Ekati Diamond Mine

2013 Aquatic Effects Monitoring Program
Summary Report




DOMINION DIAMOND™

March 31st 2014.

Ms. Violet Camsell-Blondin
Chair
Wek'èezhìi Land and Water Board
#1, 4905-48th Street
Yellowknife, NT, CA X1A 2P6

Dear Ms. Camsell-Blondin

Re: Ekati Diamond Mine 2013 Aquatic Effects Monitoring Program

Dominion Diamond Ekati Corporation (DDEC) is pleased to provide the *2013 Aquatic Effects Monitoring Program* annual report. The report is submitted under Part J Item 7 of Water Licence W2012L2-0001. In addition to the Summary Report, the 2013 AEMP consists of three separate documents:

- Ekati Diamond Mine: 2013 Aquatic Effects Monitoring Program Part 1 – Evaluation of Effects
- Ekati Diamond Mine: 2013 Aquatic Effects Monitoring Program Part 2 – Data Report
- Ekati Diamond Mine: 2013 Aquatic Effects Monitoring Program Part 3 – Statistical Report

The 2013 AEMP was conducted as specified in the Ekati Diamond Mine: Aquatic Effects Monitoring Program Plan for 2013-2015 (Rescan 2013d). This plan was developed following a detailed review of 2010 to 2012 AEMP results completed in November of 2012 and presented to stakeholders at a workshop in December 2012 (Rescan 2012b). Following the workshops, the Wek'èezhìi Land and Water Board (WLWB) solicited written comments from stakeholders to consider and provided DDEC recommendations to be incorporated into an AEMP design summary for 2013 to 2015. A summary of the changes to the evaluation of effects resulting from the three-year re-evaluation and following reviews of the annual AEMP reports beginning in 2013 is included in Section 1.4 of the Summary Report.

DDEC trusts that you will find the report to be clear and informative. Please contact Kate Shea, Environmental Advisor - Fisheries and Aquatics at kathleen.shea@ekati.ddcorp.ca or 867-880-2115 or the undersigned at claudine.a.lee@ekati.ddcorp.ca or 867-880-2232 should you have any questions.

Yours sincerely,

Dominion Diamond Ekati Corporation

Claudine Lee
Superintendent – Environment Operations
Ekati Diamond Mine

EKATI DIAMOND MINE

2013 AQUATIC EFFECTS MONITORING PROGRAM SUMMARY REPORT

March 2014
Project #0211136-0001

Citation:

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Prepared for:

DOMINION DIAMOND

Dominion Diamond Ekati Corporation

Prepared by:

ERM

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Yellowknife, Northwest Territories

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1. Introduction

1. Introduction

1.1 BACKGROUND

The Aquatic Effects Monitoring Program (AEMP) at the Ekati Diamond Mine is a requirement specified in Dominion Diamond Ekati Corporation (DDEC) Class A Water Licence (W2012L2-0001). Sampling conducted for the 2013 AEMP was permitted through the Aurora Research Institute Scientific Research Licence (15182) issued for the Ekati Diamond Mine for the collection of samples between January 1 and December 31, 2013.

The AEMP is designed to detect changes in the aquatic ecosystem that may be caused by mine activities. The 2013 AEMP was conducted as specified in the document titled *Ekati Diamond Mine: Aquatic Effects Monitoring Program Plan for 2013-2015* (Rescan 2013d). This plan was developed following a detailed review or re-evaluation of 2010 to 2012 AEMP results completed in November of 2012 and presented to stakeholders at a workshop in December 2012 (Rescan 2012b). Stakeholders that participated in the meetings and provided feedback to the program included Environment Canada (EC), Fisheries and Oceans Canada (DFO), Aboriginal Affairs and Northern Development Canada (AANDC), the Yellowknives Dene First Nation, the Independent Environmental Monitoring Agency (IEMA) and the Wek'eezhii Land and Water Board (WLWB; Rescan 2013d).

Following the workshops, the WLWB solicited written comments from stakeholders to consider and provided DDEC recommendations to be incorporated into an AEMP design summary for 2013 to 2015. A summary of the changes to the evaluation of effects resulting from the three-year re-evaluation and following reviews of the annual AEMP reports beginning in 2013 is included in Section 1.4.

As completed in the past, the 2013 AEMP report includes this Summary Report that provides an overall summary of the evaluation of effects. The main 2013 AEMP report is comprised of three parts:

1. Part 1 - Evaluation of Effects: provides the methods used to assess change in the aquatic environment and summarizes the results of the evaluation of effects;
2. Part 2 - Data Report: provides the state of the aquatic environment at the Ekati Diamond Mine in 2013, including the field methodology and results for each of the aquatic environmental components (e.g., physical limnology); and
3. Part 3 - Statistical Report: provides detailed results of statistical analyses reported in the evaluation of effects.

1.2 OBJECTIVES

The objective of the AEMP is to identify changes occurring in the aquatic environment that may be caused by the Ekati Diamond Mine activities. To that end, the following components of the aquatic ecosystem were monitored in 2013:

- hydrology (October 2012 to September 2013);
- under-ice physical limnology (April/May 2013);
- open water season physical limnology (August 2013);
- ice-covered season lake water quality (April/May 2013);

- open water season lake water quality (August 2013);
- open water season stream water quality (June, July, August, and September 2013);
- phytoplankton (August 2013);
- zooplankton (August 2013);
- lake benthos (August 2013); and
- stream benthos (August to September 2013).

Meteorological data are collected year round at the Ekati Diamond Mine. Meteorological data collected between October 2012 and September 2013 are reported in the AEMP because they are directly related to hydrology at the site (see Section 3.1 of Part 2 - Data Report).

AEMP sediment quality sampling occurs once every three years and was most recently completed in 2011. The next sediment quality monitoring will be conducted in 2014.

AEMP fish community sampling has occurred once every five years and was most recently completed in 2012. As part of a 2011 evaluation of the fish sampling program at the Ekati Diamond Mine, slimy sculpin were proposed as a sentinel species and changes to the 2012 AEMP field sampling program included the addition of slimy sculpin to be assessed with a sampling frequency of once every three years and decrease the sampling frequency of lake trout and round whitefish to once every six years to link it with the sampling frequency of slimy sculpin (and to further minimize total sampling mortality; Rescan 2011c, 2013a). Thus, slimy sculpin monitoring will be conducted in 2015 and monitoring of large-bodied fish (i.e., lake trout and round whitefish) will be conducted in 2018. The use of slimy sculpin as a sentinel species will continue to be evaluated as fish monitoring progresses.

There are three other components to the aquatic monitoring at the Ekati Diamond Mine, including Surveillance Network Program (SNP), special effects studies and monitoring programs, and environmental baseline studies (Figure 1.2-1). The SNP assesses DDEC's compliance with the Water Licence (W2012L2-0001) and sampling is completed by DDEC staff according to the Water Licence. Data from two SNP sampling stations, located at the two effluent discharge locations, 1616-30 in the Long Lake Containment Facility (LLCF) and 1616-43 in the King Pond Settling Facility (KPSF), are also incorporated into the AEMP for comparative purposes. Special effects studies are carried out on an as-needed basis to answer questions raised by the results of AEMP monitoring that require further investigation or to focus on specific topics by providing additional information not typically collected in the AEMP.

In 2013, the following monitoring studies were undertaken as part of the special effects studies and monitoring programs:

- Lac de Gras Water Quality Monitoring Station – a sampling program in the north arm of Lac de Gras beyond the current extent of the AEMP in order to determine if a new water quality monitoring station is required beyond the current site, S3;
- Nero-Nema Stream Water Quality – water hardness concentrations were compared to concentrations of water quality variables with hardness-dependent water quality benchmarks to examine the extent to which there may be differential dilution in hardness and water quality variables with hardness-dependent benchmarks;
- Grizzly Lake Biological Communities – phytoplankton, zooplankton and benthic invertebrates were sampled in August to assess if communities have been altered following observed changes in the under-ice temperature profiles in 2011 and 2012;

Figure 1.2-1

Schematic of Aquatic Monitoring Programs at the Ekati Diamond Mine

ERM

SUMMARY OF WATER MONITORING PROGRAMS AT EKATI

Surveillance Network Program (SNP)

(Monthly Reports)

- Program specified in Class A Water Licence.
- Designed to measure compliance with water licence.
- Two major compliance points are discharge from Cell E of the Long Lake Containment Facility (LLCF) and discharge from the King Pond Settling Facility (KPSF).
- If water from the two compliance points does not meet water licence criteria, no water is discharged from the facilities.

Aquatic Effects Monitoring Program

(Annual Report)

- Program is a comprehensive monitoring tool.
- Designed to be sensitive and able to determine changes in the aquatic environment regardless of the cause.
- Provides DDEC with information so that mitigation measures can be evaluated and implemented if required before any changes become a significant environmental impact (Adaptive Management).
- Program designed to determine nature and magnitude of changes.
- Program guidelines are provided in Class A Water Licence, but the program is much more comprehensive and flexible compared to the SNP. Program has been updated in response to stakeholder input and information identified during the past 16 years.

Special Effects Monitoring Programs and Studies

(Annual Report or more frequent)

e.g., Panda Diversion Channel Monitoring Program

- Designed to focus on specific issues or provide additional information not collected as part of the AEMP.
- Designed to meet the needs of other regulatory requirements of the mine (e.g., Fisheries Authorizations).

Environmental Baseline Studies

- Baseline monitoring that is conducted in geographical areas not currently being monitored and where future mining activities may occur.
- Sampling design for aquatics is typically based on AEMP design, as baseline data will form part of future AEMP.

- Hydrocarbon Exposure to Fish – a follow-up study to the results of the 2012 EROD (ethoxyresorufin-Odeethylase) activity analyses which indicated greater hydrocarbon exposure in slimy sculpin and round whitefish which may be related to mine activities. Results from this study will be presented separately from the AEMP.

Baseline studies are carried out on lakes and streams of the DDEC claim block prior to development in order to define background conditions from which mine effects can be assessed. Baseline studies were carried out by Golder Associates in the Jay Pipe area and will be presented separately.

1.3 OVERVIEW OF THE EKATI DIAMOND MINE ACTIVITIES

1.3.1 Koala Watershed

The following major activities took place in the Koala Watershed during the 2013 AEMP period (October 1, 2012 to September 30, 2013):

- Main camp housed an average of 15,914 people per month;
- Construction:
  - The Beartooth Fine-Processed Kimberlite Slurry Pipeline was completed and put into operation January 2013. This is a 4.5 km pipeline that transports fine processed kimberlite (FPK) from the process plant and deposits the material into the mined-out Beartooth Pit. The pipeline is heat-traced to allow year round operation and constructed out of fused together lengths of high-density polyethylene (HDPE) pipe. While some process plant discharge was deposited into the LLCF in all months of 2013, the majority of discharge was diverted to Beartooth pit between February and June, 2013 (see pumping summary below for details);
  - The inlet and outlet sections and related fish habitat features of the Pigeon Stream Diversion channel were completed in the winter of 2013. Consistent with the first phase of construction, the areas were drilled, blasted and excavated to remove the underlying till material, and then back-filled with 6” granite. An engineered liner system was installed, followed by substrate and habitat features. The original Pigeon Stream was kept operating in 2013 and the completed Pigeon Stream Diversion channel was flushed to remove excess sediment materials. Sandbags blocking the PSD were removed at the end of September 2013 immediately prior to freeze-up, effectively opening the PSD. A small amount of construction will be required in the winter of 2013/14 to complete the tie-in sections where flow to the original Pigeon Stream was maintained;
  - Modifications were made to several of the LLCF Cell C FPK discharge spigots to direct material further into the discharge area and allow greater utilization of the available space. These modifications involved lengthening the discharge spigots by adding additional lengths of HDPE pipe;
  - An access road was constructed at the South End of the airport runway to allow equipment access required to service the approach light towers;
  - Construction and improvement activities were completed on the Misery Haul Road. These road improvements were required to allow safe usage of the road by the HaulMax trucks that will transport kimberlite from the Misery Pit back to the Processing Plant. Main construction activities included realigning three areas that contained sharp turns, widening the road in sections that were deemed too narrow for two-way haul traffic, and general improvements to the roadway surface. Additional caribou crossings were installed based on the wildlife data provided by the remote wildlife cameras implemented in 2012; and

  - The construction of the Cell B West Road which began in August of 2011 continued as waste rock became available from the underground mine. The road will provide access to the west side of Cell C so that a pipeline can be built to further maximize tailings storage space.
- Fox Pit:
  - Kimberlite ore was transported to the process plant;
  - Waste rock was transported to the Fox Waste Rock Storage Area; and
  - Kimberlite coarse ore rejects were placed in the coarse kimberlite rejects area of the Panda/Koala Waste Rock Storage Area.
- Beartooth Pit:
  - No mining of Beartooth Pit occurred.
- Panda Pit:
  - No mining of Panda Pit occurred.
- Koala North Pit:
  - Kimberlite ore from underground was transported to the process plant; and
  - Waste rock and kimberlite coarse ore rejects from the underground were transported to the Panda/Koala Waste Rock Storage Area.
- Koala Pit:
  - Kimberlite ore from underground was transported to the process plant; and
  - Waste rock and kimberlite coarse ore rejects from the underground were transported to the Panda/Koala Waste Rock Storage Area.
- Dewatering and Discharge:
  - FPK, surface sump water and treated effluent from the sewage plant continued to be deposited into the LLCF;
  - FPK discharge and underground minewater were pumped to Beartooth Pit (total volume 1,531,563 m^3 and 316,452 m^3 respectively);
  - Grizzly Lake drawdown for use at main camp continued (total volume 94,094 m^3);
  - Water was pumped from Bearclaw to North Panda Lake from July 8, 2013 to July 20, 2013 (total volume 96,300.33 m^3);
  - Water from Cell E of the LLCF was discharged into Leslie Lake from October 1, 2012 to December 18, 2012 (on going from July, 2011) (total volume = 3,363,244.92 m^3) and from June 18, 2013 to September 30, 2013 (total volume = 3,717,624 m^3) at which point discharge was still ongoing; and
  - All water discharged from Cell E to the receiving environment met effluent quality criteria defined in the Water Licence W2009L2-0001 and W2012L2-0001.

1.3.2 The King-Cujo Watershed

The King-Cujo Watershed contains Misery Camp and the KPSF as well as Misery Pit and associated waste rock piles. The following major activities took place in the King-Cujo Watershed during the 2013 AEMP period (October 1, 2012 to September 30, 2013):

- Misery camp was re-opened in April of 2012 and housed an average of 2,245 people per month.

- Misery Pit:
  - Kimberlite ore was transported to the process plant at main camp; and
  - Waste rock was hauled to the Misery Waste Rock Storage Area.
- Dewatering and discharge:
  - Waste Rock Dam water was pumped into the KPSF from July 15 to July 24, 2013 (total volume = 49,149 m^3);
  - No water was pumped from Misery Pit in 2013;
  - Water was pumped from the KPSF to Cujo Lake from July 7 to July 12 (total volume = 66,322.9 m^3);
  - All water pumped from the KPSF to the receiving environment met effluent quality criteria defined in Water Licence W2009L2-0001 and W2012L2-0001; and
  - Desperation Pond water was pumped to Carrie Pond from June 22 to June 27, 2013 (total volume = 24,693.3 m^3). This water also met effluent quality criteria defined in Water Licence W2009L2-0001 and W2012-L2-0001. A fish removal program was carried out in July and August of 2013 in order to remove as many fish as possible from Desperation Pond prior to the infilling half of the pond with waste rock.

The year 2013 was the 16th consecutive year of post-baseline monitoring within the Koala Watershed and Lac de Gras, and the 13th consecutive year of post-baseline monitoring within the King-Cujo Watershed and Lac du Sauvage.

1.4 CHANGES TO EVALUATION OF EFFECTS FOLLOWING THE 2012 RE-EVALUATION

Seven changes were made to the evaluation of effects beginning in 2013, following the 2012 AEMP re-evaluation:

1. The list of evaluated water quality variables was altered to include total barium, total boron, total cadmium, and total vanadium. Meanwhile, total dissolved solids, ortho-phosphate-P, total aluminum, total iron, and total zinc were removed from the list of evaluated variables in both the Koala and King-Cujo watersheds. In the Koala watershed, TOC was added and total copper was removed from the list of evaluated variables.
2. Given that there is now four years of data available, water quality data collected from Leslie-Moose Stream was analyzed in accordance with the analytical approach employed for other water quality stations in the annual AEMP evaluation of effects beginning in 2012. However, the relatively small number of data points available for Leslie-Moose Stream decreases the probability of detecting statistically significant changes in evaluated variables. Thus, graphical analysis was the primary means through which change in evaluated variables and potential mine effects were assessed in Leslie-Moose Stream in 2013.
3. To better distinguish natural variation from potential mine effects in cases where temporal trends in reference lakes do not share a common slope and the trend in the monitored lake differs from a slope of zero, the slope of monitored lakes was compared to the slope of each reference lake in order. Lack of statistical differences between the slope observed in a given monitored lake and at least two reference lakes would indicate natural variability as the underlying cause of temporal trends in the monitored lake. Significant differences between the trend observed in a monitored lake and two or more reference lakes would indicate a potential mine effect. Graphical analysis and best professional judgment were used to assess the likelihood that a given trend resulted from mining operations.

4. To improve model fit of reference lake data, the reference model was selected that best fits the data using AIC to directly compare the ‘fit’ or error associated with each reference model.
5. In the event that both transformed and untransformed data satisfy parametric assumptions, the AIC was used to determine which transformation provides the best fit to the data and used the best fit model in statistical analyses.
6. The coefficient of determination was examined in cases where there is reason to suspect poor model fit for a given variable and waterbody based on graphical analysis. Low R square values would indicate that results of statistical analyses must be interpreted with caution.
7. To provide a more streamlined and explicit discussion on linkages between physical variables and biotic effects as well as trophic effects, the phytoplankton, zooplankton and benthos sections were merged into a single “biology” section (Sections 3.3 and 4.3 in Part 1 – Evaluation of Effects).

2. Methodology

2. Methodology

2.1 2013 SAMPLING LOCATIONS

The 2013 lake and stream sampling sites are provided in Table 2.1-1 and shown in Figure 2.1-1. Surface water flow diagrams through the Koala and King-Cujo watersheds are provided in Figure 2.1-2. Bathymetric maps depicting the sampling locations within each lake are provided in Figures 2.1-3 through 2.1-14 of Part 2 - Data Report.

Table 2.1-1. AEMP Sampling Locations for 2013 to 2015 Period

Location	NAD83 UTM Zone 12N		Approximate Water Column Depth (m)
	Easting (m)	Northing (m)	
Lakes			
Nanuq (Reference)	534200	7199287	28
Counts (Reference)	533825	7169850	15
Vulture (Reference)	521183	7180882	37
Grizzly	521303	7177743	40
Kodiak	518273	7175550	11
Leslie	515938	7173285	13
Moose	516630	7177852	10
Nema	513575	7171132	9
Slipper	507098	7165297	16
S2	507638	7164468	7
S3	505912	7164439	14
Cujo	538721	7162007	8
LdS2	541240	7164235	2
LdS1	541616	7164530	8
Streams			
Nanuq Outflow (Reference)	532197	7199430	
Counts Outflow (Reference)	535488	7169709	
Vulture-Polar (Reference)	521503	7179655	
Lower PDC	518587	7175997	
Kodiak-Little	517943	7174808	
1616-30 (LLCF)	514021	7173081	
Leslie-Moose	516481	7172868	
Moose-Nero	517460	7172818	
Nema-Martine	513921	7170646	
Slipper-Lac de Gras	507643	7164878	
1616-43 (KPSF)	538785	7161359	
Cujo Outflow	538942	7162432	
Christine-Lac du Sauvage	540025	7163840	

1616-30B is the SNP station for discharge from the LLCF (samples are collected within Cell E).
1616-43 is the SNP station for discharge from the KPSF (samples are collected within the facility)

Most of the AEMP sampling locations within the Koala Watershed are located downstream of mine discharge (Figure 2.1-1). Exceptions include Vulture Lake and Vulture-Polar Stream, which are internal reference sites located upstream of mine discharge in the Koala Watershed. Grizzly Lake, Kodiak Lake, Kodiak-Little Stream, and the Lower Panda Diversion Channel (PDC) are also located upstream of the LLCF, but are in close proximity of the mine which leaves them susceptible to effects from mine activities, including activities that took place prior to the establishment of the AEMP. Potential effects at these sites stem from fugitive dust deposition (i.e., from roads, the airstrip, and blasting), road runoff, and the potential for spills. In addition, Kodiak Lake and Kodiak-Little Stream are susceptible to effects associated with the weathering of the PDC, an artificial channel constructed to allow fish passage from North Panda to Kodiak Lake. Kodiak Lake and Kodiak-Little Stream are also susceptible to runoff from the ammonium nitrate building (situated near the western shore of Kodiak Lake). Downstream of the LLCF, all lakes and streams are susceptible to the quantity and quality of water discharged from the LLCF as far as Lac de Gras, which receives water from the Koala Watershed at its northern end. In addition, Nema Lake and Nema-Martine Stream are located near the active Fox Pit and are susceptible to fugitive dust and seepage from Fox Pit and its associated waste rock storage areas.

All AEMP sampling stations in the King-Cujo Watershed are located downstream of the KPSF (Figure 2.1-1). This includes Lac du Sauvage, which receives water from the King-Cujo Watershed along its western shore. The AEMP sampling stations are therefore susceptible to changes in the quantity and quality of water discharged from the KPSF.

The external reference lakes and streams (Nanuq and Counts lakes and their respective outflows) are located well away from any mine activities, outside of the zone of influence of the mine (Figure 2.1-1). Nanuq Lake is located in the northeast corner of the Ekati Diamond Mine's claim block, approximately 26 km from the nearest possible mine influence. Counts Lake is located southeast of the Ekati Diamond Mine Main Camp, approximately halfway between the camp and Misery Pit. The most proximate source of potential mine effects on Counts Lake is Misery Road, which is approximately 5 km from Counts Lake at its closest point.

2.2 2013 SAMPLING PROGRAM

Table 2.2-1 summarizes sampling components, frequency, and replication completed during the ice-covered and open water seasons as part of the 2013 AEMP sampling program.

2.3 VARIABLES EVALUATED IN 2013

The variables evaluated in the 2013 AEMP included the list of variables of interest identified in the AEMP plan for 2013 to 2015 (Tables 2.3-1; Rescan 2013d).

2.4 EVALUATION FRAMEWORK

Evaluation of the AEMP results relies on a hierarchy of steps (Figure 2.4-1). First, data was collected based on the AEMP plan for 2013 to 2015 (Rescan 2013d). The methods and results of the 2013 AEMP sampling program are reported in Part 2 – Data Report of the 2013 AEMP report.

Data were then evaluated for quality. Any large dataset is likely to contain some outliers or questionable records caused by instrument failure, transcription errors, laboratory errors, etc. Thus, questionable data were identified and excluded prior to the evaluation of effects. However, all of the data collected as part of the sampling program, including data that were excluded from subsequent analyses, is presented in Part 2 – Data Report of the 2013 AEMP report.

Figure 2.1-1
AEMP Lake and Stream Sampling Locations, 2013

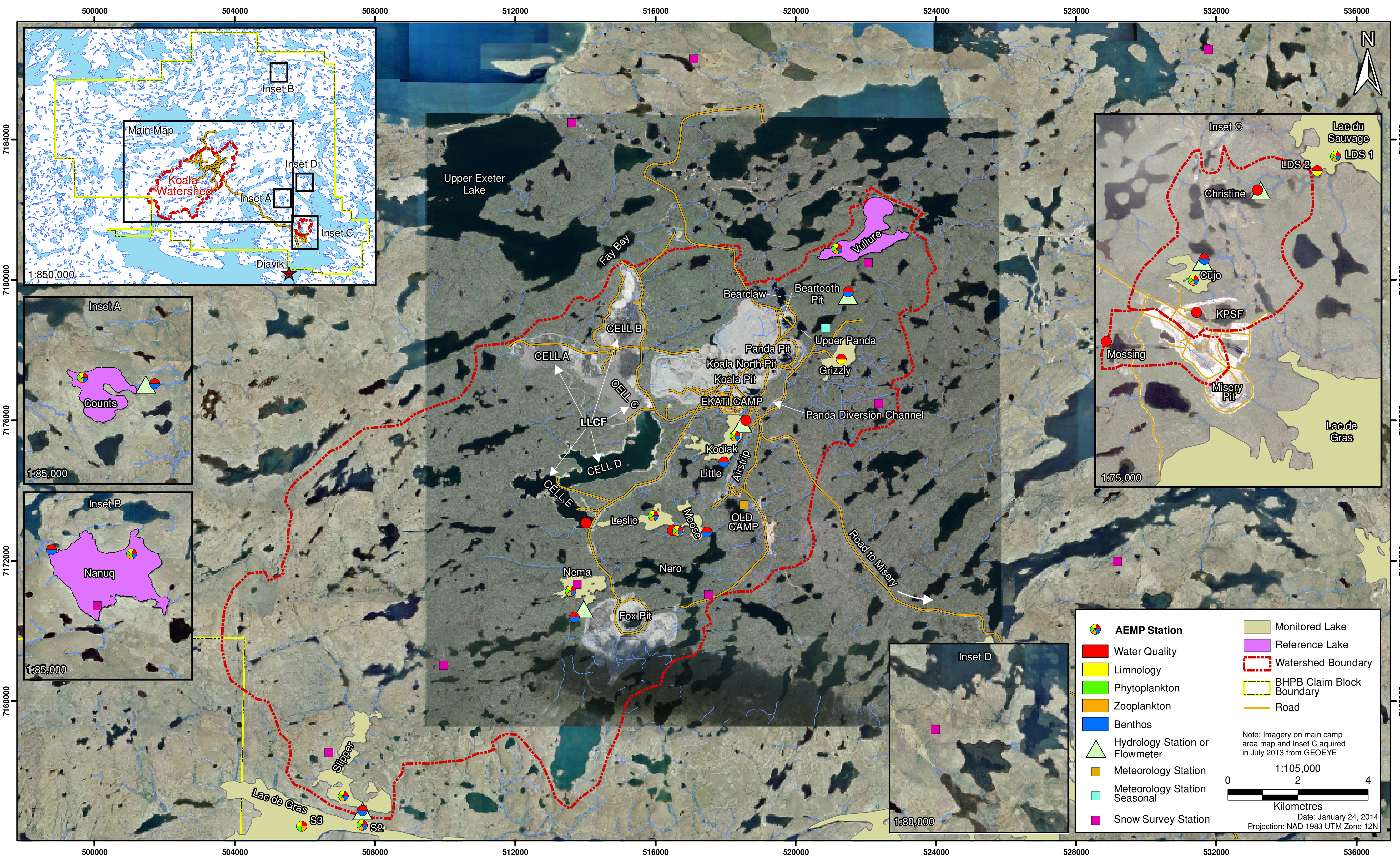


Figure 2.1-2
Surface Water Flow through the AEMP Sampling Area

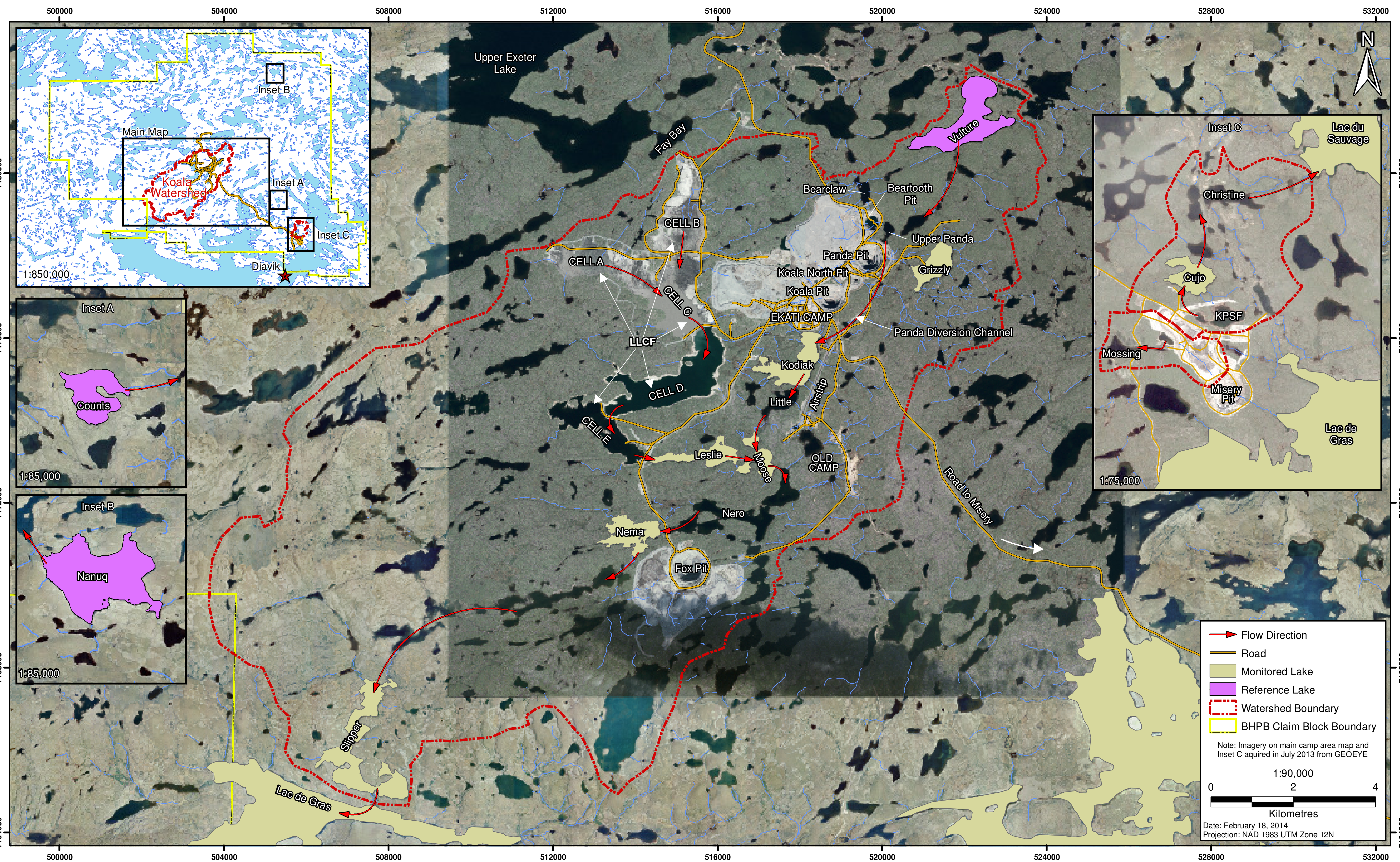


Table 2.2-1. Summary of the 2013 AEMP Sampling Program

Monitoring	Seasonal Frequency	Replication and Depths at each Lake/ Stream per Sampling Event
Lakes		
Water quality	April	n=2 @ mid water column depth
		n=2 @ 2 m from the bottom
	early August	n=3 @ 1 m below surface
		n=3 @ mid water column depth
		n=3 @ 2m from the bottom (Leslie Lake only)
Physical Limnology	April[1]	n=1 profile over deepest part of lake, or at lake station (LdG, LdS)
	early August	n=1 profile over deepest part of lake, or at lake station
Phytoplankton	early August	n=3 @ 1 m
Zooplankton	early August	n=3 vertical hauls from 1 m above bottom to surface, with flowmeter
Benthos	early August	n=3 @ 5-10 m depth (mid)
Streams		
Water quality	freshet (June)	n=2
	July	
	early/mid-August	
	fall high flows (September)	
Benthos	Early August to early September	n=5
Hydrology manual flow measurements	7 or more times per open water season (Late-May to September)	n=7 or more
Automated station installation	installation prior to freshet, maintenance during manual measurements	n=1
Hydrometric levelling surveys	4 or more times, Late-May to August	n=4 or more

n = number of samples or measurements
1: Dissolved oxygen and temperature profiles were collected 6 times throughout the ice-covered season in Cujo Lake.

Table 2.3-1. Aquatic Variables Evaluated in 2013

Physical Limnology - Lakes	Water Quality - Lakes and Streams	Aquatic Ecology
Under-ice dissolved oxygen	<u>Physical/Ions</u>	<u>Phytoplankton</u>
Secchi depth	pH	Chlorophyll *a* concentrations
Open water dissolved oxygen[1]	Total Alkalinity	Phytoplankton density
Hydrology[1,2]	Water hardness	Phytoplankton diversity
	Chloride	Relative densities of major phytoplankton taxa
	Potassium	<u>Zooplankton</u>
	Sulphate	Zooplankton biomass
		Zooplankton density
	<u>Nutrients</u>	Zooplankton diversity
	Total ammonia-N	Relative densities of major zooplankton taxa
	Nitrite-N	<u>Lake Benthos</u>
	Nitrate-N	Lake benthos density
	Total phosphate-P	Lake benthos dipteran diversity
	Total organic carbon	Relative densities of major dipteran taxa
	<u>Metals</u>	<u>Stream Benthos</u>

(continued)

Table 2.3-1. Aquatic Variables Evaluated in 2013 (completed)

Physical Limnology - Lakes	Water Quality – Lakes and Streams	Aquatic Ecology
	Total antimony	Stream benthos density
	Total arsenic	Stream benthos dipteran diversity
	Total barium	Relative densities of major dipteran taxa
	Total boron	Stream benthos EPT diversity
	Total cadmium	Relative densities of EPT taxa
	Total copper[3]	
	Total molybdenum	
	Total nickel	
	Total selenium	
	Total strontium	
	Total uranium	
	Total vanadium	

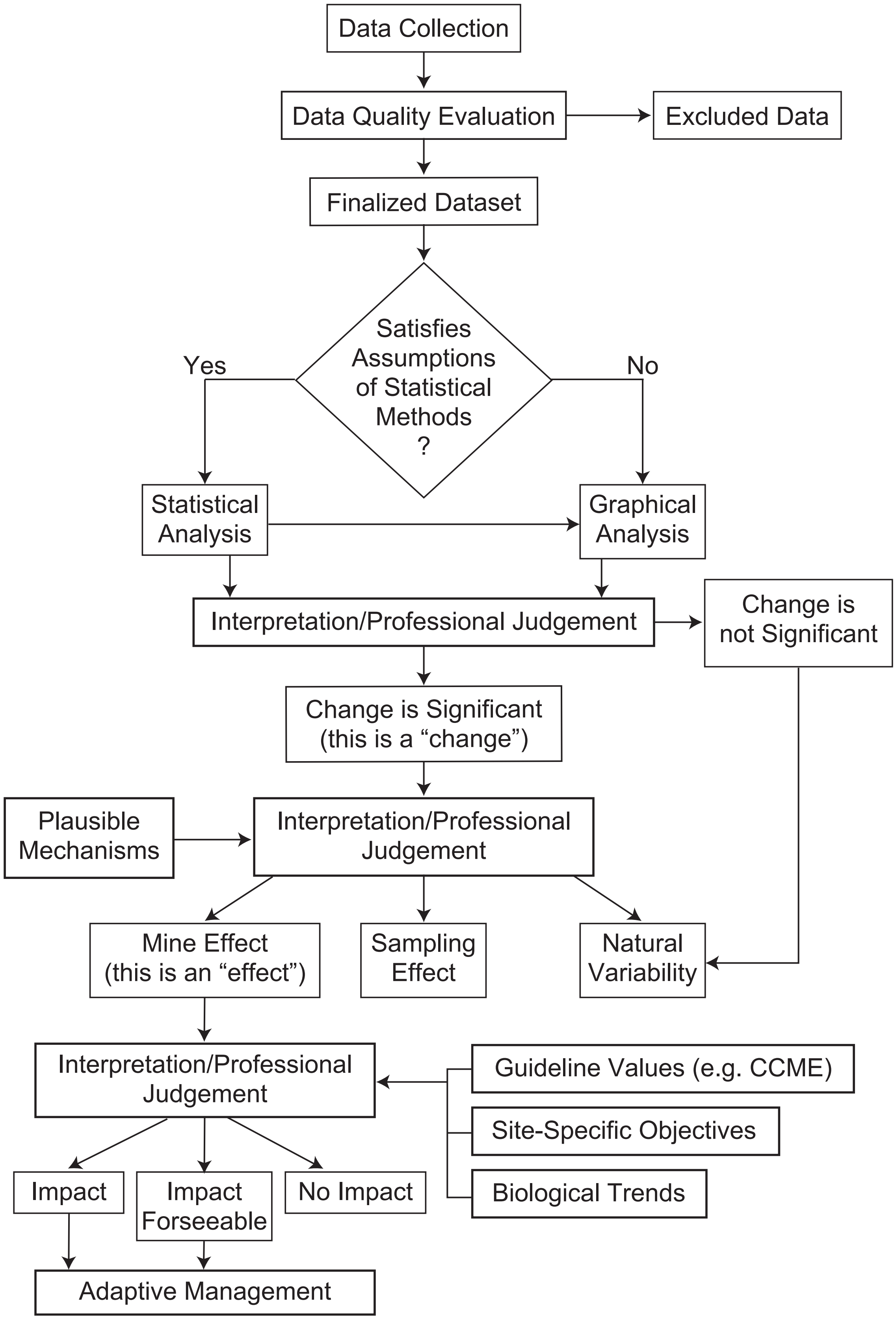
1: Open water season dissolved oxygen and 2013 results are only reported in Part 2 – Data Report and discussed where relevant in Part 1 – Evaluation of Effects.
2: Historical values of key hydrological variables are presented in Section 5 of Part 1 – Evaluation of Effects
3: King-Cujo Watershed only

The finalized dataset was graphically and statistically analysed to detect possible mine effects. Regression modelling was used to detect any changes that might be occurring in lakes and streams through time and also to determine whether temporal patterns differed between monitored and reference sites. Different regression models were applied to different variables depending on the number of years of data that were available and, in the case of water quality, the proportion of data that were greater than the analytical detection limit (see Section 2.2.4 of Part 1 - Evaluation of Effects). If statistical analyses were not possible because assumptions or data requirements were not satisfied, variables were subjected to graphical analysis only (see Section 2.2.5 of Part 1 - Evaluation of Effects). In such cases, aquatic component data were examined for historical trends and spatial gradients.

The results of statistical and graphical analyses were then interpreted using best professional judgment (see Section 2.2.6 of Part 1 - Evaluation of Effects). Graphical analysis was used to confirm and/or interpret conclusions reached by the statistical analysis. The result was an assessment of whether change had occurred and whether the change was ‘significant’, as defined by the statistical and/or graphical analyses.

Changes deemed significant were assessed to determine whether they were likely to be the result of mine activities, sampling activities, or natural variation. The identification of a change as a mine effect required the existence of plausible mechanisms that could link mine activities and change. For example, a mine effect on pH required that there be a clear spatial gradient in pH in the lakes and streams downstream of the LLCF. If reduced pH was found in one lake without corresponding changes in upstream lakes, the change was attributed to natural variation.

If a mine effect was detected, the extent to which the effect was having an impact on the environment was evaluated. Benchmark values (includes applicable CCME guideline values for the protection of aquatic life and relevant SSWQOs) and biological trends were important in the determination of mine impacts (see Section 2.3 of Part 1 - Evaluation of Effects). For example, if a biological effect (such as an increase in phytoplankton density) was associated with increasing concentrations of a water quality variable downstream of the LLCF for which a CCME guideline value or SSWQO was exceeded, the effects would likely be deemed an environmental impact. Impacts or foreseeable impacts would then lead to appropriate adaptive management measures.


Data Collection
Data Quality Evaluation
Excluded Data
Finalized Dataset
Satisfies Assumptions of Statistical Methods ?
Yes
No
Statistical Analysis
Graphical Analysis
Interpretation/Professional Judgement
Change is not Significant
Change is Significant (this is a "change")
Plausible Mechanisms
Interpretation/Professional Judgement
Mine Effect (this is an "effect")
Sampling Effect
Natural Variability
Interpretation/Professional Judgement
Guideline Values (e.g. CCME)
Site-Specific Objectives
Biological Trends
Impact
Impact Forseeable
No Impact
Adaptive Management

3. General Climatic and Hydrological Conditions in 2013

3. General Climatic and Hydrological Conditions in 2013

3.1 CLIMATIC CONDITIONS

The meteorological monitoring program at the Ekati Diamond Mine in 2013 included the operation of the Koala automated meteorological station, which has been in continuous operation since 1993, and the micrometeorological station on Polar Lake. During the winter of 2012/2013, DDEC Environment personnel monitored a Nipher Snow Gauge at the Koala meteorological station to generate monthly totals for snow-water-equivalent (SWE) precipitation. In addition, snow surveys were completed between April 22 and April 26, 2013 at twelve locations within the Ekati Diamond Mine claim block. See Part 2 - Data Report (Section 3.1) for a detailed account of meteorological monitoring as part of the 2013 AEMP.

The 12-month (October 2012 to September 2013) mean air temperature was -9.6°C at the Koala station; this is about half a degree warmer than the 12-month mean for the Kugluktuk station (Tables 3.1-2 and 3.1-3 of Part 2 – Data Report) and 1.2°C warmer than the Climate Normal (Table 3.1-2 of Part 2 – Data Report). Across Canada, the 2012/2013 winter temperature was 1.6°C above normal, making it the 18th warmest winter on record. A similar pattern was observed for the Mackenzie District (which includes the Ekati Diamond Mine), where 2012/2013 winter temperatures were 0.7°C above normal. The last time the Mackenzie District had a cooler than normal winter was 1993/1994 (Environment Canada 2013).

Observations at the Koala Nipher Snow Gauge between October 2012 and May 2013 produced snow-water-equivalent (SWE) estimates of 164 mm (uncorrected for wind effects), or 186 mm (corrected for wind effects; Table 3.1-4 of Part 2 – Data Report). The differences between these values illustrate the uncertainty associated with monitoring snow fall. A snow survey conducted at 12 sampling stations around the Ekati Diamond Mine claim block in late April 2013 yielded a mean SWE value of 43.2 mm (Table 3.1-5 of Part 2 – Data Report). This indicates that while 164 to 186 mm of snow may have fallen, a substantial portion of the snow pack is lost to sublimation and/or evaporation. The snow survey value of 43.2 mm represents the volume available for snow melt runoff during the freshet.

October 2012 to September 2013 recorded a total of 185 mm of rain at the Koala station (Table 3.1-6 of Part 2 – Data Report). Combining winter SWE (uncorrected Nipher) and summer rain, produces a total precipitation of 348 mm during the 2013 water year (October 1, 2012 to September 30, 2013; Tables 3.1-7 and 3.1-8 of Part 2 – Data Report), which is almost equal to the expected mean of 345 mm for the Ekati Diamond Mine site (Rescan 2000). Rainfall between June and August accounted for 77% of the total annual rainfall. Rainfall made up 53% of the total precipitation over the entire year. The Mackenzie District was dryer than normal in all seasons, including the driest winter and 3rd driest spring on record (66 years), with 37% and 39% less precipitation than normal in winter and spring, respectively (Environment Canada 2013).

Wind speed and direction data collected from the Koala station indicate that the prevailing wind direction during the 2012/2013 winter was from the west-northwest with a secondary component from the east (Figure 3.1-1 of Part 2 – Data Report). During the summer, the wind directions had a primarily east-northeastern component, and were more omnidirectional than in the winter (Figure 3.1-1 of Part 2 – Data Report). Calm conditions (hourly mean wind speeds of < 1.0 m/s) represented 6.2% of winter observations, and only 1.9% of summer observations.

The Polar Lake micro-meteorological station was mobilized on July 9, 2013 and taken down on September 30, 2013 (Table 3.1-9 of Part 2 – Data Report). The high latitude and continental climate of the Ekati Diamond Mine area combine to produce long, sunny days providing abundant energy to drive evaporation during the summer season. Using the Penman equation, open-water evaporation at the Polar Lake station was calculated to be 183 mm for the ice-free period (assumed to be from May 19 to October 20) with the exclusion of May, June and October as a result of missing evaporation data (Table 3.1-10 of Part 2 – Data Report).

3.2 HYDROLOGICAL CONDITIONS

Streamflow monitoring was undertaken in 2013 at four streams within the Koala Watershed (Vulture-Polar Lower PDC, Nema-Martine and Slipper-Lac de Gras), and two streams within the King-Cujo Watershed (Cujo Outflow and Christine Outflow), along with one reference watershed (Counts Outflow). Automated hydrometric monitoring stations were installed from late May to early June, and operated until late September, when stations were demobilized for winter.

Manual streamflow and concurrent stage measurements were conducted at each station approximately biweekly throughout the open water season, and more frequently during freshet high flows. Stage-discharge measurements were used to develop geometric relationships and construct rating curves for each station. Additionally, cross-sectional geometry surveys were conducted to support development of the stage-discharge curves. The cross sections surveyed at the stations will be used to monitor the stability of hydraulic controls at each monitoring location in subsequent years.

