, relative gonad size, the CES defined was a 25% change in the mean relative to reference. Type I (α) and Type II (β) error rates were set to 0.1 (Environment Canada 2012). Power analyses were conducted using the power and sample size function in G*Power 3.1 (Faul et al. 2007). Power analyses were not completed for endpoints without defined CES (Environment Canada 2012).

6.1.8 Normal Range Calculations

Normal ranges for effect endpoints at Meliadine Lake were estimated using baseline data collected from the Near-field area and reference areas between 2015 and 2017. The calculation methods used to estimate normal ranges followed the methods outlined in Barrett et al 2015.

Prior to calculating normal ranges, values below analytical detection limits were substituted with values half of the detection limit. Subsequently, statistical outliers were removed from the dataset. Statistical outliers were identified using standardized residuals, which provide a measure of the difference between observed and expected values (i.e., residuals), normalized to the variance of the dataset, and were calculated as follows:

$$\text{Standardized Residual: } x_z = \frac{x_i}{\sigma}$$

where x_z is the standardized residual, x_i is the residual of a data point, and σ is the sample standard deviation. Data points with standardized residuals greater than |3.5| (i.e., more than 3.5 standard deviations from the sample mean), were omitted from the analysis.

When the baseline data were normally distributed, the normal range was estimated for the mean of the observations as the 95% prediction interval (PI) of the data selected to represent the natural variability of the system (Barrett et al. 2015). Normality was assessed by using the Shapiro-Wilk test and the data were considered normally distributed if the probability statistic P was greater than 0.05. When the baseline data were not normally distributed, but normality could be achieved after $\log_{10}$ transformation, the normal range was defined using $\log_{10}$ transformed data and the upper and lower bounds of the normal range were back-transformed to the original scale.

When both the untransformed and transformed data sets were non-normal, the normal range boundaries were estimated as the 2.5th and 97.5th percentiles of the baseline data. In cases where the percentile method was used, 1,000 random samples were generated from the normal range dataset and the 2.5th and 97.5th percentiles were calculated from the distribution of 1,000 mean values to estimate the normal range of mean values. Finally, in cases where the untransformed data were normally distributed but the lower bound of the normal range calculated using the PI method was less than zero, the normal range was calculated using either the log-PI method or the percentiles method, depending on whether normality could be achieved after $\log_{10}$ transformation. This approach resulted in the lower bound of the normal range always being greater than zero, which was important when evaluating the potential effects related to toxicological impairment.

The normal ranges provided in this report are considered provisional during initial monitoring under the AEMP due to the limited sample sizes used in the calculations. The normal range is intended to estimate the range of natural spatial and temporal variability, and the more reference data incorporated into the calculation, the more accurate the estimate becomes. These normal ranges may be re-defined in future reports to allow for the inclusion of additional monitoring data (i.e., from reference areas only) after Mine construction has begun.

6.2 Quality Assurance and Quality Control

Quality assurance (QA) and quality control (QC) procedures were applied to field sampling, laboratory analyses, data entry, data analyses, and report preparation. Field equipment were calibrated throughout the field program following manufacturer specifications and all samples were collected by experienced personnel. Samples were labelled, preserved, and shipped according to standard protocols. Specific work instructions outlining each field task in detail were provided to the field personnel by the task manager. Detailed field notes were recorded in waterproof field books and on preprinted waterproof field data sheets in either pencil or indelible ink. Data sheets and sample labels were checked at the end of each field day for completeness and accuracy, and were scanned into electronic copies at the completion of the field program. Chain-of-custody forms were used to track shipment and receipt of samples.

Data screening was performed prior to statistical analyses. Data checks for outliers and confirmation of sex and reproductive staging were performed as follows:

- Fish health data were plotted as box plots and scatterplots to visually examine data for potential data entry errors or unusual data. Plots included total length versus carcass weight, carcass weight versus gonad weight, standard length versus total length, total length versus total body weight, carcass weight versus liver weight, total body weight versus carcass weight, age versus total length, age versus total body weight, age versus carcass weight, and age versus gonad weight.
- Outliers, as detected by the qualitative screening, were removed from the dataset only if they were determined to be the result of human error (i.e., sampling or measurement error). All outliers were checked with field data sheets and field photos as part of the screening process prior to removal from the dataset.
- Histology samples submitted to the AVC for sex and reproductive staging were visually screened for outliers by plotting total length versus total body weight, total length versus gonadosomatic index, and total length versus gonad weight. Outliers and fish identified near the size-at-maturity were selected for reassessment by the lab to confirm the accuracy of their sex and/or reproductive staging assignments.
- The separation of adults and juveniles was determined after consideration of field assessments, gonad weight and histology results. If there were inconsistencies between field assessments and histology results, gonad histology results were weighed more heavily, with consideration of all available data to assign the final gonad maturity categories and sex determination.

6.3 Results and Discussion

6.3.1 Catch Data Summaries

A total of 1,672 fish from 7 species were captured during the August 2015 and August 2017 small-bodied fish health survey at Meliadine Lake (Table 6.3-1). Fish were captured using a combination of minnow traps, seine nets, hoop nets and backpack electrofishing. The spatial extent of sampling is indicated for the Near-field area in Figure 6.1-1, Reference Area 1 in Figure 6.1-2, and Reference Area 2 in Figure 6.1-3. Species richness varied among sampling areas, with 7 species captured from the Near-field area, 6 species from Reference Area 1, and 3 species from Reference Area 2. Catch varied among sampling areas, with 285 fish captured at the Near-field area, 893 fish captured at Reference Area 1, and 494 fish captured at Reference Area 2. Catches at each sampling area were dominated by Threespine Stickleback, accounting for 86% of the total catch at the Near-field area, 96% of the catch at Reference Area 1, and 90% of the catch at Reference Area 2. Differences in catch were driven by variation in sampling effort (Table 6.3-2). Threespine Stickleback were captured primarily using minnow traps at each of the sampling areas. A gear selectivity bias was observed among sampling areas, with significantly larger Threespine Stickleback captured using minnow traps when compared to hoop nets (13%) or backpack electrofishing (11%; $P < 0.001$); suggesting minnow traps selected for larger fish when compared to other sampling methods (Figure 6.3-1).

Table 6.3-1: Species Richness and Abundance of Fish Captured at Meliadine Lake, 2015 and 2017

Species	Near-field Area	Reference Area 1	Reference Area 2	Total
Threespine Stickleback (<i>Gasterosteus aculeatus</i>)	246	860	447	1,553
Lake Trout (<i>Salvelinus namaycush</i>)	6	8	-	14
Ninespine Stickleback (<i>Pungitius pungitius</i>)	22	17	42	81
Round Whitefish (<i>Prosopium cylindraceum</i>)	1	6	-	7
Slimy Sculpin (<i>Cottus cognatus</i>)	8	1	-	9
Burbot (<i>Lota lota</i>)	1	1	5	7
Cisco (<i>Coregonus artedii</i>)	1	-	-	1
Species Richness	7	6	3	7
Abundance	285	893	494	1,672

- = not applicable.

Table 6.3-2: Catch-Per-Unit Effort for Fish Captured from Meliadine Lake, 2015 and 2017

Area	Sampling Method	Sampling Effort		THST	RNWH	LKTR	SLSC	BURB	NNST	CISC	Total
NF	Minnow Trap	584 h	Abundance	164	0	0	0	1	19	1	185
			CPUE #/h	0.28	0.00	0.00	0.00	<0.01	0.03	<0.01	0.32
	Seine Net	150 m ²	Abundance	2	0	0	0	0	0	0	2
			CPUE #/m ²	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Backpack Electrofishing	5170 s	Abundance	80	1	6	8	0	3	0	98
			CPUE #/100 s	1.55	0.02	0.12	0.15	0.00	0.06	0.00	1.90
RA1	Minnow Trap	1861 h	Abundance	586	0	1	0	1	16	0	604
			CPUE #/h	0.31	0.00	<0.01	0.00	<0.01	0.01	0.00	0.32
	Seine Net	340 m ²	Abundance	2	4	7	1	0	0	0	14
			CPUE #/m ²	0.01	0.01	0.02	<0.01	0.00	0.00	0.00	0.04
	Hoop Net	43 h	Abundance	118	0	0	0	0	1	0	119
			CPUE #/h	2.76	0.00	0.00	0.00	0.00	0.02	0.00	2.78
	Backpack Electrofishing	1241 s	Abundance	154	2	0	0	0	0	0	156
			CPUE #/100 s	12.41	0.16	0.00	0.00	0.00	0.00	0.00	12.57
RA2	Minnow Trap	1925 h	Abundance	423	0	0	0	3	33	0	459
			CPUE #/h	0.22	0.00	0.00	0.00	<0.01	0.02	0.00	0.24
	Backpack Electrofishing	339 s	Abundance	24	0	0	0	2	9	0	35
			CPUE #/100 s	7.08	0.00	0.00	0.00	0.59	2.65	0.00	10.32

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; THST = Threespine Stickleback; RNWH = Round Whitefish; LKTR = Lake Trout; SLSC = Slimy Sculpin; BURB = Burbot; NNST = Ninespine Stickleback; CISC = Cisco; CPUE = catch-per-unit-effort; # = number of fish.

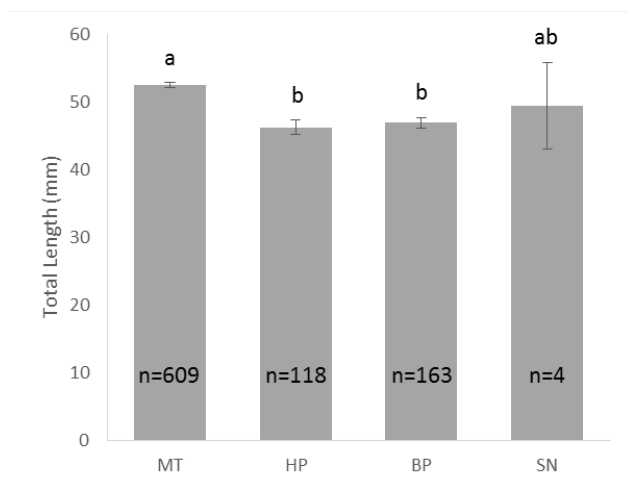


Figure 6.3-1: Total Length of Threespine Stickleback Captured From Meliadine Lake, 2015 and 2017

Note: Groups sharing the same letter are not significantly different from each other.

MT = minnow trap; HP = hoop net; BP = backpack electrofishing; SN = seine; n = sample size.

Water quality measurements were comparable among the Near-field and reference areas. Water temperatures ranged from 8.3 to 9.6°C at the Near-field area in 2015, and 11.0 to 13.7°C at Reference Area 1, and 13.6 to 13.7°C at Reference Area 2 in 2017. pH ranged from 6.2 to 6.6 at the Near-field area, 7.5 to 8.8 at Reference Area 1, and 7.7 to 7.8 at Reference Area 2. Dissolved oxygen concentrations ranged from 11.1 to 12.0 mg/L at the Near-field area, 8.7 to 10.8 at Reference Area 1, and 10.7 at Reference Area 2. Specific conductivity ranged from 49 to 52 µS/cm at the Near-field area, 55 to 88 µS/cm at Reference Area 1, and 68 µS/cm at Reference Area 2. Fish sampling effort and supporting environmental data are provided for each sampling area in Appendix 6A.

6.3.2 Population Survey

A total of 1,553 Threespine Stickleback were captured during the Meliadine Lake fish health program (Table 6.3-1). Of these, 289 were sampled during the lethal survey and an additional 605 Threespine Stickleback were processed using non-lethal methods (Appendix 6B). A combined total of 894 Threespine Stickleback were included in the population survey, while 659 individuals were released without processing (due to high catch volumes and efforts to minimize mortality associated with sampling by unnecessarily extending hold times). Threespine Stickleback sample size targets for the population survey were met at each of the sampling areas (Table 6.3-3). No young-of-the-year fish were captured during the assessment.

Table 6.3-3: Sample Sizes for the Meliadine Lake Population Survey, 2015 and 2017

Target Sample Size ^(a)	Achieved Sample Size			
	Near-field Area	Reference Area 1	Reference Area 2	Total
190	246	332	316	894

(a) Target sample size includes 90 lethal and 100 non-lethal samples.

Threespine Stickleback CPUE varied among gear types and sampling areas, with the majority of Threespine Stickleback captured using minnow traps in Meliadine Lake (Table 6.3-2). The CPUE of Threespine Stickleback captured using minnow traps was 0.28 fish per hour at the Near-field area, 0.31 fish per hour at Reference Area 1, and 0.22 fish per hour at Reference Area 2. The CPUE of Threespine Stickleback captured backpack electrofishing was 1.55 fish per 100 s at the Near-field area, 12.41 fish per 100 s at Reference Area 1, and 7.08 fish per 100 s at Reference Area 2. The CPUE of Threespine Stickleback captured using hoop nets was 2.76 fish per hour at Reference Area 1. Hoop nets were not deployed at the Near-field area or Reference Area 2. The CPUE of Threespine Stickleback captured using seines was 0.01 fish per m² at both the Near-field and Reference Area 1. Seine nets were not used at Reference Area 2. Descriptive statistics for the Threespine Stickleback population survey are provided in Table 6.3-4, with the results of statistical comparisons presented in Table 6.3-5. Data are provided in Appendix 6B, and boxplots are presented in Appendix 6C.

6.3.2.1 Length-Frequency

Length-frequency distributions of Threespine Stickleback were significantly different among sampling areas (Table 6.3-5, Figure 6.3-2, and Figure 6.3-3). Significant differences in cumulative relative frequency were observed between the Near-field area and Reference Area 1 (19%), as well as the Near-field area and Reference Area 2 (40%); however, significant differences were also observed between reference areas (27%). Differences in length frequency distributions were driven by the relative proportion of small (i.e., age 1+) and large (i.e., age 2+) Threespine Stickleback captured at each of the sampling areas (Figure 6.3-2 and Figure 6.3-3). The Near-field area and Reference Area 1 were dominated by smaller age 1+ fish, while Reference Area 2 had a greater abundance of larger age 2+ individuals. Differences in length-frequency distributions may reflect natural variation in Threespine Stickleback population structure within Meliadine Lake; however, interpretation of these results were confounded by spatiotemporal differences in size-at-age, sampling effort, and gear. Differences in size-at-age were observed among sampling areas (Table 6.3-5), with 60% and 68% larger age 1+ Threespine Stickleback collected from the Near-field area in 2015 when compared to Reference Area 1 and Reference Area 2 in 2017, respectively. This resulted in comparatively fewer fish under 40 mm at the Near-field area (Figure 6.3-3). As the Near-field and reference areas were sampled in different years, it could not be determined whether differences reflected spatial or interannual variation in size-at-age (i.e., it could not be determined whether growth rates were higher at the Near-field area when compared to the reference areas, or whether growth rates were higher in 2015 when compared to 2017). Sampling effort also varied among sampling areas. A greater proportion of Threespine Stickleback were captured using minnow traps at Reference Area 2 (95%), when compared to the Near-field area (67%), and Reference Area 1 (68%, Appendix 6A). Minnow traps selected for larger individuals when compared to Threespine Stickleback captured using hoop nets and electrofishing (Section 6.3.1), which may have increased the relative abundance of age 2+ fish captured at Reference Area 2.

Table 6.3-4: Descriptive Statistics for Threespine Stickleback Collected from Meliadine Lake, 2015 and 2017

Stage	Parameter	Near-field Area							Reference Area 1							Reference Area 2						
		n	Mean	Median	Min	Max	SD	SE	n	Mean	Median	Min	Max	SD	SE	n	Mean	Median	Min	Max	SD	SE
Adult	Age (yr)	82	1.7	2.0	1.0	2.0	0.4	<0.1	165	2.0	2.0	1.0	2.0	0.2	<0.1	235	2.0	2.0	1.0	2.0	0.2	<0.1
	Total length (mm)	82	58.7	58.1	47.6	72.1	6.3	0.7	165	59.6	60.0	37.6	76.5	7.0	0.5	235	59.2	59.0	38.5	74.0	6.0	0.4
	Total weight (g)	82	1.856	1.779	0.929	3.162	0.610	0.067	165	1.887	1.858	0.395	4.425	0.647	0.050	235	1.792	1.714	0.417	3.237	0.550	0.036
	Condition (TW)	82	0.89	0.87	0.65	1.26	0.10	0.01	165	0.86	0.85	0.59	1.23	0.11	0.01	235	0.84	0.84	0.50	1.18	0.10	0.01
Juvenile	Age (yr)	164	1.0	1.0	1.0	1.0	<0.1	<0.1	167	1.0	1.0	1.0	2.0	0.1	<0.1	81	1.0	1.0	1.0	2.0	0.2	<0.1
	Total length (mm)	164	42.4	44.0	26.7	49.7	5.0	0.4	167	38.8	38.0	31.0	53.6	3.9	0.3	81	40.7	40.2	30.0	51.9	4.1	0.5
	Total weight (g)	163	0.708	0.735	0.177	1.255	0.246	0.019	167	0.498	0.472	0.215	1.144	0.162	0.013	81	0.534	0.492	0.175	1.150	0.197	0.022
	Condition (TW)	163	0.88	0.88	0.57	1.23	0.11	0.01	167	0.83	0.81	0.59	1.37	0.12	0.01	81	0.77	0.75	0.55	1.26	0.14	0.02

n = sample size; SD = standard deviation; SE = standard error; < = less than; TW = calculated using total weight.

Table 6.3-5: Statistical Comparison of Fish Population Survey Parameters among Meliadine Lake Sampling Areas, 2015 and 2017

Parameter	Dependent Variable	Covariate	Endpoint	Statistical Test	n			Interaction <i>P</i> -value	Model <i>P</i> -value	MSE	Least Squares Mean ^(a)			Power Analysis (↑ / ↓)		n	Post-hoc <i>P</i> -value			Magnitude (%)		
					NF	RA1	RA2				NF	RA1	RA2	CES	Power ^(b)		NF*RA1	NF*RA2	RA1*RA2	NF*RA1	NF*RA2	RA1*RA2
Length-frequency	-	-	Effect	K-S test	246	332	316	-	-	-	-	-	-	-	-	-	<0.001	<0.001	<0.001	19%	40%	27%
Size-at-age	Total weight	Age 1+	Supporting	K-W test	184	172	85	-	<0.001	-	0.785	0.468	0.492	25%	1.00	38	<0.001	<0.001	<0.001	68%	60%	-5%
		Age 2+	Supporting	ANOVA _{log}	61	160	231	-	0.001	0.016	0.306	0.267	0.240		1.00 / 1.00	44 / 31	0.106	0.001	0.099	-	16%	6%
	Length	Age 1+	Supporting	K-W test	185	172	85	-	<0.001	-	44.6	38.1	40.2	-	-	-	<0.001	<0.001	<0.001	17%	11%	-5%
		Age 2+	Supporting	K-W test	61	160	231	-	0.053	-	60.8	60.0	59.0	-	-	-	<0.001	<0.001	<0.001	1%	3%	2%
Body weight	Total weight	-	Supporting	K-W test	245	332	316	-	<0.001	-	0.881	0.812	1.516	-	-	-	<0.001	<0.001	0.010	8%	-42%	-60%
Length	Length	-	Supporting	K-W test	246	332	316	-	<0.001	-	46.5	45.0	46.0	25%	1.00	11	<0.001	<0.001	0.001	3%	1%	-2%
Relative body weight	Total weight	Length	Effect	ANCOVA _{rank}	245	332	316	0.279	<0.001	2393	460	450	434	10%	1.00	32	0.027	<0.001	<0.001	2%	6%	4%

(a) Medians provided when data compared using the K-W test.

(b) For non-parametric tests power was estimated using ANOVA.

Note: Statistically significant differences indicated in **bold**.

n = sample size; NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; *P*-value = probability value; MSE = mean squared error; CES = critical effect size; < = less than; K-S = Kolmogorov–Smirnov; K-W = Kruskal-Wallis; ANOVA = analysis of variance; log = log₁₀ transformed data; ANCOVA = analysis of covariance; rank = rank transformed data; - = not applicable.

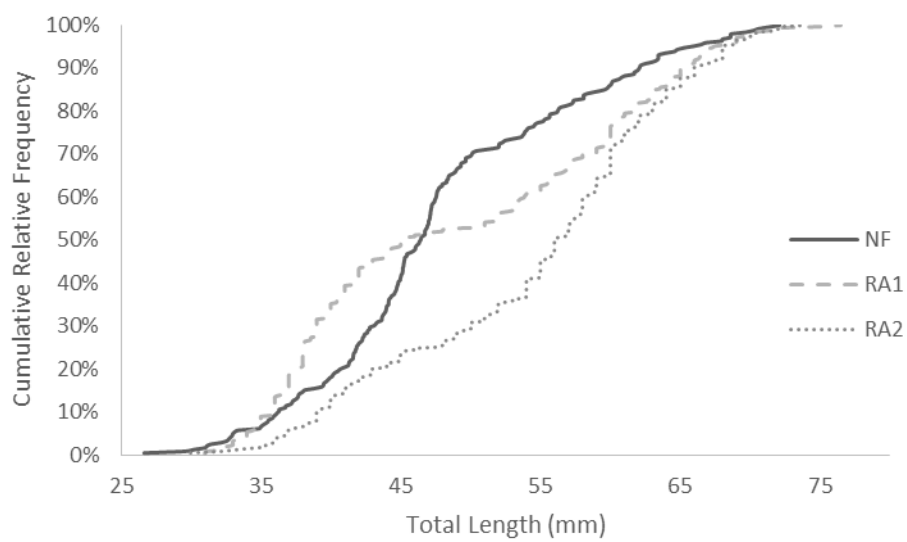


Figure 6.3-2: Cumulative Length-Frequency Distribution of Threespine Stickleback Collected from Meliadine Lake, 2015 and 2017

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2.

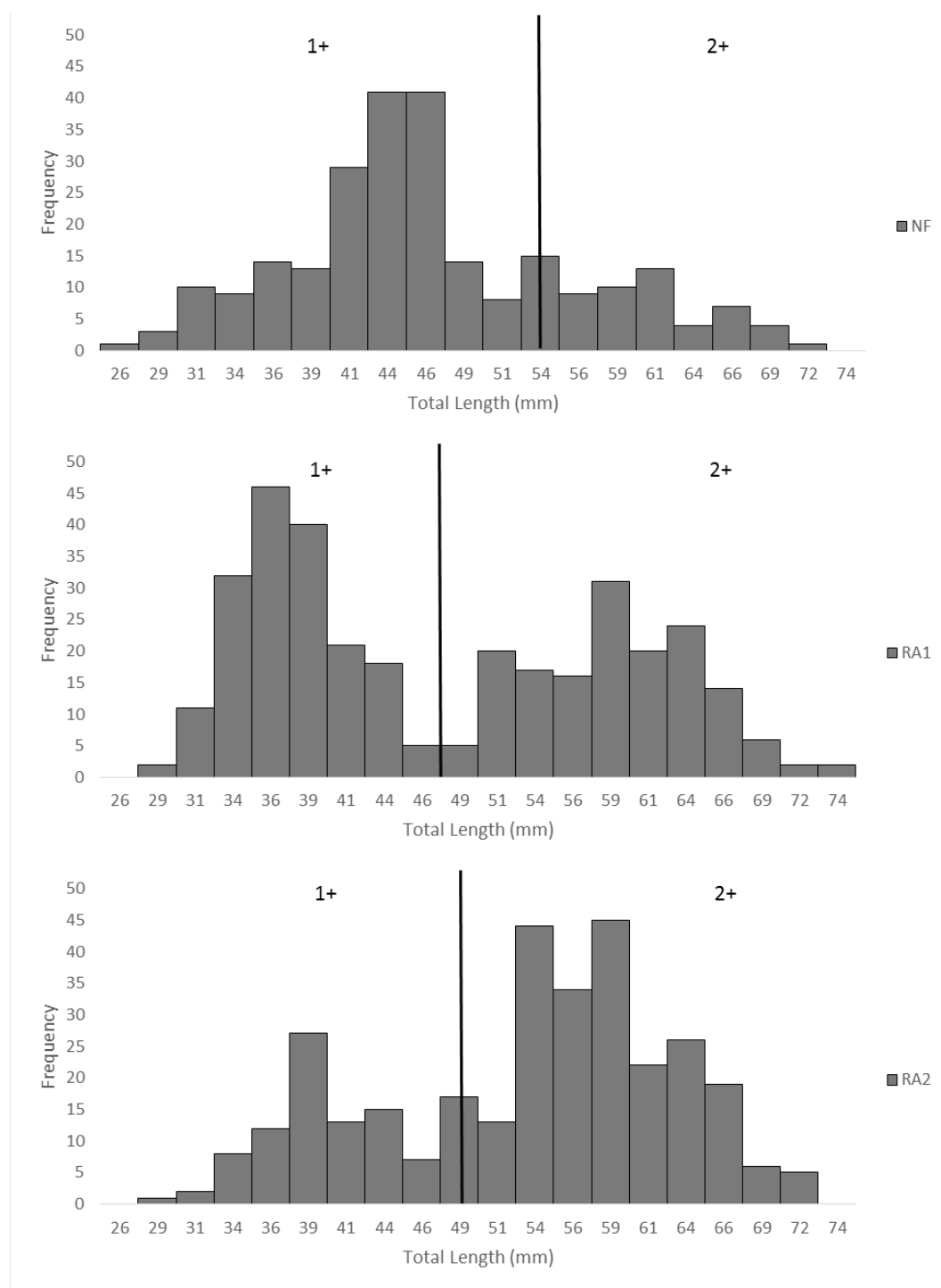


Figure 6.3-3: Length-Frequency Distributions for Threespine Stickleback Collected from Meliadine Lake, 2015 and 2017

Note: Age classes (1+ and 2+ years) delineated by a vertical line.

NF= Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2.

6.3.2.2 Size

Threespine Stickleback ranged in size from 26.7 to 76.5 mm, and 0.175 to 4.425 g (Table 6.3-4, Figure 6.3-4). Significant differences were observed for total length and body weight of Threespine Stickleback captured at each of the sampling areas (Table 6.3-5). Threespine Stickleback collected from the Near-field area were relatively larger than fish collected from Reference Area 1 (i.e., 3% longer, weighing 8% more), and longer but weighed less than Threespine Stickleback collected from Reference Area 2 (i.e., 1% longer, weighing 42% less). Significant differences were also observed between reference areas, with smaller fish collected from Reference Area 1 when compared to Reference Area 2 (i.e., 2% shorter, weighing 60% less). As with length frequency distributions (Section 6.3.2.1), these differences were primarily driven by the relative abundance and size-at-age of age 1+ and age 2+ fish at each of the sampling areas (Figure 6.3-2).

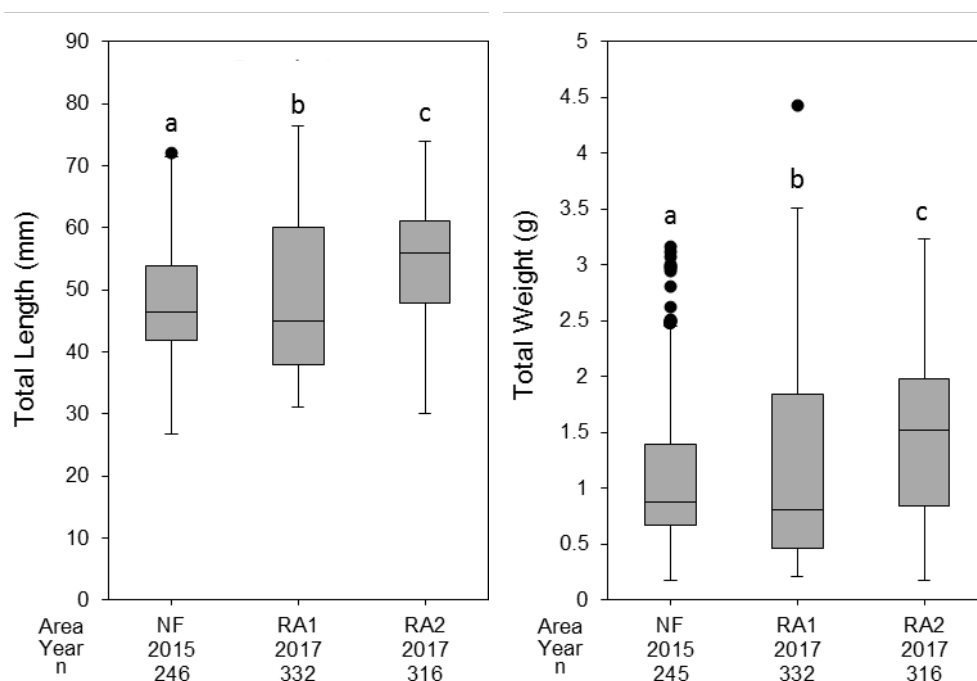


Figure 6.3-4: Length and Weight Threespine Stickleback Measured from Meliadine Lake during the Population Survey, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.2.3 Condition

Condition factor for Threespine Stickleback collected from Meliadine Lake ranged from 0.50 to 1.37 (Table 6.3-4). Relative body weights were significantly different among sampling areas (Table 6.3-5). Relative body weight was significantly greater at the Near-field area when compared to Reference Area 1 (2%), and Reference Area 2 (6%), and was significantly different between reference areas (4%; Figure 6.3-5). The magnitude of differences between the Near-field area and the reference areas were below CES of 10% (Environment Canada 2012).

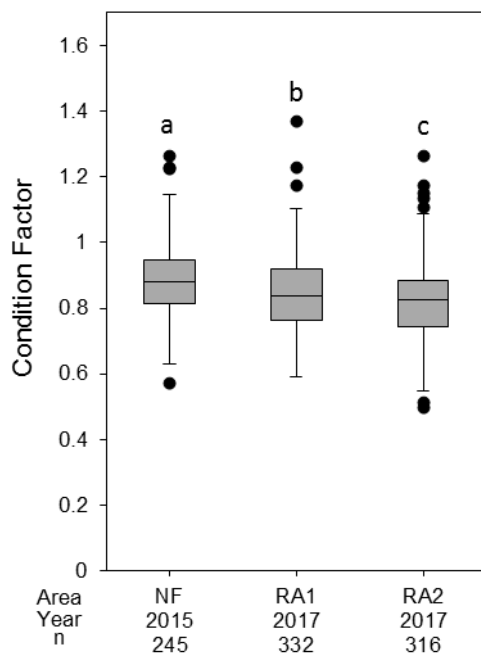


Figure 6.3-5: Condition Factor of Threespine Stickleback Collected During the Population Survey from Meliadine Lake, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.3 Lethal Survey

A total of 289 Threespine Stickleback were lethally sampled from Meliadine Lake during the fish health assessment. Target sample sizes were achieved at each sampling area, with the exception of male Threespine Stickleback from the Near-field area (Table 6.3-6). Descriptive statistics for lethally sampled Threespine Stickleback are provided in Table 6.3-7, with the results of statistical comparisons among sampling areas presented in Table 6.3-8, and statistical comparisons excluding fish parasitized by tapeworms in Table 6.3-9. As sample sizes for unparasitized fish were small (i.e., sample sizes ranged from 0 to 14), results of the lethal survey focused on all Threespine Stickleback sampled. Fish health data and statistical outliers removed from the analyses are provided in Appendix 6B, and boxplots are presented in Appendix 6C.

Table 6.3-6: Sample Sizes for the Meliadine Lake Lethal Survey, 2015 and 2017

Life Stage	Sex	Target Sample Size	Achieved Sample Size			
			Near-field	Reference Area 1	Reference Area 2	Total
Adult	Female	20	38	36	30	104
	Male	20	19	30	33	82
Juvenile		20	38	31	34	103

Table 6.3-7: Descriptive Statistics for Threespine Stickleback Lethally Sampled from Meliadine Lake, 2015 and 2017

Sex	Parameter	Near-field							Reference Area 1							Reference Area 2						
		n	Mean	Median	Min	Max	SD	SE	n	Mean	Median	Min	Max	SD	SE	n	Mean	Median	Min	Max	SD	SE
Female	Age (yr)	38	1.9	2.0	1.0	2.0	0.3	0.1	36	1.9	2.0	1.0	2.0	0.2	<0.1	30	2.0	2.0	2.0	2.0	<0.1	<0.1
	Total length (mm)	38	61.4	60.9	52.0	72.1	6.0	1.0	36	62.7	63.9	40.4	76.5	7.2	1.2	30	62.6	61.9	51.2	72.1	6.2	1.1
	Total weight (g)	38	2.081	1.974	1.091	3.162	0.61	0.1	36	2.187	2.163	0.587	4.425	0.74	0.1	30	2.09	2.17	1.16	3.22	0.57	0.1
	Carcass weight (g)	38	1.477	1.369	0.872	2.503	0.47	0.1	36	1.531	1.531	0.482	2.748	0.50	0.1	30	1.50	1.48	0.79	2.21	0.41	0.1
	Condition (TW)	38	0.88	0.88	0.65	1.08	0.08	0.01	36	0.85	0.84	0.67	1.07	0.09	0.01	30	0.84	0.83	0.67	1.18	0.11	0.02
	Condition (CW)	38	0.62	0.62	0.52	0.71	0.05	0.01	36	0.60	0.60	0.48	0.76	0.06	0.01	30	0.60	0.60	0.46	0.77	0.05	0.01
	Liver weight (g)	38	0.059	0.051	0.013	0.148	0.03	<0.1	36	0.051	0.049	0.015	0.139	0.03	<0.1	30	0.05	0.05	0.03	0.10	0.02	<0.1
	Liver somatic index (TW)	38	2.73	2.54	0.77	4.71	0.85	0.14	36	2.36	2.14	0.80	6.07	0.99	0.17	30	2.53	2.34	1.78	4.20	0.63	0.12
	Liver somatic index (CW)	38	3.84	3.80	1.08	6.62	1.08	0.18	36	3.29	3.04	1.25	7.84	1.18	0.20	30	3.49	3.45	2.35	4.97	0.65	0.12
	Gonad weight (g)	38	0.081	0.047	0.013	0.582	0.11	<0.1	36	0.071	0.044	0.006	0.461	0.09	<0.1	30	0.07	0.05	0.01	0.30	0.07	<0.1
	Gonadosomatic index (TW)	38	3.44	2.36	0.80	19.75	3.88	0.63	36	2.75	2.21	0.89	12.12	2.38	0.40	30	2.87	2.20	0.81	10.38	2.22	0.41
	Gonadosomatic index (CW)	38	4.88	3.44	1.23	30.20	5.80	0.94	36	3.96	2.90	1.14	17.40	3.60	0.60	30	4.09	3.32	1.25	17.00	3.56	0.65
	Fecundity	21	982	919	143	1790	357	78	23	725	705	276	1161	248	52	24	923	944	319	1648	413	84
	Mean egg weight (mg)	21	0.291	0.084	0.053	4.076	0.869	0.190	23	0.139	0.104	0.048	0.557	0.121	0.025	24	0.103	0.060	0.021	0.530	0.123	0.025
Male	Age (yr)	19	1.9	2.0	1.0	2.0	0.2	0.1	30	1.8	2.0	1.0	2.0	0.4	0.1	33	1.9	2.0	1.0	2.0	0.3	0.1
	Total length (mm)	19	60.6	61.7	47.6	66.5	4.5	1.0	30	54.4	55.9	37.6	70.0	8.9	1.6	33	56.9	58.2	38.5	64.8	6.0	1.0
	Total weight (g)	19	2.069	2.074	1.173	2.999	0.478	0.110	30	1.528	1.563	0.395	2.756	0.678	0.124	33	1.557	1.582	0.417	2.715	0.489	0.085
	Carcass weight (g)	19	1.566	1.624	0.682	2.230	0.393	0.090	30	1.075	1.096	0.318	1.968	0.470	0.086	33	1.209	1.270	0.342	1.856	0.354	0.062
	Condition (TW)	19	0.92	0.92	0.77	1.09	0.10	0.02	30	0.87	0.88	0.67	1.04	0.09	0.02	33	0.81	0.82	0.63	1.08	0.10	0.02
	Condition (CW)	19	0.69	0.67	0.56	0.87	0.07	0.02	30	0.62	0.63	0.52	0.71	0.05	0.01	33	0.63	0.63	0.51	0.74	0.05	0.01
	Liver weight (g)	19	0.058	0.064	0.025	0.087	0.020	0.004	30	0.027	0.026	0.007	0.067	0.017	0.003	33	0.035	0.033	0.010	0.067	0.014	0.002
	Liver somatic index (TW)	19	2.80	2.72	1.57	4.34	0.70	0.16	30	1.77	1.74	0.87	3.30	0.60	0.11	33	2.32	2.35	1.36	3.68	0.62	0.11
	Liver somatic index (CW)	19	3.69	3.64	2.44	5.20	0.73	0.17	30	2.46	2.38	0.97	4.18	0.75	0.14	33	2.96	2.99	1.78	4.56	0.75	0.13
	Gonad weight (g)	19	0.015	0.016	0.005	0.030	0.006	0.001	29	0.012	0.012	0.001	0.025	0.007	0.001	33	0.016	0.016	0.002	0.036	0.009	0.001
	Gonadosomatic index (TW)	19	0.73	0.65	0.29	1.84	0.39	0.09	29	0.77	0.77	0.16	1.32	0.33	0.06	33	1.04	0.86	0.19	2.58	0.57	0.10
	Gonadosomatic index (CW)	19	0.98	0.87	0.45	2.76	0.56	0.13	29	1.07	1.08	0.18	1.91	0.45	0.08	33	1.33	1.27	0.22	2.98	0.69	0.12
Juvenile	Age (yr)	38	1.0	1.0	1.0	1.0	<0.1	<0.1	31	1.1	1.0	1.0	2.0	0.2	<0.1	34	1.1	1.0	1.0	2.0	0.2	<0.1
	Total length (mm)	38	45.7	46.3	39.5	49.7	2.7	0.4	31	38.3	37.3	31.1	53.6	4.7	0.8	34	40.9	40.1	33.9	51.9	4.4	0.8
	Total weight (g)	38	0.875	0.883	0.556	1.255	0.158	0.026	31	0.461	0.420	0.215	1.144	0.211	0.038	34	0.545	0.459	0.298	1.108	0.211	0.036
	Carcass weight (g)	38	0.573	0.562	0.353	0.948	0.117	0.019	31	0.337	0.313	0.166	0.848	0.146	0.026	34	0.398	0.360	0.240	0.779	0.133	0.023
	Condition (TW)	38	0.91	0.91	0.72	1.22	0.09	0.01	31	0.78	0.77	0.65	1.10	0.10	0.02	34	0.77	0.77	0.64	0.95	0.08	0.01
	Condition (CW)	38	0.59	0.58	0.52	0.84	0.06	0.01	31	0.57	0.56	0.49	0.69	0.05	0.01	34	0.57	0.56	0.46	0.68	0.05	0.01
	Liver weight (g)	38	0.018	0.018	0.010	0.039	0.006	0.001	31	0.010	0.010	0.005	0.023	0.004	0.001	34	0.014	0.014	0.004	0.031	0.005	0.001
	Liver somatic index (TW)	38	2.11	2.06	1.28	3.34	0.50	0.08	31	2.35	2.22	1.01	5.18	0.86	0.15	34	2.69	2.90	0.76	5.22	0.92	0.16
	Liver somatic index (CW)	38	3.23	3.21	1.47	5.29	0.74	0.12	31	3.15	3.13	1.88	7.21	1.09	0.20	34	3.58	3.65	1.14	7.53	1.13	0.19

n = sample size; SD = standard deviation; SE = standard error; < = less than; TW = calculated using total weight; CW = calculated using carcass weight.

Table 6.3-8: Statistical Comparison of Lethal Survey Parameters Measured in Threespine Stickleback Sampled from Meliadine Lake, 2015 and 2017

Sex	Parameter	Dependent Variable	Covariate	Statistical Test	n			Interaction P-value	Model P-value	MSE	Least Squares Mean			Outliers	Power Analysis (↑ / ↓)			Post-hoc P-value			Magnitude (%)		
					NF	RA1	RA2				NF	RA1	RA2		CES	Power	n	NF*RA1	NF*RA2	RA1*RA2	NF*RA1	NF*RA2	RA1*RA2
Female	Age	Age	-	K-W test	38	36	30	-	0.095	-	2	2	2	-	25%	1.00	5	0.876	<0.001	<0.001	-	0%	0%
	Size at age	Total weight	Age 1+	ANOVA	5	2	0	-	0.005	0.030	1.314	0.604	-	Included	25%	0.23	29	0.005	-	-	118%	-	-
				ANOVA	4	2	0	-	0.002	0.011	1.241	0.604	-	Removed		0.41	10	0.002	-	-	105%	-	-
			Age 2+	ANOVA _{log}	33	34	30	-	0.464	0.014	0.328	0.341	0.304	-		0.97 / 1.00	23 / 15	-	-	-	-	-	-
		Length	Age 1+	K-W test	5	2	0	-	0.053	-	53.1	42.6	-	-	-	-	-	0.053	-	-	24%	-	-
			Age 2+	ANOVA	33	34	30	-	0.603	32.4	62.6	63.8	62.6	-		-	-	-	-	-	-	-	-
	Length-frequency	Length	-	K-S test	38	36	30	-	-	-	-	-	-	-	-	-	-	0.214	0.850	0.846	-	-	-
	Body weight	Total weight	-	ANOVA	38	36	30	-	0.745	0.419	2.081	2.187	2.090	Included	-	-	-	-	-	-	-	-	-
				ANOVA	38	35	30	-	0.954	0.371	2.081	2.123	2.090	Removed		-	-	-	-	-	-	-	-
	Length	Length	-	ANOVA	38	36	30	-	0.620	42.7	61.4	62.7	62.6	Included	25% ^(a)	1.00	4	-	-	-	-	-	-
				ANOVA	38	35	30	-	0.391	38.0	61.4	63.3	62.6	Removed		1.00	4	-	-	-	-	-	-
	Relative gonad size	Gonad weight	Total weight	ANCOVA _{rank}	35	34	28	0.903	0.260	163	49.6	46.2	51.4	Included	25%	1.00	12	-	-	-	-	-	-
				ANCOVA _{log}	34	33	28	0.103	0.562	0.023	-1.388	-1.406	-1.364	Removed		0.94 / 0.99	27 / 18	-	-	-	-	-	-
			Carcass weight	ANCOVA _{log}	35	34	28	0.127	0.930	0.025	-1.383	-1.396	-1.397	-	-	-	-	-	-	-	-	-	-
				ANCOVA _{rank}	35	34	28	0.536	0.152	179	52.3	46.1	48.1	Included	-	-	-	-	-	-	-	-	-
			Length	ANCOVA _{log}	35	33	28	0.546	0.161	0.024	-1.347	-1.418	-1.399	Removed		-	-	-	-	-	-	-	-
	Relative fecundity	Number of eggs	Total weight	ANCOVA _{rank}	20	23	24	0.680	0.005	295	41.0	24.2	37.6	-	-	-	-	0.006	0.795	0.029	70%	-	-44%
			Carcass weight	ANCOVA _{rank}	20	23	24	0.945	0.017	348	41.1	26.1	39.3	-	-	-	-	0.025	0.944	0.049	57%	-	-40%
			Length	ANCOVA _{rank}	20	23	24	0.276	0.005	302	41.9	24.4	36.6	-	-	-	-	0.005	0.578	0.052	72%	-	-40%
	Relative body weight	Total weight	Length	ANCOVA _{log}	38	36	30	0.073	0.151	0.002	0.315	0.302	0.294	Included	10%	1.00 / 1.00	16 / 13	-	-	-	-	-	-
				ANCOVA	38	35	30	0.192	0.148	0.047	2.142	2.102	2.037	Removed		1.00	14	-	-	-	-	-	-
		Carcass weight	Length	ANCOVA _{log}	38	36	30	0.388	0.161	0.002	0.164	0.149	0.149	Included	-	-	-	-	-	-	-	-	-
				ANCOVA	38	35	30	0.141	0.135	0.021	1.550	1.496	1.484	Removed		-	-	-	-	-	-	-	-
	Relative liver size	Liver weight	Total weight	ANCOVA _{rank}	38	36	30	0.350	0.075	361	56.4	46.6	54.4	Included	25%	0.98	22	0.075	0.908	0.224	21%	-	-
				ANCOVA _{log}	37	36	30	0.180	0.023	0.025	-1.267	-1.355	-1.303	Removed		0.96 / 0.99	26 / 19	0.017	0.515	0.276	22%	-	-
			Carcass weight	ANCOVA _{rank}	38	36	30	0.576	0.019	249	57.4	46.9	52.8	Included	-	-	-	0.014	0.454	0.286	23%	-	-
				ANCOVA _{log}	37	36	30	0.297	0.007	0.013	-1.265	-1.352	-1.309	Removed		-	-	0.004	0.261	0.290	22%	-	-
			Length	ANCOVA _{rank}	38	36	30	0.291	0.016	348	58.8	46.1	52.0	Included	-	-	-	0.012	0.295	0.407	28%	-	-
				ANCOVA _{log}	37	35	30	0.069	0.009	0.016	-1.254	-1.345	-1.316	Removed		-	-	0.007	0.115	0.619	23%	-	-
	Relative egg size	Mean egg weight	Total weight	ANCOVA _{rank}	20	23	24	0.157	0.114	248	36.0	38.0	28.5	-	-	-	-	-	-	-	-	-	-
			Carcass weight	ANCOVA _{rank}	20	23	24	0.327	0.069	278	36.6	38.5	27.5	-	-	-	-	0.928	0.183	0.077	-	-	33%
			Length	ANCOVA _{rank}	20	23	24	0.035	0.057	285	39.6	39.3	28.8	-	-	-	-	0.999	0.092	0.100	-	38%	-
Male	Age	Age	-	K-W test	19	30	33	-	0.244	-	2	2	2	-	25%	1.00	11	-	-	-	-	-	-
	Size at age	Total weight	Age 1+	K-W test	1	6	3	-	0.289	-	1.173	0.454	0.448	-	25%	0.20	37	-	-	-	-	-	-
			Age 2+	ANOVA	18	24	30	-	0.003	0.187	2.119	1.784	1.657	-		0.97	18	0.040	0.002	0.536	19%	28%	-
				ANOVA	1	6	3	-	0.187	12.6	47.6	39.9	42.3	Included	-	-	-	-	-	-	-	-	-
		Length	Age 1+	ANOVA	1	6	2	-	0.053	5.5	47.6	39.9	39.3	Removed		-	-	0.052	0.061	0.935	19%	21%	-
			Age 2+	K-W test	18	24	30	-	0.022	-	61.9	57.2	58.4	-		-	-	0.574	0.001	0.001	-	6%	-2%
	Length-frequency	NA	NA	K-S test	19	30	33	-	-	-	-	-	-	-	-	-	-	0.004	0.051	0.114	51%	38%	-
	Body weight	Total weight	NA	ANOVA	19	30	33	-	0.003	0.318	2.069	1.528	1.557	-	-	-	-	0.004	0.006	0.976	35%	33%	-
	Length	Length	NA	K-W test	19	30	33	-	0.007	-	61.7	55.95	58.1	-	25% ^(a)	1.00	5	0.011	<0.001	0.018	10%	6%	-4%
	Relative gonad size	Gonad weight	Total weight	ANCOVA _{log}	19	29	33	0.658	0.059	0.054	-2.012	-1.973	-1.864	-	25%	0.78 / 0.86	39 / 31	0.850	0.088	0.163	-	-29%	-
			Carcass weight	ANCOVA	19	29	33	0.478	0.059	<0.001	0.012	0.013	0.016	-	-	-	-	0.777	0.080	0.199	-	-27%	-
			Length	ANCOVA	19	29	33	0.938	0.155	<0.001	0.013	0.013	0.016	-	-	-	-	-	-	-	-	-	-
	Relative body weight	Total weight	Length	ANCOVA	19	30	33	0.326	<0.001	0.041	1.789	1.712	1.551	Included	10%	1.00	13	0.435	<0.001	0.008	-	15%	10%
				ANCOVA	19	30	32	0.185	<0.001	0.035	1.788	1.703	1.524	Removed		1.00	10	0.318	<0.001	0.001	-	17%	11%
		Carcass weight	Length	ANCOVA	19	30	33	<0.001^(b)	<0.001	0.019	1.361	1.210	1.204	Included	-	-	-	0.002	<0.001	0.987	13%	13%	-
				ANCOVA	18	30	33	<0.001^(b)	0.002	0.017	1.334	1.206	1.201	Removed		-	-	0.006	0.002	0.987	11%	11%	-
	Relative liver size	Liver weight	Total weight	ANCOVA	19	30	33	0.187	<0.001	<0.001	0.050	0.030	0.038	-	25%	0.99	15	<0.001	0.002	0.027	65%	33%	-22%
			Carcass weight	ANCOVA	19	30	33	0.164	<0.001	<0.001	0.048	0.033	0.036	-	-	-	-	<0.001	<0.001	0.290	47%	32%	-
			Length	ANCOVA	19	30	33	0.274	<0.001	182	53.7	33.9	41.1	-	-	-	-	<0.001	0.007	0.095	59%	31%	-19%

(a) Threespine Stickleback are short-lived in freshwater so length was used as a surrogate for age (Environment Canada 2012).

(b) Slopes are considered practically similar (Barrett et al. 2010).

Notes: Gonad weights with studentized residual values >4.0 were removed prior to analysis. Statistically significant differences indicated in **bold**. Exact power cannot be calculated for the KW test and was instead estimated based on ANOVA.

n = sample size; P-value = probability value; MSE = mean squared error; NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; CES = critical effect size; K-W = Kruskal-Wallis; K-S = Kolmogorov–Smirnov; ANOVA = analysis of variance; ANCOVA = analysis of covariance; log = log₁₀ transformed data; rank = rank transformed data; - and NA = not applicable.

Table 6.3-9: Statistical Comparison of Lethal Survey Parameters Measured in Threespine Stickleback Sampled from Meliadine Lake Excluding Fish Parasitized by Tapeworms, 2015 and 2017

Sex	Parameter	Dependent Variable	Covariate	Statistical Test	n			Interaction P-value	Model P-value	MSE	Least Squares Mean			Outliers	Power Analysis (↑ / ↓)			Post-hoc P-value			Magnitude (%)				
					NF	RA1	RA2				NF	RA1	RA2		CES	Power	n	NF*RA1	NF*RA2	RA1*RA2	NF*RA1	NF*RA2	RA1*RA2		
Female	Age	Age	-	K-W test	8	5	4	-	0.278	-	2	2	2	-	25%	0.79	8	-	-	-	-	-	-		
	Size at age	Total weight	Age 1+	ISS	1	2	0	-	-	-	-	-	-	-	25%	-	-	-	-	-	-	-	-		
			ANOVA	7	3	4	-	0.274	0.435	2.518	2.114	1.828	Included	0.332		21	-	-	-	-	-	-			
			ANOVA	6	3	4	-	0.037	0.241	2.756	2.114	1.828	Removed	0.470		12	0.203	0.037	0.733	-	51%	-			
		Length	Age 1+	ISS	1	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
			ANOVA	7	3	4	-	0.547	32.3	66.8	63.2	63.4	-	-		-	-	-	-	-	-	-	-		
			Length-frequency	NA	NA	K-S test	8	5	4	-	-	-	-	-		-	-	-	-	0.227	0.875	0.405	-	-	-
	Body weight	Total weight	NA	ANOVA	8	5	4	-	0.221	0.663	2.341	1.510	1.828	-	-	-	-	-	-	-	-	-			
	Length	Length	NA	ANOVA	8	5	4	-	0.157	75.5	64.9	55.0	63.4	-	25%(a)	0.95	5	-	-	-	-	-	-		
	Relative gonad size	Gonad weight	Total weight	ANCOVA	7	5	4	0.188	0.043	0.001	0.084	0.048	0.049	Included	25%	0.28	37	0.068	0.081	0.997	74%	70%	-		
				ANCOVA	6	5	4	0.107	0.011	<0.001	0.073	0.043	0.046	Removed		0.46	17	0.016	0.031	0.947	69%	58%	-		
			Carcass weight	ANCOVA _{log}	7	5	4	0.600	0.019	0.023	-1.196	-1.483	-1.442	Included	-	-	-	0.030	0.059	0.921	94%	76%	-		
				ANOVA	6	5	4	0.087	0.007	<0.001	0.074	0.043	0.044	Removed		-	-	0.013	0.016	0.999	71%	69%	-		
			Length	ANCOVA	7	5	4	0.068	0.040	0.001	0.088	0.052	0.037	Included	-	-	-	0.188	0.041	0.757	-	135%	-		
				ANCOVA _{log}	6	5	4	0.551	0.069	0.027	-1.249	-1.471	-1.495	Removed		-	-	0.153	0.095	0.977	-	76%	-		
		Relative fecundity	# eggs/female	Total weight	ANCOVA	6	2	4	0.109	0.105	40327	941	555	730	Included	-	-	-	-	-	-	-	-	-	
					ANCOVA	6	2	3	0.105	0.011	18479	951	559	583	Removed	-	-	-	0.023	0.027	0.981	70%	63%	-	
				Carcass weight	ANCOVA	6	2	4	0.119	0.093	39796	945	555	724	-	-	-	-	0.099	0.299	0.625	70%	-	-	
					Length	ANCOVA	6	2	4	0.081	0.071	35063	949	568	712	-	-	-	-	0.086	0.198	0.667	67%	-	-
		Condition	Total weight	Length	ANCOVA _{rank}	8	5	4	0.675	0.116	1.732	9.597	9.034	7.764	-	10%	0.55	14	-	-	-	-	-	-	
			Carcass weight	Length	ANCOVA	8	5	4	0.129	0.154	0.036	1.584	1.701	1.422	-	-	-	-	-	-	-	-	-	-	
		Relative liver size	Liver weight	Total weight	ANCOVA _{rank}	8	5	4	0.121	0.500	3.270	8.842	9.685	8.209	-	25%	0.83	7	-	-	-	-	-	-	-
				Carcass weight	ANCOVA _{rank}	8	5	4	0.244	0.632	3.936	9.125	9.314	8.107	-	-	-	-	-	-	-	-	-	-	
				Length	ANCOVA _{rank}	8	5	4	0.433	0.164	4.673	9.408	9.729	7.023	-	-	-	-	-	-	-	-	-	-	
		Relative egg size	Mean egg weight	Total weight	ANCOVA	6	2	4	0.573	0.692	0.001	0.104	0.106	0.083	Included	-	-	-	-	-	-	-	-	-	
					ANCOVA _{log}	6	2	4	0.402	0.422	0.017	-1.008	-1.0219	-1.130	-	-	-	-	-	-	-	-	-	-	
				Carcass weight	ANCOVA	6	2	4	0.581	0.585	0.001	0.106	0.106	0.080	Included	-	-	-	-	-	-	-	-	-	-
	ANCOVA _{log}				5	2	4	0.405	0.310	0.018	-0.999	-1.027	-1.144	-	-	-	-	-	-	-	-	-	-		
Male	Age	Age	-	K-W test	6	6	14	-	0.005	-	2	2	2	-	25%	0.79	8	0.014	<0.001	<0.001	0%	0%	0%		
	Size at age	Total weight	Age 1+	K-W test	0	5	3	-	0.764	-	-	0.448	0.448	-	25%	ISS	ISS	-	-	-	-	-	-		
			Age 2+	ANOVA	6	1	11	-	0.005	0.062	1.981	1.384	1.502	-		0.67	17	0.099	0.005	0.892	43%	32%	-		
		Length	Age 1+	K-W test	0	5	3	-	0.368	-	-	38.5	40.1	-	-	-	-	-	-	-	-	-	-		
			Age 2+	ANOVA	6	1	11	-	0.044	6.2	61.7	56.5	58.6	-		-	-	-	0.162	0.062	0.709	-	5%	-	
	Length-frequency	NA	NA	K-S test	6	6	14	-	-	-	-	-	-	-	-	-	<0.001	0.014	0.014	100%	71%	71%			
	Body weight	Total weight	NA	ANOVA	6	6	14	-	<0.001	0.168	1.981	0.599	1.300	-	-	-	-	<0.001	0.007	0.005	231%	52%	-74%		
	Length	Length	NA	ANOVA	6	6	14	-	<0.001	44.9	61.7	42.0	55.1	Included	25%(a)	1.00	5	<0.001	0.129	0.002	47%	-	-27%		
				ANOVA	6	6	13	-	<0.001	33.4	61.7	42.0	56.4	Removed		1.00	4	<0.001	0.171	<0.001	47%	-	-29%		
	Relative gonad size	Gonad weight	Total weight	ANCOVA _{log}	6	6	14	0.793	0.677	0.103	-2.165	-2.147	-2.044	-	25%	0.21 / 0.30	104 / 56	-	-	-	-	-	-		
			Carcass weight	ANCOVA _{log}	6	6	14	0.831	0.744	0.105	-2.135	-2.166	-2.049	-	-	-	-	-	-	-	-	-	-		
			Length	ANCOVA _{log}	6	6	14	0.953	0.833	0.109	-2.110	-2.169	-2.058	-	-	-	-	-	-	-	-	-	-		
	Condition	Total weight	Length	ANCOVA	6	6	14	0.162	0.001	0.017	1.509	1.275	1.213	Included	10%	0.78	13	0.105	0.001	0.738	-	24%	-		
				ANCOVA	6	6	13	0.112	0.001	0.014	1.497	1.273	1.224	Removed		0.79	12	0.091	0.001	0.801	18%	22%	-		
	Relative liver size	Carcass weight	Length	ANCOVA	6	6	14	0.221	0.007	0.008	1.202	1.119	1.047	-	-	-	-	0.524	0.010	0.439	-	15%	-		
				Liver weight	Total weight	ANCOVA _{rank}	6	6	14	0.456	0.007	8.6	18.0	8.6	13.5	Included	25%	0.97	6	0.005	0.063	0.020	110%	33%	-45%
		ANCOVA _{log}	6			6	13	0.036 ^(b)	<0.001	0.010	-1.337	-1.811	-1.577	Removed	1.00 / 1.00	4 / 4		<0.001	0.001	0.004	198%	74%	-55%		
		Carcass weight	ANCOVA _{log}		6	6	14	0.031 ^(b)	<0.001	0.013	-1.323	-1.803	-1.560	-	-	-	-	<0.001	0.002	0.007	202%	72%	-57%		
Length		ANCOVA _{log}	6	6	14	0.060	<0.001	0.014	-1.311	-1.797	-1.567	-	-	-	-	<0.001	0.001	0.016	206%	80%	-54%				

(a) Threespine Stickleback were short-lived and length was used as a surrogate for age (Environment Canada 2012).

(b) Slopes are considered practically similar (Barrett et al. 2010).

Notes: Gonad weights with studentized residual values >4.0 were removed prior to analysis. Statistically significant differences indicated in **bold**. Exact power cannot be calculated for the KW test and was instead estimated based on ANOVA.

n = sample size; P-value = probability value; MSE = mean squared error; NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; CES = critical effect size; K-W = Kruskal-Wallis; K-S = Kolmogorov–Smirnov; ANOVA = analysis of variance; ANCOVA = analysis of covariance; log = log₁₀

transformed data; rank = rank transformed data; ISS = Insufficient sample size to conduct analysis; - and NA = not applicable.

6.3.3.1 Length-Frequency

Length-frequency distributions were similar among sampling areas for female Threespine Stickleback (Table 6.3-8, Figure 6.3-6); however significant differences were observed among sampling areas for males. Male fish sampled from the Near-field area were generally larger than those sampled from the reference areas. The maximum percent difference between the Near-field area and Reference Area 1 was 51%, and between the Near-field area and Reference Area 2 was 38%. No significant differences were observed between the reference areas.

