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September 26, 2024

Wek'èezhìi Land and Water Board
#1, 4905- 48 Street
Yellowknife, Northwest Territories X1Z 3S3

To: Mason Mantla| Chair Wek'èezhìi Land and Water Board

Re: Kodiak Lake 2023 Mercury Investigation Final Report

Burgundy Diamond Mines (Burgundy) is pleased to provide the Wek'èezhìi Land and Water Board (the Board) with the *Kodiak Lake 2023 Mercury Investigation Final Report*, (the Report) for the Ekati Diamond mine (Ekati). The Report is a requirement for the Fish Response Plan (Version 3.0) [1] under the Class A Water Licence (W2022L2-0001).

Project Background

The Aquatic Response Framework (ARF), required by Part J, Condition 7 of the Water Licence, links the results of the Aquatic Effects Monitoring Program (AEMP) to specific management actions. The ARF requires Burgundy to respond should a pre-defined level of environmental change (i.e., Action Levels [Als]) is reached for any water quality or biological variables (i.e., sediment quality or fish tissue metal concentrations). The AEMP results are regularly assessed against these action levels. Any exceedances are reported to the Board, and a corresponding Response Plan is developed, reviewed, updated, and amended as needed.

As a part of the Ekati's AEMP large-bodied fish program, Lake Trout (*Salvelinus namaycus*h) and Round Whitefish (*Prosopium cylindraceum*) are sampled every six years. During the 2018 AEMP, mercury (Hg) concentrations in round whitefish from the monitored lakes within the Koala Watershed were found to exceed the Low Action Level (LAL), suggesting a mine-related effect. Additionally, increased Hg concentrations were also recorded in lake trout that was also suggested to be mine-related; This was not considered an LAL exceedance. The reason for the exceedance was uncertain due to the lack of mine-related discharges to Kodiak Lake.

On August 22, 2022, Burgundy received approval from the Board for Version 3.0 of the Fish Response Plan that included the development of the Medium Action Level and the High Action Level for Hg in large-bodied fish and issued directive:

[1] ERM. 2022. Ekati Diamond Mine: Response Plan for Fish Version 3.0. Prepared for Arctic Canadian Diamond Company by ERM Consultants Canada Ltd. Vancouver, BC

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- retroactively evaluate the 2018 High Action Level exceedance for Hg in fish tissues in Kodiak Lake and include this in the 2022 AEMP Annual Report.

In response to a memorandum submitted to the Board on March 31, 2023, further investigations were completed for the High Action Level for Hg:

- a review and statistical analysis of historical data available from the Ekati to examine spatial and temporal trends, and to identify any correlations with fish tissue Hg concentrations.
- a field study investigating total and methylmercury concentrations in the water and sediments of Kodiak Lake using ultra-trace sampling techniques was conducted. A final report was prepared that includes the study results and a comparison of the sources of water flowing into Kodiak Lake with the reference sites at Ekati.

Mercury Investigation Report

The Report describes the methods and results of the 2023 Kodiak Lake field study as well as the desktop analysis of existing monitoring data.

Key findings of the study and data analysis:

- both lake trout and round whitefish showed higher Hg concentrations compared to pre-mining conditions, despite the absence of active effluent discharge into Kodiak lake;
- the rise in fish Hg concentrations is strongly related to wetland influences and elevated primary productivity; and
- Kodiak Lake's larger drainage surface area compared to reference lakes likely contributes to Hg loading and the delivery of dissolved organic carbon, sulphate, and nutrients, which facilitate mercury methylation and bioaccumulation.

Closure

Burgundy trusts that you will find this information to be clear and informative. Should you have any questions, please contact Leslie Gault, Senior Environmental Advisor- Fisheries Aquatics, at leslie.gault@burgundydiamonds.com or 403.910.1933 ext. 2407.

Sincerely,

Signature

Leslie Gault, MSc., PBiol., RPBio.
Sr. Environmental Advisor- Fisheries and Aquatics

EKATI DIAMOND MINE

Kodiak Lake 2023 Mercury Investigation
Version 1.1

July 2024

BURGUNDY
DIAMOND MINES

Ekati Diamond Mine

Kodiak Lake 2023 Mercury Investigation
Version 1.1

July 2024

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EXECUTIVE SUMMARY

Large-bodied fish (Lake Trout [*Salvelinus namaycush*] and Round Whitefish [*Prosopium cylindraceum*]) are sampled every six years as a component of the Ekati Diamond Mine Aquatic Effects Monitoring Program (AEMP). Increasing mercury (Hg) concentrations in Round Whitefish in 2018 in monitored lakes in the Koala Watershed (compared to Reference sites) were concluded to be a mine-related effect (i.e., a Low Action Level [LAL] exceedance), and higher Hg concentrations in Lake Trout in 2018 were concluded to be potentially mine-related (i.e., not a LAL exceedance), although the cause of the exceedance was uncertain given the lack of mine-related discharges to Kodiak Lake. Following the conclusion of a LAL exceedance for Round Whitefish, the Response Plan for Fish Version 3.0 (ERM 2022) was revised to develop a Medium Action Level and High Action Level for Hg in large-bodied fish.

As part of the approval of Version 3.0 of the Fish Response Plan the Wek'èezhii Land and Water Board included a Directive to retroactively evaluate the 2018 High Action Level [HAL] exceedance for Hg in fish tissues in Kodiak Lake and include this in the 2022 AEMP Annual Report. Kodiak Lake is located in the Koala Watershed, in proximity to the Ekati Diamond Mine Main Camp. Since 2012, AEMP results as presented in Annual Reports (Rescan 2013, ERM 2019a) have identified potentially mine-related increasing THg trends in large-bodied fish of Kodiak Lake.

A memorandum describing the retroactive HAL exceedance for Hg in fish tissues in Kodiak Lake in 2018 identified possible causes of higher Hg, as well as next steps associated with the HAL exceedance investigation.

This report advances two investigations per the memorandum, and is presented in two sections:

- A review and statistical analysis of historical data sets available from the Ekati Diamond Mine was conducted to examine spatial and temporal trends in the data. Correlations to fish tissue Hg concentrations were also made.
- A report on a field study conducted in 2023 to investigate total and methylmercury concentrations in Kodiak Lake water and sediments using ultra-trace sampling techniques, as well as on the sources of water flowing into Kodiak Lake, and a comparison of these to reference areas at the Ekati Diamond Mine.

The retrospective study revealed strong correlations between Hg concentrations in large-bodied fish and indicators of heightened watershed influence, nutrient concentrations, and primary productivity in Kodiak Lake. Kodiak Lake has a large drainage area for the relative size (surface area) of the lake which suggests that Kodiak Lake is likely to experience greater influence of watershed-related environmental variables than other lakes with smaller ratios of drainage area to lake surface area. Atmospheric deposition of Hg may not play a significant role in delivering Hg to lakes included in this study, although evidence was limited due to higher detection limits for some of the data. Overall, THg in study lakes at the Ekati Diamond Mine was low compared to concentrations observed elsewhere in the Arctic.

There may be a shift in the dietary components of Round Whitefish, possibly in response to increased primary productivity, which, in turn, correlates with rising zooplankton abundance in Kodiak Lake. Zooplankton, which have more recently become a key component of Round Whitefish diet in Kodiak Lake, tend to accumulate higher levels of Hg compared to benthic invertebrates.

Kodiak Lake's MeHg concentrations in water surpassed those observed in many Reference Lakes, although it was more similar to concentrations observed in Northeast Lake. Despite having higher MeHg concentrations in water, THg concentrations in fish in Northeast Lake were not as high as those of Kodiak Lake, indicating that MeHg concentrations alone are not the only factor influencing THg concentrations in fish tissue. Kodiak Lake differed from Reference lakes with higher THg concentrations in water, indicating that there are multiple interacting factors influencing Hg concentrations in large-bodied fish species in Kodiak Lake.

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ACRONYMS AND ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Plan
Arctic Canadian	Arctic Canadian Diamond Company Ltd.
AL	Action Level
AQMP	Air Quality Monitoring Program
Burgundy	Burgundy Diamond Mines Ltd.
BV	Bureau Veritas (analytical laboratory)
CALA	Canadian Association of Laboratory Accreditation
CCME	Canadian Council of Ministers of the Environment
DL	detection limit
DO	dissolved oxygen
DOC	dissolved organic carbon
dwt	dry weight
EPA	Environmental Protection Agency
ERM	ERM Consultants Canada Ltd.
EROD	Ethoxyresorufin-O-deethylase
ha	hectare
HAL	High Action Level
Hg	Mercury
IEMA	Independent Environmental Monitoring Agency
LAL	Low Action Level
MAL	Medium Action Level
MeHg	methylmercury
NCP	Northern Contaminants Program
NWT	Northwest Territories
PAH	Polycyclic Aromatic Hydrocarbons
PDC	Panda Diversion Channel
PSD	Pigeon Stream Diversion
QA/QC	Quality Assurance and Quality Control
RDL	reporting detection limit
RPD	relative percent difference
SE	standard error
SRB	sulphate-reducing bacteria
THg	total mercury
TKN	organic Kjeldahl nitrogen

TOC	total organic carbon
WLWB, the Board	Wek’èezhìi Land and Water Board, referred to as the Board within this report with the exception of reference citations.
Wwt	wet weight

1. INTRODUCTION

1.1 BACKGROUND

The Ekati Diamond Mine Aquatic Effects Monitoring Program (AEMP) is a comprehensive tool designed to detect changes in the aquatic Receiving Environment, administrated by the Wek'èezhii Land and Water Board (WLWB, the Board). The program has been conducted annually since 1998 as required under Arctic Canadian Diamond Company Ltd.'s (Arctic Canadian; now Burgundy Diamond Mines Ltd. [Burgundy]), Class A Water Licence (W2022-0001; the Licence). The Aquatic Response Framework required by Part J, Condition 7 of the Licence links the results of the AEMP to specific management actions. This response framework requires Burgundy to undertake a response should a pre-defined level of environmental change (i.e., Action Levels [Als]) be reached for any water quality or biological variables (i.e., sediment quality or fish tissue metal concentrations); Responses Plans are developed in response to AL exceedances.

Large-bodied fish (Lake Trout [*Salvelinus namaycush*] and Round Whitefish [*Prosopium cylindraceum*]) are sampled every six years under the AEMP. Small-bodied fish (Slimy Sculpin [*Cottus cognatus*]) are monitored in the AEMP as a sentinel species for large-bodied fish and are sampled every three years.

The Fish Response Plan Version 1.0 (ERM 2016) was initially developed in 2016 in response to Low Action Level [LAL] exceedances for four metals (antimony, molybdenum, selenium, and uranium) in fish tissues, and EROD (ethoxyresorufin-O-deethylase; an indicator of exposure to polycyclic aromatic hydrocarbons [PAHs] activity) in Lake Trout and/or Round Whitefish. The Fish Response Plan has since been updated. The Fish Response Plan Version 2.0 was submitted in October 2019 (ERM 2019b), reporting on the LAL exceedance for mercury (Hg) in Round Whitefish in the 2018 AEMP. Version 3.0 of the Fish Response Plan was submitted on May 24, 2022, which included the development of the Medium AL (MAL) and High AL (HAL) for Hg and was approved by the Board on August 22, 2022. Small-bodied fish are not evaluated against the MAL and HAL that were developed for Hg.

The approved MAL and HAL for Hg were developed for large-bodied fish muscle tissue concentrations measured through the AEMP with a site-specific human consumption screening value (mg/kg wet weight [wwt] of methylmercury [MeHg]) at the site-specific consumption rate (kg/day). This criterion considers that risks to human consumers of fish resulting from Hg in fish muscle depends on both the concentration of Hg in the tissues as well as the amount of fish muscle consumed. The site-specific human consumption screening value for Hg in fish was calculated according to the United States Environmental Protection Agency/ Food and Drug Administration guidance and consumption advisory screening values (US FDA 2019). For ALs to be based on a site-specific human consumption screening value to be appropriately protective of consumers of fish at the Ekati Diamond Mine, information on consumption rates, which is a primary factor influencing potential toxicity, was sought through engagement sessions and fish consumption surveys distributed to community members (ERM 2022).

The approved MAL and HAL (Table 1.1-1) are as follows:

M1. Based on AEMP methods for measuring tissue metal concentrations in large-bodied fish, mean Hg fish tissue concentration in the portion of fish consumed (i.e., muscle) of a sampled fish species in a near-field lake exceed 70% of the site-specific human consumption screening value of 0.28 mg/kg wwt for Lake Trout and 0.23 mg/kg wwt for Round Whitefish, at the site specific-consumption rate (kg/day).

H1. Based on AEMP methods for measuring tissue metal concentrations in large-bodied fish, mean Hg fish tissue concentration in the portion of fish consumed (i.e., muscle) of a sampled fish species in a near-field lake exceed the site-specific human consumption screening value of 0.28 mg/kg wwt for Lake Trout and 0.23 mg/kg wwt for Round Whitefish, at the site-specific consumption rate (kg/day).

TABLE 1.1-1 APPROVED SITE-SPECIFIC AND STANDARD SCREENING VALUES FOR METHYLMERCURY IN LARGE-BODIED FISH AT THE EKATI DIAMOND MINE

Species		**Site-Specific Screening Value (mg/kg wet weight[1])**
Common NMW	**Scientific Name**	
Lake Trout	*Salvelinus namaycush*	0.28
Round Whitefish	*Prosopium cylindraceum*	0.23

[1] Wet weight of uncooked fish

1.2 SOURCES AND CYCLES OF MERCURY IN THE ENVIRONMENT

Mercury is a naturally occurring heavy metal that is distributed ubiquitously in the environment (US EPA 1997). Generally, natural sources of Hg include volcanic emissions, forest fires, degassing from soils, and weathering from Hg-bearing rocks (Kim and Zoh 2012; Driscoll et al. 2013). Key sources of Hg from global anthropogenic activity include the burning of fossil fuels (particularly coal), smelting activities, Hg-containing chemicals used in various domestic or industrial processes, and mining activities (US EPA 1997; Ministry for the Environment 2009; Driscoll et al. 2013). Additionally, the deposition of atmospheric Hg following long-range transport from hundreds or even thousands of kilometers away from the source (Selin 2009; Semeniuk and Dastoor 2017).

Due to the advection of atmospheric Hg by winds, atmospheric circulation patterns such as the Pacific North American Oscillation and the North Atlantic Oscillation can result in long-range transport and the accumulation of Hg in remote areas of the Arctic where there are relatively few anthropogenic sources of Hg compared to heavily industrialized areas (AMAP 2017). Although Arctic communities and industrial sites emit Hg into the atmosphere through combustion of fossil fuels and waste incineration, the atmospheric delivery of Hg to the Canadian Arctic is estimated to be predominantly from international sources (Durnford 2010).

Wetlands and peat bogs often retain a large amount of Hg (Bodaly et al. 1997; Paterson et al. 1998; Heyes et al. 2000). Microbial decomposition and methylation of terrestrial material such as peat in wetlands or in recently inundated terrestrial habitat (e.g., flooded areas that become reservoirs) result in an increase in bioavailable Hg and often elevated concentrations of Hg in fish (Heyes et al.

2000). Fluctuations in water levels, resulting in temporary flooding of adjacent riparian areas, can increase bioavailable Hg in lakes (Bodaly et al. 1997; Paterson et al. 1998; Heyes et al. 2000).

Terrestrial contributions of Hg to the AEMP lakes are expected to be strongly influenced by regional meteorological conditions, which may induce water level fluctuations and/or thawing permafrost and could therefore result in increases in fish tissue Hg concentrations across all lakes. However, terrestrial Hg contributions also depend on the composition of the landscape surrounding each lake (e.g., vegetated peat vs. bedrock) and therefore, even if lakes experience similar water level fluctuations, terrestrial contributions of Hg may be unique.

The Ekati Diamond Mine exists in a region of low-ice continuous permafrost, where much of the permafrost across the Northwest Territories (NWT) is regarded as thaw-sensitive (Heginbottom et al. 1995). Slight increases in temperature or changes in the surface energy balance can lead to permafrost thaw (Quinton et al. 2009). Global climate change, forest fires and anthropogenic structures (Bonnaventure and Lamoureux 2013; Raynolds et al. 2014) can increase rates of thawing of permafrost. The deepening of active layer thickness of permafrost thaw and development of taliks (areas of perennially thawed soil in permafrost environments) beneath bodies of water and wetlands (Bonnaventure and Lamoureux 2013; Rowland et al. 2010; Woo 2012) can contribute significantly to increased hydrological connectivity among waterbodies. Permafrost regions contain substantial reservoirs of Hg bound to organic matter, and permafrost degradation will accelerate mobilization of Hg to aquatic systems (Schuster et al. 2018).

Mercury is present in the environment in three forms: elemental Hg (Hg0), inorganic Hg compounds (with Hg1+ and Hg2+ forms), and organic Hg, such as MeHg. Both inorganic and organic forms of Hg are known to bioaccumulate. However, among both inorganic and organic forms, MeHg is typically absorbed with much higher efficiency and accumulated in higher trophic level organisms (Watras 1998). Humans and piscivorous wildlife are exposed to Hg in the environment predominantly in the form of MeHg through the dietary ingestion of fish, which bioaccumulate Hg through the ingestion of lower trophic level organisms (Rice et al. 2014). The chemical form (i.e., MeHg or inorganic Hg) and route of exposure (i.e., dietary uptake) are important factors that influence the toxicity of Hg to organisms. In controlled toxicity tests, long-term exposures of inorganic Hg in the range of 260 to > 64,000 ng/L have resulted in adverse effects to the growth, reproduction, development, and survival of aquatic organisms (including benthic invertebrate and fish species; Environment Canada 2003). In comparative toxicity tests, MeHg is often observed to be more than 10 times as toxic as inorganic Hg to aquatic organisms. Adverse effects of MeHg exposure in aquatic organisms have been observed in the range of 40 to 1,140 ng/L in invertebrates and from 930 to 63,000 ng/L in fish (Environment Canada 2003).

The bioavailability of Hg to aquatic food webs depends primarily on the rate of methylation by microbial respiration, which converts inorganic Hg to MeHg (Hsu-Kim et al. 2013). Anaerobic, dissimilatory sulphate-reducing bacteria (SRB) are thought to be the largest producers of MeHg in aquatic ecosystems, although dissimilatory iron-reducing bacteria can also play a role in lake ecosystems (Fleming et al. 2006). Microbial activity in turn is controlled by anoxic conditions, nutrients, dissolved organic matter and temperature (Gilmour et al. 1992). Biotic demethylation occurs among a broad group of bacteria utilizing both oxidative and reductive detoxification processes as a function of the presence of amount of dissolved oxygen, organic matter, sulphide, and MeHg (substrate) availability (Seller et al. 1996; Marvin-DiPasquale et al. 2000).

Abiotic demethylation in freshwater systems results from solar radiation (i.e., photodegradation) in oxic surface waters, as well as from complexation of MeHg with sulphide creating non-bioavailable forms mainly within the sediments (Seller et al. 1996; Branfireun and Roulet 2002). In aquatic environments, MeHg that has entered the food chain has the potential to biomagnify. Biomagnification of MeHg refers to the increase of tissue MeHg concentrations as the chemical passes up the food chain from one trophic level to the next. Multiple factors besides Hg concentrations in water and sediment can influence the degree of biomagnification in aquatic food webs including dissolved organic carbon, pH, ecosystem productivity, food web species composition, water temperature, and lake and watershed surface area (Lavoie et al. 2013). Fish can exhibit elevated concentrations of Hg in tissues in the absence of changes to external inputs of inorganic Hg (e.g., Hecky et al. 1991; Johnston et al. 1991). The trophic transfer of MeHg can result in predatory fish species and consumers of fish accumulating concentrations of Hg that can be orders of magnitude greater than surface water concentrations (Kidd et al. 2012).

Methylmercury production in aquatic environments has been observed to be positively correlated with temperature, as microbial activity and growth rates generally increase with higher temperatures (Wu et al. 2021; Driscoll et al. 2007). In addition to influencing the activity of methylating microorganisms, warmer water temperatures can promote the release of Hg from sediment and other sources, increasing its availability for methylation (Wright and Hamilton 1982).

In 2012, the Northern Contaminants Program (Canada) published a comprehensive scientific report titled "Canadian Arctic Contaminants Assessment Report III: Mercury in Canada's North", aimed at understanding the current state of science pertaining to Hg in the Canadian Arctic environment (NCP 2012). Various locations in the Canadian Arctic have been surveyed for Hg concentrations in the aquatic environment, including rivers and streams, lakes, wetlands and ponds (NCP 2012). Between 1998 and 2010, mean concentrations of total Hg (THg) (unfiltered water samples) in lakes located in the NWT (e.g., Mackenzie Valley and the Mackenzie Delta), Nunavut (e.g., Cornwallis Island, Devon Island, Somerset Island, Ellesmere Island, Kent Peninsula, and Victoria Island), and Northern Quebec (Nunavik) ranged from 0.5 to 3.2 ng/L (NCP 2012). In contrast, mean concentrations of MeHg (unfiltered) in the same locations (with the exception of Kent Peninsula, Victoria Island, and Nunavik, which were not analyzed for MeHg) ranged from 0.02 to 0.1 ng/L (NCP 2012). The most recent Assessment of Mercury in the Arctic (AMAP) report (2021) indicates that trends in fish tissue Hg concentrations across the global Arctic regions are variable. Key drivers in these long-term studies were regional and habitat-specific environmental conditions as well as indicators of climate change (i.e., ice cover duration, precipitation levels, etc.).

