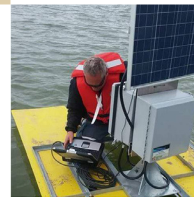
CAMP

Coordinated Aquatic Monitoring Program



Six Year Summary Report

Technical Document 3: Saskatchewan River Region

2008-2013

Submitted to:
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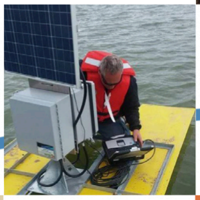

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SIX YEAR SUMMARY REPORT (2008-2013)

Technical Document 3:
Saskatchewan River Region Results

by

North/South Consultants Inc.
83 Scurfield Blvd.
Winnipeg, MB R3Y 1G4
Tel: (204) 284-3366 Fax: (204) 477-4173
Email: info@nscons.ca

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ABBREVIATIONS AND ACRONYMS

ASL	Above sea level
BCMOE	British Columbia Ministry of Environment
BMI	Benthic macroinvertebrate(s)
CAMP	Coordinated Aquatic Monitoring Program
CCME	Canadian Council of Ministers of the Environment
CEDAR-SE	Cedar Lake – Southeast
CEDAR-W	Cedar Lake - West
CL	Confidence limit
CORM	Cormorant Lake
CPUE	Catch-per-unit-effort
DL	Detection limit
DO	Dissolved oxygen
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
EPT:C	Ratio of the combined abundances of Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) to the abundance of Chironomidae (non-biting midges)
FL	Fork length
FL-at-age	Fork-length-at age
GS(s)	Generating station(s)
ISQG	Interim sediment quality guideline
K_F	Condition Factor
LEL	Lowest effect level
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
n_F	Number of fish
n_Y	Number of years sampled
PAL	Protection of aquatic life
PEL	Probable effect level
ppm	Parts per million
Q (OW)	Average discharge (cms) during the open-water period
Q (GN)	Average discharge (cms) during the gillnetting program
SAC	Sediment alert concentration
SASK	Saskatchewan River
SE	Standard error of the mean
SEL	Severe effect level
SMOOSE	South Moose Lake
SQG	Sediment quality guideline
SRR	Saskatchewan River Region
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus

TSS	Total suspended solids
WL (OW)	Average water level during the open water period
WL (GN)	Average water level during the gillnetting program
WSL	Water surface level

1.0 INTRODUCTION

The following presents a description of results of monitoring conducted under the Coordinated Aquatic Monitoring Program (CAMP) for years 1 through 6 (i.e., 2008/2009 through 2013/2014) in the Saskatchewan River Region (SRR; Figure 1-1). As described in Technical Document 1, Section 2.2.1, the SRR includes the portion of the Saskatchewan River watershed from the Saskatchewan/Manitoba border to Lake Winnipeg and Cormorant Lake. Waterbodies and sites monitored in this region over this period included one off-system waterbody and four on-system areas as follows (upstream to downstream direction):

- Saskatchewan River between the Town of The Pas and Cedar Lake;
- South Moose Lake;
- Cedar Lake - West;
- Cedar Lake - Southeast; and
- Cormorant Lake (off-system).

Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.2. As described in Technical Document 1, Section 1.2.2.1, sampling of on-system waterbodies addresses the primary objective of CAMP – to monitor aquatic ecosystem health along Manitoba Hydro's hydraulic operating system. The off-system waterbodies were included in CAMP to provide regional information collected in a manner consistent with monitoring of on-system waterbodies that will assist in interpreting any observed environmental changes over time. Such comparisons are intended to help distinguish between hydroelectric-related effects and other external factors (e.g., climate change) in each CAMP region.

A summary of monitoring conducted by sampling area is provided in Table 1-1 and monitoring areas are shown in Figure 1-1. As noted in Table 1-1, monitoring was conducted annually in some areas and on a three-year rotation at other sites. Components monitored in the SRR over this time period include hydrology, aquatic habitat, water quality, sediment quality, phytoplankton, benthic macroinvertebrates (BMI), fish community, and mercury in fish.

Results presented below include a discussion of hydrology, water quality, sediment quality, BMI, fish community, and fish mercury for key metrics, as described in Technical Document 1. Observations of note for additional metrics are also provided in the following for the water quality, BMI, and fish community components. In addition, results of an aquatic habitat survey completed in the South Moose Lake in 2011 are presented.

The terms of reference for the six year summary report specified that the reporting would include an exploratory analysis of available data for key indicators and metrics to:

- provide a preliminary evaluation of potential trends within the six year monitoring period; and
- provide an initial review of data to explore potential relationships between biological and chemical metrics and hydrological conditions.

It is recognized that although a large quantity of data was acquired over the initial six years of CAMP, these data are relatively limited in terms of monitoring for long-term trends and/or relationships with physical (and other) variables due to the short temporal period. As noted in Technical Document 1, six years of data may be insufficient to detect trends over time, notably long-term trends. Additionally, any indications of potential trends over the six year period do not necessarily imply a long-term trend is occurring, as apparent trends over this interval may simply reflect the relatively limited time period assessed in conjunction with inter-annual variability in a metric. Consideration of a longer period of record is required to evaluate for long-term trends.

In addition, many of the regions experienced high flows/water levels for most of the six year monitoring period and the lower range of the hydrographs was generally underrepresented or lacking altogether. This further limited the ability to explore broad-scale relationships between hydrological conditions and chemical and biological metrics. In addition, it is cautioned that identification of significant correlations between chemical or biological and hydrological metrics does not infer a causal relationship (i.e., correlations simply indicate that two metrics are related). Lastly, the scope of these initial analyses was limited to a relatively high-level exploratory approach. For these reasons, discussions of trends and relationships with hydrological conditions discussed herein are considered exploratory/preliminary and are expected to be revised and updated as additional data are acquired.

Table 1-1. Overview of CAMP sampling in the Lower Churchill River Region: 2008/2009-2013/2014.

Waterbody/Area	**Site Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years [1]**					
						2008/09	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**
Saskatchewan River	SASK	X	X		X			X			X
South Moose Lake	SMOOSE	X			X		X			X	
Cedar Lake - West	CEDAR-W	X			X				X		
Cedar Lake - Southeast	CEDAR-SE	X		X		X	X	X	X	X	X
Cormorant Lake	CORM		X	X		X	X	X	X	X	X

[1] Note that not all components were sampled at the frequency indicated for all waterbodies/areas. See descriptions provided for each monitoring component for details

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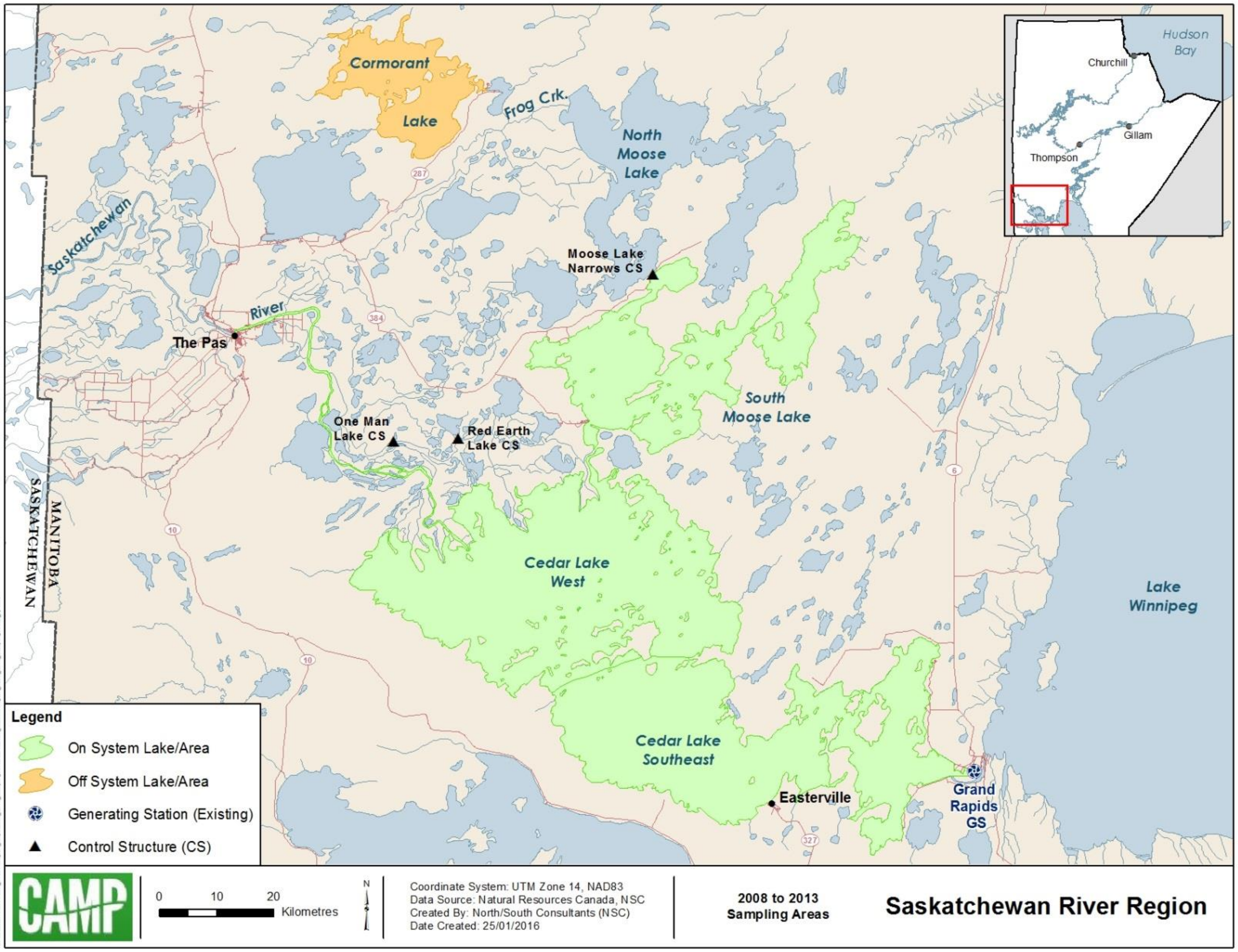


Figure 1-1. On-system and off-system waterbodies and river reaches sampled under CAMP in the Saskatchewan River Region: 2008/2009-2013/2014.

2.0 HYDROLOGY

The Saskatchewan River flows entering Manitoba are influenced by both precipitation and water use across the Saskatchewan River watershed. Flows originate from as far west as the foot of the Rocky Mountains and are affected by various operations along the way to Manitoba including municipal and recreational use, hydroelectric generation, irrigation and flood control. Between 2008 and 2013, CAMP monitoring occurred along the Saskatchewan River and on Cedar Lake, which acts as a hydroelectric reservoir for the Grand Rapids Generating Station (GS). Monitoring also occurred on South Moose Lake, which is influenced by levels on Cedar Lake. Flows for this region are reported based on the Saskatchewan River gauge at The Pas and the Grand Rapids GS.

Saskatchewan River flows in Manitoba are gauged at The Pas and between 2008 and 2013, flows were typically between the upper and lower quartile since snowpack and precipitation was generally close to average. The exceptions were in 2009, when flows dropped below the lower quartile from May to September due to below average precipitation, and in 2010, when above average precipitation led to flows above the upper quartile from mid-September through the end of the year. High summer precipitation in 2011 and 2013 (Calgary flood) also led to flow peaks well above the upper quartile in both years (Figure 2-1).

During the winter months from 2008 to 2013, the Grand Rapids GS outflows tended to fluctuate around the average between the upper and lower quartile depending on energy demand. The exceptions were the winters of 2008/2009 and 2013/2014 when outflows were more frequently above the upper quartile. Outflows were more variable during the open-water season depending on precipitation-driven inflows from the Saskatchewan River. Outflows were generally above average during the open-water seasons from 2010 to 2013, reaching record highs for much of 2013. Open-water season outflow was closer to average in 2008 and below average in 2009 (Figure 2-2).

Cedar Lake water levels were generally below average in 2008, slightly above average in 2009, near the upper quartile for most of 2010 and 2013, and above the upper quartile for most of 2011 and 2012. Cedar Lake water levels were close to average in early 2014. Cedar Lake water levels also reached record lows in March 2008 due to above average discharge at the Grand Rapids GS in early 2008 (Figures 2-3).

Water levels on South Moose Lake varied from the upper quartile in early 2008 to the lower quartile in mid-2008 and remained near the lower quartile before climbing back to near the upper quartile in late-2010. South Moose Lake water levels then remained near or above the upper quartile from 2011 to late 2013 before climbing to near record high levels which were maintained into early 2014 (Figure 2-4).

In 2008, Cormorant Lake water levels started above the upper quartile and gradually declined to below average by the end of the year. Water levels stayed below average before climbing back to near the upper quartile in late 2010. Cormorant Lake water levels were near or above the upper quartile from 2011 to 2013 and remained at record high from July 2013 to early 2014 (Figure 2-5). High levels were driven by very high local precipitation.

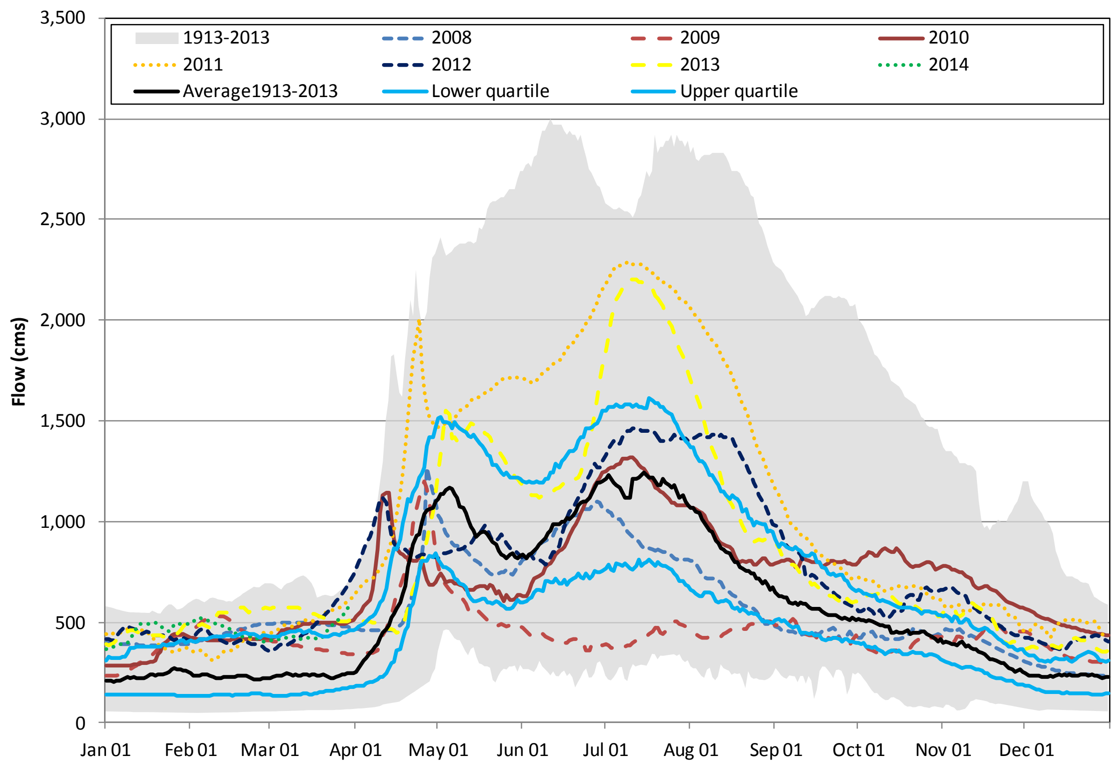


Figure 2-1. 2008-2013 Saskatchewan River flow at The Pas (05KJ001).

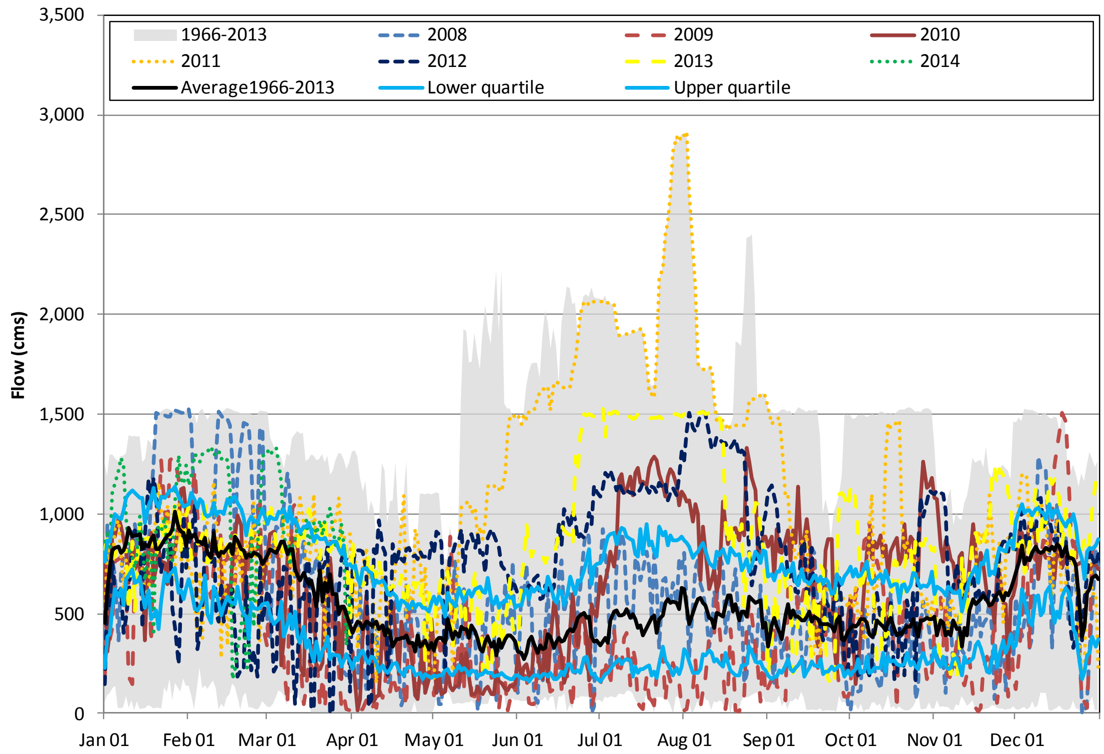


Figure 2-2. 2008-2013 Grand Rapids GS outflow.

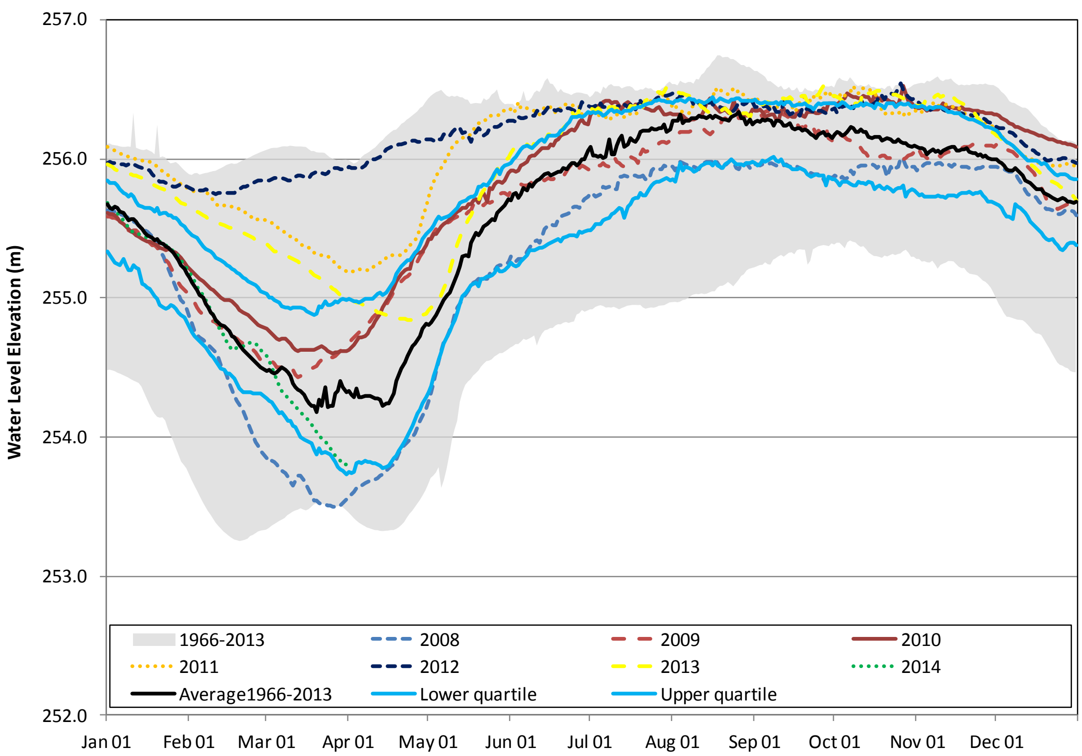


Figure 2-3. 2008-2013 Cedar Lake (05KL005) water level elevation.

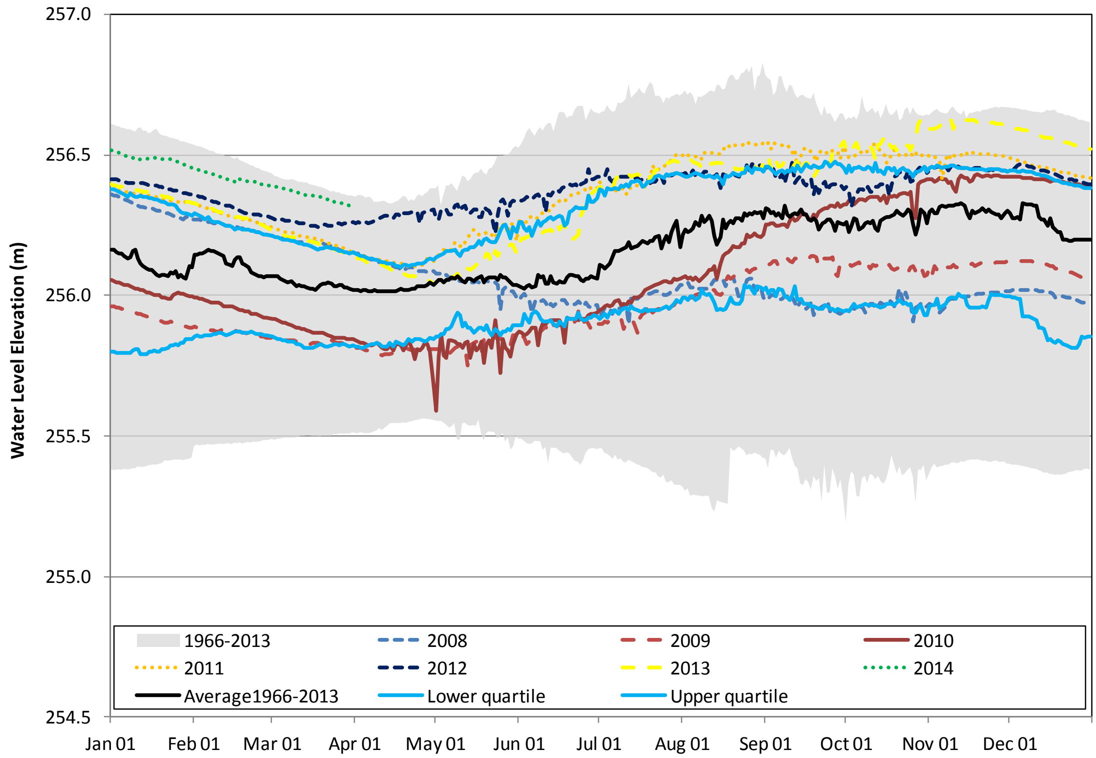


Figure 2-4. 2008-2013 South Moose Lake (05KK006) water level elevation.

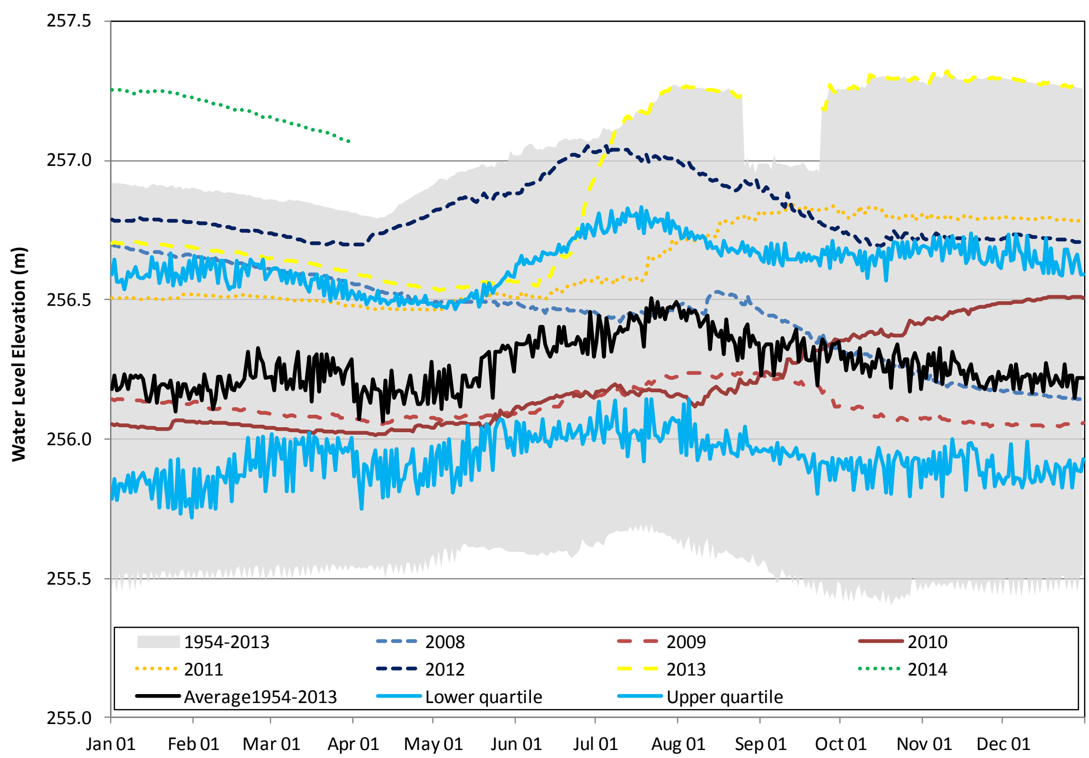


Figure 2-5. 2008-2013 Cormorant Lake (05KK002) water level elevation.

3.0 WATER QUALITY

3.1 INTRODUCTION

The following provides an overview of water quality conditions for key metrics measured over years 1-6 of CAMP in the SRR. As noted in Section 1.0, waterbodies/river reaches sampled annually included one on-system site (Cedar Lake – Southeast) and one off-system lake (Cormorant Lake). Three additional on-system areas were sampled on a rotational basis including the Saskatchewan River (near the inflow to Cedar Lake), South Moose Lake, and Cedar Lake - West (Table 3-1; Figure 3-1). Discussions with the Chemawawin Cree Nation were ongoing in 2008/2009; therefore, Cedar Lake was only sampled in spring of that year. As such, the following discussion focusses on the 2009-2013 period for Cedar Lake.

A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 3.3. In brief, the CAMP water quality program includes four sampling periods per year (referred to as spring, summer, fall, and winter) at a single location within each monitoring waterbody or area of a waterbody/river reach.

3.1.1 Objectives and Approach

The key objectives of the analysis of CAMP water quality data, which were directed in the terms of reference for preparation of this report, were to:

- evaluate whether water quality conditions are suitable for aquatic life;
- evaluate whether there are indications of temporal trends in water quality metrics; and
- provide an initial review of linkages between water quality metrics and key drivers, notably hydrological conditions, where feasible.

The first objective was addressed through comparisons of the water quality results to the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) to evaluate overall ecosystem health (Manitoba Water Stewardship [MWS] 2011).

The second objective (analysis of temporal changes or trends) was addressed through two approaches: (1) statistical analyses were undertaken to assess whether there were significant differences between years at annual sites; and (2) trends were examined visually through graphical plots for annual sites. As noted in Technical Document 1, six years of data may be insufficient to detect trends over time, notably long-term trends, and the assessment was therefore restricted to qualitative assessment of the available data for sites monitored annually.

Additionally, any indications of potential trends over the six year period do not necessarily imply a long-term trend is occurring, as apparent trends over this interval may simply reflect the relatively limited time period assessed in conjunction with inter-annual variability in a metric. Consideration of a longer period of record is required to evaluate for long-term trends. The third objective was addressed through statistical analysis of hydrological and water quality metrics to evaluate correlations between flow and water level and water quality metrics.

Statistical analyses undertaken for this component are inherently limited by the quantity of data, notably the frequency of sampling, and the absence of statistically significant differences may reflect the relatively limited amount of data. Furthermore, factors other than hydrological conditions, notably climatological conditions such as air temperature and wind, affect water quality. For these reasons, these analyses are considered to be exploratory in nature. In addition, it is cautioned that identification of significant correlations between water quality and hydrological metrics does not infer a causal relationship (i.e., correlations simply indicate that two metrics are related).

A detailed description of the approach and methods applied for analysis and reporting is provided in Technical Document 1, Section 4.3. Figures illustrating results for all sites sampled in the SRR in the following present data in an upstream to downstream direction. Site abbreviations applied in tables and figures are defined in Table 3-1.

3.1.2 Indicators

Although CAMP measures over 65 water quality parameters, results presented below focus upon three key indicators selected at CAMP workshops: dissolved oxygen (DO; and the supporting metric water temperature); water clarity; and nutrients/trophic status. Metrics for these indicators include DO and temperature, total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS), turbidity, and Secchi disk depth. A detailed description of key indicators is provided in Technical Document 1, Section 4.3.1.

Results for parameters in addition to the key metrics were also reviewed and summarized in Section 3.3 where of particular note (e.g., where there was evidence of temporal trends or where a metric did not meet MWQSOGs for PAL).

3.2 KEY INDICATORS

3.2.1 Dissolved Oxygen

Concentrations of dissolved oxygen are affected by water temperature, both in terms of the absolute amount of oxygen that can be contained in water (the capacity of water to hold oxygen is temperature-dependent) and because thermal stratification (i.e., layering of water of different temperatures) in a lake can affect the introduction and distribution of oxygen from the atmosphere. Thermal stratification can limit or prevent mixing of the water column and lead to oxygen deficits, notably near the bottom of the water column. When water near the surface of the water column cools in the fall and warms in the spring, layers of water isolated due to temperature and density differences are turned over, and the water column is mixed. For these reasons, water temperature conditions are monitored and considered when interpreting DO results.

3.2.1.1 Saskatchewan River

Lakes on the Saskatchewan River were isothermal or weakly stratified during most open-water periods (Table 3-2; Figures 3-2 to 3-5). Monitoring under CAMP indicated that the Saskatchewan River was isothermal during all periods. Weak stratification (i.e., change of exactly 1.0 °C in 1 m of water) occurred in the shallow, west basin of Cedar Lake during the summer of 2011 (between 1.0 and 2.0 m below the surface). In the southeast basin of Cedar Lake, relatively weak stratification also occurred near the surface (0-2 m) in summer 2011, and spring 2010 and 2012. In contrast, stronger thermal stratification (i.e., a greater rate of change in temperature) was observed during spring 2013 (thermocline at 3-4 m). Though temperature increased across depth in each winter in Cedar Lake – Southeast, stratification was only observed in winter 2013/2014 (thermocline at 6-7 m).Winter stratification was observed in South Moose Lake when it was sampled (thermocline at 4-5 m in 2009/2010 and at 3-4 m in 2012/2013).

Lake and river sites sampled along the Saskatchewan River were well-oxygenated during the open-water season and DO concentrations consistently exceeded the most stringent Manitoba PAL objectives for cool-water and cold-water aquatic life (6.0 and 6.5 mg/L, respectively) across the water column over the six years of monitoring (Figures 3-6 to 3-11).

In contrast, DO concentrations measured during the ice-cover season in South Moose Lake and Cedar Lake - Southeast decreased across the water column and occasionally fell below the Manitoba PAL objective for cold-water species (9.5 mg/L). DO may decrease in north temperate ecosystems that experience long periods of ice cover due to the lack of an oxygen source from the atmosphere (i.e., no or minimal reaeration due to ice).

In South Moose Lake, DO was below the cold-water PAL (9.5 mg/L) near the sediment-water interface during both winters when sampling was conducted (2009/2010 and 2012/2013); however, DO remained above the PAL objective for cool-water species (5.5 mg/L) on both occasions (Figure 3-10).

DO concentrations were below the PAL objective for cold-water species at the bottom of the water column in Cedar Lake - Southeast in 2011/2012 and 2013/2014 (Figure 3-11). This occurrence was also observed in the off-system Cormorant Lake during most winters and some summers (Figure 3-12).

DO was similar across the sites on the Saskatchewan River during the open-water season and there is no indication of spatial trends over the first six years of CAMP (Figure 3-13). However, oxygen depletion near the bottom of the water column in winter was greater in South Moose Lake than observed in Cedar Lake.

3.2.1.2 Off-system Waterbody: Cormorant Lake

Cormorant Lake was thermally stratified more frequently than the on-system sites and, with one exception (spring 2012), was stratified during each open-water period when on-system sites were stratified (Table 3-2; Figure 3-14). Although stratification was not observed during the ice-cover season, the water depth is higher at the monitoring site in Cormorant Lake than at the on-system sites and the temperature consistently increased with depth.

Cormorant Lake tended to be well-oxygenated throughout the water column in spring and fall, but DO concentrations decreased with depth during summer and winter (Figures 3-12 and 3-15). In summer 2010/2011, 2011/2012, and 2012/2013, DO decreased across the water column and concentrations near the bottom (i.e., within 1 – 10 m of the sediment) dropped below the PAL objectives for cool-water (6.0 mg/L) and/or cold-water (6.5 mg/L) species. DO near the bottom of the water column was also below the PAL objective for cold-water species (9.5 mg/L) in most winters, but consistently remained above the PAL objective for cool-water species (5.5 mg/L).

3.2.1.3 Temporal Comparisons and Trends

Examination of data for the annual on- and off-system monitoring sites (Cedar Lake - Southeast and Cormorant Lake, respectively) indicates open-water season DO concentrations and percent saturation did not vary significantly between years (Figure 3-16). There is also no indication of an increasing or decreasing trend in oxygen concentrations or saturation over the six year monitoring period at either site.

3.2.2 Water Clarity

Water clarity is measured under CAMP as total suspended solids, turbidity, and Secchi disk depth. While typically related, each of these metrics measures water clarity in a different way and therefore provides somewhat different information on this key indicator.

3.2.2.1 Saskatchewan River

Water clarity at on-system sites in the Saskatchewan River Region increased with distance downstream, likely due to settling of suspended materials as water passed through lentic areas (Figure 3-17). The highest annual open-water season mean TSS (> 48 mg/L) and turbidity (> 23 NTU) occurred in the Saskatchewan River. Water clarity was highest in Cedar Lake – Southeast (annual means for TSS < 4 mg/L and turbidity < 6 NTU) and South Moose Lake (TSS < 4 mg/L TSS and turbidity < 3 NTU; Table 3-2; Figures 3-17 and 3-18).

As with the other water clarity metrics, Secchi disk depths indicated lower clarity (i.e., lower Secchi disk depths) in the Saskatchewan River and Cedar Lake - West (means near 0.4 m), and higher clarity in Cedar Lake - Southeast and South Moose Lake (means exceeding 1.3 m). Greater inter-annual variability was noted at Cedar Lake - Southeast (means ranged from 1.3 to 3.5 m; Figure 3-19).

3.2.2.2 Off-system Waterbody: Cormorant Lake

TSS (Figure 3-17) and turbidity (Figure 3-18) at the off-system Cormorant Lake were lower than those measured at riverine and lacustrine sites along the Saskatchewan River (Figure 3-19). Secchi disk depth (Figure 3-20) measurements at Cormorant Lake were also typically higher than conditions measured elsewhere in the region. However, as discussed in Technical Document 1, Section 1.2.2.1, it is recognized that off-system waterbodies monitored under CAMP may fundamentally differ from on-system waterbodies and would not necessarily be expected to exhibit similar chemical or biological characteristics.

In contrast to the on-system waterbodies, TSS concentrations in Cormorant Lake were below the analytical detection limit of 2 mg/L in approximately 50% of samples over the six years of monitoring.

3.2.2.3 Temporal Comparisons and Trends

Statistical comparisons of water clarity metrics between years at the annual on-system site (Cedar Lake - Southeast) indicated no significant differences in mean open-water TSS concentrations, turbidity levels, or Secchi disk depths. However, qualitative assessment suggests TSS and laboratory turbidity have increased while Secchi disk depths have slightly decreased at this site over the duration of the CAMP program (Figures 3-17 to 3-19). No statistically significant inter-annual differences or trends were observed in the off-system Cormorant Lake.

3.2.3 Nutrients, Chlorophyll *a*, and Trophic Status

Trophic status is a means for describing or classifying the productivity of a waterbody and it is commonly defined based on the concentrations of major nutrients (total phosphorus and total nitrogen) and chlorophyll *a* (a measure of algal abundance). Trophic status is typically defined in categories intended to be indicative of the level of productivity as follows: low (ultra-oligotrophic or oligotrophic); moderate to moderately high (mesotrophic or meso-eutrophic); high (eutrophic); and very high (hyper-eutrophic) productivity. Trophic status may vary within a waterbody depending on the metric used to describe it.

3.2.3.1 Saskatchewan River

Lakes located along the Saskatchewan River were mesotrophic to meso-eutrophic on the basis of mean open-water season TP concentrations, and were typically mesotrophic to eutrophic based on TN and chlorophyll *a* (Table 3-2 and Figures 3-21, 3-22, and 3-23).

While TN and chlorophyll *a* were similar between the Saskatchewan River site and Cedar and South Moose lakes, TP concentrations were higher at the riverine site. The Saskatchewan River upstream of Cedar Lake was eutrophic based on mean open-water season TP concentrations, but oligotrophic based on mean TN and chlorophyll *a* concentrations (Table 3-2 and Figures 3-21, 3-22, and 3-23). The discrepancy between the trophic classifications for the riverine site relates to the fact that the classification system for TP is intended to be applied to lakes and rivers, whereas the TN and chlorophyll *a* classifications differ between lakes and rivers.

On average, open-water season TP concentrations in South Moose Lake and Cedar Lake - Southeast were below the Manitoba narrative nutrient guideline (0.025 mg/L for lakes, reservoirs and streams near the inflows to waterbodies; MWS 2011) in each year of monitoring; the exception was in 2013/2014, when the mean concentration in Cedar Lake - Southeast exceeded the guideline (Figure 3-24). In contrast, mean concentrations in the Saskatchewan River and Cedar Lake - West were at or above the narrative nutrient guideline in each year of monitoring. Frequencies of exceedances of the guideline for individual samples collected in the open-water season also differed between sites, where exceedance frequencies were: Cedar Lake – West (100% of samples); Saskatchewan River (83% of samples); Cedar Lake - Southeast (25% of samples); and South Moose Lake (0% of samples). In addition, chlorophyll *a* exceeded the CAMP trigger of 10 µg/L in 17-33% of samples collected at each site.

Based on the first six years of monitoring data, TP was significantly positively correlated to chlorophyll *a* concentrations at the annual on-system site (i.e., Cedar Lake – Southeast), though the relationship was relatively weak (Figure 3-25). Conversely, there was no significant relationship observed between TN and chlorophyll *a*. This suggests that of the two nutrients, TP may be the most limiting to phytoplankton growth in the lake, as is commonly observed in freshwater ecosystems. TN:TP molar ratios also indicated the lake was phosphorous limited (Table 3-3). Most other on-system waterbodies sampled annually under CAMP also showed either the lack of, or a weak, correlation between nutrients and chlorophyll *a* for the six year monitoring period. However, the lack of relationships may reflect the relatively limited amount of data and/or range of conditions.

The ratio of chlorophyll *a* to TP – an indicator of the efficiency of assimilating phosphorus into algae - ranged from a mean of 0.15 in the Saskatchewan River to 0.42 in Cedar Lake - Southeast. This ratio suggests that assimilation efficiency was higher in the lakes in the region than the riverine site, and on-system lakes had higher assimilation than the off-system Cormorant Lake (mean ratio of 0.23; Table 3-3 and Figure 3-26).

Similar to water clarity, TP and TN were generally higher in the Saskatchewan River and Cedar Lake - West compared to Cedar Lake - Southeast and South Moose Lake (Figure 3-27). Chlorophyll *a* concentrations were quite variable within on-system sites and there was no clear spatial pattern among these sites. However, chlorophyll *a* was somewhat lower in South Moose Lake relative to other on-system sites (Table 3-3 and Figures 3-23 and 3-27).

3.2.3.2 Off-system Waterbody: Cormorant Lake

On average, Cormorant Lake had a lower trophic status (i.e., oligotrophic to mesotrophic based on mean open-water TP, TN, and chlorophyll *a*) compared to lakes on the Saskatchewan River (Table 3-3 and Figures 3-21 to 3-23). None of the samples collected in Cormorant Lake exceeded the Manitoba narrative nutrient guideline for TP in lakes and reservoirs (0.025 mg/L).

Unlike conditions in Cedar Lake - Southeast, TN and TP were not correlated to chlorophyll *a* in Cormorant Lake (Figure 3-25). This may indicate factors other than nutrients are limiting to phytoplankton growth and/or or that bioavailability of nutrients is limited, but may also reflect the relatively limited data acquired for examination of inter-relationships.

3.2.3.3 Temporal Comparisons and Trends

No statistically significant inter-annual differences were found for TP, TN, or chlorophyll *a* (open-water seasons) at either of the annual monitoring sites. However, there appeared to be a slight increasing trend for TN concentrations at the annual Cedar Lake - Southeast site over the monitoring period (Figure 3-22). No other increasing or decreasing trends were observed for these metrics in the annual monitoring sites.

3.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

Other water quality metrics measured under CAMP, as described in Appendix 1, Section 4.3.1, were also reviewed to assess trends and to compare to water quality objectives and guidelines for the protection of aquatic life. Several non-key metrics appear to have experienced a slight increasing trend over the first six year period of CAMP at the annual Cedar Lake–Southeast site, including:

- specific conductance (Figure 3-28);
- sulphate (Figure 3-29);
- hardness (Figure 3-30); and
- major cations (calcium, magnesium, potassium, and sodium; Figures 3-31 to 3-34).

These trends were not observed in the off-system Cormorant Lake; however, sulphate declined slightly over the monitoring period in the off-system lake. All metrics that exhibited an increasing trend in Cedar Lake - Southeast were found to be positively correlated to water level and/or discharge for the 2009-2013 monitoring period (see Section 3.4).

pH, ammonia, and nitrate remained within PAL guidelines/objectives at all sites and times, both on- and off-system. Additionally, most metals were consistently within Manitoba water quality PAL objectives and guidelines. Exceptions included aluminum, which was above the PAL guideline (0.1 mg/L) in 88% of samples from the Saskatchewan River, 75% from Cedar Lake - West, and 14% from Cedar Lake - Southeast (Table 3-4). The PAL guideline for iron (0.3 mg/L) was also exceeded in 88% and 50% of samples from the Saskatchewan River and Cedar Lake - West, respectively. No exceedances of these PAL objectives or guidelines were found in the off-system Cormorant Lake; however, elevated concentrations of these metals are common in northern Manitoba lakes and rivers and are also observed in lakes and rivers unaffected by hydroelectric development (Ramsey 1991; Keeyask Hydropower Limited Partnership 2012; Manitoba Hydro and the Province of Manitoba 2015), including off-system CAMP waterbodies.

Chloride was within the Canadian Council of Ministers of the Environment (CCME (1999; updated to 2017) PAL guideline (120 mg/L) and sulphate remained within the British Columbia Ministry of the Environment (BCMOE) PAL guidelines for sulphate (309-429 mg/L; Meays and Nordin 2013) at all on- and off-system sites monitored in this region (Table 3-4).

3.4 RELATIONSHIPS WITH HYDROLOGICAL METRICS

Exploratory analyses indicated a number of significant, positive relationships, between water quality metrics in Cedar Lake and hydrological metrics, particularly for lake water level (Tables 3-5 and 3-6). Generally, relationships were strongest for weekly or monthly mean lake water level, and include:

- alkalinity (Figure 3-35);
- dissolved phosphorus (Figure 3-36);
- total organic carbon (TOC; Figure 3-37);
- specific conductance (Figure 3-38);
- hardness (Figure 3-39);
- major cations (Figures 3-40 to 3-43);
- sulphate (Figure 3-44); and
- a number of metals (Table 3-5).

However, water level exhibits a seasonal pattern in Cedar Lake and was positively correlated to Julian dates for the water quality sampling periods. In addition, several water quality metrics were positively correlated to Julian date. Collectively, this suggests that some water quality metrics may be significantly related to time of year and/or water level in Cedar Lake.

As this analysis was exploratory and was limited by the quantity of available data, these results are considered to be preliminary. Additional data and a longer period of record and/or range of conditions may be required to more definitively relate water quality to hydrological conditions in Cedar Lake or to other factors.

3.5 SUMMARY

Analysis of the six years of CAMP monitoring data collected in the SRR indicated that most water quality metrics were within PAL objectives and guidelines and metrics that exceeded PAL guidelines in this region are commonly above these benchmarks in northern Manitoba lakes and rivers, including off-system sites monitored under CAMP.

On-system lakes and the Saskatchewan River were well-oxygenated and generally did not stratify during the open-water seasons over the six-year monitoring period. However, lower concentrations of DO (i.e., concentrations below the cold-water PAL) were observed in winter near the bottom of the water column in South Moose Lake (during each year of sampling) and

Cedar Lake (at the Southeast site in 2011/2012 and 2013/2014). By comparison, the off-system monitoring site (Cormorant Lake) was more frequently stratified and prone to oxygen depletion during both the open-water and ice-cover seasons.

On-system sites in the SRR had moderate to high nutrient and chlorophyll *a* concentrations. Cedar Lake, which was more nutrient-rich and supported more algae, had a higher trophic status (meso-eutrophic to eutrophic) than South Moose Lake (mesotrophic). The Saskatchewan River was even more nutrient-rich and contained similar levels of algae as Cedar Lake. Open-water season TP concentrations at the upstream sites (Saskatchewan River and Cedar Lake - West) exceeded the Manitoba narrative guideline in 83 and 100% of samples, respectively, while Cedar Lake - Southeast had a lower rate of exceedance (25%). No samples collected in South Moose or the off-system (Cormorant) lakes had TP concentrations in excess of the guideline.

TSS, turbidity, TN, and TP decreased from the Saskatchewan River to the southeast area of Cedar Lake. Decreases in these substances likely reflect settling of suspended materials within Cedar Lake.

Data collected over the first six years of monitoring indicated slight increases in TSS, turbidity, TN, specific conductance, hardness, and most major ions (calcium, magnesium, potassium, sodium, and sulphate) and a decrease in Secchi disk depth through time at the annual on-system monitoring site (Cedar Lake - Southeast). Most of these parameters were also significantly and positively related to water level of Cedar Lake. However, positive relationships were also observed between Julian date and lake water level and for some water quality metrics. In addition, these preliminary analyses were exploratory in nature as they were inherently limited by the quantity of available data and the range of conditions encountered over the monitoring period.

Table 3-1. Inventory of water quality sampling completed in the SRR: 2008/2009-2013/2014.

Waterbody/Area/ River Reach	Site Abbreviation	Site ID	On-system	Off-system	Annual	Rotational	Sampling Years					
							2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Saskatchewan River	SASK	KJS 006	X	X		X			X			X
South Moose Lake	SMOOSE	KKS 039	X			X		X			X	
Cedar Lake-West Basin	CEDAR-W	KLS 004	X			X				X		
Cedar Lake-Southeast Basin	CEDAR-SE	KLS 001	X		X		X [1]	X	X	X	X	X
Cormorant Lake	CORM	KKS 038		X	X		X	X	X	X	X	X

[1] Site was only sampled in spring.

Table 3-2. Summary of water quality conditions measured in the SRR over the period of 2008/2009 to 2013/2014. Values represent means.

Metric		**Waterbody**				
		SASK	**SMOOSE**	**CEDAR-W**	**CEDAR-SE**	**CORM**
Years Sampled		2010/11, 2013/14	2009/10, 2012/13	2011/12	2008/09-2013/14	2008/19-2013/14
TP	(mg/L)	0.0442	0.0159	0.0263	0.0188	0.0095
	Trophic Status	Eutrophic	Mesotrophic	Meso-eutrophic	Mesotrophic	Oligotrophic
TN	(mg/L)	0.60	0.49	0.80	0.50	0.34
	Trophic Status	Oligotrophic	Mesotrophic	Eutrophic	Mesotrophic	Oligotrophic
TKN	(mg/L)	0.50	0.48	0.70	0.46	0.33
Chlorophyll *a*	(µg/L)	5.82	4.01	7.39	7.03	1.38
	Trophic Status	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Oligotrophic
TN:TP	Molar Ratio	40	71	96	71	144
DOC	(mg/L)	8.3	7.2	8.9	6.2	7.5
Nitrate/nitrite	(mg N/L)	0.106	0.0151	0.0948	0.0419	0.0092
Ammonia	(mg N/L)	0.021	0.009	0.013	0.015	0.011
Dissolved Phosphorus	(mg/L)	0.011	0.008	0.011	0.009	0.006
DO Lower than MWQSOGs for PAL	(Y/N)	N	Yes (winter 2009/2010 and 2012/2013)	N	Yes (winter 2011/2012 and 2013/2014)	Yes (summer 2010 and 2012; and winter 2009/2010, 2011/2012, 2012/2013, 2013/2014)
DO - open-water season (surface)	(mg/L)	8.39	9.24	9.39	9.13	9.80
DO - open-water season (bottom)	(mg/L)	8.35	9.01	9.08	8.71	8.16
DO - ice-cover season (surface)	(mg/L)	11.0	15.04	10.32	12.90	14.40
DO - ice-cover season (bottom)	(mg/L)	11.0	4.69	10.32	9.45	8.92
Thermal Stratification	(Y/N)	No	Yes (winter 2009/2010 and 2012/2013)	Yes (summer 2011)	Yes (spring 2010, 2012 and 2013; summer 2011; and, winter 2013/2014)	Yes (spring 2008, 2010 and 2013; and, summer 2010-2013)
Secchi Disk Depth	(m)	0.40	1.76	0.43	1.81	3.99
TSS	(mg/L)	48.7	3.4	32.1	3.2	1.7
Turbidity	(NTU)	19.8	1.97	16.0	2.90	1.14
True Colour	(TCU)	21.9	5.0	23.6	13.0	4.3
Specific Conductance	(µmhos/cm)	441	353	426	422	292
Total Dissolved Solids	(mg/L)	264	215	269	257	181
Hardness	(mg/L)	189	192	190	183	165
Hardness Category	-	Very Hard	Very Hard	Very Hard	Very Hard	Hard
pH	-	8.22	8.45	8.20	8.38	8.44
Total Alkalinity		150	185	157	153	165
Metals > MWQSOGs for PAL	-	Al, Fe	-	Al, Fe	Al	-
Aluminum	(mg/L)	0.657	0.026	0.656	0.059	0.040
Iron	(mg/L)	0.888	0.040	0.860	0.075	0.025
Mercury (26 ng/L DL only)	(mg/L)	2.7	<20	-	<20	<20
Mercury (1 ng/L DL only)	(mg/L)	2.7	<1.0	-	1.2	1.6
Calcium	(mg/L)	45.9	37.0	46.6	44.9	34.6
Magnesium	(mg/L)	18.2	24.3	17.8	17.2	19.2
Potassium	(mg/L)	3.47	2.35	3.85	3.21	1.22
Sodium	(mg/L)	20.3	8.27	21.0	19.3	2.69
Chloride	(mg/L)	13.0	4.45	12.0	11.7	1.17
Sulphate	(mg/L)	59.2	16.7	57.5	52.8	3.38

TKN = total Kjeldahl nitrogen; DOC = dissolved organic carbon; DL = detection limit

Table 3-3. Summary of water quality conditions measured in the SRR in the open-water season: 2008-2013. Values represent means.

Indicator	Metric		Units	Waterbody				
				SASK	SMOOSE	CEDAR-W	CEDAR-SE	CORM
Nutrients	TP	Mean	(mg/L)	0.0528	0.0169	0.0327	0.0204	0.0099
		Trophic Status	-	Eutrophic	Mesotrophic	Meso-eutrophic	Meso-eutrophic	Oligotrophic
	TN	Mean	(mg/L)	0.60	0.49	0.83	0.45	0.35
		Trophic Status	-	Oligotrophic	Mesotrophic	Eutrophic	Mesotrophic	Mesotrophic
	Chlorophyll *a*	Mean	(µg/L)	7.58	5.09	9.53	8.81	1.50
		Trophic Status	-	Oligotrophic	Mesotrophic	Eutrophic	Eutrophic	Oligotrophic
	TN:TP	Mean	-	30	64	56	57	159
		Nutrient Limitation	(mg/L)	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation
	Chlorophyll *a*:TP	Mean	-	0.15	0.29	0.30	0.42	0.23
	Chlorophyll *a*:TN	Mean	-	0.012	0.010	0.011	0.027	0.005
	Algal Bloom Frequency (Chlorophyll *a* >10 µg/L)	-	(%)	33	17	33	31	0
Dissolved Oxygen	DO Lower than MWQSOGs for PAL	-	(Y/N)	No	No	No	No	Yes (summer 2010 and 2012)
	DO	Surface	(mg/L)	8.39	9.24	9.39	9.13	9.80
		Bottom	(mg/L)	8.35	9.01	9.08	8.71	8.16
	Thermal Stratification	-	(Y/N)	No	No	Yes (summer 2011)	Yes (spring 2010, 2012 and 2013; and, summer 2011)	Yes (spring 2008, 2010 and 2013; and, summer 2010-2013)
Water Clarity	Secchi Disk Depth	Mean	(m)	0.40	1.76	0.43	1.81	3.99
	TSS	Mean	(mg/L)	65.4	4.2	42.4	3.8	2.0
	Turbidity	Mean	(NTU)	24.92	2.51	20.73	3.39	1.37

Table 3-4. Frequency of exceedances of MWQSOGs for metals, the CCME PAL guideline for chloride, and the BCMOE PAL guideline for sulphate measured in the Saskatchewan River Region: 2008-2013. Values in red indicate exceedances occurred at a given site.

		MWQSOGs PAL																CCME PAL	BCMOE PAL
Waterbody		**Aluminum**	**Arsenic**	**Boron**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Mercury[1]**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Uranium**	**Zinc**	**Chloride**	**Sulphate**
Objective or Guideline (mg/L)		0.1	0.15	1.5	0.000342 - 0.000526	0.1115 - 0.1795	0.01221 - 0.02006	0.3	0.00475 - 0.00996	0.000026	0.073	0.0681 - 0.1113	0.001	0.0001	0.0008	0.015	0.1564 - 0.256	120	309 - 429
Saskatchewan River	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**7**	0	0	0	0	0	**7**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**88**	0	0	0	0	0	**88**	0	0	0	0	0	0	0	0	0	0	0
South Moose Lake	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cedar Lake-West	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	# Exceedances	**3**	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**75**	0	0	0	0	0	**50**	0	0	0	0	0	0	0	0	0	0	0
Cedar Lake-Southeast	n	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
	# Exceedances	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**14**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cormorant Lake	n	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	# Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1] Only measurements made with an analytical detection limit of <0.000026 mg/L included.

Table 3-5. Linear regressions between water quality measured in Cedar Lake - Southeast and water level at Cedar Lake for the open-water season. Values in red indicate significant correlations.

Parameter	Units	Water Level (mASL) vs. Water Quality												Direction of Relationship
		Daily			Weekly			Monthly			Annually			
			R^2	p-value		R^2	p-value		R^2	p-value		R^2	p-value	
Total Alkalinity as $CaCO_3$	mg/L		0.506	0.003		0.540	0.002		0.606	0.001		0.207	0.089	+
Bicarbonate Alkalinity as HCO_3	mg/L		0.332	0.025		0.381	0.014		0.533	0.002		0.177	0.118	+
Dissolved Phosphorus	mg/L		0.162	0.137	Log	0.222	0.077	Log	0.356	0.019		0.000	0.956	+
Total Phosphorus	mg/L		0.168	0.129	Log	0.248	0.059	Log	0.109	0.034		0.005	0.800	+
Dissolved Organic Carbon	mg/L		0.221	0.077		0.178	0.117		0.282	<0.001		0.011	0.708	+
Total Organic Carbon	mg/L		0.586	0.001		0.586	0.001		0.630	<0.001		0.206	0.089	+
Laboratory Turbidity	NTU	Log	0.321	0.028	Log	0.324	0.027		0.155	0.147		0.035	0.507	+
Specific Conductance	µmhos/cm		0.454	0.006		0.493	0.004		0.484	0.004	Log	0.273	0.045	+
Chlorophyll *a*	µg/L		0.227	0.072	Log	0.281	0.042		0.240	0.064		0.038	0.484	+
Hardness as $CaCO_3$	mg/L		0.563	0.001		0.606	0.001		0.604	0.001		0.408	0.010	+
Calcium	mg/L		0.432	0.008		0.470	0.005		0.505	0.003		0.407	0.010	+
Magnesium	mg/L		0.539	0.002		0.576	0.001		0.514	0.003	Log	0.284	0.041	+
Potassium	mg/L		0.452	0.006		0.497	0.003		0.435	0.007		0.502	0.003	+
Sodium	mg/L		0.297	0.036		0.379	0.014		0.413	0.010		0.219	0.079	+
Sulphate	mg/L		0.527	0.002		0.578	0.001		0.452	0.006		0.377	0.015	+
Arsenic	mg/L		0.593	0.001		0.558	0.001		0.594	0.001		0.039	0.482	+
Barium	mg/L		0.651	<0.001		0.691	<0.001		0.679	<0.001		0.140	0.169	+
Fluoride	mg/L		0.633	0.010		0.673	0.007		0.547	0.023		0.015	0.752	+
Manganese	mg/L		0.268	0.048	Log	0.433	0.008		0.301	0.034		0.001	0.896	+
Molybdenum	mg/L		0.435	0.007		0.447	0.006		0.418	0.009		0.017	0.646	+
Silicon	mg/L		0.452	0.017	Log	0.413	0.024		0.236	0.109		0.020	0.658	+
Strontium	mg/L		0.293	0.037		0.372	0.016		0.442	0.007		0.202	0.093	+
Uranium	mg/L		0.074	0.325		0.050	0.425		0.029	0.546		0.198	0.097	
Vanadium	mg/L		0.330	0.025		0.332	0.025		0.310	0.031		0.072	0.333	+

Table 3-6. Linear regressions between water quality measured in Cedar Lake - Southeast and discharge of the Saskatchewan River at The Pas for the open-water season. Values in red indicate significant correlations.

Parameter	Units	Discharge vs. Water Quality											Direction of Relationship
		Daily			Weekly		Monthly			Annually			
			R^2	p-value	R^2	p-value		R^2	p-value		R^2	p-value	
Total Alkalinity as $CaCO_3$	mg/L		0.003	0.858	0.000	0.976		0.022	0.596		0.198	0.096	
Bicarbonate Alkalinity as HCO_3	mg/L		0.000	0.973	0.001	0.935		0.005	0.811		0.088	0.283	
Total Kjeldahl Nitrogen	mg/L		0.060	0.380	0.092	0.273		0.246	0.060	Log	0.284	0.041	+
Total Nitrogen	mg/L		0.053	0.408	0.082	0.300		0.227	0.072	Log	0.265	0.050	+
Dissolved Phosphorus	mg/L		0.001	0.915	0.003	0.842		0.021	0.610		0.028	0.554	
Total Phosphorus	mg/L		0.025	0.573	0.008	0.744		0.008	0.747		0.004	0.813	
Dissolved Organic Carbon	mg/L		0.013	0.685	0.012	0.698		0.012	0.697		0.006	0.791	
Total Organic Carbon	mg/L		0.065	0.360	0.086	0.290		0.153	0.149		0.322	0.027	+
Laboratory Turbidity	NTU		0.001	0.917	0.001	0.911		0.054	0.406		0.053	0.407	
Laboratory Conductivity	µmhos/cm		0.042	0.463	0.068	0.347		0.180	0.115		0.437	0.007	+
Chlorophyll *a*	µg/L		0.011	0.711	0.002	0.877		0.028	0.548		0.009	0.737	
In situ Specific Conductance	µS/cm		0.181	0.114	0.221	0.077		0.358	0.018		0.520	0.002	+
In situ Turbidity	NTU		0.017	0.654	0.022	0.613		0.034	0.528		0.020	0.626	
Hardness as $CaCO_3$	mg/L		0.118	0.209	0.148	0.157		0.243	0.062		0.375	0.015	+
Calcium	mg/L		0.061	0.375	0.077	0.318		0.138	0.173		0.260	0.052	
Magnesium	mg/L		0.179	0.116	0.224	0.075		0.338	0.023		0.411	0.010	+
Potassium	mg/L		0.429	0.008	0.479	0.004		0.589	0.001		0.701	< 0.0001	+
Sodium	mg/L		0.123	0.200	0.161	0.138		0.270	0.047		0.334	0.024	+
Sulphate	mg/L	Log	0.265	0.050	0.319	0.028		0.500	0.003		0.557	0.001	+
Arsenic	mg/L		0.006	0.777	0.001	0.903		0.017	0.643		0.021	0.602	
Barium	mg/L		0.025	0.575	0.043	0.460		0.125	0.196		0.234	0.068	
Fluoride	mg/L		0.006	0.844	0.012	0.784		0.067	0.500		0.214	0.210	
Lithium	mg/L		0.090	0.343	0.123	0.263	Log	0.258	0.092		0.413	0.024	+
Manganese	mg/L		0.005	0.800	0.002	0.877		0.001	0.904		0.001	0.908	
Molybdenum	mg/L		0.268	0.048	0.280	0.042		0.252	0.056		0.076	0.320	+
Rubidium	mg/L	Log	0.252	0.057	0.284	0.041		0.376	0.015		0.518	0.002	+
Silicon	mg/L		0.022	0.647	0.027	0.609		0.038	0.542		0.003	0.856	
Strontium	mg/L		0.048	0.433	0.064	0.362		0.128	0.191		0.291	0.038	+
Uranium	mg/L	Log	0.197	0.097	0.195	0.099		0.154	0.147		0.300	0.035	+
Vanadium	mg/L		0.000	0.977	0.001	0.897		0.028	0.550		0.111	0.224	

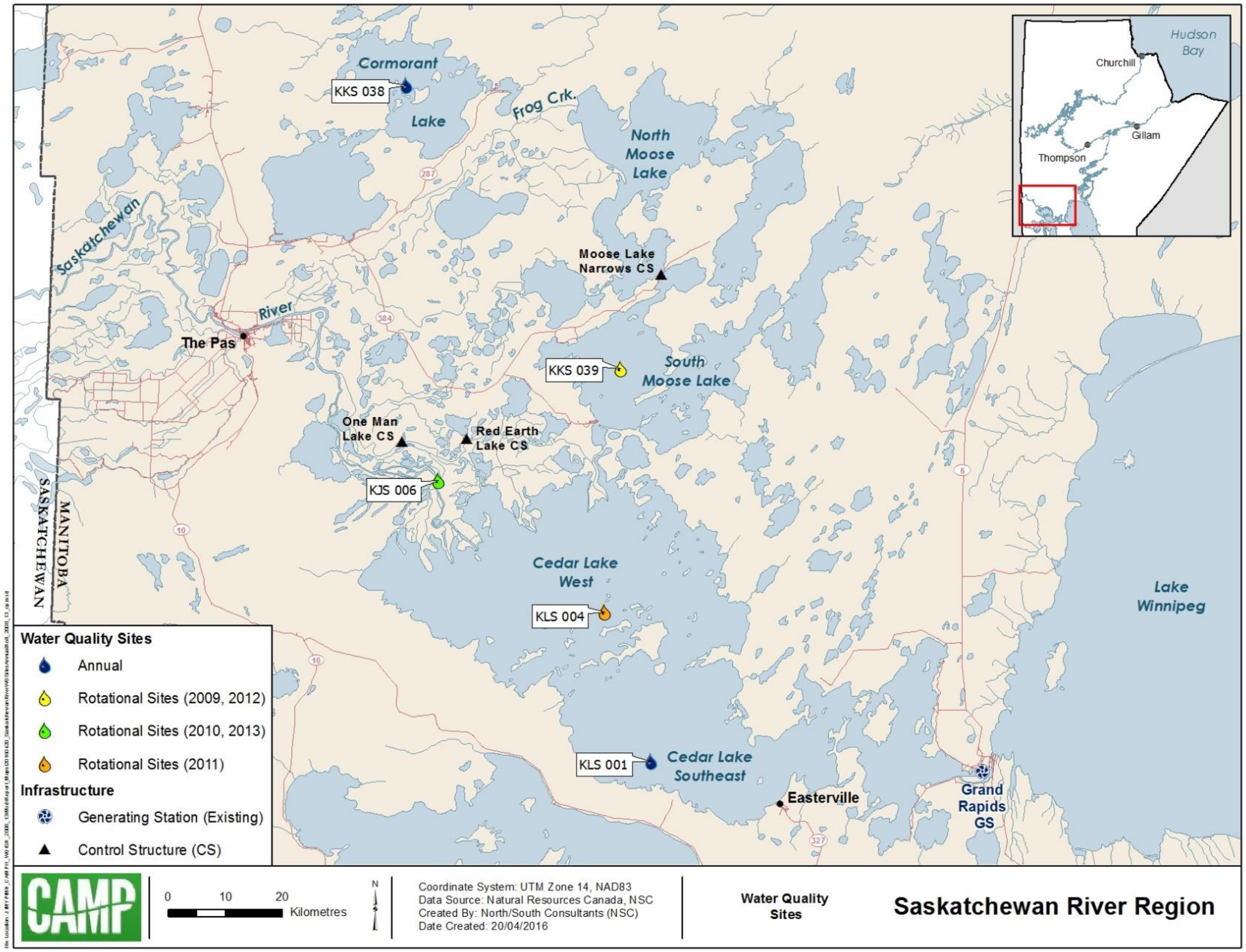


Figure 3-1. Water quality sampling sites in the Saskatchewan River Region: 2008/2009-2013/2014.