The 2013 hydrologic year began in mid-October 2012 and ended in mid-October 2013. Following winter, daily average air temperature rose above zero for the first time on May 19, 2013. There was a brief cooling period from May 21 to 23 when temperatures dropped below zero, after which conditions warmed again. Long days in late May/early June provided large amounts of solar energy to generate snow melt runoff, and the frozen ground inhibited infiltration. The majority of snowmelt and runoff occurred in the first week of June. As a result, discharge rose very quickly at the start of the freshet season. Streamflow began at the Lower PDC: the first AEMP stream to begin flowing in the area each year.

Hydrometric stations were installed between the last week of May and the first week of June. As a result, peak flow conditions were only recorded at Counts Outflow, where the peak flow occurred on June 8. The hydrograph freshet rising limb rose rapidly at Counts Outflow (Figure 3.2-7 of Part 2 – Data Report), and similarly steep rising limbs likely occurred at all other monitored sites. In 2013, between 43% and 84% of the annual runoff occurred in May and June (Figure 3.2-8 of Part 2- Data Report; see also Table 6-2 in Part 1 – Evaluation of Effects). Based on air temperature records on-site, winter freeze up is assumed to have occurred at all of the monitored streams by approximately October 20, 2013.

During the hydrologic year, 348 mm of precipitation fell in the EKATI Diamond Mine area (Table 3.1-7 of Part 2 – Data Report), close to the normal value of 345 mm. Several large rain events occurred in the summer and fall of 2013: on July 11 (29 mm), July 26 (15 mm), August 19 (17 mm) and September 9 (16 mm).Total runoff in 2013 varied from 87 mm at Christine-Lac du Sauvage to 135 mm at the PDC (Table 3.2-17 of Part 2 – Data Report). Maximum daily discharges varied from 0.137 m^3/s at Counts Outflow to 10.125 m^3/s at Slipper-Lac de Gras Stream (Table 3.2-16 of Part 2 – Data Report). Most runoff occurs during freshet (Figures 3.2-1 to 3.2-7 of Part 2 – Data Report), with the exception of Cujo Outflow, which is influenced to a larger degree by pumping from the KPSF (Table 3.2-18 of Part 2 – Data Report). Pumping of 96,300 m^3 of water from Bearclaw Lake to North Panda Lake between July 8 and 20 is also evident in the Lower PDC hydrograph (Figure 3.2-2 of Part 2 – Data Report).

4. Summary of Evaluation of Effects for the Koala Watershed and Lac de Gras

4. Summary of Evaluation of Effects for the Koala Watershed and Lac de Gras

Figure 4-1 summarizes the evaluation of effects for the Koala Watershed and Lac de Gras. Because statistical tests were two-sided and only tested for differences between reference and monitored lakes, conclusions on the direction of change were made from graphical analysis. Figures 4-2 to 4-39 provide support for the summary of effects for the Koala Watershed lakes and Lac de Gras presented below. For a discussion of graphical and regression analysis that were used to assist in interpreting statistical results for each of the variables see Part 1 – Evaluation of Effects.

Under-ice temperature profiles suggest that there has been a trend towards cooling in all lakes downstream of the LLCF as far as Nema Lake (Figure 4.2a to 4.3h). Although the cause of this shift is unclear, there is also some evidence of a general cooling trend, at all depths, in two of the reference lakes (i.e., Nanuq and Vulture lakes; Figures 4.2a and 4.3c) in recent years, suggesting that shifts in temperature profiles in monitored lakes may reflect natural climatic variability rather than mine effects. In Grizzly Lake, the shape of the temperature profile has changed in recent years. Specifically, from 2011 to 2013, under-ice temperature profiles in Grizzly Lake showed some degree of thermal stratification, with cooler surface temperatures (Figure 4.3a). The cause of the change in Grizzly Lake is unclear; however, thermal stratification was also observed in Vulture Lake in 2013 (Figure 4.2c), the one reference lake that is as deep as Grizzly Lake, suggesting that the change in the Grizzly Lake thermal profile may also reflect natural climactic variability, rather than mine effects. In contrast, a warming trend was detected in Kodiak Lake, along with corresponding changes in dissolved oxygen profiles (Figure 4.3b). The observed changes in Kodiak Lake likely stem from DDEC's efforts to improve dissolved oxygen concentrations in Kodiak Lake, which have included the use of aerators beginning in 1997. The changes in the under-ice temperature and DO profiles in Kodiak Lake correspond to the first year in which aerators were no longer used (2007). The current, stratified DO profiles likely represent undisturbed conditions in Kodiak Lake: aerators would cause mixing of the water column which would result in homogeneity of temperature and dissolved oxygen throughout the water column. Despite changes in under-ice profiles, open water season temperature and dissolved oxygen profiles in all monitored lakes were similar to previous years in all lakes. Secchi depths were also similar to those observed in previous years.

Grizzly Lake is the source of potable water for the Ekati Diamond Mine's Main Camp and was added to the statistical evaluation of effects for the AEMP in 2009. At present, biological variables and sediment quality are not monitored in Grizzly Lake as part of the AEMP. However, the change in the shape of the temperature profile may have implications for biological communities. Most species have thermal optima (i.e., temperature ranges over which they thrive) (Kravtsova 2000). All ectothermic organisms (i.e., organisms that do not generate their own body heat) are sensitive to changes in temperature, with increases in temperature resulting in higher basal metabolic rates, higher activity levels, shorter lifespans, and smaller body sizes (Angilletta 2010). Thus, changes in temperature can cause shifts in community composition and food web dynamics (Gillooly et al. 2001; Brown et al. 2004; Kingsolver and Huey 2008). Biological variables (i.e., phytoplankton, zooplankton, and benthos) were assessed in Grizzly Lake in 2013 to examine if any changes in biological communities were observed that may be related to the change in temperature profile and results are summarized in Section 6.3.

Figure 4-1

Summary of Mine-related Changes in the Variables Evaluated for the Koala Watershed and Lac de Gras, 2013

ERM

Water Quality

LLCF → Downstream

	Grizzly	Lower PDC	Kodiak	Kodiak-Little	Leslie	Leslie-Moose	Moose	Moose-Nero	Nema	Nema-Martine	Slipper	Slipper-Lac de Gras	Lac de Gras S2	Lac de Gras S3
Under-ice Temperature	◆	●	◆	●	◆	●	—	●	◆	●	—	●	—	—
Under-ice Dissolved Oxygen	—	●	◆	●	—	●	—	●	—	●	—	●	—	—
Secchi Depth	—	●	—	●	—	●	—	●	—	●	—	●	—	—
pH	≠	—	—	—	↑0-25%	↑0-25%	↑0-25%	↑0-25%	↑0-25%	↑0-25%	↑0-25%	↑0-25%	↑0-25%	↑0-25%
Total Alkalinity	—	—	—	—	↑76-100%	↑26-50%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑51-75%	↑51-75%	↑76-100%	—
Water Hardness	—	—	—	—	↑51-75%	—	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑51-75%
Chloride	—	—	—	—	↑76-100%	↑0-25%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%
Sulphate	—	—	↑51-75%	—	↑76-100%	↑26-50%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑51-75%
Potassium	—	—	—	—	↑76-100% ¥	↑26-50%	↑76-100% ¥	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑51-75%
Total Ammonia-N	—	—	—	—	↑76-100%	—	—	—	—	↑51-75%	—	—	—	—
Nitrite-N	—	—	—	—	↑76-100%	↑0-25%	↑76-100%	↑51-75%	—	—	—	—	—	—
Nitrate-N	—	—	—	—	↑76-100%	↑0-25%	↑76-100%	↑51-75%	↑76-100%	↑76-100%	↑51-75%	—	—	—
Total Phosphate-P	—	—	—	—	↑76-100% *	—	↑76-100% *	—	*	—	*	—	¥	—
Total Organic Carbon	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Antimony	—	—	—	—	—	↑0-25%	↑51-75%	↑51-75%	—	—	—	—	—	—
Total Arsenic	—	—	—	—	↑51-75%	↑26-50%	↑51-75%	—	—	—	—	—	—	—
Total Barium	—	—	—	—	↑51-75%	—	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	—
Total Boron	—	—	—	—	↑76-100%	↑26-50%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	—	—	—
Total Cadmium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Molybdenum	—	—	—	—	↑76-100%	↑0-25%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%
Total Nickel	—	—	↑51-75%	↑26-50%	↑76-100%	↑0-25%	↑76-100%	↑76-100%	↑51-75%	↑51-75%	—	—	—	—
Total Selenium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Strontium	—	—	—	—	↑76-100%	↑0-25%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑76-100%	↑51-75%
Total Uranium	—	—	—	—	↑76-100%	↑26-50%	↑76-100%	↑76-100%	↑76-100%	↑51-75%	—	—	—	—
Total Vanadium	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Biology

LLCF → Downstream

	Grizzly	Lower PDC	Kodiak	Kodiak-Little	Leslie	Leslie-Moose	Moose	Moose-Nero	Nema	Nema-Martine	Slipper	Slipper-Lac de Gras	Lac de Gras S2	Lac de Gras S3
Phytoplankton														
Chlorophyll *a* Concentration	—	●	—	●	—	●	—	●	—	●	—	●	—	—
Phytoplankton Density	—	●	—	●	—	●	—	●	—	●	—	●	—	—
Phytoplankton Diversity	—	●	—	●	↓0-25%	●	—	●	—	●	—	●	—	—
Relative Densities of Major Phytoplankton Taxa	—	●	—	●	◆	●	◆	●	◆	●	◆	●	◆	—
Zooplankton														
Zooplankton Biomass	—	●	—	●	—	●	—	●	—	●	—	●	—	—
Zooplankton Density	—	●	—	●	—	●	—	●	—	●	—	●	—	—
Zooplankton Diversity	—	●	—	●	↑76-100%	●	↓0-25%	●	↓51-75%	●	—	●	—	—
Relative Densities of Major Zooplankton Taxa	◆	●	—	●	◆	●	◆	●	◆	●	—	●	—	—
Benthos														
Lake Benthos Density	—	●	—	●	—	●	—	●	—	●	—	●	—	—
Lake Benthos Dipteran Diversity	—	●	—	●	—	●	—	●	—	●	—	●	—	—
Lake Benthos Dipteran Relative Density	—	●	—	●	◆	●	◆	●	◆	●	—	●	◆	—
Stream Benthos Density	●	●	●	●	●	—	●	—	●	—	●	—	●	●
Stream Dipteran Diversity	●	●	●	●	●	—	●	—	●	—	●	—	●	●
Stream Benthos Dipteran Relative Density	●	●	●	●	●	—	●	—	●	—	●	—	●	●
Stream Benthos EPT Diversity	●	●	●	●	●	—	●	—	●	—	●	—	●	●
Stream Benthos EPT Relative Density	●	●	●	●	●	—	●	—	●	—	●	—	●	●

Notes:

The direction and degree of change was inferred from historical data. For water quality data, differences were assessed relative to data from 2000 (August lakes and streams), 2002 (April lakes), the first year in which data was collected (i.e., TOC = 2005; chloride in streams = 2001). The season in which the greatest change occurred (i.e. April or August) is represented in the table. For phytoplankton and zooplankton data, differences were assessed relative to the first year in which data was collected (i.e. 2003 for Leslie Lake) or to baseline years (Moose and Nema lakes).

For water quality data, % change was calculated as 1-(historical concentration/current concentration). For biology data, % change was calculated as (current concentration-historical concentration)/historical concentration.

** Indicates that the upper bound of the 95% CI exceeded the SSWQO, water quality benchmark, or CCME guideline value during the ice-covered or open water season.*
≠ Indicates that the observed mean was less than the lower CCME guideline value for pH during the ice-covered or open water season.
¥ Indicates that the observed mean exceeded the SSWQO, water quality benchmark, or CCME guideline value during the ice-covered or open water season.

Legend:

Increased over time in comparison to reference lakes/streams or different from a constant*
↑ 0-25% ↑ 26-50% ↑ 51-75% ↑ 76-100%
Decreased over time in comparison to reference lakes/streams or different from a constant*
↓ 0-25% ↓ 26-50% ↓ 51-75% ↓ 76-100%
— Did not change over time or differ significantly over time from reference lakes/streams
● Variable was not sampled at this lake/stream
◆ Changed over time

Twenty-two water quality variables were evaluated in the 2013 AEMP for the Koala Watershed and Lac de Gras. Of these, concentrations of 18 variables have changed in lakes or streams in the Koala Watershed or Lac de Gras (Figure 4-1):

- pH (downstream to Lac de Gras site S3)
- total alkalinity (downstream to Lac de Gras site S2)
- water hardness (downstream to Lac de Gras site S3)
- chloride (downstream to Lac de Gras site S3)
- sulphate (downstream to Lac de Gras site S3; Kodiak Lake)
- potassium (downstream to Lac de Gras site S3)
- total ammonia-N (downstream to Slipper Lake)
- nitrite-N (downstream to Moose-Nero Stream)
- nitrate-N (downstream to Slipper Lake)
- total phosphate-P (downstream to Moose Lake)
- total antimony (downstream to Moose-Nero Stream)
- total arsenic (downstream to Moose Lake)
- total barium (downstream to Lac de Gras site S2)
- total boron (downstream to Slipper Lake)
- total molybdenum (downstream to Lac de Gras site S3)
- total nickel (downstream to Nema-Martine Stream; Kodiak Lake and Kodiak-Little Stream)
- total strontium (downstream to Lac de Gras site S3)
- total uranium (downstream to Nema-Martine Stream)

Although concentrations of eight water quality variables (water hardness, sulphate, total ammonia-N, total nitrate-N, total antimony, total barium, total molybdenum, and total nickel) have stabilised at some sites in recent years during either the ice-covered or open water season, concentrations remain elevated above baseline or reference concentrations in all 18 cases. The extent to which concentrations have changed through time generally decreases with downstream distance from the LLCF. Patterns were similar during the ice-covered and open water seasons, though concentrations were sometimes greater during the ice-covered season as a consequence of solute exclusion during freeze up. In reference lakes, concentrations of water quality variables have generally been low and stable through time. Together, the evidence suggests that the observed changes in concentrations in the 18 water quality variables identified in Figure 4-1 in lakes and streams that are downstream of the LLCF are mine effects that stem from the discharge of water from the LLCF into the receiving environment under Water Licence W2012L2-0001. In monitored lakes and streams that are not downstream of the LLCF (i.e., Grizzly Lake, Kodiak Lake and associated streams), only two water quality variables have increased through time: sulphate has increased in Kodiak Lake and total nickel has increased in Kodiak Lake and Kodiak-Little.

CCME guidelines for the protection of aquatic life exist for nine of the evaluated water quality variables, including pH, total ammonia-N, nitrite-N, total arsenic, total boron, total cadmium, total nickel, total selenium, and total uranium (CCME 2013). In addition, DDEC has established a SSWQO for six of the evaluated variables, including chloride, sulphate, potassium, nitrate-N, total molybdenum, and total vanadium. Total phosphate concentrations were compared to lake-specific benchmark trigger values that were established using guidelines set out in the Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems, the Ontario Ministry of Natural Resources, and Environment Canada (Ontario Ministry of Natural Resources 1994; CCME 2004; Environment Canada 2004). Other water quality benchmarks exist for total antimony, total barium, and total strontium. In general, the 95% confidence intervals around the fitted mean and the observed mean concentrations were below their respective CCME guideline value, SSWQO, and relevant benchmark value except for pH, total phosphate-P, and potassium (Figure 4-1). For pH and total phosphate-P, levels and concentrations in reference lakes or streams also exceeded CCME guidelines, suggesting that exceedences are not related to mine activities. In contrast, potassium exceedences were unique to the two most upstream monitored lakes and are thus likely related to mine activities.

Results from water quality analyses in the Koala Watershed and Lac de Gras suggest that changes might be expected in biological communities downstream of the LLCF as far as site S3 in Lac de Gras. However, concentrations of water quality variables that have increased in monitored lakes at the Ekati Diamond Mine for which SSWQO or species sensitivity-based CCME guidelines exist were reviewed as part of the 2012 AEMP Re-evaluation with a specific focus on identifying possible chronic toxic effects on species present in the receiving environment at the Ekati Diamond Mine (Rescan 2012b). As in previous years, concentrations of all the water quality variables in the Koala Watershed and Lac de Gras in 2013 remained below the lowest identified chronic effect level for the most sensitive species; the only exception in 2013 was potassium (Rescan 2012c). In Leslie and Moose lakes, the observed mean potassium concentrations exceeded the potassium SSWQO (41 mg/L; Rescan 2012c) during the ice-covered season. In Leslie Lake, the upper 95% confidence interval of the fitted mean during the ice-covered season also exceeded the lowest identified chronic effect level of 53 mg/L for the most sensitive species (i.e., *Daphnia magna*) (see Section 3.2.4.6 of Part 1 - Evaluation of Effects; Biesinger and Christensen 1972). Potassium plays an important role in nerve function and is therefore required by many aquatic species (Environment Canada 2002). However, potassium can become toxic at elevated concentrations, and is substantially more toxic than other major ions of earth metals (i.e., magnesium, calcium, and sodium). However, potassium toxicity may decrease as the total ion concentration increases as a consequence of strong interactions with other metals (Trotter 2001).

Concentrations of nutrients are among the water quality variables that have changed through time in the Koala Watershed and changes in nutrients can have an effect on the composition of biological communities that are not related to toxic effects. Accumulating research suggests that the ratio of available elements, especially macronutrients like carbon (C), nitrogen (N), and phosphorous (P), can play an important role in determining community composition and relative abundance by providing a competitive advantage to taxa whose relative elemental requirements best match current conditions (Sterner et al. 1997; Dobberfuhl and Elser 2000; Elser et al. 2000). For example, relatively low nitrogen environments favour phytoplankton species that are capable of fixing nitrogen (i.e., blue-green algae) while those that can take up nitrogen directly from the environment thrive when the relative availability of nitrogen increases (i.e., diatoms; Tillman et al. 1986).

The ratio of available nutrients in the Koala Watershed has shifted through time as nitrogen levels have increased. This coincides with the overall results of the 2012 AEMP Re-evaluation, which suggested that observed changes in biological community composition at the Ekati Diamond Mine likely resulted from inter-specific differences in the competitive ability of different taxonomic groups under changing quantities or ratios of macronutrients like nitrogen or phosphorus, rather than elemental toxicity (Rescan 2012b). As the trends in the evaluated water quality variables in 2013 were consistent with those observed in the 2011 and 2012 AEMP (Rescan 2012a, 2013b) it was expected that the relative availability of macronutrients would continue to be the dominant driver of change in biological communities; however, increasing potassium concentrations could also play a role in explaining changes to species composition observed in 2013. Increasing potassium concentrations may be particularly important for changes in zooplankton composition as the most sensitive species identified in the development of the SSWQO was the cladoceran *Daphnia magna* (Biesinger and Christensen 1972; Rescan 2012c).

Five changes in biological variables were observed in 2013 (Figure 4-1):

- Altered phytoplankton genera diversity in Leslie Lake (Figure 4-22);
- Altered taxonomic composition of phytoplankton assemblages in lakes downstream of the LLCF as far as site S2 in Lac de Gras (Figures 4-23 to 4-28);
- Decreased zooplankton diversity in lakes downstream of the LLC as far as Nema Lake (Figure 4-29);
- Altered taxonomic composition of zooplankton assemblages in Leslie, Moose, and Nema lakes (Figures 4-30 to 4-33b); and
- Altered taxonomic composition of lake benthos communities in lakes downstream of the LLCF as far as Nema Lake, and at site S2 in Lac de Gras (Figures 4-34 to 4-39).

Phytoplankton diversity has been stable through time in all monitored lakes of the Koala Watershed and Lac de Gras, except Leslie Lake. Phytoplankton diversity in Leslie Lake decreased from 2006 to 2011, but has returned to historical levels in 2013. Phytoplankton community composition has shifted in all lakes downstream of the LLCF as far as site S2 in Lac de Gras, with a decrease in the relative densities of Myxophyceae (blue-green algae) and an increase in the proportion of Bacillariophyceae (diatoms) through time. This shift from blue-green algae to diatoms is likely related to changes in nitrate-N concentrations, which also show a spatial gradient with downstream distance from the LLCF following the onset and subsequent expansion of underground mining operations in 2002 (see Section 3.2.4.9 of Part 1 – Evaluation of Effects).

The shift in phytoplankton community composition and associated increase in nitrogen in lakes downstream of the LLCF has been recognized for some time and DDEC has undertaken a number of adaptive management actions to reduce the amount of nitrate-N released into the receiving environment. These include the diversion of underground mine water to Beartooth Pit and the addition of phosphorous to Cell D of the LLCF to stimulate nitrogen uptake by phytoplankton (Rescan 2010, 2011a). Recent trends in nitrate-N in Cell D and Koala Watershed lakes suggest that such mitigation measures may be working because nitrate-N concentrations have stabilised in recent years (Rescan 2011a). Although water quality modelling predicts that nitrate concentrations will continue to increase in the LLCF and Koala Watershed lakes downstream of the LLCF (Rescan 2012d), results suggest that nitrogen concentrations have remained stable in 2013 (see Section 3.2.4.9 of Part 1 – Evaluation of Effects).

A second shift in phytoplankton community composition, toward increased densities of Chlorophyceae, was observed in Leslie Lake from 2010 to 2012 and in Nema and Slipper lakes in 2013 (Figure 3.3-4 and 3.3-7). This second shift in primary producer community composition may be explained by the addition of phosphorous to Cell D of the LLCF from 2009 to 2011 as an adaptive management response to increased nitrate concentrations (Rescan 2011b). The addition of phosphorous to the LLCF ceased in 2011 and in 2013, the phytoplankton assemblage in Leslie Lake returned toward historic community compositions. The increase in Chlorophyceae observed further downstream, in Nema and Slipper lakes, in 2013 may reflect a spatiotemporal lag in the effect of phosphorous additions to Cell D of the LLCF. Chlorophyceae are known to outcompete diatoms at intermediate ratios of N:P (Tillman et al. 1986; Lagus et al. 2004). In addition, concentrations of all the evaluated water quality variables in the Koala Watershed have remained below the lowest identified chronic effect level for the most sensitive species, except potassium (Rescan 2012b, 2012c). However, there was no evidence that elevated potassium concentrations have led to declines in the density of the most sensitive species (see Section 3.3.2 of

Part 1 – Evaluation of Effects). Thus, the correlations between changes in phytoplankton community composition and increases in some water quality variables (e.g., chloride, sulphate, potassium, total arsenic, etc.) may reflect shifts in the relative availability of macronutrients at the Ekati Diamond Mine, rather than species sensitivities to changes in water quality variables.

Overall, the main changes in phytoplankton community composition observed in lakes downstream of the LLCF has been a shift from blue-green algae to diatoms. Such a shift may cause cascading effects through the foodweb, where changes in phytoplankton composition may be associated with changes in the proportion of edible phytoplankton or the nutritional quality of phytoplankton. Diatoms generally have a higher fatty acid content than blue-green algae, which renders them a better quality food for herbivorous zooplankton (Lamberti 1996 as in Wehr and Sheath 2003). This may lead to changes in the nutrient content, abundance, or taxonomic composition of zooplankton, which may, in turn, cascade upward to affect higher trophic levels from secondary consumers to top predators like fish. While dominant taxa in reference lakes consist mostly of inedible organisms, dominant taxa at sites downstream of the LLCF (as far as site S3 in Lac de Gras) include large fractions of edible species from the genus *Cyclotella* (see Table 3.5-3 in Part 2 – Data Report).

Although zooplankton biomass and density have been stable through time in all monitored and reference lakes, zooplankton diversity has declined in lakes downstream of the LLCF as far as Nema Lake. Declines in zooplankton diversity have been associated with a shift in community composition that extends as far as Nema Lake. In these lakes, cladocerans (particularly *Holopedium gibberum*) and rotifers (particularly *Conochilus sp.* and *Kellicottia longispina*) have been replaced, to an extent, by copepods. Although diversity increased in Leslie Lake in 2013, the zooplankton community remained dominated by copepods. In contrast, rotifers showed signs of recovery in Nema Lake in 2013, with *K. longispina* dominating community composition to such an extent that zooplankton diversity was relatively low in Nema Lake in 2013. Similar to phytoplankton communities, overall shifts in zooplankton communities showed some evidence of tracking changes in the relative availability of macronutrients, with the relative densities of consumers with high somatic N:P ratios increasing through time and with spatial proximity to the LLCF (e.g., calanoid and cyclopoid copepods; Dobberfuhl and Elser 2000; McCarthy, Donohue, and Irvine 2006). To date, there is no evidence that elevated potassium concentrations have led to a decline in the density of *Daphnia* sp. in Leslie or Moose lakes. Thus, the observed changes in zooplankton community composition are likely driven, ultimately, by changes in the availability of macronutrients including nitrogen and phosphorus in lakes downstream of the LLCF, rather than toxic effects.

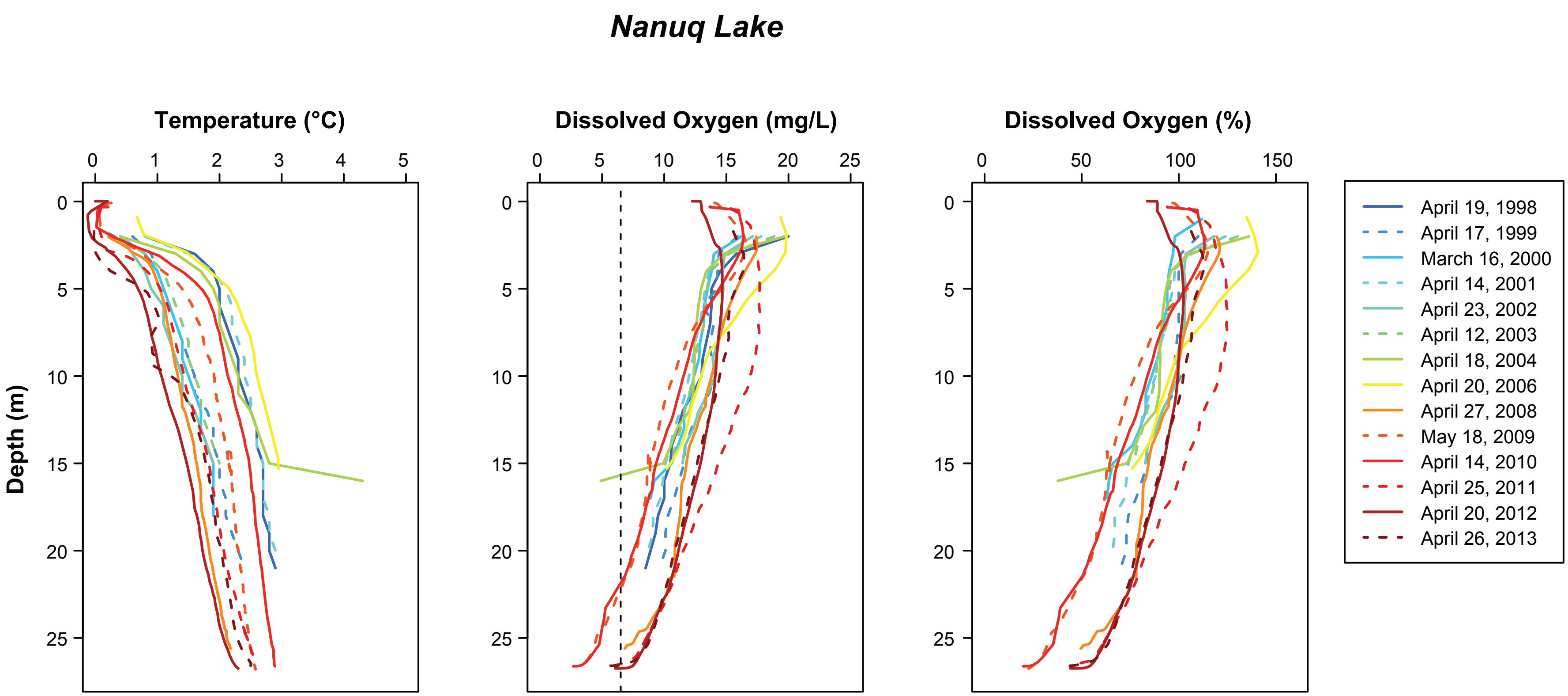
Lake benthos density, dipteran diversity, and dipteran community composition have been variable through time in all monitored and reference lakes. However, the relative densities of dipteran taxonomic communities have changed through time in Leslie and Moose lakes, a pattern that was first identified through the multivariate analyses conducted as part of the 2012 AEMP Re-evaluation (Rescan 2012b) In these lakes, the relative densities of organisms from the Chironomidae subfamily Orthocladiinae (likely from the genera *Rheocricotopus* and *Psectrocladius*) have decreased, while densities of Diamesinae (most likely organisms from the genus *Protanypus*), Prodiamesinae (most likely organisms from the genus *Monodiamesa*), and Chironominae (most likely organisms from the genera *Cladotanytarsus* and *Stempellinella*) have increased through time. Most of these shifts in taxonomic composition began around 2005. In addition, more recent changes in dipteran community composition have been observed in Nema Lake and site S2 in Lac de Gras. Similar to Leslie and Moose lakes, densities of Orthocladiinae (likely from the genera *Psectrocladius*) in Nema Lake have decreased, but with a coincidental increase in densities of Tanypodinae (likely from the genera *Procladius* and *Ablabesmyia*). Meanwhile, overall densities of Prodiamesinae (likely from the genus *Monodiamesa*) have recently increased at site S2 in Lac de Gras. Little information is available on the ecology of these groups and the cause of these shifts is unclear (Oliver and Dillon 1997). For similar reasons identified for phytoplankton and zooplankton, it is likely that changes in benthos community composition are associated with changes in macronutrient availability, rather than toxic effects.

No mine effects were detected with respect to stream benthos density, dipteran diversity, Ephemeroptera, Plecoptera, Trichoptera (EPT) diversity, or dipteran community composition.

Both zooplankton and lake benthos provide an important source of food for many species of fish. Changes in community composition could have important consequences for fish, especially if preferred prey items are replaced with non-preferred ones. Results of the 2012 AEMP Evaluation of Effects found no evidence of mine effects on monitored fish populations in the Koala Watershed (Rescan 2012b). Shifts in phytoplankton, zooplankton and benthos communities, do not appear to have influenced fish populations to date. Both round whitefish and lake trout are considered opportunistic feeders where in the absence of strong prey community-wide effects, may not exhibit strong biological changes, including any bioenergetics-related response variables. Furthermore, the mobile nature of these larger-bodied fish populations may also serve to reduce any potential effects. Lakes in the Ekati Diamond Mine study area are not isolated and individual fish are able to move freely between upstream and downstream lakes. This likely serves to buffer any potential effects or may delay the appearance of mine effects. Monitoring of fish populations will be conducted in 2015 to re-assess these results, using the slimy sculpin as a sentinel species.

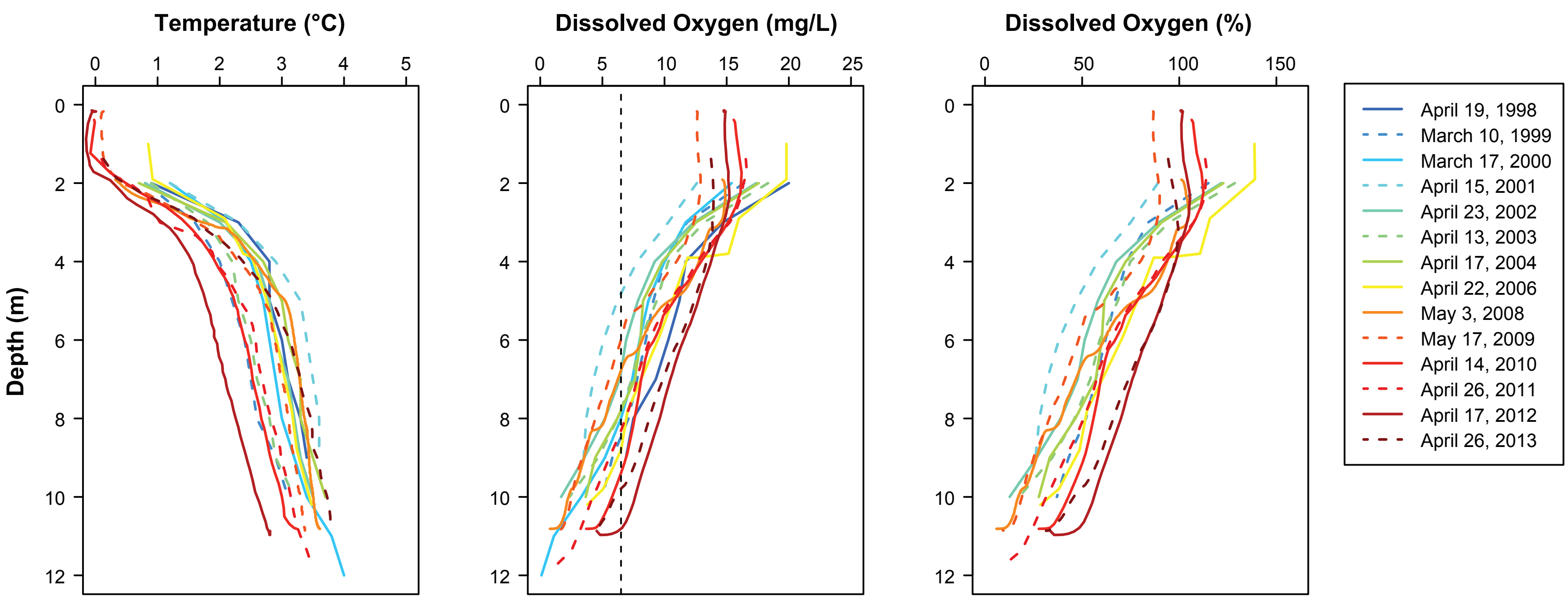
Figure 4-2a

Under-ice Dissolved Oxygen and Temperature Profiles for AEMP Reference Lakes, 1998 to 2013