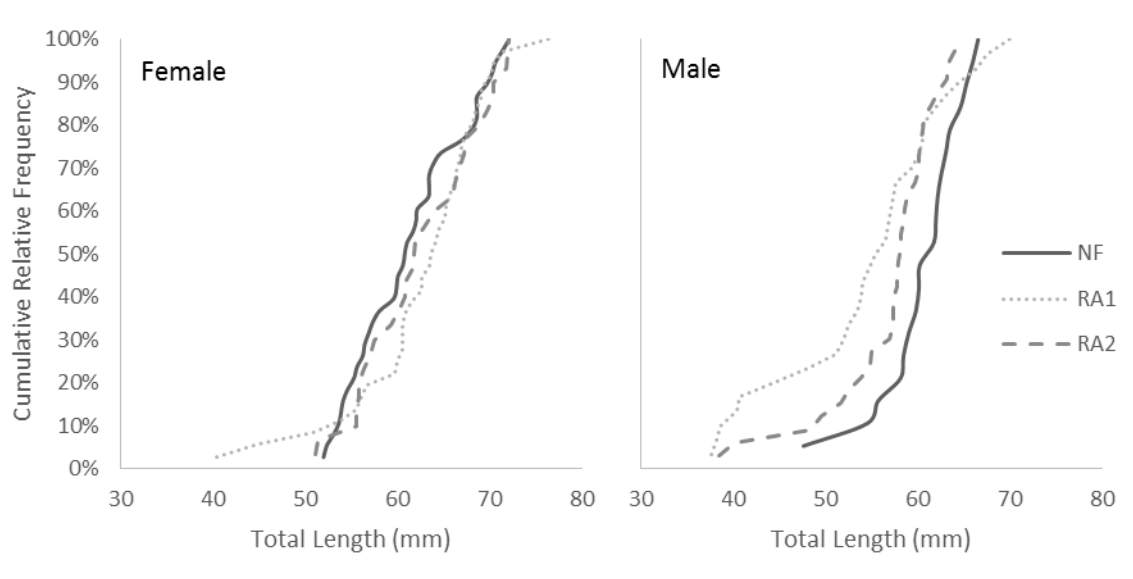


Figure 6.3-6: Cumulative Length-Frequency Distribution of Female and Male Threespine Stickleback Lethally Sampled from Meliadine Lake, 2015 and 2017

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2.

6.3.3.2 Age

Two age classes were assigned based on a length-frequency analysis of Threespine Stickleback captured during the population survey (Figure 6.3-3). Threespine Stickleback sampled from Meliadine Lake during the lethal survey were determined to range in age from 1 to 2 years (Table 6.3-7), with the majority of fish sampled reaching sexual maturity at age 2+.

The ages of female Threespine Stickleback were significantly different among sampling areas, with significant differences observed between the Near-field area and Reference Area 2, and between the reference areas (Table 6.3-8). While these sampling areas were statistically different from each other, median ages were the same resulting in a magnitude of difference of 0% (thus not exceeding the CES of 25%). No significant differences were observed between the Near-field area and Reference Area 1. No differences in age were observed among sampling areas for males.

6.3.3.3 Size-at-Age

Age 1+ Threespine Stickleback ranged in length from 26.7 to 53.9 mm at the Near-field area, 31.0 to 47.0 mm at Reference Area 1, and 30.0 to 48.8 mm at Reference Area 2. Age 2+ fish ranged in length from 54.1 to 72.1 mm at the Near-field area, 48.0 to 76.5 mm at Reference Area 1, and 49.0 to 74.0 mm at Reference Area 2.

Age 1+ female Threespine Stickleback were significantly larger at the Near-field area when compared to Reference Area 1 (24% length, 105% weight). No age 1+ female fish were sampled from Reference Area 2 for comparison. No significant differences were observed in length or weight among sampling areas for age 2+ female Threespine Stickleback. For male age 1+ fish, significant differences were observed in length; however, no significant differences were observed in weight. Threespine Stickleback sampled from the Near-field area were longer than fish sampled from Reference Area 1 (19%), and Reference Area 2 (21%). No significant differences in length were observed among reference areas. For male age 2+ fish, significant differences were observed in length and weight. Age 2+ male fish sampled from the Near-field area were heavier than fish sampled from Reference Area 1 (19%) and Reference Area 2 (28%). No significant differences were observed in length between the Near-field area and Reference Area 1. Fish sampled from the Near-field area were longer than fish sampled from Reference Area 2 (6%); while fish sampled from Reference Area 1 were shorter than fish sampled from Reference Area 2 (-2%).

6.3.3.4 Size

Lethally sampled Threespine Stickleback ranged in size from 31.1 to 76.5 mm and 0.215 to 4.425 g (Table 6.3-7). No significant differences were observed among sampling areas in length or weight for female Threespine Stickleback sampled during the lethal survey (Table 6.3-8, Figure 6.3-7). Male Threespine Stickleback sampled from the Near-field area were significantly larger than individuals sampled from Reference Area 1 (10% difference in length, 35% difference in weight) and Reference Area 2 (6% difference in length, 33% difference in weight). Significant differences were also observed between Reference Area 1 and Reference Area 2 in length (-4%), but not weight. As Threespine Stickleback are short-lived, and it can be difficult to detect a 25% difference in age, fish length was used as a surrogate effect endpoint (Environment Canada 2012). While significant differences were observed in length among sampling areas for male Threespine Stickleback, differences did not exceed the CES of 25%.

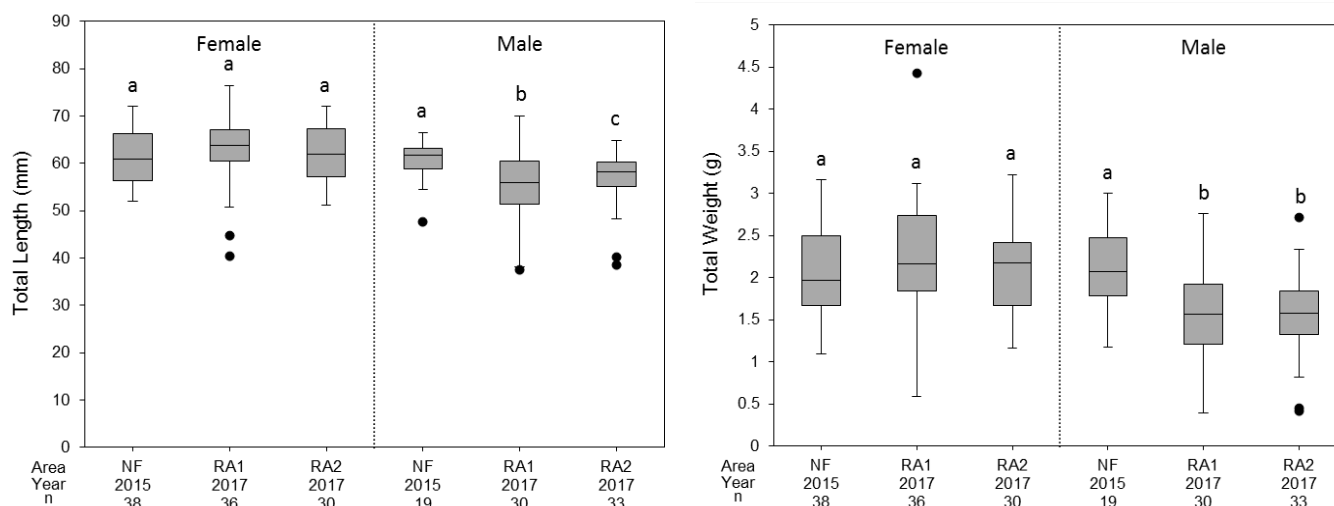


Figure 6.3-7: Length and Weight of Female and Male Threespine Stickleback Lethally Sampled From Meliadine Lake, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.
 NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.3.5 Size-at-Maturity

Fish length was a significant predictor of maturity in Threespine Stickleback, based on a binary logistic regression ($P < 0.001$). Size at maturity (i.e., the total length at which 50% of the population reaches sexual maturity, or P_{50}) was significantly different among fish parasitized and unparasitized by tapeworms ($P < 0.001$), maturing at 49.8 and 42.1 mm, respectively (Figure 6.3-8).

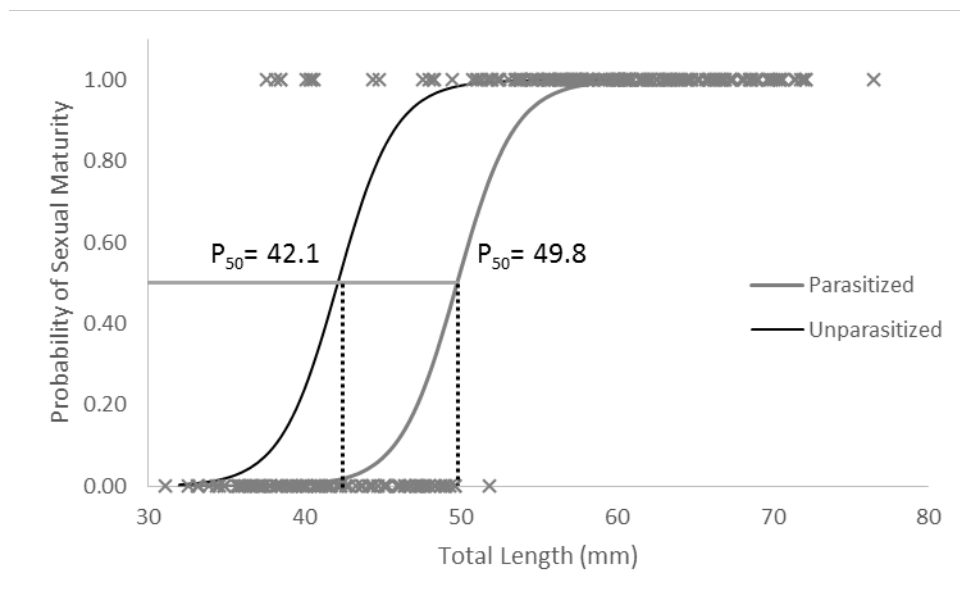


Figure 6.3-8: Size-at-Maturity of Threespine Stickleback With and Without Parasites

Notes: Plotted curve represents the modeled size at maturity. Actual data used in the analysis are represented by the symbol x. P_{50} = the total length at which 50% of the population reach sexual maturity.

6.3.3.6 Gonad Weight

The gonadosomatic index for female Threespine Stickleback ranged from 0.80 to 19.75. No significant differences were observed in relative gonad weight for female Threespine Stickleback among sampling areas (Table 6.3-8, Figure 6.3-9). For male Threespine Stickleback, the gonadosomatic index ranged from 0.16 to 2.58. Relative gonad weight was significantly lower for males sampled from the Near-field area when compared to Reference Area 2 (-29%), with the magnitude of difference exceeding the CES of 25%. No significant differences were observed between the Near-field area and Reference Area 1, or between the references areas.

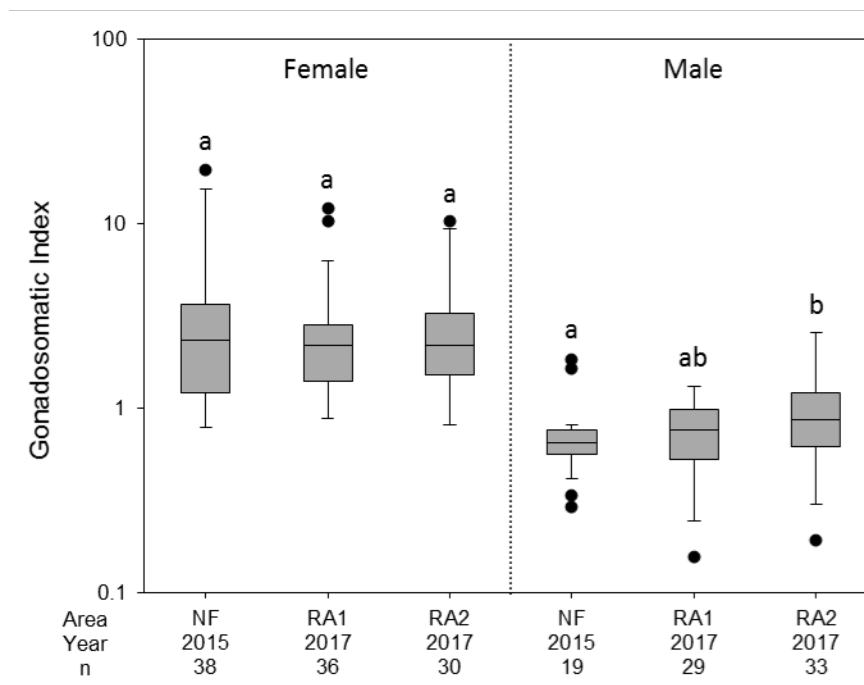


Figure 6.3-9: Gonadosomatic Index (log₁₀) of Female and Male Threespine Stickleback Lethally Sampled from Meliadine Lake, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.3.7 Fecundity

Fecundity for Threespine Stickleback sampled from Meliadine Lake ranged from 143 to 1790 eggs per female (Table 6.3-7). Relative fecundity was significantly greater at the Near-field area when compared to Reference Area 1 (70%), and significantly lower at Reference Area 1 compared to Reference Area 2 (-44%, Table 6.3-8, Figure 6.3-10). No significant differences were observed in fecundity between the Near-field area and Reference Area 2. Mean egg weight for Threespine Stickleback ranged from 0.021 g to 0.557 g (Table 6.3-7), with the exception of one ripe fish at the Near-field area that had a mean egg weight of 4.076 g. No significant differences were observed among sampling areas in mean egg weight (Table 6.3-8, Figure 6.3-10).

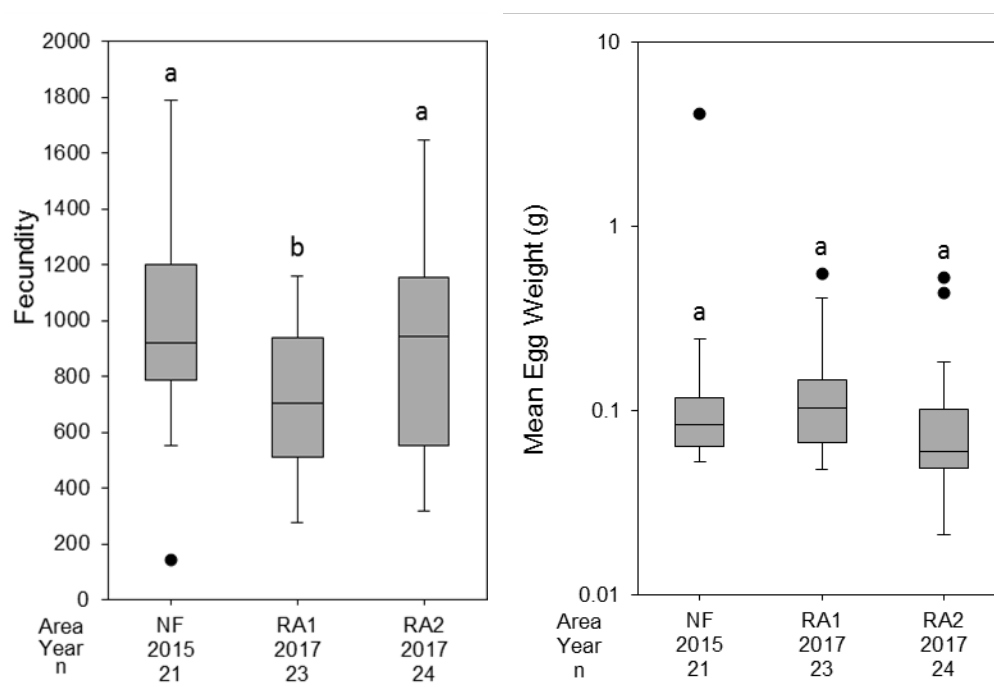


Figure 6.3-10: Fecundity and Egg Weight ($\log_{10}$) for Threespine Stickleback Sampled from Meliadine Lake, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.3.8 Condition

Condition factor for lethally sampled female Threespine Stickleback ranged from 0.65 to 1.18 in Meliadine Lake (Table 6.3-7). No significant differences were observed in relative body weight for female fish among sampling areas (Table 6.3-8, Figure 6.3-11). Condition factor for lethally sampled male Threespine Stickleback ranged from 0.63 to 1.09 in Meliadine Lake (Table 6.3-7). Relative body weight was significantly greater at the Near-field area and Reference Area 1, compared to Reference Area 2 (17% and 11%, respectively, Table 6.3-8, Figure 6.3-11).

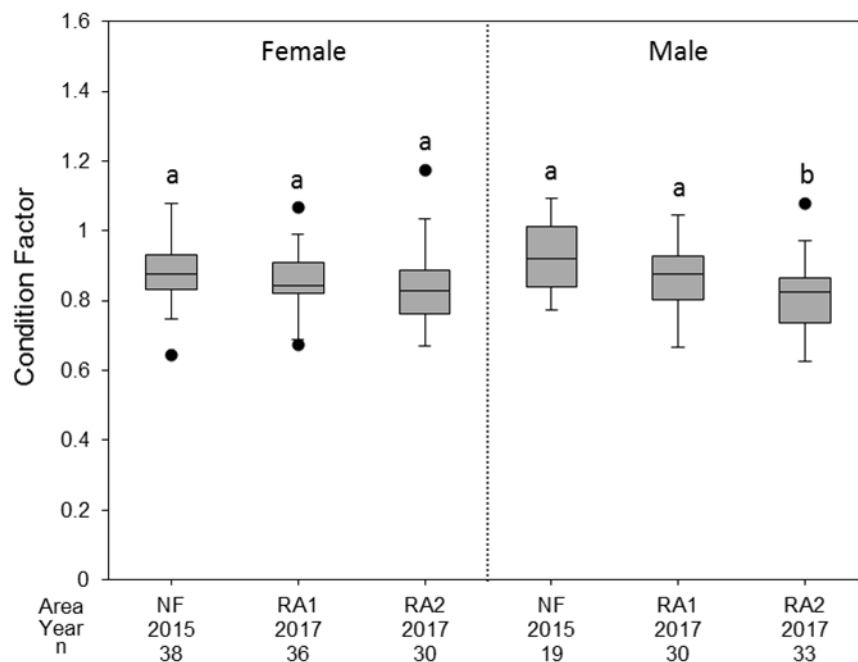


Figure 6.3-11: Condition Factor for Female and Male Threespine Stickleback Lethally Sampled from Meliadine Lake, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.3.9 Liver Weight

The liver somatic index for female Threespine Stickleback ranged from 0.77 to 6.07 (Table 6.3-7). Relative liver weight was significantly greater at the Near-field area when compared to Reference Area 1 (22%, Table 6.3-8). No significant differences were observed between the Near-field area and Reference Area 2, or between Reference Area 1 and Reference Area 2. For male Threespine Stickleback, the liver somatic index ranged from 0.87 to 4.34 (Table 6.3-7). Relative liver weight of male fish was significantly different among sampling areas (Table 6.3-8). Relative liver weight was significantly greater at the Near-field area, when compared to Reference Area 1 (65%), and Reference Area 2 (33%). Relative liver weight of male fish was significantly lower at Reference Area 1 compared to Reference Area 2 (-22%). Differences exceeded the CES of 25%, suggesting energy storage for male Threespine Stickleback was greater at the Near-field area when compared to the reference areas in Meliadine Lake. As the Near-field and reference areas were sampled in different years (i.e., the Near-field area was sampled in 2015, and the reference areas were sampled in 2017), it could not be determined whether differences in relative liver weight were related to geographic or interannual variability.

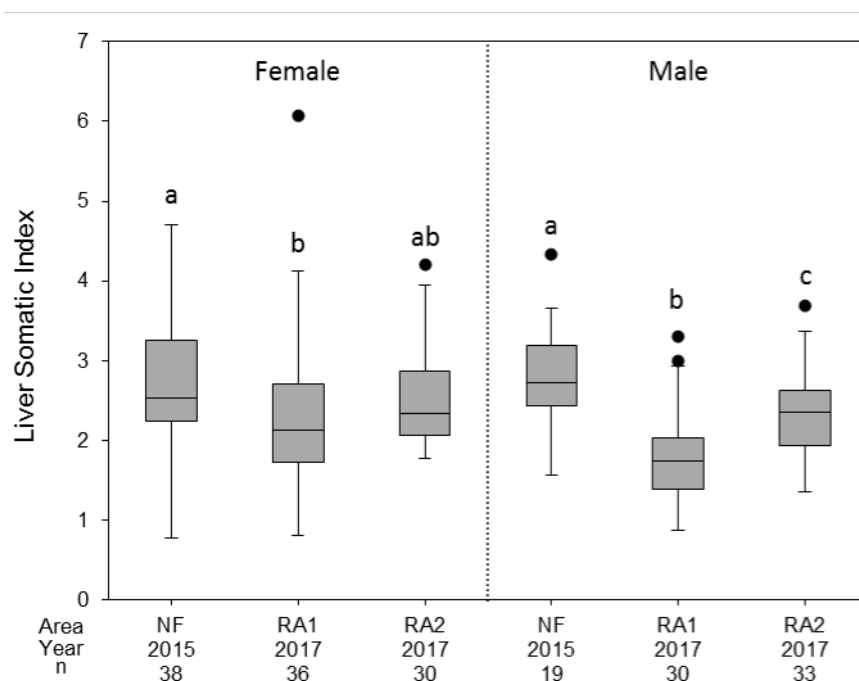


Figure 6.3-12: Liver Somatic Index of Female and Male Threespine Stickleback Lethally Sampled from Meliadine Lake, 2015 and 2017

Note: Areas sharing the same letter are not significantly different from one another.

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; n = sample size.

6.3.3.10 Pathology

External abnormalities observed in Threespine Stickleback sampled from Meliadine Lake included mild abrasion of the thymus and vent, minor skin aberrations (i.e., missing scales), and mild fin erosion (Table 6.3-10). The prevalence of external abnormalities were low, affecting only 2% of the fish sampled in Meliadine Lake, with a similar prevalence among sampling areas (Table 6.3-10). No body deformities or abnormalities of the eyes, gills, pseudobranchs, or opercula were observed.

Internal abnormalities observed in Threespine Stickleback sampled from Meliadine Lake included liver discoloration (i.e., “fatty” livers with a coffee cream colour, or focal discoloration) and swollen kidneys (Table 6.3-12). The prevalence of liver discoloration was similar among sampling areas, while swollen kidneys were more prevalent for fish sampled from Reference Area 2. Swollen kidneys were primarily observed in male Threespine Stickleback (i.e., of fish exhibiting swollen kidneys, 92% were male and 8% were female), suggesting swollen kidneys may be related to spiggin production³, rather than a physiological response to contaminant exposure. The greater prevalence of swollen kidneys at Reference Area 2 may have been related to a lower prevalence of tapeworms (Section 6.3.3.11), allowing additional resources to be allocated to nest building. These types of external and internal abnormalities are commonly observed in fish populations, and given the low rate of incidence were not considered further. Mesenteric fat content varied significantly among sampling areas ($P < 0.001$), with greater fat content observed in the Near-field area when compared to Reference Area 1 and Reference Area 2 (Table 6.3-11).

³ Spiggin is a glue like substance produced by male Threespine Stickleback and used in nest construction.

Table 6.3-10: Number of Lethally Sampled Threespine Stickleback Observed with External and Internal Abnormalities, 2015 and 2017

Assessment Type	Category	Near-field Area	Reference Area 1	Reference Area 2	Chi Square P-value
External	Body Deformities	0	0	0	0.986
	Eyes	0	0	0	0.986
	Gills	0	0	0	0.986
	Pseudobranchs	0	0	0	0.986
	Thymus	1	0	0	0.359
	Skin	0	0	1	0.370
	Fins	0	2	1	0.370
	Opercula	0	0	0	0.986
	Vent	2	0	0	0.128
Internal	Liver	10	5	10	0.323
	Spleen	0	0	0	0.986
	Gall Bladder	0	0	0	0.986
	Kidney	5	2	18	<0.001
Fish with Abnormalities		16%	7%	26%	
Total Number of Fish Surveyed		95	97	97	

Note: Significant difference indicated in **bold**.

P-value = probability value; < = less than.

Table 6.3-11: Relative Mesenteric Fat Content of Threespine Stickleback, 2015 and 2017

Mesenteric Fat	Near-field Area	Reference Area 1	Reference Area 2
0	7	37	16
1	83	55	60
2	3	5	20
3	2	0	1

0 = None; 1 = < 50%; 2 = 50%; 3 = > 50%.

6.3.3.11 Parasites

Internal parasites were frequently observed in Threespine Stickleback sampled from Meliadine Lake, and occurred in 84.2% of Threespine Stickleback from the Near-field area, 80.4% from Reference Area 1, and 64.9% of fish sampled from Reference Area 2 (Table 6.3-12). Among parasitized fish, Threespine Stickleback exhibited a low severity of parasitism in 3.6% of fish (e.g., cysts), a moderate severity of parasitism in 82.4% of fish (e.g., tapeworms), and a high severity of parasitism in 14.0% (e.g., multiple tapeworms) of Threespine Stickleback sampled. Significant differences were observed in the prevalence of parasites among sampling areas ($P < 0.001$), with fewer parasites observed in fish from Reference Area 2 when compared to the Near-field area and Reference Area 1. External parasites were not observed at any of the sampling areas.

A large tapeworm, suspected to be *Schistocephalus solidus*, was the prevalent parasite among Threespine Stickleback captured in Meliadine Lake. The tapeworm infected 221 of the 289 fish sampled. The tapeworm *S. solidus* parasitizes small-bodied fish and fish-eating birds. Small-bodied fish, such as the Threespine Stickleback, serve as an intermediate host for the parasite once the fish become infected after consuming infected copepods. The parasite develops in the body cavity until it is transmitted to the definitive host, fish-eating birds, when the fish is consumed (Barber and Huntingford 1995). Potential definitive hosts for *S. solidus* in the Near-field area of Meliadine Lake are Sandhill crane (*Grus canadensis*), which were observed in the area during the time of sampling. On average, tapeworms accounted for 17.0% of body weight in infected fish.

Table 6.3-12: Number of Threespine Stickleback Observed with External and Internal Parasites, 2015 and 2017

Parasites		Near-field Area	Reference Area 1	Reference Area 2
External	0	95	332	316
	1	0	0	0
	2	0	0	0
	3	0	0	0
Internal	0	15	19	34
	1	2	4	2
	2	78	53	51
	3	0	21	10

0 = no parasites; 1 = few parasites; 2 = moderate parasite infestation; 3 = numerous parasites.

6.3.4 Fish Tissue Chemistry

In 2015 and 2017, a total of 194 Threespine Stickleback carcass samples were analyzed for percent moisture and metals concentrations from the Near-field and reference areas of Meliadine Lake. A total of 60 samples were collected from the Near-field area in 2015, with 67 samples collected from Reference Area 1 and 67 samples collected from Reference Area 2 in 2017. Descriptive statistics for individual parameters separated by sampling area are provided in Table 6.3-13. Data are provided in Appendix 6E, and boxplots are provided in Appendix 6F.

Metals concentrations in fish tissue from the Near-field area were significantly lower than concentrations measured in Reference Area 1 and Reference Area 2 for 17 of the 36 metals examined (Table 6.3-14); the greatest magnitude differences (i.e., greater than 30%) were observed for aluminum, boron, cesium, chromium, cobalt, iron, lithium, molybdenum, nickel, titanium and vanadium concentrations. Greater concentrations were observed in the Near-field area for arsenic and tin. No significant differences were observed between the Near-field area and reference areas in concentrations of cadmium, lead, manganese and thallium. Statistical outliers removed from analyses are provided in Appendix 6D.

As tissue chemistry data for the Near-field area and reference areas were collected during the pre-operational phase of the mine, prior to operational discharge, differences in metals concentrations represent natural variability in these parameters at Meliadine Lake. However, because the Near-field area and reference areas were sampled in different years, it could not be determined whether these differences represent spatial and/or temporal variability in these parameters.

Table 6.3-13: Descriptive Statistics for Threespine Stickleback Fish Tissue Chemistry for Carcass Samples Collected from Meliadine Lake, 2015 and 2017

Parameter	Near-field Area								Reference Area 1								Reference Area 2							
	n	% < DL	Mean	Median	Min	Max	SD	SE	n	% < DL	Mean	Median	Min	Max	SD	SE	n	% < DL	Mean	Median	Min	Max	SD	SE
Moisture (%)	60	100	66	66.1	53.5	71.8	3.49	0.45	67	100	65.4	65.7	57.1	84.8	3.67	0.45	67	100	65.5	65.0	59.6	74.1	2.88	0.35
Aluminum	60	52	1.2	1.0	<1.0	4.7	1.0	0.1	67	88	2.8	2.1	<1.0	11.7	2.2	0.3	67	70	2.7	1.8	<1.0	19.2	3.7	0.5
Antimony	60	5	<0.002	<0.002	<0.002	0.004	0.001	<0.001	67	10	<0.002	<0.002	<0.002	0.008	0.001	<0.001	67	12	<0.002	<0.002	<0.002	0.014	0.002	<0.001
Arsenic	60	100	0.186	0.176	0.120	0.395	0.051	0.007	67	100	0.118	0.115	0.044	0.209	0.041	0.005	67	100	0.156	0.156	0.068	0.239	0.035	0.004
Barium	60	100	4.48	4.37	2.04	7.16	0.97	0.13	67	100	5.55	5.60	3.09	9.05	1.17	0.14	67	100	5.66	5.53	2.89	9.26	1.20	0.15
Beryllium	60	0	<0.002	<0.002	<0.002	<0.002	-	-	67	0	<0.002	<0.002	<0.002	<0.002	-	-	67	0	<0.002	<0.002	<0.002	<0.002	-	-
Bismuth	60	3	<0.002	<0.002	<0.002	0.002	<0.001	<0.001	67	4	<0.002	<0.002	<0.002	0.005	<0.001	<0.001	67	3	<0.002	<0.002	<0.002	0.005	<0.001	<0.001
Boron	60	0	<0.2	<0.2	<0.2	<0.2	-	-	67	33	<0.2	<0.2	<0.2	0.5	0.1	<0.1	67	45	<0.2	<0.2	<0.2	4.20	0.6	0.1
Cadmium	60	100	0.0063	0.0058	0.0027	0.0211	0.0032	0.0004	67	100	0.0066	0.0056	0.0021	0.0285	0.0041	0.0005	67	94	0.0060	0.0055	<0.002	0.0132	0.0025	0.0003
Calcium	60	100	23973	23300	13100	39300	4535	586	67	100	25784	25800	12700	41300	5300	648	67	100	25652	25600	14300	45800	5253	642
Cesium	60	100	0.0180	0.0157	0.0091	0.0513	0.0086	0.0011	67	100	0.0248	0.0241	0.0112	0.0478	0.0072	0.0009	67	100	0.0290	0.0270	0.0145	0.0594	0.0091	0.0011
Chromium	60	40	0.043	<0.040	<0.040	0.207	0.043	0.006	67	94	0.843	0.413	<0.040	5.730	1.173	0.143	67	96	0.513	0.285	<0.040	2.610	0.569	0.070
Cobalt	60	100	0.0080	0.0075	0.0044	0.0141	0.0024	0.0003	67	100	0.0158	0.0128	0.0053	0.0485	0.0085	0.0010	67	99	0.0149	0.0138	<0.008	0.0348	0.0050	0.0006
Copper	60	100	0.561	0.554	0.412	0.844	0.094	0.012	67	100	0.707	0.685	0.318	1.210	0.154	0.019	67	100	0.704	0.703	0.485	1.050	0.104	0.013
Iron	60	100	14.2	13.6	7.8	24.8	3.4	0.4	67	100	27.1	22.2	8.0	82.3	13.5	1.6	67	100	24.3	22.4	13.3	58.7	8.8	1.1
Lead	60	50	0.011	<0.010	<0.010	0.027	0.007	0.001	67	45	0.013	<0.010	<0.010	0.136	0.018	0.002	67	48	0.016	<0.010	<0.010	0.245	0.030	0.004
Lithium	60	0	<0.10	<0.10	<0.10	<0.10	-	-	67	57	0.18	0.12	<0.10	0.75	0.15	0.02	67	0	<0.10	<0.10	<0.10	<0.10	-	-
Magnesium	60	100	493	481	358	710	70	9	67	100	531	532	277	747	86	11	67	100	529	518	330	771	92	11
Manganese	60	100	27.5	27.2	14.7	40.8	5.8	0.7	67	100	28.2	27.9	14.5	48.1	7.5	0.9	67	100	29.6	28.4	18.1	50.4	7.1	0.9
Mercury	60	100	0.113	0.110	0.064	0.174	0.025	0.003	67	100	0.120	0.118	0.041	0.263	0.038	0.005	67	100	0.089	0.080	0.046	0.196	0.027	0.003
Molybdenum	60	100	0.0168	0.0163	0.0088	0.0375	0.0052	0.0007	67	99	0.0383	0.0308	<0.0160	0.1130	0.0233	0.0029	67	94	0.0309	0.0218	<0.0160	0.1660	0.0267	0.0033
Nickel	60	100	0.115	0.090	0.042	0.423	0.083	0.011	67	100	1.790	0.751	0.099	12.000	2.725	0.333	67	100	0.909	0.530	0.089	7.190	1.186	0.145
Phosphorus	60	100	13747	13950	8400	20100	2127	275	67	100	15108	15300	7310	22500	2685	328	67	100	15258	15300	8440	24600	2752	336
Potassium	60	100	2818	2800	2290	3430	251	32	67	100	2747	2720	1360	3450	304	37	67	100	2551	2520	1900	3150	277	34
Rubidium	60	100	2.22	2.19	1.19	3.43	0.52	0.07	67	100	2.87	2.87	1.50	4.35	0.63	0.08	67	100	3.19	3.16	1.73	4.44	0.56	0.07
Selenium	60	100	0.465	0.463	0.360	0.588	0.055	0.007	67	100	0.603	0.593	0.273	0.898	0.093	0.011	67	100	0.592	0.596	0.436	0.714	0.057	0.007
Silver	60	65	0.0018	0.0014	<0.0010	0.0137	0.0021	0.0003	67	42	0.0013	<0.0010	<0.0010	0.0117	0.0015	0.0002	67	24	<0.0010	<0.0010	<0.0010	0.0039	0.0006	0.0001
Sodium	60	100	1400	1385	781	1820	182	24	67	100	1356	1350	706	1850	198	24	67	100	1298	1280	901	2120	203	25
Strontium	60	100	19.1	19.0	10.0	29.1	3.7	0.5	67	100	20.6	20.6	9.1	28.7	4.0	0.5	67	100	19.0	18.8	11.2	31.9	3.7	0.5
Tellurium	60	0	<0.004	<0.004	<0.004	<0.004	-	-	67	0	<0.004	<0.004	<0.004	<0.004	-	-	67	0	<0.004	<0.004	<0.004	<0.004	-	-
Thallium	60	100	0.00587	0.00554	0.00282	0.01260	0.00195	0.00025	67	100	0.00535	0.00478	0.00297	0.01600	0.00234	0.00029	67	100	0.00555	0.00528	0.00322	0.00904	0.00146	0.00018
Tin	60	98	0.078	0.070	<0.020	0.210	0.039	0.005	67	37	0.021	<0.020	<0.020	0.061	0.013	0.002	67	33	0.027	<0.020	<0.020	0.088	0.021	0.003
Titanium	60	23	<0.10	<0.10	<0.10	0.39	0.07	0.01	67	48	0.16	<0.10	<0.10	0.81	0.16	0.02	67	33	0.13	<0.10	<0.10	0.95	0.14	0.02
Uranium	60	100	0.00444	0.00408	0.00216	0.01140	0.00194	0.00025	67	100	0.00457	0.00463	0.00143	0.00879	0.00186	0.00023	67	100	0.00630	0.00569	0.00140	0.01560	0.00279	0.00034
Vanadium	60	12	<0.020	<0.020	<0.020	0.030	0.005	0.001	67	33	<0.020	<0.020	<0.020	0.080	0.016	0.002	67	19	<0.020	<0.020	<0.020	0.073	0.011	0.001
Zinc	60	100	45.4	43.2	24.8	86.9	12.5	1.6	67	100	50.4	50.0	27.6	87.1	10.1	1.2	67	100	53.4	52.4	29.0	85.7	11.1	1.4
Zirconium	60	0	<0.040	<0.040	<0.040	<0.040	-	-	67	15	<0.04	<0.04	<0.04	0.12	0.02	<0.01	67	4	<0.04	<0.04	<0.04	0.49	0.06	0.01

Note: All parameters are measured in milligram per kilogram wet weight (mg/kg ww), unless otherwise specified.
n = sample size; < = less than; DL = detection limit; SD = standard deviation; SE = standard error; - = not applicable.

Table 6.3-14: Statistical Comparison of Fish Tissue Chemistry Parameters Measured in Threespine Stickleback Carcass Samples from Meliadine Lake, 2015 and 2017

Parameter	Statistical Test	n			Model P-value	MSE	Least Squares Mean			Outliers	Post-Hoc			Magnitude		
		NF	RA1	RA2			NF	RA1	RA2		NF*RA1	NF*RA2	RA1*RA2	NF*RA1	NF*RA2	RA1*RA2
Moisture	KW test	60	67	67	0.214	-	66.1	65.7	65.0	Included	-	-	-	-	-	-
	ANOVA	58	66	67	0.043	7.992	66.4	65.1	65.5	Removed	0.039	0.169	0.773	2%	-	-
Aluminum	KW test	60	67	67	<0.001	-	1.0	2.1	1.8	-	<0.001	<0.001	0.138	-52%	-44%	-
Antimony	KW test	60	67	67	<0.001	-	0.001	0.001	0.001	-	0.003	<0.001	0.187	0%	0%	-
Arsenic	KW test	60	67	67	<0.001	-	0.176	0.115	0.156	Included	<0.001	0.214	<0.001	53%	-	-30%
	ANOVA	58	67	67	<0.001	0.002	0.180	0.118	0.156	Removed	<0.001	0.002	<0.001	52%	15%	-28%
Barium	ANOVA _{log}	60	67	67	<0.001	0.009	4.38	5.43	5.54	Included	<0.001	<0.001	0.860	-19%	-21%	-
	ANOVA _{log}	59	67	66	<0.001	0.008	4.44	5.43	5.59	Removed	<0.001	<0.001	0.681	-18%	-21%	-
Beryllium	-	60	67	67	-	-	0.001	0.001	0.001	-	-	-	-	-	-	-
Bismuth	KW test	60	67	67	0.006	-	0.001	0.001	0.001	-	0.011	<0.001	0.398	0%	0%	-
Boron	KW test	60	67	67	<0.001	-	0.1	0.2	0.2	-	<0.001	<0.001	0.014	-50%	-50%	0%
Cadmium	KW test	60	67	67	0.921	-	0.0058	0.0056	0.0055	Included	-	-	-	-	-	-
	ANOVA _{log}	60	66	66	0.910	0.033	0.0057	0.0057	0.0056	Removed	-	-	-	-	-	-
Calcium	KW test	60	67	67	0.048	-	23300	25800	25600	Included	0.003	0.010	0.925	-10%	-9%	-
	ANOVA	59	66	66	0.056	21240417	23714	25548	25347	Removed	0.070	0.120	0.966	-7%	-	-
Cesium	KW test	60	67	67	<0.001	-	0.0157	0.0241	0.0270	Included	<0.001	<0.002	0.043	-35%	-42%	-12%
	ANOVA _{log}	58	67	67	<0.001	0.018	0.0160	0.0238	0.0278	Removed	<0.001	<0.001	0.011	-33%	-43%	-15%
Chromium	KW test	60	67	67	<0.001	-	0.020	0.413	0.285	-	<0.001	<0.001	0.938	-95%	-93%	-
Cobalt	KW test	60	67	67	<0.001	-	0.0075	0.0128	0.0138	-	<0.001	<0.001	0.540	-42%	-46%	-
Copper	KW test	60	67	67	<0.001	-	0.554	0.685	0.703	Included	<0.001	<0.001	0.877	-19%	-21%	-
	ANOVA _{log}	60	65	67	<0.001	0.005	0.554	0.693	0.697	Removed	<0.001	<0.001	0.977	-20%	-21%	-
Iron	KW test	60	67	67	<0.001	-	13.6	22.2	22.4	-	<0.001	<0.001	0.964	-39%	-39%	-
Lead	KW test	60	67	67	0.330	-	0.008	0.010	0.010	-	-	-	-	-	-	-
Lithium	KW test	60	67	67	<0.001	-	0.05	0.12	0.05	-	<0.001	0.001	<0.001	-58%	0%	70%
Magnesium	ANOVA	60	67	67	0.019	6999	493	531	529	Included	0.030	0.043	0.988	-7%	-7%	-
	ANOVA	60	66	67	0.009	6691	493	535	529	Removed	0.012	0.038	0.907	-8%	-7%	-
Manganese	ANOVA _{log}	60	67	67	0.194	0.011	26.8	27.2	28.9	-	-	-	-	-	-	-
Mercury	ANOVA _{log}	60	67	67	<0.001	0.015	0.110	0.114	0.085	Included	0.790	<0.001	<0.001	-	30%	30%
	ANOVA _{log}	60	65	66	<0.001	0.012	0.110	0.114	0.084	Removed	0.723	<0.001	<0.001	-	32%	31%
Molybdenum	KW test	60	67	67	<0.001	-	0.0163	0.0308	0.0218	-	<0.001	<0.001	0.005	-47%	-25%	34%
Nickel	KW test	60	67	67	<0.001	-	0.090	0.751	0.530	-	<0.001	<0.001	0.278	-88%	-83%	-
Phosphorus	ANOVA	60	67	67	0.002	6506743	13747	15108	15258	Included	0.009	0.003	0.938	-9%	-10%	-
	ANOVA	60	66	66	0.001	5780281	13747	15226	15117	Removed	0.002	0.005	0.963	-10%	-9%	-
Potassium	KW test	60	67	67	<0.001	-	2800	2720	2520	Included	1.000	<0.001	<0.001	-	11%	8%
	ANOVA _{log}	60	66	67	<0.001	0.002	2808	2757	2536	Removed	0.544	<0.001	<0.001	-	11%	8%
Rubidium	ANOVA	60	67	67	<0.001	0.328	2.22	2.87	3.19	-	<0.001	<0.001	0.003	-23%	-31%	-11%
Selenium	KW test	60	67	67	<0.001	-	0.463	0.593	0.596	Included	<0.001	<0.001	0.993	-22%	-22%	-
	ANOVA _{log}	60	65	67	<0.001	0.002	0.462	0.599	0.589	Removed	<0.001	<0.001	0.705	-23%	-22%	-
Silver	KW test	60	67	67	0.004	-	0.0014	0.0010	0.0010	-	0.631	0.069	0.389	-	40%	-
Sodium	KW test	60	67	67	0.004	-	1385	1350	1280	Included	0.999	0.079	0.072	-	8%	5%
	ANOVA	59	66	66	<0.001	30663	1410	1366	1285	Removed	0.329	<0.001	0.026	-	10%	6%
Strontium	ANOVA	60	67	67	0.033	14.31	19.1	20.6	19.0	Included	0.085	0.982	0.047	-7%	-	8%
	ANOVA	60	66	66	0.005	12.87	19.1	20.7	18.8	Removed	0.034	0.873	0.007	-8%	-	10%
Tellurium	-	60	67	67	-	-	0.002	0.002	0.002	-	-	-	-	-	-	-
Thallium	KW test	60	67	67	0.033	-	0.00554	0.00478	0.00528	-	0.340	0.835	0.121	-	-	-
Tin	KW test	60	67	67	<0.001	-	0.070	0.020	0.020	-	<0.001	<0.001	0.463	248%	248%	-
Titanium	KW test	60	67	67	<0.001	-	0.05	0.10	0.10	-	<0.001	<0.001	0.591	-50%	-50%	-
Uranium	ANOVA _{log}	60	67	67	<0.001	0.035	0.00410	0.00418	0.00573	Included	0.966	<0.001	<0.001	-	-28%	-32%
	ANOVA _{log}	60	67	66	<0.001	0.033	0.00410	0.00418	0.00585	Removed	0.964	<0.001	<0.001	-	-30%	-34%
Vanadium	KW test	60	67	67	<0.001	-	0.010	0.020	0.020	-	<0.001	<0.001	0.942	-50%	-50%	-
Zinc	ANOVA _{log}	60	67	67	<0.001	0.009	43.9	49.4	52.3	Included	0.009	<0.001	0.319	-11%	-16%	-
	ANOVA _{log}	59	67	67	<0.001	0.009	43.4	49.4	52.3	Removed	0.003	<0.001	0.303	-12%	-17%	-
Zirconium	KW test	60	67	67	<0.001	-	0.02	0.02	0.02	-	<0.001	<0.001	0.933	0%	0%	-

Note: Statistically significant differences indicated in bold.

n = sample size; P-value = probability value; MSE = mean squared error; NF = Near-field area; RA1 = Reference Area 1; RA2 = Reference Area 2; K-W = Kruskal-Wallis; ANOVA = analysis of variance; log = log₁₀ transformed data; < = less than; - = not applicable.

6.3.4.1 Comparison to Guidelines

Mercury concentrations in fish tissue of the Threespine Stickleback sampled from Meliadine Lake were below the Canadian Food Inspection Agency (CFIA) human consumption guideline of 0.5 mg/kg ww for commercial sale (CFIA 2014).

6.4 Normal Ranges

Provisional normal ranges were calculated for fish health and tissue chemistry parameters based on data collected from Threespine Stickleback and Lake Trout in the Near-field area in 2015 (Golder 2016a), and Threespine Stickleback collected from the reference areas in 2017. Provisional normal ranges are provided for:

- Threespine Stickleback and Lake Trout fish health parameters (Table 6.4-1)
- Threespine Stickleback metal concentrations in carcass tissue (Table 6.4-2)
- Lake Trout metal concentrations in muscle tissue (Table 6.4-3)
- Lake Trout metal concentrations in liver tissue (Table 6.4-4)
- Lake Trout metal concentrations in kidney tissue (Table 6.4-5)

Differences were observed between baseline data collected from the Near-field area and normal ranges for several Threespine Stickleback fish health and tissue chemistry parameters. Male Threespine Stickleback sampled from the Near-field area exceeded normal ranges for total length, total weight, carcass weight, condition factor, and liver somatic index. No differences in fish health parameters were observed for females. With respect to tissue chemistry parameters, arsenic and tin were elevated in the Near-field area, while chromium, iron, molybdenum, nickel, rubidium, and selenium were below normal ranges. As the Near-field area and reference areas were sampled in separate years, it could not be determined from the baseline data whether these differences reflect spatial or temporal differences in these parameters. Baseline deviations from normal range for Threespine Stickleback health and tissue chemistry parameters may need to be considered during future monitoring.

Table 6.4-1: Normal Ranges for Threespine Stickleback and Lake Trout Fish Health Parameters

Species	Sex	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
							Lower Bound	Upper Bound
THST	Female	Total Length (mm)	2015, 2017	106	0	PI	58.8	65.2
		Total Weight (g)	2015, 2017	105	1	PI	1.780	2.380
		Carcass Weight (g)	2015, 2017	106	0	PI	1.260	1.720
		Condition (CW)	2015, 2017	106	0	PI	0.58	0.63
		Condition (TW)	2015, 2017	106	0	PI	0.81	0.90
		Liver Somatic Index	2015, 2017	105	1	PI	3.02	3.95
		Gonadosomatic Index	2015, 2017	104	2	%ile	2.68	5.40
	Male	Total Length (mm)	2015, 2017	82	0	%ile	53.7	59.9
		Total Weight (g)	2015, 2017	82	0	PI	1.370	1.960
		Carcass Weight (g)	2015, 2017	82	0	PI	1.020	1.460
		Condition (CW)	2015, 2017	81	1	PI	0.61	0.66
		Condition (TW)	2015, 2017	82	0	PI	0.81	0.91
		Liver Somatic Index	2015, 2017	82	0	PI	2.51	3.38
		Gonadosomatic Index	2015, 2017	81	0	logPI	0.77	1.33

Species	Sex	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
							Lower Bound	Upper Bound
LKTR	Female	Fork Length (mm)	2015	32	0	PI	577	695
		Total Weight (g)	2015	32	0	logPI	2017	3371
		Carcass Weight (g)	2015	32	0	logPI	1729	2797
		Condition (CW)	2015	32	0	PI	0.84	0.95
		Condition (TW)	2015	32	0	PI	0.98	1.13
		Liver Somatic Index	2015	32	0	%ile	1.12	1.60
		Gonadosomatic Index	2015	32	0	%ile	0.88	6.46
	Male	Fork Length (mm)	2015	29	0	PI	516	636
		Total Weight (g)	2015	29	0	PI	1574	2854
		Carcass Weight (g)	2015	29	0	PI	1380	2497
		Condition (CW)	2015	29	0	PI	0.90	0.99
		Condition (TW)	2015	29	0	PI	1.01	1.13
		Liver Somatic Index	2015	29	0	PI	0.83	0.99
		Gonadosomatic Index	2015	29	0	%ile	0.80	2.28

THST = Threespine Stickleback; LKTR = Lake Trout; TW = calculated using total weight; CW = calculated using carcass weight; PI = prediction interval; logPI = prediction interval calculated using log₁₀ transformed data; %ile = prediction interval calculated using percentiles.

Table 6.4-2: Normal Ranges for Threespine Stickleback Metal Concentrations in Carcass Tissue

Species	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
						Lower Bound	Upper Bound
THST	Moisture (%)	2015, 2017	192	2	PI	63.5	67.7
	Aluminum (mg/kg ww)	2015, 2017	190	4	%ile	1.1	3.2
	Antimony (mg/kg ww)	2015, 2017	190	4	%ile	0.0010	<0.0020
	Arsenic (mg/kg ww)	2015, 2017	192	2	PI	0.117	0.182
	Barium (mg/kg ww)	2015, 2017	194	0	logPI	4.33	6.05
	Beryllium (mg/kg ww)	2015, 2017	194	0	%ile	0.0010	<0.0020
	Bismuth (mg/kg ww)	2015, 2017	191	3	%ile	0.0010	<0.0020
	Boron (mg/kg ww)	2015, 2017	192	2	%ile	0.11	0.28
	Cadmium (mg/kg ww)	2015, 2017	191	3	logPI	0.0041	0.0075
	Calcium (mg/kg ww)	2015, 2017	193	1	PI	21593	28550
	Cesium (mg/kg ww)	2015, 2017	193	1	logPI	0.0170	0.0293
	Chromium (mg/kg ww)	2015, 2017	191	3	%ile	0.087	0.920
	Cobalt (mg/kg ww)	2015, 2017	191	3	logPI	0.0084	0.0156
	Copper (mg/kg ww)	2015, 2017	193	1	logPI	0.559	0.745
	Iron (mg/kg ww)	2015, 2017	192	2	%ile	16.0	29.6
	Lead (mg/kg ww)	2015, 2017	192	2	%ile	0.007	0.019
	Lithium (mg/kg ww)	2015, 2017	191	3	%ile	0.05	0.16
	Magnesium (mg/kg ww)	2015, 2017	194	0	PI	458	579
	Manganese (mg/kg ww)	2015, 2017	194	0	logPI	23.3	32.9
	Mercury (mg/kg ww)	2015, 2017	193	1	logPI	0.082	0.126
	Molybdenum (mg/kg ww)	2015, 2017	192	2	%ile	0.0172	0.0436
	Nickel (mg/kg ww)	2015, 2017	190	4	%ile	0.242	1.740
	Phosphorus (mg/kg ww)	2015, 2017	193	1	PI	12886	16490
	Potassium (mg/kg ww)	2015, 2017	193	1	PI	2506	2911
	Rubidium (mg/kg ww)	2015, 2017	194	0	PI	2.28	3.27
	Selenium (mg/kg ww)	2015, 2017	193	1	PI	0.490	0.619
	Silver (mg/kg ww)	2015, 2017	191	3	%ile	0.0007	0.0019
	Sodium (mg/kg ww)	2015, 2017	193	1	%ile	1218	1474
	Strontium (mg/kg ww)	2015, 2017	194	0	PI	16.8	22.3
	Tellurium (mg/kg ww)	2015, 2017	194	0	%ile	0.002	<0.004
	Thallium (mg/kg ww)	2015, 2017	192	2	logPI	0.00425	0.00648
	Tin (mg/kg ww)	2015, 2017	192	2	%ile	0.020	0.064

Species	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
						Lower Bound	Upper Bound
	Titanium (mg/kg ww)	2015, 2017	190	4	%ile	0.06	0.19
	Uranium (mg/kg ww)	2015, 2017	192	2	logPI	0.00335	0.00626
	Vanadium (mg/kg ww)	2015, 2017	190	4	%ile	0.011	0.023
	Zinc (mg/kg ww)	2015, 2017	194	0	logPI	41.1	57.4
	Zirconium (mg/kg ww)	2015, 2017	193	1	%ile	0.02	0.04
	Lipid Content (%)	2015, 2017	100	0	PI	3.63	6.92

THST = Threespine Stickleback; mg/kg ww = milligram per kilogram wet weight; PI = prediction interval; logPI = prediction interval calculated using log₁₀ transformed data; %ile = prediction interval calculated using percentiles; < = less than.

Table 6.4-3: Normal Ranges for Lake Trout Metal Concentrations in Muscle Tissue

Species	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
						Lower Bound	Upper Bound
LKTR	Moisture (%)	2015	60	0	%ile	74.5	77.6
	Aluminum (mg/kg ww)	2015	59	1	%ile	0.20	0.58
	Antimony (mg/kg ww)	2015	60	0	%ile	0.0010	0.0028
	Arsenic (mg/kg ww)	2015	59	1	%ile	0.049	0.147
	Barium (mg/kg ww)	2015	59	1	%ile	0.005	0.015
	Beryllium (mg/kg ww)	2015	60	0	-	-	-
	Bismuth (mg/kg ww)	2015	60	0	-	-	-
	Boron (mg/kg ww)	2015	60	0	-	-	-
	Cadmium (mg/kg ww)	2015	58	2	%ile	0.0005	<0.0010
	Calcium (mg/kg ww)	2015	59	1	%ile	60.7	220.0
	Cesium (mg/kg ww)	2015	59	1	logPI	0.0380	0.0695
	Chromium (mg/kg ww)	2015	59	1	%ile	0.006	0.025
	Cobalt (mg/kg ww)	2015	59	1	%ile	0.0020	<0.0040
	Copper (mg/kg ww)	2015	60	0	PI	0.184	0.288
	Iron (mg/kg ww)	2015	59	1	logPI	1.95	3.37
	Lead (mg/kg ww)	2015	58	2	%ile	0.0020	0.0037
	Lithium (mg/kg ww)	2015	60	0	-	-	-
	Magnesium (mg/kg ww)	2015	60	0	%ile	261.00	299.00
	Manganese (mg/kg ww)	2015	59	1	logPI	0.071	0.115
	Mercury (mg/kg ww)	2015	59	1	logPI	0.3600	0.6990
	Molybdenum (mg/kg ww)	2015	60	0	%ile	0.0020	<0.0040
	Nickel (mg/kg ww)	2015	59	1	%ile	0.020	<0.040
	Phosphorus (mg/kg ww)	2015	60	0	PI	2386.0	2858.0
	Potassium (mg/kg ww)	2015	60	0	PI	4013.0	4678.0
	Rubidium (mg/kg ww)	2015	60	0	PI	6.150	9.450
	Selenium (mg/kg ww)	2015	60	0	PI	0.391	0.545
	Silver (mg/kg ww)	2015	60	0	-	-	-
	Sodium (mg/kg ww)	2015	59	1	logPI	236.0	298.0
	Strontium (mg/kg ww)	2015	59	1	%ile	0.037	0.211
	Tellurium (mg/kg ww)	2015	60	0	%ile	0.0020	0.0055
	Thallium (mg/kg ww)	2015	60	0	PI	0.00705	0.01070
	Tin (mg/kg ww)	2015	60	0	PI	0.038	0.074
	Titanium (mg/kg ww)	2015	59	1	%ile	0.015	0.042
	Uranium (mg/kg ww)	2015	60	0	-	-	-
	Vanadium (mg/kg ww)	2015	60	0	-	-	-
	Zinc (mg/kg ww)	2015	59	1	logPI	2.75	3.40
	Zirconium (mg/kg ww)	2015	60	0	-	-	-
	Lipid Content (%)	2015	59	1	logPI	0.73	2.48

LKTR = Lake Trout; mg/kg ww = milligram per kilogram wet weight; PI = prediction interval; logPI = prediction interval calculated using log₁₀ transformed data; %ile = prediction interval calculated using percentiles; < = less than; - = not applicable.

Table 6.4-4: Normal Ranges for Lake Trout Metal Concentrations in Liver Tissue

Species	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
						Lower Bound	Upper Bound
LKTR	Moisture (%)	2015	60	0	PI	73.8	77.2
	Aluminum (mg/kg ww)	2015	59	1	logPI	0.51	2.27
	Antimony (mg/kg ww)	2015	59	1	%ile	0.0010	0.0025
	Arsenic (mg/kg ww)	2015	59	1	%ile	0.0693	0.1310
	Barium (mg/kg ww)	2015	59	1	%ile	0.005	0.012
	Beryllium (mg/kg ww)	2015	60	0	-	-	-
	Bismuth (mg/kg ww)	2015	59	1	%ile	0.0010	<0.0020
	Boron (mg/kg ww)	2015	60	0	-	-	-
	Cadmium (mg/kg ww)	2015	58	2	logPI	0.0810	0.1910
	Calcium (mg/kg ww)	2015	58	2	%ile	55.6	92.7
	Cesium (mg/kg ww)	2015	59	1	logPI	0.0249	0.0419
	Chromium (mg/kg ww)	2015	59	1	%ile	0.005	0.011
	Cobalt (mg/kg ww)	2015	59	1	logPI	0.0889	0.2470
	Copper (mg/kg ww)	2015	60	0	%ile	14.600	26.500
	Iron (mg/kg ww)	2015	60	0	logPI	87.30	374.00
	Lead (mg/kg ww)	2015	59	1	%ile	0.0020	0.0059
	Lithium (mg/kg ww)	2015	60	0	-	-	-
	Magnesium (mg/kg ww)	2015	60	0	PI	165.00	199.00
	Manganese (mg/kg ww)	2015	60	0	PI	1.530	2.030
	Mercury (mg/kg ww)	2015	59	1	logPI	0.3790	1.0200
	Molybdenum (mg/kg ww)	2015	60	0	PI	0.1410	0.2160
	Nickel (mg/kg ww)	2015	59	1	%ile	0.020	<0.040
	Phosphorus (mg/kg ww)	2015	60	0	PI	3498.0	4081.0
	Potassium (mg/kg ww)	2015	60	0	PI	3013.0	3736.0
	Rubidium (mg/kg ww)	2015	60	0	PI	6.990	11.200
	Selenium (mg/kg ww)	2015	59	1	PI	2.350	3.770
	Silver (mg/kg ww)	2015	59	1	%ile	0.1320	0.3380
	Sodium (mg/kg ww)	2015	60	0	PI	1034.0	1456.0
	Strontium (mg/kg ww)	2015	59	1	logPI	0.055	0.095
	Tellurium (mg/kg ww)	2015	58	2	%ile	0.0020	<0.0040
	Thallium (mg/kg ww)	2015	60	0	logPI	0.08380	0.15800
	Tin (mg/kg ww)	2015	59	1	%ile	0.027	0.053
	Titanium (mg/kg ww)	2015	59	1	%ile	0.013	0.038
	Uranium (mg/kg ww)	2015	58	2	%ile	0.00042	0.00211
	Vanadium (mg/kg ww)	2015	58	2	%ile	0.012	0.047
	Zinc (mg/kg ww)	2015	60	0	PI	29.80	37.70
	Zirconium (mg/kg ww)	2015	60	0	-	-	-
	Lipid Content (%)	2015	60	0	logPI	5.40	9.64

LKTR = Lake Trout; mg/kg ww = milligram per kilogram wet weight; PI = prediction interval; logPI = prediction interval calculated using log₁₀ transformed data; %ile = prediction interval calculated using percentiles; < = less than; - = not applicable.