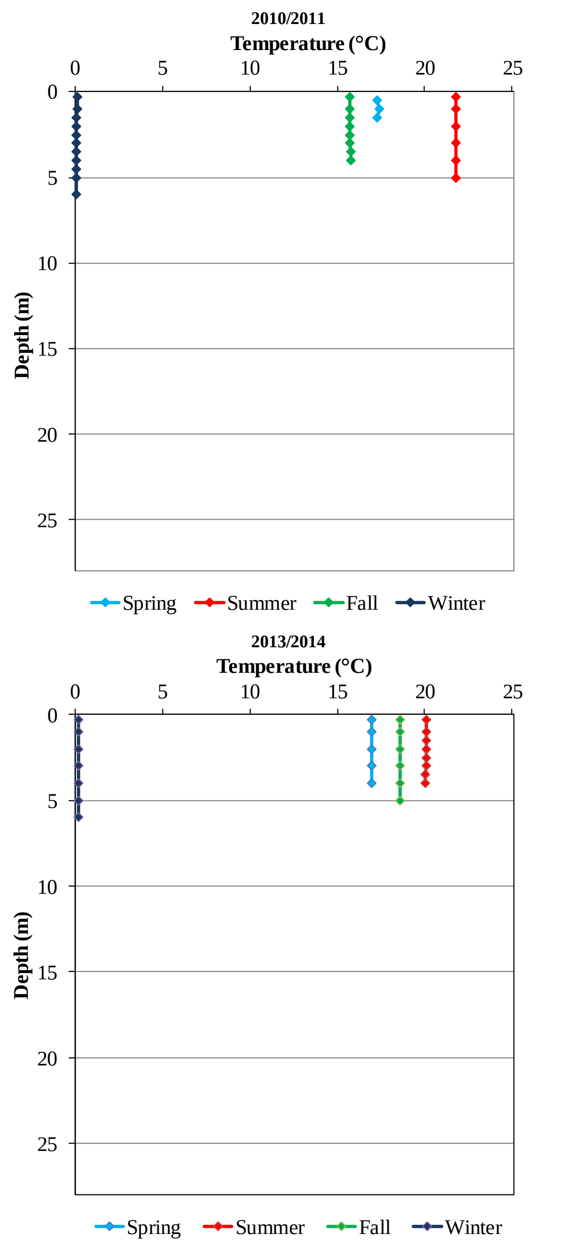


Figure 3-2. Temperature depth profiles in Saskatchewan River: 2008/2009-2013/2014.

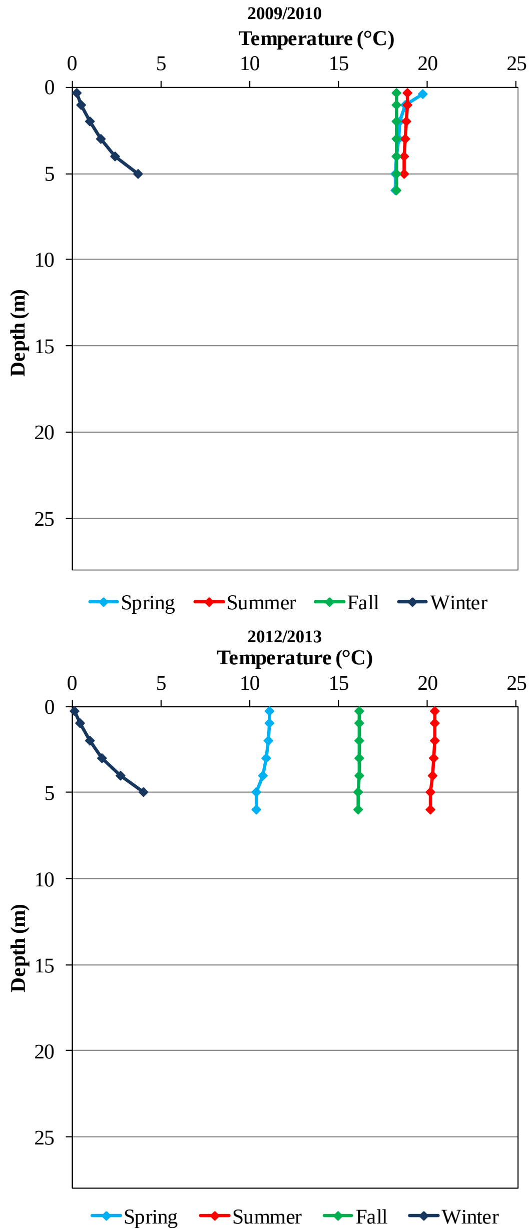


Figure 3-3. Temperature depth profiles in South Moose Lake: 2008/2009-2013/2014.

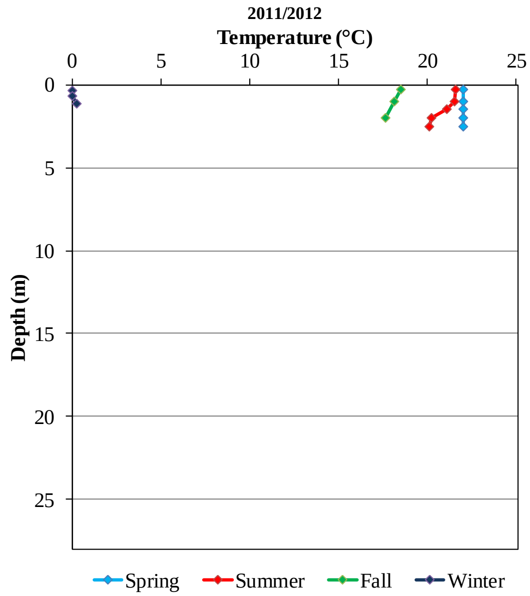


Figure 3-4. Temperature depth profiles in Cedar Lake-West Basin: 2008/2009-2013/2014.

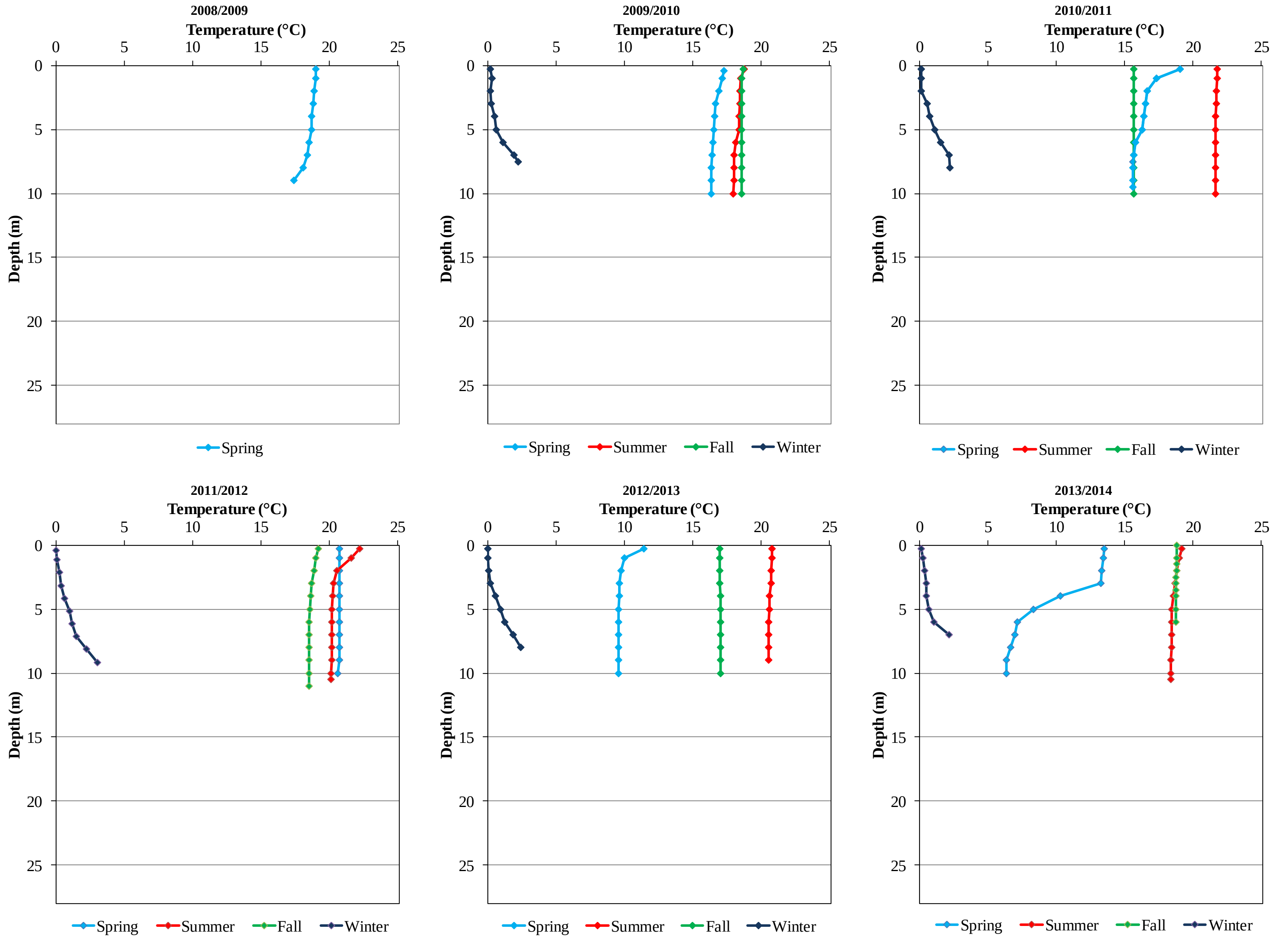


Figure 3-5. Temperature depth profiles in Cedar Lake-Southeast Basin: 2008/2009-2013/2014.

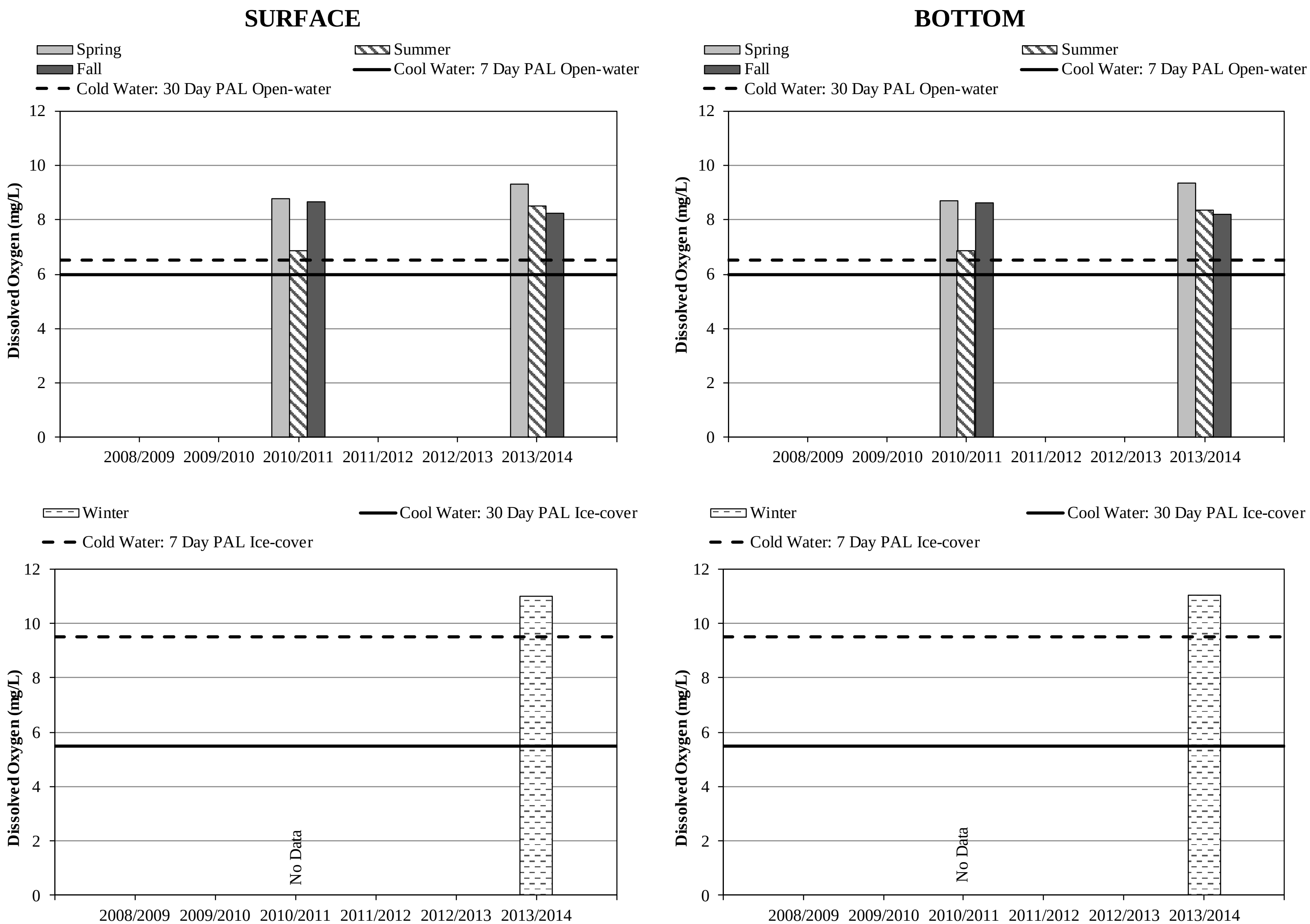


Figure 3-6. Dissolved oxygen measured near the surface and bottom of the water column in the Saskatchewan River and comparison to MB PAL objectives: 2008/2009-2013/2014.

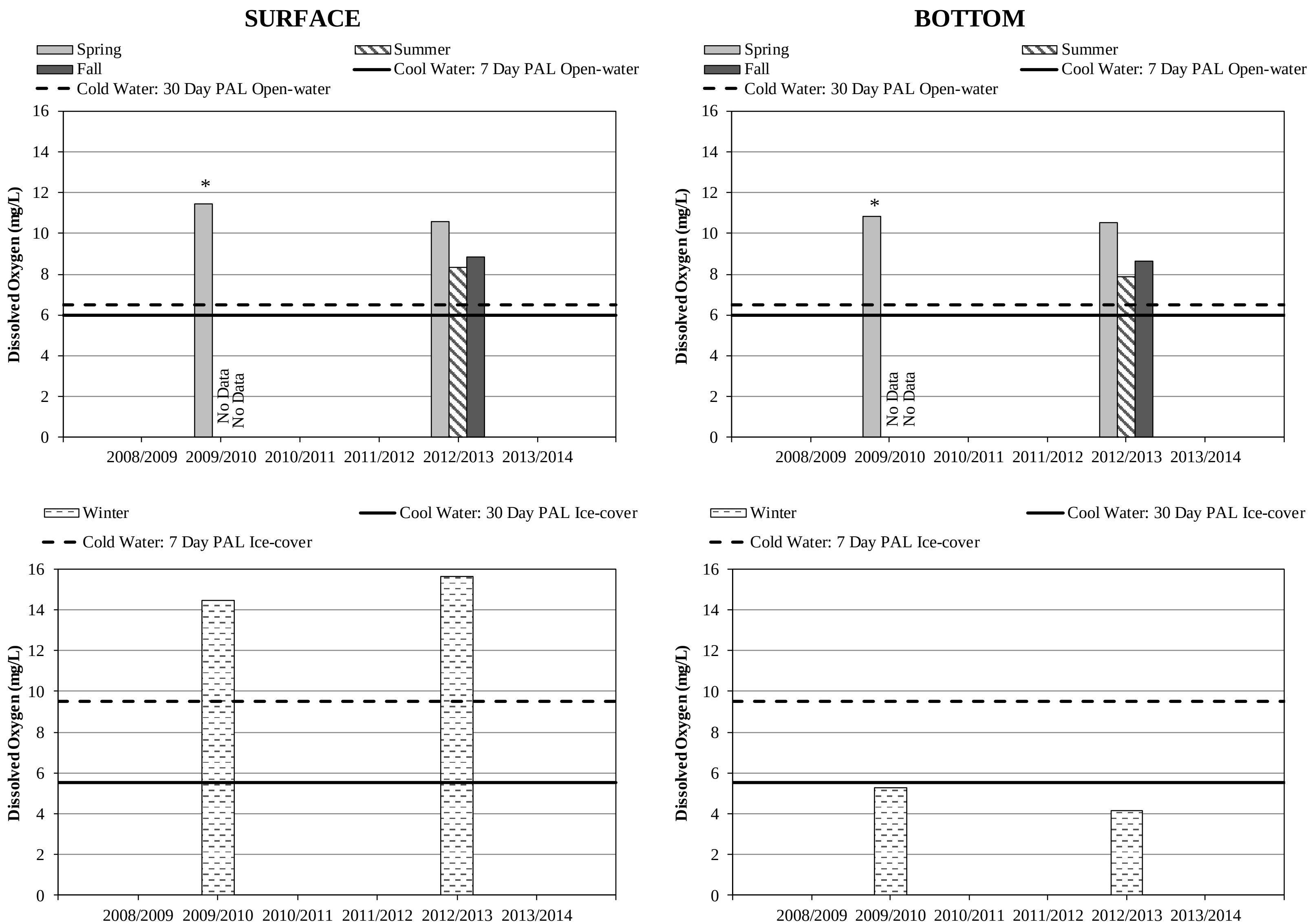


Figure 3-7. Dissolved oxygen measured near the surface and bottom of the water column in South Moose Lake and comparison to MB PAL objectives: 2008/2009-2013/2014. Values indicated with an asterisk are considered suspect.

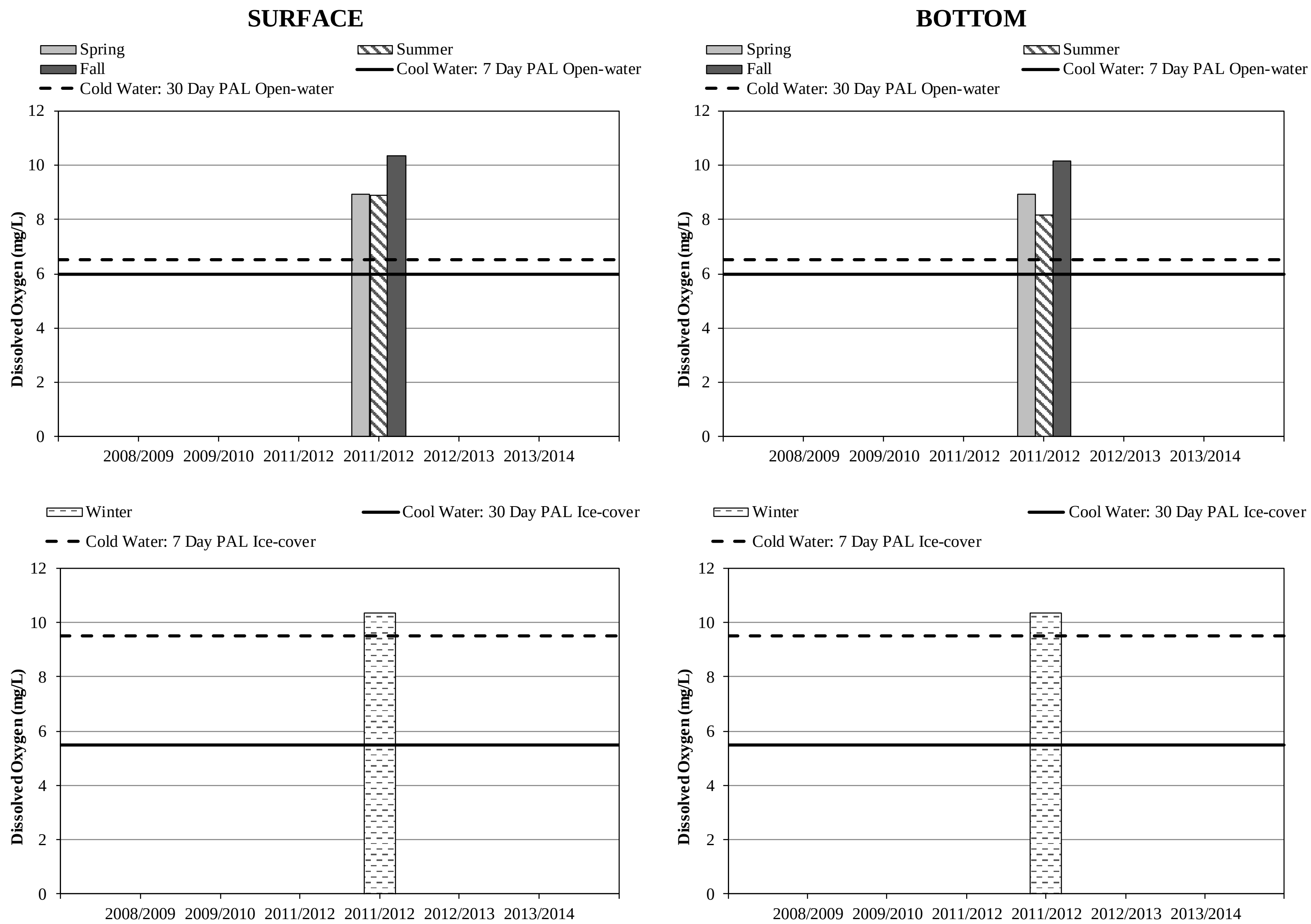
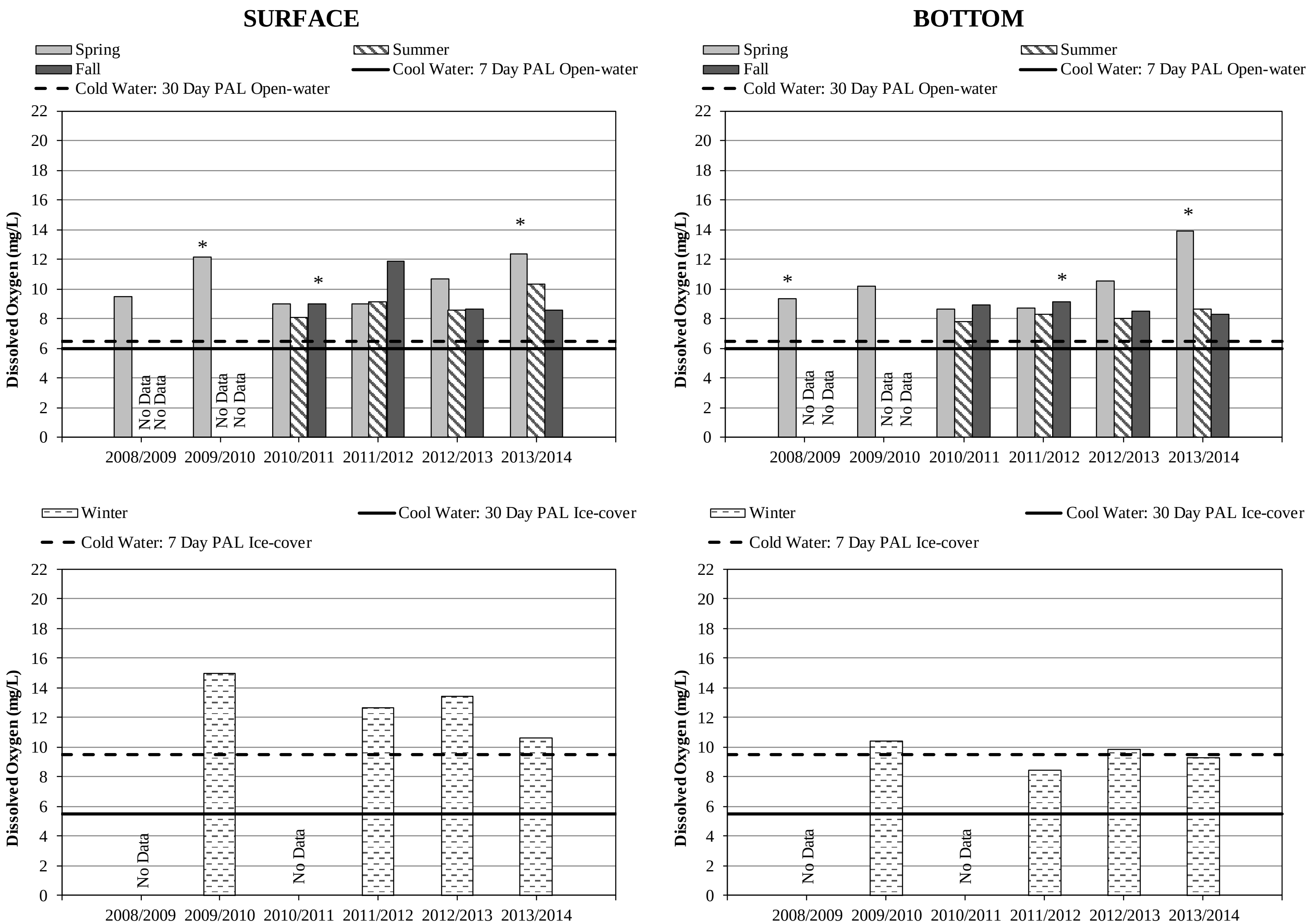


Figure 3-8. Dissolved oxygen measured near the surface and bottom of the water column in Cedar Lake-West Basin and comparison to MB PAL objectives: 2008/2009-2013/2014.



* Values are considered suspect.

Figure 3-9. Dissolved oxygen measured near the surface and bottom of the water column in Cedar Lake-Southeast Basin and comparison to MB PAL objectives: 2008/2009-2013/2014.

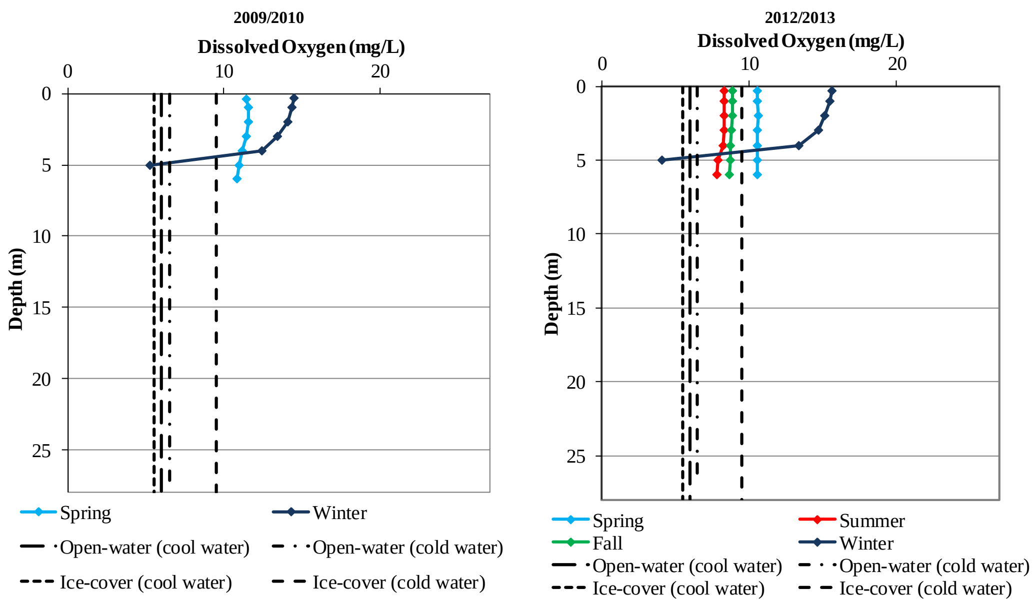


Figure 3-10. Dissolved oxygen depth profiles in South Moose Lake and comparison to MB PAL objectives: 2008/2009-2013/2014. Data from spring 2009 are considered suspect.

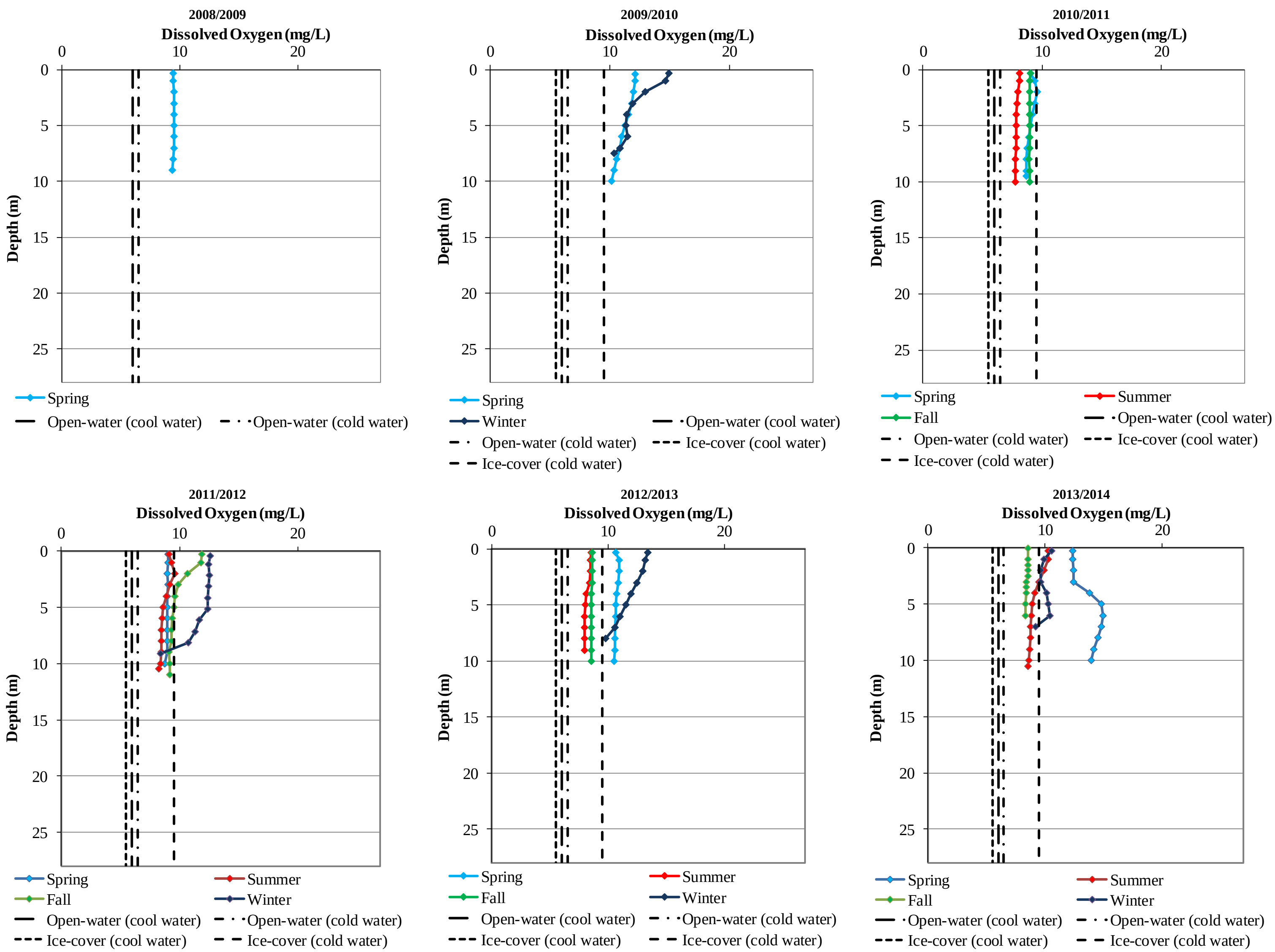
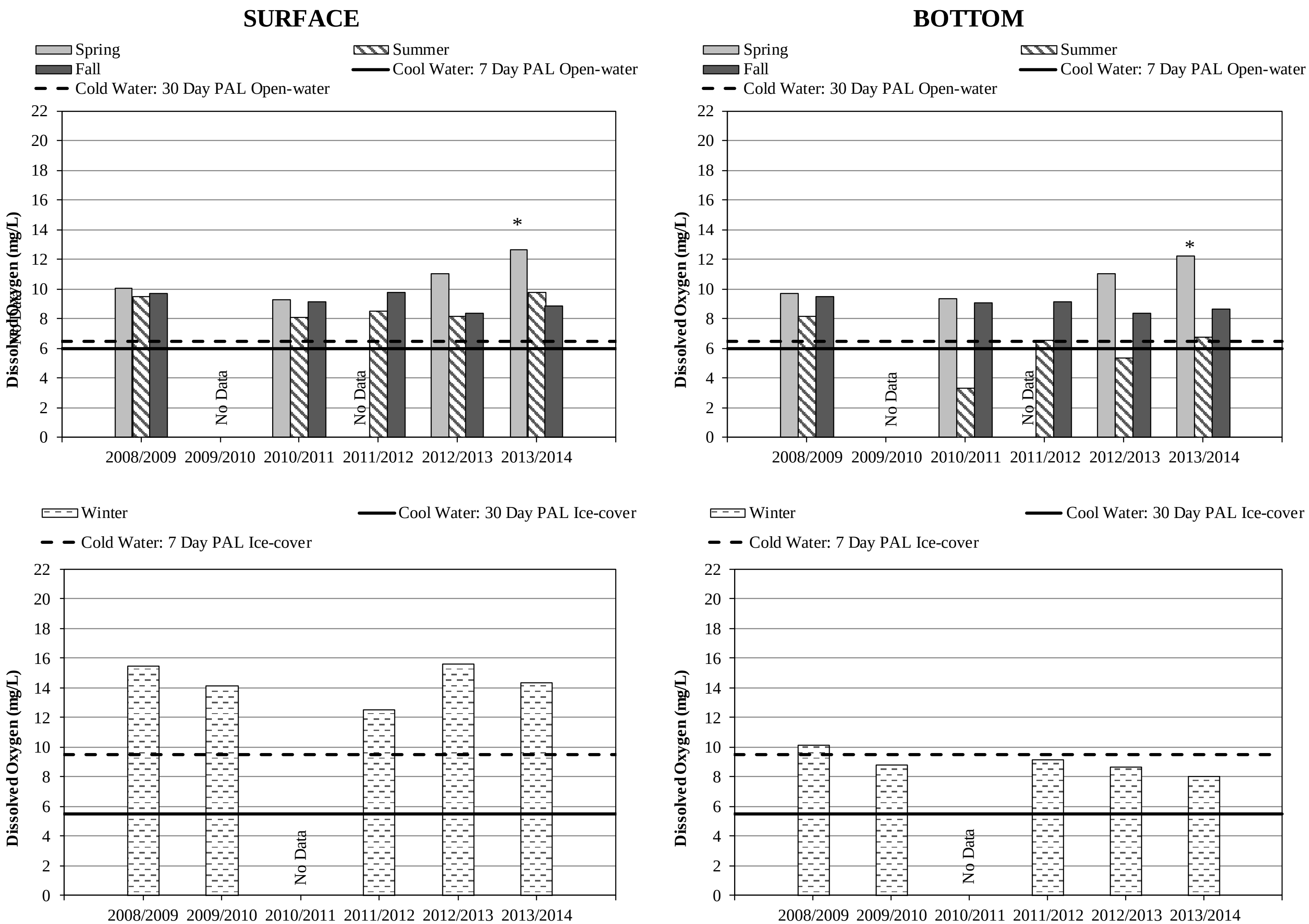


Figure 3-11. Dissolved oxygen depth profiles in Cedar Lake-Southeast Basin and comparison to MB PAL objectives: 2008/2009-2013/2014. Data from spring 2009 and 2013, and fall 2011 are considered suspect.



* Values are considered suspect.

Figure 3-12. Dissolved oxygen measured near the surface and bottom of the water column in the off-system Cormorant Lake and comparison to MB PAL objectives: 2008/2009-2013/2014.

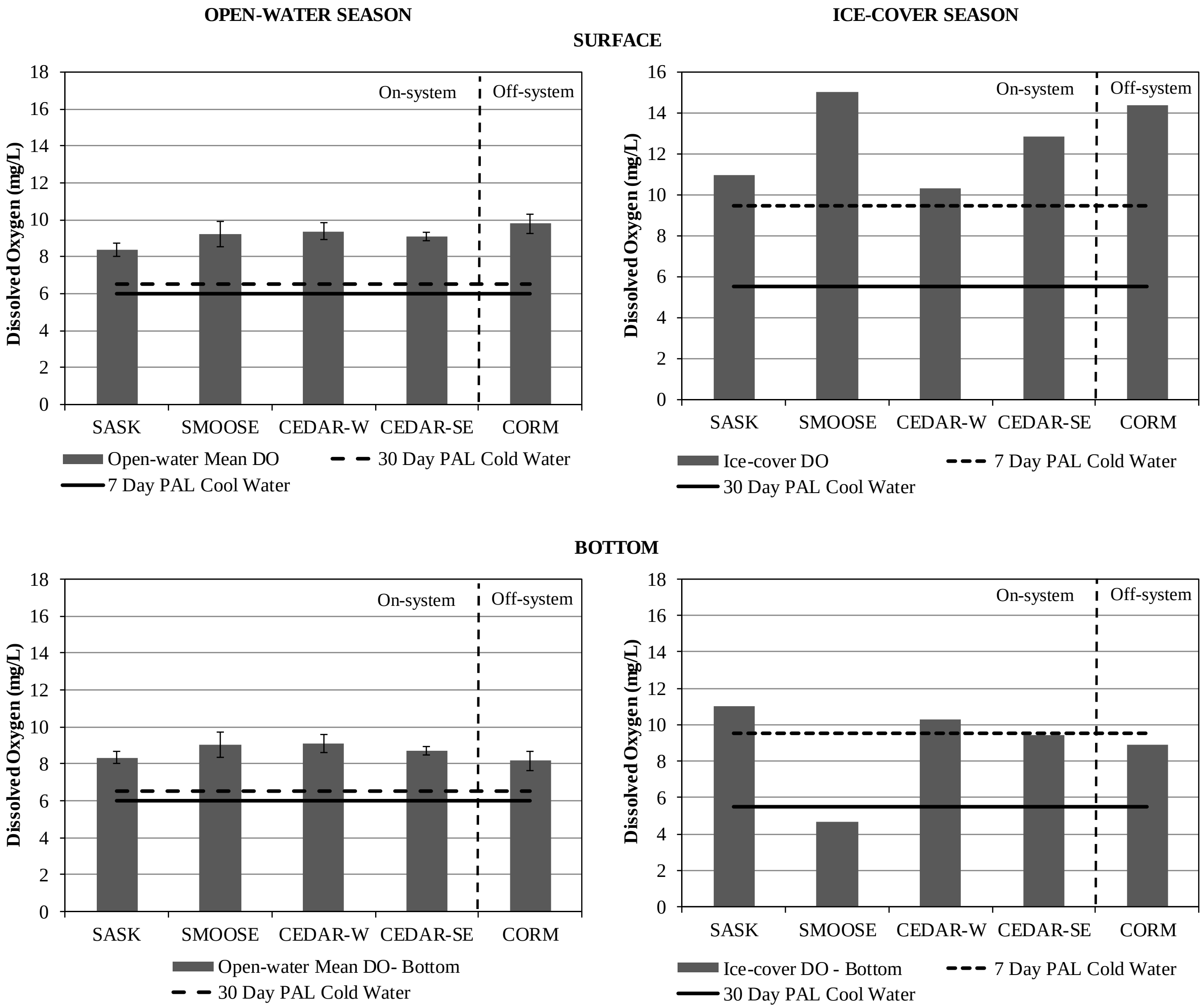


Figure 3-13. Dissolved oxygen (mean±SE) measured near the surface and bottom of the water column in the Saskatchewan River Region: 2008/2009-2013/2014.

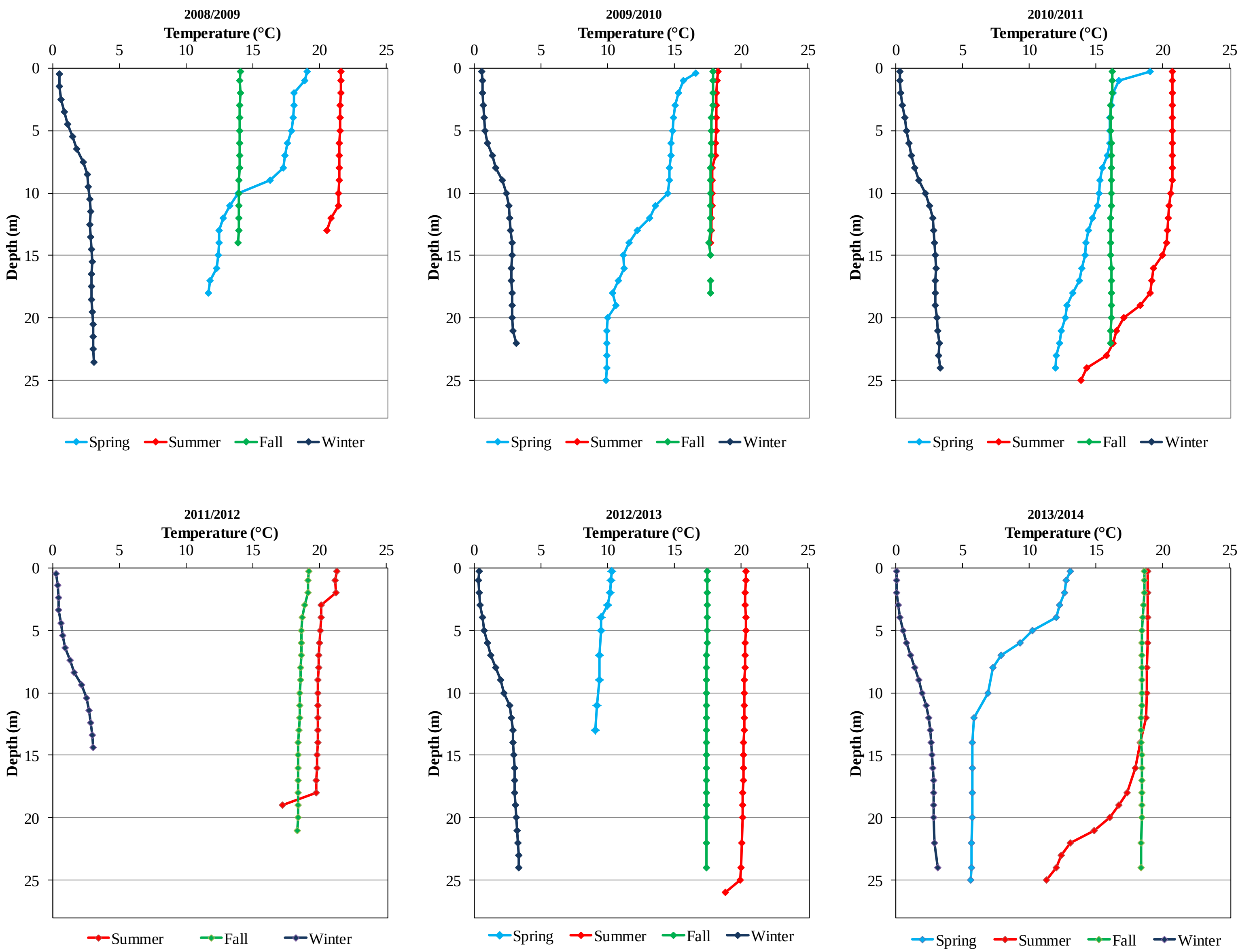


Figure 3-14. Temperature depth profiles in Cormorant Lake: 2008/2009-2013/2014.

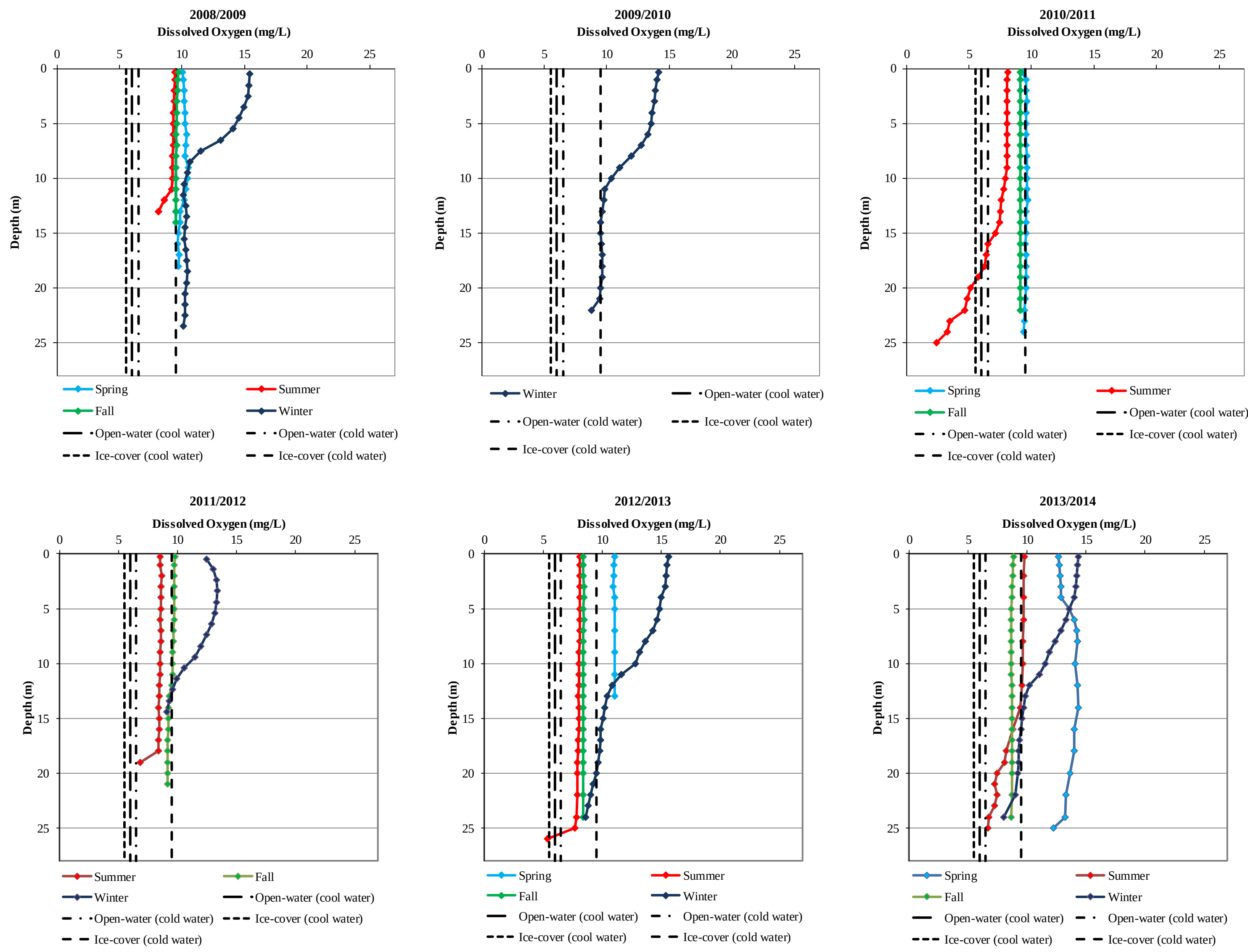
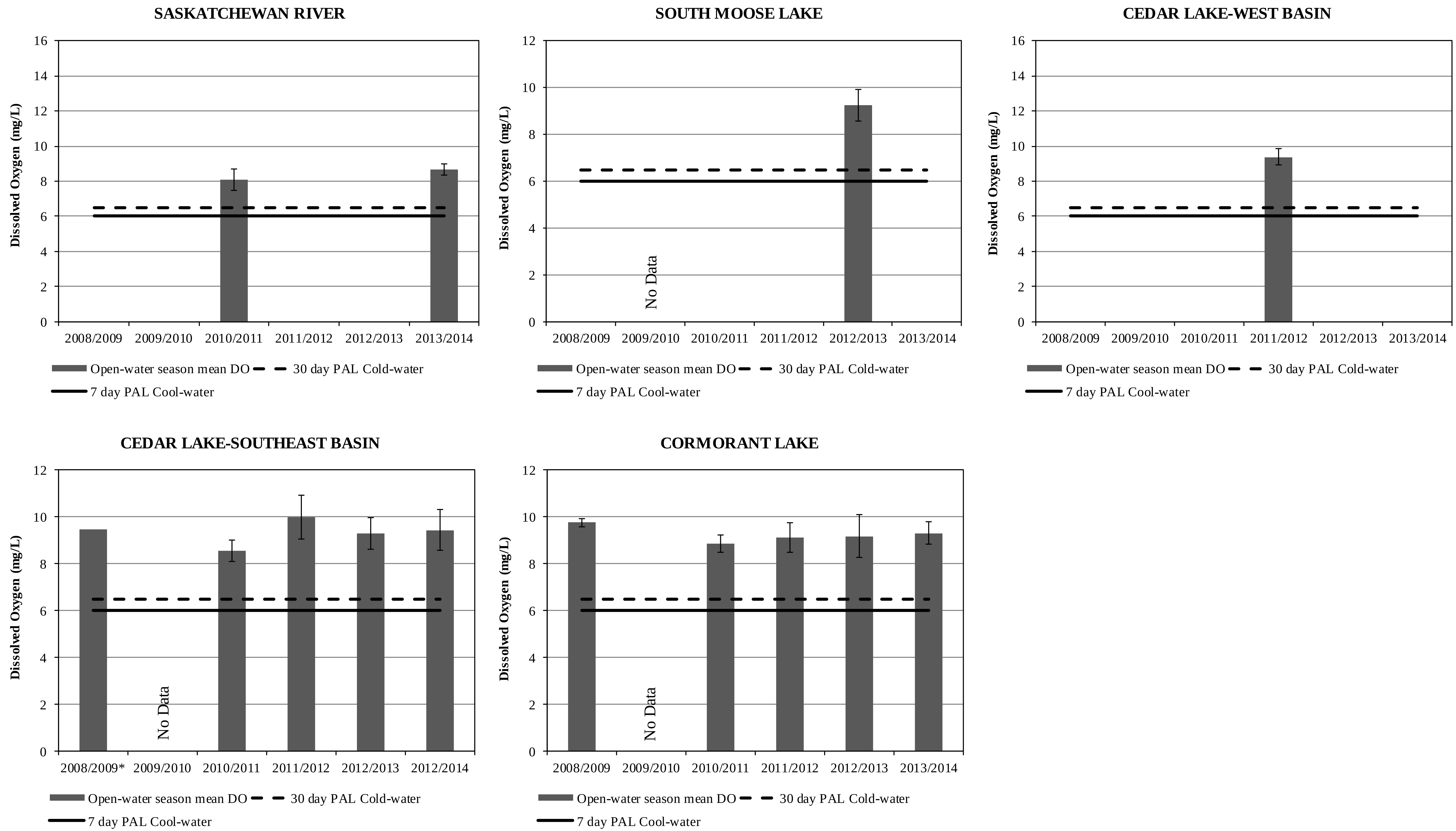
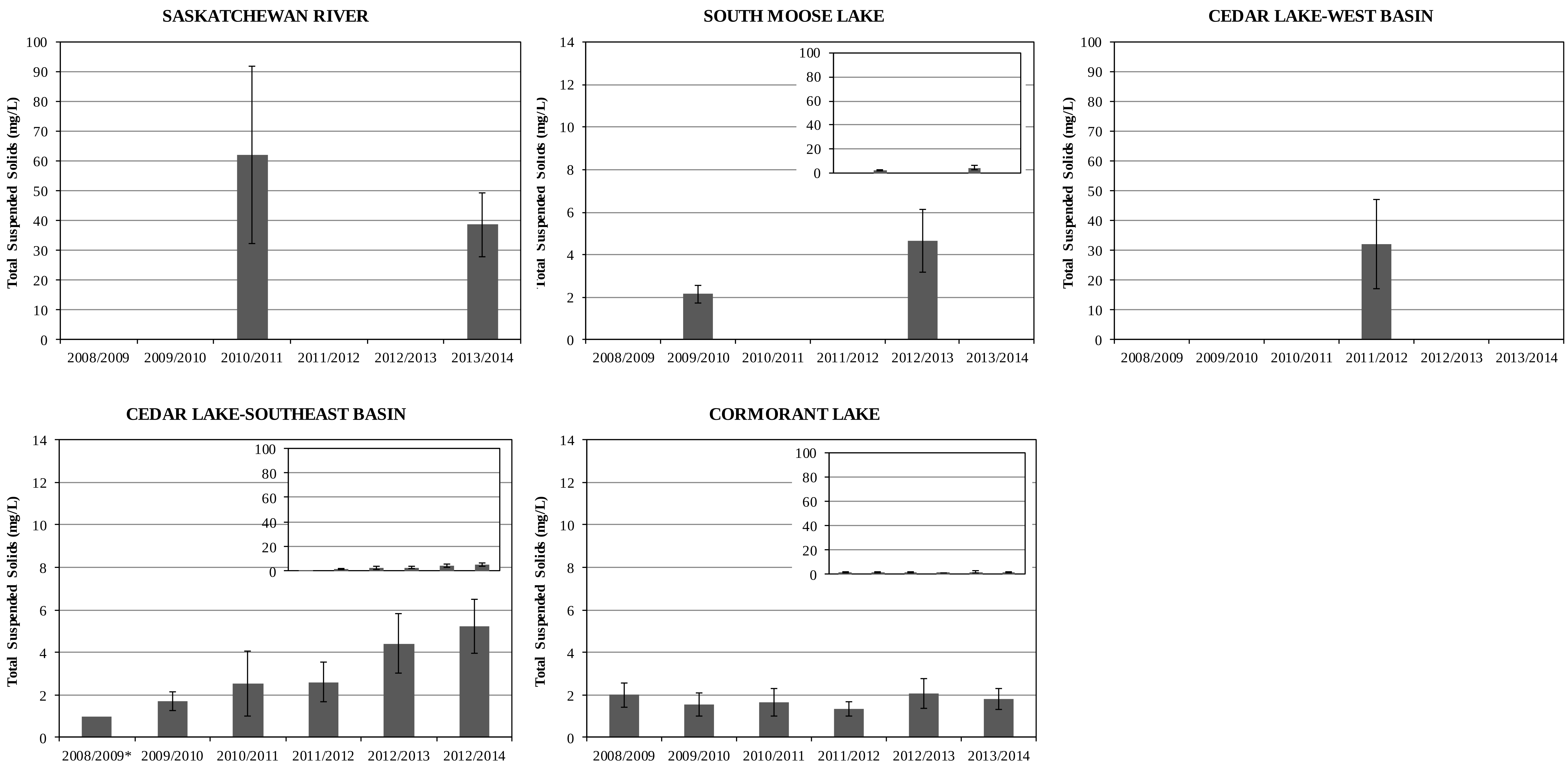


Figure 3-15. Dissolved oxygen depth profiles in Cormorant Lake and comparison to MB PAL objectives: 2008/2009-2013/2014. Data from spring 2013 are considered suspect.



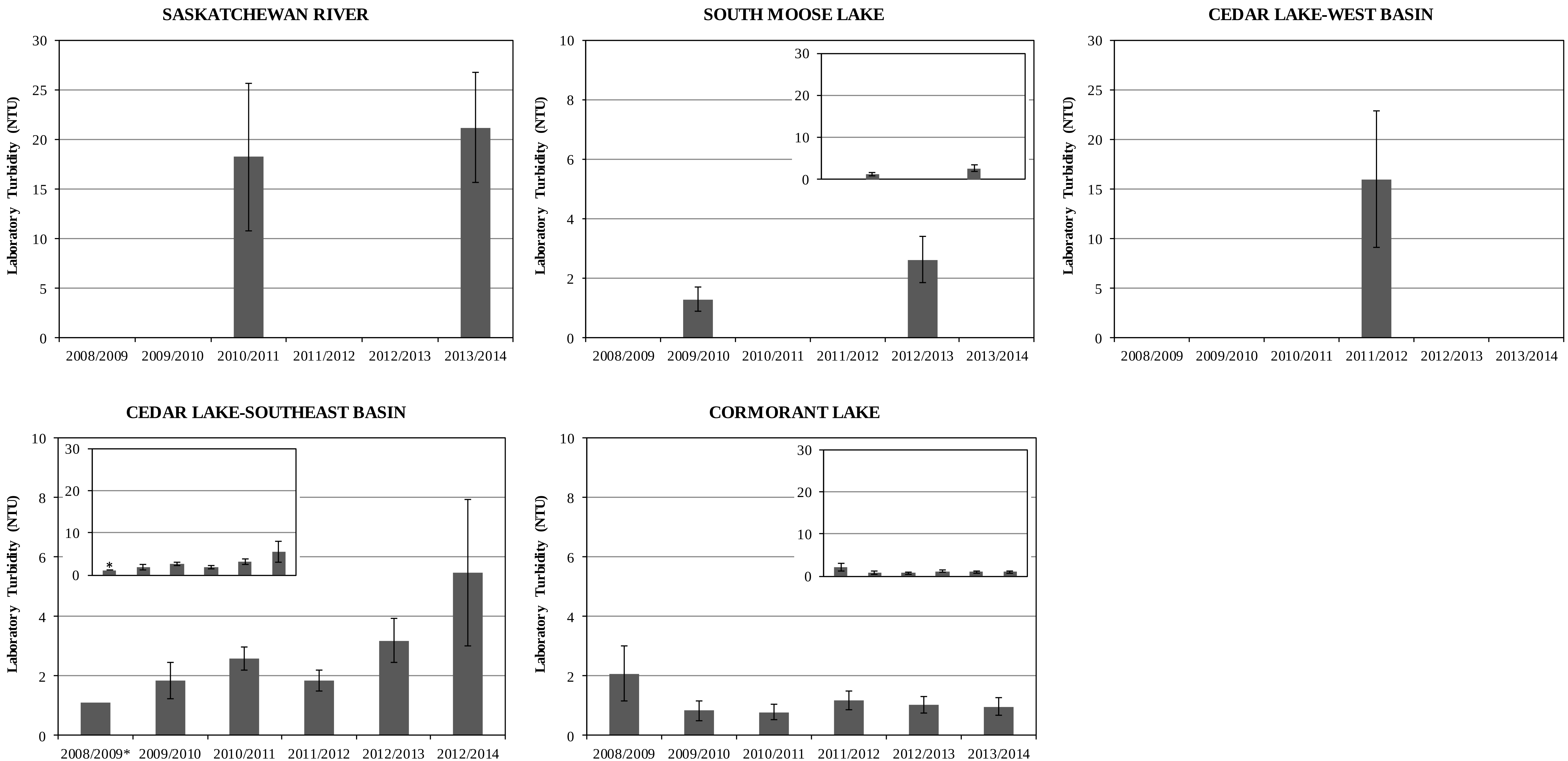
* Site only sampled in spring.

Figure 3-16. Open-water season dissolved oxygen concentrations (mean±SE) in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014. No significant inter-annual differences were observed at the annual monitoring sites (CEDAR-SE or CORM).



* Site only sampled in spring.

Figure 3-17. Total suspended solids (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014.



* Site only sampled in spring.

Figure 3-18. Laboratory turbidity (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014.