1.3 STUDY AREA

Kodiak Lake is located in the Koala Watershed by the Ekati Diamond Mine (Figure 1.3-1), in proximity to the Ekati Diamond Mine Main Camp. This lake has been monitored by the Ekati Diamond Mine AEMP program since 1994 (including the baseline monitoring years). Since 2012, AEMP Annual Reports results (Rescan 2013, ERM 2019a) have identified potentially mine-related increasing THg trends in large-bodied fish of Kodiak Lake. The AEMP looks at spatial and temporal trends to determine significance in evaluated variables but does not look across endpoints to determine how other measured variables may be correlated with or contributing to increasing Hg bioaccumulation in large-bodied fish.

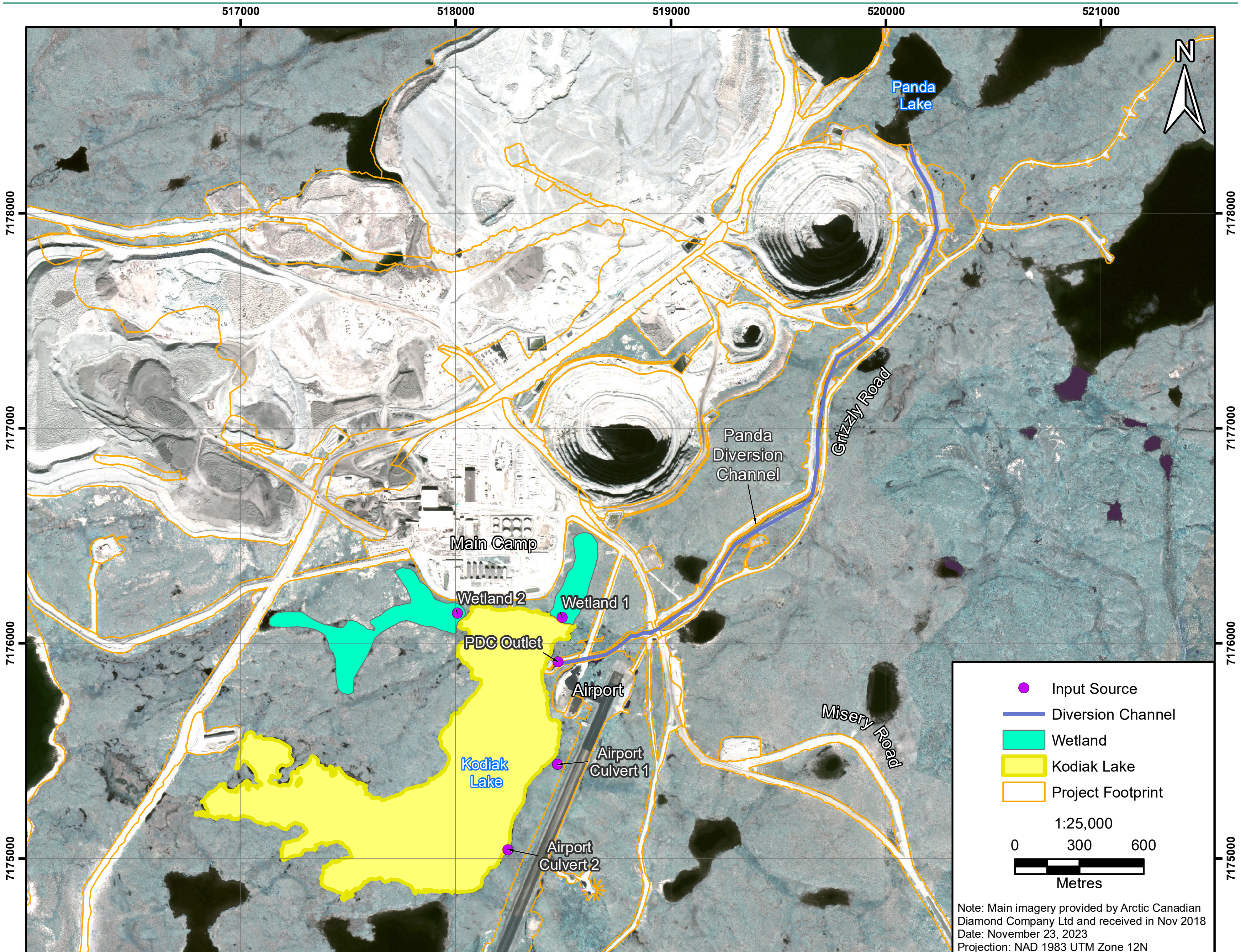


Figure 1.3-1: Main Camp and Kodiak Lake, Ekati Diamond Mine, 2023

Kodiak Lake has an abundance of hydrological inflows; there are wetland areas on the North end of the lake, and constructed culverts that pass under the site airstrip on the east side which drain a large complex of wetlands to the east of the airstrip. There is a constructed channel called the Panda Diversion Channel (PDC) which flows into Kodiak Lake. The PDC was constructed in 1997 as compensation for the loss of stream habitat during the development of the Ekati Diamond Mine. While Kodiak Lake does not receive Mine Discharge, it did accept treated effluent from the camp from 1997 to 1999, and water quality was temporarily impacted by the construction and initial flushing of the PDC (Rescan 2003). However, the influence of these activities appears to have largely dissipated over time (ERM 2019a). Kodiak Lake also is proximate to other potential atmospheric point sources, including the airstrip, which receives several in and out-bound flights per week, and from fuel combustion associated with mining activity (i.e., power generation).

1.3.1 HIGH ACTION LEVEL EXCEEDANCE IN KODIAK LAKE IN 2018

Large-bodied fish (Lake Trout and Round Whitefish) were sampled in 2018 as part of the 2018 AEMP (ERM 2019a). Increasing Hg concentrations in Round Whitefish in monitored lakes in the Koala Watershed (compared to Reference sites) were concluded to be a mine-related effect (i.e., a LAL exceedance), and higher Hg concentrations in Lake Trout in 2018 were concluded to be potentially mine-related (i.e., not a LAL exceedance; ERM 2019a). Following the conclusion of a LAL exceedance for Round Whitefish, the Response Plan for Fish was revised to develop a MAL and HAL for Hg in large-bodied fish. Small-bodied fish are monitored in the AEMP as an indicator species for large-bodied fish and are not evaluated against the MAL and HAL.

Follow the public review of the Response Plan for Fish Version 3.0, the Board detailed in its Reasons for Decision that with six years between large-bodied fish sampling years there may be value in looking back at the most recent data (i.e., 2018) with approved HAL for the concentration of Hg in fish tissue, given that there appears to be a change in Hg concentrations that may be valuable to have more information on. Thus, as part of their approval of Version 3.0 of the Fish Response Plan the Board included a Directive to evaluate the 2018 HAL exceedance for Kodiak Lake and include this in the 2022 AEMP Annual Report (WLWB 2022).

> *"Decision #5: The Board directs Arctic to provide an evaluation of the High AL exceedance for Kodiak Lake in 2018 in the 2022 AEMP Annual Report."*

A memorandum describing the retroactive 2018 HAL exceedance for Hg in Kodiak Lake was submitted to the Board on March 31, 2023. Describing possible causes of higher Hg, as well as next steps associated with the HAL exceedance investigation. The LAL exceedance for Round Whitefish Hg concentrations in 2018 was then evaluated against the new MAL and HAL in the Response Plan for Fish Version 2.0 (ERM 2019b). Mercury muscle tissue concentrations from 2018 were found to exceed the HAL (i.e., 0.23 mg/kg wwt) in Kodiak Lake for Round Whitefish (average 0.325 mg/kg wwt, ERM 2022a). The concentration of Hg in Lake Trout muscle tissue was also higher than the site-specific consumption guideline (i.e., 0.26 mg/kg wwt) at a mean of 0.518 mg/kg wwt; however, because it did not originally trigger a LAL exceedance in the 2018 AEMP, it was not concluded to have an AL exceedance under the new Response Plan for Fish.

Possible causes identified in the response plan included long-range transport, terrestrial sources such as fluctuations in water levels, permafrost thaw, wildfires, and changes in limnology in Kodiak which influence methylation processes. Arctic Canadian committed to advancing an investigation to gain a better understanding of the cause of the HAL exceedance prior to the next large-bodied sampling program in 2024.

This report advances two investigations per the memorandum, and is presented in two sections:

- A review and statistical analysis of historical data sets available from the Ekati Diamond Mine was conducted to examine spatial and temporal trends in the data. Correlations to fish tissue Hg concentrations were also made.
- A report on THg and MeHg concentrations in Kodiak Lake water and sediments using ultra-trace sampling techniques, as well as on the sources of water flowing into Kodiak Lake, and a comparison of these findings to those of Reference lakes and their watersheds at the Ekati Diamond Mine.

2. DESKTOP ANALYSIS OF EXISTING MONITORING DATA

2.1 OBJECTIVES

As discussed in Section 1.2, many environmental variables have the potential to influence Hg bioavailability and concentrations in freshwater fish. To further understand how the Hg concentrations in large-bodied fish at Kodiak Lake may be responding to natural and anthropogenic environmental conditions, a correlational analysis was used to examine the potential covariation of aquatic, atmospheric, and landscape-level environmental variables, with the Hg concentrations of fish since the start of the baseline period through to 2018.

2.2 METHODS

2.2.1 DATA SOURCES

Historical Hg data from the AEMP and Air Quality Monitoring Program (AQMP) at the Ekati Diamond Mine have been used to support a statistical model for understanding the changes in Hg levels in Kodiak Lake (Table 2.2-1). Additional, supplementary Reference site data is included from sampling Nanuq Lake in 2008 from a follow-up Special Study investigating unusual observations of elevated hydrocarbons in fish bile and parasite prevalence (Rescan 2008), and Northeast Lake in 2017 which was included in the Sable Comprehensive Aquatic Baseline Report as an Appendix to the 2018 AEMP Data Report (ERM 2019c).

2.2.1.1 AQUATICS DATA

Data collection for the AEMP program at Ekati Diamond Mine began in 1994. Water, sediment, and biotic data were obtained from the information presented in the AEMP annual reports (Table 2.2-2). Relevant methods of sample collection are available in the AEMP Design Plan Version 8.1 (ERM 2023b).

Additional variables were generated for use in the 2022 AEMP Re-evaluation report specifically for this analysis as follows. The relative thermal resistance to mixing (referred to here as stratification strength) was used to approximate the strength of thermal stratification in the water column of lakes and was calculated according to Welch and Jacoby (2004). Stratification of the water column creates an oxygenated upper water layer (epilimnion) and de-oxygenated lower water layer (hypolimnion).

2.2.1.2 TERRESTRIAL DATA

Data collection for the AQMP program at Ekati Diamond Mine began in 1998. Measurements of the concentrations of Hg in dustfall, snow, terrestrial soils, and lichen were obtained from the data presented in the AQMP annual reports. Detailed field sampling and laboratory analysis methodologies are provided in Lichen Monitoring at the Ekati Diamond Mine, NWT: 2014 Re-Measurement (Enns 2015). Samples selected for this investigation were designated as being representative of conditions near a study lake if they were <1000 m from the perimeter of the lake; this allowed for sampling sites to easily correspond to a lake of interest. These sites are reflective of previous AQMP monitoring sites and contain a mixture of dustfall, lichen, snow core chemistry and soil (Figure 2.2-1).

TABLE 2.2-1 HISTORICAL DATA SOURCES REVIEWED IN THIS REPORT

Program	Historical Data Sources	Used in Multiple Correlation Analysis*	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
AEMP	Large Bodied Fish Mercury	Y			x[1]		x					x					x	x[2]				x					x[3]	x
	Water Quality	Y		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Sediment Quality	Y		x			x	x	x	x	x	x		x	x		x	x	x	x	x			x		x	x	
AQMP	Dust Fall	N																x	x	x	x			x			x	
	Snow Chemistry	N													x			x						x			x	
	Lichen	Y													x			x			x			x			x	
	Soil	N																						x			x	

Notes:

Highlighted rows indicate years included in the correlational analyses.

[1] Round Whitefish collected in 1995 only.

[2] Samples collected in 2008 were from Nanuq Lake only (Rescan 2008).

[3] Samples collected in 2017 were from Northeast Lake only (ERM 2019c).

TABLE 2.2-2 RATIONALE FOR VARIABLES EVALUATED IN THIS STUDY

Evaluated Variables	Source	Rationale
Fish age	AEMP	Older fish tend to have higher Hg concentrations
Secchi Depth	AEMP	Depth of light extinction/de-oxygenated zone
Dissolved Oxygen (DO)	AEMP	SRB require anoxic conditions
Oxygen saturation	AEMP	SRB require anoxic conditions
Turbidity	AEMP	Indicator of degree of light penetration/ productivity/total dissolved solids
pH	AEMP	Acidic conditions favoured by SRB
Conductivity	AEMP	Indicator of watershed influence on water quality
Total Kjeldahl Nitrogen	AEMP	Indicator of primary productivity
Water total organic carbon	AEMP	Indicator of watershed influence on water quality
Maximum lake depth	AEMP	Deeper lakes tend to have anoxic zones
Stratification depth	AEMP	Indicates the size of the de-oxygenated zone
Relative Thermal Resistance to Mixing	AEMP Re-evaluation	Indicator of strength of stratification
Chlorophyll *a*	AEMP	Primary productivity
Sulphate	AEMP	Required substrate for SRB
Mercury in sediment	AEMP	Sediment is main reservoir of SRB
Selenium in sediment	AEMP	Selenium can be protective of Hg accumulation in fish
Sediment total organic carbon	AEMP	SRB require organic matter for food
Lichen mercury concentration	AQMP	Indicator of atmospheric and terrestrial Hg contributions
Snow chemistry	AQMP	Indicator of wet deposition of mercury during winter
Soil chemistry	AQMP	Indicator of terrestrial Hg contributions
Dustfall chemistry	AQMP	Indicator of atmospheric particulate deposition of Hg
Drainage area size	Calculated	Indicator of relative influence of watershed on lake water quality

Note:

AEMP = Aquatic Effects Monitoring Program

AQMP = Air Quality Monitoring Program

SRB = sulphate-reducing bacteria

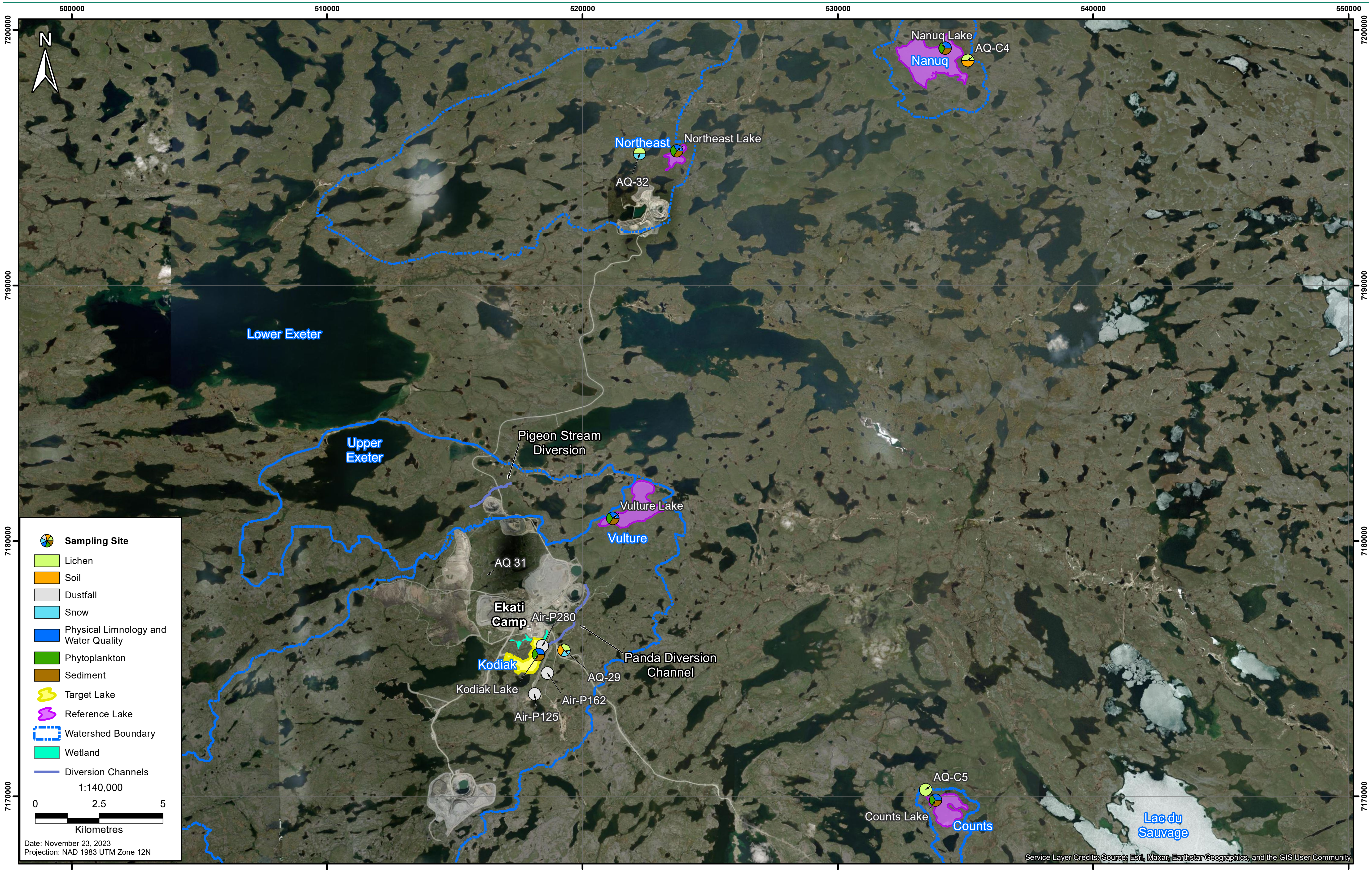


Figure 2.2-1: AEMP and AQMP Sampling Locations used for the Desktop Historical Data Analysis, Ekati Diamond Mine, 2023

Lichens can be used as indicators of all possible terrestrial Hg sources as they integrate airborne contributions, and soil concentrations. They concentrate a variety of pollutants in their tissues which will decrease or increase proportionally with ambient air emissions (Olmes et al.1985; Seaward 1992b, 1992a; Carvalho and Freitas 2011; Enns 2015). Snow chemistry monitors air constituents such as total suspended solids nitrates, sulphates, ammonia, chromium and other analytes. Measurements of Hg in snow samples gives an indication of the amount of wet deposition of Hg during the period of which the snow accumulates.

The Ekati site has been studied extensively during exploration, development and operations, resulting in a large accumulation of spatial data. To support the Hg study, watershed boundaries that had been developed for other purposes, were assessed for inconsistencies and incorporated into this work. New watershed delineations and partitioning of existing watersheds to represent identified sub-drainage areas were done based on a 1 metre resolution digital elevation model (DEM) that was sourced from light detection and ranging (LiDAR) data acquired in 2013. The data was imported in ArcGIS 10.8.2 where it was processed to produce flow direction and flow accumulation grids, which were then used to create a raster of classified drainage groups that were converted to vector polygons and appropriate polygons merged.

2.2.2 DATA ANALYSIS

To address variability in the average size of Lake Trout and Round Whitefish sampled across different lakes, where larger fish tend to have higher Hg muscle concentrations, Hg concentrations in fish were adjusted for the median size of fish in each lake in each sampling year to remove population level artifacts from the analysis. To generate the size-adjusted Hg concentrations, we used an analysis of covariance (ANCOVA) with log10-transformed Hg concentration as the dependent variable, $\log_{10}$-transformed fork length (mm) as the continuous covariate and a lake by year interaction term to generate estimates for each lake in each year separately. Median fork lengths were calculated across the entire dataset for each fish species (438 mm for Lake Trout and 371 mm for Round Whitefish). These median lengths were used to calculate the concentration of Hg in each fish if it were the median length. This was accomplished by calculating the least-squares regression for each fish species x lake x sampling year and using the residuals of the Hg concentration from each fish to estimate of the Hg concentration for a fish of that length in each lake and year combination. Discussion of mercury concentrations in fish in the text will refer to the uncorrected Hg concentrations, unless otherwise specified, with the intention of reporting on the real measured mercury concentrations in fish as these are relevant to the comparison to benchmarks. The size-corrected Hg concentrations are presented in most figures, as indicated by axis labels. The intention of the figures is to objectively visualize the statistical behaviour of the data.