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

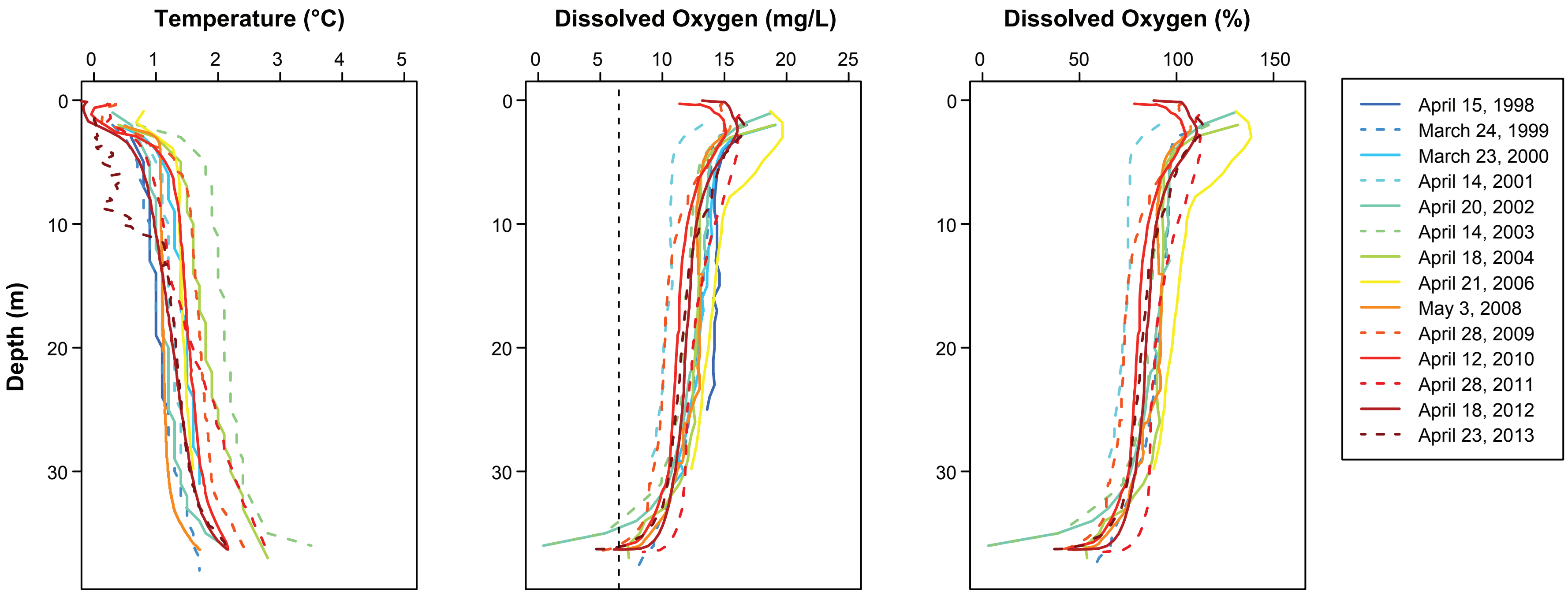
Counts Lake



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

ERM

Vulture Lake

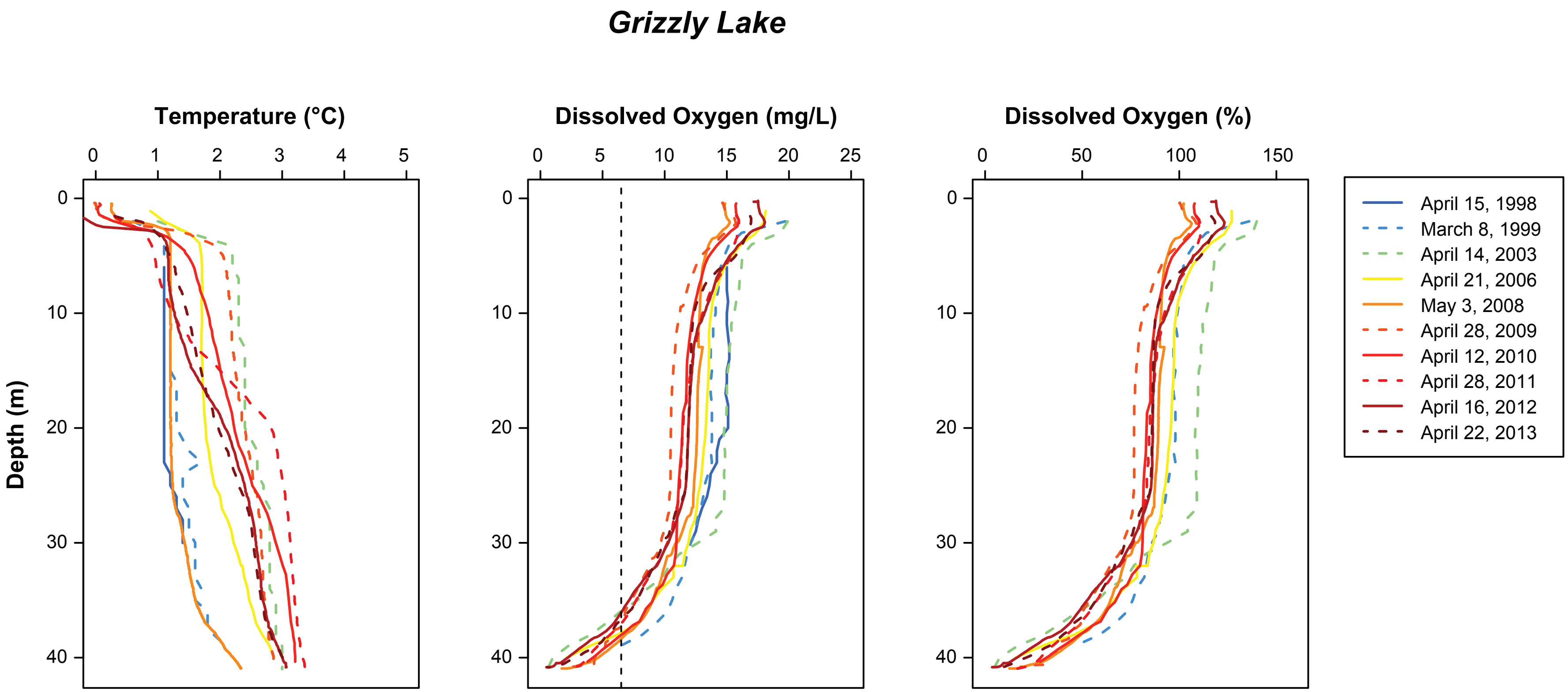


Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-3a

Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013

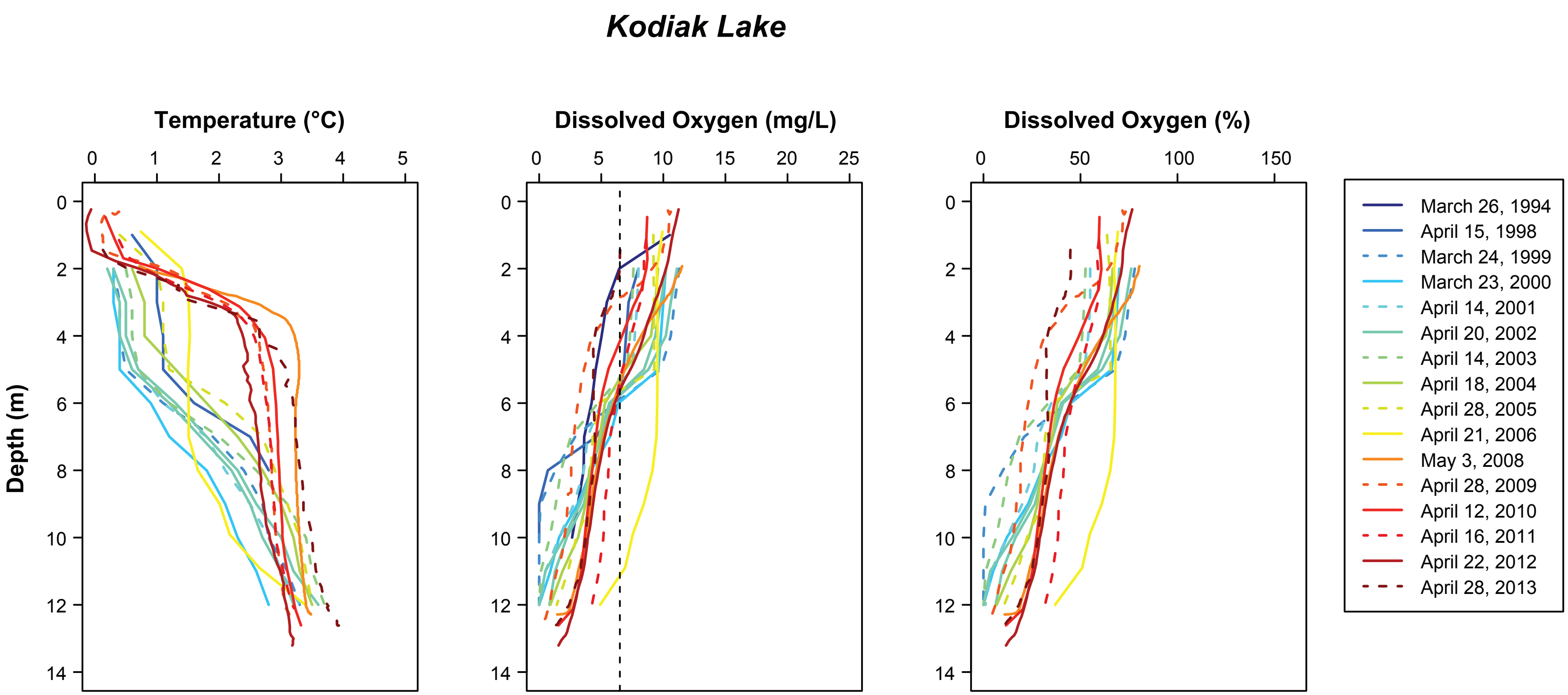
ERM



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-3b

Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013

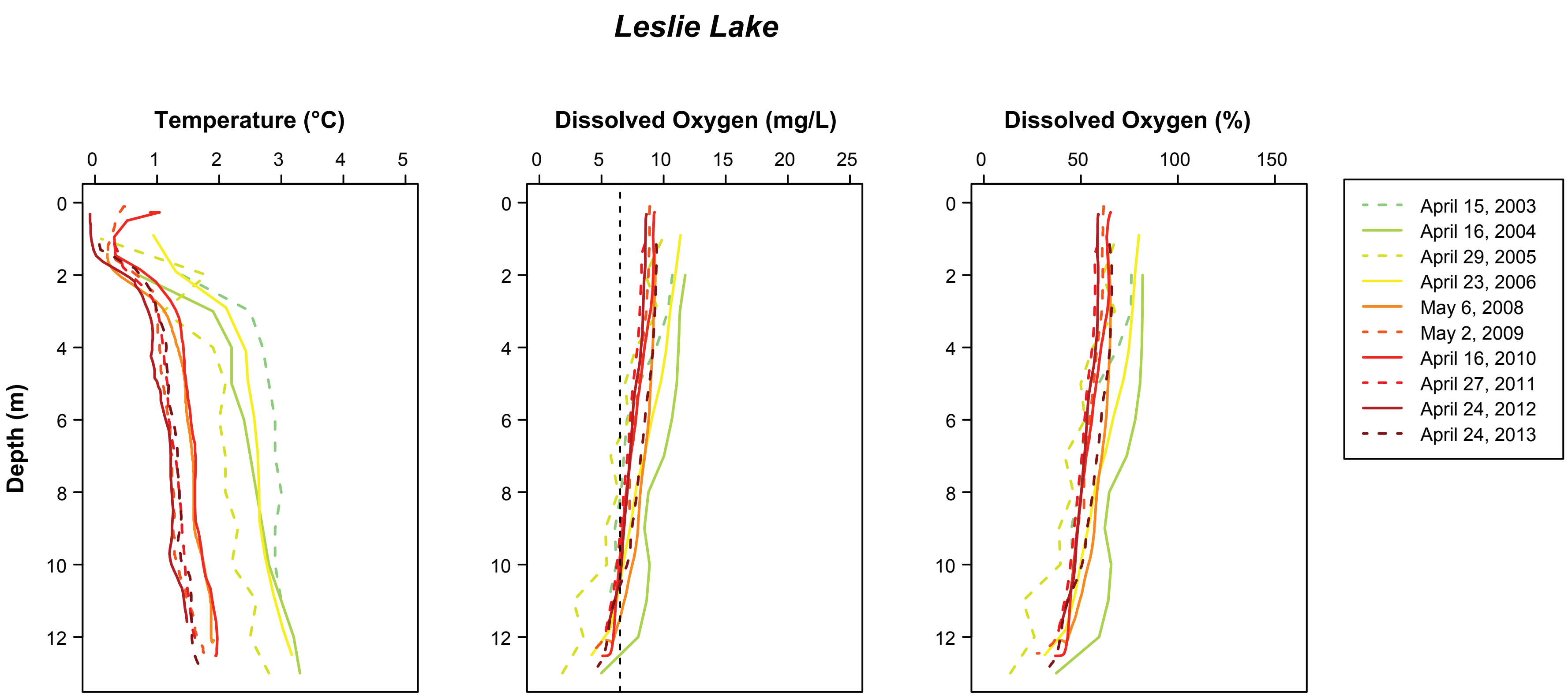


Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-3c

Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013

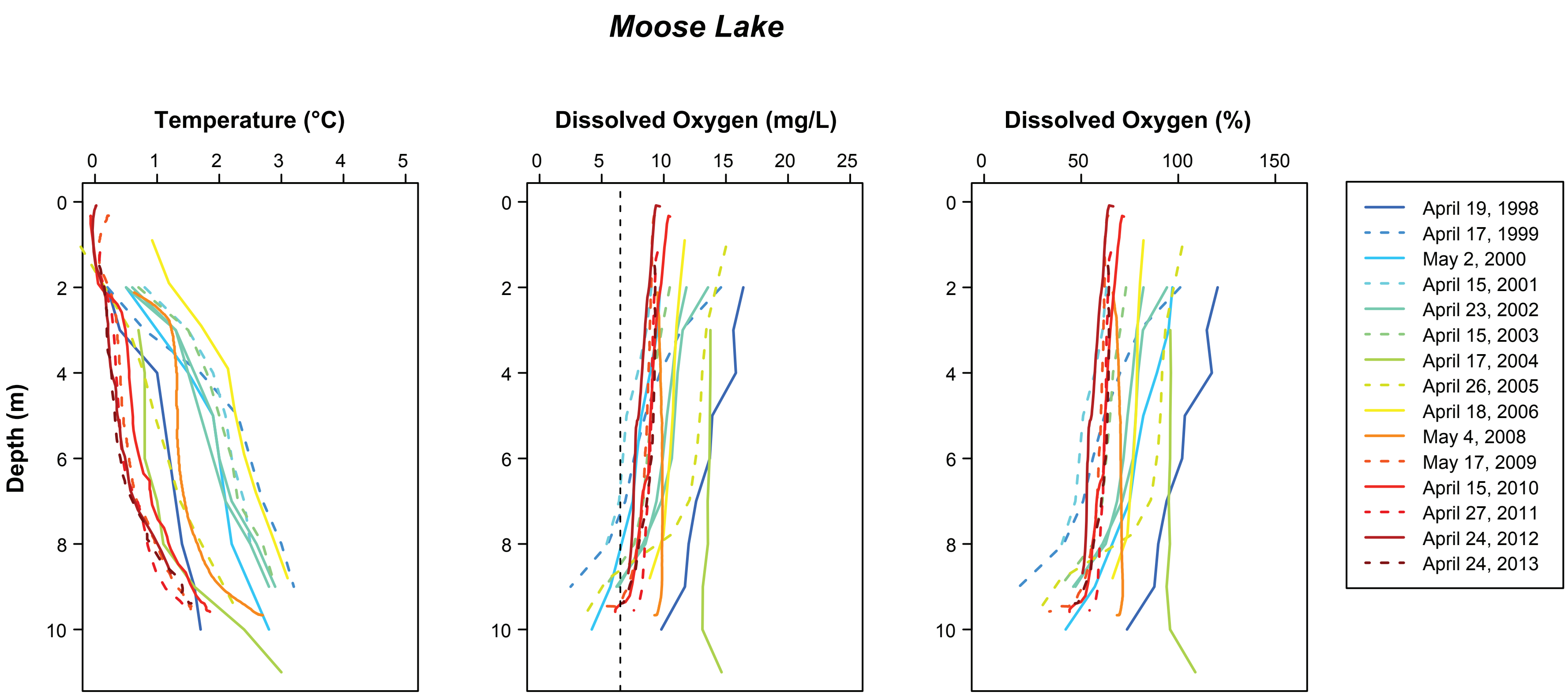
ERM



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-3d

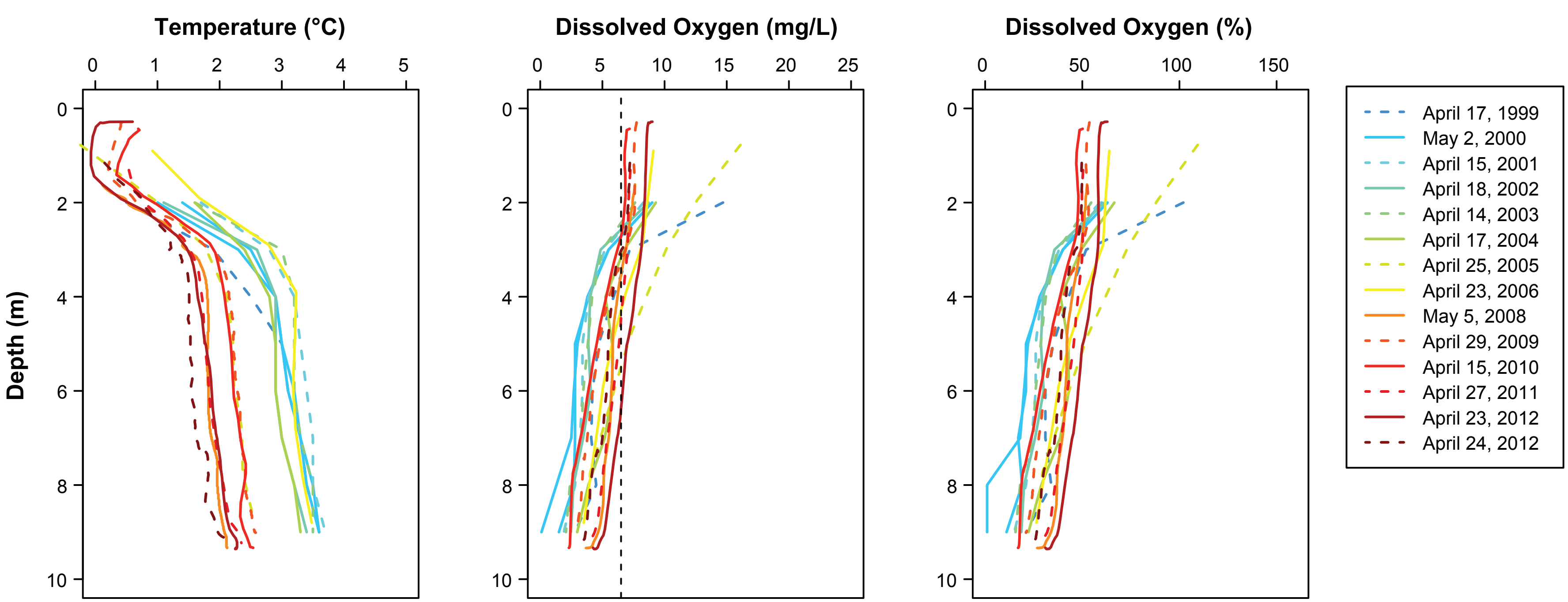
Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

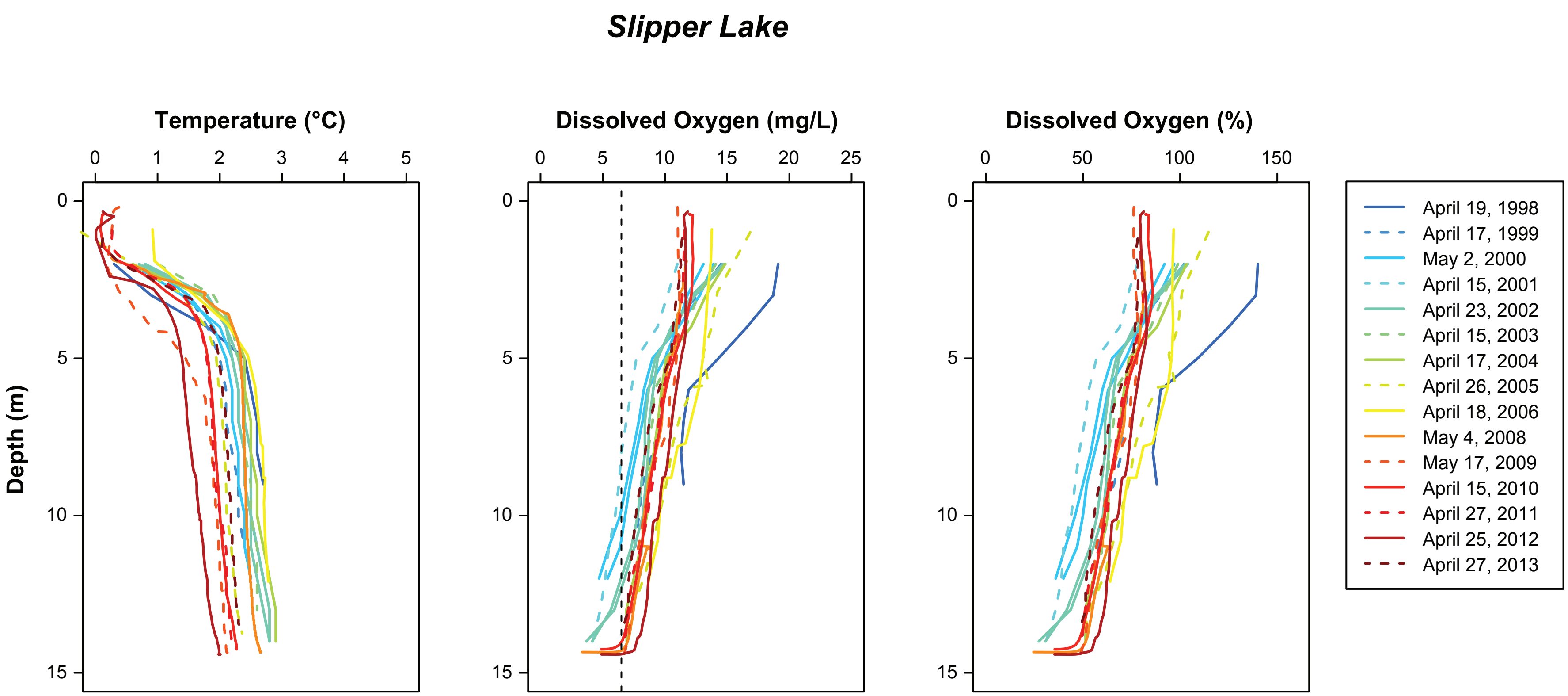
Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013

Nema Lake



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

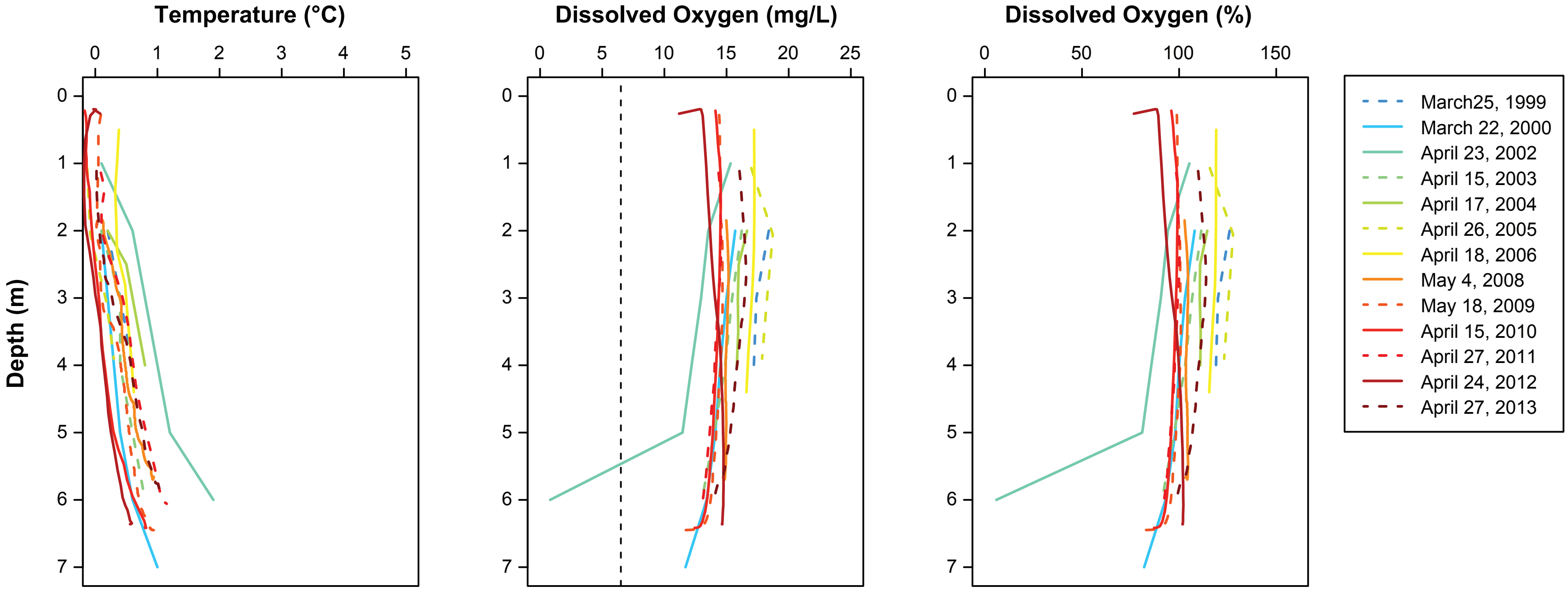
Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-3g
Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013

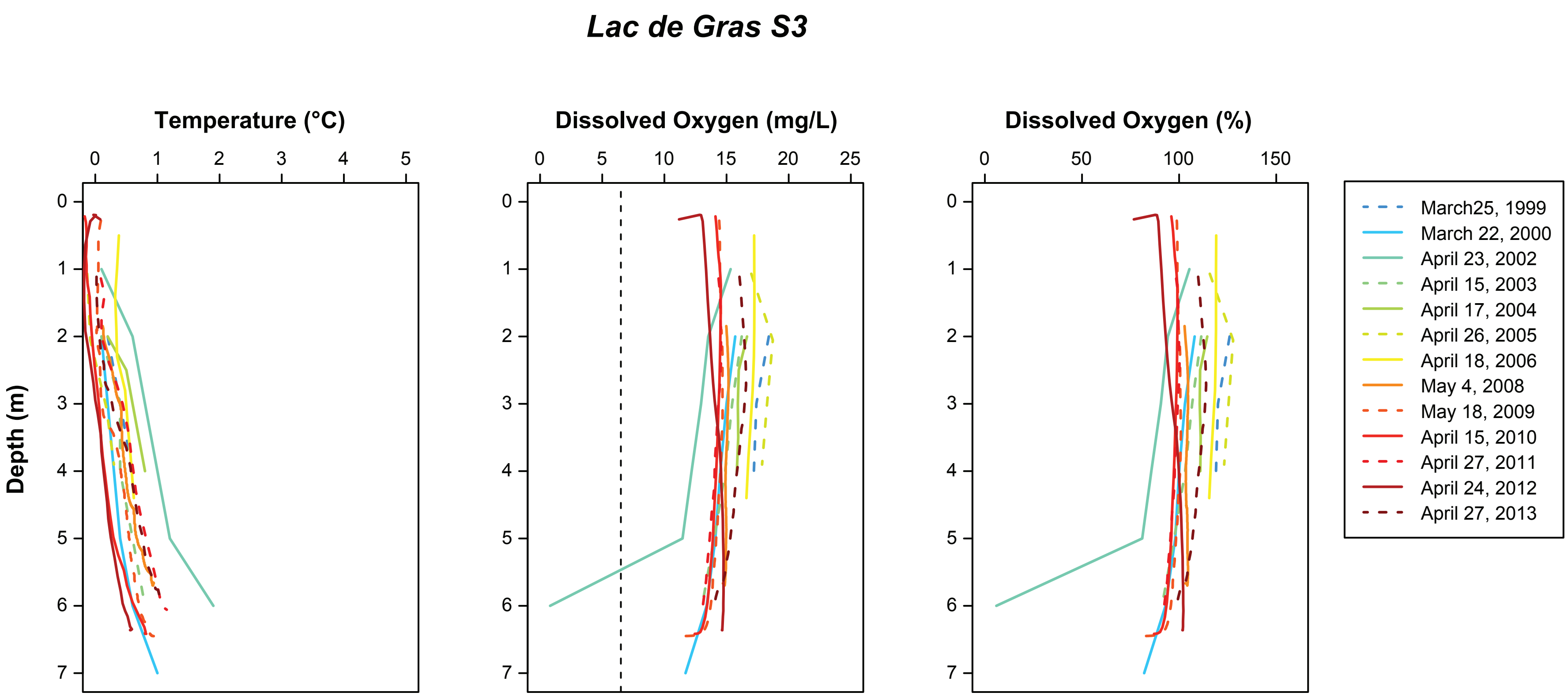
Lac de Gras S2



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-3h

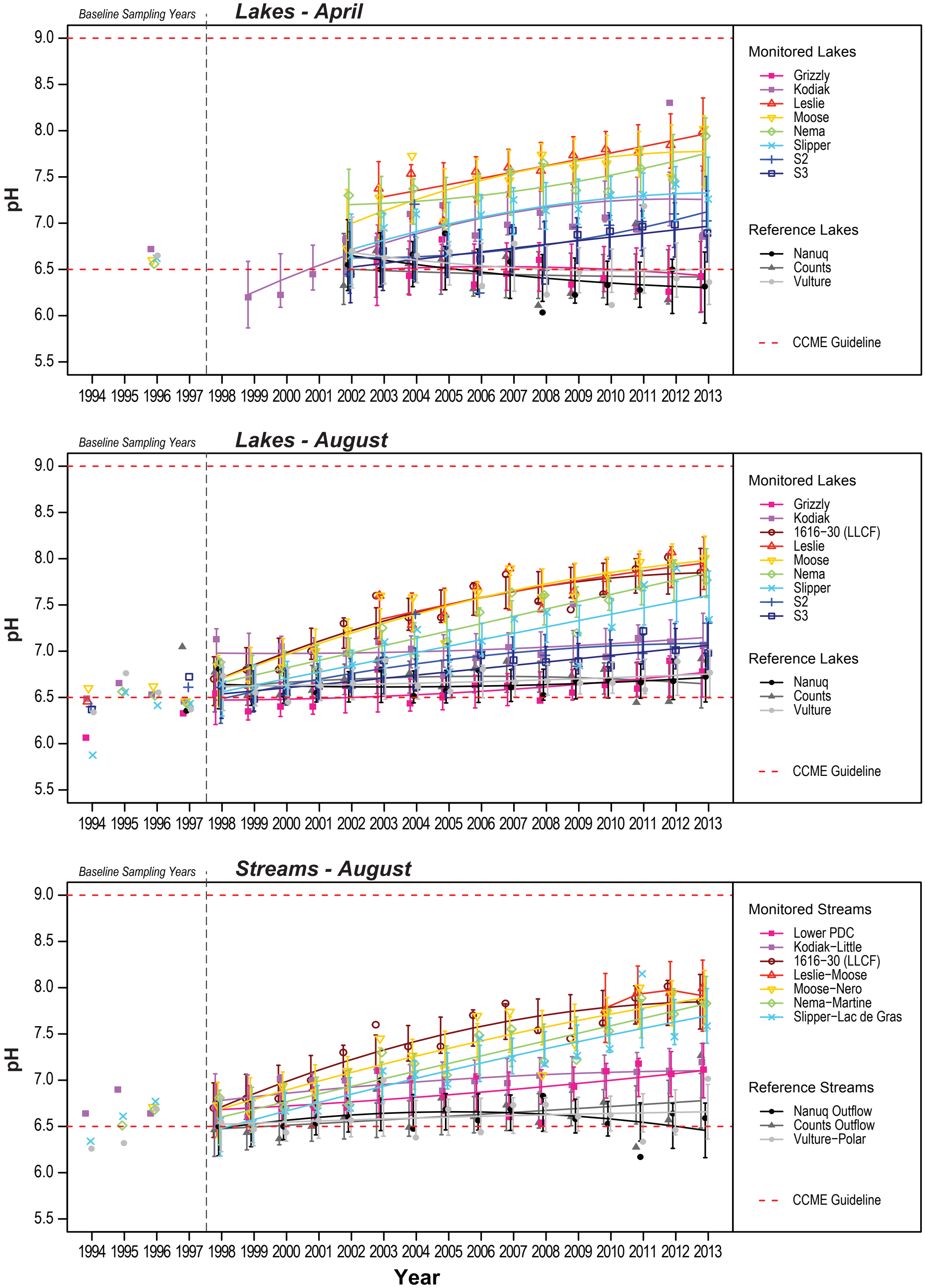
Under-ice Dissolved Oxygen and Temperature Profiles for Koala Watershed Lakes and Lac de Gras, 1994 to 2013



Note: Data collected and supplied by DDEC.
Vertical dashed line represents the CCME guideline for dissolved oxygen (6.5 mg/L).

Figure 4-4

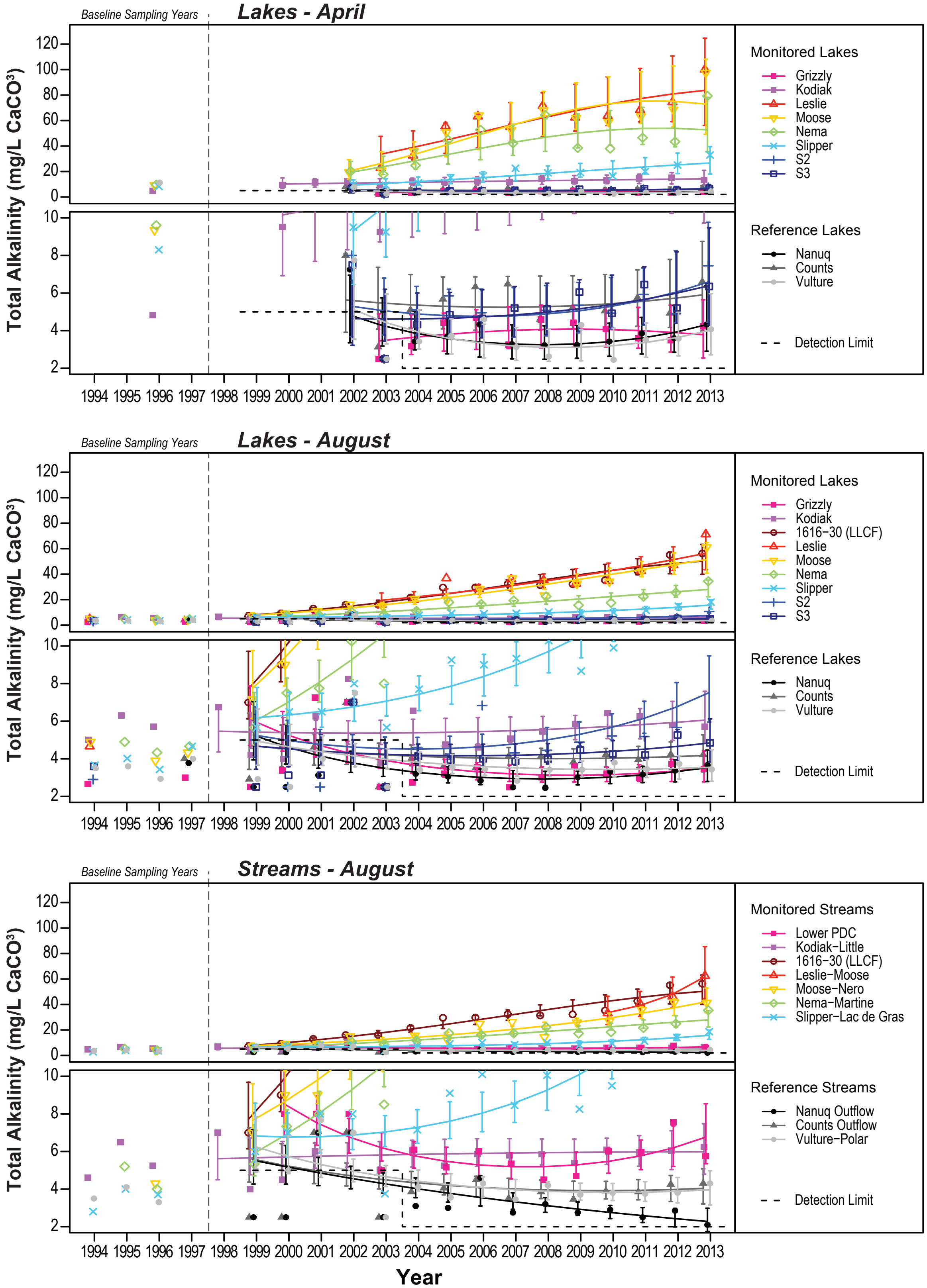
Observed and Fitted Means for pH in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
CCME guideline = 6.5 - 9.0.

Figure 4-5

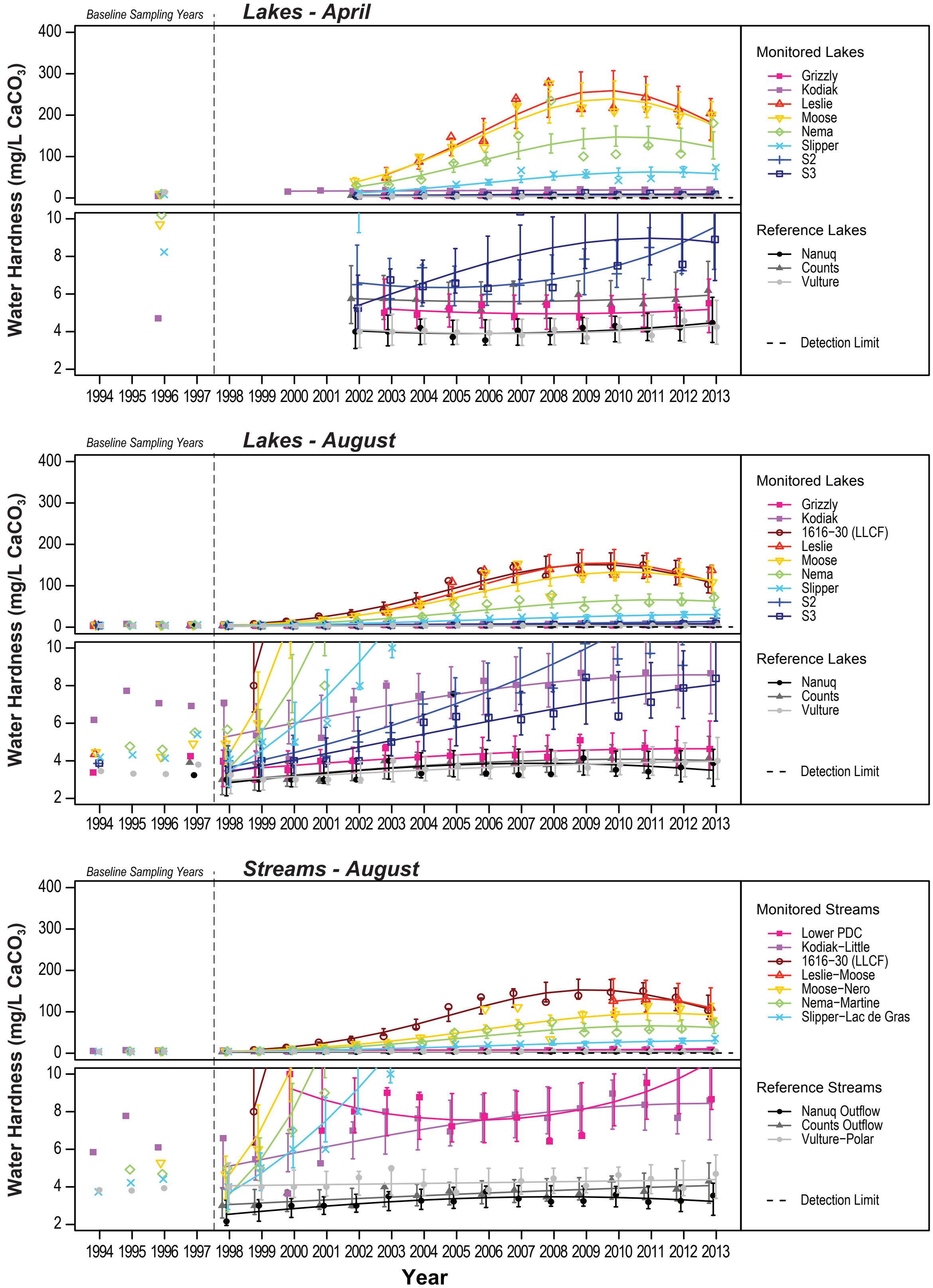
Observed and Fitted Means for Total Alkalinity in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



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

Figure 4-6

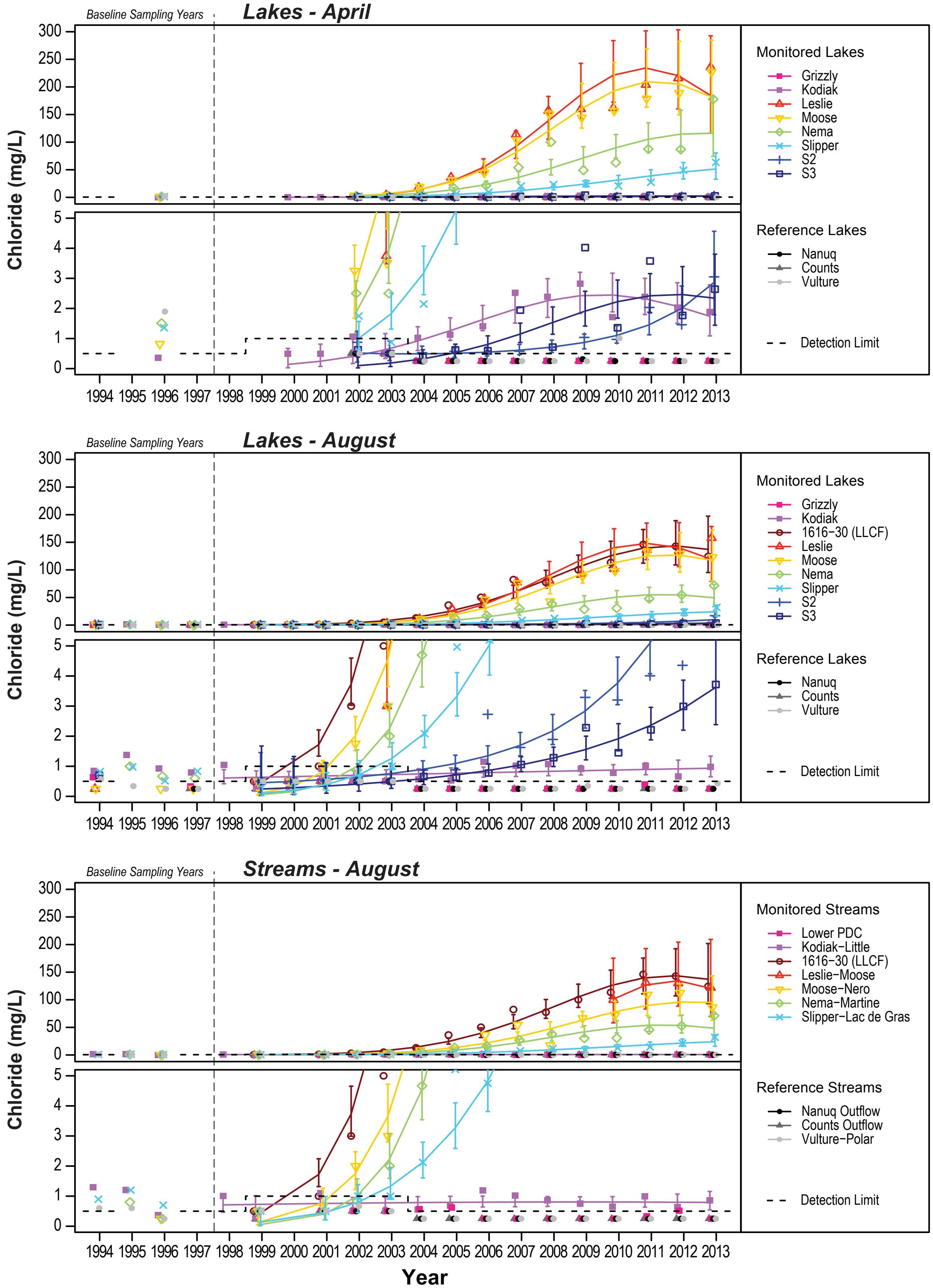
Observed and Fitted Means for Water Hardness in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



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

Figure 4-7

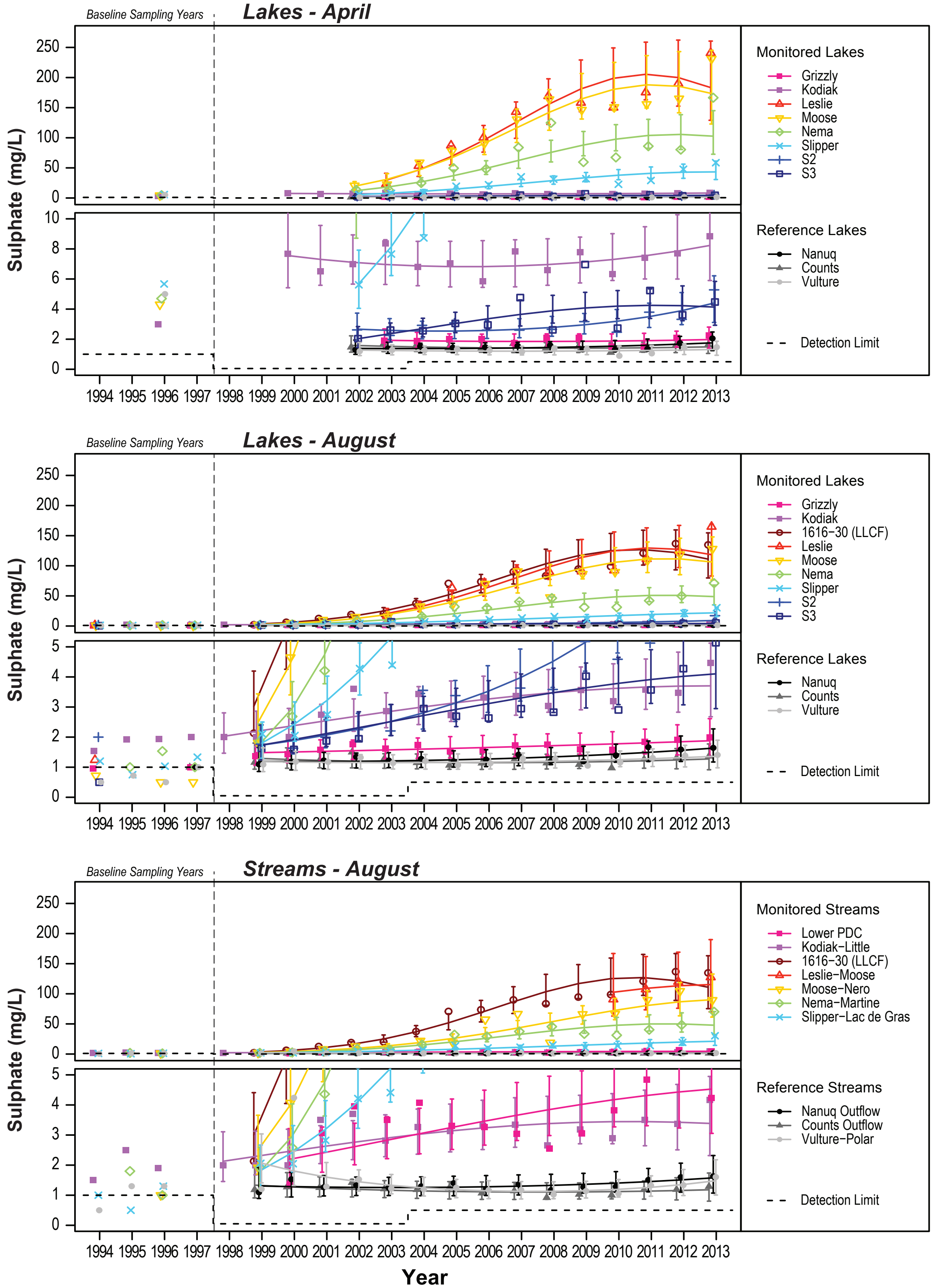
Observed and Fitted Means for Chloride Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = 116.6 X ln(Hardness) - 204.1, where hardness = 10 - 160 mg/L.

Figure 4-8

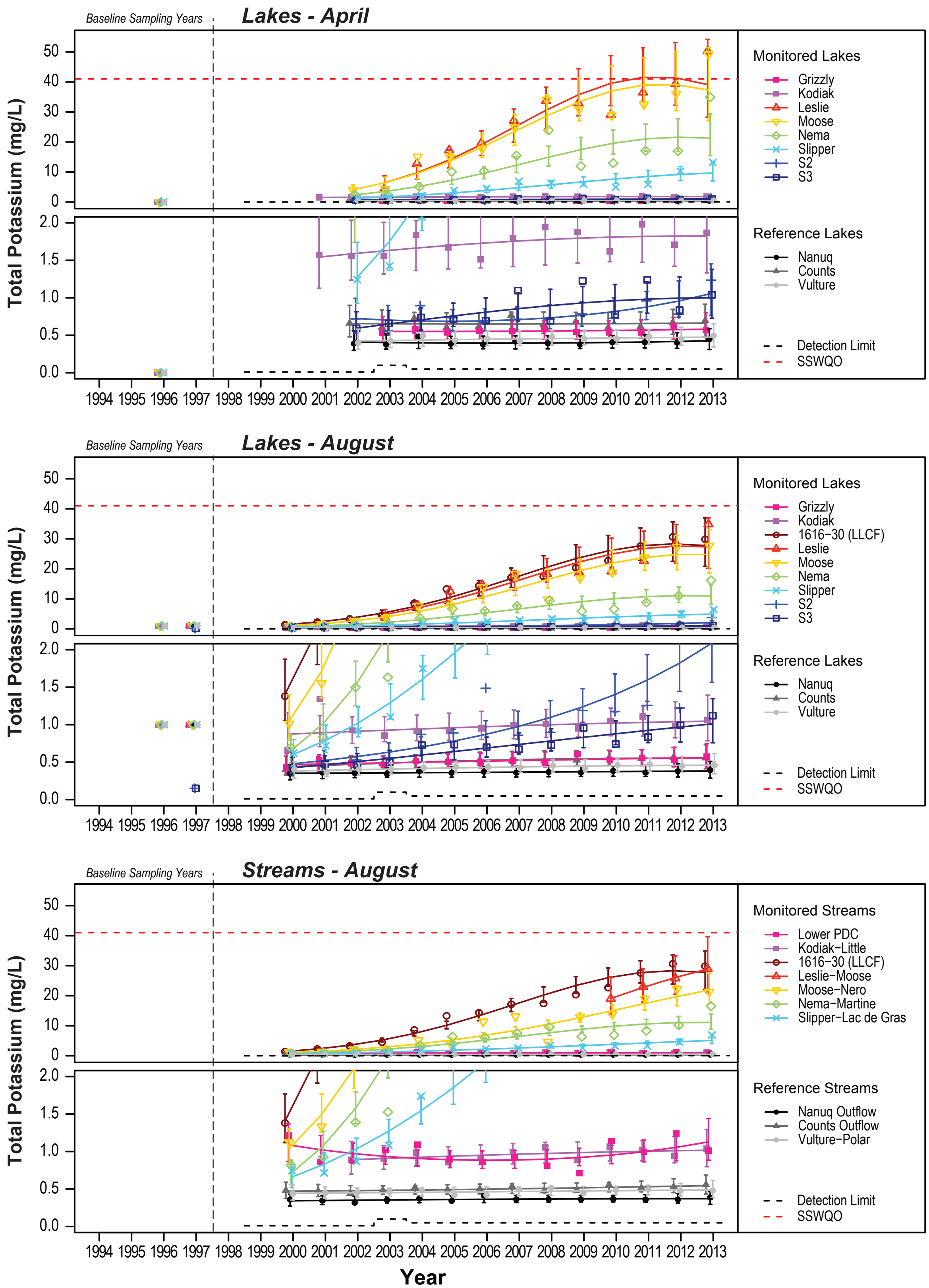
Observed and Fitted Means for Sulphate Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = $e^{(0.9116 \times \ln(Hardness) + 1.712)}$ *mg/L, where hardness < 160 mg/L.*

Figure 4-9

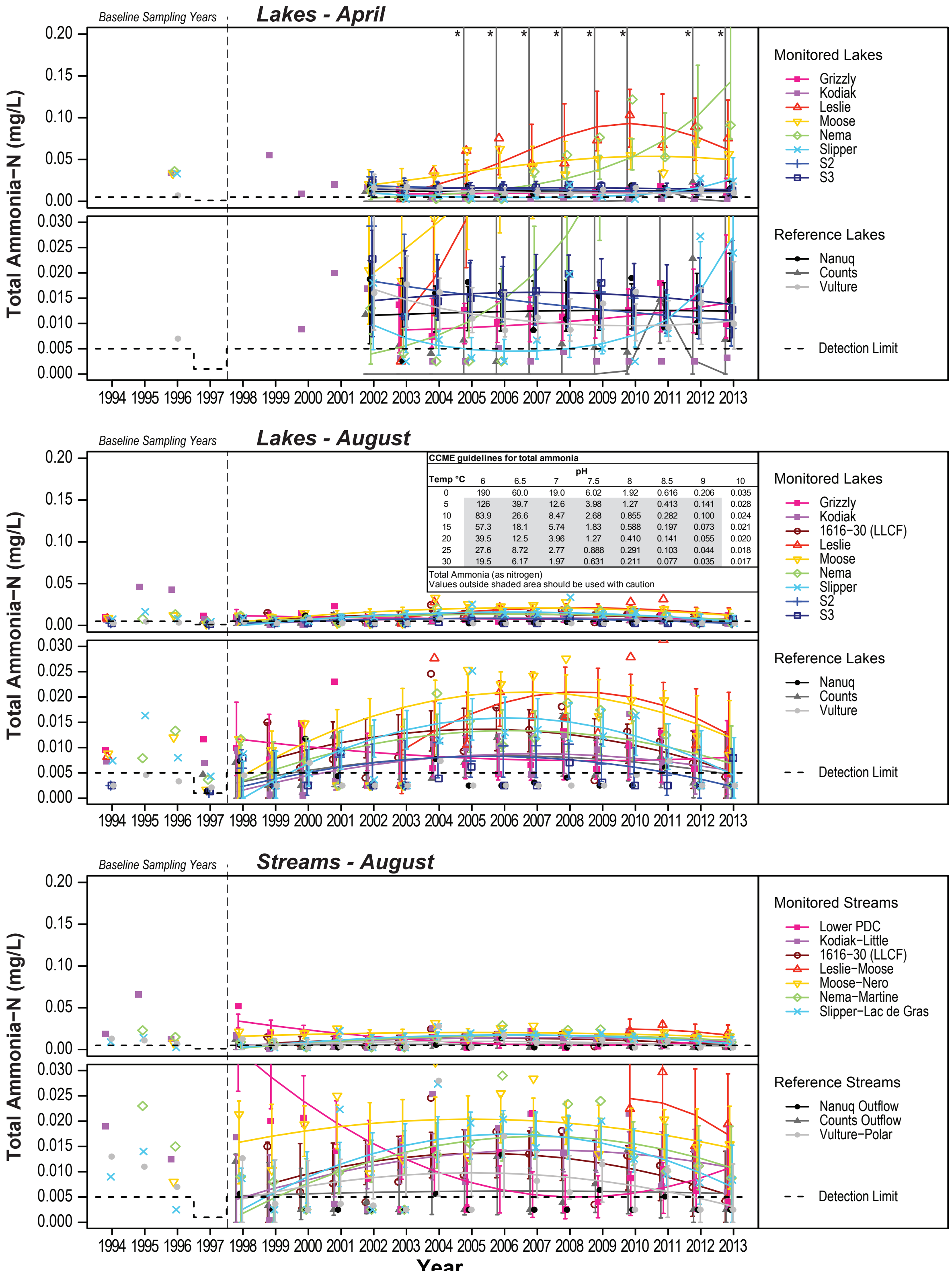
Observed and Fitted Means for Potassium Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = 41 mg/L.