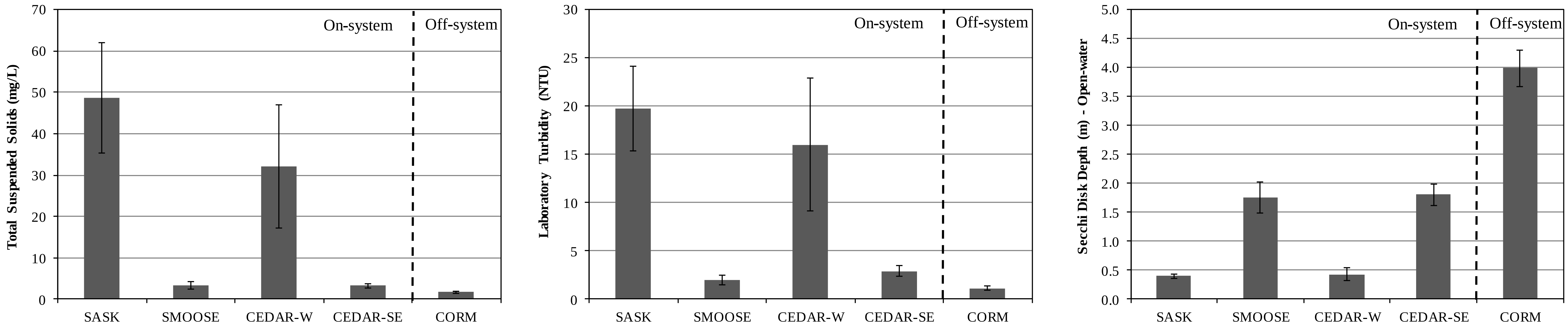
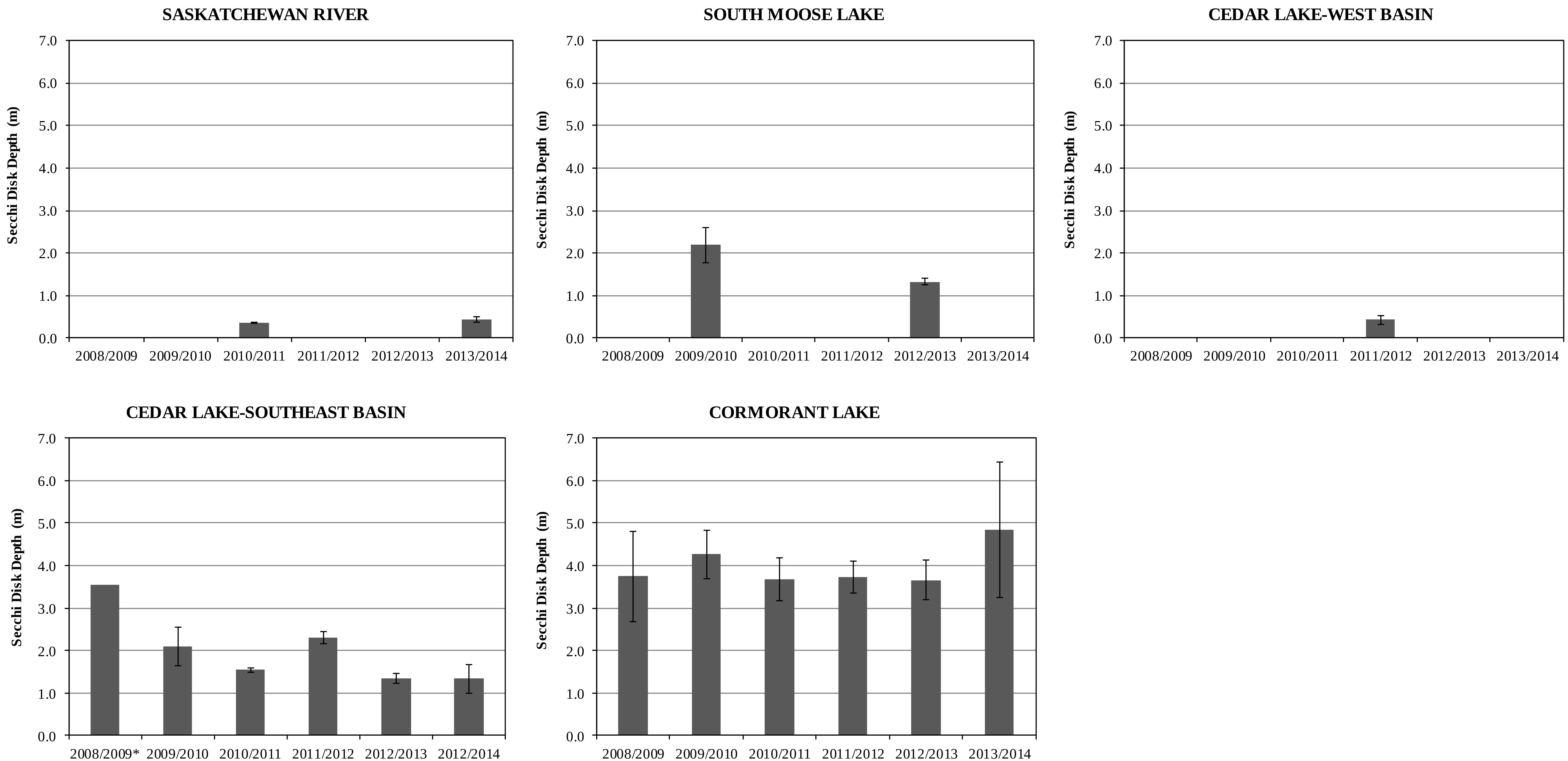
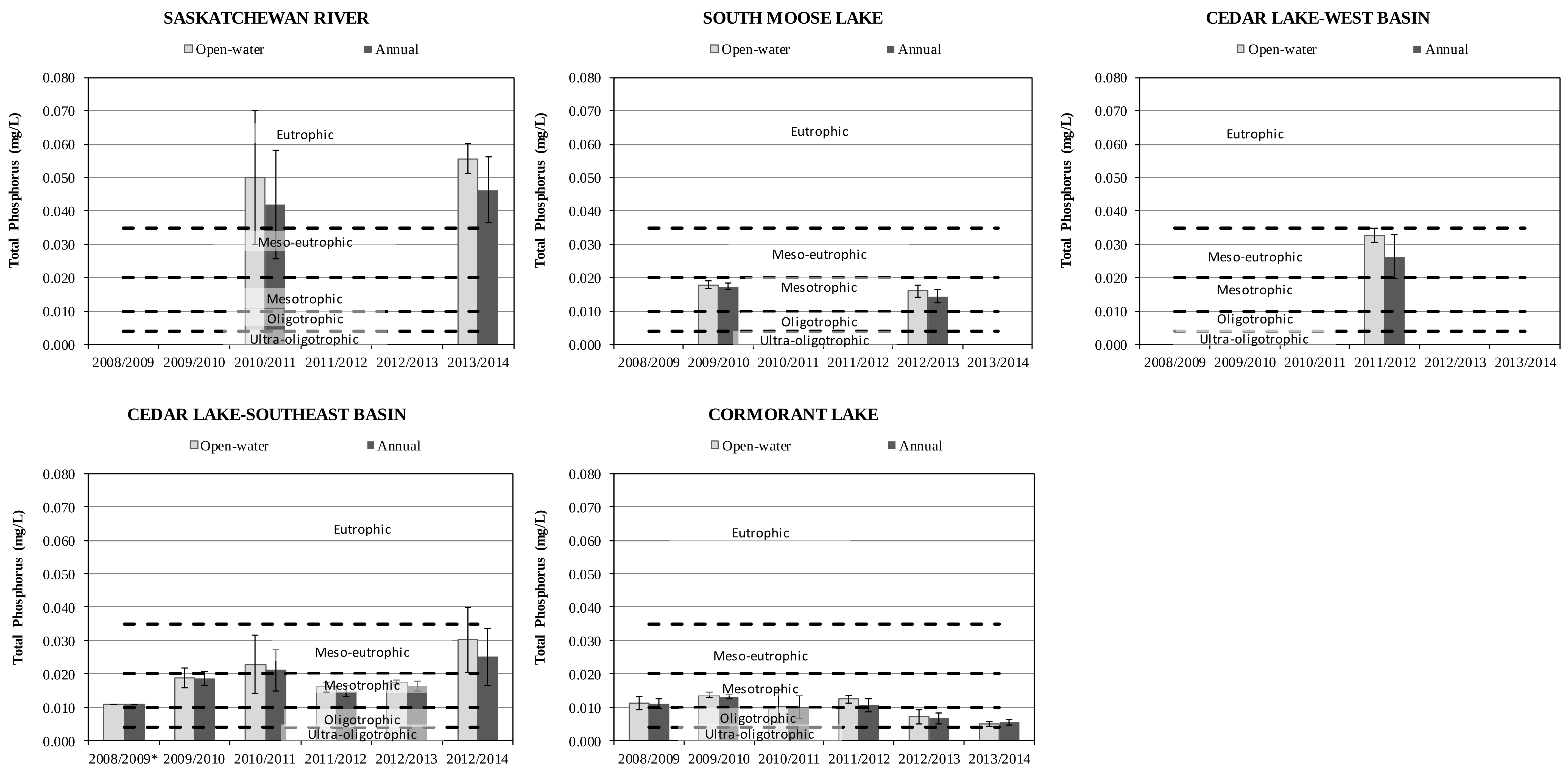


Figure 3-19. Total suspended solids, laboratory turbidity, and Secchi disk depth (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014.



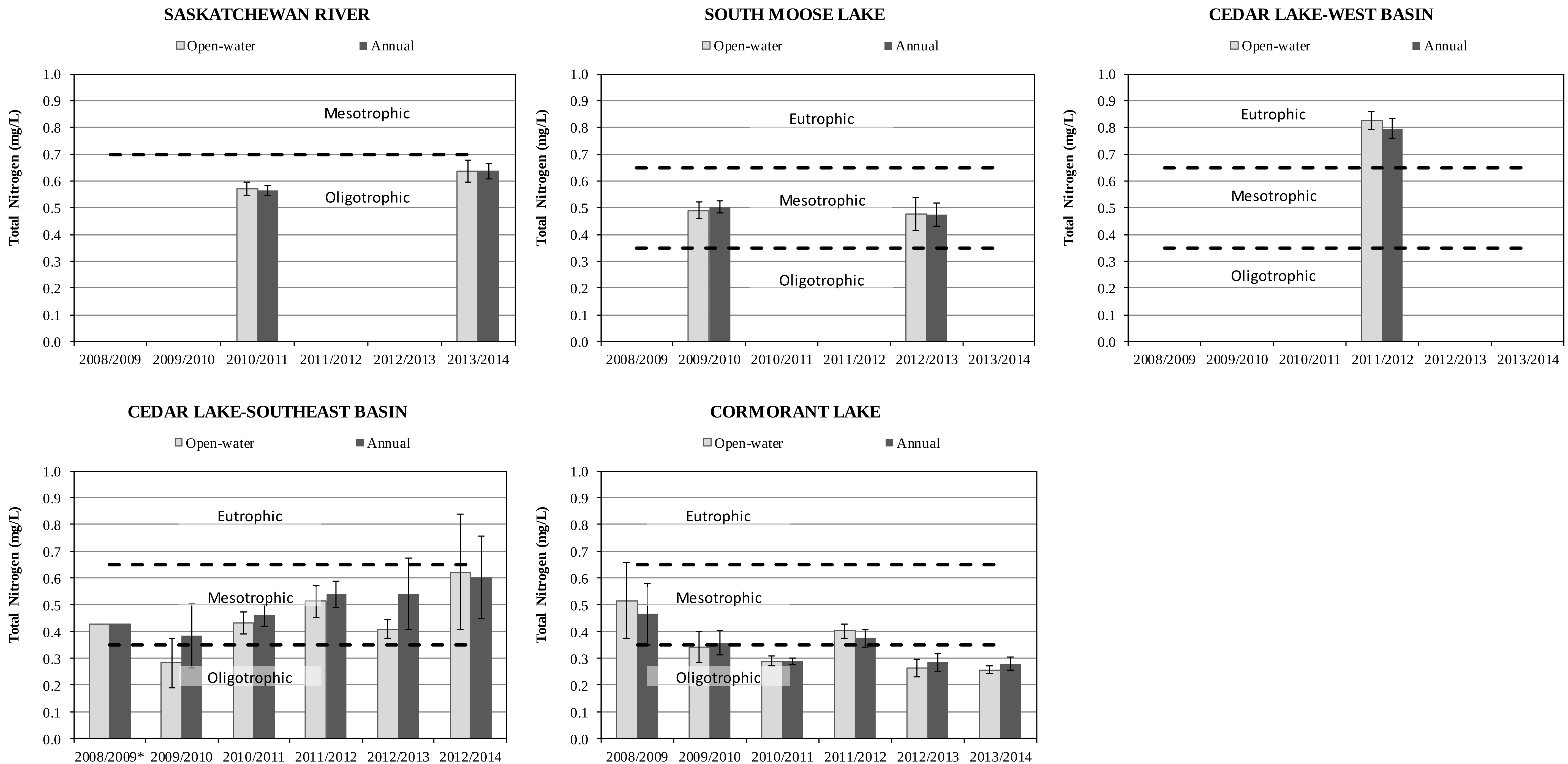
* Site only sampled in spring.

Figure 3-20. Secchi disk depths (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014. No significant inter-annual differences were observed at the annual monitoring sites (CEDAR-SE or CORM).



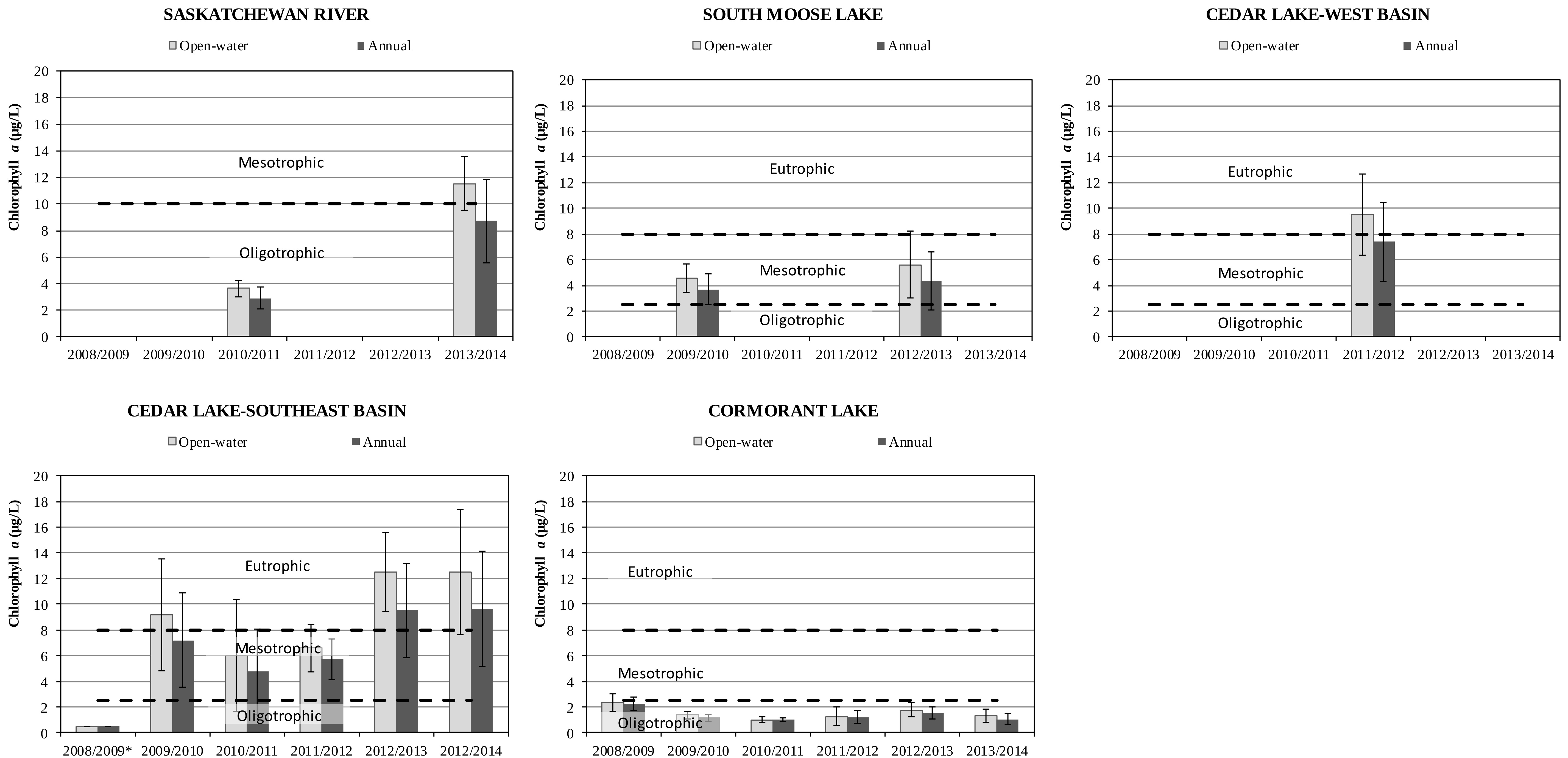
* Site only sampled in spring.

Figure 3-21. Total phosphorous (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014. No significant inter-annual differences were observed for the open-water period at the annual monitoring sites (CEDAR-SE or CORM).



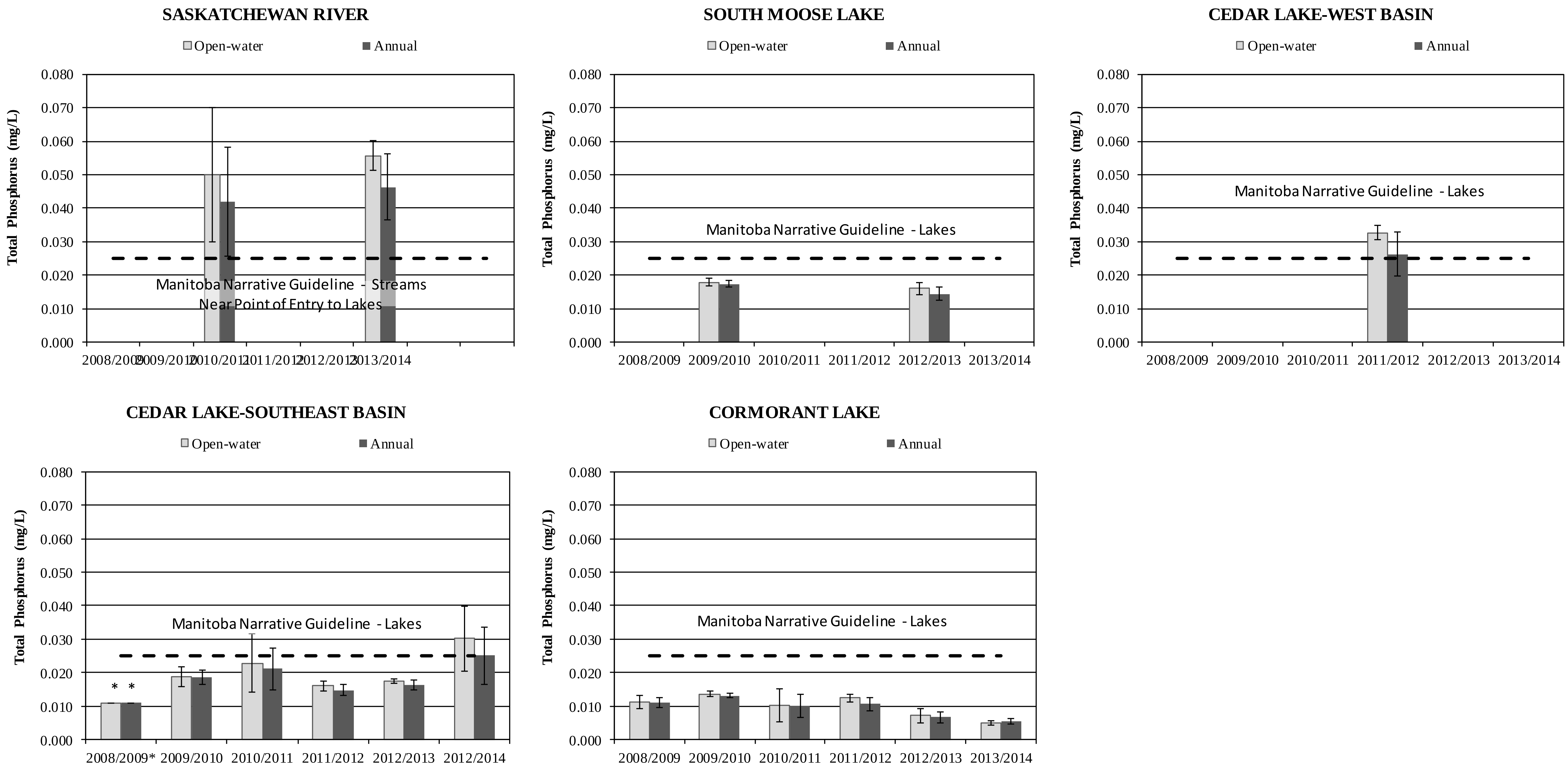
* Site only sampled in spring.

Figure 3-22. Total nitrogen (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014. No significant inter-annual differences were observed for the open-water period at the annual monitoring sites (CEDAR-SE or CORM).



* Site only sampled in spring.

Figure 3-23. Chlorophyll *a* (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014. No significant inter-annual differences were observed for the open-water period at the annual monitoring sites (CEDAR-SE or CORM).



* Site only sampled in spring.

Figure 3-24. Total phosphorus (mean±SE) measured in the Saskatchewan River region and off-system waterbody and comparison to the Manitoba narrative nutrient guidelines: 2008/2009-2013/2014.

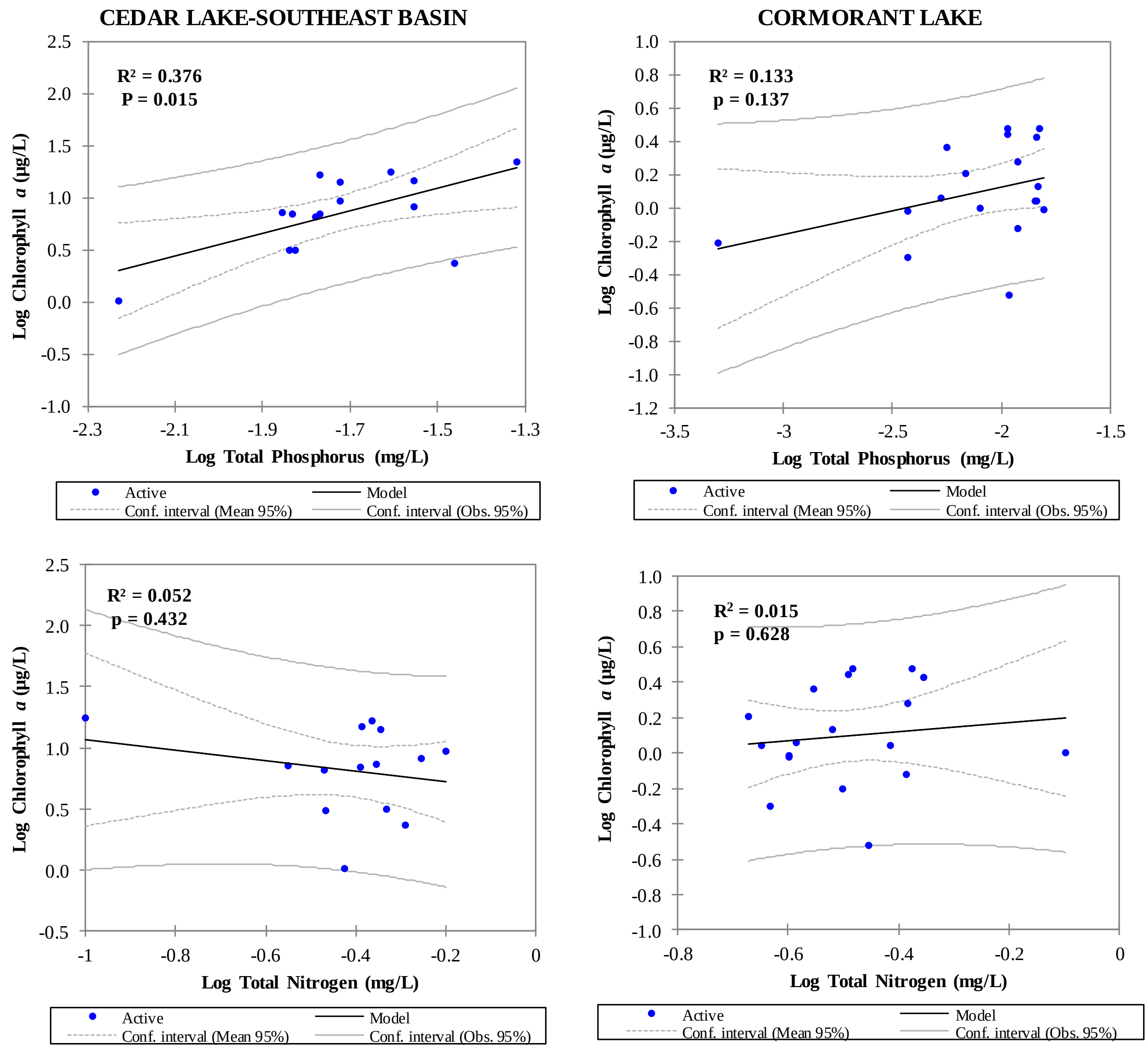


Figure 3-25. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* in Cedar Lake-Southeast Basin and the off-system waterbody: 2008-2013.

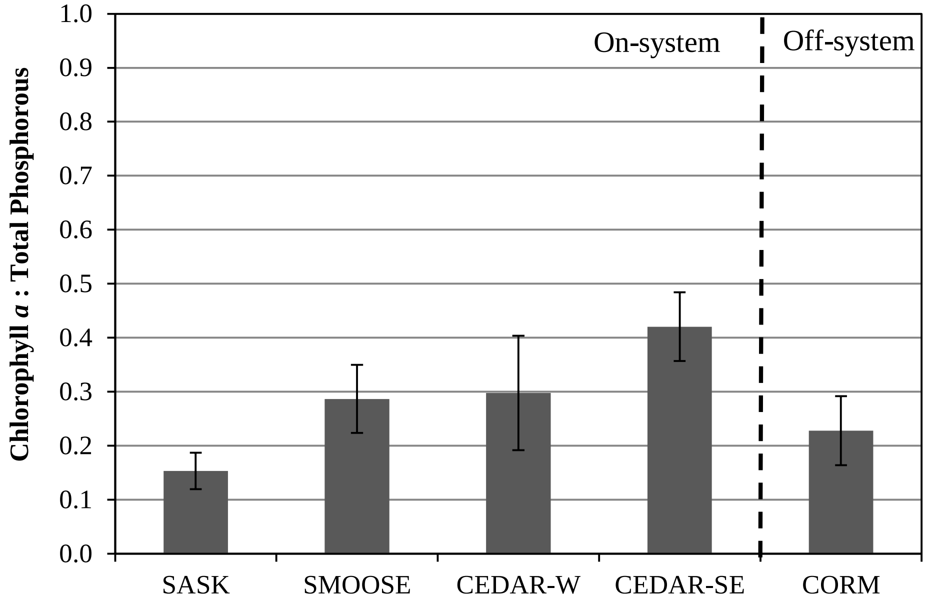


Figure 3-26. Chlorophyll *a* to total phosphorus ratios (mean±SE) measured in the Saskatchewan River region and off-system waterbody: open-water seasons 2008-2013.

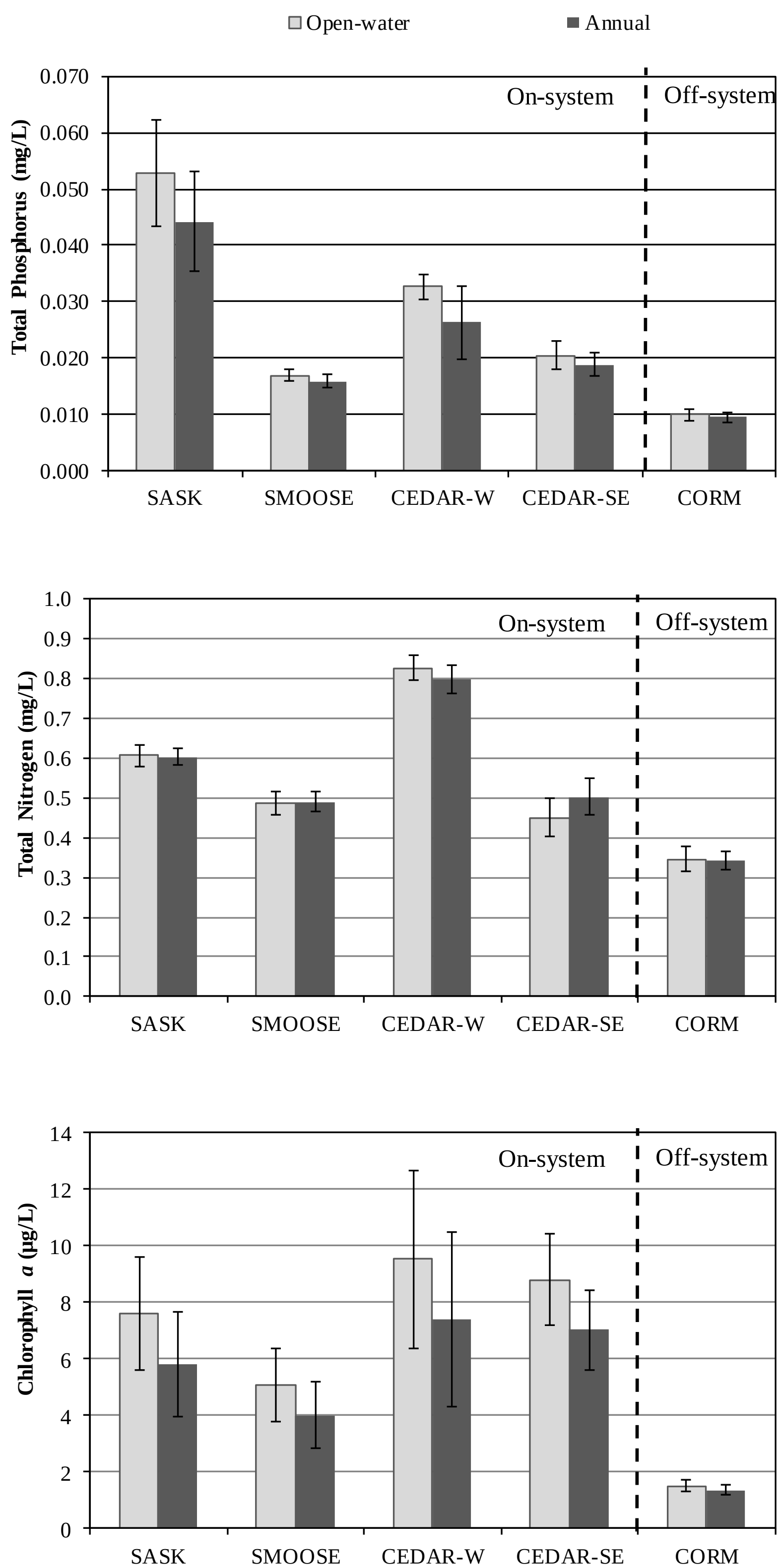
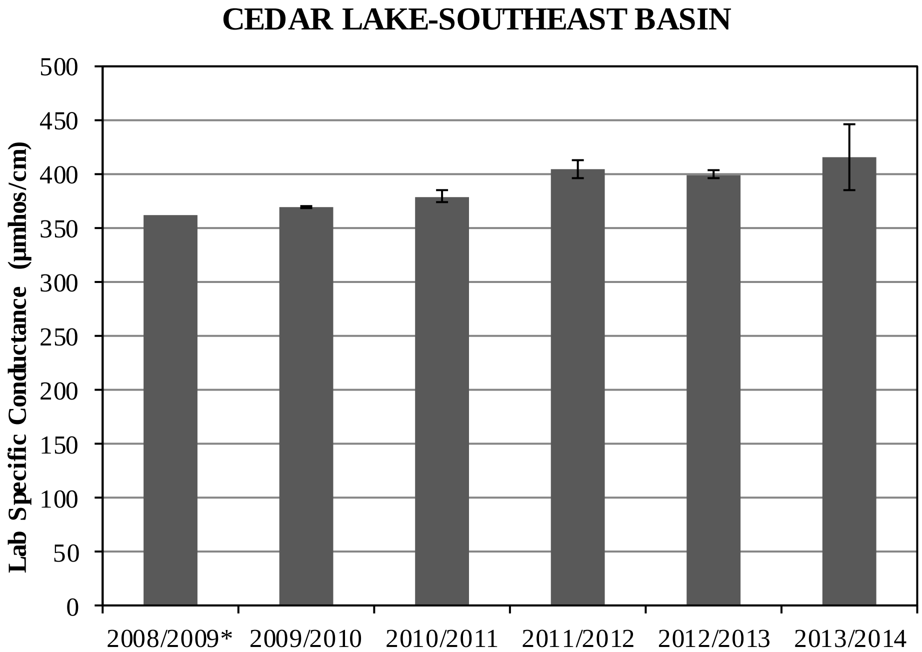
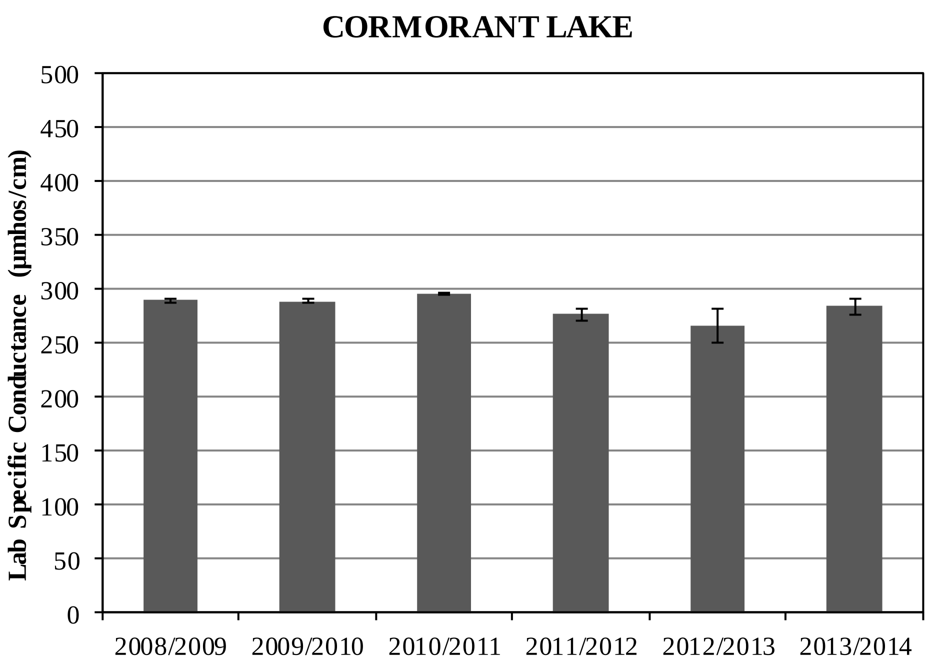


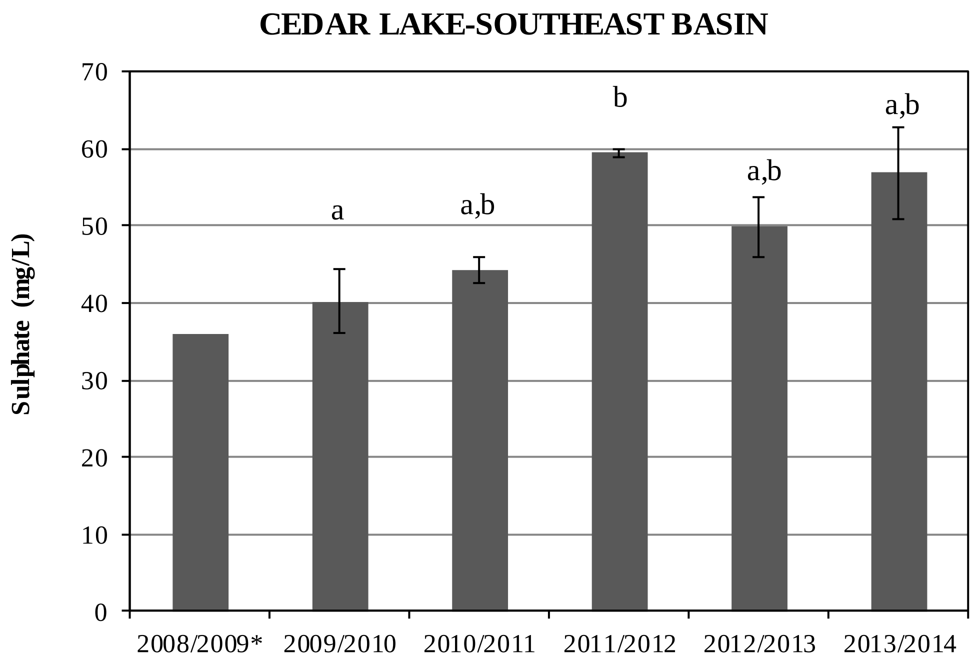
Figure 3-27. Total phosphorus, total nitrogen, chlorophyll *a* (mean±SE) measured in the Saskatchewan River region and off-system waterbody: 2008/2009-2013/2014.

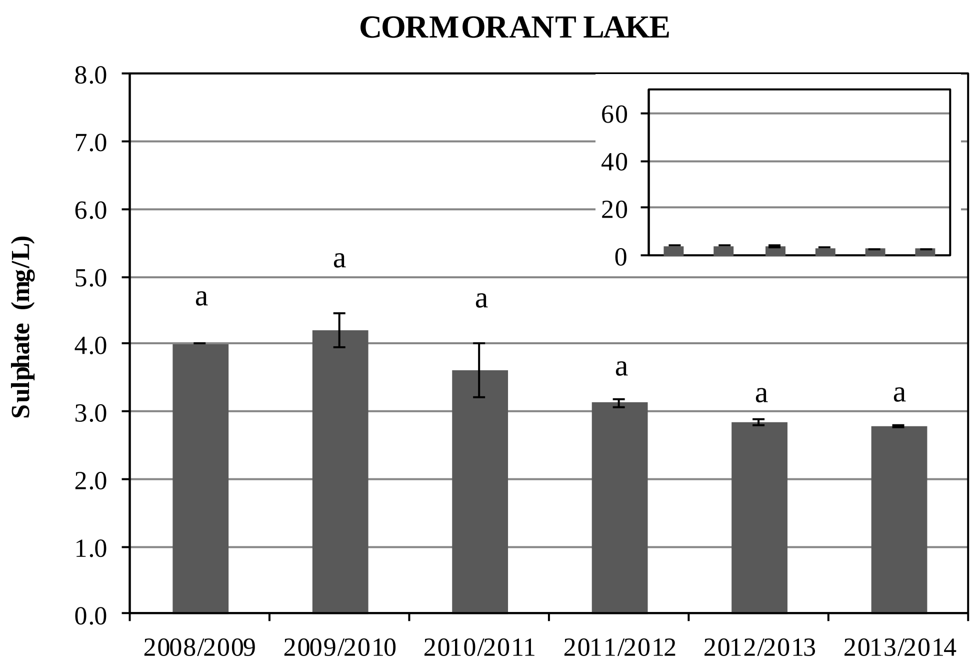




* Site only sampled in spring.

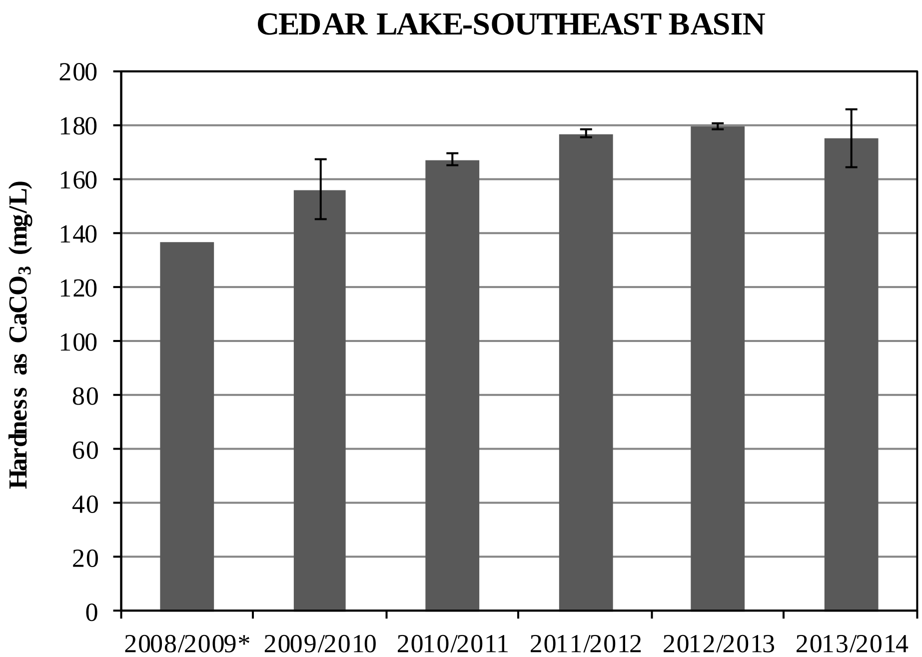
Figure 3-28. Open-water season laboratory specific conductance (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. No significant inter-annual differences were observed at the annual monitoring sites.

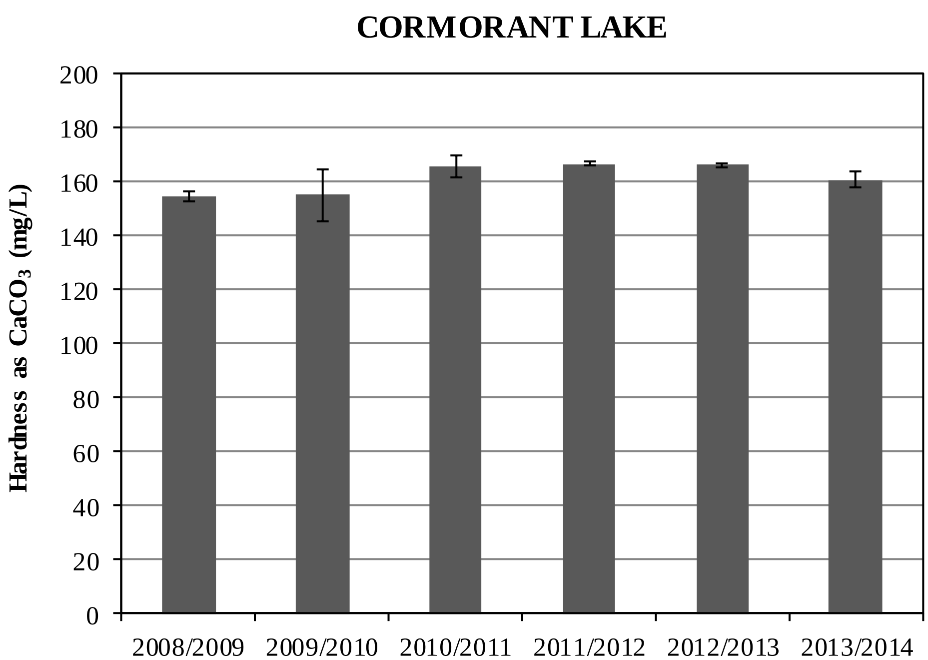




* Site only sampled in spring.

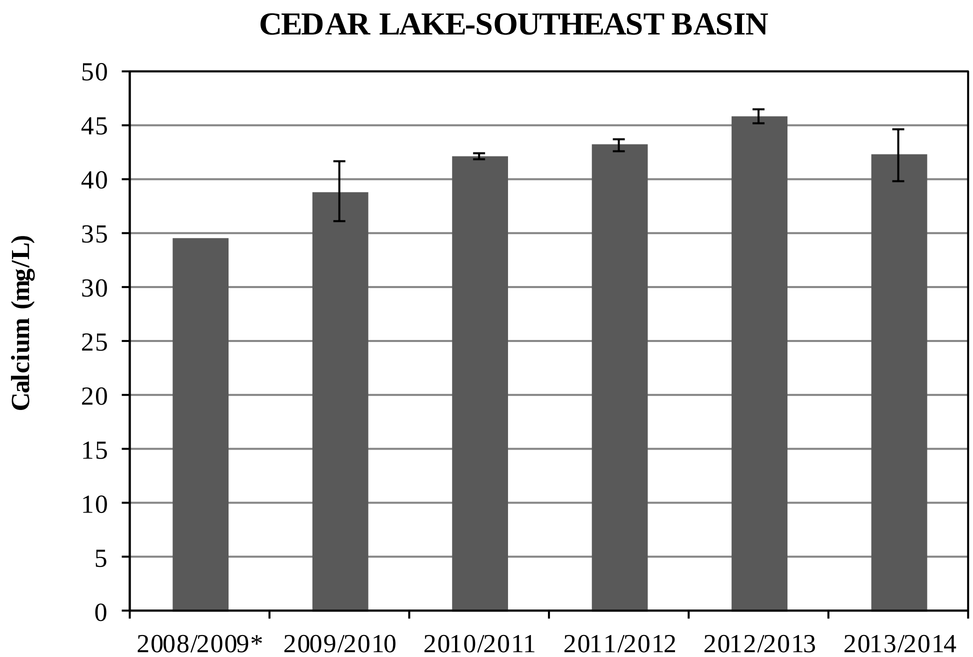
Figure 3-29. Open-water season sulphate concentrations (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

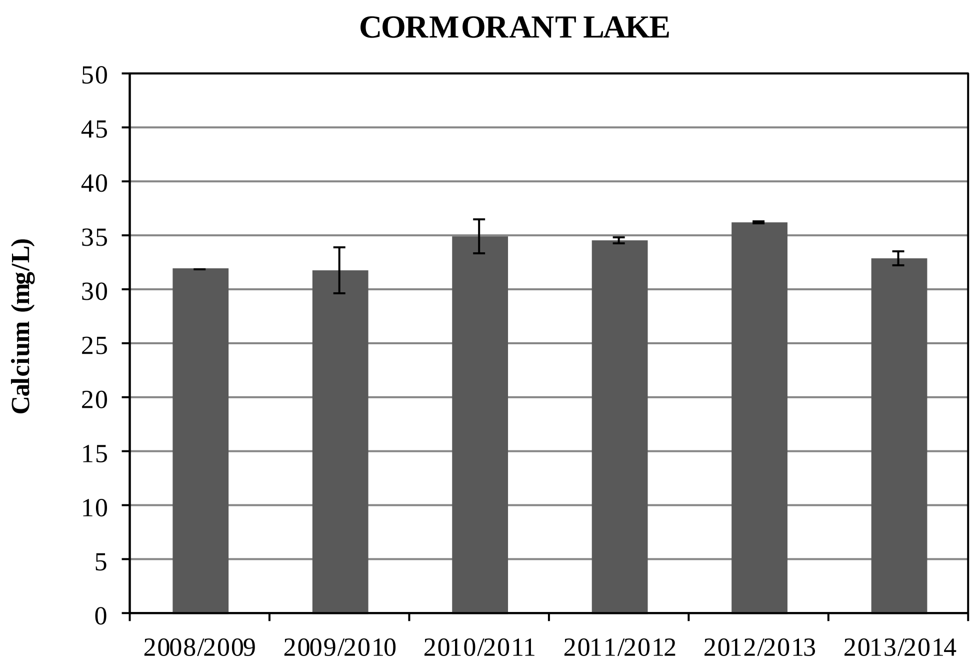




* Site only sampled in spring.

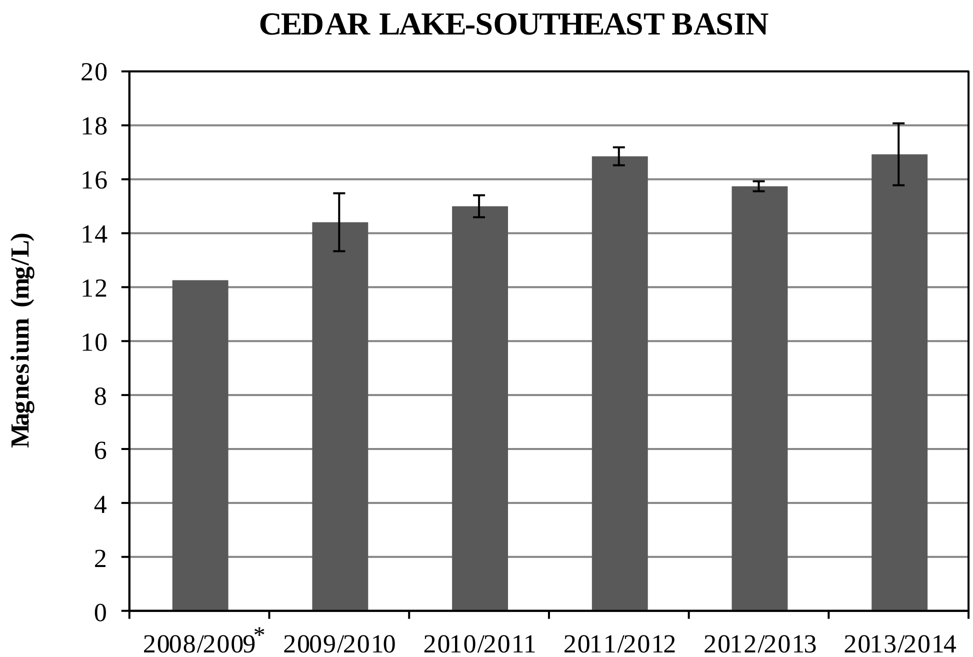
Figure 3-30. Open-water season hardness concentrations (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. No significant inter-annual differences were observed at the annual monitoring sites.

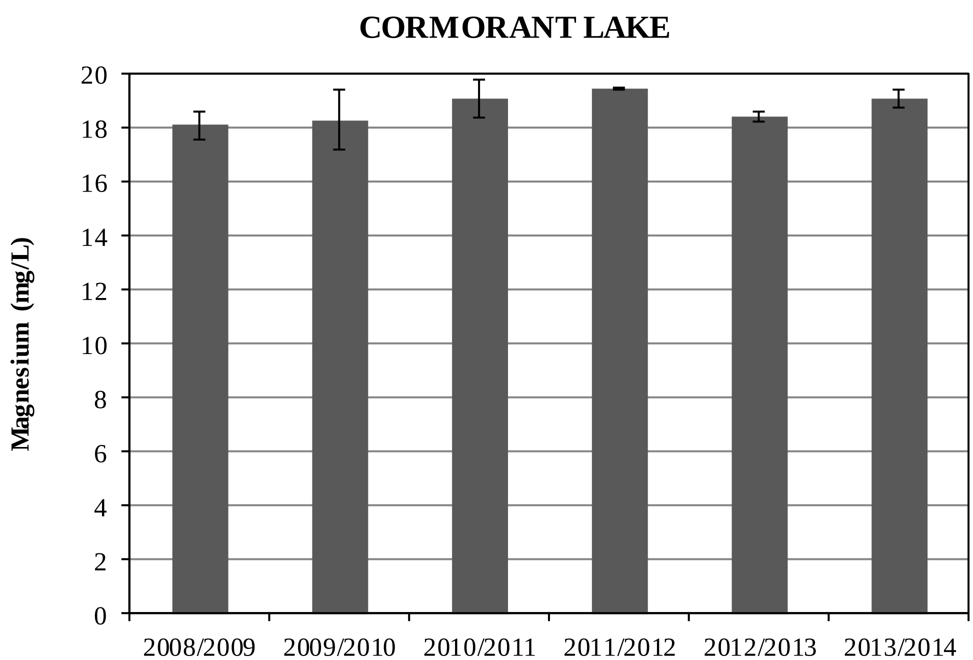




* Site only sampled in spring.

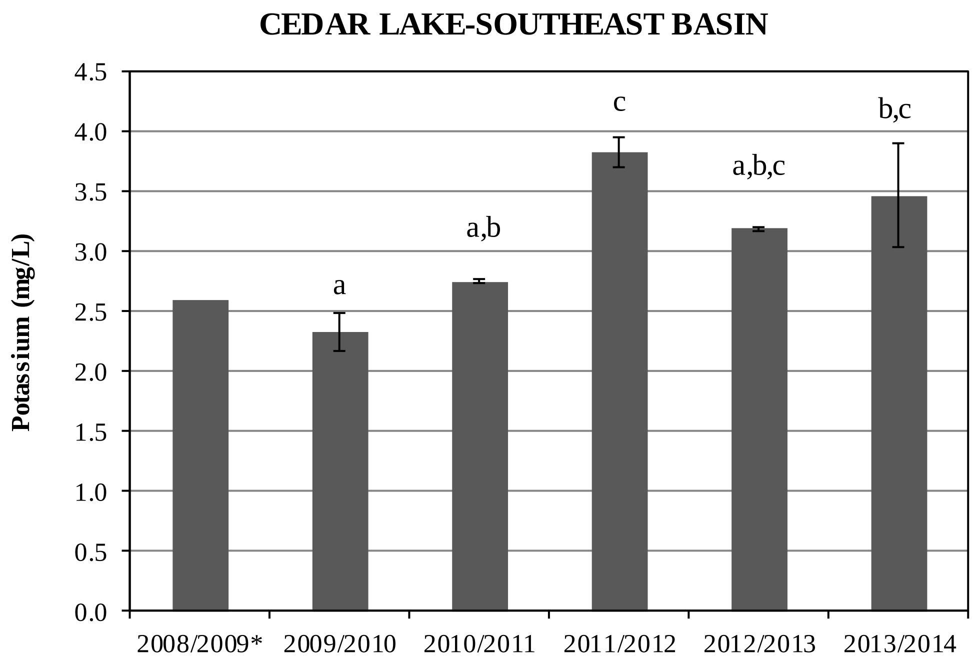
Figure 3-31. Open-water season calcium concentrations (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. No significant inter-annual differences were observed at the annual monitoring sites.

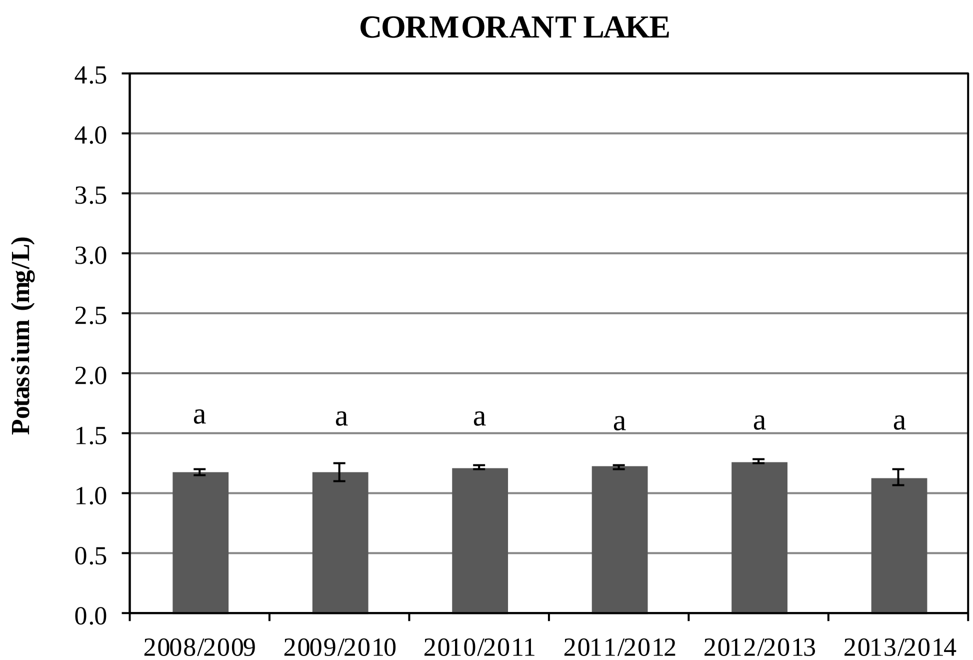




* Site only sampled in spring.

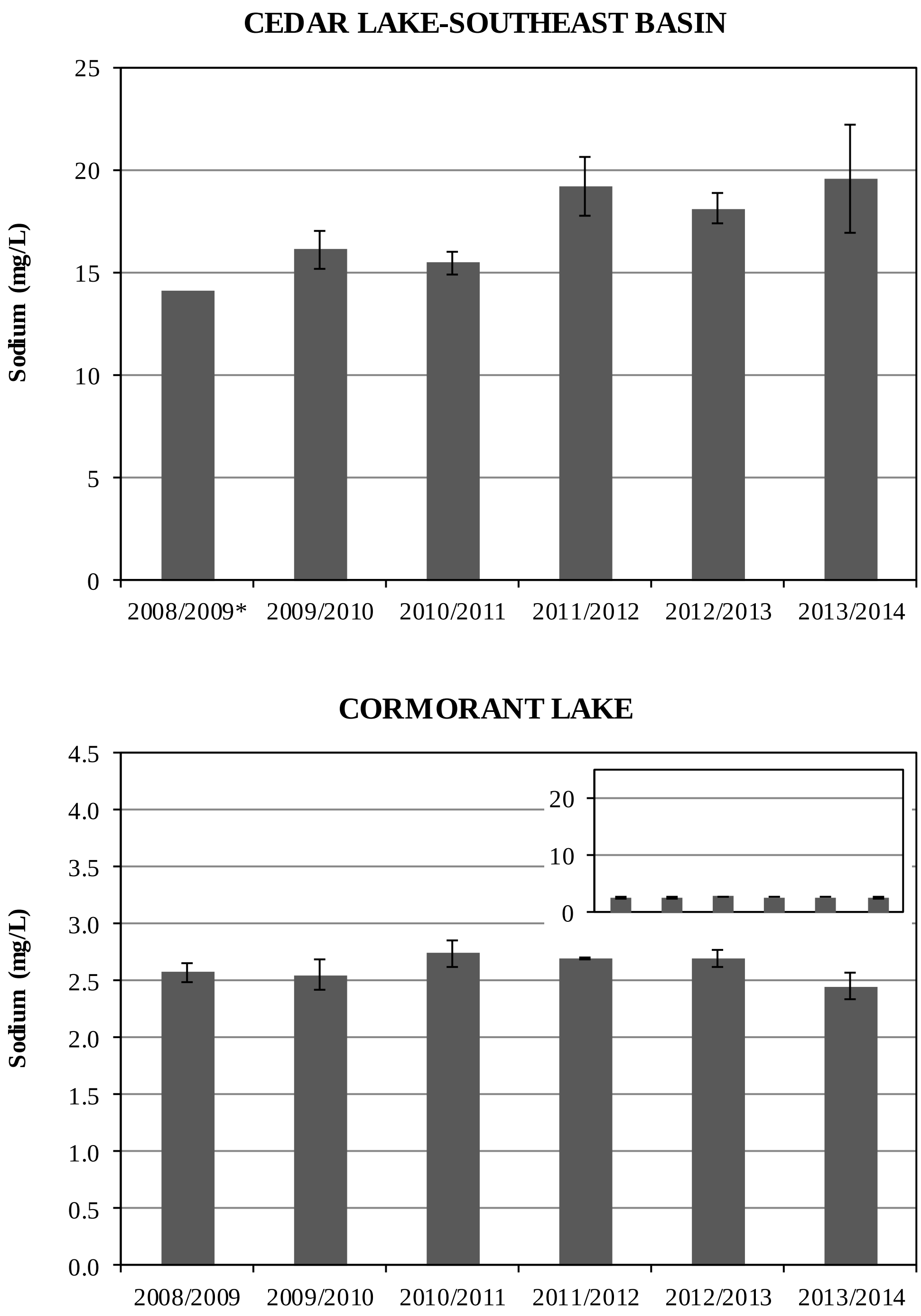
Figure 3-32. Open-water season magnesium concentrations (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. No significant inter-annual differences were observed at the annual monitoring sites.





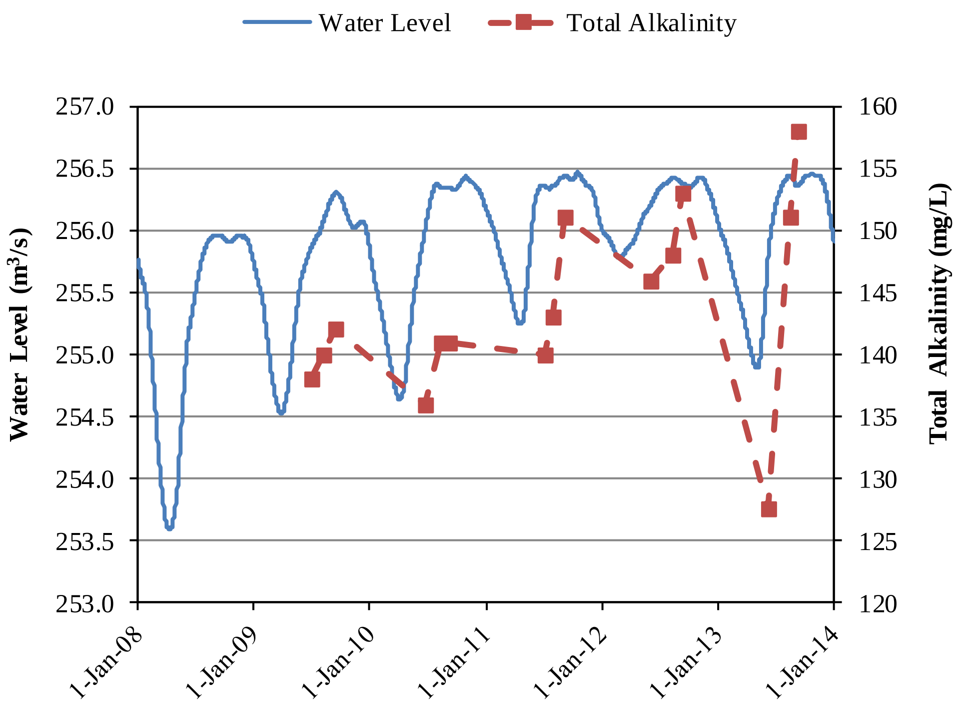
* Site only sampled in spring.

Figure 3-33. Open-water season potassium concentrations (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



* Site only sampled in spring.

Figure 3-34. Open-water season sodium concentrations (mean±SE) at the annual on-system (Cedar Lake - Southeast) and off-system (Cormorant Lake) sites. No significant inter-annual differences were observed at the annual monitoring sites.



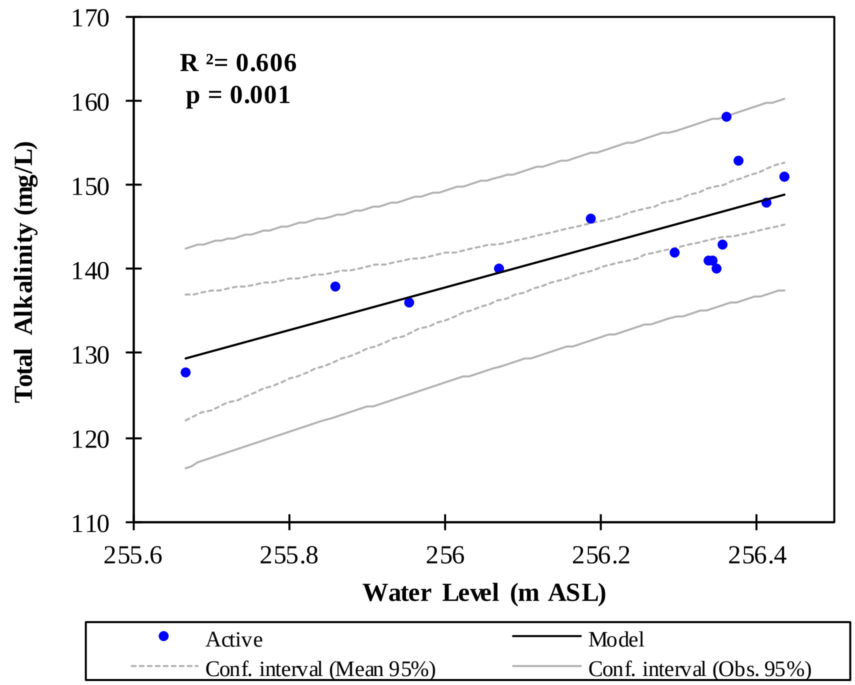
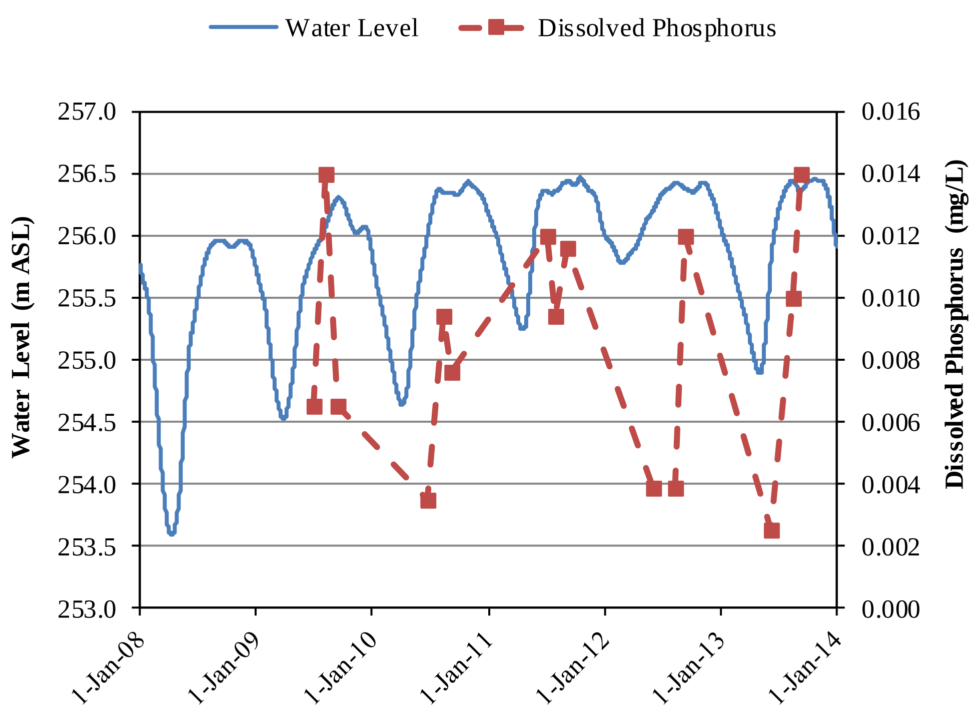


Figure 3-35. Open-water season total alkalinity versus water level (30-day mean) in Cedar Lake: 2009-2013.



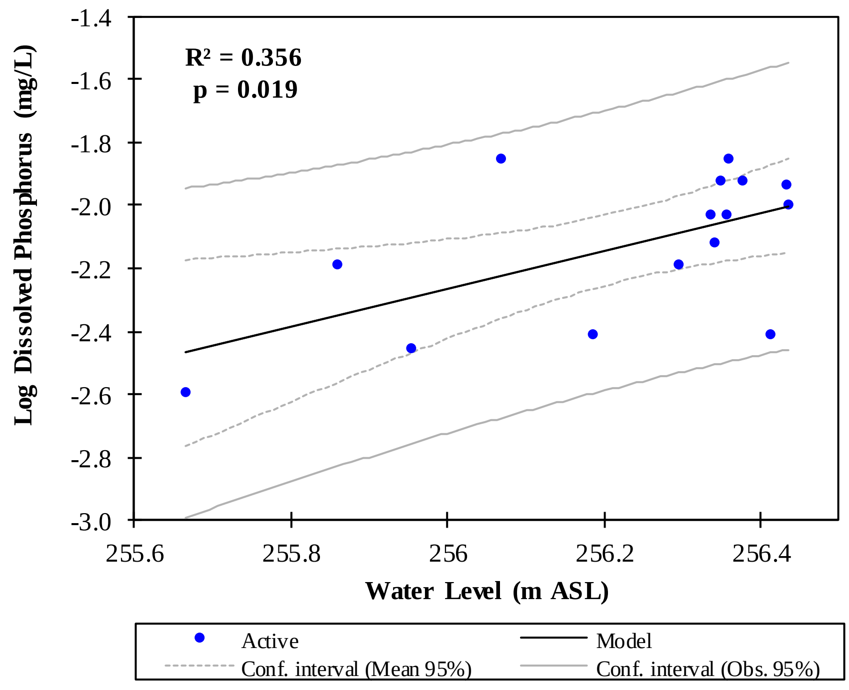


Figure 3-36. Open-water season dissolved phosphorus versus water level (30-day mean) in Cedar Lake: 2009-2013.