Water quality measurements were standardized to a mean of zero and variance of one (i.e., z-scores) prior to correlation analysis. Water quality, sediment quality, physical lake parameters, lichen Hg concentrations, and the concentration of Hg in fish tissue were tested for pairwise correlations using Pearson correlation, and all available pairwise data. However, the reader should be cautious to avoid interpreting correlations as being representative of causative agents of Hg concentrations observed in fish. Data included in the analysis centered on the years when large-bodied fish were collected; however, if matching data from other components was not available from the same year, the data from the year previous was used in the analysis (see Table 2.2-1). This step was necessary for the inclusion of sediment quality data for 2012 and 2018 large-bodied sampling programs, and to increase the sample size and thus, the confidence in the analysis. All statistical analysis was conducted in R (R Core Version 4.3.1; R Core Team 2023).

Sampling programs collecting data that could be used to examine potential Hg inputs from atmospheric or terrestrial sources (AQMP, lichen, snow and soil) began in 2005, whereas large-bodied fish sampling began in 1997. This limited the timescale over which the data could be used for correlations, only one year of terrestrial data overlapped with a large-bodied fish program. The majority (Table 2.2-3) of terrestrial/air quality data collected was found to have Hg concentrations below the detection limits (DLs) which largely prevented correlational analysis. Lichen Hg concentrations were included in the correlational analysis; however, remaining data sets were assessed separately through graphical analysis. R^2 values of >0.50 were considered to be a “good” correlation, 0.30 to 0.50 were considered to be a “fair” correlation, and >0.30 was considered to be “low” correlation in this analysis.

TABLE 2.2-3 SAMPLES WITH MERCURY CONCENTRATIONS MEASURING BELOW DETECTION LIMITS FROM AQMP HISTORICAL DATA SETS

Data Set	2005	2008	2009	2010	2011	2014	2015	2016	2017
Dustfall	-	3/3 (100%)	9/9 (100%)	9/9 (100%)	9/9 (100%)	3/3 (100%)	2/3 (66.7%)	9/9 (100%)	9/9 (100%)
Snow	4/4 (100%)	5/5 (100%)	-	-	-	5/5 (100%)	-	-	3/5 (60%)
Lichen	0/21 (0%)	0/35 (0%)	-	-	0/39 (0%)	0/37 (0%)	-	-	0/26 (0%)
Soil	-	-	-	-	-	2/4 (50%)	-	-	1/2 (50%)

Notes: Data indicates (number of samples having data below the Hg detection limits / total number of Hg samples) and (percent of Hg samples below the detection limits).

Dashes (-) indicate data not collected

2.3 RESULTS AND DISCUSSION

As presented in the 2018 AEMP, the concentrations of Hg in muscle tissue of Lake Trout and Round Whitefish were higher in Kodiak Lake than were observed in the Reference Lakes, concluding that there were mine-related effects observed on the Hg in Round Whitefish tissue. However, no likely or plausible source could be identified. Mercury concentrations increased in Round Whitefish muscle tissues from Kodiak Lake between 1994 and 2018 (ERM 2019a). Lake Trout showed increased Hg in muscle tissue from Kodiak Lake over time, and a potentially mine-related effect was identified (ERM 2019a). Lake Trout in Kodiak Lake in general were larger than the average size of fish in Reference Lakes, while Round Whitefish were slightly smaller (Figure 2.3-1). In Kodiak Lake, the Lake Trout were on average 463 ± 98 mm (mean ± Standard Deviation), and Round Whitefish were on average 363 ± 102 mm, compared to average size in all Reference Lakes of 430 ± 108 mm and 383 ± 107 mm for Lake Trout and Round Whitefish, respectively. Size-adjusted Hg concentrations in fish were used for all analyses to correct for larger fish tending to have higher Hg concentrations, allowing the analysis to focus on correlations with environmental variables.

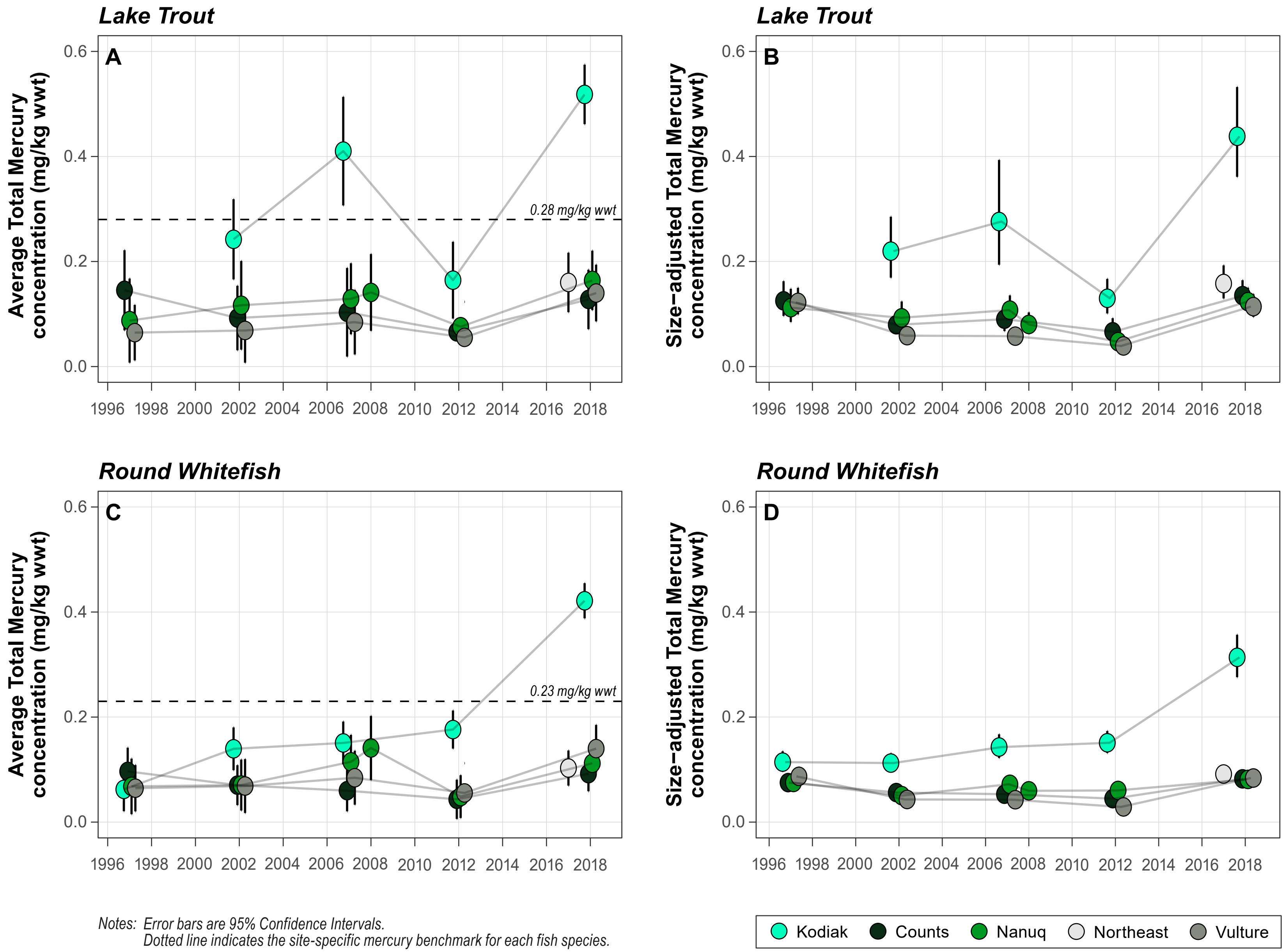


Figure 2.3-1: Total Mercury Concentrations in Large-Bodied Fish, Ekati Diamond Mine, 1997 to 2018

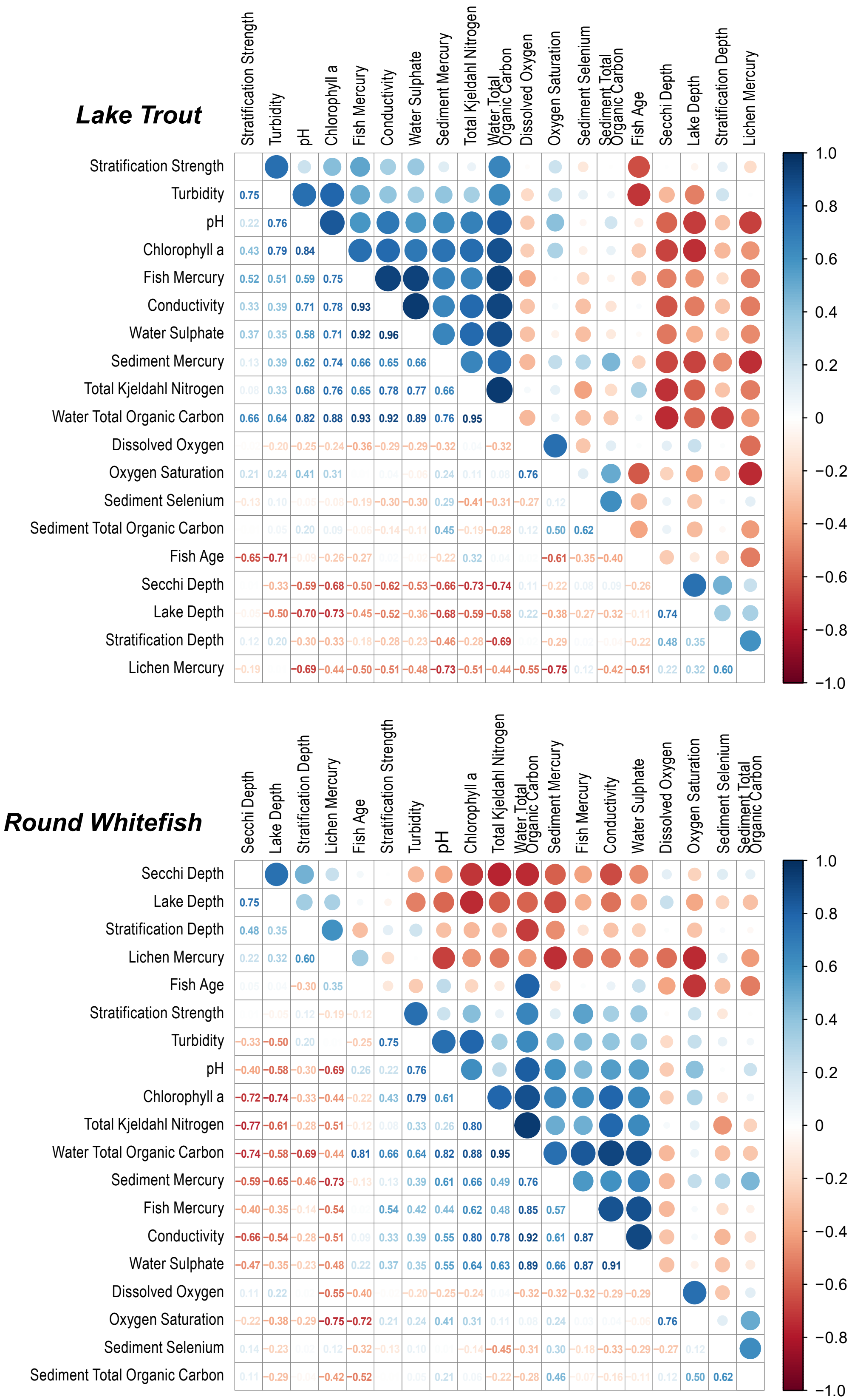
Correlation matrices for Lake Trout and Round Whitefish provided similar results, where the strongest correlations to environmental variables were largely identical, with the strength of the correlations generally being stronger for Lake Trout than for Round Whitefish (Figure 2.3-2). Lake Trout tend to feed at a higher trophic position than Round Whitefish (Scott and Crossman 1973), and thus accumulate more Hg in their muscle than Round Whitefish (Scott and Crossman 1973; Figure 2.3-1). Lake Trout are known to consume small fish, likely including Round Whitefish juveniles, which aligns with the expectation that Hg concentrations would be increased at higher trophic level. The patterns of correlations with environmental variables are largely similar for these two fish species, therefore this Section focuses on Hg accumulation patterns in large-bodied fish as a whole. Differences between fish species will be discussed where relevant.

The size-adjusted Hg in fish tissues showed strong correlations to many of the environmental variables examined, including THg in sediment, and to water quality variables including total organic carbon (TOC), conductivity, sulphate, pH, total Kjeldahl nitrogen (TKN) and chlorophyll *a*. There was good correlation between size-adjusted Hg concentrations in fish and the THg concentration in sediment (r=0.66 for Lake Trout, and r=0.57 for Round Whitefish). Size-adjusted Hg in fish muscle was correlated with the total organic carbon (TOC) content of lake water (r=0.93 for Lake Trout, and r=0.85 for Round Whitefish), conductivity (r=0.93 for Lake Trout, and r=0.87 for Round Whitefish), sulphate (r=0.92 for Lake Trout, and r=0.87 for Round Whitefish), and pH (r=0.59 for Lake Trout, and r=0.44 for Round Whitefish). Mercury in fish muscle was also correlated with total Kjeldahl nitrogen (TKN) (r=0.65 for Lake Trout, and r=0.48 for Round Whitefish) and chlorophyll *a* (r=0.75 for Lake Trout, and r=0.62 for Round Whitefish).

Influence of Watershed-sourced Environmental Variables on Mercury Concentrations in Fish

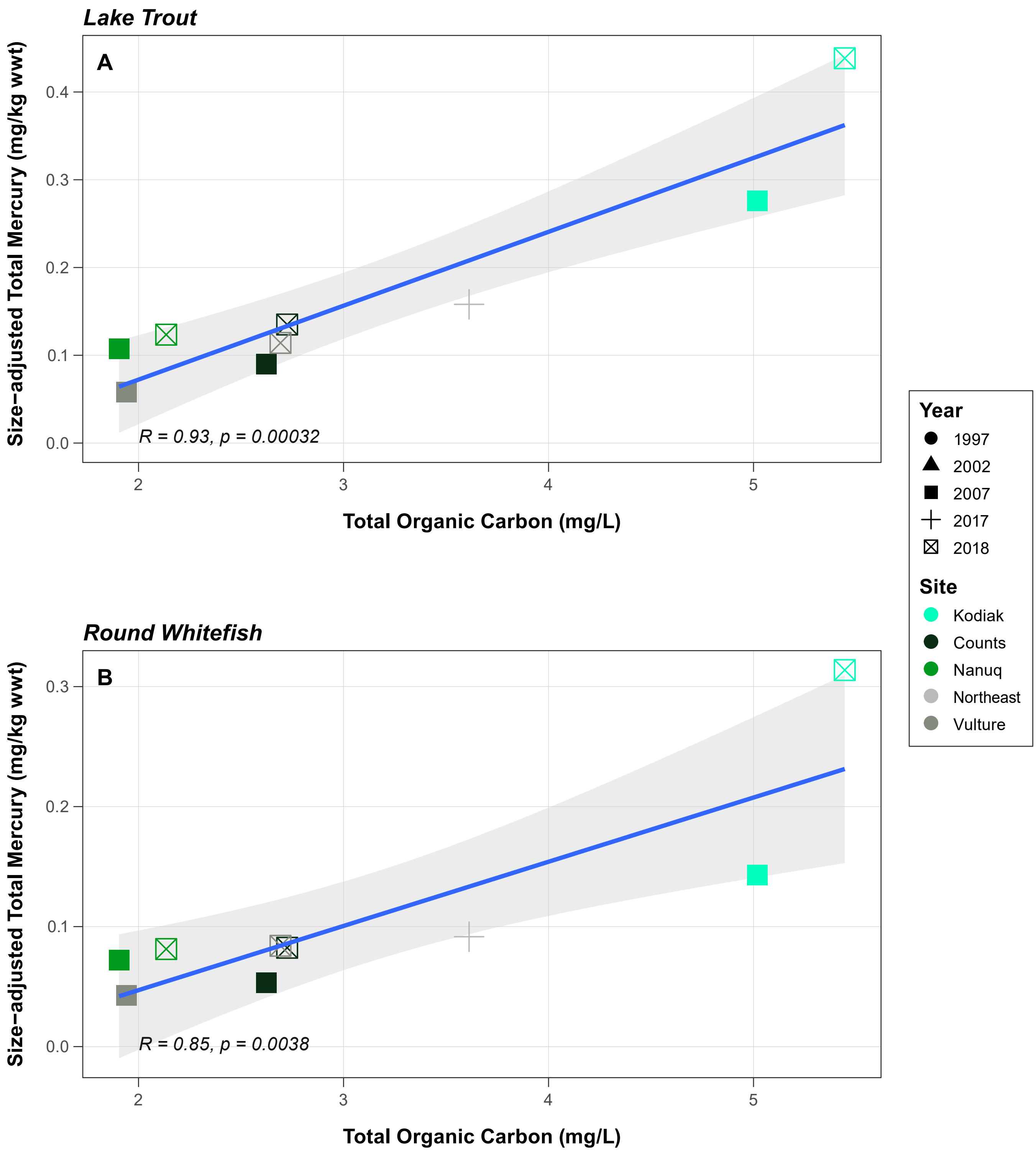
Strong correlations of environmental variables with fish tissue Hg concentrations in this study appear to be indications of wetland and watershed influence in lakes (Figure 2.3-2). Total organic carbon content (Figure 2.3-3) and sulphate (Figure 2.3-4) concentrations in lake water tend to be associated with the degree of watershed influence (Gergel et al. 1999), and these in turn can drive differences in conductivity (Figure 2.3-5) and pH (Figure 2.3-6) in lake water.

Higher measured values of conductivity in lakes can be driven by sulphate concentrations and has been suggested as a means of monitoring the activity of SRB (Lyew and Sheppard 2001). Sulphate metabolism in lakes occurs through SRB, and this tends to produce alkalinity which also neutralizes the pH of the system. Natural sulphate sources to freshwater ecosystems include natural weathering of bedrock and wetlands (Wiener et al. 2006), which increase with the degree of influence of lakes' watershed. Sulphate-reducing bacteria are also thought to be the main methylators of Hg in freshwater systems, and increasing sulphate concentrations in lakes, up to a point, will result in larger communities of SRB in the system (Branfireun et al. 1999; Gilmour et al. 1992).



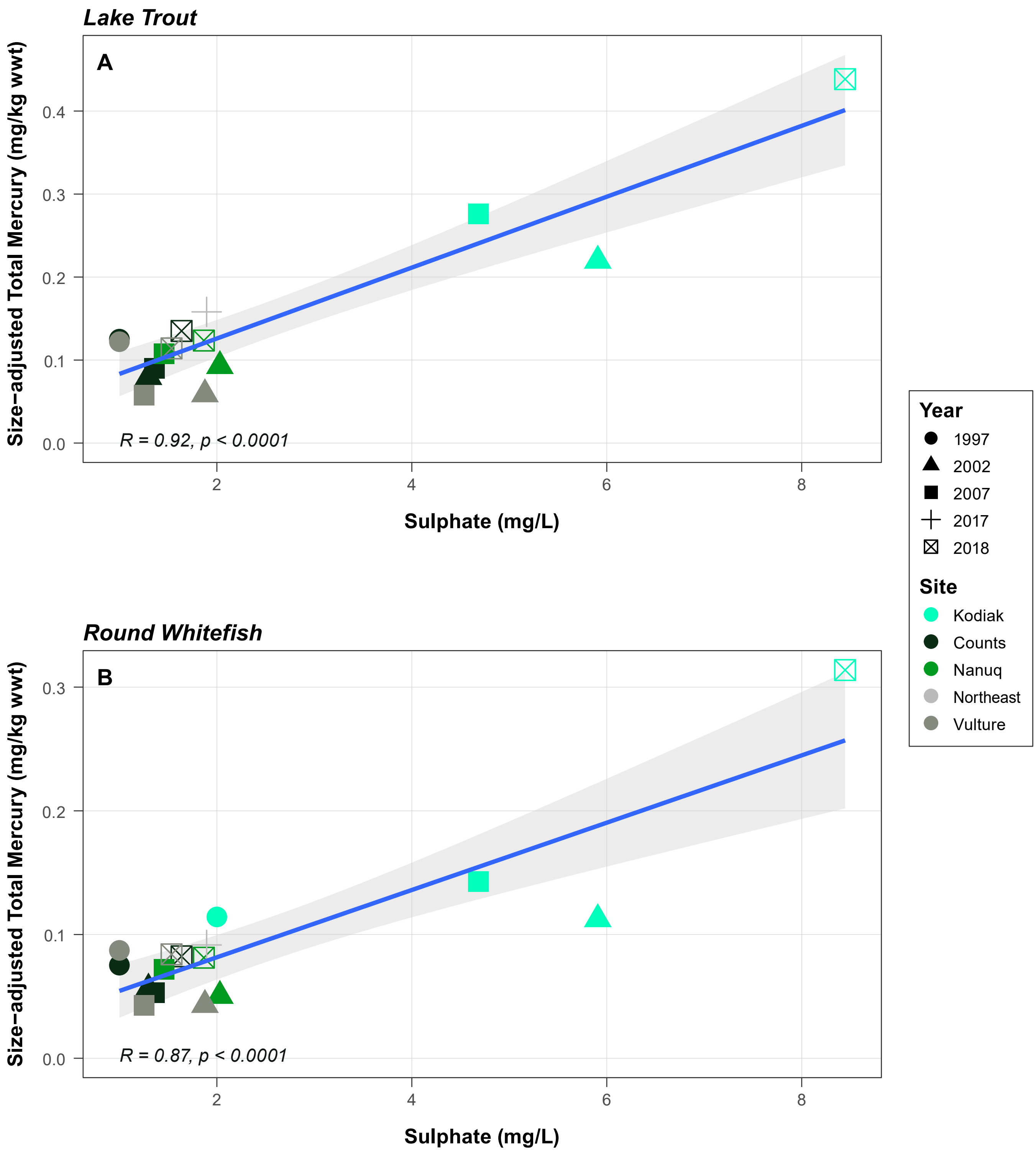
Notes: Colour of dots and values is referring to a positive (blue) or negative (red) correlation to each variable. The size of the dot is proportional to the strength of the correlation, Large is closer to +/-1, while small is closer to 0.