Figure 4-10

Observed and Fitted Means for Total Ammonia-N Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



CCME guidelines for total ammonia

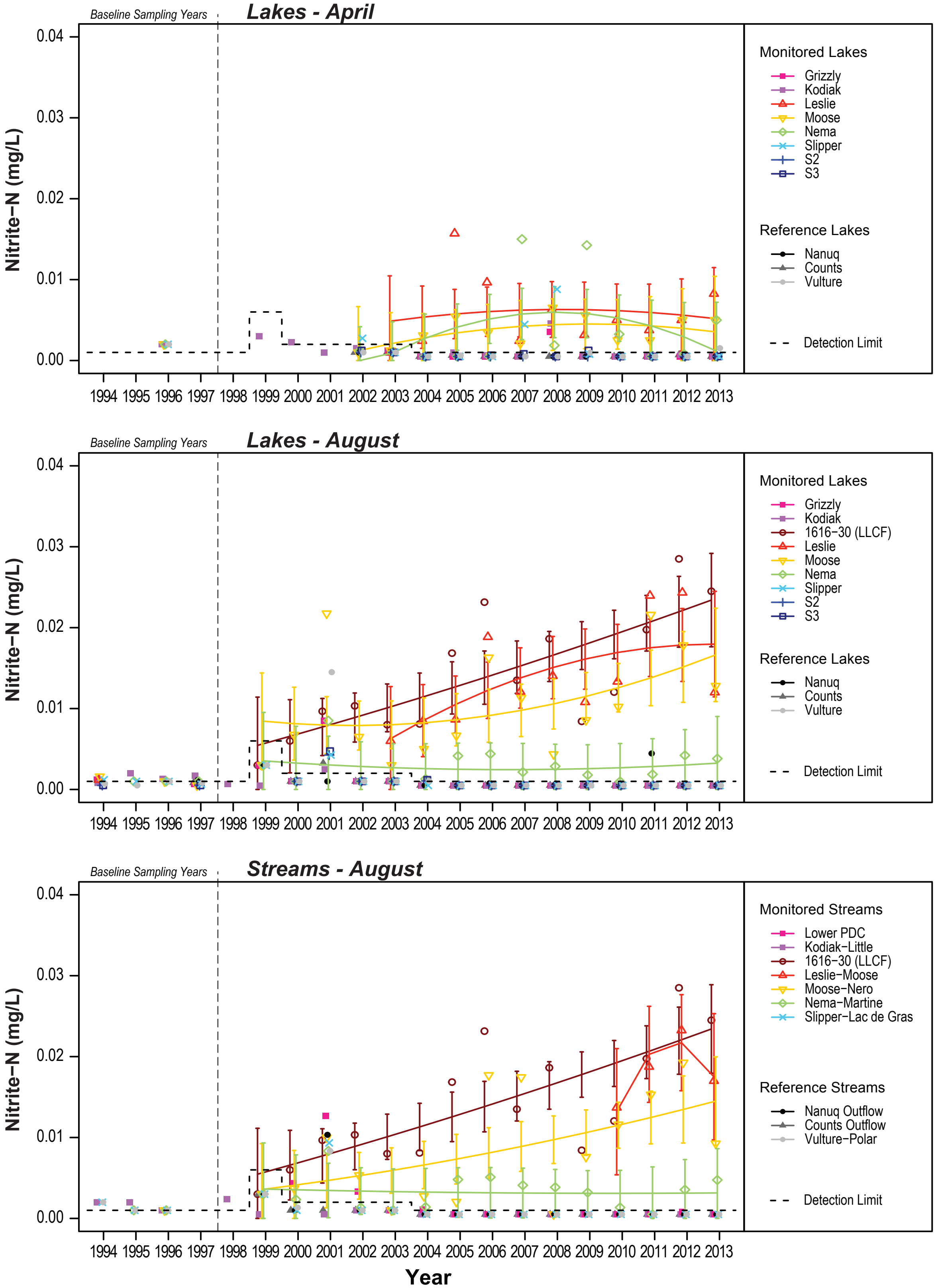
Temp °C	pH 6	6.5	7	7.5	8	8.5	9	10
0	190	60.0	19.0	6.02	1.92	0.616	0.206	0.035
5	126	39.7	12.6	3.98	1.27	0.413	0.141	0.028
10	83.9	26.6	8.47	2.68	0.855	0.282	0.100	0.024
15	57.3	18.1	5.74	1.83	0.588	0.197	0.073	0.021
20	39.5	12.5	3.96	1.27	0.410	0.141	0.055	0.020
25	27.6	8.72	2.77	0.888	0.291	0.103	0.044	0.018
30	19.5	6.17	1.97	0.631	0.211	0.077	0.035	0.017

Total Ammonia (as nitrogen)
Values outside shaded area should be used with caution

Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
WL = Maximum average concentration premitted in water licence W2009L2-0001. WL Criterion = 2.0 mg/L.
CCME Guideline is pH and temperature dependent (see inset table).
** Upper 95% Confidence Interval on the fitted mean of Counts Lake in April 2005 = 2.10×10^{283} mg/L, 2006 = 1.08×10^{250} mg/L, 2007 = 1.12×10^{211} mg/L, 2008 = 2.35×10^{166} mg/L, 2009 = 9.97×10^{115} mg/L, 2010 = 8.54×10^{59} mg/L, 2012 = 1.49×10^{64} mg/L, 2013 = 4.98×10^{131} mg/L, and of Nema Lake in 2013 = 0.274 mg/L.*

Figure 4-11

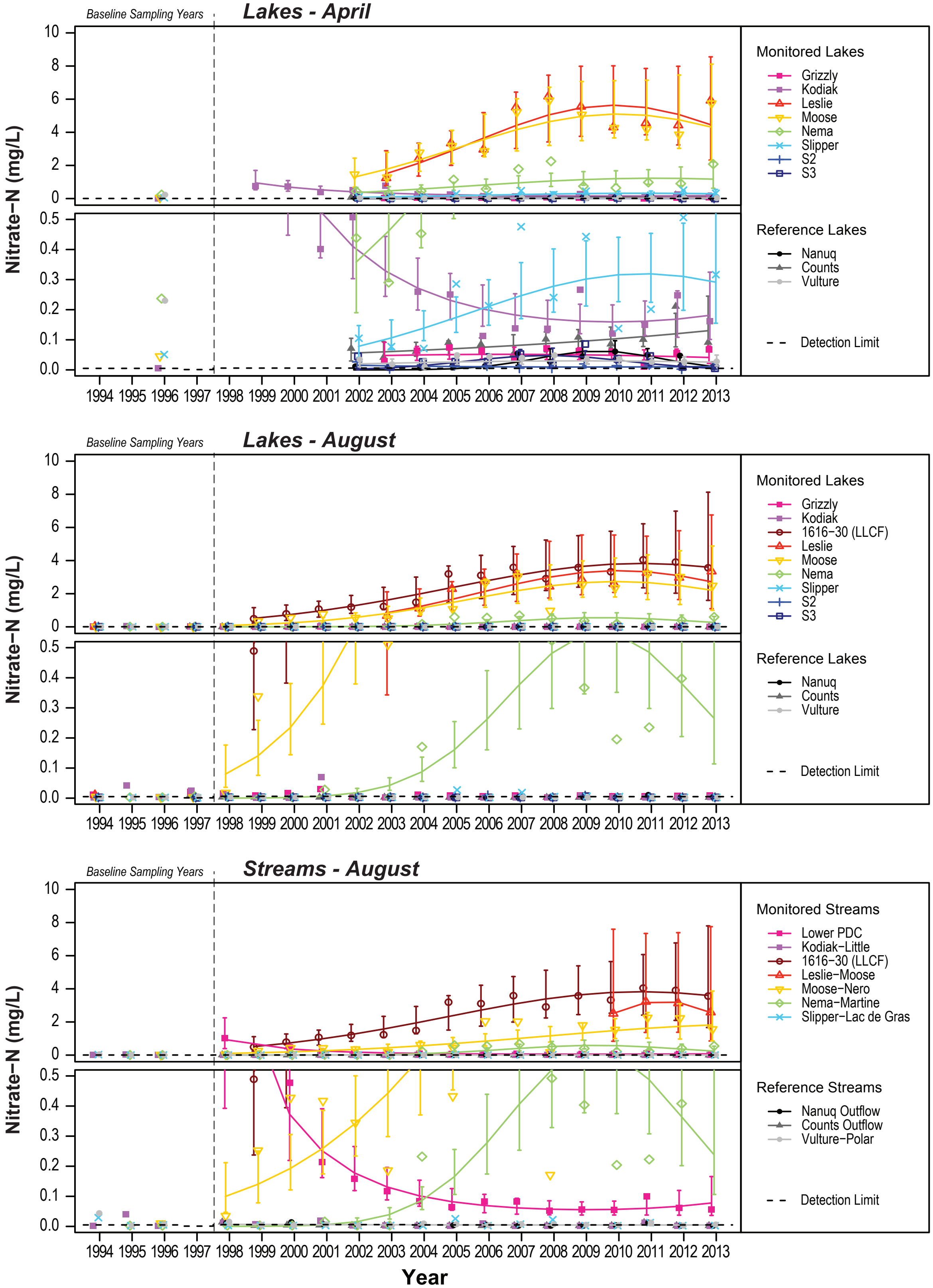
Observed and Fitted Means for Nitrite-N Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
CCME Guideline = 0.06 mg/L.

Figure 4-12

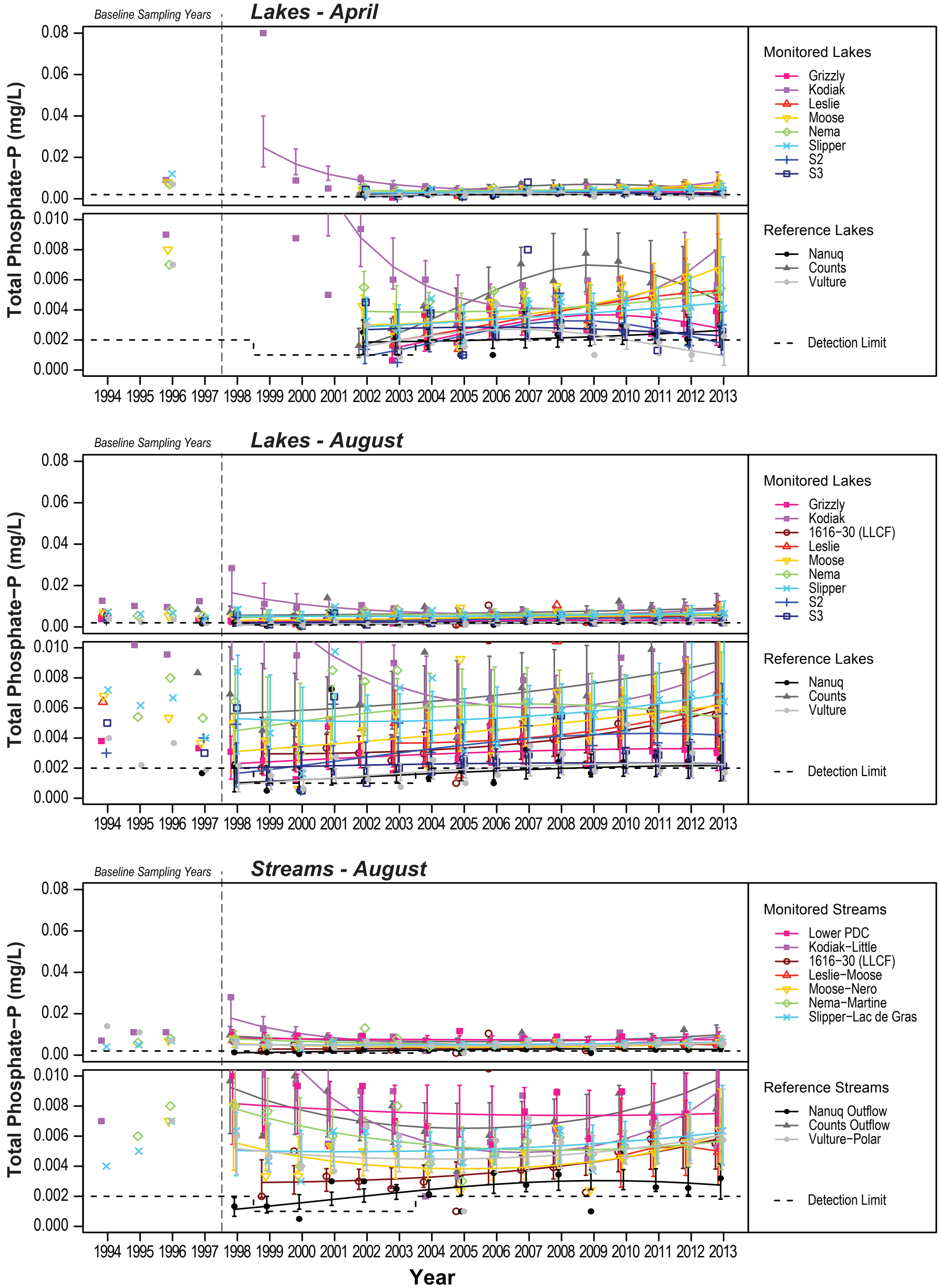
Observed and Fitted Means for Nitrate-N Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = $e^{0.9518 \times \ln(Hardness) - 2.032}$ mg/L, where hardness < 160mg/L.

Figure 4-13

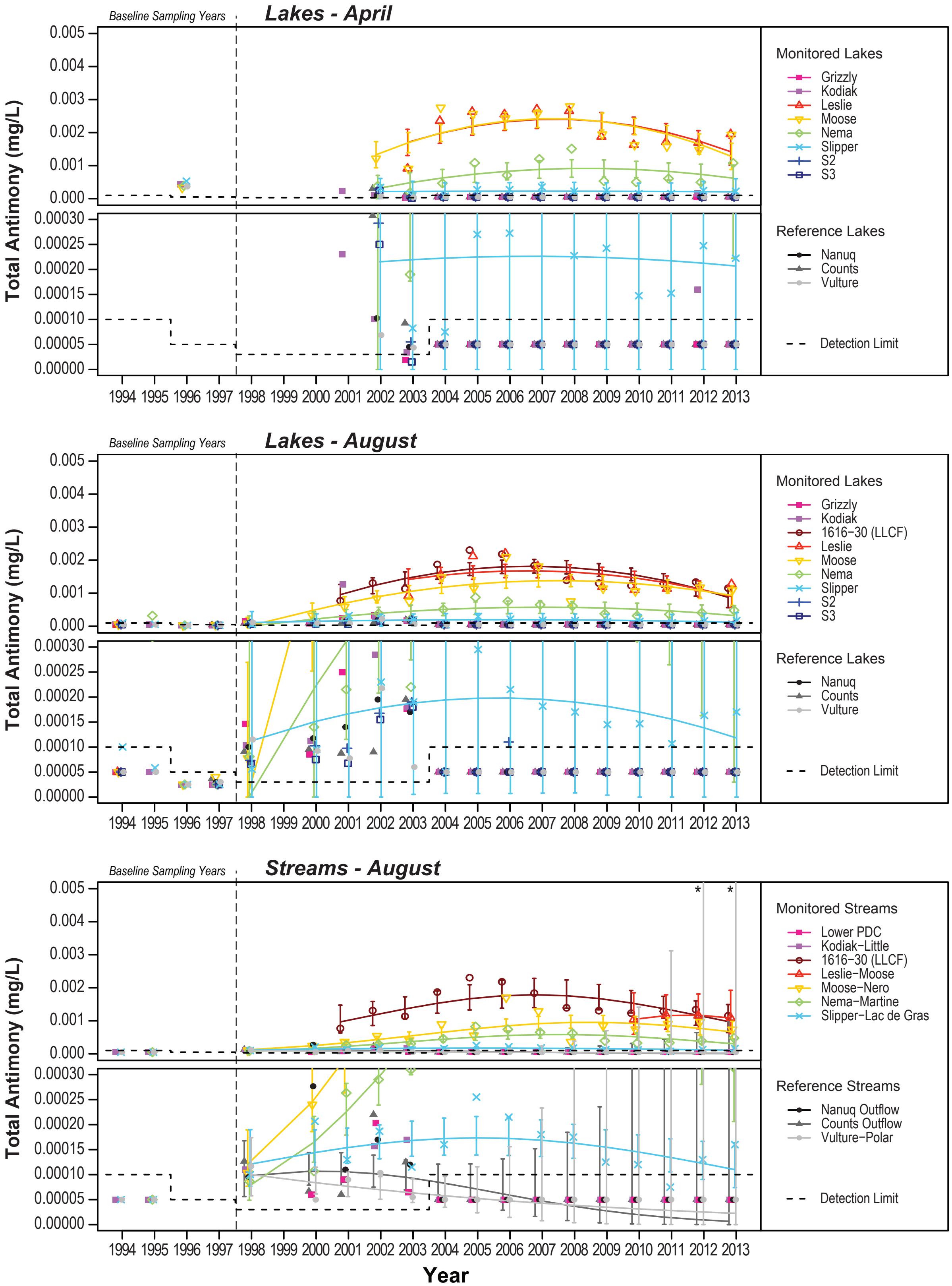
Observed and Fitted Means for Total Phosphate-P Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



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

Figure 4-14

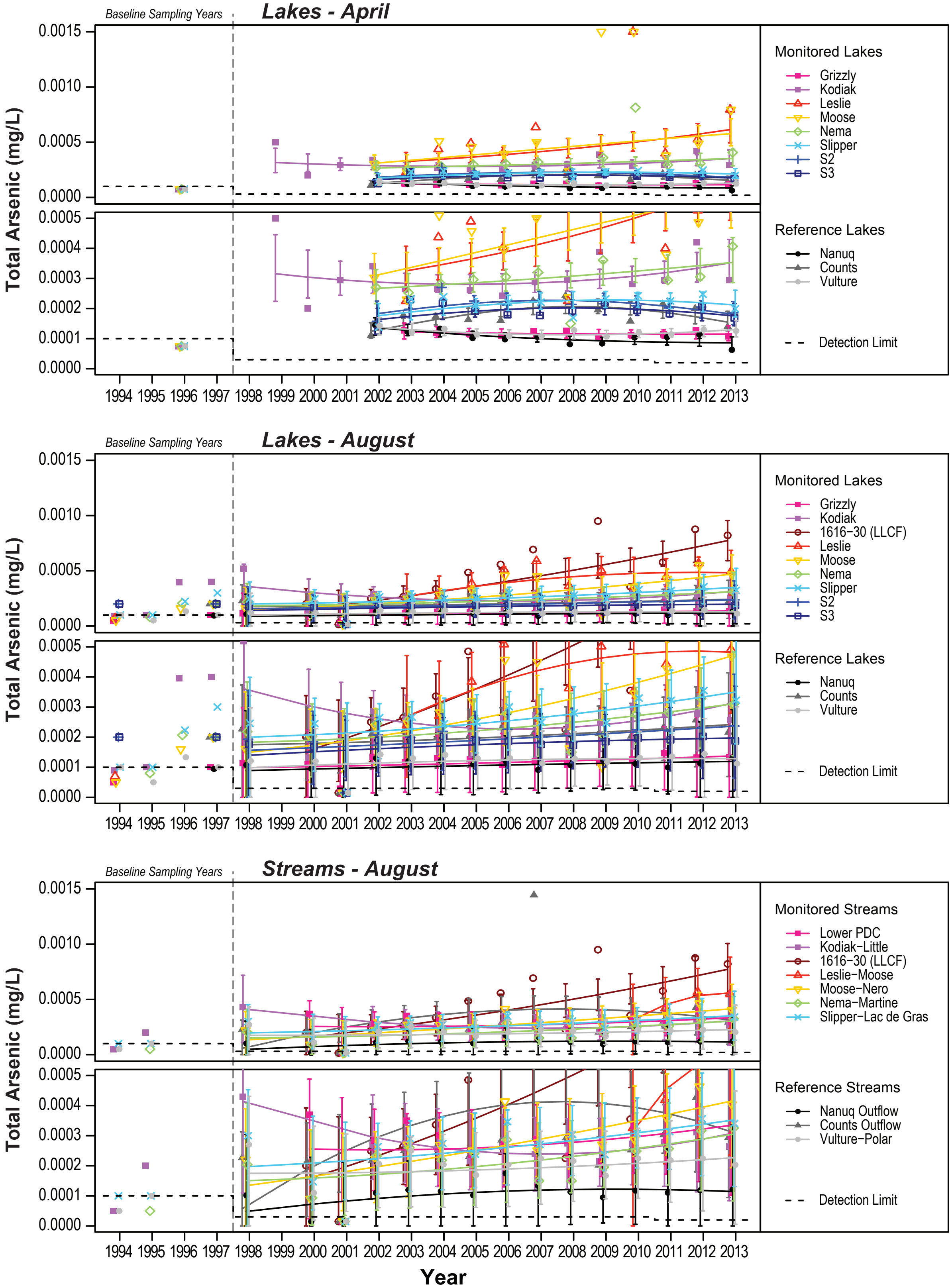
Observed and Fitted Means for Total Antimony Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
** Upper 95% Confidence Interval on the fitted mean of Vulture-Polar Stream in August 2012 = 0.0076 mg/L, 2013 = 0.0202 mg/L.*
Water quality benchmark (Fletcher et al. 1996) = 0.02 mg/L.

Figure 4-15

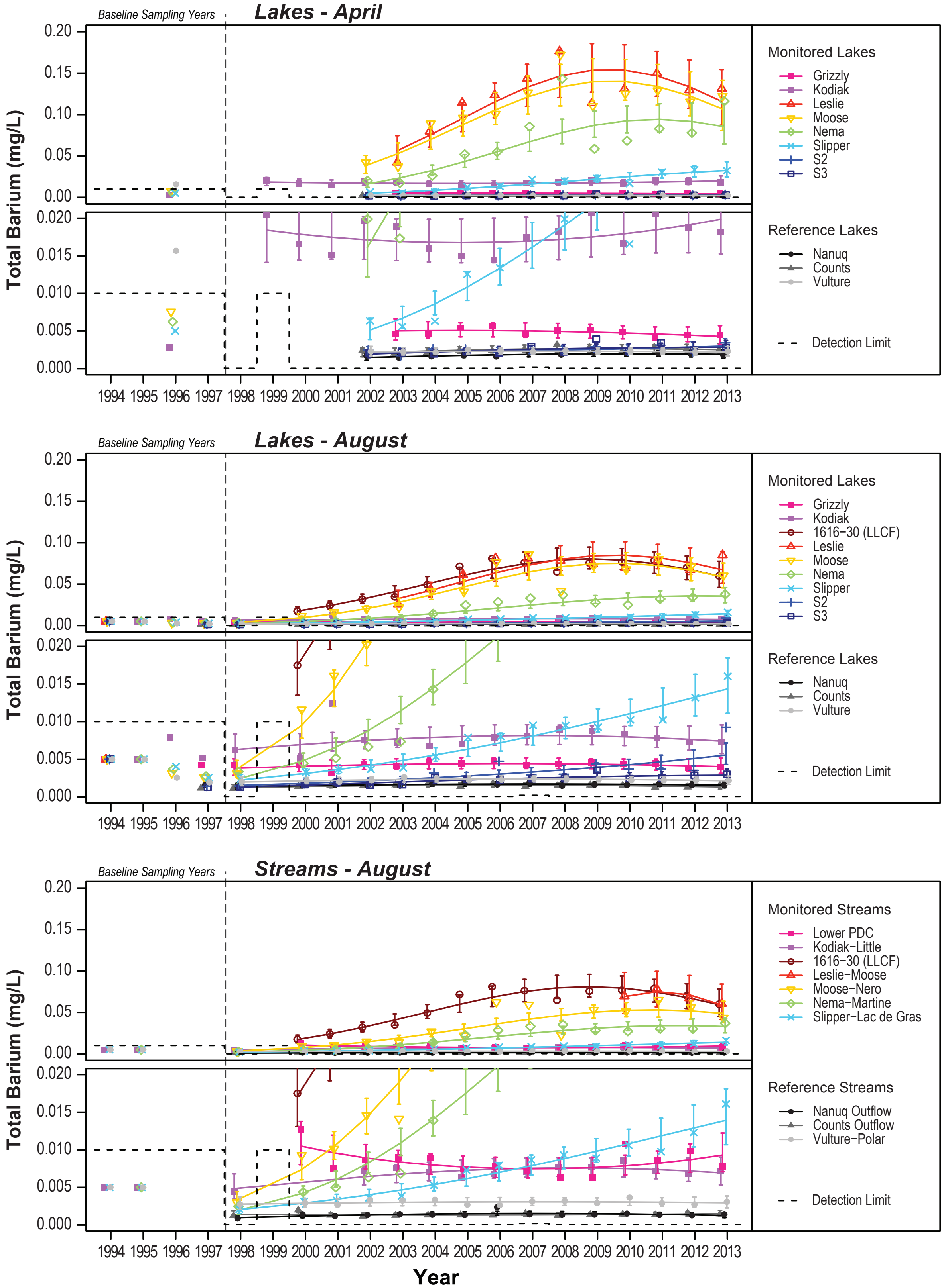
Observed and Fitted Means for Total Arsenic Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
WL = Maximum average concentration premitted in water licence W2009L2-0001. WL = 0.50 mg/L. CCME Guideline = 0.005 mg/L.

Figure 4-16

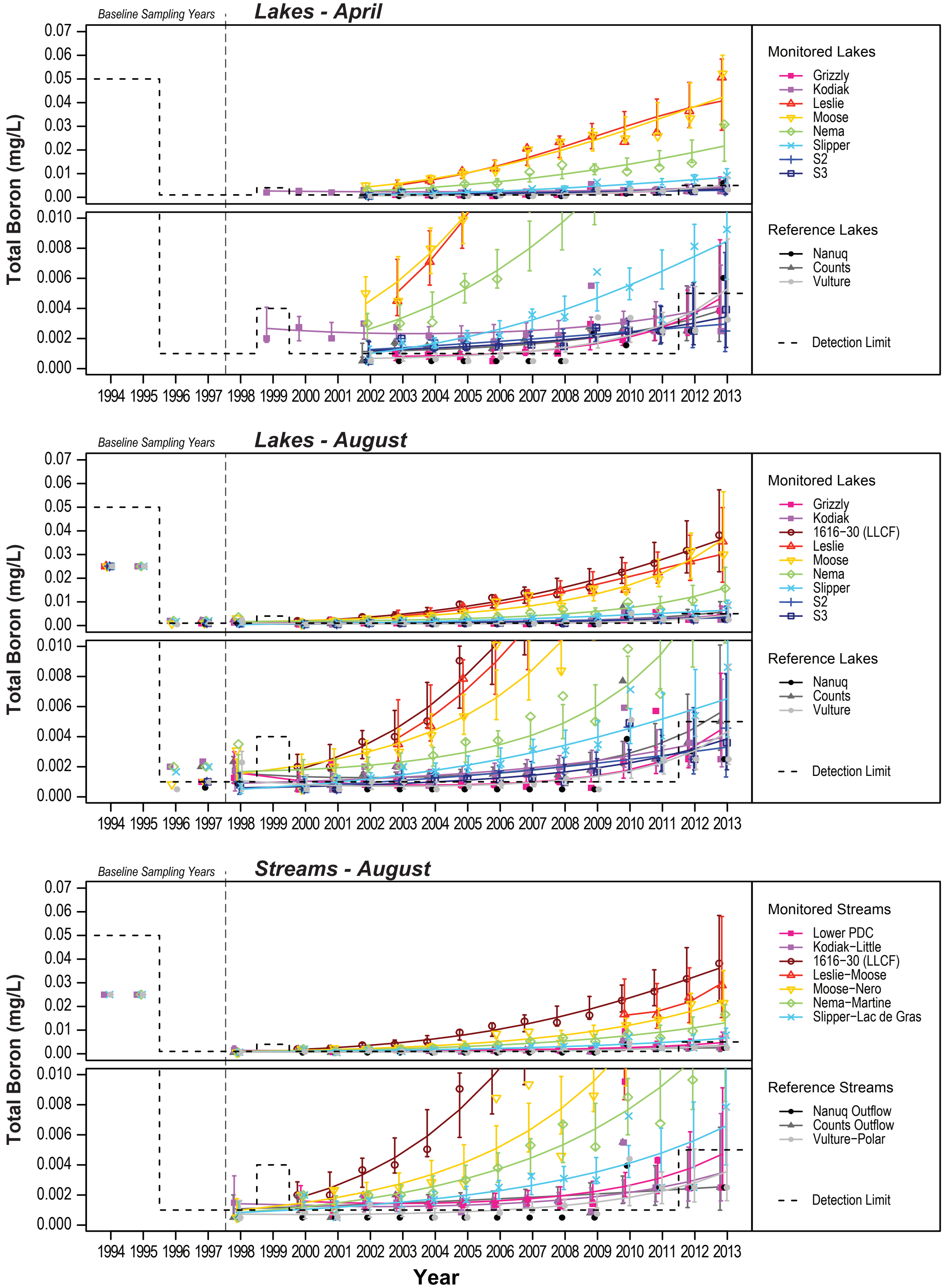
Observed and Fitted Means for Total Barium Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
Water quality benchmark (Haywood and Drinnan 1983) = 1 mg/L.

Figure 4-17

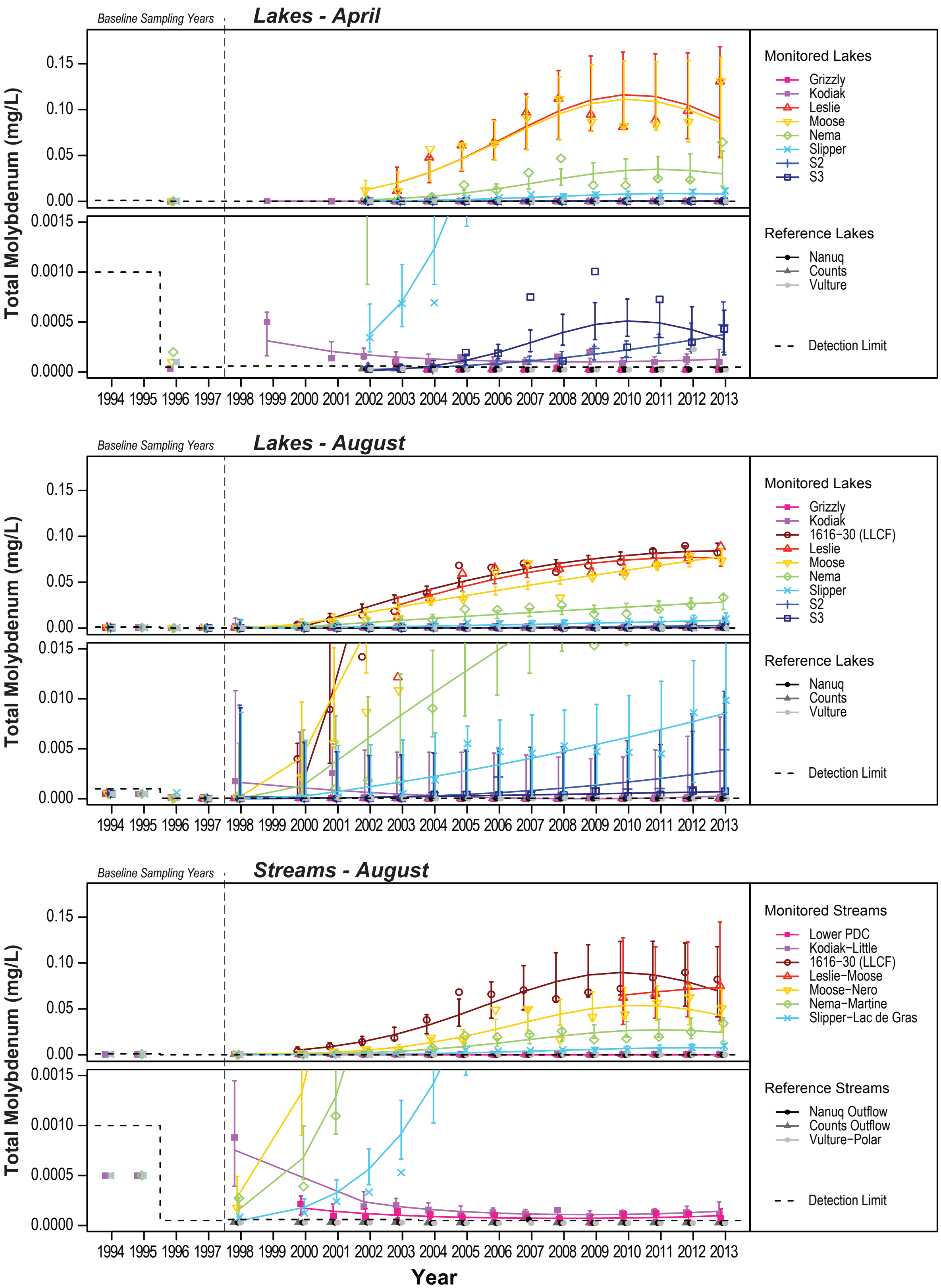
Observed and Fitted Means for Total Boron Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
CCME Guideline = 1.5 mg/L.

Figure 4-18

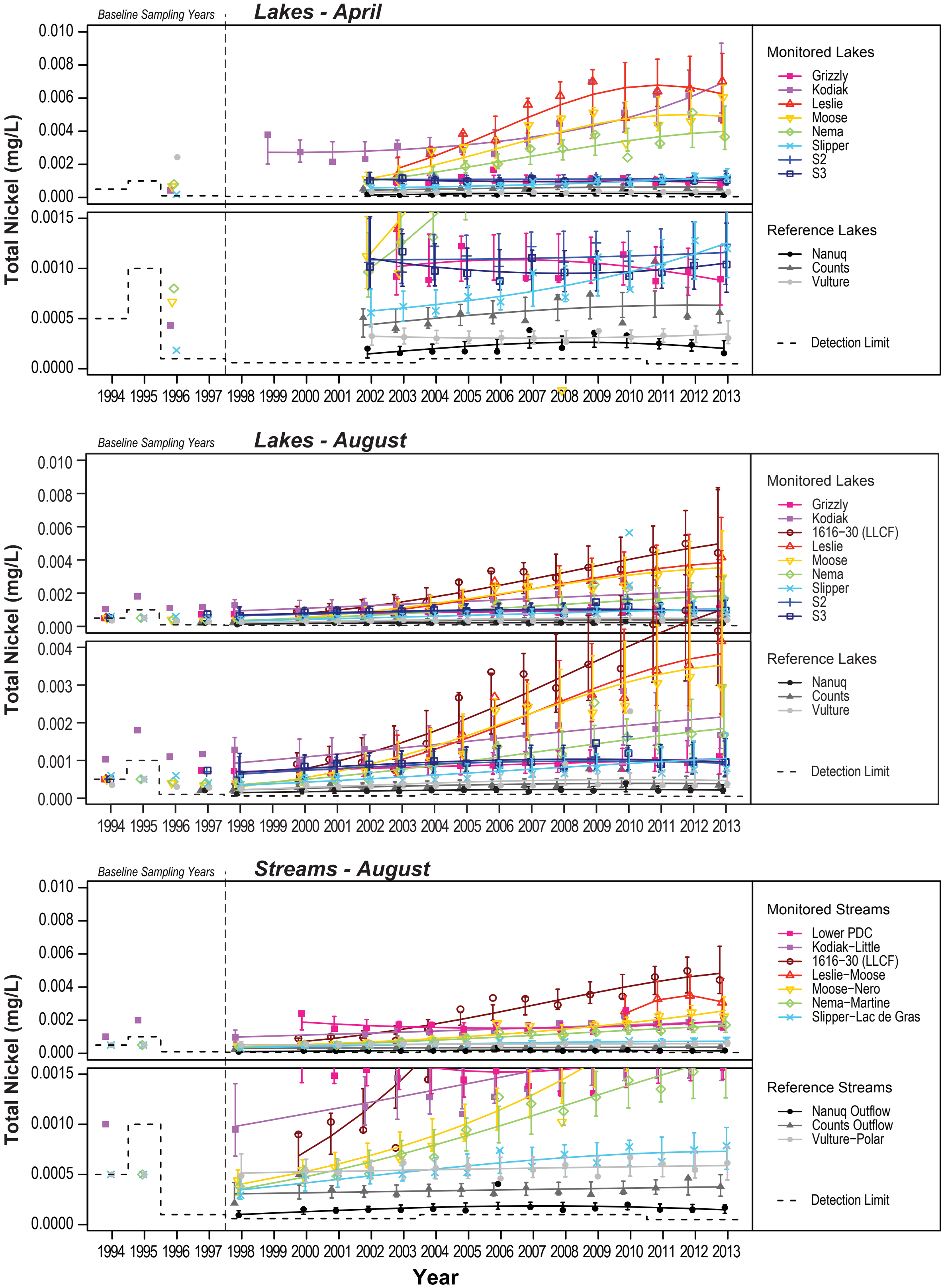
Observed and Fitted Means for Total Molybdenum Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = 19.38 mg/L.

Figure 4-19

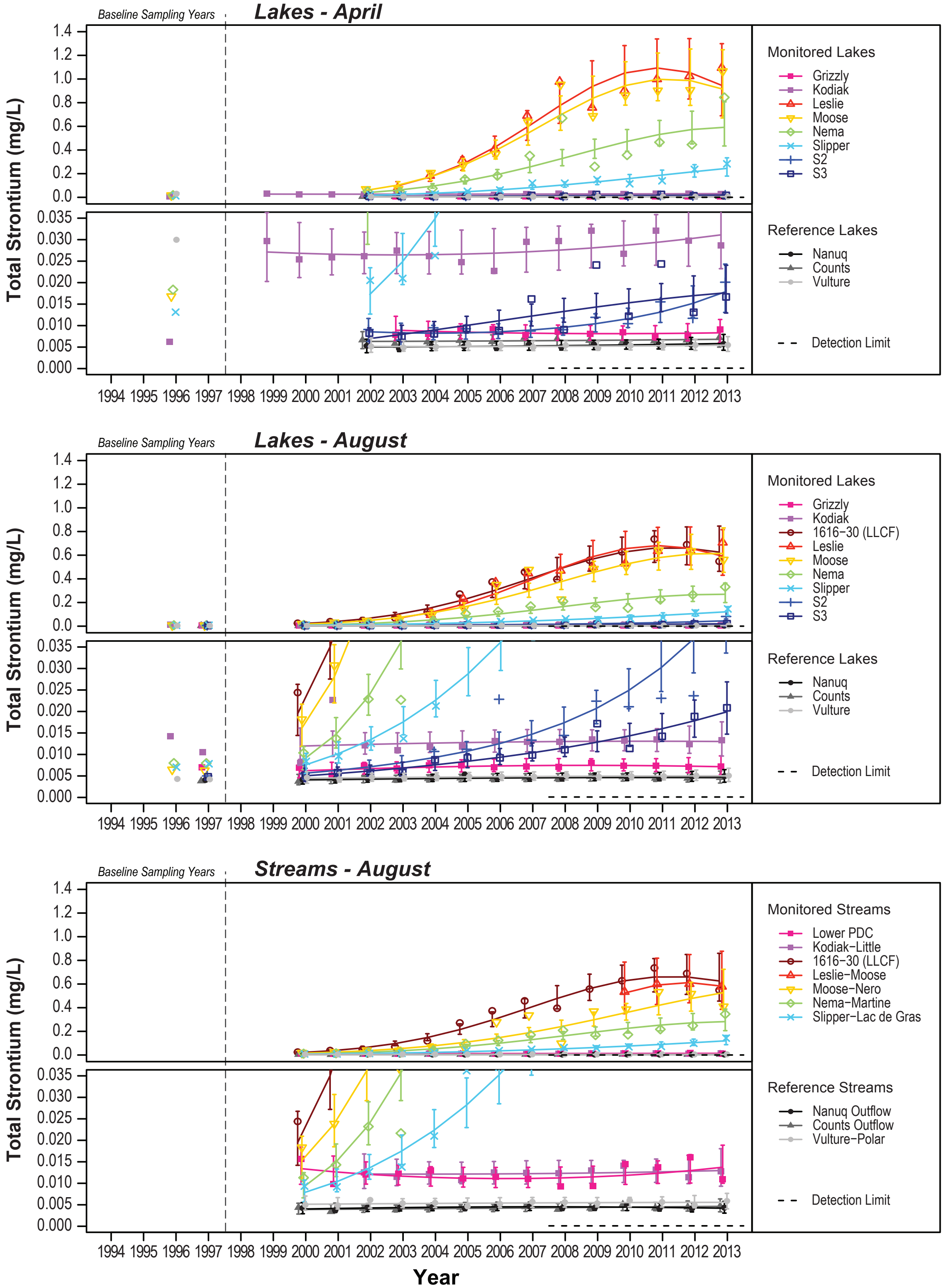
Observed and Fitted Means for Total Nickel Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
WL = Maximum average concentration premitted in water licence W2009L2-0001. WL = 0.15 mg/L.
CCME Guideline = $e^{0.76 X (\ln Hardness) + 1.06}$ /1000 mg/L, where hardness = 60 - 180 mg/L, 0.025 mg/L where hardness < 60 mg/L, and 0.15 mg/L where hardness > 180 mg/L.

Figure 4-20

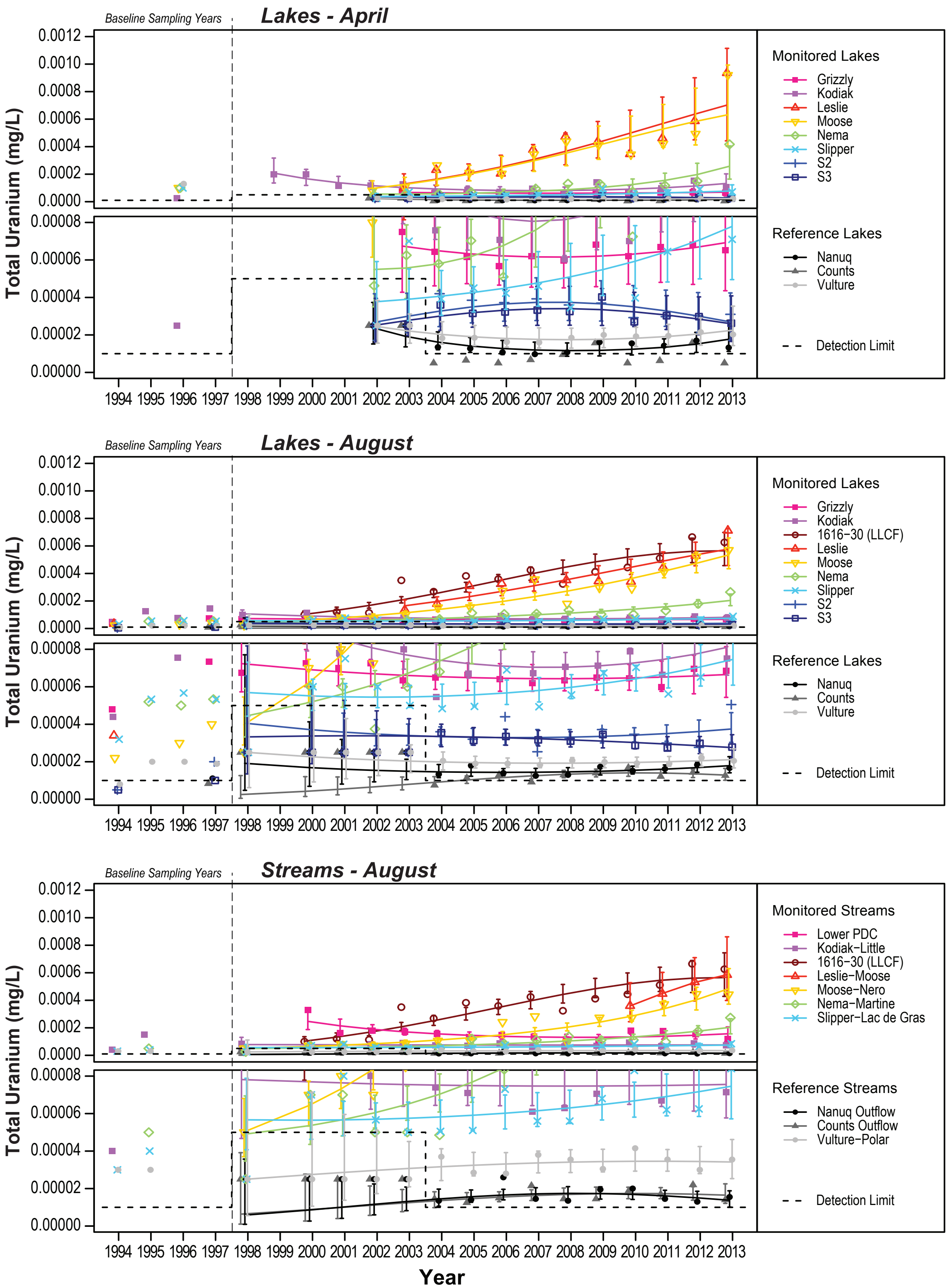
Observed and Fitted Means for Total Strontium Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
Water quality benchmark (Golder 2011) = 6.242 mg/L.