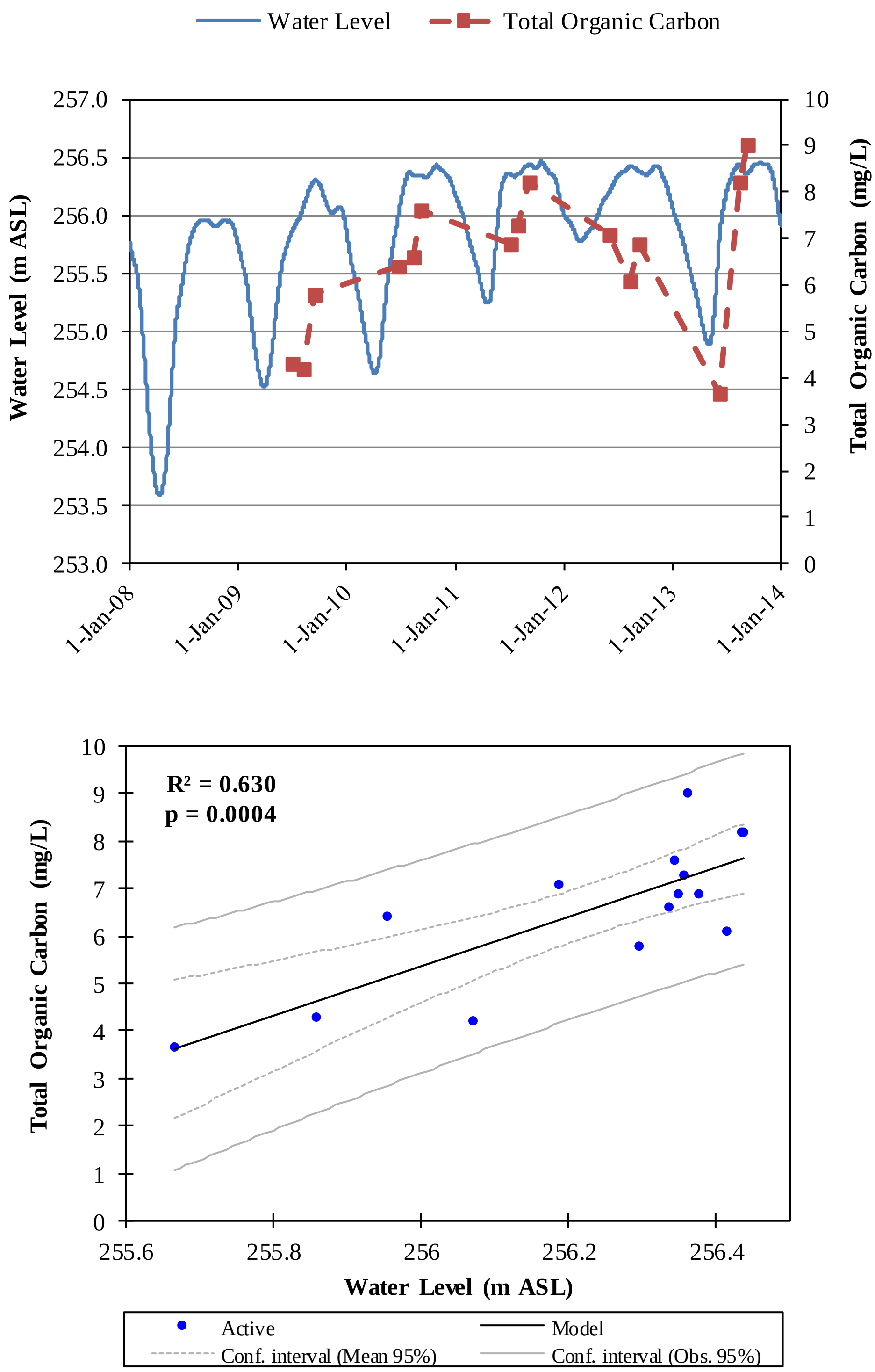
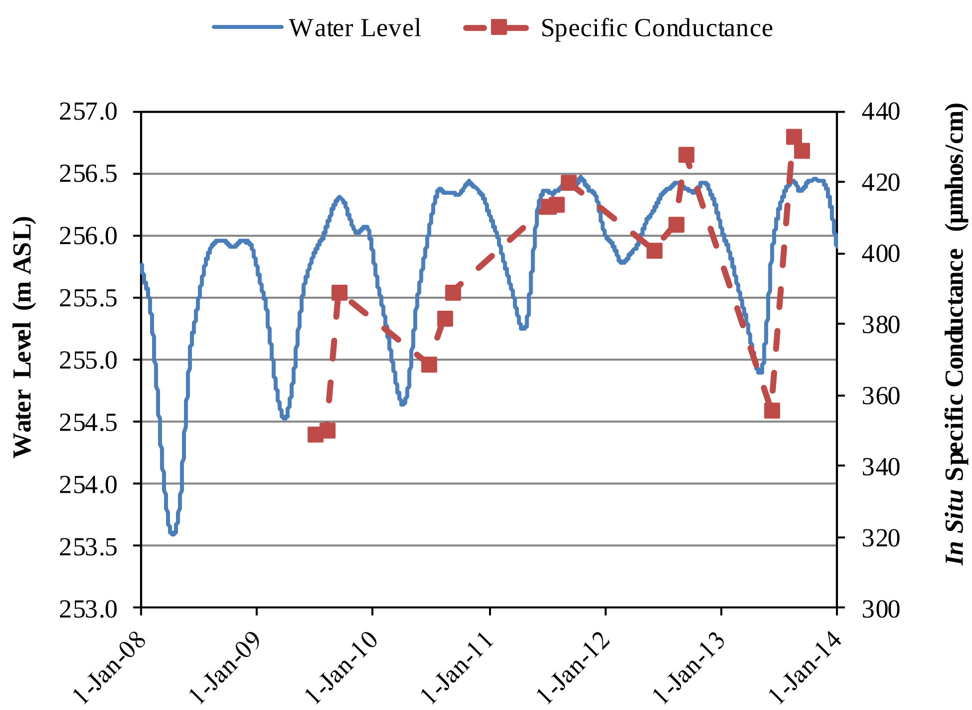


Figure 3-37. Open-water season total organic carbon versus water level (30-day mean) in Cedar Lake: 2009-2013.



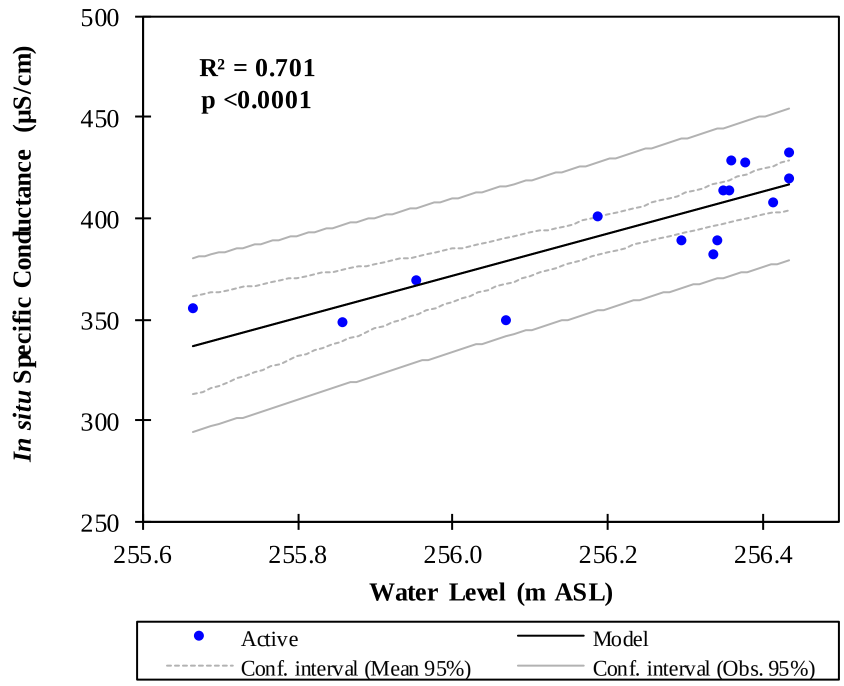


Figure 3-38. Open-water specific conductance versus water level (30-day mean) in Cedar Lake: 2009-2013.

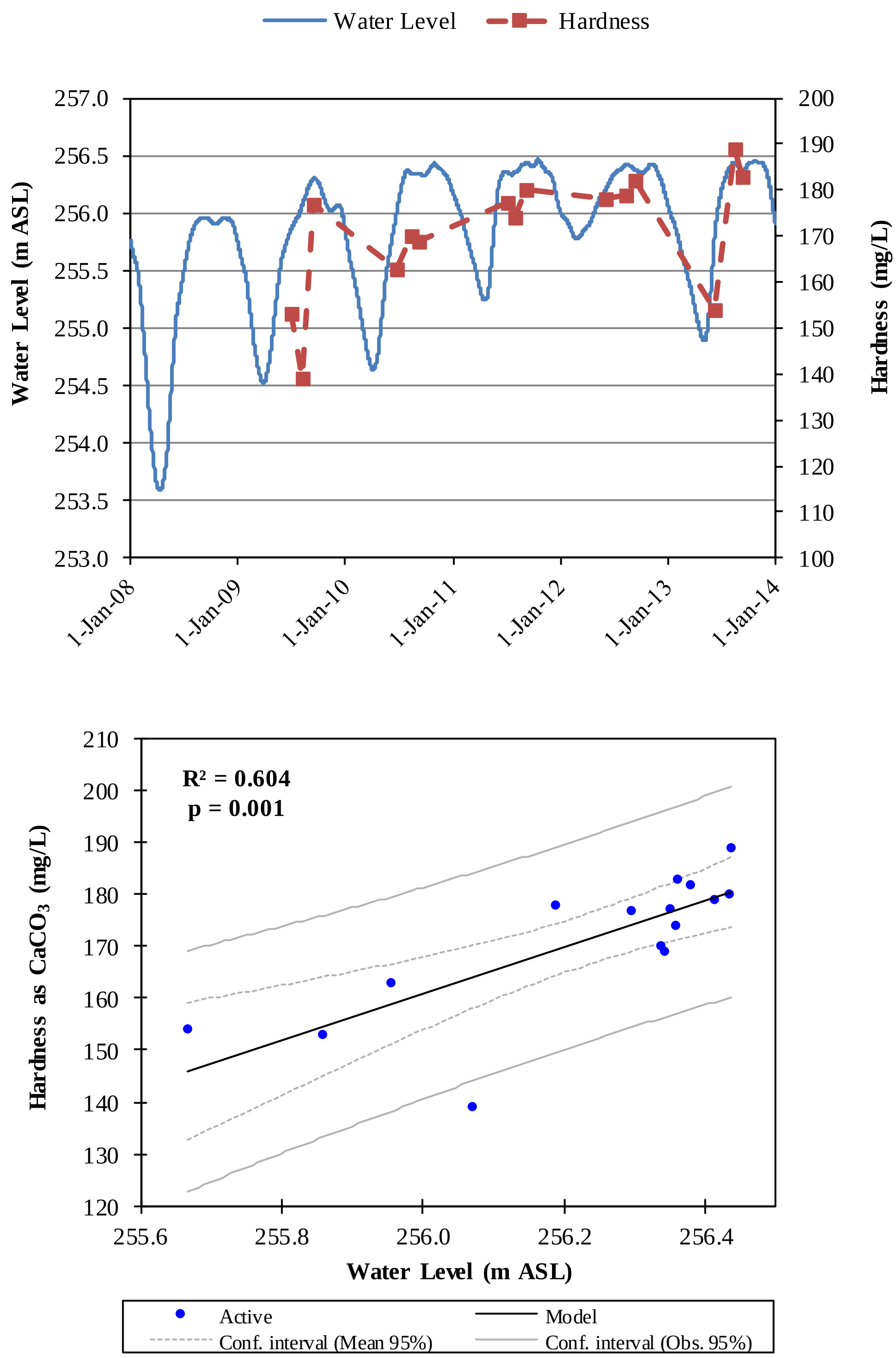
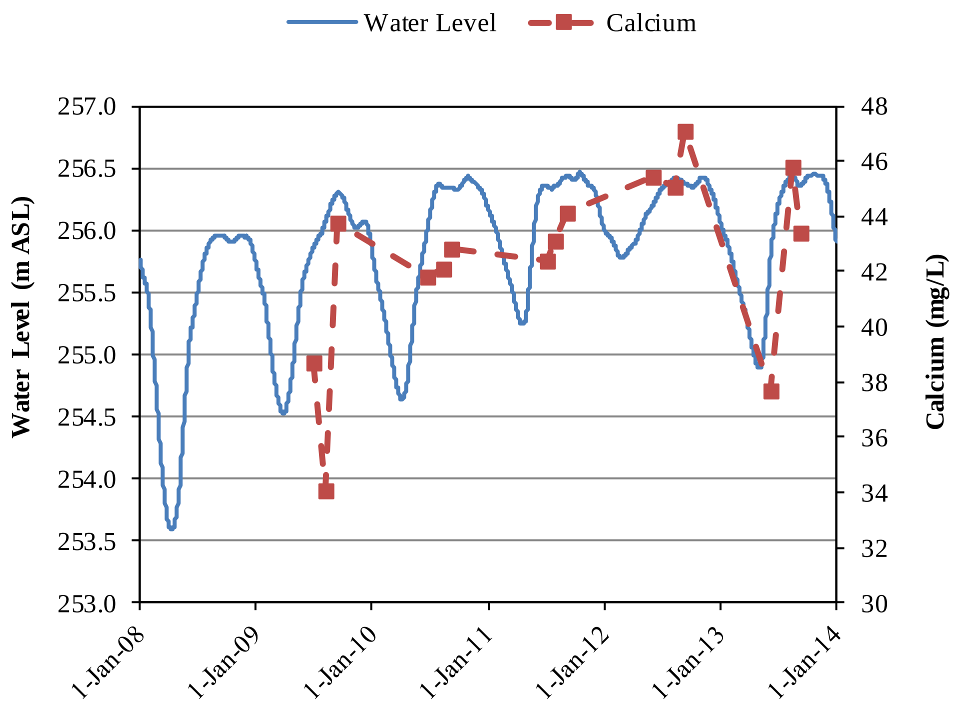


Figure 3-39. Open-water season hardness water level (30-day mean) in Cedar Lake: 2009-2013.



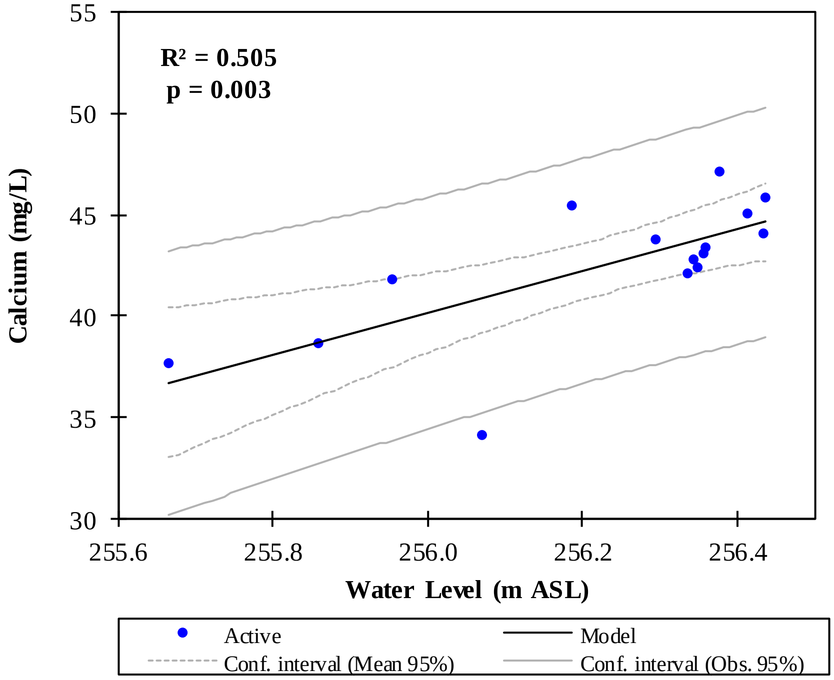
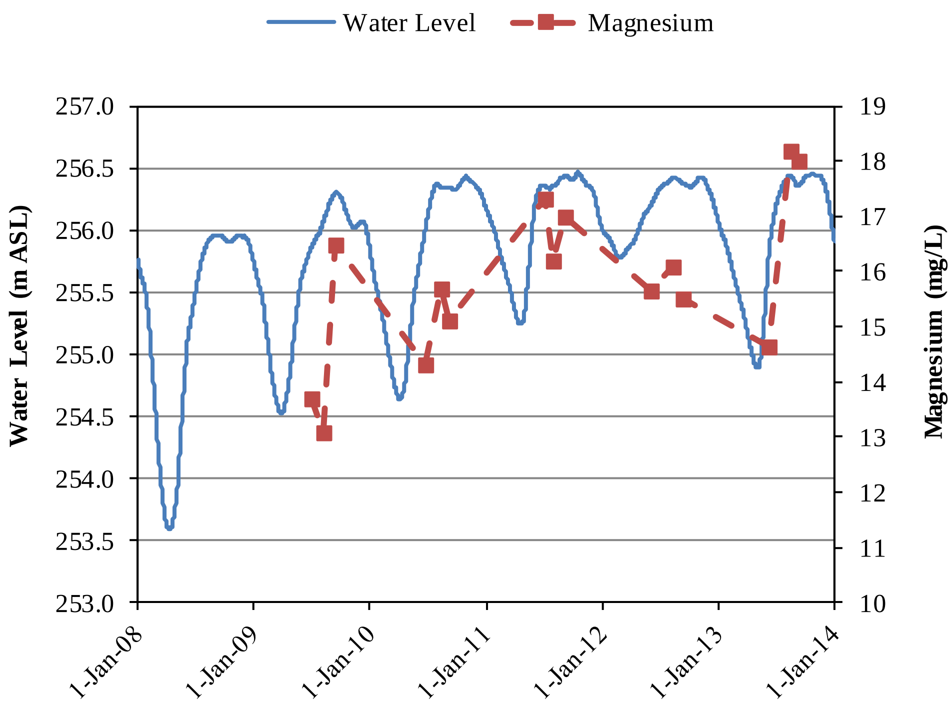


Figure 3-40. Open-water season calcium versus water level (30-day mean) in Cedar Lake: 2009-2013.



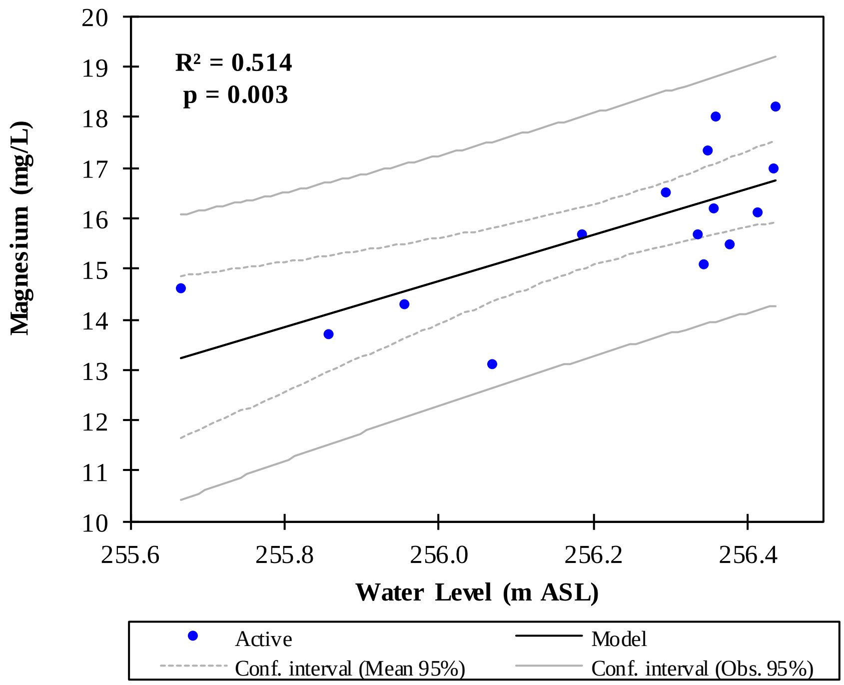
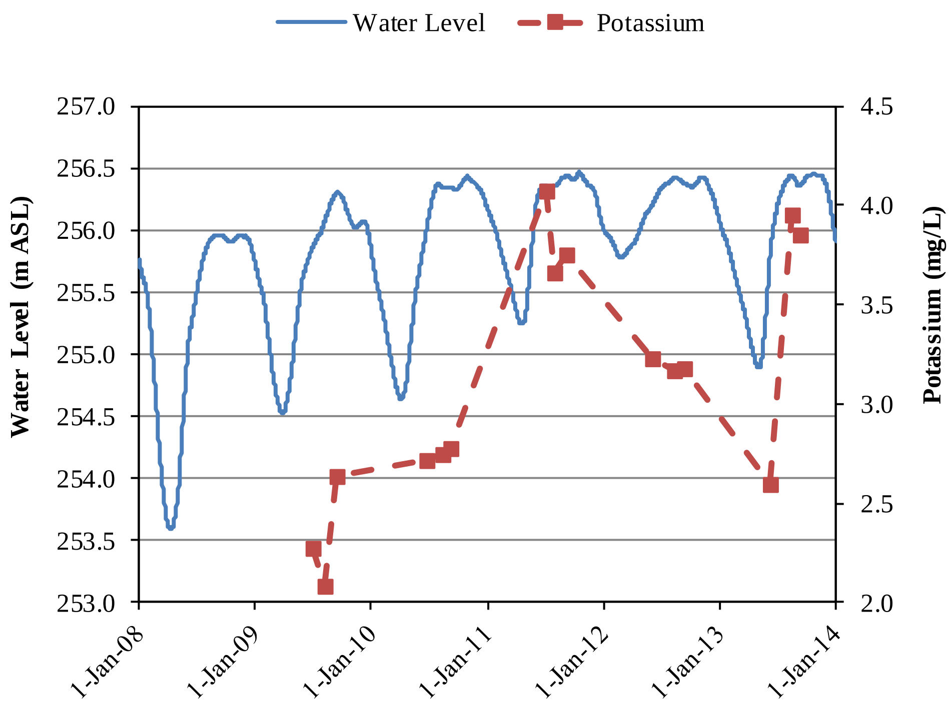


Figure 3-41. Open-water season magnesium versus water level (30-day mean) in Cedar Lake: 2009-2013.



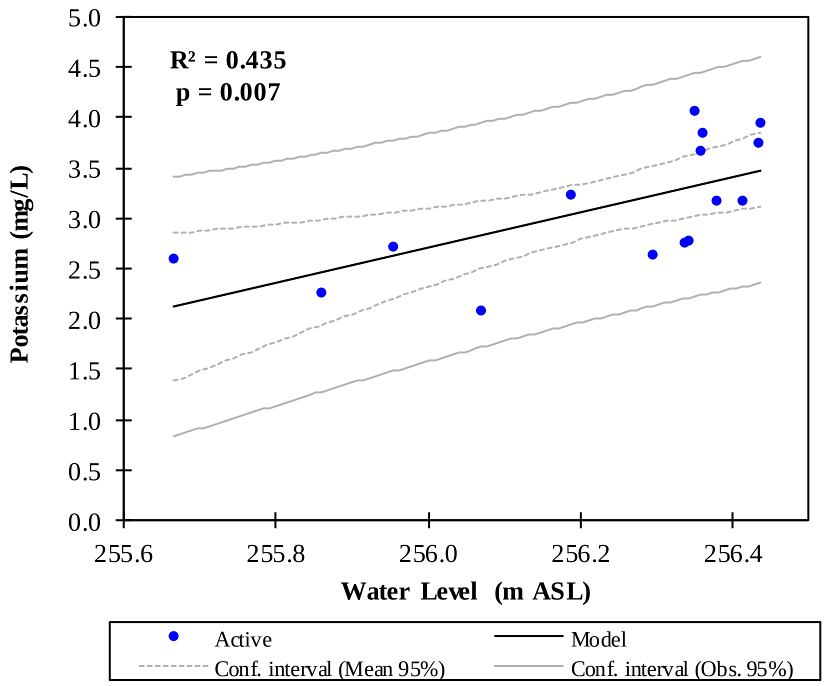


Figure 3-42. Open-water season potassium versus water level (30-day mean) in Cedar Lake: 2009-2013.

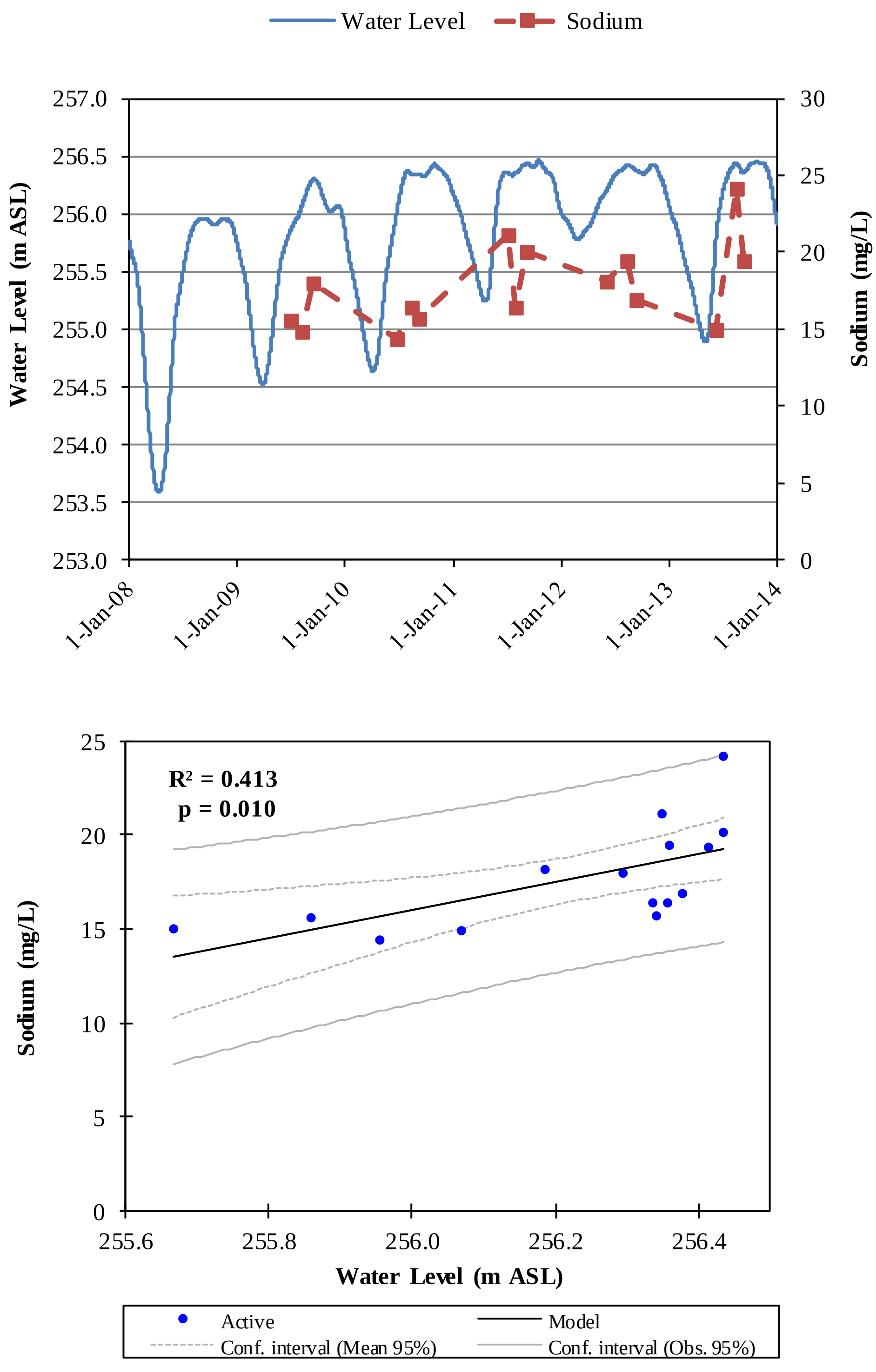
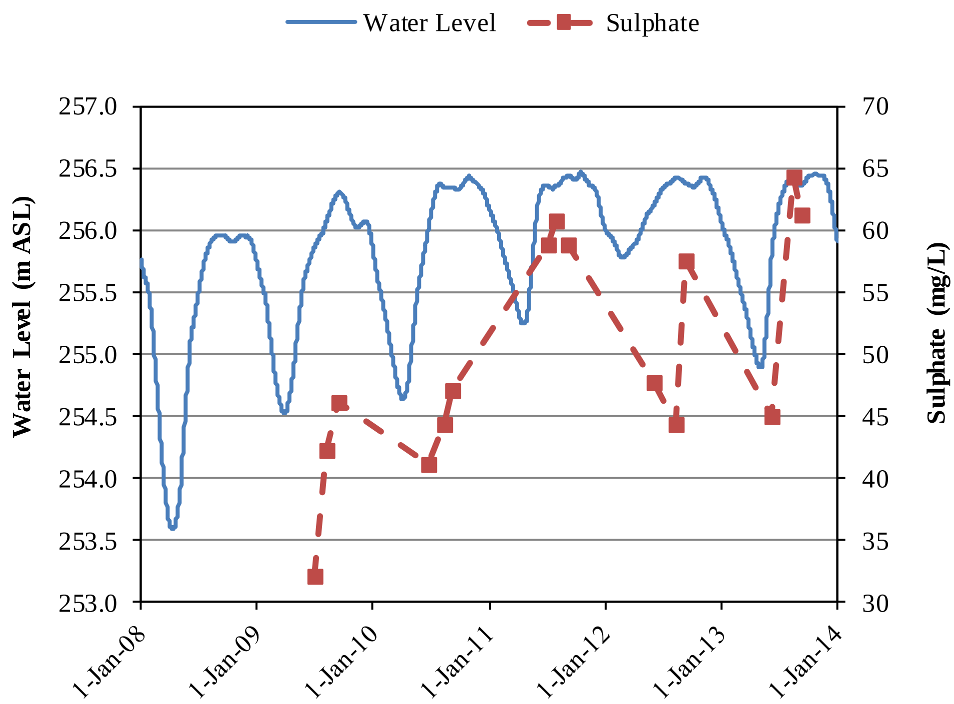


Figure 3-43. Open-water season sodium versus water level (30-day mean) in Cedar Lake: 2009-2013.



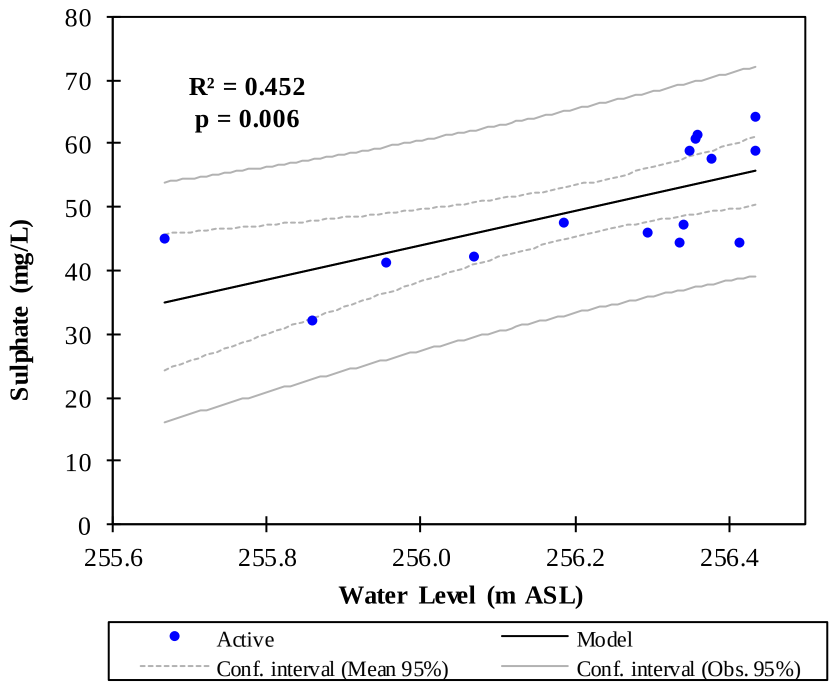


Figure 3-44. Open-water season sulphate versus water level (30-day mean) in Cedar Lake: 2009-2013.

4.0 SEDIMENT QUALITY

4.1 INTRODUCTION

The following provides an overview of sediment quality conditions measured under CAMP in the SRR in the first six years of the program; a description of the sediment quality program sampling methods is provided in Technical Document 1, Section 3.4.1. In brief, sediment quality is monitored in surficial sediments (upper 5 cm) on a six year rotational basis, beginning in 2011, at selected sites under CAMP. Three samples (i.e., a triplicate) were collected at each site. Sediment quality in the SRR was measured in 2011 in Cedar Lake – southeast and the off-system Cormorant Lake (Figure 4-1).

4.1.1 Objectives and Approach

The key objective of the analysis of CAMP sediment quality data was to evaluate whether conditions are suitable for aquatic life. As described in Technical Document 1, Section 4.4, the key objective was addressed through comparisons to sediment quality guidelines (SQGs) for the protection of aquatic life. SQGs that were applied include the Manitoba SQGs (MWS 2011) where available, supplemented with Ontario SGQs (Persaud et al. 1993; Fletcher et al. 2008) and the British Columbia sediment alert concentration (SAC) for selenium (BCMOE 2014, 2017), recently adopted as an interim sediment quality guideline (ISQG) by Alberta Environment and Sustainable Resource Development (2014). There are two values specified for both Manitoba and Ontario SQGs with similar intended interpretations: SQG (Manitoba) and lowest effect level (LEL; Ontario) are values below which adverse effects to biota are expected to occur rarely; and the probable effect level (PEL; Manitoba) and severe effect level (SEL; Ontario) which are levels above which adverse effects are expected to occur frequently. Concentrations lying between the SQG/LEL and the PEL/SEL reflect a condition of increased risk of adverse effects. As only one year of data is available for sediment quality, inter-annual differences and temporal trends could not be examined for this component.

4.1.2 Indicators

Key sediment quality indicators have not yet been identified for CAMP reporting. Sediment quality was described for those metrics for which there are SQGs as summarized above and described in greater detail in Technical Document 1, Section 4.4.

4.2 SASKATCHEWAN RIVER

Surficial sediment samples from Cedar Lake – southeast were dominated by silt/clay (99%; Figure 4-2) and had moderate levels of TOC (Table 4-1 and Figure 4-3). The particle size and TOC content were similar to that observed in the off-system Cormorant Lake (see Section 4.3).

Several metrics exceeded the Ontario LELs in Cedar Lake including TOC (Figure 4-3), TP (Figure 4-4), and total Kjeldahl nitrogen (TKN; Figure 4-5), iron (Figure 4-6), manganese (Figure 4-7), and nickel (Figure 4-8). However all metrics were below the higher Ontario sediment quality benchmarks (i.e., SELs).

All but one metal (arsenic), including cadmium, chromium, copper, lead, mercury, and zinc, were on average within the Manitoba SQGs (Figures 4-9 to 4-15). Arsenic marginally exceeded the Manitoba SQG but not the PEL in Cedar Lake; concentrations were only slightly higher than those measured in the off-system Cormorant Lake (Figure 4-9). The selenium concentration in Cedar Lake sediments was relatively low (mean < 1 µg/g) and below the BC SAC and the AB ISQG (2.0 µg/g; Figure 4-16). Nutrient concentrations were similar, while most metals were lower, in Cedar Lake than the off-system lake. Results for additional metrics are presented in Table 4-2.

4.3 OFF-SYSTEM WATERBODY: CORMORANT LAKE

Although particle size and nutrient levels were generally similar between Cedar Lake and Cormorant Lake, metal concentrations were similar to, or slightly higher in, the off-system lake. In addition, more metrics exceeded sediment quality benchmarks in Cormorant Lake than Cedar Lake – southeast. (Figure 4-2 to 4-16). TOC (Figure 4-3), TP (Figure 4-4), and TKN (Figure 4-5) exceeded the Ontario LEL, but not the SEL, in each lake. Similar to Cedar Lake – southeast, lead, mercury, and zinc (Figures 4-13 to 4-15) were within the Manitoba SQGs, and iron, manganese and nickel (Figures 4-6 to 4-8) exceeded the Ontario LEL but not the SEL. In contrast, arsenic (Figure 4-9) was elevated beyond the Manitoba SQG in Cedar Lake – southeast basin but not Cormorant Lake, and chromium (Figure 4-11) and copper (Figure 4-12) exceeded the Manitoba SQG in the off-system waterbody. Additionally, the average cadmium concentration in Cormorant Lake was equal to the Manitoba SQG (Figure 4-10). At both sites, selenium was marginally above the analytical detection limit (0.5 µg/g) but well below the BC SAC and the AB ISQG.

4.4 SUMMARY

Nutrients (TOC, TP, and TKN) were in excess of the lower sediment quality benchmarks in Cedar Lake – southeast. Conversely, the majority of metals for which there are benchmarks were within sediment quality benchmarks in Cedar Lake - southeast and with one exception, where exceedances of benchmarks occurred in Cedar Lake, exceedances were also observed in the off-system Cormorant Lake. The exception occurred for arsenic which marginally exceeded the Manitoba SQG in Cedar Lake. While particle size and nutrient concentrations were similar between the on- and off-system lakes, a number of metals were higher, and more metals exceeded benchmarks, in Cormorant Lake sediments.

Metrics that exceeded sediment quality benchmarks in Cedar Lake were also above these benchmarks, and concentrations were similar to those observed, in other lakes and rivers monitored under CAMP (Table 4-1). The exceedances of Manitoba SQGs for cadmium and copper in Cormorant Lake were the only such occurrences observed for sites monitored under CAMP.

Table 4-1. Sediment quality (means of triplicate samples) monitoring results for key metrics. Shading indicates concentrations at or above a sediment quality benchmark.

Region	Waterbody	Sand (%)	Silt (%)	Clay (%)	TKN (µg/g)	TP (µg/g)	TOC (%)	Arsenic (µg/g)	Cadmium (µg/g)	Chromium (µg/g)	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Manganese (µg/g)	Mercury (µg/g)	Nickel (µg/g)	Selenium (µg/g)	Zinc (µg/g)
WRR	PDB	88.1	7.56	4.35	717	370	0.50	1.76	0.028	11.6	4.6	9450	3.78	272	<0.05	7.53	<0.5	20
	LDB	12.2	66.7	21.1	2283	735	2.15	4.49	0.171	25.2	13.8	18267	8.02	1056	0.075	18.1	<0.5	48
	MANIG	1.54	39.4	59.0	5983	1063	5.18	5.40	0.289	43.2	25.8	31500	17.4	569	0.085	31.3	0.75	80
SRR	CEDAR-SE	0.60	34.6	64.8	4137	910	3.92	6.58	0.335	33.7	24.6	31700	13.0	583	<0.05	33.8	0.89	80
	CORM	1.12	29.5	69.4	4223	850	3.29	4.34	0.606	59.2	37.3	37867	20.6	877	0.083	43.1	0.67	111
LKWPGR	LWPG	-	-	-	3483	667 [1]	-	5.05	0.260	57.0	32.3	31233	13.4	630	<0.05	44.0	0.86	78
	LWPGOSIS	92.9	5.41	1.68	987	241	0.95	1.19	0.066	7.1	4.2	4683	2.36	273	<0.05	5.78	<0.5	12
UCRR	GRV	1.36	39.9	58.7	3023	1188	2.16	5.16	0.434	76.5	27.1	49700	18.3	3543	<0.05	55.3	<0.5	111
	SIL-4	85.1	4.97	9.92	817	1790	0.99	43.5	0.330	21.0	10.6	125000	16.0	13500	<0.05	21.3	<0.5	39
LCRR	NIL	3.98	61.5	34.5	3393	973	2.66	4.54	0.192	55.7	22.2	38967	12.6	1597	<0.05	35.9	<0.5	78
	GAU-Sand	99.4	0.47	<0.1	657	123	0.53	0.56	<0.02	2.5	1.4	2480	1.15	41	<0.05	1.82	<0.5	<10
	GAU-Silt/Clay	26.0	47.9	26.1	6977	786	5.65	2.53	0.165	44.5	22.2	28467	9.36	552	<0.05	30.9	0.59	74
CRDR	3PT	0.33	47.1	52.7	1350	775	1.11	4.94	0.160	68.3	28.5	39100	13.0	2235	<0.05	45.6	<1.1	88
	LEFT	1.03	40.5	58.5	7003	942	5.62	3.02	0.273	60.8	33.9	37000	15.6	463	<0.05	45.3	0.46	79
UNRR	CROSS	1.37	55.7	42.9	3097	1005	2.75	6.48	0.199	52.0	22.8	31933	12.3	804	<0.05	37.6	0.67	74
	SET	1.49	24.1	74.4	3937	1012	3.10	5.10	0.309	80.1	28.3	51467	17.4	1303	<0.05	53.6	<0.5	117
LNRR	BURNT	5.87	70.7	23.5	673	604	0.88	2.12	0.104	35.5	14.6	19000	6.54	493	<0.05	24.8	<1.1	41
	SPLIT	3.46	51.0	45.5	1053	459	1.00	3.46	0.130	50.0	21.1	25733	9.63	575	<0.05	34.5	<1.1	65
	ASSN	0.14	56.2	43.6	1280	533	1.30	2.78	0.170	40.3	16.8	23933	9.57	579	<0.05	27.8	<1.1	57
	Mean > MB SQG							5.9	0.6	37.3	35.7		35		0.17			123
	Mean > MB PEL							17	3.5	90	197		91.3		0.486			315
	Mean > ON LEL				550	600	1					20000		460		16		
	Mean > ON SEL				4800	2000	10					40000		1100		75		
	Mean > BC SAC																2.0	

[1] Data from 2009 (not measured in 2011).

Table 4-2. Sediment quality (means of triplicate samples) monitoring results for other metals.

Region	Waterbody	Aluminum (µg/g)	Antimony (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Bismuth (µg/g)	Boron (µg/g)	Calcium (µg/g)	Cesium (µg/g)	Cobalt (µg/g)	Magnesium (µg/g)	Molybdenum (µg/g)	Potassium (µg/g)	Rubidium (µg/g)	Silver (µg/g)
WRR	PDB	4327	<0.10	26.7	<0.10	<0.02	2.4	2673	0.333	3.71	1807	0.076	580	6.24	<0.10
	LDB	10700	<0.10	86.4	0.41	0.087	8.2	7590	0.891	8.26	5753	0.183	1943	21.2	<0.10
	MANIG	23333	0.24	155	0.81	0.238	13.2	6117	1.27	10.5	7317	0.468	3427	38.8	0.14
SRR	CEDAR-SE	20133	0.45	242	0.79	0.220	8.4	21300	1.30	11.3	14267	0.503	3060	24.7	0.18
	CORM	27933	0.25	193	0.95	0.328	15.4	26233	2.36	15.2	22667	0.369	5357	51.5	0.16
LKWPGR	LWPG	23967	0.41	204	0.92	0.240 [1]	17.2	27433	2.41 [1]	13.6	21500	0.778	5153	47.0 [1]	0.14
	LWPGOSIS	2767	<0.10	28.6	<0.10	0.037	6.0	93233	0.259	2.45	26700	0.165	685	4.8	<0.10
UCRR	GRV	35333	0.13	384	1.39	0.479	12.5	6220	3.96	20.9	11467	0.854	7633	86.6	0.17
	SIL-4	10010	<0.10	1280	1.40	0.242	6.2	4320	1.28	44.6	2920	4.65	1783	23.0	<0.10
LCRR	NIL	26633	<0.10	175	1.05	0.333	12.2	6343	3.28	14.3	9967	0.319	5617	61.6	0.12
	GAU-Sand	784	<0.10	5.80	<0.10	<0.02	<3.0	810	0.065	0.79	380	0.083	143	1.12	<0.10
	GAU-Silt/Clay	20800	<0.10	106	0.83	0.252	10.4	6043	2.57	10.8	7780	0.362	3977	45.6	0.13
CRDR	3PT	28650	<0.10	192	0.96	0.318	13.2	7680	3.10	16.4	13300	0.339	6260	67.4	0.21
	LEFT	27567	0.12	157	1.07	0.341	17.7	7723	3.10	15.1	11267	0.612	5843	55.4	0.17
UNRR	CROSS	21033	0.23	146	0.69	0.212	16.4	24767	2.02	12.5	21000	0.304	4270	41.2	0.17
	SET	35633	0.17	241	1.31	0.363	22.7	7373	3.70	19.6	18700	0.346	7397	76.8	0.21
LNRR	BURNT	12633	<0.10	69.5	0.51	0.135	13.0	51700	1.30	8.28	30533	0.216	2620	25.6	0.14
	SPLIT	20400	0.14	128	0.75	0.191	17.1	63400	1.93	11.5	28567	0.295	4373	39.9	0.21
	ASSN	16700	<0.10	82.1	0.69	0.171	18.5	80900	1.67	9.87	36600	0.189	3473	31.3	0.12

Table 4-2. continued.

Region	Waterbody	Sodium (µg/g)	Strontium (µg/g)	Sulfur (µg/g)	Tellurium (µg/g)	Thallium (µg/g)	Tin (µg/g)	Titanium (µg/g)	Tungsten (µg/g)	Uranium (µg/g)	Vanadium (µg/g)	Zirconium (µg/g)
WRR	PDB	116	9.26	<5.0	<0.10	<0.10	<5.0	309	<0.050	0.607	15.5	2.10
	LDB	147	22.4	<5.0	<0.10	0.11	<5.0	346	<0.050	1.36	35.1	5.13
	MANIG	199	32.7	<5.0	<0.10	0.25	<5.0	364	<0.050	2.36	61.6	7.90
SRR	CEDAR-SE	294	68.2	13.3	<0.10	0.25	<5.0	96.8	<0.050	1.54	51.7	7.24
	CORM	348	38.0	<5.0	<0.10	0.34	<5.0	736	0.078	1.17	63.2	6.84
LKWPGR	LWPG	464	52.3	2667	<0.10 [1]	0.31	-	854	0.073 [1]	1.69 [1]	65.8	10.1
	LWPGOSIS	462	128	673	<0.10	<0.10	<5.0	145	<0.050	0.328	6.99	1.09
UCRR	GRV	327	42.0	<5.0	<0.10	0.54	<5.0	2023	0.195	4.71	83.0	13.8
	SIL-4	117	29.4	<5.0	<0.10	0.19	<5.0	500	0.814	3.69	66.9	3.85
LCRR	NIL	388	31.8	<5.0	<0.10	0.37	<5.0	1323	0.140	2.32	54.8	12.1
	GAU-Sand	30	2.83	<5.0	<0.10	<0.10	<5.0	130	<0.050	0.293	3.58	1.35
	GAU-Silt/Clay	303	23.2	<5.0	<0.10	0.28	<5.0	1002	0.120	2.34	42.6	11.7
CRDR	3PT	409	36.2	<5.0	<0.10	0.37	<5.0	1665	0.140	1.55	65.3	20.5
	LEFT	456	32.2	<5.0	<0.10	0.32	<5.0	1267	0.127	2.35	61.7	16.8
UNRR	CROSS	452	42.1	<5.0	<0.10	0.26	<5.0	985	0.098	1.29	52.7	12.3
	SET	751	40.0	<5.0	<0.10	0.40	<5.0	1510	0.119	1.79	75.7	18.4
LNRR	BURNT	250	35.3	<5.0	<0.10	0.14	<5.0	846	0.100	0.802	33.0	14.9
	SPLIT	362	57.0	320	<0.10	0.24	<5.0	1081	0.077	0.959	50.3	23.7
	ASSN	279	52.5	<5.0	<0.10	0.19	<5.0	808	0.091	0.790	41.3	10.2

[1] Data from 2009 (not measured in 2011).

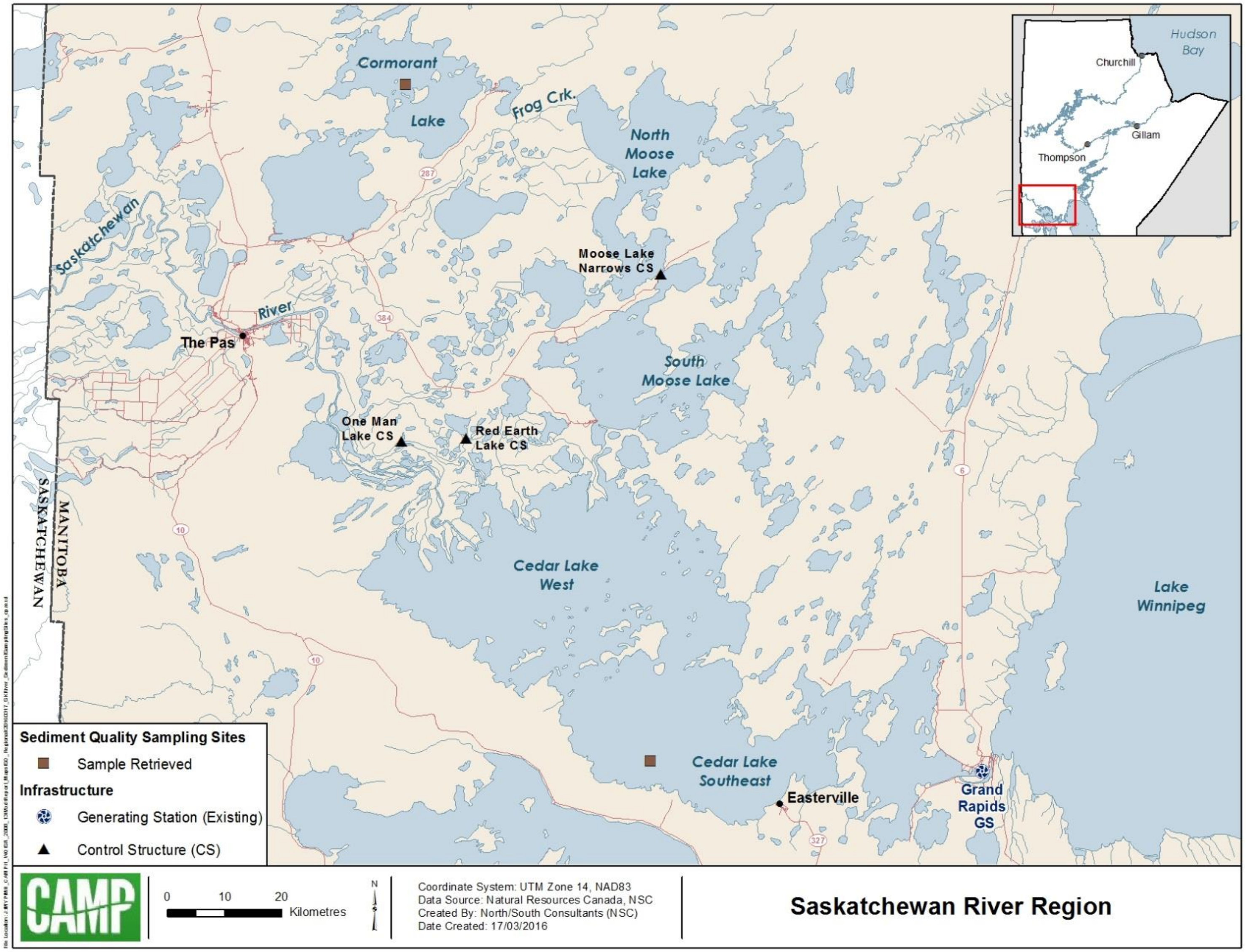


Figure 4-1. Sediment quality sampling sites in the Saskatchewan River region: 2008-2013.

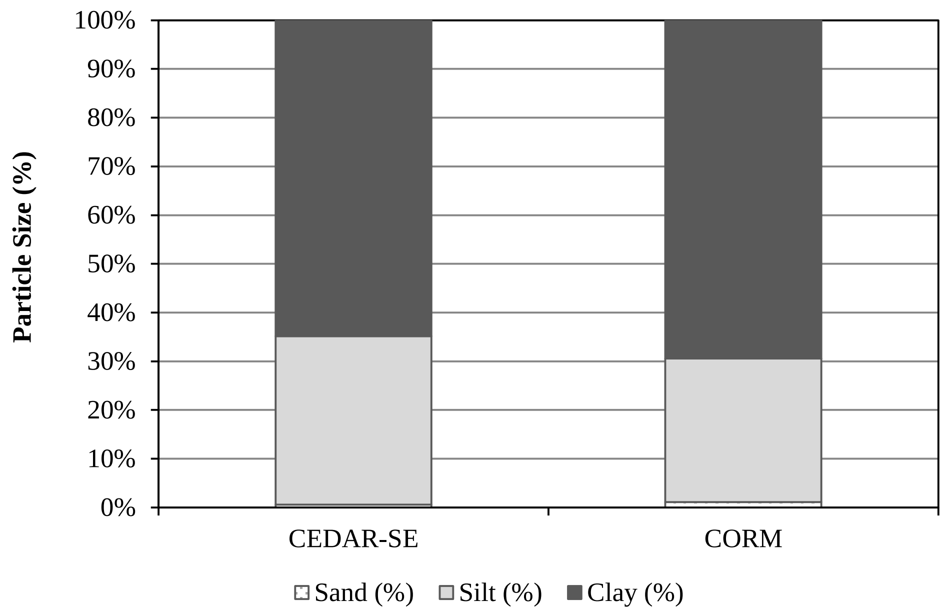


Figure 4-2. Particle size of surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM).

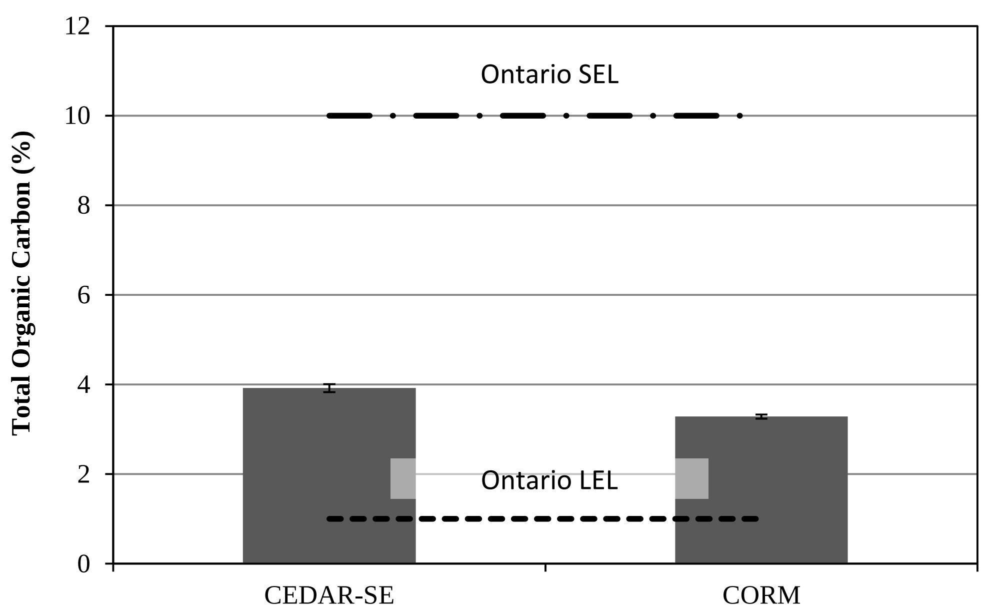


Figure 4-3. Percentage of total organic carbon (mean±SE) in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Ontario sediment quality guidelines.

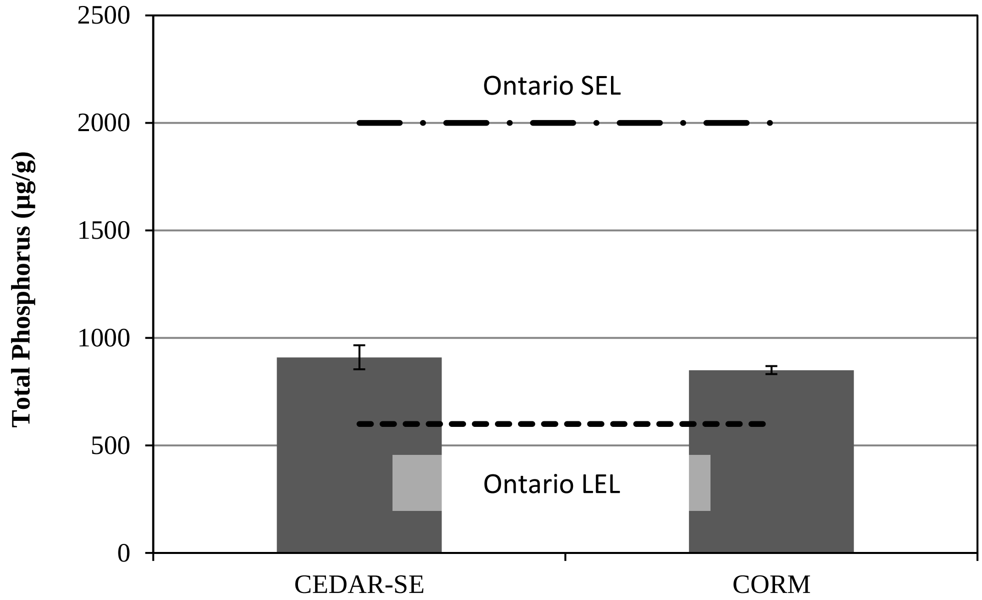


Figure 4-4. Mean (±SE) concentrations of total phosphorus in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Ontario sediment quality guidelines.

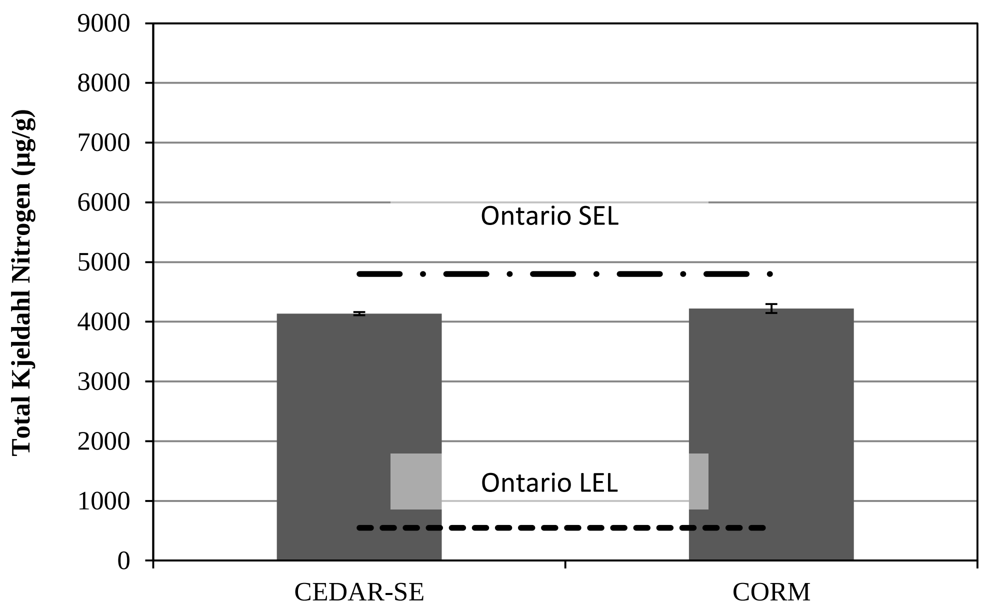


Figure 4-5. Mean (±SE) concentrations of total Kjeldahl nitrogen in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Ontario sediment quality guidelines.

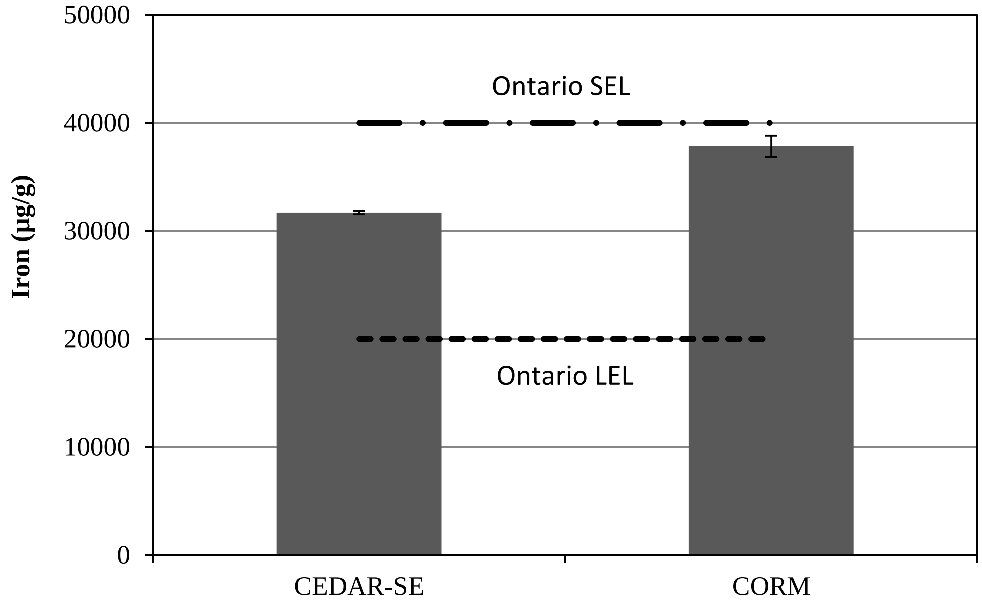


Figure 4-6. Mean (±SE) concentrations of iron in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM) and comparison to Ontario sediment quality guidelines.

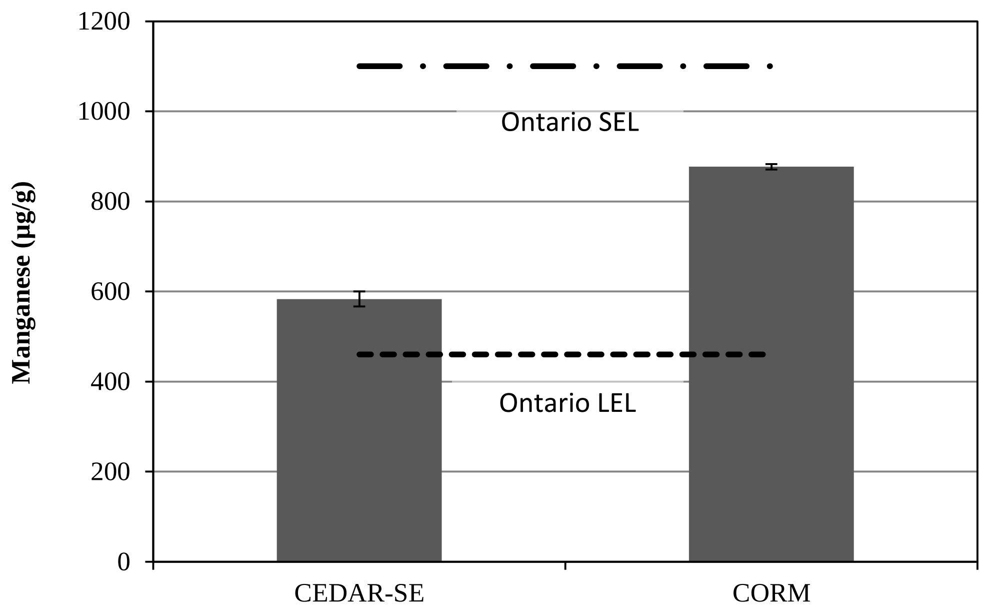


Figure 4-7. Mean (±SE) concentrations of manganese in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM) and comparison to Ontario sediment quality guidelines.

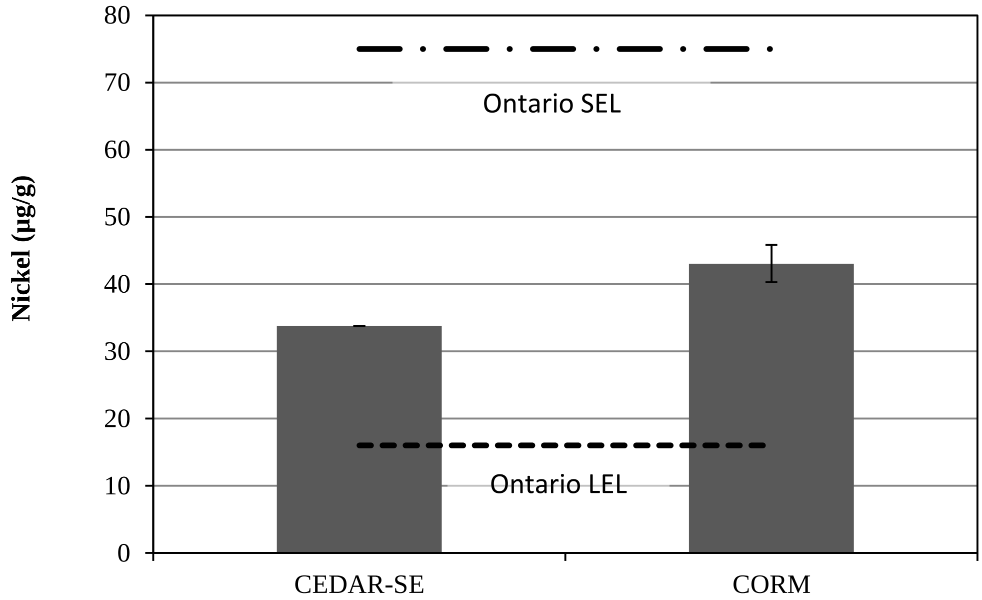


Figure 4-8. Mean (±SE) concentrations of nickel in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM) and comparison to Ontario sediment quality guidelines.

