Appendix G3

EEM Cycle 2 Interpretive Report

ENVIRONMENTAL EFFECTS MONITORING: CYCLE 2, MEADOWBANK MINE INTERPRETIVE REPORT

June 26, 2015

Submitted To:

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EXECUTIVE SUMMARY

Introduction

Agnico Eagle Mines Ltd: Meadowbank Division began discharging treated effluent during 2009, and was subsequently required under the Metal Mining Effluent Regulations (MMER) to monitor effects of that effluent on fish and fish habitat. This is the mine's Second EEM Interpretive Report, and it is submitted to Environment Canada on behalf of Agnico Eagle Mines Limited, Val-d'Or, Québec. This report documents the results of the adult fish population survey and the benthic invertebrate community survey completed for the mine's Cycle 2 EEM biological monitoring studies, as well as the sub-lethal toxicity testing carried out on the Meadowbank Division effluent since the drafting of the Cycle 2 Study Design.

Fish Population Survey

Lake Trout was the sentinel fish species used in the 2014 Cycle 2 EEM survey; other species are not present in sufficient numbers. Lake Trout from the exposed area in Third Portage North Lake (TPN) were compared to those from two reference lakes, Innuguguayalik Lake (INUG) and Pipedream Lake (PDL). The study was designed as a non-lethal study, with additional data collected from incidental mortalities. The parameters examined were size distribution, age distribution, weight adjusted for length, liver weight adjusted for weight and length, weight at age and length at age. The Lake Trout from TPN were similar to those from PDL with a significant difference ($P<0.05$) only for the weight versus length relationship. Lake Trout from TPN were 4.2% heavier than Lake Trout from PDL when adjusted for length. Compared to Lake Trout from the INUG reference area, those from TPN were 5.7% heavier when adjusted for length ($P=0.000$), 11.3% shorter when adjusted for age determined from otoliths ($P=0.015$) and 28.4% lighter when adjusted for age determined from otoliths ($P=0.010$). It should be noted that the power of tests involving otolith age was low due to the small sample sizes, which increases the potential for both false positives and false negatives.

The Cycle 1 EEM study did not find any effects on the Lake Trout populations.

Benthic Invertebrate Community Survey

This 2014 survey of benthic invertebrates focused on the exposure area in Third Portage North Lake (TPN), with INUG and PDL as local reference areas. This is the second invertebrate community survey for the Meadowbank Mine under the MMER. Benthos have been sampled from TPN and INUG since 2006, while PDL has been sampled since 2009. TPN was in a baseline condition from 2006 to 2008, and has been in an 'exposed' condition since 2009. Benthic invertebrates were collected on August 22 (TPN) and 23 (INUG, PDL), 2014. Effects assessment involved use of baseline period data dating back to 2006, and involved testing of before-after-control-impact (BACI) and trend over time variations.

Sediments in the three sampling areas have been similar among sampling years, consisting largely of fines (silt and clay sized materials), and relatively low concentrations of organic carbon (normally 1 to 3 %). Benthic communities of the three study areas were similar in 2014, and similar to what had been described in previous years. The communities were dominated numerically by chironomids (50 to 80%) and Sphaeriidae (16 to 32%). Sub-dominant taxa in each of the three sample areas were, variously, Nematoda, Naididae, Tubificidae, Lumbriculidae and Acarina.

Total abundances in 2014 were generally <1,000 organisms per m^2, similar to what was observed in 2011. INUG and PDL sample areas produced an average of about four families per sample, whereas TPN produced an average of about 3 (2 to 4) families per sample in 2014. The number of taxa observed was generally lower in 2014 in all sample areas relative to what was observed in 2013, but within the range of values previously observed across the complete data record. Reflecting somewhat lower taxa richness per sample, equitability was generally higher in 2014 in each of the sample areas, with INUG producing values of about 0.5-0.8, PDL producing values ranging between about 0.4 and 0.8, and TPN producing values ranging between about 0.35 and 0.9.

None of the BACI or Time Trend contrasts for log of abundance, log of richness and equitability was statistically significant. BACI and time trend ANOVA's always explained < 1% of the variation of the total variation (i.e., potential mine-related effects were trivially small). Mantel tests on Bray-Curtis distances likewise produced non-statistically significant p values. Variations in Bray-Curtis distances were illustrated in a plot of non-metric multidimensional axis scores. Variations in axis scores for TPN always well overlapped variation in scores for the two reference lakes.

Mercury in Fish Flesh

Agnico Eagle Mines Ltd. has monitored mercury concentrations in the Meadowbank Division effluent since August 2009. Concentrations have remained below or near the detection limit of 0.01 µg/L. There was, therefore, no requirement to conduct a fish tissue survey during Cycle 2.

Sub-Lethal Toxicity

Cycle 2 tests with fathead minnows and *Pseudokirchneriella subcapitata* were similar to Cycle 1 in that little or no inhibition was observed in any of the samples tested. Inhibition of *Ceriodaphnia dubia* survival and reproduction and of *Lemna minor* growth was often significant but was highly variable from sample to sample in both Cycle 1 and Cycle 2. The potential for effects on the receiving water has been eliminated with the closure of the effluent stream.

Cessation of Discharge and Implications for EEM

In the future, the Meadowbank mine does not expect to discharge any water from the Portage Attenuation Pond (Tailings Storage Facility) to the receiving environment; rather, beginning in 2015, it will be combined with freshwater from Third Portage Lake and used to re-flood the Portage and Goose pits as part of mine reclamation. Discharge from the Vault Attenuation Pond to Wally Lake began in 2014 and will continue until the end of production. The implications of this to the EEM process will be discussed with Environment Canada.

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1.0 INTRODUCTION

1.1 Meadowbank Mine

The Meadowbank Mine (65°N, 96°W) is one of Canada's most northerly operating mines, located approximately 75-km north of the Hamlet of Baker Lake, Kivalliq District, Nunavut (Figure 1). Mine construction began in 2008 under Nunavut Water Board Type A License 2AM-MEA0815 and Fisheries and Oceans Canada Authorization for Works or Undertaking Affecting Fish Habitat NU-03-0191.3 and NU-03-0191.4. Meadowbank has been in operation since 2009, with mining activities formally underway since March 2010, and projected to occur until Q3, 2017. Mining at Meadowbank is occurring in three open pits (Goose Pit, Portage Pit and Vault Pit), all of which are currently operational. Much of the pit development is located in close proximity to the mill, office and lodging infrastructure, with the exception of the Vault Pit which is approximately 10 km northeast of the main mine site (Figure 2).

Mine construction activities near the Goose Pit and Portage Pit from 2008 to 2012 included the isolation of portions of two lakes using dikes. Dewatering of these impoundments into adjacent lakes started in 2009 and on December 31, 2009, Environment Canada notified AEM that the Meadowbank Mine is subject to MMER.

1.2 Regulatory Background

The Metal Mining Effluent Regulations (MMER), under the Fisheries Act, imposes liquid effluent limits for pH, cyanide, metals and suspended solids, and prohibits the discharge of a liquid effluent that is acutely lethal to fish. The MMER also requires mines to conduct Environmental Effects Monitoring (EEM) studies of fish, fish habitat and the use of fisheries resources in aquatic receiving environments. Under the MMER, Agnico Eagle Mines Limited (AEM) is required to conduct aquatic monitoring studies on the potential effects of the Meadowbank Division Mine's final liquid effluent on Third Portage Lake North (TPN).

Schedule 5, Parts 1 and 2, of the MMER requires each operating mine to conduct an EEM program consisting of the following components:

- **Effluent characterization and water quality monitoring** studies including sublethal toxicity testing; and,
- **Biological monitoring studies** consisting of a study design, field studies, data assessment and reporting.

AEM conducted its Cycle 1 Biological Monitoring Study in August 2011, collecting fish and benthos from the exposure area in Third Portage Lake North (TPN) (Figure 2) and from two reference areas, one each in Innuguguayalik Lake (INUG) and Pipedream Lake (PDL)(Figure 2). The results of that first study were reported to Environment Canada in June 2012 (Azimuth, 2012). A study design for a proposed Cycle 2 EEM Study was submitted to Environment Canada on February 14, 2014. The Technical Advisory Panel (TAP) reviewed the study design and provided comments to AEM Meadowbank Division. These comments were addressed by AEM, and the Meadowbank Cycle 2 EEM study design was accepted by

Environment Canada on July 21, 2014 (Appendix 1). This report describes the results of the Second Biological Study undertaken in the summer of 2014, pursuant to AEM's requirement under the MMER.

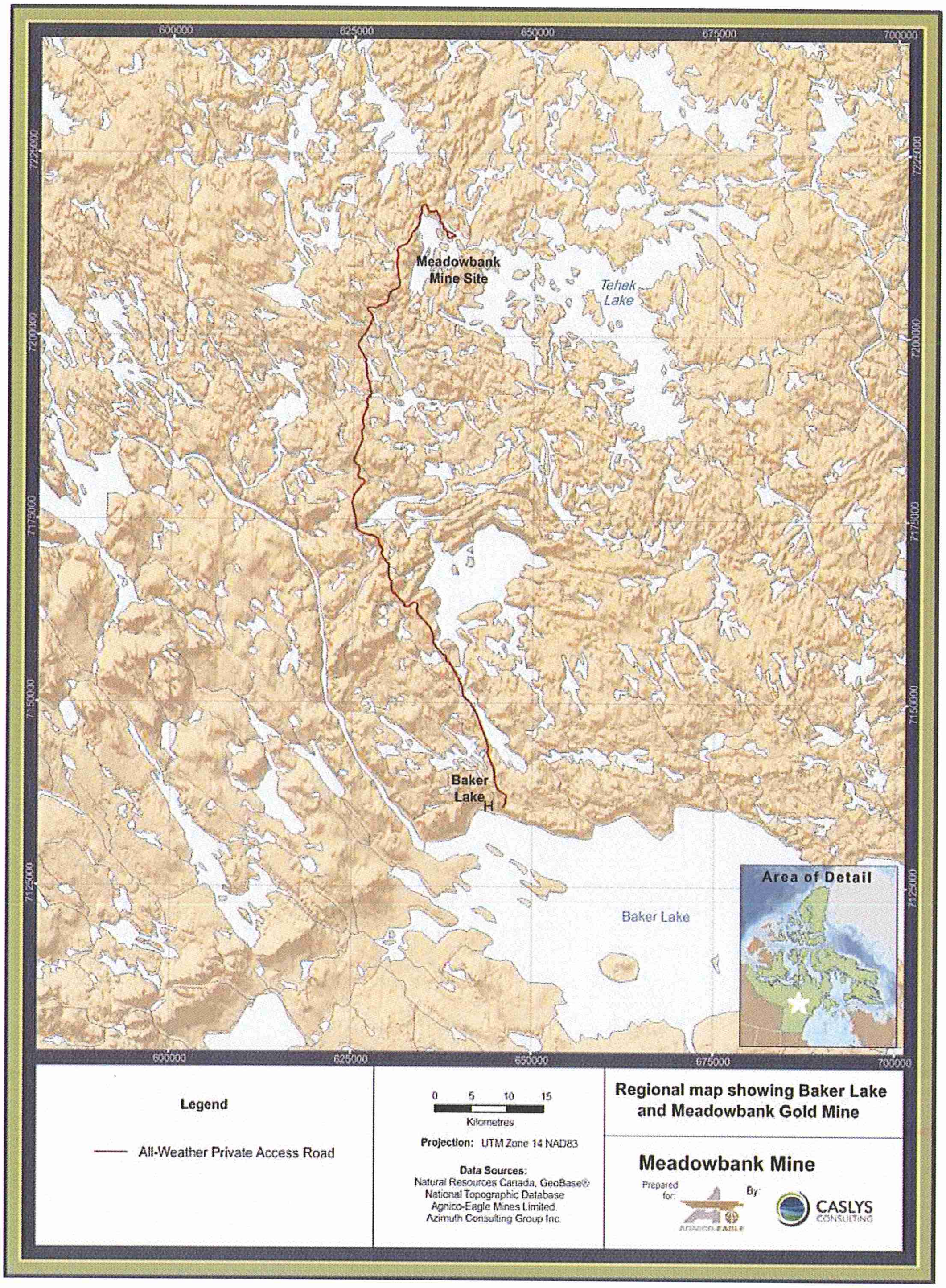


Figure 1. Location of Meadowbank Mine.

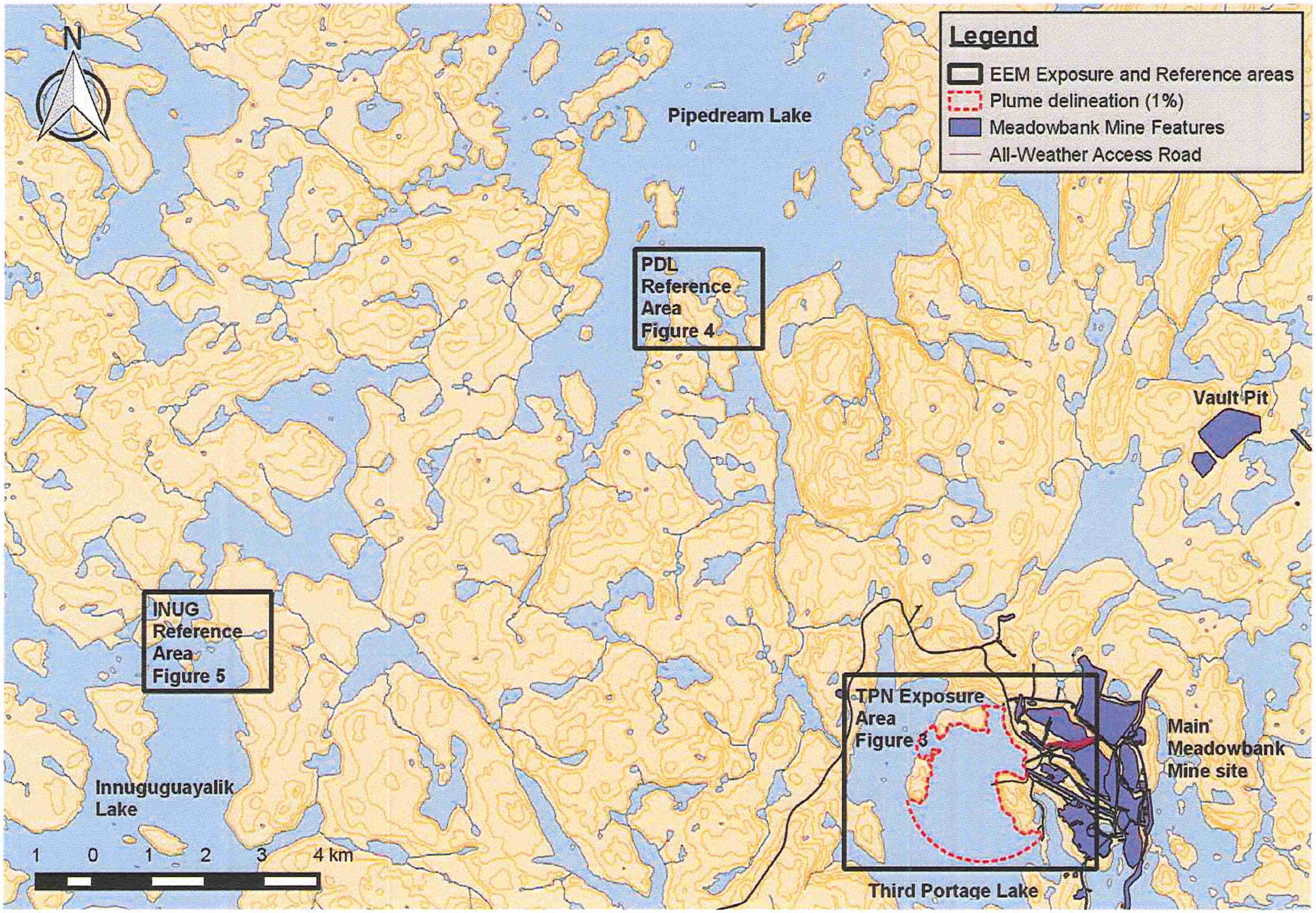


Figure 2. Map of the study area.

1.3 Concordance with Requirements

The Concordance Table (Table 1) provides a list of the MMER Interpretative Report requirements, and identifies where in this document the required information can be found.

Table 1. Concordance table identifying the sections of this report that address specific MMER reporting requirements.

MMER Requirement	Where Found in the Document
16. The data collected during the biological monitoring studies shall be used to: Calculate the arithmetic mean, the median, the standard deviation, the standard error and the minimum and maximum values in the sampling areas.	Raw data and summaries can be found in Section 3 and Appendix 2 for fish, and Section 4 and Appendix 5 for invertebrates. The raw data have also been submitted to the Environment Canada digital database.
17(a) Description of any deviation from the study design that occurred while the biological monitoring studies were being conducted and any impact that the deviation had on the studies.	Section 2.3
17(b) The latitude and longitude of sampling areas in degrees, minutes and seconds and a description of the sampling areas sufficient to identify the location of the sampling areas.	Digital data submission, Sections 3 and 4 and Appendix 2.
17(c) The dates and times when the samples were collected.	Sections 3 and 4
17(d) The sample sizes.	Sections 3 and 4
17(e) The results of the data assessment made under Section 16 and any supporting raw data	Section 3 for fish Section 4 for invertebrates
17(f) Based on (e), summary of effects on fish, fish tissues, invertebrates	Section 3 for fish A fish tissue study was not required (Section 5) Section 4 for invertebrates
17(g) Comparison of effects observed in (f) to results of sublethal toxicity testing.	Sections 3, 4, 6 and 7
17(h) conclusions of the biological monitoring studies taking into account: results of previous studies submitted under the study design; the presence of anthropogenic, natural or other factors that are not related to the effluent under study and that may reasonably be expected to contribute to any observed effect; the results of the statistical analysis conducted under paragraph 16(c) a description of the quality assurance/quality control measures that were implemented and the data related to the implementation of those measures.	Sections 3, 4, 6 and 7 Appendices 3, 4 and 6
17(i) A description of how the results will impact the study design for subsequent biological monitoring studies	Section 7
17(j) the date when the next biological monitoring study will be conducted.	Executive Summary Section 7

2.0 STUDY DESIGN UPDATE

2.1 Mining and Wastewater Management Overview

A detailed description of the Meadowbank Mine wastewater treatment system is provided in the EEM Cycle 2 Study Design (C. Portt and Associates, 2014). No changes in the wastewater treatment system occurred between the submission of the Study Design and the Cycle 2 field work in August 2014.

It is important to distinguish between the two major water-related "processes" that were in operation at the Meadowbank Mine prior to and during the EEM field work:

- *Reclaim Water* – All mining-related water (e.g., from the mill and/ or stormwater management pond (Tear Drop Pond), was segregated, and stored or actively pumped into the reclaim pond as make-up water. The reclaim pond was located within the North Cell of the TSF and was scheduled to move to the South Cell in 2015. Reclaim water has not been discharged to the receiving environment.
- *Contact Water* – the South Cell of the TSF (Portage Attenuation Pond) contained residual localized mine site drainage that may have been in contact with PAG material (i.e. from the Portage Waste Rock facility drainage which was directed to the south cell or from ST-16 to the North Cell) and water that was collected and actively pumped from the mine pits, either from surface water sources, groundwater sources or from dike water seepage.

Relevant to this EEM, mine effluent did not contain water that had come into contact with milled tailings. Contact water from the South Cell was either pumped to the North Cell or discharged. In 2015, pit water is scheduled to be re-directed to Goose Pit, and the South Cell, which has a capacity of 10 million tonnes, will be used for tailings storage and, as per water management plans, will become the new reclaim pond. To date, the Meadowbank mine has not and, in the future, does not expect to discharge any reclaim water to the receiving environment; rather, beginning in 2015, it will be combined with freshwater from Third Portage Lake and used to re-flood the pits as part of mine reclamation. Effluent is only discharged to the environment periodically (Table 2, Table 3, and Table 4), and during 2014 it was only discharged from June 14 to July 9, and not during the Cycle 2 EEM field studies conducted from August 22 to 27, 2014 (Table 4).

Effluent from the Meadowbank Mine was generally not acutely toxic during 2014, though the LC50 for *Daphnia magna* on July 5, 2014, was 91.6%, which is indicative of some toxicity (Table 5). Toxicity test results for sublethal endpoints for 2014 are presented in (Table 6).

There have been no exceedances of the MMER effluent discharge limits for deleterious substances at the Meadowbank Mine up to December 2014.

Table 2. Meadowbank Division effluent volume (m^3) for 2012.

Date	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12
1	0	0	0	0	0	14970	22690	6669	6300	0	3700	0
2	0	0	0	0	0	26748	25740	4172	6460	0	8670	0
3	0	0	0	0	0	28320	16070	2850	6140	0	13180	0
4	0	0	0	0	0	31210	20560	1080	5240	0	14410	0
5	0	0	0	0	0	30732	26540	4740	0	0	14420	0
6	0	0	0	0	0	31930	11710	570	6420	0	14360	0
7	0	0	0	0	0	31400	10980	2370	5980	0	14570	0
8	0	0	0	0	0	32170	13740	1820	6280	0	12050	0
9	0	0	0	0	0	27430	13690	2510	5720	0	5200	0
10	0	0	0	0	0	31790	4690	2131	6630	0	12570	0
11	0	0	0	0	0	30300	10960	4790	5670	0	8060	0
12	0	0	0	0	0	14060	3710	5560	5530	0	6200	0
13	0	0	0	0	2470	12760	6070	3530	5890	0	0	0
14	0	0	0	0	5780	13810	11600	5520	6550	0	0	0
15	0	0	0	0	6120	12810	17390	14430	6170	0	0	0
16	0	0	0	0	11990	24610	14370	9230	5160	0	0	0
17	0	0	0	0	14262	20330	0	6070	6050	0	0	0
18	0	0	0	0	15788	19573	7310	5970	5810	0	0	0
19	0	0	0	0	16340	23397	6830	4910	1970	0	0	0
20	0	0	0	0	13880	16060	3770	0	0	0	0	0
21	0	0	0	0	17320	16460	8510	5510	2360	0	0	0
22	0	0	0	0	10090	5010	25770	0	0	0	0	0
23	0	0	0	0	15060	17953	11700	0	3230	0	0	0
24	0	0	0	0	12720	18097	0	0	4710	0	0	0
25	0	0	0	0	19880	23010	1020	5870	6530	0	0	0
26	0	0	0	0	17340	30300	5590	5760	6140	0	0	0
27	0	0	0	0	16520	26140	10190	5470	5360	0	0	0
28	0	0	0	0	9010	16860	18050	6190	0	0	0	0
29	0	0	0	0	17730	14745	6170	6390	0	0	0	0
30	0		0	0	19400	17920	2410	6160	0	0	0	0
31	0		0		8640		3011	6300		0		0
Total	**0**	**0**	**0**	**0**	**250340**	**660905**	**340841**	**136572**	**132300**	**0**	**127390**	**0**

Table 3. Meadowbank Division effluent volume (m^3) for 2013.

Date	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13
1	0	0	0	0	0	0	0	0	11820	11510	0	0
2	0	0	0	0	0	0	0	0	9390	5170	0	0
3	0	0	0	0	0	0	0	0	10988	5330	0	0
4	0	0	0	0	0	0	0	0	11770	5250	0	0
5	0	0	0	0	0	0	0	0	11900	4800	0	0
6	0	0	0	0	0	0	0	0	11720	4880	0	0
7	0	0	0	0	0	0	0	0	11570	5210	0	0
8	0	0	0	0	0	0	0	0	10070	5940	0	0
9	0	0	0	0	0	0	0	0	11440	3030	0	0
10	0	0	0	0	0	0	0	0	11700	0	0	0
11	0	0	0	0	0	0	0	0	11900	0	0	0
12	0	0	0	0	0	0	0	0	11460	0	0	0
13	0	0	0	0	0	0	0	0	6360	0	0	0
14	0	0	0	0	0	0	0	0	11010	0	0	0
15	0	0	0	0	0	0	0	0	12870	5740	0	0
16	0	0	0	0	0	0	0	0	8710	11500	0	0
17	0	0	0	0	0	0	0	0	5550	12200	0	0
18	0	0	0	0	0	0	0	0	3650	2400	0	0
19	0	0	0	0	0	0	0	0	11620	0	0	0
20	0	0	0	0	0	0	0	0	11190	0	0	0
21	0	0	0	0	0	0	0	0	9740	0	0	0
22	0	0	0	0	0	0	0	5260	11490	0	0	0
23	0	0	0	0	0	0	0	5067	11350	0	0	0
24	0	0	0	0	0	0	0	11423	11370	0	0	0
25	0	0	0	0	0	0	0	9450	9250	0	0	0
26	0	0	0	0	0	0	0	5830	11370	0	0	0
27	0	0	0	0	0	0	0	9590	11240	0	0	0
28	0	0	0	0	0	0	0	12380	10800	0	0	0
29	0		0	0	0	0	0	11550	9560	0	0	0
30	0		0	0	0	0	0	11940	4760	0	0	0
31	0		0		0		0	11950		0		0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**94440**	**307618**	**82960**	**0**	**0**

Table 4. Meadowbank Division effluent volume (m^3) for 2014.

Date	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
1	0	0	0	0	0	0	5440	0	0	0	0	0
2	0	0	0	0	0	0	4750	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	3900	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	5750	0	0	0	0	0	0
11	0	0	0	0	0	5950	0	0	0	0	0	0
12	0	0	0	0	0	5740	0	0	0	0	0	0
13	0	0	0	0	0	12810	0	0	0	0	0	0
14	0	0	0	0	0	13120	0	0	0	0	0	0
15	0	0	0	0	0	6370	0	0	0	0	0	0
16	0	0	0	0	0	7390	0	0	0	0	0	0
17	0	0	0	0	0	5900	0	0	0	0	0	0
18	0	0	0	0	0	5980	0	0	0	0	0	0
19	0	0	0	0	0	5848	0	0	0	0	0	0
20	0	0	0	0	0	6260	0	0	0	0	0	0
21	0	0	0	0	0	5714	0	0	0	0	0	0
22	0	0	0	0	0	12060	0	0	0	0	0	0
23	0	0	0	0	0	11710	0	0	0	0	0	0
24	0	0	0	0	0	13950	0	0	0	0	0	0
25	0	0	0	0	0	13640	0	0	0	0	0	0
26	0	0	0	0	0	13300	0	0	0	0	0	0
27	0	0	0	0	0	13360	0	0	0	0	0	0
28	0	0	0	0	0	12750	0	0	0	0	0	0
29	0		0	0	0	13280	0	0	0	0	0	0
30	0		0	0	0	2841	0	0	0	0	0	0
31	0		0		0		0	0		0		0
Total	**0**	**0**	**0**	**0**	**0**	**193723**	**14090**	**0**	**0**	**0**	**0**	**0**

Table 5. Final effluent analytical results (2 pages).