Table 6.4-5: Normal Ranges for Lake Trout Metal Concentrations in Kidney Tissue

Species	Parameter	Baseline Period	Sample Size	Outliers Removed	Calculation Method	Normal Range	
						Lower Bound	Upper Bound
LKTR	Moisture (%)	2015	60	0	%ile	81.2	83.6
	Aluminum (mg/kg ww)	2015	59	1	logPI	0.71	1.85
	Antimony (mg/kg ww)	2015	60	0	%ile	0.0034	0.0077
	Arsenic (mg/kg ww)	2015	59	1	%ile	0.1570	0.3900
	Barium (mg/kg ww)	2015	60	0	%ile	0.035	0.115
	Beryllium (mg/kg ww)	2015	60	0	-	-	-
	Bismuth (mg/kg ww)	2015	58	2	%ile	0.0010	0.0020
	Boron (mg/kg ww)	2015	60	0	-	-	-
	Cadmium (mg/kg ww)	2015	60	0	logPI	0.1890	0.4800
	Calcium (mg/kg ww)	2015	59	1	logPI	123.0	178.0
	Cesium (mg/kg ww)	2015	59	1	logPI	0.0210	0.0353
	Chromium (mg/kg ww)	2015	59	1	%ile	0.009	0.032
	Cobalt (mg/kg ww)	2015	60	0	logPI	0.0738	0.1540
	Copper (mg/kg ww)	2015	59	1	%ile	0.657	0.905
	Iron (mg/kg ww)	2015	59	1	logPI	94.00	165.00
	Lead (mg/kg ww)	2015	59	1	%ile	0.0020	0.0061
	Lithium (mg/kg ww)	2015	60	0	-	-	-
	Magnesium (mg/kg ww)	2015	60	0	PI	117.00	137.00
	Manganese (mg/kg ww)	2015	59	1	logPI	0.278	0.443
	Mercury (mg/kg ww)	2015	59	1	logPI	0.46	1.16
	Molybdenum (mg/kg ww)	2015	60	0	logPI	0.0392	0.0651
	Nickel (mg/kg ww)	2015	59	1	logPI	0.122	0.281
	Phosphorus (mg/kg ww)	2015	60	0	PI	2242.0	2623.0
	Potassium (mg/kg ww)	2015	60	0	PI	2294.0	2782.0
	Rubidium (mg/kg ww)	2015	60	0	PI	4.750	7.390
	Selenium (mg/kg ww)	2015	59	1	logPI	1.610	2.590
	Silver (mg/kg ww)	2015	59	1	%ile	0.0010	0.0028
	Sodium (mg/kg ww)	2015	60	0	PI	1770.0	2205.0
	Strontium (mg/kg ww)	2015	59	1	PI	0.244	0.395
	Tellurium (mg/kg ww)	2015	60	0	%ile	0.0043	0.0113
	Thallium (mg/kg ww)	2015	60	0	PI	0.02190	0.03360
	Tin (mg/kg ww)	2015	59	1	%ile	0.061	0.156
	Titanium (mg/kg ww)	2015	59	1	logPI	0.051	0.131
	Uranium (mg/kg ww)	2015	59	1	logPI	0.00080	0.00303
	Vanadium (mg/kg ww)	2015	59	1	%ile	0.010	0.026
	Zinc (mg/kg ww)	2015	60	0	PI	15.90	20.30
	Zirconium (mg/kg ww)	2015	60	0	-	-	-
	Lipid Content (%)	2015	59	0	logPI	2.98	6.20

LKTR = Lake Trout; mg/kg ww = milligram per kilogram wet weight; PI = prediction interval; logPI = prediction interval calculated using log₁₀ transformed data; %ile = prediction interval calculated using percentiles; - = not applicable.

7.0 PLANKTON TARGETED STUDY

Plankton monitoring was conducted as a targeted study to evaluate if plankton will be a useful long-term monitoring tool for the Mine. The plankton study included sampling and analysis of depth-integrated nutrients, chlorophyll a, phytoplankton, and zooplankton over three years in Meliadine Lake (2015, 2016, and 2017) and two years in the peninsula lakes⁴ (2015 and 2016). Samples were collected from multiple locations in each lake across several seasons and years to assess seasonal, temporal, and spatial variation in potential monitoring endpoints (e.g., plankton abundance, biomass, richness, and community composition). Compiled data from the plankton study were analyzed to characterize baseline plankton communities in Meliadine Lake and to evaluate the usefulness of plankton as a long-term monitoring tool.

This report section provides a summary of data collected during the 2015 to 2017 baseline plankton sampling programs in Meliadine Lake. Statistical analyses of spatial, temporal, and seasonal variability in the plankton community are presented. Analysis of nutrient concentrations in relation to effluent discharges in the Near-field exposure area are discussed, along with an analysis of potential effects on plankton abundance, distribution and community composition. The overall suitability of plankton as a monitoring tool is evaluated with recommendations for potential monitoring endpoints which could be utilized during future monitoring years.

7.1 Methods

The plankton baseline program consisted of three sampling events during open-water conditions in 2015, 2016 and 2017, and was based on the Meliadine AEMP design plan (Golder 2016b). The 2015 program specifically targeted the exposure areas of Meliadine Lake, with additional sampling in the peninsula lakes. The 2016 program targeted both exposure and reference areas of Meliadine Lake, with additional sampling in the peninsula lakes. The 2017 program targeted the exposure and reference areas of Meliadine Lake and included only chlorophyll a sampling in the peninsula lakes.

Sampling was conducted in July (late spring), August (summer), and September (fall) during each annual sampling program (Table 7.1-1), in conjunction with the water quality sampling program. Five stations were sampled in each of the Near-field (NF) and Mid-field (MF) exposure areas of Meliadine Lake in all years, and in three reference areas of Meliadine Lake in 2016 and 2017 only. Plankton samples in Meliadine Lake were collected from a target water depth of 8 to 10 m. Three stations in each of the peninsula lakes (A8, B7, and D7) were sampled in 2015 to 2017 from a target water depth of 1.5 to 2.5 m (Figure 1.1-2). Not all stations were consistently sampled during each field program. Weather conditions (e.g., fog, high winds) occasionally resulted in delays in the field programs and loss/damage of sampling equipment (i.e., plankton net) resulted in the inability to collect some zooplankton samples.

The plankton sampling program consisted of the following components:

- measurements of total water depth (m) and Secchi depth (m)
- collection of depth-integrated water samples for nutrient analysis (soluble reactive silica [SRSi], TN, and TP) from the euphotic zone (Meliadine Lake only)
- collection of chlorophyll a samples
- collection of phytoplankton and zooplankton samples

⁴ Chlorophyll a was also sampled at the peninsula lakes in 2017

Table 7.1-1:Plankton Sampling Stations and Sampling Summary in Meliadine Lake

Waterbody	Area	Station	Depth (m)	NAD83, 15V		2015			2016			2017		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall	Late Spring	Summer	Fall	Late Spring	Summer	Fall
Meliadine Lake	Near-field Exposure (MEL-01)	MEL-01-01	10.0	542690	6989132	DIN, Chl, P	DIN, Chl, P	DIN, P, QC-dup ^(a,b,c)	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)
		MEL-01-02	7.9	542665	6989282	DIN, Chl, P, QC-dup ^(a,b,c)	DIN, Chl, P	DIN, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P
		MEL-01-03	9.5	542638	6988979	DIN, Chl, P,	DIN, Chl, P	-	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P, QC-dup ^(a)	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P	DIN, Chl, P
		MEL-01-04	8.8	543145	6989086	DIN, Chl, P	DIN, Chl, P	DIN,, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P
		MEL-01-05	9.0	542140	6989358	DIN, Chl, P	DIN, Chl, P, QC-dup ^(a,b,c)	DIN, P	DIN, Chl, P ^(d) , QC-dup ^(b,c)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P,	DIN, Chl, P	DIN, Chl, P
	Mid-field Exposure (MEL-02)	MEL-02-01	8.6	537511	6992932	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P
		MEL-02-02	8.0	537093	6992642	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P
		MEL-02-03	9.1	537497	6992332	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P
		MEL-02-04	7.7	537961	6992341	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)
		MEL-02-05	9.2	537831	6992692	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P	DIN, Chl, P, QC-dup ^(a)
	Reference Area 1 (MEL-03)	MEL-03-01	7.2	533317	6998541	-	-	-	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P	DIN, Chl, P
		MEL-03-02	18.8	533256	6998671	-	-	-	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P, QC-dup ^(a)	DIN, Chl, P	DIN, Chl, P, QC-dup ^(b,c)	DIN, Chl, P
		MEL-03-03	10.2	532962	6998844	-	-	-	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P
		MEL-03-04	8.2	533628	6998672	-	-	-	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P, QC-dup ^(a)	DIN, Chl, P
		MEL-03-05	8.7	534001	6998272	-	-	-	DIN, Chl, P ^(d)	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P	DIN, Chl, P
	Reference Area 2 (MEL-04)	MEL-04-01	8.2	525647	7000878	-	-	-	-	DIN, Chl, P	-	-	DIN, Chl, P	-
		MEL-04-02	10.5	526149	7001519	-	-	-	-	DIN, Chl, P, QC-dup ^(a,b,c)	-	-	DIN, Chl, P	-
		MEL-04-03	9.7	525351	7001359	-	-	-	-	DIN, Chl, P	-	-	DIN, Chl, P	-
		MEL-04-04	9.1	525401	7001085	-	-	-	-	DIN, Chl, P	-	-	DIN, Chl, P	-
		MEL-04-05	7.4	525735	7001129	-	-	-	-	DIN, Chl, P	-	-	DIN, Chl, P	-
	Reference Area 3 (MEL-05)	MEL-05-01	9.3	530926	6990858	-	-	-	-	DIN, Chl, P, QC-dup ^(c)	-	-	DIN, Chl, P	-
		MEL-05-02	9.4	530669	6990884	-	-	-	-	DIN, Chl, P, QC-dup ^(a,b)	-	-	DIN, Chl, P, QC-dup ^(b,c)	-
		MEL-05-03	8.5	530735	6991374	-	-	-	-	DIN, Chl, P, QC-dup ^(c)	-	-	DIN, Chl, P	-
		MEL-05-04	10.2	530570	6991223	-	-	-	-	DIN, Chl, P, QC-dup ^(b)	-	-	DIN, Chl, P, QC-dup ^(a)	-
		MEL-05-05	8.6	530240	6991162	-	-	-	-	DIN, Chl, P	-	-	DIN, Chl, P	-

(a) DIN QC-dup samples.
(b) Phytoplankton QC-dup samples.
(c) Zooplankton QC-dup samples.
(d) Zooplankton samples were not collected during the late spring sampling program in 2016, because the plankton net was misplaced.

NAD = North American Datum; Chl = indicates that chlorophyll a samples were collected; DIN = indicates that depth-integrated nutrient samples were collected; N = mid-column nutrient samples were collected; P = plankton samples were collected; - = the site was not included in the sampling plan for a particular field program, or was not sampled due to weather, environment, or schedule limitations; QC-dup = indicates that a quality control duplicate sample was collected.

7.1.1 Field Methods

7.1.1.1 Supporting Environmental Variables, Nutrients, and Chlorophyll a

During the time of sampling, local weather data (i.e., air temperature, wind conditions, and rainfall) was collected. At each sampling station, water depth and physico-chemical measurements were recorded. Total depth of the water column was measured either by using a sounding line or a boat-mounted sonar unit. In situ physico-chemical measurements of specific conductivity, DO, pH, and water temperature were collected at each lake station using a submersible multi-sensor probe system (Hanna HI-9828 multiprobe). In situ physico-chemical measurements were taken just below the surface and every 1 m thereafter throughout the water column, ending at 1 m above the lake bed. Secchi depth was measured using a 20 cm diameter Secchi disk at each station; this information was used to estimate the euphotic zone depth for depth-integrated sample collection.

Depth-integrated composite samples were collected at all Meliadine Lake stations for analysis of chlorophyll a and nutrient concentrations. Given the shallow nature of the peninsula lakes, depth-integrated samples were not collected at these locations. Instead, discrete samples at mid-column depth were collected for analysis of chlorophyll a and nutrients.

The euphotic zone is defined as the extent of the water column that is exposed to sufficient sunlight for photosynthesis to occur (typically to a depth in the water column where 1% of the surface irradiance is measured). While in the field, the euphotic zone was calculated as two times the Secchi depth (Koenings and Edmundson 1991; AENV 2006).

Once the euphotic depth was determined, a Kemmerer sampler was used to collect discrete water samples starting at the surface, and continuing every 2 m through the extent of the euphotic zone. If the total water column depth was less than two times the Secchi depth, a water sample was collected every 2 m from the surface to 2 m above the lake bed.

Equal volumes of water from each discrete depth were combined into a large, clean bucket to create a composite, depth-integrated sample. From this composite sample, single sub-samples were collected for nutrient analysis, triplicate sub-samples were collected for chlorophyll a analysis, and a single subsample was taken for phytoplankton community analysis as described in Section 7.1.1.2.

Sample bottles for nutrient analysis were provided by ALS (Edmonton), which is an analytical laboratory accredited by CALA. Water samples were processed (i.e., filtered and/or preserved as required, and refrigerated) at site according to the instructions provided by ALS. Water samples requiring filtration were filtered through a 0.45 µm Millipore filter in a Nalgene filter tower, using a vacuum pump, before being preserved with laboratory-provided preservative based on the required analysis. Water samples were kept cool through refrigeration before shipping, and during shipping by adding ice-packs to the coolers. Samples were shipped to ALS as soon as possible after sample collection and processing.

Samples were analyzed for TN, dissolved nitrogen, total Kjeldahl nitrogen (TKN), dissolved Kjeldahl nitrogen, total ammonia, nitrate, nitrite, TP, dissolved phosphorus, dissolved orthophosphate, and SRSi.

Water samples for chlorophyll a analysis were collected at each station during all field programs. Measurement of chlorophyll a concentration in water is a standard method to estimate phytoplankton biomass. Chlorophyll a is the primary photosynthetic pigment in phytoplankton and is frequently used as an indicator of phytoplankton biomass and primary production.

Triplicate water samples for chlorophyll *a* analysis were filtered through a 47 mm diameter Whatman glass fiber type-C filter (nominal pore size: 1.2 µm) in a glass filter tower, using a vacuum pump under low light conditions to prevent photo-shock in the algal cells. A volume of 300 to 500 millilitres (mL) of water was filtered for each chlorophyll *a* sample. The filters were folded in half, placed in a pre-labelled Petri dish, wrapped with aluminum foil, and frozen. Frozen filters were submitted to the Biogeochemical Analytical Service Laboratory at the University of Alberta, Edmonton, Alberta, for spectrophotometric analysis of chlorophyll *a*.

7.1.1.2 Phytoplankton Collection

A single water sample for phytoplankton analysis (either depth-integrated [Meliadine Lake stations] or discrete samples [peninsula lake stations]) was used to fill a 250-mL amber Nalgene bottle. Phytoplankton samples were preserved with approximately 4 mL of Lugol's solution. Samples were sealed, labelled, and stored in the dark (inside coolers) for transportation to Plankton Resources, Winnipeg, Manitoba, for taxonomic identification (to the lowest practical taxonomic level), and abundance and biomass estimates.

7.1.1.3 Zooplankton Collection

Zooplankton samples were collected using a 30 cm diameter, 80 µm mesh Nitex zooplankton net with a detachable "dolphin" bucket having a screen mesh size of 73 µm. A single zooplankton sample was collected at each sampling station. At Meliadine Lake stations, vertical hauls were collected from the water column at an ascent rate of approximately 0.5 m/s, starting at approximately 1.5-m from bottom, being careful to avoid disturbing the bottom sediments. The haul depth for each station was recorded. Horizontal hauls, at a 1-m depth below the surface (for a horizontal tow length of 6 m), were used to collect samples from the peninsula lakes.

Zooplankton samples were not collected in July 2016 due to loss of the plankton net (Table 7.1-1).

Zooplankton samples were deposited into wide-mouth 250-mL clear Nalgene sample bottles, filling to approximately half full. Half of an Alka-Seltzer tablet was added to the sample bottle to prevent contortion of organisms from preservation shock, for easier identification. The samples were preserved on the day of sampling in the laboratory by doubling the sample volume with 10% phosphate-buffered formalin solution (i.e., if the zooplankton sample is 125 mL, then 125 mL of formalin was added, for a total sample volume of 250 mL).

Zooplankton samples were sealed, labelled and stored in coolers for transportation to Biological Environmental Services in Victoria, British Columbia, taxonomic identification (to the lowest practical taxonomic level), and abundance and biomass estimates.

7.1.2 Laboratory Methods

Laboratory methods for nutrient analysis including the laboratory test code, laboratory test description and analytical method references are further described in the laboratory certificate of analysis (Attachment A). Laboratory procedures for chlorophyll *a* analysis include extraction, filtration and spectrophotometric analysis. Chlorophyll concentrations were calculated using the absorbencies at specified wavelengths and the original extraction and filtration volumes. Laboratory methods for phytoplankton and zooplankton enumeration, identification, and QA/QC procedures are further described in Appendix 7A.

7.1.3 Data Analysis

7.1.3.1 Depth-Integrated Samples

Descriptive statistics (i.e., minimum, median, maximum, mean, standard error, standard deviation) for depth-integrated nutrients and chlorophyll *a* were calculated to evaluate spatial and temporal data collected in Meliadine Lake. Where concentrations were below the detection limit (DL), the concentration was set to half the value of the DL for calculating summary statistics. The percentage of non-detect samples in the data set was reported for each parameter.

7.1.3.2 Trophic Status

Trophic status is a useful means of classifying lakes and can be used as an indicator to describe the productivity of a system. Trophic status of a waterbody can be evaluated by examining the concentrations of chlorophyll *a*, nutrients, and water transparency. Chlorophyll *a* is the primary photosynthetic pigment in phytoplankton, and is often used as a surrogate measure of phytoplankton biomass and production in lakes (Franklin et al. 2012). The essential nutrients necessary for phytoplankton growth are nitrogen, phosphorus, carbon, and for some groups (e.g., diatoms), silica. The primary nutrient that often limits phytoplankton growth in lakes is phosphorus (Schindler 1974); therefore, phosphorus is often used to establish the trophic status of lakes. Secchi depth (a measure of water transparency) can be used as a coarse surrogate of phytoplankton biomass, because in many waterbodies, Secchi depth is inversely related to phytoplankton biomass (Dodds and Whiles 2010); therefore, Secchi depth is also considered when evaluating trophic status.

The three main classes of trophic status are the following:

- oligotrophic (nutrient-poor, unproductive systems)
- mesotrophic (moderately productive systems)
- eutrophic (nutrient-rich, highly productive systems)

The trophic status of Meliadine Lake was evaluated by examining the nutrient data (TP), chlorophyll *a* concentrations, and water transparency (Secchi depth). The trophic status was determined using the Vollenweider (1970) trophic classification scheme for lakes (Table 7.1-2), the CCME (2004) trigger ranges (Table 7.1-3), and the Carlson (1977) Trophic State Index (TSI; Table 7.1-4). Of the three commonly used variables to calculate TSI, chlorophyll *a* is considered the best predictor of the overall trophic status of lakes (Carlson and Simpson 1996). As a result, the overall trophic status of Meliadine Lake was determined using the TSI value calculated based on chlorophyll *a* concentrations, and this classification was supported by TSI values calculated based on nutrient availability (TP) and water transparency.

Table 7.1-2: General Trophic Classification of Lakes

Trophic Status	Total Phosphorus (mg/L)		Chlorophyll a (µg/L)		Secchi Depth (m)	
	Mean	Range	Mean	Range	Mean	Range
Oligotrophic	0.008	0.003 to 0.018	1.7	0.3 to 4.5	9.9	5.4 to 28.3
Mesotrophic	0.027	0.011 to 0.096	4.7	3.0 to 11.0	4.2	1.5 to 8.1
Eutrophic	0.084	0.016 to 0.386	14.3	3.0 to 78.0	2.5	0.8 to 7.0

Source: Vollenweider 1970.

mg/L = milligrams per litre; µg/L = micrograms per litre.

Table 7.1-3: Trophic Classification of Canadian Lakes Based on Total Phosphorus Trigger Ranges

Trophic Status	Total Phosphorus (mg/L)
Ultra-oligotrophic (very nutrient-poor)	<0.004
Oligotrophic (nutrient-poor)	0.004 to 0.010
Mesotrophic (containing a moderate level of nutrients)	0.010 to 0.020
Meso-eutrophic (containing moderate to high levels of nutrients)	0.020 to 0.035
Eutrophic (nutrient-rich)	0.035 to 0.100
Hyper-eutrophic (very nutrient-rich)	>0.100

Sources: CCME 2004; Environment Canada 2004.

mg/L = milligrams per litre; <= less than; >= greater than.

The TSI is a numerical trophic state index for lakes that classifies lakes on a scale of 0 to 100 (Carlson 1977).

The index number is calculated from Secchi depth, chlorophyll a, and TP using the following equations (Carlson 1977):

$$TSI (TP) = 10 \left(6 - \frac{\ln \frac{48}{TP}}{\ln 2} \right) \quad \text{Equation 1}$$

$$TSI (Chl) = 10 \left(6 - \frac{2.04 - 0.68 \ln Chl}{\ln 2} \right) \quad \text{Equation 2}$$

$$TSI (Secchi) = 10 \left(6 - \frac{\ln Secchi}{\ln 2} \right) \quad \text{Equation 3}$$

where:

- TSI = trophic state index
- TP = total phosphorus
- ln = the natural log
- Chl = chlorophyll a
- Secchi = Secchi depth

Values calculated using these equations are multiplied by 10 to give the scale a range of 0 to 100. The numerical scales for each of the three TSIs are presented in Table 7.1-4.

Table 7.1-4: Comparison of Trophic State Index Classification and General Trophic Classification of Lakes

Trophic State Index	Total Phosphorus (mg/L)	Chlorophyll a (µg/L)	Secchi Depth (m)	General Trophic Classification
<30 to 40	0 to 0.012	0 to 2.6	>8.0 to 4	Oligotrophic
40 to 50	0.012 to 0.024	2.6 to 20	4 to 2	Mesotrophic
50 to 70	0.024 to 0.096	20 to 56	2 to 0.5	Eutrophic
70 to 100+	0.096 to 0.38+	56 to 155+	0.5 to <0.25	Hyper-eutrophic

Source: Carlson 1977.

mg/L = milligrams per litre; µg/L = micrograms per litre; < = less than; > = greater than.

7.1.3.3 *Phytoplankton and Zooplankton*

Phytoplankton and zooplankton data were analyzed separately, but the same approach was used for both datasets. The following variables were calculated for each sample:

- total abundance (abundance as organisms per litre [org/L])
- total biomass (biomass as milligrams per cubic metre [mg/m³])
- total taxonomic richness (richness as number of taxa [no. of taxa] at a station)
- relative abundances (as percentages) of major taxonomic groups
- relative biomass (as percentages) of major taxonomic groups

Abundance and biomass data were divided into major taxonomic groups. Phytoplankton groups were Cyanobacteria, Chlorophyceae (chlorophytes), Chrysophyceae (chrysophytes), Cryptophyceae (cryptophytes), Dinophyceae (dinoflagellates), Bacillariophyceae (diatoms), and Euglenophyceae (euglenoids). Zooplankton groups were Cladocera (cladocerans), Calanoida (calanoid copepods), Cyclopoida (cyclopoid copepods), Rotifera (rotifers), and copepod nauplii. Cyclopoid and calanoid copepods were considered separately because of taxonomic and ecological differences. Copepod nauplii were not identified as either cyclopoid or calanoid copepods, but occurred in high abundances in certain samples; therefore, they were treated as a unique taxonomic group for plotting purposes.

Mean total abundance and mean total biomass were calculated for each area (e.g., Near-field exposure area) and plotted as bar graphs showing mean and standard error (SE). Zooplankton abundance and biomass (wet weight) values were corrected for volume of water filtered, based on haul depth or length and net dimensions, to obtain comparable values across stations.

Mean taxonomic richness at the species level was summarized for each area and plotted as a bar graph for both phytoplankton and zooplankton. Taxonomic richness provides an indication of the diversity at a station; higher richness values typically indicate more healthy and balanced communities. For stations where duplicate QC samples were collected, total taxonomic richness was calculated as the average richness of the two duplicate samples.

7.1.3.4 *Spatial and Temporal Trends*

Nutrient concentrations, chlorophyll a, and plankton community variables were compared visually among-areas by season and year to explore seasonal, inter-annual and spatial trends. The following variables were plotted for each area and sampling event:

- mean total nitrogen and total phosphorus concentrations
- mean chlorophyll a concentration
- mean total phytoplankton and zooplankton abundance and biomass
- total nitrogen, total phosphorus and chlorophyll a concentrations, plotted for each station in the Near-field area
- mean total phytoplankton and zooplankton richness
- mean relative proportion accounted for by each major taxonomic group, based on abundance and biomass, plotted as stacked bars (for phytoplankton and zooplankton)

Scatter plots were used to evaluate the strength of the relationship between chlorophyll a concentrations and phytoplankton biomass, and to evaluate the spatial variability of each variable against concentrations of depth-integrated nutrients.

7.1.3.5 *Statistical Analysis*

The objective of the statistical comparisons of plankton data collected in Meliadine Lake was to compare data collected from the Near-field exposure area (MEL-01) with the Mid-field exposure area (MEL-02) and the three reference areas (MEL-03, MEL-04, and MEL-05). Descriptive statistics (i.e., minimum, maximum, median, mean, standard deviation, standard error) were calculated to compare and evaluate spatial and temporal data collected in Meliadine Lake. Hypothesis testing (e.g., one-way ANOVA or Kruskal-Wallis test) was used to compare plankton endpoints (e.g., abundance, biomass, richness) and nutrient and chlorophyll a concentrations among sampling areas, years, and seasons. Multivariate analysis (nMDS) was also used to investigate differences in community structure among areas. Statistical tests were performed using SYSTAT 13.1 for Windows (Systat Software 2009) or PRIMER version 7.0.13 software (Quest Research 2017).

Hypothesis Testing

Univariate hypothesis testing was used to identify differences in plankton community endpoints among areas and years. A significance level (alpha, α) of 0.1 was used for analysis of variance models, and an α of 0.05 was used for testing statistical assumptions (i.e., normality and homogeneity of variances). Prior to conducting ANOVAs, the assumptions of parametric statistical tests were verified using the Shapiro-Wilk test for normality and Levene's test for homogeneity of variances on untransformed and log-transformed data. Data that violated assumptions of normality or equality of variances were transformed and the effectiveness of the transformations was verified. If the assumptions of the ANOVA were not met, the non-parametric equivalent of ANOVA (i.e., Kruskal-Wallis test) was used.

Mean values for each parameter from the exposure and reference areas were initially compared to one another in an overall ANOVA. Tukey's honestly significant difference (HSD) method was used for multiple unplanned (i.e., *a posteriori*) comparisons following the overall ANOVA. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, a P value of 0.1 was used for these tests.

For variables that did not meet parametric test assumptions (e.g., chlorophyll *a*), the Kruskal-Wallis test was used to test for differences among sampling areas. Kruskal-Wallis tests were considered significant at $P < 0.1$. The multiple-comparison procedure controls the experiment wise error rates for the Type I error and, therefore, holds the probability of correctly finding no difference at $1-\alpha$. However, under this scenario, the task of correctly detecting differences that are significant is more difficult (Daniel 1990). To maintain a sufficiently small Type II error (β) with the multiple comparisons, a larger α (or P -value) was used. The contrasts were tested at $P = 0.1$, and the multiple comparisons were conducted with $P = 0.15$.

Multivariate Analysis

Non-metric multidimensional scaling (nMDS), a multivariate ordination technique, was used to investigate differences in plankton community structure among areas in 2016 and 2017. nMDS takes a pair-wise matrix of similarities among cases calculated from the original taxonomic data (biomass by station-year), and then reduces it to a small number of underlying dimensions of variation among cases. In this way, nMDS can visually simplify a multidimensional taxonomic data-set in two or three dimensions that capture the major patterns of variation in community composition.

The plankton taxonomic data were analyzed at the lowest taxonomic level. A square root transformation was applied to improve the separation of the data among stations on the nMDS plots. Transforming the data also reduced weighting of the analysis by the most abundant taxa. The appropriate data transformation was determined by examining "shade plots" created in PRIMER. Alternative data transformations were explored; however, stronger transformations (i.e., fourth-root and Log $X+1$ transformations), heavily down-weighted the data.

Following the data transformation, a Bray-Curtis resemblance matrix was generated, and the nMDS procedure was applied to this matrix. Using rank order information, nMDS determined the relative positions of stations in two dimensions based on community composition. Goodness-of-fit was determined by examining the Shepard diagrams as well as the stress values, which were calculated from the deviations in the Shepard diagrams. Two dimensions were selected for each nMDS after confirming that the final stress value of the two-dimensional configuration was sufficiently low (less than 0.2; Clarke 1993). Points that fall close together on the nMDS ordination plot represent samples with similar community composition; points that are far apart from each other represent samples with dissimilar community composition.

7.2 Quality Assurance and Quality Control

The QA/QC practices applied during this study and detailed results of the QC analyses are provided in Appendix 7A. Quality assurance (QA) components of the program included the use of trained personnel and an accredited analytical laboratory; QC components included assessments of duplicate samples for DIN, phytoplankton, and zooplankton. A summary of key QC results is provided below.

Key QC findings for the 2015 to 2017 plankton monitoring programs are as follows:

■ **Nutrients and Chlorophyll a:**

- A total of 9% of paired concentrations in duplicate DIN samples had a relative percent difference (RPD) greater than 20%. Each of the three RPD exceedances came from duplicate samples collected at MEL-02-05 in September 2017, where RPDs for concentrations of nitrate, and total and dissolved nitrogen, exceeded 20%. DIN samples at most stations in September 2017 had notably higher concentrations of nitrogen than during any other sampling event; results of the QA/QC analyses suggest that elevated nitrate and total nitrogen concentrations should be interpreted with caution, as analyses of these parameters show some variability.
- All RPDs for the other two sets of DIN duplicate samples collected in 2017 were below 20%.
- Concentrations of dissolved parameters were generally lower than corresponding total concentrations for the DIN samples. Dissolved concentrations were higher than total concentrations for 1.2% of comparisons.
- RPDs for total phosphorus concentrations in 2017 were below 20% in all samples.
- Chlorophyll a samples collected in September 2017 were collected using a different type of filter than during previous sampling events. The analytical laboratory was able to analyze chlorophyll a concentrations from the filters submitted in September 2017; however, the lab noted that the difference in the filter used may have affected the results of the analysis. As a result, chlorophyll a data from the September 2017 sampling event was omitted from statistical analyses presented in this report.

■ **Phytoplankton:**

- The dominant taxon was consistent between duplicate samples for phytoplankton biomass and abundance.
- RPDs for total phytoplankton biomass and abundance were below 50% for all duplicates.
- RPDs above 50% were observed in the majority of duplicates for major phytoplankton taxonomic groups; however, graphical presentation of the relative abundance of major phytoplankton groups showed that variation between duplicates was actually low and that the proportions of major groups were similar between duplicates.
- Data screening of the phytoplankton taxonomic results identified taxonomic richness in the sample collected in MEL-02-02 in July 2016 to be unusually low. The inconsistency of this sample compared to all other stations in both years suggests a potential error during field collection or processing of this sample.

■ **Zooplankton:**

- The dominant taxon was consistent between duplicate samples for zooplankton biomass and abundance in 17 of the 20 duplicate samples. In three samples, different taxa were dominant by biomass or abundance between replicate samples; however, RPDs between biomass and abundance estimates for each duplicate sample were below 50% in each case.
- RPDs for total zooplankton biomass and abundance were below 50% for all duplicates.

- RPDs above 50% were observed in the majority of duplicates for major zooplankton taxonomic groups; however, graphical presentation of the relative abundance of major zooplankton groups showed that variation between duplicates was actually low and that the proportions of major groups were similar between duplicates.

Differences between original and QC samples were deemed minor, and within the range of variability expected in plankton data. Based on this assessment, the plankton monitoring data are considered adequate to meet the needs of the AEMP for the Mine.

7.3 Results and Discussion

The results from the plankton sampling programs completed in Meliadine Lake in 2015 to 2017 are summarized in Sections 7.3.1 to 7.3.4. Chlorophyll a sampling results in the peninsula lake are summarized in Section 3.3.2.3. Results from previous sampling programs in the peninsula lakes in 2015 and 2016 were presented in *Aquatic Effects Monitoring Program – 2016 Annual Report* (Golder 2017a). Detailed results are provided in the following appendices:

- Appendix 7B: Depth-Integrated Nutrients and Chlorophyll a
- Appendix 7C: Trophic Status
- Appendix 7D: Phytoplankton Community Results
- Appendix 7E: Zooplankton Community Results

7.3.1 Depth-Integrated Nutrients and Chlorophyll a

Depth-integrated nutrient and chlorophyll a results for samples collected from Meliadine Lake in 2015 to 2017 are provided in Appendix 7B. Summary statistics (count, minimum, median, mean, maximum, standard error, standard deviation) for depth-integrated nutrients are provided in Tables 7B-1 to 7B-3. Summary statistics for chlorophyll a are provided in table 7B-4. Raw data for depth-integrated nutrients and chlorophyll a are provided in are provided in Tables 7B-5 and 7B-6 respectively.

In general, concentrations of most depth-integrated nutrients were low, with few observable spatial or temporal trends. Concentrations of TN were low in most samples; however, TN was notably higher in samples collected in September 2017 than in other seasons and years (Figure 7.3-1). In 2017, TN ranged from a mean concentration of 0.30 mg-N/L (MEL-03) to 0.31 mg-N/L (MEL-01) in September, compared to a range of 0.12 mg-N/L (MEL-03) to 0.22 mg-N/L (MEL-01) in August and 0.12 mg-N/L (MEL-03) to 0.18 mg-N/L (MEL-01) in July. In September 2017, TN concentrations were relatively similar among the reference and exposure areas, suggesting that TN concentrations may have been naturally elevated in Meliadine Lake during the time of sampling. TN concentrations in 2015 and 2016 were generally slightly lower at most stations than in 2017 with no discernible trend among years or stations in July or August.

Concentrations of TP were generally above detection limits but low throughout the lake in 2015, 2016 and 2017 (Figure 7.3-2). Some variability in TP concentrations was observed across sampling areas and seasons, but no consistent trends were apparent. Across all years, TP concentrations ranged from a mean concentration of 0.0043 mg-P/L (MEL-03) to 0.0068 mg-P/L (MEL-01) in July, from 0.0036 mg-P/L (MEL-05) to 0.0072 mg-P/L (MEL-02) in August, and from 0.0046 mg-P/L (MEL-02) to 0.0072 mg-P/L (MEL-01) in September.

Concentrations of nitrate, nitrite, ammonia, and orthophosphate were below detection limits in the majority of samples collected in 2015, 2016 and 2017. Minor spatial differences were observed in silica concentrations throughout Meliadine Lake, with the highest median concentrations in the Near-field area in July 2017 (0.6 mg/L) and August 2017 (0.55 mg/L) and slightly lower concentrations in the reference areas where the highest median concentration of silica across all seasons and years reached 0.26 mg/L.

Chlorophyll a concentrations varied among years in the majority of areas in Meliadine Lake; however, some consistent seasonal and spatial trends were observed (Figure 7.3-3). In July, chlorophyll a in the Near-field area was higher in 2015 (2.3 ± 0.07 µg/L) than in 2016 (1.9 ± 0.05 µg/L) and 2017 (1.5 ± 0.09 µg/L), with a similar trend observed in the Mid-field exposure area. In 2016 and 2017, chlorophyll a concentrations were higher in the exposure areas than in Reference Area 1, where chlorophyll a had a mean concentration of 1.0 ± 0.02 µg/L and 0.5 ± 0.03 µg/L respectively. In August, chlorophyll a concentrations were variable among years, with concentrations highest in 2016 in most areas, and among the exposure and reference areas with higher concentrations in the Near-field exposure area than in the reference areas in 2016 and 2017. Chlorophyll a concentrations in August 2016 ranged from a high of 1.9 ± 0.07 µg/L at MEL-01 to a low of 0.7 ± 0.03 µg/L at MEL-03. In August 2017, concentrations ranged from a high of 1.3 ± 0.2 µg/L at MEL-01 to a low of 0.6 ± 0.02 µg/L at MEL-03. Chlorophyll a in September was highly variable among years in the Near-field exposure area and relatively consistent in the Mid-field exposure area and the reference area. Concentrations ranged from 2.0 ± 0.05 µg/L at MEL-01 to 1.0 ± 0.08 µg/L at MEL-03 in 2016 and from 1.2 ± 0.1 µg/L at MEL-02 to 0.6 ± 0.02 µg/L at MEL-01 in 2017.

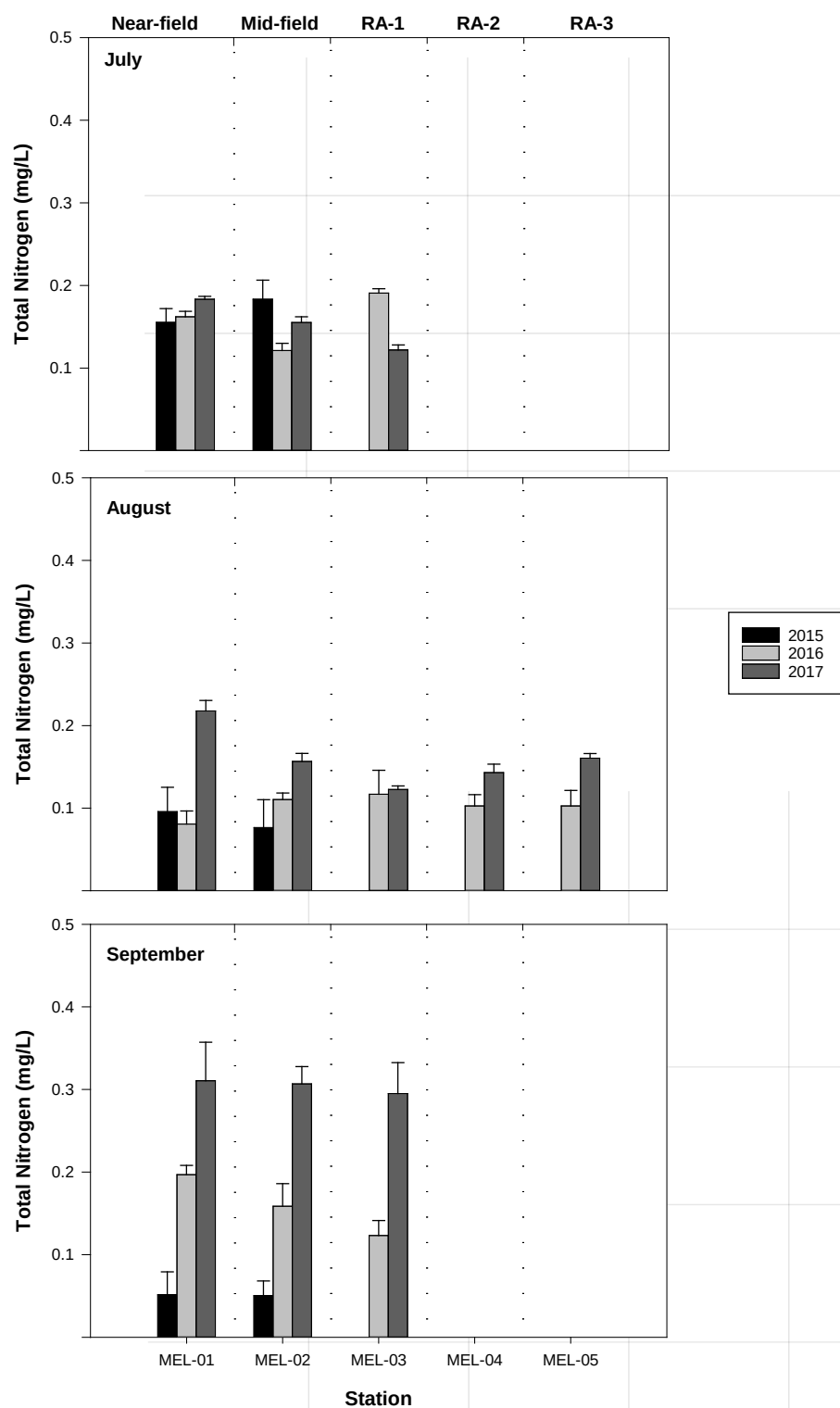


Figure 7.3-1: Mean Total Nitrogen Concentrations in Meliadine Lake, 2015 - 2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September.

RA=Reference Area; mg/L = milligrams per litre.

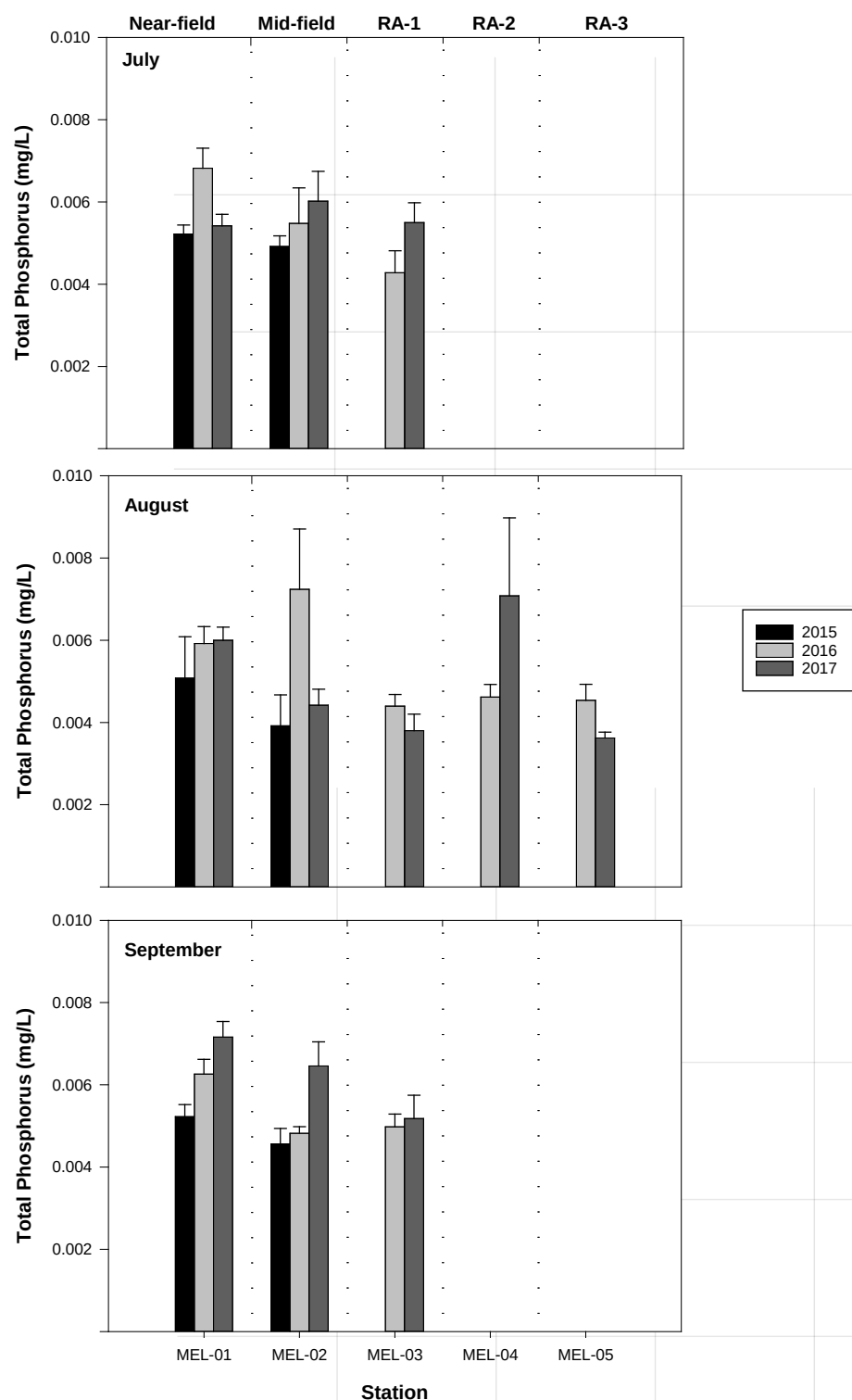


Figure 7.3-2: Mean Total Phosphorus Concentrations in Meliadine Lake, 2015 – 2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September.

RA=Reference Area; mg/L = milligrams per litre.

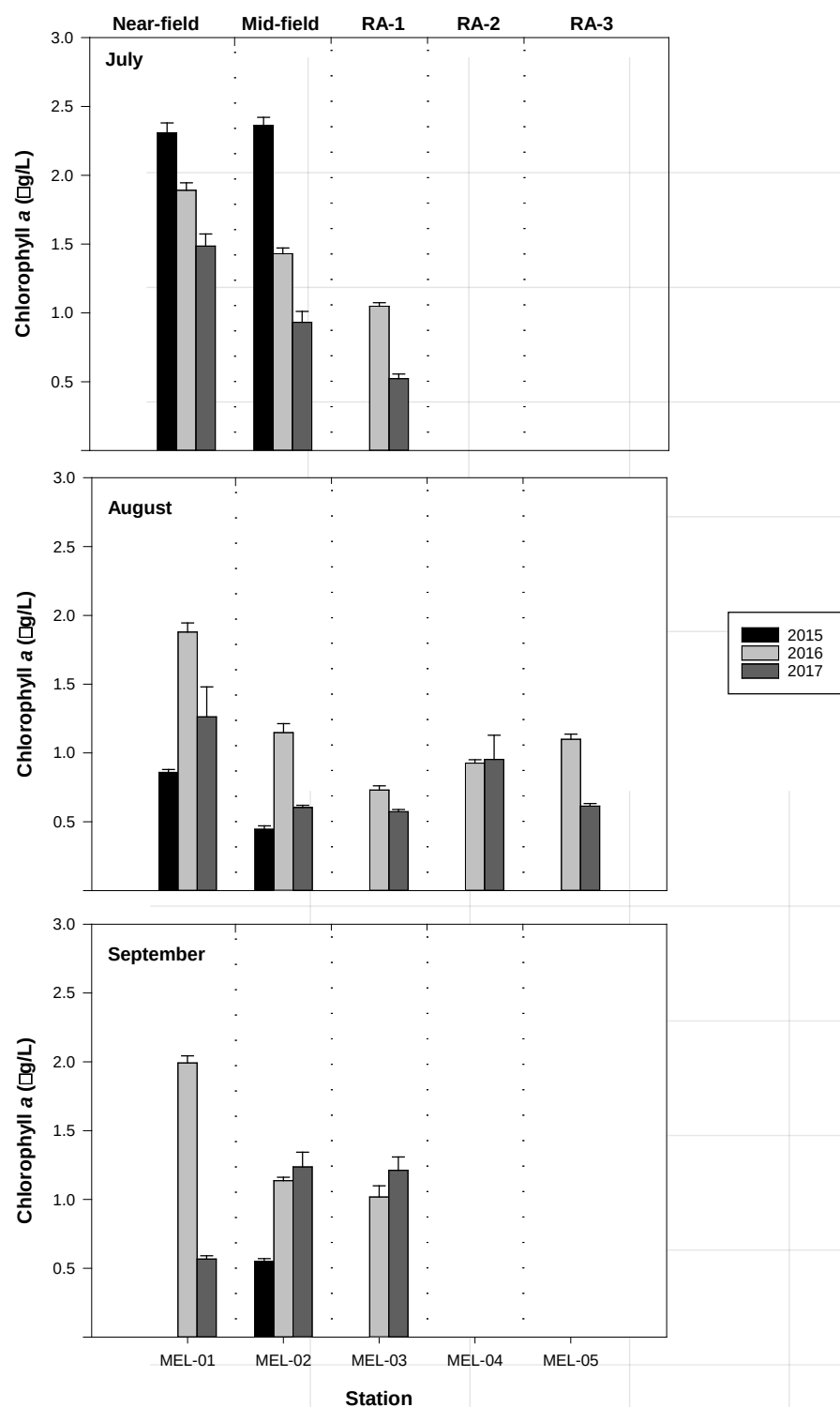


Figure 7.3-3: Mean Chlorophyll a Concentrations in Meliadine Lake, 2015 – 2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September. RA=Reference Area; µg/l = micrograms per litre. September 2017 samples were collected with different filters and are not directly comparable to other samples.

7.3.1.1 Statistical Comparisons of Nutrients and Chlorophyll a

Statistical comparisons of depth-integrated nutrients and chlorophyll a concentrations were made among years for each sampling area and season Table 7.3-1. Variability among years in all seasons and areas was generally high for concentrations of total nitrogen, total phosphorus, and chlorophyll a. Significant differences were observed among years for each variable in at least one area within each season. Several seasonal and annual trends were also evident in nutrient and chlorophyll a concentrations in the Near-field and Mid-field exposure areas, for which three years of sampling allowed pairwise comparisons between years (Table 7.3-2).

Table 7.3-1: Results of Statistical Analysis for Nutrients and Chlorophyll a Comparing Years

Station	Variable	Transformation	Statistical Test	July	August	September
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
MEL-01	Total Nitrogen	log(x)	ANOVA	0.187	0.001	<0.001
	Total Phosphorus	log(x)	ANOVA	0.014	0.560	0.011
	Chlorophyll a	none	ANOVA / t-test	<0.001	<0.001	<0.001
MEL-02	Total Nitrogen	log(x)	ANOVA	0.035	0.052	<0.001
	Total Phosphorus	log(x)	ANOVA	0.525	0.070	0.014
	Chlorophyll a	none	ANOVA	<0.001	<0.001	<0.001
MEL-03	Total Nitrogen	log(x)	t-test	<0.001	0.814	0.004
	Total Phosphorus	log(x)	t-test	0.129	0.261	0.767
	Chlorophyll a	none	t-test	<0.001	<0.001	<0.001
MEL-04	Total Nitrogen	log(x)	t-test	–	0.048	–
	Total Phosphorus	log(x)	t-test	–	0.266	–
	Chlorophyll a	none	t-test	–	<0.001	–
MEL-05	Total Nitrogen	log(x)	t-test	–	0.035	–
	Total Phosphorus	log(x)	t-test	–	0.076	–
	Chlorophyll a	none	t-test	–	<0.001	–

Note: *P*-values representing significant differences among years ($P < 0.1$) are **bolded**.

ANOVA= Analysis of Variance; t-test= Two-sample t-test; *P*-value = probability value; < = less than; – = no samples collected.

Results of statistical analyses for comparisons of nutrients and chlorophyll a concentrations among years are summarized below:

- Total nitrogen concentrations were significantly different among years in all areas except in MEL-01 in July and MEL-03 and MEL-05 in August (Table 7.3-1). A significant trend of increasing total nitrogen was observed in each exposure area in September, along with a significant increase in nitrogen from previous years in August 2017 in the Near-field exposure area (Table 7.3-2).
- Total phosphorus concentrations were less variable among years, but significantly different in MEL-01 in July, MEL-02 in August, and MEL-01 and MEL-02 in September (Table 7.3-1). Concentrations of total phosphorus significantly increased from previous years in September 2017 in each exposure area, while total phosphorus in July was significantly higher in 2016 than in 2015 or 2017 (Table 7.3-2).
- Chlorophyll a concentrations were significantly different among years within all areas in July, August and September (Table 7.3-1). Chlorophyll a concentrations significantly decreased in July from 2015 to 2017 in the Near-field and Mid-field exposure areas (Table 7.3-2). In August, chlorophyll a was significantly higher in 2016 than in 2015 or 2017 and in September chlorophyll a was significantly lower in 2015 than in 2016 or 2017 in the Mid-field exposure area.

Table 7.3-2: Pairwise Comparisons for Statistical Analyses of Nutrients and Chlorophyll a Comparing Years

Year	Variable	Trans-formation ^(a)	Statistical Test	July			August			September		
				2015 / 2016	2015 / 2017	2016 / 2017	2015 / 2016	2015 / 2017	2016 / 2017	2015 / 2016	2015 / 2017	2016 / 2017
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
MEL-01	Total Nitrogen	log(x)	ANOVA / Tukey's	0.887	0.184	0.362	0.882	0.004	0.002	0.007	<0.001	0.042
	Total Phosphorus	log(x)	ANOVA / Tukey's	0.018	0.914	0.038	0.645	0.593	0.996	0.156	0.008	0.199
	Chlorophyll a	none	ANOVA / Tukey's	0.002	<0.001	0.001	<0.001	<0.001	<0.001	-	-	-
MEL-02	Total Nitrogen	log(x)	ANOVA / Tukey's	0.028	0.414	0.252	0.455	0.042	0.315	0.010	<0.001	0.002
	Total Phosphorus	log(x)	ANOVA / Tukey's	0.827	0.495	0.837	0.079	0.930	0.145	0.897	0.018	0.039
	Chlorophyll a	none	ANOVA / Tukey's	<0.001	<0.001	<0.001	<0.001	0.026	<0.001	<0.001	<0.001	0.904

(a) Distributions of all variables violated the assumption of normality even after transformation; however, the results are considered reliable as the assumption of equal variances was not violated and ANOVA is robust against violations of the assumption of normality.

Note: *P*-values representing significant differences between years ($P < 0.1$) are **bolded**.

ANOVA= Analysis of Variance; Tukey's= Tukey's Honestly Significant Difference Test; *P*-value = probability value; < = less than; - = September samples omitted from statistical analysis due to use of different filter type.

Samples collected during the August sampling event were carried forward for further evaluation of spatial variability among the five areas of Meliadine Lake. Data collected in 2015 was omitted from statistical comparisons among areas in Meliadine Lake due to a lack of sampling in the reference areas. Differences observed in the concentrations of total nitrogen, total phosphorus, and chlorophyll a in August 2016 and August 2017 in Meliadine Lake are summarized below:

- In 2016, total nitrogen concentrations were not significantly different among any of the five sampling areas ($P = 0.695$) (Table 7.3-3). In 2017, total nitrogen was significantly higher in the Near-field exposure area than in the Mid-field and reference areas. Significant differences in nitrogen concentrations were also observed between MEL-02 and MEL-03, and between MEL-03 and MEL-05 in 2017.
- Total phosphorus concentrations varied significantly overall among areas in 2016 ($P = 0.051$) and 2017 ($P = 0.054$); however few significant differences were observed in pairwise comparisons between areas (Table 7.3-3). Significant differences were only observed between MEL-02 and MEL-03 in 2016, and between MEL-04 and MEL-05 in 2017.
- Chlorophyll a concentrations were significantly different among areas in both 2016 and 2017 (Table 7.3-3). Pairwise comparisons revealed that chlorophyll a concentrations were significantly different between all areas except between MEL-02 and MEL-05 in 2016. In 2017, the Near-field exposure area was significantly higher compare to other areas and there was no significant difference among any of the other areas.

Table 7.3-3: Results of Statistical Analysis and Pairwise Comparisons for Nutrients and Chlorophyll a Comparing Areas, August 2016-2017

Year	Variable	Transform ^(a)	Statistical Test	Overall Comparison	MEL-01 / MEL-02	MEL-01 / MEL-03	MEL-01 / MEL-04	MEL-01 / MEL-05	MEL-02 / MEL-03	MEL-02 / MEL-04	MEL-02 / MEL-05	MEL-03 / MEL-04	MEL-03 / MEL-05	MEL-04 / MEL-05
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
2016	Total Nitrogen	log(x)	ANOVA /Tukey's	0.695	0.759	0.646	0.903	0.907	1	0.998	0.997	0.986	0.984	1
	Total Phosphorus	log(x)	ANOVA /Tukey's	0.051	0.705	0.585	0.713	0.667	0.079	0.119	0.103	0.999	1	1
	Chlorophyll a	none	ANOVA /Tukey's	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.016	0.949	0.040	<0.001	0.103
2017	Total Nitrogen	log(x)	ANOVA /Tukey's	<0.001	0.001	<0.001	<0.001	0.002	0.086	0.817	0.997	0.488	0.045	0.634
	Total Phosphorus	log(x)	ANOVA /Tukey's	0.054	0.725	0.435	0.913	0.359	0.987	0.261	0.968	0.112	1	0.085
	Chlorophyll a	none	ANOVA /Tukey's	<0.001	<0.001	<0.001	<0.001	<0.001	0.778	0.999	0.907	0.608	0.999	0.778

(a) Distributions of all variables violated the assumption of normality even after transformation; however, the results are considered reliable as the assumption of equal variances was not violated and ANOVA is robust against violations of the assumption of normality.

Note: *P*-values representing significant differences between areas (*P*<0.1) are **bolded**.

ANOVA= Analysis of Variance; Tukey's= Tukey's Honestly Significant Difference Test; *P*-value = probability value; < = less than.

7.3.1.2 Evaluation of Variability of Nutrients in Near-field Area Relative to Phytoplankton Biomass and Chlorophyll a

Scatter plots of nutrients, chlorophyll a, and phytoplankton biomass were made to assess variability of biomass and chlorophyll a in relation to variability in nutrient concentrations (i.e., TN and TP) in the Near-field exposure area (Figure 7.3-4). Spatial variability in nutrient concentrations in the Near-field exposure area during each sampling event was generally lower than the variability among seasons and among years. Temporal variability in concentrations of TN was observed; however, changes in TN did not result in corresponding increases in phytoplankton biomass or chlorophyll a. In general, higher concentrations of total phosphorus and total nitrogen did not result in higher phytoplankton biomass or chlorophyll a, as evidenced in August, where comparatively high biomass and chlorophyll a occurred across a range of nutrient concentrations. Overall, nutrient concentrations were consistently low and varied among seasons with limited spatial variability evident as a result of potential nutrient inputs from treated STP effluent discharge in the Near-field exposure area.