Figure 2.3-2: Correlation of Total Mercury Concentrations in Large-bodied Fish with Environmental Variables, 1994 to 2018



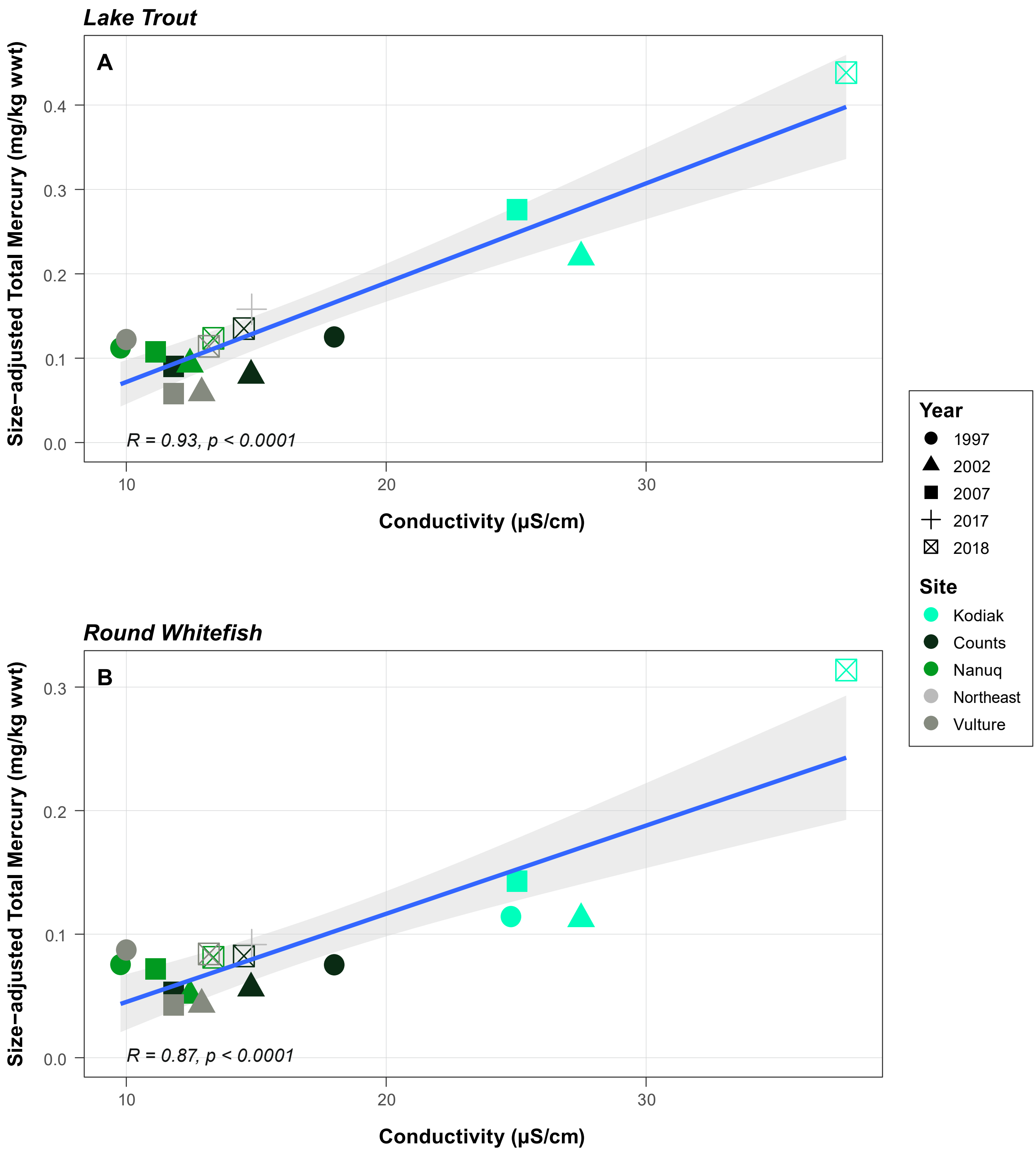
Note: Grey band represents the 95% Confidence Interval of the estimate.

Figure 2.3-3: Correlation of Total Organic Carbon of Lake Water in Lake Water with Mercury Concentrations in Large-bodied Fish



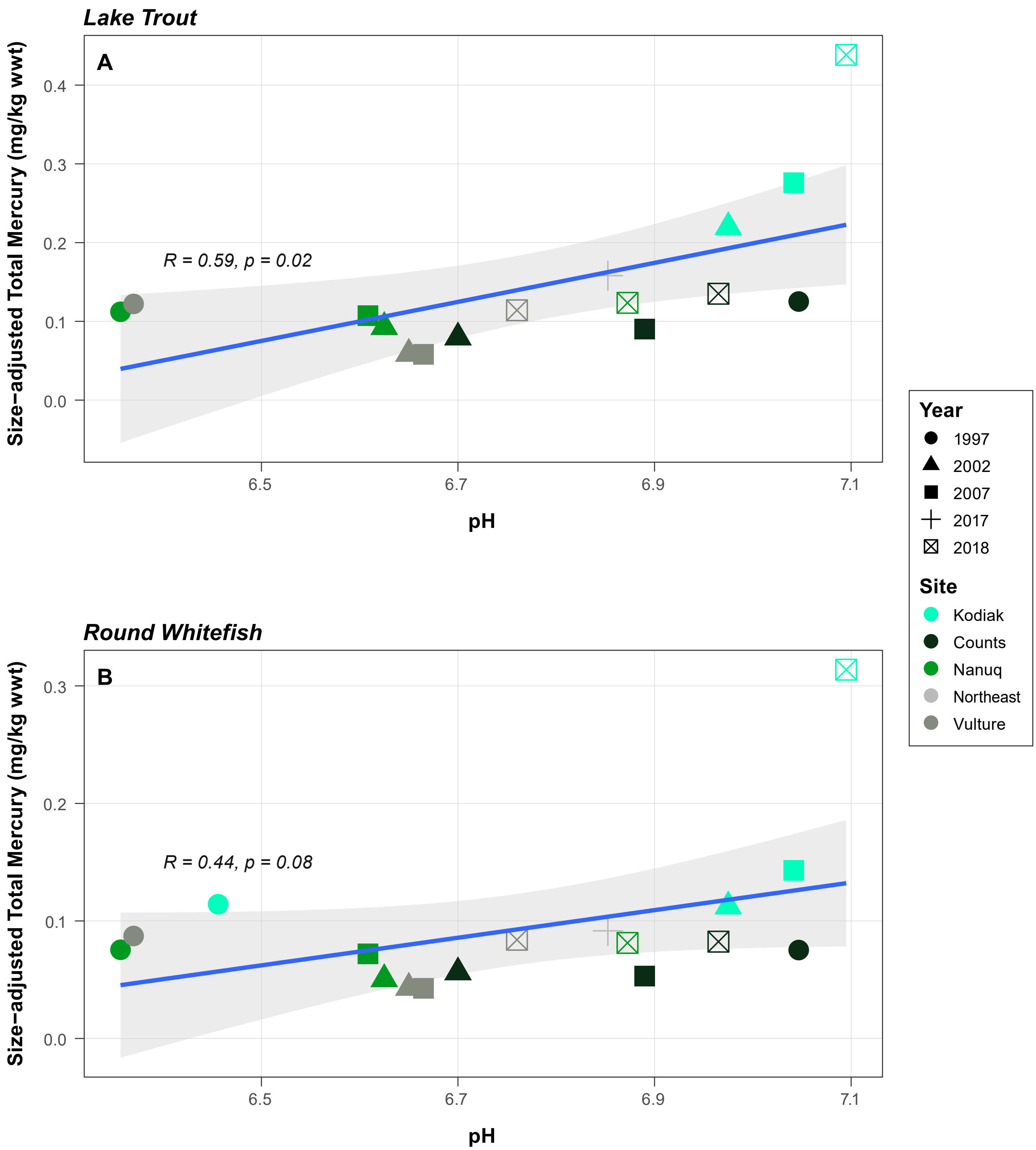
Note: Grey band represents the 95% Confidence Interval of the estimate.

Figure 2.3-4: Correlation of Sulphate Concentrations of Lake Water with Mercury Concentrations in Large-bodied Fish



Note: Grey band represents the 95% Confidence Interval of the estimate.

Figure 2.3-5: Correlation of Conductivity of Lake Water with Mercury Concentrations in Large-bodied Fish



Note: Grey band represents the 95% Confidence Interval of the estimate.

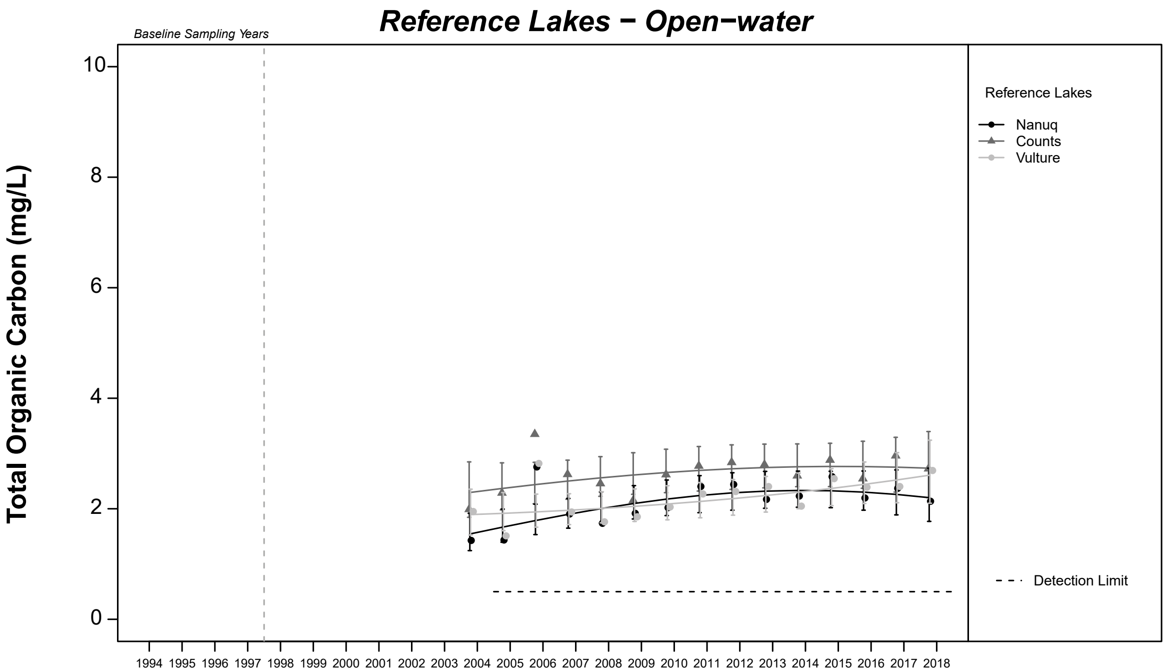
Figure 2.3-6: Correlation of pH of Lake Water with Mercury Concentrations in Large-bodied Fish

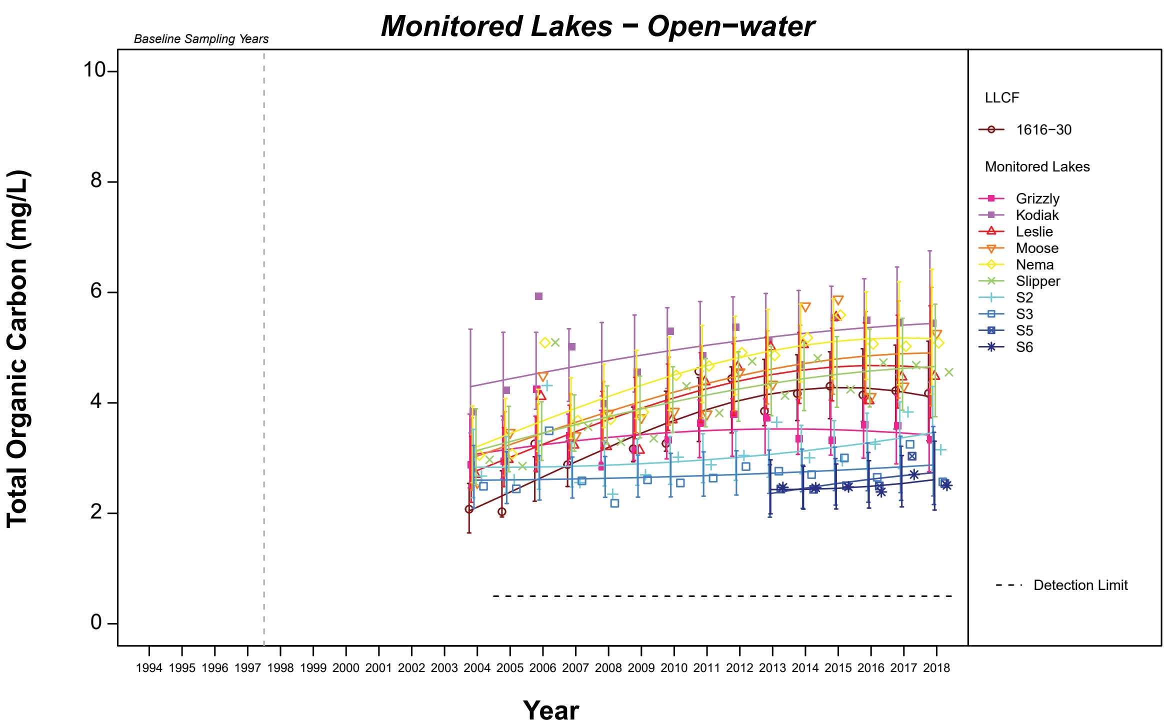
Optimal concentrations for methylation have been reported to range from 1 to 30 mg/L of sulphate (Gilmour et al. 1992; Benoit et al. 1998), where sulphate concentrations in Kodiak Lake vary between 2 to 8 mg/L (Figure 2.3-4). Reference Lakes all had sulphate concentrations below 2 mg/L, which is at the low end of what is considered the optimal concentration range.

Total organic carbon in water samples has consistently been highest in Kodiak Lake, compared to all other monitored lakes in the Koala Watershed (Figure 2.3-7). Total organic carbon, and in particular, the dissolved organic carbon (DOC) component is strongly correlated with the degree of watershed influence on lakes (Gergel et al. 1999). Terrestrially sourced DOC enters the lake through precipitation, leaching, and decomposition. Productive wetlands are also a major source of DOC to lakes (Kowalczewski et al. 1978). Dissolved organic carbon is a component of the TOC measurement, which also includes particulate organic carbon.

Dissolved organic carbon plays several key roles in Hg methylation in freshwater ecosystems. It is a substrate for methylating bacteria (i.e., SRB), a transport system for inorganic Hg and MeHg from outside of the system, and also limits light penetration by colouring the water (reviewed by Ravichandran 2004). The TOC content of water from lakes in this study was itself highly correlated with Secchi depth, chlorophyll *a*, and stratification depth, indicating the presence of a stronger and shallower thermocline in study lakes. Thermoclines in lakes are a zone of rapidly changing temperature. The differences in density limit mixing between the upper, warmer, well-oxygenated water and the colder, less oxygenated bottom waters. In lakes with high suspended solids or TOC, the Thermocline is closely linked to the depth of light penetration, below which, photosynthesis is no longer possible, and the oxygen concentration diminishes, creating the anerobic conditions favorable for SRB. A shallower thermocline in a lake can be indicative of a larger de-oxygenated zone capable of supporting a larger community of SRB. Given that Methylmercury can be photo-degraded, reduced light penetration will result in less demethylation (Garcia et al. 2005).

Watershed level influences (via the above measured indicators) on study lakes appear to be increasing over time, possibly as a landscape-level response to climate change. This would be expected to increase the transport of Hg (Klaminder et al. 2008), DOM and nutrients from watersheds to Arctic Lakes, as Permafrost is a reservoir of Hg and TOC. Warmer temperatures will increase the Hg methylation rates in Arctic environments (Hudelson et al. 2020). Further discussion of the above is in Section 1.2. Kodiak Lake has, by far, the largest drainage area compared to the surface area of the lake itself (Table 2.3-1) when compared to other AEMP Reference Lakes. Excluding the influence of the PDC, the drainage area of Kodiak Lake is nearly 10 times the overall size of the lake. The PDC drains directly to Kodiak Lake and the inclusion of the PDC headwaters drainage area increases the relative drainage area to approximately 25 times the lake surface area. The Reference Lakes comparatively all have much smaller relative drainage areas to lake surface area, ranging from approximately three to five times the drainage area to individual lake surface area (Table 2.3-1).





Notes: Symbols represent observed mean values. Solid lines represent fitted curves.
Error bars indicate the upper and lower 95% confidence intervals of the modelled concentrations.

Figure 2.3-7: Open-water Total Organic Carbon Observed data and Fitted Means for Koala Watershed, Lac de Gras, and References Lakes, 1994 to 2018

TABLE 2.3-1 RELATIVE INFLUENCE OF WATERSHED SIZE TO LAKE AREA

Lake	Lake Surface Area (Hectares)	Lake Drainage Area (Hectares)	Relative Watershed Influence*
Kodiak	90.67	874.30	9.64
Kodiak including PDC headwaters	90.67	2,314.41	25.53
Counts	116.22	456.56	3.93
Nanuq	309.63	1,554.71	5.02
Northeast	35.22	102.09	2.90
Vulture	176.00	488.98	2.78

Notes: PDC = Panda Diversion Channel

*Larger numbers indicate greater drainage surface area for the relative surface area of the lake.