	Arsenic	Copper	Cyanide	Lead	Nickel	Zinc	Total Suspended Solids	Radium 226	pH	Daphnia magna	Rainbow trout
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**Bq/L**	**units**	**LC50 %**	**LC50 %**
Max month avg Conc	0.50	0.30	1	0.20	0.50	0.50	15	0.37	6-9.5		
Max grab Conc	1.00	0.60	2	0.40	1.00	1.00	30	1.11	6-9.5		
Date											
15-May-12	<0.0005	0.0049	0.0190	<0.0003	0.0143	0.0050	1	<0.002	7.69	>100	>100
22-May-12	NMR	NMR	NMR	NMR	NMR	NMR	20	NMR	7.24	NMR	NMR
28-May-12	NMR	NMR	NMR	NMR	NMR	NMR	10	NMR	7.01	NMR	NMR
4-Jun-12	NMR	NMR	NMR	NMR	NMR	NMR	5	NMR	6.95	NMR	NMR
11-Jun-12	NMR	NMR	NMR	NMR	NMR	NMR	10	NMR	6.98	NMR	NMR
18-Jun-12	NMR	NMR	NMR	NMR	NMR	NMR	4	NMR	7.01	NMR	NMR
25-Jun-12	NMR	NMR	NMR	NMR	NMR	NMR	5	NMR	7.10	NMR	NMR
2-Jul-12	NMR	NMR	NMR	NMR	NMR	NMR	2	NMR	6.99	NMR	NMR
9-Jul-12	NMR	NMR	NMR	NMR	NMR	NMR	7	NMR	7.04	NMR	NMR
10-Jul-12	NMR	NMR	NMR	NMR	NMR	NMR	NMR	NMR	NMR	>100	>100
18-Jul-12	NMR	NMR	NMR	NMR	NMR	NMR	2	NMR	7.90	NMR	NMR
26-Jul-12	NMR	NMR	NMR	NMR	NMR	NMR	4	NMR	7.81	NMR	NMR
1-Aug-12	NMR	NMR	NMR	NMR	NMR	NMR	6	NMR	7.90	NMR	NMR
7-Aug-12	NMR	NMR	NMR	NMR	NMR	NMR	NA	NMR	7.61	>100	>100
13-Aug-12	NMR	NMR	NMR	NMR	NMR	NMR	3	NMR	6.96	NMR	NMR
21-Aug-12	NMR	NMR	NMR	NMR	NMR	NMR	6	NMR	6.94	NMR	NMR
27-Aug-12	NMR	NMR	NMR	NMR	NMR	NMR	4	NMR	6.95	NMR	NMR
3-Sep-12	NMR	NMR	NMR	NMR	NMR	NMR	2	NMR	7.38	NMR	NMR
11-Sep-12	NMR	NMR	NMR	NMR	NMR	NMR	3	NMR	7.26	NMR	NMR

	Arsenic	Copper	Cyanide	Lead	Nickel	Zinc	Total Suspended Solids	Radium 226	pH	Daphnia magna	Rainbow trout
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**Bq/L**	**units**	**LC50 %**	**LC50 %**
18-Sep-12	0.0023	0.0071	0.1380	0.0099	0.0308	0.0090	4	0.0500	7.25	NMR	NMR
26-Sep-12	NMR	NMR	NMR	NMR	NMR	NMR	4	NMR	7.71	NMR	NMR
5-Nov-12	0.0078	0.0067	0.2450	<0.0003	0.0470	<0.001	6	0.0480	6.77	>100	>100
22-Aug-13	0.0034	0.0056	0.2320	<0.0003	0.0600	0.0050	4	0.0350	7.60	77.1	>100
27-Aug-13	NMR	NMR	NMR	NMR	NMR	NMR	7	NMR	8.02	NMR	NMR
3-Sep-13	NMR	NMR	NMR	NMR	NMR	NMR	4	NMR	7.36	NMR	NMR
9-Sep-13	NMR	NMR	NMR	NMR	NMR	NMR	7	NMR	6.87	NMR	NMR
19-Sep-13	NMR	NMR	NMR	NMR	NMR	NMR	3	NMR	7.02	NMR	NMR
24-Sep-13	NMR	NMR	NMR	NMR	NMR	NMR	8	NMR	7.04	NMR	NMR
2-Oct-13	NMR	NMR	NMR	NMR	NMR	NMR	7	NMR	7.18	NMR	NMR
7-Oct-13	0.0014	0.0045	0.2460	<0.0003	0.0678	0.0030	4	0.0250	7.38	>100	>100
16-Oct-13	NMR	NMR	NMR	NMR	NMR	NMR	7	NMR	6.94	NMR	NMR
10-Jun-14	0.0013	0.0046	0.331	<0.0003	0.0421	0.004	7	0.035	6.64	>100	>100
16-Jun-14	NMR	NMR	0.269	NMR	0.0297	NMR	11	NMR	6.60	NMR	NMR
24-Jun-14	NMR	NMR	0.358	NMR	0.0381	NMR	6	NMR	7.32	NMR	NMR
30-Jun-14	NMR	NMR	0.312	NMR	0.0362	NMR	9	NMR	NA	NMR	NMR
5-Jul-14	0.0029	0.006	0.45	0.0011	<0.0005	0.003	9	0.04	7.21	91.6	>100

NMR = No measurement required.

Table 6. Sublethal endpoints and associated chemical and physical parameters for final effluent in 2013 and 2014.

Date	22/08/2013	24/09/2013	16/10/2013	30/06/2014
Parameters				
Alkalinity (mg $CaCO_3$/L)	103	103	115	82
Aluminium (mg/L)	1.16	0.953	2.31	1.59
Ammonia (mg N/L)	0.04	-	0.04	-
Ammonia nitrogen (NH3-NH4) (mg N/L)	9.7	12.2	12.1	7.6
Cadmium (mg/L)	0.00013	0.00005	<0.00002	0.00004
Hardness (mg $CaCO_3$/L)	471	364	581	355
Iron (mg/L)	0.06	0.06	0.13	0.07
Mercury (mg/L) (max allowance of 0.10µg/L)	<0.00001	<0.00001	<0.00001	0.00002
Molybdenum (mg/L)	0.0269	0.031	0.041	0.0214
Nitrate (mg N/L)	3.9	3.9	5.6	1.1
Selenium (mg/L)	0.003	0.001	0.007	0.001
Conductivity (µs/cm)	1303	1274	1566	37
Temperature (^{0}C)	16.27	10.6	8.9	14.6
Fathead Minnow IC25	-	-	84.9	>100
Fathead Minnow LC50	-	-	>100	>100
Ceriodaphnia dubia IC25	-	-	5.18	7
Ceriodaphnia dubia LC50	-	-	17.7	33.3
Freshwater Alga (*Pseudokirchneriella subcapitata* IC25	-	-	>90.9	>100
Lemna minor IC25 dry weight %v/v	-	-	3.94	12.9
Lemna minor IC25 frond number %v/v	-	-	40.7	5.83

2.2 Effluent Mixing in the Receiving Environment

Since July 2012 the effluent has been discharged via a diffuser at the location shown in Figure 2 and Figure 3. Effluent mixing in the north basin of Third Portage Lake was modeled by Golder Associates in 2010 (Appendix C *In* C. Portt and Associates, and Kilgour & Associates Ltd., 2014). Golder used the CORMIX model to predict plume mixing and dilution for 24 different sets of conditions covering the range of possible conditions: four scenarios of lake current (i.e., near stagnant, average 4-day low wind, average daily wind, and 10-year peak hourly wind), modeled at two current directions (i.e., co-flowing and cross-flowing) and three effluent buoyancy scenarios (i.e., neutral, positive and negative). Key results were as follows:

- Effluent dilution of 100:1 was not achieved within 250 m of the effluent discharge outfall (this triggers the fish study).
- The scenario of near stagnant lake currents resulted in the lowest modeled mixing potential, and was therefore used for the delineation of the potential exposure area.
- The upward jet of water at the diffuser location is predicted to be entrained by the lake current, where additional mixing would occur as the negatively buoyant plume sinks to the lake bottom. The effluent plume would then move along the lake bottom and gradually mix with ambient water.
- The potential exposure area (1% effluent dilution zone) would be a circular region bounded by the shoreline with a radius of 1400 m centered at the location of the diffuser outfall (Figure 3).

As indicated above in section 2.1, during 2014 effluent was only discharged from June 14 to July 9, and not during the Cycle 2 EEM field studies conducted from August 22 to 27, 2014.

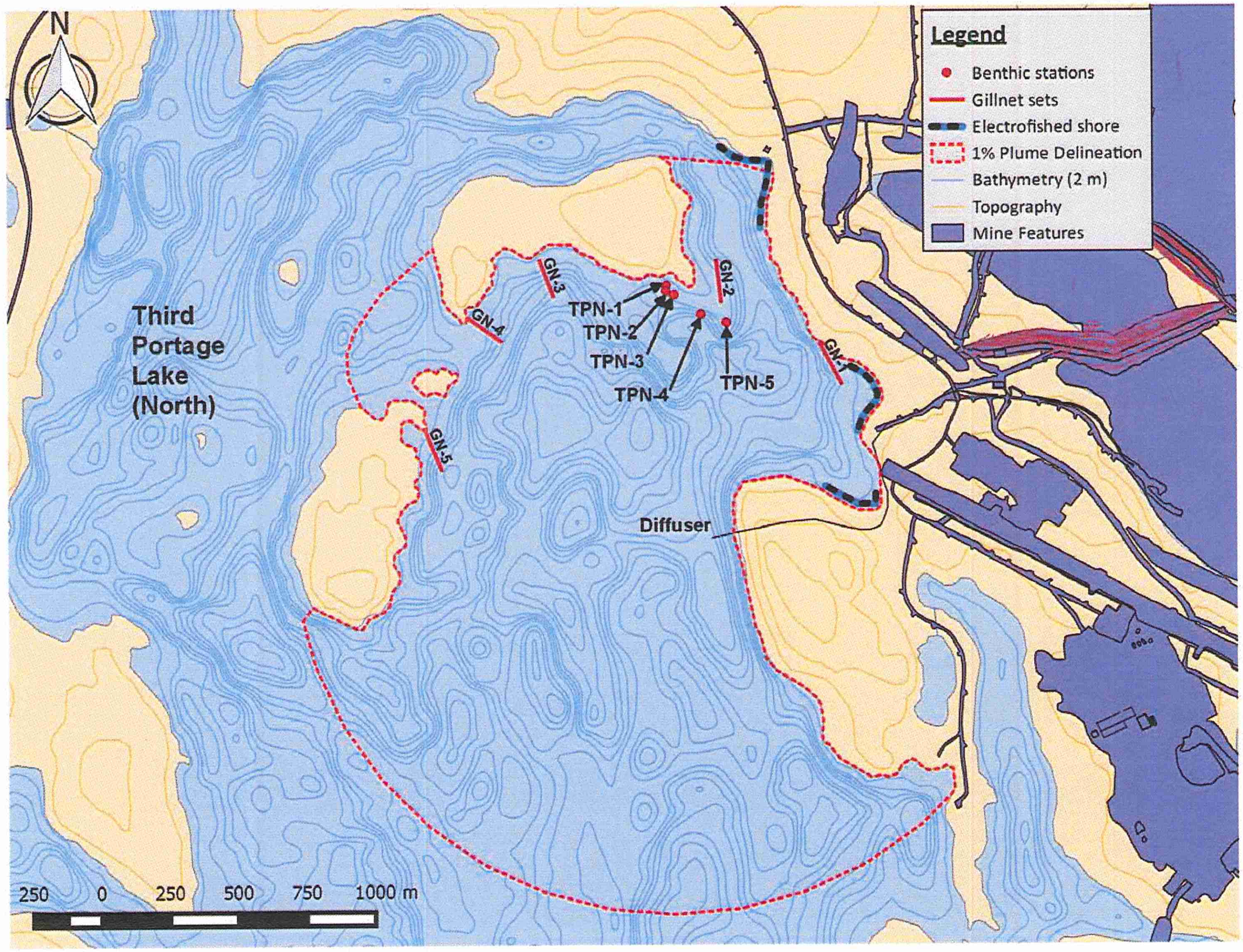


Figure 3. Exposure area showing the diffuser location, the 1% effluent plume, and gill net, electrofishing and benthic invertebrate sampling locations.

2.3 Overview of Study Design and Changes

2.3.1 Adult Fish Survey

The Cycle 2 study design report (C. Portt and Associates, and Kilgour & Associates Ltd., 2014) proposed a non-lethal study of Lake Trout (*Salvelinus namaycush*) captured by gill netting in one exposure area (TPN; Figure 3) and two reference areas (INUG and PDL; Figure 4 and Figure 5), assessing the weight versus length relationship (condition), with a target sample size of 25 fish per area. Following discussions with Environment Canada it was agreed that age-related relationships would be examined using age determinations based on pectoral fin rays collected from released lake trout and that the target sample size would be 60 fish per site. It was also agreed that Lake Trout liver weight and gonad weight and status would be determined, and otoliths would also be used for age determinations, for Lake Trout which died. These data were also to be included in the Cycle 2 assessment. The feasibility of collecting a small-bodied fish was also assessed during the Cycle 2 study, as requested by Environment Canada during discussions following the submission of the study design report.

2.3.2 Benthic Invertebrate Community Survey

The Cycle 2 benthic invertebrate study was undertaken as proposed in the study design report (C. Portt and Associates, and Kilgour & Associates Ltd., 2014), except that it was agreed during discussions with Environment Canada to use a Before-After-Control-Impact (BACI) statistical design, similar to the ongoing monitoring program (CREMP) that has been undertaken annually at the mine since 2006. The CREMP includes annual sampling of water chemistry, sediment chemistry, phytoplankton and benthic invertebrates at multiple exposed and multiple reference sites, and is superior to the standard EEM design in its ability to detect effects (differences between the exposed location(s) and reference locations). In this Cycle 2 EEM study there were two reference areas (Figure 4 and Figure 5) and one exposure area (Figure 3), with five sampling stations nested within each of these areas. Two sub-samples of the benthic community were collected from each sampling station and composited. Locations and water depths were targeted to be approximately that of the 2011 Cycle 1 EEM study, while ensuring that sampling stations were a minimum of 20 m apart to maintain some amount of independence of stations.

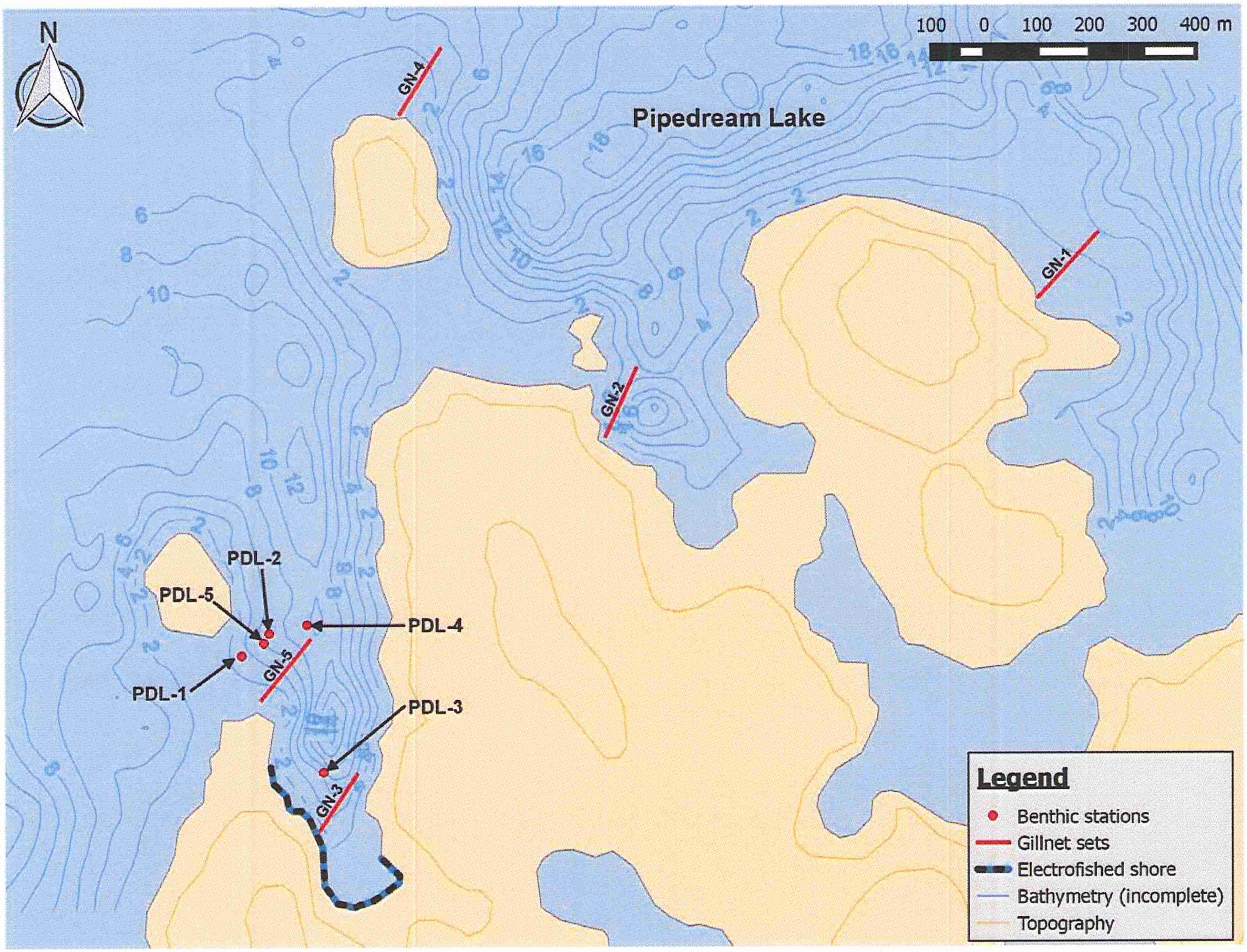


Figure 4. Pipedream Lake reference area (PDL).

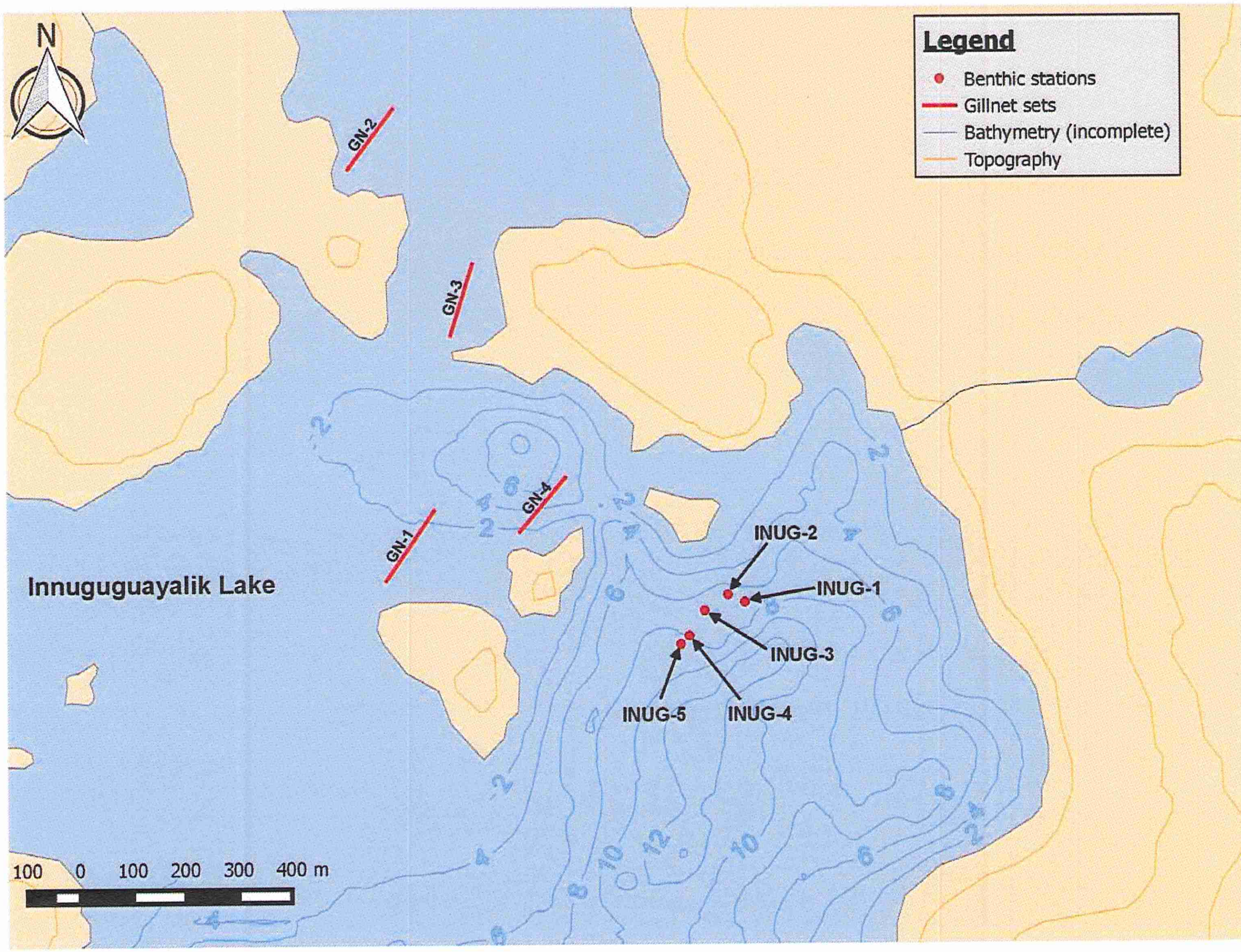


Figure 5. Innuguguayalik Lake reference area (INUG).

3.0 ADULT FISH SURVEY

3.1 Introduction

The adult fish survey, a key component of the metal mining effluent regulations, was completed as a component of the Cycle 2 EEM Biological Monitoring Studies. The Cycle 1 EEM adult fish survey was completed by Azimuth Consulting Group in August 2011 and submitted to Environment Canada in 2012 (Azimuth, 2012).

3.2 Materials and Methods

3.2.1 Field Work

3.2.1.1 Gill Net Fish Collections and Measurements

Fish were collected in the exposure area (TPN) in Third Portage Lake from August 22 to 23, from the PDL reference area in Pipedream Lake from August 24 to 25, and from the INUG reference area in Innuguguayalik Lake from August 26 to 27, 2014. The target species was Lake Trout, which dominated the catch. Index gill nets comprised of six panels of stretched mesh (sizes 126, 102, 76, 51, 38, and 25 mm) were used as the only means of fish capture for this study. Each panel of gill net was 1.8 m (6 feet) deep by 22.7 m (25 yards) long, so that the length of a six-panel gang was 136.4 m (150 yards). Gill nets were set within each sampling area, with the specific locations determined based on local habitat conditions. It was found that shallow nearshore or shoal areas yielded the greatest number of fish. The UTM coordinates of each end of each net were determined using a Garmin model GPSmap 76CSx and the depth was determined using a handheld Sonar unit. The date and time of deployment and lifts were also recorded. These data are provided in Appendix 2.

Nets were lifted and reset periodically. Soak time between lifts and total set duration were determined in the field based on local conditions and catch, with the objective of achieving the necessary sample sizes while minimizing the total mortality of Lake Trout and incidental catch. The number of individuals of each species captured in each lift of each net was recorded.

All Lake Trout captured alive were processed in the field and released. The net location and lift time was recorded for each Lake Trout and each was examined for external anomalies. Fork length was determined to the nearest mm using a standard fish measuring board. The weight of fish greater than 200 grams was determined to the nearest 10 grams using a Rapala electronic hanging scale. The weight of fish less than 200 grams was determined to the nearest 0.1 g using an Ohaus Scout Pro Model SP6001 electronic balance. The leading pectoral fin ray from the right side of the fish was collected for age determination.

Dead Lake Trout were taken to the laboratory at the mine site for processing. Length, weight and external condition were determined in the same way as for live individuals. The body cavity was opened and the viscera were examined for any anomalies. The gonads were examined to determine the sex, maturity, and gonad condition of the specimen. Females with opaque ovaries containing developing eggs visible with the naked eye were considered to be sexually mature. Females with translucent ovaries that did not contain eggs which were visible to the naked eye were considered to be immature. Females with opaque ovaries, and in some cases atretic eggs from the previous spawning season, but which did not appear to be developing eggs to spawn the following spring are referred to as undeveloped females. Females with large eggs that appeared to be suitable to spawn in the current year were termed resting females. Males with opaque testes were considered to be mature, and males with small translucent testes were considered to be immature. The liver and gonads were removed and weighed to the nearest 0.1 g using an Ohaus Scout Pro Model SP6001 electronic balance, or the nearest 0.01 g using an Ohaus Scout Pro Model SP202 electronic balance. The calibration of balances was confirmed each time they were set up, using the appropriate calibration weights.

3.2.1.2 Exploration of Alternative Capture Methods

Angling to capture Lake Trout was undertaken in TPN at the outset of the study. Electrofishing was conducted at Third Portage North and Pipedream Lakes to assess the potential to capture sufficient numbers of young-of-the-year Lake Trout and adult Slimy Sculpin. Electrofishing was conducted using a Halltech backpack electrofisher set at 950 volts and 250 hertz and a dip net by a two-person crew in wadeable near-shore areas. The locations where electrofishing began and ended were identified with a handheld GPS and the start and end times and elapsed electroseconds were also recorded. Captured fish were measured to the nearest mm and released near their point of capture.

3.2.1.3 Supporting Environmental Variables

Specific conductivity (µS/cm), pH, dissolved oxygen (mg/L) and temperature (°C) were determined within the Exposure and Reference Areas with an YSI Professional Plus. Meter calibration was undertaken daily following the methods in the user manual. Parameter resolution and accuracy are as follows:

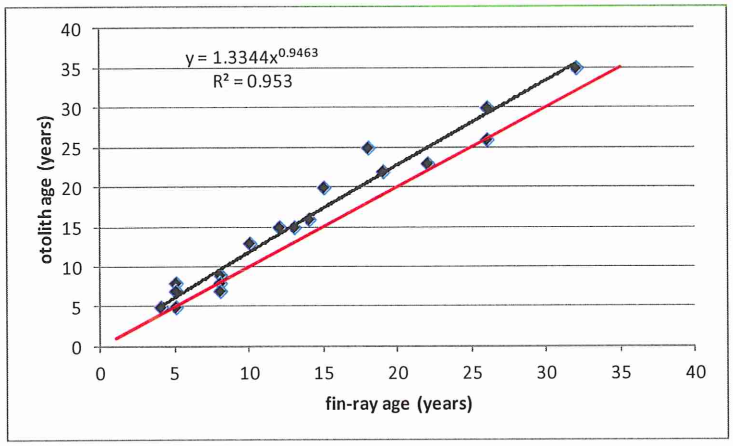
- Specific conductivity, resolution: 1 µS/cm, accuracy: the greater of ±1% of reading or 1 µS/cm.
- pH, resolution: 0.01 units, accuracy: ±0.2 units.
- Dissolved oxygen, resolution: 0.1 mg/L, accuracy: the greater of ±2% of reading or 0.2 mg/L.
- Temperature, resolution: 0.1°C, accuracy: ±0.2°C.