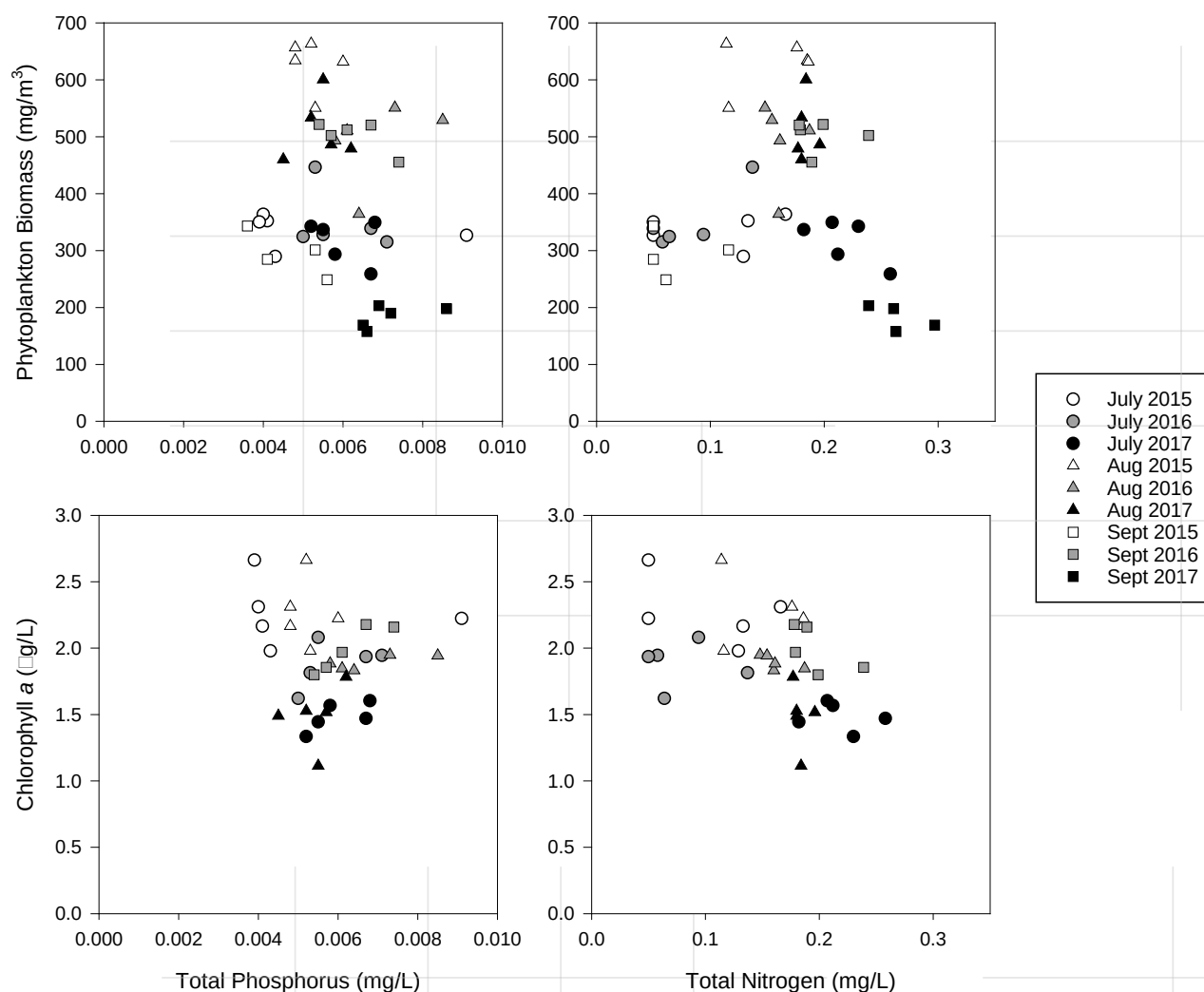


Figure 7.3-4: Nutrients versus Phytoplankton Biomass and Chlorophyll a Concentration at MEL-01, 2015 – 2017

Note: Chlorophyll a data from September 2017 was excluded due to difference filter used for field collection.

µg/L = micrograms per litre; mg/m³ = milligrams per cubic metre; mg/L = milligrams per litre.

7.3.2 Trophic Status Classification

Total phosphorus, chlorophyll *a*, and water transparency (Secchi depth) were collected as part of the water quality sampling program and were used to characterize the trophic status of Meliadine Lake. Summary tables for total phosphorus, chlorophyll *a*, Secchi depth and trophic status index are provided in Appendix 7C, Tables 7C-1 and C-2.

Chlorophyll *a* concentrations were within the oligotrophic range throughout Meliadine Lake in 2015, 2016, and 2017, according to the general trophic classification systems of lakes (Table 7.1-2; Vollenweider 1970). Mean chlorophyll *a* concentrations in 2015 ranged from 0.45 µg/L at MEL-02 in August to 2.36 µg/L at MEL-02 in July, in 2016, from 0.73 µg/L at MEL-03 in August to 1.99 µg/L at MEL-01 in September, and in 2017 from 0.52 µg/L at MEL-03 in July to 1.49 µg/L at MEL-01 in July (Appendix 7C, Table 7C-1).

Concentrations of total phosphorus were also consistent with an oligotrophic (nutrient-poor) classification based on the CCME (2004) trigger ranges (i.e., between 0.004 and 0.010 mg/L) at the majority of locations, with the exception of three samples collected at MEL-02 in August 2015, and MEL-03 and MEL-05 in August 2017, each of which indicated an ultra-oligotrophic (very nutrient-poor) classification (i.e., <0.004 mg/L; Table 7.1-3). The mean concentration of total phosphorus in 2015 ranged from 0.0039 mg-P/L at MEL-02 in August to 0.0052 mg-P/L at MEL-01 in September, in 2016, from 0.0043 mg-P/L at MEL-03 in July to 0.0072 mg-P/L at MEL-02 in August, and in 2017 from 0.0036 mg-P/L at MEL-05 in August to 0.0072 mg-P/L at MEL-01 in September (Appendix 7C, Table 7C-1).

Secchi depths collected throughout Meliadine Lake were consistent with an oligotrophic classification (Table 7.1-4). During the 2015 sampling program, mean Secchi depth in Meliadine Lake ranged from 5.3 m at MEL-01 in September to 6.4 m at MEL-02 in August. In 2016, mean Secchi depth ranged from 5.1 m at MEL-02 in July to 7.4 m at MEL-05 in August. In 2017 mean Secchi depth ranged from 5.1 m at MEL-01 in July to 8.9 m at MEL-05 in August.

Based on the TSI calculations for chlorophyll *a* from the open-water sampling period, the overall trophic status of Meliadine Lake was considered to be oligotrophic (Appendix 7C, Table 7C-2). TSI based on chlorophyll *a* concentrations in the Near-field exposure area ranged from 26.2 (August) to 38.6 (July) in 2015, from 36.7 (August) to 37.3 (September) in 2016, and from 33.9 (September) to 34.4 (August) in 2017. TSI (chl) was similarly low in the Mid-field exposure area, ranging from 22.4 (August) to 39 (July) in 2015, from 31.5 (August) to 34.1 (July) in 2016, and from 25.6 (August) to 31.3 (September) in 2017. TSI (chl) reached a maximum of 31 and 25 in the reference areas in 2016 and 2017 respectively. TSI values based on total phosphorus concentrations and secchi depth were also low and supported the oligotrophic classification based on the TSI for chlorophyll *a* in Meliadine Lake (Appendix 7C, Table 7C-2).

7.3.3 Phytoplankton

Descriptive statistics that summarize the phytoplankton abundance, biomass, and richness by season, year and area are provided in Appendix 7D, Table 7D-1. Relative abundance of major phytoplankton groups from samples collected in Meliadine Lake is provided in Appendix 7D, Table 7D-2. Raw phytoplankton taxonomic data for Meliadine Lake are provided in Appendix 7D, Tables 7D-3 to 7D-5.

7.3.3.1 *Abundance*

Phytoplankton abundance varied spatially and seasonally throughout Meliadine Lake in 2015, 2016 and 2017, with similar spatial and seasonal trends observed during each year (Table 7.3-5). Abundance was notably higher in the Near-field exposure area than in the Mid-field exposure area or the reference areas in all seasons and years. Abundance was also consistently highest in July at all stations, although this trend was mostly evident in the Near-field and Mid-field exposure areas as abundance varied only slightly between seasons in Reference Area 1. Mean phytoplankton abundance in the Near-field exposure area (MEL-01) in July 2015 ranged from $4,370,493 \pm 116,312$ cells/L in 2017 to $4,910,893 \pm 258,185$ cells/L in 2015, compared to a maximum of $2,909,414 \pm 154,628$ cells/L in August and $2,900,894 \pm 92,690$ cells/L in September. Abundance in the Mid-field exposure area (MEL-02) was similarly high in July 2015 reaching $4,625,510 \pm 164,279$ cells/L, but was lower in July 2016 and 2017. Mean abundance in Reference Area 1 reached a high of $2,412,771 \pm 178,375$ cells/L in July compared with $2,087,709 \pm 80,645$ cells/L in August and $2,182,880 \pm 189,068$ cells/L in September. Phytoplankton abundance was lower in August and September in both exposure areas and the spatial trend was less apparent than in July; however, abundance remained highest in the Near-field exposure area in all years. Abundance was relatively consistent between the different reference areas in August, ranging from $1,630,267 \pm 203,485$ cells/L at MEL-04 in 2016 to $2,176,504 \pm 169,119$ cells/L at MEL-05 in 2017. In September, abundance was highest in the Near-field exposure area but notably lower in 2017 than in 2015 or 2016, ranging from only $1,139,912 \pm 56,537$ cells/L at MEL-02 to $1,818,246 \pm 130,896$ cells/L at MEL-01.

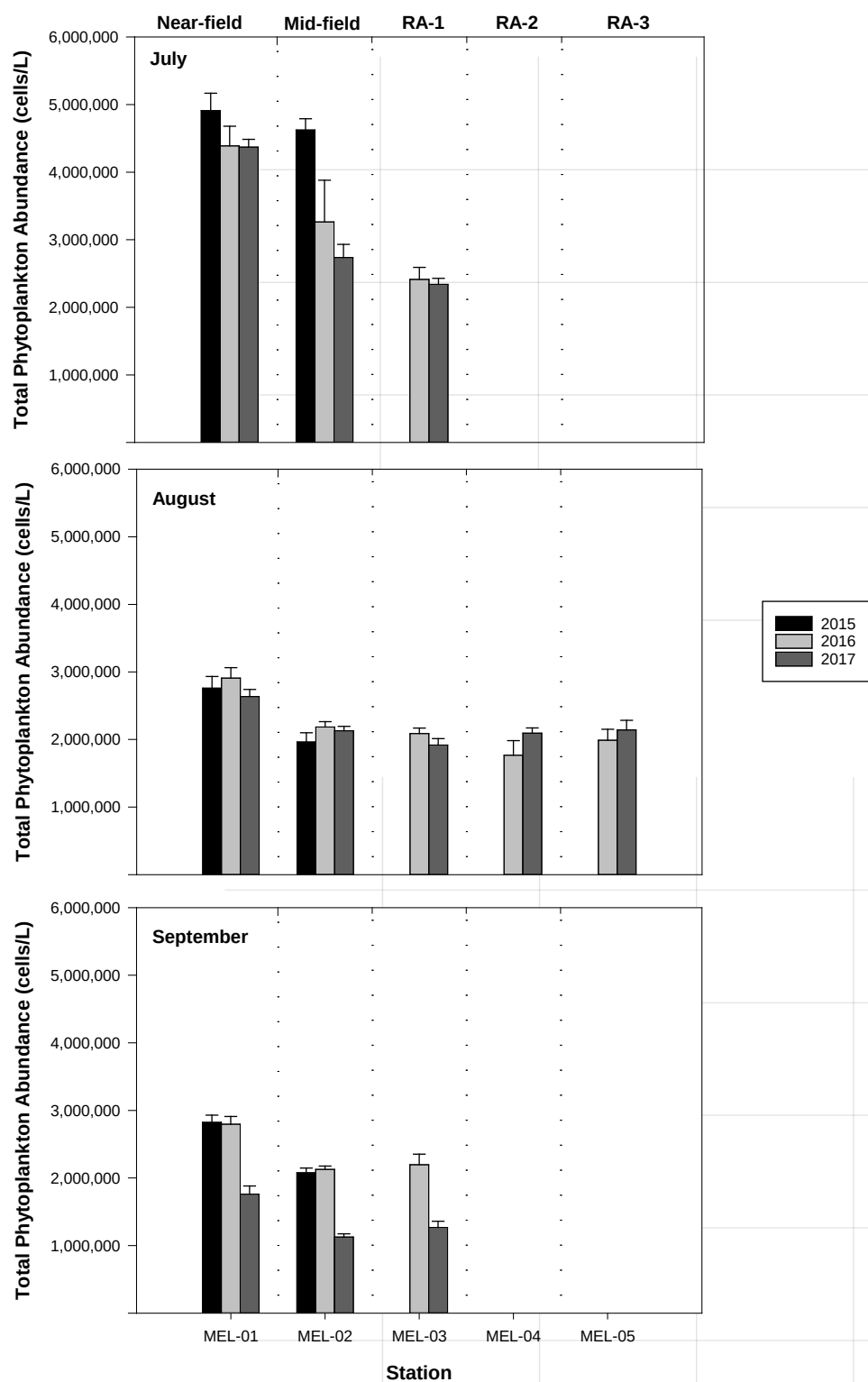


Figure 7.3-5: Total Phytoplankton Abundance in Meliadine Lake, 2015-2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September.

RA=Reference Area; cells/L = cells per litre.

7.3.3.2 *Biomass*

Phytoplankton biomass generally followed a similar spatial and seasonal trend as abundance in most years (Figure 7.3-6). Within each season in a given year, biomass was highest in the Near-field exposure area than in the Mid-field exposure area or the reference areas. In July, mean phytoplankton biomass ranged from $490 \pm 33 \text{ mg/m}^3$ to $627 \pm 20 \text{ mg/m}^3$ in the Near-field exposure area, from $305 \pm 26 \text{ mg/m}^3$ to $606 \pm 21 \text{ mg/m}^3$ in the Mid-field exposure area, and from $226 \pm 7 \text{ mg/m}^3$ to $319 \pm 14 \text{ mg/m}^3$ in Reference Area 1. Biomass in August was lower than in July but remained consistently higher in the Near-field exposure area than in the reference areas, ranging from $316 \pm 17 \text{ mg/m}^3$ to $351 \pm 24 \text{ mg/m}^3$ at MEL-01. By comparison, biomass in the reference areas in August ranged from $156 \pm 29 \text{ mg/m}^3$ at MEL-04 in 2016 to $231 \pm 8 \text{ mg/m}^3$ at MEL-03 in 2016. In September, biomass followed the same spatial trend; however, biomass was notably higher in 2016 than in 2015 or 2017. Mean biomass in September 2016 ranged from $246 \pm 23 \text{ mg/m}^3$ in Reference Area 1 to $503 \pm 12 \text{ mg/m}^3$ in the Near-field exposure area. Biomass in September 2015 and 2017 reached a high of $295 \pm 20 \text{ mg/m}^3$ and $184 \pm 9 \text{ mg/m}^3$ respectively in the Near-field exposure area with lower biomass in the Mid-field exposure area and in Reference Area 1 in 2017.

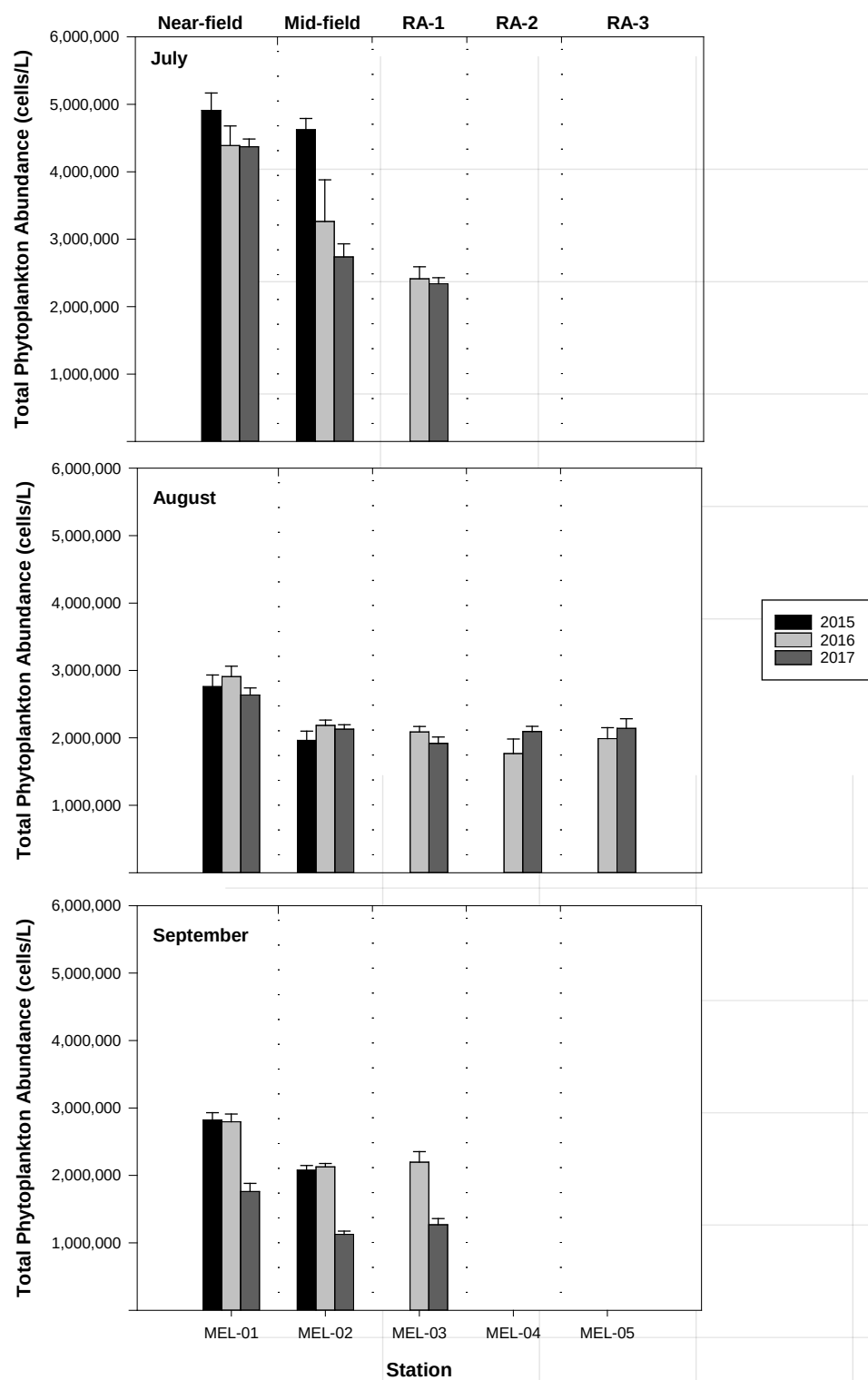


Figure 7.3-6: Total Phytoplankton Biomass in Meliadine Lake, 2015-2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September.

RA=Reference Area; mg/m³ = milligrams per cubic metre.

7.3.3.3 Community Composition by Abundance

A total of 113 distinct phytoplankton taxa were identified in samples collected in Meliadine Lake in 2015, 2016 and 2017. Overall, the relative abundance of major phytoplankton groups was similar throughout Meliadine Lake during most seasons and years. The most abundant, or dominant, taxa during each sampling program were golden algae of the group Chrysophyceae. Abundant taxa in the majority of samples collected included *Uroglena volvox*, *Chrysococcus* sp., *Chrysochromulina* sp., and *Dinobryon* sp., all from the group Chrysophyceae (Appendix 7D, Tables 7D-3 and 7D-4). Diatoms (Bacillariophyceae) were generally the next most abundant phytoplankton group in most samples; diatom abundance showed minor spatial and seasonal variation but also variation between sampling years within a given area. Chlorophyte (Chlorophyceae) and cryptomonad (Cryptophyceae) abundance varied seasonally, while cyanobacteria and dinoflagellates (Dinophyceae) were largely absent from the phytoplankton community in Meliadine Lake making up less than 1% the total relative abundance of phytoplankton in most samples.

In July, the relative abundance of most major phytoplankton groups varied slightly between the exposure area and reference area and among years (Figure 7.3-7). Abundance was primarily dominated by chrysophytes which represented between 73% and 89% of all phytoplankton collected in 2015 through 2017 in Meliadine Lake. Diatoms were generally in low abundance; however, a greater proportion of diatoms was present in the Near-field exposure area than in the reference area in 2016 and 2017. Diatoms contributed between 8% and 22% of total phytoplankton abundance in in Near-field exposure area, between 3% and 13% in the Mid-field exposure area, and between 4% and 5% in Reference Area 1 in July. Diatom abundance was also notably lower in the exposure areas in July in 2017 than in 2015 and 2016. Phytoplankton from other major groups including cyanobacteria, dinoflagellates, chlorophytes, and cryptomonads were in low abundance (<5%) in the exposure areas July, while chlorophytes and cryptomonads were slightly more abundant in the reference area in 2016 at 7% and 6% respectively.

In August, the relative abundance of phytoplankton was consistent between exposure and reference areas and among sampling years (Figure 7.3-8). Abundance was again dominated by chrysophytes, which represented between 70% and 81% of phytoplankton in all years. Diatoms were generally in lower abundance in August than in July with the largest proportion of diatoms occurring in the exposure areas in 2015 (8% to 10%). In 2016 and 2017 the proportion of diatoms in the phytoplankton community was consistent between the exposure and reference areas, ranging from 3% to 4% across all areas in each year. Chlorophytes were notably more abundant in August across all areas than in July, ranging from 9% to 14% of total abundance in the exposure areas and between 7% and 14% in the reference areas in 2016 and 2017. Similarly, cryptomonads were also more abundant in August than in July, ranging from 3% to 11% of total abundance in the exposure areas and 9% to 15% in the reference areas.

In September, the relative abundance of phytoplankton varied little between exposure and reference areas with some variability evident between years (Figure 7.3-9). Abundance was dominated by chrysophytes which represented between 70% and 83% of phytoplankton in all years. The relative abundance of diatoms in September was similar to that of July, ranging between 6% and 14% across all areas and years. In contrast with July, a higher proportion of diatoms was collected in the exposure areas in September in 2017 than in 2015 and 2016. The proportion of chlorophytes and cryptomonads varied little by area, ranging from 4% to 12% and 4% to 8% respectively, and the proportions of each group were generally similar to that of August. The Mid-field exposure area in September 2016 contained the highest proportion of cyanobacteria (1.2%) observed during the sampling programs.

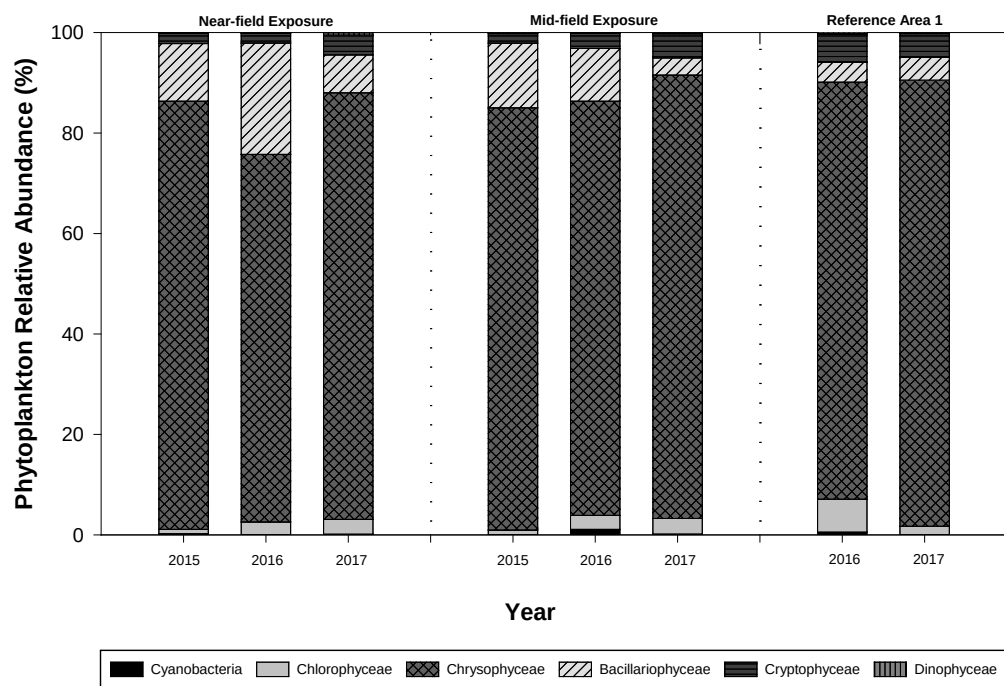


Figure 7.3-7: Relative Abundance of Major Phytoplankton Groups in July, Meliadine Lake, 2015-2017

Notes: Bars represent mean values for each area (n=5). Phytoplankton was not sampled at MEL-01-03 in September 2015.

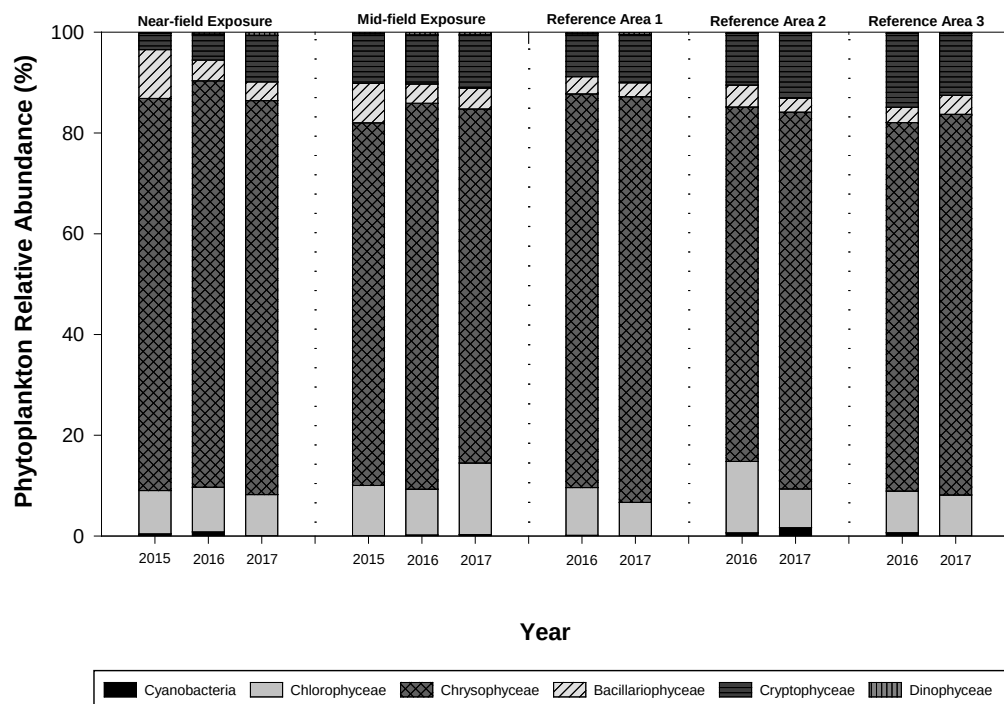


Figure 7.3-8: Relative Abundance of Major Phytoplankton Groups in August, Meliadine Lake, 2015-2017

Note: Bars represent mean values for each area (n=5).

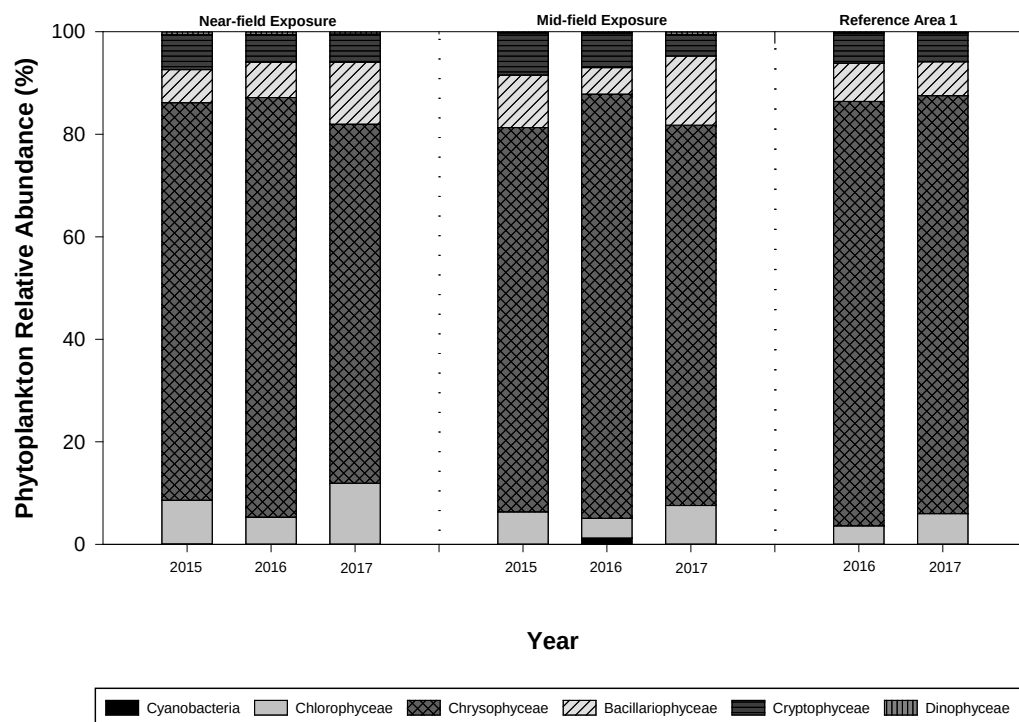


Figure 7.3-9: Relative Abundance of Major Phytoplankton Groups in September, Meliadine Lake, 2015-2017

Note: Bars represent mean values for each area (n=5).

7.3.3.4 Community Composition by Biomass

The relative biomass of major phytoplankton groups in Meliadine Lake followed similar spatial and seasonal trends as relative abundance (Figure 7.3-10 to Figure 7.3-12). In general, variability in relative biomass was as high among years in each area and season as it was among areas or seasons during a given year. As with abundance, chrysophytes contributed the most to relative biomass in all areas in Meliadine Lake in 2015, 2016 and 2017. Chrysophytes contributed between 66% and 83% of total biomass in July, between 55% and 71% in August, and between 50% and 76% in September. Diatom biomass varied among years and seasons with the highest proportion of diatom biomass observed in the exposure areas in July 2016 (18% at MEL-01) and in September 2017 (19% at MEL-01 and 17% at MEL-02). The relative proportions of chlorophytes, cryptomonads and dinoflagellates by biomass followed similar trends as abundance with higher proportions of each group in August and September than in July, and no discernable trends between exposure and reference areas or among years. Dinoflagellates generally contributed more to relative biomass compared to relative abundance (i.e., larger cells but rare), while the relative biomass of other major groups was generally proportional to their relative abundance (i.e., smaller cells but common).

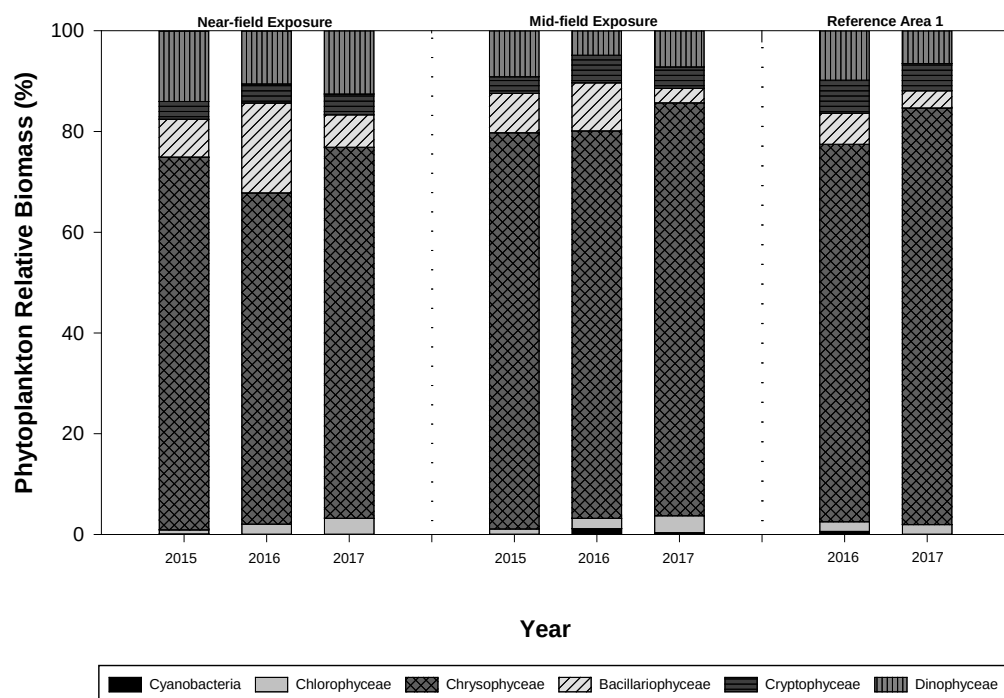


Figure 7.3-10: Relative Biomass of Major Phytoplankton Groups in July, Meliadine Lake, 2015-2017

Notes: Bars represent mean values for each area (n=5). Phytoplankton was not sampled at MEL-01-03 in September 2015.

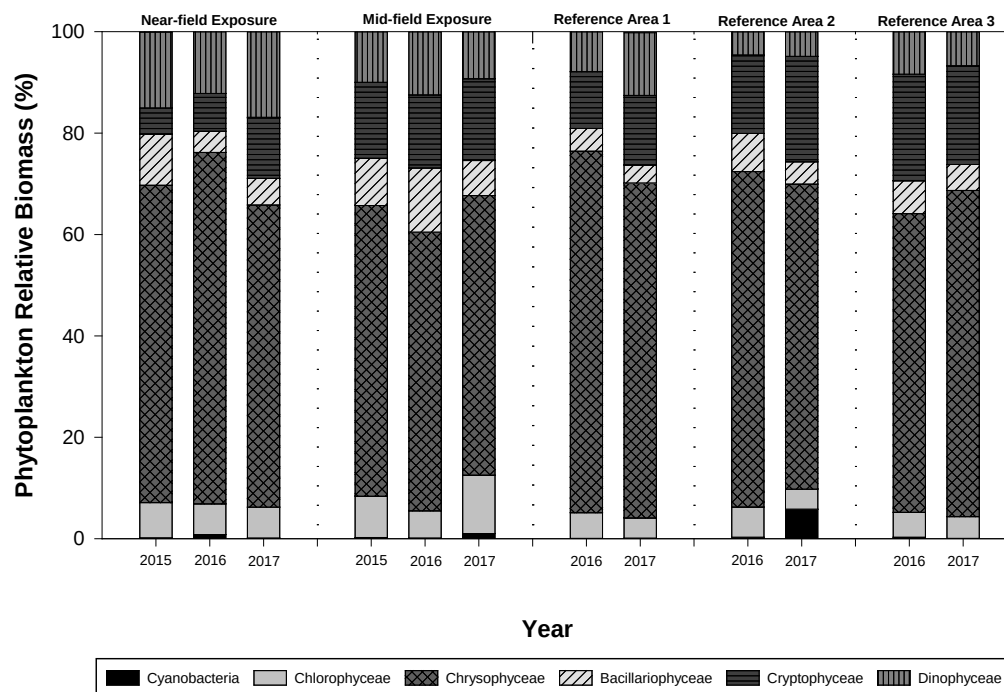


Figure 7.3-11: Relative Biomass of Major Phytoplankton Groups in August, Meliadine Lake, 2015-2017

Notes: Bars represent mean values for each area (n=5).

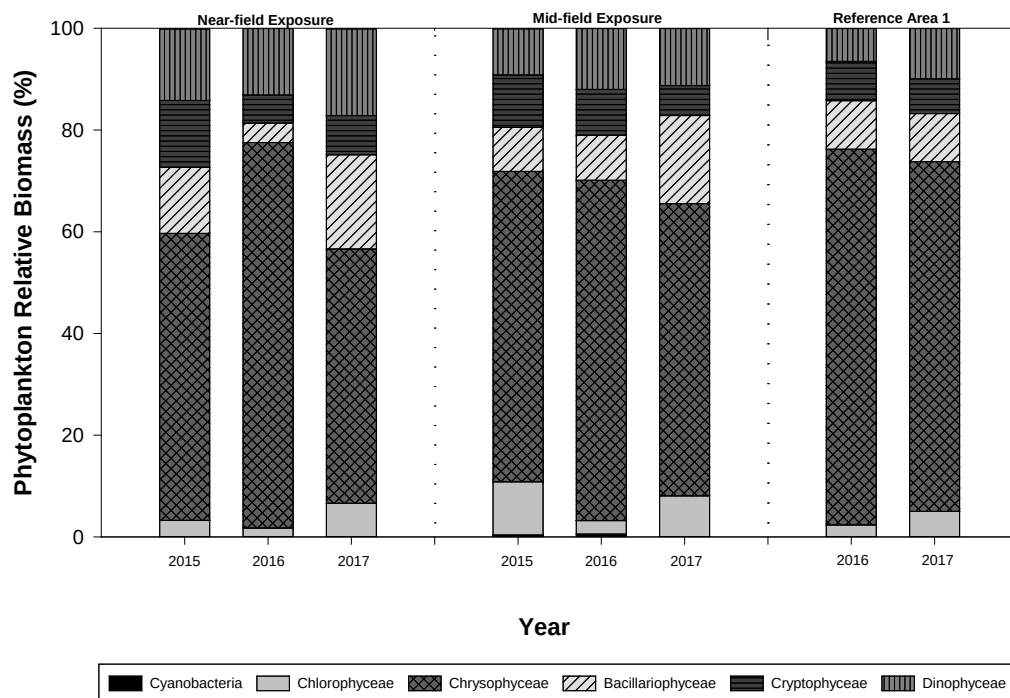


Figure 7.3-12: Relative Biomass of Major Phytoplankton Groups in September, Meliadine Lake, 2015-2017

Notes: Bars represent mean values for each area (n=5).

7.3.3.5 Species Richness

Species richness was relatively consistent throughout much of Meliadine Lake with few observable trends among seasons, years or stations (Figure 7.3-13). Richness in July and August varied little between the exposure areas and the reference areas and among years. Mean richness in July ranged from 34 ± 1 taxa to 41 ± 1 taxa while richness in August ranged from 37 ± 1 taxa to 42 ± 1 taxa. Species richness in September varied slightly among years as richness in 2017 was notably lower than in 2015 or 2016. Richness in September ranged from 28 ± 1 taxa to 33 ± 1 taxa in 2017 and from 37 ± 1 taxa to 40 ± 1 taxa in 2015 and 2016 combined. Species richness also tended to be higher in the exposure areas in September 2017 than in Reference Area 1.

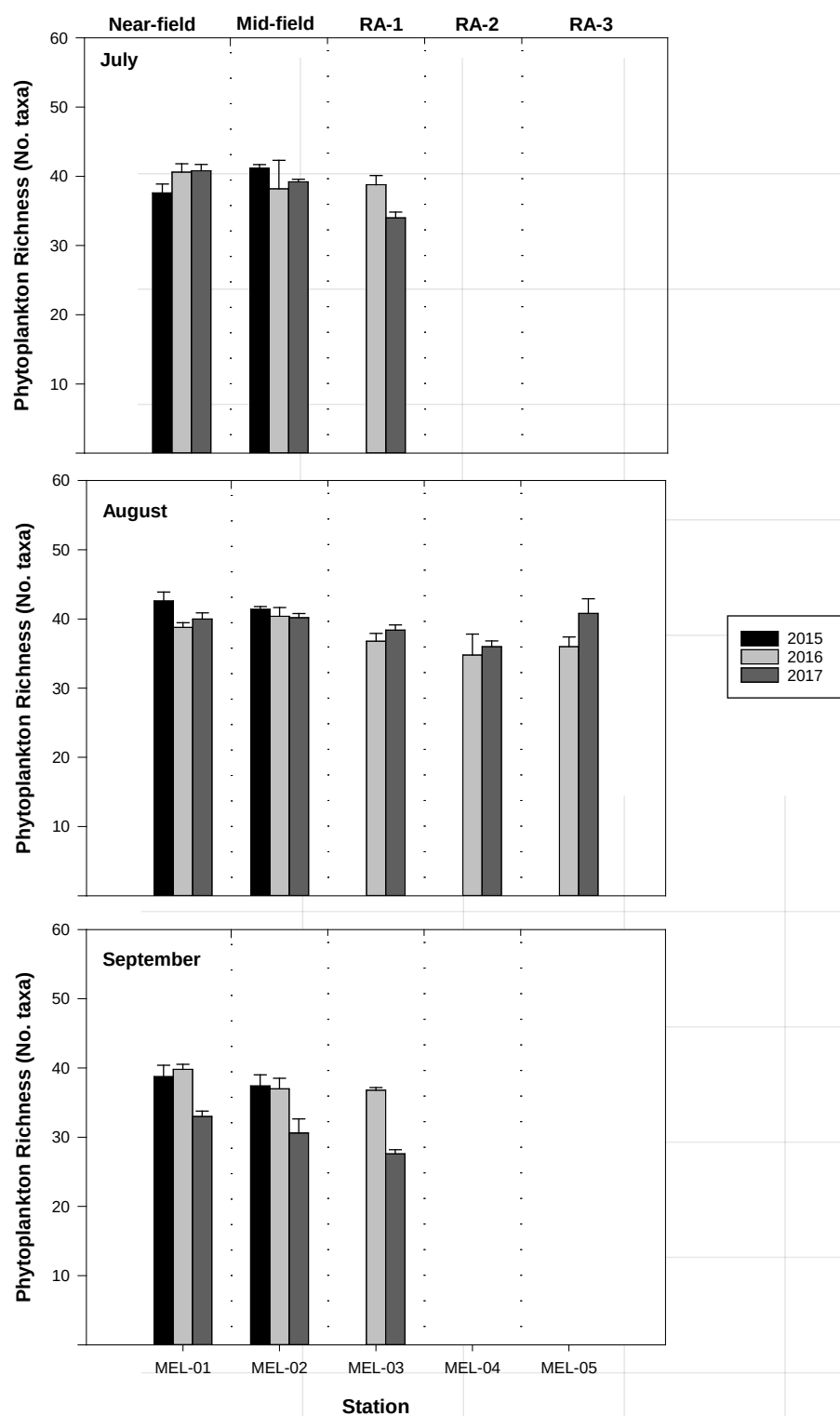


Figure 7.3-13: Total Phytoplankton Species Richness in Meliadine Lake, 2015-2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September.

RA=Reference Area.

7.3.3.6 Statistical Comparisons of Phytoplankton Community Variables

Statistical comparisons of phytoplankton community variables were made among years for each sampling area and season Table 7.3-4. In general, variability in phytoplankton abundance, biomass, and species richness among years in July and September was high with lower variability among years in August. Several seasonal and annual trends were also evident in the Near-field and Mid-field exposure areas, for which three years of sampling allowed for pairwise comparisons between years (Table 7.3-2).

Table 7.3-4: Results of Statistical Analysis for Phytoplankton Community Variables Comparing Years

Station	Variable	Transform	Statistical Test	July	August	September
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
MEL-01	Abundance	None	ANOVA	0.208	0.379	0.010
	Biomass	None	ANOVA	0.019	0.613	0.003
	Richness	None	ANOVA	0.139	0.089	0.015
MEL-02	Abundance	None	ANOVA	0.009	0.403	0.008
	Biomass	None	ANOVA	0.006	0.454	0.002
	Richness	None	ANOVA	0.068	0.270	0.143
MEL-03	Abundance	None	t-test	0.728	0.326	0.005
	Biomass	None	t-test	0.001	0.114	0.006
	Richness	None	t-test	0.029	0.141	<0.001
MEL-04	Abundance	None	t-test	–	0.133	–
	Biomass	None	t-test	–	0.259	–
	Richness	None	t-test	–	0.188	–
MEL-05	Abundance	None	t-test	–	0.617	–
	Biomass	None	t-test	–	0.752	–
	Richness	None	t-test	–	0.100	–

Note: P-values representing significant differences between years ($P < 0.1$) are bolded.

ANOVA= Analysis of Variance; t-test= Two-sample t-test; P-value = probability value; < = less than; – = no sample collected.

Results of statistical analyses for comparisons of abundance, biomass, and richness of phytoplankton community variables among years are summarized below:

- Phytoplankton abundance was significantly different among years at MEL-02 in July and at MEL-01, MEL-02 and MEL-03 in September (Table 7.3-4). No significant differences in abundance were observed among years in August. In the Near-field exposure area, abundance was significantly lower in 2017 than in 2015 or 2016 in September (Table 7.3-5). In the Mid-field exposure area, abundance was significantly higher in 2015 than in 2016 or 2017 in July.
- Phytoplankton biomass was significantly different among years in all areas in July and September with no significant differences among years in August (Table 7.3-4). In July, biomass was significantly higher among years in the exposure areas in 2015 than in 2016 or 2017 (Table 7.3-5). In September, biomass was significantly higher in 2016 in the exposure areas than in 2015 or 2017.
- Phytoplankton species richness was significantly different among years in at least one area in each season, including in the Near-field exposure area in August (Table 7.3-4). Analysis of the pairwise comparisons between years, however, showed that richness only varied significantly between 2017 and both 2015 and 2016 in September (Table 7.3-5).

Table 7.3-5: Pairwise Comparisons for Statistical Analyses of Phytoplankton Community Variables Comparing Years

Year	Variable	Transform ^(a)	Statistical Test	July			August			September		
				2015 / 2016	2015 / 2017	2016 / 2017	2015 / 2016	2015 / 2017	2016 / 2017	2015 / 2016	2015 / 2017	2016 / 2017
				P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value
MEL-01	Abundance	None	ANOVA / Tukey's	0.293	0.270	0.998	0.582	0.969	0.445	0.638	<0.001	<0.001
	Biomass	None	ANOVA / Tukey's	0.009	0.025	0.827	0.860	0.731	0.426	<0.001	<0.001	<0.001
	Richness	None	ANOVA / Tukey's	0.247	0.171	0.968	0.062	0.246	0.681	0.837	0.007	0.002
MEL-02	Abundance	None	ANOVA / Tukey's	0.067	0.012	0.611	0.296	0.581	0.848	0.833	<0.001	<0.001
	Biomass	None	ANOVA / Tukey's	0.016	0.003	0.590	0.440	0.997	0.480	0.007	<0.001	<0.001
	Richness	None	ANOVA / Tukey's	0.659	0.796	0.970	0.324	0.428	0.975	0.986	0.114	0.149

(a) Distributions of all variables violated the assumption of normality even after transformation; however, the results are considered reliable as the assumption of equal variances was not violated and ANOVA is robust against the assumption of normality.

Note: P-values representing significant differences between years ($P < 0.1$) are **bolded**.

ANOVA= Analysis of Variance; Tukey's= Tukey's Honestly Significant Difference Test; P-value = probability value; < = less than.

Samples collected during the August sampling event were carried forward for further evaluation of spatial variability among the five areas of Meliadine Lake. Data collected in 2015 was omitted from statistical comparisons among areas in Meliadine Lake due to a lack of sampling in the reference areas. A summary of statistical comparisons of variables among Near-field and Mid-field areas and the three reference areas in August 2016 and 2017 is presented in Table 7.3-6.

Table 7.3-6: Results of Statistical Analysis for Phytoplankton Community Variables Comparing Areas, August 2016-2017

Year	Variable	Transform	Statistical Test	Overall Comparison	MEL-01 / MEL-02	MEL-01 / MEL-03	MEL-01 / MEL-04	MEL-01 / MEL-05	MEL-02 / MEL-03	MEL-02 / MEL-04	MEL-02 / MEL-05	MEL-03 / MEL-04	MEL-03 / MEL-05	MEL-04 / MEL-05
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
2016	Abundance	None	ANOVA /Tukey's	<0.001**	0.035**	0.014**	<0.001**	0.008**	0.993	0.151	0.957	0.304	0.999	0.440
	Biomass	None	ANOVA /Tukey's	<0.001**	0.062**	0.016**	<0.001**	0.013**	0.967	0.068**	0.942	0.219	1.000	0.261
	Chlorophyll a	None	KW / DSCF	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	0.016**	0.949	0.040**	<0.001**	0.103*
	Richness	None	KW / DSCF	0.081**	0.866	0.554	0.647	0.500	0.259	0.322	0.211	1.000	1.000	1.000
2017	Abundance	None	ANOVA /Tukey's	0.004**	0.025**	0.003**	0.021**	0.062**	0.838	1.000	0.992	0.874	0.593	0.984
	Biomass	None	ANOVA /Tukey's	<0.001**	0.001**	<0.001**	<0.001**	0.001**	0.930	0.830	0.998	0.999	0.988	0.943
	Chlorophyll a	None	KW / DSCF	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	0.778	0.999	0.907	0.608	0.999	0.778
	Richness	None	KW / DSCF	0.065**	0.993	0.946	0.170	0.880	0.768	0.105*	0.878	0.219	0.718	0.516

Note: Significant differences (**bold**) are denoted as: * = $P<0.15$, ** = $P<0.1$.
KW= Kruskal Wallis; DSCF= Dwass-Steel-Chritchlow-Fligner Test for Pairwise Comparisons; ANOVA= Analysis of Variance; Tukey's= Tukey's Honestly Significant Difference Test; P -value = probability value; < = less than.

Differences observed in the abundance, biomass, and richness of the phytoplankton community in August 2016 and August 2017 in Meliadine Lake are summarized below:

- In 2016, phytoplankton abundance was significantly different ($P < 0.001$) among the five sampling areas: the Near-field exposure area, the Mid-field exposure area, Reference Area 1, Reference Area 2 and Reference Area 3 (Table 7.3-6). Pairwise comparisons showed that abundance in the Near-field exposure area was significantly higher than in the Mid-field exposure area and each of the three reference areas. There was no significant difference in abundance between the Mid-field exposure area and the reference areas or among the reference areas.
- In 2017, phytoplankton abundance was also significantly different ($P = 0.004$) among all areas (Table 7.3-6). Pairwise comparisons showed the same relationship in abundance among areas in 2017 as observed in 2016, with only the Near-field exposure area being significantly higher than the other areas.
- Phytoplankton biomass in 2016 was significantly different ($P < 0.001$) among the sampling areas (Table 7.3-6). Pairwise comparisons of biomass estimates showed a similar trend as abundance in 2016 with the exception of a significant difference between the Mid-field exposure area and MEL-04 ($P = 0.068$).
- Phytoplankton biomass in 2017 was significantly different ($P < 0.001$) among areas overall (Table 7.3-6). Pairwise comparisons showed the same relationship between areas as abundance in 2017 with the only significant difference occurring between the Near-field exposure area and each of the other four areas.
- Analysis of variance results suggest phytoplankton species richness was significantly different among areas overall in 2016 ($P = 0.081$) and 2017 ($P = 0.065$) (Table 7.3-6). Pairwise comparisons of species richness, however, revealed there was no significant difference among areas in terms of richness, except between MEL-02 and MEL-04 in 2017.

7.3.3.7 Multivariate Analysis

Two nMDS dimensions were derived from the phytoplankton biomass data collected in Meliadine Lake. Phytoplankton biomass in 2016 and 2017 were analyzed separately to enable a good fit of the ordination results. The stress value of the final configuration was 0.17 for August 2016 and 0.15 for August 2017, which represent a “fair” fit (<0.2) of the ordination results to the input data in qualitative terms (Clarke 1993). According to the categories provided by Clarke (1993), some interference may be present which could confound the interpretations made from the plots so results should be interpreted with caution.

The nMDS ordination of the samples by area illustrate the degree of similarity in community composition among stations in each area. Most of the stations in 2016 clustered together by area with more similarities present among the reference areas than among the exposure areas (Figure 7.3-14). Differences in taxonomic composition by biomass were especially apparent between the Near-field exposure area and all other areas in August 2016. The Mid-field exposure area more closely resembled that of the reference areas and stations clustered relatively close together. Some variability in taxonomic composition was apparent in the reference areas, especially in MEL-05, for which individual stations were not closely related. In August 2017, most stations were also clustered together by area (Figure 7.3-15). Stations in the Near-field exposure area were again clustered separately from the Mid-field and reference areas indicating taxa composition by biomass was different in the Near-field area in 2017. Some variability in taxa composition was also evident in MEL-04 in August 2017 where the majority of stations did not cluster together with the other reference areas.

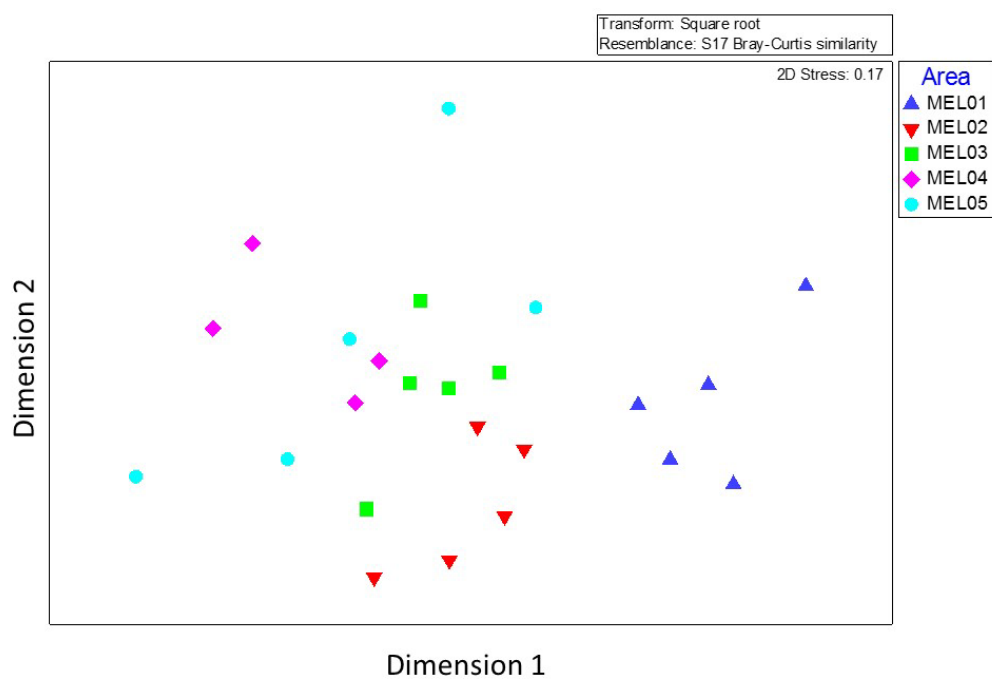


Figure 7.3-14: Ordination Plot of August Phytoplankton Biomass in Meliadine Lake in 2016

Note: MEL-04-03 was excluded from analysis due to major differences in phytoplankton community compared to other locations.

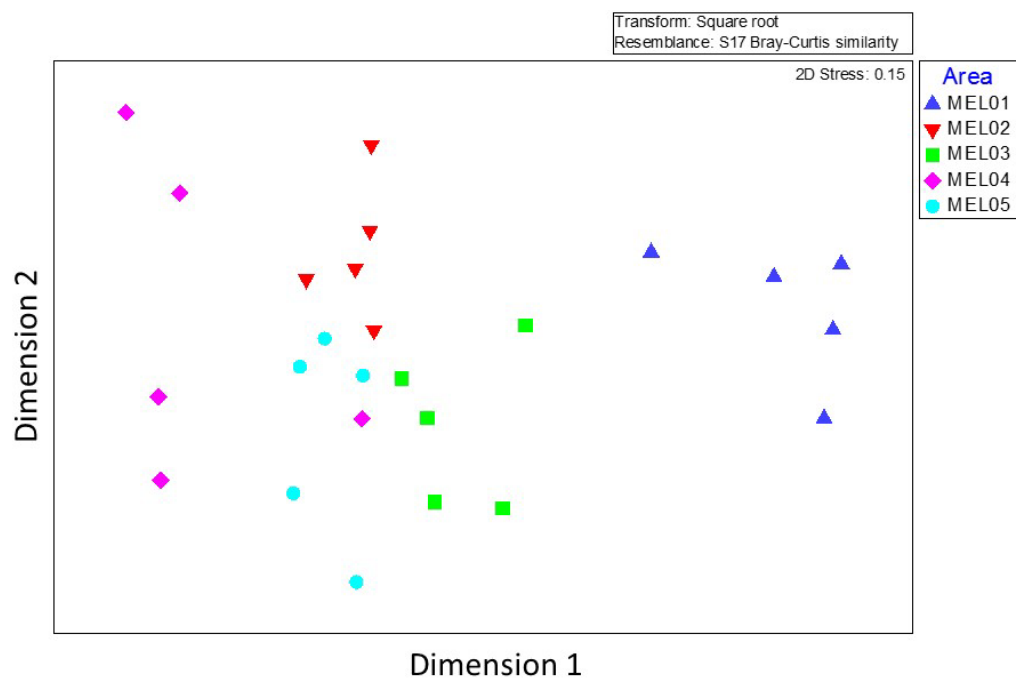


Figure 7.3-15: Ordination Plot of August Phytoplankton Biomass in Meliadine Lake in 2017

7.3.3.8 Relationship Between Phytoplankton Biomass and Chlorophyll a

The correlation between chlorophyll a concentration and total phytoplankton biomass based on biovolume was examined to evaluate whether chlorophyll a can be used as an indicator of phytoplankton biomass. Data collected in 2015 and September 2017 were excluded from the regression analysis due to reliability concerns (see Section 7.2). Based on data from all years combined, there was a significant but weak linear relationship ($P = <0.0001$; $r^2 = 0.46$) between phytoplankton biomass and chlorophyll a concentration (Figure 7.3-16). Much of the unexplained variation between the two variables is likely explained by a disproportionate effect by certain phytoplankton groups on the proportion of chlorophyll a in phytoplankton wet weight (Kasprzak et al. 2008; Felip and Catalan 2000). For example, dinoflagellates generally have a disproportionately lower amount of chlorophyll a for their size when compared with phytoplankton of the groups chlorophyta and cyanobacteria (Kasprzak et al. 2008; Felip and Catalan 2000). Overall, a generally linear trend is apparent, which suggest that chlorophyll a is a suitable surrogate for taxonomic estimates of phytoplankton biomass in the future. Additional data points from future monitoring years will help to define the relationship between chlorophyll a and phytoplankton biomass in Meliadine Lake, and may produce a more reliable data transformation equation for in situ profiles.

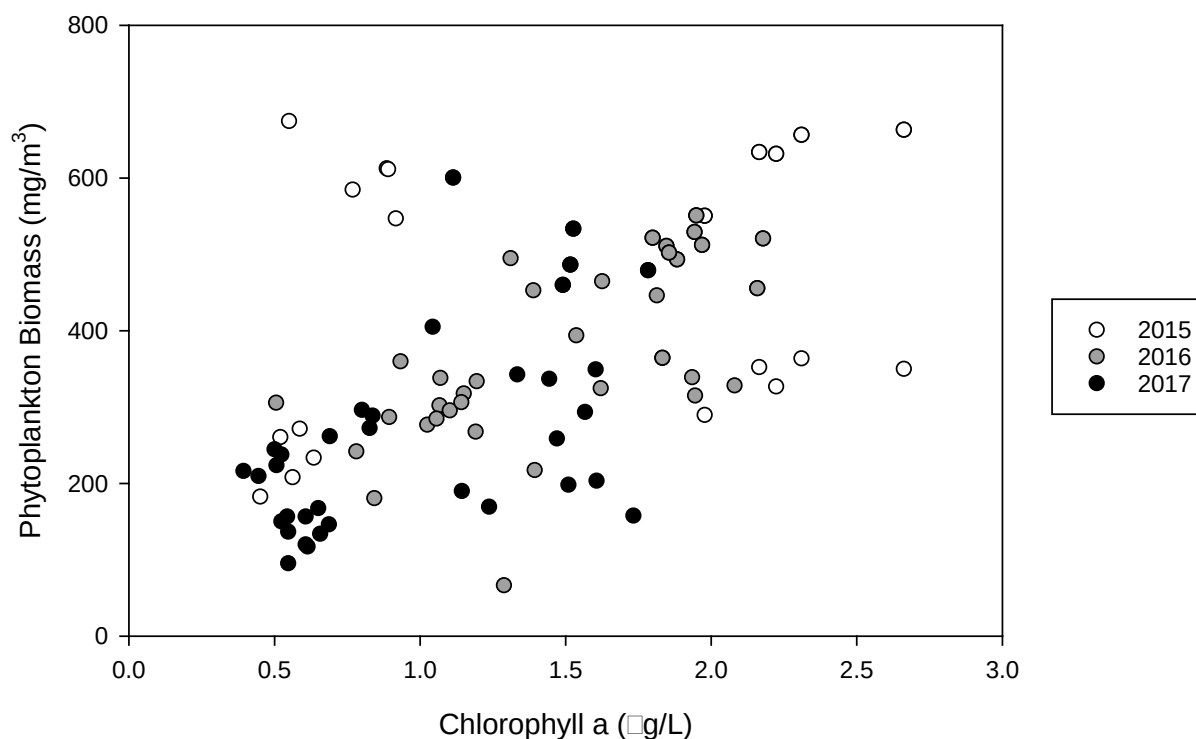


Figure 7.3-16: Chlorophyll a vs. Phytoplankton Biomass in Meliadine Lake, 2016-2017

Note: Chlorophyll a and biomass data from September 2017 were excluded due to different filters used for field collection.
mg/m³ = milligrams per cubic metre; µg/L = micrograms per litre.