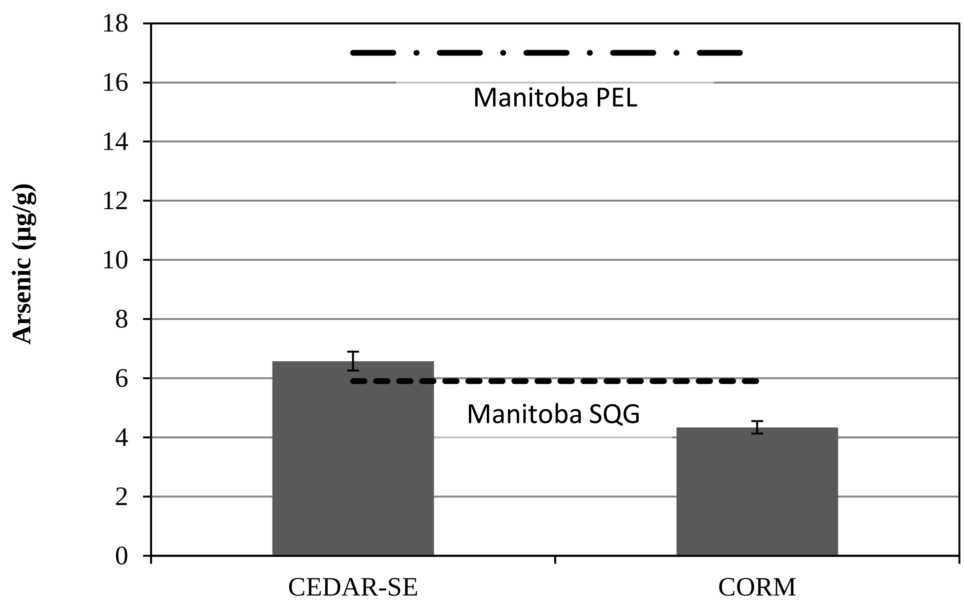


Figure 4-9. Mean (±SE) concentrations of arsenic in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Manitoba sediment quality guidelines.

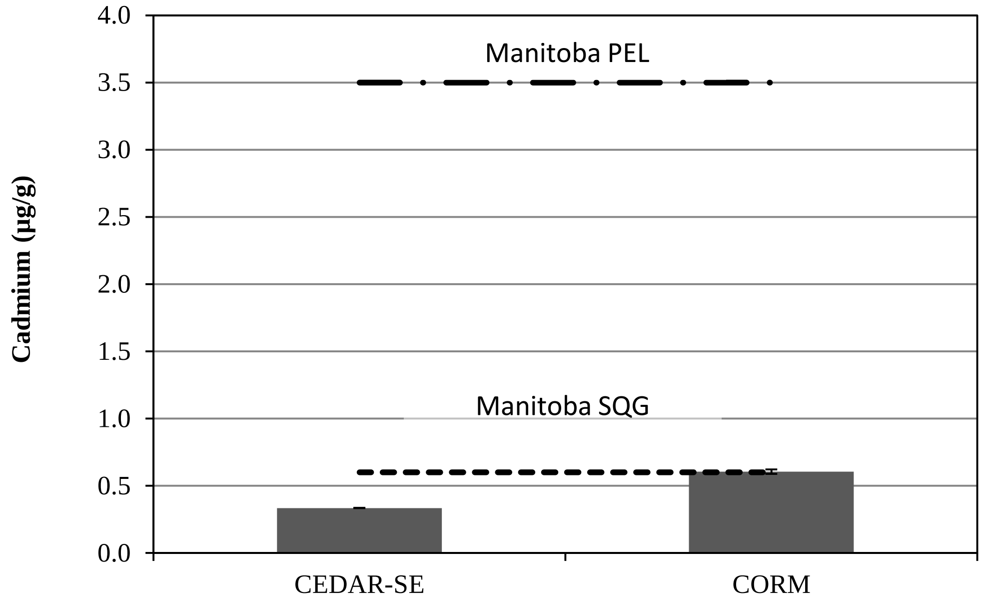


Figure 4-10. Mean (±SE) concentrations of cadmium in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Manitoba sediment quality guidelines.

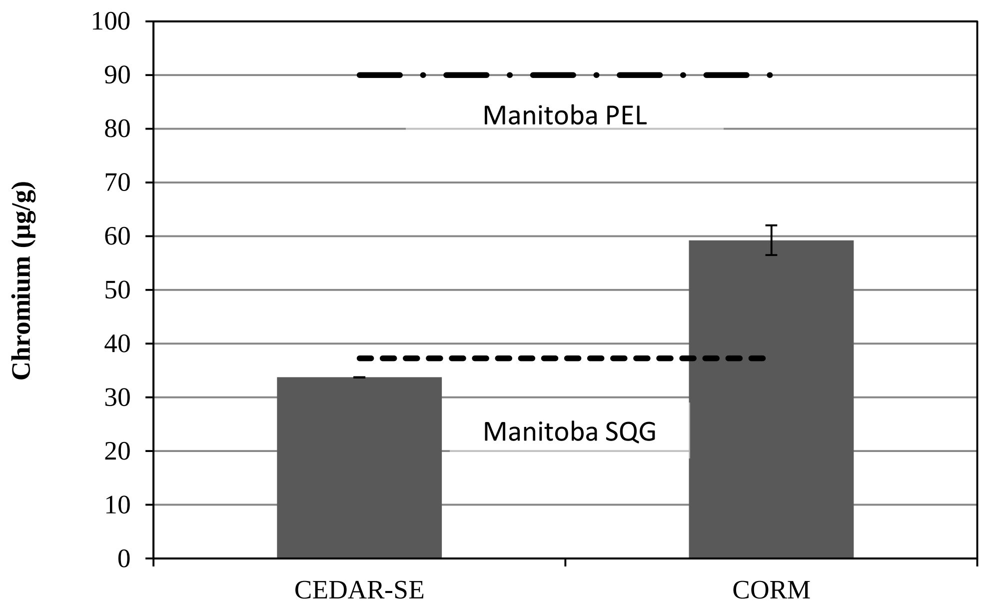


Figure 4-11. Mean (±SE) concentrations of chromium in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Manitoba sediment quality guidelines.

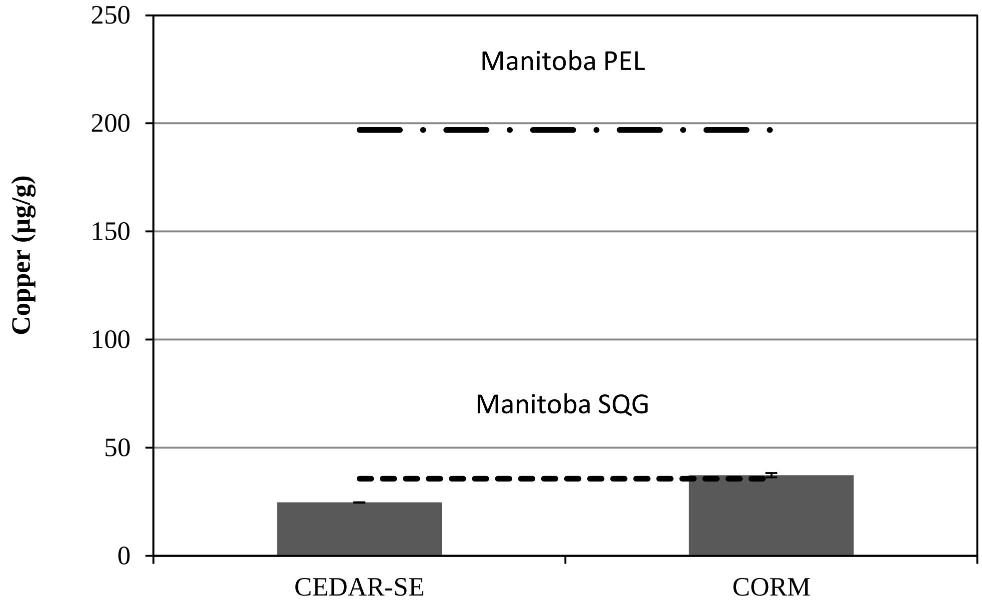


Figure 4-12. Mean (±SE) concentrations of copper in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Manitoba sediment quality guidelines.

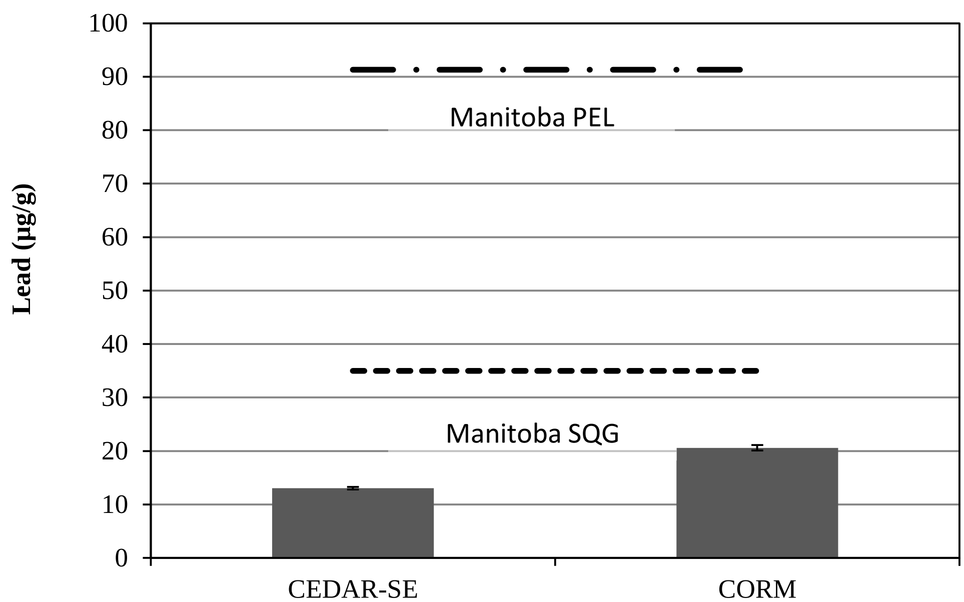


Figure 4-13. Mean (±SE) concentrations of lead in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Manitoba sediment quality guidelines.

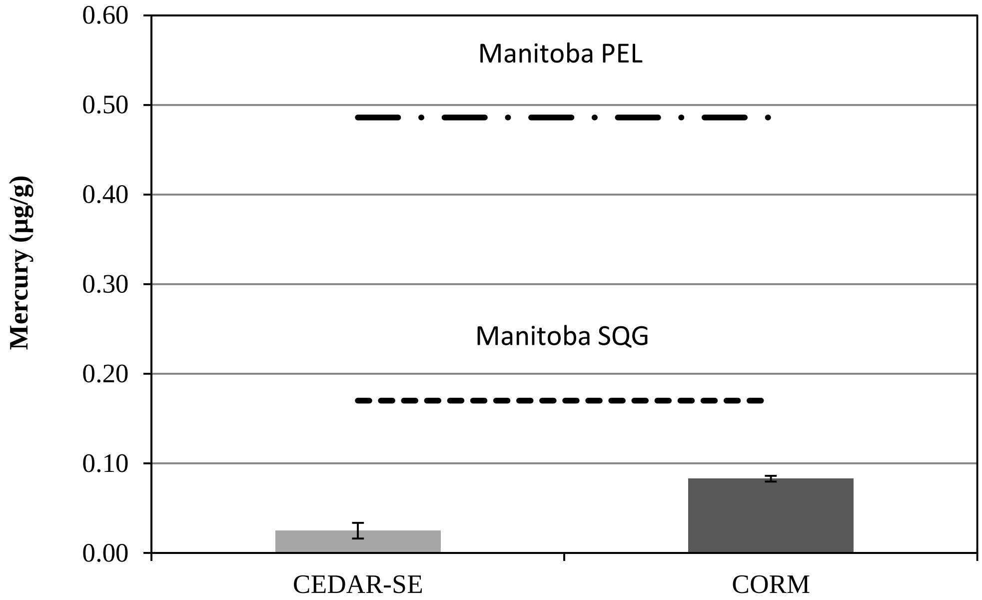


Figure 4-14. Mean (±SE) concentrations of mercury in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM), and comparison to Manitoba sediment quality guidelines. Means indicated in light grey were below the analytical detection limit.

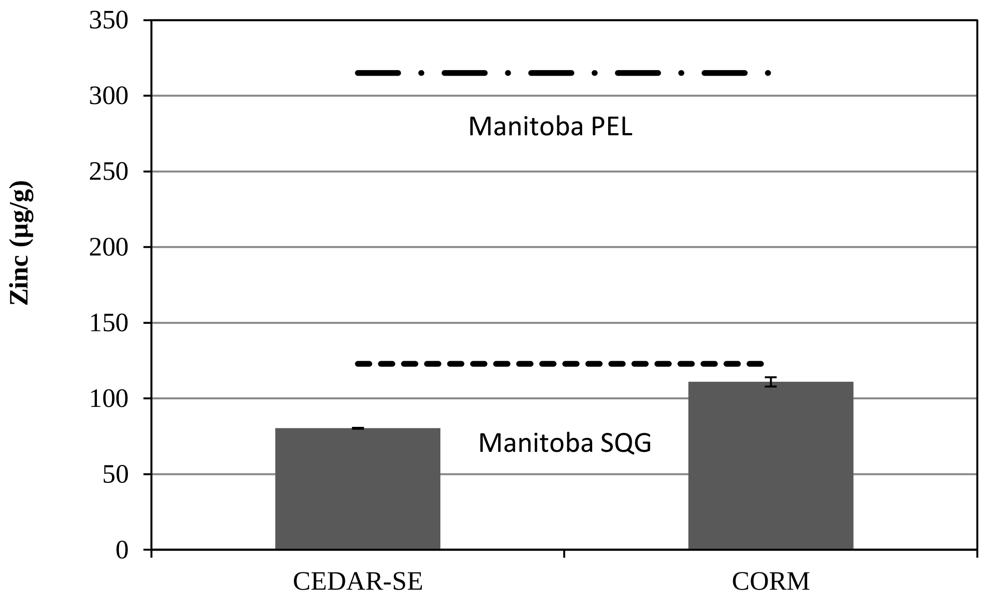


Figure 4-15. Mean (±SE) concentrations of zinc in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM) and comparison to Manitoba sediment quality guidelines.

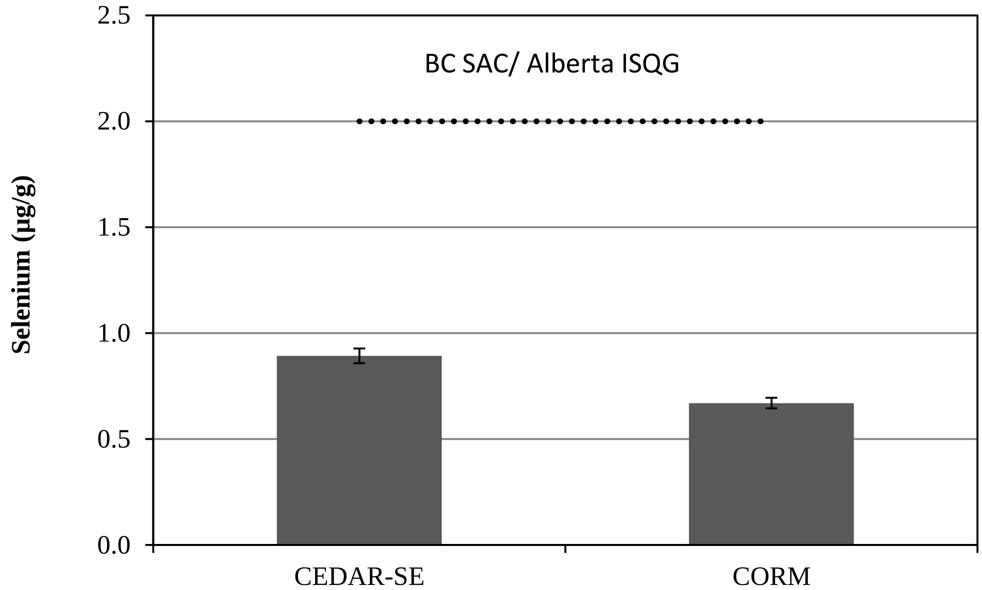


Figure 4-16. Mean (±SE) concentrations of selenium in surficial sediment from Cedar Lake - Southeast (CEDAR-SE) and Cormorant Lake (CORM) and comparison to the BC sediment alert concentration and the Alberta ISQG.

5.0 BENTHIC MACROINVERTEBRATES

5.1 INTRODUCTION

The following provides an overview of the BMI community for key metrics measured over 2010-2013 under CAMP in the SRR. Data are restricted to this four-year time period as the sampling design was modified in 2010 to reduce the inherent variability within the BMI data (Technical Document 1, Section 1.6.3). As noted in Section 1.0, waterbodies sampled annually included one on-system lake (Cedar Lake - Southeast, hereafter referred to as Cedar Lake) and one off-system lake (Cormorant Lake). Two additional on-system areas were sampled on a rotational basis, including the Saskatchewan River, within the delta at the inflow to Cedar Lake (2010, 2013) and South Moose Lake (2012; Figure 5-1).

A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 3.5. In brief, the CAMP benthic macroinvertebrate program is comprised of sample collection at nearshore (water depth ≤1 m, sampled with travelling kick/sweep) and offshore (water depth 5-10m, sampled with Ekman/petite Ponar dredge) habitat sites in the late summer/fall within each monitoring waterbody (annual and rotational). In contrast to other SRR waterbodies, the nearshore of the Saskatchewan River was sampled with an Ekman/petite Ponar due the predominance of soft, silt/clay sediments and steep shoreline in the accessible sampling area. Depending on the water level at time of sampling, sample collection in the nearshore habitat could include sites that are periodically dewatered, the frequency and duration of dewatering depending on the elevation along the shoreline where samples were collected in relation to the hydrograph. Offshore habitats were always permanently wetted.

5.1.1 Objectives and Approach

The primary objectives for the analysis of CAMP BMI data, which were directed in the terms of reference for preparation of this report, were to:

- evaluate whether there are indications of temporal trends in key BMI metrics; and
- provide an initial review of linkages between BMI metrics and key drivers, notably hydrological conditions.

The first objective (analysis of temporal changes or trends) was addressed through two approaches: (1) statistical analyses were undertaken to assess whether there were significant differences between years at annual sites; and (2) trends were examined visually through graphical plots for annual sites. The mean and standard error (± SE) were calculated to characterize key indicators for each aquatic habitat type sampled for each waterbody. Supporting environmental variables were also described to aid in the understanding of BMI metrics. It should be noted that four years of data are insufficient to detect trends over time, notably long-term trends, and the assessment was therefore restricted to qualitative assessment of the available data for sites monitored annually. Additionally, any indications of potential trends over the four year period do not necessarily imply a long-term trend is occurring, as apparent trends over this interval may simply reflect the relatively limited time period assessed in conjunction with inter-annual variability in a metric. Consideration of a longer period of record is required to evaluate for long-term trends.

The second objective (linkages with hydrological conditions) was addressed through inspection of differences among key indicators in the nearshore and offshore environments and differences in water levels and flow among sampling years. Statistical analyses were not conducted because the four years of data utilizing a consistent sampling design were not considered sufficient to support a statistical analysis.

A detailed description of the approach and methods applied for analysis and reporting is provided in Technical Document 1, Section 4.5. Site abbreviations applied in tables and figures are defined in Table 1-1. Results are presented separately for nearshore and offshore habitats, because these may be affected differently by annual changes in water levels and flows.

5.1.2 Indicators

Although a large number of indicators may be used to describe the BMI community, four key BMI indicators were selected at CAMP workshops: abundance/density; composition; taxa richness; and diversity. The metrics presented for these indicators include: total number of invertebrates; the ratio of Ephemeroptera, Plecoptera, and Trichoptera (EPT) to Chironomidae (EPT:C); total taxonomic richness (family-level); EPT richness (family-level); and Simpson's Diversity Index. A detailed description of key indicators and metrics is provided in Technical Document 1, Section 4.5.1.

In addition to descriptions of the key metrics, observations for an additional BMI metric (number of Ephemeroptera taxa) are presented in Section 5.4 to assess whether it should be included in the suite of key metrics.

Section 5.2 describes supporting habitat variables that may aid in the interpretation of BMI metrics.

5.2 SUPPORTING HABITAT VARIABLES

Supporting habitat variables consisted of: (i) measures related to water depth to enable calculation of where sampling was conducted in the nearshore zone in relation to the annual cycle of wetting and drying; and (ii) characterization of the substrate (Table 5-1). In 2010, relative benchmarks were established along the shore at each waterbody. The distance from the benchmark along the shore to the water level at time of sampling and the high water mark were recorded; a shorter distance indicates a relatively higher water level at the time of sampling (Table 5-1). Additionally, gauged water levels (i.e., elevations) and discharges were provided by Manitoba Hydro for locations in the SRR (Section 2.0). Relationships between select BMI indicators and hydrology metrics are described in Section 5.5.

Sediment samples were collected at nearshore and offshore replicate stations for particle size analysis and TOC content to provide a quantitative description of sediment composition. Results for particle size analysis and organic carbon content in the nearshore are provided in Figures 5-2 and 5-3, respectively. Particle size and organic carbon are presented for the offshore environment in Figures 5-4 and 5-5.

5.2.1 Saskatchewan River

Substrate distribution maps and overall aquatic habitat characteristics for South Moose Lake are detailed in the Aquatic Habitat Inventory, Section 8.0. Supporting habitat variables collected in conjunction with the BMI program are described below.

The nearshore habitat of on-system South Moose Lake and Cedar Lake consisted mainly of coarser, hard substrate (boulder, cobble) and, as such, supporting sediment samples were not collected for laboratory analysis (Table 5-1). Sediments at the Saskatchewan River site consisted mainly of silt/clay (60-86% silt/clay; Figure 5-2). The TOC content of nearshore sediments of the river site was low (<2%; Figure 5-3). The offshore habitat of the Saskatchewan River and on-system lakes consisted mainly of silt/clay (Figure 5-4). The TOC content of offshore habitat in the Saskatchewan River was low (<2%), while the sediments in Cedar Lake were relative rich (approximately 20% TOC) (Figure 5-5).

5.2.2 Off-system Waterbody: Cormorant Lake

The nearshore habitat of Cormorant Lake consisted of mainly large, hard substrate (boulder, cobble); as such sediment samples were not collected for laboratory analysis (Table 5-1). As with the on-system lakes, substrates are finer in the offshore habitat. However, there was a greater proportion of sand (40-63% sand) in comparison to the on-system waterbodies (Figure 5-4). TOC content was consistently low (approximately 1%; Figure 5-5).

5.3 KEY INDICATORS

5.3.1 Total Number of Invertebrates

Differences in the numbers of organisms are influenced by a variety of physical (e.g., substrate type, flow conditions), biological (e.g., benthic algal biomass), and chemical (e.g., dissolved oxygen and nutrient concentrations) factors. As such, the total number of invertebrates measured in a waterbody is a reflection of numerous aquatic habitat variables that have been integrated by the community over time.

Comparative abundances for all sites and years for the nearshore environment are provided in Figure 5-6. Yearly results for the offshore environment are provided in Figure 5-7.

5.3.1.1 Saskatchewan River

The mean total abundance of BMIs in nearshore habitat varied among years at Cedar Lake. Abundance was comparable to South Moose Lake when both sites were sampled in the same year (Figure 5-6). Abundance at the Saskatchewan River site was similar in both years of sampling (2010 and 2013) but cannot be compared to the data gathered at the lake sites, due to the difference in sampling method.

Despite a nearly threefold change in overall abundance, the composition of the invertebrate community in the nearshore of Cedar Lake was fairly consistent between 2010 and 2011: in both years, non-insects comprised an average of 81% of the sampled invertebrates, and amphipods were the dominant non-insect taxon. In 2012 and 2013, the proportion of non-insects to insects was roughly even and amphipods remained the predominant non-insect group. The abundance of amphipods is likely linked to the suitability of the nearshore habitat, where the cobble shoreline likely provides suitable food in the form of detritus and attached algae (periphyton). The composition of the insect community varied among years, with Ephemeroptera being predominant in all years except 2013, when Corixidae were the most abundant insect group. As with the non-insects, the insects were dominated by herbivores/detritivores. South Moose Lake was only sampled in 2012; at this time non-insects comprised approximately 80% of the catch. Amphipods were common (24%) but Oligochaeta, which were almost absent in Cedar Lake, comprised almost 40% of the catch. Chironomidae and Ephemeroptera were the predominant insect groups.

The nearshore BMI community at the Saskatchewan River site was comprised primarily of Oligochaeta and Ephemeroptera, specifically Ephemeridae (burrowing mayflies); both groups are typical of silt/clay sediments. However, the relative abundance differed among years, with

Ephemeroptera comprising ~60% of the catch in 2010 and Oligochaeta comprising ~ 70% of the catch in 2013.

As with the nearshore habitat, the mean density of BMIs in offshore habitat in Cedar Lake varied among years and was greatest in 2011; overall abundance in Cedar Lake was higher than other waterbodies in the SRR (Figure 5-7). As in the nearshore, non-insects were more abundant than insects; however, the major non-insect groups were comprised of not only Amphipoda, but also Oligochaeta and Bivalvia, which were uncommon in the nearshore. As is often observed in deep water environments with a fine substrate, Chironomidae comprised the majority of the insects captured, but numbers varied considerably among years. Many of the groups collected were detritivores, and the relatively higher mean density of BMIs may reflect the notably higher TOC content of sediments in Cedar Lake compared to other on-system waterbodies (Section 5.2.1). In addition to the Chironomidae, the relative abundance of Oligochaeta was also quite variable, going from 48% of all organisms collected in 2012 to virtually absent in 2013. This indicates a high degree of spatial and/or temporal variability. The higher density in 2011 appears to be due to an increased density of Bivalvia and Chironomidae relative to other sampling years.

The total density of invertebrates in offshore Moose Lake were less than half that recorded in Cedar Lake. As with Cedar Lake, the majority of invertebrates were non-insects, with Oligochaeta and Bivalvia being most abundant. In contrast to Cedar Lake, Amphipoda were uncommon, which may be related to the lower amount of organic matter (Table 5-1). Almost all insects were Chironomidae.

Insects and non-insects were present in roughly equal proportions in offshore samples collected from the Saskatchewan River in 2010 and 2013, and Oligochaeta were the dominant taxon in both years. Trichoptera and Bivalvia were also abundant in both years, each accounting for a minimum of 15% of the organisms collected. This site was the only location where Trichoptera formed a notable portion of the sample. Trichoptera were Hydropsychidae, which build nets to filter material from flowing water. The insect community in the riverine offshore environment also included burrowing species of Ephemeroptera, as was observed in the nearshore, and Chironomidae.

5.3.1.2 Off-system Waterbody: Cormorant Lake

The mean abundance of BMIs in the nearshore habitat of Cormorant Lake was lower than abundances observed for on-system lakes in all sampling years (Figure 5-6). Similar to on-system lakes, the nearshore habitat of Cormorant Lake consisted of large, hard substrate (mainly boulder with cobble; Section 5.2). Insects were relatively more abundant than non-insects in all years other than 2013, when both groups were approximately equally represented. The non-insects were comprised principally of Oligochaeta and Amphipoda, though relative abundances were highly variable. Ephemeroptera and Chironomidae comprised a substantial portion of the insects in 2010 and 2012 but other insects, including other dipterans comprised a substantial part of the community in 2011 and 2013.

The mean density of BMIs in the offshore habitat of Cormorant Lake was lower in comparison to densities observed for Cedar Lake but comparable to other on-system sites (Figure 5-7). The offshore habitat of Cormorant Lake consisted of a greater proportion of sand in comparison to the on-system lakes (Section 5.2). Similar to Cedar Lake, non-insects were consistently more abundant than insects, although the difference was less pronounced in 2010 than other years (2011-2013). Amphipoda consistently formed a substantial part of the community. While Bivalvia and Gastropoda were less abundant, they each generally accounted for 10-20% of the organisms collected. In contrast to the on-system lakes where Chironomidae were relatively the most abundant insect, both Chironomidae and Ephemeroptera were relatively abundant.

5.3.1.3 Temporal Comparisons and Trends

Abundance of BMIs differed among years, but there were no years were abundance was significantly greater or less than all other years (Figures 5-6 and 5-7). There were no indications of increasing or decreasing trends over the four year sampling period at sites sampled annually.

The relationship between water levels and flows and abundance is discussed in Section 5.5.

5.3.2 Ratio of EPT to Chironomidae

Ephemeroptera, Plecoptera, and Trichoptera are generally considered to be more sensitive, and Chironomidae less sensitive, to environmental stress (e.g., nutrient enrichment, low dissolved oxygen concentrations). Although Chironomidae are often described as being tolerant to adverse conditions, many taxa belong to this group and the perceived tolerance of the group as a whole may be attributable to only a few taxa. Chironomidae are relatively more abundant on fine textured sediments (e.g., silt/clay, sand) than Ephemeroptera, Plecoptera, and Trichoptera. Fine substrates are more common in deeper areas of waterbodies, especially with less water flow; therefore, a low EPT:C ratio may also reflect differences in substrate.

The ratio of EPT:C for all sites and years for the nearshore environment are provided in Figure 5-8. Yearly results for the offshore environment are provided in Figure 5-9.

5.3.2.1 Saskatchewan River

The mean ratio of EPT to chironomids (EPT:C) in nearshore habitat varied considerably among years and on-system lakes (Figure 5-8). Nearshore habitat in the Saskatchewan River and on-system lakes was typically dominated by EPT (ratios of 9.0 to 10.7 at the river site, ratio of 1.7 at South Moose Lake, and ratios of 2.0 to 17.1 at Cedar Lake -Southeast). The dominance of EPT is expected in areas where the substrate consists of coarse material (boulders and cobble). The ephemeropterans at the Saskatchewan River site were numerically abundant in comparison to chironomids, despite the presence of fine-textured sediments due to the presence of burrowing species.

The mean EPT:C in offshore habitat varied minimally among years and somewhat among on-system lakes but was less than 0.5 in both South Moose Lake and Cedar Lake - Southeast (Figure 5-9). The predominance of chironomids is expected on the fine-textured sediments of these sites. EPT continued to be numerically dominant in the offshore habitat of the Saskatchewan River (Figure 5-9). The exceptionally high ratio of 148.6 in 2013 was due to the absence of chironomids at two replicate stations; when these two replicates were removed, the ratio decreased to 12.0. The relative scarcity of Chironomidae in the offshore of the Saskatchewan River site is unexpected, given the substrate composition.

5.3.2.2 Off-system Waterbody: Cormorant Lake

Similar to the on-system Cedar Lake - Southeast, the mean EPT:C ratio in the nearshore habitat of Cormorant Lake fluctuated among years (Figure 5-8). EPT:C ratios in 2010 (0.6) and 2012 (0.4) indicated a predominance of chironomids, whereas those in 2011 (4.6) and 2013 (2.0) indicated EPT were more numerically abundant in comparison to chironomids.

In 2010 and 2011, the EPT:C ratio in the offshore of Cormorant Lake was near one; however, in 2012 and 2013 the ratio increased to near three and was notably higher than on-system lakes (Figure 5-9).

5.3.2.3 Temporal Comparisons and Trends

The EPT:C ratio exhibited notable inter-annual variability, including statistically significant differences in both the on-system and off system annual sites (Figures 5-8 and 5-9). No obvious increasing or decreasing trends were noted for the annual sites over the four year sampling period.

The potential relation to water levels is discussed in Section 5.5.

5.3.3 Total Richness

The number of unique taxa (total taxonomic richness) reflects habitat diversity, with more diverse habitats typically supporting a richer fauna than less diverse habitats. Richness also provides information about the degree of perturbation (either natural [e.g., increased scouring during high flow events] or anthropogenic [e.g., increased suspended sediments in surface waters related to surface disturbance]) that has occurred at a site, with sampling events associated with more taxa often suggesting that fewer perturbations have recently occurred at that site.

Total richness for all sites and years for the nearshore environment are provided in Figure 5-10. Yearly results for the offshore environment are provided in Figure 5-11.

5.3.3.1 Saskatchewan River

The mean total richness (family-level) of BMIs in nearshore habitat was relatively consistent over time at the Cedar Lake site and the two years of sampling on the Saskatchewan River (Figure 5-10). Total richness in the predominantly boulder with cobble nearshore of on-system lakes was lower in South Moose Lake (2012, 15 families) than in Cedar Lake - Southeast (2012, 21 families). In the predominantly clay substrate of the nearshore habitat sampled in the Saskatchewan River, total richness was much lower (6 families).

The mean total richness of BMIs in offshore habitat displayed similar patterns to that observed in the nearshore habitat, although the total number of families was lower. Richness was comparable among years at the Cedar Lake site and the Saskatchewan River site. Cedar Lake was again the richest site (11 families, 2012), in comparison to South Moose Lake (5 taxa) (Figure 5-11). In the offshore habitat sampled in the Saskatchewan River, total richness was lower than Cedar Lake but comparable to Moose Lake with between six and seven families represented.

5.3.3.2 Off-system Waterbody: Cormorant Lake

The mean total richness of BMIs in the nearshore habitat of off-system Cormorant Lake was comparable to that observed in Cedar Lake – Southeast in 2010-2012, but markedly lower in 2013, when richness was comparable to South Moose Lake (Figure 5-10).

As with the nearshore sites, the mean total richness of BMIs in the offshore habitat of Cormorant Lake was comparable to the range observed in Cedar Lake - Southeast (Figure 5-11).

5.3.3.3 Temporal Comparisons and Trends

Total taxonomic richness was comparable among years at the Cedar Lake and Saskatchewan River sites in both the nearshore and offshore (Figures 5-10 and 5-11). Richness tended to decrease during 2010-2013 at the Cormorant Lake site in both the nearshore and offshore, although, as discussed below, this change may reflect extreme high water that occurred on the lake during this period, rather than a long-term trend. The potential relation to water levels is discussed in Section 5.5.

5.3.4 Ephemeroptera, Plecoptera, and Trichoptera Richness

EPT richness is the total number of distinct taxa (family-level) within the groups, Trichoptera, Ephemeroptera, and Plecoptera. EPT richness as an indicator of aquatic health is based on the premise that high-quality waterbodies typically have the greatest richness.

EPT richness for all sites and years for the nearshore environment are provided in Figure 5-10. Yearly results for the offshore environment are provided in Figure 5-11.

5.3.4.1 Saskatchewan River

The mean EPT richness (family-level) in nearshore habitat of on-system waterbodies followed a pattern similar to that for total richness (Figures 5-10).

The mean EPT richness in offshore habitat varied minimally among years and was low, with up to an average of three families present (Figures 5-11).

5.3.4.2 Off-system Waterbody: Cormorant Lake

In the nearshore of Cormorant Lake, mean EPT richness was higher than (2010), lower than (2011, 2013), and within the range of (2012) richness values observed for on-system lakes (Figure 5-10). With the exception of 2012, the mean EPT richness in the offshore habitat of Cormorant Lake was somewhat higher than that for on-system lakes and varied between two and four families represented (Figure 5-11).

5.3.4.3 Temporal Comparisons and Trends

EPT richness exhibited notable inter-annual variability, including statistically significant differences (Figures 5-10 and 5-11). There is a possible decreasing trend in the nearshore habitat of Cormorant Lake; no obvious trends were noted for Cedar Lake - Southeast over the four year sampling period.

Potential relationship to water levels and flows is discussed in Section 5.5.

5.3.5 Simpson's Diversity Index

Simpson's Diversity Index may provide more information about benthic macroinvertebrate community structure than abundance or richness alone. Simpson's Diversity Index summarizes the relative abundance of various taxa and provides an estimate of the probability that two individuals in a sample belong to the same taxa. Simpson's Diversity Index de-emphasizes rare taxa, while highlighting common taxa and evenness among taxa (i.e., similarity of population sizes of different species; Mandaville 2002). The higher the index, the less likely it is that two individuals belong to the same taxa and indicates that the taxa present are similar in relative abundance (Magurran 1988, 2004). Simpson's Diversity Index values range from zero (indicating a low level of diversity) to one (indicating a high level of diversity).

Simpson's Diversity Index for all sites and years for the nearshore environment are provided in Figure 5-12. Yearly results for the offshore environment are provided in Figure 5-13.

5.3.5.1 Saskatchewan River

Simpson's Diversity Index for the BMI community in nearshore and offshore habitats of on-system lakes varied little, generally ranging from 0.7-0.8 (Figures 5-12 and 5-13). Diversity was lower at the Saskatchewan River site, ranging from 0.47 and 0.59.

5.3.5.2 Off-system Waterbody: Cormorant Lake

The diversity index in Cormorant Lake was generally similar to that in the on-system lakes, typically ranging from 0.7-0.8, although it was marginally higher in the nearshore in 2011 and lower in offshore in 2013 (Figures 5-12 and 5-13).

5.3.5.3 Temporal Comparisons and Trends

Simpson's Diversity Index exhibited inter-annual variability, including statistically significant differences, but the magnitude of differences was small (Figures 5-12 and 5-13).

5.4 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

Ephemeroptera have been identified as being sensitive to environmental disturbances (e.g., increased shoreline erosion, increased frequency in water level fluctuation; Mandaville 2002; Merritt and Cummins 1996). Ephemeroptera richness (genus-level) was examined as this metric may be useful over time for describing trends at sites and illustrating linkages to hydrology, as well as to other physical (i.e., habitat) and chemical (i.e., surface water quality) metrics as additional data are acquired through CAMP.

5.4.1 Ephemeroptera Richness

5.4.1.1 Saskatchewan River

Ephemeropteran richness in the predominantly boulder with cobble nearshore of on-system lakes varied from a low of three genera in South Moose Lake (2012) and Cedar Lake - Southeast (2013) to a high of five genera in Cedar Lake - Southeast (2012; Figure 5-14). In the predominantly clay substrate of the nearshore habitat sampled in the Saskatchewan River, ephemeropteran richness was lower than in the on-system lakes with only one genus represented.

In the offshore habitat, an average of only one or two Ephemeroptera genera were represented (Figure 5-15).

5.4.1.2 Off-system Waterbody: Cormorant Lake

Overall, mean Ephemeroptera richness in Cormorant Lake was similar to that of Cedar Lake - Southeast (Figures 5-14 and 5-15).

5.4.1.3 Temporal Comparisons and Trends

Ephemeroptera richness varied among years, including some statistically significant differences (Figures 5-14 and 5-15). No obvious increasing or decreasing trends were noted for the annual sites over the four year sampling period.

5.5 RELATIONSHIPS WITH HYDROLOGICAL METRICS

Changes in water level will primarily affect benthic communities in the shallow margins of waterbodies. Typically, chironomids and oligochaetes are able to tolerate the conditions of periodic exposure in the upper littoral zone as well as be able to rapidly take advantage of newly wetted habitat, colonizing bare substrates within a month (Fisher and Lavoy 1972; Scheifhacken et al. 2007). Other invertebrate groups are less tolerant of exposure, resulting in reduced species diversity in habitats that are frequently dewatered. In riverine habitats, changes in discharge can also affect aquatic invertebrate assemblages by causing an increase in drift, whereby organisms leave the substrate and are carried downstream.

Water level and discharge may also affect the offshore invertebrate community through indirect means, such as increased sedimentation occurring after high water levels or discharge erode shorelines and mobilize sediments. Hydrology may also affect trophic conditions (e.g., nutrients) and other factors such as water temperature.

Given that only four years of benthic invertebrate data were collected from the annual sites using the current sampling design, statistical analyses comparing average water levels and flows during the open water season prior to invertebrate sample collection (i.e., the “growing season” for a particular sampling event) and key indicators for which the preceding statistical analysis showed significant between year differences (i.e., total abundance, richness and diversity) was not conducted. However, both nearshore and offshore data were inspected in relation to average water levels and flows to determine whether a relationship might be present that would merit further examination when more data are available.

Examination of the seasonal hydrographs indicated considerable variation over the growing season, with little consistency among years (i.e., in some years lowest levels occurred in spring and water levels increased through the growing season, in others water levels declined during summer, while in others there were erratic peaks). Given the importance of dewatering and the duration of wetting to invertebrate colonization of nearshore habitat, seasonal hydrographs were inspected to determine whether the duration of wetting could have contributed to observed inter-annual differences.

5.5.1 Summary of Seasonal Water Levels and Flows on SRR Waterbodies, 2010-2013

During 2010-2013, flows in the Saskatchewan River during the open-water season ranged from average (2010) to somewhat above average (2012), to high flood flows in 2011 and 2013. By late summer/fall, during sample collection, flows had generally moderated to average summer levels, although at times they were still above typical fall levels. Water level on Cedar Lake is regulated such that, despite the difference in inflow, water elevation during sampling was near average, at the upper end of the annual range of the lake. Typical overwinter drawdown is two metres but during 2010-2013, drawdown was generally 1 m and in 2012 only ~0.5 m.

South Moose Lake is also regulated, but water levels are managed to limit drawdown and the typical range on the lake is less than 0.5 m. During the year of sampling (2012), water level was at or above the upper quartile but varied little (<0.3 m) during the course of the preceding year.

Cormorant Lake, the off system reference waterbody, experienced high local inflows beginning in 2011. Water levels rose from average in 2010, to above upper quartile in 2011 and 2012, to record levels in 2013. The average seasonal range in Cormorant Lake is 0.5 m; elevation in 2011-2013 was ~0.3-0.7 m above maximum average summer levels.

5.5.2 Potential Relationships between BMI Monitoring Results and Seasonal Water Levels and Flows

Data collected to date indicate that the BMI community of the SRR is well-adapted to at least some of the major hydrological effects of flow regulation. The benthic community in the nearshore of Cedar Lake was comparable in abundance to South Moose Lake and 2-5 times more abundant than that of the off-system reference lake (Cormorant Lake) (Figure 5-6). However, with the exception of 2012, the entire area sampled at the Cedar Lake site would have been dewatered during the winter months, and invertebrates would need to have either survived freezing conditions or re-colonized in spring. This annual disruption also does not result in the loss of taxa, as richness was comparable to the natural Cormorant Lake and considerably greater than South Moose Lake, where most of the area sampled was not dewatered on an annual basis (Figure 5-10).

The BMI site on the Saskatchewan River is located where the river enters the delta of Cedar Lake, but the environment appears markedly different from the Cedar Lake site, based on the dominance of burrowing Ephemeroptera and the presence of Trichoptera in offshore habitat. This site was sampled after average flows in 2010 and flood flows (twice average) in 2013, but abundance and richness was comparable in both years. There were some marked changes in relative abundance, for example in 2012, Oligochaeta comprised a small portion of the nearshore fauna while in 2013 they dominated; however, this may not be directly attributable to changes in water flow, as a similar pattern was evident in the offshore zone. The relatively harsh environment at this location supports fewer species, resulting in lower diversity, despite the high abundance of individual taxa (e.g., burrowing mayflies).

The abundance of invertebrates in the offshore of Cedar Lake was markedly higher than all other areas of the SRR (2-5-fold) (Figure 5-7). The high abundance may be due to the high TOC levels in the sediments; however, there was no evidence of loss of taxa (reduced richness) as a result of this enrichment in comparison to other SRR sites; in fact richness was considerably higher than at either the river site or South Moose Lake (Figure 5-11). Simpson's index of diversity was also high, indicating that a range of taxa were well represented (Figure 5-13).

BMI abundance in Cedar Lake was much greater than in Cormorant Lake in both the nearshore and offshore (Figures 5-6 and 5-7). Richness and diversity in Cormorant Lake was marginally higher in 2010 and 2011 than 2012 and 2013. As discussed above, samples collected in the nearshore in 2013 would have been in areas that had not been wetted earlier in the growing season and so may have been adversely affected. However, a similar pattern of decreasing richness was observed in the offshore, indicating that other environmental factors may have contributed to the observed change.

As noted previously, four years of data are insufficient to support a statistical analysis to determine whether average water levels or discharge during the growing season are related to key benthic invertebrate metrics. However, key metrics in relation to the average water level and discharge during the growing season during a given year in the two annual lakes were inspected to determine whether there were any obvious relationships (Table 5-2, Figures 5-16 and 5-17). Water levels on Cedar Lake are regulated and average water level during the growing season was relatively constant. As such, there was no relationship observed between water level and metrics calculated for the nearshore BMI community (Table 5-2). Water levels on unregulated Cormorant Lake during the growing season were more variable, but there was no indication of a consistent relationship with key BMI metrics (Table 5-2). BMI abundance and species composition in the offshore environment is not directly affected by episodic wetting and drying and may, therefore, be more responsive to average conditions during the growing season. Inspection of graphs indicting results for invertebrate abundance, richness, and diversity for Cedar (Figure 5-16) and Cormorant (Figure 5-17) lakes does not indicate a clear relationship, at least within the range of conditions sampled during 2010-2013. As more data are gathered over a greater range of hydrological conditions, relationships with water levels and discharge may become apparent.

5.6 SUMMARY

The BMI community of the lakes of the SRR was generally dominated by Amphipoda, Ephemeroptera and, in some sites, Oligochaeta, in the cobble nearshore habitat, and primarily Oligochaeta, Chironomidae, Amphipoda, and Bivalvia in the fine-textured sediments of the offshore habitat. Non-insects were often more abundant than insects. The BMI were variable both among years and within years at a sampling site.

The BMI community at the Saskatchewan River site was much less diverse, and was dominated by Oligochaeta and one genus of burrowing Ephemeroptera.

Invertebrate density at Cormorant Lake, the off-system lake in the SSR, was lower than the on-system lakes, but species richness and diversity were similar to Cedar Lake. The same major BMI groups dominated, although insects tended to be relatively more abundant than non-insects.

The invertebrate community, in terms of total abundance, richness and diversity, showed remarkably little effect of two major perturbations associated with flow regulation, including overwinter dewatering (Cedar Lake, 2010, 2011, 2013) and high flood flows in a river channel (Saskatchewan River, 2011). Moreover, the BMI of a highly regulated lake (Cedar Lake) were comparable to or greater in abundance, richness and diversity than a lake that experienced less effects of flow regulation (South Moose Lake) or the off-system reference lake (Cormorant Lake).

Overall, analysis of the four years of BMI data collected in the SRR indicated that most of the key metrics, including the additional metric Ephemeroptera richness, did not show a consistent increasing or decreasing trend over this time period. The one exception occurred in the nearshore habitat of the off-system Cormorant Lake where a decreasing trend in total richness was apparent and statistically significant. While other consistent temporal trends were not noted, statistically significant inter-annual variability was observed for metrics in the two habitat types sampled (e.g., EPT:C ratio in the nearshore and offshore of Cedar Lake - Southeast and Cormorant Lake; Simpson's Diversity Index in the offshore habitat of Cedar Lake - Southeast and Cormorant Lake).

Table 5-1. Supporting variables measured in the nearshore and offshore habitats of the Saskatchewan River Region: 2010 – 2013.

Waterbody	Date	Nearshore				Offshore				Relative Water Level[3]		Gauged Water Level (daily mean)	
		Water Depth (mean max, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description[1]	Benthic Substrate Texture/Analysis[1, 2]	Water Depth (mean, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description (predominant)	Benthic Substrate Texture/Analysis[1]	Current (m)	High (m)	(WSL m)	(Q m^3/s)
SASK	4-Sep-10	0.8	medium	clay, organic matter	silt loam	6.4	low	clay, organic matter	silty clay loam (loam)	0.72	n.r.	--	807.00
CEDAR-SE	9-Sep-10	0.5	standing	boulder, cobble	--	6.2	standing	clay, organic matter	clay loam (sandy clay loam)	1.03	n.r.	256.28	--
CORM	6-Sep-10	0.9	standing	boulder, cobble	--	7.4	standing	clay, organic matter (sand)	sandy loam (clay)	1.28	n.r.	256.23	--
CEDAR-SE	27-Aug-11	0.6	standing	boulder, cobble (gravel)	--	6.2	standing	organic matter, silt	clay loam, loam	0.92	0.92	256.46	--
CORM	29-Aug-11	1.0	standing	boulder, cobble	--	7.9	standing	clay, silt, organic matter	loam	0.71	n.r.	256.79	--
SMOOSE	21-Aug-12	1.2	standing	cobble, boulder	--	6.8	standing	clay, silt	silt (silt loam)	0.63	0.63	256.43	--
CEDAR-SE	28-Aug-12	0.8	standing	cobble, boulder	--	6.2	standing	organic matter, silt	loam	1.20	n.r.	256.39	--
CORM	22-Aug-12	1.2	standing	cobble, boulder (gravel)	--	8.0	standing	clay, silt	loam (clay loam, sandy loam)	0.59	0.47	256.89	--
SASK	25-Aug-13	0.3	standing	clay	loam (silt loam)	6.3	low	clay	loam, silty clay, sand	0.65	0.35	--	906.00
CEDAR-SE	17-Aug-13	0.4	standing	boulder, cobble	--	6.1	standing	organic matter	silt loam	1.05	0.60	256.33	--
CORM	23-Aug-13	0.8	standing	boulder (cobble)	--	8.3	standing	clay	sandy loam (loamy sand)	0.28	0.00	257.25	--

[1] substrate type and texture: parentheses indicate present to a lesser extent.
[2] -- indicates habitat type not sampled (due to high water velocity) or no sediment sample collected (due to predominantly hard substrate).
[3] Relative water level is the distance up the shore to the benchmark installed for the BMI program.
n.r means data was not recorded.

Table 5-2. Average abundance, total richness, Simpson's Diversity, and hydrological metrics (average water level and discharge for the "growing season") for Cedar Lake and Cormorant Lake in the nearshore and offshore environments, 2010 to 2013.

Cedar Lake

Year	Abundance (Number/Kicknet Or Number/m^2)	Richness	Diversity	Water Level (mASL)	Discharge (m^3/s)
Nearshore					
2010	1068	19.60	0.69	256.2	934.6
2011	2712	21.00	0.76	256.4	1903.5
2012	1995	21.40	0.78	256.3	1196.7
2013	1588	18.20	0.76	256.2	1551.9
Offshore					
2010	5081	9.20	0.79	256.2	919.3
2011	9612	10.20	0.79	256.4	1903.5
2012	6766	11.00	0.71	256.3	1196.7
2013	4011	10.80	0.81	256.2	1551.9

Cormorant Lake

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	644	19.60	0.77	256.2	no data
2011	514	17.80	0.79	256.6	no data
2012	756	16.20	0.72	257.0	no data
2013	244	11.40	0.65	256.9	no data
Offshore					
2010	1927	12.80	0.82	256.2	no data
2011	2023	11.60	0.86	256.6	no data
2012	1195	9.40	0.75	257.0	no data
2013	1907	8.60	0.72	256.9	no data

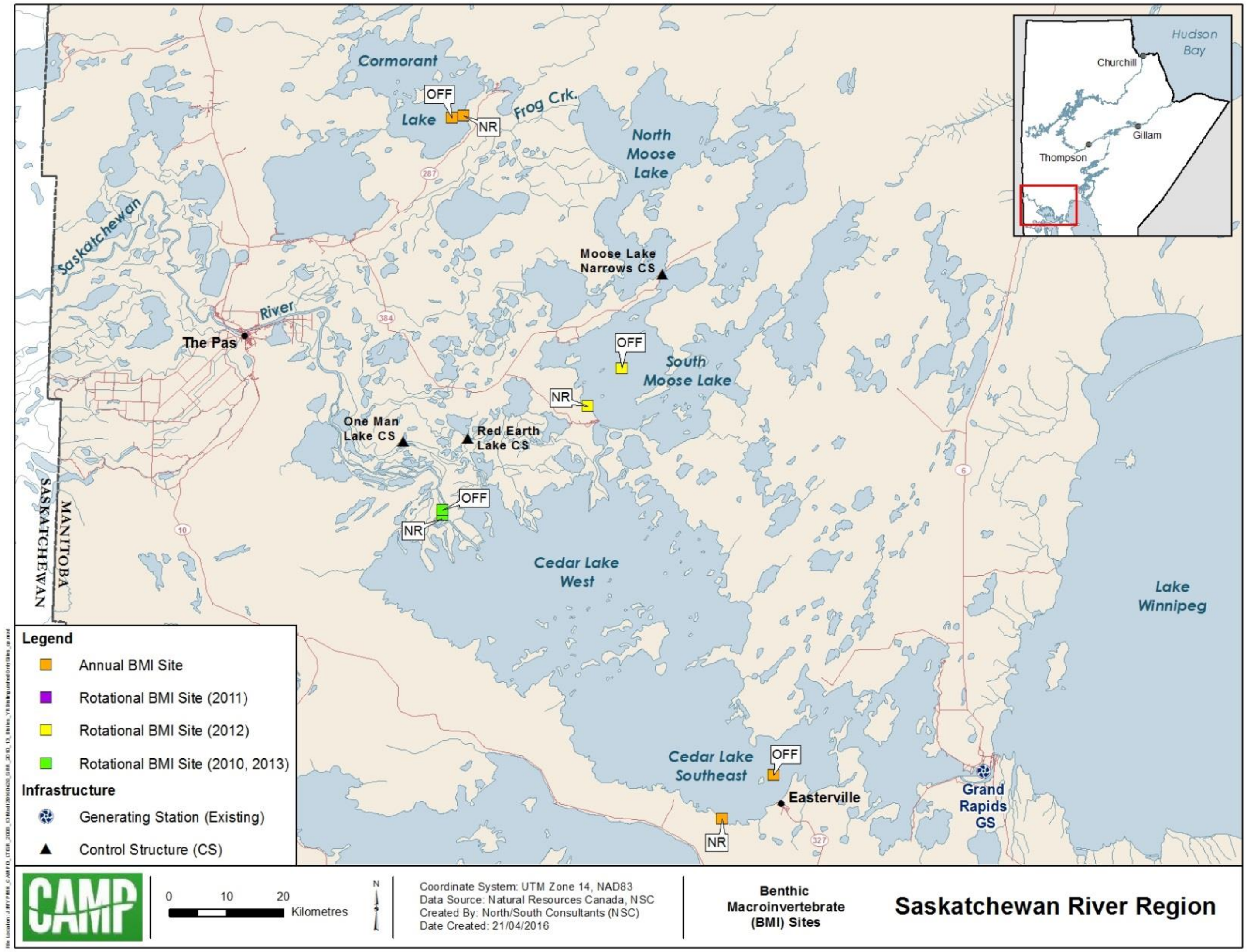
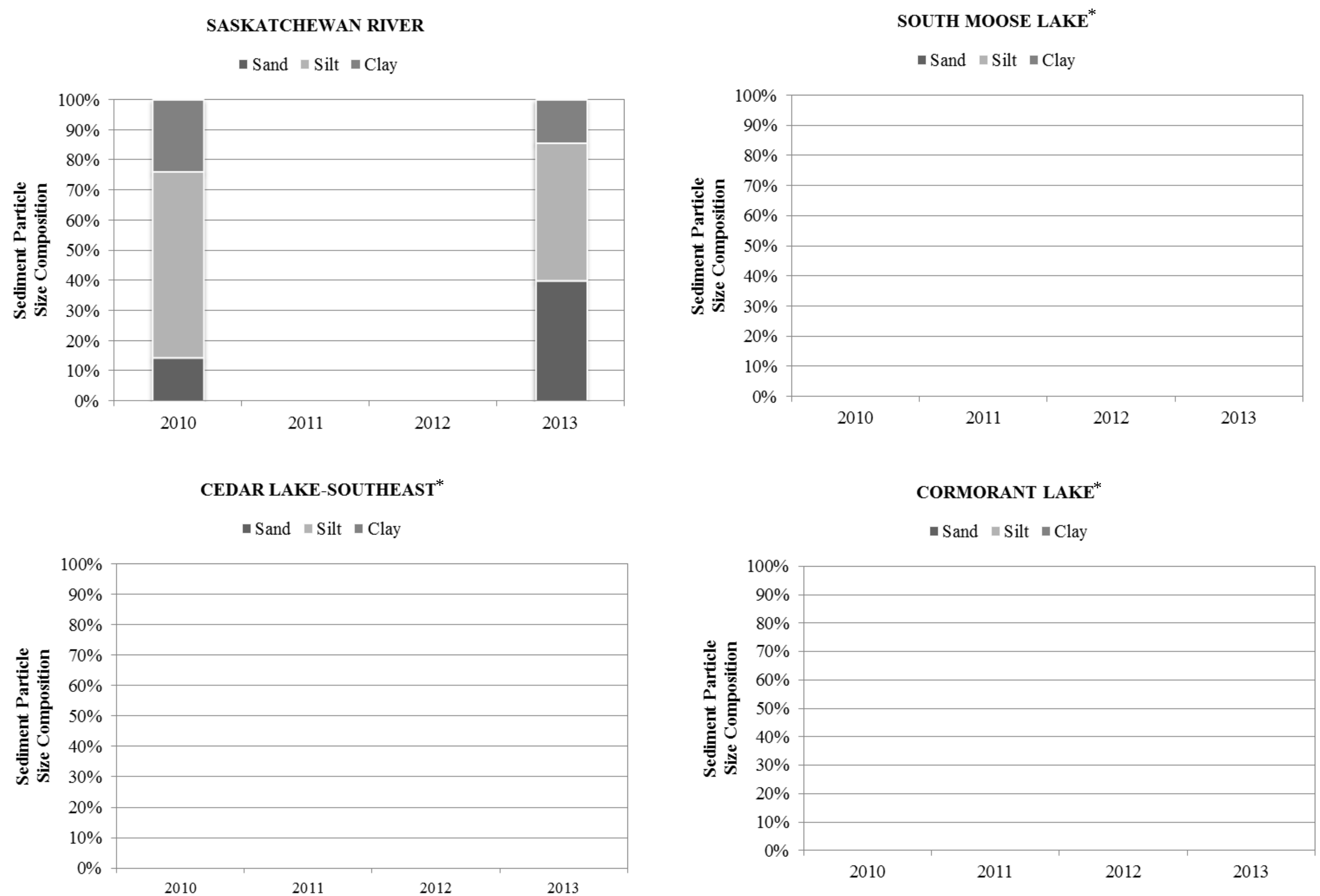
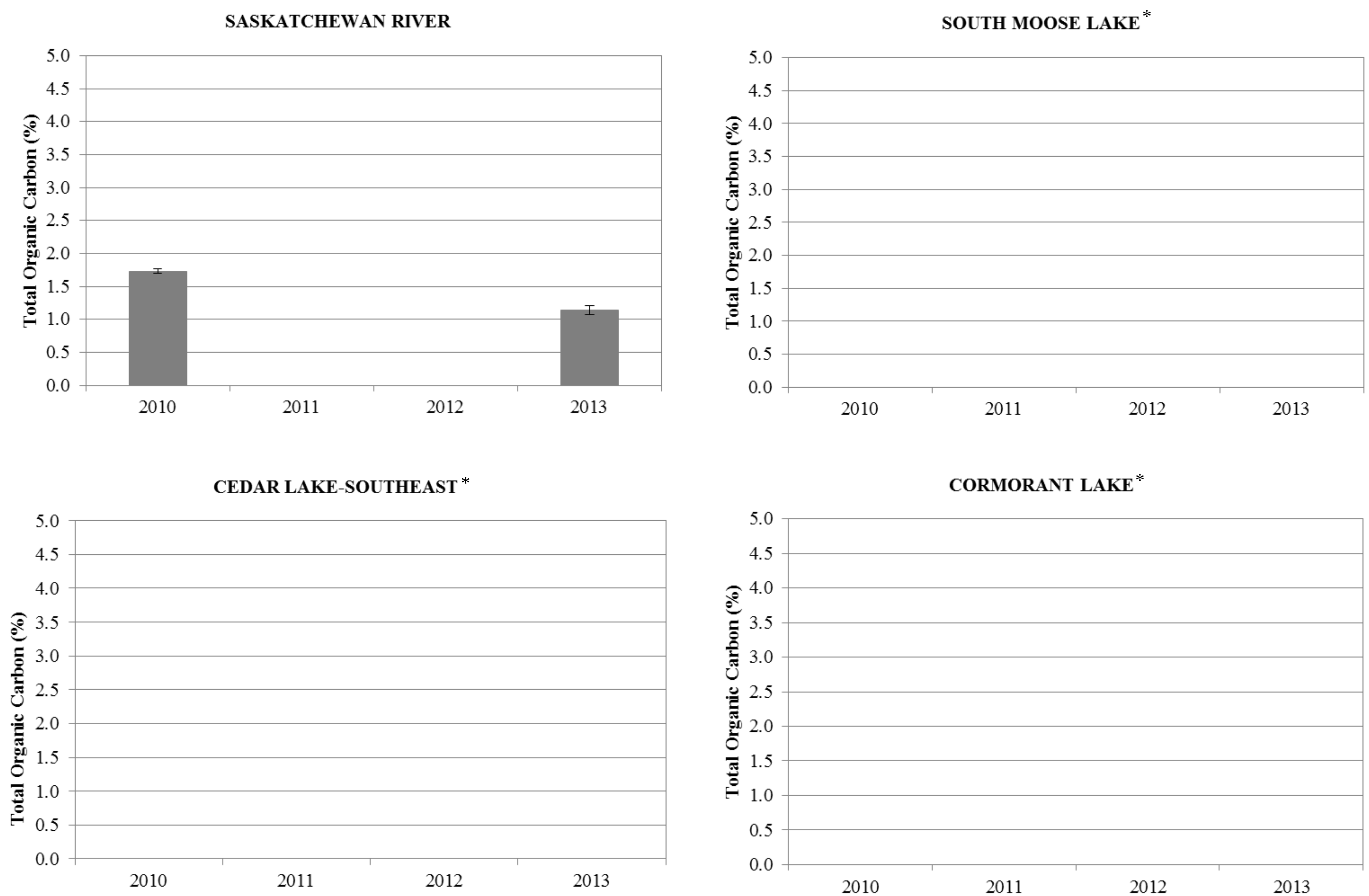


Figure 5-1. Benthic macroinvertebrate sampling sites in the Saskatchewan River Region: 2010 – 2013.



* No sediment samples collected at South Moose Lake, Cedar Lake – southeast, and Cormorant Lake due to predominantly hard substrate.

Figure 5-2. Sediment particle size composition (mean % of sand, silt, clay) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013.



* No sediment samples collected at South Moose Lake, Cedar Lake – southeast, and Cormorant Lake due to predominantly hard substrate.

Figure 5-3. Total organic carbon (mean ± SE) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013.

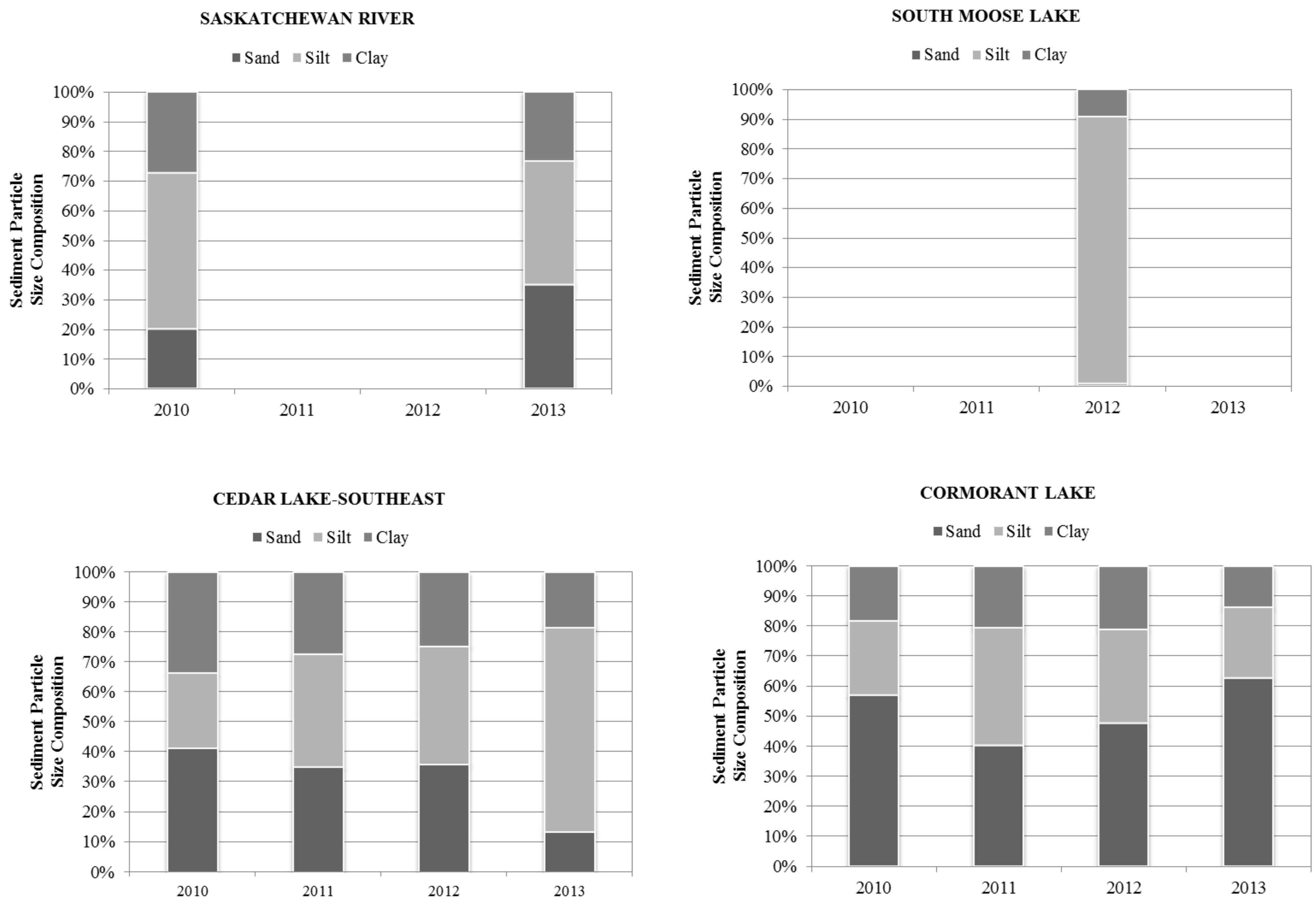


Figure 5-4. Sediment particle size composition (mean percent of sand, silt, clay) in the offshore habitat of the Saskatchewan River Region, by year: 2010 – 2013.