3.2.2 Age Determination

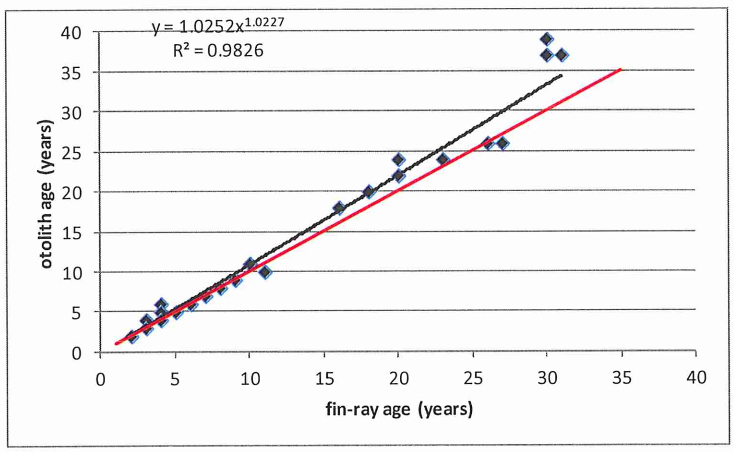
Aging of fish was completed by Louise Stanley, a fish aging expert who provides consulting services. Otoliths were mounted whole on a glass slide with CrystalBond thermoplastic adhesive and ground to the core on one side, flipped to adhere the core area to the glass, and then ground to a thin section on the other side. The proximal end of each fin ray was ground flat and then cut away from the rest of the ray with wire cutters. The flat proximal end was mounted on a glass slide with CrystalBond thermoplastic adhesive and the remaining fin ray ground away to leave a thin section. Age was estimated based on the number of annuli counted using transmitted light and a Leica GZ6 Stereo Zoom microscope. The number of annuli on fin rays and otoliths were determined independently (i.e. without reference to each other) when both were available for a fish. Age was estimated by C. Portt from fin rays and otoliths from 29 fish selected randomly from those for which both structures were available.

Age determined from fin rays tended to be less than age determined from otoliths, particularly for older fish (Figure 6). It is generally accepted that otolith ages are more accurate than fin-ray ages, particularly for older fish. The otolith age versus fin-ray age relationship for each lake, as described by a power equation determined using least squares regression (Figure 6), was used to calculate adjusted fin-ray ages to reduce error associated with age based on fin ray sections.

a) TPN



b) PDL



c) INUG

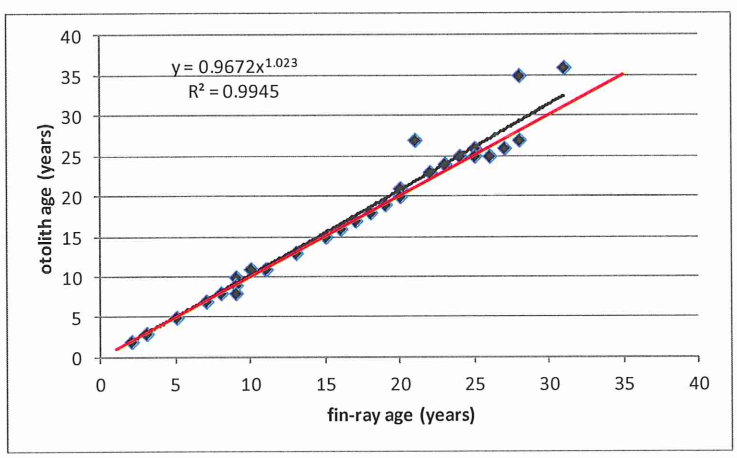


Figure 6. Plots of otolith age versus fin-ray age and the equations describing the relationships used to adjust fin-ray ages for each lake. The red lines represent equal fin-ray and otolith ages.

3.2.3 Lake Trout Data Analysis

Data for individual fish were entered into an Excel spreadsheet, and the entered values were compared with the original data sheets. Data entry errors were corrected.

Condition (K) was calculated using the formula:

$$K = \frac{100 \bullet weight}{length^3}.$$

Gonado-somatic index (GSI) was calculated using the formula:

$$GSI = \frac{100 \bullet gonadweight}{totalweight}.$$

Hepato-somatic index (HSI) was calculated using the formula:

$$HSI = \frac{100 \bullet liverweight}{totalweight}.$$

Box plots or scatterplots of the data were examined. Aberrant values were compared to the original data sheets to ensure they were not data entry errors. Fish with clearly aberrant values for one or more of the measured parameters that were not due to transcription errors were considered to be probable recording errors. Most were eliminated from the dataset but in cases where the nature of the error and the correct value was clear the value was corrected.

Statistical analyses were carried out using SYSTAT™ Version 13. Summary statistics (sample size, mean, minimum, maximum, standard deviation, standard error) were generated for each parameter, by lake. Comparisons were made between fish from the three lakes using the statistical techniques presented in Table 7. Analyses were conducted on all sexes combined as sex was not known for the individuals that were released and there were too few individuals for which sex was known to permit meaningful comparisons for either males or females.

Age distributions and length distribution were analyzed using the two-sample Kolmogorov-Smirnov test of raw data to compare each pair of sites. Analysis of covariance (ANCOVA) was performed on log-transformed data. Where ANCOVA was used, the data were analyzed using the complete model, which includes the interaction term (Area x independent variable) and the reduced model, which excludes the interaction term. Differences in slopes or intercepts were considered significant at the 5% level (i.e., $P \leq 0.05$). Significant interactions can be difficult to interpret, and complicate the computation of effect size. In cases where the interaction term accounted for < 2% of the total variation in the response variable the reduced model was considered to be appropriate and was used to assess significance and effect sizes, as per Barrett et al. (2010). When there were significant differences in intercepts, pairwise comparisons were made using Tukey's honestly significant difference test.

Residuals from each ANCOVA were examined for normality and outliers. Observations producing large Studentized residuals (i.e., > 4) were removed from the data set, and the analyses were repeated and variations in conclusions considered. This process was continued until no additional outliers were identified.

The percent difference in least-square means between Third Portage North and each of the two reference lakes was calculated as:

$$\%\text{Difference} = \frac{\overline{X}_{\text{exposure}} - \overline{X}_{\text{reference}}}{\overline{X}_{\text{reference}}}$$

When log transformed data were analyzed, the least-mean square values used were antilogs of the calculated values.

Table 7. Statistical analyses conducted to compare fish populations between the Exposure and Reference Areas

Dependent variable	Independent variable	Statistical technique
Body weight	Length	ANCOVA
Liver weight	Body weight, length	ANCOVA
Length	Age	ANCOVA
Body weight	Age	ANCOVA
Length Distribution		Kolmogorov-Smirnov
Age Distribution		Kolmogorov-Smirnov

3.2.4 Power Analysis

Power analysis was used to determine, *a posteriori*, the probability of detecting a 10% (weight versus length) or 25% (length versus age, weight versus age, liver weight) increase in the parameters of interest, assuming a 10% probability of committing a Type I error, and given the sample sizes, mean values, and the unexplained variability (i.e. the population standard deviation) from this study. Power was calculated by re-arranging the following power equation (Green, 1989):

$$n = \frac{1.5(t_\alpha + t_\beta)^2 \sigma^2}{\delta^2}$$

where:

- n is the number of fish
- σ is the population standard deviation,
- δ is the specified effect size,

- t_α is the Students *t* statistic for a two-tailed test with significance level α,
- t_β is the Students *t* statistic for a one-tailed test with significance level β.

3.3 Results

3.3.1 Physico-Chemical Character of Capture Areas

The locations of the sampling Areas are shown in Figure 2, and the location of individual nets shown for each Area in Figure 3, Figure 4 and Figure 5. The general limnology and water chemistry of the sampling areas is provided in Section 4 of this report.

3.3.2 Sampling Effort and Catches

3.3.2.1 Gill Net Catches

The location, depth and set and lift dates and times for each gill net are provided in Appendix 2. Gill nets were set at five locations in TPN and PDL and at four locations in INUG (Figure 3, Figure 4 and Figure 5). One gill net was removed in the evening from TPN and from INUG, leaving four nets and three nets set overnight, respectively. All five nets were set overnight in PDL. The mean daytime soak time was 2.6 hours in INUG and 3.4 hours in PDL and TPN (Table 8). Mean overnight set soak time ranged from 14.3 hours in TPN to 16.8 hours in PDL (Table 8).

Table 8. Number and mean soak time of daytime and overnight gill net lifts, by lake.

	Innuguguayalik (INUG)		Pipedream (PDL)		Third Portage North (TPN)	
set type	number of lifts	mean soak time (hours)	number of lifts	mean soak time (hours)	number of lifts	mean soak time (hours)
daytime	5	2.6	7	3.4	11	3.4
overnight	3	15.3	5	16.8	4	14.3
total	8	7.4	12	9.0	15	6.3

The numbers of fish that were released alive or were dead in gill net catches are presented, by lake and species, in Table 9. Lake Trout were the most abundant species in the catches in all three lakes with a total of 292 captured. Lower numbers of Arctic Char (*Salvelinus alpines;* n=13) and Round Whitefish (*Prosopium cylindraceum*; n=17) were captured in all three lakes and a single Arctic Grayling (*Thymallus arcticus*) was captured in INUG Lake. The only grayling captured was dead. Among the other three species, overall mortality rate was greatest for Round Whitefish (71%) and similar for Lake Trout (37%) and Arctic Char (31%).

Table 9. Numbers of fish that were released alive or were dead in gill net catches, by lake and species.

	Lake Trout		Arctic Char		Round Whitefish		Arctic Grayling	
waterbody	alive	dead	alive	dead	alive	dead	alive	dead
INUG	77	42	2	2	1	11	0	1
PDL	64	41	5	2	3	1	0	0
TPN	44	24	2	0	1	0	0	0
total	185	107	9	4	5	12	0	1

Mean Lake Trout CPUE in INUG was more than twice the CPUE in the other two lakes (Table 10), however, the CPUEs are not unbiased. The net set with the highest CPUE in the evening in TPN was removed due to concern that too many lake trout would be captured if it was left overnight. The net set with the lowest CPUE during the daytime in INUG Lake was removed because it caught no fish on the first lift and was in an exposed location where it would have been difficult to lift if the wind direction changed overnight. Nonetheless, the data strongly suggest that CPUE was higher in INUG than in the other two lakes. Mean CPUE was slightly higher in overnight sets than in daytime sets in all three lakes (Table 10).

Table 10. Mean catch-per-unit-effort (CPUE; number of Lake Trout captured per hour of soak time) for daytime and overnight gill net sets, by lake.

	set type		
waterbody	daytime	overnight	overall
INUG	1.9	2.1	2.0
PDL	0.9	1.0	0.9
TPN	0.6	0.8	0.7

3.3.2.2 Catches Using Alternative Capture Methods

No fish were captured by angling (total of 4 person-hours) in Third Portage North. Electrofishing effort (in electroseconds) and catches in Third Portage North and Pipedream Lakes are presented in Table 11 which also provides the mean, minimum and maximum total length of captured individuals. Catches in Third Portage Lake were low, with only two Lake Trout and eleven Slimy Sculpin captured with 5715 electroseconds of effort covering 1.10 km of shoreline. Catch-per-unit-effort was higher in Pipedream Lake for both Lake Trout and Slimy Sculpin, where effort was 1461 electroseconds covering 0.53 km of shoreline.

Table 11. Summary of electrofishing effort, catches, and mean, minimum and maximum total length by species.

Lake	electro-seconds/km	Species	number caught	total length (mm)		
				mean	minimum	maximum
Pipedream	1461/0.503	Lake Trout	4	58	43	88
		Slimy Sculpin	11	57	44	73
		Burbot	1	82	65	98
Third Portage North	5715/0.995	Lake Trout	2	43	43	43
		Slimy Sculpin	11	52	46	60

3.3.3 Lake Trout Characteristics

3.3.3.1 Overview

The numbers of Lake Trout processed by lake, sex, and maturity are presented in (Table 12). Lengths and weights were determined for 118 Lake Trout from INUG, 110 Lake Trout from PDL and 67 Lake Trout from TPN. Fin rays were aged from all but three of these fish. The majority of the mortalities from each lake were immature, and these included a number of fish for which sex could not be determined. The number of mature fish for which additional measurements are available (i.e. the number of mature mortalities) per lake was 17, 10 and 9 for INUG, PDL and TPN respectively, for a total of 36 mature fish (Table 12).

Table 12. Number of Lake Trout examined from each waterbody by sex and maturity. Fish for which neither sex nor maturity are available (na) were released alive.

waterbody	sex	maturity			total
		i	m	na	
INUG	f	10	7	2	19
	m	2	10		12
	u	10			10
	na			77	77
	total	22	17	79	118
PDL	f	5	3		8
	m	1	7		8
	u	24			24
	na			70	70
	total	30	10	70	110
TPN	f	3	5		8
	m		4		4
	u	11			11
	na			44	44
	total	14	9	44	67
Total		66	36	193	295

Less than half of the mature females were developing eggs that would be spawned in the current year (Table 13). All of the mature males appeared to be developing gonads in preparation for spawning in the current year (Table 13). The numbers of mature individuals that were developing gonads in preparation to spawn in the current year were too low to permit meaningful comparisons of gonad weights among lakes.

Table 13. Number of mature individuals that were developing gonads to spawn in the current year and that were not sufficiently developed to spawn in the current year (undeveloped).

	female		male	
waterbody	**developing**	**undeveloped**	**developing**	**undeveloped**
INUG	3	4	10	0
PDL	2	1	7	0
TPN	1	4	4	0
total	6	9	21	0

The summary statistics for each parameter measured or calculated are presented in Table 15. The gonads could not be discerned in some immature individuals; consequently there are no weights for these. The data for each specimen are provided in the digital submission to Environment Canada.

3.3.3.2 Ageing QA/QC

The differences between the ages estimated by the primary aging expert (L. Stanley) and those estimated by C Portt are summarized in Table 14. Ages were identical for 55% of the otolith ages and 41% of the fin-ray ages. Ages were within ±2 for 86% of the otolith ages and 83% of the fin-ray ages. The QA/QC ages tended to be lower than the original ages more often than they were higher. The primary and QA/QC ages are provided in Appendix 3.

Table 14. Magnitude of differences between age estimations by two different investigators (age-QA/QC age) and their frequency.

	aging structure	
difference in estimated age (years)	otolith	fin ray
-7	1	0
-5	1	0
-4	0	1
-3	2	4
-2	2	2
-1	3	4
0	16	12
1	2	3
2	2	3
total number	29	29

Table 15. Lake Trout summary statistics.

Lake	statistic	fork length (mm)	weight (g)	liver weight (g)	gonad weight (g)	condition	LSI	GSI	fin ray age (years)	otolith age (years)
TPN	N	67	67	19	12	67	19	12	66	19
	Minimum	130	23.7	0.60	0.80	0.87	0.57	0.22	1	5
	Maximum	860	6,540	44.80	256.60	1.38	2.28	17.58	32	35
	Mean	460	1581.6	13.711	58.492	1.09	1.10	3.40	15	15
	Standard error	22.3	164.2	3.347	20.869	0.015	0.089	1.373	1.0	2.1
	Standard deviation	182.8	1343.7	14.588	72.292	0.126	0.390	4.756	7.9	9.3
PDL	N	110	110	39	19	110	40	19	110	36
	Minimum	117	14.7	0.21	0.04	0.82	0.3	0.05	1	2
	Maximum	947	10,520	144.70	1427.50	1.35	1.51	13.57	38	39
	Mean	455	1614.3	9.716	110.169	1.04	0.96	2.51	16	11
	Standard error	19.2	164.7	3.883	74.245	0.01	0.038	0.865	0.9	1.8
	Standard deviation	201.8	1727.4	24.251	323.628	0.101	0.238	3.772	9.1	11.0
INUG	N	118	118	40	31	118	40	30	116	41
	Minimum	133	21.3	0.20	0.20	0.81	0.49	0.06	2	2
	Maximum	891	10,200	60.94	252.10	1.44	1.59	15.28	39	36
	Mean	476	1512.4	9.672	33.958	1.04	0.95	1.72	17	14
	Standard error	14.4	141.5	2.044	10.642	0.01	0.040	0.510	0.7	1.5
	Standard deviation	155.9	1537.3	12.926	59.25	0.105	0.250	2.794	7.8	9.7

3.3.3.3 Lesions, Deformities and Parasites

No lesions were observed that were not consistent with having occurred while entangled in a gill net. One Lake Trout from INUG had a deformed (probably previously damaged) right pectoral fin. Encysted cestodes were observed in the livers of the majority of the Lake Trout examined internally from INUG and PDL. These occurred in TPN as well but were not recorded.

3.3.3.4 Between lake comparisons

The results of between-lake comparisons are summarized in Table 16 and each is discussed below.

Condition

Fish weight is plotted against fork length in Figure 7. There were no significant differences in the slopes of the log of total weight versus the log of length regression, but the intercepts differed. Both INUG and PDL were significantly different from TPN (p=0.000 and p=0.009 respectively). The intercepts for INUG and PDL were not significantly different (p=0.515). Lake Trout from TPN were 5.7% and 4.2% heavier than those from INUG and PDL respectively, when adjusted for length (Table 16). These differences are less than the 10% critical effect size.

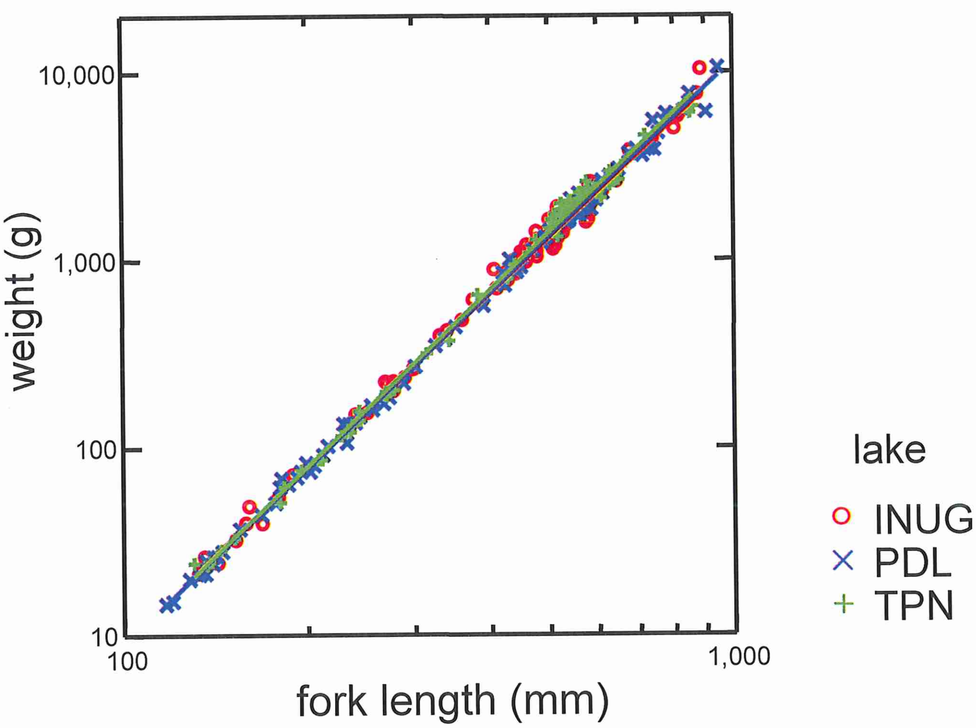


Figure 7. Plot of fish weight versus fork length (log scales).

Liver weight

A plot of liver weight versus weight is presented in Figure 8. There were significant differences in the slopes of the log of liver weight versus the log of body weight relationships, however, the r^2 value was only reduced by 0.003 when the interaction term was removed (Table 16). Therefore, comparison of least square means with the reduced ANCOVA was considered appropriate. The intercepts of the log of liver weight versus log of weight relationship were not significantly different (Table 16).

There were significant differences in the slopes of the log of liver weight versus log of fork length relationships (Figure 9), however, the r^2 value was only reduced by 0.003 when the interaction term was removed (Table 16). Therefore, comparison of least square means with the reduced ANCOVA was considered appropriate. The intercepts of the log of liver weight versus log of fork length relationships differed significantly (Table 16). Pairwise comparisons using Tukey's honestly significant difference test indicated that there was a significant difference between the INUG and TPN intercepts (p=0.046) but not between the PDL and TPN intercepts (p=0.167) or between the INUG and PDL intercepts (p=0.783). The mean liver weight for TPN was 23.0% heavier and 17.8% heavier, respectively, than that for INUG and PDL, when adjusted for length (Table 16).

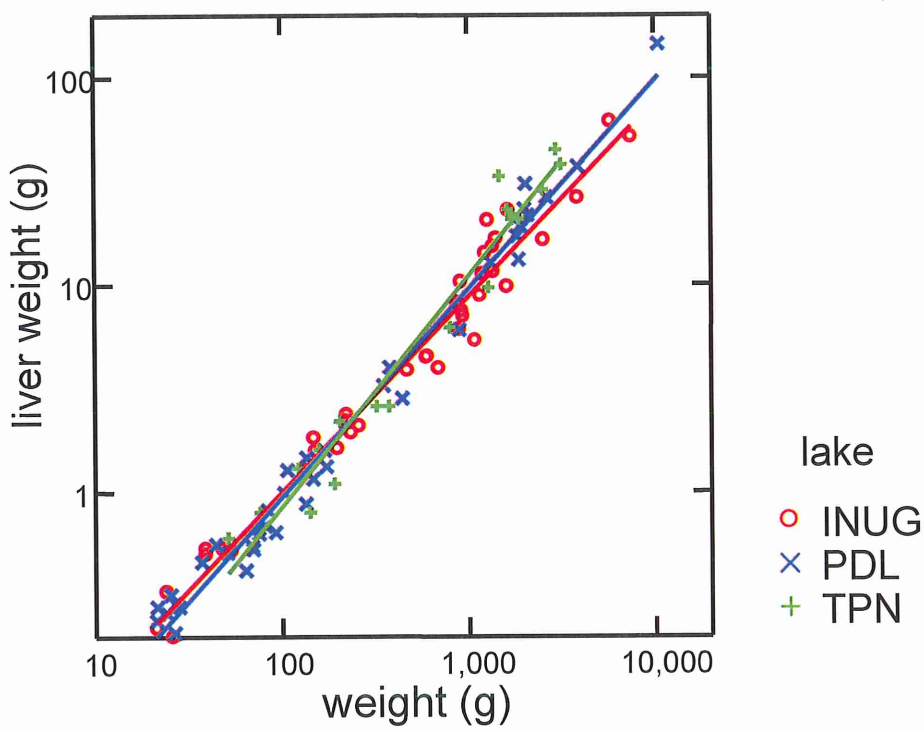


Figure 8. Plot of liver weight versus weight (log scales).

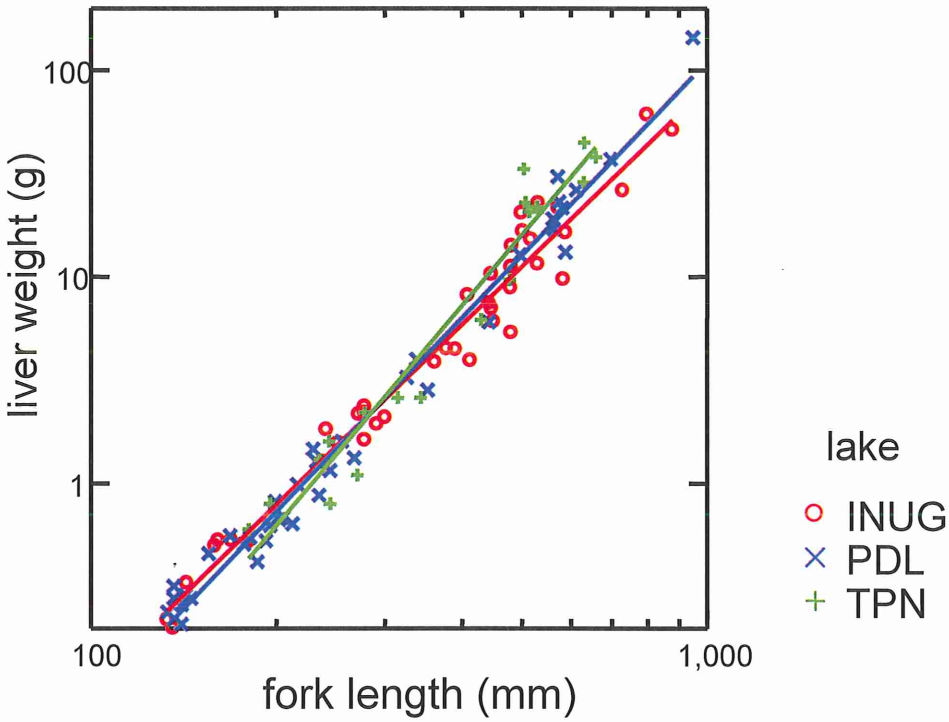


Figure 9. Plot of liver weight versus fork length (log scales).

Table 16. Summary of between-lake comparisons using ANCOVA. When intercepts differ among lakes p-values for comparisons between Third Portage North and the other two lakes were calculated using Tukey's honestly significant difference test. N is the number of fish required per location when there is one exposed area and two reference areas.