7.3.4 Zooplankton

Descriptive statistics that summarize the zooplankton abundance, biomass, and richness by season, year and area are provided in Appendix 7E, Table 7E-1. Relative abundance of major zooplankton groups from samples collected in Meliadine Lake is provided in Appendix 7E, Table 7E-2. Raw zooplankton taxonomic data for Meliadine Lake are provided in Appendix 7E, Tables 7E-3 to 7E-5.

7.3.4.1 Abundance

Zooplankton abundance varied spatially, seasonally and among years in Meliadine Lake in 2015 through 2017 (Figure 7.3-17). In July, abundance did not vary considerably among samples collected in 2015 and 2017 or among the exposure and reference areas; zooplankton samples were not collected in July 2016. Mean abundance in July 2017 ranged from $35,983 \pm 5,280$ org/m³ at MEL-02 to $43,135 \pm 3,845$ org/m³ at MEL-03. Zooplankton abundance in August was highly variable among years within the exposure areas with less variability evident in the reference areas. Abundance in August ranged from $18,313 \pm 3,299$ org/m³ (2017) to $72,531 \pm 11,361$ org/m³ (2016) in the Near-field exposure area and from $28,570 \pm 3,047$ org/m³ (2017) to $51,677 \pm 12,467$ org/m³ (2015) in the Mid-field exposure area. Abundance was lower in the reference areas than in the Near-field exposure area in 2016, but was generally higher than in each of the exposure areas in 2017. Zooplankton abundance in September was notably lower than in July and August in most cases, and varied more among years than among the exposure and reference areas. Abundance in September was highest in 2015, reaching $41,509 \pm 3,552$ org/m³ at MEL-01 and $27,744 \pm 4,306$ org/m³ at MEL-02 compared to a high of $18,991 \pm 5,123$ org/m³ in other years.

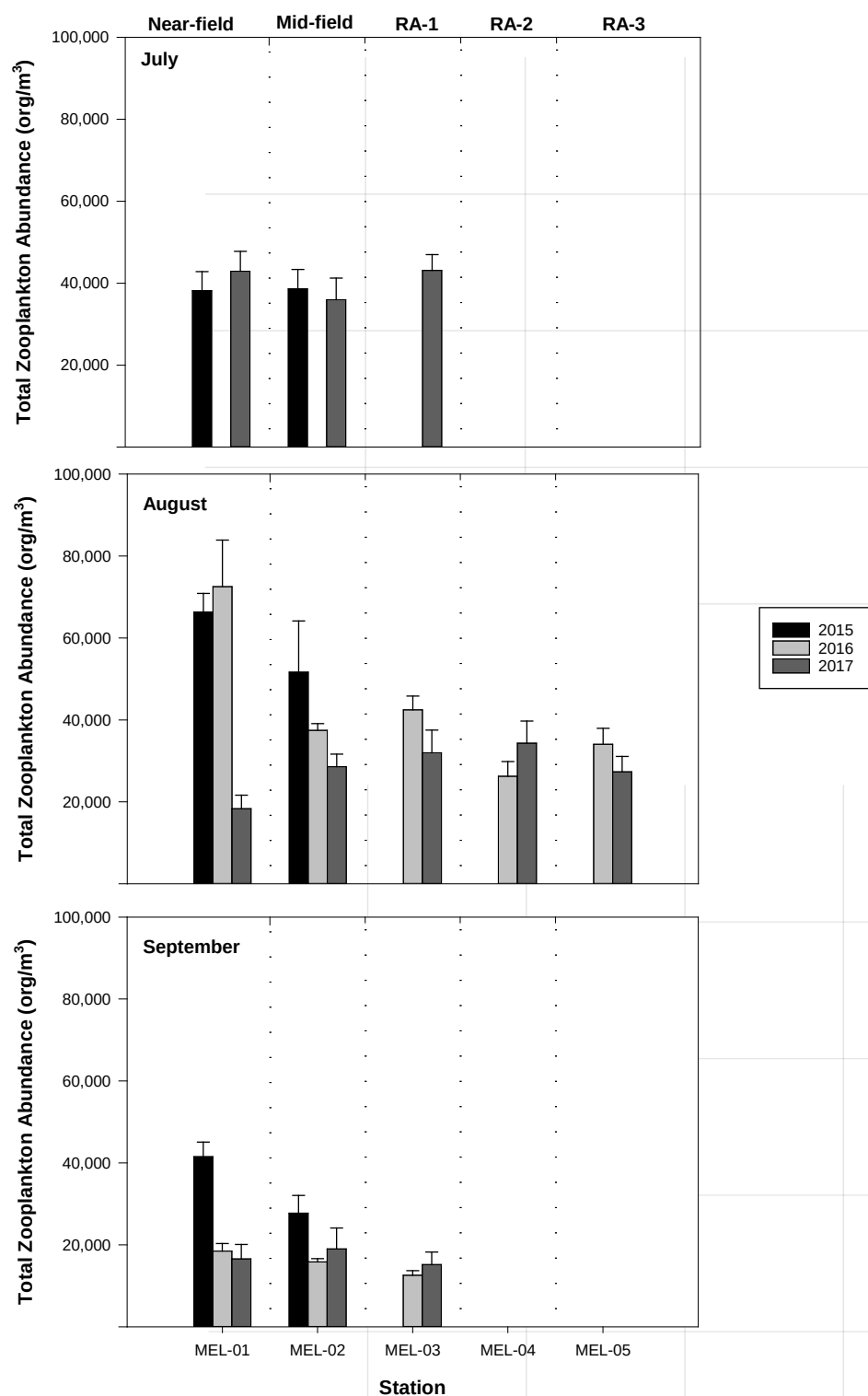


Figure 7.3-17: Total Zooplankton Abundance in Meliadine Lake, 2015-2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September. No samples could be collected in July 2016 due to loss of plankton net.

RA=Reference Area; org/m3 = organisms per cubic metre.

7.3.4.2 *Biomass*

Zooplankton biomass generally followed a similar spatial and seasonal trend as abundance in most years, but with considerably higher biomass in 2015 relative to other years (Figure 7.3-18). In July, mean biomass was highest in 2015 in the Near-field exposure area ($299 \pm 33 \text{ mg/m}^3$) and the Mid-field exposure area ($411 \pm 34 \text{ mg/m}^3$). Biomass in July 2017 was lower in the Near-field exposure area ($106 \pm 15 \text{ mg/m}^3$) and the Mid-field exposure area ($154 \pm 33 \text{ mg/m}^3$) than in the reference area ($229 \pm 26 \text{ mg/m}^3$). In August, biomass was notably higher in 2015 than in other years reaching $761 \pm 71 \text{ mg/m}^3$ at MEL-01 and $816 \pm 161 \text{ mg/m}^3$ at MEL-02. Biomass in August in 2016 and 2017 was generally consistent among the Mid-field exposure and reference areas, ranging from $126 \pm 18 \text{ mg/m}^3$ (MEL-05 in 2016) to $201 \pm 5 \text{ mg/m}^3$ (MEL-02 in 2016). In the Near-field exposure area, biomass was slightly higher and more variable than in the reference areas in 2016 ($235 \pm 59 \text{ mg/m}^3$) but lower and less variable than in the reference areas in 2017 ($106 \pm 15 \text{ mg/m}^3$). In September, biomass was lower overall than in July and August and higher in 2015 than in other years. Biomass in 2015 was $289 \pm 31 \text{ mg/m}^3$ at MEL-01 and $348 \pm 50 \text{ mg/m}^3$ at MEL-02 compared with a range from $34 \pm 6 \text{ mg/m}^3$ (MEL-03 in 2016) to $74 \pm 9 \text{ mg/m}^3$ (MEL-01 in 2016) in all areas in 2016 and 2017 combined.

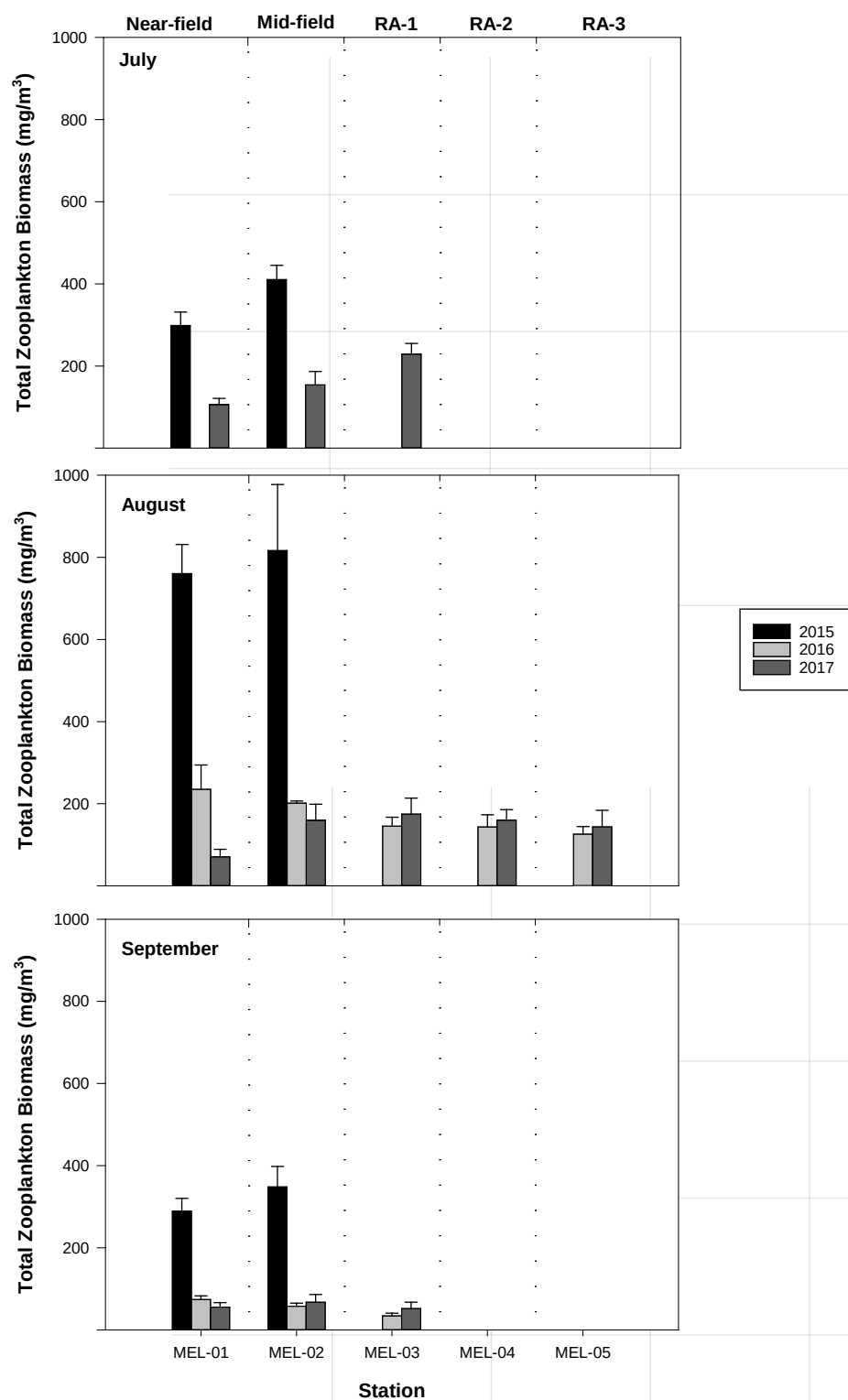


Figure 7.3-18: Total Zooplankton Biomass in Meliadine Lake, 2015-2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September. No samples could be collected in July 2016 due to loss of plankton net.

RA=Reference Area; mg/m3 = milligram per cubic metre.

7.3.4.3 Community Composition as Abundance

A total of 26 distinct zooplankton taxa were identified in samples collected in Meliadine Lake in 2015, 2016 and 2017 (Appendix 7E, Tables 7E-3 and 7E-4). The overall relative abundance of major zooplankton groups varied spatially, seasonally and among years in Meliadine Lake. The most abundant, or dominant, taxa during each sampling program were generally rotifers, followed by copepod nauplii. Calanoid copepods were generally in low abundance, while the abundance of cladocerans and cyclopoid copepods varied among seasons and sampling locations. Abundant taxa identified included the rotifer taxa *Kellicottia* sp., *Keratella* sp., *Conochilus* sp., and *Polyarthra* sp., along with the cladoceran species *Daphnia longiremis*. In terms of biomass, the dominant zooplankton groups in most areas were either cladocerans or rotifers, while the relative biomass of calanoid copepods was notably higher during some sampling events (e.g., August 2017) than during others.

In July, the relative abundance of most major zooplankton groups varied among the exposure and reference areas and varied only slightly between years (Figure 7.3-19). Abundance in the exposure areas was dominated by rotifers which accounted for 76% and 80% of abundance in the Near-field exposure area and 66% and 52% in the Mid-field exposure area in 2015 and 2017 respectively. The relative abundance of rotifers in Reference Area 1 in 2017 was notably lower as rotifers accounted for only 36% of zooplankton abundance while cladocerans (30%) and copepod nauplii (21%) were also abundant. Calanoid and cyclopoid copepods were generally in low abundance in July, though the abundance of each was higher in the reference area (6% and 8%) than in the Near-field exposure area (2% and 1%) in 2017.

In August, relative abundance of zooplankton varied spatially with some variability among years within each area (Figure 7.3-20). Rotifers were relatively more abundant in the Near-field exposure area in each year than in the Mid-field or reference areas. The proportion of rotifers by abundance ranged from 56% to 70% in the Near-field exposure area compared to 35% to 58% in the Mid-field exposure area and 26% to 55% in the reference area. Copepod nauplii were moderately abundant in most areas and were notably more abundant in the reference areas in 2016 (28% to 44%) than in the Near-field exposure area (6%). Cladocerans were also moderately abundant in all areas, with no discernable spatial trend in 2016 and slightly higher relative abundance in the reference areas (28 to 36%) than in the exposure areas (18% to 20%) in 2017. The relative abundance of calanoid and cyclopoid copepods was consistently low (1% to 10%) among all areas in each year.

In September relative abundance followed a similar trend as July with spatial variation among areas and only minor variability between years (Figure 7.3-21). Rotifers accounted for 73% to 79% of total zooplankton abundance in the Near-field exposure area, compared to 49% to 60% in the Mid-field exposure area and 60% to 74% in Reference Area 1. Copepod nauplii were generally the next most abundant group, the relative abundance of which varied among areas and years. Cladocerans were notably more abundant in the Mid-field exposure area (11% to 20%) in each year than in the Near-field exposure area (2% to 12%) or the reference area (7% to 8%). The relative abundance of calanoid and cyclopoid copepods was low (<6%) throughout the exposure and reference areas in September.

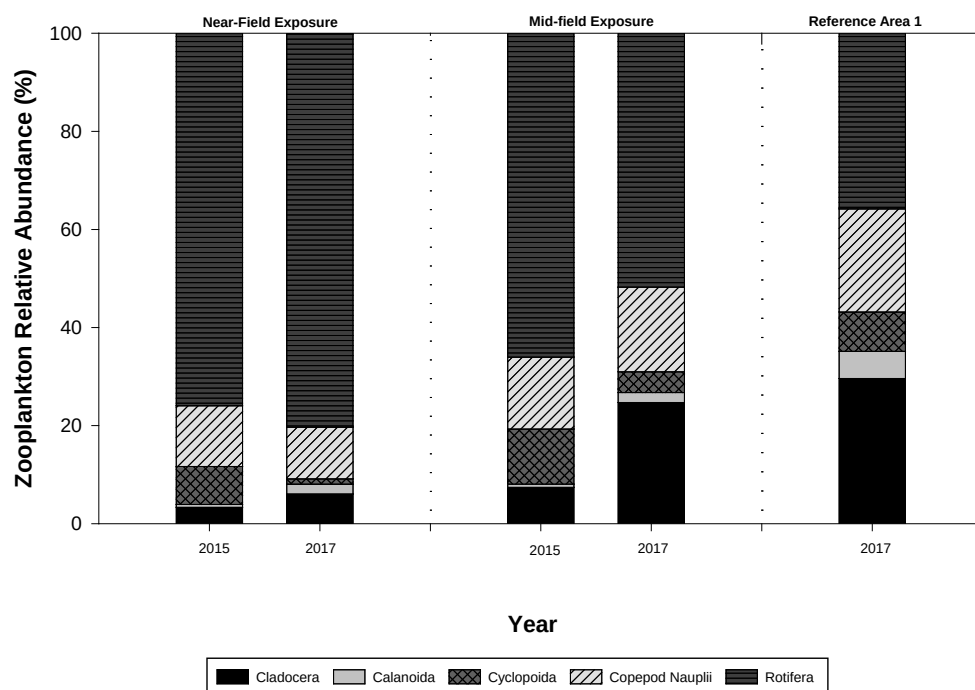


Figure 7.3-19: Relative Abundance of Major Zooplankton Groups in July, Meliadine Lake, 2015-2017

Notes: Bars represent mean values for each area (n=5). Zooplankton was not sampled in July 2016 due to loss of plankton net.

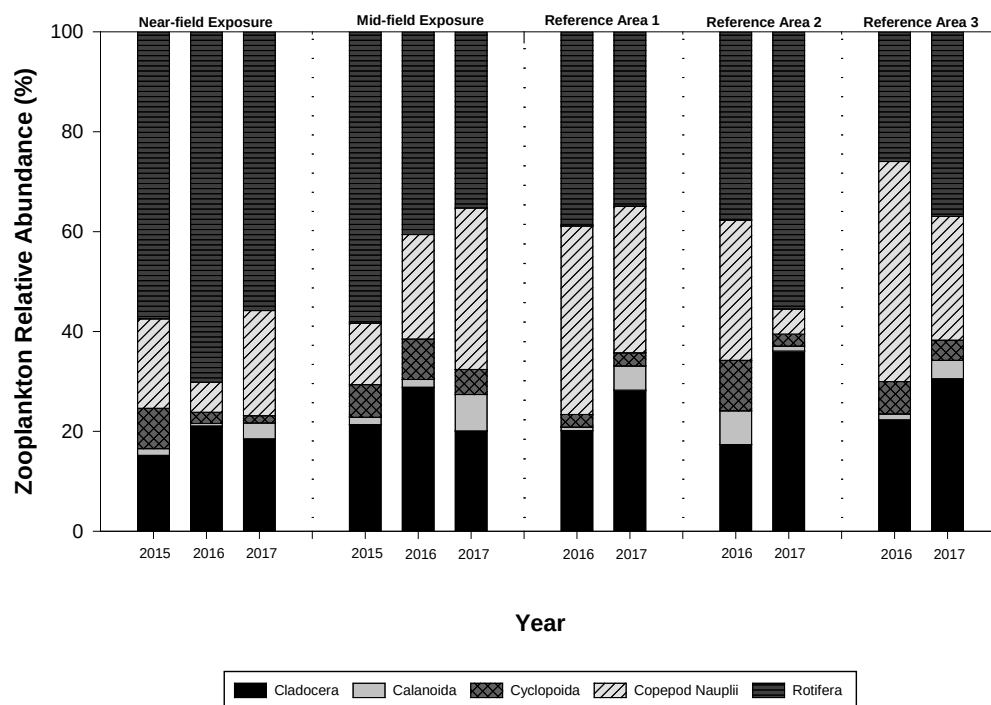


Figure 7.3-20: Relative Abundance of Major Zooplankton Groups in August, Meliadine Lake, 2015-2017

Note: Bars represent mean values for each area (n=5).

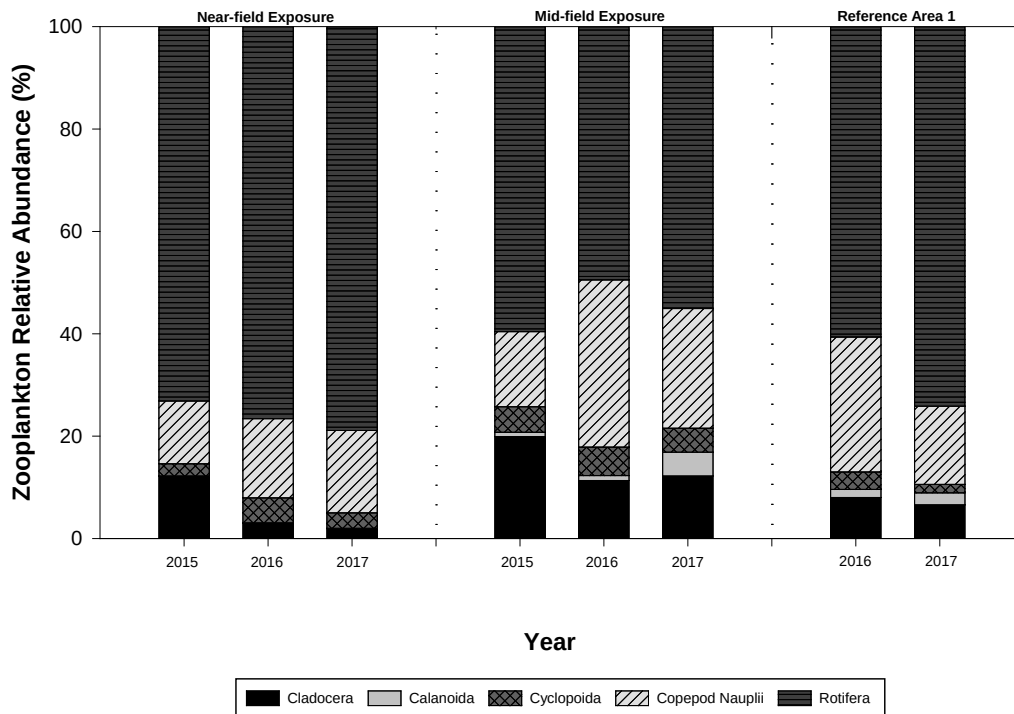


Figure 7.3-21: Relative Abundance of Major Zooplankton Groups in September, Meliadine Lake, 2015-2017

Note: Bars represent mean values for each area (n=5).

7.3.4.4 Community Composition as Biomass

The relative biomass of major zooplankton groups in the Near-field exposure area was generally dominated by smaller zooplankton taxa (rotifers) while biomass in the reference areas was mostly dominated by larger zooplankton taxa (cladocerans) in all seasons and years (Figure 7.3-22 to Figure 7.3-24). Biomass in July was dominated by rotifers in the exposure areas in 2015 (78% at MEL-01 and 58% at MEL-02) with cladocerans accounting for the majority of the remaining biomass. In July 2017, biomass was dominated by rotifers in the Near-field exposure area (58%) and by cladocerans in the Mid-field exposure area (63%) and the reference area (62%). Cyclopoid and calanoid copepods combined accounted for a greater proportion of biomass in the reference area (28%) than in the Near-field (15%) or Mid-field (17%) exposure areas.

In August, biomass tended to be dominated by larger taxa in most areas except in the Near-field exposure area in 2015 and 2016. Biomass was dominated by rotifers in the Near-field exposure area in 2015 and 2016 due to an overall high abundance of rotifers during the sampling events. Biomass in the Near-field area in 2017 was dominated by cladocerans (59%) and calanoid copepods (20%) and relative biomass overall was similar to the Mid-field exposure area and the reference areas. Biomass in the reference areas was dominated by cladocerans in 2016 and 2017 and was consistent between years in Reference areas 1 and 3 but varied between years in Reference Area 2. A notably higher proportion of rotifers contributed to overall biomass in 2017 (34%) than in 2016 (2%) in Reference Area 2 while the proportion of cyclopoid and calanoid copepods was much lower in 2017 (9%) than in 2016 (47%).

Relative biomass in September was fairly consistent among years within each area, and was dominated by rotifers in the Near-field exposure area (62 to 90%) and by a mix of rotifers or cladocerans in the Mid-field exposure area and the reference area. In 2017, calanoid copepods accounted for a much larger proportion of overall biomass in the Mid-field exposure area (29%) and the reference area (24%) than in the Near-field exposure area (0.3%).

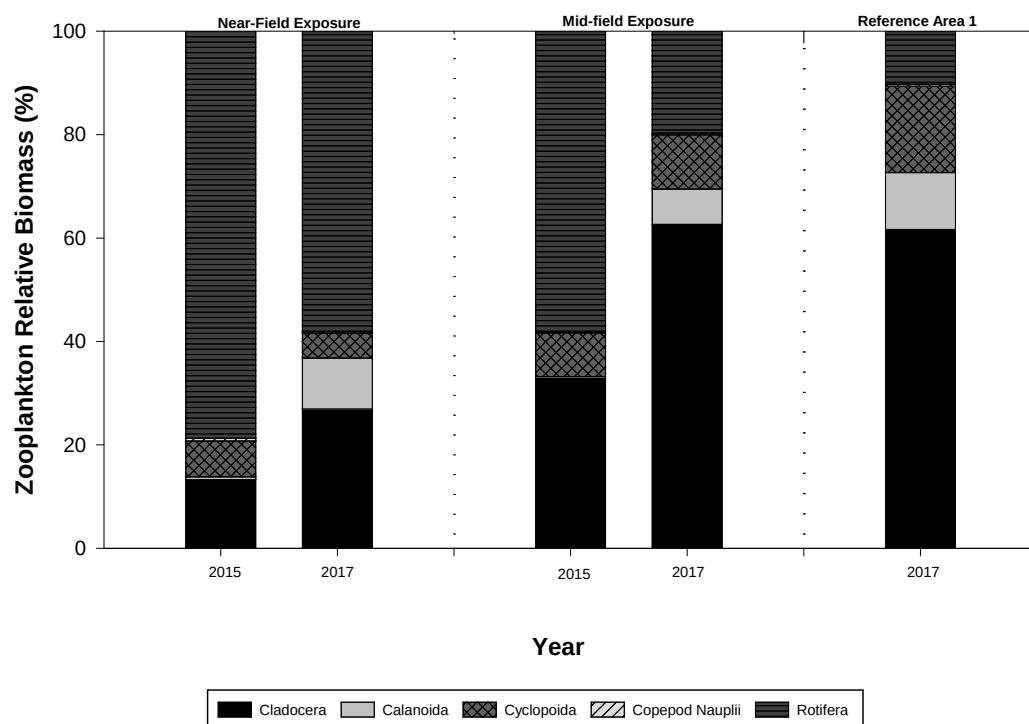


Figure 7.3-22: Relative Biomass of Major Zooplankton Groups in July, Meliadine Lake, 2015-2017

Notes: Bars represent mean values for each area (n=5). Zooplankton was not sampled in July 2016 due to loss of plankton net.

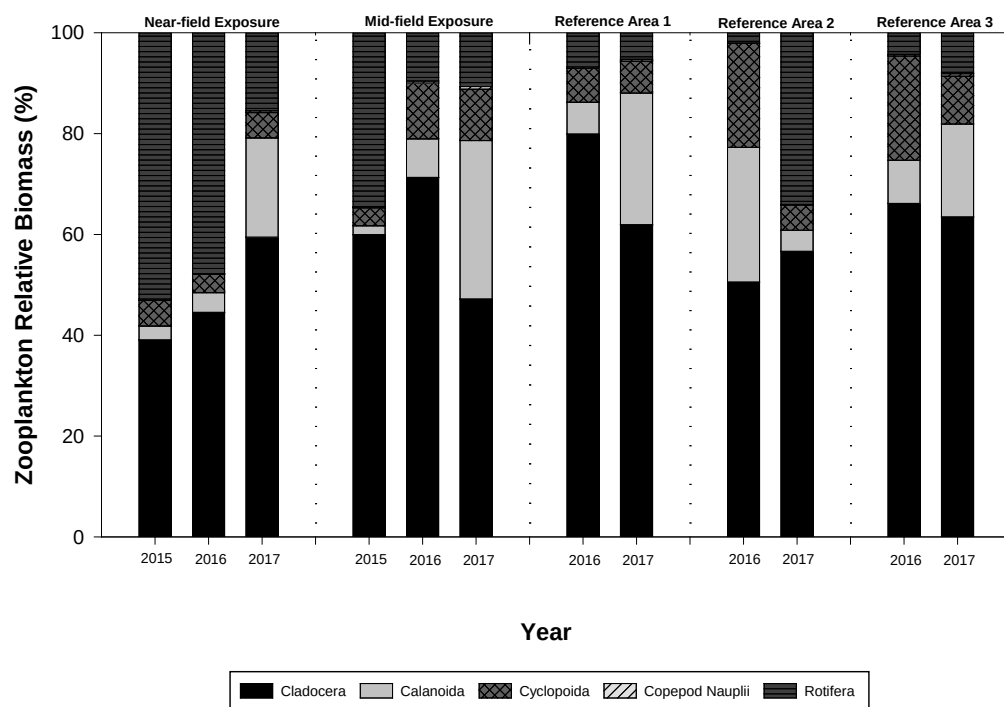


Figure 7.3-23: Relative Biomass of Major Zooplankton Groups in August, Meliadine Lake, 2015

Note: Bars represent mean values for each area (n=5).

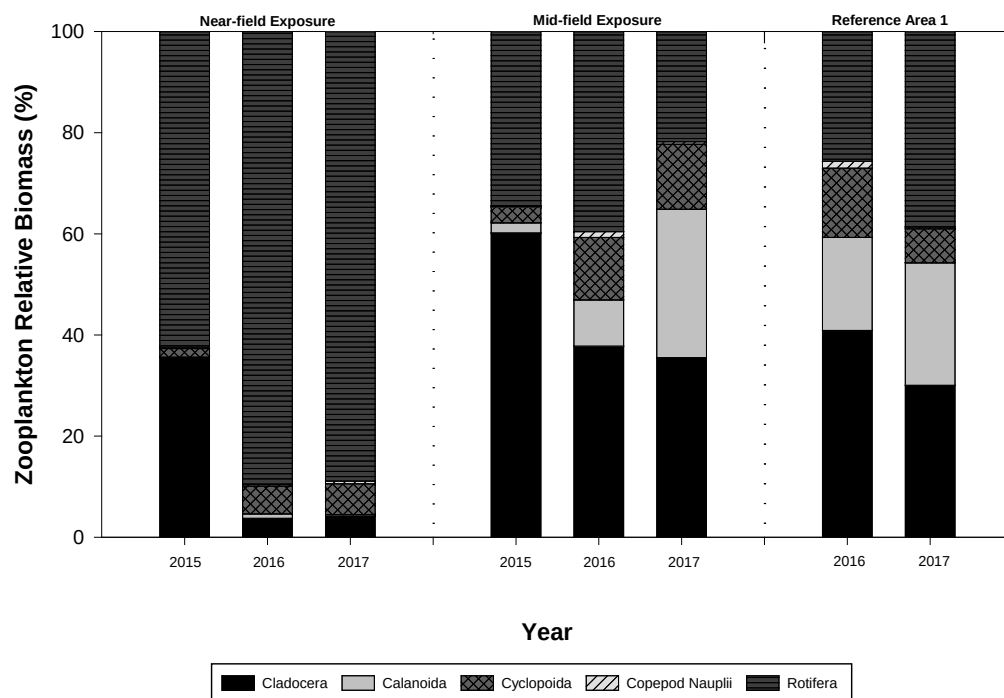


Figure 7.3-24: Relative Biomass of Major Zooplankton Groups in September, Meliadine Lake, 2015-2017

Note: Bars represent mean values for each area (n=5).

7.3.4.5 *Species Richness*

Zooplankton species richness was relatively consistent throughout Meliadine Lake, with minor variability among years, seasons and areas (Figure 7.3-25). The spatial trend for richness in July varied among years with lower mean richness in the Near-field exposure area than in the Mid-field exposure area in 2015, and higher mean richness in the Near-field exposure area than in the Mid-field or reference areas in 2017. In August, richness was somewhat variable among years in the Near-field exposure area but was relatively consistent overall among the different exposure and reference areas. Mean richness was highest at MEL-01 in 2016 reaching 13 ± 1 taxa compared to a mean of 11 to 12 taxa at other stations in August. Richness in September was lower in the Near-field exposure area than in reference area in each year with a mean richness of 11 ± 1 taxa at MEL-01 compared with a mean richness of 12 to 13 taxa in Reference Area 1.

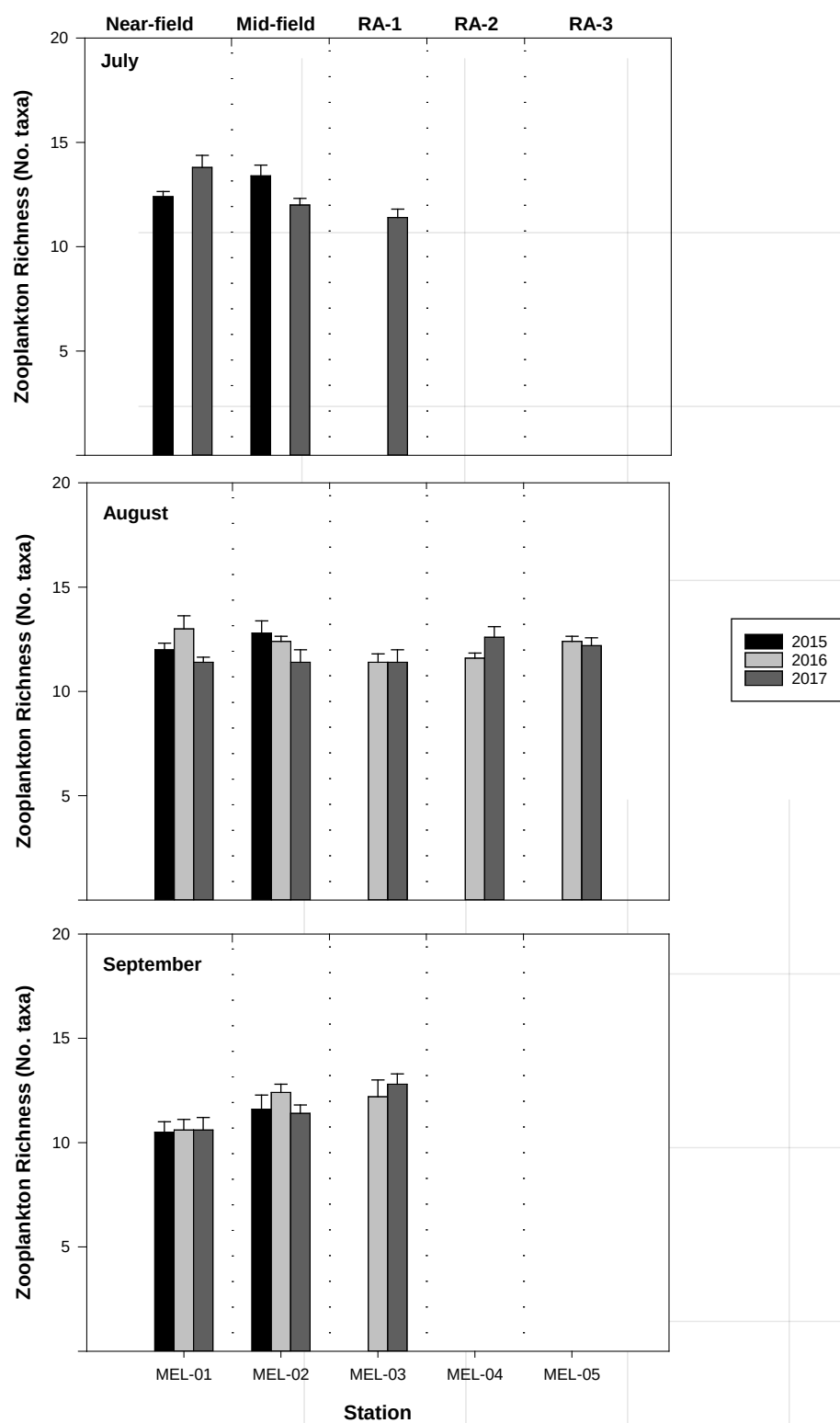


Figure 7.3-25: Zooplankton Species Richness in Meliadine Lake, 2015-2017

Notes: Mean values are presented for each area. Error bars represent standard error (SE). MEL-04 and MEL-05 were not sampled in July or September. No samples could be collected in July 2016 due to loss of plankton net.

RA=Reference Area.

7.3.4.6 Statistical Comparisons of Zooplankton Community Variables

Statistical comparisons of zooplankton community variables were made among different years within each sampling area and season Table 7.3-7. In general, variability in zooplankton abundance, biomass, and richness among years was high in the Near-field and Mid-field exposure areas and lower in the reference areas. Several seasonal and annual trends were evident in the Near-field and Mid-field exposure areas, for which three years of sampling allowed for pairwise comparisons among years (Table 7.3-8).

Table 7.3-7: Results of Statistical Analyses for Zooplankton Community Variables Comparing Years

Station	Variable	Transformation	Statistical Test	July	August	September
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
MEL-01	Abundance	None	ANOVA / t-test	0.497	<0.001	0.248
	Biomass	None	ANOVA / t-test	0.002	<0.001	<0.001
	Richness	None	ANOVA / t-test	0.074	0.063	0.990
MEL-02	Abundance	None	ANOVA / t-test	0.722	0.130	0.122
	Biomass	None	ANOVA / t-test	0.001	0.001	<0.001
	Richness	None	ANOVA / t-test	0.054	0.171	0.371
MEL-03	Abundance	None	t-test	–	0.152	0.460
	Biomass	None	t-test	–	0.536	0.331
	Richness	None	t-test	–	1	0.544
MEL-04	Abundance	None	t-test	–	0.255	–
	Biomass	None	t-test	–	0.688	–
	Richness	None	t-test	–	0.130	–
MEL-05	Abundance	None	t-test	–	0.248	–
	Biomass	None	t-test	–	0.704	–
	Richness	None	t-test	–	0.668	–

Note: P-values representing significant differences among years ($P < 0.1$) are bolded.

ANOVA= Analysis of Variance; t-test= Two-sample t-test; P-value = probability value; < = less than; – = no sample collected.

Results of statistical analyses for comparisons of zooplankton abundance, biomass, and richness among years are summarized below:

- Zooplankton abundance was only significantly different among years at MEL-01 in August (Table 7.3-7). No significant differences in abundance were observed among years in July or September or in the Mid-field exposure or reference areas. Abundance at MEL-01 in August was significantly lower in 2017 than in 2015 or 2016 but not significantly different between 2015 and 2016 (Table 7.3-8).
- Zooplankton biomass was significantly different among years in the Near-field and Mid-field exposure areas in all seasons, but not significantly different among years in the reference areas (Table 7.3-7). Biomass was significantly higher in each of the exposure areas in 2015 than in 2016 and 2017 in July, August and September (Table 7.3-8). Biomass was not significantly different between 2016 and 2017 in August or September.
- Zooplankton richness was significantly different among years overall in the Near-field exposure area in July and August and in the Mid-field exposure area in July (Table 7.3-7). Analysis of the pairwise comparisons between years, however, showed that richness did not vary significantly between years at MEL-01 in August (Table 7.3-8).

Table 7.3-8: Pairwise Comparisons for Statistical Analyses of Zooplankton Community Variables Comparing Year

Year	Variable	Transformation ^(a)	Statistical Test	July			August			September		
				2015 / 2016	2015 / 2017	2016 / 2017	2015 / 2016	2015 / 2017	2016 / 2017	2015 / 2016	2015 / 2017	2016 / 2017
				P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value
MEL-01	Abundance	None	ANOVA / Tukey's	–	–	–	0.823	0.002	0.001	0.001	<0.001	0.890
	Biomass	None	ANOVA / Tukey's	–	–	–	<0.001	<0.001	0.124	<0.001	<0.001	0.727
	Richness	None	ANOVA / Tukey's	–	–	–	0.269	0.602	0.055	0.991	0.991	1
MEL-02	Abundance	None	ANOVA / Tukey's	–	–	–	0.397	0.114	0.688	0.118	0.287	0.836
	Biomass	None	ANOVA / Tukey's	–	–	–	0.002	0.001	0.949	<0.001	<0.001	0.972
	Richness	None	ANOVA / Tukey's	–	–	–	0.842	0.163	0.369	0.527	0.959	0.378

(a) Distributions of all variables violated the assumption of normality even after transformation; however, the results are considered reliable as the assumption of equal variances was not violated and ANOVA is robust against violations of the assumption of normality.

Note: P-values representing significant differences between years ($P < 0.1$) are bolded.

ANOVA= Analysis of Variance; Tukey's= Tukey's Honestly Significant Difference Test; P-value = probability value; < = less than; – = no pairwise comparison conducted as only two sampling events were conducted in July and variables were analyzed using a t-test.

Samples collected during the August sampling event were carried forward for further evaluation of spatial variability among the five areas of Meliadine Lake. Data collected in 2015 was omitted from statistical comparisons among areas in Meliadine Lake due to a lack of sampling in the reference areas. A summary of statistical comparisons of variables among Near-field and Mid-field exposure areas and the three reference areas in August 2016 and 2017 is presented in Figure 7.3-9.

Table 7.3-9: Results of Statistical Analyses for Zooplankton Community Variables Comparing Areas

Year	Variable	Transformation	Statistical Test	Overall Comparison	MEL-01 / MEL-02	MEL-01 / MEL-03	MEL-01 / MEL-04	MEL-01 / MEL-05	MEL-02 / MEL-03	MEL-02 / MEL-04	MEL-02 / MEL-05	MEL-03 / MEL-04	MEL-03 / MEL-05	MEL-04 / MEL-05
				<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
2016	Abundance	log(x)	ANOVA /Tukey's	<0.001	0.020	0.076	<0.001	0.004	0.964	0.221	0.954	0.066	0.662	0.576
	Biomass	None	ANOVA /Tukey's	0.131	0.947	0.323	0.302	0.162	0.738	0.713	0.485	1.000	0.993	0.995
	Richness	log(x)	ANOVA /Tukey's	0.045	0.856	0.054	0.126	0.856	0.319	0.558	1.000	0.992	0.319	0.558
2017	Abundance	None	ANOVA /Tukey's	0.136	0.474	0.214	0.108	0.597	0.981	0.881	1.000	0.995	0.940	0.785
	Biomass	None	ANOVA /Tukey's	0.242	0.365	0.227	0.365	0.556	0.998	1.000	0.997	0.998	0.965	0.997
	Richness	None	ANOVA /Tukey's	0.284	1.000	1.000	0.430	0.771	1.000	0.430	0.771	0.430	0.771	0.976

Note: P-values representing significant differences between years (P<0.1) are **bolded**.
ANOVA= Analysis of Variance; Tukey's= Tukey's Honestly Significant Difference Test; *P-value* = probability value; < = less than.

Differences observed in the abundance, biomass, and richness of the zooplankton community in August 2016 and August 2017 in Meliadine Lake are summarized below:

- In 2016, zooplankton abundance was significantly different ($P < 0.001$) among the five sampling areas (Table 7.3-9). Abundance in the Near-field exposure area in 2016 was significantly higher than in the Mid-field exposure area and each of the three reference areas. There was no significant difference in abundance between the Mid-field exposure area and the reference areas or among the reference areas, with the exception of a significant difference between MEL-03 and MEL-04 ($P = 0.066$). In 2017, zooplankton abundance was not significantly different among or between any of the sampling areas.
- Zooplankton biomass was not significantly different among the sampling areas in 2016 ($P = 0.131$) or 2017 ($P = 0.242$) (Table 7.3-9).
- Zooplankton species richness was significantly different among areas in August 2016 ($P = 0.045$) but not in August 2017 ($P = 0.284$) (Table 7.3-9). In 2016, richness was only significantly different between MEL-01 and MEL-03 ($P = 0.054$).

7.3.4.7 *Multivariate Analyses*

Two nMDS dimensions were derived from the zooplankton biomass data collected in Meliadine Lake. Zooplankton biomass in 2016 and 2017 were plotted separately to enable a good fit of the ordination results. The stress value for the final configuration was 0.12 for August 2016 and 0.13 for August 2017. According to the categories provided by Clarke (1993), these stress levels reflect a “fair” ordination with a relatively low risk of drawing false inferences. Stations in the Near-field and Mid-field exposure areas clustered close together by area and separately from the reference area stations in 2016 with a few exceptions (Figure 7.3-26). In the Near-field exposure area, community composition by biomass was relatively consistent among stations except at one station (MEL-01-05) which had comparatively low biomass but a similar distribution of taxa overall. Stations in the Mid-field exposure area also clustered together in 2016 and one station from the MEL-03 area (MEL-03-01) clustered close to the exposure areas, while the majority of other reference stations clustered further from the exposure areas.

In August 2017, clustering of stations by area was less distinct suggesting fewer differences in taxonomic composition among areas (Figure 7.3-27). In both years, the overall spread of stations observed in the nMDS plots suggests that variability in taxonomic composition by biomass was relatively high in August 2016 and 2017.

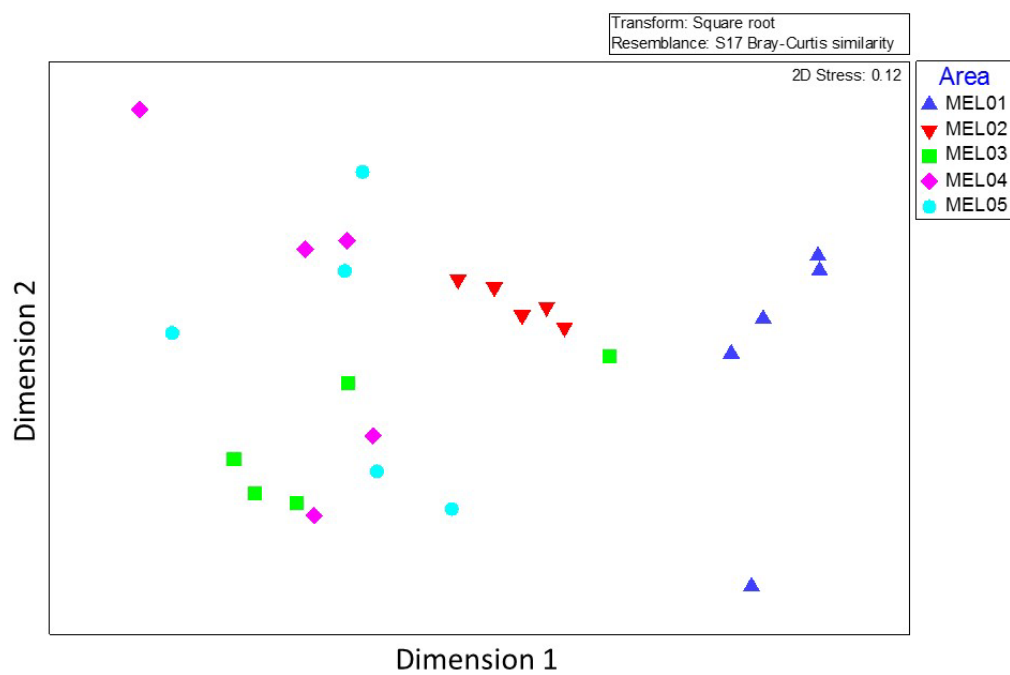


Figure 7.3-26: Ordination Plot of August Zooplankton Biomass in Meliadine Lake in 2016

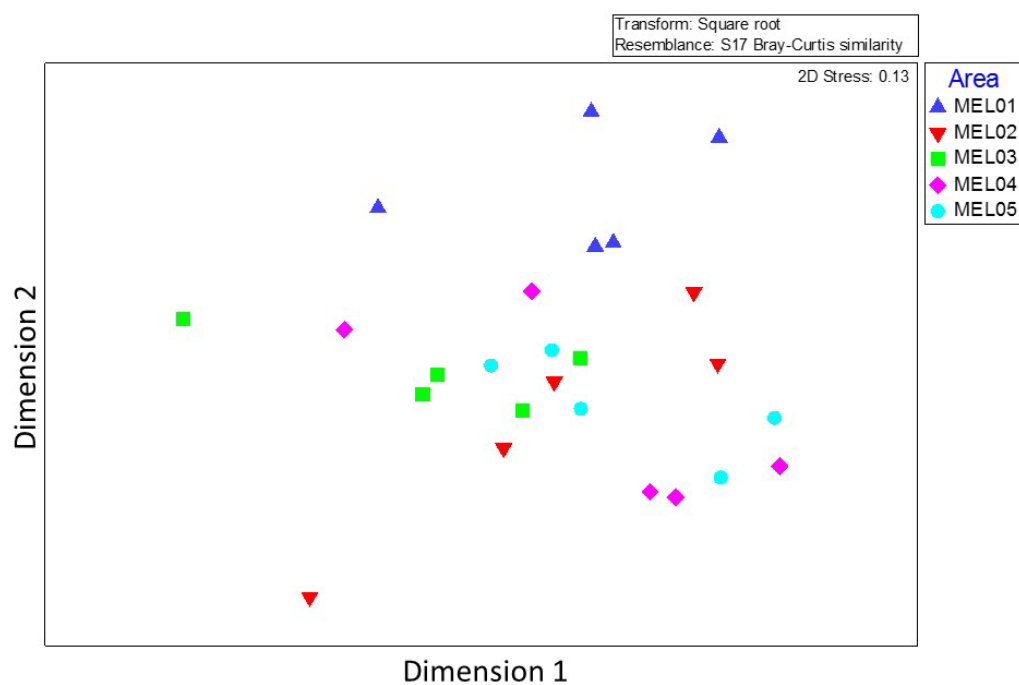


Figure 7.3-27: Ordination Plot of August Zooplankton Biomass in Meliadine Lake in 2016

7.3.5 Utility of Plankton as a Monitoring Tool

Long-term monitoring of plankton communities provides an assimilated measure of effects that integrates changes to biological, physical, and chemical factors over time. Plankton communities can be useful as early indicators of environmental change because of their rapid responses to changing environmental conditions (Bellinger and Sigee 2010; Uday Bhan et al. 2013). Plankton can provide information on seasonal dynamics, changes in nutrient availability, assessment of trophic status, and possible anthropogenic contamination.

Phytoplankton communities dominate primary production in lakes and are of ecological importance as the base of the aquatic food web. Phytoplankton can be particularly effective as early warning indicators of change because of their rapid response to changes in nutrient availability (Paerl et al 2007; Bellinger and Sigee 2010). Routine monitoring of phytoplankton incorporated into the AEMP can be used to characterize existing natural variability in community composition and to provide an indication of potential changes to trophic status in the lake.

Zooplankton also play an important role in the food web by linking primary producers and higher trophic level organisms such as fish. Growth and distribution of zooplankton communities are dependent on both abiotic (e.g., temperature, stratification, and lake size) and biotic (e.g., food limitation, predation, and competition) parameters and responses to environmental change can, therefore, be more difficult to predict (Ferdous and Muktadir 2009). Seasonal succession and natural year-to-year variation also contribute to inherent variability of these communities (Wetzel 2001; Paterson 2002), which can limit their usefulness as a monitoring tool.

Based on the plankton dataset collected from Meliadine Lake, the phytoplankton dataset (i.e., chlorophyll *a*, phytoplankton abundance, biomass, and composition of major taxonomic groups, along with supporting nutrient data collection) is a good monitoring tool for Meliadine Lake to detect potential effects resulting from nutrient enrichment. Due to high variability in zooplankton, it is not a good monitoring tool for Meliadine Lake.

7.3.6 Key Findings from Plankton Monitoring Program

Key findings from the plankton study were as follows:

- Nutrients during plankton sampling events in Meliadine Lake were generally low with variability observed among years and seasons, and spatial variability observed in total nitrogen concentrations in August 2017. Total nitrogen in August 2017 was significantly higher in the Near-field exposure area than in the reference areas; however, concentrations of total phosphorus were not significantly different among areas.
- Chlorophyll *a* exhibited high annual variability and was generally higher in Near-field stations compared to other areas.
- Trophic status calculations indicated conditions were oligotrophic in all areas and years.
- Higher phytoplankton abundance and biomass was observed in the Near-field exposure area compared to other areas.
- Seasonal and temporal variability were potentially confounding factors for the evaluation of spatial trends in the phytoplankton community. Variability among years was generally high in July and September but low in August indicating that August represented the most useful target month for analysis of spatial trends. In August, spatial trends were consistent among years with higher abundance and biomass in the Near-field exposure area than in the Mid-field exposure area or the reference areas.

- Phytoplankton communities in Meliadine Lake were generally dominated by the Chrysophyceae (golden algae). Limited spatial variability was observed in relative abundance and biomass of major taxonomic groups. However, multivariate analysis indicated differences among areas in community composition at the species level.
- Chlorophyll a concentrations had a significant, but weak linear relationship with phytoplankton biomass, with a moderate amount of variability between the two measurements, especially in 2015. Given this relationship, the current results suggest chlorophyll a is a potentially useful indicator of phytoplankton biomass in Meliadine Lake. The addition of data collected during future studies may help to further refine the relationship and may allow for additional methods such as using variable proportions of biomass and chlorophyll a rather than a constant conversion factor to explain the interaction between the two estimates of biomass (Kasprzak et al. 2008).
- Zooplankton biomass was primarily dominated by cladocerans and rotifers in all areas of Meliadine Lake. Among-year variability in the zooplankton community sampled in each area was high. Consistent spatial trends in zooplankton abundance or biomass could not be discerned due to the high temporal and seasonal variability.
- Higher chlorophyll a concentration and phytoplankton biomass, and unique phytoplankton community structure (based on multivariate analysis) in the Near-field area may be an indicator of potential effects of nutrient enrichment originating from the exploration camp STP. However, TP concentrations were not unusually elevated in the Near-field area, but were highest in this area in September during each year of monitoring. Further investigation is recommended to evaluate whether annual TP loads were sufficient to result in the observed spatial trend in chlorophyll a concentration and phytoplankton biomass, and whether other water chemistry variables also show changes consistent with an effect from the STP discharge.
- Long-term monitoring of plankton communities provides an integrated measure of effects that integrates changes to biological, physical, and chemical factors over time. Plankton communities can be useful as early indicators of environmental change because of their rapid responses to changing environmental conditions. Routine monitoring of phytoplankton incorporated into the AEMP can be used to characterize existing natural variability in community composition and to provide an indication of potential changes to trophic status in the lake.

8.0 CONCLUSIONS

8.1 Summary

8.1.1 Water Quality

Water quality monitoring activities were carried out at Meliadine Lake and the peninsula lakes in 2017 in support of the AEMP and Water License requirements for the Mine. This monitoring was completed to characterize water quality conditions so adaptive management strategies can be identified, as required. Meliadine Lake was sampled at five stations within each of the Near-field area, Mid-field area, and three reference areas during open-water conditions and at the Near-field and Mid-field areas during ice-covered conditions. Three peninsula lakes were sampled during open-water conditions.

Water quality data collected at Meliadine Lake and peninsula lakes in 2015, 2016 and 2017 were assessed to provide information on temporal and spatial variability of water quality in these waterbodies. The assessment consisted of a visual evaluation of time series plots developed for each water quality parameter and statistical analysis and comparison between the Near-field, Mid-field, and reference areas. Water quality results were compared to the applicable Canadian water quality guidelines for the protection of aquatic life, drinking water guidelines, or site-specific objectives developed for the Mine.

Water quality in Meliadine Lake, during ice-covered and open-water conditions, can be characterized as lacking stratification within the water column and being generally well oxygenated. The lake water was circumneutral to basic, with moderate sensitivity to acid deposition. Concentration of TDS, hardness, alkalinity, specific conductivity, nutrients, and metals were low and none of the relevant guidelines or objectives were exceeded.

Water quality in Meliadine Lake was similar across all years. Some spatial and seasonal variability was observed, but concentrations remained low and were orders of magnitude below the guidelines. In 2017 specific conductivity, major cations, chloride, sulphate, and some metals (i.e., total arsenic, barium, cobalt, copper, nickel, silicon, and strontium) concentrations were slightly higher at the exposure areas as compared to the reference areas; among exposure areas, the Near-field area tended to have slightly higher concentrations as compared to the Mid-field area. Also, specific conductivity, hardness, chloride, major cations, ammonia and some metals (e.g., barium, boron, copper, strontium) had slightly higher concentrations during ice-covered conditions as compared to the open-water conditions.

Water quality at peninsula lakes measured similar across all years, with some variability was observed among lakes. Generally, peninsula lakes were well oxygenated, with pH values indicative of slightly basic conditions, low sensitivity to acid deposition, and low to moderate ionic strength. Parameters concentrations at peninsula lakes were low and none of the relevant guidelines were exceeded.

Peninsula Lake A8 had specific conductivity, hardness, and concentrations of TDS (including chloride and sulphate), and some metals such as arsenic, barium, and strontium slightly higher as compared to the other two peninsula lakes. Peninsula Lake D7 had slightly higher concentrations of phosphorus, major ions (bicarbonate and fluoride), and some metals such as boron, lithium, molybdenum, selenium, uranium, and vanadium as compared to the other two lakes. Specific conductivity, hardness, alkalinity, TDS, major ions, and some metals (e.g., arsenic, barium, lithium, and strontium) were generally slightly higher in the peninsula lakes as compared to Meliadine Lake.

Provisional normal range concentrations were calculated for ecologically relevant water quality parameters for Meladine Lake for ice-covered conditions based on data collected at Mid-field area and for open-water conditions based on data collected at the reference areas. Similarly, normal range concentrations were calculated for each peninsula lake. These normal ranges will be used to evaluate the 2018 data collected from the exposure areas. The normal ranges may be updated (annually or every three-years) with new data collected from the reference areas.

8.1.2 Sediment Quality

A total of 35 sediment quality samples from Meladine Lake, five samples from Lake A8, four samples from Lake B7, and three samples from Lake D7 were collected and analyzed for particle size, nutrients, and metals. The sediment quality data gathered in 2015 and 2016 form a baseline dataset for comparisons to future monitoring of sediment quality trends during the life of the mine.

Under baseline conditions, concentrations of arsenic, chromium, and copper exceed guideline values. Arsenic concentrations in Meladine Lake were generally highest in the MEL 01 (Near-field exposure) area. Due to the close relation between fine sediments and metals in Meladine Lake, data were normalized to fine sediments prior to running statistical tests. Even after normalization some sediment quality parameters (arsenic, iron, mercury, strontium, and sulfur) were higher in the Near-field as compared to reference areas. The Mid-field area had similar particle size distribution to reference areas, but concentrations of some parameters (arsenic, chromium, cobalt, lead, manganese, molybdenum, nickel, uranium, and zinc) were higher in the Mid-field than in reference areas.

After normalization to grain size, normal range for sediment quality parameters were collected using data for the whole lake. These normal ranges will be used to evaluate the future sediment quality data collected from the exposure areas and may be updated as new data are collected from the reference areas.