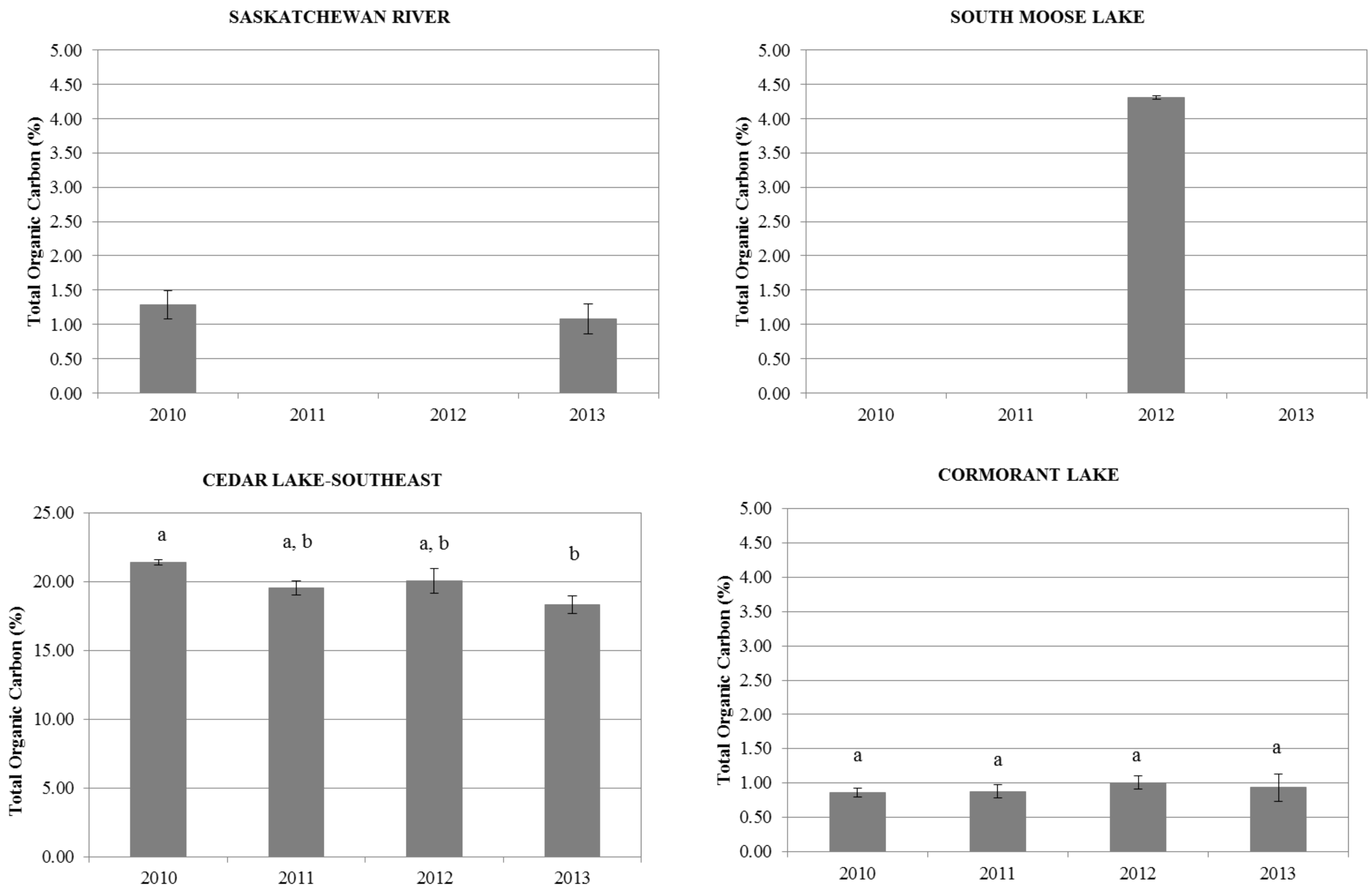


Figure 5-5. Total organic carbon (mean ± SE) in the offshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

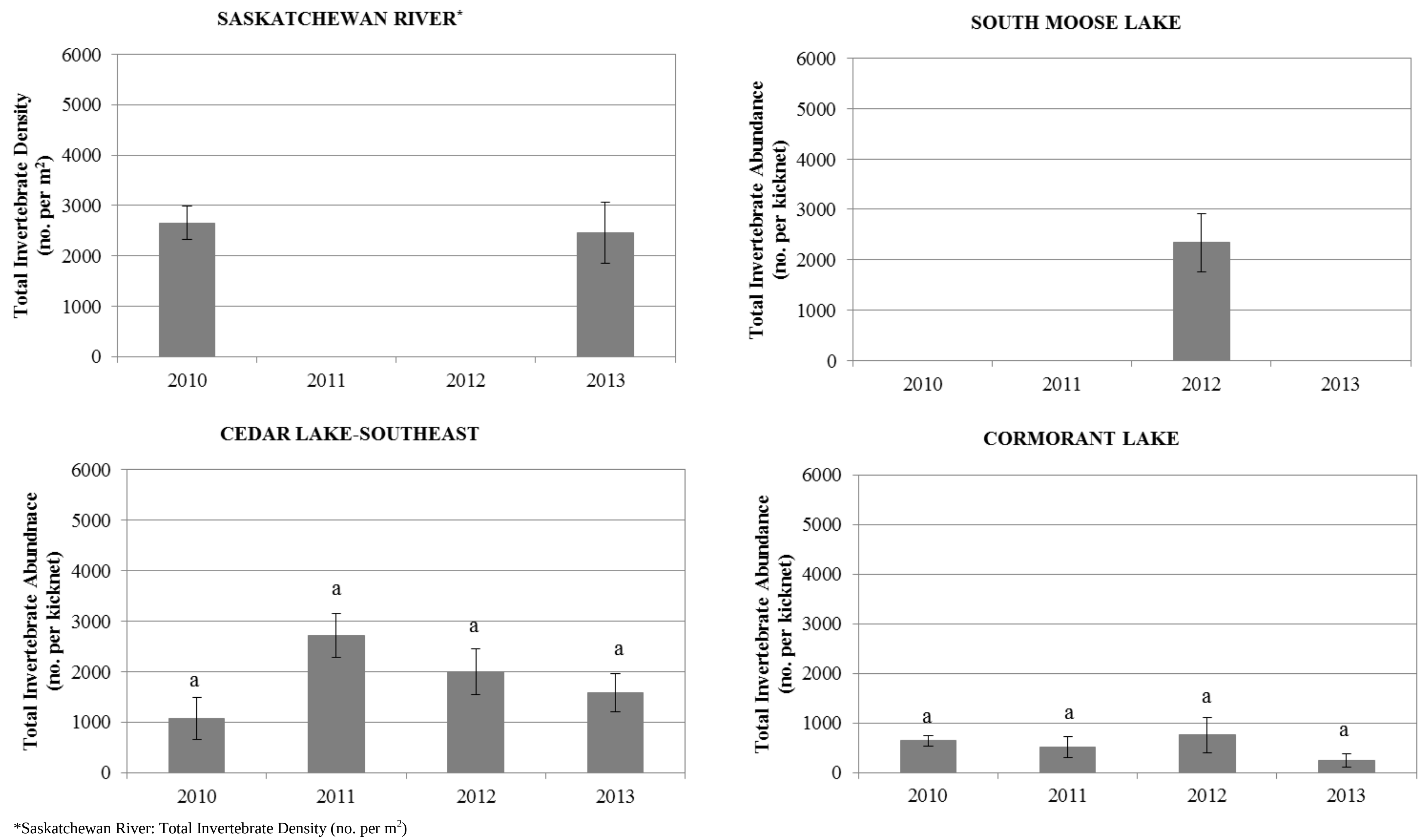


Figure 5-6. Total invertebrate abundance (mean ± SE) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Cedar Lake – Southeast and Cormorant Lake).

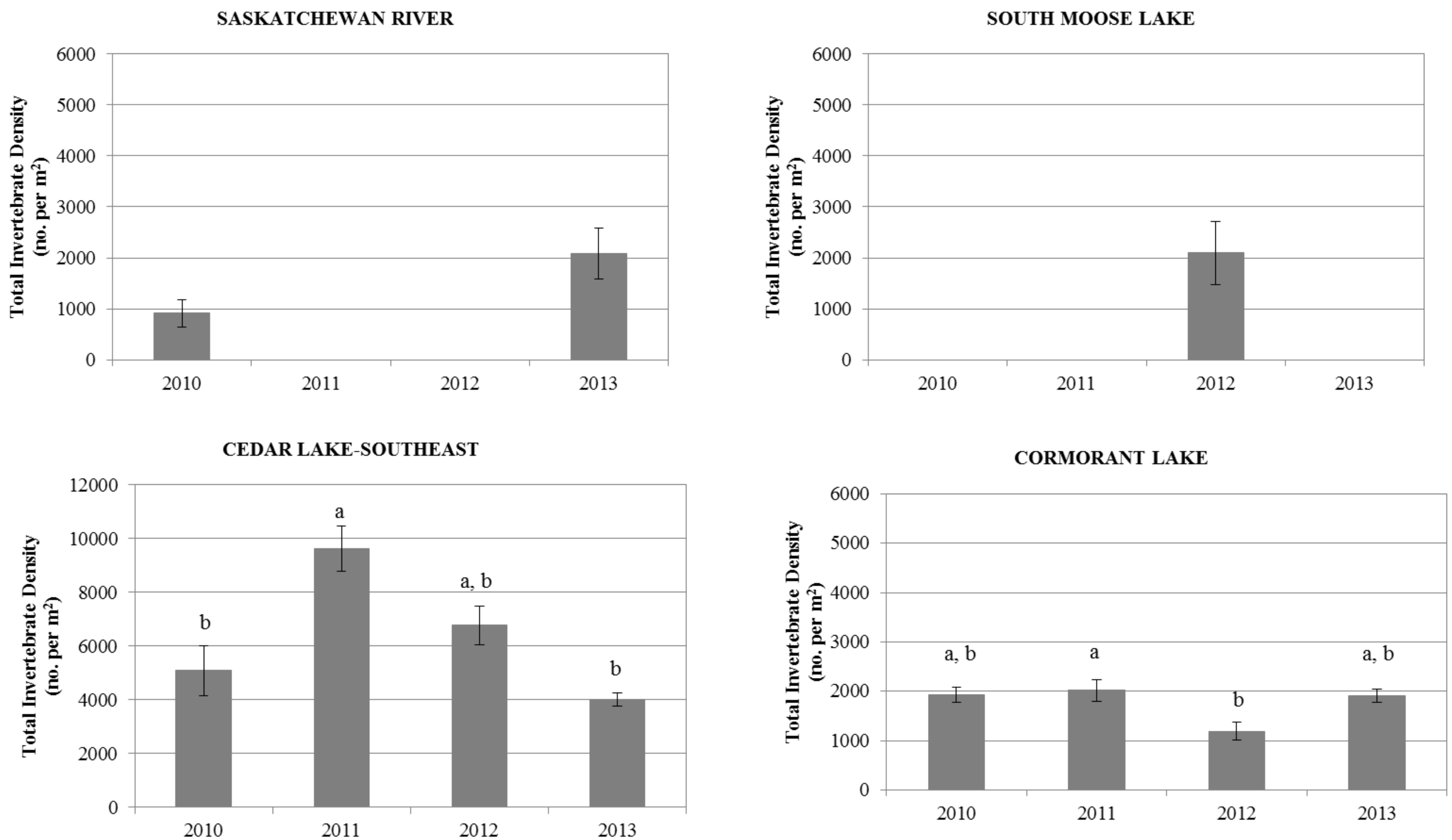


Figure 5-7. Total invertebrate density (mean ± SE) in the offshore of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

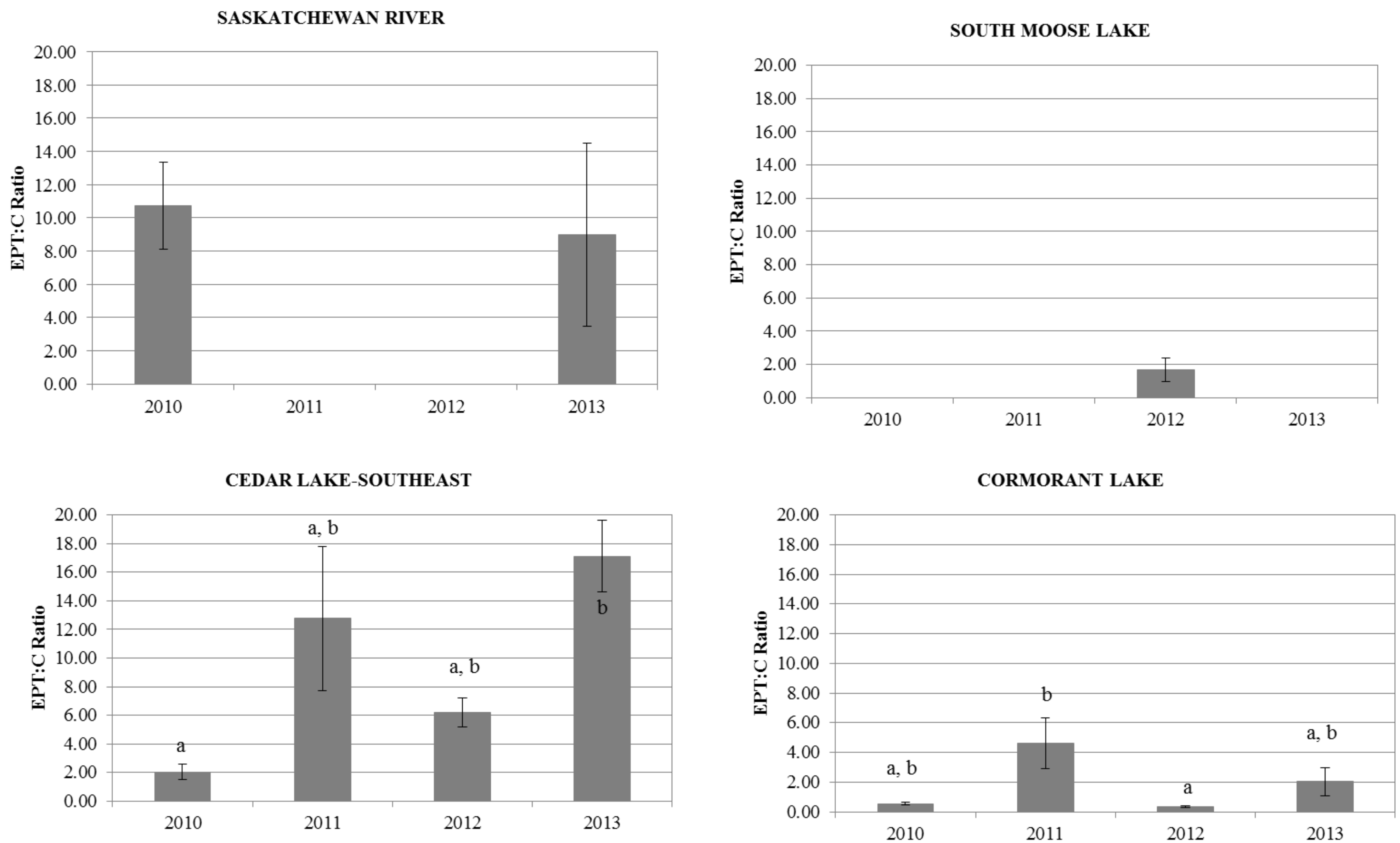


Figure 5-8. EPT:C ratio (mean ± SE) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

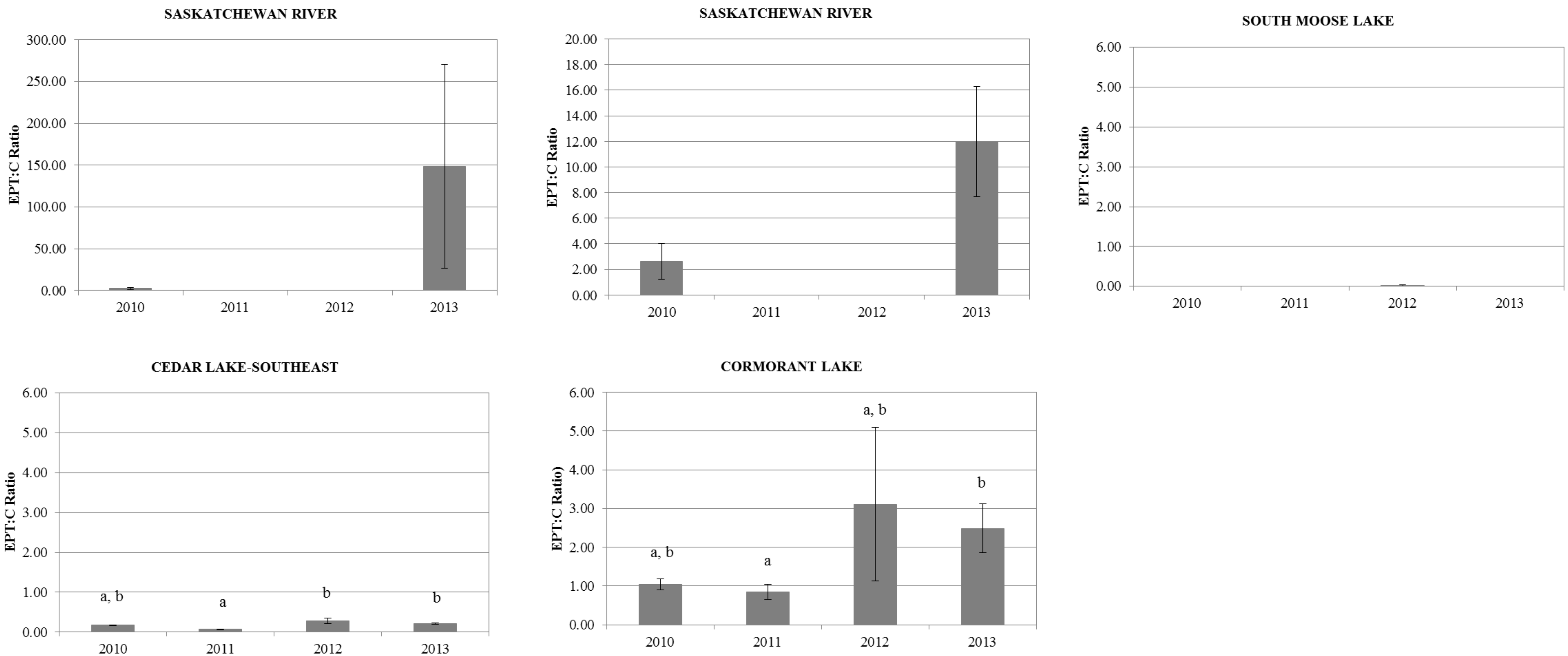


Figure 5-9. EPT:C ratio (mean ± SE) in the offshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Note that results for the Saskatchewan River are shown with (left panel) and without (right panel) two samples that contained no Chironomidae. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

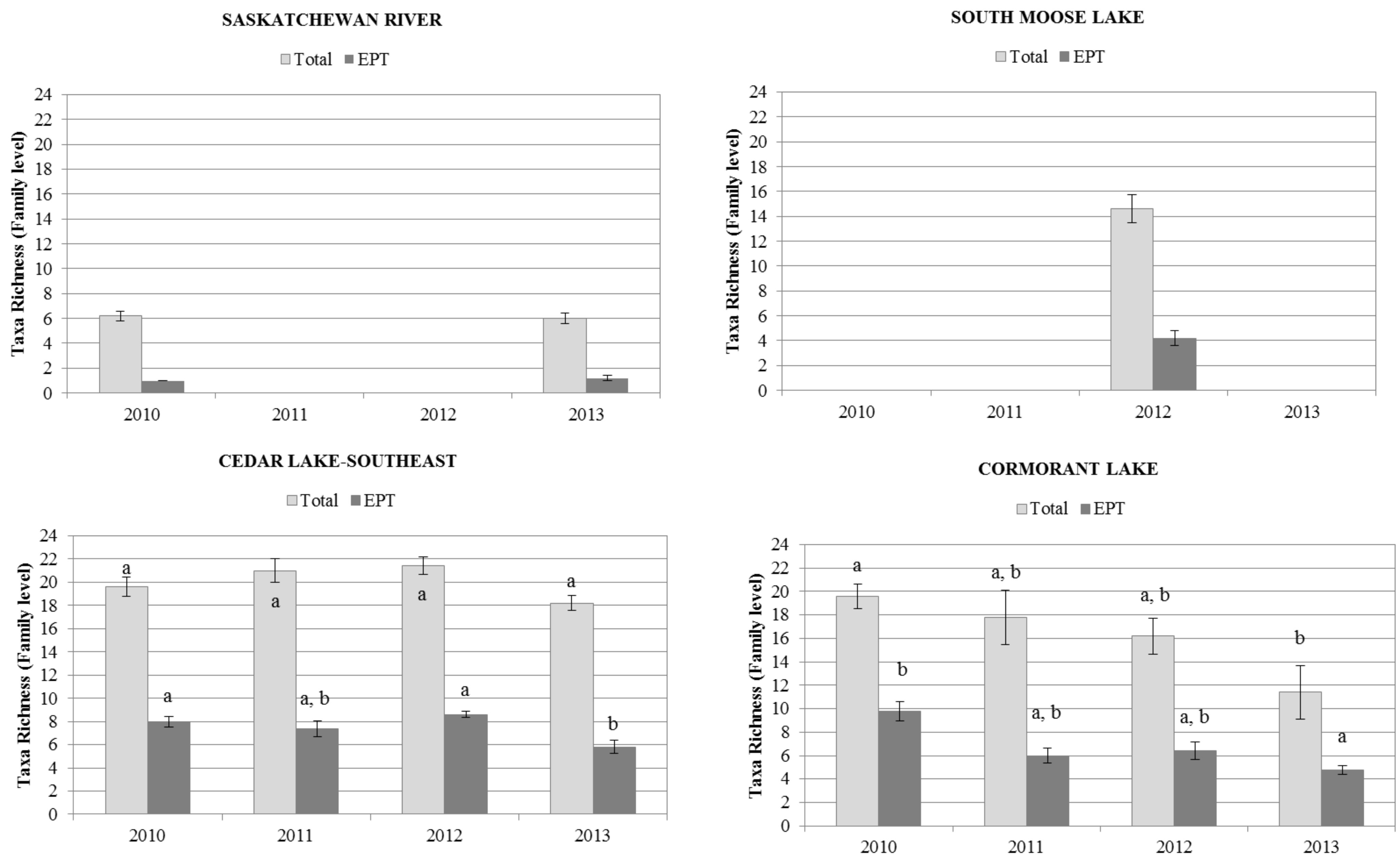


Figure 5-10. Taxonomic richness (total and EPT to family level; mean ± SE) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

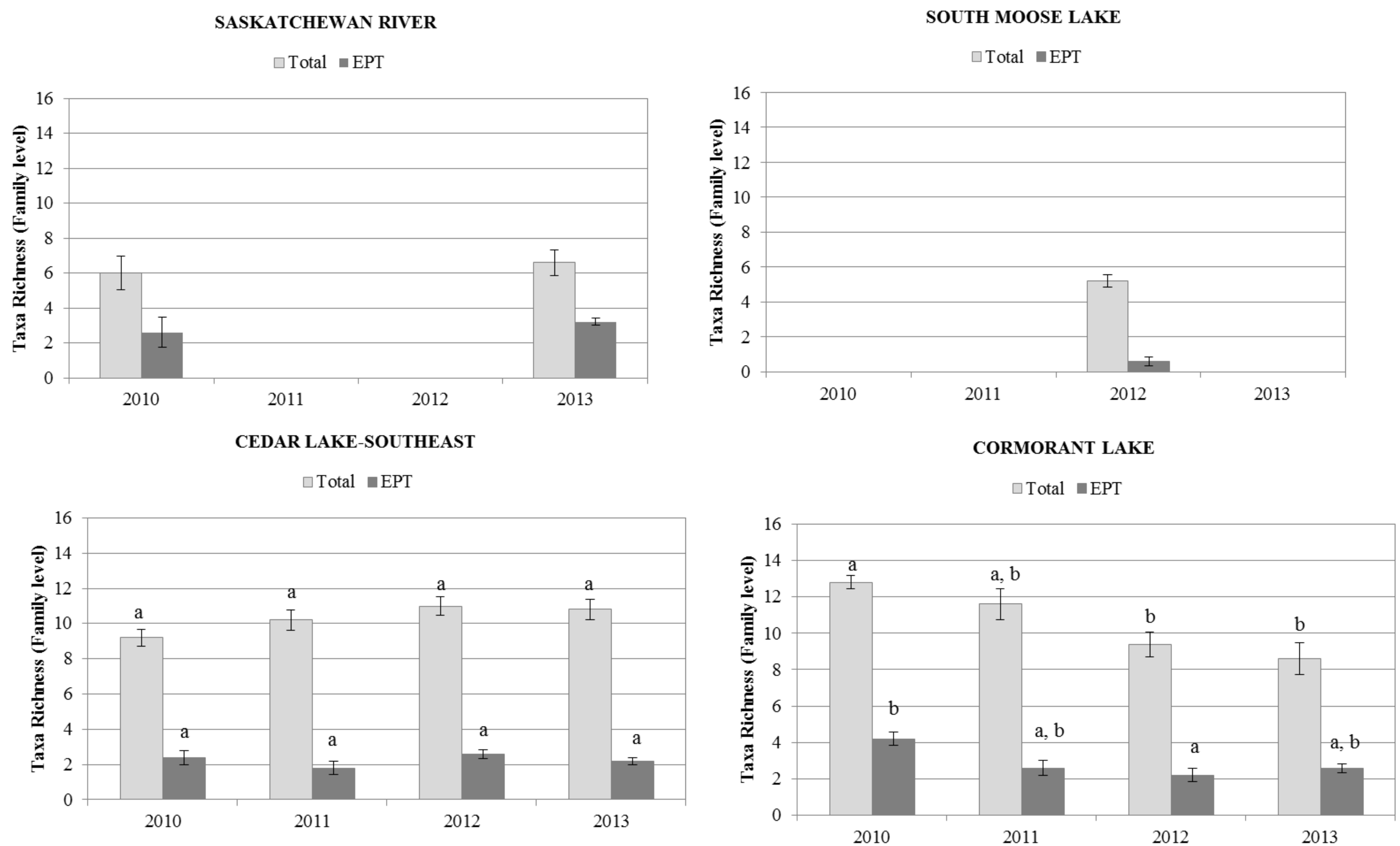


Figure 5-11. Taxonomic richness (total and EPT to family level; mean ± SE) in the offshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

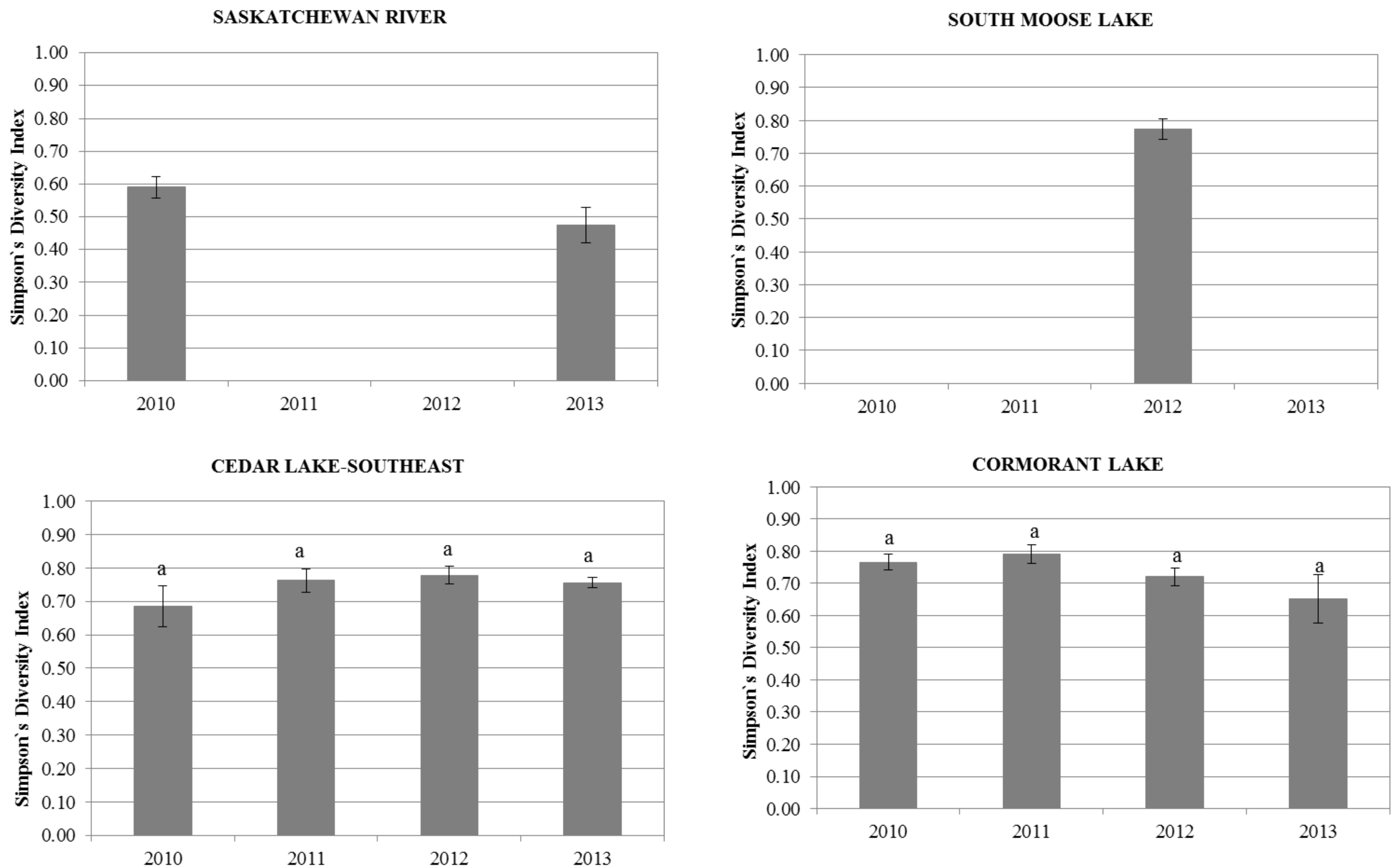


Figure 5-12. Simpson's Diversity Index (mean ± SE) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Cedar Lake – Southeast and Cormorant Lake).

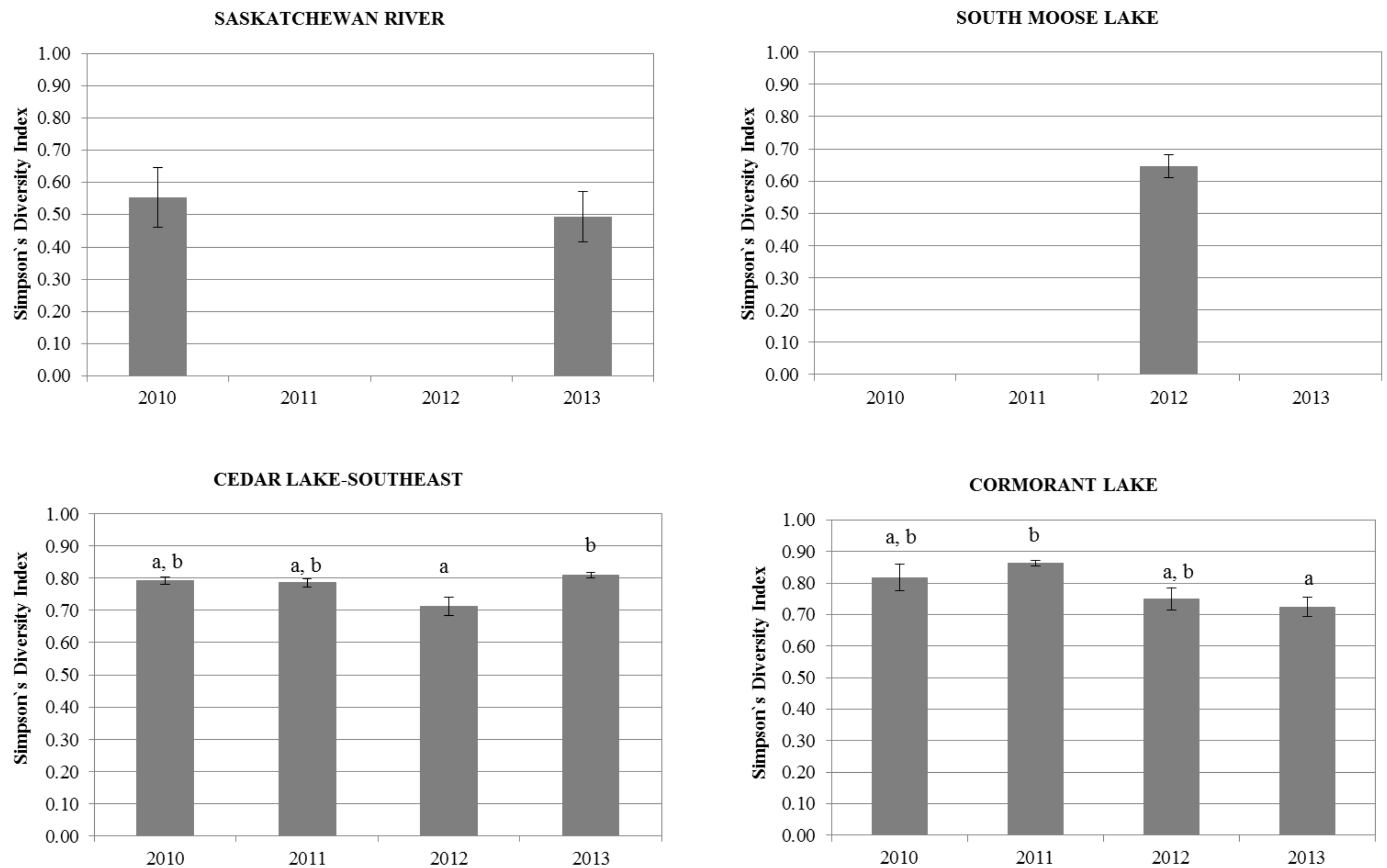


Figure 5-13. Simpson's Diversity Index (mean ± SE) in the offshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

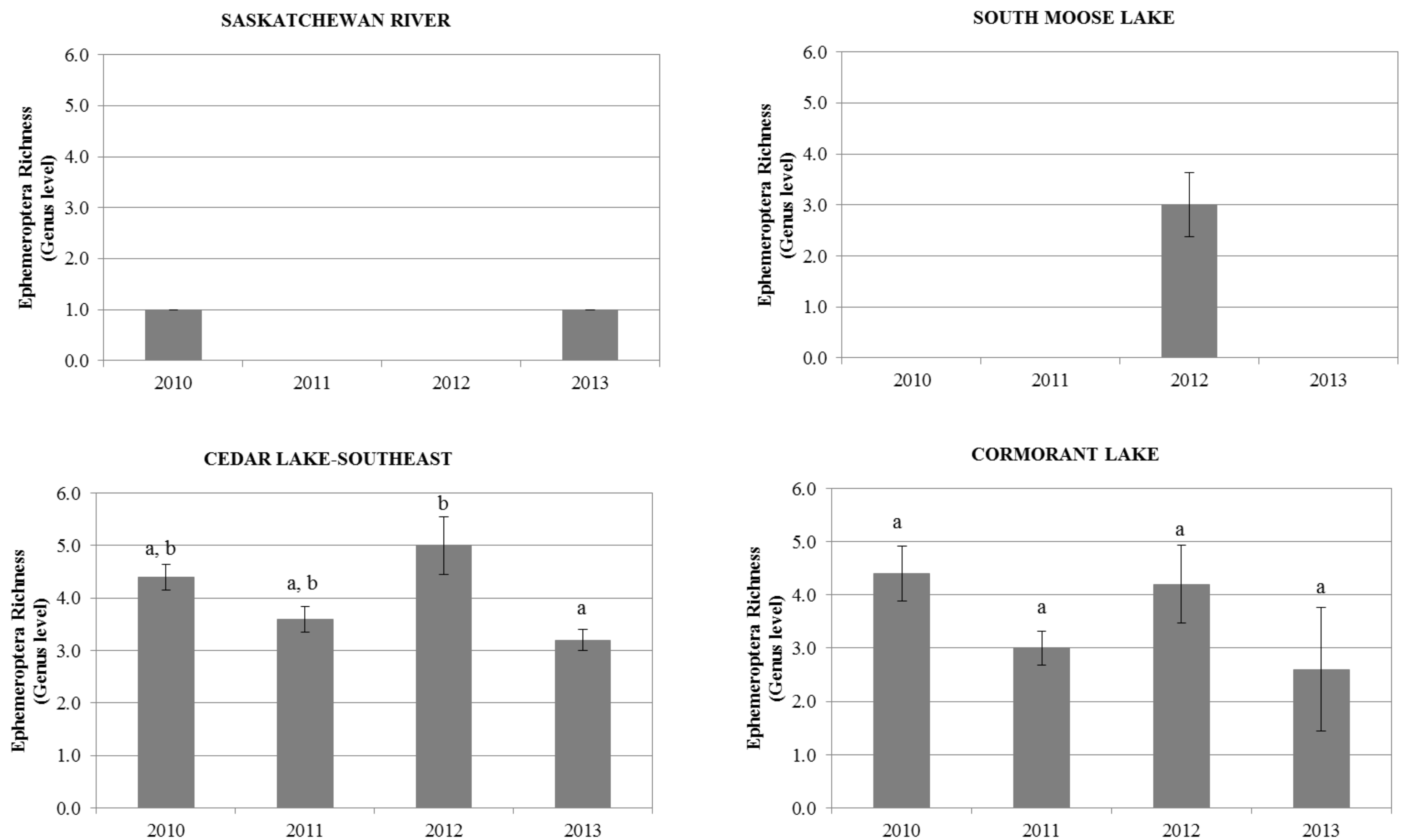


Figure 5-14. Ephemeroptera richness (genus level; mean ± SE) in the nearshore habitat of the Saskatchewan River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

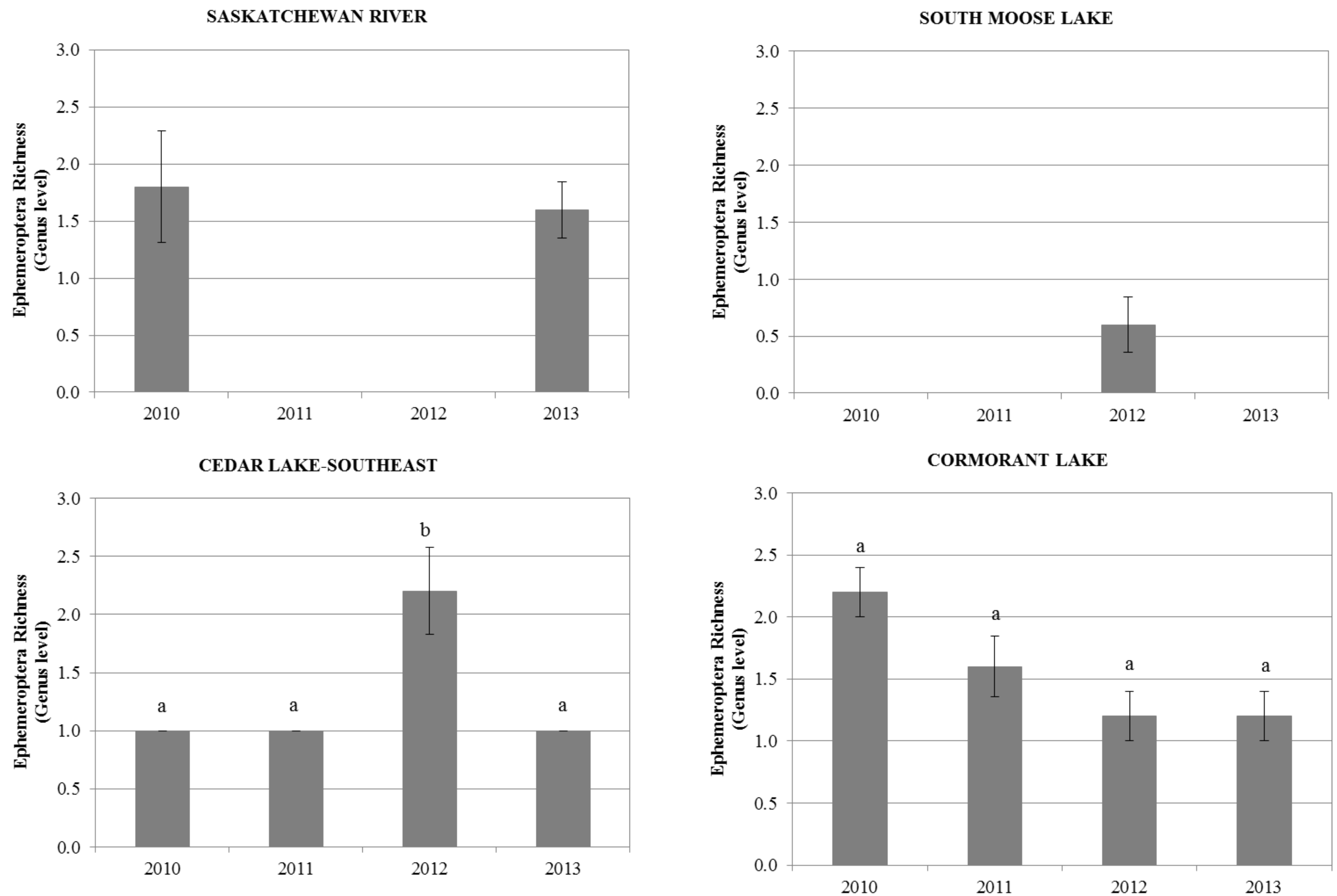


Figure 5-15. Ephemeroptera richness (genus level; mean ± SE) in the offshore habitat of the Saskatchewan Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

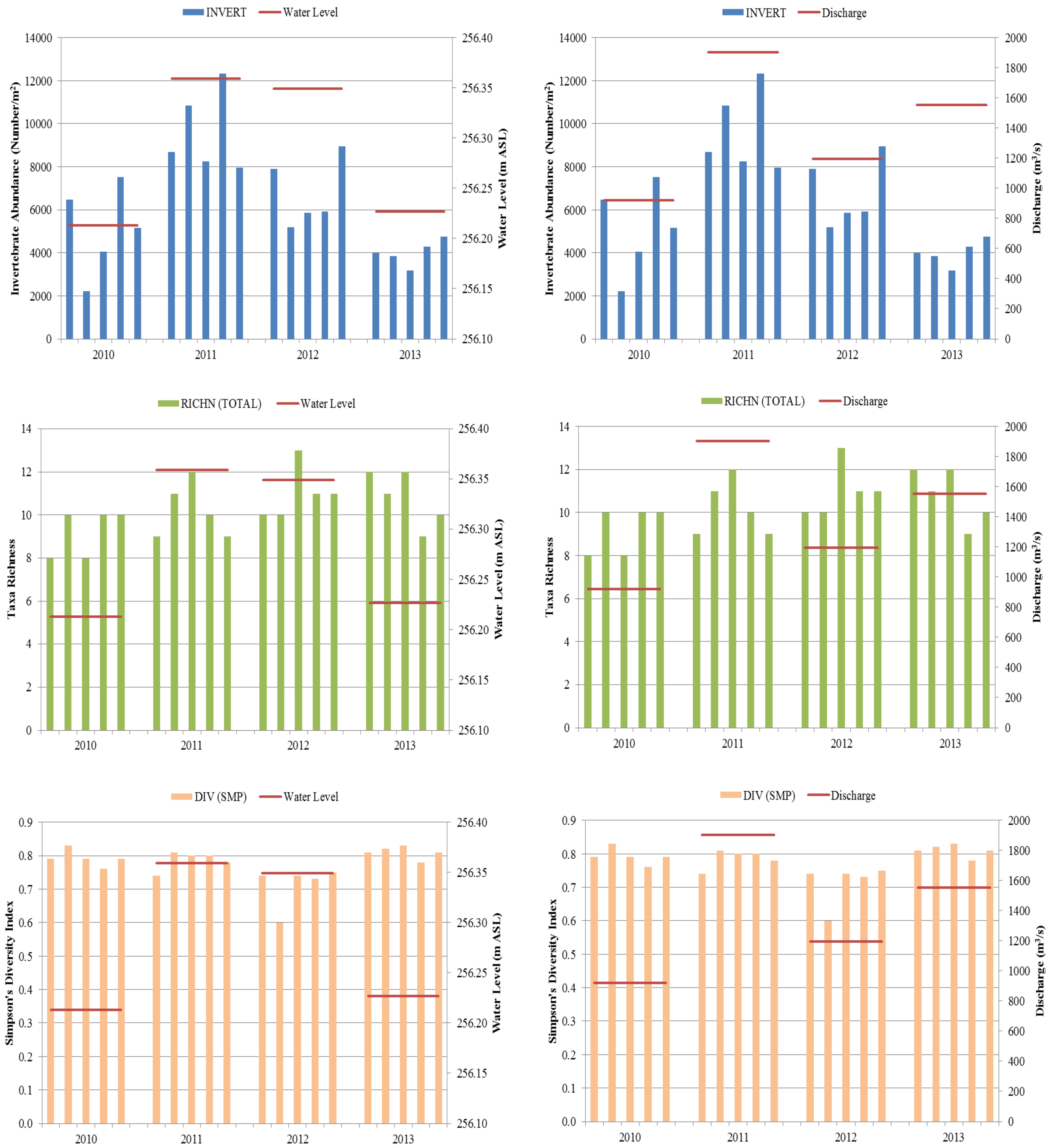


Figure 5-16. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Cedar Lake site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

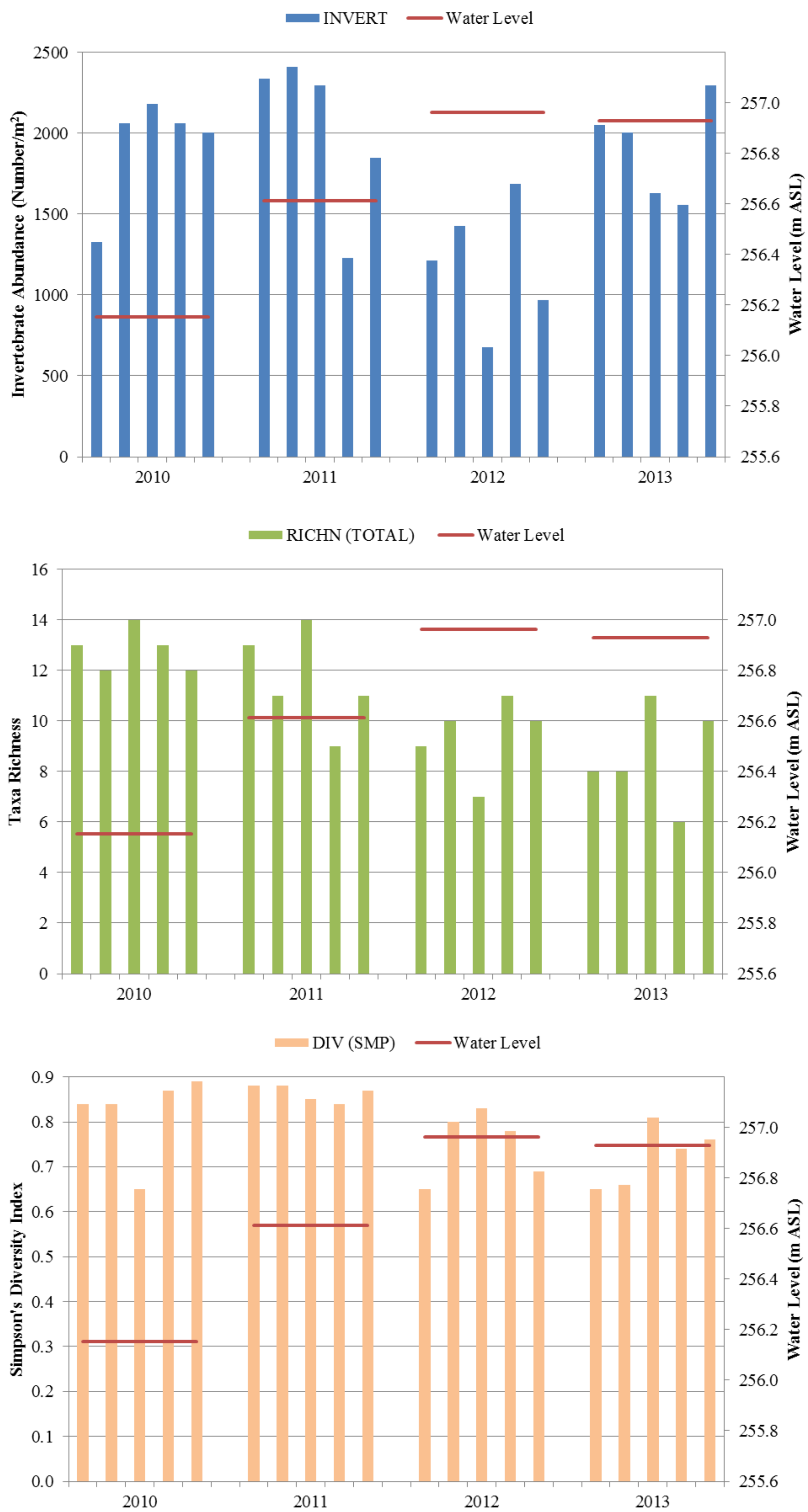


Figure 5-17. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Cormorant Lake site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

6.0 FISH COMMUNITY

6.1 INTRODUCTION

The following provides an overview of the fish community component of CAMP using key metrics measured over years 1 to 6 in the SRR. As noted in Section 1.0, waterbodies/river reaches sampled annually included one on-system (Cedar Lake - Southeast) and one off-system (Cormorant Lake) waterbody. Three additional on-system waterbodies were sampled on a rotational basis: the Saskatchewan River; South Moose Lake; and Cedar Lake - West (Table 6-1; Figure 6-1). A discussion of the rationale for the selection of these waterbodies is provided in Technical Document 1 and the site abbreviations used in the tables and figures are described in Table 6-1. Sampling was completed at all locations and sampling periods as intended. Cedar Lake - Southeast was not sampled in 2008. Eight of the eleven 2010 Saskatchewan River sites were in Cedar Lake - West. Prior to the 2013 surveys, all Saskatchewan River sites were moved into the Saskatchewan River. For the purposes of the 6-year synthesis report, only the results of the 2013 fish community sampling of the Saskatchewan River were used.

All analyses presented below have been conducted on the results of annual or rotational index gillnetting studies. A detailed description of the sampling methods is presented in Section 3.6 of Technical Document 1. A complete list of all fish species captured in standard gang and small mesh index gill nets set in SRR waterbodies, 2008-2013, is presented in Table 6-2.

6.1.1 Objectives and Approach

The key objectives for the analysis of CAMP fish community data, which were directed in the terms of reference for preparation of this report, were to:

- evaluate whether there are indicators of temporal changes or trends in fish community metrics; and
- provide an initial review of potential linkages between fish metrics and key drivers, notably hydrological conditions, where feasible.

The first objective (analysis of temporal changes or trends) was addressed through two approaches: (1) statistical analyses were undertaken, where possible, to assess whether there were significant differences between years at annual locations; and (2) graphical plots for annual sites were examined visually for trends. As noted in Technical Document 1, six years of data may be insufficient to detect trends over time, notably long-term trends, and the assessment was therefore restricted to a qualitative assessment of the available data for sites monitored annually. Additionally, any indications of potential trends over the six-year period do not necessarily imply a long-term trend is occurring, as apparent trends over this interval may simply reflect the relatively limited time period assessed in conjunction with inter-annual variability in a metric. Consideration of a longer period of record is required to evaluate for long-term trends.

The second objective was addressed by regression analysis of hydrological (discharge and/or water level) and selected fish community metrics where potential linkages were considered meaningful. Statistical analyses undertaken for this component are inherently limited by the quantity of data and the absence of statistically significant differences may reflect the relatively limited amount of data. Furthermore, factors other than hydrological conditions, notably abiotic and biotic variables such as water quality, habitat quantity and quality, benthos production, and predator/prey interactions, affect the fish community. For these reasons, these analyses are considered to be exploratory in nature. In addition, it is cautioned that the identification of significant correlations between fish community metrics and hydrological variables does not infer a causal relationship (i.e., correlations simply indicate that two metrics are related).

6.1.2 Indicators

The following sections describe four key fish community indicators: diversity; abundance; condition; and growth. The metrics presented for these indicators include: Hill's effective species richness index (Hill's Index); catch-per-unit-effort (CPUE) for both standard gang and small mesh index gillnets; Fulton's condition factor (K_F); and length-at-age. A description of and the rationale for the selection of the metrics and indicators is provided in Section 4.6.1 of Technical Document 1.

6.2 KEY INDICATORS

6.2.1 Diversity (Hill's Index)

Changes in aquatic habitat can result in a shift in species composition. The Hill's Index is a mathematical measure of species diversity in a community based on how many different species there are (i.e., species richness) and how abundant each species (i.e., evenness) is in the community. The diversity index increases with an increase in the number of species and, for a given number of species, is maximized when all of the species are equally abundant. Generally, diverse communities are indicators of a healthier ecosystem as greater diversity increases the ability of the community to respond to environmental stressors.

6.2.1.1 Saskatchewan River Region

The mean annual Hill's number for on-system waterbodies ranged from a high of 7.1 in Cedar Lake - West to a low of 3.7 in South Moose Lake (Table 6-3; Figure 6-2). The mean Hill's number for the 6-year sampling period was generally similar between most on-system waterbodies (Figure 6-2). However, the Hill's number for South Moose Lake was considerably lower than other locations. Species richness (12-15 species) and composition, particularly for large-bodied fish, were relatively similar between all surveyed waterbodies except in South Moose Lake, where 90% of the catch was comprised of only four species, with Yellow Perch (*Perca flavescens*) particularly abundant (>60% of the catch). In other waterbodies, catches were more evenly distributed among a greater number of species, which resulted in an increased evenness compared with South Moose Lake. Although annual survey timing varied among waterbodies, it is unlikely the main reason for the observed difference in South Moose Lake diversity.

6.2.1.2 Off-system Waterbodies: Cormorant Lake

The mean annual Hill's number for Cormorant Lake (7.1) was similar to Cedar Lake - West and Cedar Lake - Southeast (Table 6-3; Figure 6-2). The number of species (17 species) was slightly higher than on-system lakes, but Cormorant Lake shared a similar fish community composition with the on-system waterbodies, particularly Cedar Lake - Southeast and Cedar Lake - West (Table 6-2).

6.2.1.3 Temporal Comparisons and Trends

Sites sampled annually (Cedar Lake - Southeast and Cormorant Lake) were examined for temporal trends. The mean annual Hill's number for Cedar Lake - Southeast showed variability among sampling years with no particular increasing or decreasing trend (Figure 6-2). Over the 6-year sampling period, the Hill's number ranged from 5.7 in 2012 to 8.1 in 2011. There was less variability in the Hill's number for Cormorant Lake with values ranging from 6.3 in 2012 to 7.4 in 2010 (most years were between 7.0 and 7.4).

The decreased Hill's number in Cedar Lake - Southeast in 2012 was due primarily to a large increase in the abundance of Yellow Perch from an average of 16% of the total catch from all other years to 44% in 2012. Abundance of other species remained relatively consistent.

In 2012, Cormorant Lake had reduced richness (11 species) and abundance of several key species (e.g., Northern Pike [*Esox lucius*], Lake Whitefish [*Coregonus clupeaformis*], and Walleye [*Sander vitreus*]), which decreased diversity. Three species accounted for more than

75% of the catch in 2012; whereas these same three species averaged 62% of the catches in other years.

6.2.2 Abundance (Catch-Per-Unit-Effort)

The abundance of fish in a waterbody is influenced by a variety of physical (e.g., substrate type, flow conditions), biological (e.g., benthos production, predator/prey interactions), and chemical (e.g., dissolved oxygen) factors. Fish abundance is difficult to quantify as the number and type of fish species captured is affected by the type of sampling equipment as a result of size selectivity of the gear and the types of habitat that can be effectively sampled. CPUE is a measure of the abundance of fish captured in a standardized length of net over a fixed amount of time.

6.2.2.1 Saskatchewan River Region

Fish Community

In standard gangs, the mean CPUE ranged from a high of 60 fish/100 m/24 h in Cedar Lake - West to a low of 13 fish/100 m/24 h in the Saskatchewan River (Table 6-3). The highest catch rates in SRR on-system waterbodies, by species, were typically for White Sucker (*Catostomus commersonii*), Walleye and Northern Pike, with Cisco (*Coregonus artedi*), Yellow Perch, and Sauger (*Sander canadensis*) common in some waterbodies (Figure 6-3). Although catch rates differed, species composition in standard gang catches was similar between South Moose Lake and Cedar Lake - Southeast, with White Sucker, Cisco, Yellow Perch, and Walleye consistently among the most frequently captured species (Figure 6-3). The same species were captured in Cedar Lake - West, but Sauger catch rates were much higher than in other on-system waterbodies. Yellow Perch and Cisco were rare or absent from the Saskatchewan River catches while Northern Pike were most abundant. These differences in the catch rates of certain species were likely a result of differences in habitat characteristics between waterbodies.

The total mean catch rates of large-bodied fish were similar among all three on-system lacustrine waterbodies and at least four times the rate in the Saskatchewan River (Figure 6-4). Variation in mean total CPUE did not appear to be linked to differences in annual survey timing among waterbodies (fall in South Moose Lake and the Saskatchewan River and summer in both Cedar Lake basins).

In small mesh gangs, the mean CPUE was substantially more variable among on-system waterbodies than in standard gangs, ranging from a high of 436 fish/30 m/24 h in South Moose Lake to a low of 1 fish/30 m/24 h in the Saskatchewan River (Table 6-3). Small mesh gillnet catch compositions in South Moose Lake and Cedar Lake - Southeast were dominated by Yellow Perch and Spottail Shiner (*Notropis hudsonius*; Figure 6-3). Catches in Cedar Lake - West were smaller and were dominated by Trout-perch (*Percopsis omiscomaycus*). Very few small-bodied fish were captured in the Saskatchewan River with Goldeye (*Hiodon alosoides*) the most abundant species captured (Figure 6-3).

Lake Whitefish

Lake Whitefish mean CPUE for standard gangs was generally low in on-system waterbodies throughout the region, ranging from a high of 2 fish/100 m/24 h in South Moose Lake to a low of 0 fish in Cedar Lake – West and the Saskatchewan River (Table 6-3). Catch rate variation was low in all areas, and there was no overlap of quartiles between South Moose Lake and other on-system waterbodies, suggesting a difference in abundance (Figure 6-5). South Moose Lake was surveyed during fall, which may have increased catch rates for this fall-spawning species.

Northern Pike

Northern Pike mean CPUE for standard gangs ranged from a high of 9 fish/100 m/24 h in South Moose Lake to a low of 2 fish/100 m/24 h in Cedar Lake - Southeast (Table 6-3). Northern Pike CPUE was substantially higher in South Moose Lake than other on-system waterbodies as indicated by a complete lack of overlap of interquartiles (Figure 6-6). The other three on-system waterbodies showed small variation.

Walleye

Walleye mean CPUE ranged from a high of 13 fish/100 m/24 h in Cedar Lake - Southeast to a low of 3 fish/100 m/24 h in the Saskatchewan River (Table 6-3; Figure 6-7). Among SRR on-system waterbodies, catch rates of Walleye in Cedar Lake – Southeast were higher than those of South Moose Lake and the Saskatchewan River as shown by the lack of overlap in interquartile ranges (Figure 6-7).

White Sucker

White Sucker mean CPUE in standard gangs ranged from a high of 24 fish/100 m/24 h in South Moose Lake to a low of 3 fish/100 m/24 h in the Saskatchewan River (Table 6-3; Figure 6-8). The CPUE in South Moose Lake was considerably higher than in other on-system waterbodies, as evidenced by the separation of the lower quartiles and minimum values of its box plot with the upper quartiles and maximum values of those for the other on-system waterbodies (Figure 6-8).

6.2.2.2 Off-system Waterbodies: Cormorant Lake

Fish Community

The mean CPUE in Cormorant Lake was 56 fish/100 m/24 h in standard gangs and 146 fish/30 m/24 h in small mesh gangs (Table 6-3). The large-bodied fish community was dominated by White Sucker and Walleye, with Northern Pike, Cisco, and Lake Whitefish also common (Figure 6-3). The small mesh catch composition was very similar to Cedar Lake – Southeast with Yellow Perch, Spottail Shiner, and Emerald Shiner (*Notropis atherinoides*) the most frequently captured species (Figure 6-3).

The overall CPUE for the total catch in standard gangs in Cormorant Lake was similar to all on-system lacustrine waterbodies (Figure 6-4). In contrast, the overall CPUE in Cormorant Lake was substantially greater than the Saskatchewan River. Catch rates in Cormorant Lake were generally lower for Yellow Perch, Cisco, and Sauger than on-system lakes, but higher for White Sucker and Lake Whitefish (Figure 6-3).

Lake Whitefish

Lake Whitefish mean CPUE for standard gangs was 5 fish/100 m/24 h, which was substantially higher than for on-system waterbodies (Table 6-3). Although catch rate variation was high, there was no overlap of interquartiles with those of any on-system waterbodies (Figure 6-5).

Northern Pike

Northern Pike had a mean CPUE in standard gangs of 4 fish/100 m/24 h (Table 6-3). Northern Pike CPUE in Cormorant Lake was most similar to the range observed in the on-system Cedar Lake - West and the Saskatchewan River and was much lower than in South Moose Lake (Figure 6-6).

Walleye

Walleye had a mean CPUE in standard gangs of 13 fish/100 m/24 h (Table 6-3). Walleye CPUE in Cormorant Lake was within the range observed in Cedar Lake - Southeast and Cedar Lake - West, but was substantially higher than that in South Moose Lake and the Saskatchewan River (Figure 6-7).

White Sucker

White Sucker had a mean CPUE in standard gangs of 26 fish/100 m/24 h (Table 6-3). The interquartile ranges of mean annual CPUE at Cormorant Lake overlapped with those of South Moose Lake, indicating that White Sucker catch rates were comparable between these lakes

(Figure 6-8). However, catch rates for this species in the other regional waterbodies were lower than in Cormorant Lake.

6.2.2.3 Temporal Comparisons and Trends

Fish Community

Sites sampled annually (Cedar Lake - Southeast and Cormorant Lake) were examined for temporal trends. The mean total CPUE values for annually sampled waterbodies showed variability among years (Figure 6-4). Over the 6-year sampling period, overall mean CPUE for Cedar Lake - Southeast ranged from 49 fish/100 m/24 h in 2013 to 73 fish/100 m/24 h in 2011. Cormorant Lake CPUE ranged from 46 fish/100 m/24 h in 2012 to 65 fish/100 m/24 h in 2009. Both lakes showed similar levels of variability as evidenced by the nearly identical interquartile ranges (Figure 6-4).