Depend-ent variable	Independ-ent variable	Data excluded	Procedure	Error MS	Interaction *p*-Value	Area *p*-value	r^2	LS Mean INUG	LS Mean PDL	LS Mean TPN	% Difference (p-value) INUG	% Difference (p-value) PDL	Power (ES)	N to achieve 90% Power
log of body weight	log of length	none	ANCOVA	0.002	0.170		0.996							
			Reduced ANCOVA	0.002		**0.000**	0.996	767	778	811	5.7 **(0.000)**	4.2 **(0.009)**	100 (10%)	16
log of liver weight	log of body weight	none	ANCOVA	0.012	0.013		0.979							
			Reduced ANCOVA	0.013		0.102	0.976	3.17	3.29	3.75	18.3	14.0	97.8 (25%)	19
	log of length	none	ANCOVA	0.014	0.005		0.974							
			Reduced ANCOVA	0.016		0.058	0.971	3.14	3.28	3.86	23.0 **(0.046)**	17.8 (0.167)	95.2 (25%)	16
log of length	log of otolith age	none	ANCOVA	0.003	0.114		0.949							
			Reduced ANCOVA	0.003		**0.001**	0.946	340	310	301	-11.3 **(0.015)**	-2.7 (0.752)	100 (25%)	5
log of weight	log of otolith age	none	ANCOVA	0.029	0.046		0.947							
			Reduced ANCOVA	0.030		**0.000**	0.943	395	301	283	-28.4 **(0.010)**	-6.0 (0.857)	77.6 (25%)	42
log of length	log of adjusted age	none	ANCOVA	0.004	0.085		0.912							
			Reduced ANCOVA	0.004		0.201	0.911	432	424	415	-3.8	-2.1	100 (25%)	7
		fish 76	ANCOVA	0.003	0.031		0.922							
			Reduced ANCOVA	0.004		0.141	0.920	433	421	416	-3.8	-1.1	100 (25%)	7
log of weight	log of adjusted age	none	ANCOVA	0.038	0.034		0.909							
			Reduced ANCOVA	0.039		0.573	0.907	830	791	776	-6.5	-1.8	67.8 (25%)	55
		fish 76, 30	ANCOVA	0.033	0.001		0.922							
			Reduced ANCOVA	0.033		0.324	0.918	847	794	773	-8.8	-2.7	66.4 (25%)	46

Growth

Otolith Age

A plot of fork length versus otolith age is presented in Figure 10. ANCOVA indicated that there was no significant difference in the slopes of the log of length versus log of otolith age relationship among lakes (Table 16). Reduced ANCOVA indicated that there were significant differences in the intercepts among the lakes (Table 16). Pairwise comparisons using Tukey's honestly significant difference test indicated that there was a significant difference between the intercept for INUG and the intercept for PDL (p=0.006) and the intercept for TPN (p=0.015), but no significant difference between the intercepts for TPN and PDL (p=0.752).

A plot of weight versus otolith age is presented in Figure 11. ANCOVA indicated that there was a significant difference in the slopes of the log of weight versus otolith age among lakes, however, the r^2 value was only reduced by 0.004 when the interaction term was removed (Table 16). Therefore, comparison of least square means with reduced ANCOVA was considered appropriate. Reduced ANCOVA indicated that there were significant differences in the intercepts among the lakes (Table 16). Pairwise comparisons using Tukey's honestly significant difference test indicated that there was a significant difference between the intercept for INUG and the intercept for PDL (p=0.024) and the intercept for TPN (p=0.010), but no significant difference between the intercepts for TPN and PDL (p=0.857).

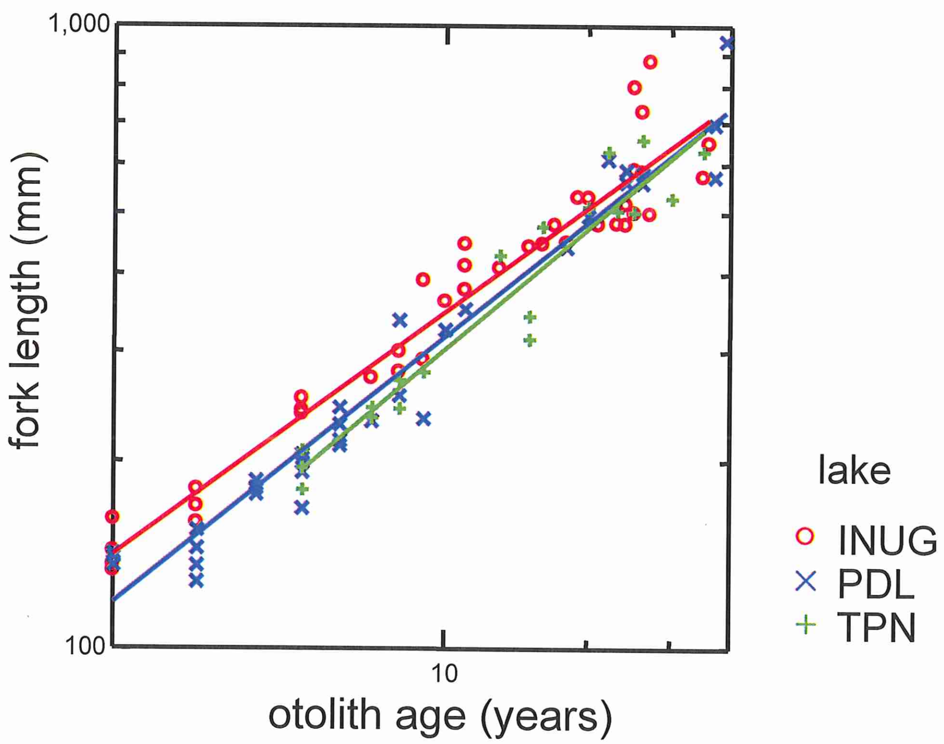


Figure 10. Plot of fork length versus otolith age (log scales).

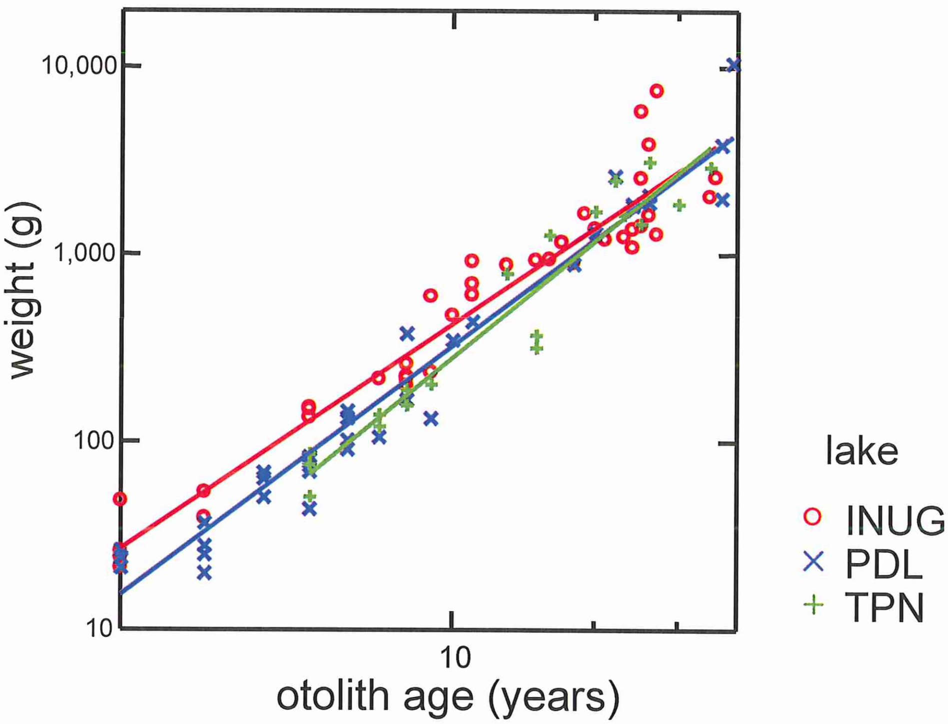


Figure 11. Plot of weight versus otolith age (log scales).

Adjusted Age

A plot of fork length versus adjusted age is presented in Figure 12. ANCOVA indicated that there was no significant difference in the slopes of the log of fork length versus log of adjusted age among lakes (Table 16). Reduced ANCOVA indicated that there were no significant differences in the intercepts among the lakes (Table 16). Removal of fish number 76, which was identified as an outlier, did not change this result (Table 16).

A plot of weight versus adjusted age is presented in Figure 13. ANCOVA indicated that there was a significant difference in the slopes of the log of weight versus log of adjusted age among lakes (Table 16), however, the r^2 value was only reduced by 0.002 when the interaction term was removed (Table 16). Therefore comparison of least square means with reduced ANCOVA was considered appropriate. Reduced ANCOVA indicated that there were no significant differences in the intercepts among the lakes (Table 16). Removal of fish number 76 and 30, which were identified as outliers, did not change this result (Table 16).

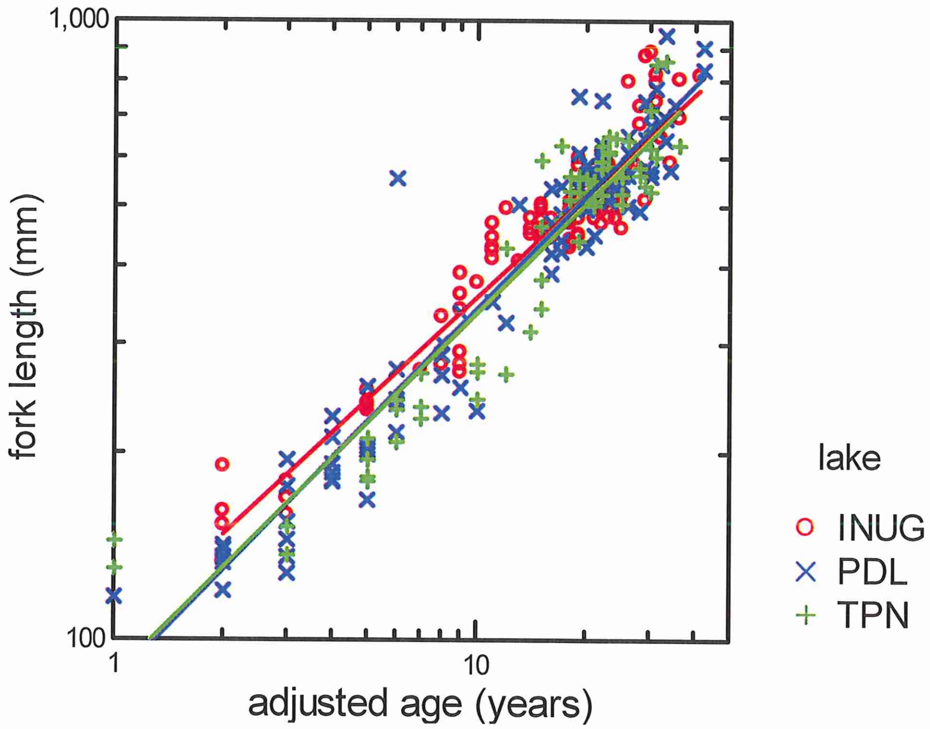


Figure 12. Plot of fork length versus adjusted age (log scales).

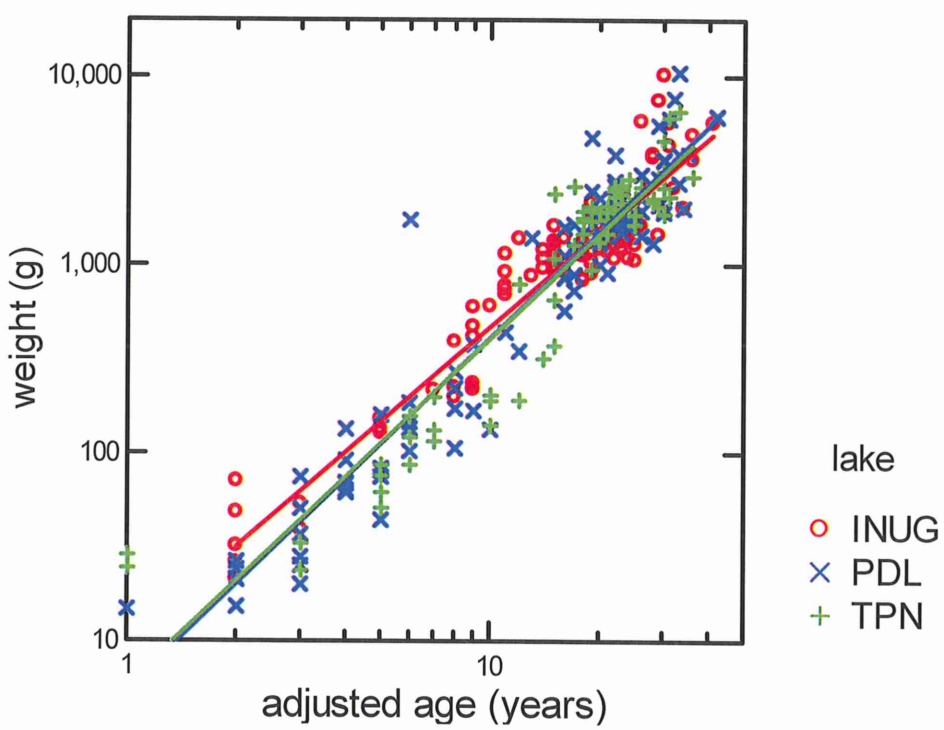


Figure 13. Plot of weight versus adjusted age (log scales).

Length Distribution

The fork length-frequency distributions for each lake are shown in Figure 14. All three lakes exhibited bi-modal distributions which were more pronounced in Pipedream and Third Portage North. The distributions were compared between pairs of lakes using the Kolmogrov-Smirnov test, which indicated that there was a significant difference in length distributions between Innug and Pipedream and Innug and Third Portage North (Table 17). There was no significant difference between the length distributions in Pipedream and Third Portage North (Table 17).

Table 17. Kolmogorov-Smirnov two-sided probabilities of differences in the fork length distributions between each pair of lakes.

	INUG	PDL	TPN
INUG	1.000		
PDL	0.000	1.000	
TPN	0.010	0.983	1.000

Age Distribution

The fin-ray age-frequency distributions for each lake are shown in Figure 15. All three lakes exhibited bi-modal distributions which were more pronounced in Pipedream and Third Portage North. The distributions were compared between pairs of lakes using the Kolmogorov-Smirnov test, which indicated that there was no significant difference in fin-ray age distributions between Third Portage North and either Innug or Pipedream but the age distributions in Innug and Pipedream were significantly different (Table 18).

Table 18. Kolmogorov-Smirnov two-sided probabilities of differences in the fin ray age distributions between each pair of lakes.

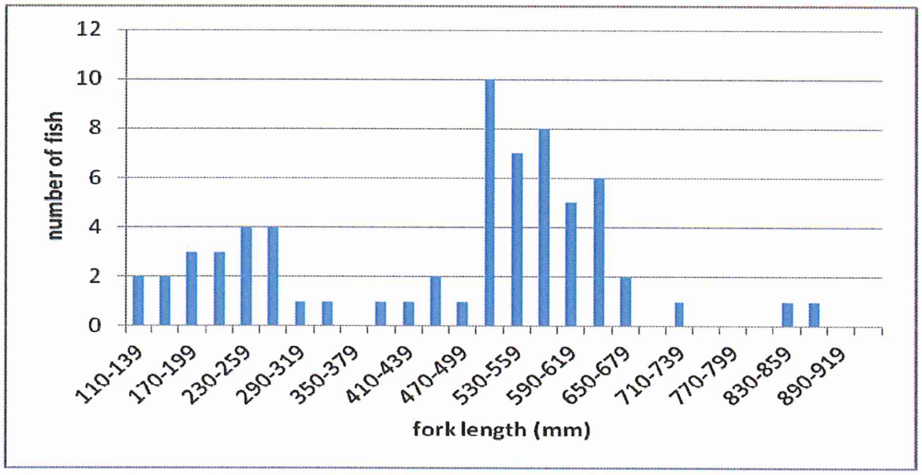
	INUG	PDL	TPN
INUG	1.000		
PDL	0.038	1.000	
TPN	0.420	0.909	1.000

The adjusted age-frequency distributions for each lake are shown in Figure 16. All three lakes exhibited bi-modal distributions which were more pronounced in Pipedream and Third Portage North. The distributions were compared between pairs of lakes using the Kolmogorov-Smirnov test, which indicated that there was no significant difference in age distributions between the three lakes (Table 19). The otolith age-frequency distributions were not compared because they are confounded by mortality rates which were higher among small individuals.

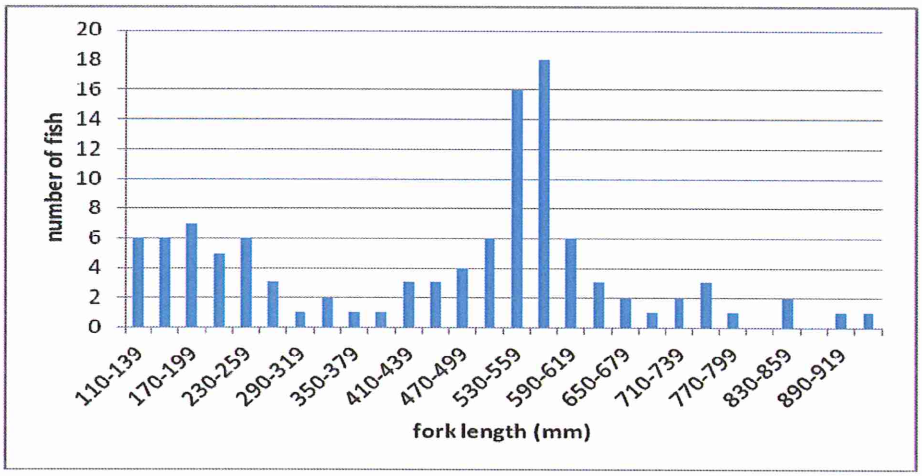
Table 19. Kolmogorov-Smirnov two-sided probabilities of differences in the adjusted age distributions between each pair of lakes.

	INUG	PDL	TPN
INUG	1.000		
PDL	0.106	1.000	
TPN	0.794	0.681	1.000

a) TPN



b) PDL



c) INUG

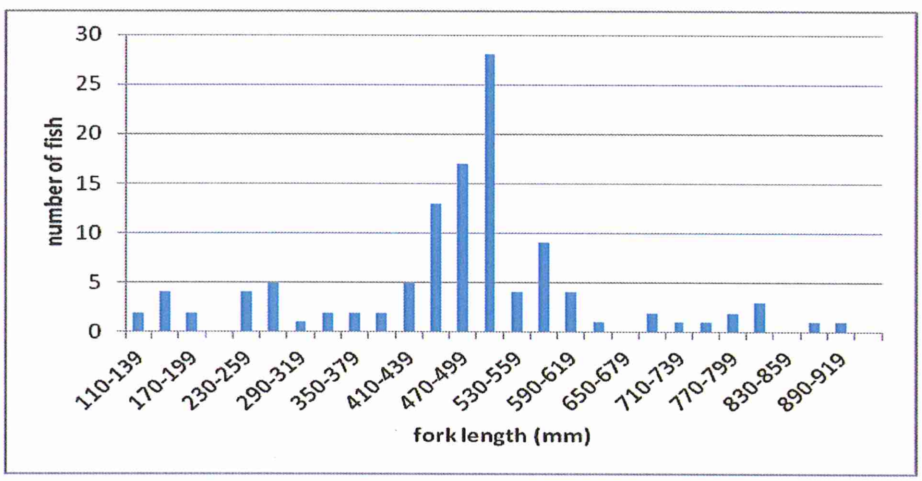
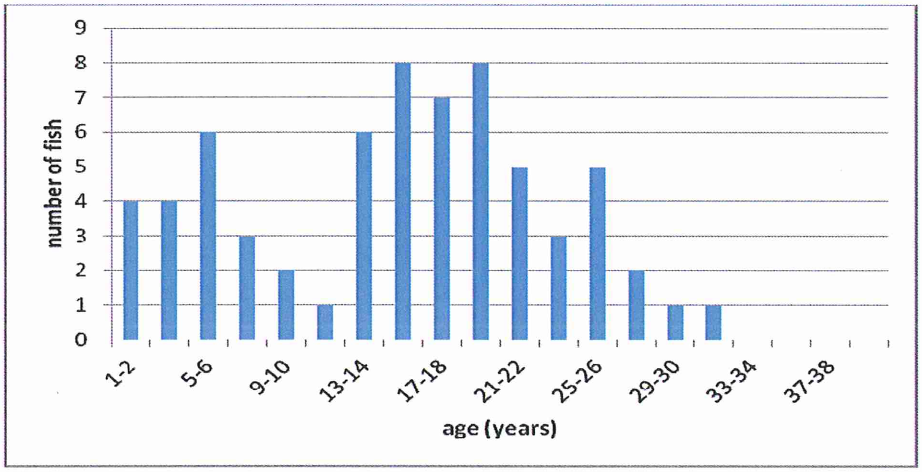
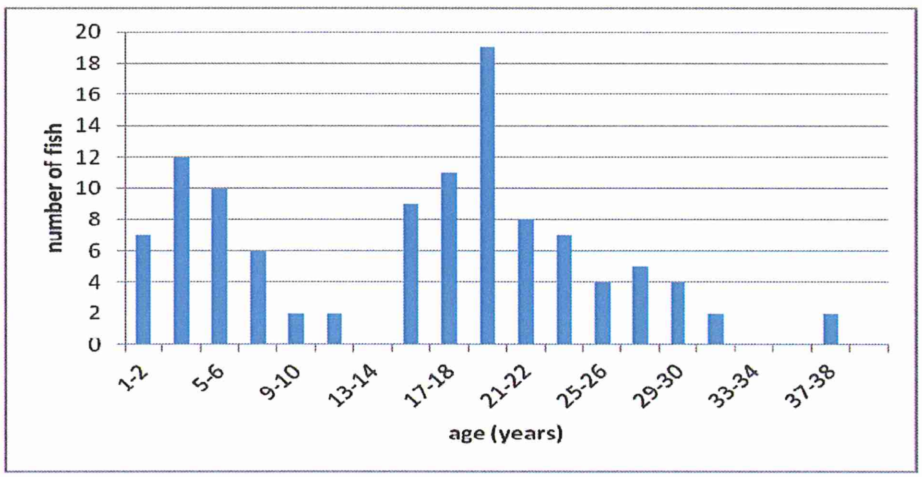


Figure 14. Length-frequency distributions.

a) TPN



b) PDL



c) INUG

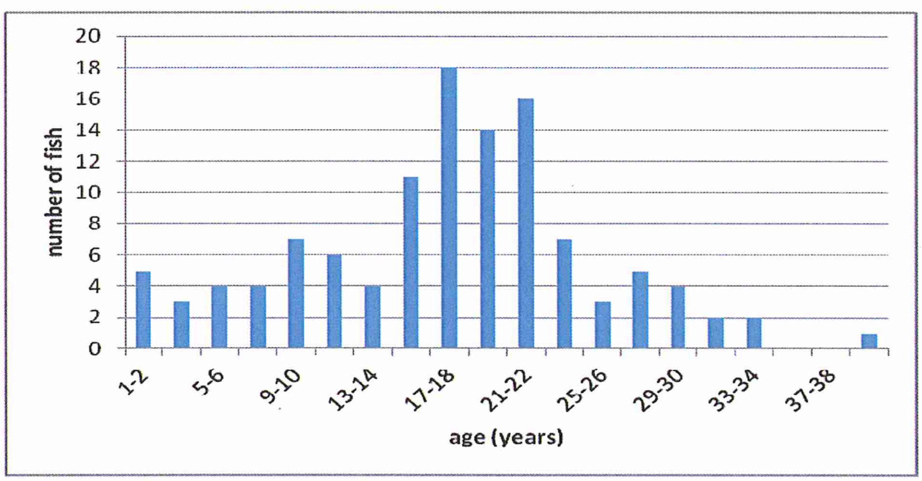


Figure 15. Fin-ray age-frequency distributions.

a) TPN

b) PDL

c) INUG

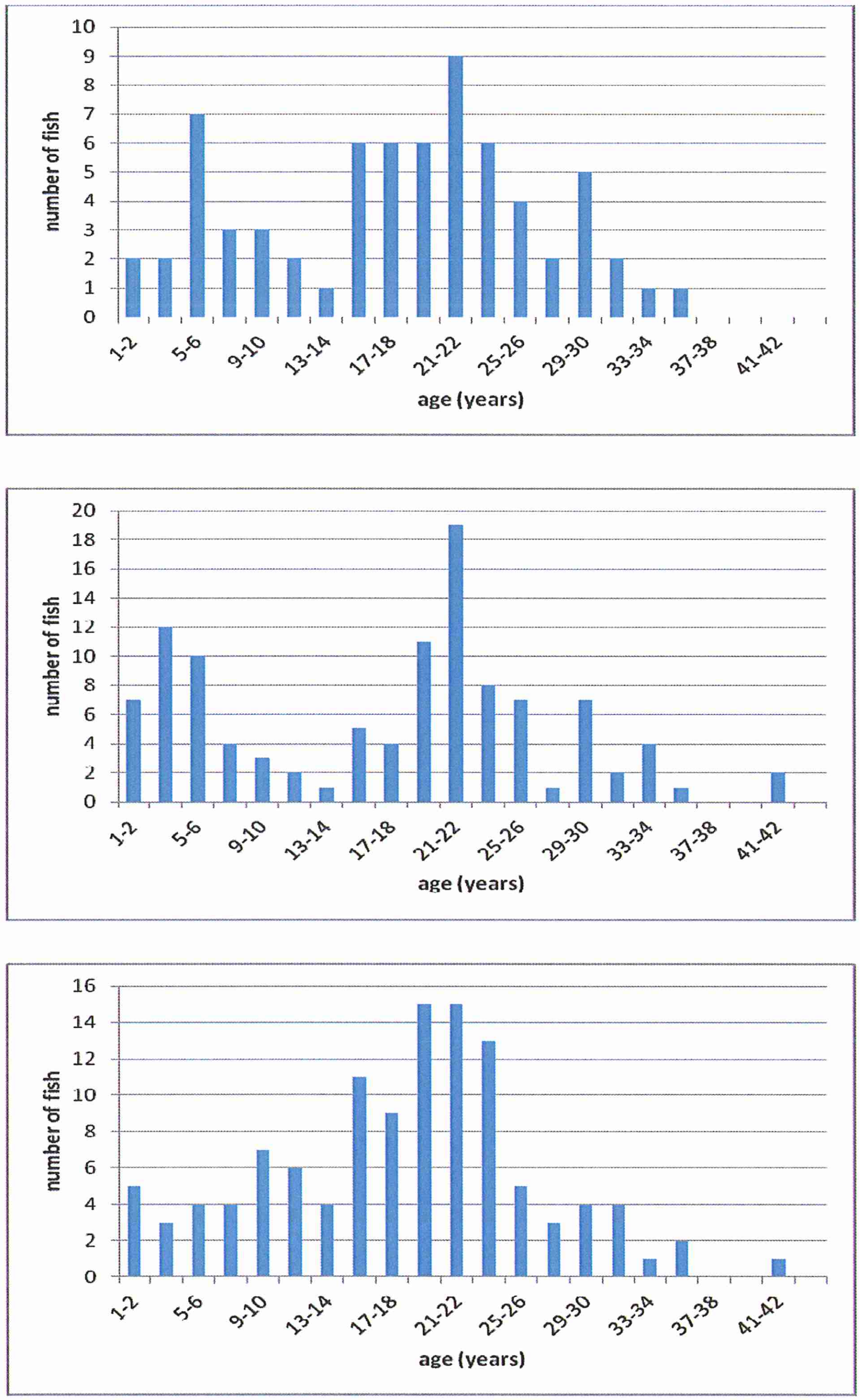


Figure 16. Adjusted fin-ray age-frequency distributions.

3.3.4 Power Analysis

The probability of detecting effects as large as or larger than the critical effect sizes, for each of the calculated fish endpoints, is provided in Table 16, as is the number of fish required to detect a difference equal to the critical effect size based on the error mean square from this study. Power was greater than 90% except for the weight versus age relationships.