Sediment samples from the peninsula lakes were also relatively sandy, with concentrations of arsenic and chromium and copper that exceeded ISQGs and PELs, and concentrations of copper that exceeded the ISQGs). The lowest concentrations of these three parameters were observed in Lake B7.

8.1.3 Benthic Invertebrate Community

Benthic invertebrate communities sampled in Meladine Lake exposure and reference areas during 2015 and 2016 baseline sampling programs were representative of subarctic systems. These years reflect conditions prior to discharge of the Type A Water Licence effluent to the Near-field area of Meladine Lake.

In the Meladine Lake exposure and reference areas, benthic invertebrate communities were characterized by low total density and low to moderate richness. Both community variables were within the ranges expected for subarctic lake environments. SDI values were moderate to high, which indicated the invertebrate communities were diverse. Evenness was more variable and ranged from low to moderate. Collectively, these two indices suggest that baseline benthic communities sampled at most stations in the reference and exposure areas had moderate to high diversity with few taxa that were overly dominant. Benthic communities were dominated by midges (family Chironomidae) with the tribe Chironomini as the most dominant chironomid group in all areas sampled within Meladine Lake. The bivalve family Pisidiidae was the sub-dominant group at the majority of stations.

Spatial and temporal differences in community structure between Near-field, Mid-field and reference areas were observed during this evaluation of the 2015 and 2016 data. In particular, the benthic invertebrate community of the Near-field area was found to differ from those in the three reference areas in 2016. These differences may be attributed to potential differences in the physical habitat sampled (i.e., substrate type), or possibly, mild nutrient enrichment in the Near-field area from the exploration camp STP discharge. Overall, the Near-field area community was most similar to the community at Reference Area 1.

Within-station variation in total invertebrate density and richness, based on five subsamples collected per station, was found to be generally within acceptable ranges for benthic invertebrate communities characterized by low density in oligotrophic lakes. Collection of both composite samples of five grabs and a subset of individual subsamples will continue to allow evaluation of the within-station variability.

Meaningful normal ranges for the benthic community, as an input to the Response Framework, could not be estimated at this time, due to variability in the available data related to substrate differences between reference and exposure areas, and a potential nutrient enrichment.

8.1.4 Fish Health and Fish Tissue

Threespine Stickleback were captured in sufficient numbers from the Near-field and reference areas of Meliadine Lake to meet sampling requirements for the fish health and tissue chemistry components of the AEMP. Threespine Stickleback were abundant throughout shallow areas of Meliadine Lake (i.e., less than 3 m), and susceptible to capture using minnow traps, and backpack electrofishing. A gear selectivity bias was observed, with larger Threespine Stickleback captured in minnow traps when compared to other gear types.

The timing of sampling during the August 2015 and August 2017 surveys was appropriate for assessing reproductive development in Threespine Stickleback. Threespine Stickleback were determined to be spawning in Meliadine Lake during the August 2015 and 2017 sampling periods, based on the presence of male secondary sex characteristics and the occurrence of ripe and spent individuals of both sexes. Threespine Stickleback are a spring spawning species; however, extended spawning seasons have been observed for some populations (Wootton et al. 1978; Chellappa et al. 1989). Based on this information and our observations, Threespine Stickleback likely spawn from June through to August in Meliadine Lake.

The majority of Threespine Stickleback captured in Meliadine Lake were infected by *S. solidus*, a tapeworm that competes with the host for available resources and has been found to decrease the energy allocated to storage and spawning in Threespine Stickleback (Schultz et al. 2006; Rushbrook et al. 2007), as well as delay sexual maturity. The parasite was abundant at each of the areas sampled (i.e., 76% of fish sampled), and has the potential to confound the detection of changes in energy storage and reproductive endpoints that may result from mine operations.

Population structure for Threespine Stickleback varied among sampling areas, with larger individuals collected from the Near-field area when compared to Reference Area 1 and Reference Area 2 (Table 8.1-1). Fish health endpoints were similar for female Threespine Stickleback among sampling areas (Table 8.1-2). Male Threespine Stickleback sampled from the Near-field area were longer, heavier, and had greater relative liver weights than individuals sampled from the reference areas (Table 8.1-2). Threespine Stickleback sampled from the Near-field area had lower relative gonad weights and greater relative body weights when compared to Reference Area 2, exceeding CES; however these differences were not observed relative to Reference Area 1. Fish health parameters for male Threespine Stickleback sampled from the Near-field area also exceeded normal ranges for

length, body weight, carcass weight, condition factor, and liver somatic index. With respect to tissue chemistry, significant differences were observed between the Near-field and reference areas for the majority of parameters examined, with lower metal concentrations generally observed at the Near-field area (Table 8.1-3). When compared to normal ranges, arsenic and tin were elevated in the Near-field area, while chromium, iron, molybdenum, nickel, rubidium, and selenium were below normal ranges.

Table 8.1-1: Summary of Statistically Significant Differences in Threespine Stickleback Fish Health Endpoints Collected During the Population Survey, 2015 and 2017

Parameter	CES	NF*RA1	NF*RA2
Length-frequency distribution	(a)	↑	↑
Size-at-age 1+	-	↑	↑
Size-at-age 2+	-	-	↑
Total Length	-	↑	↑
Body weight	-	↑	↓
Relative body weight (TW)	10%	↑	↑

(a) Length-frequency is an effect endpoint for non-lethal sampling in the EEM program, however a CES is not defined (Environment Canada 2012).

CES = critical effect size; NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; ↑ = endpoint significantly greater at Near-field Area compared to reference area; ↓ = endpoint significantly lower at the Near-field Area compared to reference area; - = not applicable; TW = calculated using total weight.

Table 8.1-2: Summary of Statistically Significant Differences in Threespine Stickleback Fish Health Endpoints Sampled During the Lethal Survey, 2015 and 2017

Sex	Parameter	CES	NF*RA1	NF*RA2
Female	Age	25%	-	↔
	Size-at-age 1+	25%	↑↑	-
	Size-at-age 2+	25%	-	-
	Length-frequency	-	-	-
	Body Weight	-	-	-
	Length	25% ^(a)	-	-
	Relative gonad size	25%	-	-
	Relative fecundity	-	↑	-
	Relative body weight	10%	-	-
	Relative liver size	25%	↑	-
	Relative egg size	-	-	-
Male	Age	25%	-	-
	Size-at-age 1+	25%	-	-
	Size-at-age 2+	25%	↑	↑↑
	Length-frequency	-	↑	↑
	Body Weight	-	↑	↑
	Length	25% ^(a)	↑	↑
	Relative gonad size	25%	-	↓↓
	Relative body weight	10%	-	↑↑
	Relative liver size	25%	↑↑	↑↑

(a) Threespine Stickleback are short-lived in freshwater so length was used as a surrogate for age (Environment Canada 2012).

CES = critical effect size; NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; ↑ = endpoint significantly greater at Near-field Area compared to reference area; ↑↑ = endpoint significantly greater at Near-field Area compared to reference area and exceeded CES; ↓ = endpoint significantly lower at Near-field Area compared to reference area; ↓↓ = endpoint significantly lower at Near-field Area compared to reference area and exceeded CES; ↔ = distributions were significantly different, but magnitude was zero; - = no difference, or not applicable.

Table 8.1-3: Summary of Statistically Significant Differences in Threespine Stickleback Fish Tissue Chemistry Endpoints for Fish Sampled During the Lethal Survey, 2015 and 2017

Parameter	NF*RA1	NF*RA2
Moisture	↑	-
Aluminum	↓	↓
Antimony	↔	↔
Arsenic	↑	↑
Barium	↓	↓
Beryllium	-	-
Bismuth	↔	↔
Boron	↓	↓
Cadmium	-	-
Calcium	↓	-
Cesium	↓	↓
Chromium	↓	↓
Cobalt	↓	↓
Copper	↓	↓
Iron	↓	↓
Lead	-	-
Lithium	↓	↔
Magnesium	↓	↓
Manganese	-	-
Mercury	-	↑
Molybdenum	↓	↓
Nickel	↓	↓
Phosphorus	↓	↓
Potassium	-	↑
Rubidium	↓	↓
Selenium	↓	↓
Silver	-	↑
Sodium	-	↑
Strontium	↓	-
Tellurium	-	-
Thallium	-	-
Tin	↑	↑
Titanium	↓	↓
Uranium	-	↓
Vanadium	↓	↓
Zinc	↓	↓
Zirconium	↔	↔

NF = Near-field Area; RA1 = Reference Area 1; RA2 = Reference Area 2; ↑ = endpoint significantly greater at Near-field Area compared to reference area; ↓ = endpoint significantly lower at Near-field Area compared to reference area; ↔ = distributions were significantly different, but magnitude was zero; - = no difference, or not applicable.

In general, Threespine Stickleback were similar between the Near-field and reference areas; however, differences were observed in population structure and tissue chemistry parameters. Threespine Stickleback sampled from the Near-field area were generally larger and exhibited lower metal concentrations relative to fish sampled from the reference areas. It could not be determined from the baseline data whether these differences resulted from geographic or interannual variation, as the Near-field and reference areas were sampled in separate years. For example, differences in growth and energy storage may reflect better or more rapid growing conditions in 2015, rather than differences between sampling areas. As a consequence, it was difficult to assess the similarity of the Near-field and reference areas in Meliadine Lake with respect to these endpoints. During future AEMP sampling, the Near-field and reference areas will be sampled in the same year and at the same time (i.e., August), controlling for this factor.

Power analyses of fish health endpoints indicated that lethal sampling of 30 female and 30 male Threespine Stickleback would be sufficient to reliably detect differences that met or exceeded CES (Table 6.3-8); with the exception of relative gonad size for male fish, which would require 39 samples. Power analyses were based on all fish sampled in the baseline dataset, and fewer fish may be required if parasitized fish were excluded from data analyses, subsequently reducing endpoint variability. Sample size requirements for unparasitized fish were not estimated using the baseline dataset, as insufficient samples were obtained to adequately describe endpoint variation.

In summary, Threespine Stickleback were confirmed to be a suitable sentinel species for the Meliadine Gold Project AEMP. Baseline data were reported for fish health and fish tissue chemistry parameters for the Near-field area, Reference Area 1, and Reference Area 2. Provisional normal ranges were developed for Threespine Stickleback and Lake Trout using the baseline dataset, and will be modified in the future, as necessary, to include future reference area data.

8.1.5 Plankton

Plankton monitoring was conducted as a targeted study to characterize baseline conditions for the plankton community in Meliadine Lake and to evaluate the usefulness of plankton as a potential long-term monitoring tool. Plankton sampling was carried out during the 2015 to 2017 open-water seasons: July, August and September. Samples of phytoplankton, zooplankton, chlorophyll a, and nutrients were collected in five areas of Meliadine Lake (Near-field, Mid-field and three reference areas). Spatial and temporal trends observed in plankton communities were compared to changes in nutrient concentrations, and potentially confounding factors for future effluent monitoring studies were evaluated. Results from the targeted study show that there is spatial and seasonal variability observed in the majority of plankton endpoints. However, the use of phytoplankton communities and chlorophyll a are expected to be the most useful monitoring tools to be carried forward to provide an integrated measure of biological effects.

Trophic status calculations indicated conditions in Meliadine Lake were oligotrophic in all areas and years. Of the three commonly used variables to calculate TSI (i.e., total phosphorus, chlorophyll a, and Secchi Depth), chlorophyll a is considered the best predictor of the overall trophic status of lakes (Carlson and Simpson 1996). The strength of the relationship between chlorophyll a and phytoplankton biomass was also investigated to assess the suitability of chlorophyll a concentration as a potential surrogate for estimating phytoplankton biomass. The results suggest that chlorophyll a is a potentially useful indicator of phytoplankton biomass in this system.

Higher chlorophyll a concentrations and phytoplankton biomass, and unique phytoplankton community structure (based on multivariate analysis) in the Near-field area may be an indicator of potential effects of nutrient enrichment originating from the exploration camp STP-effluent outfall. However, TP concentrations were not unusually elevated in the Near-field area, but were highest in this area in September during each year of monitoring.

Zooplankton biomass was primarily dominated by cladocerans and rotifers in all areas of Meliadine Lake. Among-year variability in the zooplankton community sampled in each area was high. Consistent spatial trends in zooplankton abundance or biomass could not be discerned due to the high temporal and seasonal variability. Inherent variability in the zooplankton community may limit the usefulness of zooplankton community endpoints for long-term monitoring.

The targeted study provided useful information to characterize plankton communities in Meliadine Lake and to inform selection of monitoring tools for incorporation into the AEMP.

8.2 2018 Monitoring Plan

As per the AEMP design plan, water quality monitoring in Meliadine Lake and the peninsula lakes is an annual program, while monitoring for sediment quality, BIC, and fish health and fish tissue moves to the EEM schedule after pre-operations data have been collected. Pre-operations data (or pre-discharge of effluent from CP1) were collected in 2015 to 2017 following the AEMP design plan (Golder 2016b) approved under Water Licence 2AM-MEL-1631.

Meliadine Mine triggered under the MMER in 2016 after dewatering of Lake H17. The Cycle 1 study design was submitted to Environment and Climate Change Canada (ECCC) in August 2017 and is currently under review by the technical advisory panel. The field program will be conducted in August 2018 once the study design has been approved by the technical advisory panel.

The first discharge from CP1 was planned during September to October 2017 but did not occur. Agnico Eagle anticipates initiating the first discharge from CP1 in June 2018. As per the AEMP design plan, sediment quality, BIC, and fish health and fish tissue data may need to be collected to monitor the potential effects of this discharge.

9.0 CLOSURE

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GLOSSARY

Term	Definition
Abundance	The number or quantity of cells or organisms in a particular area or volume of sample.
Alkalinity	A measure of the acid-neutralizing capacity carbonates, bicarbonates and hydroxides present in water. Alkalinity is typically reported in units of mg/L calcium carbonate (CaCO ₃).
Aquatic Effects Monitoring Program	A monitoring program designed to evaluate the effect of mining activities and mitigation on the aquatic environment. Mg.
Benthic Invertebrates	Aquatic animals without backbones (e.g., insects, worms, snails, clams crustaceans) that live on/in the bottom substrate of a waterbody.
Biomass	The mass of all the cells or organisms in a particular area or volume of sample.
Bray-Curtis Index	An index used to summarize the overall difference in community structure between reference and exposure areas.
Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life	Guidelines established by the Canadian Council of Ministers of the Environment to protect aquatic life (i.e., fish, aquatic plants, and benthic invertebrates) in Canadian surface waters.
Chlorophyll a	A photosynthetic pigment found in plants, responsible for the conversion of inorganic carbon and water into organic carbon. The concentration of chlorophyll a is often used as an indicator of algal biomass.
Community	The groups of organisms living together in the same area, usually interacting or depending on each other for existence.
Community composition	The species present and their relative proportions in an assemblage of organisms.
Dominance	The predominance of one or more species in a community.
Drinking Water Quality Guidelines (DWQG)	Health Canada guidelines used to evaluate the suitability of water for human consumption.
Effluent	The out-flow water or wastewater from a water processing system or device, or the final water which is discharged from a treatment plant. For purposes of this document, effluent is the water that is discharged from the water treatment plant to Meliadine Lake.
Ekman grab	A sampling device used to collect a discrete sample of bottom sediment.

Term	Definition
Euphotic zone	The extent of the water column that is exposed to sufficient sunlight for photosynthesis to occur (typically to a depth in the water column where 1% of the irradiance is measured, or two times the Secchi depth).
Exposure area	An area that receives direct discharge from mining operations.
Homogeneity of variance	Statistical term for the assumption that the variance within each of the groupings/populations is equal.
In situ	Refers to measurements or data recorded in the field, at the sampling site.
Interim Sediment Quality Guideline (ISQG)	In reference to the Canadian sediment quality guidelines (CCME 2001), the concentration above which adverse effects may occur, and below which they are not expected to occur.
Kemmerer	A plastic or Teflon water sampling device that is opened, lowered into the water to the desired sample collection depth; a weighted messenger device is used to close the Kemmerer and sample water from the desired depth.
Metalloid	A class of chemical elements intermediate in properties between metals and non-metals; e.g., arsenic and boron.
Mean	Arithmetic average value.
Metals	A class of chemical elements that are good conductors of electricity and heat, and have the capacity to form positive ions in solution; e.g., aluminum, copper, iron, and zinc.
Normal Range	An estimate of natural variability.
Nutrients	Substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Nutrient Enrichment	The type of effect resulting from an increase in the nutrients to an ecosystem, which may impact primary productivity.
Oligotrophic	Trophic state classification for lakes characterized by low concentration of nutrients and low organic productivity. Oligotrophic
Otolith	A calcified structure that can be used to estimate fish age.
<i>P</i> -value	Statistical value used to determine the significance of a relationship or difference, e.g., $P < 0.1$.
Parameter	A particular physical, chemical, or biological property that is being measured.

Term	Definition
pH	The negative logarithm of the concentration of the hydronium ion (H ⁺). The pH is a measure of the acidity or alkalinity of an aqueous solution, expressed on a scale from 0 to 14, where 7 is neutral, values below 7 are acidic, and values over 7 are alkaline.
Phytoplankton	Small, free-floating algae that are suspended in the water column.
Probable Effects Level (PEL)	Canadian sediment quality guideline for the protection of freshwater quality life (CCME 2001), representing the concentration above which adverse effects may but will not always occur.
Oxic	Relates to the amount of dissolved oxygen in a water column relative to the guideline to support aquatic life (CCME 1999); water described as oxic has oxygen above the guideline.
R ²	A coefficient of determination, a statistical measure of how well a regression line approximates the real data points.
Reference area	An area that is reasonably similar in terms of monitored components and features to the exposure area, though not necessarily identical, but has no potential to be affected by the mine.
Richness	The number of different taxonomic groups present in a given area or sample volume.
Secchi Depth	A parameter used to determine the clarity of surface waters. The measurement is made with a Secchi disk, a black and white disk that is lowered into the water and the depth is recorded at which it is no longer visible. Higher Secchi depth readings indicate clearer water that allows sunlight to penetrate to a greater depth. Lower readings indicate turbid water that can reduce the penetration of sunlight. Limited light penetration can be a factor in diminished aquatic plant growth beneath the surface, thus reducing the biological re-aeration at greater depths.
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material.
Standard deviation (SD)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
Simpson's Diversity Index	A measure of the number of taxonomic groups or species present within an area of habitat or in a sample, as well as the abundance of each of those groups. Index values range from 0 to 1; the greater the diversity, the greater the index value.

Term	Definition
Standard error (SE)	The standard deviation (positive square-root of the variation) of the errors associated with a series of measurements.
Simpson's Evenness Index	A measure of how evenly the total invertebrate density is distributed among the taxa in an area or sample. Index values range from 0 to 1; higher numbers indicate a greater equality among all taxa present in a sample and low values represent low evenness (i.e., a high degree of dominance by one or a few organisms).
Specific conductivity	A temperature-corrected measure of a water sample's ability to conduct electricity; measurements are corrected to 25°C. Waters with higher concentrations of dissolved ions conduct electricity more efficiently than waters with low ionic concentrations.
Taxa	A group of organisms of any taxonomic rank (e.g., family, genus, species).
Total dissolved solids (TDS)	Organic and inorganic substances that are dissolved in water and will pass through a 0.45 micrometre (µm) filter.
Total Kjeldahl nitrogen	A measure of ammonia and organic nitrogen. It is used as an indicator of biologically available nitrogen.
Total suspended solids (TSS)	A measurement of the concentration of particulate matter found in water.
Transformation	The process of converting data through replacement of a variable by a function of that variable.
Variable	A characteristic, number or quantity whose associated value may change or be studied.
Water Column	The water in any waterbody from the surface down to the substrate.
Zooplankton	Small, sometimes microscopic animals that live suspended in the water column.

ABBREVIATIONS AND ACRONYMS

Term	Definition
#	number
<	less than
>	greater than
≤	less than or equal to
±	plus or minus
Σ	sum
%SE	percent standard error of the mean
5X	five times
α	alpha
%ile	Prediction interval calculated using percentiles
AEMP	Aquatic Effects Monitoring Program
AENV	Alberta Environment
Agnico Eagle	Agnico Eagle Mines Limited
ALS	ALS Environmental Laboratory
ANCOVA	analysis of covariance
ANOVA	analysis of variance
ANOSIM	Analysis of similarities
AVC	Atlantic Veterinary College
BCI	Bray-Curtis index
BCMoe	British Columbia Ministry of Environment
BURB	Burbot (<i>Lota lota</i>)
BP	Backpack Electrofishing
CA	cortical alveolar

Term	Definition
CaCO ₃	calcium carbonate
CALA	Canadian Association for Laboratory Accreditation Inc.
CCME	Canadian Council of Ministers of the Environment
CES	Critical effects sizes
CFIA	Canadian Food Inspection Agency
Chl	chlorophyll a sample
CISCO	Cisco
CPUE	Catch-per-unit-effort
CV	Coefficient of variation
CW	Calculated using carcass weight
CWQG	Canadian Water Quality Guidelines
BIC	Benthic Invertebrate Community
DELT	Deformities, Erosions, Lesions, Tumours
DIN	depth-integrated nutrient
DL	detection limit
DO	dissolved oxygen
DOC	dissolved organic carbon
DSCE	Dwass-Steel-Chritchlow-Fligner Test for Pairwise Comparision
dup	duplicate
DWQG	Drinking Water Quality Guidelines
ECCC	Environment and Climate Change Canada
EEM	Environmental Effects Monitoring
Feb	February
FEIS	Final Environmental Impact Statement

Term	Definition
GE	Germinal epithelium
Golder	Golder Associates Ltd.
GPS	global positioning system
GSI	gonadosomatic index
GVBD	germinal vesicle breakdown
GVM	germinal vesicle migration
HP	Hoop Net
ID	identifier
K-S	Kolmogorov-Smirnov test
K-W	Kruskal Wallis test
INAC	Indigenous and Northern Affairs Canada
ISS	Insufficient Sample Size
ISQG	Interim Sediment Quality Guideline
LKTR	Lake Trout (<i>Salvelinus namaycush</i>)
LogPi	95% prediction intervals were defined calculated using log transformed data and then upper and lower by back transforming boundaries were back-transformed to the original data scale
Log ₁₀	Logarithm base 10
LSI	liversomatic index
LTL	lowest taxonomic level
Max	maximum
MSE	Mean squared error
MF	Mid-field
Min	minimum
Mine	Meliadine Gold Mine

Term	Definition
MMER	Metal Mining Effluent Regulations
MT	Minnow Trap
M-W U	Mann-Whitney U Statistical Test
n	Number / Sample Size
N	North
	Mid-column nutrient sample
NA	not applicable
NAD 83	North American Datum 1983
NE	northeast
NF	Near-field
nMDS	Non-metric Multidimensional Scaling
NNST	Ninespine Stickleback (<i>Pungitius pungitius</i>)
NW	northwest
OM	oocyte maturation
P	plankton sample
P _i	the proportion of the i th taxon
<i>P-value</i>	Probability value
<i>P</i> ₅₀	50% probability
<i>P</i>	Probability
PI	95% prediction intervals
PEL	Probable Effect Level
PG	Primary growth
POF	postovulatory follicle complex
QA	quality assurance

Term	Definition
QC	quality control
R	R statistic
r^2	coefficient of determination
RA1	Reference Area 1
RA2	Reference Area 2
REP	replicate
RNWH	Round Whitefish (<i>Prosopium cylindraceum</i>)
RPD	relative percent difference
S	south
Sc1	primary spermatocyte
Sc2	secondary spermatocyte
SD	standard deviation
SDI	Simpson's Diversity Index
SE	southeast
	standard error
SEI	Simpson's Evenness Index
Sg1	primary spermatogonia
Sg2	secondary spermatogonia
SLSC	Slimy Sculpin (<i>Cottus cognatus</i>)
SN	Seine Net
SQ	Sediment Quality Samples
SR	studentized residuals
SRSi	soluble reactive silica
SSW	south-southwest

Term	Definition
SSWQO	Site-Specific Water Quality Objectives
St	spermatid
STP	Sewage Treatment Plant
SW	southwest
Sz	spermatozoa
TDP	Total Dissolved Phosphorus
TDS	total dissolved solids
THST	Threespine Stickleback (<i>Gasterosteus aculeatus</i>)
TKN	Total Kjeldahl Nitrogen
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSI	Trophic State Index
TSS	total suspended solids
T-test	Two-sample t-test
Tukey's HSD	Tukey's Honest Significant Difference Test
TW	Calculated using total weight
UTM	Universal Transverse Mercator
Vtg1	primary vitellogenic
Vtg2	secondary vitellogenic
Vtg3	tertiary vitellogenic
W	west
WAD	weak acid dissociable
WNW	west-northwest

Term	Definition
WRS	Pairwise Wilcoxon Rank Sum Test
WSW	west-southwest

UNITS OF MEASURE

Unit	Definition
°C	degrees Celsius
cells/L	number of cells per litre
cm	Centimetre
g	Gram
h/hr	hours
m ²	square metres
Kg	Kilogram
Km	kilometre
m ²	square metres
mg	milligram
mg CaCO ₃ /L	milligrams calcium carbonate per litre
mg/kg dw	Milligram per kilogram dry weight
mg/kg ww	milligrams per kilogram wet weight
mg/L	milligrams per litre
mg/m ³	milligrams per cubic metre
mg-N/L	milligrams of nitrogen per litre
mg-P/L	milligrams of phosphorus per litre
mL	millilitre
mm	millimetre
Mt	Million tonnes
Org/L	Organism per litre
org/m ²	organisms per square metre
org/m ³	organisms per cubic metre
µg/g dw	micrograms per gram dry weight

Unit	Definition
µg/L	micrograms per litre
µm	micrometre
µS/cm	microsiemens per centimetre
NTU	nephelometric turbidity units
s	seconds
y/yr	years

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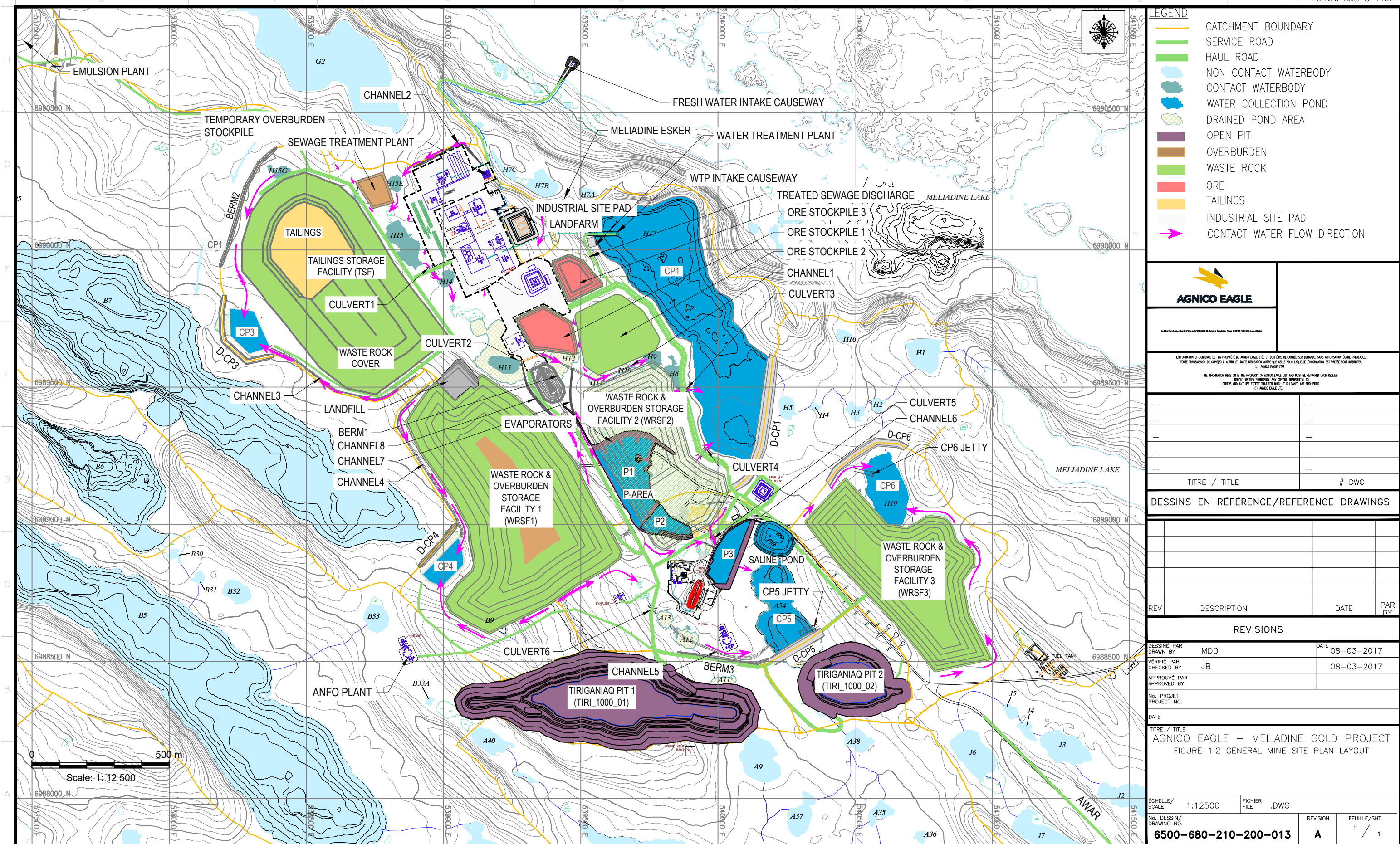
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APPENDIX 2A

Meliadine Mine Layout



APPENDIX 3A – 3F

Water Quality

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3A1.0 INTRODUCTION

This appendix describes the quality assurance and quality control (QA/QC) procedures implemented during the 2017 water quality monitoring program completed in support of the Aquatic Effects Monitoring Program (AEMP) for the Meliadine Gold Mine Project (Project). An evaluation of the QC data and implications for the interpretation of the AEMP study results is also included, along with procedures implemented to improve accuracy of in-situ measurements and to minimize data gaps.

Data integrity is determined by the QA/QC procedures that are applied during all aspects of a monitoring program, from sample collection to data analysis and reporting. Quality assurance (QA) procedures include training of personnel, data management, and other technical practices designed to confirm that high quality data are consistently generated. Quality control (QC) procedures include steps to measure and evaluate data quality, as well as the corrective actions that are applied when data quality objectives are not achieved.

3A2.0 QUALITY ASSURANCE

Quality assurance procedures implemented during the 2017 water quality monitoring program activities are classified into three categories of data management: field operations, laboratory analyses, and office operations.

3A2.1 Field Operations

Quality assurance procedures for field operations involve field crew training, pre-field meetings, and the use of standardized methods and explicit instructions for collecting and handling field data. Field staff for the Project were trained to be proficient in standardized field sampling procedures, data recording, and equipment operation. Field work was completed according to approved specific work instructions that were developed for the Project based on standardized technical procedures developed by Golder Associates Ltd. (Golder). Golder's technical procedures are consistent with information and field protocols described in relevant scientific literature (e.g., CCME 2011).

The specific work instructions for the water sampling programs included the exact locations of sampling sites and detailed step-by-step instructions for field tasks, including:

- equipment calibration and maintenance
- sample collection, handling, preservation, labelling, storage, and shipping
- record keeping and sample tracking

Contact information for members of the Project team and the analytical laboratory were also included in the work instructions, along with references to applicable technical procedures. Field data were recorded on standardized field data sheets or in a bound field notebook. Chain-of-custody forms were used to track samples sent to the analytical laboratory, and receipt of the samples at the laboratory was confirmed. The crew lead was responsible for tracking samples to confirm that all required samples were collected, chain-of-custody and analytical request forms were complete and correct, and that labelling and documentation procedures were followed. Field crews checked in with component managers, as needed, and submitted daily reports to provide updates on completed tasks.

Quality assurance procedures also included pre-field meetings held with the field crew and project/component manager prior to the start of each field program. The purpose of the field program, role of each crew member, specific details of the work instructions, equipment needs, field logistics, and contingency plans were discussed at each meeting.

3A2.2 Laboratory Analyses

Water samples collected in 2017 were analyzed by a Canadian Association for Laboratory Accreditation Inc. (CALA) accredited laboratory; therefore, confidence in the reliability of the analytical data produced by the laboratory is considered high. To receive accreditation, a laboratory must pass an evaluation of its internal procedures, analytical methods, and QC processes.

A designated member of the Project team was responsible for liaising with the analytical laboratory.

3A2.3 Office Operations

Quality assurance procedures implemented for office-based tasks included the following:

- having trained personnel complete data management, analysis, and reporting tasks
- using standardized data storage, manipulation, and summary tools, as required
- establishing a data management system to support consistency, QC, and data retrieval
- senior review of data deliverables at appropriate milestones

3A3.0 QUALITY CONTROL

Similar to QA procedures, QC procedures implemented during the 2017 water quality monitoring program activities can be classified into three categories: field operations, laboratory analyses, and office operations.

3A3.1 Field Operations

Quality control procedures implemented during field operations included the collection of QC samples, including the following:

- **Travel blanks:** These samples were used to detect sample contamination that could have resulted from ambient conditions in the field, during shipping, or at the laboratory. Travel blanks were provided by the laboratory and consisted of sample bottles filled with deionized water. They accompanied the water samples during all stages of storage and transportation, but were not exposed to sampling or filtering equipment.
- **Equipment blanks:** These samples were used to assess the adequacy of the decontamination of sample collection and filtration equipment. Equipment blanks consisted of deionized water provided by the analytical laboratory that has been rinsed through the field sampling equipment. The rinsate was then distributed to sample bottles, and handled in the same manner as the collected water samples (e.g., filtered for dissolved parameters and preserved, as required).

- **Field blanks:** These samples were used to detect potential sample contamination during sample collection, handling, shipping, and analysis. Field blanks consisted of deionized water provided by the analytical laboratory; the water was transported to a field sampling site, processed the same as the other surface water quality samples (e.g., filtered, preserved), and then submitted along with the other samples for analysis.
- **Duplicate samples:** These samples were used to check the precision of field sampling methods and laboratory analyses. Duplicate samples consisted of paired water samples collected at the same time and location, using the same methods.

Quality control samples collected in 2017 represented approximately 24% the total number of water samples submitted for analysis. All QC samples were submitted “blind” to the analytical laboratory and analyzed for the same set of parameters as the other water samples.

Winkler samples were collected periodically throughout the 2017 open-water (i.e., July and August) programs to confirm the reliability of in situ measurements. A Kemmerer was used to collect water from a depth at which a DO measurement was taken; water was then transferred to a biochemical oxygen demand bottle. Bottles were filled so that no air space was present in the sample bottle. Each DO titration was performed as soon as possible after sample collection. Dissolved oxygen (DO) concentrations determined based on the Winkler titrations were compared to corresponding meter readings.

3A3.2 Laboratory Analysis

Quality control samples were prepared by the analytical laboratory and analyzed along with the field-collected samples to confirm the quality and reliability of the analytical results. Quality control sample types included duplicate analyses, spiked samples, and method blanks.

The laboratory QC results were reviewed to confirm the quality of the data and to determine if the laboratory identified any questionable results or specific parameters. The laboratory QC results are not presented or discussed in this report.

3A3.3 Office Operations

Quality control operations implemented in the office focussed on confirming and maintaining the quality of in situ measurement data and analytical results, as well as verifying the accuracy of data summaries (i.e., summary statistics and plots). Field data entered into the Project database were compared against the field data sheets and field notebook to confirm their accuracy. Unaltered data files from the laboratory were saved to the Project directory and were used as a reference to confirm the accuracy of the data entered into the Project database. Laboratory data were also screened for quality (Section 3A-3.3.1). Backup files were created before each major data analysis operation and calculations were reviewed to confirm the accuracy of the results.

3A3.3.1 Laboratory Data Screening

A series of standard data screening steps were completed upon receipt of water chemistry results from the analytical laboratory to identify potential data quality issues including:

- verification that all requested parameters and samples were analyzed
- verification that the appropriate detection limits (DLs) were used and data were reported in the appropriate units
- verification that data for measured in situ field and laboratory parameters (e.g., specific conductivity)¹ were similar
- data logic checks (e.g., comparison of measured and calculated results for total dissolved solids; comparison of dissolved to total metals)
- identification of outliers
- review of the travel, field, and equipment blanks (Section 3A-3.5.2.1) for evidence of contamination
- review of duplicate sample results (Section 3A-3.5.2.2) for unacceptable variation
- review of laboratory QC results (i.e., sample temperature and integrity of containers upon receipt, holding times, laboratory blanks and recoveries from spiked samples, internal duplicates, ion balance, review of laboratory qualifiers and notes)
- review of the final dataset for completeness, and confirmation that sources of unexpected values and trends have been identified

Prompt completion of the screening steps allowed for potential re-analysis of samples by the laboratory to verify questionable data or to generate data for missing parameters. If samples were re-analyzed by the laboratory and the data were still considered questionable, qualifiers for consideration during data summary and analysis steps were added to the dataset, or the data were excluded from further analyses.

3A3.4 Quality Control Data Evaluation

3A3.4.1 Blanks

Analytical results for travel, field, and equipment blanks were reviewed and considered notable if concentrations were greater than or equal to five times the corresponding DL. This criterion is based on the United States Environmental Protection Agency (US EPA) Practical Quantitation Limit, which accounts for the potential for reduced accuracy when concentrations approach or are below DLs (Alberta Environment 2006; US EPA 2000). Because DLs do not apply to the pH in the deionized water used to prepare field blanks, pH is considered an exception to this criterion.

¹ If large discrepancies were identified, the laboratory data were considered correct.

In the event that parameter concentrations in the blank samples exceeded five times the DL, the results were examined to determine if:

- the concentration in a blank QC sample was higher than the concentrations measured in corresponding surface water samples
- the result is limited to a single blank sample or if it is apparent in corresponding water samples
- there was a consistent bias in the results for the parameter across all samples
- if the notable result was severe enough to warrant invalidating the affected data

3A3.4.2 Duplicate Samples

Differences between concentrations measured in duplicate water samples were evaluated based on the relative percent difference (RPD):

$$RPD = \frac{C1 - C2}{\frac{(C1 + C2)}{2}} * 100$$

Where: RPD is relative percentage difference

C1 is the concentrations in the first sample

C2 is the concentration in the second or duplicate sample

The RPD was only calculated if both of the paired concentrations in the duplicate samples were greater than five times the DL. The RPD for a given parameter was flagged if it was greater than 20%. The number of flagged parameters was compared to the total number of analyzed parameters to evaluate analytical precision. Analytical precision was rated as follows:

- high, if fewer than 10% of parameters were flagged
- moderate, if 10 to 30% of parameters were flagged
- low, if more than 30% were flagged

3A3.4.3 Dissolved and Total Concentrations

Dissolved nutrient and metal concentrations were compared to total concentrations as a measure of analytical precision (Section 3A-3.5.2.3). Where results of the total and dissolved concentrations were more than five times the DL and the RPD between the dissolved and total concentration was more than or equal to 20%, the dissolved concentration was flagged as suspicious.

3A3.4.4 Notable Results

For any notable results identified, the laboratory was contacted as soon as possible to confirm the results and re-run the analyses (if necessary). If the original results were confirmed by the laboratory, data were reviewed further to identify other causes for the notable results, including field sampling procedures, and where necessary, implementation of corrective measures before the subsequent sampling event. Invalidation of data, where necessary, was not completed on samples from a single sampling event but rather was based on the results for all samples collected during the annual program.

3A3.5 Quality Control Results

3A3.5.1 Water Quality Field Measurements

The multi-parameter Manta II water quality meter was used to collect in situ measurements of water temperature, pH, DO, and specific conductivity throughout the water column at each sampling site in 2017. Although maintenance and calibration procedures were completed, as specified in the specific work instructions (Section 3A-2.1), these meters occasionally did not function reliably for DO during ice-covered conditions, when cold conditions can affect the functionality of the probes (Table 3A-1). Dissolved oxygen concentrations determined based on the Winkler titrations that were completed during the open-water sampling programs were in good agreement with corresponding in situ meter readings (the average RPD between paired DO results was 8.27%; Table 3A-2).

Table 3A-1: In-Situ Measurements Data Quality Summary

Quality Criteria	Deficiencies		Decision
	Affected Sampling Station	Description	
Probes are in working order	MEL-01 and MEL-02	Maintenance and calibration was completed, but once in the field, the DO probe was not functioning properly during ice-covered conditions (January and February)	Collect samples for Winkler titration and compare results
Data are within expected ranges for northern lakes	MEL-01	86% of the DO concentrations measured during ice-covered conditions (January and February) were above the expected range ^(a)	DO concentrations above the expected range were excluded from analyses
	MEL-02	92% of the DO concentrations measured during ice-covered conditions (January and February) were above the expected range ^(a)	

Notes: ^(a) the expected or acceptable range of DO values included a maximum concentration of 14 mg/L; DO = dissolved oxygen.

To confirm that the final dataset of in-situ measurements was of the highest quality possible, it was determined that the in situ DO concentrations greater than 14 mg/L recorded in winter of 2017 during ice-covered conditions would be excluded from the baseline report.

Table 3A-2: Comparison of Winkler Tests Results and Dissolved Oxygen Probe Results

Station	Date	Winkler DO Result (mg/L)	DO Probe Result (mg/L)	RPD (%)
MEL-01-04	16 July 2017	10.6	10.6	0
MEL-03-04	21 July 2017	11.2	11.1	0.90
A8-03	17 July 2017	10.3	10.1	1.96
D7-01	22 July 2017	11.0	11.2	1.80
MEL-01-05	9 August 2017	8.7	10.5	18.75
MEL-03-05	13 August 2017	10.2	10.9	6.64
MEL-04-05	15 August 2017	9.7	10.7	9.80
MEL-05-05	12 August 2017	10.0	10.8	7.69
A8-03	14 August 2017	9.9	10.8	8.70
B7-03	8 August 2017	9.4	10.9	14.78
D7-03	10 August 2017	9.0	11.0	20.00
Average				8.27

Notes: DO – dissolved oxygen; RPD = relative percent difference; mg/L = milligrams per litre; % = percent.

3A3.5.2 Laboratory Results

To maintain sample integrity, water samples for laboratory analyses were submitted as soon as possible after collection. However, holding time exceedances are a common issue for unpreserved water samples collected during water quality programs in remote areas, because transport of samples to the laboratory is subject to the availability of scheduled charter flights. Holding times may also be exceeded for preserved and unpreserved samples if the laboratory is unable to initiate testing promptly following sample receipt. Analytical hold times were met for most parameters, with the exception of pH, total dissolved solids, total suspended solids, turbidity, nitrate, nitrite, and orthophosphate for some or all samples.

Through the 2017 water quality program, 12 blank samples and 10 discrete duplicate samples were collected at Meliadine Lake and Peninsula lakes (Table 3A-3). Review of results are provided in Sections 3A-3.5.2.1 and 3A-3.5.2.2 and a comparison of dissolved to total concentrations provided in Section 3A-3.5.2.3.

Table 3A-3: Count of Quality Control Samples Collected During the 2017 Water Quality Programs

QC Type	Ice-covered Conditions		Open-water Conditions			Total
	19 to 20 January	18 to 19 February	16 to 23 July	8 to 15 August	1 to 5 September	
Blank Samples						12
Field Blank	0	2	0	2	1	5
Equipment Blank	0	2	1	1	1	5
Travel Blank	0	2	0	0	0	2
Duplicates	0	2	3	4	1	10

3A3.5.2.1 Blank Samples

A total of 12 blank QC samples were collected and analyzed during the 2017 water quality monitoring program, including five field blanks, five equipment blanks, and two travel blanks (Table 3A-3). All parameter concentrations in the blank samples that were above the corresponding DL were reviewed individually (Table 3A-4). Of all the parameters analyzed in the 12 QC samples, notable detections (i.e., parameter concentrations that were measured at more than five times the DL) were 2.1% of all blank sample results. Results by each type of blank sample are reviewed below.

Equipment blanks had the highest number of notable detections (i.e., 3.1%; concentrations more than five times the DL). Of the notable detections, most were found in the equipment blank during the ice-covered conditions program in February. Parameters with notable detections in equipment blank samples were: ions (calcium and sodium), nutrients (nitrate, dissolved and total phosphorus), total metals (antimony, manganese and zinc), and dissolved metals (antimony, barium, lead and zinc) from equipment blanks collected in February, July, August, and September (Table 3A-4).

Field blanks had 1.3% notable detections and were limited to sodium, total and dissolved phosphorus, and dissolved antimony from field blanks collected in February and September; there were no notable detections in the August field blank (Table 3A-4).

Travel blanks had 1.2% notable results and were related to total and dissolved phosphorus from one of the February travel blanks (Table 3A-4).

The notable detections in the water quality field, equipment, and travel blank samples were not of a magnitude that would be expected to have any influence on the results for the surface water quality samples (i.e., the results for the field blanks were considered acceptable). With the exception of total and dissolved phosphorus, notable results measured in blank samples were in concentrations considerably (one or two orders of magnitude) lower than concentrations in the water quality samples collected during the program. Total and dissolved phosphorus results measured during the February sampling program were deemed unreliable and excluded from data analysis due to potential contamination as indicated by the blank samples results.

3A3.5.2.2 Discrete Water Quality Duplicate Samples

During the 2017 sampling program, 10 duplicate discrete samples were collected (Tables 3A-3 and 3A-5). Of the 10 pairs of duplicate samples, three duplicates (i.e., MEL-05-01 [August], MEL-04-05 [August], and MEL-02-05 [September]) had moderate analytical precision (between 10 and 25% of the duplicate parameters were notable); the rest of duplicate samples had high analytical precision (between 1 and 7% of the duplicate parameters were notable).

Parameters that had notable results (i.e., parameter concentration higher than five time DL and RPD greater than 20%) in at least one duplicate sample included the following:

- Calcium (September), total suspended solids (September), total alkalinity (February), dissolved organic carbon (August)
- Nutrients (nitrate [September], total phosphorus [February and July] and dissolved phosphorus [February and September])
- Total metals (aluminum [July, August, and September], arsenic [August and September], cobalt [August], copper [July and August], iron [August and September], lead [August and September], manganese [August], nickel [August], tin [September], and zinc [July, August, and September])
- Dissolved metals (aluminum [July and September], cobalt [July and August], copper [September], iron [July, August, and September], lead [August and September], manganese [July, August, and September], nickel [September], tin [August and September], uranium [August], and zinc [July, August, and September])

The overall analytical precision for 2017 water quality program was 7.3 % and was considered high.

3A3.5.2.3 Dissolved to Total Results Comparison

Dissolved concentrations measured in the discrete water quality samples were compared to their corresponding total concentrations. During the 2017 sampling program, 2.7% of the dissolved parameter concentrations in the dataset failed to meet quality criteria (i.e., total and dissolved concentrations were more than five times the DL, and dissolved concentrations were more than 20% higher than total concentrations). These parameters included dissolved aluminum, arsenic, cesium, copper, cobalt, iron, lead, manganese, nickel, tin, uranium, zinc, and zirconium.

Based on these results, the overall precision of the discrete water quality dataset is considered high.

Table 3A-4: Results of Water Quality Blank Samples Collected in 2017

Sample Type	Units	DL1 ^(a)	DL2 ^(a)	DL3 ^(a)	Alert Limit	Field Blank	Equipment Blank	Travel Blank	Field Blank	Equipment Blank	Trip Blank	Equipment Blank	Field Blank	Field Blank	Equipment Blank	Equipment Blank	Field Blank			
Sampling Season						Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Open-water	Open-water	Open-water	Open-water	Open-water	Open-water
Sample Collection Date						18-Feb-17	18-Feb-17	18-Feb-17	19-Feb-17	19-Feb-17	19-Feb-17	18-Jul-17	14-Aug-17	15-Aug-17	16-Aug-17	1-Sep-17	5-Sep-17			
Conventional Parameters																				
Hardness, as CaCO ₃	mg/L	1.0	-	-	>5X DL	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			
pH	pH units	0.1	-	-	>5X DL	4.62	5.34	5.11	5.37	5.15	5.04	5.57	5.31	5.18	5.23	5.2	5.03			
Specific conductivity	µS/cm	0.2	2.0	-	>5X DL	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0			
Total alkalinity, as CaCO ₃	mg/L	2.0	-	-	>5X DL	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0			
Total dissolved solids	mg/L	3.0	4.0	10	>5X DL	<4.0	<4.0	<4.0	4.9	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0			
Total dissolved solids (calculated)	mg/L	1.0	-	-	>5X DL	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			
Total suspended solids	mg/L	5.0	1.0	-	>5X DL	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			
Turbidity	NTU	0.10	-	-	>5X DL	0.15	0.13	<0.10	0.14	0.16	<0.10	0.1	0.23	0.26	0.27	0.15	0.16			
Major Ions																				
Bicarbonate	mg/L	5.0	-	-	>5X DL	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0			
Calcium	mg/L	0.020	-	-	>5X DL	<0.020	0.026	<0.020	0.044	0.306	<0.020	0.058	<0.020	<0.020	0.036	<0.020	0.031			
Carbonate	mg/L	5.0	-	-	>5X DL	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0			
Chloride	mg/L	0.50	-	-	>5X DL	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50			
Fluoride	mg/L	0.020	-	-	>5X DL	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020			
Hydroxide	mg/L	5.0	-	-	>5X DL	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0			
Magnesium	mg/L	0.0040	-	-	>5X DL	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050			
Potassium	mg/L	0.020	-	-	>5X DL	<0.020	<0.020	<0.020	0.033	<0.020	<0.020	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Sodium	mg/L	0.0050	-	-	>5X DL	<0.0050	<0.0050	<0.0050	0.0337	<0.0050	<0.0050	0.145	<0.010	<0.010	0.028	<0.010	0.014			
Sulphate	mg/L	0.050	-	-	>5X DL	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Other Parameters																				
Cyanide	mg/L	0.0020	0.0050	-	>5X DL	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010			
Nutrients and Chlorophyll a																				
Dissolved phosphorus	mg/L	0.0010	-	-	>5X DL	0.0169	0.0134	0.0016	0.0293	0.0016	0.0222	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010			
Nitrate	mg/L	0.0050	-	-	>5X DL	<0.0050	<0.0050	<0.0050	<0.0050	0.0304	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050			
Nitrate + nitrite	mg/L	0.0051	-	-	>5X DL	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051			
Nitrite	mg/L	0.0010	-	-	>5X DL	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010			
Orthophosphate	mg/L	0.0010	-	-	>5X DL	<0.0010	0.0031	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010			
Total ammonia	mg/L	0.0050	-	-	>5X DL	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050			
Total Kjeldahl nitrogen	mg/L	0.050	-	-	>5X DL	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Total nitrogen	mg/L	0.050	-	-	>5X DL	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Total phosphorus	mg/L	0.0010	-	-	>5X DL	0.0058	0.0466	0.0024	0.0054	0.0224	0.0357	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010			
Total organic carbon	mg/L	0.50	-	-	>5X DL	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50			
Dissolved organic carbon	mg/L	0.50	0.56	-	>5X DL	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50			
Reactive silica, as SiO ₂	mg/L	0.010	-	-	>5X DL	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010			
Silica	mg/L	0.010	-	-	>5X DL	-	-	-	-	-	-	-	-	-	-	-	-			
Total Metals																				
Aluminum	mg/L	0.00030	-	-	>5X DL	<0.00030	0.00079	<0.00030	<0.00030	<0.00030	<0.00030	<0.00070	<0.00070	<0.00070	0.00078	<0.00070	<0.00070			
Antimony	mg/L	0.000020	-	-	>5X DL	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000527	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020			
Arsenic	mg/L	0.000020	-	-	>5X DL	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020			
Barium	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000049	<0.000020	<0.000020	0.000028	<0.000020	<0.000020			
Beryllium	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010			
Bismuth	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050			
Boron	mg/L	0.0010	-	-	>5X DL	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050			
Cadmium	mg/L	0.0000050	-	-	>5X DL	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050			
Chromium	mg/L	0.00006	-	-	>5X DL	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010			
Cobalt	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050			
Copper	mg/L	0.00010	-	-	>5X DL	<0.00010	0.00015	<0.00010	<0.00010	0.00013	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010			
Iron	mg/L	0.0010	-	-	>5X DL	<0.0010	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010			
Lead	mg/L	0.000010	-	-	>5X DL	<0.000010	0.000044	<0.000010	<0.000010	0.000038	<0.000010	<0.000010	<0.000010	<0.000010	0.000018	<0.000010	<0.000010			
Lithium	mg/L	0.00050	-	-	>5X DL	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050			
Manganese	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.00009	<0.000050	<0.000050	0.000263	<0.000050	<0.000050			
Mercury	ug/L	0.00050	0.00060	-	>5X DL	<0.50	0.7	<0.50	<0.50	<0.50	<0.50	0.6	<0.50	<0.50	1.9	0.7	<0.50			
Molybdenum	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050			
Nickel	mg/L	0.000060	-	-	>5X DL	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050			
Selenium	mg/L	0.000040	-	-	>5X DL	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040			
Silicon	mg/L	0.050	-	-	>5X DL	-	-	-	-	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Silver	mg/L	0.000005	-	-	>5X DL	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050			
Strontium	mg/L	0.000050	-	-	>5X DL	<0.000050	0.0001	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050			
Sulphur	mg/L	0.50	-	-	>5X DL	-	-	-	-	-	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50			
Thallium	mg/L	0.000005	-	-	>5X DL	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020			
Tin	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020			

Sample Type	Units	DL1 ^(a)	DL2 ^(a)	DL3 ^(a)	Alert Limit	Field Blank	Equipment Blank	Travel Blank	Field Blank	Equipment Blank	Trip Blank	Equipment Blank	Field Blank	Field Blank	Equipment Blank	Equipment Blank	Field Blank
Sampling Season						Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Ice-covered	Open-water	Open-water	Open-water	Open-water	Open-water	Open-water
Sample Collection Date						18-Feb-17	18-Feb-17	18-Feb-17	19-Feb-17	19-Feb-17	19-Feb-17	18-Jul-17	14-Aug-17	15-Aug-17	16-Aug-17	1-Sep-17	5-Sep-17
Titanium	mg/L	0.00010	-	-	>5X DL	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Uranium	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.0000030	<0.0000030	<0.0000030	<0.0000030	<0.0000030	<0.0000030
Vanadium	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Zinc	mg/L	0.00080	-	-	>5X DL	<0.00080	0.00495	<0.00080	<0.00080	0.00342	<0.00080	0.00068	<0.00050	<0.00050	0.00204	0.00163	<0.00050
Zirconium	mg/L	0.00030	-	-	>5X DL	-	-	-	-	-	-	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals																	
Aluminum	mg/L	0.00030	-	-	>5X DL	<0.00030	0.00031	<0.00030	<0.00030	0.00043	<0.00030	0.00109	<0.00050	<0.00050	0.00076	0.00051	<0.00050
Antimony	mg/L	0.000020	-	-	>5X DL	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000218	0.000174
Arsenic	mg/L	0.000020	-	-	>5X DL	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Barium	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	0.000085	<0.000050	<0.000050	0.000083	<0.000020	<0.000020	0.000147	0.000032	<0.000020
Beryllium	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Bismuth	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Boron	mg/L	0.0010	-	-	>5X DL	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium	mg/L	0.0000050	-	-	>5X DL	<0.0000050	<0.0000050	<0.0000050	0.0000055	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Chromium	mg/L	0.000060	-	-	>5X DL	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	0.00021	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.0000143	<0.0000050	<0.0000050	0.0000246	<0.0000050	<0.0000050
Copper	mg/L	0.00010	-	-	>5X DL	<0.00010	0.00013	<0.00010	0.00013	0.00039	<0.00010	0.00014	<0.00010	<0.00010	0.00012	<0.00010	<0.00010
Iron	mg/L	0.0010	-	-	>5X DL	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lead	mg/L	0.000010	-	-	>5X DL	<0.000010	0.000079	<0.000010	0.000015	<0.000010	<0.000010	0.0000099	<0.0000050	0.0000182	0.0000205	<0.0000050	0.0000074
Lithium	mg/L	0.00050	-	-	>5X DL	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00074	<0.00050	<0.00050
Manganese	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	0.000069	<0.000050	<0.000050	0.000087	<0.000050	<0.000050	0.00022	0.000201	<0.000050
Mercury	µg/L	0.00050	-	-	>5X DL	<0.50	0.7	<0.50	<0.50	<0.50	<0.50	0.5	<0.50	<0.50	2	0.6	<0.50
Molybdenum	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Nickel	mg/L	0.000060	-	-	>5X DL	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Selenium	mg/L	0.000040	-	-	>5X DL	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040
Silicon	mg/L	0.050	-	-	>5X DL	-	-	-	-	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Silver	mg/L	0.0000050	-	-	>5X DL	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Strontium	mg/L	0.000050	-	-	>5X DL	<0.000050	0.000116	<0.000050	0.000114	0.000168	<0.000050	0.00019	<0.00010	<0.00010	0.00011	<0.00010	<0.00010
Sulphur	mg/L	0.50	-	-	>5X DL	-	-	-	-	-	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Thallium	mg/L	0.0000050	-	-	>5X DL	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020
Tin	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000037	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Titanium	mg/L	0.00010	-	-	>5X DL	-	-	-	-	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Uranium	mg/L	0.000010	-	-	>5X DL	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020
Vanadium	mg/L	0.000050	-	-	>5X DL	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Zinc	mg/L	0.00080	-	-	>5X DL	<0.00080	0.00799	<0.00080	0.00179	<0.00080	<0.00080	0.00185	<0.00050	<0.00050	0.00107	0.00062	<0.00050
Zirconium	mg/L	0.00030	-	-	>5X DL	-	-	-	-	-	-	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060

(a) Samples were typically analyzed at DL1; however, a second (DL2) or third (DL3) DL was required for some parameters.

Note: **Bolded** values were over fives times the DL and therefore failed the QC check.

DL = detection limit; mg/L = milligrams per litre; - = no data/not applicable; >5X = greater than five times; < = less than; CaCO₃ = calcium carbonate; µS/cm = microSiemens per centimetre; NTU = Nephelometric Turbidity Units; SiO₂ = silicon dioxide; µg/L = micrograms per litre.