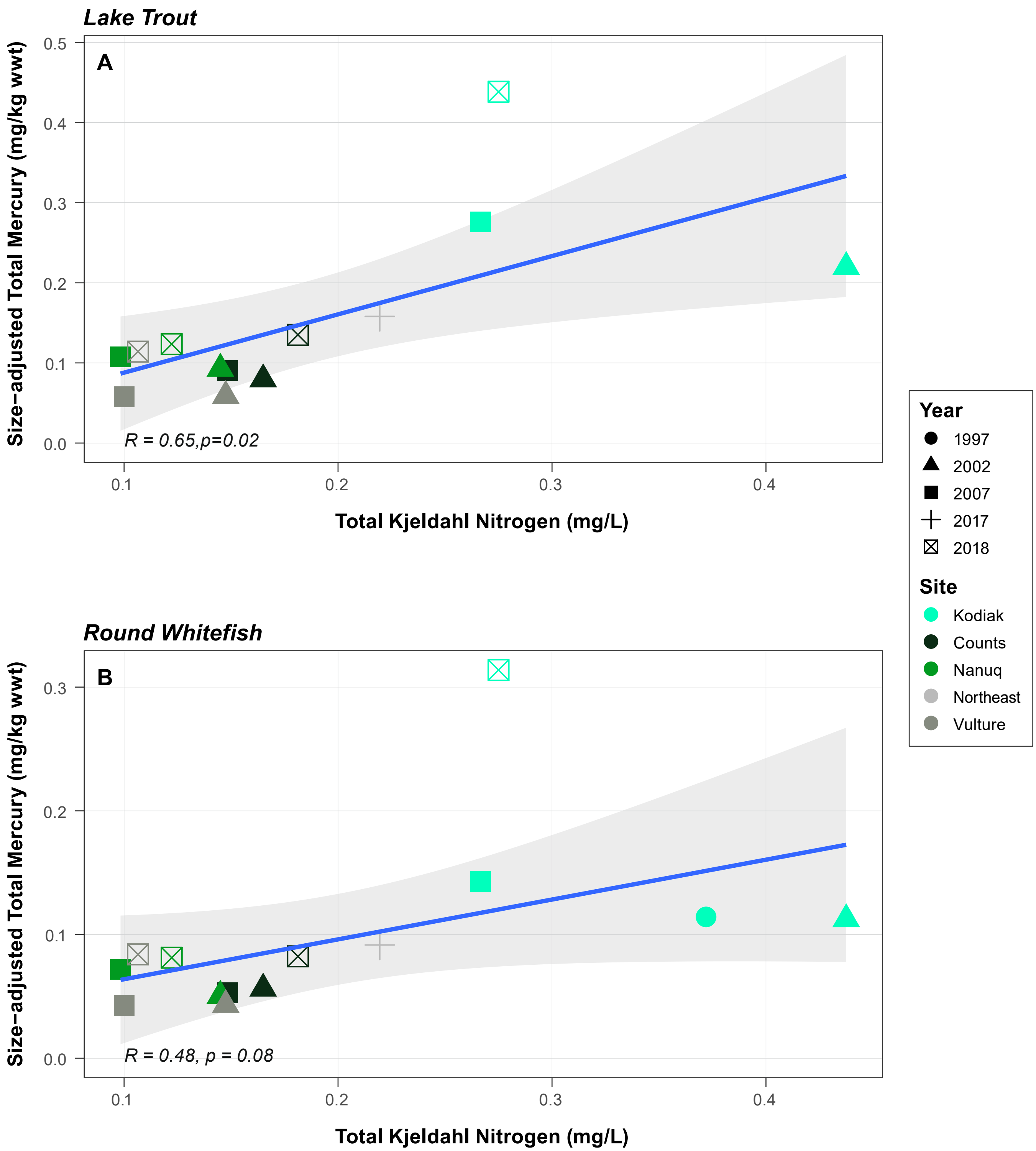
Influence of Nutrients and Productivity on Mercury Concentrations in Fish

The concentration of Hg in fish tissues was also well-correlated with nutrient concentrations and measures of primary productivity in the lakes (Figures 2.3-8 and 2.3-9). The addition of nutrients to aquatic systems generally has the effect of increasing the productivity of the system, when nutrients in that system are in limited supply. Nitrate is an important nutrient in the growth of SRB (Compeau and Bartha 1985; Schaefer et al. 2011). Thus, Increasing the nitrogen content can enhance the activity of SRB, thereby increasing the production of MeHg.

Increasing primary productivity in the system can reduce light penetration in the water column, which can affect water temperature and stratification but also has the potential reduce the amount of solar radiation, which drives abiotic demethylation processes. Additionally, primary productivity can result in increased decomposition of senesced algal growth, increasing biological oxygen demand, influencing the size of the de-oxygenated zone in seasonally or permanently stratified waterbodies.

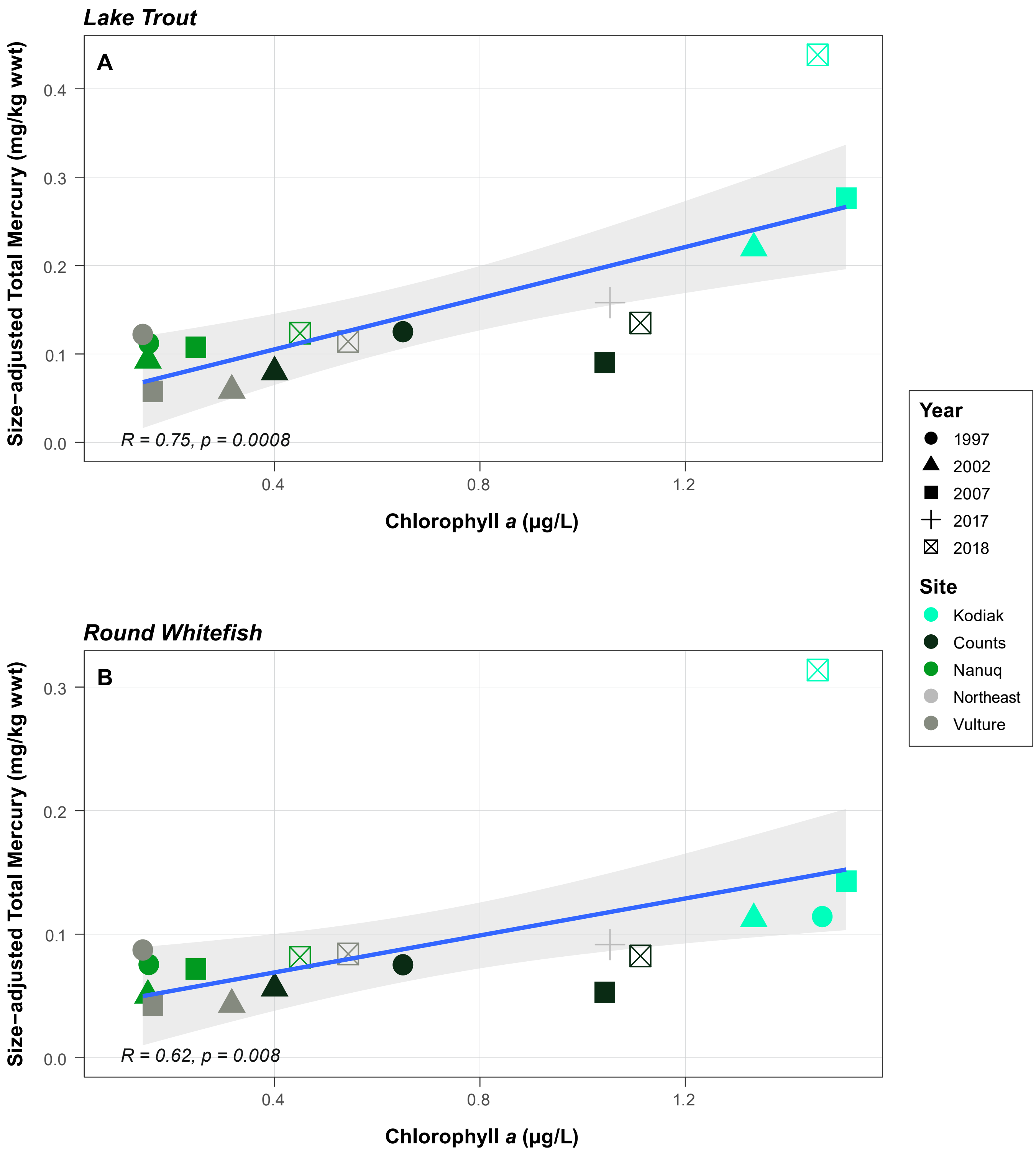
Implications of Diet Shifts in Large-Bodied Fish

With increases in primary productivity of phytoplankton, there is often a concomitant increase in the abundance of zooplankton, which consume the phytoplankton, as has been observed in Kodiak Lake (Figure 2.3-10, ERM 2019a). With increasing abundance of zooplankton, Round Whitefish in Kodiak Lake could also consume more zooplankton (Figure 2.3-11, ERM 2019a). Zooplankton tend to accumulate Hg to a greater extent than benthic invertebrates and can be an important source of Hg to for fish in sub-Arctic lakes than benthic invertebrates (Power et al. 2002), an increase of zooplankton in the diet, of is a potential contributing actor to increasing Hg in fish in Kodiak Lake. The diet of Lake Trout is not routinely studied at the Ekati Diamond Mine, as the AEMP uses a non-lethal sampling program to maintain the smaller populations of these predatory fish. Lake Trout are mainly piscivorous fish, although they will also consume zooplankton and benthic invertebrates, particularly in juvenile stages (Scott and Crossman 1973). In lakes surrounding Ekati, Lake Trout occupy the top position in the foodweb, and thus would be expected to have the most Hg exposure through dietary influence.



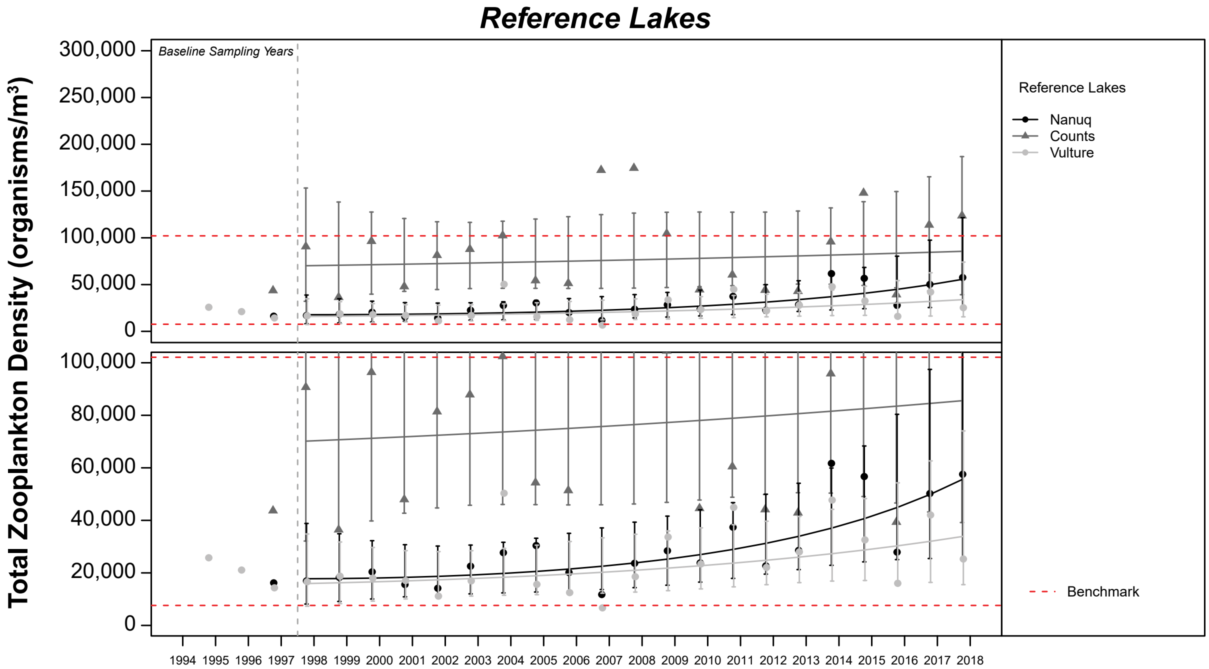
Note: Grey band represents the 95% Confidence Interval of the estimate.

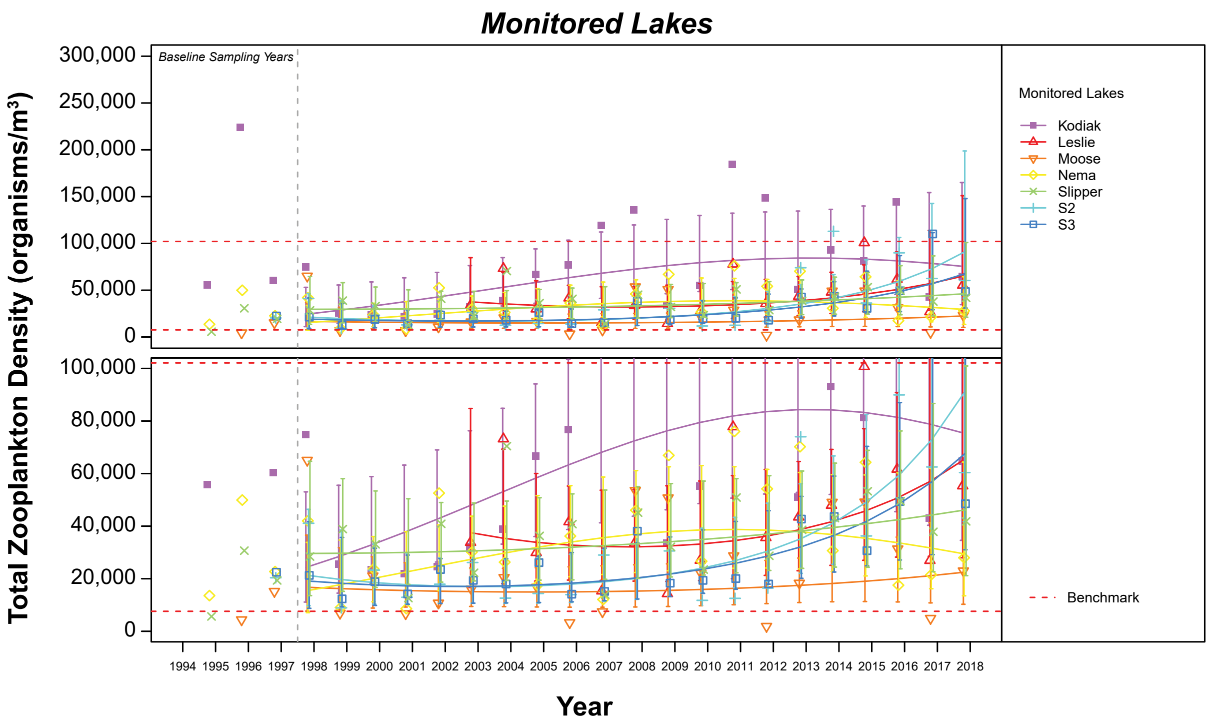
Figure 2.3-8: Correlation of Total Kjeldahl Nitrogen in Lake Water with Mercury Concentrations in Large-bodied Fish



Note: Grey band represents the 95% Confidence Interval of the estimate.

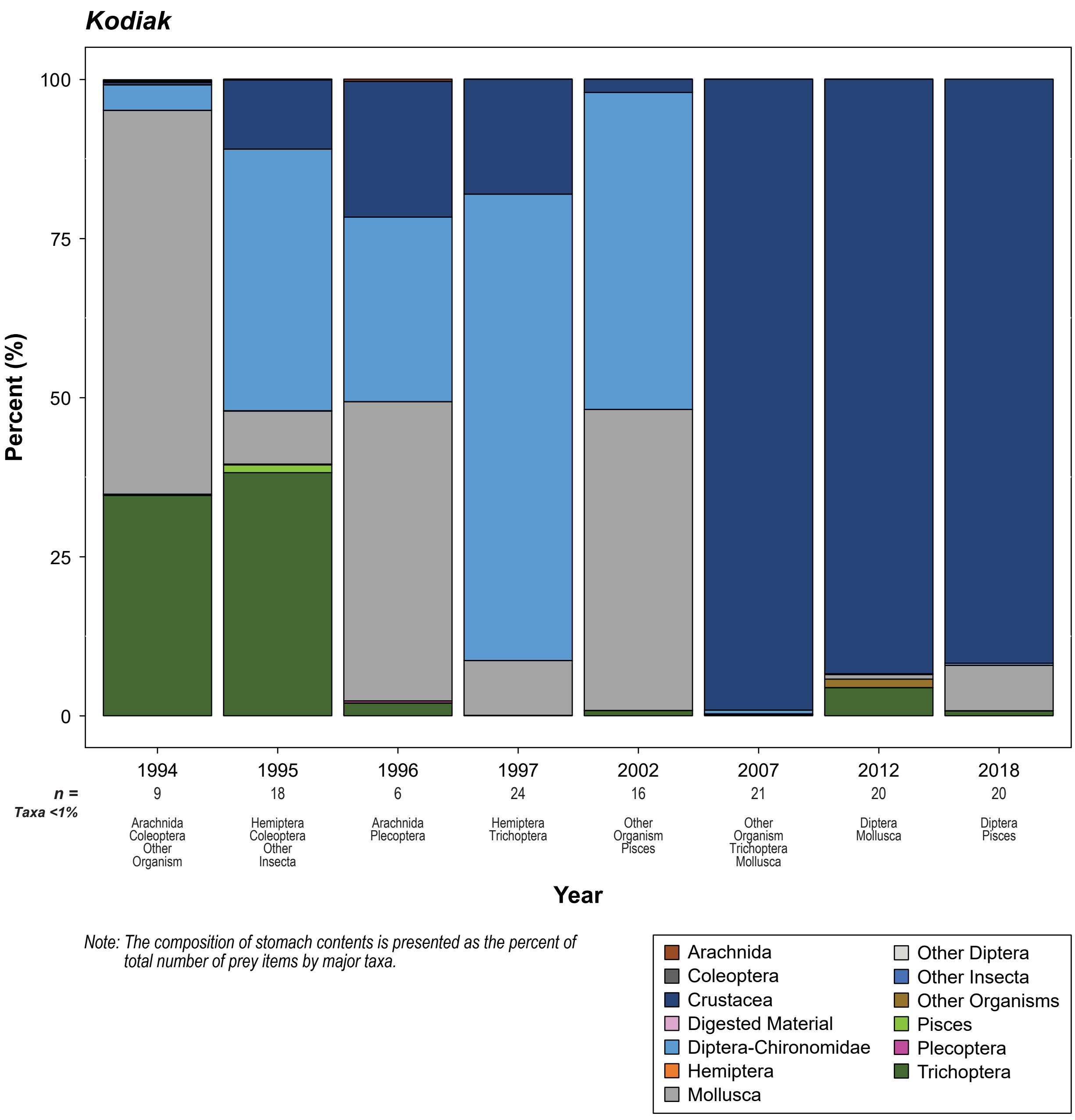
Figure 2.3-9: Correlation of Chlorophyll *a* Concentration in Lake Water with Mercury Concentrations in Large-bodied Fish





Notes: Symbols represent observed mean values. Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
Benchmark= 7,604 - 102,106 organisms/m³.

Figure 2.3-10: Total Zooplankton Density Observed and Fitted Means for Koala Watershed, Lac de Gras and Reference Lakes, 1994 to 2018



Note: The composition of stomach contents is presented as the percent of total number of prey items by major taxa.

Figure 2.3-11: Round Whitefish Stomach Contents by Number for Kodiak Lake, 1994 to 2018

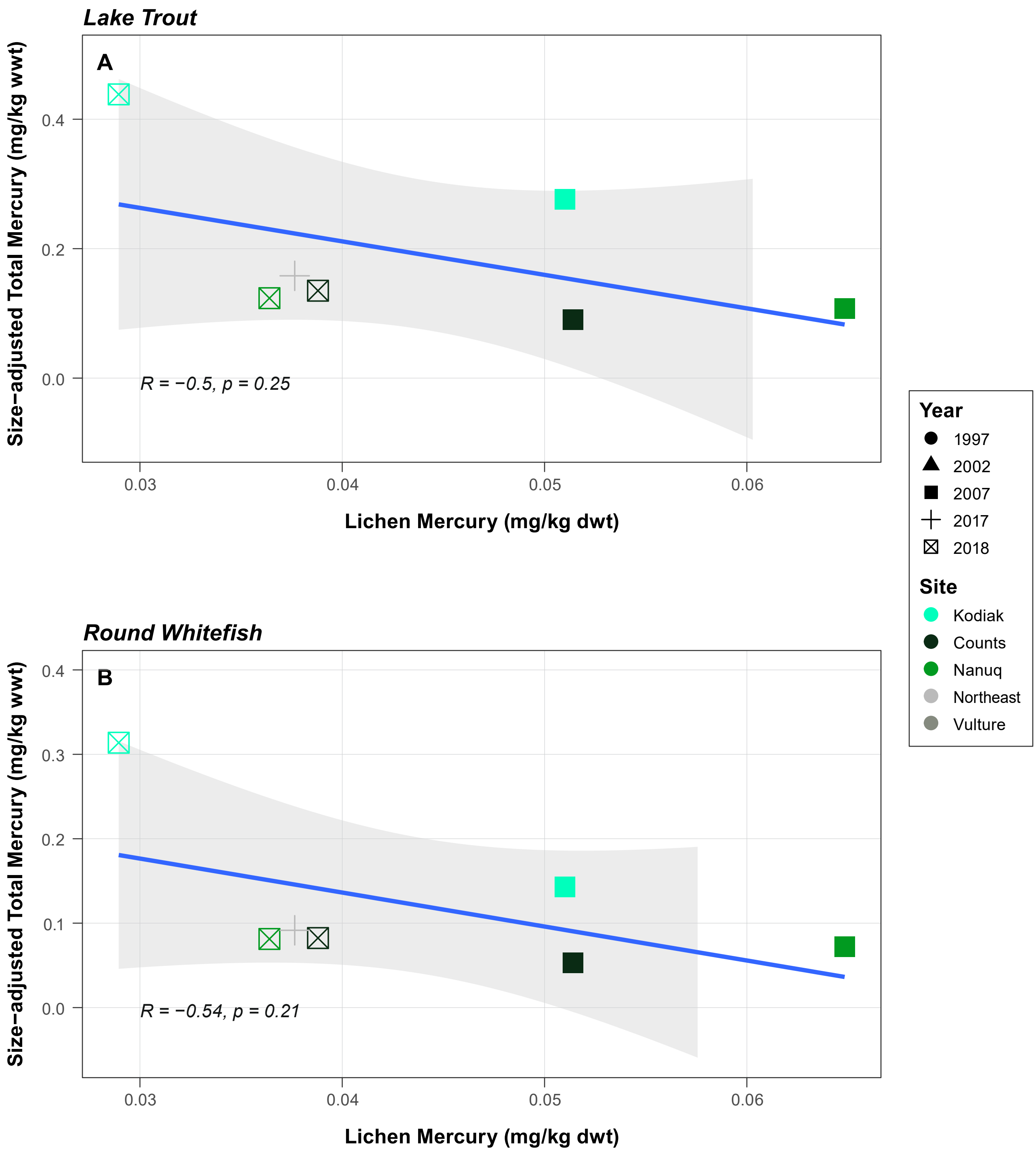
Limited Evidence that Atmospheric Deposition Does Not Correlate with Fish Mercury Concentrations

Although the atmospheric deposition data was limited due to high detection limits; with the available data (lichen concentrations) there was no strong evidence that atmospheric sources, nor terrestrial contributions influenced the concentrations of Hg in large-bodied fish of the study lakes. As discussed in the methods, it was not possible to include data from the AQMP dustfall collections, or snow chemistry data, as these data sets had almost no measurable Hg (Table 2.2-1). Lichen tissues, however; had measurable concentrations of Hg, but these showed a small, negative correlation with fish tissue Hg (Figure 2.3-12). Lichen tissues are an indicator of the terrestrial sources of Hg, where they integrate soil, dustfall, and snow chemistry influences. If atmospheric contributions played a role in contributing Hg to Kodiak Lake, these likely would have appeared as measurable concentrations of Hg in AQMP samples, and ultimately as a positive correlation with fish tissue Hg, however the precision of analytical detection limits may have limited measurements.