The age versus length relationships would require the fewest fish to detect the critical effect size followed by, in order of increasing sample size requirements, weight versus length, liver weight versus weight, liver weight versus length and age versus weight.

3.4 Summary and Discussion

The results of inter-lake comparisons are summarized in Table 20. The only statistically significant difference between TPN and PDL was in body weight adjusted for length, which was 4.2% heavier in TPN; this is less than half the critical effect size of 10%. There were more significant differences between TPN and INUG (Table 20), but only weight adjusted for otolith age exceeded the critical effect size. Again, it should be noted that there was insufficient power to detect a 25% difference in the weight versus otolith age relationships and thus an increased probability of both type 1 (false positive) and type 2 (false negative) errors.

In field studies such as this, reference areas are not exact replicates of an exposed area and small differences are to be expected. For example, in a multi-year, multi-reference area study of white sucker Munkittrick et al (2000) found variation in condition factor (weight divided by length^3) of white sucker (*Catostomus commersonii*) between reference areas in a single year and also between years at individual reference areas. Recognition that such differences exist is one reason that critical effect sizes, defined as effect sizes above which an effect may be indicative of higher risk to the environment, were adopted by Environment Canada for EEM programs (Environment Canada, 2010, 2012).

The results of this study differ from the Cycle 1 EEM study (Azimuth 2012) which found no significant differences between Third Portage North and the Innug and Pipedream reference areas.

Table 20. Summary of between lake comparisons calculated with no outliers removed. P-values for pair-wise comparisons are provided where there was a significant difference in the overall p-value for the reduced ANCOVA. Critical effect sizes are from Environment Canada (2012).

dependent variable	independent variable	overall p-value	TPN vs INUG % Difference (p-value)	TPN vs PDL % Difference (p-value)	critical effect size
log of body weight	log of length	0.000	5.7 (0.000)	4.2 (0.009)	10%
log of liver weight	log of body weight	0.102	18.3	14.0	25%
log of liver weight	log of length	0.058	23.0 (0.046)	17.8 (0.167)	25%
log of weight	log of otolith age	0.000	-28.4 (0.010)	-6.0 (0.857)	25%
	log of adjusted age	0.573	-6.5	-1.8	25%
log of length	log of otolith age	0.001	-11.3 (0.015)	-2.7 (0.752)	25%
	log of adjusted age	0.201	-3.8	-2.1	25%
length distribution			0.010	0.983	
fin ray age distribution			0.420	0.909	
adjusted age distribution			0.794	0.681	

3.4.1 Recommendations for Future Fish Surveys, if Required

Based on the low catch-per-unit effort of other fish species captured in Third Portage North in this cycle, Lake Trout remain the only feasible sentinel species. It is not feasible to assess reproductive investment because only a portion of mature individuals spawn each year. Therefore fish surveys are limited to examining relationships based on length, weight, liver weight and age. Power analysis based on the results of this study indicate that a sample size of less than 20 Lake Trout per site would be adequate to detect the critical effect sizes for the weight versus length, liver weight versus weight, liver weight versus length and length versus age relationships with α and β both equal to 0.1. More than twice as many fish per site would be required to achieve this power for the weight versus age relationships (Table 16).

Age interpretation is more susceptible to error than measurements of length or weight. While fin rays may be preferred to otoliths because the former can be removed without killing the fish, ages estimated from fin rays often produce underestimates of fish age (compared to age determined from otoliths). This is especially true for older fish (while scales are worse; Schram and Fabrizio, 1998). Age underestimation with fin rays was clearly demonstrated in Cycle 1 and Cycle 2, so a correction factor for fin-ray ages was developed using the data from fish for which both fin rays and otoliths were used to estimate age. Regardless of the aging method, there will be errors in the estimated ages, and these tend to be more common and larger in slow-growing fish such as the lake trout that are the subject of this study. The adjustment of fin ray ages to otolith ages adjusts bias, but not errors in age estimation. Campana *et al* (2008) reported that otolith growth in the oldest Arctic lake trout which they examined was so low as to be unresolvable under conventional examination with a dissecting scope. In populations exhibiting bi-modal age and weight distributions, estimating growth rate is challenging and interpreting the cause of differences, when they are observed, is too.

The MMEEM Guidance document recognizes the uncertainty in accurately determining ages, and cautions "*Problems associated with determining the age of some species of fish should be discussed and reviewed before effects on weight-at-age and age are used to choose a path through the EEM program.*" Given the problems associated with determining the age (and therefore weight-at-age) of slow-growing, long-lived lake trout in low productivity northern lakes, such as the lakes that are the subject of this study, weight-at-age or age are probably not appropriate for choosing a path through the EEM program due to their unreliability. The necessity of using fin rays as the aging structure in a non-lethal survey adds to the unreliability as does the lack of knowledge of sex, as male and female lake trout grow at different rates.

Based on Cycle 1 data, a sample size of 61 lake trout per site is required to achieve the desired power for the weight versus age relationship while the sample sizes based on this study range from 42 to 55. These calculations are based on power analyses using an error mean square that is derived using standard linear regression techniques that assume no error in the independent variable (in this case age). We know that this is not the case. Although the Cycle 1 EEM fish study was intended to be a non-lethal survey, approximately 50% of the lake trout that were captured died. In this study, 35% of the captured Lake Trout died. These percentages are conservative, because some fish may have died following the removal of a leading pectoral fin spine and release.

Pipedream Lake is more similar to Third Portage North than Innug in terms of nearly all of the effect and supporting endpoints that were examined for fish. Therefore it is considered to be a more appropriate reference area than Innug and it is recommended that if future EEM studies of Third Portage Lake are required that only Pipedream Lake be sampled as a reference area. In order to minimize the number of fish harmed or killed, it is recommended that any future EEM study be a lethal study with a target sample size of 20 Lake Trout per lake.

4.0 BENTHIC INVERTEBRATE COMMUNITY SURVEY

4.1 Introduction

This 2014 survey of benthic invertebrates focused on Third Portage North Lake (TPN), with INUG and PDL being included as local reference areas, and is the second invertebrate community survey for the Meadowbank Mine under the MMER. Benthos have been sampled from TPN and INUG since 2006, while PDL has been sampled since 2009 as part of the CREMP. TPN was in a baseline condition from 2006 to 2008, and has been in an 'exposed' condition since 2009, when dewatering of lake water began.

The previous Cycle 1 EEM program, in 2011, involved the collection of three petite Ponar grabs, pooled per station, per Environment Canada's (2012) guidance. AEM has been collecting benthos more extensively under its CREMP, which involves the collection of two grabs pooled per station. The AEM Study Design for this Cycle 2 EEM program demonstrated that the statistical power of the benthos monitoring program would be significantly higher with two-grab data, if the mine incorporated both before-exposure and after-exposure period data. AEM and Environment Canada ultimately agreed that AEM would collect two grabs in 2014 (from their EEM sampling stations), and would use historically collected baseline and exposure period data to augment the statistical power of the overall program. This report, therefore, describes the two-grab survey that was completed, and incorporates the historical two-grab benthos data that were collected from TPN and INUG annually from 2006, and in PDL annually from 2009.

4.2 Materials and Methods

4.2.1 Benthic Sample Collection

Benthic invertebrates were collected on August 22 (TPN) and 23 (INUG, PDL), 2014, from the locations provided in Table 21. Samples were collected from a boat using cleaned, stainless steel petite Ponar grabs (0.023 m^2). Samples were washed on site using a 500-µm stainless-steel mesh, transferred to a 1-L plastic bottle, and preserved with 10% buffered formalin. Sample sediments always sieved down such that the residue (sediments and animals) amounted to less than around 100 ml of material. Duplicate samples (< ~200 ml), per station, were pooled on site. Sample containers were packed in coolers/plastic totes and transported to Zaranko Environmental Assessment Services (ZEAS), the company providing taxonomic services for the project, and the company that was used for the identification of all previous samples back to 2006.

Table 21. Benthos collection sample location waypoints.

Area	Station	Latitude (dd mm ss)	Longitude (dd mm ss)	Northing (m)	Easting (m)
INUG	1	65 03 09.2	96 23 23.5	622816	7216849
	2	65 03 09.7	96 23 25.9	622784	7216863
	3	65 03 08.8	96 23 29.4	622740	7216833
	4	65 03 07.3	96 23 31.7	622711	7216785
	5	65 03 06.8	96 23 33.1	622695	7216769
PDL	1	65 06 16.8	96 13 11.6	630555	7222993
	2	65 06 18.1	96 13 07.4	630607	7223036
	3	65 06 09.4	96 13 00.4	630710	7222771
	4	65 06 18.5	96 13 01.9	630679	7223052
	5	65 06 17.5	96 13 08.3	630597	7223017
TPN	1	65 02 08.1	96 06 11.2	636388	7215546
	2	65 02 07.4	96 06 11.5	636386	7215525
	3	35 02 06.9	96 06 09.1	636416	7215511
	4	65 02 04.4	96 06 02.0	636514	7215438
	5	65 02 03.3	96 05 55.0	636607	7215408

4.2.2 Supporting Environmental Variables

4.2.2.1 Water

Specific conductivity (µS/cm), pH, dissolved oxygen (mg/L) and temperature (°C) were determined at the time of benthic invertebrate sample collection within the Exposure and Reference Areas with an YSI Professional Plus. Meter calibration was undertaken daily following the methods in the user manual. Parameter resolution and accuracy are as follows:

- Specific conductivity; resolution: 1 µS/cm, accuracy: the greater of ±1% of reading or 1 µS/cm.
- pH; resolution: 0.01 units, accuracy: ±0.2 units.
- Dissolved oxygen; resolution: 0.1 mg/L, accuracy: the greater of ±2% of reading or 0.2 mg/L.
- Temperature; resolution: 0.1°C, accuracy: ±0.2°C.

These parameters were measured at 1 m intervals from surface to 1 m off bottom, at each sampling station, to document the level of stratification at the time of benthic invertebrate sampling.

Water depth at the point of sampling was determined using an electronic sonar device.

Water samples were collected from each benthos sampling location on September 3, 2014, under Agnico Eagle's CREMP water quality monitoring program, as per the previous EEM study. Water was collected from three randomly selected locations (stations) within each sampling area. Waters were not thermally or chemically (determined by conductivity) stratified, so water was collected from 3 m below surface. Samples in the past have all similarly been collected from 3 m below surface.

Water was analyzed for the following analytes by ALS Environmental:

- Physical tests (conductivity, hardness, pH, total suspended solids, turbidity);

- Metals (aluminum, cadmium, iron, molybdenum, arsenic, copper, lead, nickel, zinc, radium 226, cyanide, selenium);
- Anions and Nutrients (alkalinity, ammonia, bromide, chloride, fluoride, nitrate, nitrite, total Kjeldahl nitrogen, ortho phosphate, silicate, sulfate); and
- Other (dissolved organic carbon, total organic carbon).

Detection limits for water quality parameters are provided in Table 22.

Table 22. Water Quality Detection Limits.

Parameter	Detection Limit	Units
Physical Tests		
Hardness (as $CaCO_3$)	0.50	mg/L
Anions and Nutrients		
Ammonia, Total (as N)	0.0050	mg/L
Bromide (Br)	0.050	mg/L
Chloride (Cl)	0.10	mg/L
Fluoride (F)	0.020	mg/L
Nitrate (as N)	0.0050	mg/L
Nitrite (as N)	0.0010	mg/L
Orthophosphate-Dissolved (as P)	0.0010	mg/L
Phosphorus (P)-Total Dissolved	0.0020	mg/L
Phosphorus (P)-Total	0.0020	mg/L
Silicate (as SiO_2)	0.50	mg/L
Sulfate (SO_4)	0.50	mg/L
Cyanides		
Cyanide, Total	0.0050	mg/L
Cyanide, Free	0.0050	mg/L
Organic / Inorganic Carbon		
Dissolved Organic Carbon	0.50	mg/L
Total Organic Carbon	0.50	mg/L
Total Metals		
Aluminum (Al)-Total	0.0030	mg/L
Antimony (Sb)-Total	0.00010	mg/L
Arsenic (As)-Total	0.00010	mg/L
Barium (Ba)-Total	0.000050	mg/L
Beryllium (Be)-Total	0.00010	mg/L
Bismuth (Bi)-Total	0.00050	mg/L
Boron (B)-Total	0.010	mg/L
Cadmium (Cd)-Total	0.000010	mg/L
Calcium (Ca)-Total	0.050	mg/L
Chromium (Cr)-Total	0.00010	mg/L
Cobalt (Co)-Total	0.00010	mg/L
Copper (Cu)-Total	0.00050	mg/L
Iron (Fe)-Total	0.010	mg/L
Lead (Pb)-Total	0.000050	mg/L
Lithium (Li)-Total	0.00050	mg/L
Magnesium (Mg)-Total	0.10	mg/L
Manganese (Mn)-Total	0.000050	mg/L
Mercury (Hg)-Total	0.000010	mg/L
Molybdenum (Mo)-Total	0.000050	mg/L
Nickel (Ni)-Total	0.00050	mg/L
Phosphorus (P)-Total	0.050	mg/L
Potassium (K)-Total	0.10	mg/L
Selenium (Se)-Total	0.00010	mg/L
Silicon (Si)-Total	0.050	mg/L
Silver (Ag)-Total	0.000010	mg/L
Total Metals (continued)		
Sodium (Na)-Total	0.050	mg/L
Strontium (Sr)-Total	0.00020	mg/L
Sulfur (S)-Total	0.50	mg/L
Thallium (Tl)-Total	0.000010	mg/L
Tin (Sn)-Total	0.00010	mg/L
Titanium (Ti)-Total	0.010	mg/L
Uranium (U)-Total	0.000010	mg/L
Vanadium (V)-Total	0.0010	mg/L
Zinc (Zn)-Total	0.0030	mg/L
Dissolved Metals		
Dissolved Mercury Filtration Location	-	-
Dissolved Metals Filtration Location	-	-
Aluminum (Al)-Dissolved	0.0010	mg/L
Antimony (Sb)-Dissolved	0.00010	mg/L
Arsenic (As)-Dissolved	0.00010	mg/L
Barium (Ba)-Dissolved	0.000050	mg/L
Beryllium (Be)-Dissolved	0.00010	mg/L
Bismuth (Bi)-Dissolved	0.00050	mg/L
Boron (B)-Dissolved	0.010	mg/L
Cadmium (Cd)-Dissolved	0.000010	mg/L
Calcium (Ca)-Dissolved	0.050	mg/L
Chromium (Cr)-Dissolved	0.00010	mg/L
Cobalt (Co)-Dissolved	0.00010	mg/L
Copper (Cu)-Dissolved	0.00020	mg/L
Iron (Fe)-Dissolved	0.010	mg/L
Lead (Pb)-Dissolved	0.000050	mg/L
Lithium (Li)-Dissolved	0.00050	mg/L
Magnesium (Mg)-Dissolved	0.10	mg/L
Manganese (Mn)-Dissolved	0.000050	mg/L
Mercury (Hg)-Dissolved	0.000010	mg/L
Molybdenum (Mo)-Dissolved	0.000050	mg/L
Nickel (Ni)-Dissolved	0.00050	mg/L
Phosphorus (P)-Dissolved	0.050	mg/L
Potassium (K)-Dissolved	0.10	mg/L
Selenium (Se)-Dissolved	0.00010	mg/L
Silicon (Si)-Dissolved	0.050	mg/L
Silver (Ag)-Dissolved	0.000010	mg/L
Sodium (Na)-Dissolved	0.050	mg/L
Strontium (Sr)-Dissolved	0.00020	mg/L
Sulfur (S)-Dissolved	0.50	mg/L
Thallium (Tl)-Dissolved	0.000010	mg/L
Tin (Sn)-Dissolved	0.00010	mg/L
Titanium (Ti)-Dissolved	0.010	mg/L
Uranium (U)-Dissolved	0.000010	mg/L
Vanadium (V)-Dissolved	0.0010	mg/L
Zinc (Zn)-Dissolved	0.0010	mg/L
Plant Pigments		
Chlorophyll a	0.010	ug

4.2.2.2 Sediment

Sediment samples were collected from each benthic invertebrate sampling station and analyzed for:

- Total organic carbon (%) and,
- Sediment particle size (% gravel, sand, silt/clay), per the Wentworth Classification.

Detection limits for sediment quality measures are provided in Table 23 below.

Table 23. Sediment Measures Detection Limits.

Parameter	Detection Limit	Units
% Gravel (> 2 mm)	1	%
% Sand (2 mm to 0.063 mm)	1	%
% Silt (0.063 mm to 4 μm)	1	%
% Clay (<4 μm)	1	%
Total Organic Carbon	0.1	%

4.2.3 Data Analysis

4.2.3.1 Data

The data in this interpretive report included all prior annually collected benthic community samples from 2006 to 2014 for TPN, INUG and PDL. There were always five sample stations per area as part of AEM's sampling design, with the exception of in 2006 when only three stations were sampled in TPN and INUG. In total, there were 116 two-grab benthos samples in the data set per the table below.

Table 24. Number of benthos sampling stations per area, by year.

Area	Year									Grand Total
	2006	2007	2008	2009	2010	2011	2012	2013	2014	
INUG	3	5	5	5	5	5	5	5	5	43
PDL				5	5	5	5	5	5	30
TPN	3	5	5	5	5	5	5	5	5	43
Grand Total	6	10	10	15	15	15	15	15	15	116

4.2.3.2 Descriptors of Benthic Community Composition

Benthos counts were provided in an Excel spreadsheet. Organisms were identified to lowest practical level. The data were 'rolled up' to the level of Family for the purpose of the analysis in this EEM Interpretive Report. Acarina were identified to genus only in 2014, and not in other years (only identified to Acarina in previous years). The 2014 genera were rolled up to Acarina to be consistent with level of identification in previous years.

For each sample, the following descriptors of community composition and indices were calculated, as per the federal guidance for metal mining EEM (Environment Canada, 2012):

- Abundance (total number of animals per m^2);
- Taxon Richness (number of Families),
- Evenness (E), where,

$$E = 1/\sum (p_i^2)/S;$$

- Bray-Curtis (BC) Distance Index, where,

$$BC = \frac{\sum |y_{i1} - y_{i2}|}{\sum (y_{i1} - y_{i2})}$$

Where, y_{i1} = abundance of family *i* in sample 1, y_{i2} = abundance of family *i* in sample 2.

Bray-Curtis distances were computed between all pairs of the n=116 samples. Abundances were raw values (not transformed).

The Bray-Curtis distance matrix was used as the input distance matrix for an NMDS-based ordination carried out in SYSTAT. Two NMDS axes were produced by the ordination. Pearson correlations between raw taxa (family) abundances and sample scores on each of the NMDS axes were computed. A scatterplot of taxa correlations was produced in order to illustrate the relationship between taxa abundances and NMDS axis scores. Scatterplots of NMDS sample scores, by year, was produced in order to illustrate variations in benthic community composition among sample areas, over time.

4.2.3.3 Testing for Effluent Related Effects

If mine effluent releases abruptly altered the benthic community of TPN, the effect on the community should be manifest as a change in the natural difference between reference and exposure areas, from before to during exposure. This effect pattern is termed here the before-after-control-impact (BACI) hypothesis. If, in contrast, mine effluent releases are gradually altering benthic communities in TPN, the effect on the community should be manifest as a change in the trend over time. This effect pattern is termed here the Time Trend hypothesis.

Analysis of variance was used to test these two contrasts for total abundance, richness and equitability:

1. BACI contrast: i.e., a change in the difference between reference (INUG) and exposure (TPN) means, from baseline (2006 to 2008) to exposure (2009 to 2014) periods.
2. Time Trend contrast: i.e., a difference in the linear time trend in the exposure (2009 to 2014) period, between reference (INUG, PDL) and exposure (TPN) means.

The two hypotheses were tested using planned contrasts per Zar (1984) and Hoke et al. (1990). Contrast coefficients for the two tests are provided in Table 25 below.

Borcard and Legendre (2013) recommended Mantel tests as an appropriate procedure for testing that Bray-Curtis distances differ in magnitude between reference and exposed communities. The Mantel test determines whether the correlation between Bray Curtis distances and a hypothesized distance is stronger than would be observed through random chance. The hypothesized distance matrices here were Euclidean distance matrices, based on contrast coefficients provided in the table below. Mantel tests were completed using the Excel Add-In 'PopTools'. For each of the two Mantel tests completed, the original correlation between the Bray-Curtis distance matrix and the Euclidean distance matrix was compared to correlations for 999 random permutations of the two distance matrices. The rank of the observed Mantel r relative to the 999 random r values was used to provide an approximate probability value for the tests.

There were 18 area-year combinations used to test each hypothesis. With normally n=5 two-grab samples per year per area, there was a total of n=86 (BACI) and n=90 (Time Trend) observations available.

Table 25. Contrast coefficients used in the analyses of variance tests

Area	Year	Exposure	BACI Coefficient	Time Trend Coefficient
INUG	2006	Before	-0.167	
	2007		-0.167	
	2008		-0.167	
	2009	After/During	0.083	-0.139
	2010		0.083	-0.083
	2011		0.083	-0.028
	2012		0.083	0.028
	2013		0.083	0.083
	2014		0.083	0.139
PDL	2009	After/During		-0.139
	2010			-0.083
	2011			-0.028
	2012			0.028
	2013			0.083
	2014			0.139
TPN	2006	Before	0.167	
	2007		0.167	
	2008		0.167	
	2009	After/During	-0.083	-0.278
	2010		-0.083	-0.167
	2011		-0.083	-0.056
	2012		-0.083	0.056
	2013		-0.083	0.167
	2014		-0.083	0.278
Sum of C_i^2			0.250	0.324
Detectable ES (SD's)			0.93	1.06

4.2.3.4 Effect Sizes

Environment Canada (2012) recommends the following equation for computing effect sizes for simple reference vs. exposure designs:

$$ES = \frac{\overline{X}_{ref} - \overline{X}_{exp}}{SD} \quad [2]$$

Where

- $\overline{X}_{ref}$ is the average benthic community index value in the Reference Area

- $\overline{x}_{exp}$ is the average benthic community index value in the Exposure Area
- SD is the within-Area standard deviation, here the combined pooled SD based on the square root of the mean-squared error from ANOVA.

That equation and formulation for effect size is appropriate for simple reference vs. exposure contrasts, but is not easily applied to complex designs such as those used here; i.e., BACI and difference in Time Trends.

Eta squared (η^2) is an alternative expression of effect size that is more generic (Dattalo, 2008). It is calculated as the ratio of the effect variance ($SS_{contrast}$) to the total variance (SS_{total}), or

$$\eta^2 = \frac{SS_{contrast}}{SS_{total}}.$$

Environment Canada (2012) deems 2 σ as the critical effect size for benthic community indices of composition. For simple reference vs. exposure contrasts a difference of 2 σ will produce an η^2 of 0.5 (i.e., 50% of the variation will be explained by the effect). For more complex designs, then, $\eta^2 > 0.5$ would be analogous to a difference of 2 σ. Herein, we computed η^2 as a measure of the effect size, for each of the univariate contrasts.

We did not compute an effect size for the Mantel tests on Bray-Curtis distances since there is no guidance on how to do so (Environment Canada, 2012; Borcard and Legendre, 2013).

4.2.3.5 Statistical Power

The ability to detect an effect depends on sample size; where the study relies on a contrast of Reference versus Exposure locations, sample sizes refer to the number of replicate stations within both Reference and Exposure Areas. Environment Canada (2012) has deemed that effects that exceed two times the standard deviation of observations (i.e., ±2SDs) among stations will require further investigation. Therefore, it is necessary to calculate the probability that a difference of ± 2 SDs could be detected with a certain number of stations in both control and impact sampling Areas.

In this study, power was assessed using the conventional power equation given by Green (1989):

$$n = \frac{\left(\sum C_i^2\right)\left(t_\alpha + t_\beta\right)^2 \sigma^2}{\delta^2}$$

where,

n is the number of samples, C^2_i is the contrast coefficients squared, σ is the population standard deviation, δ is the specified effect size, t_α is the Students t statistic for a two-tailed test with significance level α, and t_β is the Students t statistic for a one-tailed test with significance level β. The $\sum C^2_i$ is normally 2 (i.e., $1^2 - 1^2 = 2$) for a two-sample contrast of Reference and Exposure Areas.

By re-arrangement, and by setting α, t_β can be solved iteratively. Alternatively, the detectable effect size δ, can be solved if both α and β are set. Here, with n=5, and $\alpha = \beta = 0.05$, , this study had the ability to detect an effect size for BACI contrasts of about 0.9σ, and an effect size for time trend contrasts of about 1.1σ (Table 25). Those detectable effect sizes are about ½ the effect size that is deemed important to detect in EEM (Environment Canada, 2012).

4.3 Results

4.3.1 Supporting Environmental Variables

4.3.1.1 General Limnology

The three benthos sampling areas were similar in terms of general character. The sampling areas in INUG and PDL were just over 8 m deep, while the sampling area in TPN was just over 9 m deep. Temperature profiles in all three areas were similar with waters being nearly 10°C from surface to 1 m off bottom (Figure 17). Dissolved oxygen profiles were similar, with between 9 and 11 mg/L from surface to 1 m off bottom. There was no indication of a DO depression near the sediments in TPN, whereas there was a minor oxygen depression near the sediment water interface in both INUG and PDL. Water depths for stations in 2014 were similar to what was surveyed in previous years (Figure 18).

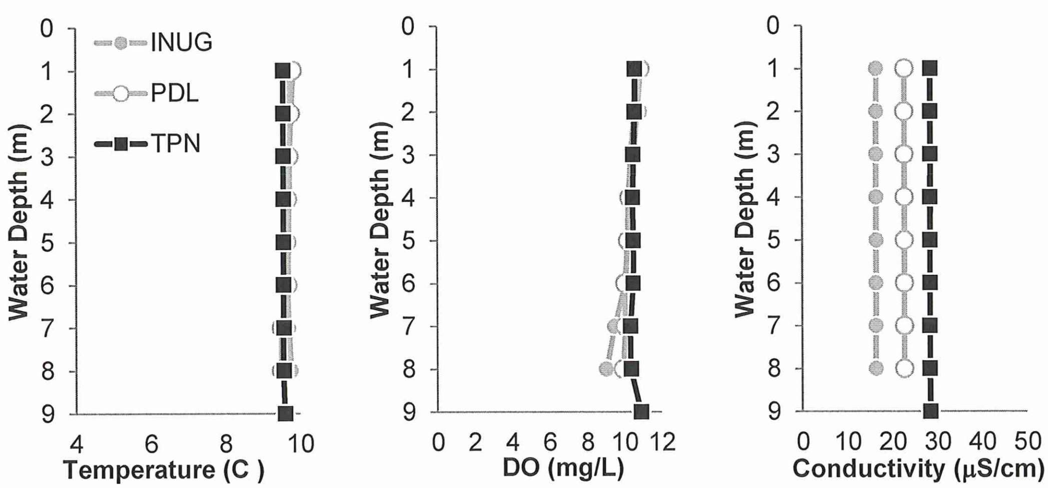


Figure 17. Depth profiles for water temperature, dissolved oxygen (DO) and conductivity, in each of the three benthos sampling areas, INUG, PDL and TPN. Values at each 1 m interval were the average from five sampling stations.