Figure 4-21

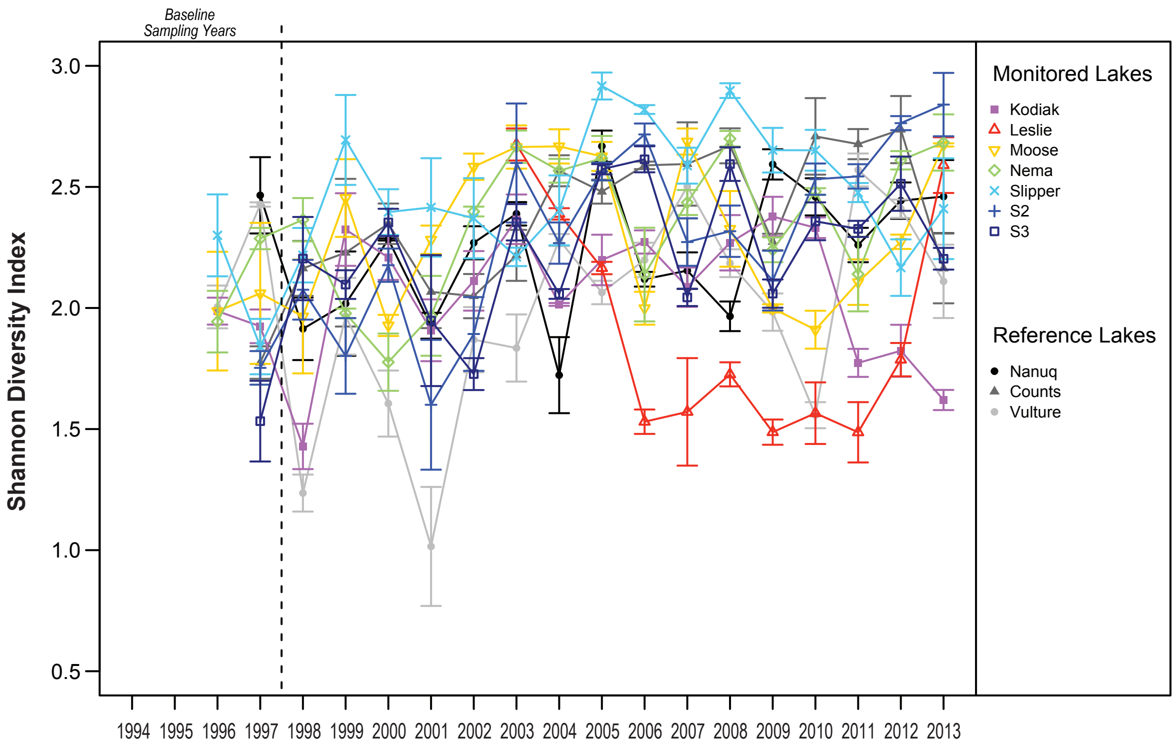
Observed and Fitted Means for Total Uranium Concentrations in Koala Watershed Lakes and Streams and Lac de Gras, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
CCME Guideline = 0.015 mg/L.

Figure 4-22

Average Diversity Indices for Phytoplankton in Koala Watershed Lakes and Lac de Gras, August 1996 to 2013



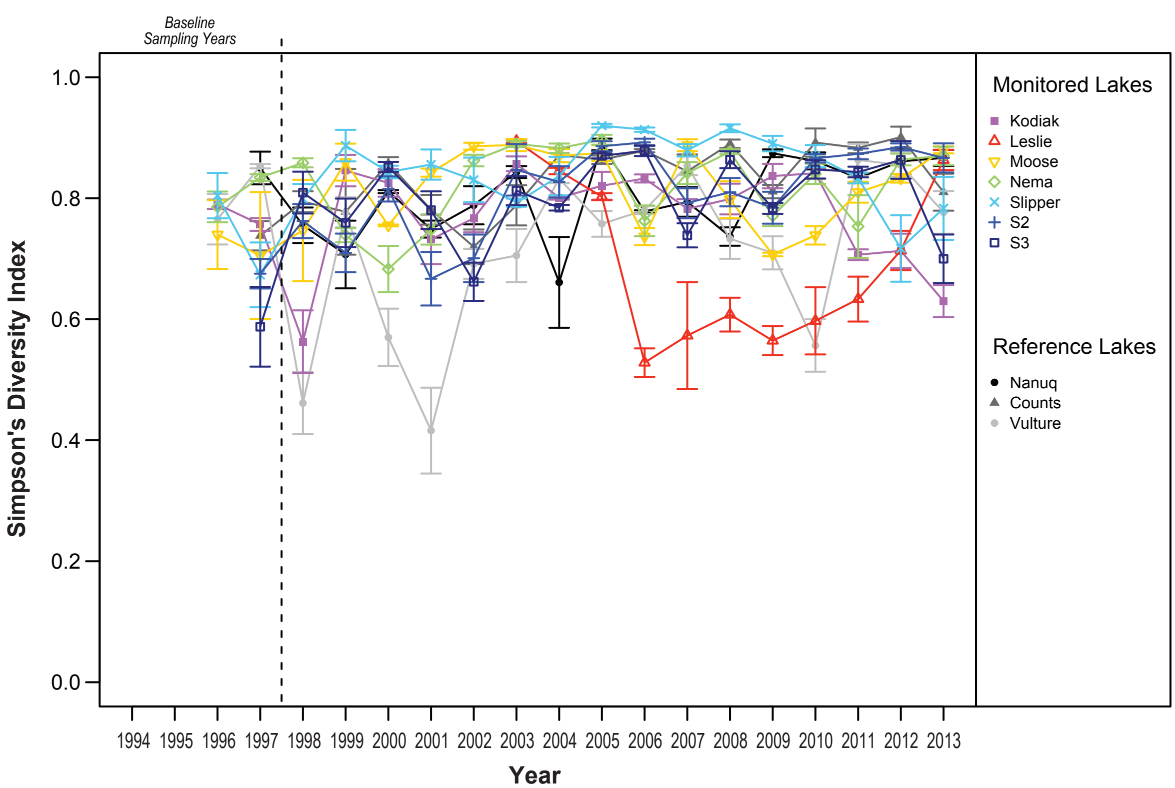


Figure 4-23

Average Phytoplankton Density by Taxonomic Group for AEMP Reference Lakes, 1996 to 2013

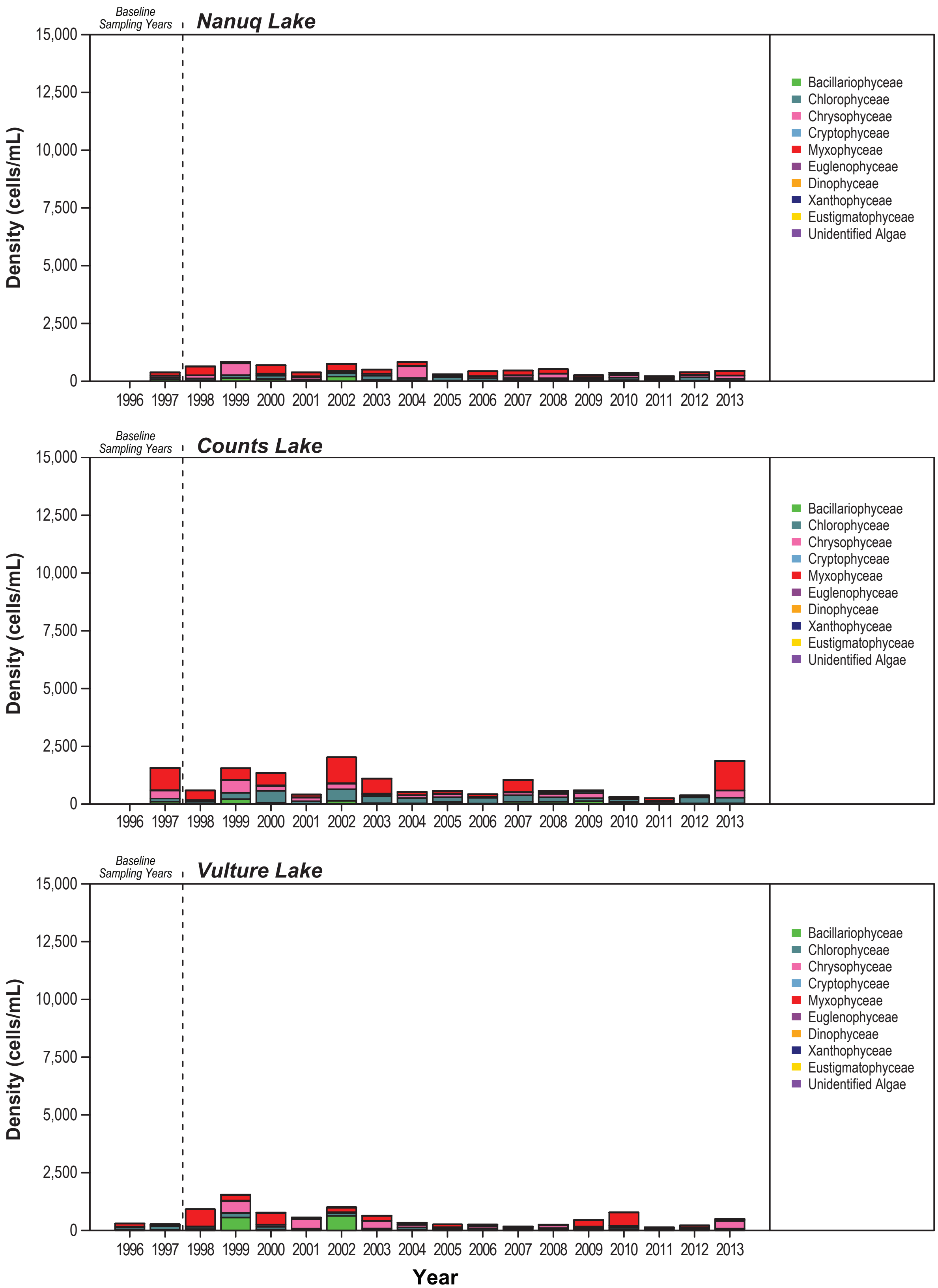
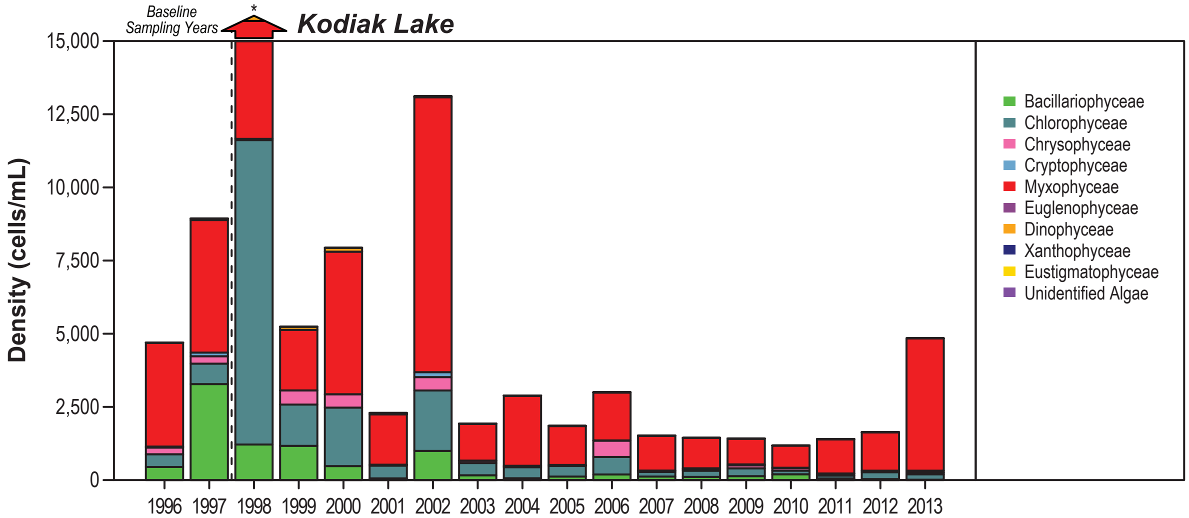
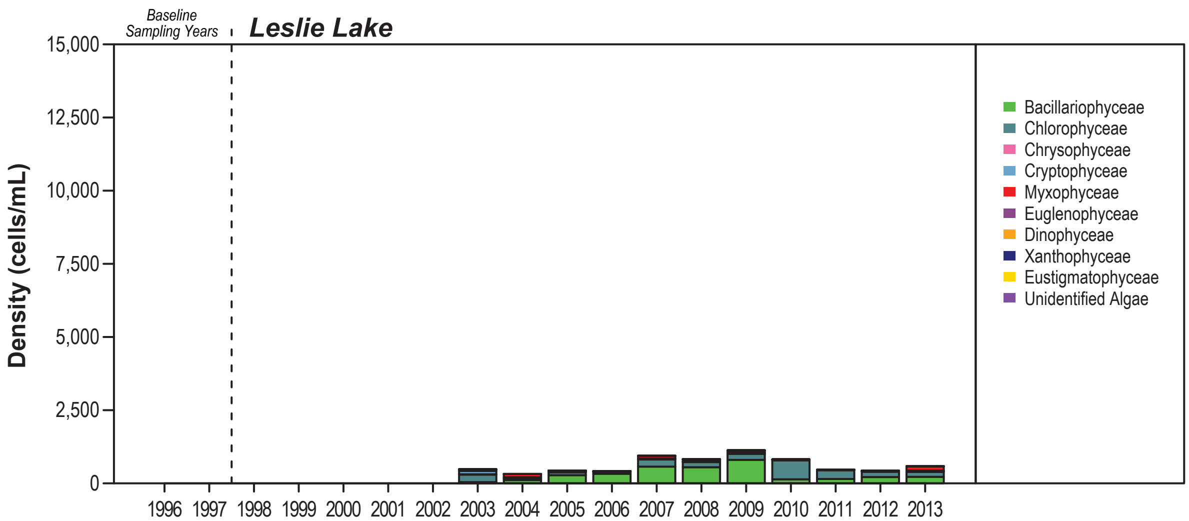
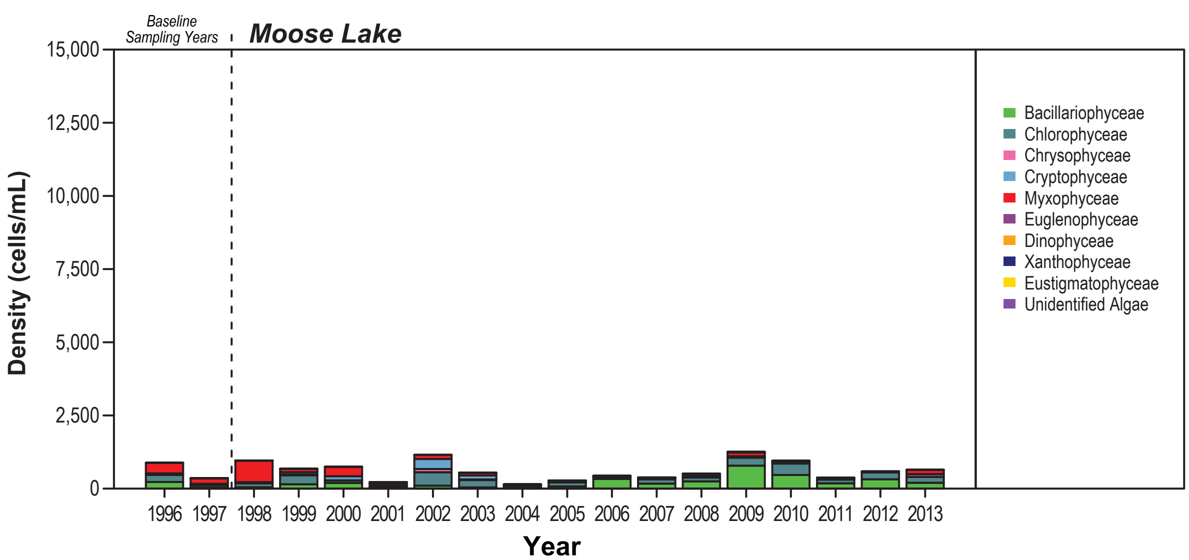


Figure 4-24a

Average Phytoplankton Density by Taxonomic Group for Lakes of the Koala Watershed, 1996 to 2013







*Note: * Total density = 16, 434; Myxophyceae = 4, 551; Dinophyceae = 225.*

Figure 4-24b

Average Phytoplankton Density by Taxonomic Group for Lakes of the Koala Watershed, 1996 to 2013

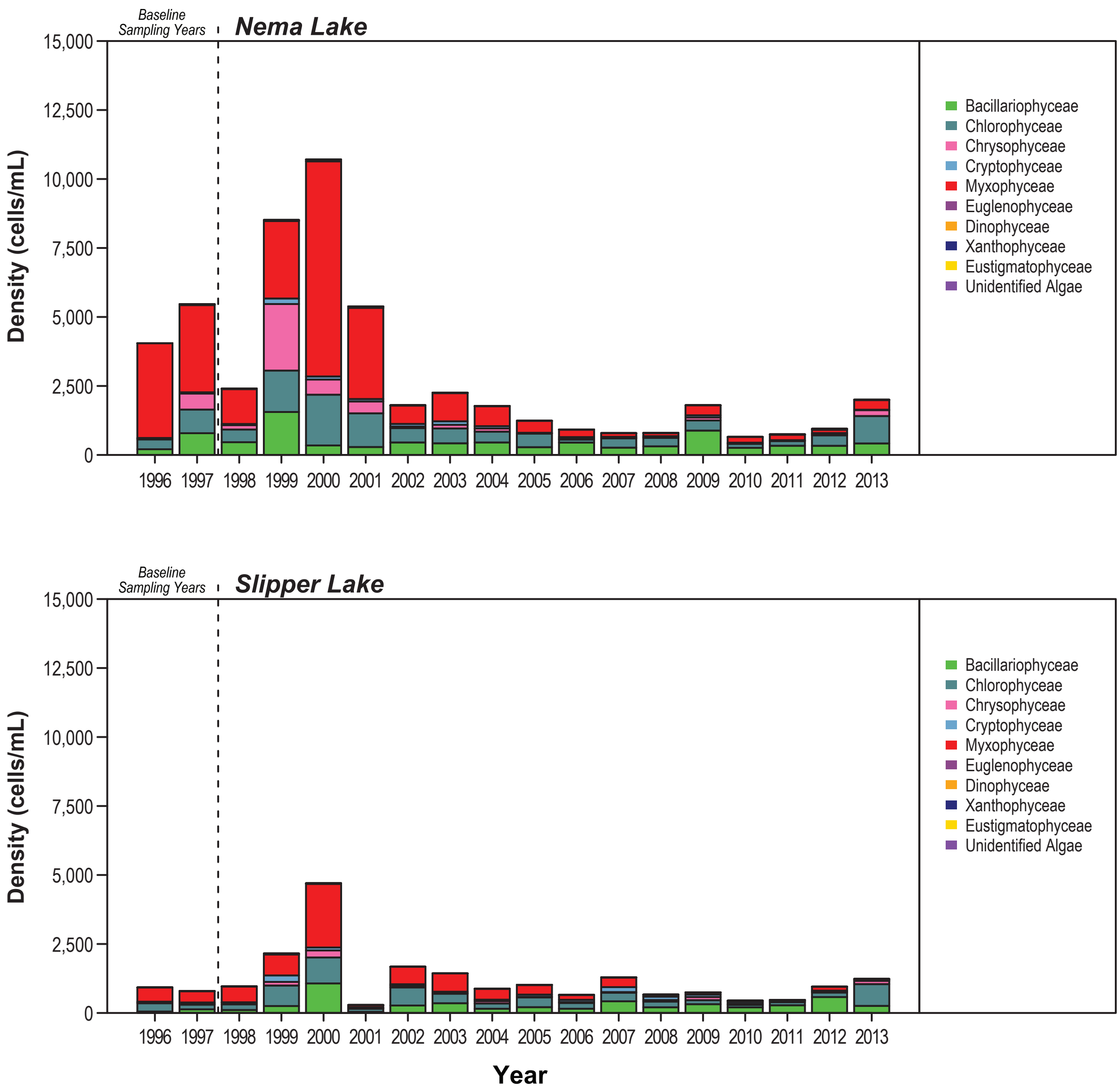


Figure 4-25

Average Phytoplankton Density by Taxonomic Group for Lac de Gras, 1996 to 2013

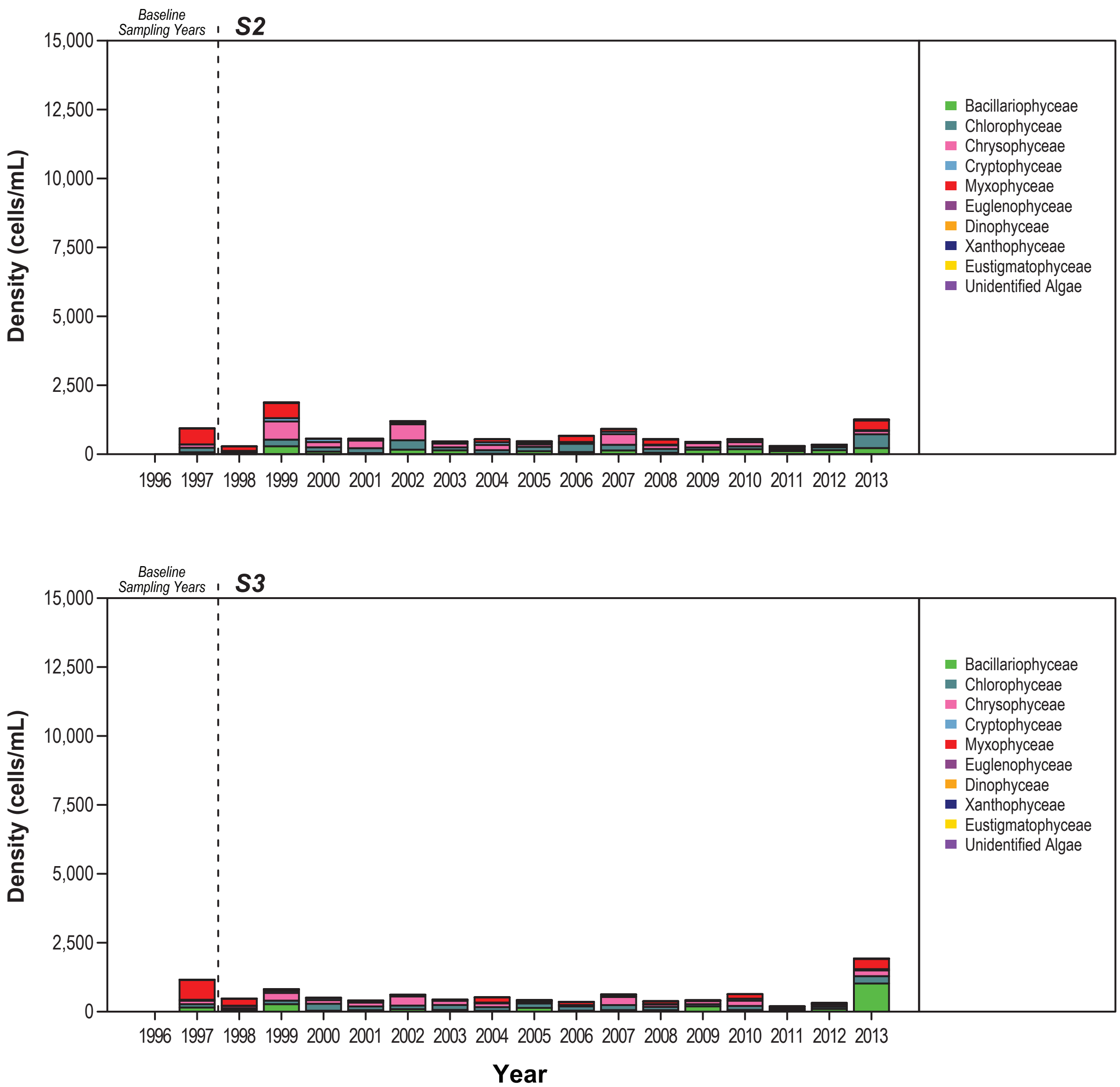


Figure 4-26

Relative Densities of Phytoplankton Taxa in AEMP Reference Lakes, 1996 to 2013

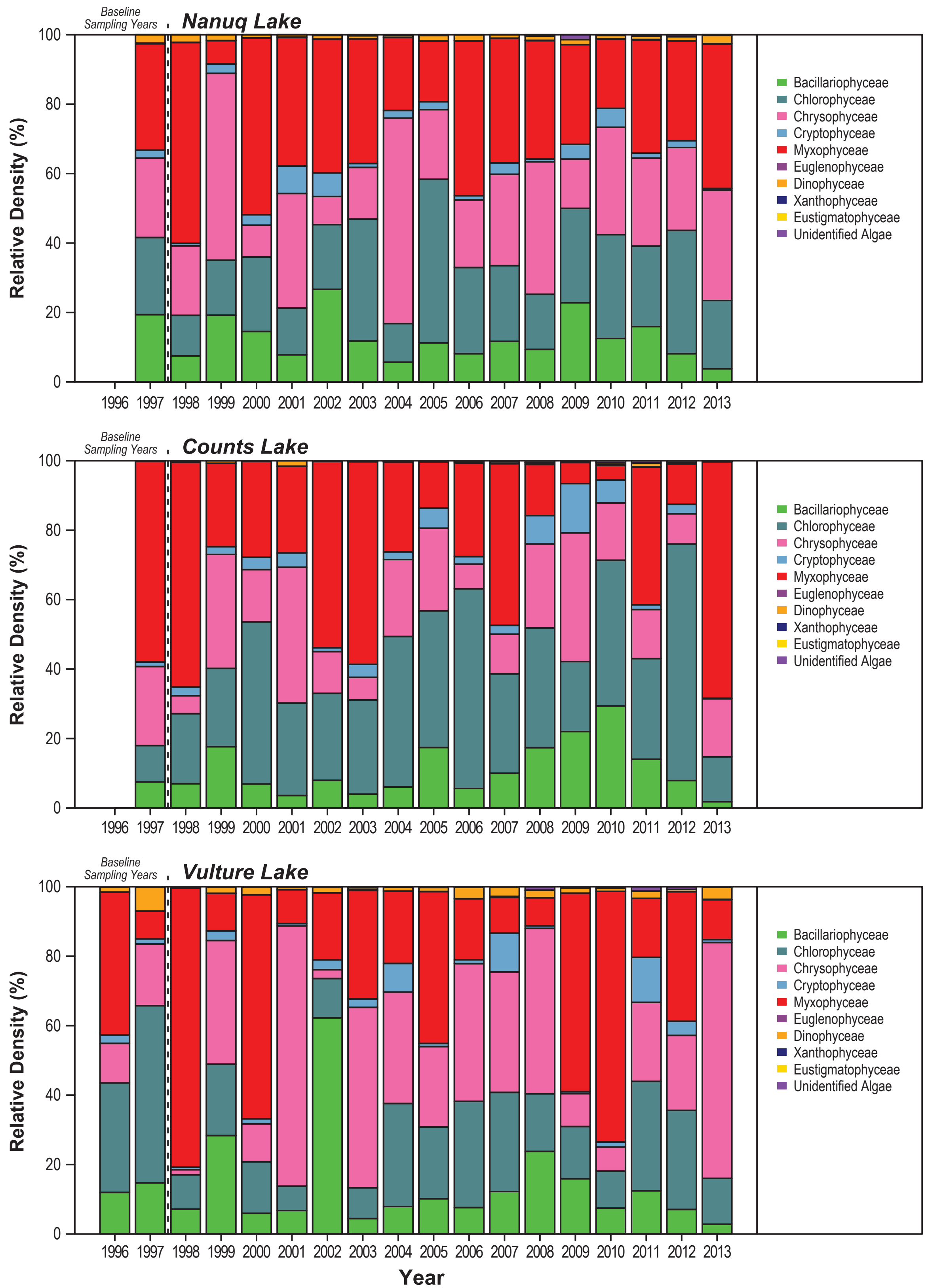


Figure 4-27a

Relative Densities of Phytoplankton Taxa in Lakes of the Koala Watershed, 1996 to 2013

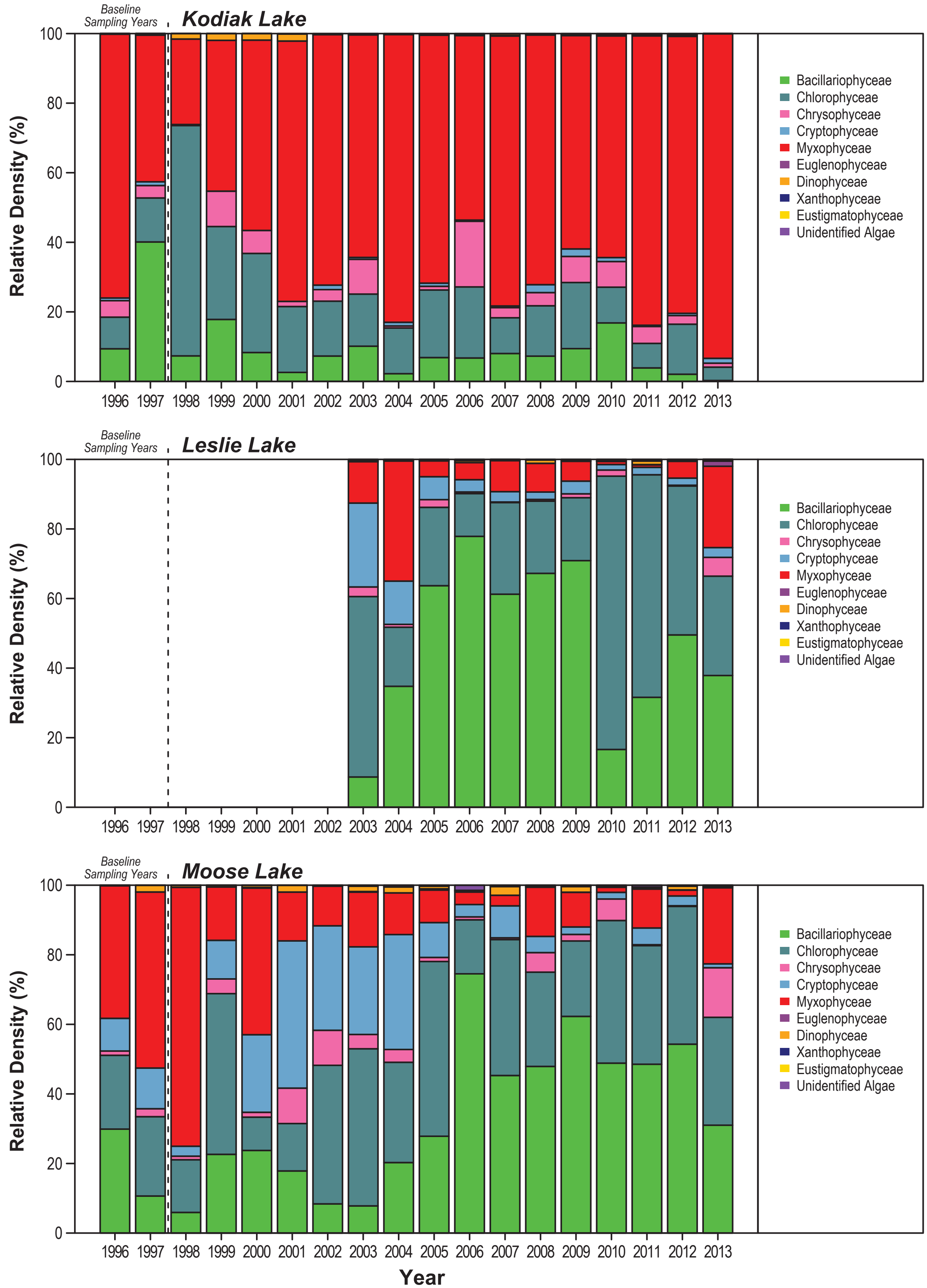


Figure 4-27b

Relative Densities of Phytoplankton Taxa in Lakes of the Koala Watershed, 1996 to 2013

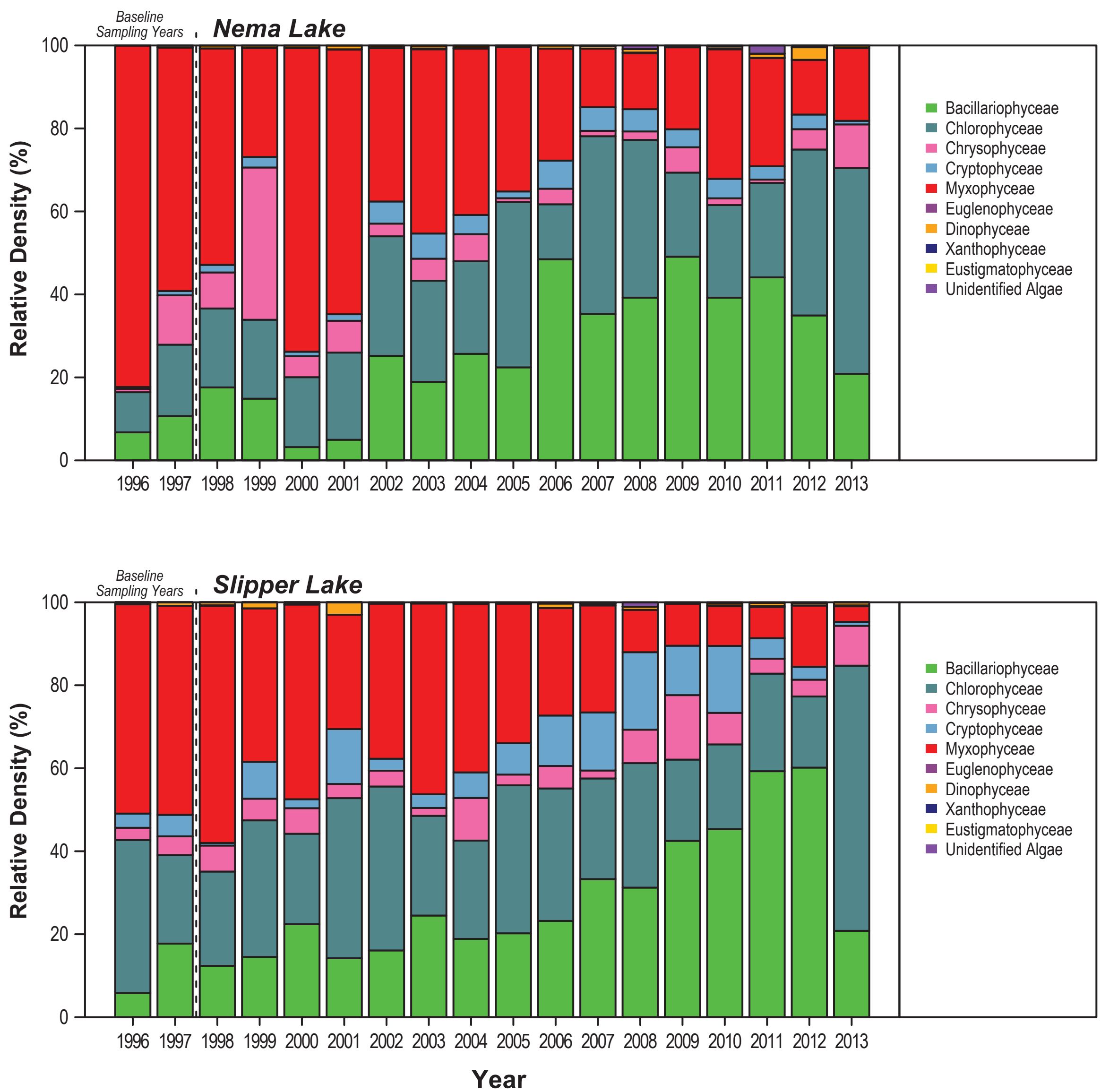
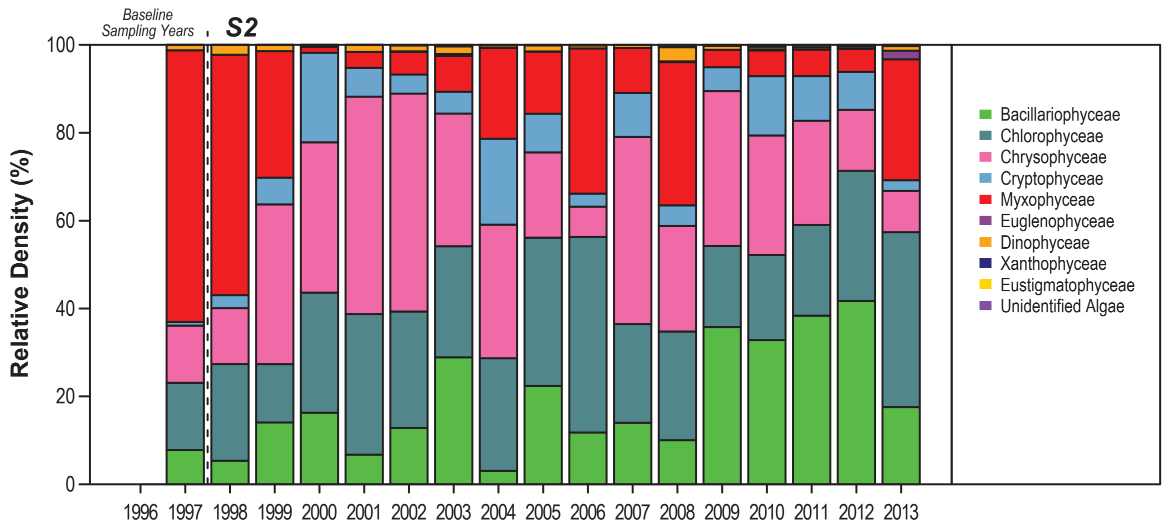


Figure 4-28

Relative Densities of Phytoplankton Taxa in Lac de Gras, 1996 to 2013



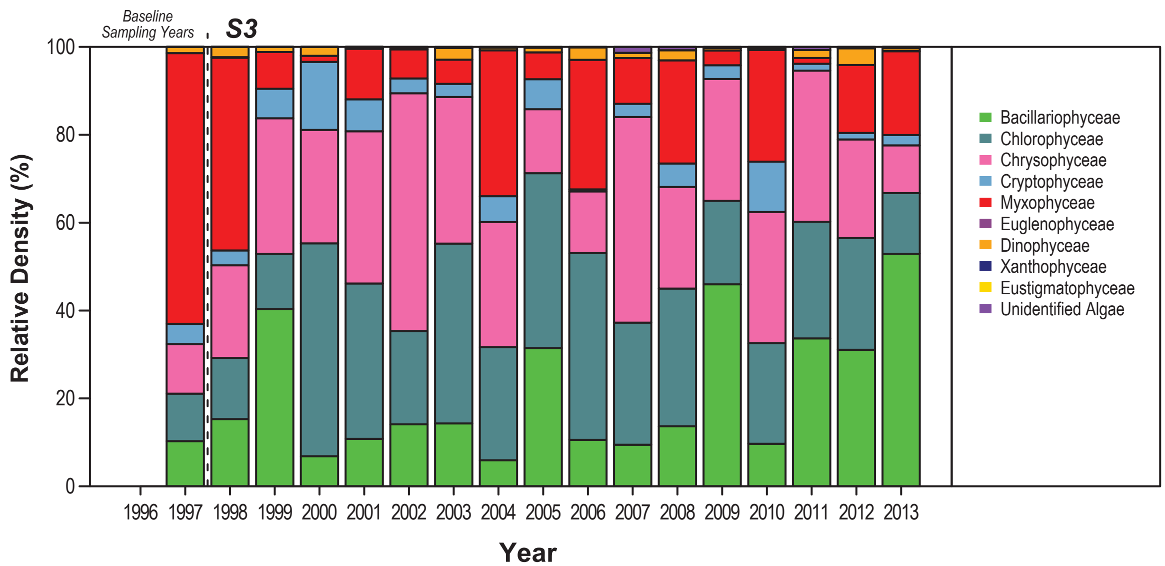
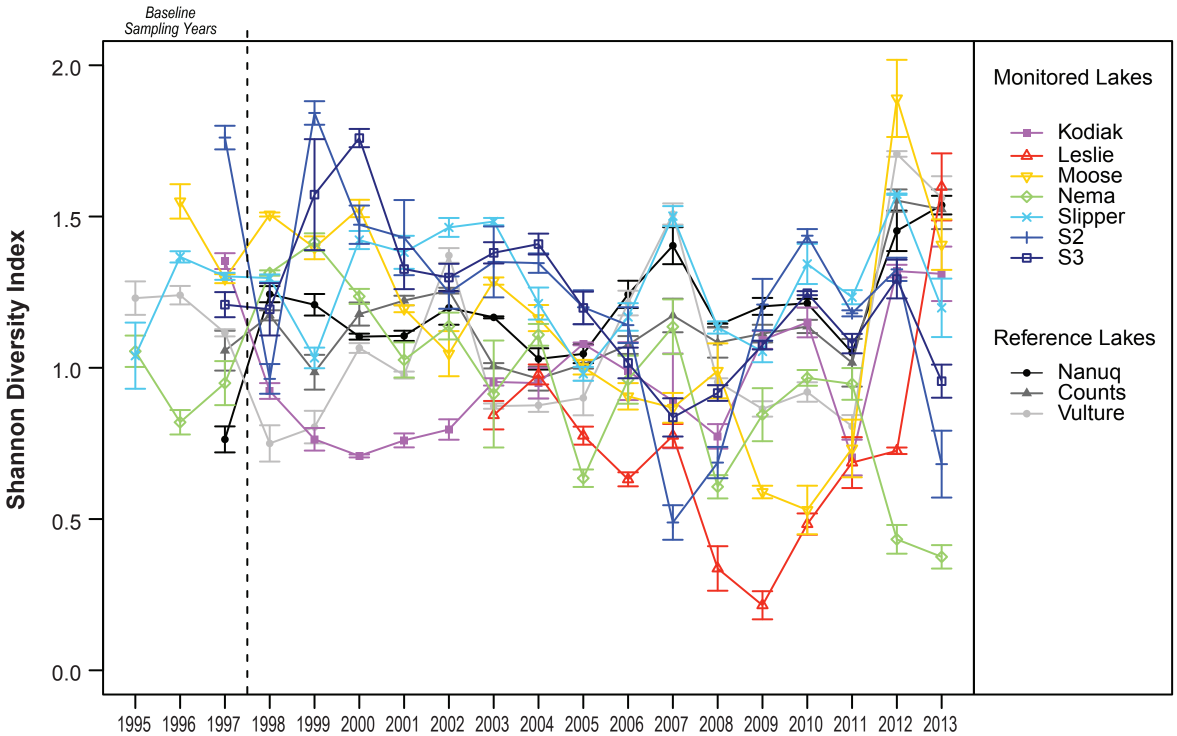


Figure 4-29

Average Diversity Indices for Zooplankton in Koala Watershed Lakes and Lac de Gras, August 1995 to 2013



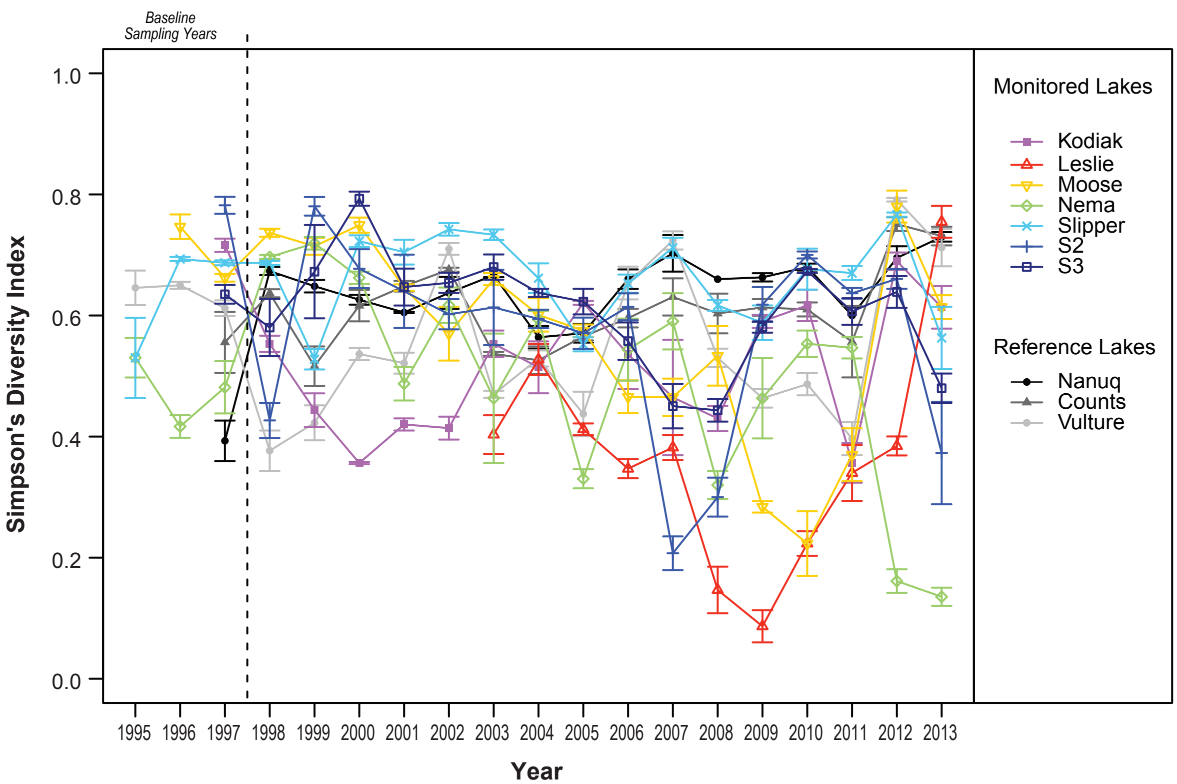


Figure 4-30

Average Zooplankton Density by Taxonomic Group for AEMP Reference Lakes, 1995 to 2013