2.4 CONCLUSIONS

This retrospective study revealed strong correlations between Hg concentrations in large-bodied fish and indicators of heightened watershed influence, nutrient concentrations, and primary productivity in Kodiak Lake. Watershed influences, in particular higher concentrations of TOC, suggest the potential for increased transportation and or methylation of Hg in the system. Kodiak Lake has an unusually large drainage area for the size of the lake which further suggests that Kodiak Lake should experiencing greater influence of watershed-related environmental variables than Reference Lakes. However, the reader should be cautious to avoid interpreting correlations as being representative of causative agents of Hg concentrations observed in fish. Due to the experimental design, any environmental differences observed between Kodiak Lake and the Reference Lakes will result in some degree of correlation with fish Hg concentrations.
The methylation of Hg in freshwater ecosystems is highly tied to the overall limnological processes of the system, so the correlations may be representative of covarying processes that interact with each other, but do not directly impact Hg bioaccumulation. Most often, the manipulation of any single variable will not be sufficient to change the course of Hg bioaccumulation.

There may be a shift in the dietary components of Round Whitefish, possibly in response to increased primary productivity (as measured by chlorophyll *a*). Atmospheric deposition and terrestrial inputs of Hg may not be significant contributors to fish Hg concentrations in Kodiak Lake, although data was limited by detection limits. Kodiak Lake appears to occupy a unique position in the landscape compared to Reference Lakes, where watershed-level influences play a much larger role in shaping the limnology of the lake. It is likely that climate change is playing a role in accentuating these watershed influences.



Note: Grey band represents the 95% Confidence Interval of the estimate.

Figure 2.3-12: Correlation of Lichen Mercury Concentrations with Mercury Concentrations in Large-bodied Fish

3. 2023 KODIAK LAKE MERCURY STUDY

3.1 OBJECTIVES AND HYPOTHESES

As discussed in Section 1.3.1, large-bodied fish from Kodiak Lake are experiencing higher THg concentrations than is observed in fish from Reference Lakes. To further understand Hg sources and rates of methylation of Kodiak Lake, measurements of THg and MeHg in lake sediments, lake water, and water from all possible inflows of water to Kodiak Lake were collected concurrently with the AEMP sampling program in 2023. Concentrations of THg in lake water at the Ekati Diamond Mine are typically well below regulatory thresholds and standard analytical limits (ERM 2023a), and as such, ultra-trace level methods were employed to develop a better resolution of the potential sources and cycling of mercury in Kodiak Lake.

Higher inputs of Hg to a lake will result in greater mercury bioaccumulation in aquatic foodwebs. If external sources of Hg are contributing excess Hg to Kodiak Lake, this would be detected as high Hg concentrations in water flowing to Kodiak Lake. Alternatively, increases in the methylation of an existing pool of mercury in a lake can also contribute to greater rates of bioaccumulation of mercury in the absence of additional inputs to the system. There is clear experimental evidence that changing the loading of mercury to a system will yield a concomitant response in the amount of MeHg which accumulates in fish; however, the timing and size of the response will vary based on site-specific factors (Munthe et al. 2007).

The methylation of Hg in freshwater systems is intricately linked to the overall limnological function of lakes. As discussed in Section 1.2 and throughout the desktop analysis of existing data sets in Section 2, many environmental variables can influence Hg methylation rates in lakes. Understanding the rate of Hg methylation is a key factor in determining whether the bioaccumulation of Hg in large-bodied fish species in Kodiak Lake is a function of Hg inputs to Kodiak Lake, internal limnological function, or a combination of these factors.

3.2 METHODS

3.2.1 SAMPLING LOCATIONS

Water and sediment samples were collected at established AEMP sampling stations in Kodiak Lake, and all AEMP Reference Lakes (Counts, Nanuq, Northeast, and Vulture lakes; Table 3.2-1, Figure 3.2-1). Several natural and constructed inflows to Kodiak Lake were also identified and sampled to describe possible external sources of Hg.

TABLE 3.2-1 SUMMARY OF LAKE WATER, STREAM WATER, WETLAND WATER, AND SEDIMENT SAMPLING LOCATIONS, 2023

Sample Name	Site Type	UTM Coordinates	
		Easting (m)	Northing (m)
Kodiak Lake	Monitored Lake	518273	7175550
Counts Lake	Reference Lake	533825	7169850
Nanuq Lake	Reference Lake	534209	7199275

Sample Name	Site Type	UTM Coordinates	
		Easting (m)	Northing (m)
Northeast Lake	Reference Lake	523693	7195264
Vulture Lake	Reference Lake	521225	7180807
Kodiak Airport Culvert 1	Kodiak Culvert	518473	7175437
Kodiak Airport Culvert 2	Kodiak Culvert	518244	7175042
Panda Diversion Channel Outlet	Constructed Stream	518476	7175914
Panda Diversion Channel Start	Constructed Stream	520102	7178301
Kodiak Wetland 1	Kodiak Wetland	518495	7176121
Kodiak Wetland 2	Kodiak Wetland	518009	7176140
Upper Pigeon Stream – R7	Reference Stream	517220	7182260
Nanuq Inlet	Reference Stream	534352	7199839

[1] Coordinates are in North American Datum (NAD) 83, UTM Zone 12N.

The primary water source for Kodiak Lake comes from the PDC, which was constructed in 1997 as compensation for the loss of stream habitat during the development of the Ekati Diamond Mine. The PDC connects Panda Lake to the north of the Mine Camp, with Kodiak Lake. Both ends of the channel were sampled such that it may be possible to determine if the PDC itself was producing Hg for delivery to Kodiak, or merely acting as a water conveyance, which would be apparent if the water flowing out from the PDC was higher in THg and MeHg than the water at the headwaters of the PDC. Reference inflow water samples were collected from an inflow to Nanuq Lake, and from the AEMP sampling site (UPS-R7) in Upper Pigeon Stream, which is upstream of the Pigeon Stream Diversion (PSD) channel but has similar water flow to the PDC. The PSD is a newer diversion channel constructed at the Ekati Diamond Mine from 2011 to 2014 as compensation for the loss of stream habitat during the development of the Pigeon Pit.

Two naturally occurring wetlands which supply water to Kodiak Lakes were identified to the west and north sides of the lake (Figure 3.2-1). Finally, two culverts which pass under the Ekati airport strip connect a large complex of wetlands to the east of the airport strip, with Kodiak Lake.
No reference wetlands could be sampled as there are none identified connected to the Reference Lakes.

3.2.2 SAMPLE COLLECTION

Water and sediment samples were collected between August 12 and 22, 2023. This period coincides with the with the timing of the yearly AEMP sampling program and ensures samples are comparable to existing data sets, as mercury concentrations can vary through the year (ERM 2022). Samples were sent to Bureau Veritas (BV) in 2 shipments: August 17 and 25, 2023.

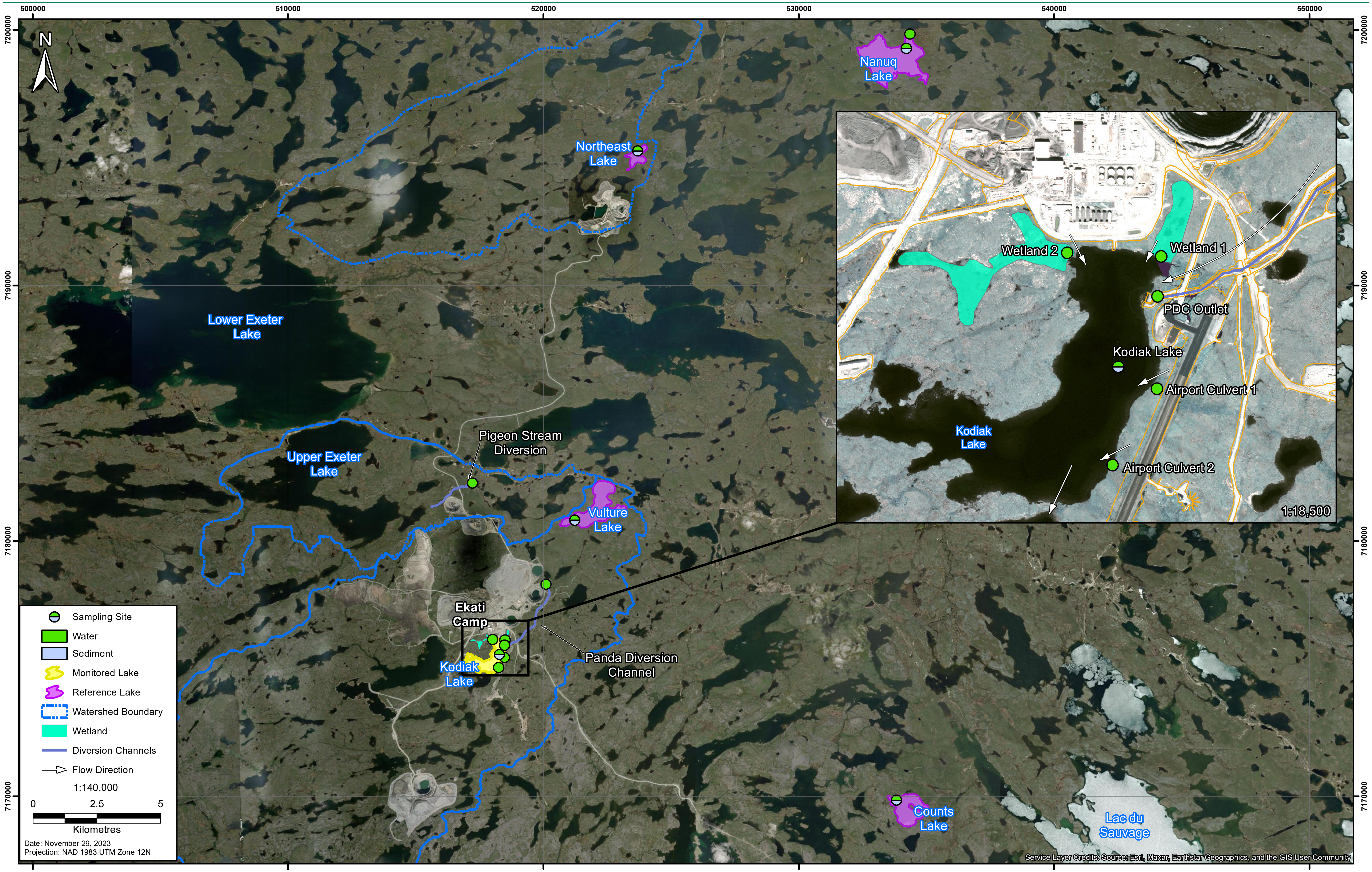


Figure 3.2-1: Sampling Locations for the Mercury Study at the Ekati Diamond Mine, 2023

The following samples were collected (Table 3.2-2):

- Ultra Low-Level Mercury – Total (ng/L)
- Ultra Low Mercury - Dissolved, lab filtered (ng/L)
- Methylmercury (Total) in Water (ng/L)
- Methylmercury (Dissolved) (ng/L)
- Total Metals by ICPMS – Total Mercury (Hg) (ng/g)
- Mercury by CVAF – Total (wwt) Methylmercury (ng/g)

TABLE 3.2-2 MERCURY SAMPLES COLLECTED, KODIAK LAKE AND REFERENCE SITES, 2023

Site	Sample Type					
	Water				Sediment	
	Total Mercury (ng/L)	Dissolved Total Mercury (ng/L)	Methylmercury (ng/L)	Dissolved Methylmercury (ng/L)	Total Mercury (ng/g)	Methylmercury (ng/g)
Kodiak Lake	X	X	X	N/A	X	X
Counts Lake	X	X	X	N/A	X	X
Nanuq Lake	X	X	X	N/A	X	X
Northeast Lake	X	N/A	X	X	X	X
Vulture Lake	X	X	X	N/A	X	X
Airport Culvert 1	X	N/A	X	X		
Airport Culvert 2	X	X	X	N/A		
Panda Diversion Channel (PDC) Outlet	X	X	X	N/A		
PDC Start	X	X	X	N/A		
Pigeon Stream Diversion (PSD)Channel	X	N/A	X	N/A		
Nanuq Inlet	X	X	X	N/A		
Wetland 1	X	X	X	N/A		
Wetland 2	X	X	X	N/A		

Notes:

N/A indicates samples collected but data not available due to lab error.

Additionally, a subset of water samples filtered with a 0.45 µm Supor® polyethersulfone (PES) membrane filter to measure dissolved mercury concentrations in water. Samples were kept cold, and shipped on ice to BV (Calgary, AB) on August 25, 2023. Analytical DLs are given in Table 3.2-3.

TABLE 3.2-3 ANALYTICAL DETECTION LIMITS FOR MERCURY ANALYSES

Analytical Endpoint	Method	Detection Limit	Units
Water			
Ultra Low Level Total Mercury by CV-AFS	US EPA Standard Method1631E[1] (modified)	0.1	ng/L
Methylmercury by CV-AFS	US EPA Standard Method 1630[2] (modified)	0.05	ng/L
Sediment			
Total Mercury by ICP-MS	US EPA Standard Method 6020[3] (modified)	50-100	ng/g (dwt)
Methylmercury in Sediment/Soil by CV-AFS	US EPA Standard Method1630[1] (modified)	0.050	ng/g (dwt)

Notes:

CV-AFS = Cold Vapour Atomic Fluorescence Spectroscopy; US EPA = United States Environmental Protection Agency; ICP-MS = Inductively-Coupled Mass Spectrometry

[1] EPA (2002)

[2] EPA (1998)

[3] EPA (1994)

Samples were collected in accordance with *Method 1669 Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels* (US EPA 1996). Sampling was not conducted during poor weather (i.e., rain, wind) so as to reduce the potential for contamination. Wildfires were prominent in the immediate vicinity of the Ekati Diamond Mine causing a large amount of smoke in the area, where wildfire smoke is a known source of atmospheric Hg contamination. As such, daily field blanks were generated to assess the possibility of contamination.

All sample bottles and containers, preservatives and filters were provided by BV (analytical laboratory) and were verified Hg-free. Total mercury in water samples were collected into 3 x 40 ml clear borosilicate glass bottles. Methylmercury in water samples was collected into 250 ml borosilicate amber glass bottles, pre-charged with trace grade hydrochloric acid preservative. Total mercury in sediment samples was collected into sterilized 1 L Whirlpak bags. Methylmercury in sediment samples was collected into 120 ml clear borosilicate glass jars. All samples were kept cool at 4˚C until sample analysis. Metals-free water was provided by BV for collection of blanks. Analytical methods and detection limits are outlined in Table 3.2-3.

Sediment and water samples were collected following protocols outlined in the AEMP Design Plan Version 8.1 (ERM 2023b). Briefly, water samples were collected with an acid-washed 1.7 L GO-FLO Water sampling bottle (General Oceanics Inc, Miami, FL), which collects a water sample at a depth of approximately 10 m. Sediment samples were collected with a standard (6 x 6 x 6 inch) Ekman grab sampler (Wildco, Yulee, FL). Upon retrieval the top of the Ekman was opened and several acid-washed polycarbonate core tubes were inserted into the sediment sample. The core tubes were plugged and removed from the Ekman and all but 2 cm of sediment was discarded, such that the sediment sample collected represents only surficial lake sediments. The surface sediments were then transferred to sediment sample bags or jars and kept cold until processed.

3.2.3 DATA ANALYSIS

For data presentation, the square root of the DL was substituted when the measured concentrations was below the DL. Duplicate results, if available, were averaged to obtain an overall mean.

Percent MeHg was calculated as follows:

$$\left(\frac{[MeHg]}{[THg]}\right) * 100\%$$

Dissolved Hg was calculated as follows:

$$\left(\frac{[Hg]\ in\ filtered\ sample}{[Hg]\ in\ unfiltered\ sample}\right) * 100\%$$

3.2.4 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Forty-one QA/QC samples were collected included field duplicates (sediment and water), field blanks (water), equipment blanks, and bottle blanks. Duplicate values received from the laboratory were compared using relative percent difference (RPD) to evaluate precision, as follows:

$$RPD = \frac{|C_1 - C_2|}{\frac{C_1 + C_2}{2}} \times 100\ \%$$

An RPD of <20% is considered acceptable when the concentrations of the two samples are 5x the reporting DL (RDL). Higher RPD is acceptable when concentrations are lower (BC ENV 2013).

3.3 RESULTS AND DISCUSSION

3.3.1 QA/QC RESULTS

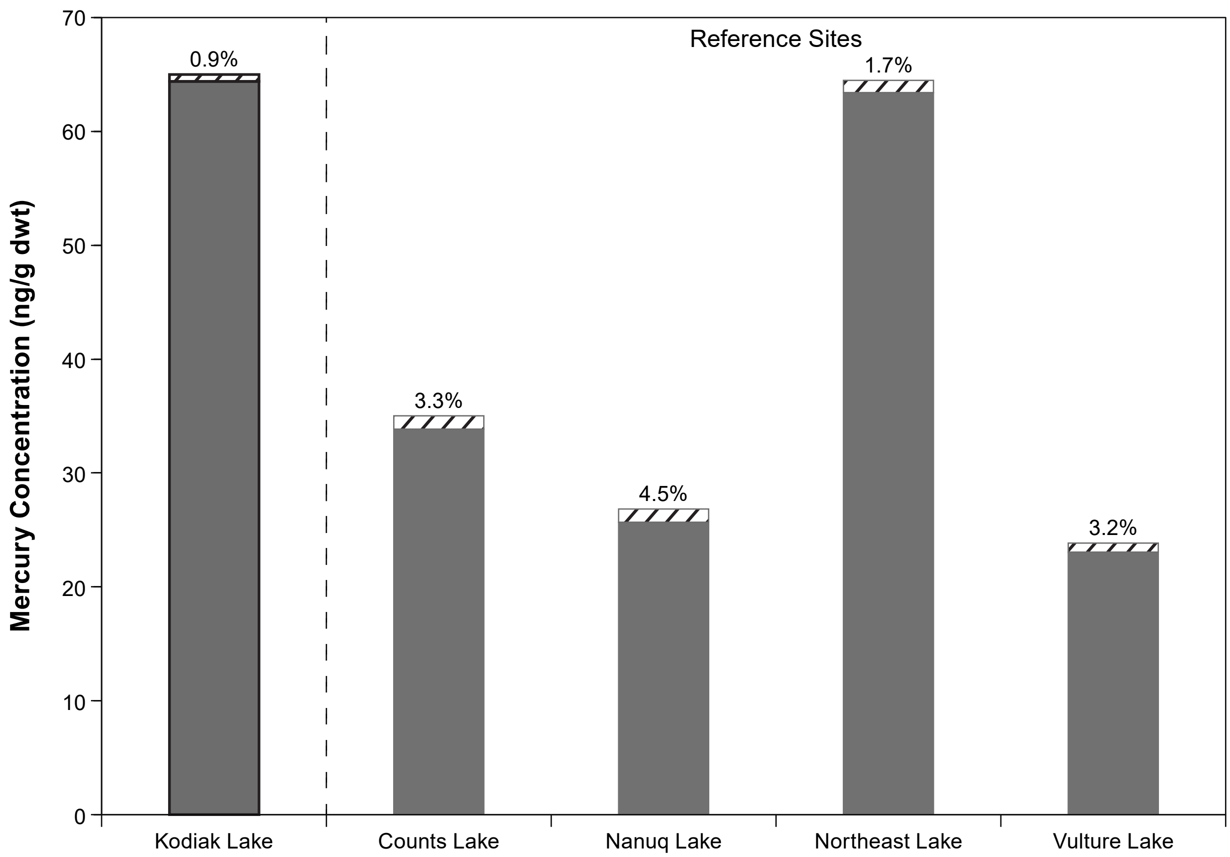
A small number of field blank samples (4 of 16) contained measurable Hg concentrations, which is not unexpected with sampling at ultra-trace concentrations (Appendix A-1); however, blank contamination was <17% of field sample concentrations, indicating good performance of field sampling protocols and no correlation with atmospheric smoke conditions. The highest concentration measured in a field blank was 48% of the THg concentration in the field sample collected at the same time from the Ekati Airport Culvert 1 site. However, given the strong agreement between THg concentrations in water samples collected from both culverts which were expected to have similar mercury concentrations, the contamination was most likely limited to the field blank. Duplicate water and sediment samples had acceptable RPD, with the exception of one MeHg in water sample which was slightly above the acceptable RPD. MeHg concentrations measured in water samples were very close to DLs where acceptable RPD can be difficult to achieve, as such MeHg concentrations in water should be interpreted with caution.