Table 3A-5: Water Quality Results in Duplicate Samples Collected in 2017

Location		Units	DL1 ^(a)	DL2 ^(a)	DL3 ^(a)	DL4 ^(a)	RPD Alert Limit	MEL-01-05			MEL-02-04			MEL-01-05			A8-01			B7-03			MEL-02-01			MEL-05-01			MEL-03-01			MEL-04-05			MEL-02-05		
Sample Name								Sample Ice-covered	Duplicate Ice-covered	RPD (%)	Sample Ice-covered	Duplicate Ice-covered	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)	Sample Open-water	Duplicate Open-water	RPD (%)
Sampling Season																																					
Sample Collection Date																																					
Conventional Parameters																																					
Hardness, as CaCO ₃	mg/L	1.0	-	-	-	-	>20%	28.2	28.4	0.7	26.9	26.3	2.3	24.4	24.3	0.4	113	114	0.9	63.2	64.2	1.6	23	22.2	3.5	22.6	22.4	0.9	20	20.2	1	20.7	20.2	2.4	22.3	26.6	17.6
pH	pH units	0.1	-	-	-	-	>20%	7	6.98	0.3	6.98	6.99	0.1	7.19	7.22	0.4	7.67	7.78	1.4	7.63	7.66	0.4	7.31	7.41	1.4	7.44	7.45	0.1	7.41	7.3	1.5	7.13	7.15	0.3	7.27	7.21	0.8
Specific conductivity	µS/cm	0.2	2	-	-	-	>20%	96.5	95.3	1.3	88	88.3	0.3	79.3	78.8	0.6	305	300	1.7	161	161	0	74.9	76	1.5	73.3	73	0.4	69	70.2	1.7	68.4	67.5	1.3	73.5	76.3	3.7
Total alkalinity, as CaCO ₃	mg/L	2.0	-	-	-	-	>20%	13	16.6	24.3	16.5	17.6	6.5	16.7	16.3	2.4	47.4	46	3	37.3	37.7	1.1	16.3	16.5	1.2	17.5	17.4	0.6	15.9	16.1	1.3	15.8	15.5	1.9	16.9	17.2	1.8
Total dissolved solids	mg/L	13	4.0	20	10	-	>20%	53	52	n/c	62	58	n/c	51	45	n/c	197	194	1.5	102	105	2.9	46	47	n/c	41	40	n/c	43	34	n/c	32	30	n/c	53	52	n/c
Total dissolved solids (calculated)	mg/L	1.0	-	-	-	-	>20%	44	46	4.4	42.9	43.2	0.7	40.8	40.5	0.7	151	150	0.7	76.7	77.8	1.4	38	37.4	1.6	36.3	36.3	0	33.7	34.1	1.2	34.6	33.8	2.3	38.6	41.4	7
Total suspended solids	mg/L	3.0	5.0	1.0	-	-	>20%	<1.0	1.3	n/c	1.1	<1.0	n/c	<1.0	1.2	n/c	<1.0	<1.0	n/c	1.1	<1.0	n/c	1.1	1	n/c	<1.0	<1.0	n/c	<1.0	<1.0	n/c	<1.0	1	n/c	3.3	6.6	66.7
Turbidity	NTU	0.10	-	-	-	-	>20%	0.15	0.15	n/c	0.18	0.18	n/c	0.37	0.34	n/c	0.5	0.52	3.9	0.44	0.38	n/c	0.28	0.35	n/c	0.25	0.25	n/c	0.29	0.26	n/c	0.29	0.4	n/c	0.53	0.5	5.8
Major Ions																																					
Bicarbonate	mg/L	5.0	-	-	-	-	>20%	15.8	20.3	n/c	20.1	21.5	n/c	20.4	19.9	n/c	57.8	56.1	3	45.5	46	1.1	19.9	20.1	n/c	21.4	21.2	n/c	19.4	19.6	n/c	19.3	18.9	n/c	20.6	21	n/c
Calcium	mg/L	0.020	-	-	-	-	>20%	8.92	8.76	1.8	8.21	8.18	0.4	7.73	7.68	0.6	37.4	37.5	0.3	20.7	21.6	4.3	7.15	6.91	3.4	7.14	7.06	1.1	6.25	6.39	2.2	6.57	6.42	2.3	7	8.64	21
Carbonate	mg/L	5.00	-	-	-	-	>20%	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c
Chloride	mg/L	0.50	-	-	-	-	>20%	12.5	12.3	1.6	11.1	11.1	0	10.5	10.5	0	60	60.2	0.3	20.3	20.3	0	9.48	9.36	1.3	8.34	8.41	0.8	8.19	8.16	0.4	8.17	8.13	0.5	9.39	9.57	1.9
Fluoride	mg/L	0.020	-	-	-	-	>20%	0.029	0.028	n/c	0.027	0.027	n/c	0.026	0.025	n/c	0.036	0.035	n/c	<0.020	0.025	n/c	0.032	0.027	n/c	0.028	0.026	n/c	0.024	0.029	n/c	0.029	0.028	n/c	0.024	0.026	n/c
Hydroxide	mg/L	5.00	-	-	-	-	>20%	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c	<5.0	<5.0	n/c
Magnesium	mg/L	0.0040	-	-	-	-	>20%	1.54	1.55	0.6	1.39	1.4	0.7	1.24	1.24	0	4.99	4.94	1	2.36	2.5	5.8	1.25	1.21	3.3	1.15	1.15	0	1.07	1.02	4.8	1.04	1.01	2.9	1.18	1.21	2.5
Potassium	mg/L	0.020	-	-	-	-	>20%	1.07	1.09	1.9	1.02	1.04	1.9	0.999	0.904	0.6	2.02	2.02	0	1.23	1.39	12.2	0.957	0.935	2.3	0.907	0.905	0.2	0.875	0.824	6	0.845	0.814	3.7	0.989	1.05	6
Sodium	mg/L	0.0050	-	-	-	-	>20%	5.83	6.08	4.2	5.43	5.53	1.8	4.97	4.95	0.4	8.27	8.25	0.2	3.95	4.11	4	4.77	4.61	3.4	4.27	4.39	2.8	4.07	4.09	0.5	4.17	3.98	4.7	4.85	5.14	5.8
Sulphate	mg/L	0.30	0.050	-	-	-	>20%	5.47	5.46	0.2	4.71	4.68	0.6	4.72	4.7	0.4	8.54	8.58	0.5	4.71	4.74	0.6	4.12	3.98	3.5	3.63	3.6	0.8	3.35	3.6	7.2	3.94	3.83	2.8	3.94	4.06	3
Other Parameters																																					
Cyanide	mg/L	0.0050	0.0020	-	-	-	>20%	<0.0020	<0.0020	n/c	<0.0020	<0.0020	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c
Nutrients and Chlorophyll a																																					
Dissolved phosphorus	mg/L	0.0010	-	-	-	-	>20%	0.0155	0.0336	73.7	0.0105	0.0176	50.5	0.0023	0.0039	n/c	0.002	0.0025	n/c	0.0028	0.0027	n/c	0.0026	0.0038	n/c	0.0022	0.0018	n/c	0.0015	0.0019	n/c	0.0014	0.0022	n/c	0.0035	0.0072	69.2
Nitrate	mg/L	0.0050	-	-	-	-	>20%	0.0071	0.0095	n/c	0.0069	0.0097	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	0.144	0.211	37.7
Nitrate + nitrite	mg/L	0.0051	-	-	-	-	>20%	0.0071	0.0107	n/c	0.0069	0.0097	n/c	<0.0051	<0.0051	n/c	<0.0051	<0.0051	n/c	<0.0051	<0.0051	n/c	<0.0051	<0.0051	n/c	<0.0051	<0.0051	n/c	<0.0051	<0.0051	n/c	<0.0051	<0.0051	n/c	0.144	0.211	n/c
Nitrite	mg/L	0.0010	-	-	-	-	>20%	<0.0010	0.0012	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	0.0011	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c
Orthophosphate	mg/L	0.0010	-	-	-	-	>20%	0.0014	<0.0010	n/c	0.0011	0.0012	n/c	0.0011	0.0011	n/c	<0.0010	<0.0010	n/c	0.0012	0.0012	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	<0.0010	n/c	<0.0010	0.0011	n/c	<0.0010	<0.0010	n/c
Total ammonia	mg/L	0.0050	-	-	-	-	>20%	0.0238	0.0239	n/c	0.0186	0.022	n/c	<0.0050	<0.0050	n/c	0.0084	0.0097	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	<0.0050	n/c	<0.0050	0.0085	n/c
Total Kjeldahl nitrogen	mg/L	0.050	-	-	-	-	>20%	0.19	0.16	n/c	0.124	0.094	n/c	0.176	0.218	n/c	0.304	0.348	13.5	0.341	0.359	5.1	0.159	0.163	n/c	0.138	0.114	n/c	0.129	0.135	n/c	0.137	0.121	n/c	0.22	0.255	14.7
Total nitrogen	mg/L	0.050	-	-	-	-	-	0.197	0.17	n/c	0.131	0.104	n/c	0.176	0.218	n/c	0.304	0.348	13.5	0.341	0.359	5.1	0.159	0.163	n/c	0.138	0.114	n/c	0.13	0.135	n/c	0.137	0.121	n/c	0.364	0.466	24.6
Total phosphorus	mg/L	0.0010	-	-	-	-	>20%	0.0251	0.0322	24.8	0.0221	0.0164	29.6	0.0052	0.0057	9.2	0.0074	0.0057	26	0.0056	0.0073	26.4	0.0043	0.0037	n/c	0.0031	0.0034	n/c	0.003	0.0041	n/c	0.0031	0.0028	n/c	0.0079	0.0074	6.5
Total organic carbon	mg/L	0.50	0.74	-	-	-	>20%	3.58	3.61	0.8	3.03	3.06	1	3.03	3.1	2.3	3.61	3.6	0.3	4.79	4.23	12.4	2.92	3	2.7	2.66	2.09	24	2.14	2.29	n/c	2.29	2.34	n/c	2.91	3.08	5.7
Dissolved organic carbon	mg/L	0.50	1.0	-	-	-	>20%	3.57	3.59	0.6	2.94	2.9																									

3A3.6 Data Quality Summary

The results of the QC review (Section 3A-3.5) indicated that the water quality data recorded in the field and reported by the laboratory were of generally high quality. Key findings are summarized in Table 3A-6.

Table 3A-6: Data Quality Summary during 2017 Water Quality Programs

QC Criteria	QC Sample Type	Findings
Probes functioning as intended and measurements are within expected ranges and in agreement with corresponding laboratory results	Review of in-situ measurements	20% of DO measurements were above the expected range; all exceedances occurred in winter
Parameters concentration should be less than five time detection limit	Equipment blanks	3.1% of parameters failed to meet the criteria
		Affected parameters included calcium, sodium, nitrate, total and dissolved phosphorus, total and dissolved antimony, total manganese, total and dissolved zinc, dissolved barium, and dissolved lead
	Field blanks	1.3% of parameters failed to meet the criteria
		Affected parameters included sodium, total and dissolved phosphorus, and dissolved antimony
	Travel blanks	1.2% of parameters failed to meet the criteria
		Affected parameters included total and dissolved phosphorus
Parameters with concentrations greater than five time detection limit should not differ by more than 20% in duplicate samples	Duplicates – discrete samples	7.5% of paired concentrations in duplicate samples failed this criteria
		Affected parameters included calcium, total suspended solids, total alkalinity, dissolved organic carbon, nitrate, total and dissolved phosphorus, total and dissolved aluminum, total arsenic, total and dissolved cobalt, total and dissolved copper, total and dissolved iron, total and dissolved lead, total and dissolved manganese, total and dissolved nickel, total and dissolved tin, total and dissolved zinc, and dissolved uranium.
Parameters with total and dissolved concentrations greater than five times detection limit, the dissolved concentration should be no more than 20% higher than the total concentration	Dissolved to total comparison – discrete samples	2.7% of parameters failed to meet the criteria
		Affected parameters included dissolved aluminum, arsenic, cesium, copper, cobalt, iron, lead, manganese, nickel, tin, uranium, zinc, and zirconium.
	Dissolved to total comparison – blanks	1.7% of parameters failed to meet the criteria
		Affected parameters included dissolved antimony and barium.

The water quality data are considered adequate to meet the needs of the AEMP for the Project.

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- Alberta Environment. 2006. Guidelines for Quality Assurance and Quality Control in Surface Water Quality Programs in Alberta. Edmonton, AB, Canada. 67 pp. ISBN: 0-7785-5081-8 (Print Edition); 0-7785-5082-6 (On-line Edition).
- CCME (Canadian Council of Ministers of the Environment) 2011. Protocol Manual for Water Quality Sampling in Canada. Canadian Council of Ministers of the Environment. 2011.
- USEPA (United States Environmental Protection Agency). 2000. EPA Quality Manual for Environmental Programs. CIO 2105-P-01-0 (formerly 5360 A1).

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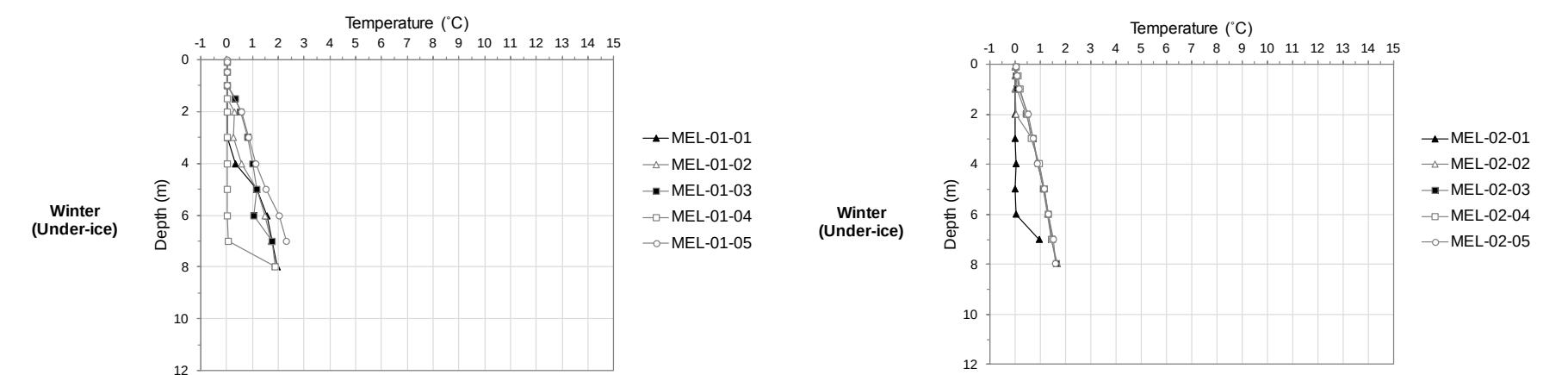
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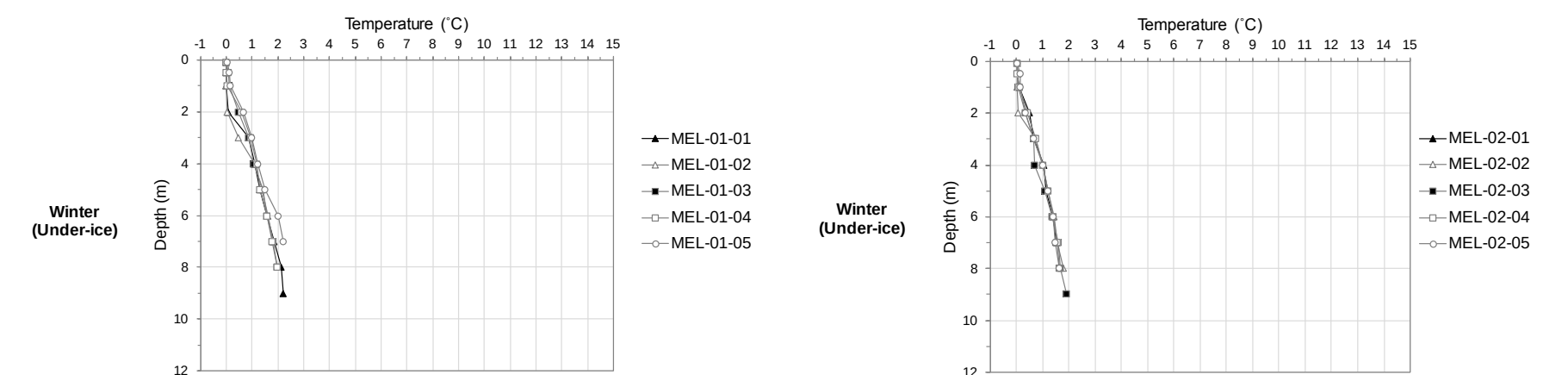
3B1.0 MELIADINE LAKE

3B1.1 TEMPERATURE



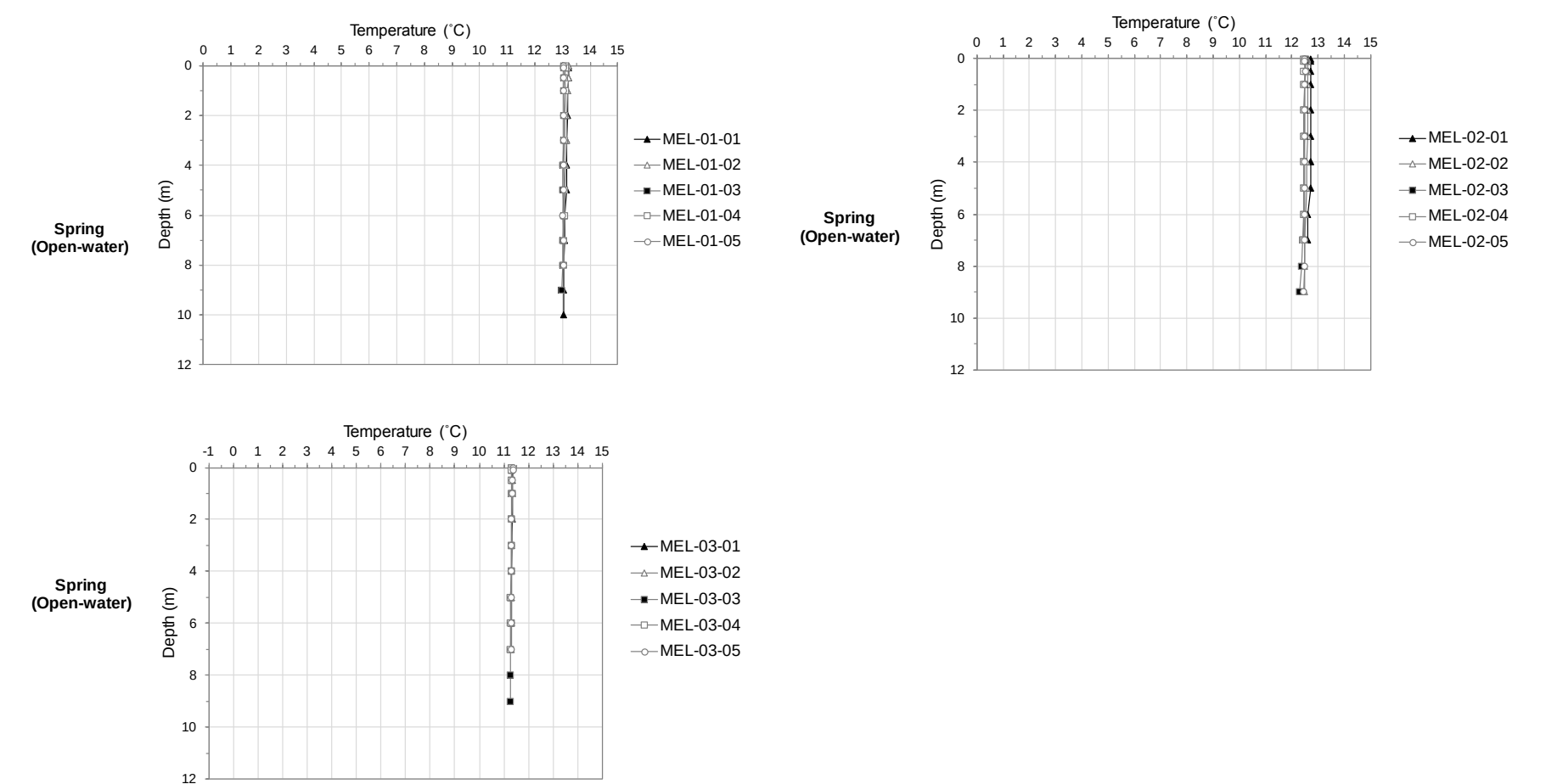
m = metre; °C = degrees Celsius; MEL-01 = near-field; MEL-02 = mid-field.

Figure 3B.1-1: Temperature (°C) Profiles at Stations on Meliadine Lake, Under-ice (January) 2017



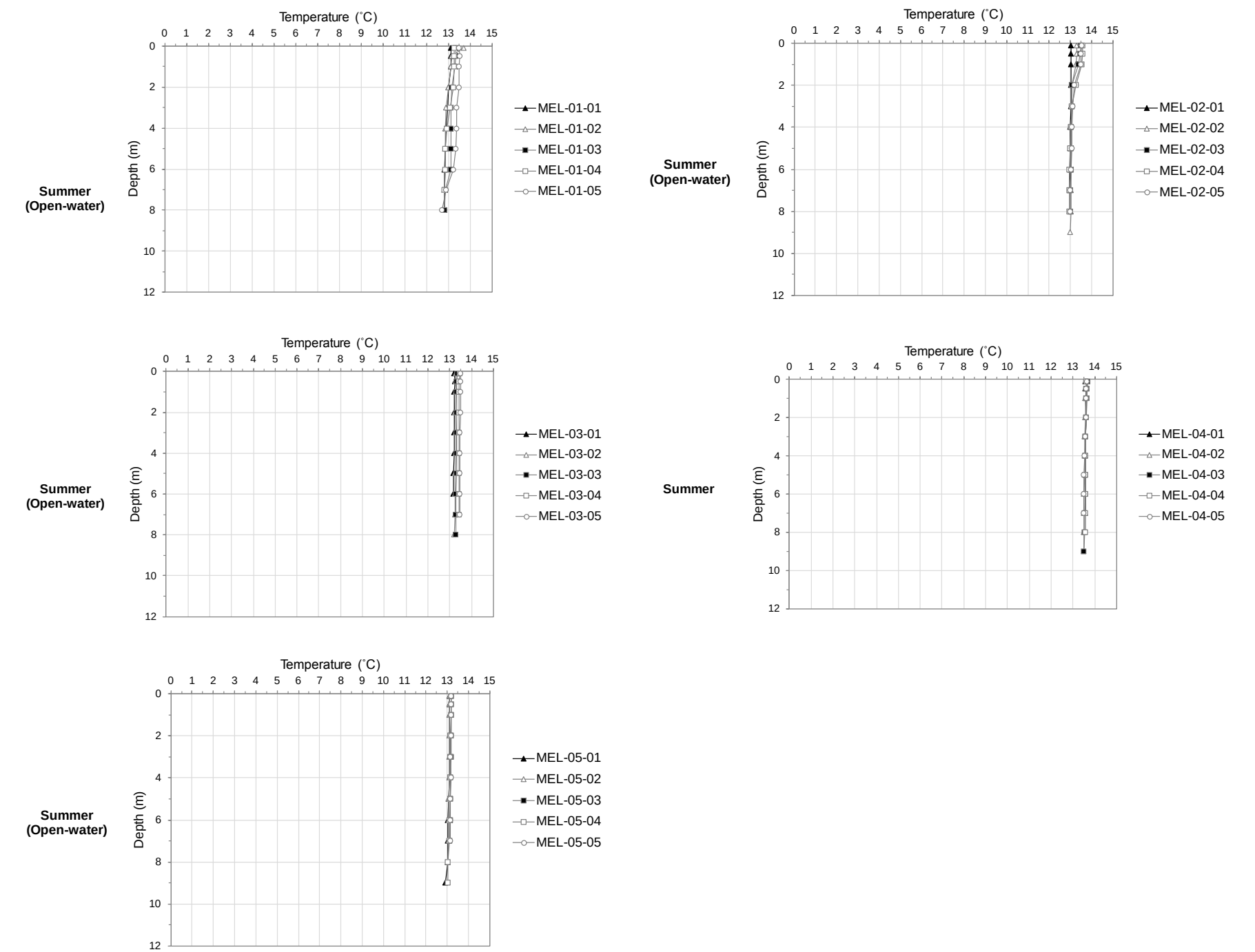
m = metre; °C = degrees Celsius; MEL-01 = near-field; MEL-02 = mid-field.

Figure 3B.1-2: Temperature (°C) Profiles at Stations on Meliadine Lake, Under-ice (February) 2017

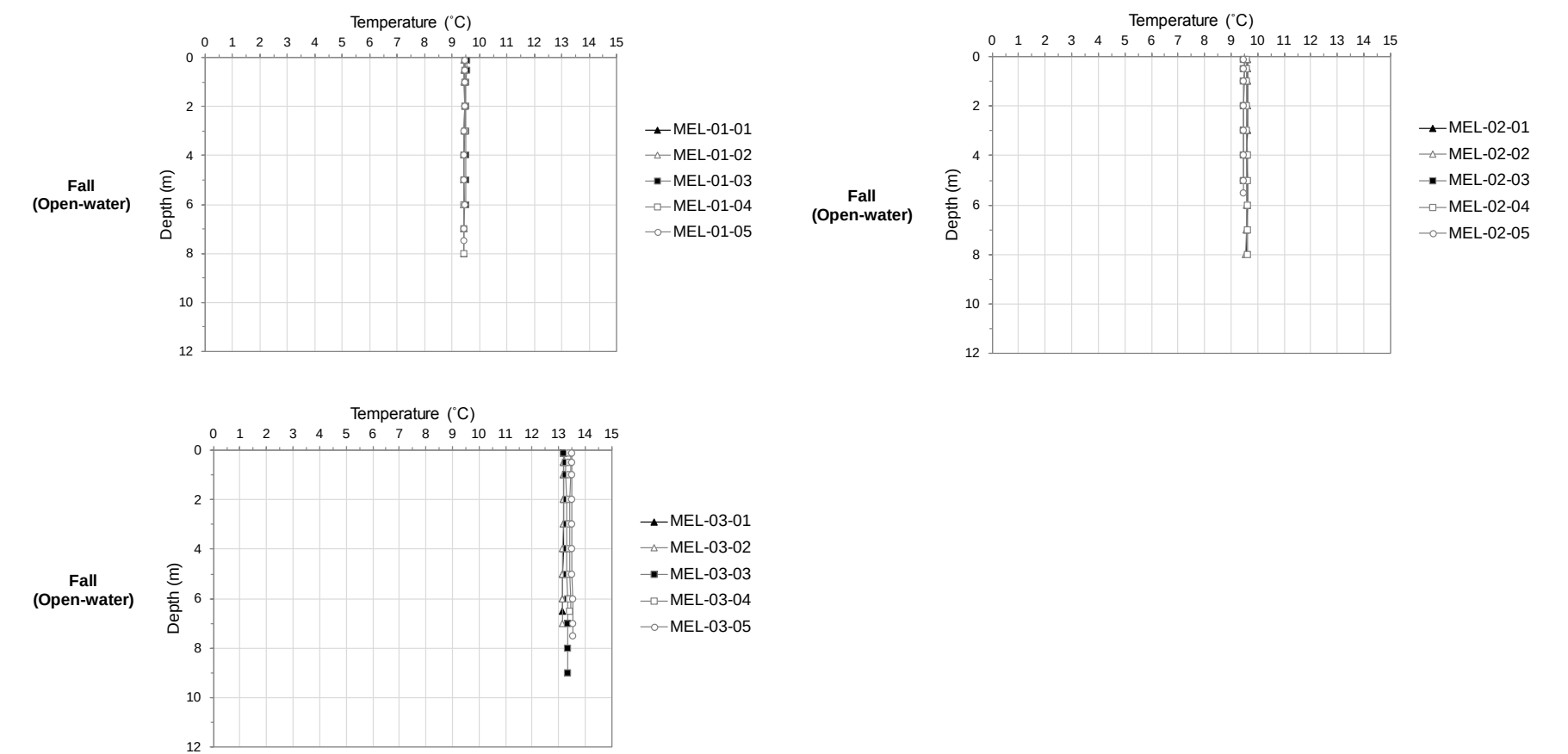


m = metre; °C = degrees Celsius; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.

Figure 3B.1-3: Temperature (°C) Profiles at Stations on Meliadine Lake, Open-Water (July) 2017



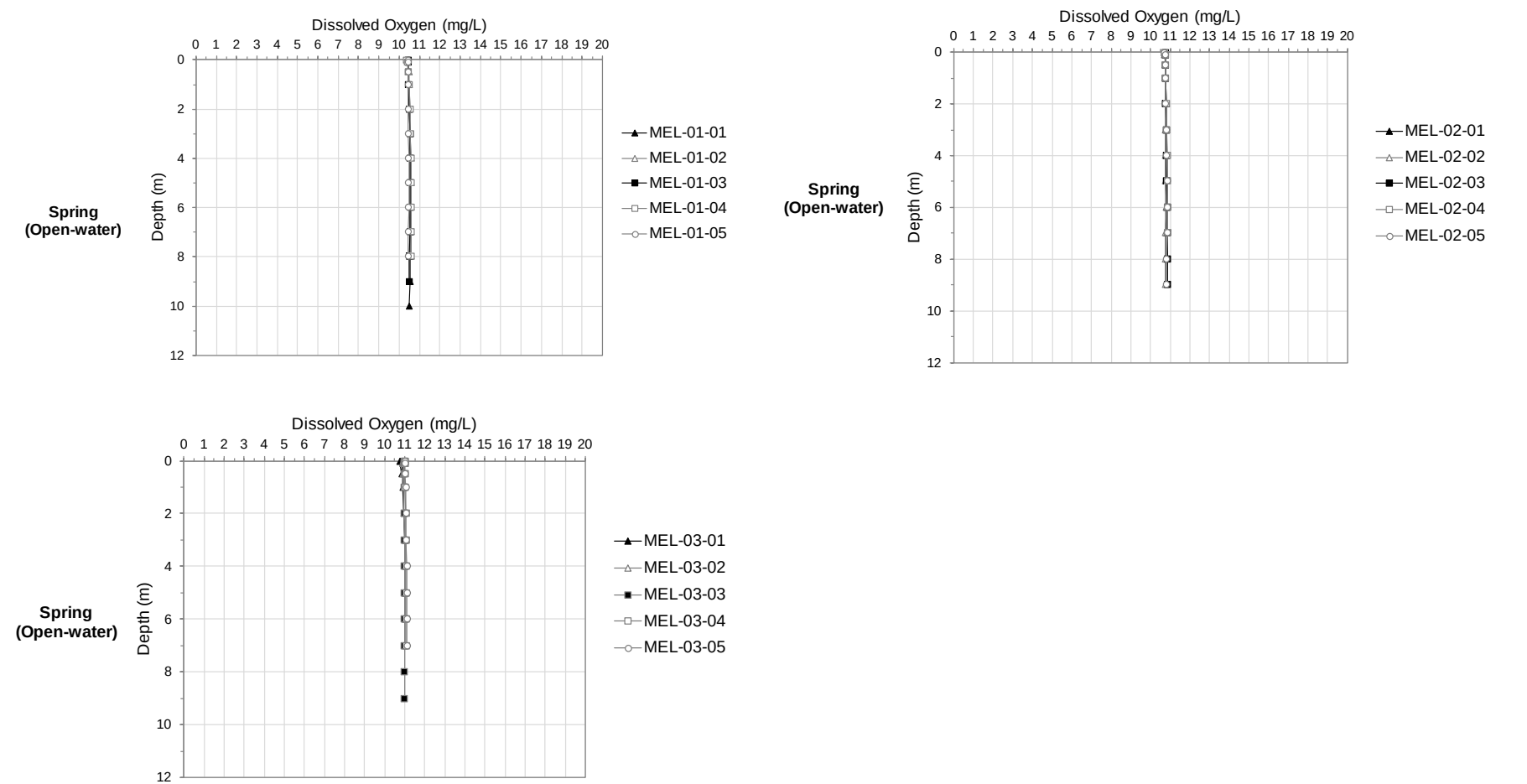
m = metre; °C = degrees Celsius; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1; MEL-04 = reference area 2; MEL-05 = reference area 3.
Figure 3B.1-4: Temperature (°C) Profiles at Stations on Meliadine Lake, Open-water (August) 2017



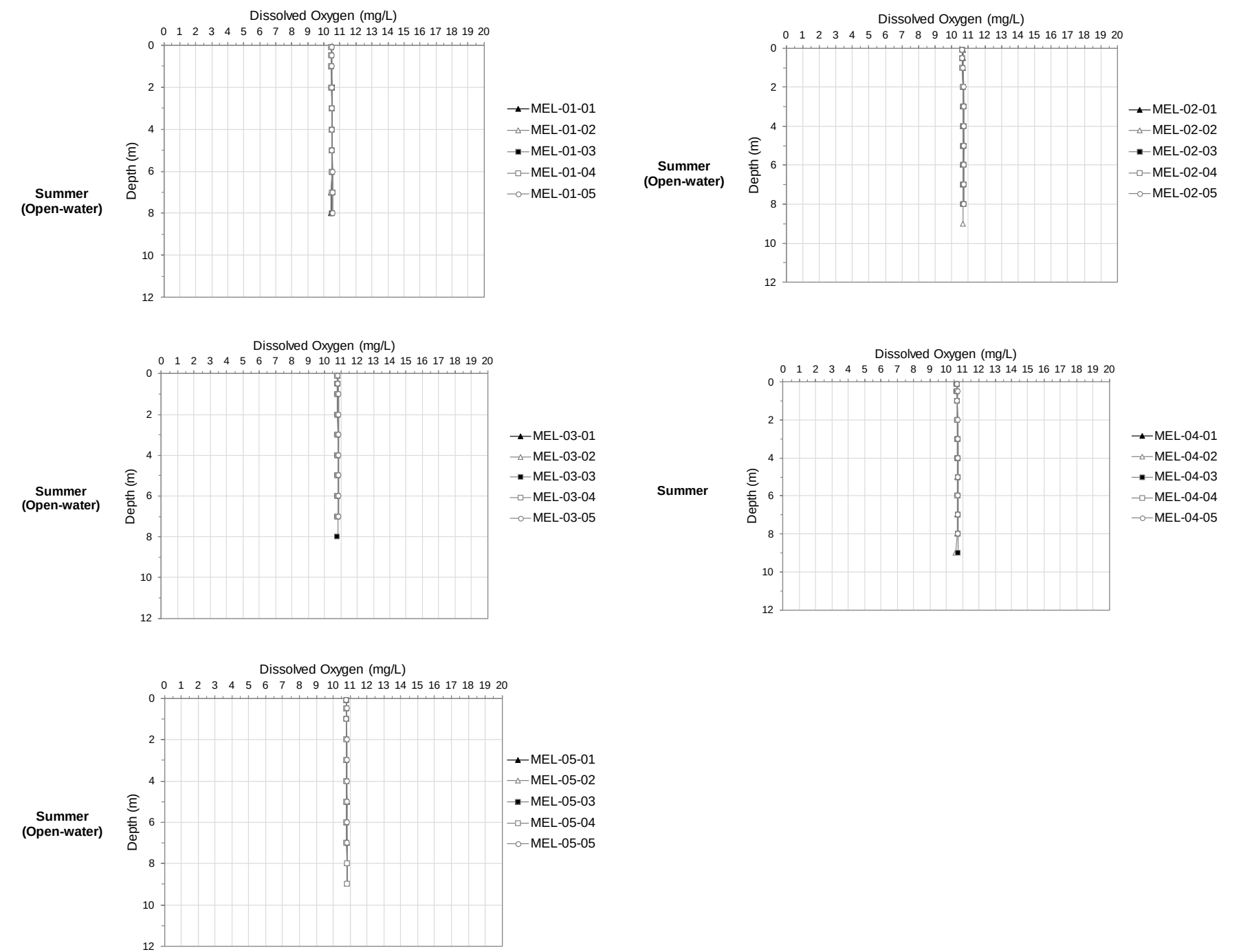
m = metre; °C = degrees Celsius; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.1-5: Temperature (°C) Profiles at Stations on Meliadine Lake, Open-water (September) 2017

3B1.2 DISSOLVED OXYGEN

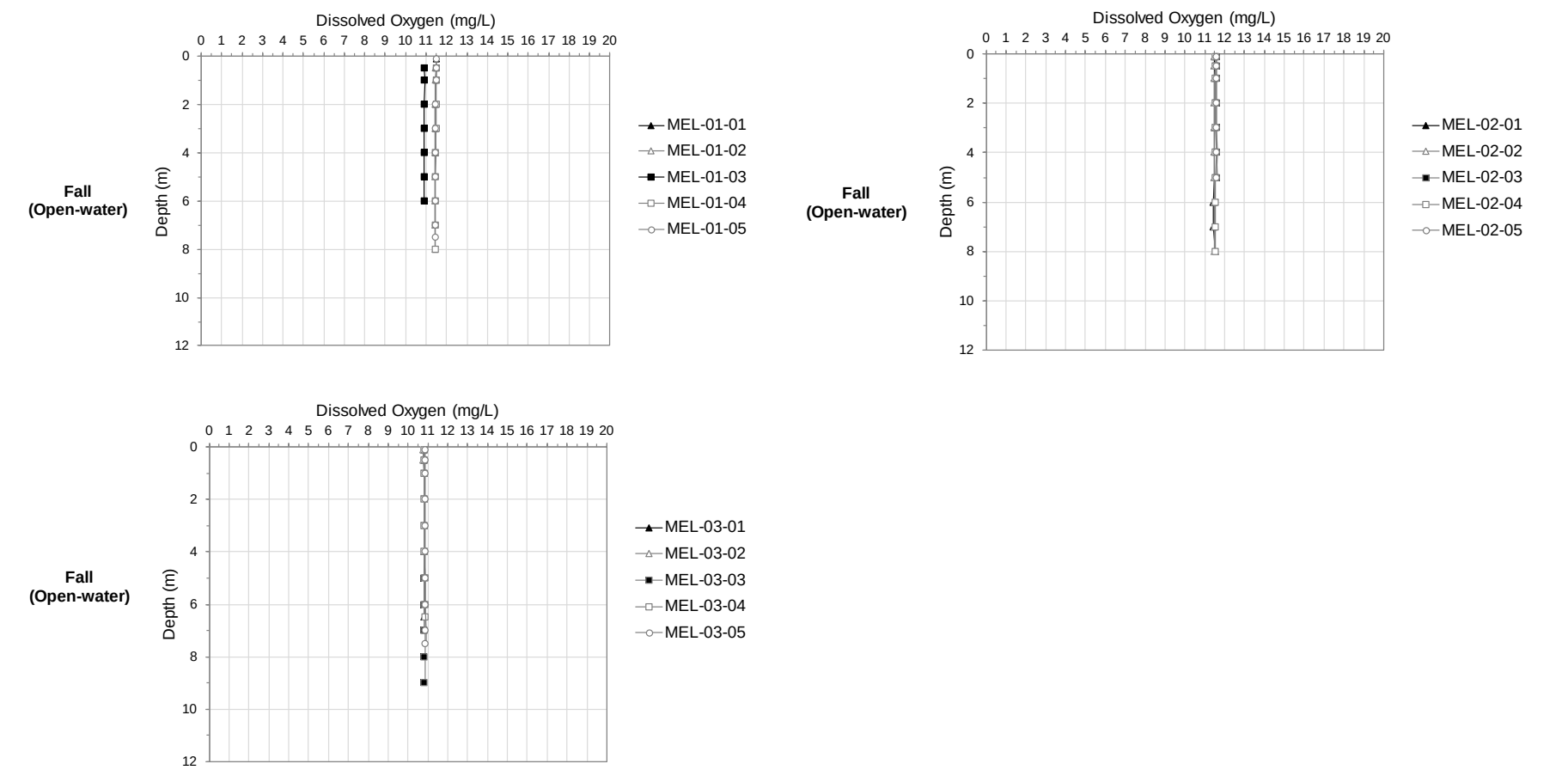
Dissolved oxygen measured during under-ice conditions were outside the acceptable range. Data was deemed unreliable and excluded.



m = metre; mg/L = milligrams per litre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.2-1: Dissolved Oxygen (mg/L) Profiles at Stations on Meliadine Lake, Open-water (July) 2017

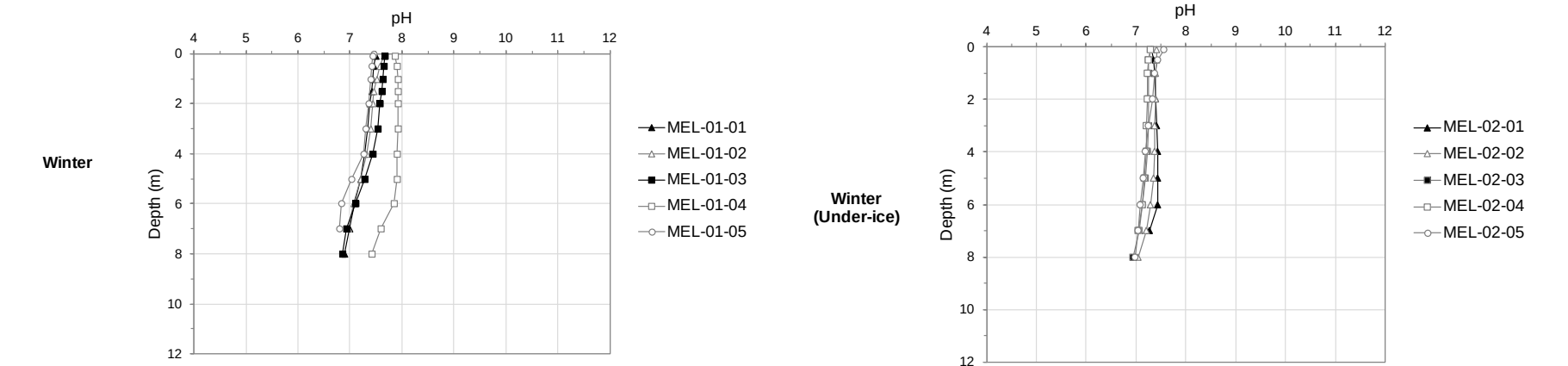


m = metre; mg/L = milligrams per litre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1; MEL-04 = reference area 2; MEL-05 = reference area 3.
Figure 3B.2-2: Dissolved Oxygen (mg/L) Profiles at Stations on Meliadine Lake, Open-water (August) 2017

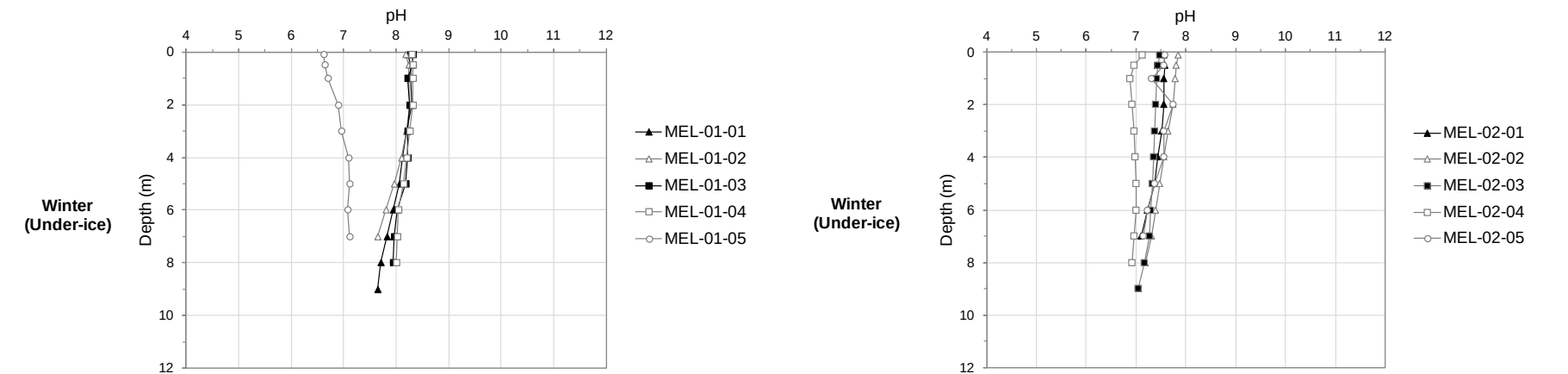


m = metre; mg/L = milligrams per litre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.2-3: Dissolved Oxygen (mg/L) Profiles at Stations on Meliadine Lake, Open-water (September) 2017

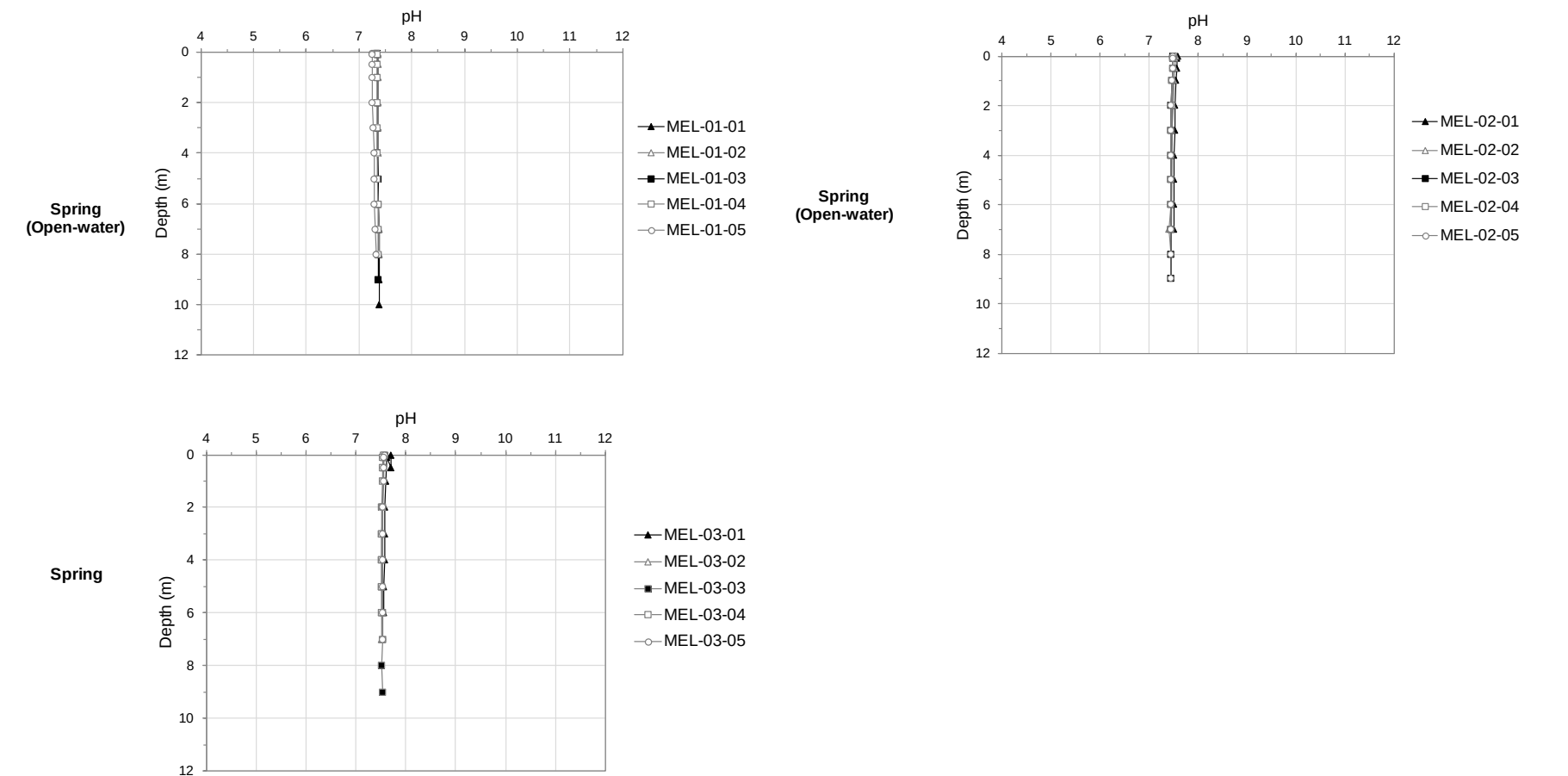
3B1.3 pH



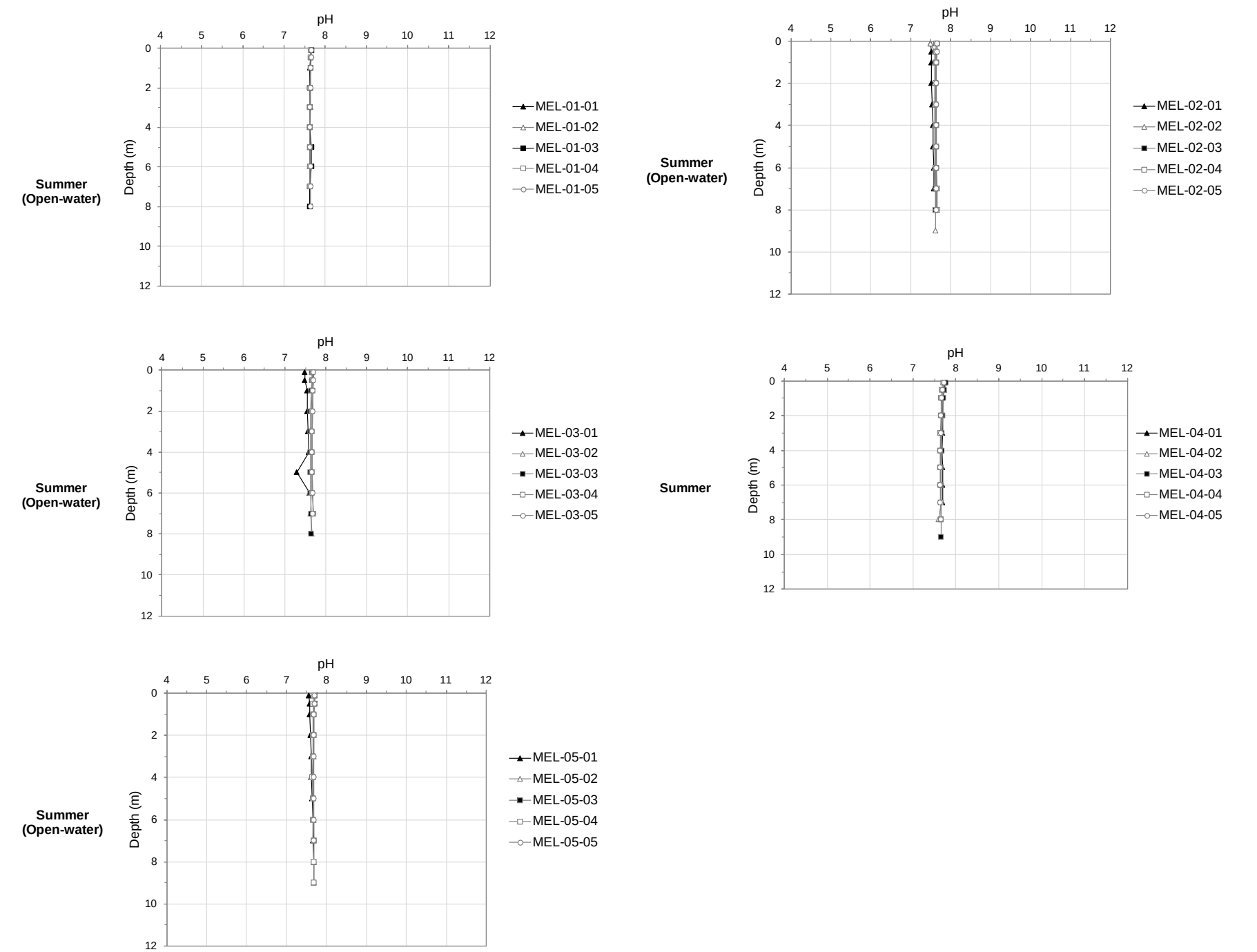
m = metre; MEL-01 = near-field; MEL-02 = mid-field.
Figure 3B.3-1: pH Profiles at Stations on Meliadine Lake, Under-ice (January) 2017



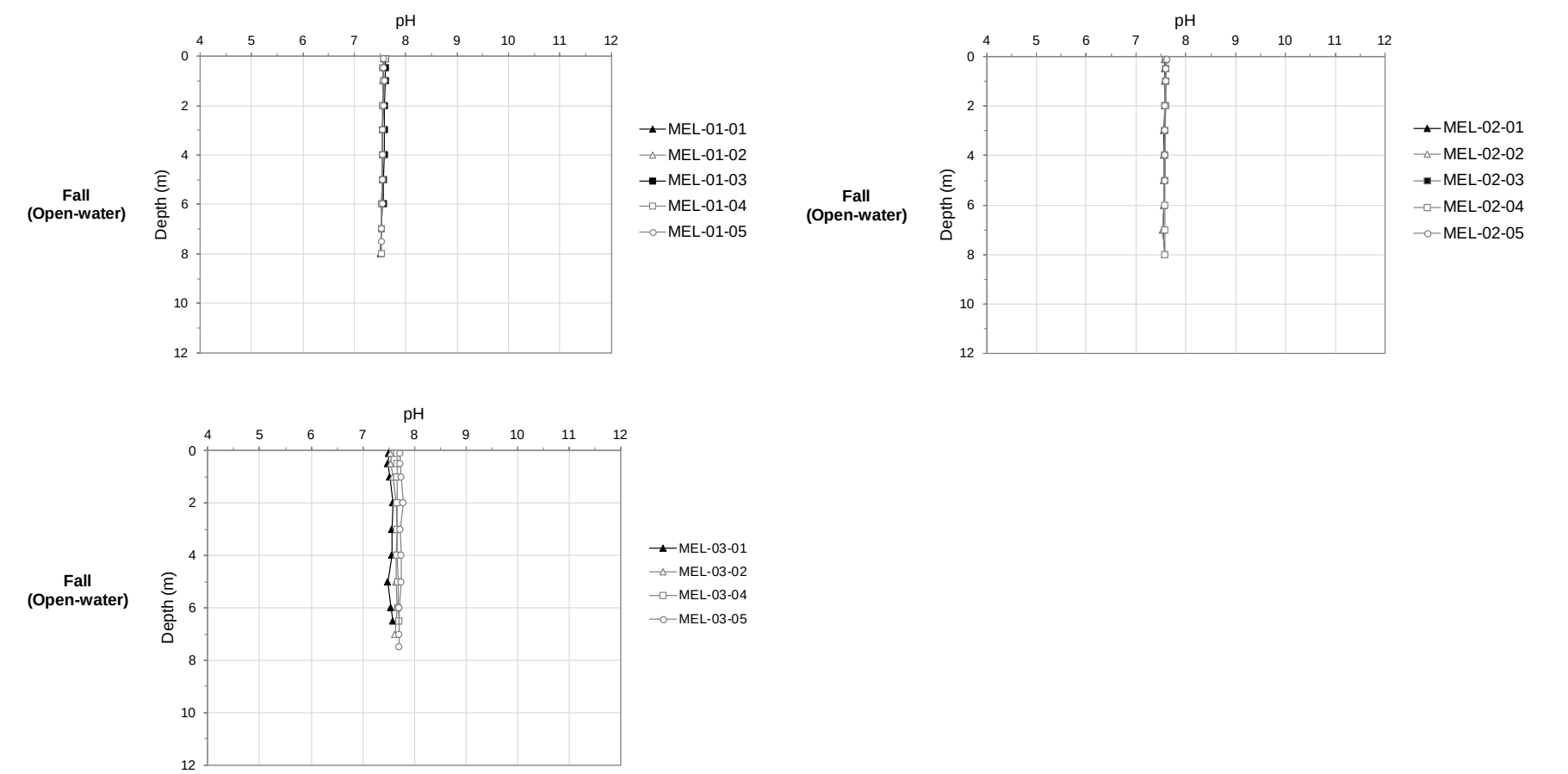
m = metre; MEL-01 = near-field; MEL-02 = mid-field.
Figure 3B.3-2: pH Profiles at Stations on Meliadine Lake, Under-ice (February) 2017



m = metre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.3-3: pH Profiles at Stations on Meliadine Lake, Open-water (July) 2017

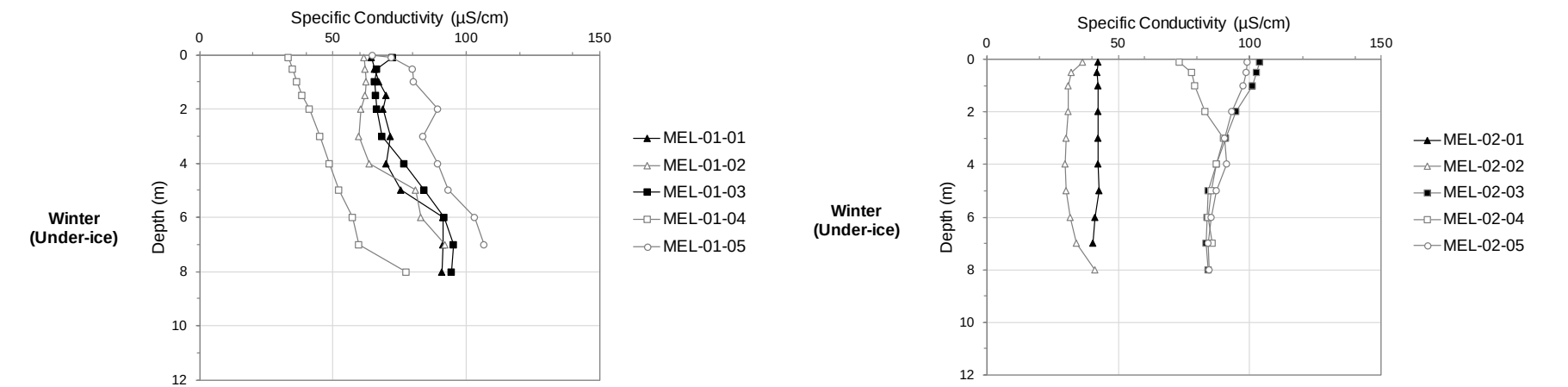


m = metre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1; MEL-04 = reference area 2; MEL-05 = reference area 3.
Figure 3B.3-4: pH Profiles at Stations on Meliadine Lake, Open-water (August) 2017

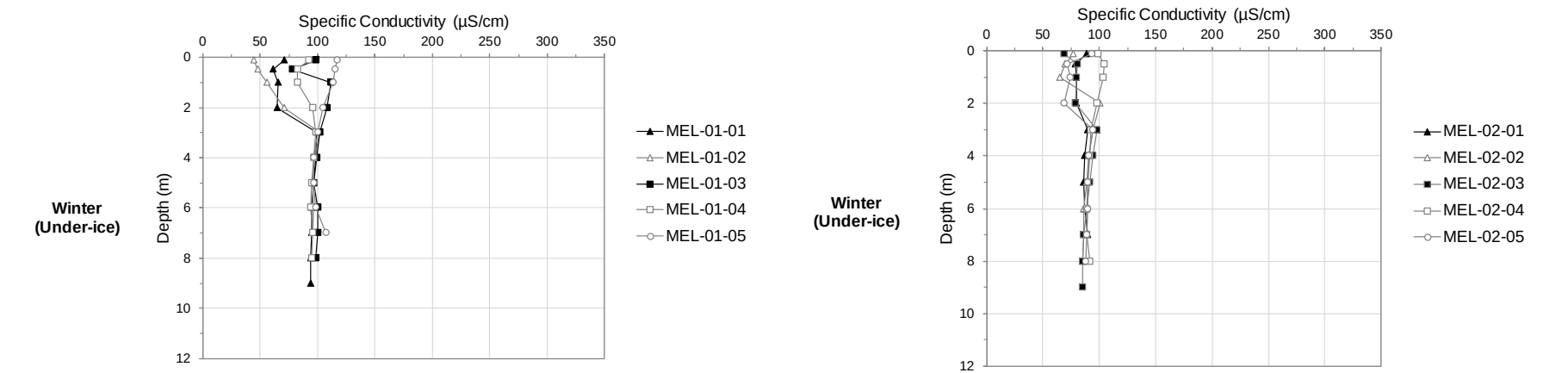


m = metre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.3-5: pH Profiles at Stations on Meliadine Lake, Open-water (September) 2017