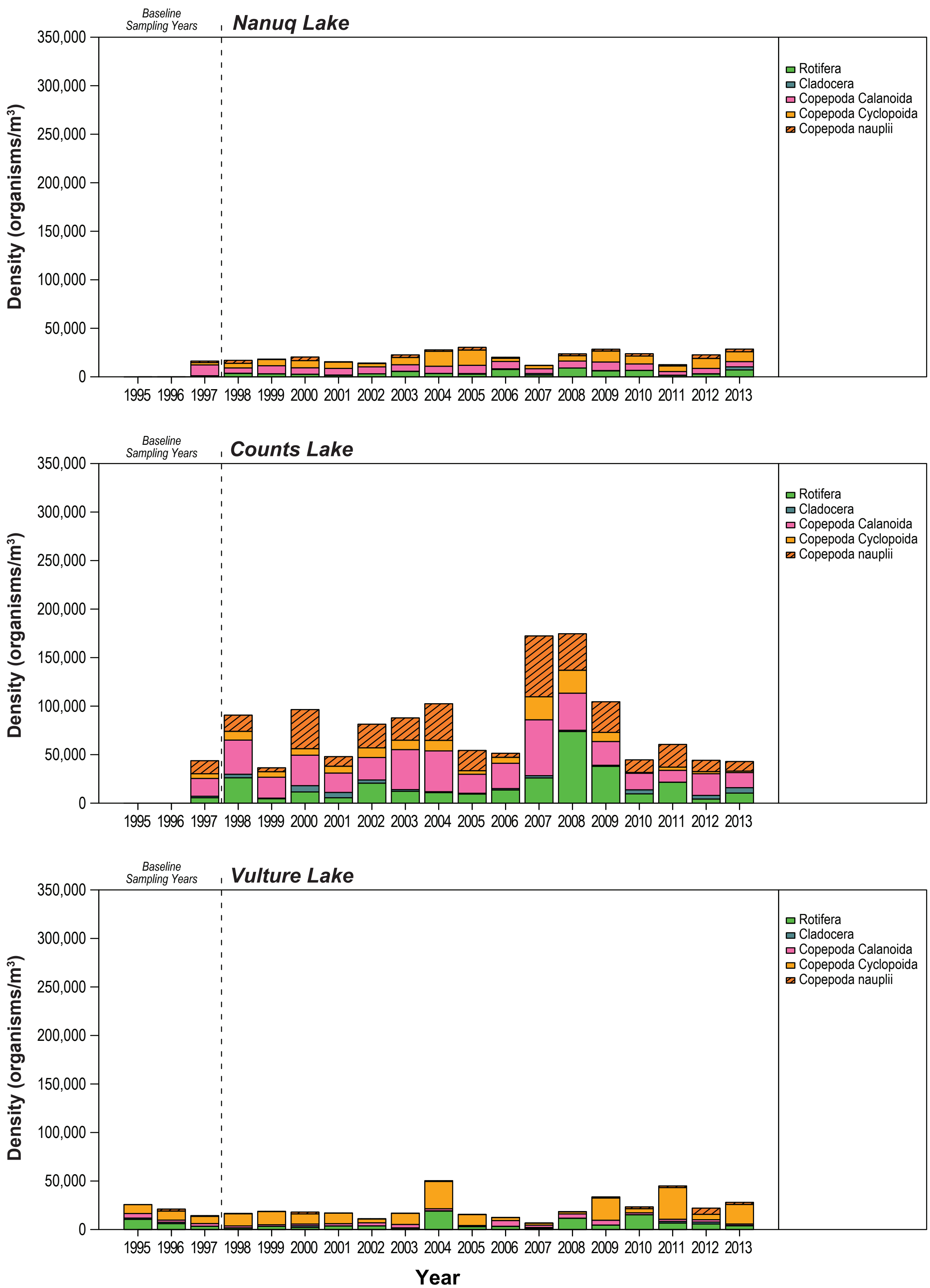


Figure 4-31a

Average Zooplankton Density by Taxonomic Group for Lakes of the Koala Watershed, 1995 to 2013

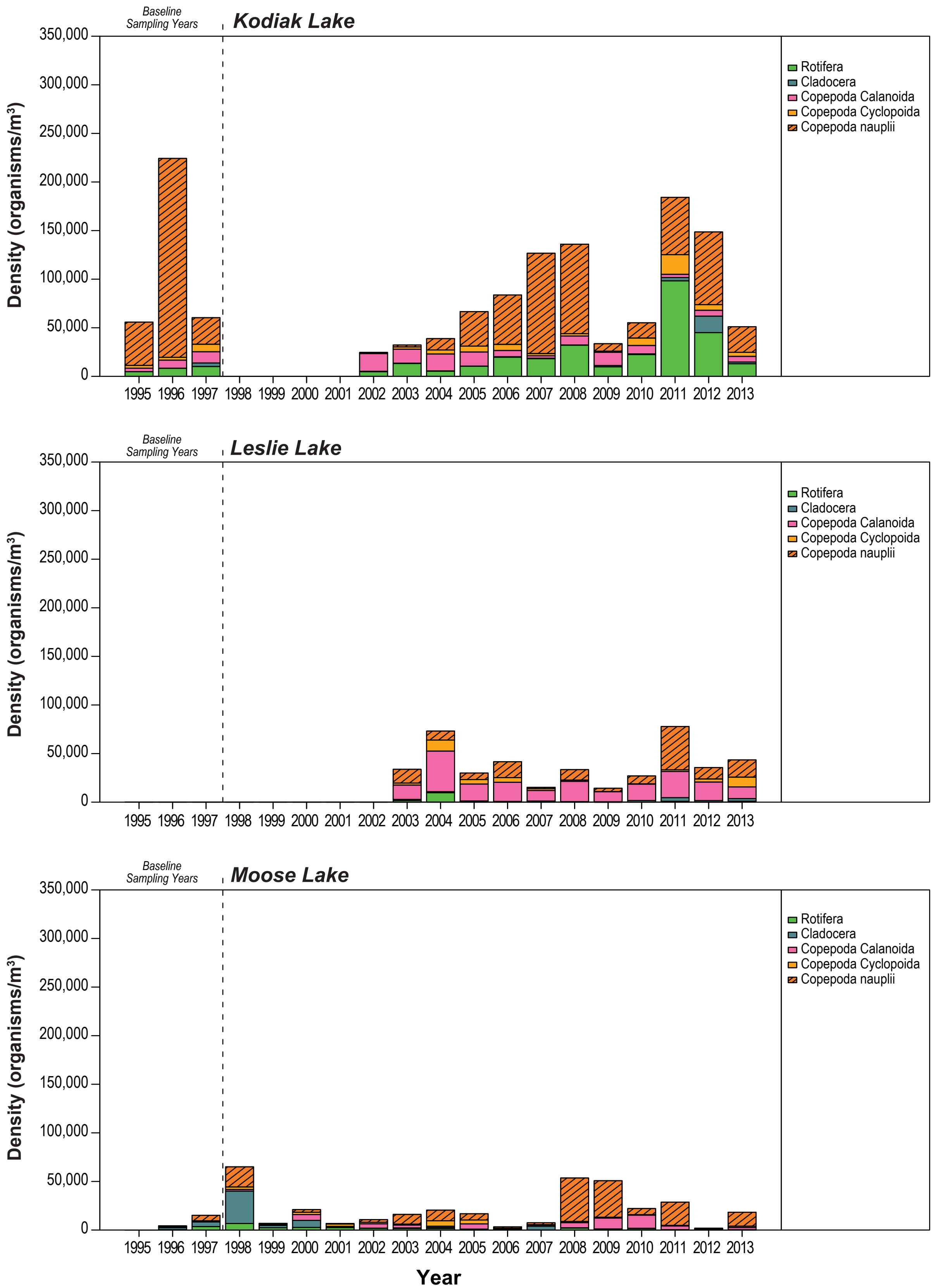
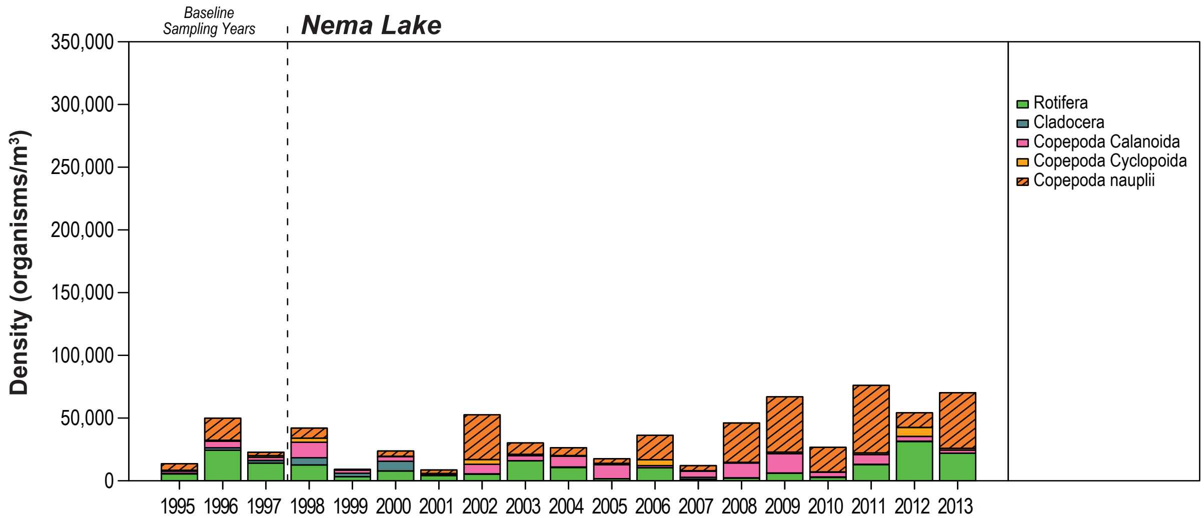


Figure 4-31b

Average Zooplankton Density by Taxonomic Group for Lakes of the Koala Watershed, 1995 to 2013



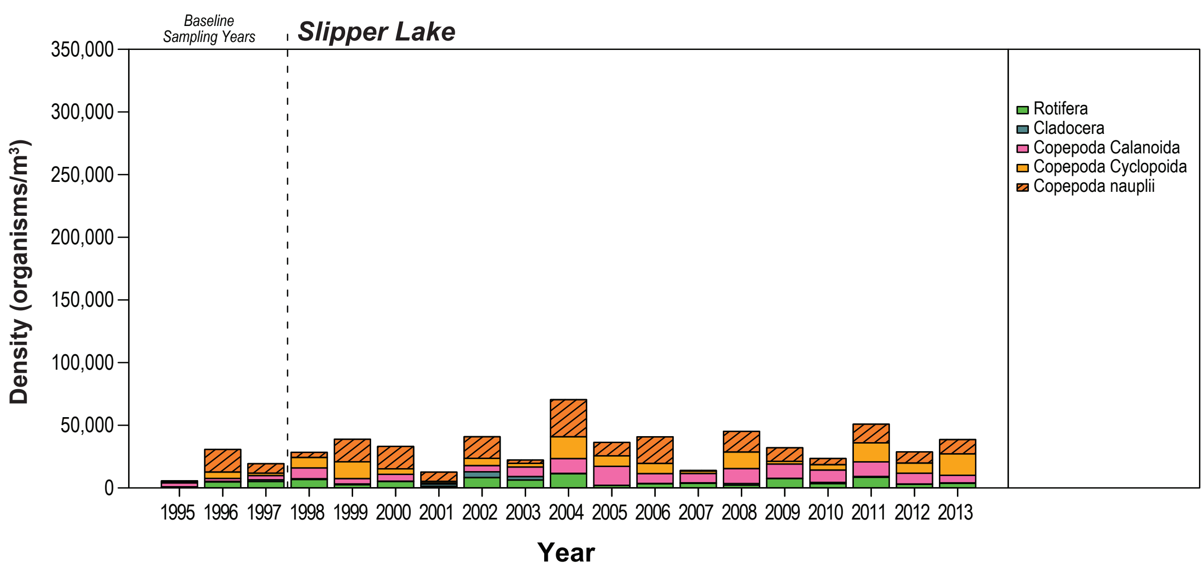


Figure 4-32

Relative Densities of Zooplankton Taxa in AEMP Reference Lakes, 1995 to 2013

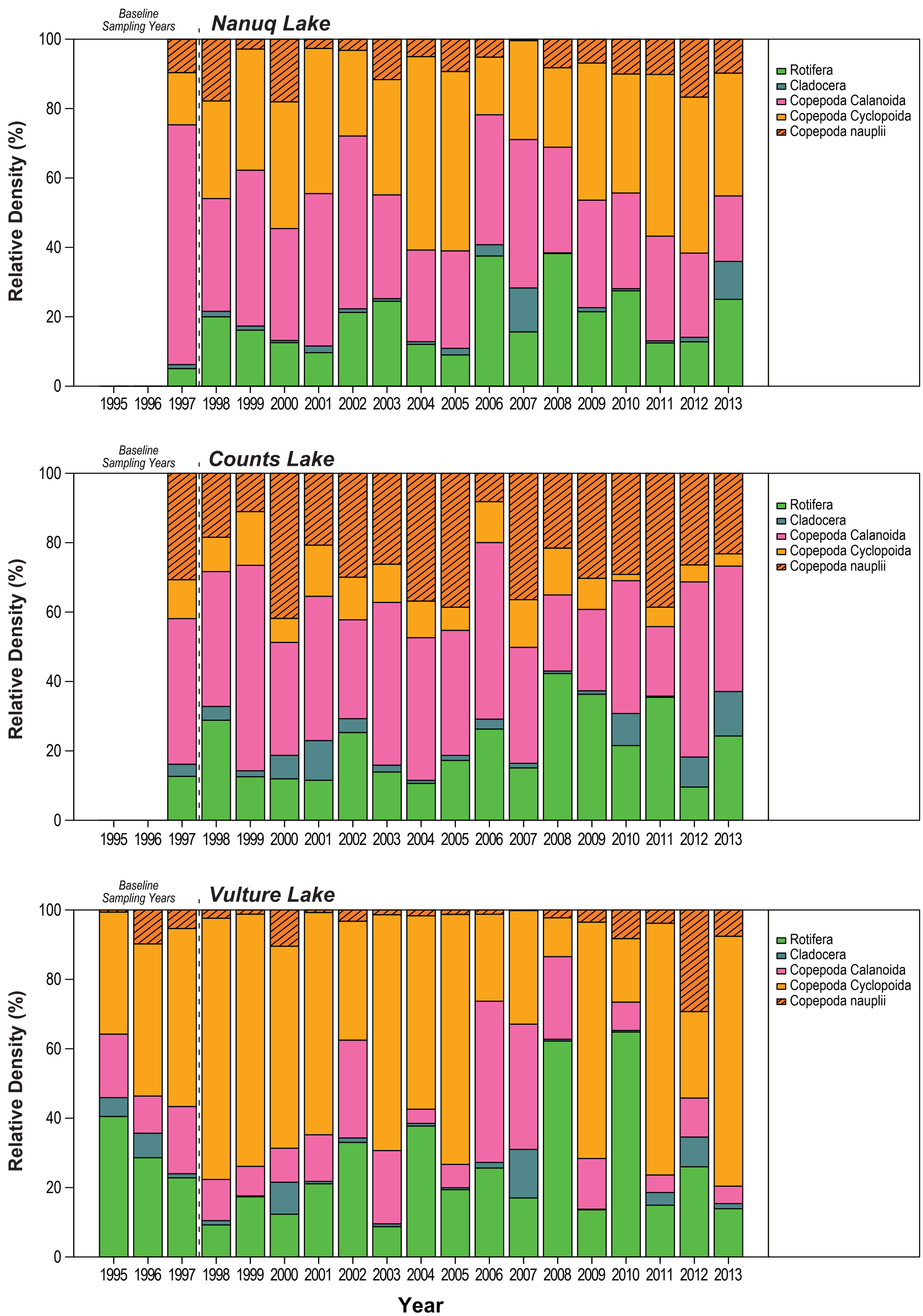


Figure 4-33a

Relative Densities of Zooplankton Taxa in Lakes of the Koala Watershed, 1995 to 2013

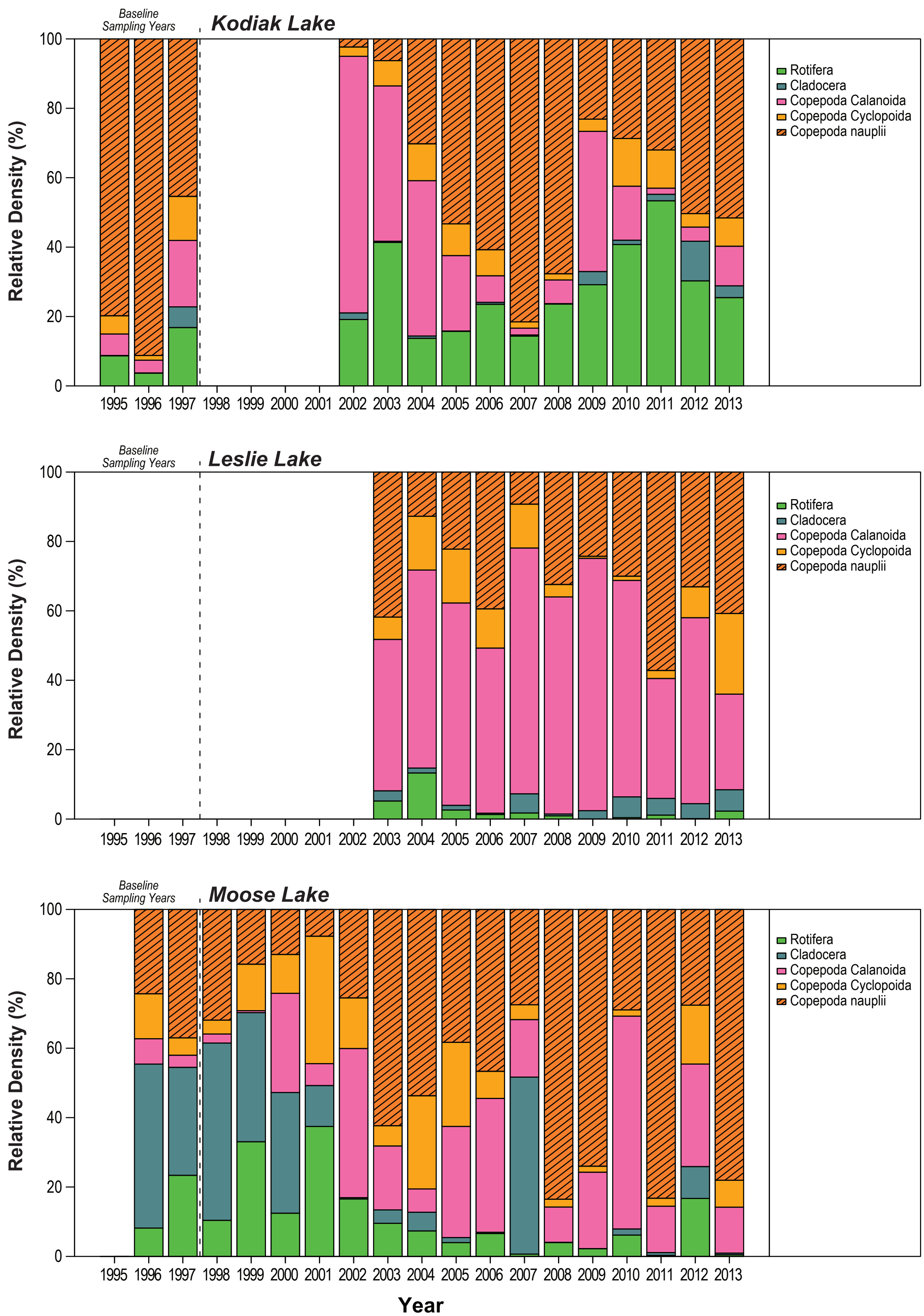
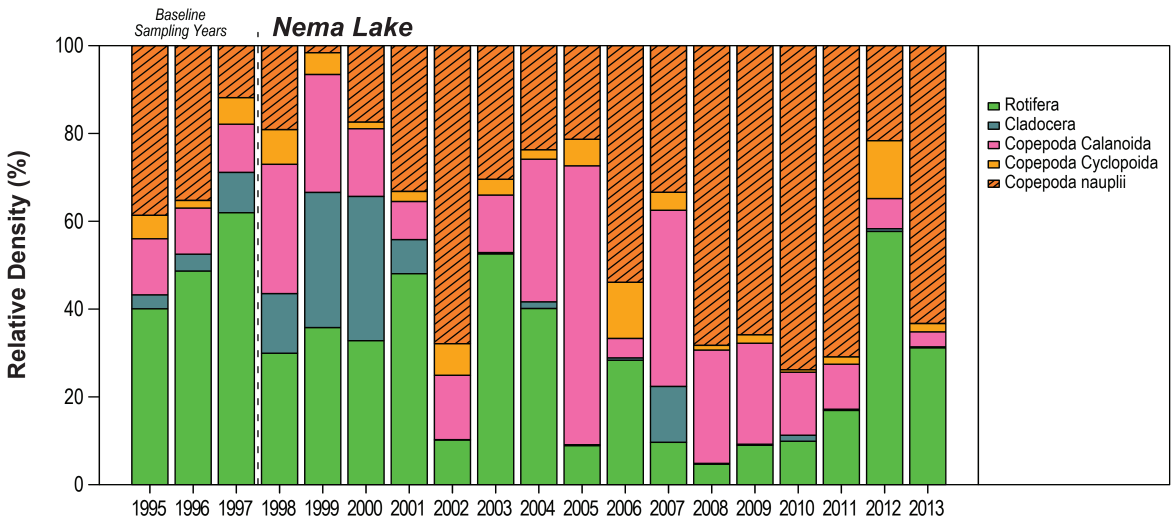


Figure 4-33b

Relative Densities of Zooplankton Taxa in Lakes of the Koala Watershed, 1995 to 2013



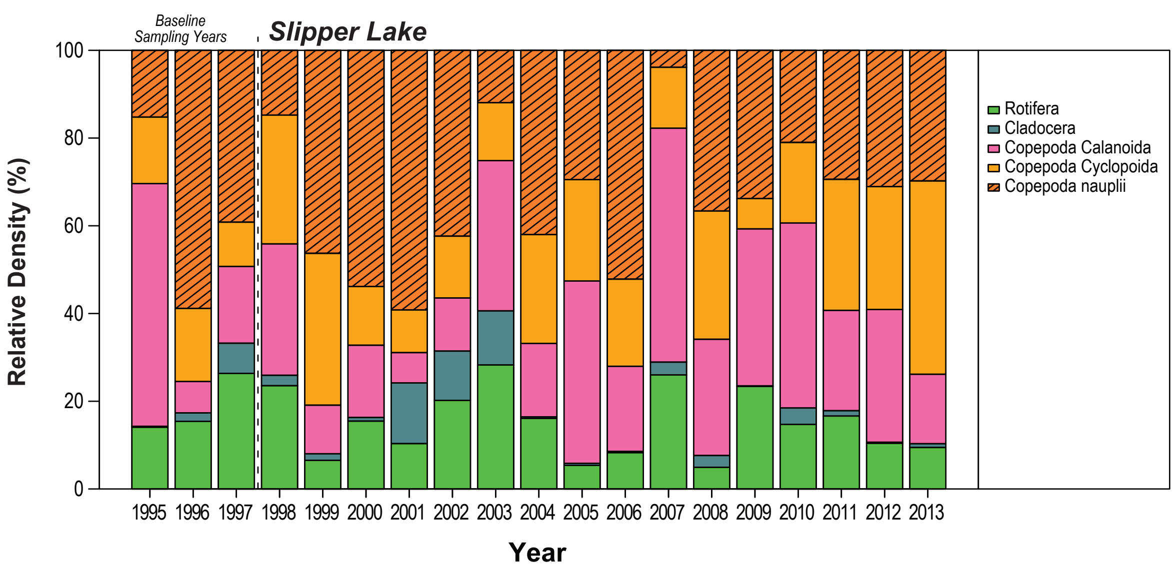


Figure 4-34

Average Diptera Density by Taxonomic Group for AEMP Reference Lakes, 1994 to 2013

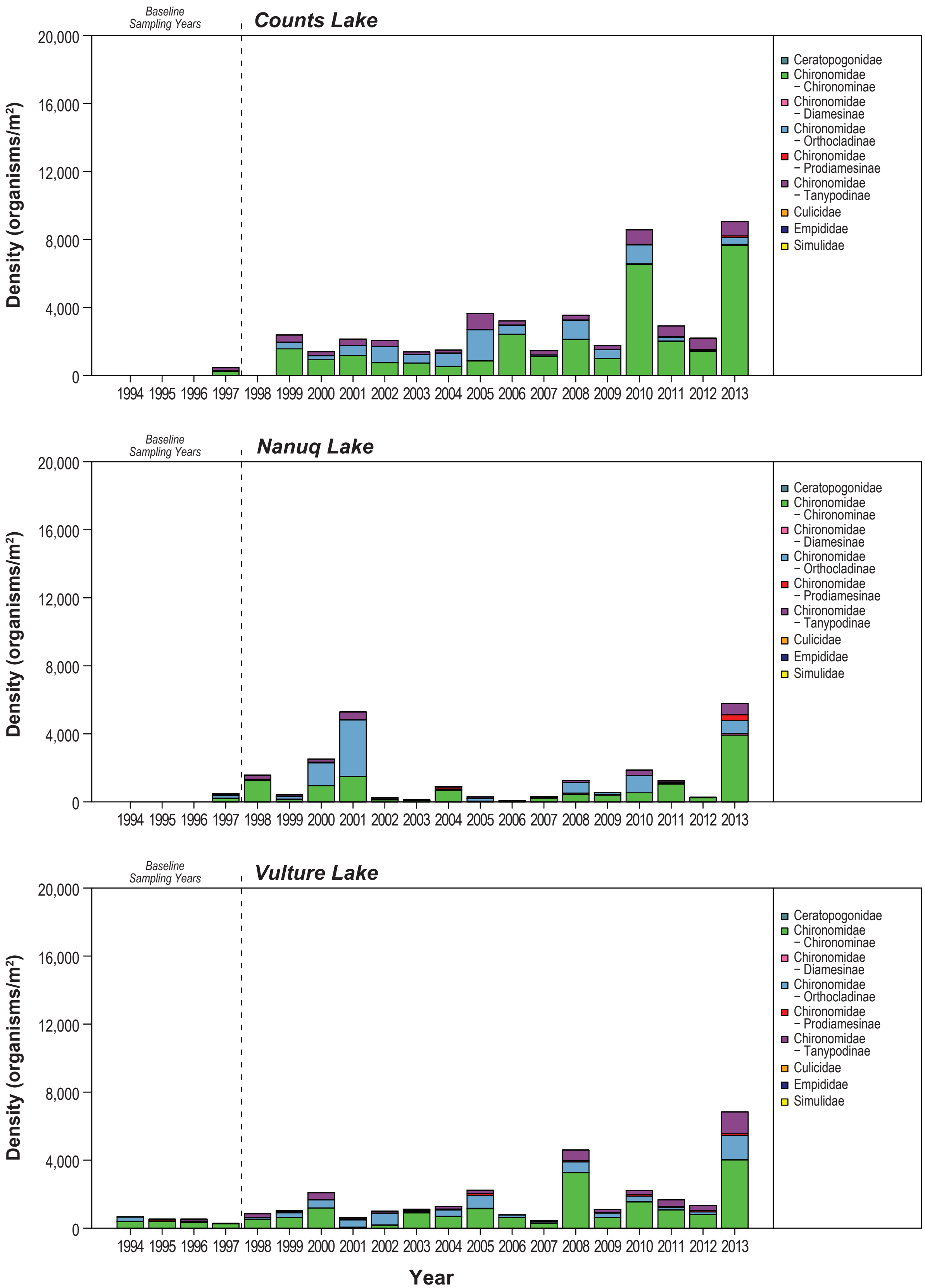


Figure 4-35

Average Diptera Density by Taxonomic Group for Lakes of the Koala Watershed and Lac de Gras, 1994 to 2013

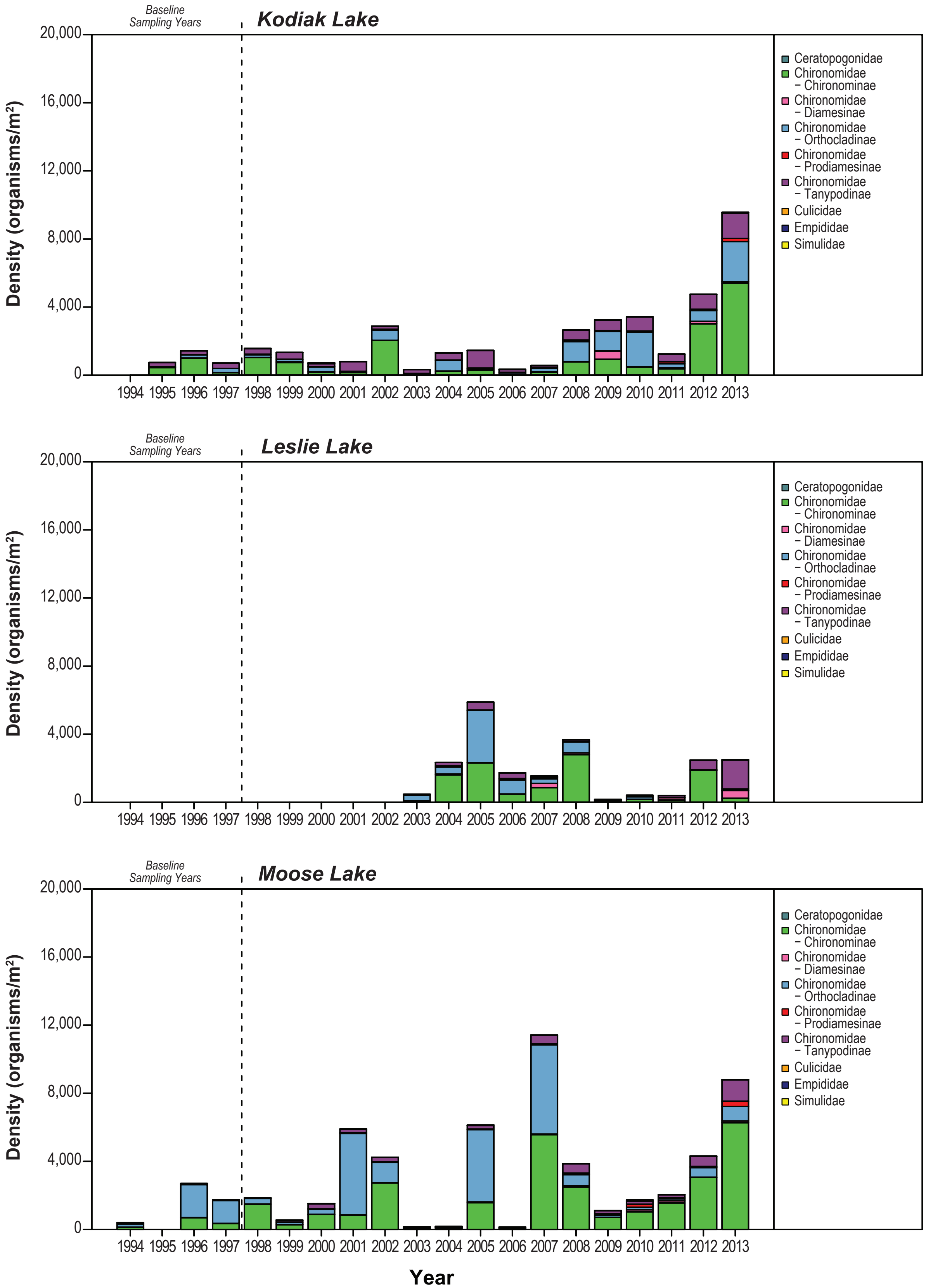


Figure 4-36

Average Diptera Density by Taxonomic Group for Lakes of the Koala Watershed and Lac de Gras, 1994 to 2013

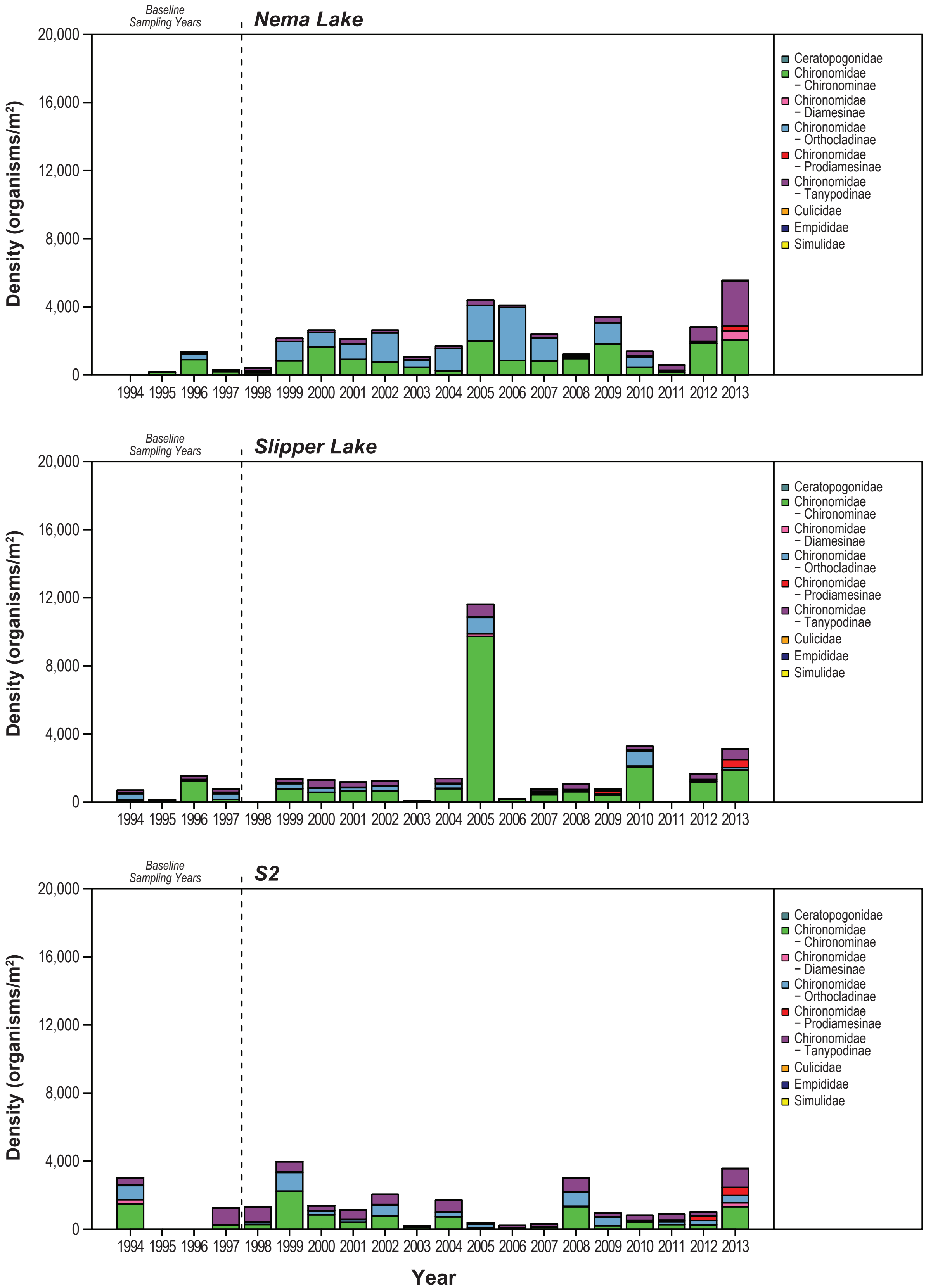
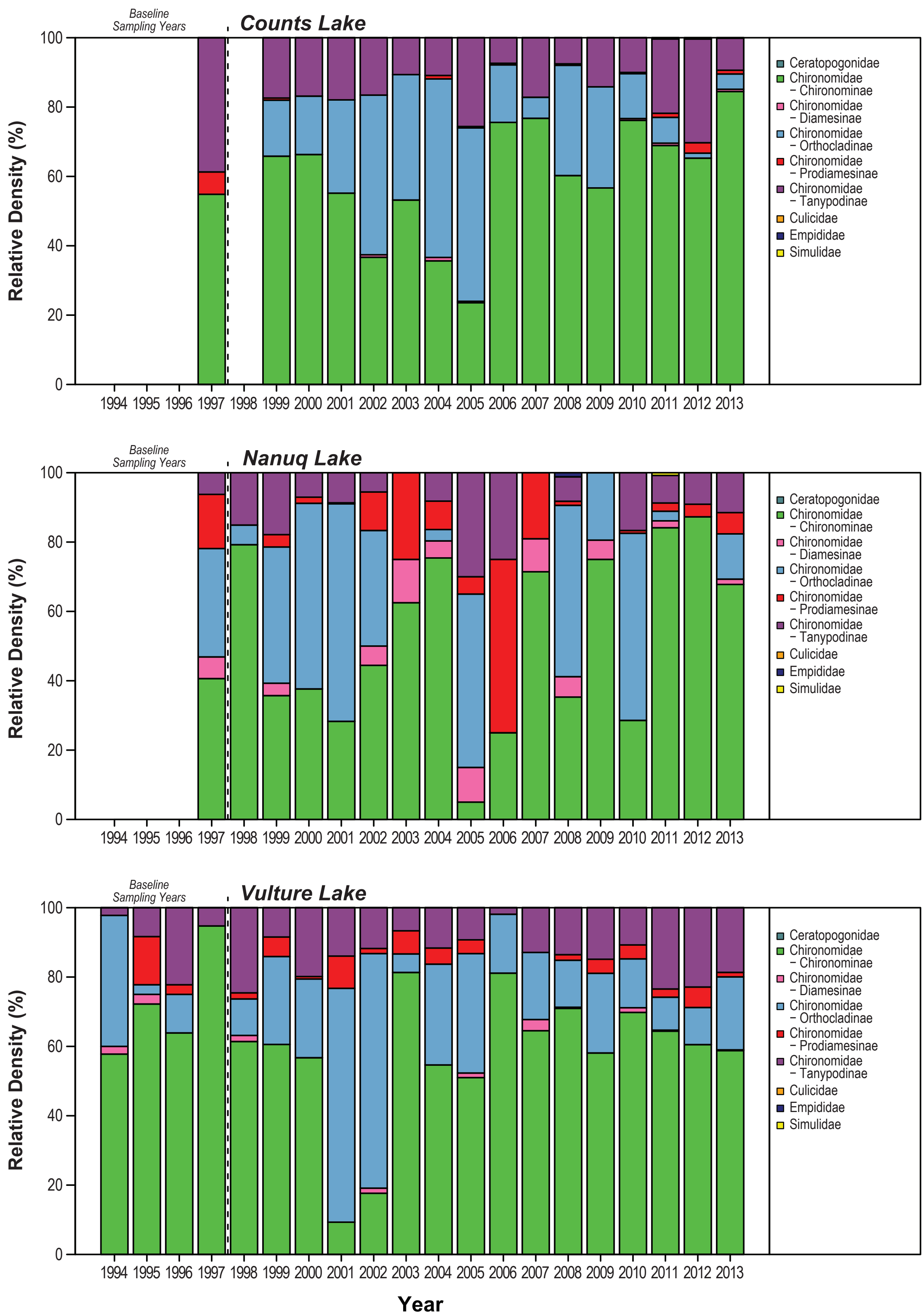
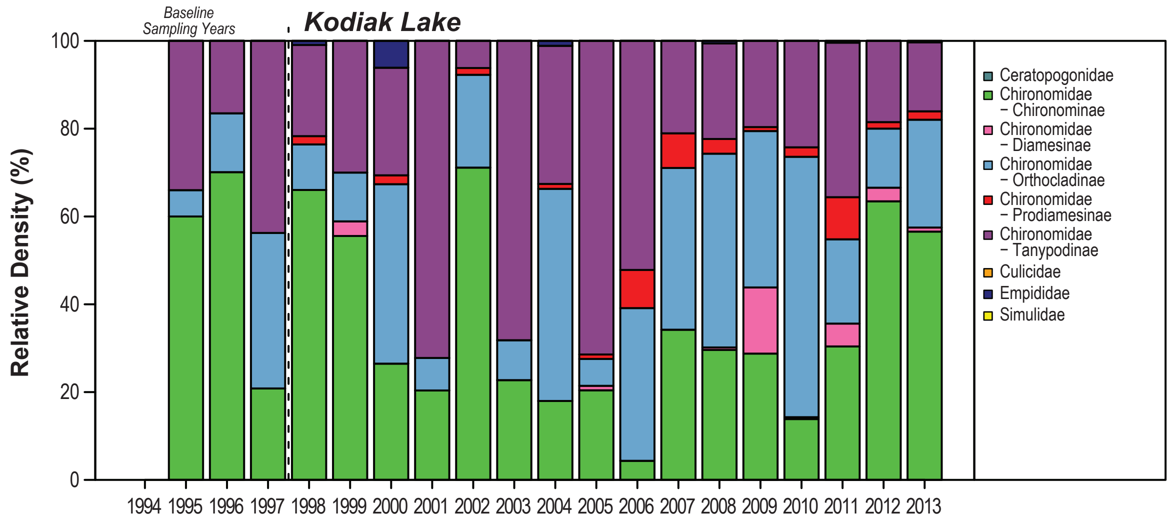


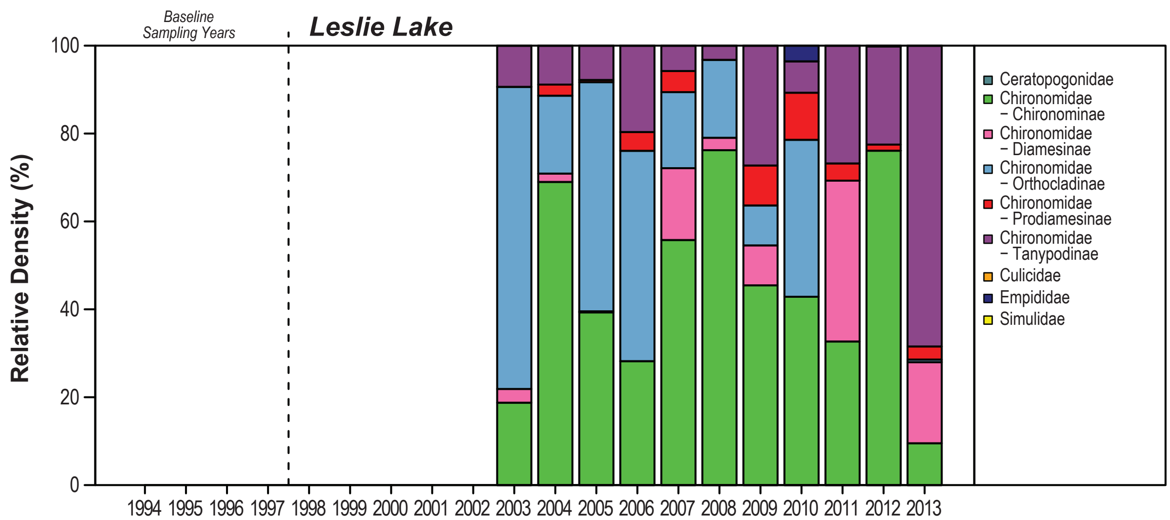
Figure 4-37

Relative Densities of Diptera Taxa in AEMP Reference Lakes, 1994 to 2013



Relative Densities of Diptera Taxa in Lakes of the Koala Watershed and Lac de Gras, 1994 to 2013