3.3.2 MERCURY IN LAKE SEDIMENTS

Due to laboratory error, THg concentrations in sediment could not be analyzed within the hold time required for DLs to meet Canadian Association of Laboratory Accreditation (CALA) standards, which results in higher RDLs. As such, only two sediment samples from 2023 had THg concentrations that were above the adjusted RDL. Using the available data from the two samples with THg above the RDL, these were compared to data collected from the same lakes in 2021 and reported in the AEMP, to ensure consistent data across these two sampling periods. Data from 2023 THg in sediments was within 28% of the THg concentrations measured in sediments from the same lakes most recently in the 2021 AEMP. An RPD of 28% is considered acceptable with concentrations < 5x the RDL, where the RDL was 50-100 ng/g dwt in 2023. As such, to provide some context for discussing sediment THg concentrations between lakes in this study, the 2021 data on THg in lake sediments is discussed below. Analytical results of THg in sediments collected in 2023 for this study are presented in Appendix A-2.

The THg concentration in sediment collected from Kodiak Lake in 2021 was 43.7 ng/g dwt, which was somewhat higher than the average THg concentration of 35.1 ± 6.8 ng/g dwt in sediment from Reference Lakes in 2021 (Figure 3.3-1). Northeast Lake had the highest THg concentration in 2021 at 54.3 ng/g dwt; however, it was nearly identical to Kodiak Lake sediment in 2023 (64.3 ng/g dwt and 65.0 ng/g dwt for Northeast Lake and Kodiak Lake, respectively). Measured concentrations of mercury in sediments were well below the CCME interim sediment quality guidelines of 170 ng/g dwt (CCME 1999), suggesting that the concentration of Hg in lake sediments at the Ekati Diamond Mine does not play a large role in determining the bioaccumulation of Hg in large-bodied fish in Kodiak Lake.

The ratio of MeHg to THg (i.e., % MeHg) is often used to determine the relative methylation efficiency of an ecosystem (Krabbenhoft et al. 1999, Sunderland et al. 2006). Methylmercury concentrations were consistent in sediment samples collected across all lakes in 2023 (Figure 3.3-2). Methylmercury concentrations ranged from 0.6 ng/g dwt in Kodiak Lake to 1.193 ng/g dwt in Nanuq Lake. The relative proportion of MeHg (to THg) in sediment ranged from 0.9% in Kodiak Lake, and 1.7 to 4.5% in Reference lakes (Figure 3.3-1) and were similar to that reported in large scale assessments (Fleck et al. 2016). Assessment of sediment mercury concentrations across western North America indicates that locations where the % MeHg of sediments exceeded 6% corresponded to increasing bioaccumulation of MeHg in aquatic foodwebs (Krabbenhoft et al. 1999). As such, Hg methylation in lake sediments at the Ekati Diamond Mine may not be the primary driver in determining bioaccumulation of Hg in large-bodied fish species in all lakes.



Notes: Figure labels are showing percent methylmercury as a proportion of total mercury.
Total mercury concentrations presented are taken from 2021 AEMP data.
Methylmercury concentrations were collected in 2023 for this study. See discussion for rationale.

Figure 3.3-1: Total Mercury and Percent Methylmercury Concentrations in Lake Sediment, Ekati Diamond Mine, 2023

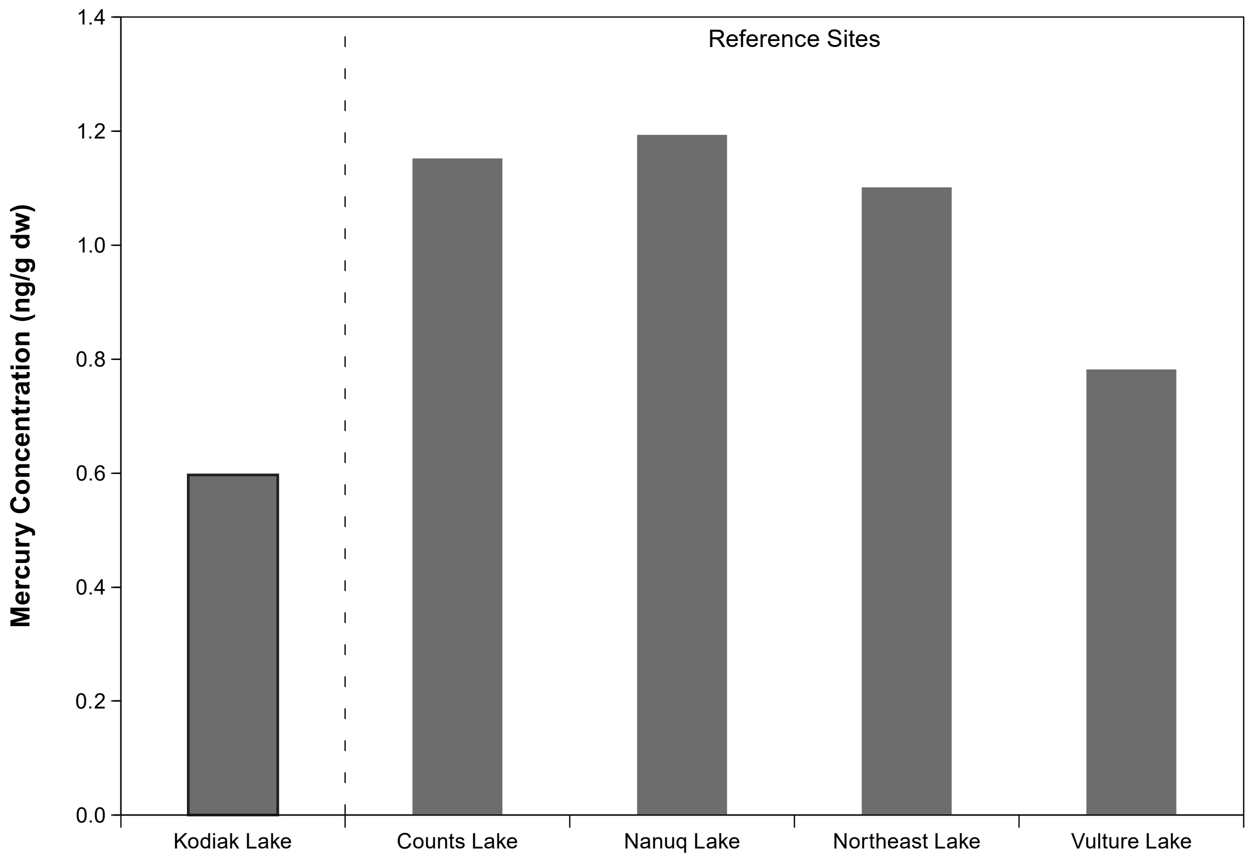


Figure 3.3-2: Methylmercury Concentrations in Lake Sediment, Ekati Diamond Mine, 2023

3.3.3 MERCURY CONCENTRATIONS IN LAKE WATER AND LAKE INFLOWS

Kodiak Lake water had higher THg concentrations in 2023 compared to samples collected at Reference Lakes; 0.59 ng/L vs 0.28 ± 0.04 ng/L, respectively (Figure 3.3-3). Methylmercury concentrations in lake water were below the RDL (<0.050 ng/L) for Counts, Nanuq and Vulture lakes, 0.061 ng/L (10.5%) in Kodiak Lake and 0.096 ng/L (23.7%) in Northeast Lake (Figure 3.3-3). Total and MeHg concentrations in water collected for this study all fell well below CCME water quality guidelines for protection of aquatic life of 26 ng/L (CCME 2003).

The THg concentrations from all inflows to Kodiak Lake were higher (ranging from 0.89 to 1.56 ng/L) than concentrations observed in Kodiak Lake water itself (Figure 3.3-4), indicating that these inflows were delivering exogenous sources of Hg to Kodiak Lake, and likely contributed to the higher THg concentrations observed in Kodiak Lake compared to Reference Lakes. Moreover, Kodiak Lake appears to have many more identifiable sources of water flowing into it than Reference Lakes, indicating the much higher influence of the relatively large surrounding drainage area to Kodiak Lake compared to Reference Lakes (Table 2.3-1). Although Kodiak Lake has higher sediment Hg concentrations than most Reference Lakes, Northeast Lake has higher sediment THg than Kodiak Lake, yet the Hg concentration in fish in Northeast Lake are in the range of other Reference Lakes. However, the uniquely higher THg concentration in Kodiak Lake water stands out as the primary difference in Hg concentrations measured in this study between Kodiak Lake and Reference Lakes at the Ekati Diamond Mine.

Most inflows to Kodiak Lake did not appear to contribute any exogenous MeHg to Kodiak Lake. Methylmercury concentrations from inflows to Kodiak Lake ranged from below the RDL for Kodiak Wetlands 1 and 2, and the PDC outlet. The upper end of the PDC had a small amount of MeHg in the water at 0.09 ng/L, but this appears to have been removed from water flow as it passes through the channel. Similar to the PDC, the reference stream site in Upper Pigeon Stream (AEMP sampling site R7) had no detectable MeHg in the stream water. Nanuq inflow had MeHg concentrations consistent with that observed in the airport culverts (0.16 ng/L); however, at the time of sampling Nanuq inlet was stagnant and not flowing, and Hg concentrations in these samples are largely representative of wetland conditions.

Both Ekati airport culverts had the highest MeHg concentrations of all samples collected (0.16 ng/L in culvert 1 and 0.3 ng/L in culvert 2). The % MeHg of water from these two sampling sites was also higher than observed in any other flowing water sources at 16.2% at Airport Culvert 1, and 20.5% at Airport Culvert 2. These two culverts drain a large complex of wetland areas to the east of Kodiak Lake, travelling beneath the Ekati airport runway and emptying to Kodiak Lake. Wetlands and peat bogs often retain a large amount of Hg (Bodaly et al. 1997; Paterson et al. 1998; Heyes et al. 2000) and are sites of high production of MeHg (Mitchell et al. 2008). This MeHg can be transported, along with DOC to lakes; typically, lakes with higher wetland influence in the watershed will have higher Hg bioaccumulation in the foodweb (Grieb et al. 1990; Miskimmen 1991; Moslemi-Aqdam et al. 2022).

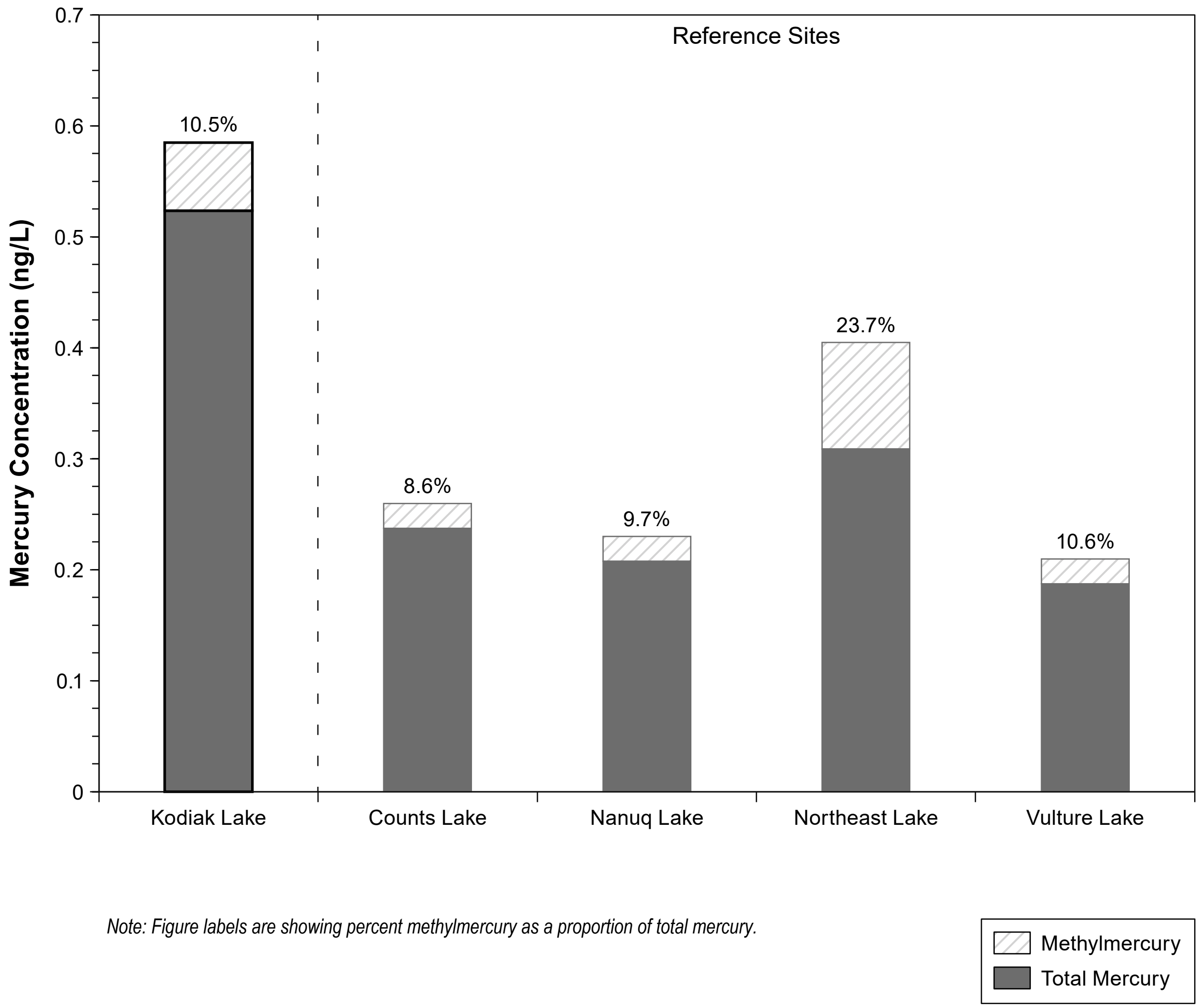
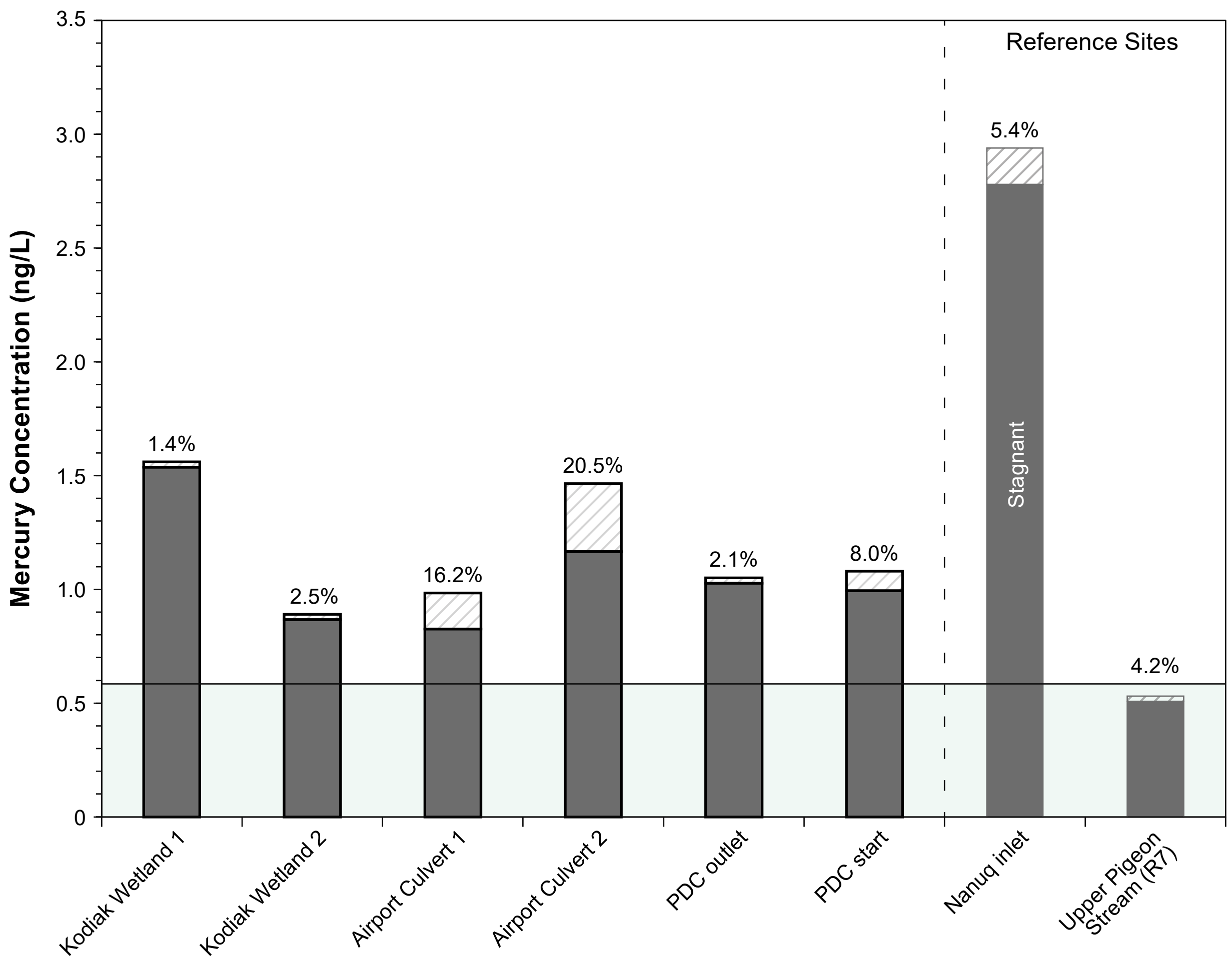


Figure 3.3-3: Total and Methylmercury Concentrations in Lake Water, Ekati Diamond Mine, 2023



Notes: Figure labels are showing percent methylmercury as a proportion of total mercury.
Horizontal line represents the concentration of total mercury in Kodiak Lake water samples in 2023 for reference.
PDC = Panda Diversion Channel

Figure 3.3-4: Total and Methylmercury Concentrations in Lake Inflows, Ekati Diamond Mine, 2023

The influence of several weekly flights to and from the Ekati Diamond Mine site are unlikely to contribute to deposition of mercury from plane exhaust to the airport culvert water sources, given that there was no strong evidence to suggest that atmospheric deposition of mercury is in the vicinity of Kodiak Lake. Particularly given the absence of detectable concentrations of Hg in AQMP samples collected immediately adjacent to the airport strip (Section 2.3; Figure 2.2-1).