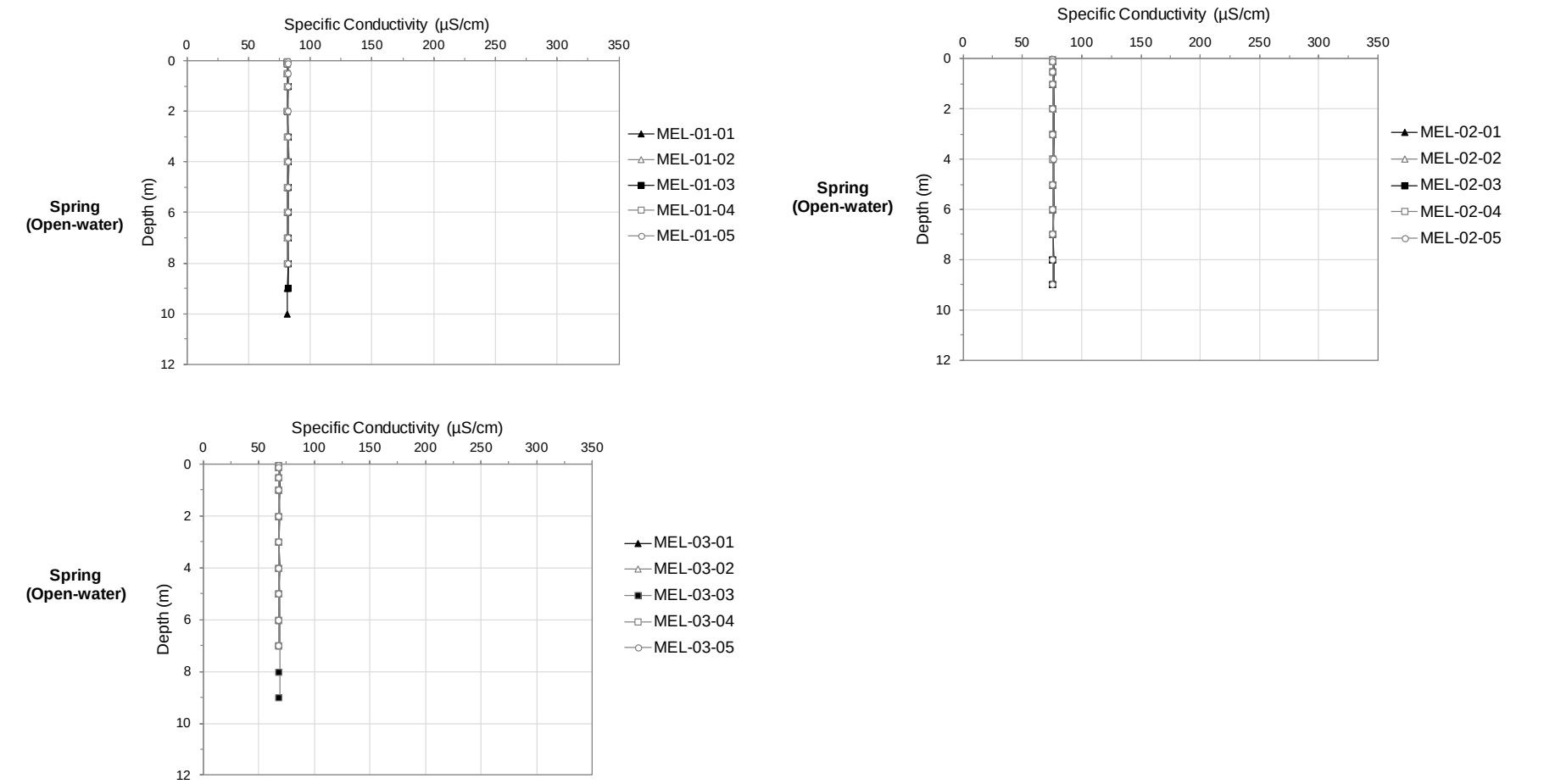
3B1.4 SPECIFIC CONDUCTIVITY



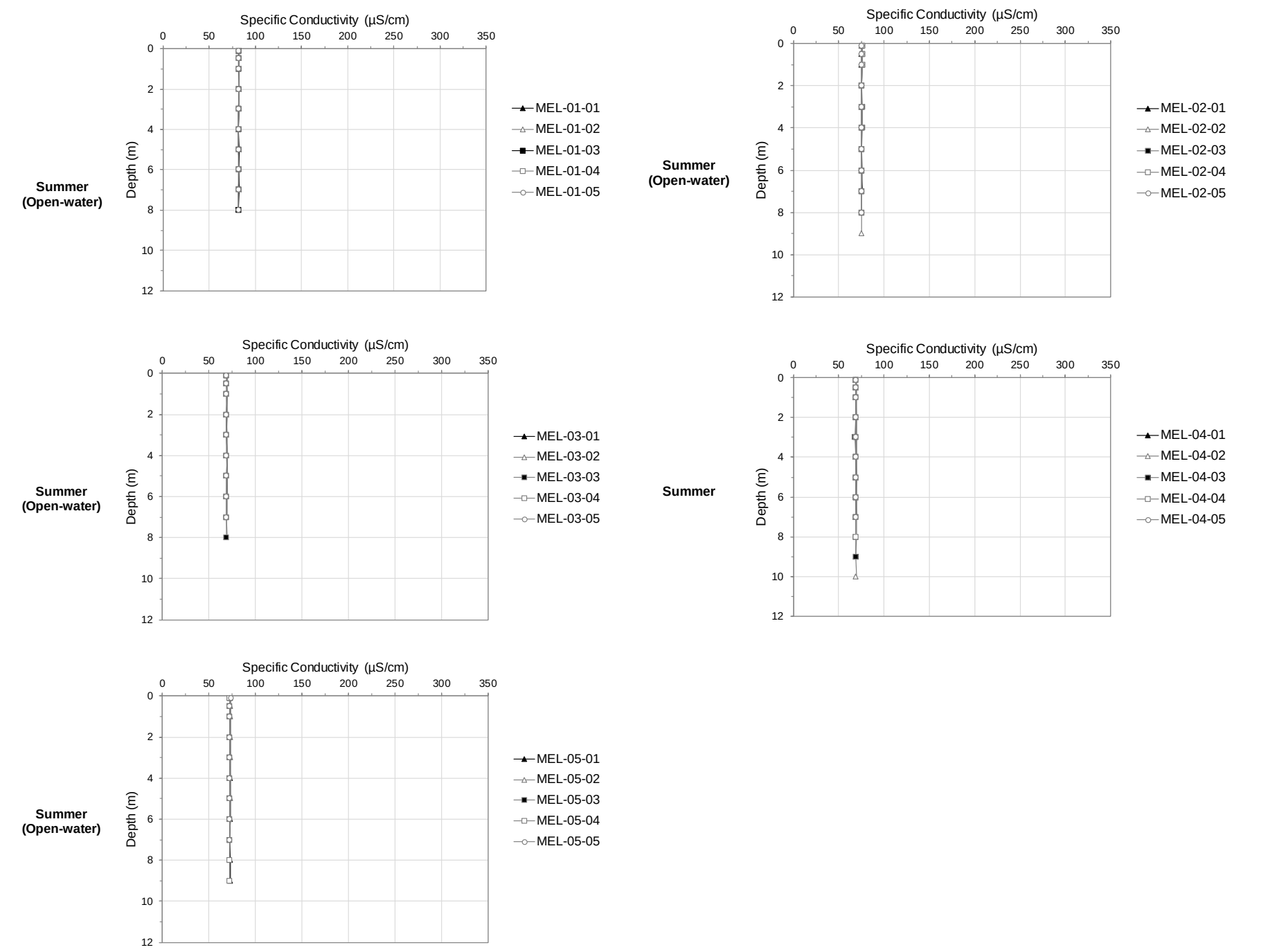
m = metre; µS/cm = microSiemens per centimetre; MEL-01 = near-field; MEL-02 = mid-field.
Figure 3B.4-1: Specific Conductivity (µS/cm) Profiles at Stations on Meliadine Lake, Under-ice (January) 2017



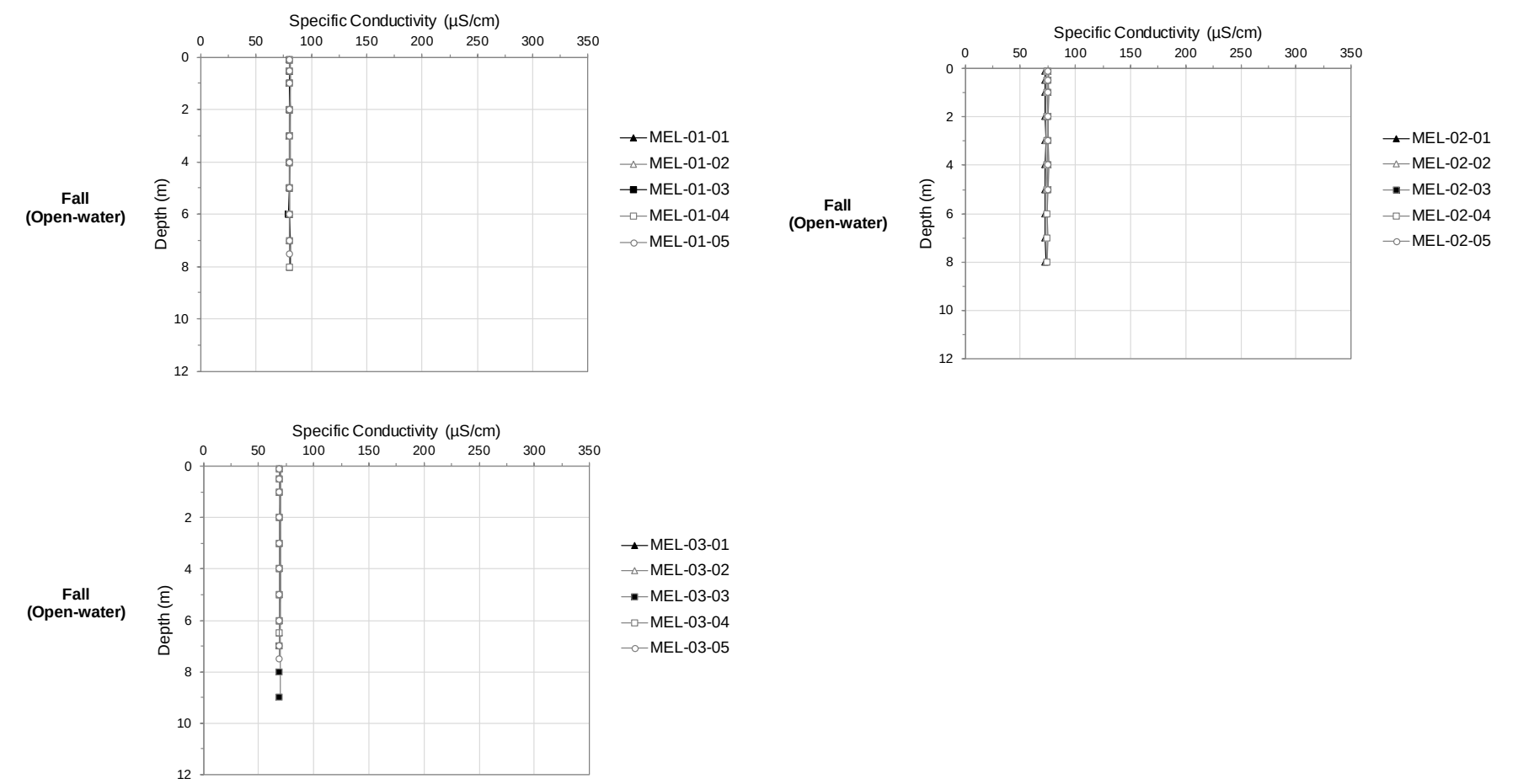
m = metre; µS/cm = microSiemens per centimetre; MEL-01 = near-field; MEL-02 = mid-field.
Figure 3B.4-2: Specific Conductivity (µS/cm) Profiles at Stations on Meliadine Lake, Under-ice (February) 2017



m = metre; µS/cm = microSiemens per centimetre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.4-3: Specific Conductivity (µS/cm) Profiles at Stations on Meliadine Lake, Open-water (July) 2017

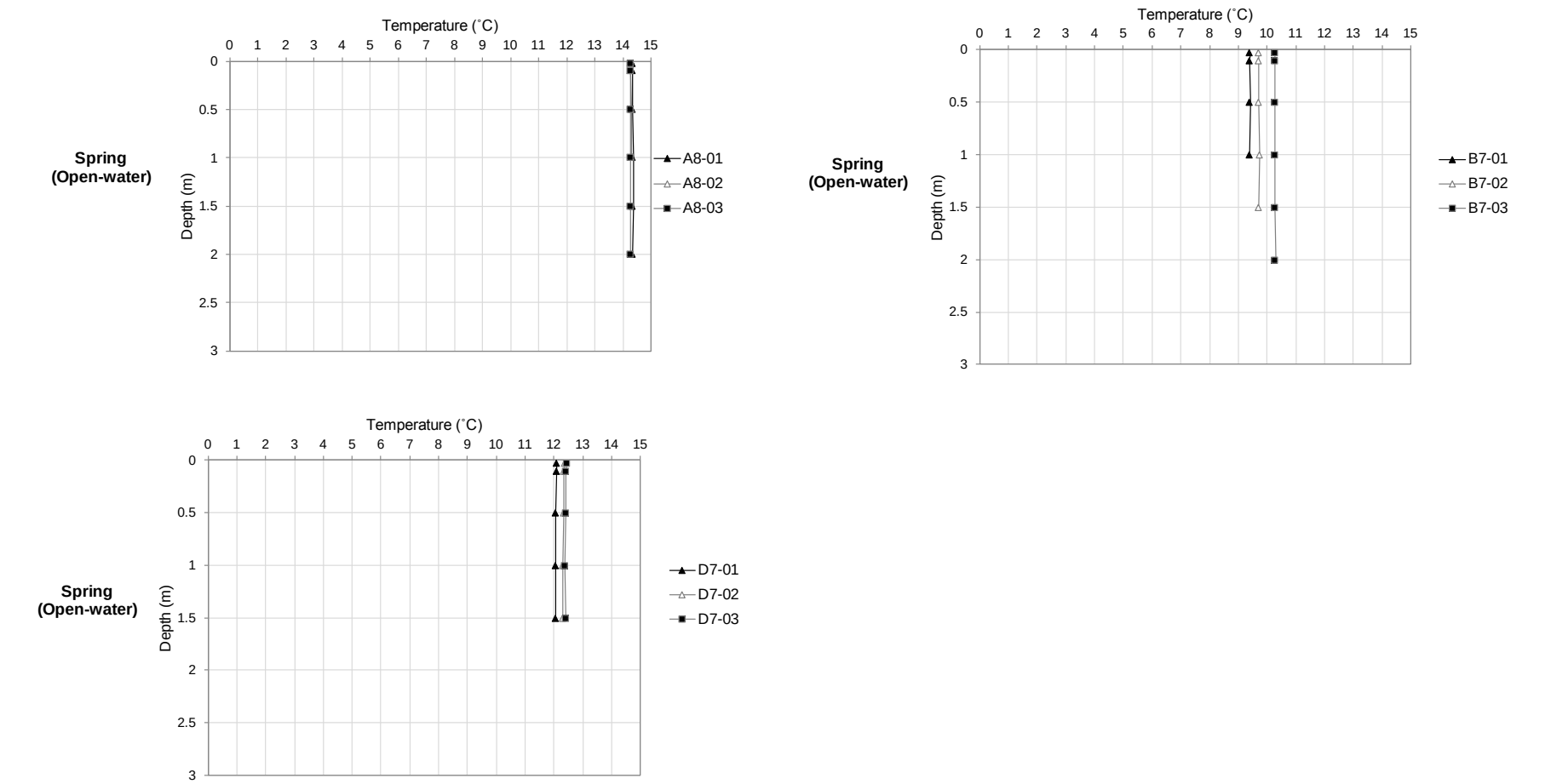


M = Metre; µS/Cm = microSiemens per centimetre; MEL-01 = Near-Field; MEL-02 = Mid-Field; MEL-03 = reference area 1; MEL-04 = reference area 2; MEL-05 = reference area 3.
Figure 3B.4-4: Specific Conductivity (µS/cm) Profiles at Stations on Meliadine Lake, Open-water (August) 2017

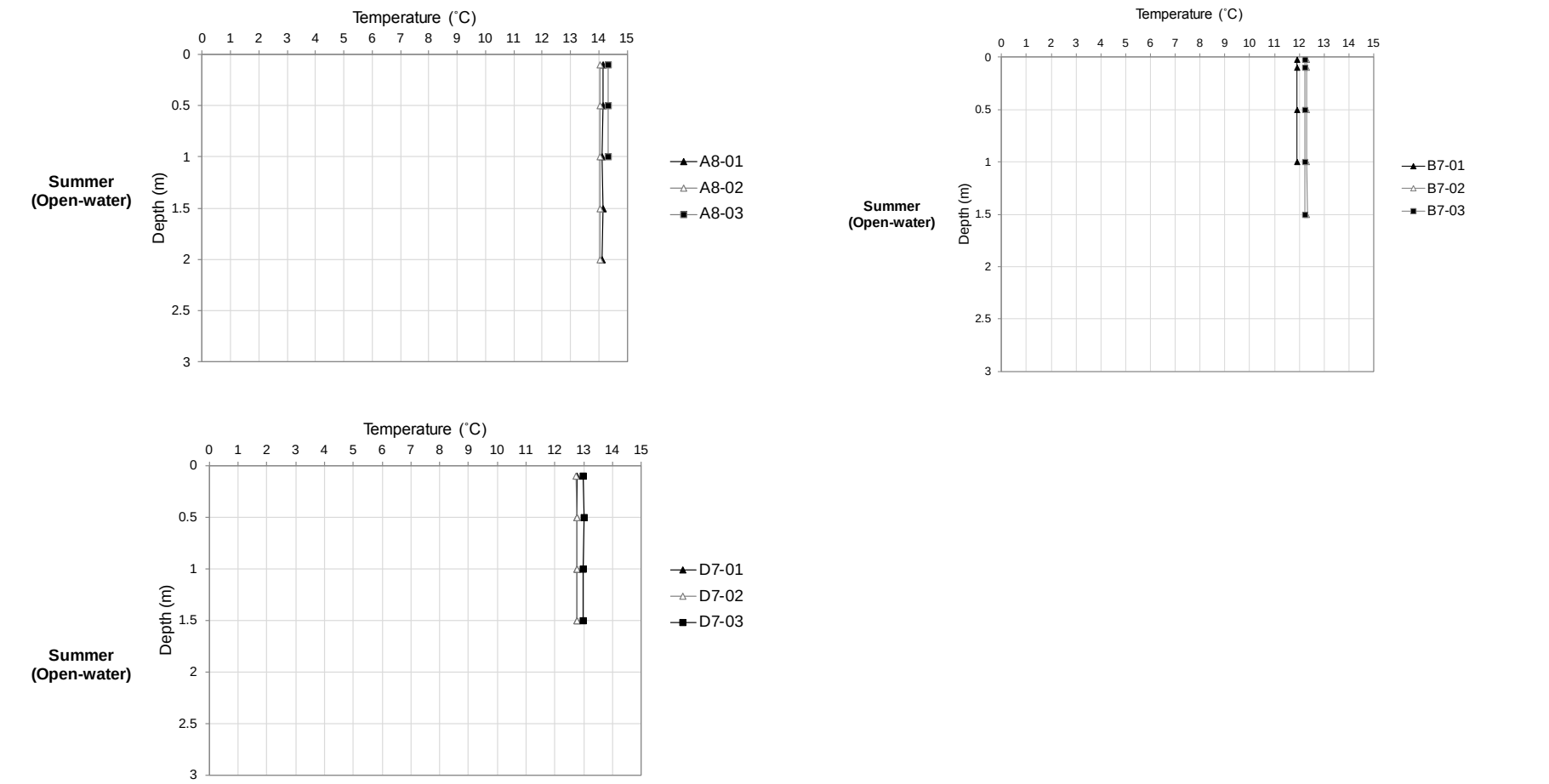


m = metre; µS/cm = microSiemens per centimetre; MEL-01 = near-field; MEL-02 = mid-field; MEL-03 = reference area 1.
Figure 3B.4-5: Specific Conductivity (µS/cm) Profiles at Stations on Meliadine Lake, Open-water (September) 2017

3B2.0 PENINSULA LAKES
3B2.1 TEMPERATURE

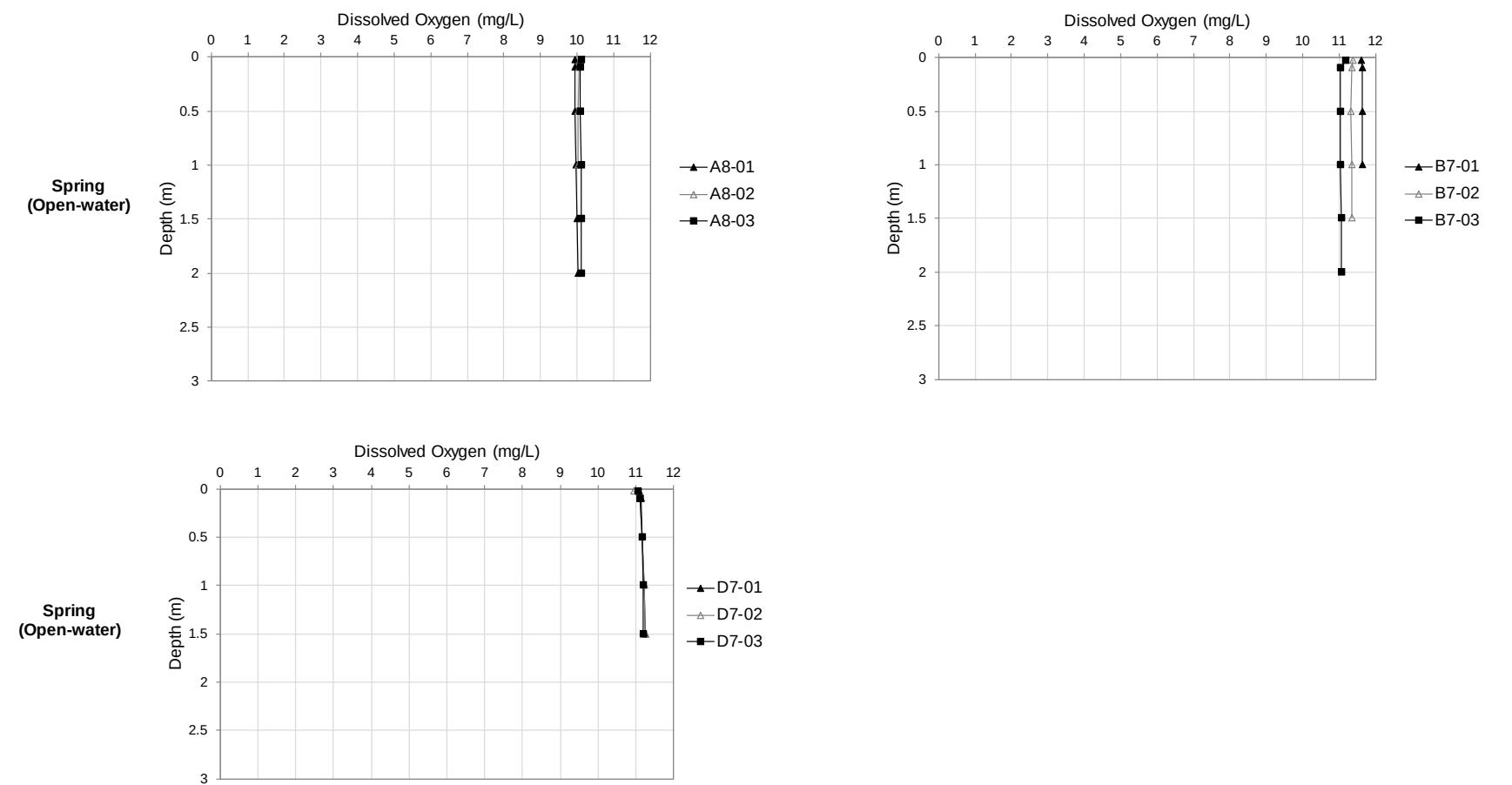


m = metre; °C = degrees Celsius; A8, B7 and D7 = Peninsula Lakes
Figure 3B.5-1: Temperature (°C) Profiles at Stations on Peninsula Lake, Open-water (July) 2017

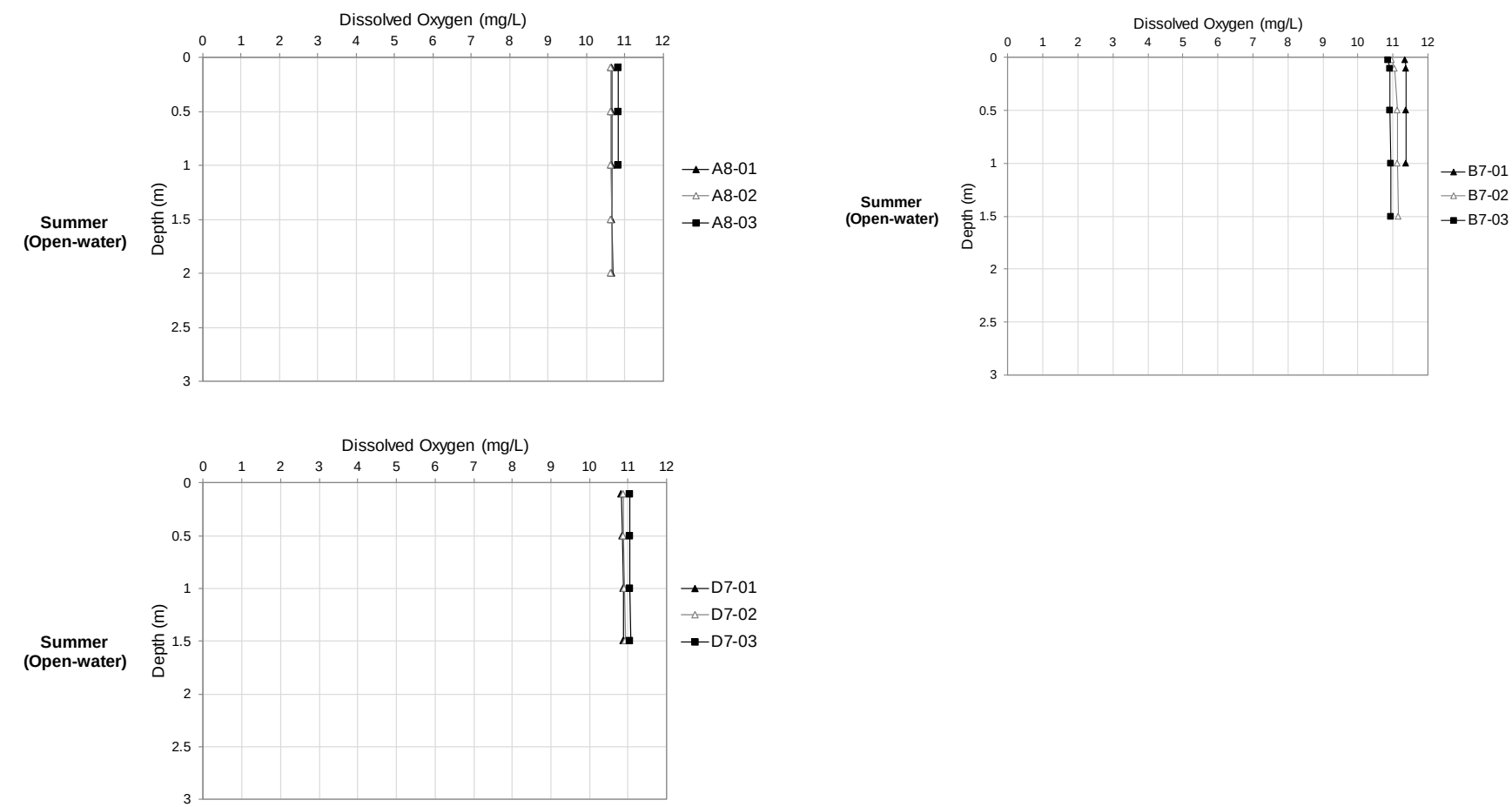


m = metre; °C = degrees Celsius; A8, B7 and D7 = Peninsula.
Figure 3B.5-2: Temperature (°C) Profiles at Stations on Peninsula Lake, Open-water (August) 2017

3B2.2 DISSOLVED OXYGEN

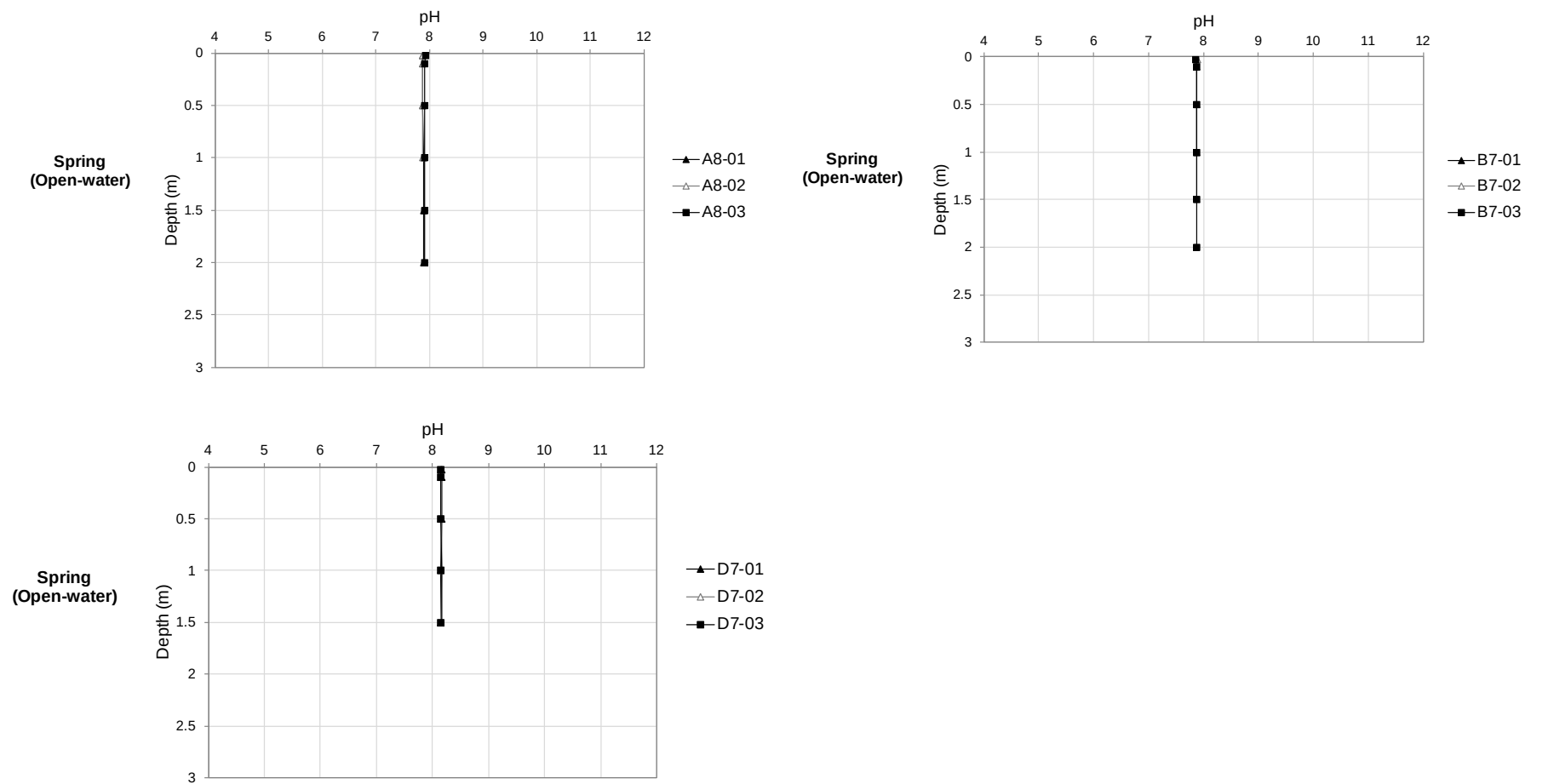


m = metre; mg/L = milligrams per litre; A8, B7 and D7 = Peninsula Lakes
Figure 3B.6-1: Dissolved Oxygen (mg/L) Profiles at Stations on Peninsula Lake, Open-water (July) 2017

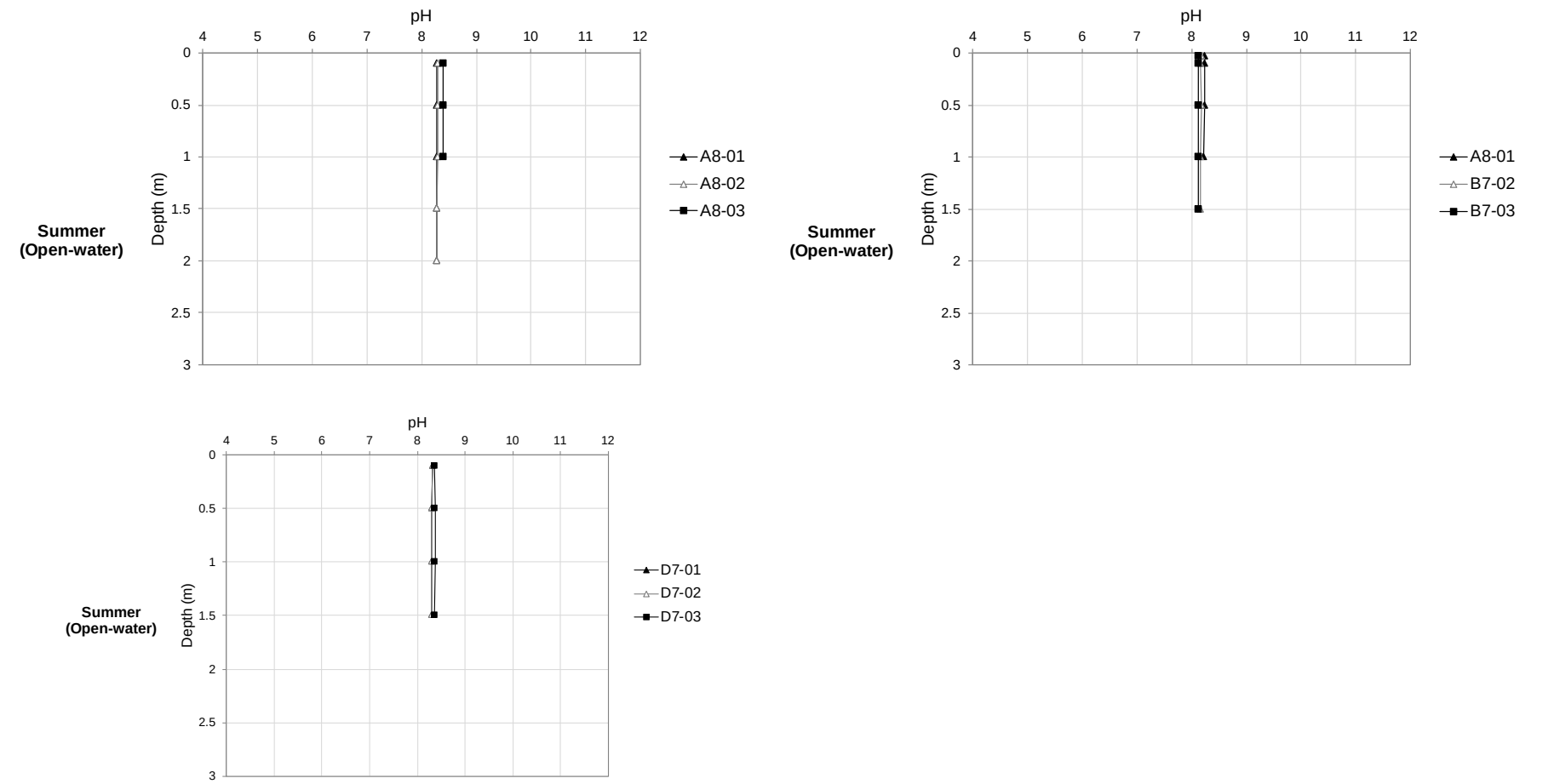


m = metre; mg/L = milligrams per litre; A8, B7 and D7 = Peninsula Lakes
Figure 3B.6-2: Dissolved Oxygen (mg/L) Profiles at Stations on Peninsula Lake, Open-water (August) 2017

3B2.3 pH

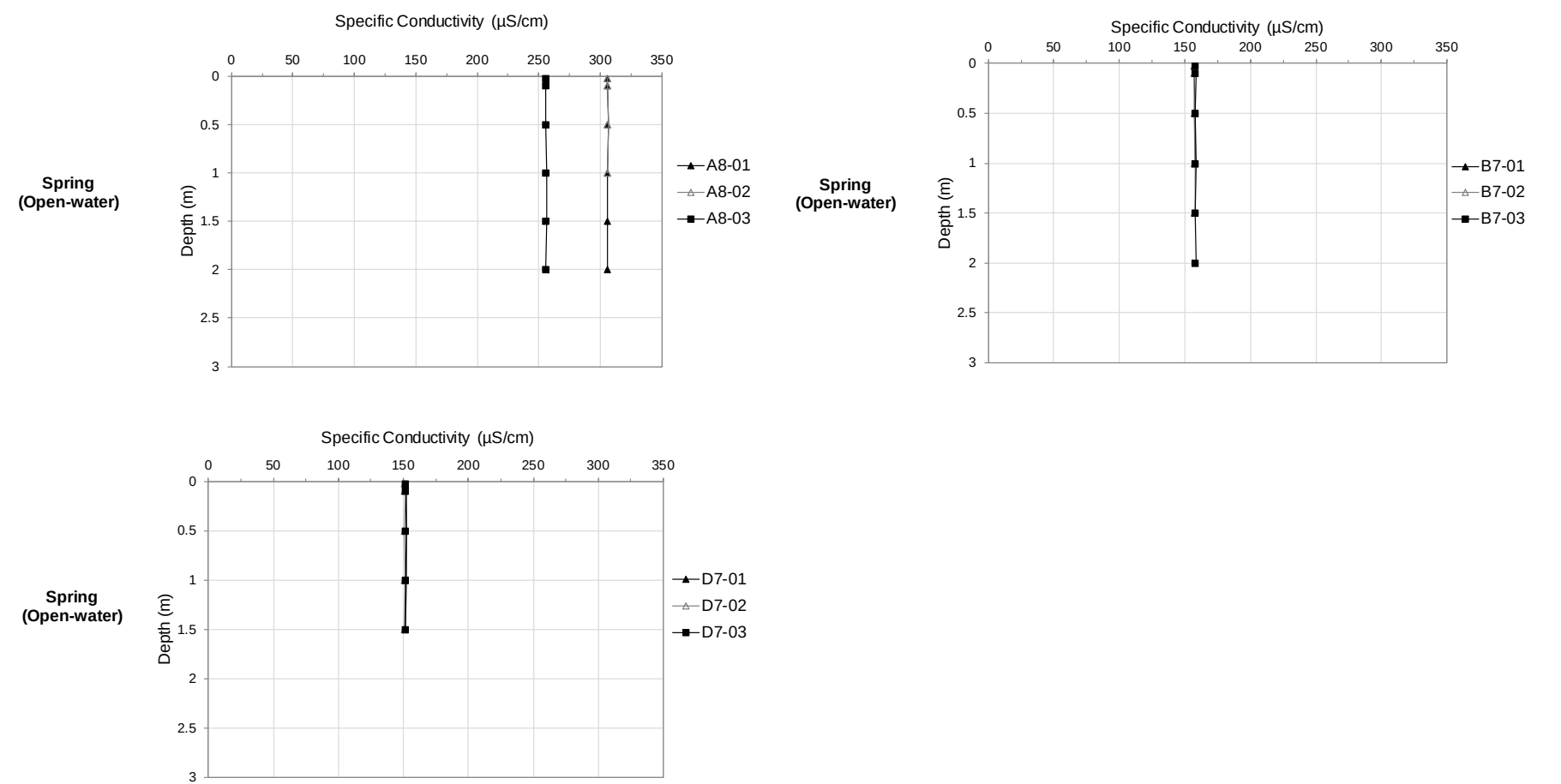


m = metre; MEL-01 = near-field; A8, B7 and D7 = Peninsual Lakes.
Figure 3B.7-1: pH Profiles at Stations on Peninsula Lake, Open-water (July) 2017

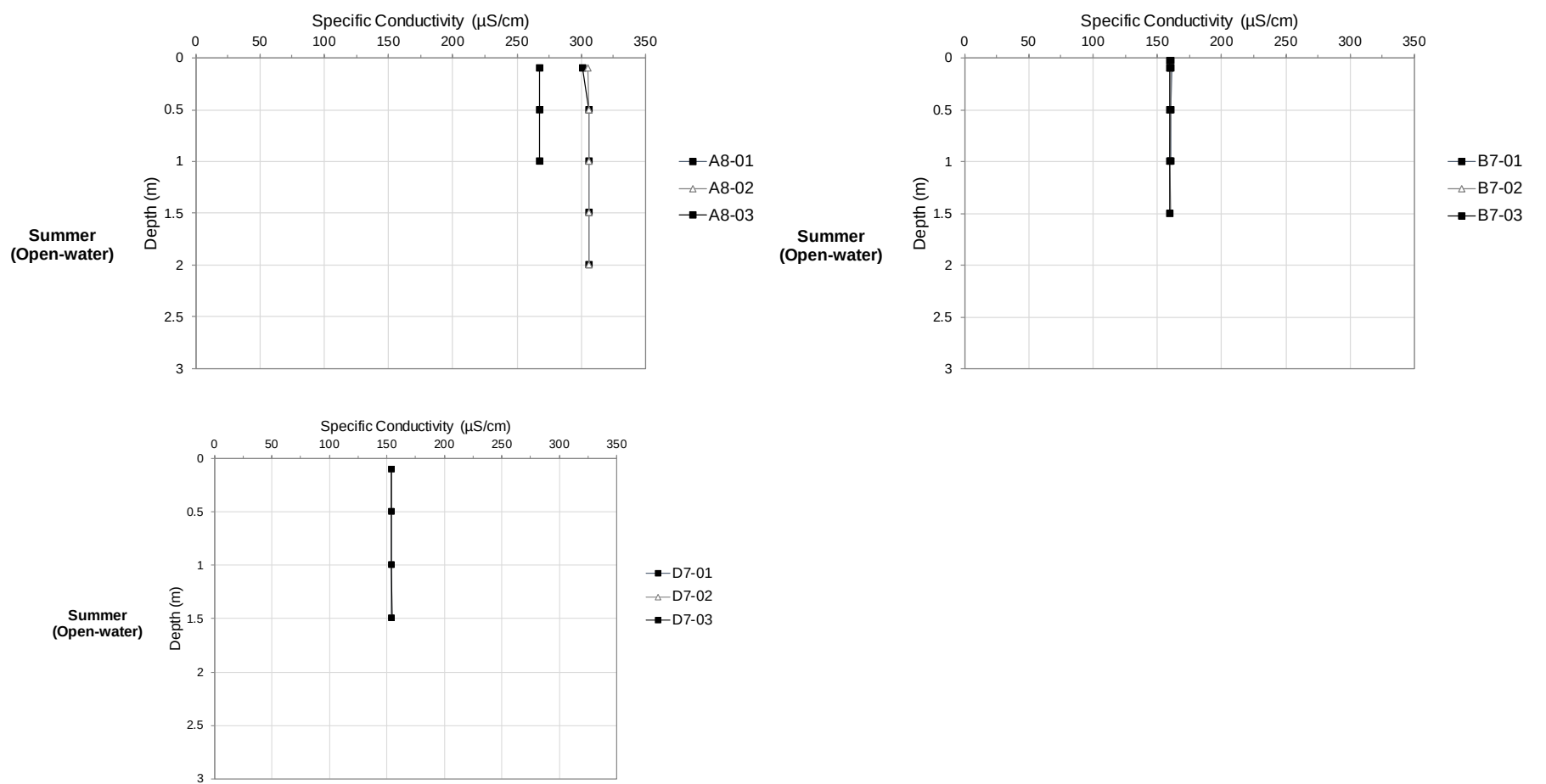


m = metre; MEL-01 = near-field; MEL-02 = mid-field; A8, B7 and D7 = Peninsual Lakes.
Figure 3B.7-2: pH Profiles at Stations on Peninsula Lake, Open-water (August) 2017

3B2.4 SPECIFIC CONDUCTIVITY



m = metre; µS/cm = microSiemens per centimetre; A8, B7 and D8 = Peninsula Lakes.
Figure 3B.8-1: Specific Conductivity (µS/cm) Profiles at Stations on Peninsula Lake, Open-water (July) 2017



M = Metre; µS/Cm = microSiemens per centimetre; A8, B7 and D7 = Peninsula Lakes.
Figure 3B.8-2: Specific Conductivity (µS/cm) Profiles at Stations on Peninsula Lake, Open-water (August) 2017

Table 3B.1-1: Field Profiles at Meliadine Near-Field, January 2017

Station	Date	Depth (m)	Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
MEL-01-01							
MEL-01-01	19-Jan-17	0.1	0.0	108	.. ^(a)	64	7.5
MEL-01-01	19-Jan-17	0.5	0.0	110	.. ^(a)	66	7.5
MEL-01-01	19-Jan-17	1.0	0.0	111	.. ^(a)	67	7.4
MEL-01-01	19-Jan-17	1.5	0.0	114	.. ^(a)	70	7.4
MEL-01-01	19-Jan-17	2.0	0.0	118	.. ^(a)	69	7.4
MEL-01-01	19-Jan-17	3.0	0.0	125	.. ^(a)	71	7.3
MEL-01-01	19-Jan-17	4.0	0.4	130	.. ^(a)	70	7.3
MEL-01-01	19-Jan-17	5.0	1.2	134	.. ^(a)	76	7.2
MEL-01-01	19-Jan-17	6.0	1.6	137	.. ^(a)	91	7.1
MEL-01-01	19-Jan-17	7.0	1.8	137	.. ^(a)	91	7.0
MEL-01-01	19-Jan-17	8.0	2.0	134	.. ^(a)	91	6.9
MEL-01-02							
MEL-01-02	19-Jan-17	0.1	0.0	112	.. ^(a)	62	7.7
MEL-01-02	19-Jan-17	0.5	0.0	112	.. ^(a)	62	7.6
MEL-01-02	19-Jan-17	1.0	0.0	113	.. ^(a)	63	7.5
MEL-01-02	19-Jan-17	1.5	0.0	116	.. ^(a)	62	7.5
MEL-01-02	19-Jan-17	2.0	0.3	117	.. ^(a)	61	7.4
MEL-01-02	19-Jan-17	3.0	0.3	118	.. ^(a)	60	7.4
MEL-01-02	19-Jan-17	4.0	0.6	119	.. ^(a)	64	7.3
MEL-01-02	19-Jan-17	5.0	1.2	113	.. ^(a)	81	7.2
MEL-01-02	19-Jan-17	6.0	1.5	106	.. ^(a)	83	7.1
MEL-01-02	19-Jan-17	7.0	1.7	98	13.3	92	7.0
MEL-01-03							
MEL-01-03	19-Jan-17	0.1	0.0	112	.. ^(a)	72	7.7
MEL-01-03	19-Jan-17	0.5	0.0	111	.. ^(a)	67	7.7
MEL-01-03	19-Jan-17	1.0	0.0	112	.. ^(a)	66	7.6
MEL-01-03	19-Jan-17	1.5	0.3	114	.. ^(a)	66	7.6
MEL-01-03	19-Jan-17	2.0	0.6	116	.. ^(a)	66	7.6
MEL-01-03	19-Jan-17	3.0	0.8	117	.. ^(a)	68	7.5
MEL-01-03	19-Jan-17	4.0	1.0	117	.. ^(a)	77	7.4
MEL-01-03	19-Jan-17	5.0	1.2	116	.. ^(a)	84	7.3
MEL-01-03	19-Jan-17	6.0	1.0	111	.. ^(a)	92	7.1
MEL-01-03	19-Jan-17	7.0	1.8	107	.. ^(a)	95	6.9
MEL-01-03	19-Jan-17	8.0	1.9	103	14.0	95	6.9
MEL-01-04							
MEL-01-04	19-Jan-17	0.1	0.0	119	.. ^(a)	33	7.9
MEL-01-04	19-Jan-17	0.5	0.0	115	.. ^(a)	35	7.9
MEL-01-04	19-Jan-17	1.0	0.0	115	.. ^(a)	36	7.9
MEL-01-04	19-Jan-17	1.5	0.0	115	.. ^(a)	39	7.9
MEL-01-04	19-Jan-17	2.0	0.0	115	.. ^(a)	41	7.9
MEL-01-04	19-Jan-17	3.0	0.0	116	.. ^(a)	45	7.9
MEL-01-04	19-Jan-17	4.0	0.0	116	.. ^(a)	49	7.9
MEL-01-04	19-Jan-17	5.0	0.0	117	.. ^(a)	52	7.9
MEL-01-04	19-Jan-17	6.0	0.0	117	.. ^(a)	58	7.9
MEL-01-04	19-Jan-17	7.0	0.1	111	.. ^(a)	60	7.6
MEL-01-04	19-Jan-17	8.0	1.9	110	13.9	77	7.4
MEL-01-05							
MEL-01-05	19-Jan-17	0.0	0.0	116	.. ^(a)	65	7.5
MEL-01-05	19-Jan-17	0.1	0.0	115	.. ^(a)	72	7.4
MEL-01-05	19-Jan-17	0.5	0.0	114	.. ^(a)	80	7.4
MEL-01-05	19-Jan-17	1.0	0.0	115	.. ^(a)	80	7.4
MEL-01-05	19-Jan-17	2.0	0.6	117	.. ^(a)	89	7.4
MEL-01-05	19-Jan-17	3.0	0.9	118	.. ^(a)	84	7.3
MEL-01-05	19-Jan-17	4.0	1.1	115	.. ^(a)	89	7.3
MEL-01-05	19-Jan-17	5.0	1.5	110	.. ^(a)	93	7.0
MEL-01-05	19-Jan-17	6.0	2.1	91	12.3	103	6.8
MEL-01-05	19-Jan-17	7.0	2.3	84	11.3	107	6.8

-(a) = values were not included as they did not pass the QC criteria (i.e., were outside the acceptable range)

Table 3B.1-3: Field Profiles at Meliadine Near-Field, July 2017

Station	Date	Depth (m)	Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
MEL-01-01							
MEL-01-01	16-Jul-17	0.0	13.2	103	10.4	82	7.3
MEL-01-01	16-Jul-17	0.1	13.2	103	10.4	82	7.4
MEL-01-01	16-Jul-17	0.5	13.2	103	10.5	82	7.4
MEL-01-01	16-Jul-17	1.0	13.2	103	10.5	82	7.4
MEL-01-01	16-Jul-17	2.0	13.2	103	10.5	82	7.4
MEL-01-01	16-Jul-17	3.0	13.1	104	10.5	82	7.4
MEL-01-01	16-Jul-17	4.0	13.1	104	10.5	82	7.4
MEL-01-01	16-Jul-17	5.0	13.2	104	10.5	82	7.4
MEL-01-01	16-Jul-17	6.0	13.1	104	10.5	82	7.4
MEL-01-01	16-Jul-17	7.0	13.1	104	10.5	82	7.4
MEL-01-01	16-Jul-17	8.0	13.1	103	10.5	82	7.4
MEL-01-01	16-Jul-17	9.0	13.1	103	10.5	82	7.4
MEL-01-01	16-Jul-17	10.0	13.1	103	10.5	82	7.4
MEL-01-02							
MEL-01-02	16-Jul-17	0.0	13.2	102	10.4	82	7.4
MEL-01-02	16-Jul-17	0.1	13.2	103	10.5	82	7.4
MEL-01-02	16-Jul-17	0.5	13.2	103	10.5	82	7.4
MEL-01-02	16-Jul-17	1.0	13.2	103	10.5	82	7.4
MEL-01-02	16-Jul-17	2.0	13.2	104	10.5	82	7.4
MEL-01-02	16-Jul-17	3.0	13.1	104	10.6	82	7.4
MEL-01-02	16-Jul-17	4.0	13.1	104	10.6	82	7.4
MEL-01-02	16-Jul-17	5.0	13.1	104	10.6	82	7.4
MEL-01-02	16-Jul-17	6.0	13.1	104	10.6	82	7.4
MEL-01-02	16-Jul-17	7.0	13.1	104	10.6	82	7.4
MEL-01-02	16-Jul-17	8.0	13.0	104	10.6	82	7.4
MEL-01-03							
MEL-01-03	16-Jul-17	0.0	13.1	103	10.4	82	7.3
MEL-01-03	16-Jul-17	0.1	13.1	103	10.4	82	7.3
MEL-01-03	16-Jul-17	0.5	13.0	103	10.4	82	7.3
MEL-01-03	16-Jul-17	1.0	13.1	103	10.5	82	7.3
MEL-01-03	16-Jul-17	2.0	13.1	103	10.5	82	7.3
MEL-01-03	16-Jul-17	3.0	13.0	103	10.5	82	7.3
MEL-01-03	16-Jul-17	4.0	13.0	103	10.5	82	7.3
MEL-01-03	16-Jul-17	5.0	13.0	103	10.5	82	7.4
MEL-01-03	16-Jul-17	6.0	13.0	103	10.5	82	7.4
MEL-01-03	16-Jul-17	7.0	13.0	103	10.5	82	7.4
MEL-01-03	16-Jul-17	8.0	13.0	103	10.5	82	7.4
MEL-01-03	16-Jul-17	9.0	13.0	103	10.5	82	7.4
MEL-01-04							
MEL-01-04	16-Jul-17	0.0	13.1	102	10.3	82	7.3
MEL-01-04	16-Jul-17	0.1	13.1	102	10.4	82	7.3
MEL-01-04	16-Jul-17	0.5	13.1	103	10.5	82	7.3
MEL-01-04	16-Jul-17	1.0	13.1	103	10.5	82	7.3
MEL-01-04	16-Jul-17	2.0	13.1	103	10.5	82	7.3
MEL-01-04	16-Jul-17	3.0	13.1	104	10.6	82	7.3
MEL-01-04	16-Jul-17	4.0	13.1	104	10.6	82	7.4
MEL-01-04	16-Jul-17	5.0	13.1	104	10.6	82	7.4
MEL-01-04	16-Jul-17	6.0	13.1	104	10.6	82	7.4
MEL-01-04	16-Jul-17	7.0	13.1	104	10.6	82	7.4
MEL-01-04	16-Jul-17	8.0	13.1	104	10.6	82	7.4
MEL-01-05							
MEL-01-05	16-Jul-17	0.0	13.0	102	10.4	82	7.3
MEL-01-05	16-Jul-17	0.1	13.0	103	10.4	82	7.3
MEL-01-05	16-Jul-17	0.5	13.0	103	10.4	82	7.3
MEL-01-05	16-Jul-17	1.0	13.0	103	10.4	82	7.3
MEL-01-05	16-Jul-17	2.0	13.0	103	10.4	82	7.3
MEL-01-05	16-Jul-17	3.0	13.0	103	10.4	82	7.3
MEL-01-05	16-Jul-17	4.0	13.0	103	10.5	82	7.3
MEL-01-05	16-Jul-17	5.0	13.0	103	10.5	82	7.3
MEL-01-05	16-Jul-17	6.0	13.0	103	10.5	82	7.3
MEL-01-05	16-Jul-17	7.0	13.0	103	10.4	82	7.3
MEL-01-05	16-Jul-17	8.0	13.0	103	10.4	82	7.3

Table 3B.1-5: Field Profiles at Meliadine Near-Field, September 2017

Station	Date	Depth (m)	Temperature (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
MEL-01-01							
MEL-01-01	04-Sep-17	0.1	9.5	102	11.5	80	7.6
MEL-01-01	04-Sep-17	0.5	9.5	102	11.5	80	7.6
MEL-01-01	04-Sep-17	1.0	9.5	102	11.5	80	7.6
MEL-01-01	04-Sep-17	2.0	9.5	102	11.5	80	7.6
MEL-01-01	04-Sep-17	3.0	9.5	102	11.5	80	7.6
MEL-01-01	04-Sep-17	4.0	9.4	102	11.5	80	7.6
MEL-01-01	04-Sep-17	5.0	9.4	101	11.5	80	7.5
MEL-01-01	04-Sep-17	6.0	9.4	102	11.5	80	7.5
MEL-01-01	04-Sep-17	7.0	9.4	101	11.5	80	7.5
MEL-01-01	04-Sep-17	8.0	9.4	101	11.5	80	7.5
MEL-01-02							
MEL-01-02	04-Sep-17	0.1	9.4	102	11.5	80	7.6
MEL-01-02	04-Sep-17	0.5	9.4	102	11.5	80	7.6
MEL-01-02	04-Sep-17	1.0	9.4	102	11.5	80	7.6
MEL-01-02	04-Sep-17	2.0	9.5	102	11.5	80	7.6
MEL-01-02	04-Sep-17	3.0	9.4	102	11.5	80	7.5
MEL-01-02	04-Sep-17	4.0	9.4	102	11.5	80	7.5
MEL-01-02	04-Sep-17	5.0	9.4	102	11.4	80	7.5
MEL-01-02	04-Sep-17	6.0	9.4	101	11.4	80	7.5
MEL-01-02	04-Sep-17	7.0	9.4	101	11.4	80	7.5
MEL-01-03							
MEL-01-03	04-Sep-17	0.1	9.6	103	10.9	80	7.6
MEL-01-03	04-Sep-17	0.5	9.5	103	10.9	80	7.6
MEL-01-03	04-Sep-17	1.0	9.5	103	10.9	80	7.6
MEL-01-03	04-Sep-17	2.0	9.5	103	10.9	80	7.6
MEL-01-03	04-Sep-17	3.0	9.5	103	10.9	80	7.6
MEL-01-03	04-Sep-17	4.0	9.5	103	10.9	80	7.6
MEL-01-03	04-Sep-17	5.0	9.5	103	10.9	80	7.6
MEL-01-03	04-Sep-17	6.0	9.5	103	10.9	80	7.6
MEL-01-04							
MEL-01-04	04-Sep-17	0.1	9.5	101	11.5	80	7.6
MEL-01-04	04-Sep-17	0.5	9.5	101	11.5	80	7.6
MEL-01-04	04-Sep-17	1.0	9.5	101	11.5	80	7.6
MEL-01-04	04-Sep-17	2.0	9.5	101	11.5	80	7.6
MEL-01-04	04-Sep-17	3.0	9.5	102	11.5	80	7.6
MEL-01-04	04-Sep-17	4.0	9.4	101	11.5	80	7.6
MEL-01-04	04-Sep-17	5.0	9.4	101	11.5	80	7.5
MEL-01-04	04-Sep-17	6.0	9.4	101	11.5	80	7.5
MEL-01-04	04-Sep-17	7.0	9.4	101	11.5	80	7.5
MEL-01-04	04-Sep-17	8.0	9.4	101	11.5	80	7.5
MEL-01-05							
MEL-01-05	04-Sep-17	0.1	9.5	102	11.5	80	7.6
MEL-01-05	04-Sep-17	0.5	9.5	102	11.5	80	7.6
MEL-01-05	04-Sep-17	1.0	9.5	102	11.5	80	7.6
MEL-01-05	04-Sep-17	2.0	9.5	102	11.5	80	7.6
MEL-01-05	04-Sep-17	3.0	9.4	102	11.5	80	7.6
MEL-01-05	04-Sep-17	4.0	9.4	102	11.5	80	7.5
MEL-01-05	04-Sep-17	5.0	9.4	102	11.5	80	7.5
MEL-01-05	04-Sep-17	6.0	9.5	101	11.5	80	7.5
MEL-01-05	04-Sep-17	7.0	9.4	101	11.5	80	7.5
MEL-01-05	04-Sep-17	7.5	9.4	101	11.5	80	7.5