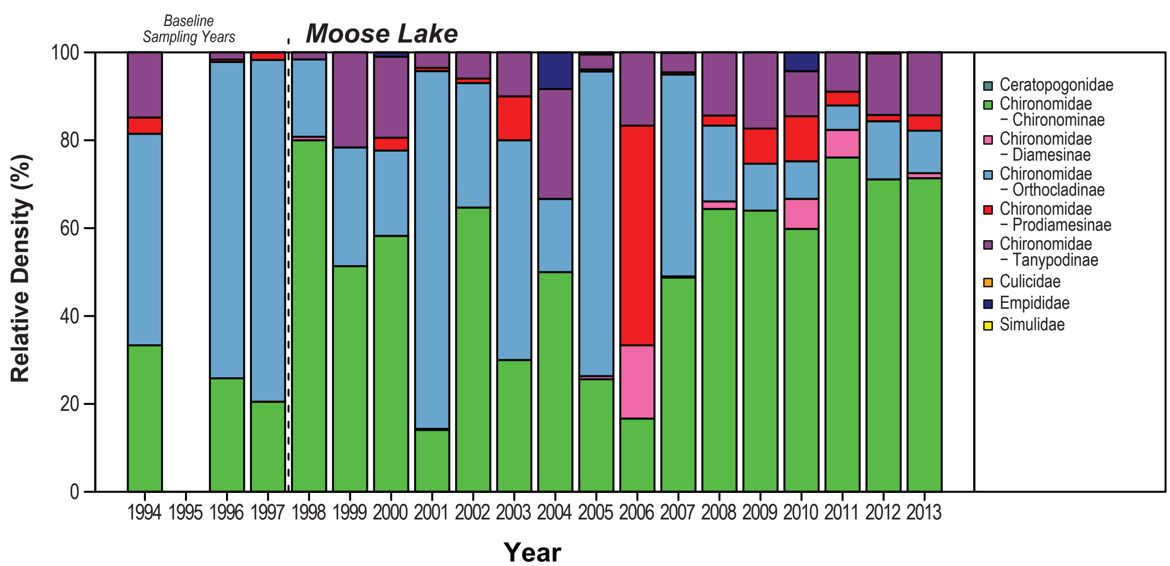
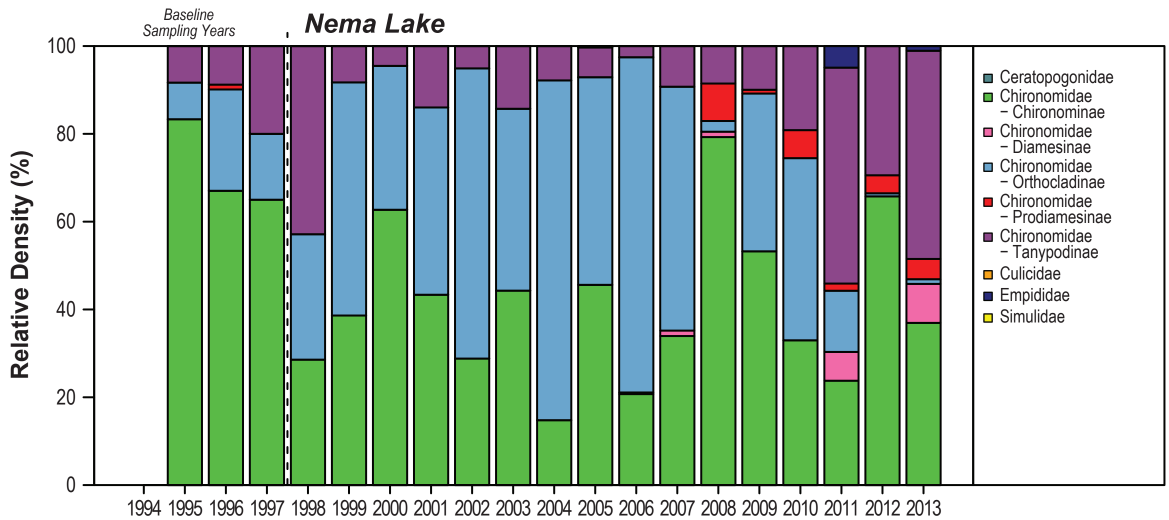
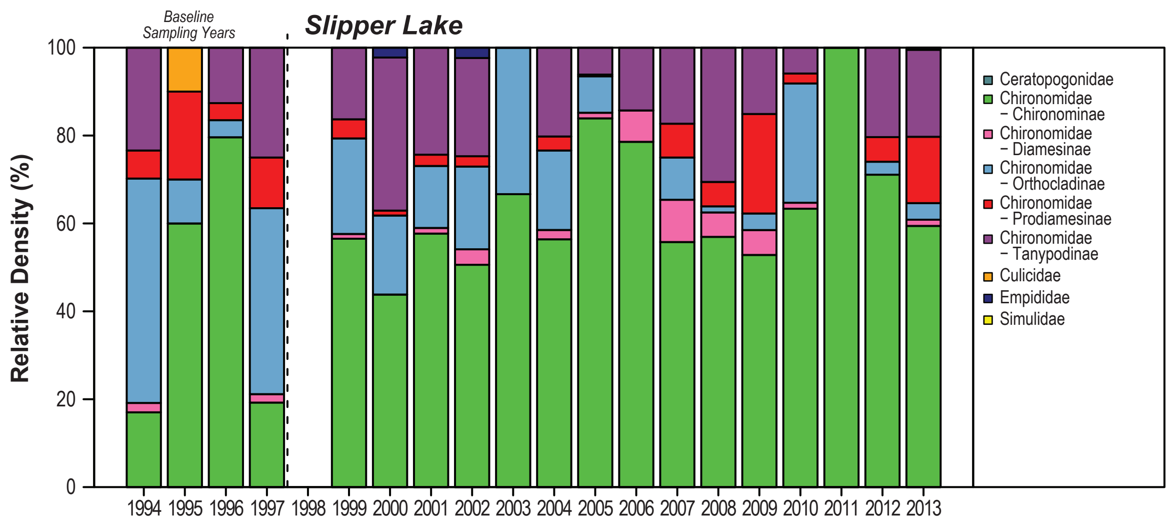
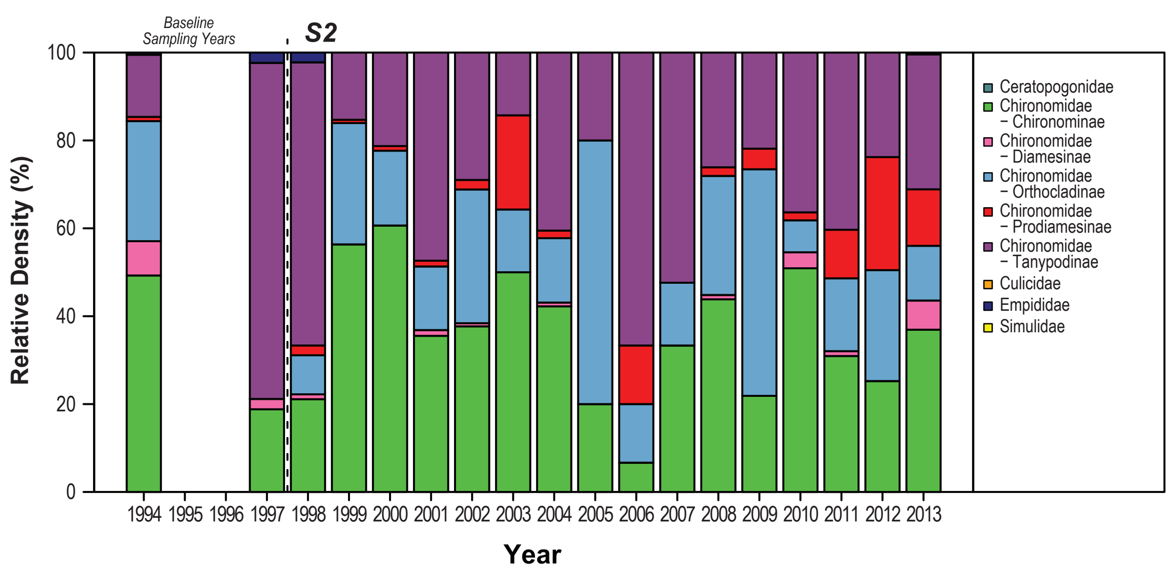


Figure 4-39

Relative Densities of Diptera Taxa in Lakes of the Koala Watershed and Lac de Gras, 1994 to 2013







5. Summary of Evaluation of Effects for the King-Cujo Watershed and Lac du Sauvage

5. Summary of Evaluation of Effects for the King-Cujo Watershed and Lac du Sauvage

Figure 5-1 summarizes the evaluation of effects for the King-Cujo Watershed and Lac du Sauvage. Because statistical tests were two-sided and only tested for differences between reference and monitored lakes, conclusions on the direction of change were made from graphical analysis. Figures 5-2 to 5-16 illustrate regression analyses and graphical representations of historical data that were used to assist in interpreting statistical results and provide support for the summary of effects for the King-Cujo Watershed lakes and Lac du Sauvage presented below. For additional details, please refer to Part 1 – Evaluation of Effects.

No mine effects were detected with respect to physical limnology variables (i.e., temperature, dissolved oxygen, and Secchi depths) in monitored lakes during either the ice-covered or open water season in 2013 (Figure 5-1). Under-ice DO concentrations were greater than the CCME guideline value of 6.5 mg/L throughout the majority of the water column in most monitored sites in the King-Cujo Watershed and Lac du Sauvage(CCME 2013). In Cujo Lake, DO measurements were less than CCME guidelines throughout most of the water column by early April 2013, through to the last sampling date during the ice-covered season, though some improvement occurred following snow clearance in April. This pattern reflects historical DO profiles in Cujo Lake. Data from reference lakes suggests that deeper sections of sub-Arctic lakes are generally less than the CCME threshold during the ice-covered period. Although, the low under-ice dissolved oxygen concentrations in Cujo Lake may be related to elevated TOC concentrations in Cujo Lake, dissolved oxygen and TOC concentrations were not measured during baseline years, making it difficult to discern whether the correlation results from mine operations or represents undisturbed conditions in the King-Cujo Watershed.

A total of 23 water quality variables were evaluated for lakes and streams in the King-Cujo Watershed and Lac du Sauvage in the 2013 AEMP. Of these, concentrations of 13 variables have changed through time in monitored sites downstream of the KPSF (Figure 5-1). Concentrations remain elevated above baseline or reference concentrations in ten cases:

- pH (downstream to Christine-Lac du Sauvage Stream)
- total alkalinity (downstream to Christine-Lac du Sauvage Stream)
- water hardness (downstream to Christine-Lac du Sauvage Stream)
- chloride (downstream to Cujo Outflow)
- sulphate (downstream to Christine-Lac du Sauvage Stream)
- potassium (downstream to Christine-Lac du Sauvage Stream)
- total barium (downstream to Christine-Lac du Sauvage Stream)
- total boron (downstream to Christine-Lac du Sauvage Stream)
- total molybdenum (Christine-Lac du Sauvage Stream)
- total strontium (downstream to Christine-Lac du Sauvage Stream)

Figure 5-1

Summary of Mine-related Changes in the Variables Evaluated for the King-Cujo Watershed and Lac du Sauvage, 2013

Water Quality

	KPSF → Downstream: Cujo Lake	Cujo Outflow	Chirstine-Lac du Sauvage	Lac du Sauvage LdS1	Lac du Sauvage LdS2
Under-ice Temperature	—	●	●	—	●
Under-ice Dissolved Oxygen	—	●	●	—	●
Secchi Depth	—	●	●	—	●
pH	▲ (0-25%)	▲ (0-25%)	▲ (0-25%)	€	€
Total Alkalinity	▲ (76-100%)	▲ (76-100%)	▲ (51-75%)	—	—
Water Hardness	▲ (76-100%)	▲ (76-100%)	▲ (76-100%)	—	—
Chloride	▲ (76-100%)	▲ (76-100%)	—	—	—
Sulphate	▲ (76-100%)	▲ (76-100%)	▲ (76-100%)	—	—
Potassium	▲ (76-100%)	▲ (76-100%)	▲ (51-75%)	—	—
Total Ammonia-N	—	—	—	—	—
Nitrite-N	—	—	—	—	—
Nitrate-N	—	—	—	—	—
Total Phosphate-P	*	—	—	*	*
Total Organic Carbon	■	■	■	—	—
Total Antimony	—	—	*	—	—
Total Arsenic	—	—	—	—	—
Total Barium	▲ (76-100%)	▲ (76-100%)	▲ (26-50%)	—	—
Total Boron	▲ (76-100%)	▲ (51-75%)	▲ (51-75%)	—	—
Total Cadmium	—	—	—	—	—
Total Copper	—	—	—	—	—
Total Molybdenum	▲ (76-100%)	▲ (76-100%)	▲ (51-75%)	—	—
Total Nickel	—	—	—	—	—
Total Selenium	—	—	—	—	—
Total Strontium	▲ (76-100%)	▲ (76-100%)	▲ (51-75%)	—	—
Total Uranium	—	—	—	—	—
Total Vanadium	—	—	—	—	—

Biology

	KPSF → Downstream: Cujo Lake	Cujo Outflow	Chirstine-Lac du Sauvage	Lac du Sauvage LdS1	Lac du Sauvage LdS2
Phytoplankton					
Chlorophyll *a* Concentration	—	●	●	—	●
Phytoplankton Density	—	●	●	—	●
Phytoplankton Diversity	—	●	●	—	●
Relative Densities of Major Phytoplankton Taxa	—	●	●	—	●
Zooplankton					
Zooplankton Biomass	—	●	●	—	●
Zooplankton Density	—	●	●	—	●
Zooplankton Diversity	—	●	●	—	●
Relative Densities of Major Zooplankton Taxa	—	●	●	—	●
Benthos					
Lake Benthos Density	—	●	●	—	●
Lake Benthos Dipteran Diversity	—	●	●	—	●
Lake Benthos Dipteran Relative Density	◆	●	●	◆	●
Stream Benthos Density	●	—	—	●	●
Stream Dipteran Diversity	●	—	—	●	●
Stream Benthos Dipteran Relative Density	●	—	—	●	●
Stream Benthos EPT Diversity	●	—	—	●	●
Stream Benthos EPT Relative Density	●	—	—	●	●

Notes:

[+]The direction and degree of change was inferred from historical data. For water quality data, differences were assessed relative to data from 2000 (August lakes and streams), 2002 (April lakes), the first year in which data was collected (i.e., TOC = 2005; chloride in streams = 2001). The season in which the greatest change occurred (i.e. April or August) is represented in the table.

[+] For water quality data, % change was calculated as 1-(historical concentration/current concentration). For biology data, % change was calculated as (current concentration-historical concentration)/historical concentration.

** Indicates that the upper bound of the 95% CI exceeded the SSWQO, water quality benchmark, or CCME guideline value during the ice-covered or open water season.*

€ Indicates that the lower bound of the 95% CI was less than the lower CCME guideline value for pH during the ice-covered or open water season.

Legend:

Increased over time in comparison to reference lakes/streams or different from a constant[+]
▲ 0-25% ▲ 26-50% ▲ 51-75% ▲ 76-100%
Decreased over time in comparison to reference lakes/streams or different from a constant[+]
▼ 0-25% ▼ 26-50% ▼ 51-75% ▼ 76-100%
— Did not change over time or differ significantly over time from reference lakes/streams
● Variable was not sampled at this lake/stream
◆ Changed over time
■ Elevated, but has not changed through time

In two cases (total copper, and total ammonia-N), concentrations have returned to baseline concentrations in recent years, with no mine effects detected since 2012. In one case, TOC, concentrations have been consistently elevated in comparison to reference lakes and streams downstream as far as Christine-Lac du Sauvage Stream, but have not increased over time.

TOC is a measure of the amount of live and decomposing organic matter in the water column. Increases in TOC may reflect increases in available nutrients, which stimulate the growth and reproduction of aquatic organisms. In oligotrophic (i.e., nutrient poor) systems, like those found in the sub-Arctic, changes in nutrient levels may not be detected because of the speed with which available nutrients are incorporated into biotic material. Thus, increases in TOC may indicate an increase in the overall productivity of a system, which may also be reflected in changes in the biomass of primary producers (e.g., phytoplankton, periphyton), primary consumers (e.g., zooplankton, benthic invertebrates), or secondary consumers (e.g., fish), depending on how far up the food web the changes have progressed. However, neither the biomass nor the density of phytoplankton, zooplankton, or benthos has changed through time in the King-Cujo Watershed or Lac du Sauvage (Figure 5-1). Increases in TOC may also be associated with reductions in dissolved oxygen because bacteria consume oxygen as they decompose organic matter. Under-ice dissolved oxygen concentrations in Cujo Lake have historically been less than the CCME guidelines throughout the majority of the water column (see Section 4.1.3 of Part 1 – Evaluation of Effects TOC concentrations were not measured during baseline years, making it difficult to discern whether the correlation results from mine operations or represents undisturbed conditions in the King-Cujo Watershed. Since TOC concentrations have not been increasing through time, elevated concentrations migh reflect baseline conditions.

Overall, the extent to which concentrations of water quality variables have changed through time generally decreases with downstream distance from the KPSF. Patterns were similar during the ice covered and open water seasons, though concentrations were sometimes elevated during the ice covered season, relative to the open water season, as a consequence of solute exclusion during freeze up. In reference lakes, concentrations have generally been low and stable through time. Together, the evidence suggests that the observed changes in concentrations in the variables listed in Figure 5-1 are mine effects that stem from the discharge of water from the KPSF into the receiving environment under Water Licence W2012L2-0001.

CCME guidelines for the protection of aquatic life exist for ten of the evaluated water quality variables, including pH, total ammonia-N, nitrite-N, total arsenic, total boron, total cadmium, total copper, total nickel, total selenium, and total uranium (CCME 2013). In addition, DDEC has established SSWQO for six of the evaluated variables, including chloride, sulphate, potassium, nitrate-N, total molybdenum, and total vanadium. Total phosphate concentrations were compared to lake-specific benchmark trigger values that were established using guidelines set out in the Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems, the Ontario Ministry of Natural Resources, and Environment Canada (Ontario Ministry of Natural Resources 1994; CCME 2004; Environment Canada 2004). Other water quality benchmarks also exist for total antimony, total barium, and total strontium. With the exception of pH, the 95% confidence intervals around the fitted mean and the observed mean concentrations were below their respective CCME guidelines values, SSWQOs, or relevant benchmark values (Figure 5-1). The lower 95% confidence interval on the fitted mean pH at site LdS1 was less than the CCME guideline; however, similar patterns were observed in all reference lakes and streams, suggesting that it is not related to mine activities.

Results from water quality analyses in the King-Cujo Watershed and Lac du Sauvage suggest that changes might be expected in biological communities downstream of the KPSF as far as Christine-Lac du Sauvage. However, concentrations of water quality variables that have increased in monitored lakes at the Ekati Diamond Mine for which SSWQO or species sensitivity-based CCME guidelines exist were reviewed as part of the 2012 AEMP Re-evaluation with a specific focus on identifying possible chronic toxic effects on species present in the receiving environment at the Ekati Diamond Mine (Rescan 2012b). As in previous years, concentrations of all the water quality variables in the King-Cujo Watershed and Lac du Sauvage in 2013 remained below the lowest identified chronic effect level for the most sensitive species (Rescan 2012b). Thus, populations of even the most sensitive species were not expected to experience deleterious effects as a result of concentrations of the evaluated water quality variables in the Ekati Diamond Mine monitored lakes. However, one change in biological variables was observed in 2013:

- change in lake benthos dipteran community composition in Cujo Lake and site LdS1.

No mine effects were detected with respect to phytoplankton biomass, density, diversity, or community composition in the King-Cujo Watershed or Lac du Sauvage.

Zooplankton biomass, density, diversity, and overall community composition have remained relatively stable through time in Cujo Lake and site LdS1 in Lac du Sauvage. However, although no mine effects were detected with respect to zooplankton diversity or community composition, a close examination of zooplankton species compositions suggests that the rotifer *Conochilus sp.* and the cladoceran *Holopedium gibberum*, have been largely absent from Cujo Lake since 2002. A similar trend was observed in lakes downstream of the LLCF. *Conochilus sp.* returned to Cujo Lake in 2011, but was once again absent from Cujo Lake in 2012 and 2013. The reason for the change in composition of cladoceran genera remains unclear.

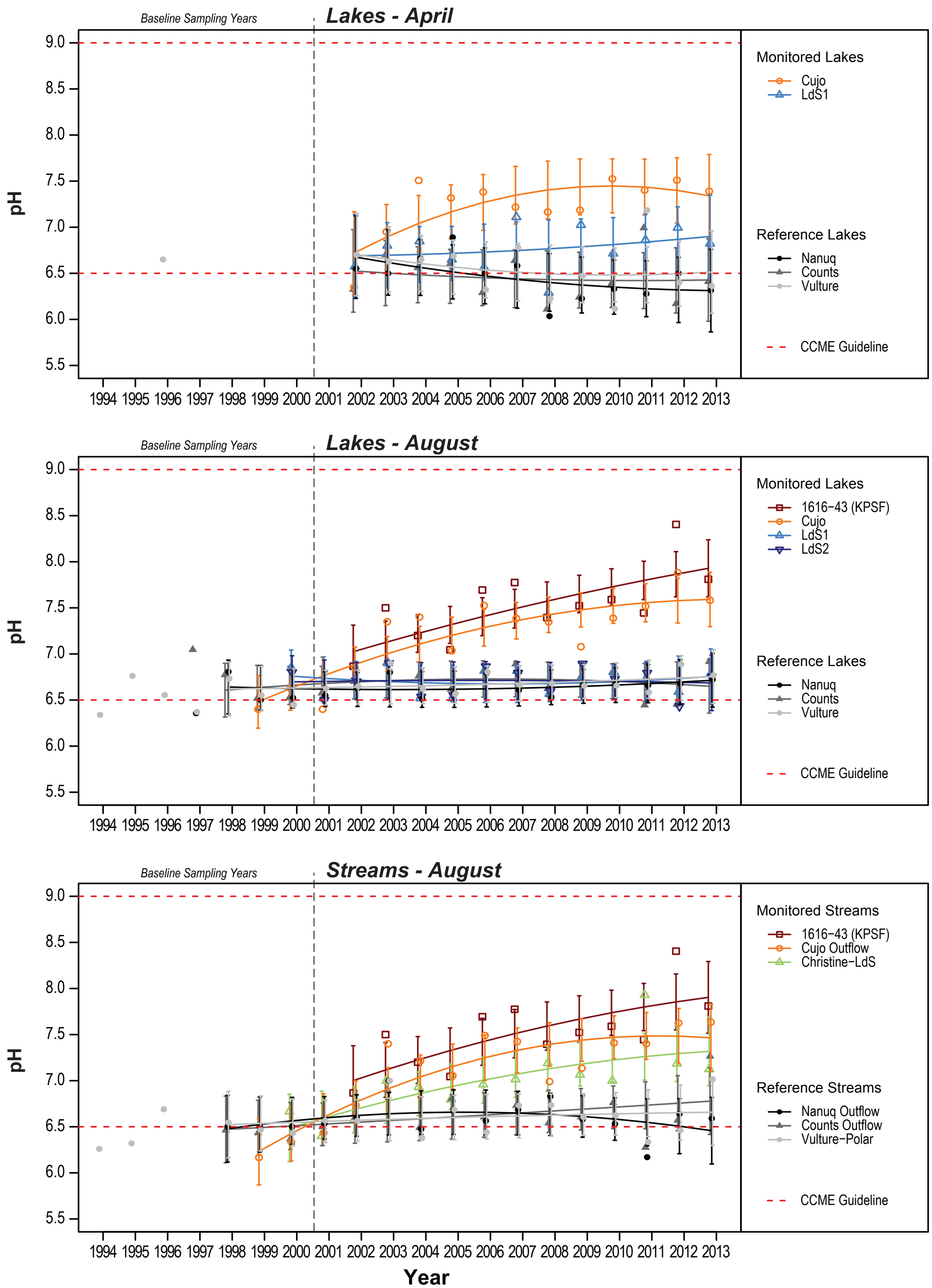
Lake benthos density has been stable through time in all monitored and reference lakes of the King-Cujo Watershed and Lac du Sauvage. Although dipteran diversity has been variable through time, diversity has been relatively stable in monitored and reference lakes since 2007. Shifts in the benthos community composition have been observed in Cujo Lake and at site LdS1 in Lac du Sauvage (Figure 5.-15 and 5-16), in which the relative densities of organisms from the Chironomidae sub-family Orthocladiinae (most likely organisms from the genera *Psectrocladius* and *Zalutschia* in Cujo Lake and from the genus *Heterotanytarsus* at site LdS1) have decreased through time while densities of organisms from the subfamilies Tanypodinae (most likely organisms from the genera *Procladius* and *Ablabesmyia*) and Prodiamesinae (most likely organisms from the genus *Monodiamesa*) have increased through time. Organisms from the subfamily Chironominae (likely organism from the genera *Cladotanytarsus*, *Corynocera* and *Stictochironomus*) have also increased through time in Cujo Lake. Most of these changes began in Cujo Lake in 2005 and were first identified through the multivariate analyses conducted as part of the 2012 AEMP re-evaluation (Rescan 2012b). The shift in taxonomic composition was more recently observed at site LdS1 in 2013. Unfortunately, little information is available on the ecology of these benthic invertebrates and the cause of these shifts is unclear (Oliver and Dillon 1997). However, these shifts are similar to those that have occurred in Leslie and Moose lakes in the Koala Watershed and concentrations of all the evaluated water quality variables in the King-Cujo Watershed have remained below the lowest identified chronic effect level for the most sensitive species. Thus, the observed changes in lake benthos community composition are likely driven, ultimately, by changes in the availability of macronutrients including nitrogen and phosphorus in lakes downstream of the KPSF.

No mine effects were detected with respect to stream benthos density, dipteran diversity or EPT diversity, or dipteran or EPT community composition in the King-Cujo Watershed.

Lake benthos provide an important source of food for many species of fish. Changes in community composition could have important consequences for fish, especially if preferred prey items are replaced with non-preferred ones. Similar to the Koala Watershed, results of the 2012 AEMP Evaluation of Effects found no evidence of major mine effects on monitored fish populations in the King-Cujo Watershed (Rescan 2012b). Thus, shifts in lake benthos communities do not appear to have influenced fish populations to date. Both round whitefish and lake trout are considered opportunistic feeders where in the absence of strong prey community-wide effects, may not exhibit strong biological changes, including any bioenergetics-related response variables. Furthermore, the mobile nature of these larger-bodied fish populations may also serve to reduce any potential effects. Lakes in the Ekati Diamond Mine study area are not isolated and individual fish are able to move freely between upstream and downstream lakes. This likely serves to buffer any potential effects or may delay the appearance of mine effects. Monitoring of fish populations will be conducted in 2015 to re-assess these results, using the slimy sculpin as a sentinel species.

Figure 5-2

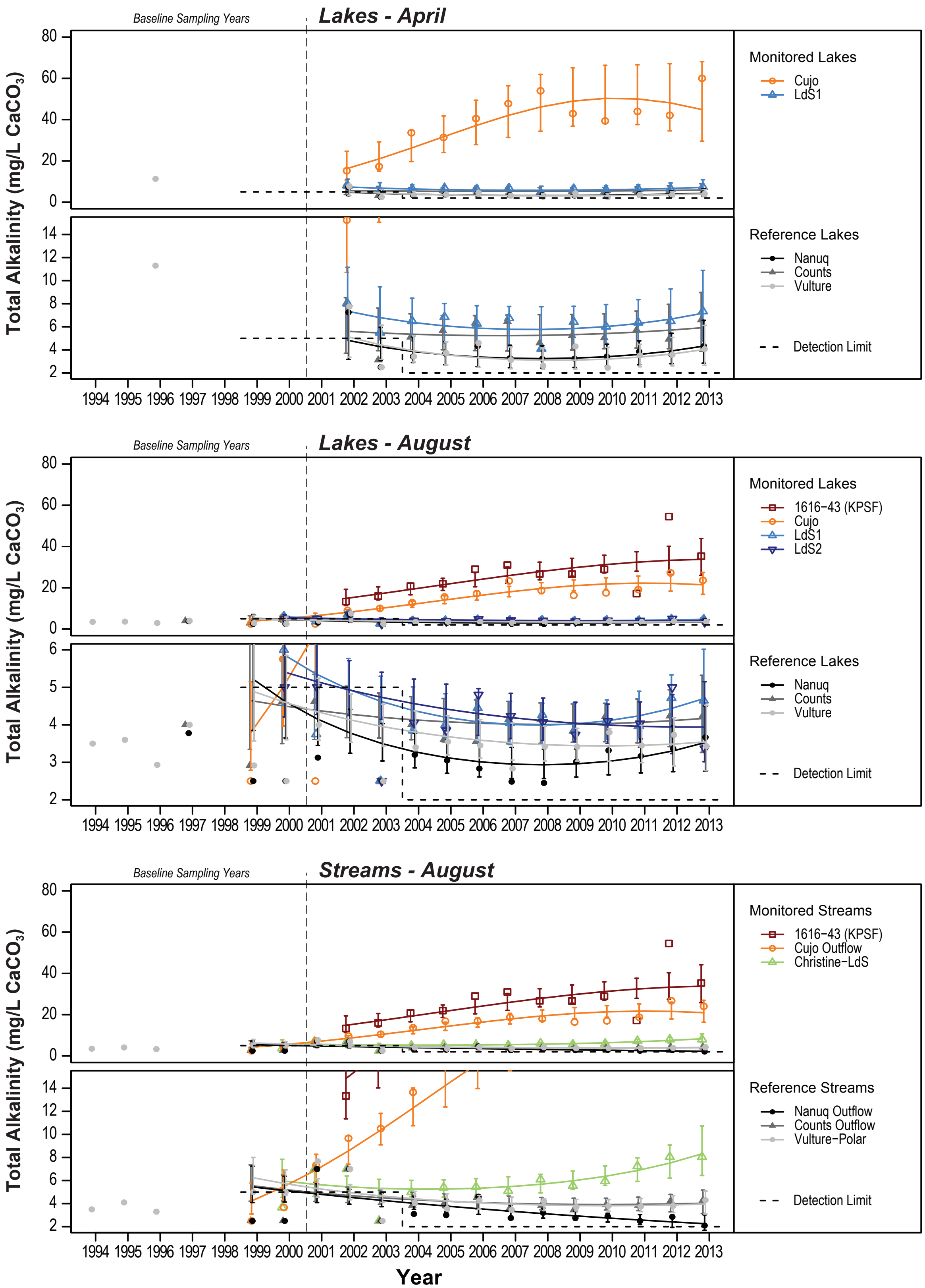
Observed and Fitted Means for pH in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
CCME guideline = 6.5 - 9.0

Figure 5-3

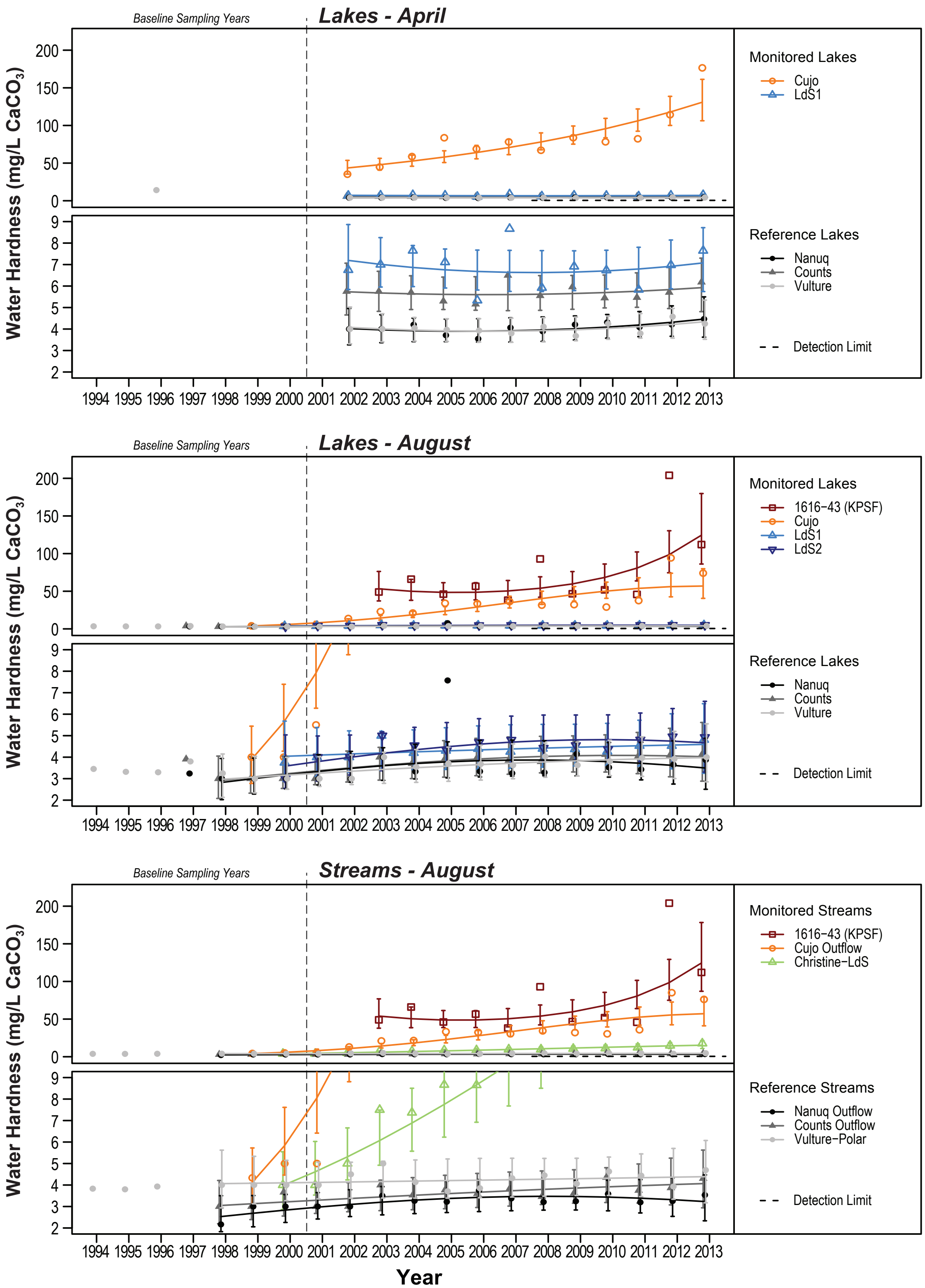
Observed and Fitted Means for Total Alkalinity in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



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

Figure 5-4

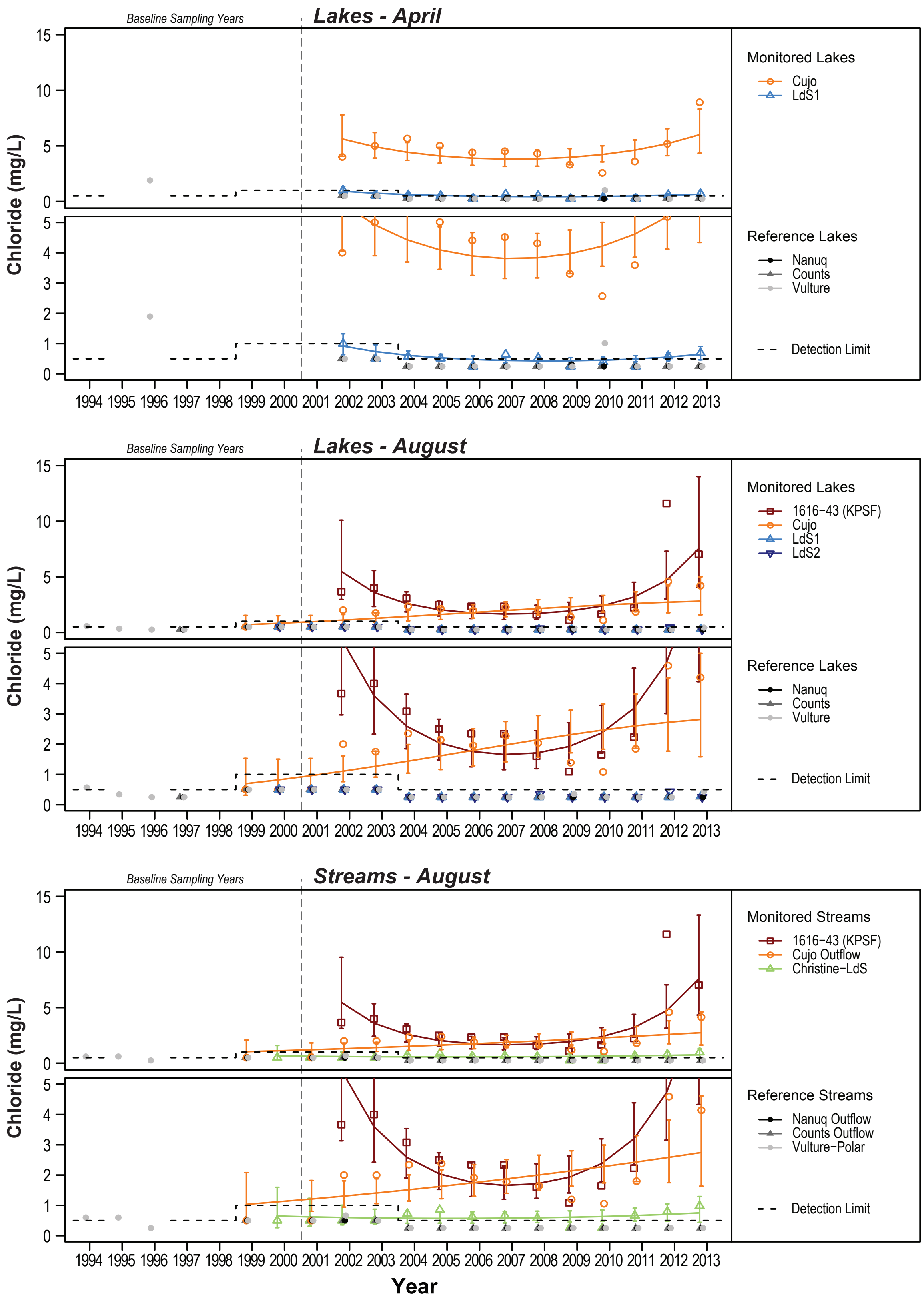
Observed and Fitted Means for Water Hardness in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



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

Figure 5-5

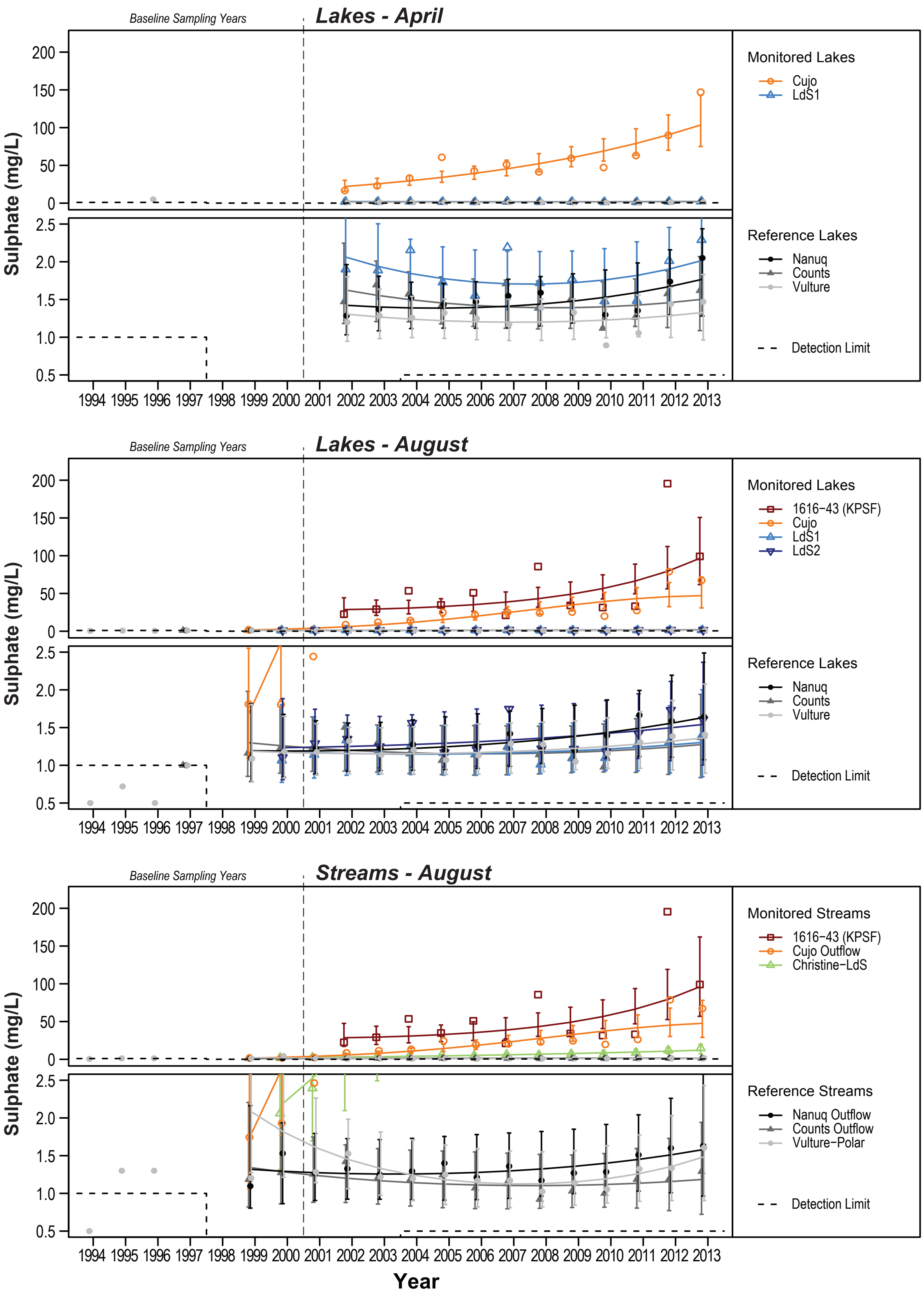
Observed and Fitted Means for Chloride Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = 116.6 X ln(Hardness) - 204.1, where hardness = 10 - 160 mg/L.

Figure 5-6

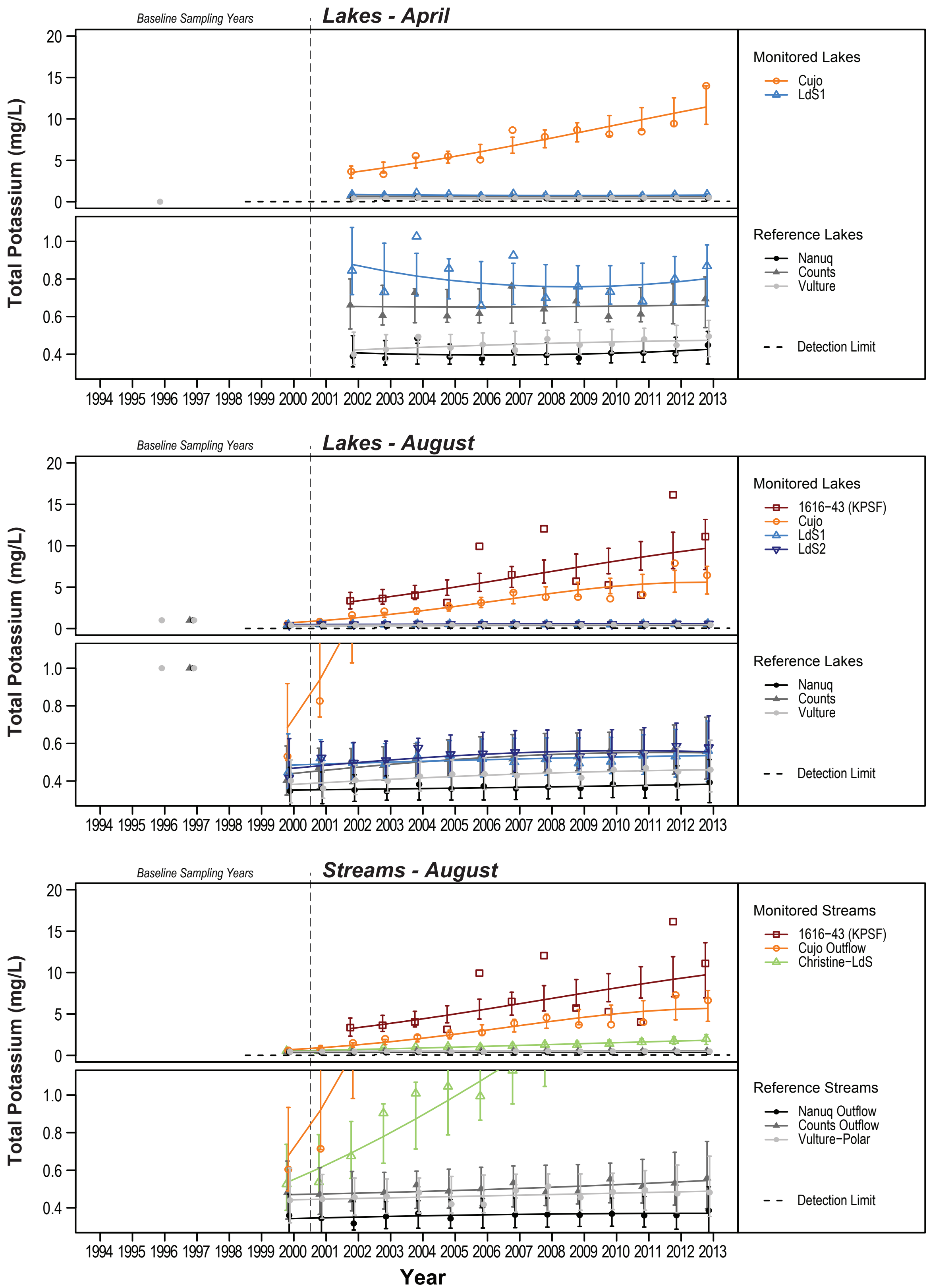
Observed and Fitted Means for Sulphate Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = $e^{(0.9116 \times \ln(Hardness) + 1.712)}$ mg/L, where hardness < 160 mg/L.