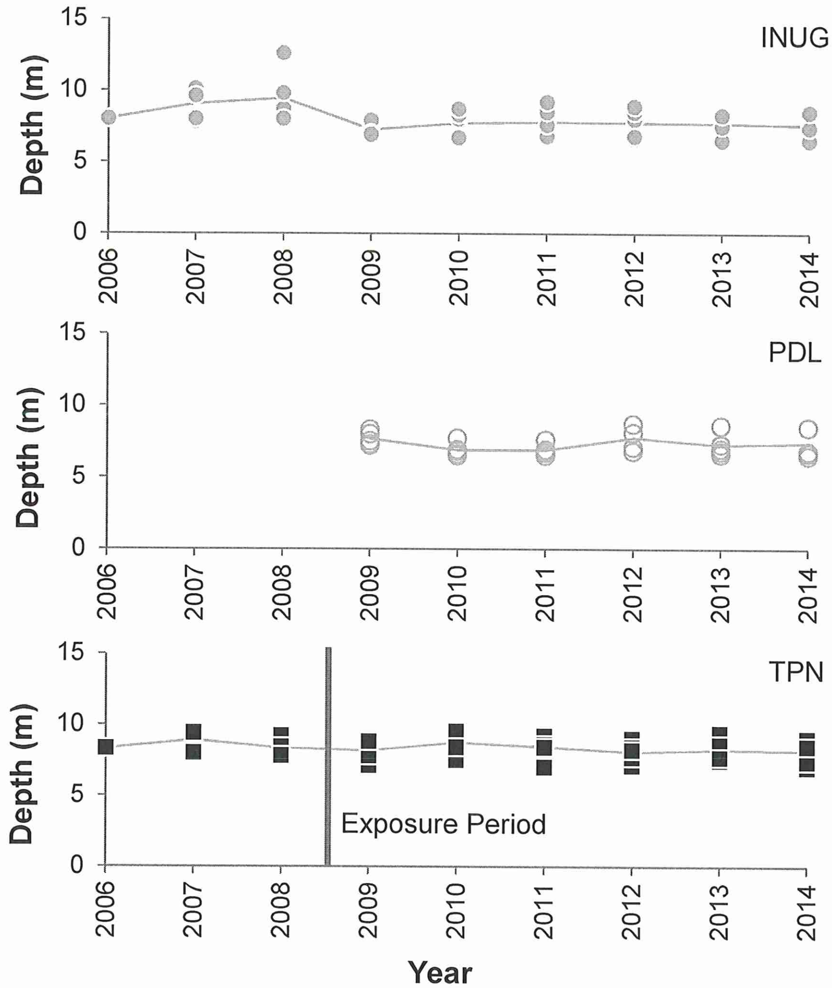


Figure 18. Variations in water depth among years for INUG, PDL and TPN.

Figure Note: the line illustrates variations in annual averages.

4.3.1.2 Laboratory Water Chemistry

Detailed chemistry results for the benthos sampling areas is provided in Table 26 below. QA/QC for analytical chemistry is provided in Appendix 4. All RPD values were ≤ 20%, such that the quality of the water chemistry data is deemed sufficient.

The waters from the three lakes were very 'soft'. INUG had a hardness of about 5.5 mg/L, whereas PDL and TPN had a water hardness each of about 9 mg/L. Calcium concentrations were ~ 1 mg/L in INUG, ~ 2 mg/L in PDL and ~ 2.2 mg/L in TPN.

Total ammonia was generally at non-detectable concentrations in INUG and PDL (i.e. < 0.005 mg/L), whereas concentrations in TPN were detectable but near 0.01 mg/L. Chloride concentrations in TPN were around 0.76 mg/L, or similar to what was measured in INUG (0.73 mg/L), and very low relative to the water quality guideline of 120 mg/L. Measured concentrations, without exception, were below (within) CCME guidelines (Table 26). Orthophosphate and total phosphorus were at non-detectable concentrations in all three lakes. Sulphate concentrations were ~ 0.9 mg/L in INUG, ~ 1.6 mg/L in PDL, and about 5 mg/L in TPN. Sulphate concentrations were therefore elevated in TPN relative to the control lakes. Sulphates have been increasing in TPN from baseline concentrations of ~ 2 mg/L since release of effluents into TPN (Azimuth, 2015).

Many of the metals were at or near non-detectable concentrations in all three lakes, including Sb, Be, Bi, B, Cr, Co, Cu, Fe, Pb, Li, Hg, Ni, P, Se, Ag, Tl, Sn and V. Consistent with historical data reported in AEM CREMP annual reports Azimuth (2015), concentrations of the metals Ba, Mn and Mo were modestly higher in TPN than in the reference lakes. Concentrations of the cations Ca, K and Na were higher in TPN than the two reference lakes, reflecting the higher hardness in TPN. Hardness has been increasing in TPN since the release of effluent into the lake in 2009 (Azimuth, 2015). Sulfur was at non-detectable concentration in INUG (i.e. < 0.5 mg/L), was just above the detection limit in PDL (~ 0.55 mg/L), and was about 3x the detection limit in TPN (~ 1.7 mg/L).

Silicon concentrations were below the detection limit of 0.05 mg/L in TPN, but were about 0.011 mg/L in INUG and 0.13 mg/L in PDL.

Table 26. Detailed water quality for the benthos monitoring areas.

Variable	Units	CCME	INUG-1	INUG-2	INUG-3	PDL-1	PDL-2	PDL-3	TPN-1	TPN-2	TPN-3
Physical Tests											
Hardness (as $CaCO_3$)	mg/L		5.61	5.54	5.72	8.85	9.06	9.04	9.46	9.01	9.37
Anions and Nutrients											
Ammonia, Total (as N)	mg/L		<0.0050	0.0163	<0.0050	<0.0050	0.0158	<0.0050	0.0107	0.0104	0.0109
Bromide (Br)	mg/L		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	mg/L	120	0.73	0.75	0.73	0.60	0.62	0.60	0.76	0.76	0.76
Fluoride (F)	mg/L		0.063	0.066	0.064	0.039	0.040	0.039	0.068	0.068	0.068
Nitrate (as N)	mg/L	13	<0.0050	0.0059	<0.0050	<0.0050	<0.0050	<0.0050	0.0528	0.0535	0.0534
Nitrite (as N)	mg/L	0.06	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	<0.0010
Orthophosphate-Dissolved (as P)	mg/L		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Phosphorus (P)-Total Dissolved	mg/L		<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0021	<0.0020	<0.0020	<0.0020
Phosphorus (P)-Total	mg/L		0.0026		<0.0020	<0.0020		<0.0020			
Silicate (as SiO_2)	mg/L		<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Sulfate (SO_4)	mg/L		0.88	0.90	0.88	1.63	1.67	1.63	5.00	4.98	5.00
Cyanides											
Cyanide, Total	mg/L		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cyanide, Free	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon											
Dissolved Organic Carbon	mg/L		1.78	1.78	1.63	1.52	1.55	1.58	1.24	1.33	1.21
Total Organic Carbon	mg/L		2.05	1.60	2.08	1.88	1.44	1.83	1.32	1.34	1.15
Total Metals											
Aluminum (Al)-Total	mg/L	0.1	0.0143	0.0171	0.0099	0.0048	0.0123	0.0060	0.0146	0.0132	0.0126
Antimony (Sb)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	0.005	0.00010	<0.00010	0.00011	0.00018	0.00016	0.00019	0.00018	0.00018	0.00020
Barium (Ba)-Total	mg/L		0.00206	0.00177	0.00185	0.00201	0.00193	0.00196	0.00315	0.00292	0.00305
Beryllium (Be)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Total	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Total	mg/L	1.5	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (Cd)-Total	mg/L	0.00009	0.000013	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Calcium (Ca)-Total	mg/L		1.16	1.12	1.16	2.23	2.31	2.24	2.30	2.19	2.28

Variable	Units	CCME	INUG-1	INUG-2	INUG-3	PDL-1	PDL-2	PDL-3	TPN-1	TPN-2	TPN-3
Chromium (Cr)-Total	mg/L	0.001	0.00013	0.00014	0.00011	0.00013	0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L		0.00085	<0.00050	<0.00050	0.00055	0.00056	0.00052	<0.00050	<0.00050	0.00051
Iron (Fe)-Total	mg/L	0.3	0.021	0.016	0.016	<0.010	<0.010	<0.010	<0.010	<0.010	0.011
Lead (Pb)-Total	mg/L	0.001	0.000125	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Total	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00055	0.00056	<0.00050
Magnesium (Mg)-Total	mg/L		0.70	0.67	0.73	0.79	0.80	0.79	0.90	0.86	0.89
Manganese (Mn)-Total	mg/L		0.00198	0.00149	0.00150	0.000866	0.000927	0.000920	0.00216	0.00203	0.00207
Mercury (Hg)-Total	mg/L	0.000026	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Total	mg/L		<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000220	0.000212	0.000202
Nickel (Ni)-Total	mg/L	0.025	<0.00050	<0.00050	<0.00050	0.00058	0.00070	0.00058	<0.00050	<0.00050	0.00131
Phosphorus (P)-Total	mg/L		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Potassium (K)-Total	mg/L		0.38	0.37	0.40	0.36	0.35	0.35	0.51	0.49	0.52
Selenium (Se)-Total	mg/L	0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Silicon (Si)-Total	mg/L		0.112	0.108	0.118	0.128	0.134	0.133	<0.050	<0.050	<0.050
Silver (Ag)-Total	mg/L	0.0001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sodium (Na)-Total	mg/L		0.633	0.523	0.569	0.490	0.472	0.483	1.19	1.13	1.17
Strontium (Sr)-Total	mg/L		0.00687	0.00643	0.00672	0.00944	0.00939	0.00933	0.0110	0.0102	0.0103
Sulfur (S)-Total	mg/L		<0.50	<0.50	<0.50	0.59	0.60	0.61	1.74	1.68	1.72
Thallium (Tl)-Total	mg/L	0.0008	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Tin (Sn)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00014	<0.00010	<0.00010
Titanium (Ti)-Total	mg/L		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Total	mg/L	0.015	0.000047	0.000043	0.000044	0.000025	0.000025	0.000023	0.000047	0.000045	0.000045
Vanadium (V)-Total	mg/L		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Total	mg/L	0.03	<0.0030	<0.0030	<0.0030	<0.0030	0.0045	<0.0030	<0.0030	<0.0030	0.0044

4.3.1.3 Sediment Character

Sediments were largely fines (silt and clay) comprising collectively > 90% of the sediment material in INUG and PDL, and normally > 50% in TPN in 2014 (Table 27). Organic materials comprised between 0.2% and 3.8% in 2014, with sediments from TPN generally containing less organic matter than sediments from either INUG or PDL (Table 27). Variations in TOC were generally consistent among years within a sampling area (Figure 19). There was no variation in observed TOC in INUG or TPN in 2007 and 2008 because only single samples were analyzed those years. Sediment texture has remained relatively consistent among years within sampling areas, with the exception of TPN in 2014, when one sample had a lower fines content (~23%), whereas fines typically accounted from between 50% and 90% (Figure 20).

Table 27. Depth and percent TOC, sand, silt and clay at the 2014 benthic invertebrate sampling stations.

Area	Station	Depth (m)	TOC (%)	Sand (%)	Silt (%)	Clay (%)
INUG	1	7.0	2.8	7.2	68.6	24.2
	2	6.5	2.2	17.6	63.5	18.9
	3	7.4	3.4	5.0	71.7	23.4
	4	8.5	3.8	2.5	75.3	22.2
	5	8.5	3.1	3.4	67.1	29.5
PDL	1	6.5	2.3	15.2	73.8	11.0
	2	6.7	2.4	14.8	72.6	12.6
	3	8.5	1.9	19.7	67.9	12.4
	4	8.5	1.6	8.0	70.6	21.3
	5	6.8	2.7	12.6	69.8	17.7
TPN	1	7.0	0.2	76.3	16.8	6.1
	2	9.0	2.2	17.5	59.0	23.5
	3	7.4	0.7	47.2	37.7	13.3
	4	9.0	0.8	21.3	46.7	31.8
	5	8.5	0.2	11.5	44.3	41.8

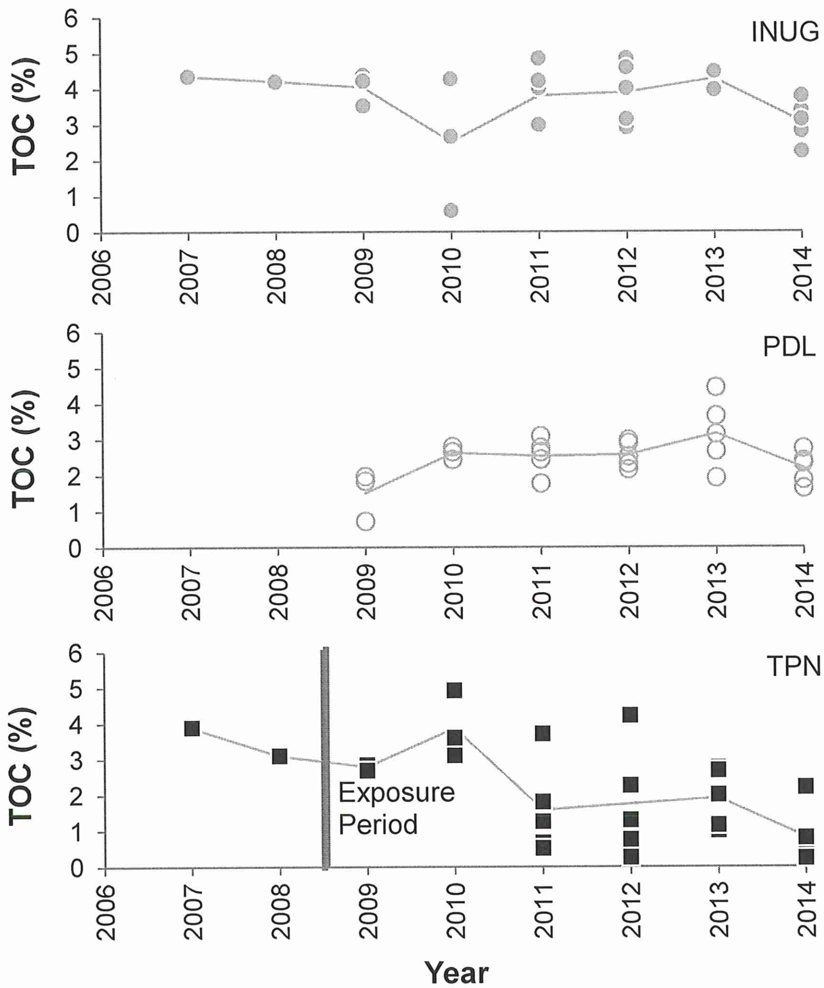


Figure 19. Variations in total organic carbon (TOC) in sediment among years for INUG, PDL and TPN.

Figure Note: the line illustrates variations in annual averages.

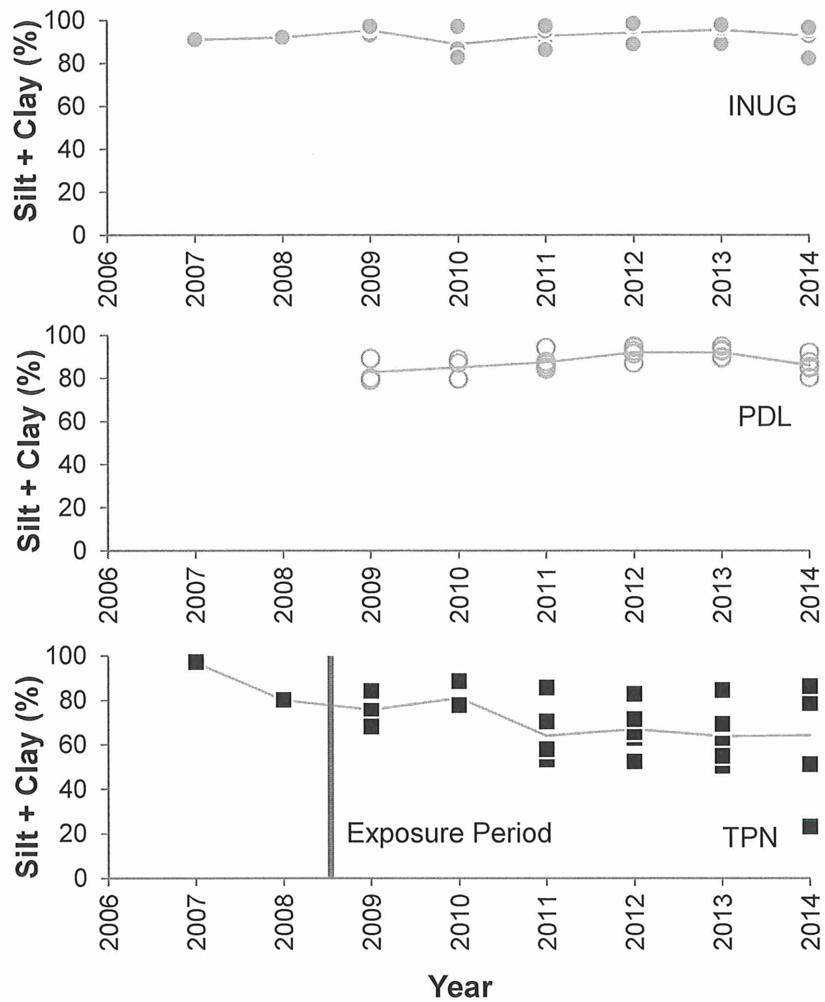


Figure 20. Variations in silt+clay (fines) in sediment among years for INUG, PDL and TPN.

Figure Note: the line illustrates variations in annual averages.

4.3.2 Invertebrate Community Composition

4.3.2.1 General Description

Benthic communities of the three study areas were generally similar in 2014, and similar to what had been described in previous years. The communities were dominated numerically by chironomids (50 to 80%) and Sphaeriidae (16 to 32%; Table 28). Sub-dominant taxa in each of the three sample areas were, variously, Nematoda, Naididae, Tubificidae, Lumbriculidae and Acarina. One individual Limnephilidae caddisfly (*Grensia praeterita,* see Appendix 5 – benthos detailed taxonomic data) was present in INUG in 2014, whereas there were none present in the other two sample areas. Quality assurance for the laboratory sorting of invertebrate samples is provided in Appendix 6.

There were 10 chironomid genera in the INUG stations, with *Procladius*, *Stichtochironomus*, *Microtendipes* and *Micropsectra* present in each station. There were four chironomid genera found in PDL in 2014, with *Stichtochironomus* and *Procladius* found in every station. There were eight chironomid genera found in TPN, with *Micropsectra*, *Stichtochironomus*, *Heterotrissocladius*, *Procladius* and *Thienemannimyia* found in at least 4 of 5 stations each. In all three sample areas, the Sphaeriidae were all of the *Pisidium* and *Sphaerium* genera.

Variations in indices of composition (total abundance, richness, equitability) over time and within sample areas are illustrated in Figure 21 through Figure 23. Total abundances in 2014 were generally <1,000 organisms per m^2, lower than what was observed in 2013, but similar to what was observed in 2011 (all sample areas; Figure 21). INUG and PDL sample areas produced an average of about four families per sample, whereas TPN produced an average of about 3 (2 to 4) families per sample (Figure 22) in 2014. The number of taxa observed was generally lower in 2014 in all sample areas relative to what was observed in 2013, but within the range of values previously observed across the complete data record. Reflecting somewhat lower taxa richness per sample, equitability was generally higher in 2014 in each of the sample areas, with INUG producing values of about 0.5-0.8, PDL producing values ranging between about 0.4 and 0.8, and TPN producing values ranging between about 0.35 and 0.9 (Figure 23).

All but Empididae had positive correlations with NMDS axis 1 scores, with chironomids and sphaeriids having the largest associations (Figure 24). The first NMDS axis is, therefore, another measure of total abundance and diversity. Sphaeriids, Acarina and Lubriculidae worms had the largest positive correlations with NMDS axis 2 scores, while Ostracoda and Chironomidae had the largest negative correlations with axis 2 scores. There was more variation in axis 1 than in axis 2 scores, generally and within years (Figure 25). Further, scores for TPN tended to be very similar to scores from INUG and PDL within years, the single exception being in 2006 when TPN produced more negative axis 1 scores than INUG, reflecting lower overall abundances of benthic organisms in 2006.

Table 28. Relative abundances of benthos taxa (families or higher level) by year for INUG, PDL and TPN. Averages of total abundance, family richness and equitability are also provided.

Taxon	INUG									PDL						TPN								
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2006	2007	2008	2009	2010	2011	2012	2013	2014
Nematoda	3	2	5	2	1	3	2	5	3	1	3	2	3	5	9	1	2	3	2		3	2	1	1
Turbellaria		3	<1	1	1		2	3		<1														
Enchytraeidae								1																
Naididae								1	1														<1	1
Tubificidae	1	2	1	1	1	<1	1	2	1	5	3	4		4	6		4		<1	2	1			
Lumbriculidae	3	3	<1	3	3	5	3	2	1	1	1	2	1	1	2			<1		1	1	1	2	1
Acarina	5	5	2	3	4	2	4	1	1	2	1	4	2	1	2	1	2	<1	2	2	2	1	3	3
Ostracoda	7	<1	6	9	9	4	5	6	1	9	8	3	2	7		3	1	12	7	5	8	13	5	2
Notostraca		1	<1	<1		2	1																	
Limnephilidae				<1	2			<1	1	1	1	1	2	2			1	3	1	1	1	1	1	
Chironomidae	47	57	71	50	37	41	45	57	60	60	54	54	64	57	52	76	60	71	53	71	51	67	69	78
Empididae	1		<1																					
Sphaeriidae	33	27	15	31	43	42	37	22	32	20	28	31	26	23	29	18	31	10	35	18	34	16	18	16
Indices																								
Abundance	841	1,043	2,143	1,339	704	1,096	1,152	2,470	752	1,930	1,013	991	1,026	1,513	548	2,196	1,457	1,191	1,365	1,391	630	1,352	1,526	504
Family Richness	5.33	5.8	6.4	6.2	5	5.8	6.2	8	3.8	6.2	5.2	5.2	4.4	6.2	4.4	4	4.6	4.4	4.8	5.2	4.4	4.8	5.6	3.2
Equitability	0.57	0.43	0.38	0.46	0.53	0.48	0.5	0.31	0.58	0.42	0.49	0.48	0.46	0.42	0.57	0.47	0.46	0.47	0.52	0.41	0.57	0.45	0.36	0.52

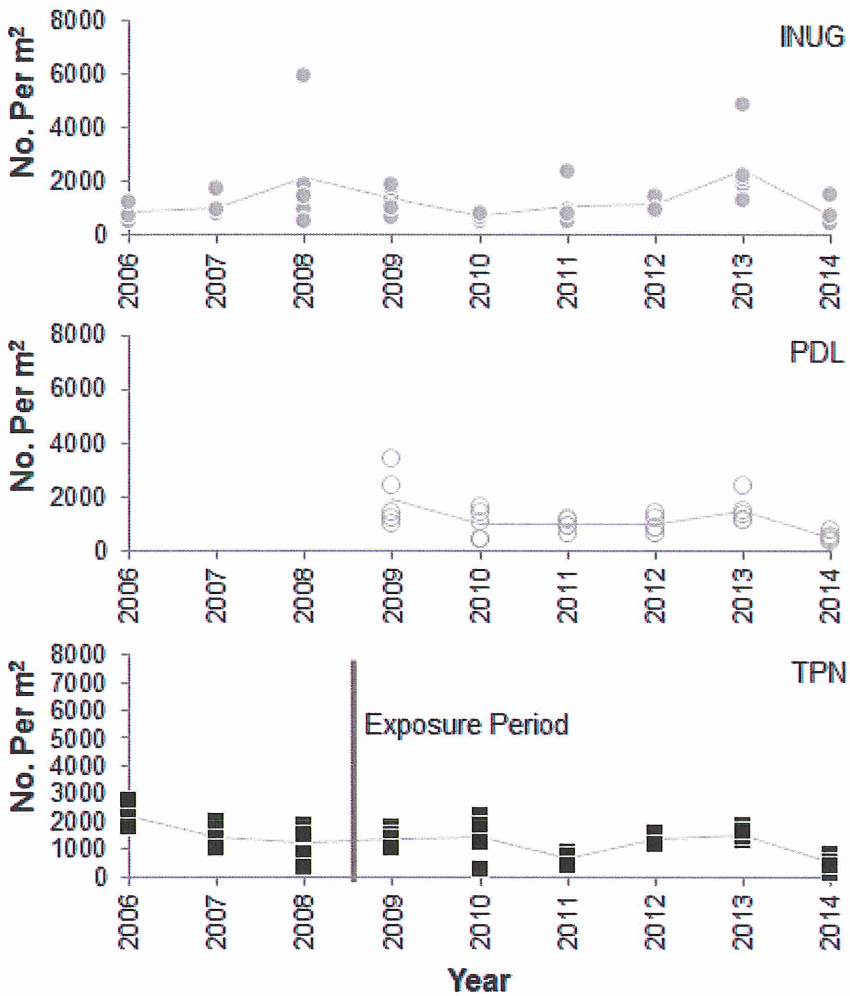


Figure 21. Variations in number of organisms per m^2 among years for INUG, PDL and TPN.

Figure Note: the line illustrates variations in annual averages.