There were no significant differences in catch rates among years for Cedar Lake - Southeast (Figure 6-9) and no trends in CPUE were apparent over the five years of sampling. The 2009 CPUE for Cormorant Lake was significantly higher than in 2012 and there was some indication of a slightly decreasing trend in catch rates since 2009.

Lake Whitefish

Lake Whitefish catch rates were consistently low in Cedar Lake - Southeast with no significant differences among years (Figure 6-10). There was no evidence of a temporal trend.

Mean annual Lake Whitefish CPUE for Cormorant Lake was relatively steady from 2008 to 2011, ranging from 6 to 8 fish/100 m/24 h (Figure 6-5), with no significant differences among those years (Figure 6-10). However, mean CPUE showed a decline from 2011 to 2013 with the latter value significantly lower than catch rates from 2008, 2010, and 2011 (Figure 6-10). There were no strong linkages between annual survey timing variation and differences in CPUE that may help to explain differences in Lake Whitefish CPUE among years. For example, the CPUE from October sampling in 2011 was similar to the CPUE from August sampling in 2010, while sampling in 2013 that resulted in a very low CPUE was conducted at a similar time period to all other years excluding 2011.

Northern Pike

The mean annual CPUE for Northern Pike has typically shown only small variation in annually monitored lakes (Figure 6-6). In Cedar Lake - Southeast, mean CPUE ranged from 2-3 fish/100 m/24 h with no statistically significant differences among years and no apparent increasing or decreasing trends over time (Figure 6-11).

In Cormorant Lake, excluding 2011, mean Northern Pike CPUE ranged from 3 to 4 fish/100 m/24 h (Figure 6-6). Mean CPUE for Cormorant Lake in 2011 (8 fish/100 m/24 h) was more than double the catch rate of any other year and was significantly higher than the CPUE values for all other years (Figure 6-11). It is possible that the increased catches of Northern Pike in 2011 were related to the timing of the survey, which occurred in early October and was much later than any other survey year. Apart from the high value in 2011, there were no apparent increasing or decreasing trends in Northern Pike CPUE in Cormorant Lake over time (Figure 6-11).

Walleye

The mean annual CPUE for Walleye in Cedar Lake - Southeast varied from 8 fish/100 m/24 h in 2012 to 19 in 2009 (Figure 6-7). There was a pattern of alternating high (2009, 2011, 2013) and low (2010, 2012) values, with the value in 2009 significantly higher than that in 2012 (Figure 6-12).

The variation of Walleye catches at Cormorant Lake was much smaller, with mean annual Walleye CPUE in Cormorant Lake ranging from 10-16 fish/100 m/24 h and no significant differences among years (Figure 6-12). There were no apparent consistently increasing or decreasing trends and no association between CPUE and survey timing variation.

White Sucker

Mean annual White Sucker CPUE in Cedar Lake – Southeast decreased each year, starting from a high of 16 fish/100 m/24 h in 2009 and reaching a low of 8 fish/100 m/24 h in 2013 (Figure 6-8). However, the difference among years was not statistically significant (Figure 6-13).

The mean CPUE in Cormorant Lake fell from a high of 32 fish/100 m/24 h in 2008 to a low of 18 fish/100 m/24 h in 2011 and then increased in 2012 and 2013, reaching 26 fish/100 m/24 h in 2013 (Figure 6-8). The 2011 and 2012 capture rates were significantly lower than 2008 and 2009 (Figure 6-13).

6.2.3 Condition (Fulton's Condition Factor)

Condition is a measure of an individual fish's health calculated from the relationship between its weight and length. Fulton's condition factor (K_F) is a mathematical equation that quantitatively describes the girth or "fatness" of a fish. The condition factor differs among fish species, and, for a given species, can be influenced by the age, sex, season, stage of maturity, amount of fat, and muscular development. Generally, fish in better condition (more full-bodied/fatter) are assumed to have better nutritional and health status. Lack of food, poor water quality, or disease can cause stress that results in lower condition.

6.2.3.1 Saskatchewan River Region

Lake Whitefish

Mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length was 1.35 in South Moose Lake (Figure 6-14). Annual sample sizes of Lake Whitefish within that size range from Cedar Lake - Southeast were too small (n < 20 fish) for analysis and comparison. Lake Whitefish were not captured in Cedar Lake - West or the Saskatchewan River.

Northern Pike

Mean Fulton's condition factor of Northern Pike between 400 and 699 mm from Cedar Lake - Southeast was higher (0.77) than in other on-system lakes (0.70-0.72), but lower than the Saskatchewan River (0.80).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from on-system waterbodies ranged from 1.14 in Cedar Lake - West to 1.23 in the Saskatchewan River (Figure 6-16). The mean condition of Walleye was relatively consistent among on-system waterbodies (Figure 6-16).

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from on-system waterbodies was higher in the Saskatchewan River and Cedar Lake – West at about 1.70 compared to in Cedar Lake - Southeast where is was 1.59 (Figure 6-17).

6.2.3.2 Off-system Waterbodies: Cormorant Lake

Lake Whitefish

Mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length from Cormorant Lake was 1.29 (Figure 6-14). The value was lower than in South Moose Lake and there was no interquartile overlap.

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length from Cormorant Lake was 0.72, which was similar to the values for South Moose Lake and Cedar Lake - West, but lower than the values for the Saskatchewan River and Cedar Lake - Southeast (Figure 6-15).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from Cormorant Lake was 1.05, and was lower than all other sampled waterbodies in the region (Figure 6-16). The interquartile range for Walleye condition in Cormorant Lake showed no overlap with those of the on-system waterbodies (Figure 6-16), suggesting a difference in condition.

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from Cormorant Lake was 1.43 which, like Walleye, was lower than in on-system waterbodies (Figure 6-17).

6.2.3.3 Temporal Comparisons and Trends

Lake Whitefish

Annual sample sizes of Lake Whitefish between 300 and 499 mm in fork length from Cedar Lake - Southeast were too small (n < 20 fish) for statistical analysis of temporal trends. Mean condition for Cormorant Lake catches ranged from 1.25-1.34 (Figure 6-14), with the value for 2009 significantly higher than that for 2012 (Figure 6-18). Although an insufficient number of Lake Whitefish were captured in 2013 for inclusion in the analysis, the available data suggest a declining trend in Lake Whitefish condition in Cormorant Lake (Figure 6-18).

Northern Pike

There was little variation in the condition of pike at both annual sites. The annual mean condition of Northern Pike between 400 and 699 mm in fork length in Cedar Lake - Southeast ranged from a high of 0.78 in 2009 and 2010 to a low of 0.76 in 2013 (Figure 6-15) with no statistically significant differences (Figure 6-19). At the off-system Cormorant Lake, the annual K_F ranged from 0.74 in 2009 to 0.70 in 2013 (Figure 6-15). The difference in mean condition between 2009 and 2013 was statistically significant (Figure 6-19). While the mean K_F value appears to have decreased over the sampling period in Cormorant Lake, the difference (0.04) may not be biologically relevant. Continued monitoring will indicate whether this pattern persists.

Walleye

The mean condition of Walleye between 300 and 499 mm in fork length has shown some variability in both annually sampled waterbodies (Figure 6-16). In Cedar Lake - Southeast, the condition appears to have decreased over time, with the mean condition ranging from 1.24 in 2009 to 1.13 in 2013. Mean condition for the 2009 and 2010 catches were significantly higher than for 2011-2013, and mean condition for 2011 was significantly higher than for 2012 and 2013 (Figure 6-20).

Over the six-year period, the condition of Walleye from Cormorant Lake ranged from a high of 1.10 in 2011 to a low of 1.00 in 2012 and 2013 (Figure 6-16). Multiple statistically significant differences were identified over the years, but of particular note is that values from 2012 and 2013 were significantly lower than all other years (Figure 6-20). A similar decreasing trend to that observed at the on-system location was observed in Cormorant Lake if the results of the 2011 catch are omitted. The highest mean condition was noted from 2011 when sampling occurred much later than in most other years.

White Sucker

The mean condition of White Sucker between 300 and 499 mm in fork length was measured infrequently in each of the annually sampled waterbodies, so minimum sample sizes of 20 fish were rarely achieved (Figure 6-17). In Cedar Lake - Southeast, mean condition ranged from 1.61 in 2010 to 1.56 in 2012 with the 2010 value significantly higher than 2012 (Figure 6-21). Insufficient numbers of fish were caught at Cormorant Lake to analyze for temporal trends.

6.2.4 Growth (Length-at-age)

Changes in the age or size distribution of a fish population can be caused by changes in growth, adult mortality, or recruitment success. Study of growth is the determination of body length as a function of age. Growth rates will differ for each species, and within a species, successive cohorts may grow differently depending on environmental conditions. Growth was characterized from length-at-age and focused on the length distribution of fish of a given year-class selected for each species based on the following:

- when the species was large enough to be recruited into the gear;
- young enough to be prior to, or at, the age of first maturity; and
- enough fish in the year class to be able to conduct statistical analyses.

6.2.4.1 Saskatchewan River Region

Lake Whitefish

Lake Whitefish were not a common species in on-system waterbodies; therefore, there were insufficient individuals captured to generate an annual mean length at age plot for Cedar Lake - Southeast (Figure 6-22), nor a fork length-at-age box plot for Cedar Lake - Southeast (Table 6-3).

Sufficient 4 and 5 year old Lake Whitefish were only captured in one year at South Moose Lake for analysis. The mean length-at-age 4 for Lake Whitefish captured at South Moose Lake was 374 while the mean length-at-age 5 was 398 mm (Figures 6-23 and 6-24).

Northern Pike

Northern Pike captured in annually sampled Cedar Lake - Southeast ranged from 1-14 years of age, with most of the fish captured over the 6-year sampling period aged between two and five years of age (Figure 6-25). Growth was more rapid for the first four to five years, after which growth slowed. Small sample sizes caused large variation in mean lengths of fish older than seven years.

Northern Pike mean lengths-at-age 4 for standard mesh gangs in the Saskatchewan River, South Moose Lake, and Cedar Lake - Southeast (560-602 mm) were much larger than for Cedar Lake - West (349 mm) (Figure 6-26).

Walleye

Walleye captured in annually sampled Cedar Lake - Southeast ranged from 1-17 years of age, with most of the fish captured over the 6-year sampling period aged between two and nine years of age (Figure 6-27). Steady, rapid growth was noted until age 8, after which growth generally slowed. Small sample sizes caused large variation in mean lengths of fish older than 12 years.

Walleye mean length-at-age 3 for standard mesh gangs was 367 mm in South Moose Lake and was considerably higher than at the other two on-system lakes where the mean length was between 220 and 250 mm (Figure 6-28).

6.2.4.2 Off-system Waterbodies: Cormorant Lake

Lake Whitefish

Lake Whitefish captured in the annually sampled Cormorant Lake ranged from 1-29 years of age, with most of the fish captured over the 6-year sampling period aged between four and five and 10 and 15 years of age (Figure 6-22). Growth was steady and relatively rapid until approximately age seven, after which it appeared to slow. Mean lengths of older cohorts were generally between 400 and 450 mm.

Lake Whitefish mean lengths-at-ages 4 and 5 from Cormorant Lake were 272 and 281 mm, respectively (Figures 6-23 and 6-24). The fork length at age was considerably smaller at Cormorant Lake compared to South Moose Lake for both ages, but this comparison is based on the small number of Lake Whitefish captured at South Moose Lake.

Northern Pike

Northern Pike captured in the annually sampled Cormorant Lake ranged from 1-14 years of age, with most of the fish captured over the 6-year sampling period aged between four and seven years of age (Figure 6-25). Steady growth was noted for the first seven years of life, after which growth slowed and the mean fork length-at-age stabilized between about 650 and 800 mm.

Mean length-at-age 4 for Northern Pike from Cormorant Lake was 557 mm (Figure 6-26). Values were similar between Cormorant Lake and most on-system waterbodies (Figure 6-26). Only Cedar Lake - West showed a substantial difference in mean length-at-age 4 from Cormorant Lake (Figure 6-26).

Walleye

Walleye captured in the annually sampled Cormorant Lake ranged from 0 (i.e., young-of-the-year) to 25 years of age, with most of the fish captured over the 6-year sampling period between three and seven years of age (Figure 6-27). The mean length for most ages older than one year in Cormorant Lake were higher than corresponding ages in Cedar Lake - Southeast. Steady, rapid growth was noted until approximately age 8, after which growth slowed. The high variability in the fork length of fish older than 17 years is likely a result of the small sample sizes.

Mean length-at-age 3 for Walleye from Cormorant Lake was 298 mm (Figure 6-28). Walleye growth rates in Cormorant Lake appeared to be intermediate between South Moose Lake and the two Cedar Lake basins with no overlap among any of them (Figure 6-28).

6.2.4.3 Temporal Comparisons and Trends

Lake Whitefish

Lake Whitefish were not common in Cedar Lake - Southeast. Therefore, it was not possible to look at temporal trends in Lake Whitefish growth among on-system waterbodies.

The annual mean lengths-at-ages 4 and 5 for Lake Whitefish in Cormorant Lake showed only small variation (Figures 6-23 and 6-24) with only three years of data available for each age, but there were no apparent trends and no significant differences among years (Figure 6-29).

Northern Pike

The annual mean length-at-age 4 for Northern Pike in Cedar Lake - Southeast ranged from 495 mm in 2010 to 639 mm in 2011 (Figure 6-26) with the length for 4 year-old pike in 2011 being significantly longer than those captured in 2009 and 2010 (Figure 6-30) and a slight increasing trend over time. However, small annual sample sizes may have influenced observations.

At the off-system Cormorant Lake, the annual mean length-at-age 4 ranged from 530 mm in 2012 to 578 mm in 2008 and 2013 (Figure 6-26). There were no obvious temporal trends and no statistically significant differences (Figure 6-30). As in Cedar Lake - Southeast, annual sample sizes for age-4 Northern Pike were small (3-11 fish), likely influencing variation among years.

Walleye

The annual mean length-at-age 3 for Walleye captured in 2012 from Cedar Lake - Southeast (274 mm) was noticeably higher than other years (232-244 mm; Figure 6-28), and the difference was statistically significant (Figure 6-31). However, no increasing or decreasing trends in the length-at-age 3 for Walleye from Cedar Lake - Southeast were apparent.

At the off-system Cormorant Lake, the annual mean length-at-age 3 ranged from 329 mm in 2012 to 256 mm in 2009 (Figure 6-28). Mean length of age-3 Walleye from 2009 was significantly shorter than all other years (Figure 6-31). Although there appears to have been a slight increase in mean length-at-age 3 over time, small sample sizes in some years may have affected results.

6.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

One additional fish community metric (relative abundance), as described in Technical Document 1, Section 4.6.1.1, was derived to assess trends in the fish community. Information on this metric is included here because the analyses conducted for Manitoba Hydro and the Province of Manitoba's regional cumulative effects assessment (2015) on longer-term datasets for other regions indicated that a shift in species composition over time may have occurred in several hydro-affected waterbodies. However, the available information for Cedar Lake suggests that there has been negligible change to the relative abundance of large-bodied species since 1999 (Jansen and Dawson 2007).

The relative abundance of fish species captured in standard gang index gill nets set at SRR waterbodies between 2008 and 2013 are shown in Figure 6-32. In the Saskatchewan River, White Sucker, Northern Pike, and Walleye were generally the dominant species (Figure 6-32). The same three species were among the most dominant in South Moose Lake, though Cisco and Yellow Perch were also substantial components of its fish community (Figure 6-32).

In the only year it was sampled, Sauger were the most abundance species (34% of the catch) in Cedar Lake - West, while White Sucker, Walleye, Cisco, Northern Pike, and Yellow Perch each comprised at least 7% of the total catch (Figure 6-32).

Cedar Lake - Southeast catches from 2010-2013 were all similar in composition with Cisco contributing 26-40% towards the total catch and Walleye, White Sucker, Sauger, and Yellow Perch accounting for most of the remainder of the catch (53-69%; Figure 6-32). In contrast, Cisco were relatively uncommon in 2009 from Cedar Lake - Southeast while White Sucker and Walleye proportions were somewhat higher.

In Cormorant Lake, White Sucker was consistently the dominant species, accounting for 32-53% of the total catch (Figure 6-32). Walleye and, to a lesser extent, Northern Pike, Lake Whitefish, and Cisco were also common components of the fish community. There were no substantive differences in the relative abundance of fish captured in Cormorant Lake among years, but there were slightly higher proportions of Northern Pike and coregonines and lower proportions of White Sucker in 2011 than in all other years. The later sampling period for 2011 relative to other years is likely the main reason for the observed differences.

6.4 RELATIONSHIPS WITH HYDROLOGICAL METRICS

While it is recognized that fish community indicators/metrics are influenced by many abiotic and biotic variables (e.g., water quality, water levels and flows, habitat quantity and quality, benthos production, and predator/prey interactions), relationships between hydrological variables and fish community metrics were examined, where potential linkages were considered meaningful, as defined by the terms of reference for this report. These analyses are considered to be exploratory in nature. In addition, it is cautioned that identification of significant correlations between fish community metrics and hydrological variables does not infer a causal relationship.

A quantitative consideration of hydrological conditions and fish community metrics for annual sites (Cedar Lake - Southeast and Cormorant Lake) using water level data from gauges on Cedar Lake and Cormorant Lake and discharge data from the Saskatchewan River at The Pas provided by Manitoba Hydro indicated one statistically significant relationship for Cormorant Lake (Table 6-4).

The only statistically significant relationship was a negative relationship between Total CPUE and water level during the sampling period in Cormorant Lake (Table 6-4, Figure 6-33).

6.5 SUMMARY

A few of the key findings of the six years of CAMP monitoring include:

- Fish community diversity was much lower in South Moose Lake than in any other SRR waterbody. Species composition varied among waterbodies, but was most different in the Saskatchewan River.
- Walleye and White Sucker were consistently among the most abundant large-bodied fish in catches from all SRR waterbodies, but Cisco (Cedar Lake - Southeast) and Sauger (Cedar Lake - West), were also common in certain locations.
- The overall CPUE for the total catch in standard gangs was similar in all three on-system lacustrine waterbodies, and in the off-system Cormorant Lake, but was much lower in the Saskatchewan River.
- Growth rate for Walleye was lower in Cedar Lake (both basins) than in other SRR waterbodies.

Statistical analysis of the six years of data has indicated there has been annual variation in many of the fish community metrics over the period of 2008-2013, with a few apparent temporal trends. For example, total and Lake Whitefish CPUE in Cormorant Lake decreased over time.

Additionally, mean condition for Northern Pike and Walleye decreased over time in one or both annually sampled lakes.

A quantitative consideration of hydrological conditions and fish community metrics found only one statistically significant relationship: a negative relationship between total CPUE and water level during the sampling period in Cormorant Lake.

Table 6-1. Inventory of fish community sampling completed in the SRR: 2008-2013.

Location	**Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
						2008	**2009**	**2010**	**2011**	**2012**	**2013**
Saskatchewan River [1]	SASK	X			X			X			X
South Moose Lake	SMOOSE	X			X		X			X	
Cedar Lake – West	CEDAR-W	X			X				X		
Cedar Lake – Southeast	CEDAR-SE	X		X			X	X	X	X	X
Cormorant Lake	CORM		X	X		X	X	X	X	X	X

[1] All but three sites surveyed in the Saskatchewan River in 2010 had to be moved following a reassessment prior to 2013 sampling. As a result, SASK 2010 data could not be compared among years and were not used in statistical analyses.

Table 6-2. Fish species captured in standard gang and small mesh index gill nets set in Saskatchewan River Region waterbodies, 2008-2013.

Species	**Species Abbreviation**	**SASK** n_Y**=1**	**SMOOSE** n_Y**=2**	**CEDAR-W** n_Y**=1**	**CEDAR-SE** n_Y**=5**	**CORM** n_Y**=6**
Goldeye	GOLD	X		X		
Mooneye	MOON	X*				
Lake Chub	LKCH					X*
Common Shiner	CMSH					X*
Emerald Shiner	EMSH		X	X	X*	X*
Spottail Shiner	SPSH		X	X	X	X
Fathead Minnow	FTMN		X*			
Longnose Sucker	LNSC	X	X*		X	X
White Sucker	WHSC	X	X	X	X	X
Shorthead Redhorse	SHRD	X	X*	X	X*	
Northern Pike	NRPK	X	X	X	X	X
Cisco	CISC	X	X	X	X	X
Lake Whitefish	LKWH		X		X	X
Trout-perch	TRPR		X	X	X	X
Burbot	BURB	X*	X*	X	X*	X
Sculpin (unidentified)	COTT					X*
Mottled Sculpin	MTSC				X*	
Slimy Sculpin	SLSC					X*
Yellow Perch	YLPR		X	X	X	X
Logperch	LGPR				X	X
Sauger	SAUG	X	X*	X	X	X
Walleye	WALL	X	X	X	X	X

n_Y = number of years sampled
*species is observed infrequently in catches (i.e., in fewer than 80% of sampling years).

Table 6-3. Summary of fish community metrics, including Hill's index, catch-per-unit-effort (CPUE), Fulton's condition factor (K_F), and fork length-at-age (mm), calculated for Saskatchewan River Region waterbodies, 2008-2013.

Component	Waterbody	Hill's Index			CPUE [1]			K_F [2]			FL-at-age [3]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
Diversity	SASK	1	6.5	0.4	-	-	-	-	-	-	-	-	-
	SMOOSE	2	3.7	0.2	-	-	-	-	-	-	-	-	-
	CEDAR-W	1	7.1	-	-	-	-	-	-	-	-	-	-
	CEDAR-SE	5	6.7	0.4	-	-	-	-	-	-	-	-	-
	CORM	6	7.1	0.1	-	-	-	-	-	-	-	-	-
Standard gang	SASK	-	-	-	153	13.0	-	-	-	-	-	-	-
	SMOOSE	-	-	-	1416	53.3	10.6	-	-	-	-	-	-
	CEDAR-W	-	-	-	741	59.6	-	-	-	-	-	-	-
	CEDAR-SE	-	-	-	4121	59.0	3.8	-	-	-	-	-	-
	CORM	-	-	-	5408	56.2	2.9	-	-	-	-	-	-
Small mesh	SASK	-	-	-	4	1.2	-	-	-	-	-	-	-
	SMOOSE	-	-	-	3089	435.8	70.4	-	-	-	-	-	-
	CEDAR-W	-	-	-	218	58.1	-	-	-	-	-	-	-
	CEDAR-SE	-	-	-	3106	162.9	43.3	-	-	-	-	-	-
	CORM	-	-	-	3142	145.7	25.9	-	-	-	-	-	-
Lake Whitefish	SASK	-	-	-	0	0.0	-	0	-	-	-	-	-
											-	-	-
	SMOOSE	-	-	-	45	1.7	0.1	43	1.35	0.05	6	374	-
											5	412	14
	CEDAR-W	-	-	-	0	0.0	-	0	-	-	-	-	-
											-	-	-
	CEDAR-SE	-	-	-	12	0.2	0.1	12	1.47	0.09	2	353	13
											1	431	-
	CORM	-	-	-	514	5.3	1.1	343	1.29	0.01	31	272	1
											23	296	8
Northern Pike	SASK	-	-	-	47	4.0	0.8	46	0.80	0.01	7	602	22
	SMOOSE	-	-	-	230	8.6	2.1	189	0.72	0.01	52	571	12
	CEDAR-W	-	-	-	53	4.7	-	25	0.70	-	13	349	-
	CEDAR-SE	-	-	-	155	2.3	0.3	141	0.79	0.02	28	560	26
	CORM	-	-	-	411	4.3	0.8	312	0.72	0.01	42	557	4

Table 6-3. continued.

Component	Waterbody	Hill's Index			CPUE [1]			K_F [2]			FL-at-age [3]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
Walleye	SASK	-	-	-	28	2.5	0.9	28	1.24	0.02	1	352	-
	SMOOSE	-	-	-	134	5.2	2.9	80	1.16	0.03	21	367	9
	CEDAR-W	-	-	-	124	10.3	-	103	1.14	-	4	220	-
	CEDAR-SE	-	-	-	918	13.4	2.1	687	1.19	0.02	96	248	7
	CORM	-	-	-	1229	13.1	0.9	860	1.05	0.02	111	298	2
White Sucker	SASK	-	-	-	39	3.2	0.6	39	1.71	0.02	-	-	-
	SMOOSE	-	-	-	654	24.2	2.2	1	1.48	-	-	-	-
	CEDAR-W	-	-	-	144	11.5	-	135	1.69	-	-	-	-
	CEDAR-SE	-	-	-	833	11.6	1.2	284	1.59	0.02	-	-	-
	CORM	-	-	-	2490	25.7	2.5	630	1.42	0.01	-	-	-

[1] CPUE = fish/100 m/24 h except for small mesh gangs where it is fish/30 m/24 h

[2] Fork lengths analyzed for K_F were 300-499 mm for Lake Whitefish, Walleye and White Sucker, and 400-699 mm for Northern Pike

[3] Ages analyzed are 3 years for Walleye, 4 years for Northern Pike; 4 and 5 years for Lake Whitefish

n_Y = number of years sampled

n_F = number of fish: caught (CPUE), measured for length and weight (K_F), aged and measured for length-at-age

SE = standard error.

Table 6-4. Significant results of linear regressions of fish community metrics (catch-per-unit-effort [CPUE] and Fulton's condition factor [K_F]) against hydrological metrics[1] for Saskatchewan River Region waterbodies sampled annually between 2008 and 2013. Gray shading indicates an off-system waterbody.

Metric	Species	Waterbody	Hydrology Metric	df	F	p	R^2	Direction
CPUE	Total	CORM	WL (GN)	3	14.49	0.032	0.83	-

[1] Q (OW) = average discharge (cms) during the open water period (approximate average annual date of ice-free conditions in each waterbody to end of sampling period)

Q (GN) = average discharge (cms) during the gillnetting program

WL (OW) = average water level (m ASL) during the open water period (approximate average annual date of ice-free conditions in each waterbody to end of sampling period)

WL (GN) = average water level (m ASL) during the gillnetting program

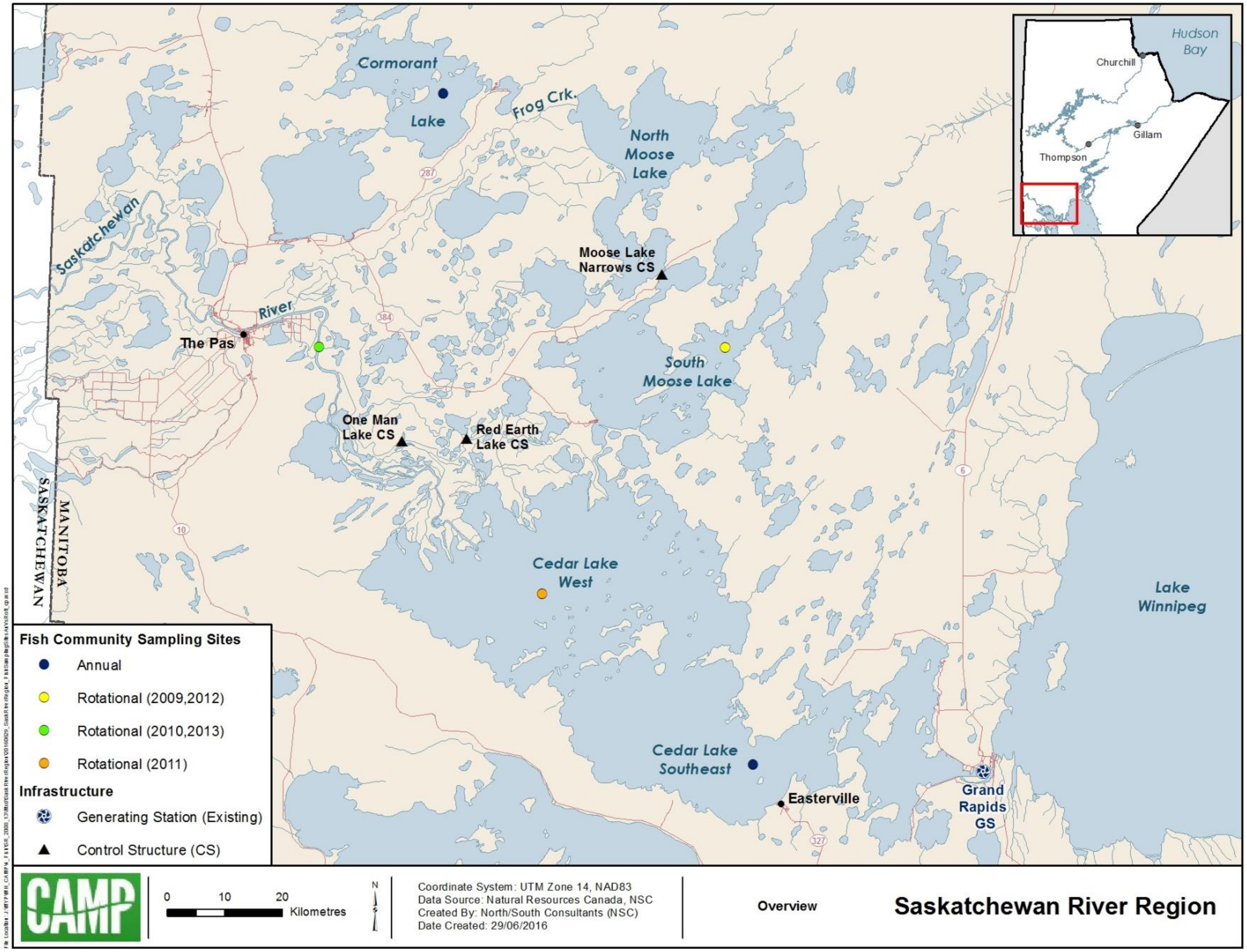


Figure 6-1. Waterbodies sampled in the Saskatchewan River Region: 2008-2013.

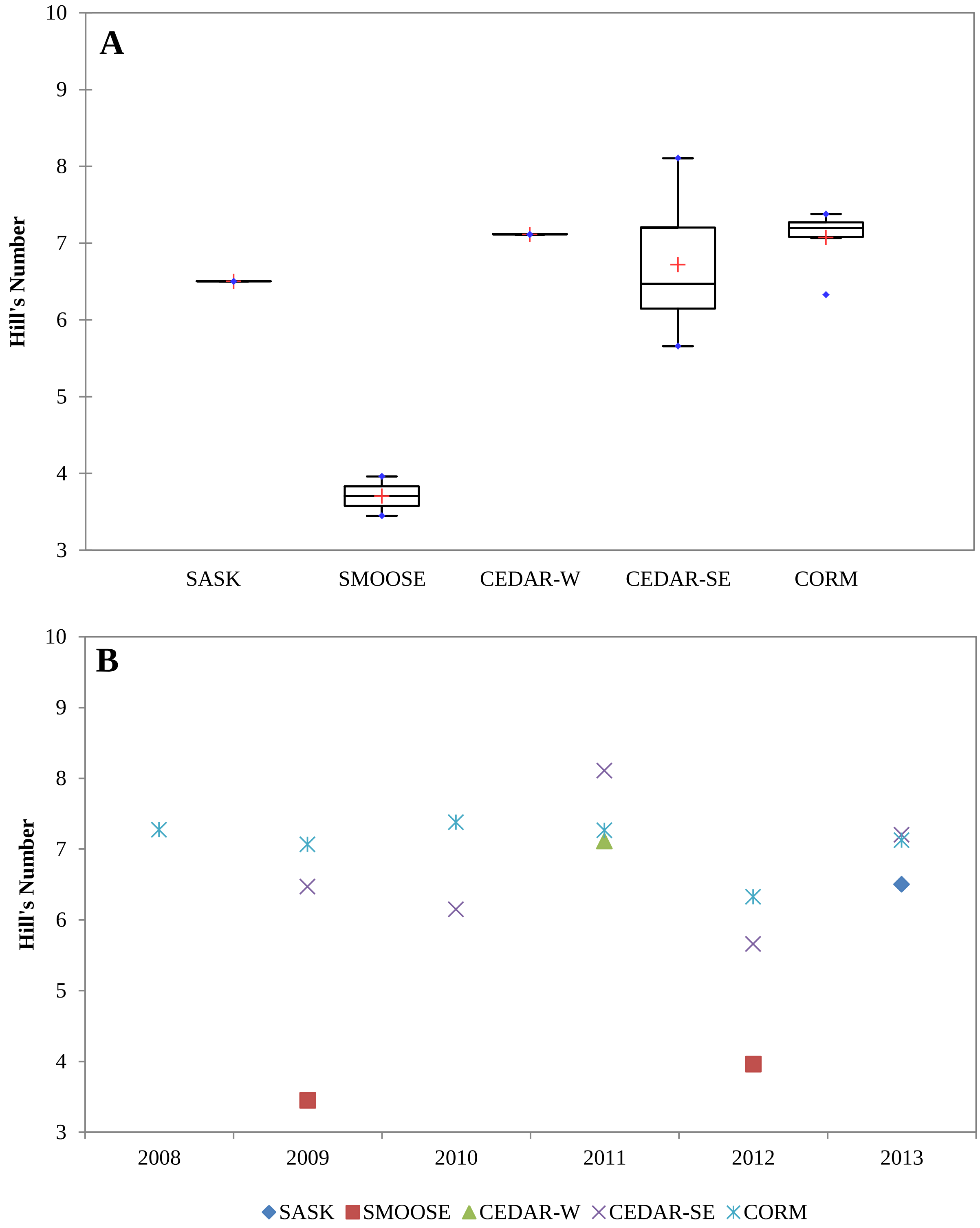


Figure 6-2. Annual mean Hill's effective species richness index (Hill's number) for standard gang and small mesh index gill nets set in Saskatchewan River Region waterbodies, 2008-2013; by waterbody (A) and by year (B).

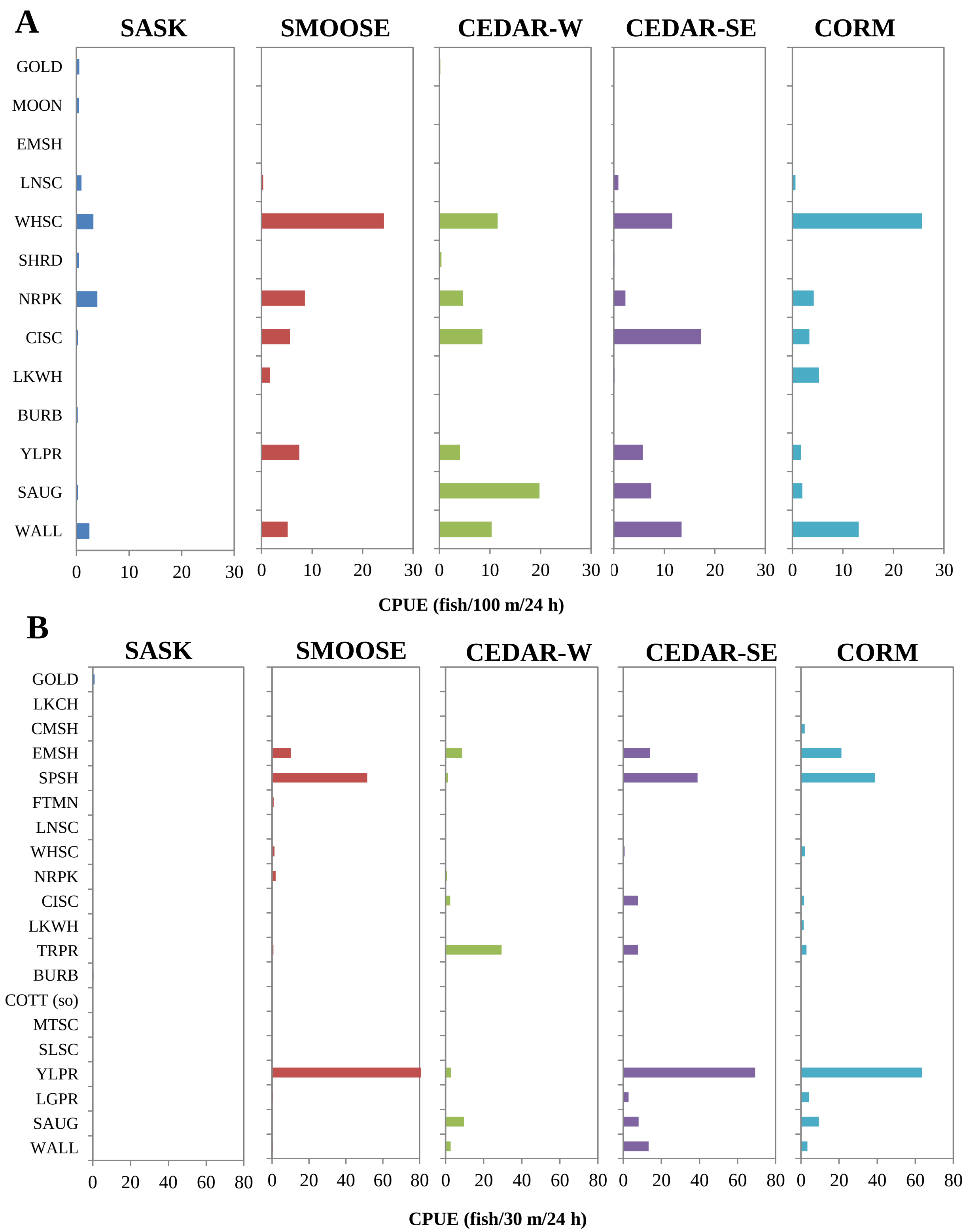


Figure 6-3. Mean catch-per-unit-effort in (A) standard gang (fish/100 m/24 h) and (B) small mesh (fish/30 m/24 h) index gill nets set in Saskatchewan River Region waterbodies, 2008-2013.

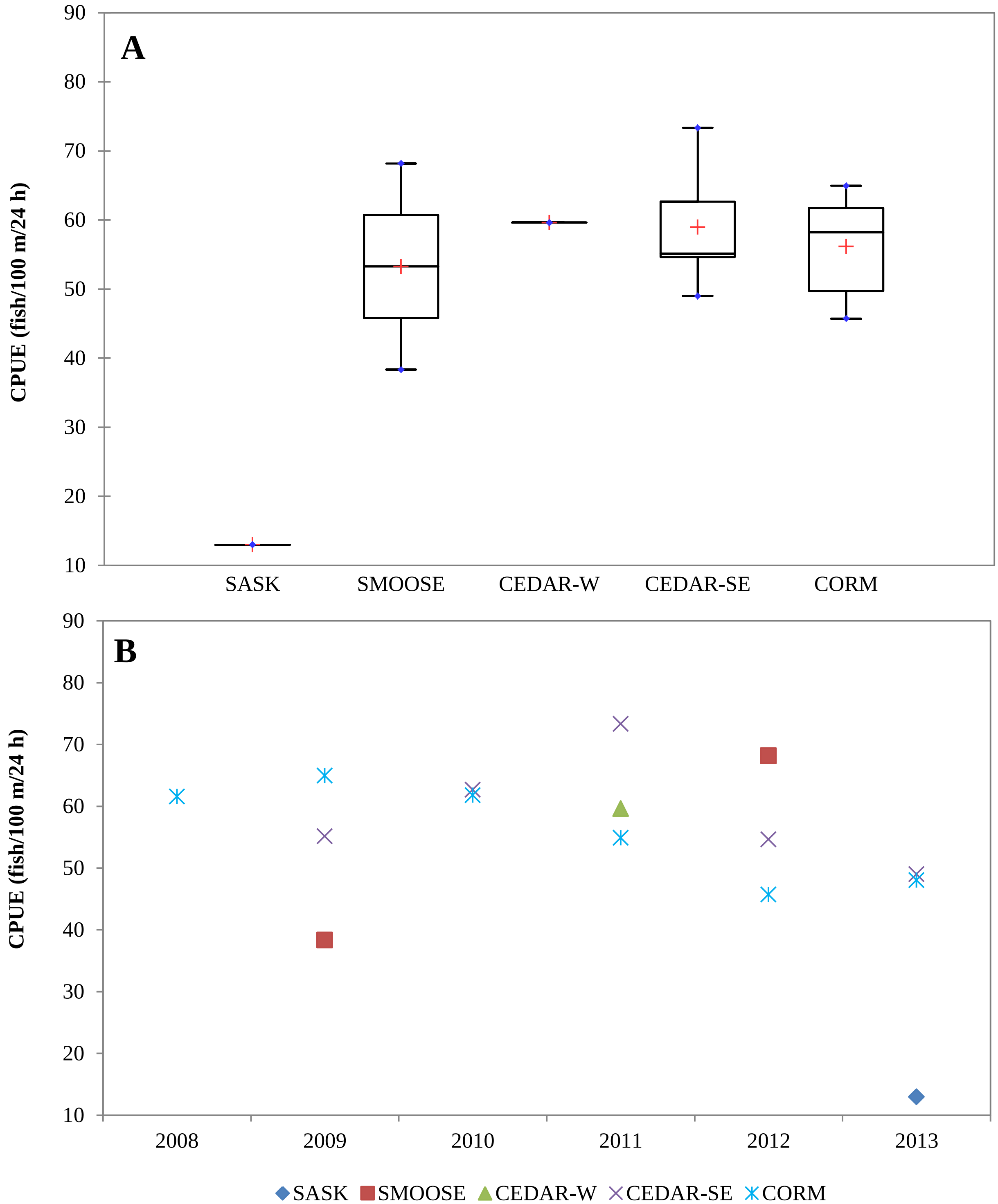
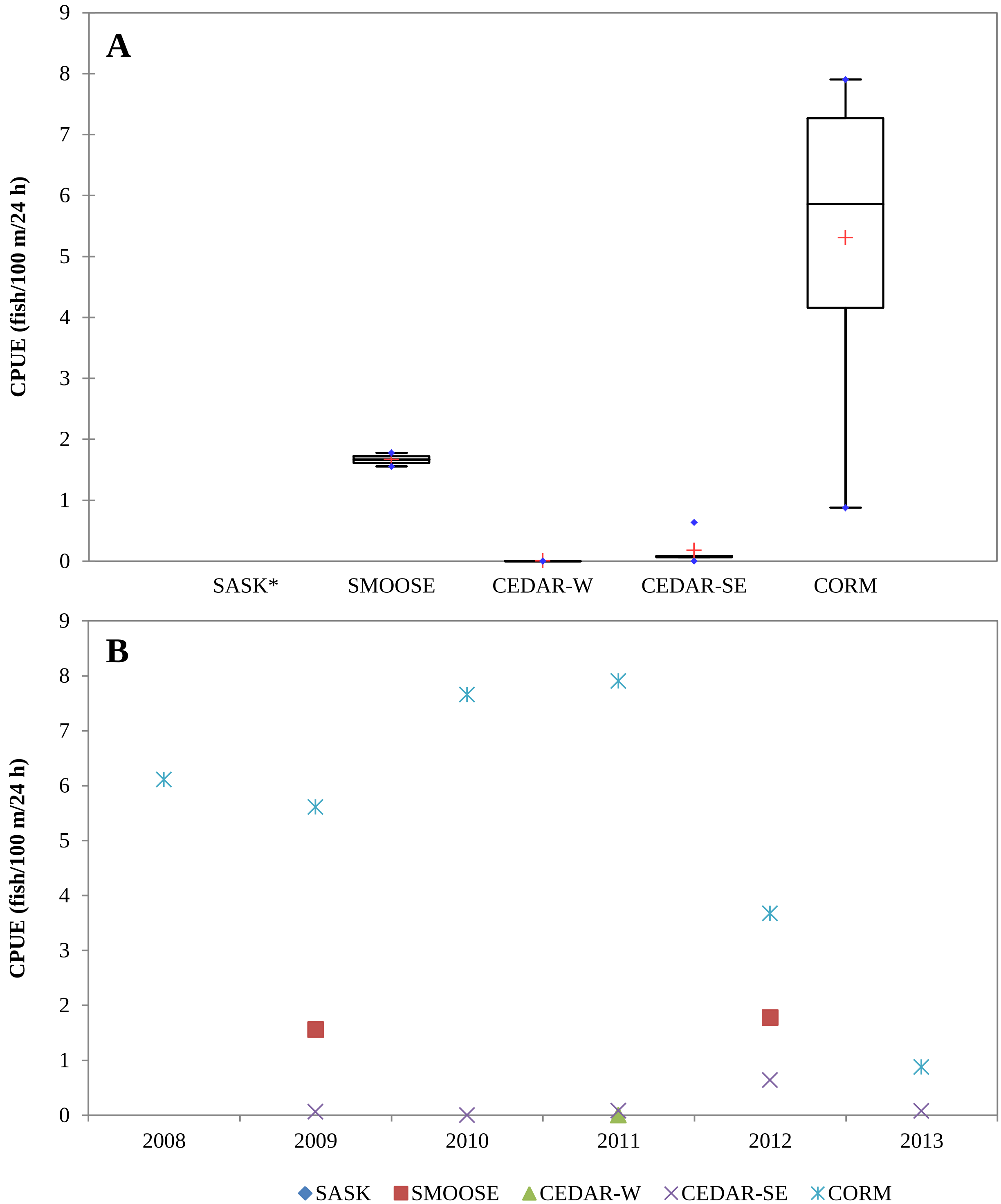


Figure 6-4. Annual mean catch-per-unit-effort (CPUE) calculated for the total catch in standard gang index gill nets set in Saskatchewan River Region waterbodies, 2008-2013.



*Lake Whitefish not a key species for SASK, data not analysed.

Figure 6-5. Annual mean catch-per-unit-effort (CPUE) calculated for Lake Whitefish captured in standard gang index gill nets set in Saskatchewan River Region waterbodies, 2008-2013; by waterbody (A) and by year (B).

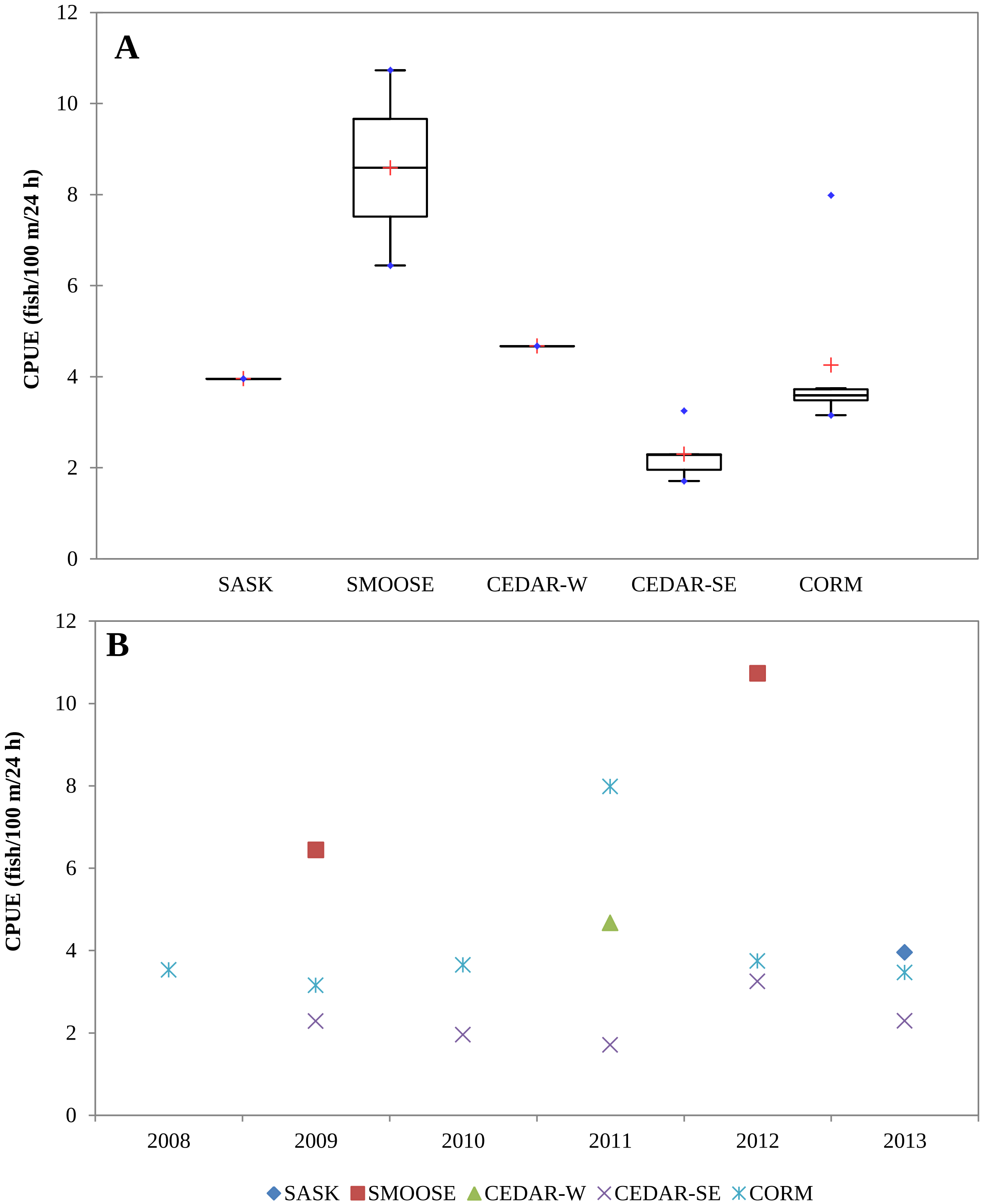


Figure 6-6. Annual mean catch-per-unit-effort (CPUE) calculated for Northern Pike captured in standard gang index gill nets set in Saskatchewan River Region waterbodies, 2008-2013; by waterbody (A) and by year (B).

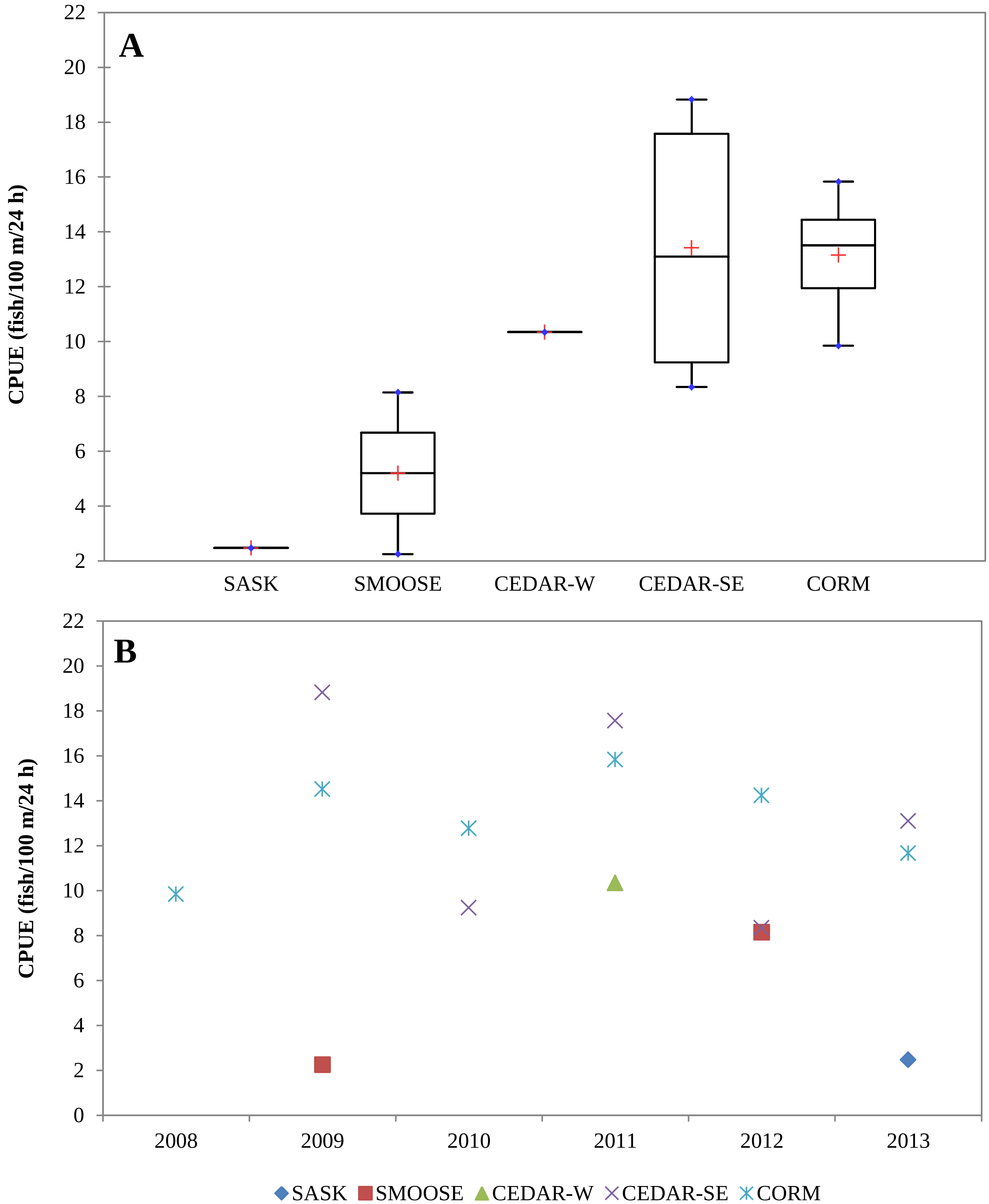


Figure 6-7. Annual mean catch-per-unit-effort (CPUE) calculated for Walleye captured in standard gang index gill nets set in Saskatchewan River Region waterbodies, 2008-2013; by waterbody (A) and by year (B).

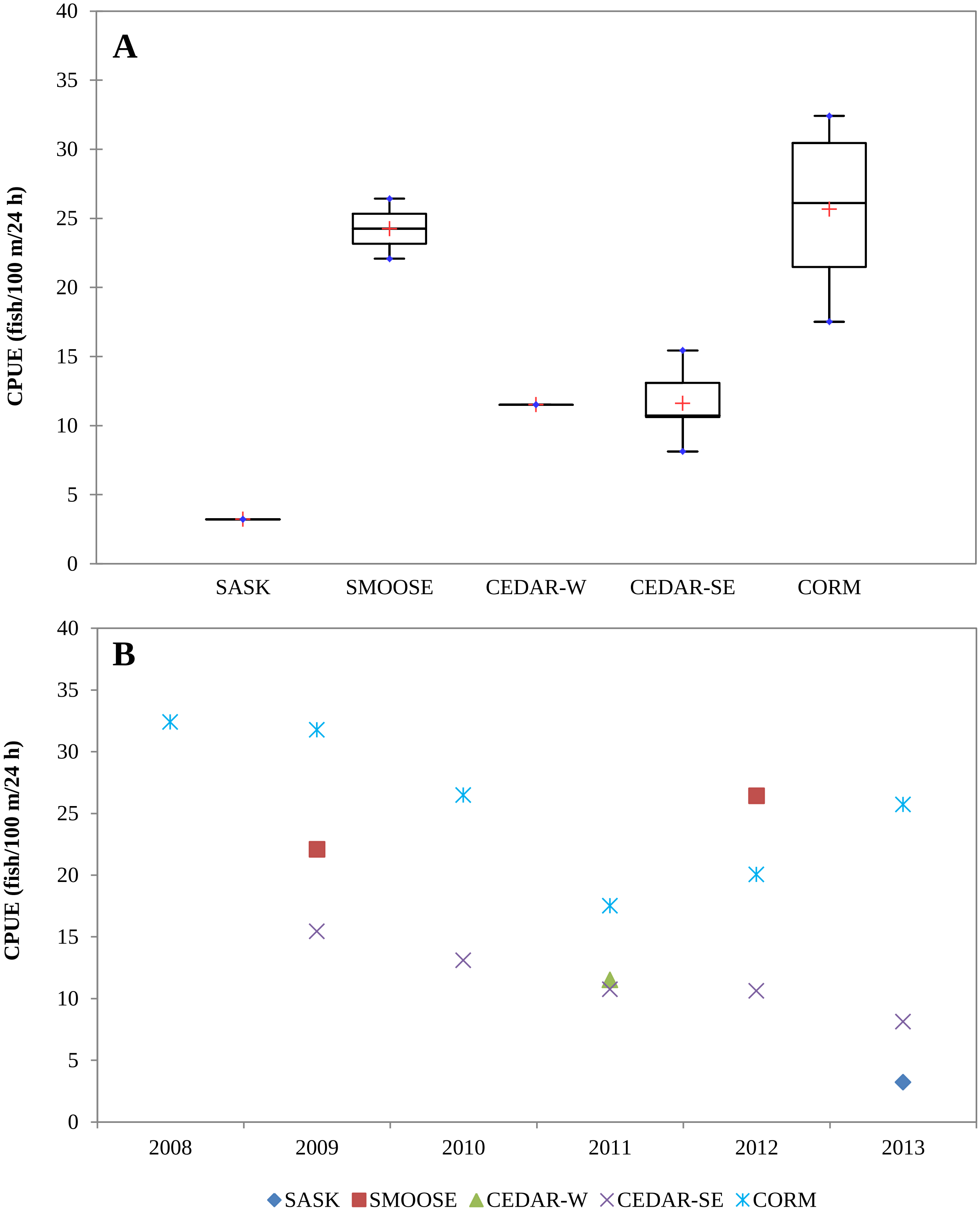


Figure 6-8. Annual mean catch-per-unit-effort (CPUE) calculated for White Sucker captured in standard gang index gill nets set in Saskatchewan River Region waterbodies, 2008-2013; by waterbody (A) and by year (B).

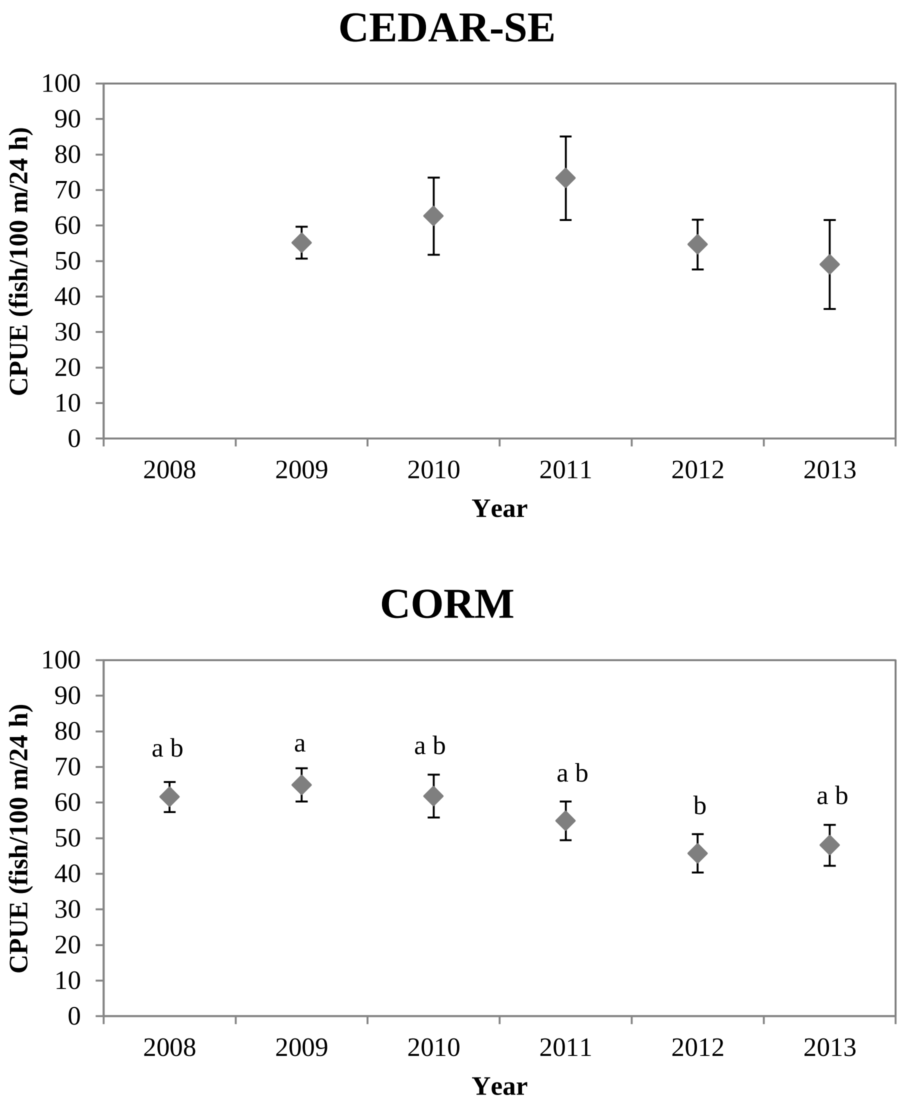


Figure 6-9. Total catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

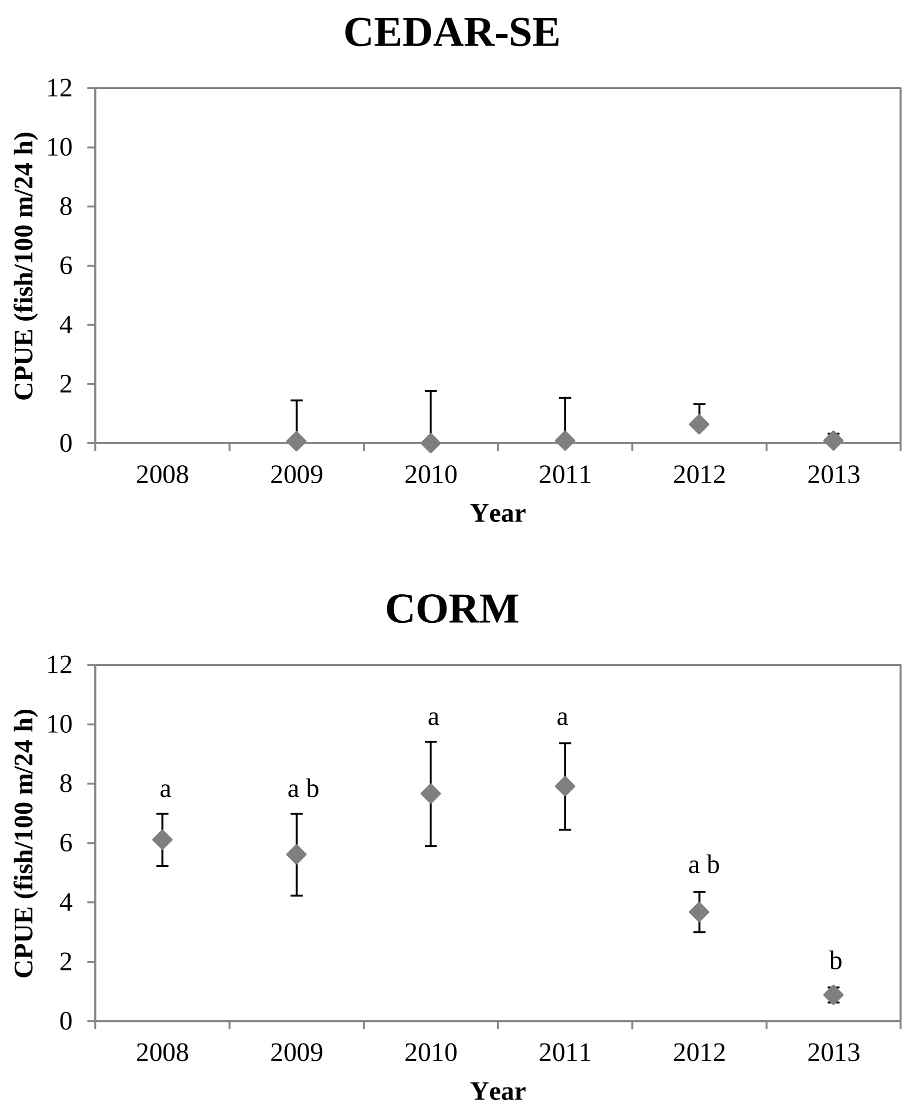


Figure 6-10. Lake Whitefish catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference. Lower error bars for CEDAR-SE are negative values and are not included in the figure.