Figure 5-7

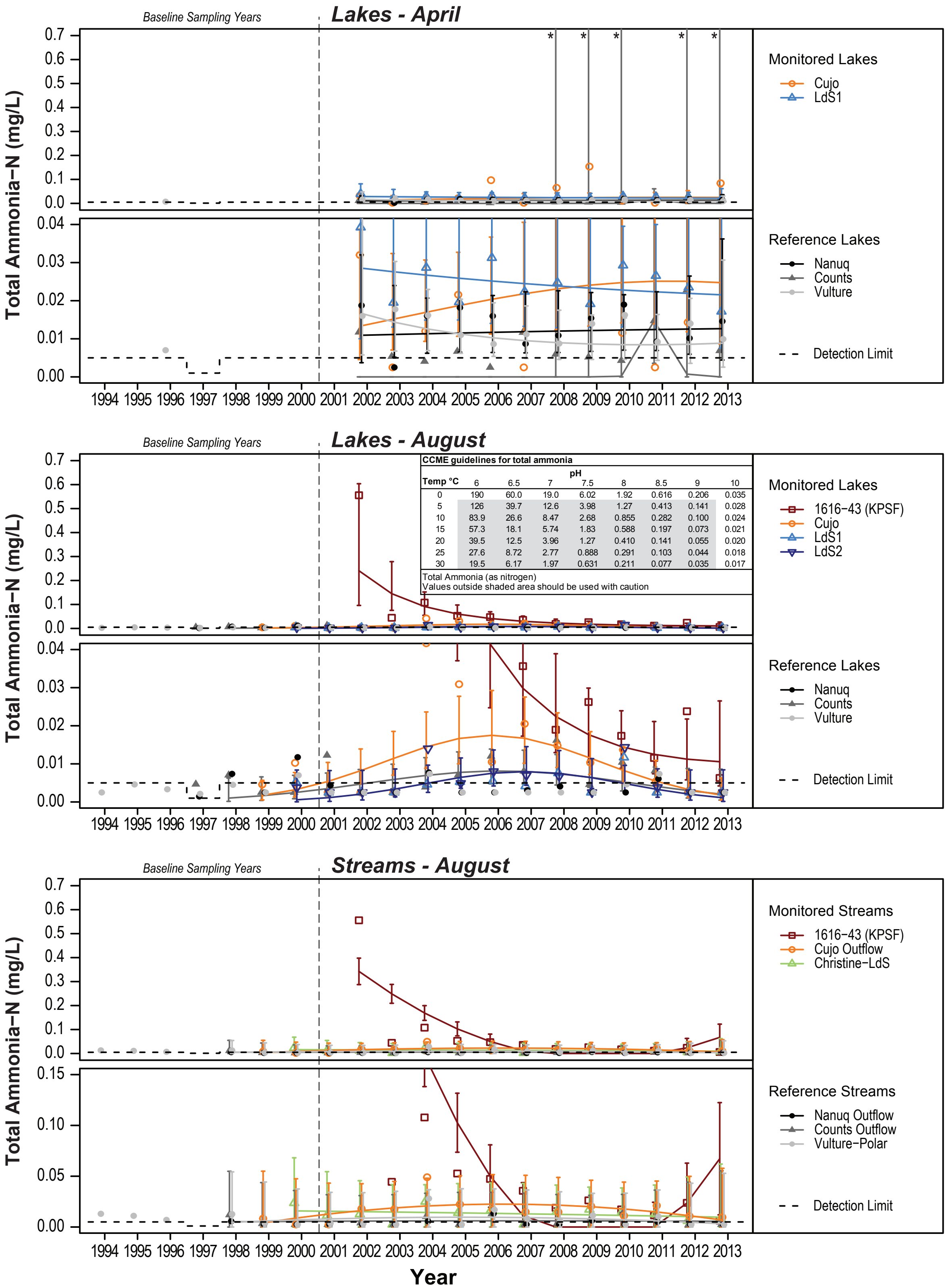
Observed and Fitted Means for Potassium Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = 41 mg/L.

Figure 5-8

Observed and Fitted Means for Total Ammonia-N Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



CCME guidelines for total ammonia

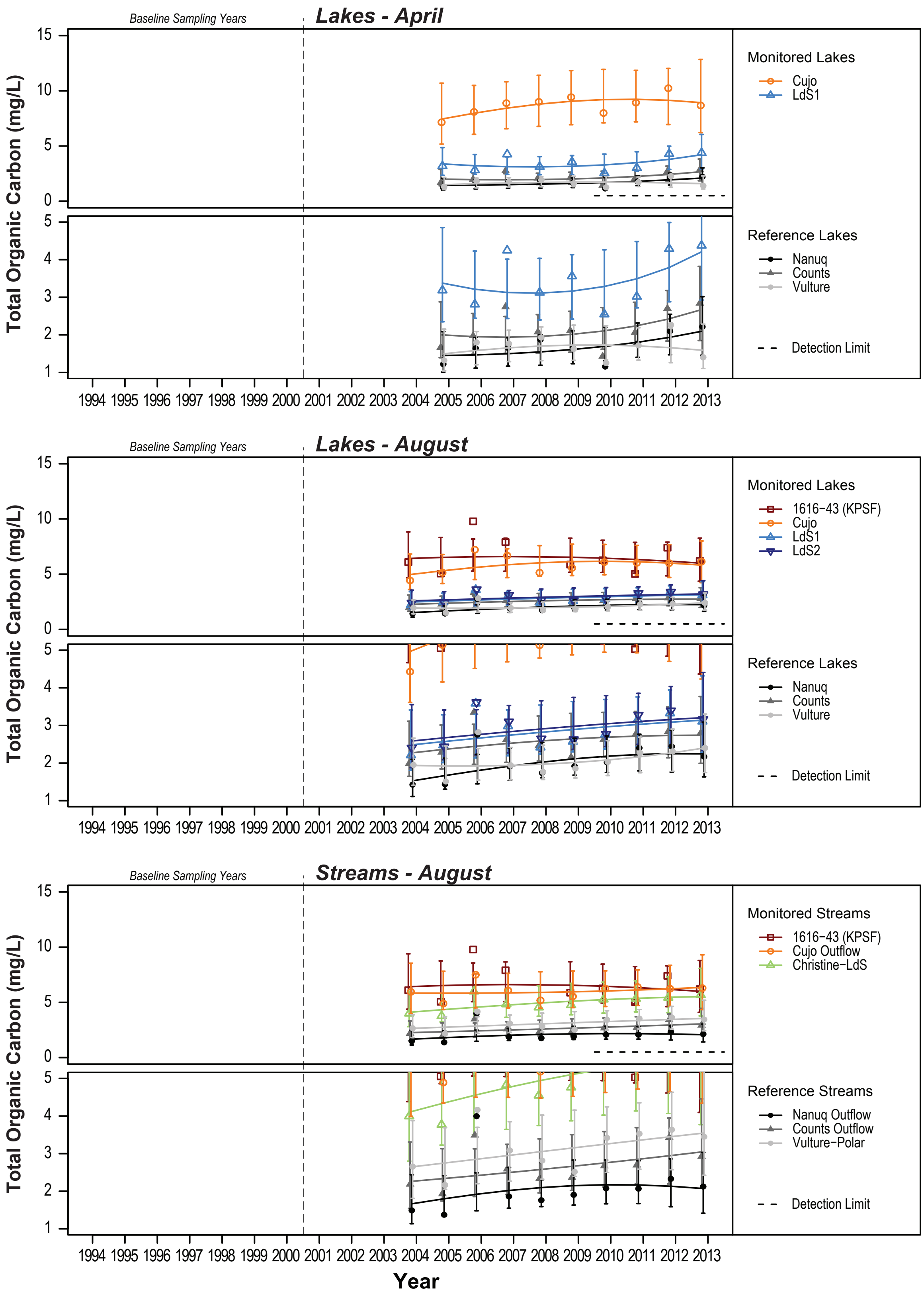
Temp °C	pH 6	6.5	7	7.5	8	8.5	9	10
0	190	60.0	19.0	6.02	1.92	0.616	0.206	0.035
5	126	39.7	12.6	3.98	1.27	0.413	0.141	0.028
10	83.9	26.6	8.47	2.68	0.855	0.282	0.100	0.024
15	57.3	18.1	5.74	1.83	0.588	0.197	0.073	0.021
20	39.5	12.5	3.96	1.27	0.410	0.141	0.055	0.020
25	27.6	8.72	2.77	0.888	0.291	0.103	0.044	0.018
30	19.5	6.17	1.97	0.631	0.211	0.077	0.035	0.017

Total Ammonia (as nitrogen)
Values outside shaded area should be used with caution

Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
WL = Maximum average concentration premitted in water licence W2009L2-0001.
WL Criterion = 2.0 mg/L. CCME Guideline is pH and temperature dependent (see inset table).
** Upper 95% Confidence Interval on the fitted mean of Counts Lake in April 2008 = 4.64x10^{272} mg/L, 2009 = 1.85x10^{190} mg/L, 2010 = 5.86x10^{98} mg/L, 2012 = 1.82x10^{105} mg/L, and 2013 = 9.34x10^{214} mg/L.*

Figure 5-9

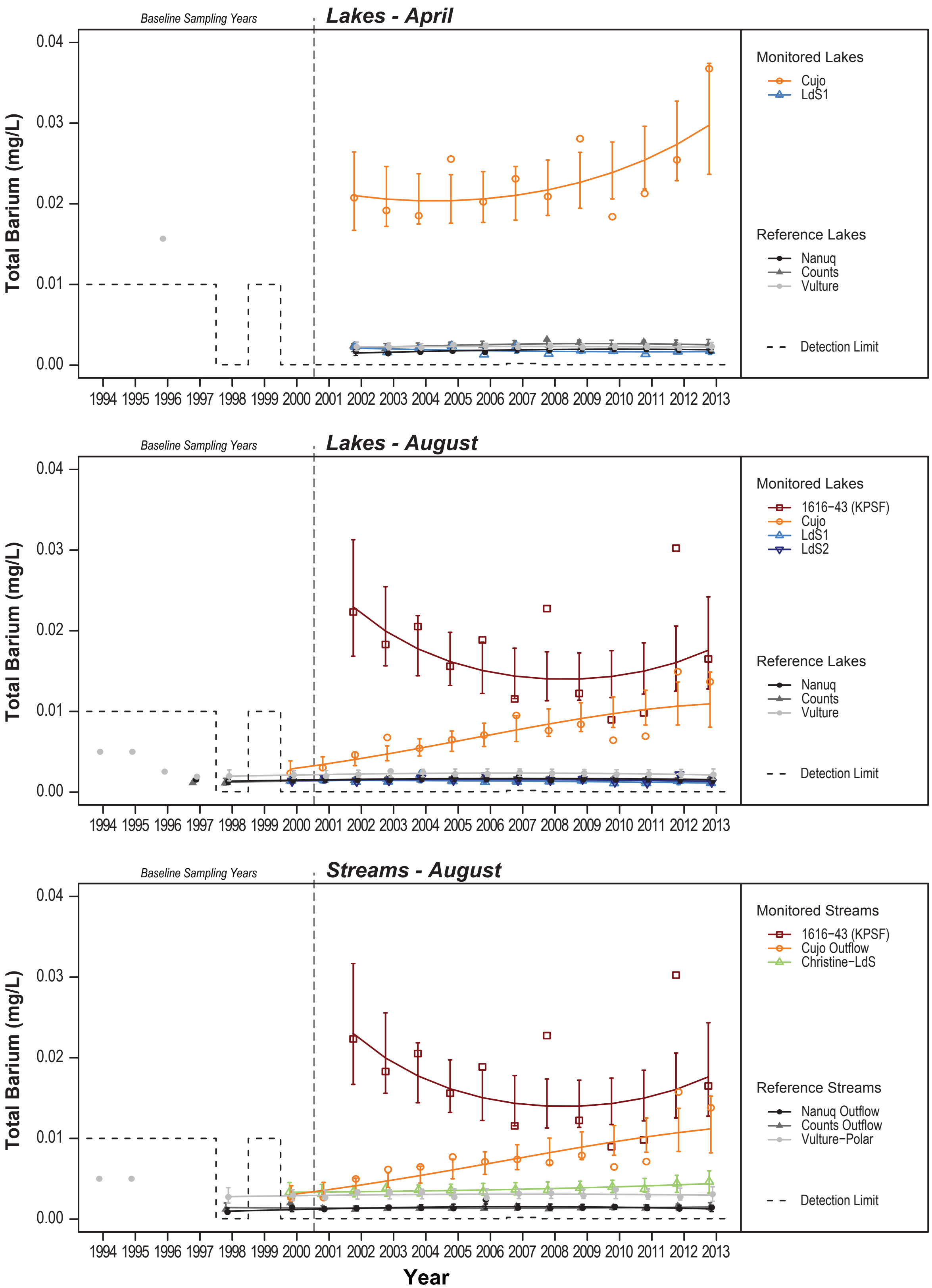
Observed and Fitted Means for Total Organic Carbon Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



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

Figure 5-10

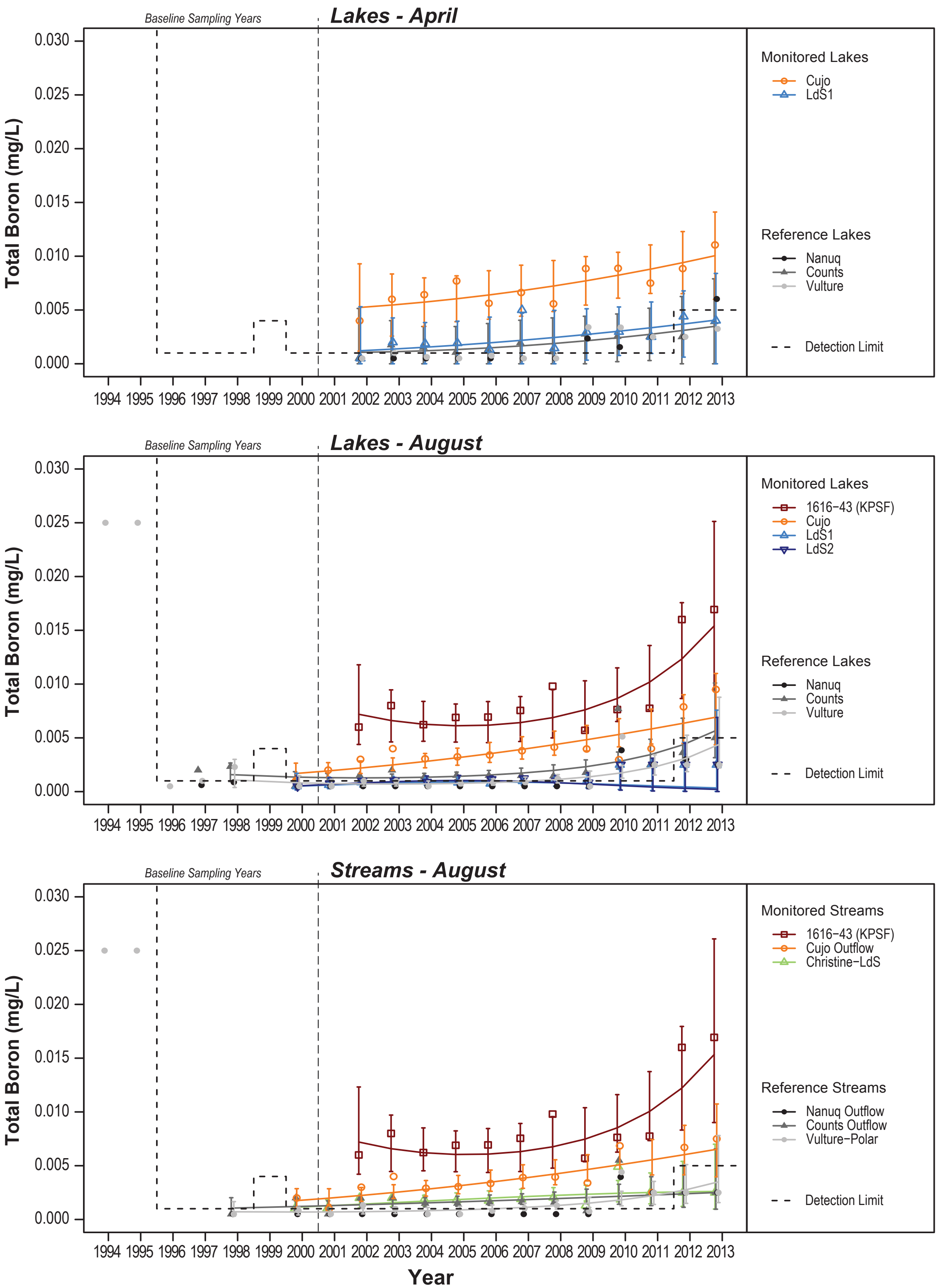
Observed and Fitted Means for Total Barium Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
Water quality benchmark (Haywood and Drinnan 1983) = 1 mg/L.

Figure 5-11

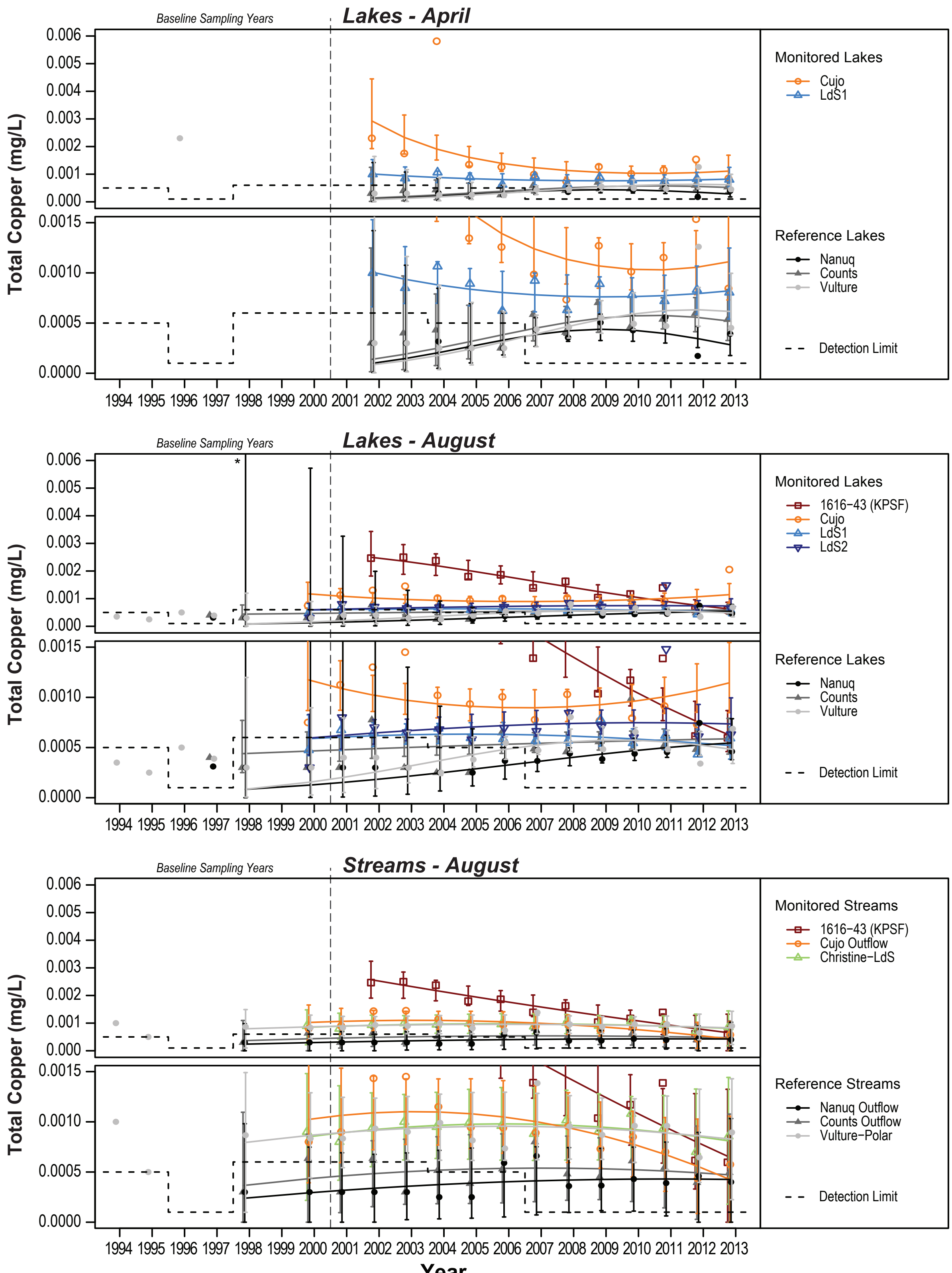
Observed and Fitted Means for Total Boron Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
CCME Guideline = 1.5 mg/L.

Figure 5-12

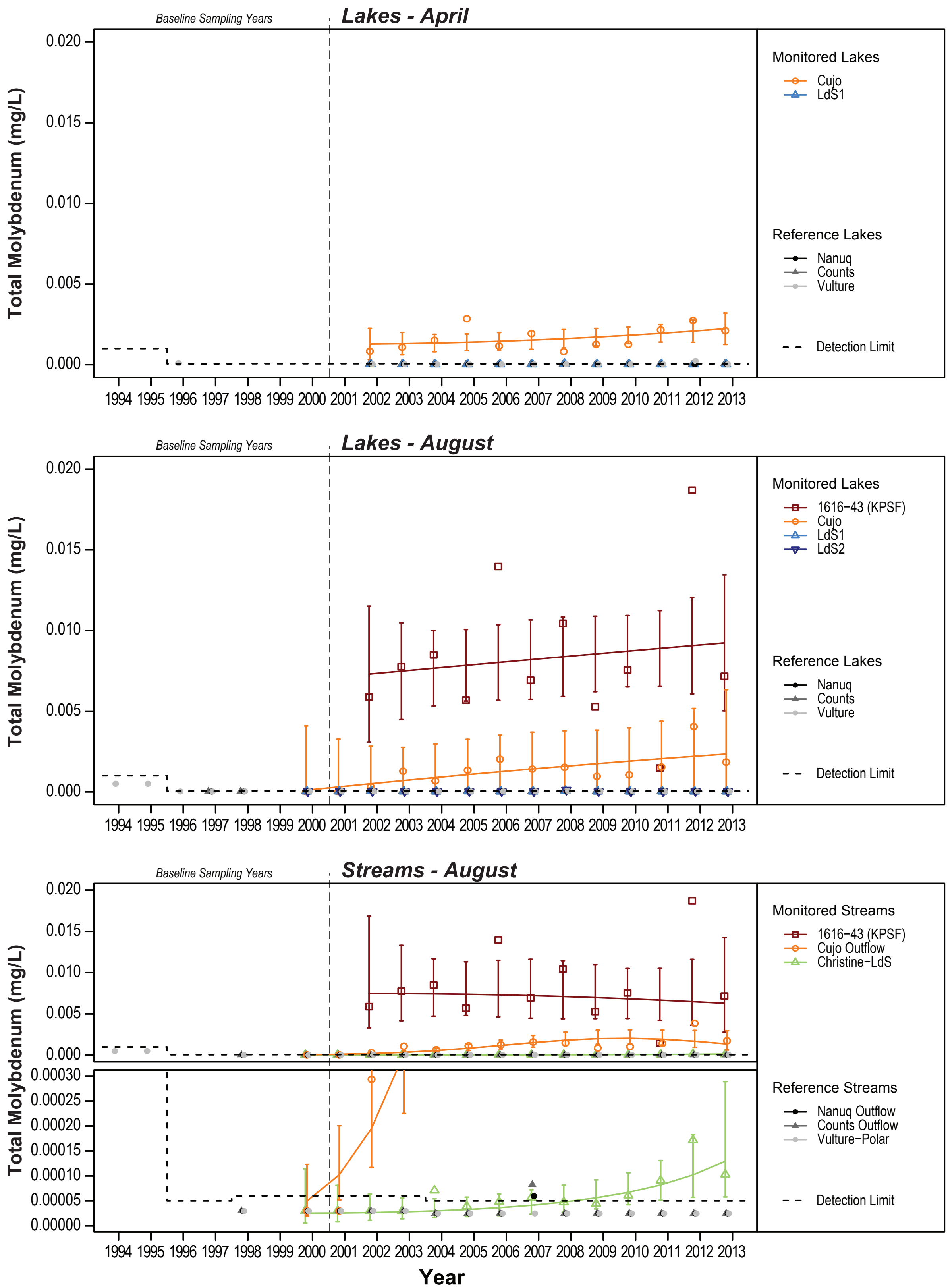
Observed and Fitted Means for Total Copper Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
WL = Maximum average concentration premitted in water licence W2009L2-0001. WL = 0.10 mg/L. CCME Guideline = $e^{0.8545 X (lnHardness) - 1.465 * 0.2}$*/1000 mg/L, where hardness < 180 mg/L and 0.004 mg/L where hardness is ≥ to 180 mg/L . Minimum benchmark = 0.002 mg/L.*
** Upper 95% Confidence Interval on the fitted mean of Nanuq in August 1998 = 0.022 mg/L.*

Figure 5-13

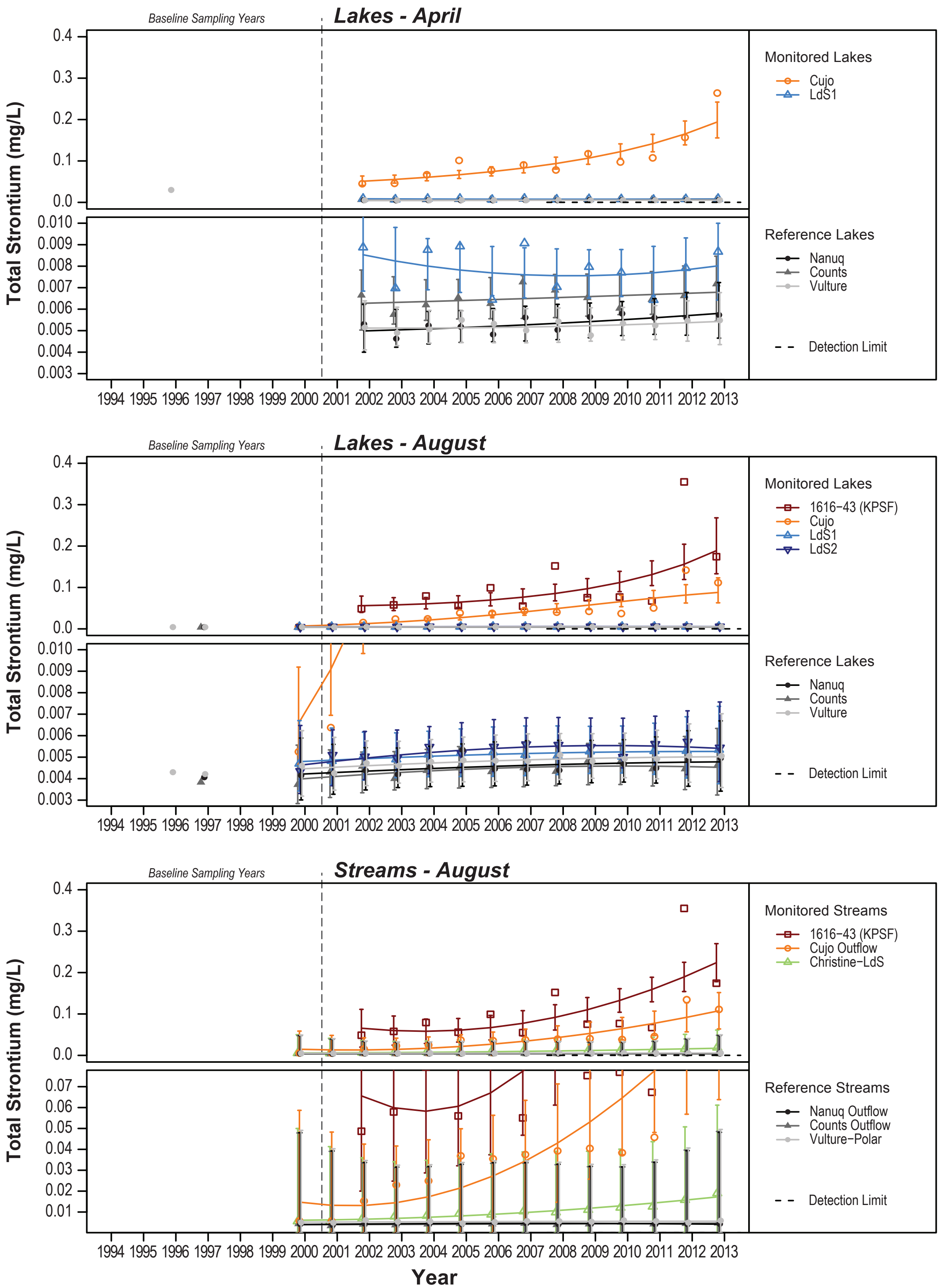
Observed and Fitted Means for Total Molybdenum Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
SSWQO = 19.38 mg/L.

Figure 5-14

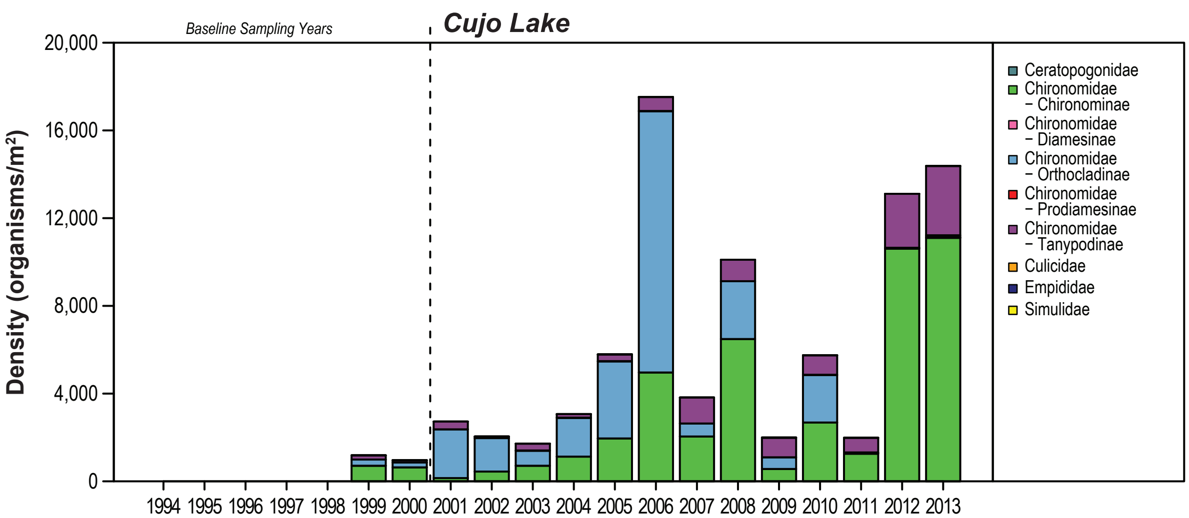
Observed and Fitted Means for Total Strontium Concentrations in King-Cujo Watershed Lakes and Streams and Lac du Sauvage, 1994 to 2013



Notes: Symbols represent observed mean values.
Solid lines represent fitted curves.
Error bars indicate upper and lower 95% confidence intervals of the fitted means.
Water quality benchmark (Golder 2011) = 6.242 mg/L.

Figure 5-15

Average Density of Diptera Taxa for Lakes of the King-Cujo Watershed, 1994 to 2013



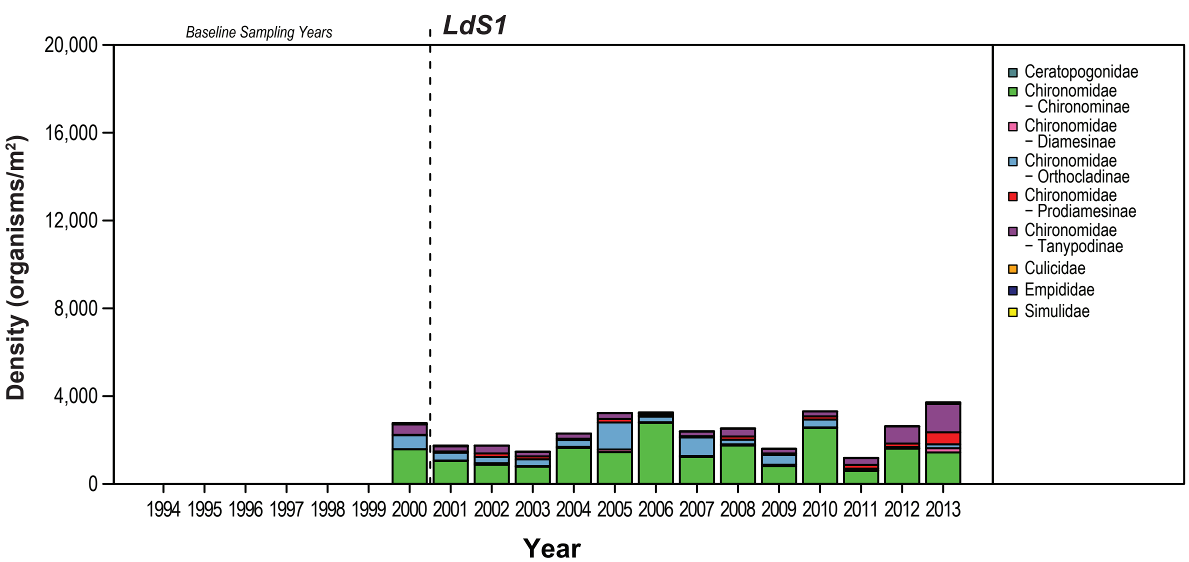
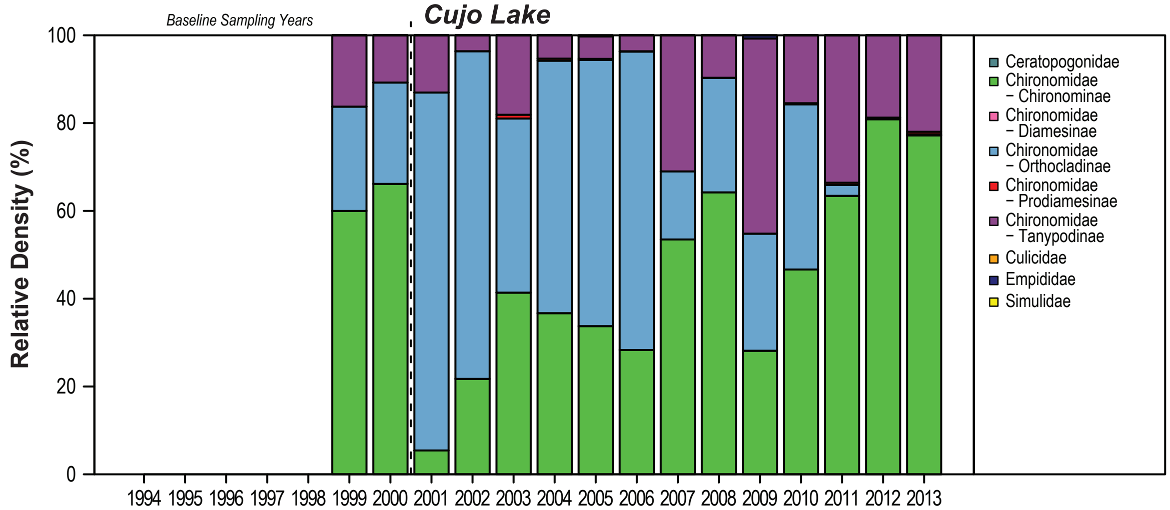
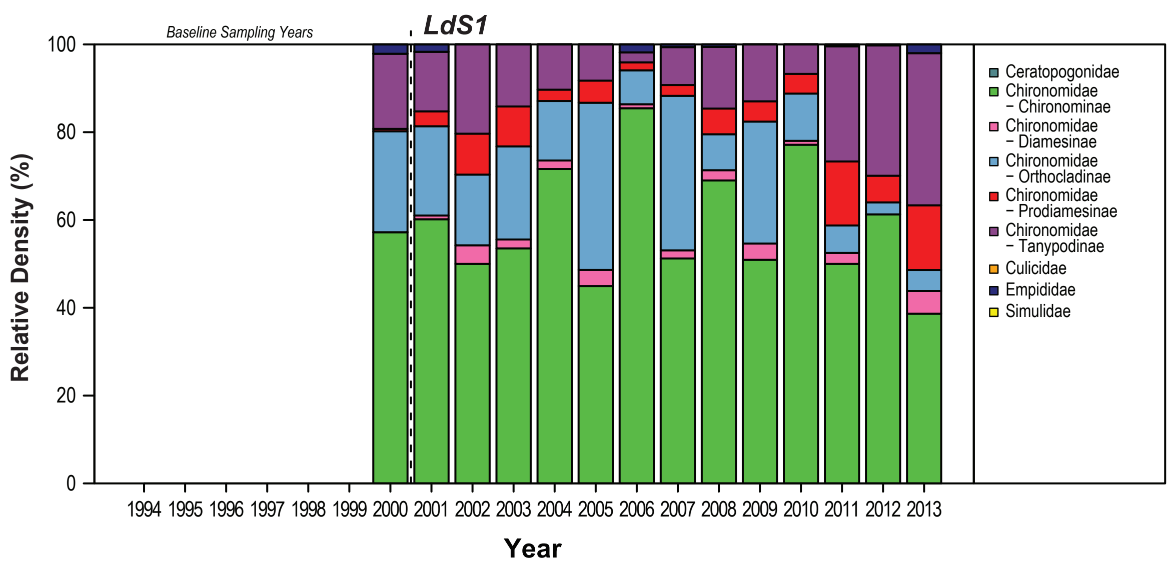


Figure 5-16

Relative Density of Diptera Taxa in Lakes of the King-Cujo Watershed, 1994 to 2013





6. Summary of Special Studies

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6.1 LAC DE GRAS

In 2012, mine effects were detected downstream of the Long Lake Containment Facility (LLCF) as far as site S3 in Lac de Gras for eight water quality variables (Rescan 2013c). Site S3 marks the current downstream extent of the AEMP sampling program for the Koala Watershed. In August 2013 an additional sampling program was therefore undertaken in the north arm of Lac de Gras beyond the current extent of the AEMP to determine if a new water quality monitoring station is required. Details on the methods and results are provided in Sections 2.9 and 3.9 of Part 2 – Data Report.

For physical limnology variables, graphical analysis indicated that conditions at the additional three sites in Lac de Gras are similar to those observed at sites S2 and S3. In contrast, analysis of water quality variables suggested that mine effects previously detected in Lac de Gras have extended beyond site S3. For eight water quality variables (i.e., pH, alkalinity, hardness, chloride, sulphate, total potassium, total molybdenum, and total strontium), levels or concentrations at site S4 were comparable to those recorded at site S3. Results also suggest that effects may have extended as far as sites S5 and S6 for five of these variables (i.e., chloride, hardness, potassium, sulphate, total strontium).

Because there are other direct influences on Lac de Gras, such as other mine operations, it is possible that influences from these other sources could be confounding water quality results in Lac de Gras, and that differences among sites may not be entirely due to Ekati Diamond Mine operations, particularly at the farthest field site S6, which is located near the main body of Lac de Gras. Of the 46 water quality variables collected and screened in the laboratory, three variables (i.e., nitrate-N, total aluminum, total nickel) appeared to be elevated at site S6 relative to all other sites in Lac de Gras during sampling in 2013, suggesting that water quality at site S6 may be affected by other influences in Lac de Gras.

Since concentrations of a number of variables at site S4 are comparable to those at site S3, sampling at sites S5 and S6 would improve the ability of detecting effects in Lac de Gras. Based on this information, it is recommended that water quality sampling at sites S5 and S6 be included in future AEMP sampling. It is recommended that both sites S5 and S6 be sampled given the potential for confounding effects at site S6. Sampling at both of these locations is likely necessary in order to better detect potential effects related to discharge from the LLCF.

6.2 NERO-NEMA STREAM MONITORING

During the Water Licence Renewal Public Hearing, a question was raised regarding whether hardness-dependent benchmarks would be protective of the aquatic environment over time. Specifically, it was suggested that hardness might dilute more quickly than other variables with hardness-dependent benchmarks. It was suggested that the issue could be investigated by measuring hardness and concentrations of water quality variables with hardness-dependent benchmarks both in the LLCF discharge and downstream of discharge concurrently over the open water season. As part of its decision on the 2012 AEMP re-evaluation, the WLWB requested that a study examining possible differences in dilution among water quality variables, including hardness, be completed during the 2013 open water season (Rescan 2013d). Thus, weekly water quality sampling was conducted at Nero-Nema Stream during effluent discharge from the LLCF in 2013 to investigate differential dilution between hardness and water quality variables with hardness-dependent benchmarks. Weekly sampling was conducted concurrently in the LLCF discharge through the SNP.

Together, results provided a good indication that most water quality variables with hardness-dependent benchmarks are likely being diluted at the same rate or faster than water hardness downstream of the LLCF at Nero-Nema Stream. The only exceptions were copper and manganese, the two water quality variables that are not included as part of the AEMP Evaluation of Effects for lakes of the Koala Watershed and Lac de Gras (Rescan 2013d).

Elevated concentrations of total copper have been historically observed at two sites that are not downstream of the LLCF: the Lower PDC and Kodiak Lake (Rescan 2013b). Thus, concentrations of total copper at Nero-Nema Stream may be greater than those observed at the LLCF owing to elevated concentrations at sites upstream of Nero-Nema Stream. During the most recent AEMP re-evaluation, it was suggested that total copper be removed from the list of evaluated water quality variables as results from the most recent AEMP Evaluation of Effects had detected no change in total copper concentrations through time (Rescan 2012b, 2013b). Concentrations of total copper at Nero-Nema Stream remained below the benchmark during effluent discharge in 2013. Although a benchmark exists for total manganese, it has never been included in the list of evaluated AEMP water quality variables as concentrations of total manganese have remained low and have shown no increasing trend through time (Rescan 2012b, 2013b). Total manganese remained below the benchmark during effluent discharge in 2013.

Although findings from this special study suggest that most water quality variables with hardness-dependent benchmarks are likely being diluted at the same rate or faster than water hardness downstream of the LLCF, results should be considered with caution. Given that discharge occurred continuously throughout the study period, it was not possible to monitor the decrease over time in hardness and concentration of water-quality variables at Nero-Nema Stream. Instead, corresponding weekly samples taken at SNP station 1616-30 were used to compare water quality at the LLCF and Nero-Nema Stream, thus substituting space for time, which may not be ideal.

6.3 GRIZZLY LAKE BIOLOGICAL COMMUNITIES

Biological communities (phytoplankton, zooplankton and benthic invertebrates) were sampled in Grizzly Lake in August 2013 to assess if communities have changed following observed changes (thermal stratification with cooler surface temperatures) in the under-ice temperature profiles of Grizzly Lake in 2011 and 2012 (Rescan 2013c).

One potential change in biological variables was observed in Grizzly Lake in 2013:

- Altered taxonomic composition of the zooplankton assemblage through time

Recent changes in the thermal profile of Grizzly Lake were found to have no effect on variables assessed for phytoplankton or benthos

Zooplankton biomass, density, and diversity in Grizzly Lake have appeared to remain relatively stable through time. However, the relative density of zooplankton groups in Grizzly Lake may have shifted through time as densities of rotifers appear to have increased. Increases in rotifer density contrasts patterns observed in other monitored lakes within the Koala Watershed and is consistent with what might be expected as a result of increasing water temperatures. However, the lack of data from 2004 to 2012 makes it difficult to determine whether these changes in rotifer density represent a real trend though time and a mine effect, rather than representing natural variability through time. It is thus recommended that an additional year of phytoplankton and zooplankton monitoring be conducted in Grizzly Lake in order to better detect potential effects.

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