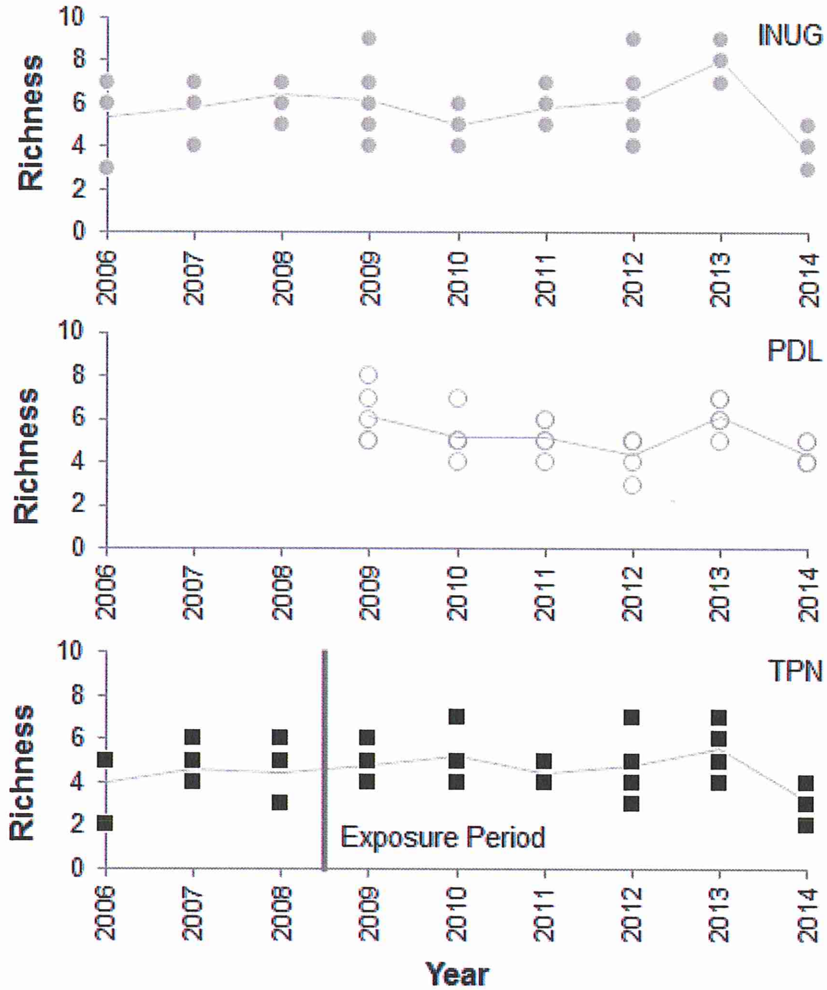


Figure 22. Variations in taxa richness (number of families) among years for INUG, PDL and TPN.

Figure Note: the line illustrates variations in annual averages.

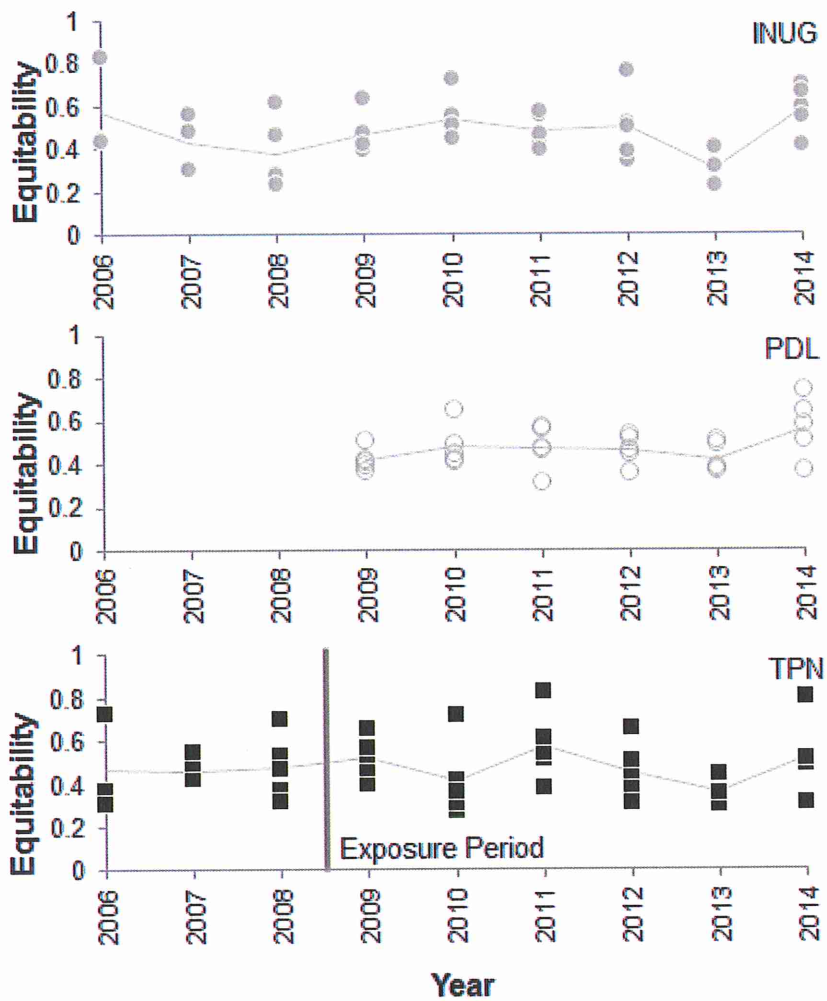


Figure 23. Variations in equitability among years for INUG, PDL and TPN.

Figure Note: the line illustrates variations in annual averages.

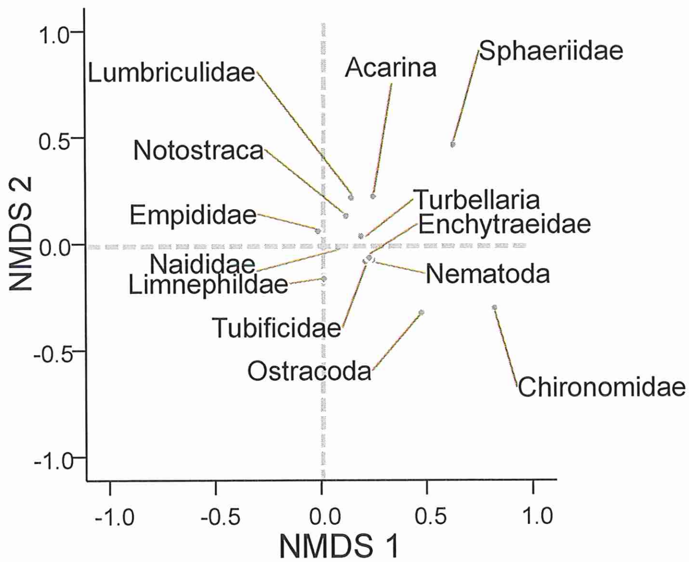


Figure 24. Scatterplot of Pearson correlation coefficients between taxa abundances and NMDS axis scores.

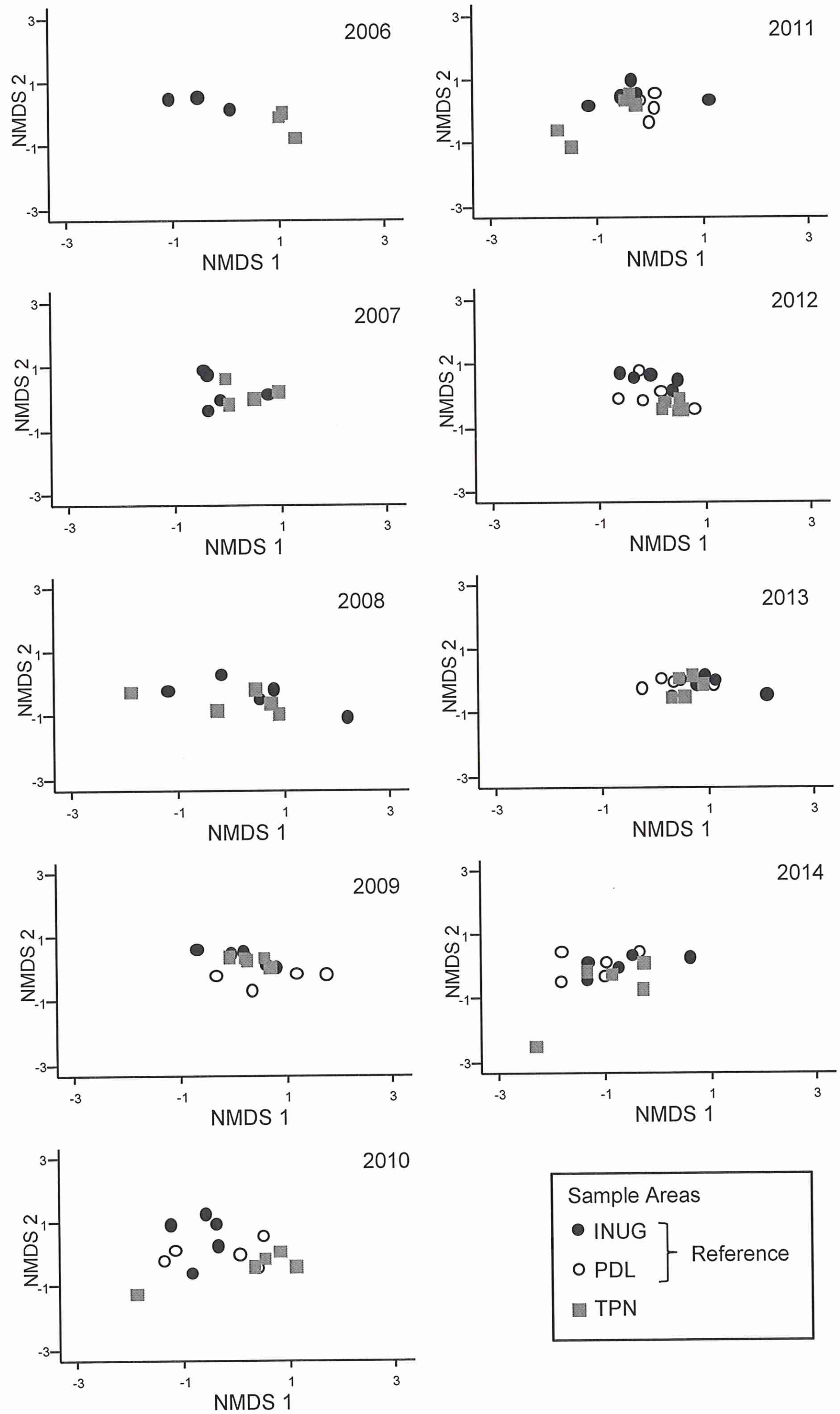


Figure 25. Scatterplots of NMDS axis scores for benthos community samples from INUG, PDL and TPN, by year.

4.3.2.2 Hypothesis Tests

None of the BACI or Time Trend contrasts for log of abundance, log of richness and equitability was statistically significant (all p > 0.05; Table 29). The BACI contrast for log of abundance produced a p-value of 0.093, but explained a trivial amount of variation (2.3% of total variation).

Variations in abundance, richness and equitability are illustrated in Figure 21 through Figure 23. Before-after differences and linear time trends for all three indices in TPN were highly similar to what was observed in the two reference lakes. Variation explained (with the exception of the BACI contrast for log of abundance) was always < 1% (Table 29).

Mantel tests on Bray-Curtis distances likewise produced non-statistically significant p-values (both p > 0.05; Figure 26). The p-value for the BACI Mantel was 0.307, whereas the p-value for the Time Trend contrast was 0.082. The variations in Bray-Curtis distances are illustrated in Figure 26. Variation in axis 1 and 2 scores for TPN always well overlapped variation in scores for the two reference lakes.

Table 29. Results of analysis of variance (ANOVA). Estimates of within-area variation (standard deviations) are also provided, as are estimated effect sizes for the BACI contrasts. The percent of total variation explained by the contrasts is also provided.

Hypothesis	Variable	Source	Type III SS	df	Mean Squares	F-Ratio	p-Value	η^2 x 100 = Explained Variation (%)
BACI	Log Abundance	Years and Areas	2.925	17	0.1721	3.35	0.000	
		Contrast	0.149	1	0.1487	2.90	0.093	2.3
		Error	3.490	68	0.0513			
	Log Richness	Years and Areas	0.769	17	0.0452	3.80	0.000	
		Contrast	0.009	1	0.0086	0.73	0.397	0.5
		Error	0.809	68	0.0119			
	Equitability	Years and Areas	0.467	17	0.0274	1.50	0.122	
		Contrast	0.001	1	0.0008	0.04	0.836	0.05
		Error	1.244	68	0.0183			
Difference in Time Trend After	Log Abundance	Years and Areas	3.180	17	0.187	4.61	0.000	
		Contrast	0.050	1	0.0495	1.22	0.273	0.8
		Error	2.924	72	0.0406			
	Log Richness	Years and Areas	0.725	17	0.0426	4.94	0.000	
		Contrast	0.005	1	0.0053	0.62	0.435	0.4
		Error	0.622	72	0.0086			
	Equitability	Years and Areas	0.450	17	0.0264	1.92	0.029	
		Contrast	0.013	1	0.0132	0.96	0.331	0.9
		Error	0.990	72	0.0137			

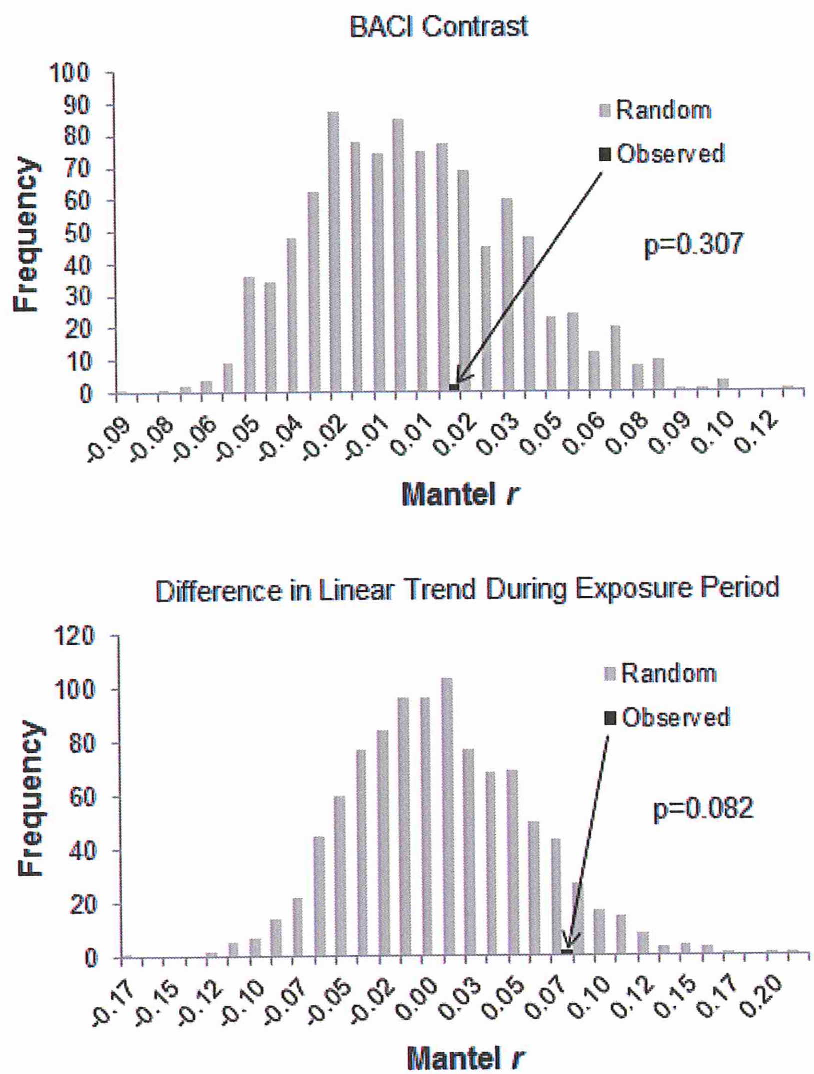


Figure 26. Histograms illustrating the random distribution of Mantel r values (testing for effect-related variations in Bray-Curtis distances), relative to the observed Mantel r for the BACI contrast (upper panel) and for the difference in linear time trends (lower panel).

4.4 Discussion

The benthic community of TPN, in 2014, largely consisted of chironomids and sphaeriid fingernail clams, similar to what the community consisted of in all other surveys including those from the baseline period 2006 to 2008. The community of TPN was, further, very similar to what has been described from INUG and from PDL. The composition of the benthic communities, their index values and associated statistics are consistent with a conclusion that there were no effects of mine effluent exposure on benthos of TPN.

Sediments in the three sampling areas have been likewise similar, consisting largely of fines (silt and clay sized materials), and relatively low concentrations of organic carbon (normally 1 to 3 %). The surface waters in each of the three sampling areas has been of very low hardness with concentrations of metals and nutrients that are well below CCME water quality guidelines, and near detection limits. There has been some elevation of cations (Ca, Mg, K) in TPN associated with effluent treatment, but the changes are trivial relative to the concentrations that would be required in order to elicit a toxicity response (Mount et al., 1997).

4.4.1 Recommendations for Next Cycle

AEM is currently committed to carrying out the same benthos survey annually as part of its commitment to the government of Nunavut. In the event that AEM is required to undertake another EEM benthos sampling program, it is recommended that AEM repeat the survey that has just been completed and described, and that is part of their routine sampling program for CREMP.

5.0 FISH TISSUE SURVEY

Mines are required to carry out a study of mercury concentrations in fish tissue if mercury has been detected at concentrations ≥0.10 µg/L in effluent (Environment Canada, 2012). Agnico Eagle Mines Ltd. has monitored mercury concentrations in the Meadowbank Division effluent since August 2009. Concentrations have remained below or near the detection limit of 0.01 µg/L. There was, therefore, no requirement to conduct a fish tissue survey during Cycle 2.

6.0 SUBLETHAL TOXICITY TESTING

6.1 Introduction

Sub-lethal toxicity testing must be carried out two times per year for the first three years and once a year after the third year of the MMER EEM program on effluent discharged from regulated facilities. A summary of the results of the toxicological tests carried out on Meadowbank Mine effluent are presented here.

6.2 Materials and Methods

Laboratory testing of Meadowbank Mine wastewater was undertaken using four different tests: Fathead Minnow (*Pimephales promelas*) 7-Day Survival and Growth Test (EPS 1/RM/22, Environment Canada, 1992), *Ceriodaphnia dubia* Survival and Reproduction Test (EPS 1/RM/21, Environment Canada, 2007a), the *Pseudokirchneriella subcapitata* 72-hour Growth Inhibition Test (EPS 1/RM/25, Environment Canada, 2007b), and the growth inhibition test with *Lemna minor* (EPS 1/RM/37, Environment Canada, 2007c). All four test protocols were run on final treated effluent at times of normal mine operation.

6.3 Results

Mine effluent was not acutely lethal to fathead minnows in laboratory tests conducted between 2012 and 2014, although small but measurable growth inhibition was observed in two of four samples tested. Two of four test samples were acutely toxic to *Ceriodaphnia dubia* while reproductive effects were observed in all tested samples. There was no inhibitory effect observed in growth of *Pseudokirchneriella subcapitata* exposed to any of the effluent samples. Test results with *Lemna minor* were highly variable but inhibitory effects on frond growth and production were evident in all of the samples (Table 30).

Table 30. Sublethal toxicity data for 2012, 2013 and 2014.

Sample Collection Date	Test Species and Endpoint						
	Pimephales promelas		*Ceriodaphnia dubia*		*Pseudokirchneriella subcapitata*	*Lemna minor*	
	LC50	Growth IC25	LC50	Reproduction IC25	Growth IC25	Frond growth (dry wt.) IC25	Frond No. IC25
28-05-2012	>100%	>100%	NA[1]	NA[1]	>90.9%	29.32%	23.18%
13-08-2012	>100%	>100%	>100%	27.44%	>90.9%	59.95%	92.98%
09-11-2012	>100%	NA[2]	>100%	17.3%	>90.9%	66.75%	90.92%
16-10-2013	>100%	84.9	17.7%	5.18%	>90.9%	3.94%	40.7%
30-06-2014	>100%	>100%	33.3%	7%	>90.9%	12.9%	5.83%
Geometric Mean	>100%	96.0%	49.27%	11.45%	>90.9%	21.24%	34.15%

Table Notes: Values represent percent effluent required to cause the effect; LC50 = concentration causing 50% mortality; IC25 = concentration causing 25% reduction in the sub-lethal endpoint, either growth, reproduction or frond number.
[1]Mortality in the control was >20%.
[2]Test was invalidated in the laboratory.

6.4 Discussion

Cycle 2 tests with fathead minnows and *Pseudokirchneriella subcapitata* were similar to Cycle 1 in that little or no inhibition was observed in any of the samples tested. Inhibition of *Ceriodaphnia dubia* survival and reproduction and of *Lemna minor* growth was often significant but was highly variable from sample to sample in both Cycle 1 and Cycle 2. The potential for effects on the receiving water have been eliminated with the closure of the effluent stream (see Section 2.1).

A rough estimate of the extent of the 25% effect zone in the receiving environment can be calculated by dividing the farthest extent of the 1% plume by the geometric mean of the IC25. Studies conducted in Cycle 1 indicated the maximum extent of the 1% plume to be approximately 1400 m from the discharge. The potential zone of effect for sublethal inhibition of fathead minnows and *Pseudokirchneriella subcapitata* is extremely small given the limited response in test organisms. For *Lemna minor* and *Ceriodaphnia dubia,* potential effect zones may extend for 66 m and 122 m respectively from the discharge point.

7.0 SUMMARY AND CONCLUSIONS

Lake Trout was the sentinel fish species used in the 2014 Cycle 2 EEM survey; other species are not present in sufficient numbers. Lake Trout from the Exposure area in Third Portage North Lake (TPN) were compared to Lake Trout from two reference lakes – Innuguguayalik Lake (INUG) and Pipedream Lake (PDL) in late August of 2014. Only a portion of the mature Lake Trout spawn in any given year, so reproductive endpoints could not be examined.

The parameters examined were size distribution, age distribution, weight adjusted for length, liver weight adjusted for weight and length, weight at age and length at age. The Lake Trout from TPN were similar to those from PDL with a significant difference (P<0.05) only for the weight versus length relationship. Lake Trout from TPN were 4.2% heavier than Lake Trout from PDL when adjusted for length, which is less than half the critical effect size of 10%. Lake Trout from TPN were significantly heavier than Lake Trout from the INUG reference area when adjusted for length (5.7%, P=0.000), and there were also significant differences in liver weight adjusted for length (23%; P=0.046), length adjusted for otolith age (-11.3%, P=0.015), and weight adjusted for otolith age (-28.4%, P=0.010). Of these, only weight adjusted for otolith age exceeded the critical effect size and, again, it should be noted that there was insufficient power to detect a 25% difference in the weight versus otolith age relationships and thus an increased probability of both type 1 (false positive) and type 2 (false negative) errors. Based on these results, PDL is the more appropriate reference lake.

This 2014 survey of benthic invertebrates focused on the exposure area in Third Portage North Lake (TPN), with INUG and PDL as local reference areas. This is the second invertebrate community survey for the Meadowbank Mine under the MMER. Benthos have been sampled from TPN and INUG since 2006, while PDL has been sampled since 2009 as part of the mines Comprehensive Environmental Monitoring Program (CREMP). The Cycle 2 EEM benthic invertebrate survey employed the same sampling methods as the CREMP program so that a before-after-control-impact (BACI) design could be used. Benthic invertebrates were collected on August 22 (TPN) and 23 (INUG, PDL), 2014. Effects assessment involved use of baseline period data dating back to 2006, and testing of before-after-control-impact (BACI) and trend over time variations. None of the BACI or Time Trend contrasts for log of abundance, log of richness and equitability was statistically significant. BACI and time trend ANOVA's always explained <1% of the variation of the total variation (i.e., potential mine-related effects were trivially small). Mantel tests on Bray-Curtis distances, likewise, produced non-statistically significant p values.

The Meadowbank mine has not discharged reclaim water to date and does not intend to discharge any reclaim water in the future. The Meadowbank mine does not expect to discharge contact water from the Portage Attenuation Pond to the receiving environment in the future; rather, beginning in 2015, reclaim and site contact water will be combined with freshwater from Third Portage Lake and used to re-flood the pits as part of mine reclamation. Discharge from the Vault Attenuation Pond to Wally Lake began in 2014 and will continue until the end of production. The implications of this to the EEM process will be discussed with Environment Canada.