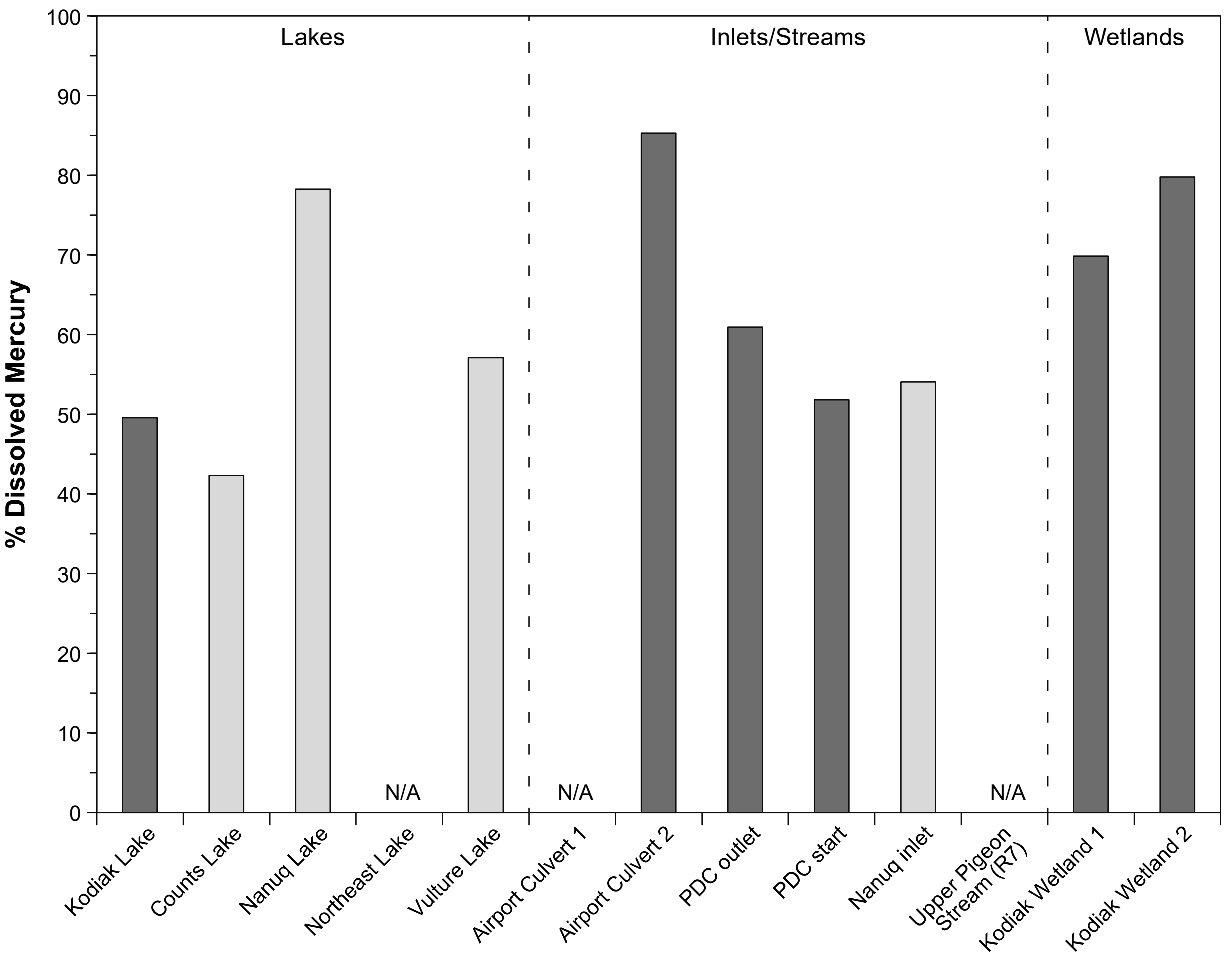
Dissolved Hg in the water column is indicative of Hg that is complexed with DOC in the water, and this complex enhances the methylation of Hg (Herrero Ortega et al. 2018). The proportion of dissolved THg in water samples ranged from 42.3 to 85.3% (Figure 3.3-5). Inflows to Kodiak Lake had slightly higher dissolved proportion of THg than did reference Nanuq Inlet, suggesting that the Hg transported to Kodiak Lake is potentially more bioavailable than at Reference sites.

Bioaccumulation of Hg in foodwebs is largely dependent on the concentration of MeHg in water (Mason et al. 2005, Morel et al. 1998, Munthe et al. 2007). Methylation of Hg is traditionally thought to occur mainly in lake sediments; however, more recent evidence suggests that SRB in anaerobic zones of highly stratified water columns are also important in the methylation cycle (Hsu-Kim 2013).

Although Northeast Lake had similar or higher THg and MeHg in sediment, and MeHg in water concentrations than Kodiak Lake, the concentration of Hg in large-bodied fish from these lakes was lower (Figure 2.3-1). Northeast Lake is the smallest lake in the current study (35.2 ha) but has a much smaller relative drainage area than Kodiak Lake (2.90 versus 9.64 to 25.53 relative drainage area; Table 2.3-3), suggesting that the influence of the drainage area would be much lower than is experienced by Kodiak Lake. Northeast Lake is more similar to Reference Lakes for most of the environmental variables that were correlated with higher THg in large-bodied fish, as discussed in Section 2. Sulphate, conductivity, TOC, and TKN, in Northeast Lake water were all within the ranges of what was observed in References Lakes in this study (Figures 2.3-4, 2.3-5, 2.3-7, and 2.3-8). Lower concentrations of TOC in the water column of Northeast Lake are indicative of a much smaller watershed influence and is consistent with this lake having a much smaller relative drainage area compared to Kodiak Lake.

3.4 CONCLUSIONS

In summary, this investigation into the concentrations of Hg in sediment and water of Kodiak Lake has revealed that a combination of interacting factors may be contributing to the higher Hg accumulation in large-bodied fish in this lake. Kodiak Lake has an unusually large drainage area, with several wetlands and streams delivering exogenous Hg to the lake, which is not observed in any other Reference Lakes in the study. The consistency in the % MeHg in lake sediment samples of this study indicates lower rates of in situ methylation in sediment compartments. This suggests that the convention of lake sediments being the predominant driver of Hg bioaccumulation in foodwebs, may not hold for these study lakes. Instead, this study suggests the possibility that methylation occurring in the water column of study lakes may play a role in driving variations in Hg concentrations in fish tissue.



Notes: N/A represents data not available due to lab error.
Dark grey bars are Kodiak Lake and associated inflows.
Light grey bars are reference sites.
PDC = Panda Diversion Channel.

Figure 3.3-5: Dissolved Total Mercury Concentrations in Lakes and Lake Inflows, Ekati Diamond Mine, 2023

Along with the differences in watershed influences, Kodiak Lake's THg levels in sediment, as well as MeHg in water, surpassed those observed in many Reference Lakes, although they were very similar to concentrations observed in Northeast Lake. A key difference of all measures of Hg concentrations between Kodiak Lake and most Reference Lakes in this study was that the THg concentration in Kodiak Lake water, while low compared to concentrations observed elsewhere in the Arctic, was almost double the average concentrations observed in Reference Lakes. This difference in THg concentrations in Kodiak Lake water showed the same trend as the Hg concentrations in fish of these lakes and may be key to understanding the mechanisms of increasing concentrations of Hg in the Kodiak Lake large-bodied fish. The results of this study underscore the complexity of the mechanisms governing Hg bioaccumulation, with a much stronger influence of landscape-level variables such as watershed influence, and indications of expected impacts from climate change.

4. SUMMARY

In Kodiak Lake, an increase in mercury (Hg) levels has been observed in Lake Trout and Round Whitefish compared to pre-mining conditions, despite the absence of active effluent discharge into the lake. The rise in fish Hg concentrations over time is most correlated with factors indicating high influence of wetlands, as well as indicators of elevated rates of primary productivity. Kodiak Lake has a far greater drainage surface area than the Reference Lakes, which may be driving both Hg loading and the delivery of DOC (as a component of TOC), sulphate and nutrients to Kodiak Lake which are favourable conditions for the methylation of Hg by anoxic SRB and bioaccumulation in lake foodwebs. More recent apparent shifts in fish diets, potentially towards a higher proportion of zooplankton (known for their higher Hg content), may be further contributing to the observed trend in large-bodied fish species in Kodiak Lake. Atmospheric contributions of Hg to these study lakes at the Ekati Diamond Mine appear to be negligible.

Mercury levels in lake sediment do not seem to be the driving force behind the differences in tissue concentrations. THg levels in Kodiak Lake are higher than Reference lakes; however, the % MeHg in Kodiak Lake does not reflect the expected increase based on the likely higher methylation rates. While methylation rates are likely higher in Kodiak Lake, MeHg concentrations in water can sometimes appear lower due to rapid removal from the water column. Overall, it appears that Kodiak Lake is subject to multiple unique interacting factors which are having a strong influence on bioaccumulation patterns in large-bodied fish species.

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APPENDIX A ANALYTICAL MERCURY CONCENTRATIONS

1. APPENDIX A-1

Mercury samples were collected from August 12 to 22, 2023. Dissolved mercury samples were filtered using a 0.45 µm, 15 mm diameter capsule filter (Gelman Supor 12175, or equivalent) prior to analysis. Total mercury in water samples were analyzed by CVAAS according to method EPA 6020 m, with a detection limit of 0.10 mg/kg. Methyl mercury in water samples were determined using cold vapor atomic fluorescence spectrometry, according to method EPA 1630m, with a detection limit of 0.050 ng/g.

Table A-1 Mercury Concentrations in Water Samples from Kodiak Lake, Input Sources, Wetlands and Reference Sources at Ekati Diamond Mine, August 2023

Sampling Date	Sample ID	Lab Sample ID	Site	Northing	Easting	Dissolved or Whole Water Sample	QA/QC Type	Analytical Parameter	Results (ng/L)
15-Aug-23	FRP23-water-082*	BYS055	Kodiak Lake	518273	7175550	Dissolved	-	Ultra-Trace Total Mercury	0.31
15-Aug-23	FRP23-water-082	BYS055				Whole	-	Ultra-Trace Total Mercury	0.59
15-Aug-23	FRP23-water-063	BYS056				Whole	-	Methyl Mercury	<0.05
14-Aug-23	FRP23-water-091*	BYS015	Counts Lake	533825	7169850	Dissolved	-	Ultra-Trace Total Mercury	0.11
14-Aug-23	FRP23-water-091	BYS015				Whole	-	Ultra-Trace Total Mercury	0.26
14-Aug-23	FRP23-water-101	BYS016				Whole	-	Methyl Mercury	<0.05
13-Aug-23	FRP23-water-111*	BYS003	Nanuq Lake	534209	7199275	Dissolved	-	Ultra-Trace Total Mercury	0.18
13-Aug-23	FRP23-water-111	BYS003				Whole	-	Ultra-Trace Total Mercury	0.23
13-Aug-23	FRP23-water-106	BYS004				Whole	-	Methyl Mercury	<0.05
22-Aug-23	FRP23_WATER_001	BXR790	Northeast Lake	523693	7195264	Whole	-	Ultra-Trace Total Mercury	0.4
22-Aug-23	FRP23_WATER_008	BXR789				Whole	-	Methyl Mercury	0.096
22-Aug-23	FRP23_WATER_006*	BXR791				Dissolved	-	Methyl Mercury	<0.05

Sampling Date	Sample ID	Lab Sample ID	Site	Northing	Easting	Dissolved or Whole Water Sample	QA/QC Type	Analytical Parameter	Results (ng/L)
14-Aug-23	FRP23-water-088*	BYS017	Vulture Lake	521225	7180807	Dissolved	-	Ultra-Trace Total Mercury	0.12
14-Aug-23	FRP23-water-088	BYS017				Whole	-	Ultra-Trace Total Mercury	0.21
14-Aug-23	FRP23-water-098	BYS018				Whole	-	Methyl Mercury	<0.05
20-Aug-23	FRP23-water-116	BXR798	Airport Culvert 1	518473	7175437	Whole	-	Ultra-Trace Total Mercury	0.97
20-Aug-23	FR23_WATER_018	BXR799				Whole	-	Methyl Mercury	0.16
20-Aug-23	FR23_WATER_062*	BXR801				Dissolved	-	Methyl Mercury	0.2
15-Aug-23	FRP23-water-081*	BSY049	Airport Culvert 2	518244	7175042	Dissolved	-	Ultra-Trace Total Mercury	1.25
15-Aug-23	FRP23-water-081	BSY049				Whole	-	Ultra-Trace Total Mercury	1.44
15-Aug-23	FRP23-water-104	BYS050				Whole	-	Methyl Mercury	0.19
15-Aug-23	FRP23-water-095*	BYS058	Kodiak Wetland 1	518495	7176121	Dissolved	-	Ultra-Trace Total Mercury	1.09
15-Aug-23	FRP23-water-095	BYS058				Whole	-	Ultra-Trace Total Mercury	1.56
15-Aug-23	FRP23-water-072	BYS057				Whole	-	Methyl Mercury	<0.05
15-Aug-23	FRP23-water-090*	BYS061	Kodiak Wetland 2	518009	7176140	Dissolved	-	Ultra-Trace Total Mercury	0.71
15-Aug-23	FRP23-water-090	BYS061				Whole	-	Ultra-Trace Total Mercury	0.89
15-Aug-23	FRP23-water-071	BYS062				Whole	-	Methyl Mercury	<0.05
15-Aug-23	FRP23-water-089*	BYS063	PDC outlet	518476	7175914	Dissolved	-	Ultra-Trace Total Mercury	0.64
15-Aug-23	FRP23-water-089	BYS063				Whole	-	Ultra-Trace Total Mercury	1.05
15-Aug-23	FRP23-water-103	BYS064				Whole	-	Methyl Mercury	<0.05
15-Aug-23	FRP23-water-096*	BYS065	PDC start	520102	7178301	Dissolved	-	Ultra-Trace Total Mercury	0.51
15-Aug-23	FRP23-water-096	BYS065				Whole	-	Ultra-Trace Total Mercury	1.08
15-Aug-23	FRP23-water-102	BYS066				Whole	-	Methyl Mercury	<0.05
13-Aug-23	FRP23-water-110*	BYS001		534352	7179839	Dissolved	-	Ultra-Trace Total Mercury	1.59

Sampling Date	Sample ID	Lab Sample ID	Site	Northing	Easting	Dissolved or Whole Water Sample	QA/QC Type	Analytical Parameter	Results (ng/L)
13-Aug-23	FRP23-water-110	BYS001	Nanuq inlet			Whole	-	Ultra-Trace Total Mercury	2.94
13-Aug-23	FRP23-water-107	BYS002				Whole	-	Methyl Mercury	0.16
18-Aug-23	FRP23-water-073	BXR810	UPS (R7)	517220	7182260	Whole	-	Ultra-Trace Total Mercury	0.53
18-Aug-23	FRP23-water-067	BXR811				Whole	-	Methyl Mercury	<0.05
20-Aug-23	FR23_WATER_004	BXR800	Airport Culvert 1	518473	7175437	Whole	Duplicate	Ultra-Trace Total Mercury	1
15-Aug-23	FRP23-water-083*	BYS051	Airport Culvert 2	518244	7175042	Dissolved	Duplicate	Ultra-Trace Total Mercury	1.16
15-Aug-23	FRP23-water-083	BYS051				Whole	Duplicate	Ultra-Trace Total Mercury	1.49
15-Aug-23	FRP23-water-068	BYS052				Whole	Duplicate	Methyl Mercury	0.41
15-Aug-23	FRP23-water-084*	BYS059	Kodiak Lake	518273	7175550	Dissolved	Duplicate	Ultra-Trace Total Mercury	0.27
15-Aug-23	FRP23-water-084	BYS059				Whole	Duplicate	Ultra-Trace Total Mercury	0.58
15-Aug-23	FRP23-water-070	BYS060				Whole	Duplicate	Methyl Mercury	0.1
22-Aug-23	FRP23_WATER_002	BXR788	Northeast Lake	523693	7195264	Whole	Duplicate	Ultra-Trace Total Mercury	0.41
15-Aug-23	FRP23-water-112*	BYS067	PDC start	520102	7178301	Dissolved	Duplicate	Ultra-Trace Total Mercury	0.61
15-Aug-23	FRP23-water-112	BYS067				Whole	Duplicate	Ultra-Trace Total Mercury	1.1
15-Aug-23	FRP23-water-099	BYS068				Whole	Duplicate	Methyl Mercury	0.15
18-Aug-23	FRP23-water-078	BXR812	UPS (R7)	517220	7182260	Whole	Duplicate	Ultra-Trace Total Mercury	0.52
18-Aug-23	FRP23-water-064	BXR813				Whole	Duplicate	Methyl Mercury	<0.05
20-Aug-23	FR23_WATER_085	BXR797	Airport Culvert 1	518473	7175437	Whole	Field Blank	Ultra-Trace Total Mercury	0.29
20-Aug-23	FR23_WATER_020	BXR796				Whole	Field Blank	Methyl Mercury	<0.05
14-Aug-23	FRP23-water-092	BYS019	Counts Lake	533825	7169850	Whole	Field Blank	Ultra-Trace Total Mercury	<0.10
14-Aug-23	FRP23-water-100	BYS020				Whole	Field Blank	Methyl Mercury	<0.05

Sampling Date	Sample ID	Lab Sample ID	Site	Northing	Easting	Dissolved or Whole Water Sample	QA/QC Type	Analytical Parameter	Results (ng/L)
15-Aug-23	FRP23-water-079	BYS069	Kodiak Lake	518273	7175550	Whole	Field Blank	Ultra-Trace Total Mercury	0.12
15-Aug-23	FRP23-water-066	BYS070				Whole	Field Blank	Methyl Mercury	<0.05
13-Aug-23	FRP23-water-109	BYS005	Nanuq Lake	534352	7179839	Whole	Field Blank	Ultra-Trace Total Mercury	0.11
13-Aug-23	FRP23-water-105	BYS006				Whole	Field Blank	Methyl Mercury	<0.05
22-Aug-23	FRP23-water-119	BXR792	Northeast Lake	523693	7195264	Whole	Field Blank	Ultra-Trace Total Mercury	0.11
22-Aug-23	FRP23-water-120	BXR794				Whole	Field Blank	Ultra-Trace Total Mercury	<0.10
22-Aug-23	FRP23-water-012	BXR793				Whole	Field Blank	Methyl Mercury	<0.05
22-Aug-23	FRP23-water-011*	BXR795				Dissolved	Field Blank	Methyl Mercury	<0.05
18-Aug-23	FRP23-water-077	BXR814	UPS (R7)	517220	7182260	Whole	Field Blank	Ultra-Trace Total Mercury	<0.10
18-Aug-23	FRP23-water-061	BXR815				Whole	Field Blank	Methyl Mercury	<0.05
14-Aug-23	FRP23-water-087	BYS021	Vulture Lake	521225	7180807	Whole	Field Blank	Ultra-Trace Total Mercury	<0.10
14-Aug-23	FRP23-water-097	BYS022				Whole	Field Blank	Methyl Mercury	<0.05
13-Aug-23	FRP23-water-094	BYS000	Equipment blank #1	534352	7179839	Whole	Equipment Blank	Ultra-Trace Total Mercury	<0.10
13-Aug-23	FRP23-water-108	BYR999				Whole	Equipment Blank	Methyl Mercury	<0.05
15-Aug-23	FRP23-water-086	BYS054	Equipment blank #2	-	-	Whole	Equipment Blank	Ultra-Trace Total Mercury	<0.10
15-Aug-23	FRP23-water-069	BYS053				Whole	Equipment Blank	Methyl Mercury	<0.05
23-Aug-23	FRP23-water-118	BXR871	Equipment blank #3	-	-	Whole	Equipment Blank	Ultra-Trace Total Mercury	0.15
23-Aug-23	FRP23_WATER_117	BXR869				Whole	Equipment Blank	Ultra-Trace Total Mercury	<0.10
23-Aug-23	FRP23_WATER_007*	BXR872				Dissolved	Equipment Blank	Methyl Mercury	<0.05
23-Aug-23	FRP23_WATER_005	BXR870				Whole	Equipment Blank	Methyl Mercury	<0.05
16-Aug-23	FRP23-water-075	BYR964	Bottle Room	-	-	Whole	Bottle Room Blank	Ultra-Trace Total Mercury	<0.10
16-Aug-23	FRP23-water-065	BYR965				Whole	Bottle Room Blank	Methyl Mercury	<0.05

** Sample has been split.*

2. APPENDIX A-2

Table A-2 Mercury Concentrations in Sediment Samples from Kodiak Lake and Reference Lakes Ekati Diamond Mine, August 2023

Sampling Date	Sample ID	Lab Sample ID	Site	Northing	Easting	QA/QC Type	Analytical Parameter	Results (ng/g dwt)
12-Aug-23	FRP23-sed-020	BYR806	Kodiak Lake	0518288	7175633	-	Total Mercury	65
12-Aug-23	FRP23-sed-008	BYR807				-	Methyl Mercury	0.12
14-Aug-23	FRP23-sed-015	BYR849	Counts Lake	0533693	7169833	-	Total Mercury	<100
14-Aug-23	FRP23-sed-002	BYR850				-	Methyl Mercury	0.13
13-Aug-23	FRP23-sed-019	BYR830	Nanuq Lake	0534658	7199076	-	Total Mercury	<50
13-Aug-23	FRP23-sed-005	BYR831				-	Methyl Mercury	0.13
22-Aug-23	FRP23-sed-017	BXR914	Northeast Lake	0523362	7195089	-	Total Mercury	61
22-Aug-23	FRP23-sed-007	BXR915				-	Methyl Mercury	0.2
14-Aug-23	FRP23-sed-013	BYR851	Vulture Lake	0522170	7182147	-	Total Mercury	<100
14-Aug-23	FRP23-sed-003	BYR852				-	Methyl Mercury	0.10
22-Aug-23	FRP23-sed-018	BXR916	Northeast Lake	0523369	7195089	Duplicate	Total Mercury	68
22-Aug-23	FRP23-sed-009	BXR917				Duplicate	Methyl Mercury	0.062

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