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Appendix 1 Correspondence with Environment Canada

Appendix 2 Gill Net Set and Catch Data

Appendix 2. Gill net set data and catch. Fish captured alive were released at the point of capture.

waterbody	net set ID	start depth (m)	start easting/ northing	end depth (m)	end easting/ northing	lift ID	Aug. 2014 set date	set time	Aug. 2014 lift date	lift time	soak time (hours)	Lake Trout dead	Lake Trout alive	Arctic Char dead	Arctic Char alive	Round White-fish dead	Round White-fish alive	Arctic Gray-ling dead	Arctic Gray-ling alive
Third Portage North (TPN)	1	2.3	636949.173/ 7215328.279	5.3	637026.635/ 7215181.789	A	22	13:40	22	15:54	2.23	1	3	0	0	0	0	0	0
						B	22	15:54	22	20:00	4.1	0	1	0	0	0	0	0	0
						C	22	20:00	23	9:13	13.22	8	8	0	2	0	1	0	0
						D	23	9:13	23	14:15	5.03	0	0	0	0	0	0	0	0
	2	4.4	636571.735/ 7215636.345	4.0	636587.553/ 7215486.041	A	22	14:04	22	16:31	2.45	0	0	0	0	0	0	0	0
						B	22	16:31	22	20:23	3.87	0	1	0	0	0	0	0	0
						C	22	20:23	23	10:15	13.87	2	4	0	0	0	0	0	0
	3	1.9	635925.401/ 7215638.787	23.4	635974.349/ 7215508.666	A	22	14:25	22	16:54	2.48	0	2	0	0	0	0	0	0
						B	22	16:54	22	20:53	3.98	0	3	0	0	0	0	0	0
						C	22	20:53	23	11:34	14.68	6	8	0	0	0	0	0	0
	4	1.2	635661.826/ 7215427.578	10.9	635782.502/ 7215341.658	A	22	14:57	22	17:27	2.5	0	1	0	0	0	0	0	0
						B	22	17:27	22	21:30	4.05	2	7	0	0	0	0	0	0
	5	1.8	635505.053/ 7215009.641	10.9	635562.348/ 7214869.773	A	22	15:28	22	17:50	2.37	0	0	0	0	0	0	0	0
						B	22	17:50	22	22:10	4.33	2	0	0	0	0	0	0	0
						C	22	22:10	23	13:25	15.25	3	6	0	0	0	0	0	0
Pipedream (PDL)	1	2.6	632063.661/ 7223675.285	na	632176.240/ 7223798.582	A	24	14:07	24	17:43	3.6	0	4	0	0	0	0	0	0
						B	24	17:43	25	8:07	14.4	2	16	0	0	0	0	0	0
	2	2.8	631243.65/ 7223411.019	4.4	631301.631/ 7223540.252	A	24	13:50	24	17:07	3.28	0	2	0	0	0	0	0	0
						B	24	17:07	25	9:30	16.38	10	9	2	5	0	1	0	0
	3	1.6	630695.966/ 7222649.368	2.1	630772.949/ 7222766.454	A	24	12:56	24	16:08	3.2	0	0	0	0	0	0	0	0
						B	24	16:08	24	19:22	3.23	0	0	0	0	0	2	0	0
						C	24	19:22	25	14:30	19.13	13	4	0	0	0	0	0	0
	4	2.4	630856.618/ 7224028.782	2.3	630933.406/ 7224152.871	A	24	14:35	24	18:21	3.77	0	6	0	0	0	0	0	0
						B	24	18:21	25	10:45	16.4	7	12	0	0	0	0	0	0
	5	1.7	630592.509/	7.4	630684.216/	A	24	13:14	24	16:24	3.17	0	6	0	0	0	0	0	0

waterbody	net set ID	start depth (m)	start easting/ northing	end depth (m)	end easting/ northing	lift ID	Aug. 2014 set date	set time	Aug. 2014 lift date	lift time	soak time (hours)	Lake Trout dead	Lake Trout alive	Arctic Char dead	Arctic Char alive	Round White-fish dead	Round White-fish alive	Arctic Gray-ling dead	Arctic Gray-ling alive
			7222909.647		7223022.506	B	24	16:24	24	19:50	3.43	0	3	0	0	1	0	0	0
						C	24	19:50	25	13:18	17.47	9	2	0	0	0	0	0	0
Innugu-guayalik (INUG)	1	1.6	622139.250/ 7216893.060	1.6	622229.697/ 7217026.966	A	26	14:29	26	16:40	2.18	0	9	0	0	0	0	0	0
						B	26	16:40	26	19:33	2.88	0	1	0	0	0	0	0	0
						C	26	19:33	27	8:17	12.73	15	18	0	2	6	0	0	0
	2	1.4	622070.647/ 7217679.925	3.4	622156.626/ 7217794.907	A	26	14:53	26	17:31	2.63	3	7	0	0	0	0	0	0
						B	26	17:31	27	10:10	16.65	12	25	1	0	5	0	1	0
	3	1.4	622262.624/ 7217362.522	1.8	622304.637/ 7217498.01	A	26	15:43	26	18:17	2.57	0	0	0	0	0	1	0	0
	4	1.4	622391.925/ 7216985.346	5.3	622477.572/ 7217088.447	A	26	16:02	26	18:42	2.67	0	3	0	0	0	0	0	0
						B	26	18:42	27	11:20	16.63	12	14	1	0	0	0	0	0

Appendix 3 Individual Fish Data

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
TPN	1	1A	602	2300	28								A
TPN	2	1A	621	2570	26								A
TPN	3	1A	550	1920	18								A
TPN	4	1A	657	3130	26	26	38.0	24.1	f	m	u		D
TPN	5	3A	539	1910	18								A
TPN	6	3A	562	2080	21								A
TPN	7	4A	560	1930	15								A
TPN	8	1B	717	4580	26								A
TPN	9	2B	540	2040	25								A
TPN	10	3B	562	2260	24								A
TPN	11	3B	518	1320	17								A
TPN	12	3B	524	1840	22								A
TPN	14	4B	502	1460	18	25	33.3	256.6	f	m	RST		D
TPN	15	4B	628	2490	19	22	28.7	22.8	f	m	u		D
TPN	16	4B	523	1980	19								A
TPN	17	4B	576	2600	19								A
TPN	18	4B	650	2660	20								A
TPN	19	4B	592	2300	19								A
TPN	20	4B	640	2590	23								A
TPN	21	4B	860	6540	29								A
TPN	22	4B	211	86	4								A
TPN	23	5B	428	788	10	13	6.2	3.5	f	i			D
TPN	24	5B	314	317	12	15	2.6	2.1	f	i			D
TPN	25	1C	530	1770	15								A
TPN	26	1C	645	2850	21								A
TPN	27	1C	560	2030	16								A
TPN	28	1C	628	2610	14								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
TPN	29	1C	513	1460	15								A
TPN	30	1C	144	28.6	1								A
TPN	31	1C	152	33	2								A
TPN	32	1C	227	115.3	6								A
TPN	33	2C	609	2130	20								A
TPN	34	2C	555	1990	16								A
TPN	35	2C	580	2370	20								A
TPN	36	2C	269	197.8	6								A
TPN	37	2C	528	1710	16		21.8	71.7	m	m	RST		D
TPN	38	2C	512	1700	15	20	20.7	64.0	m	m	RST		D
TPN	39	3C	850	6050	27								A
TPN	40	3C	381	650	13								A
TPN	41	3C	594	2380	13								A
TPN	42	3C	560	2260	22								A
TPN	43	3C	511	1740	18								A
TPN	44	3C	578	2150	24								A
TPN	45	3C	268	190.1	10								A
TPN	46	3C	183	61.7	4								A
TPN	47	3C	235	120.8	5	7	1.3		u	i			D
TPN	48	3C	244	139.6	8	7	0.8		u	i			D
TPN	49	3C	243	156.8	5	8	1.6		u	i			D
TPN	50	3C	476	1270	14	16	9.7	18.9	f	m	u		D
TPN	51	3C	629	2940	32	35	44.8	112.3	m	m	RST		D
TPN	52	3C	529	1860	26	30	20.8	90.4	m	m	RST		D
TPN	53	5C	440	940	16								A
TPN	54	5C	464	1080	13								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
TPN	55	5C	555	1910	17								A
TPN	56	5C	615	2520	20								A
TPN	57	5C	543	2050	18								A
TPN	58	5C	342	370	13	15	2.6	0.8	f	i			D
TPN	59	5C	237	131.9	6								A
TPN	60	5C	208	86.3	5	5			u	i			D
TPN	61	5C	195	75.7	4	5	0.8		u	i			D
TPN	62	1C	505	1631	22	23	22.9	34.7	f	m	u		D
TPN	63	1C	270	188.6	8	8	1.1		u	i			D
TPN	64	1C	278	202.2	8	9	2.2		u	i			D
TPN	65	1C	180	51	4	5	0.6		u	i			D
TPN	67	1C	137	23.7	2				u	i			D
TPN	68	1C	130	24.3	1				u	i			D
PDL	69	5A	850	7640	29								A
PDL	70	5A	423	730	16								A
PDL	71	5A	443	860	15								A
PDL	72	5A	595	2130	20								A
PDL	73	5A	564	1920	19								A
PDL	74	5A	120	15.2	2								A
PDL	75	2A	641	2720	30								A
PDL	76	2A	555	1730	6								A
PDL	77	1A	833	6180	38								A
PDL	78	1A	560	2230	21								A
PDL	79	1A	612	2250	24								A
PDL	80	1A	539	1600	22								A
PDL	81	4A	645	2890	26								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
PDL	82	4A	651	3020	24								A
PDL	83	4A	552	1930	22								A
PDL	84	4A	596	2300	20								A
PDL	85	4A	564	1840	23								A
PDL	86	5B	731	3870	32								A
PDL	87	5B	521	1640	21								A
PDL	88	5B	117	14.7	1								A
PDL	89	1B	905	6110	38								A
PDL	90	1B	629	2780	20								A
PDL	91	1B	541	1890	19								A
PDL	92	1B	536	1870	17								A
PDL	93	1B	597	2080	20								A
PDL	94	1B	573	2000	27								A
PDL	95	1B	566	1880	18								A
PDL	96	1B	560	1810	19								A
PDL	97	1B	562	1931	24								A
PDL	98	1B	492	1300	25								A
PDL	99	1B	562	1730	20								A
PDL	100	1B	502	1430	24								A
PDL	101	1B	450	910	19								A
PDL	102	1B	544	2090	23								A
PDL	103	1B	557	1760	18								A
PDL	104	1B	580	2080	26	26	21.6	72.5	m	m	RST		D
PDL	105	1B	560	1900	27	26	19.1	49.6	m	m	RST		D
PDL	106	1B	288	220.9	7								A
PDL	107	2B	778	5990	28								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
PDL	108	2B	677	3650	27								A
PDL	109	2B	570	1850	19								A
PDL	110	2B	539	1630	17								A
PDL	111	2B	240	135.3	6								A
PDL	112	2B	301	270.5	7								A
PDL	113	2B	273	184.3	6								A
PDL	114	2B	256	159.2	5								A
PDL	115	2B	180	61.5	4								A
PDL	116	4B	741	5500	26								A
PDL	117	4B	560	1860	19								A
PDL	118	4B	511	1480	21								A
PDL	119	4B	550	1970	21								A
PDL	120	4B	610	2460	17								A
PDL	121	4B	535	1580	15								A
PDL	122	4B	515	1420	19								A
PDL	123	4B	549	1890	21								A
PDL	124	4B	534	1590	20								A
PDL	125	4B	584	2260	18								A
PDL	126	4B	947	10520	30	39	144.7	1427.5	f	m	RST		D
PDL	127	4B	611	2630	20	22	26.4	80.8	m	m	RST		D
PDL	128	4B	587	1860	20	24	13.2	37.3	m	m	RST		D
PDL	129	2B	495	1310	18	20	12.8	39.5	m	m	RST		D
PDL	130	2B	570	2030	22		30.6	227.5	f	m	RST		D
PDL	131	2B	695	3870	30	37	37.1	33.9	f	m	u		D
PDL	132	5C	755	4730	17								A
PDL	133	5C	504	1390	12								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
PDL	134	5C	505	1370	18								A
PDL	135	5C	711	3580	27								A
PDL	136	5C	420	850	15								A
PDL	137	5C	431	1000	18								A
PDL	138	5C	537	1620	20								A
PDL	139	5C	471	1120	15								A
PDL	140	5C	560	1850	19								A
PDL	141	5C	541	1860	17								A
PDL	142	5C	487	1230	16								A
PDL	143	1C	744	3840	20								A
PDL	144	1C	540	1640	16								A
PDL	145	1C	541	1720	20								A
PDL	146	1C	390	570	15								A
PDL	147	2B	337	376.6	8	8	3.99	0.26	u	i			D
PDL	148	2B	244	145.6	6	6	1.16	0.30	f	i		cestodes	D
PDL	149	2B	232	106.1	7	7	1.28		u	i		cestodes	D
PDL	150	2B	202	74.4	5	5	0.67	0.04	u	i		cestodes	D
PDL	151	2B	216	102.1	6	6	0.99		u	i		cestodes	D
PDL	152	2B	145	27.94	3	3	0.28		u	i		cestodes	D
PDL	153	2B	155	36.91	3	3	0.46		u	i		cestodes	D
PDL	154	4B	177	50.6	3	4	0.51		u	i		cestodes	D
PDL	155	4B	140	26.33	2	2	0.21		u	i			D
PDL	156	4B	140	24.11	2	2	0.26		u	i		cestodes	D
PDL	157	4B	136	21.28	2	2	0.28		u	i		cestodes	D
PDL	158	3C	441	887.4	16	18	6.06	1.16	m	i		cestodes	D
PDL	159	3C	573	2000	31	37	23.1	43.1	m	m	RST		D

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
PDL	160	3C	561	1820	23	24	17.1	78.2	m	m	RST	cestodes	D
PDL	161	3C	267	172	7		1.33		u	i			D
PDL	162	3C	205	80.4	5	5	0.69		u	i		cestodes	D
PDL	163	3C	181	68.5	4	4	0.55		u	i		cestodes	D
PDL	164	3C	192	69.4	4	5	0.53		u	i		cestodes	D
PDL	165	3C	212	91.4	4	6	0.64	0.15	f	i		cestodes	D
PDL	166	3C	128	19.98	3	3			u	i		cestodes	D
PDL	167	3C	133	21.14	2		0.24		u	i		cestodes	D
PDL	168	3C	136	25.14	3	3	0.32		u	i		cestodes	D
PDL	169	3C	142	26.44	2	2	0.29		u	i		cestodes	D
PDL	170	5C	351	438.1	10	11	2.83	0.26	u	i		cestodes	D
PDL	171	5C	325	348.3	11	10	3.26	0.74	f	i		cestodes	D
PDL	172	5C	234	133.3	9	9	0.88	0.25	f	i			D
PDL	173	5C	255	167.3	8	8	1.60		u	i		cestodes	D
PDL	174	5C	229	134.1	4	6	1.47		u	i			D
PDL	175	5C	186	63.6	4	4	0.42	0.15	f	i		cestodes	D
PDL	176	5C	199	83	5	5	0.82		u	i		cestodes	D
PDL	177	5C	168	43.9	5	5	0.56		u	i		cestodes	D
PDL	178	5C	195	74.6	3		0.63		u	i		cestodes	D
INUG	179	1A	697	3630	34								A
INUG	180	1A	470	1080	21								A
INUG	181	1A	503	1300	21								A
INUG	182	1A	460	1080	15								A
INUG	183	1A	584	1820	18								A
INUG	184	1A	430	860	17								A
INUG	185	1A	518	1380	20								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
INUG	186	1A	518	1440	21								A
INUG	187	1A	450	990	15								A
INUG	188	2A	578	1560	20							skinny fish	A
INUG	189	2A	495	1240	17								A
INUG	190	2A	332	390	8								A
INUG	191	2A	524	1450	22								A
INUG	192	2A	452	1080	14								A
INUG	193	2A	510	1330	17								A
INUG	194	2A	462	1060	24								A
INUG	195	2A	648	2580	31	36		39.5	f	m	RST		D
INUG	196	2A	583	1620	25	26	9.72	9.51	f	m	u	cestodes	D
INUG	197	2A	361	470	9	10	3.85	1.16	f	i		cestodes	D
INUG	198	4A	795	5690	30								A
INUG	199	4A	590	2010	32								A
INUG	200	4A	190	70.8	2								A
INUG	201	1B	520	1410	18								A
INUG	202	1C	461	960	14								A
INUG	203	1C	480	1180	20								A
INUG	204	1C	520	1460	23								A
INUG	205	1C	505	1340	15								A
INUG	206	1C	512	1340	22								A
INUG	207	1C	522	1460	20							fat	A
INUG	208	1C	519	1870	19								A
INUG	209	1C	479	1390	16								A
INUG	210	1C	480	1020	18								A
INUG	211	1C	483	1270	17								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
INUG	212	1C	524	1450	21								A
INUG	213	1C	513	1450	28								A
INUG	214	1C	532	1450	23								A
INUG	215	1C	475	1200	15								A
INUG	216	1C	234	127.5	5								A
INUG	217	1C	270	221.8	9								A
INUG	218	1C	341	413.8	9								A
INUG	219	1C	153	31.9	2								A
INUG	220	2B	615	2290	21								A
INUG	221	2B	430	770	11								A
INUG	222	2B	517	1590	20								A
INUG	223	2B	817	5690	39								A
INUG	224	2B	443	830	17								A
INUG	225	2B	462	1180	15								A
INUG	226	2B	585	2470	22								A
INUG	227	2B	480	1200	14							damaged right pec	A
INUG	228	2B	441	980	15								A
INUG	229	2B	503	1610	15								A
INUG	230	2B	590	1980	21								A
INUG	231	2B	500	1230	22								A
INUG	232	2B	568	1900	19								A
INUG	233	2B	518	1490	22								A
INUG	234	2B	587	2020	22								A
INUG	235	2B	505	1220	19								A
INUG	236	2B	525	1390	20								A

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
INUG	237	2B	891	10200	29							deep fish	A
INUG	238	2B	567	1800	22								A
INUG	239	2B	515	1170	18								A
INUG	240	2B	510	1120	17								A
INUG	241	2B	425	740	11								A
INUG	242	2B	470	1140	11								A
INUG	243	2B	438	860	17								A
INUG	244	2B	452	1060	18								A
INUG	245	4B	805	4910	34							skinny fish	A
INUG	246	4B	741	4310	30								A
INUG	247	4B	820	5820	30								A
INUG	248	4B	682	3750	27								A
INUG	249	4B	509	1640	19								A
INUG	250	4B	497	1270	15								A
INUG	251	4B	510	1410	18								A
INUG	252	4B	519	1280	24								A
INUG	253	4B	508	1400	18								A
INUG	254	4B	601	2150	18								A
INUG	255	4B	471	1130	17								A
INUG	256	4B	497	1380	12								A
INUG	257	4B	541	1620	22								A
INUG	258	4B	504	1260	19								A
INUG	259	4B	878	7490	28	27	51.3	218.5	m	m	RST		D
INUG	260	4B	798	5810	25	25	60.94	73.57	f	m	u		D
INUG	261	4B	729	3880	27	26	26.10	108.43	m	m	RST		D
INUG	262	4B	573	2040	28	35	21.44	50.53	m	m	RST		D

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
INUG	263	4B	501	1420	24	25	16.58	51.73	m	m	RST		D
INUG	264	4B	449	899.9	18	18	6.05	5.01	f				D
INUG	265	4B	412	692.6	11	11	3.93	0.39	m	i			D
INUG	266	4B	377	603.8	10	11	4.48	2.51	f	i			D
INUG	267	4B	291	234.4	9	9	1.93	0.44	f	i		cestodes	D
INUG	269	2B	480	1090	23	24	5.35	24.68	m	m	RST		D
INUG	270	2B	517	1360	23	24	15.15	17.06	f				D
INUG	271	2B	530	1370	20	20	11.50	12.13	f	i			D
INUG	272	2B	499	1280	21	27	20.31	21.79	f	m	RST	cestodes	D
INUG	273	2B	446	940	16	16	7.00	30.06	m	m	RST		D
INUG	274	2B	169	39.1	3	3	0.53		u	i			D
INUG	275	1C	531	1650	19	19	22.69	252.10	f	m	RST		D
INUG	276	1C	480	1200	20	21	11.14	39.25	m	m	RST		D
INUG	277	1C	408	874.2	13	13	8.13	12.45	m	m	RST		D
INUG	278	1C	446	914.6	11	11	10.27	0.55	m	i			D
INUG	279	1C	278	222.4	8	8	2.35		u	i		cestodes	D
INUG	281	1C	278	198.5	8	8	1.62	0.20	f	i			D
INUG	282	1C	241	148.6	5	5	1.82		u	i		cestodes	D
INUG	283	1C	588	2550	26	25	16.36	20.10	f	m	u	cestodes	D
INUG	284	1C	442	927.7	15	15	7.40	16.09	m	m	RST	cestodes	D
INUG	285	1C	390	594.6	9	9	4.44	1.67	f	i		cestodes	D
INUG	286	1C	278	217.7	9	8	2.20	0.43	f	i		cestodes	D
INUG	287	1C	159	39.2	3	3	0.50		u	i		cestodes	D
INUG	288	1C	136	26	2	2	0.20		u	i			D
INUG	289	1C	133	21.3	2	2	0.22		u	i			D
INUG	290	2B	481	1240	22	23	14.11	18.25	f	m	u	cestodes	D

Lake	Fish #	Net/ lift	fork length (mm)	weight (g)	fin-ray age	otolith age	liver weight (g)	gonad weight (g)	sex	maturity	gonad condition	deformities lesions parasites	alive/ dead
INUG	291	2B	479	1160	17	17	8.81	23.72	m	m	RST		D
INUG	292	2B	272	215.7	7	7	2.16	0.42	f	i		cestodes	D
INUG	293	2B	238	134.5	5	5	1.27	0.26	f	i		cestodes	D
INUG	294	2B	252	151.8	5	5	1.57	0.20	f	i		cestodes	D
INUG	295	2B	180	53.8	3	3	0.52		u	i		cestodes	D
INUG	296	2B	161	48.2	2	2	0.53		u	i			D
TPN	66	1C	138	24.7					u	i			D
INUG	280	1C	300	259.1		8	2.08		u	i		cestodes	D
INUG	268	4B	143	24.1		2	0.33		u	i			D

Fish Aging QA/QC

Fish number	estimated age				QA/QC age minus primary age	
	QA/QC age		primary age determination			
	otolith	fin ray	otolith	fin ray	otolith	fin ray
4	26	23	26	26	0	-3
49	7	6	8	5	-1	1
58	12	15	15	13	-3	2
61	5	4	5	4	0	0
63	7	7	8	8	-1	-1
64	9	7	9	8	0	-1
147	8	7	8	8	0	-1
148	6	6	6	6	0	0
152	3	3	3	3	0	0
158	18	13	18	16	0	-3
160	24	20	24	23	0	-3
162	7	5	5	5	2	0
171	9	8	10	11	-1	-3
195	34	27	36	31	-2	-4
262	30	26	35	28	-5	-2
263	18	24	25	24	-7	0
264	16	18	18	18	-2	0
265	11	9	11	11	0	-2
266	11	9	11	10	0	-1
269	21	25	24	23	-3	2
274	3	3	3	3	0	0
276	23	21	21	20	2	1
277	14	14	13	13	1	1
281	8	8	8	8	0	0
282	6	5	5	5	1	0
288	2	2	2	2	0	0
289	2	2	2	2	0	0
291	17	17	17	17	0	0
296	2	2	2	0	0	2

Fish Data QA/QC Notes

The following data recording errors were detected during data entry.
Fish number 61: the weight was recorded in kilograms (1.631) instead of grams (16310). The weight was changed to grams.
Fish number 63: the sex was recorded as i (immature). It was changed to u (unknown).
Fish 47 and 48 the gonad condition was recorded as unknown instead of immature. The gonad condition was changed to immature.

Fish 264 and 270 maturity was recorded as u. This code is only valid for sex (u=unknown) or gonad condition (u=undeveloped). Both individuals were female. Maturity was left blank (and thus still unknown) for both fish.

The following data recording errors were detected after examining scatterplots of the total weight versus fork length and determining that the values were out by an order of magnitude due to adding an extra zero or leaving off a zero. The balance used to weigh these live fish weighed to the nearest 10 g, and therefore the last digit could only be zero. Consequently the following changes were considered appropriate.

Fish number 101: the total weight was recorded as 9100g which was an order of magnitude high. The weight was changed to 910 g.

Fish number 198: total weight was recorded as 569 g which was an order of magnitude too low. The weight was changed to 5690 g.

The following recording errors weres detected by examining a scatterplot of liver weight versus total weight.

Fish number 195: the liver weight was recorded as 336.5 which was an order of magnitude too high. The value was deleted from the dataset.

Fish number 166: the liver weight was recorded as 0.06 which was an order of magnitude too low. The value was deleted from the dataset.

Appendix 4 Water Chemistry Quality Assurance

Appendix 5 Benthic Community Data

Appendix 5. Benthic community data. August 22 and 23, 2014.

Area	INUG					PDL					TPN				
Station	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
ROUNDWORMS															
P. Nemata	-	5	-	-	1	1	2	1	7	-	-	-	-	1	-
ANNELIDS															
P. Annelida															
WORMS															
Cl. Oligochaeta															
F. Enchytraeidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Naididae															
S.F. Tubificinae															
immatures with hair chaetae	-	-	-	1	-	-	1	3	-	3	-	-	-	-	-
S.F. Rhyacodrilinae															
Rhyacodrilus coccineus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
F. Lumbriculidae															
Lumbriculus	-	-	1	1	-	-	-	-	2	1	-	-	1	-	-
ARTHROPODS															
P. Arthropoda															
MITES															
Cl. Arachnida															
O. Acarina															
F. Acalyptonotidae															
Acalyptonotus	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-
Hygrobates	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
F. Lebertiidae															

Area	INUG					PDL					TPN				
Station	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Lebertia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
F. Oxidae															
Frontipoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SEED SHRIMPS															
Cl. Ostracoda	-	2	-	-	-	-	-	-	-	-	1	1	-	-	-
SPRINGTAILS															
Cl. Entognatha															
O. Collembola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INSECTS															
Cl. Insecta															
CADDISFLIES															
O. Trichoptera															
F. Limnephilidae															
Grensia praeterita	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TRUE FLIES															
O. Diptera															
MIDGES															
F. Chironomidae															
chironomid pupae	1	-	-	1	-	-	-	1	-	-	-	-	-	1	-
S.F. Chironominae															
Micropsectra	2	3	3	5	1	3	-	-	-	-	4	-	2	3	2
Microtendipes	2	4	3	19	10	-	-	-	-	-	-	-	-	-	-
Paratanytarsus	-	-	-	1	1	-	-	-	-	-	8	-	2	3	-
Stictochironomus	11	2	3	1	2	13	15	6	4	5	-	2	6	3	-
Tanytarsus	1	-	1	6	-	-	-	-	-	1	-	-	-	-	-
S.F. Diamesinae															

Area	INUG					PDL					TPN				
Station	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Protanypus	-	-	-	1	1	-	-	-	-	-	-	1	-	1	-
S.F. Orthocladiinae															
Abiskomyia	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Heterotrissocladius	-	-	-	-	-	-	-	-	-	-	1	-	4	4	10
Psectrocladius	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Zalutschia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
S.F. Prodiamesinae															
Monodiamesa	1	-	-	3	-	-	-	2	-	-	-	-	-	-	-
S.F. Tanypodinae															
Procladius	1	2	2	5	2	2	3	-	1	8	6	-	7	1	2
Thienemannimyia complex	-	1	-	-	1	-	-	-	-	1	9	-	4	3	-
MOLLUSCS															
P. Mollusca															
CLAMS															
Cl. Bivalvia															
F. Sphaeriidae															
Cyclocalyx/Neopisidium	7	1	3	22	12	2	12	3	8	3	1	-	11	4	2
Cyclocalyx	-	3	3	1	-	-	4	-	-	4	-	-	-	-	-
Sphaerium nitidum	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-
TOTAL NUMBER OF ORGANISMS	27	23	19	70	34	22	38	16	23	27	31	4	38	24	19
TOTAL NUMBER OF TAXA [a]	8	9	8	14	12	6	7	5	6	9	8	3	9	9	6
[a] **Bold entries excluded from taxa count**															

				Area		**INUG**						**PDL**							**TPN**				
				Station		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**			**1**	**2**	**3**	**4**	**5**

Appendix 6 Benthic Community Data Quality Assurance

Table 1. Calculation of subsampling error for benthic macroinvertebrate samples from Meadowbank Mine CREMP (2014).

Station	Whole Organisms	Number of Organisms in Fraction 1	Number of Organisms in Fraction 2	Number of Organisms in Fraction 3	Number of Organisms in Fraction 4	Actual Density*	Precision % range		Accuracy min	Accuracy max
BAP-3	0	317	344	-	-	661	7.8	-	4.1	-

*whole large organisms excluded in calculations.

min = minimum absolute % error.

max = maximum absolute % error.

Table 2. Percent recovery of benthic macroinvertebrates from samples collected at Meadowbank Mine (EEM and CREMP) in 2014. The EEM samples are indicated by the blue highlight.

Station	Number of Organisms Recovered (initial sort)	Number of Organisms in Re-sort	Percent Recovery
BAP-5	181	184	98.4%
BES-3	156	164	95.1%
INUG-4	68	70	97.1%
PDL-5	27	27	100.0%
TE-2	60	62	96.8%
TPE-3	222	229	96.9%
TPS-4	229	233	98.3%
		Average % Recovery	97.5%

QA/QC notes

All 65 samples were sorted in their entirety except for Samples BAP-2 and BAP-4 which were both sorted to one half fraction. Samples BAP-2 and BAP-4 took 5 hours to sort.

Due to the similarity of immature *Cyclocalyx* and *Neopisidium*, clams < 3.0 mm in size were identified as *Cyclocalyx/Neopisidium*.

Pupae were not counted toward total number of taxa unless they were the sole representative of their taxa group.