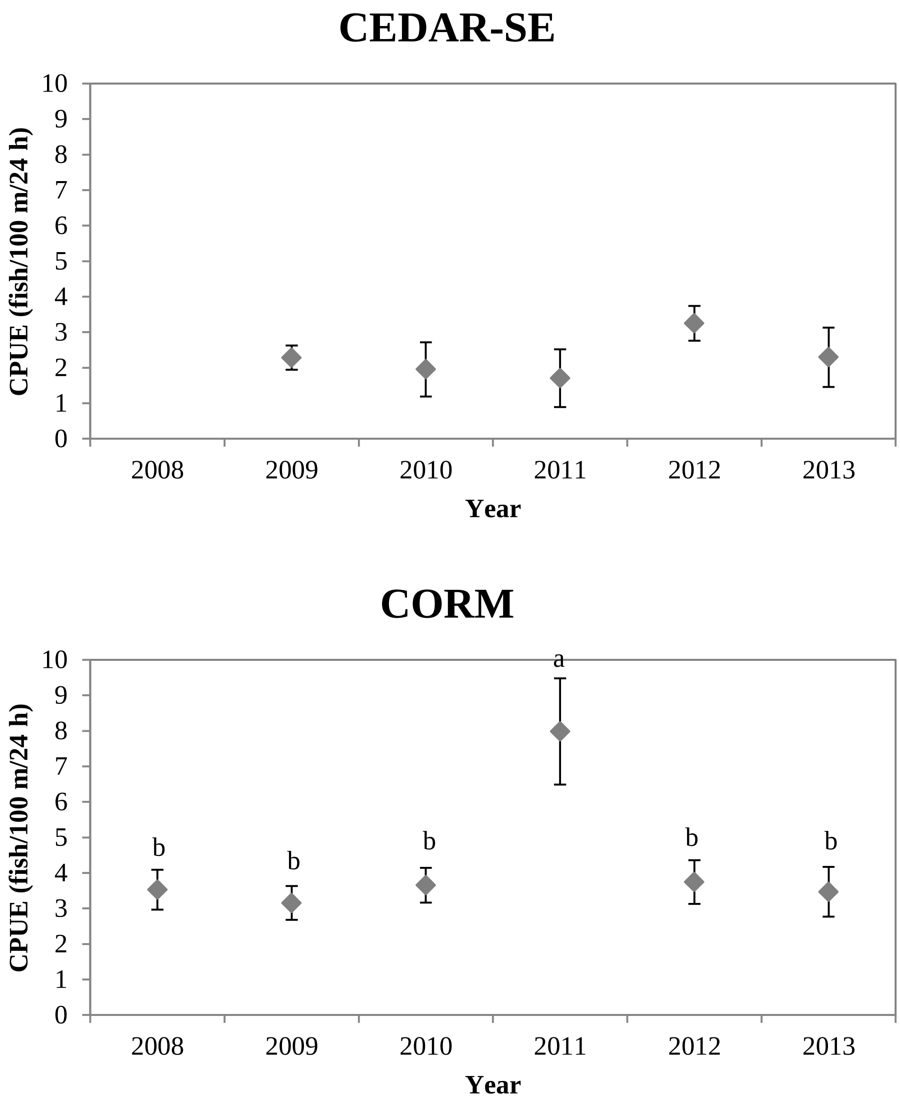
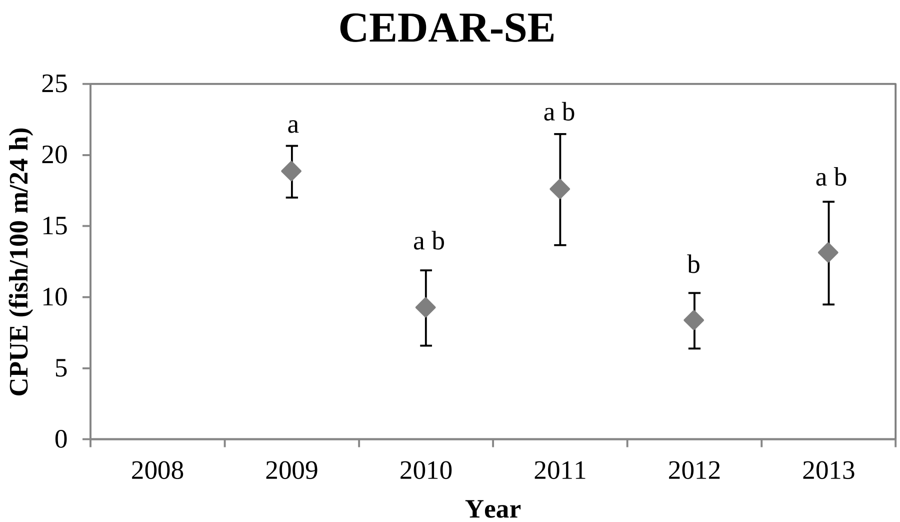


Figure 6-11. Northern Pike catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



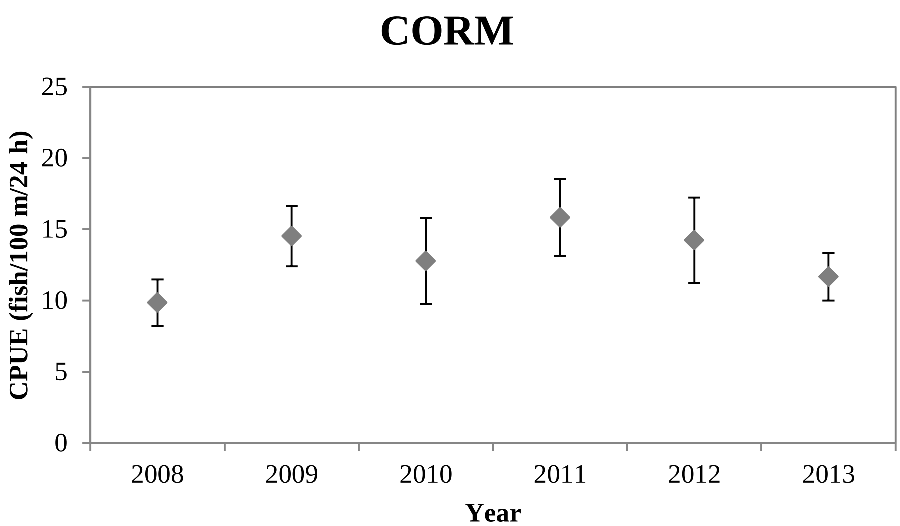


Figure 6-12. Walleye catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

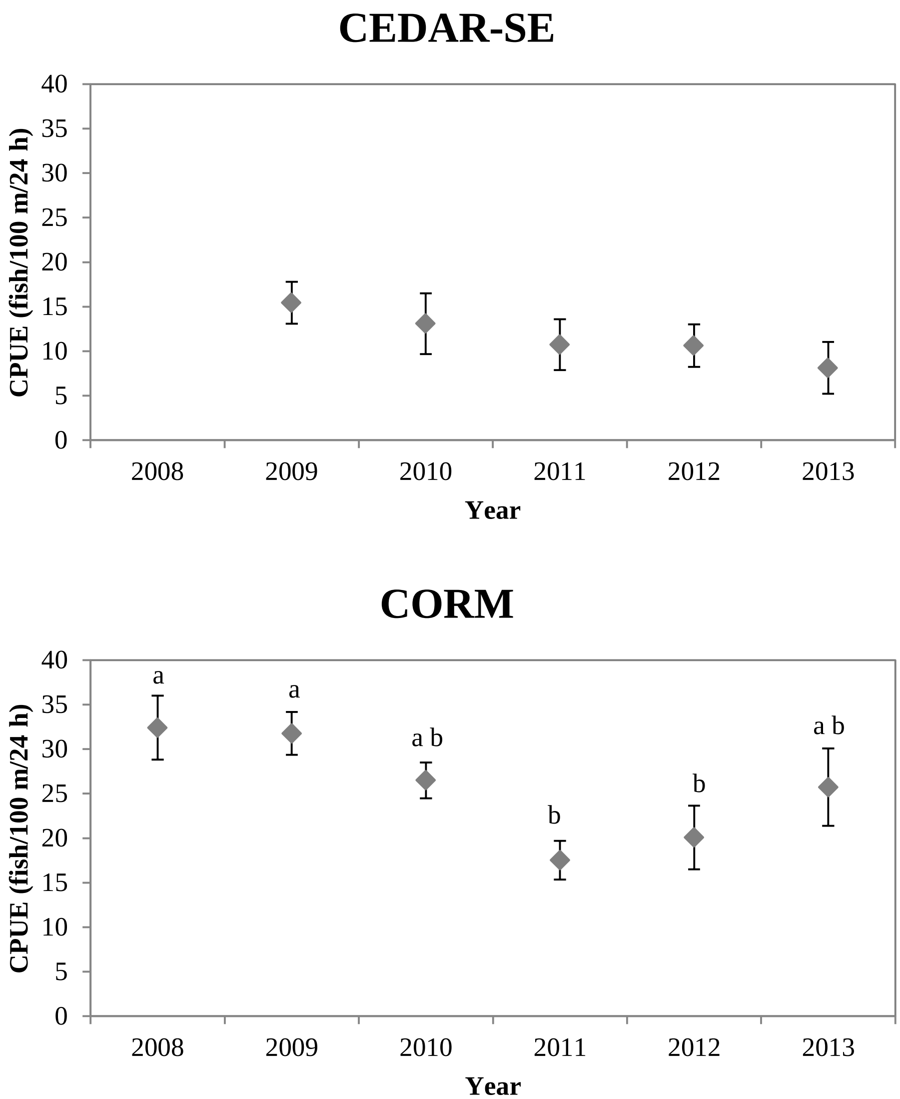
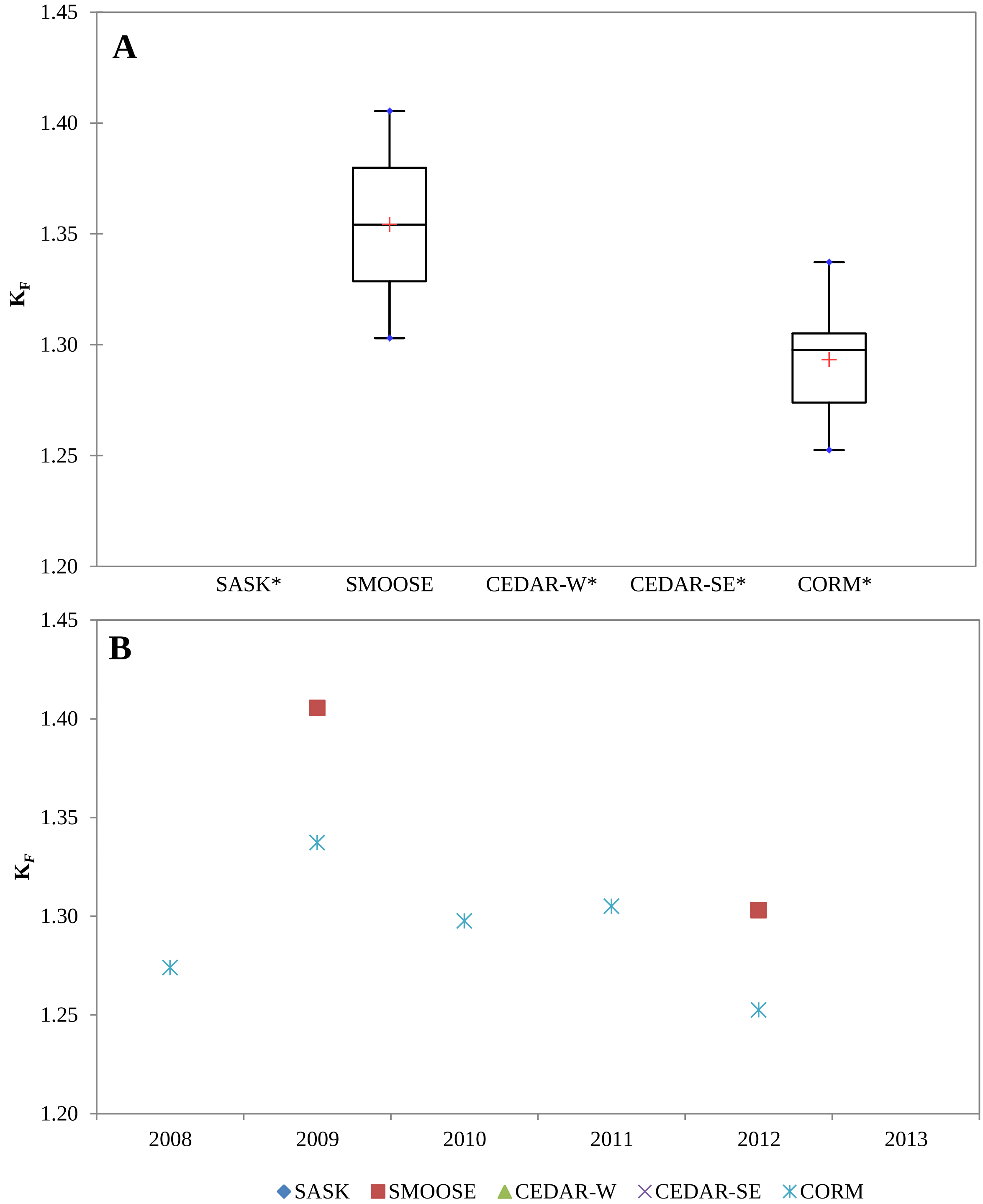
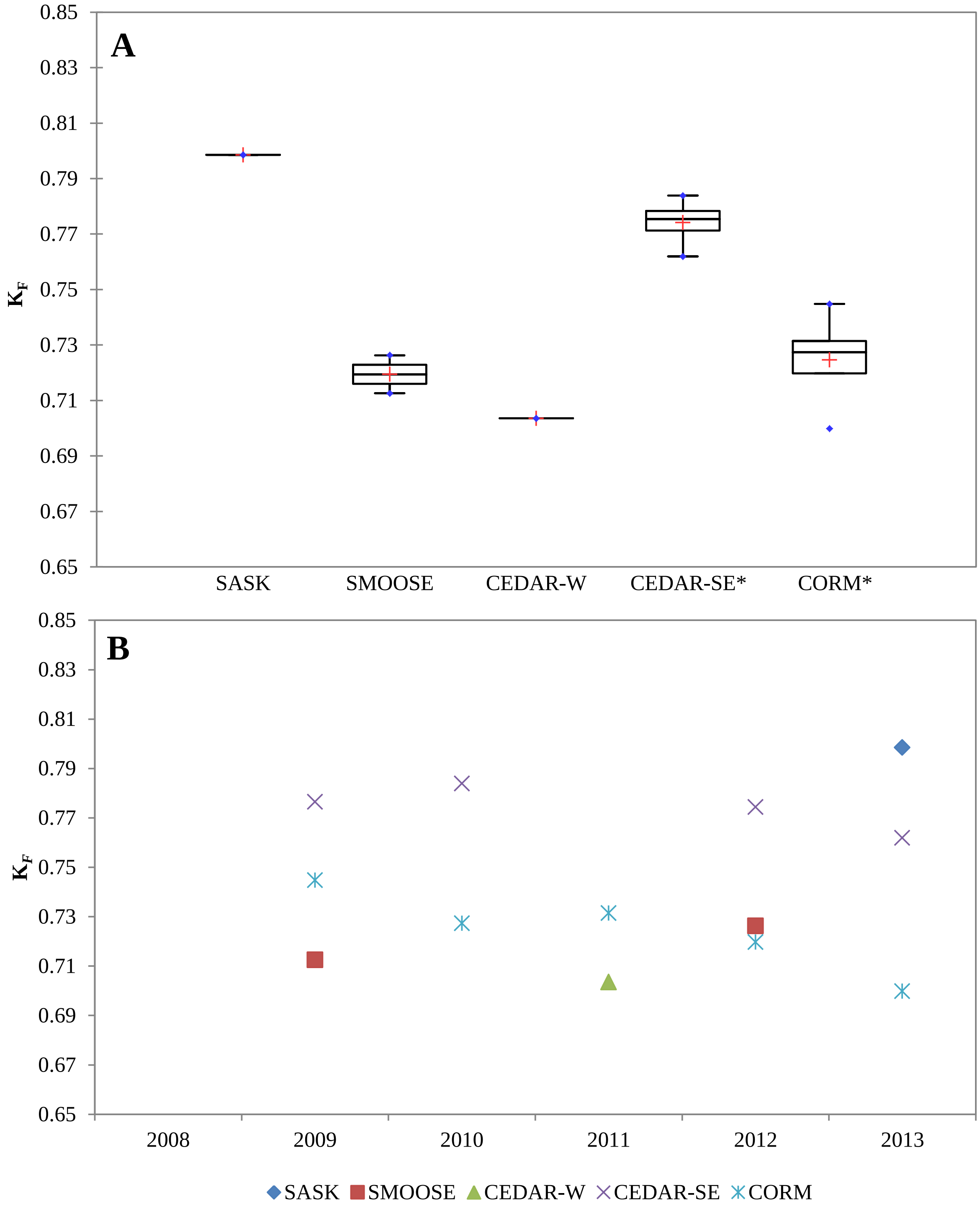


Figure 6-13. White Sucker catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



*Lake Whitefish not a key species for SASK; too few fish were measured at CEDAR-W and CEDAR-SE all years, and CORM in 2013.

Figure 6-14. Annual mean Fulton's condition factor (K_F) calculated for Lake Whitefish between 300 and 499 mm in fork length captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



*Too few fish were measured at CEDAR-SE in 2011 and CORM in 2008.

Figure 6-15. Annual mean Fulton's condition factor (K_F) calculated for Northern Pike between 400 and 699 mm in fork length captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

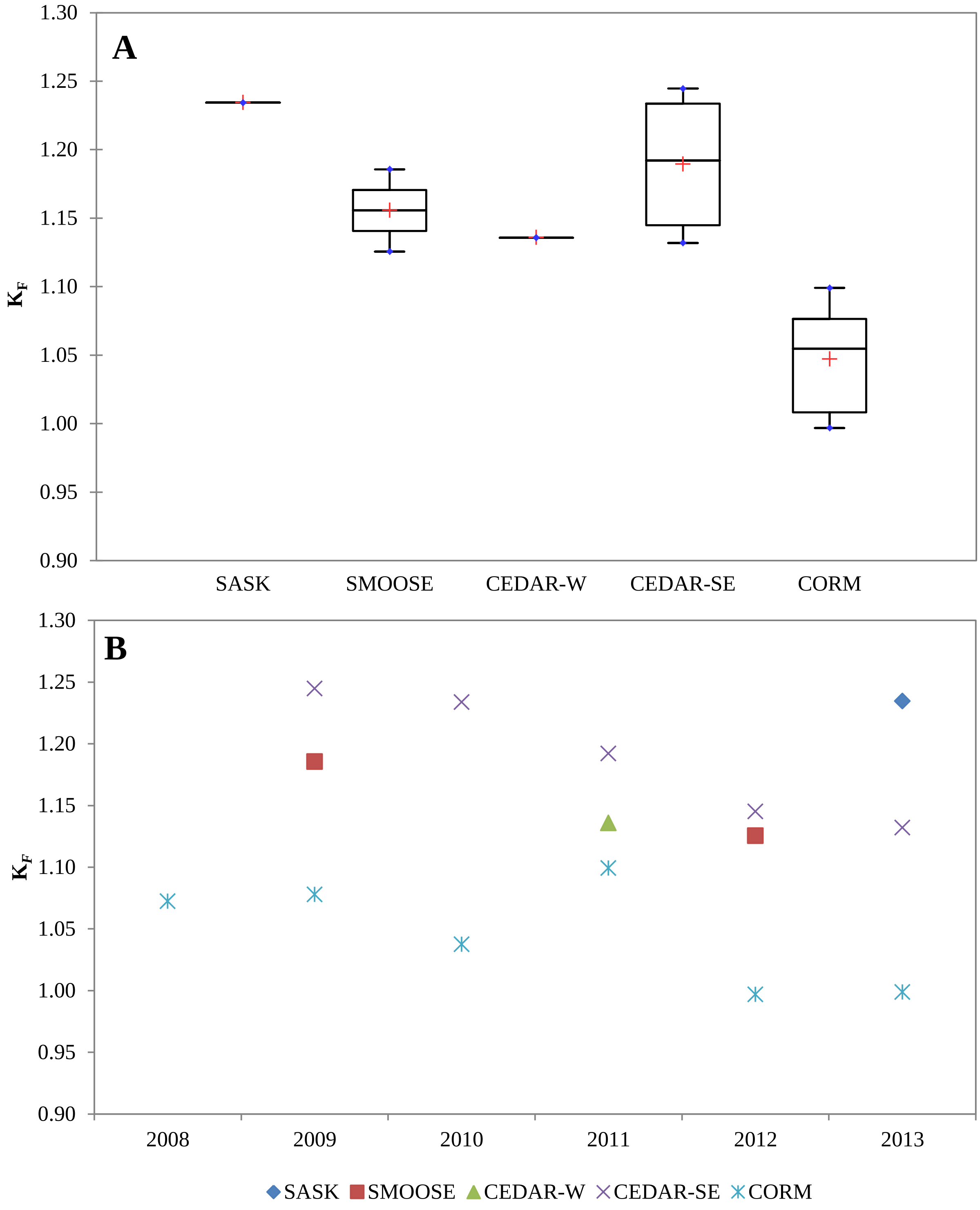
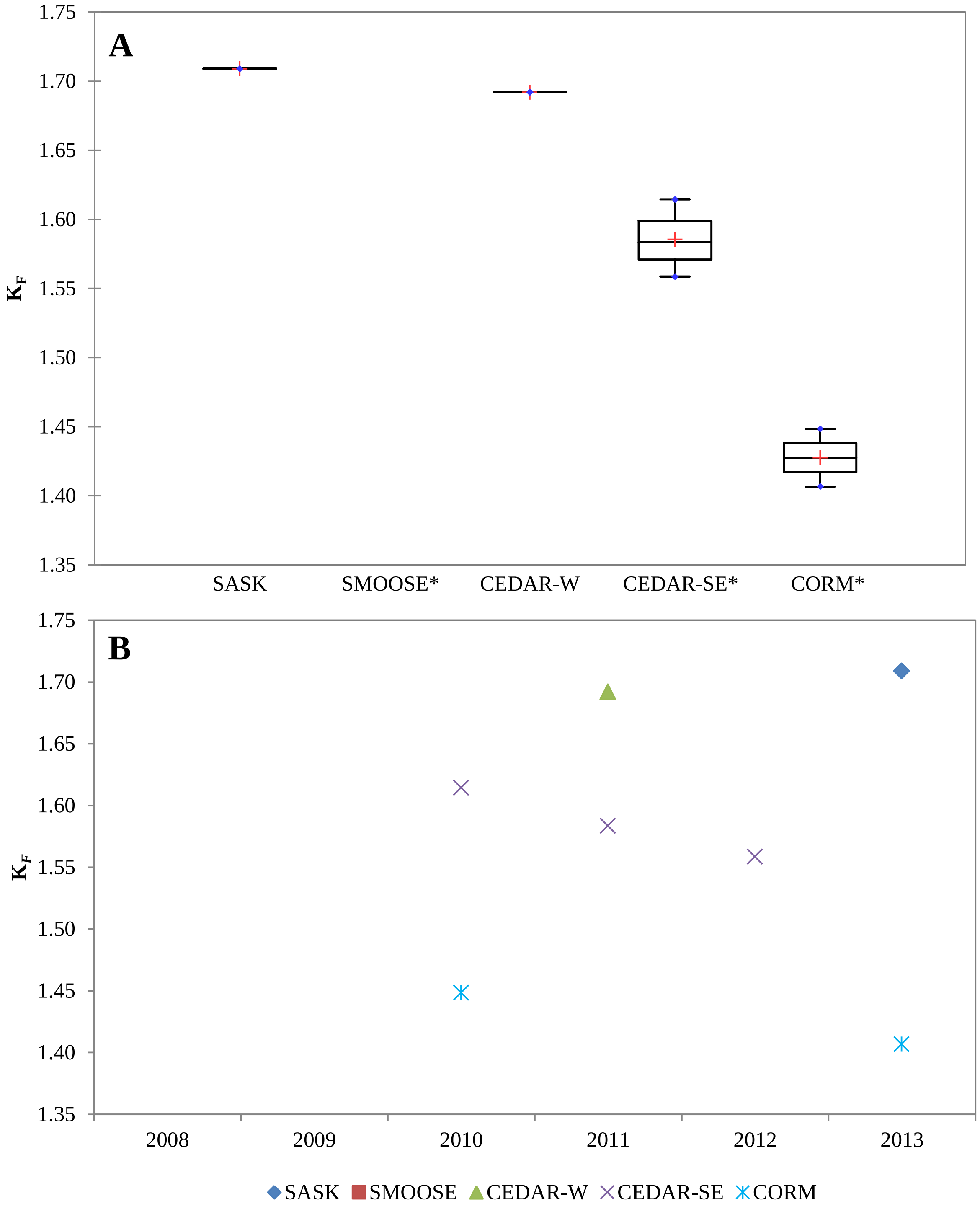


Figure 6-16. Annual mean Fulton's condition factor (K_F) calculated for Walleye between 300 and 499 mm in fork length captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



*Too few fish were measured at SMOOSE in all years, at CEDAR-SE in 2008 and 2013, and at CORM in 2008, 2009, 2011, and 2012.

Figure 6-17. Annual mean Fulton's condition factor (K_F) calculated for White Sucker between 300 and 499 mm in fork length captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

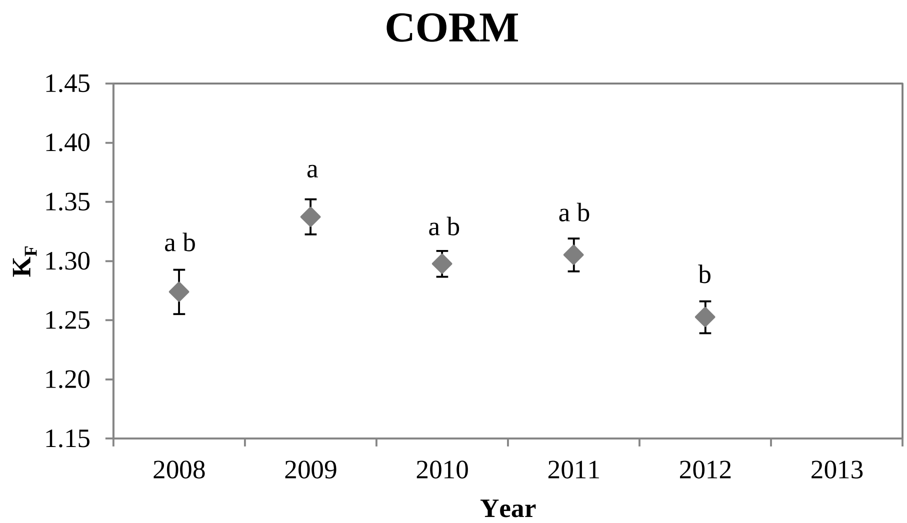
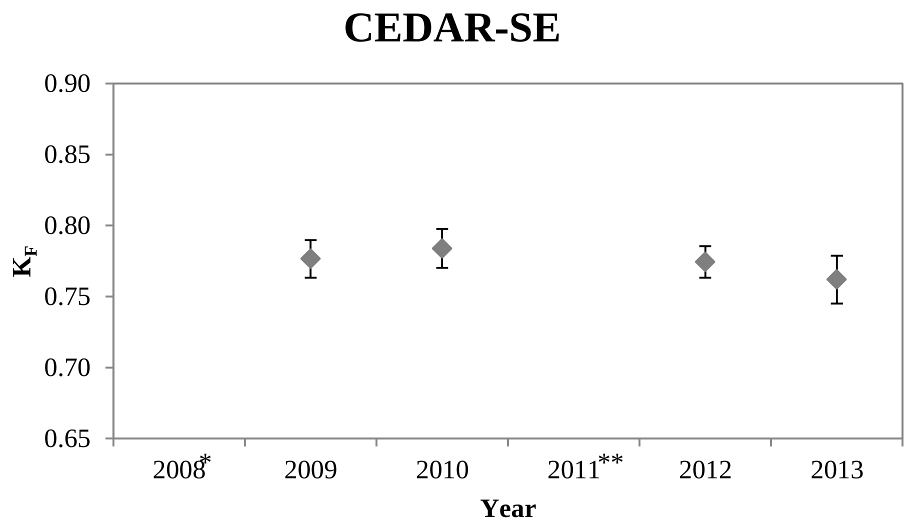
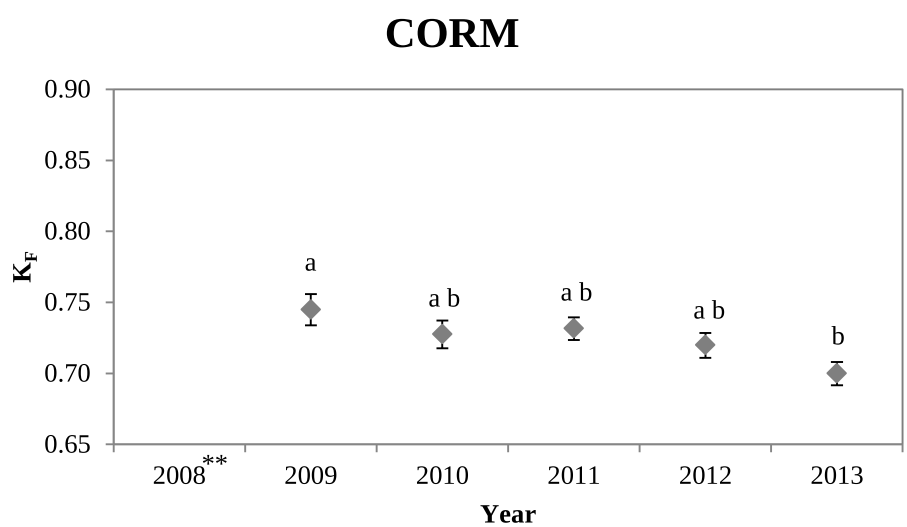


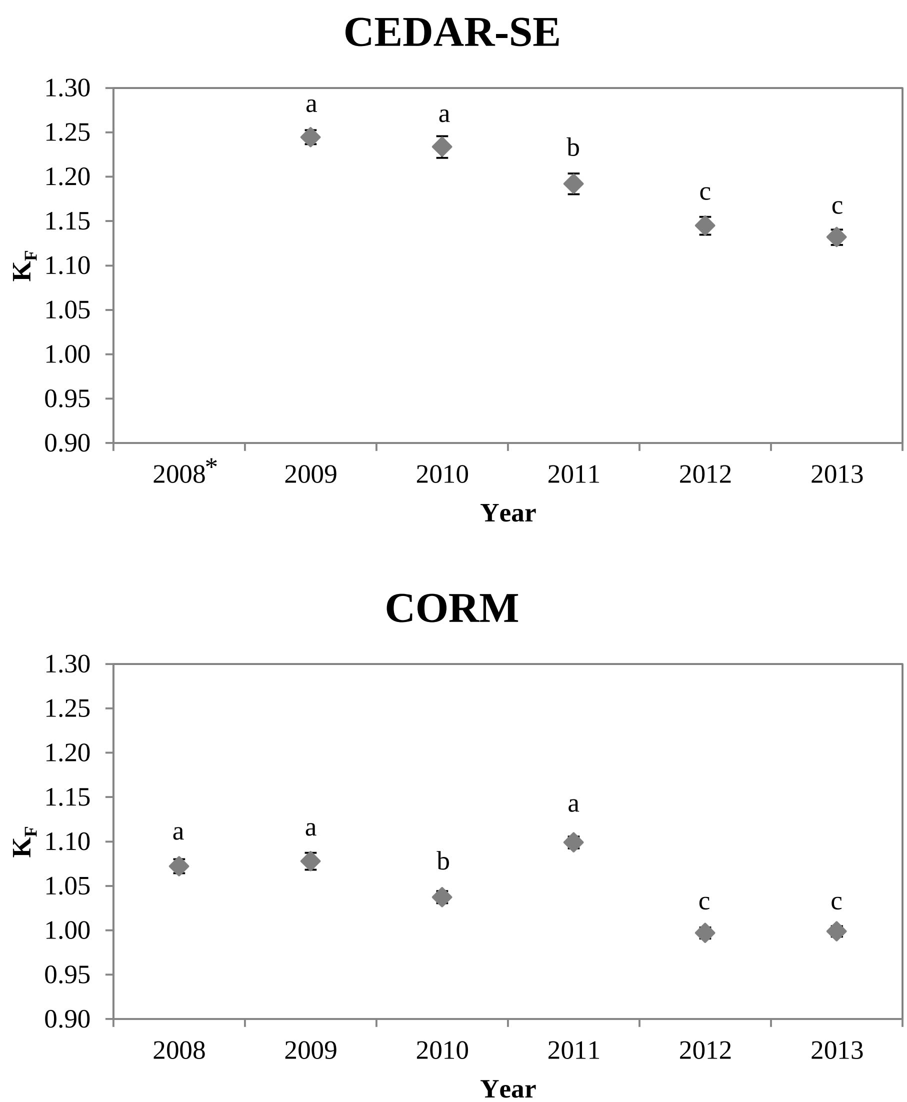
Figure 6-18. Fulton's condition factor (K_F; mean ± SE) of Lake Whitefish between 300 and 499 mm in fork length captured at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference. Note: Insufficient numbers of Lake Whitefish were captured in CEDAR-SE for statistical analyses.





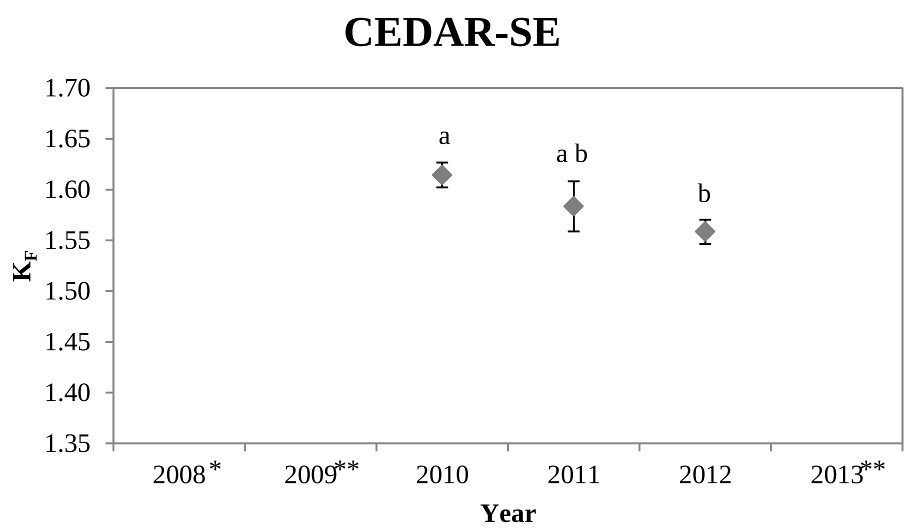
* Not sampled
** Too few fish were assessed for condition.

Figure 6-19. Fulton's condition factor (K_F; mean ± SE) of Northern Pike between 400 and 699 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



* Not sampled.

Figure 6-20. Fulton's condition factor (K_F; mean ± SE) of Walleye between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



* Not sampled.
** Too few fish were assessed for condition.

Figure 6-21. Fulton's condition factor (K_F; mean ± SE) of White Sucker between 300 and 499 mm in fork length captured at Cedar Lake - Southeast. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference. Note: too few fish were assessed for condition in most years at CORM.

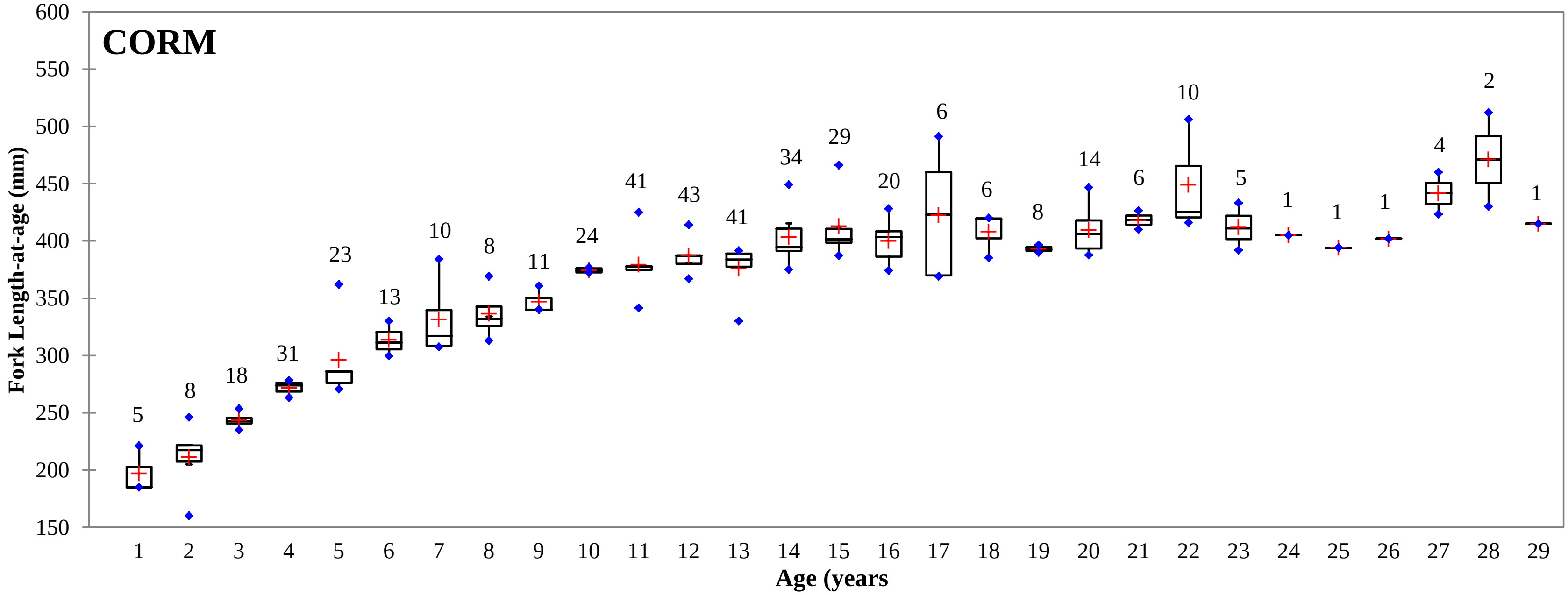
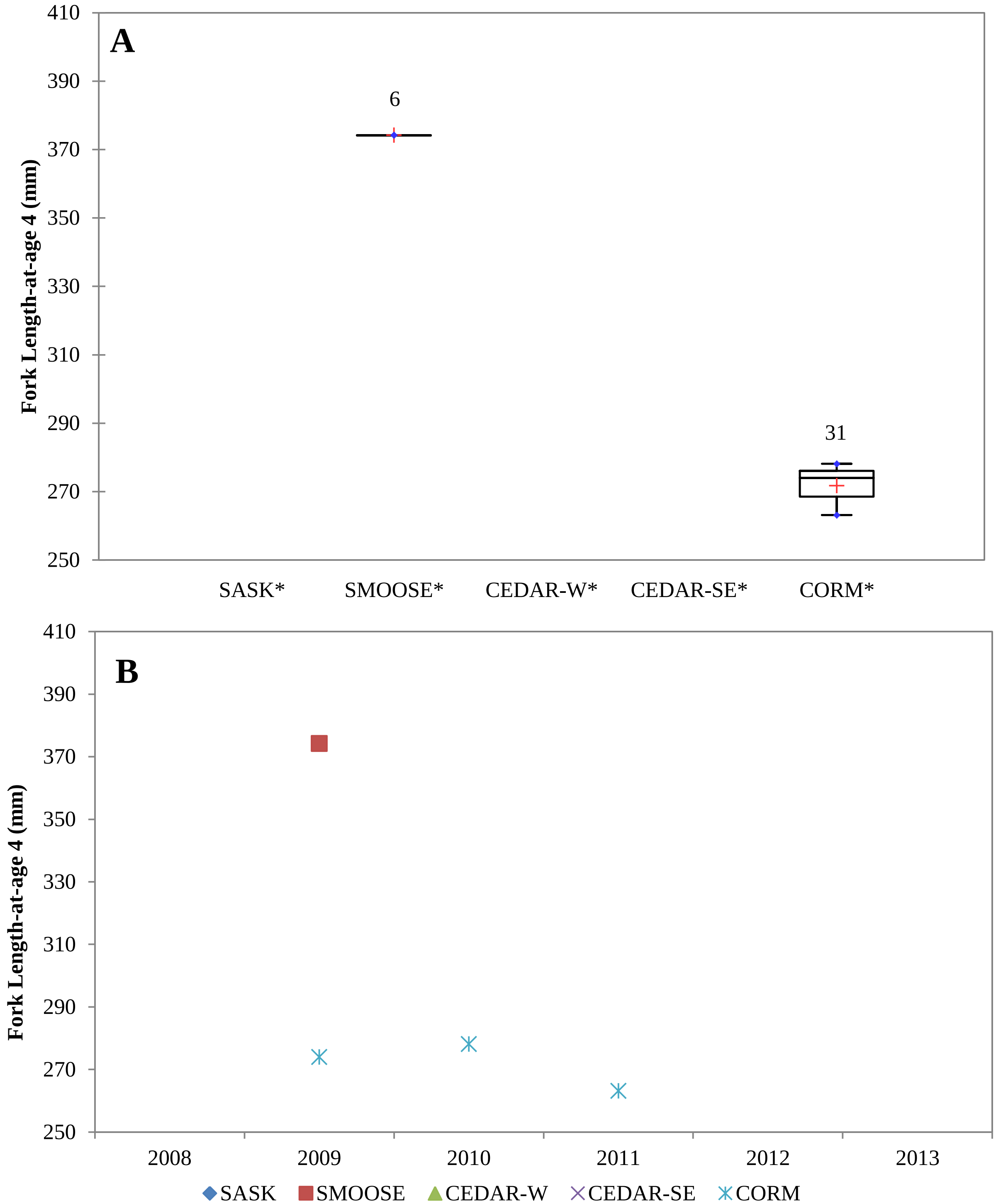
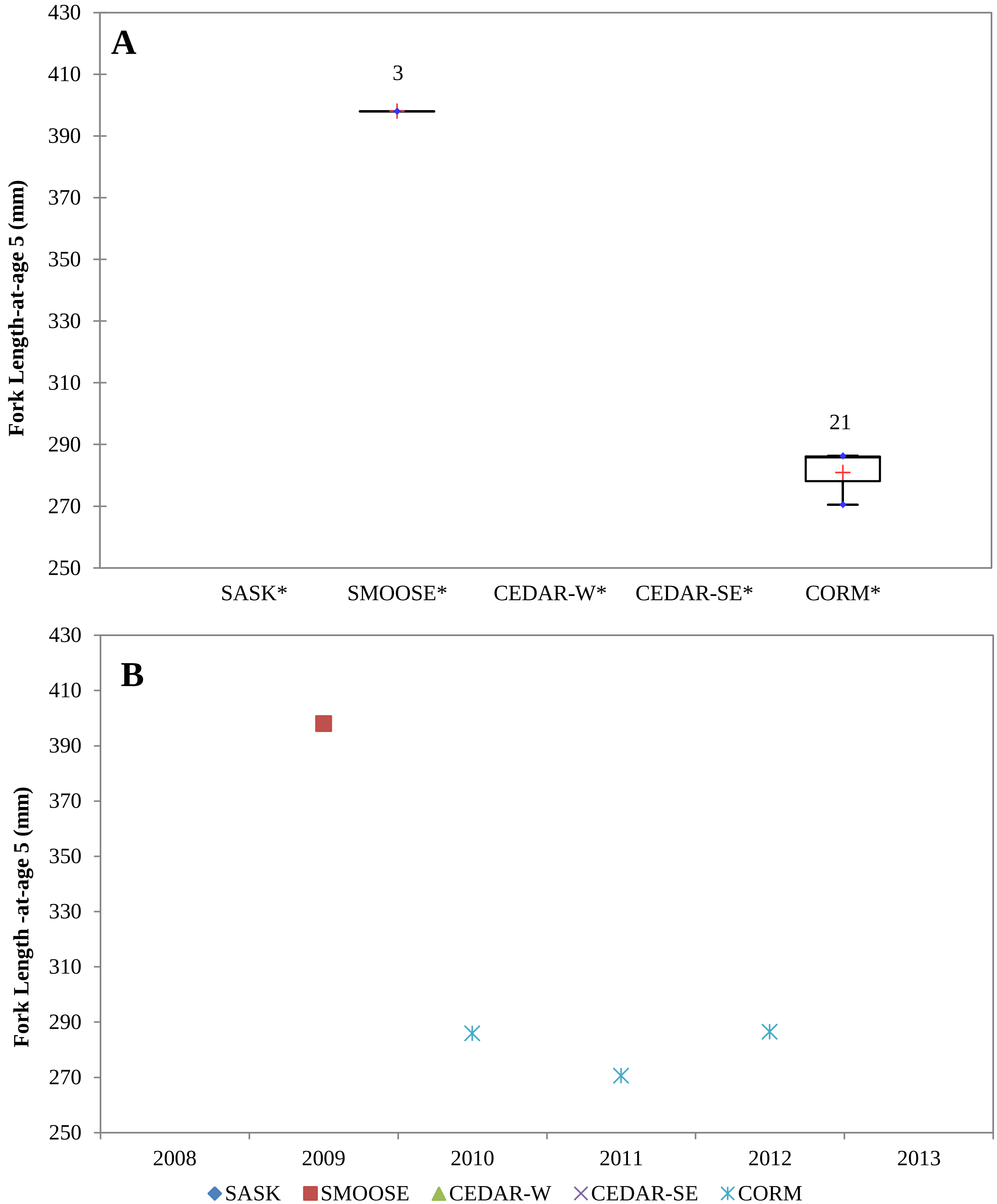


Figure 6-22. Annual mean length-at-age (mm) of Lake Whitefish captured in gill nets set at annual sampling locations in the Saskatchewan River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



*Lake Whitefish not a key species for SASK; too few age-4 fish were captured at SMOOSE in 2012, at CEDAR-W in 2011, at CEDAR-SE in all years and at CORM in 2008, 2012, and 2013.

Figure 6-23. Annual mean length-at-age 4 (mm) of Lake Whitefish captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 4-year-old fish captured over the 6-year sampling period is shown above the box for each waterbody.



*Lake Whitefish not a key species for SASK; too few age-5 fish were captured at SMOOSE in 2012, at CEDAR-W in 2011, at CEDAR-SE in all years and at CORM in 2008, 2009, and 2013.

Figure 6-24. Annual mean length-at-age 5 (mm) of Lake Whitefish captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 5-year-old fish captured over the 6-year sampling period is shown above the box for each waterbody.

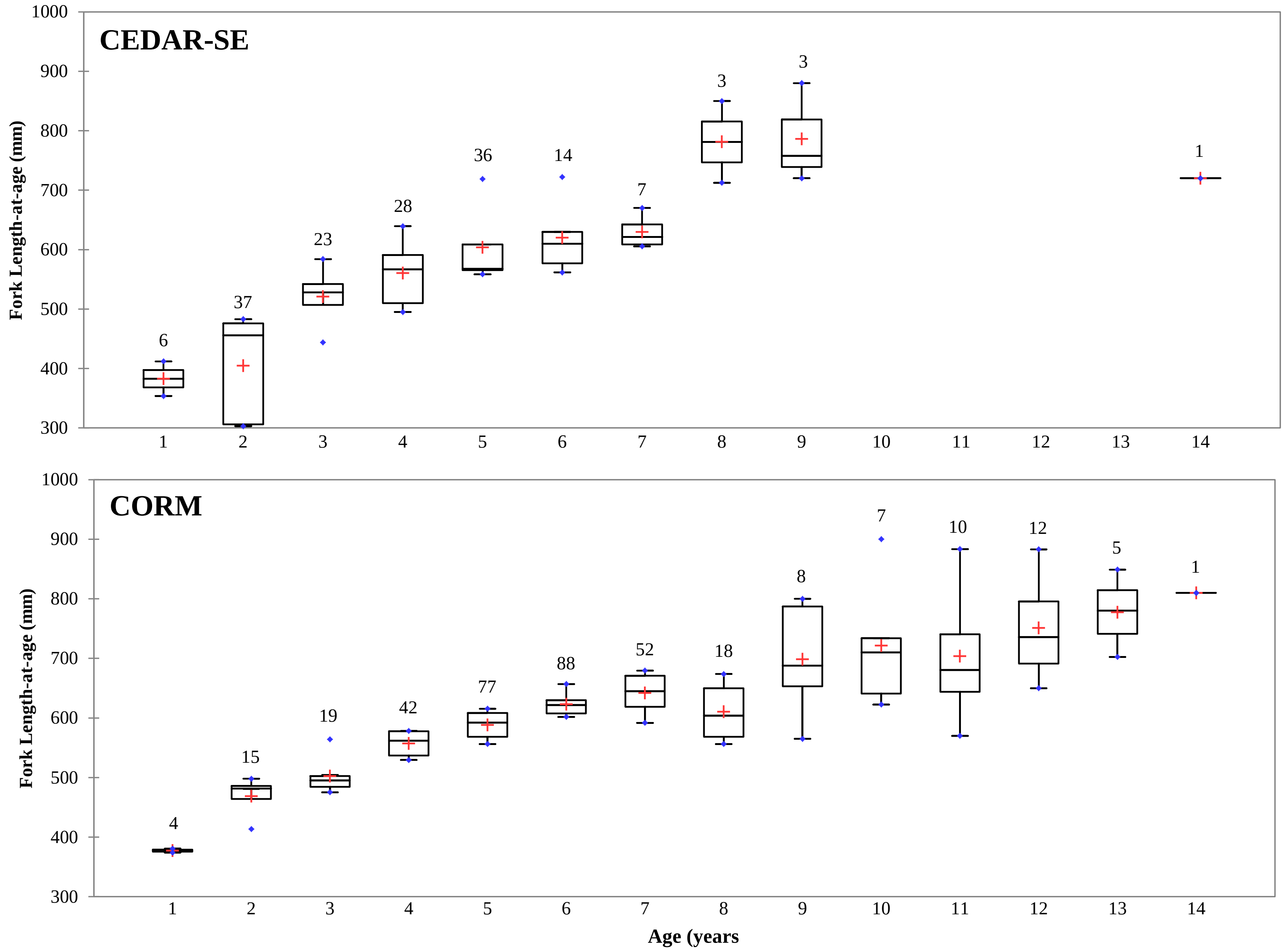


Figure 6-25. Annual mean length-at-age (mm) of Northern Pike captured in gill nets set at annual sampling locations in the Saskatchewan River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.

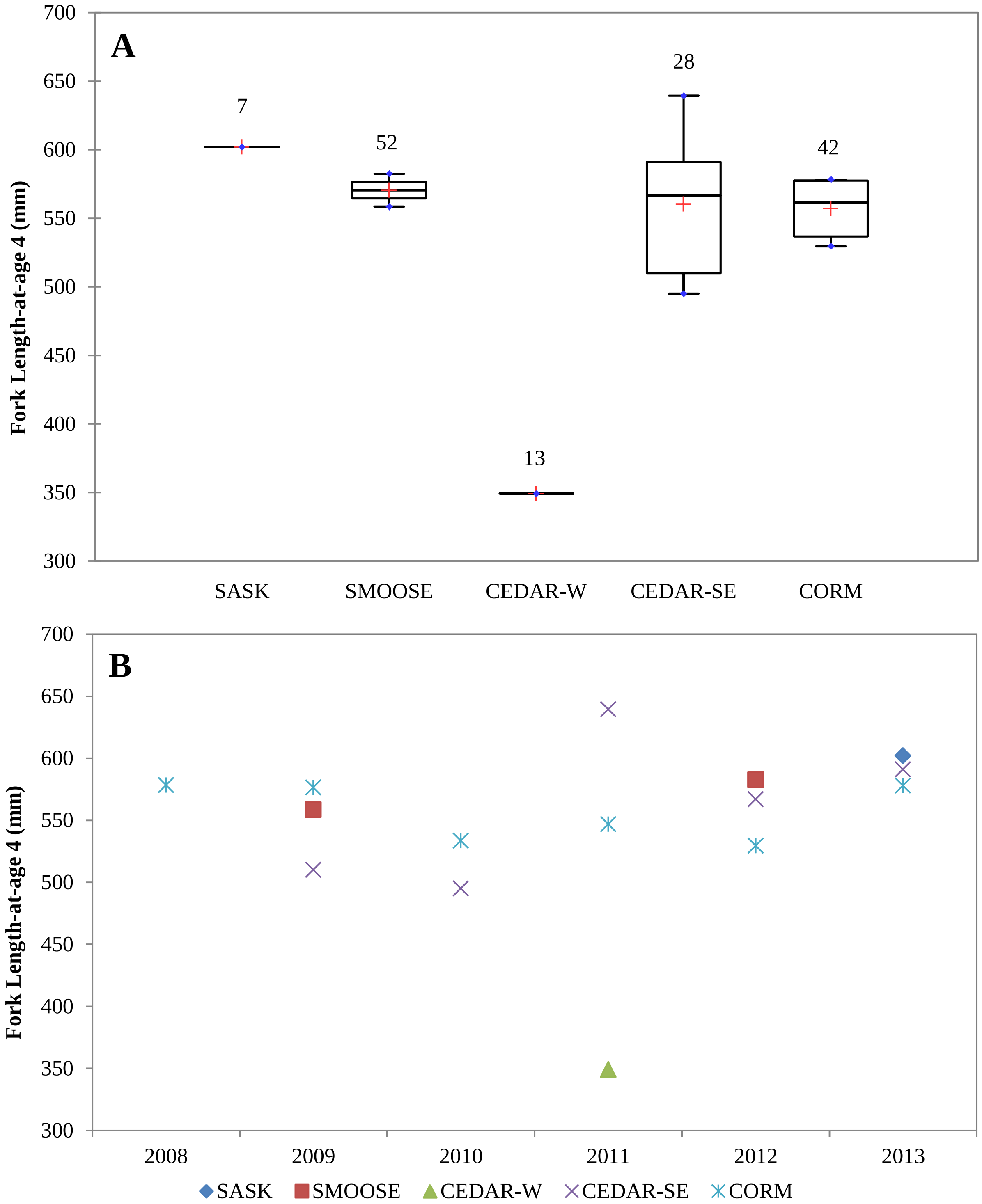


Figure 6-26. Annual mean length-at-age 4 (mm) of Northern Pike captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 4-year-old fish captured over the 6-year sampling period is shown above the box for each waterbody.

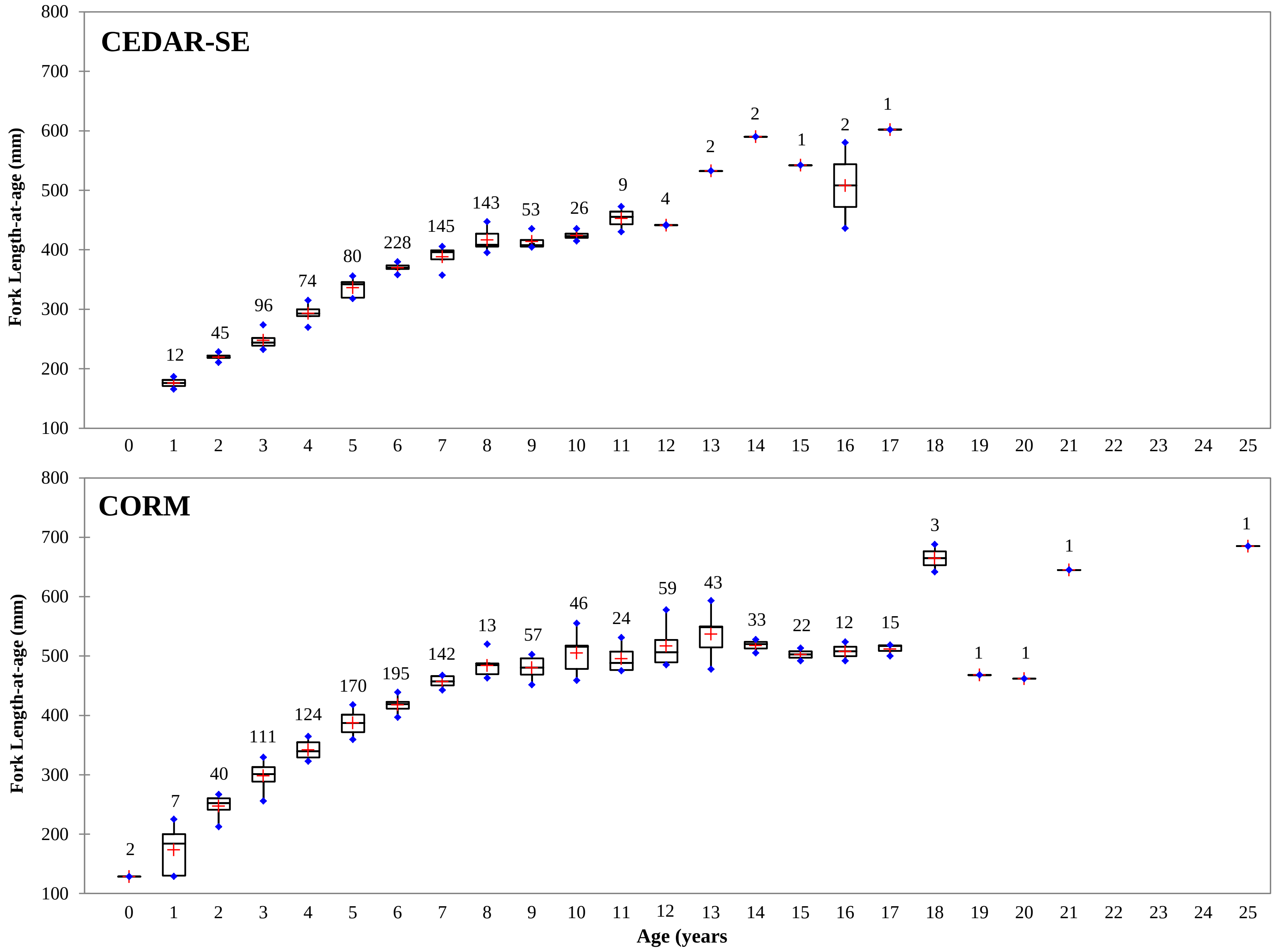
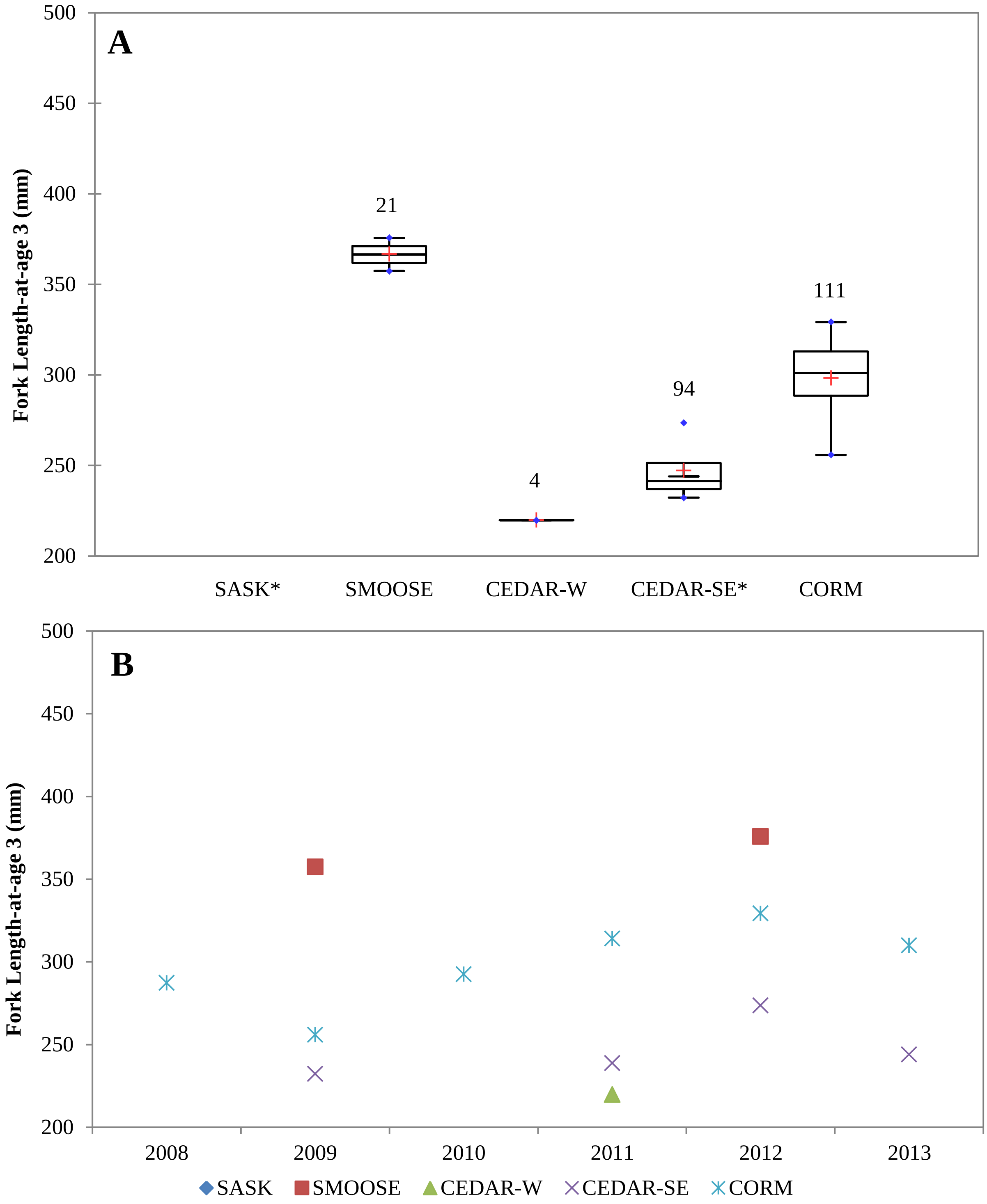
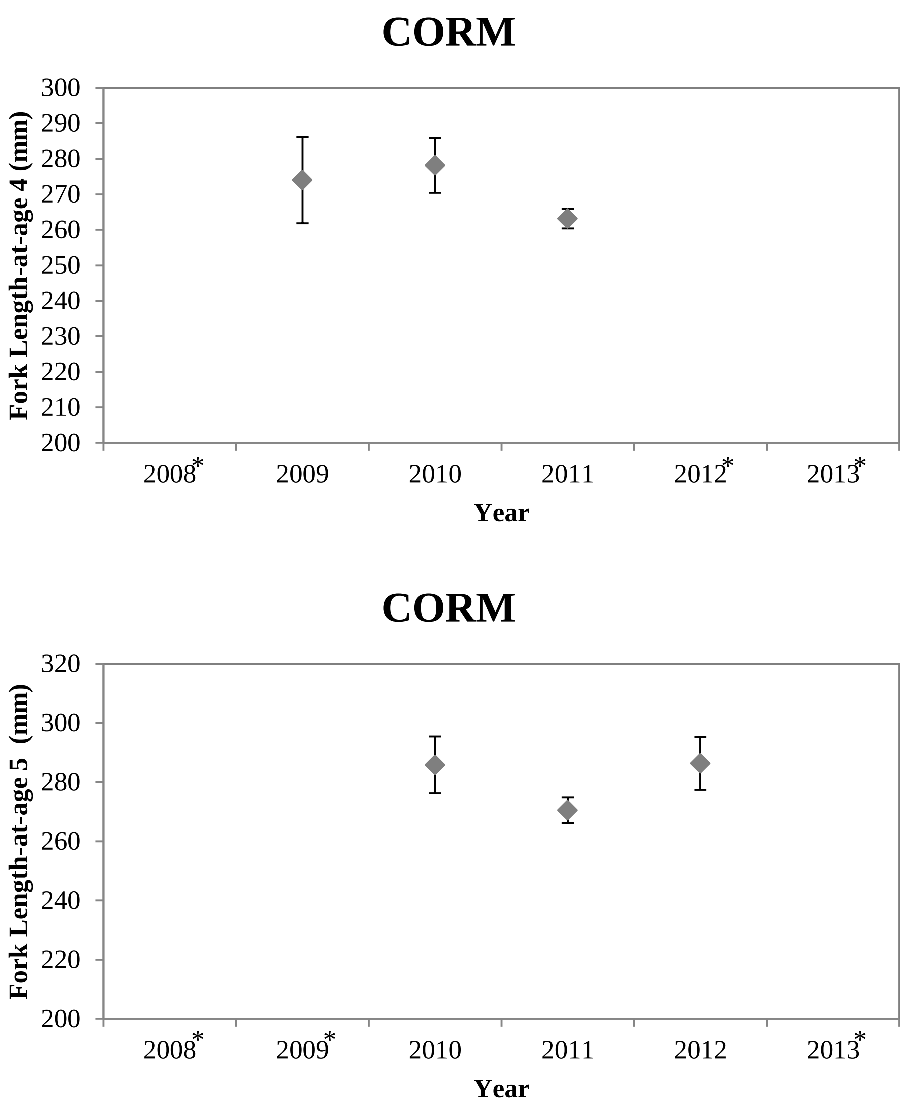


Figure 6-27. Annual mean length-at-age (mm) of Walleye captured in gill nets set at annual sampling locations in the Saskatchewan River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



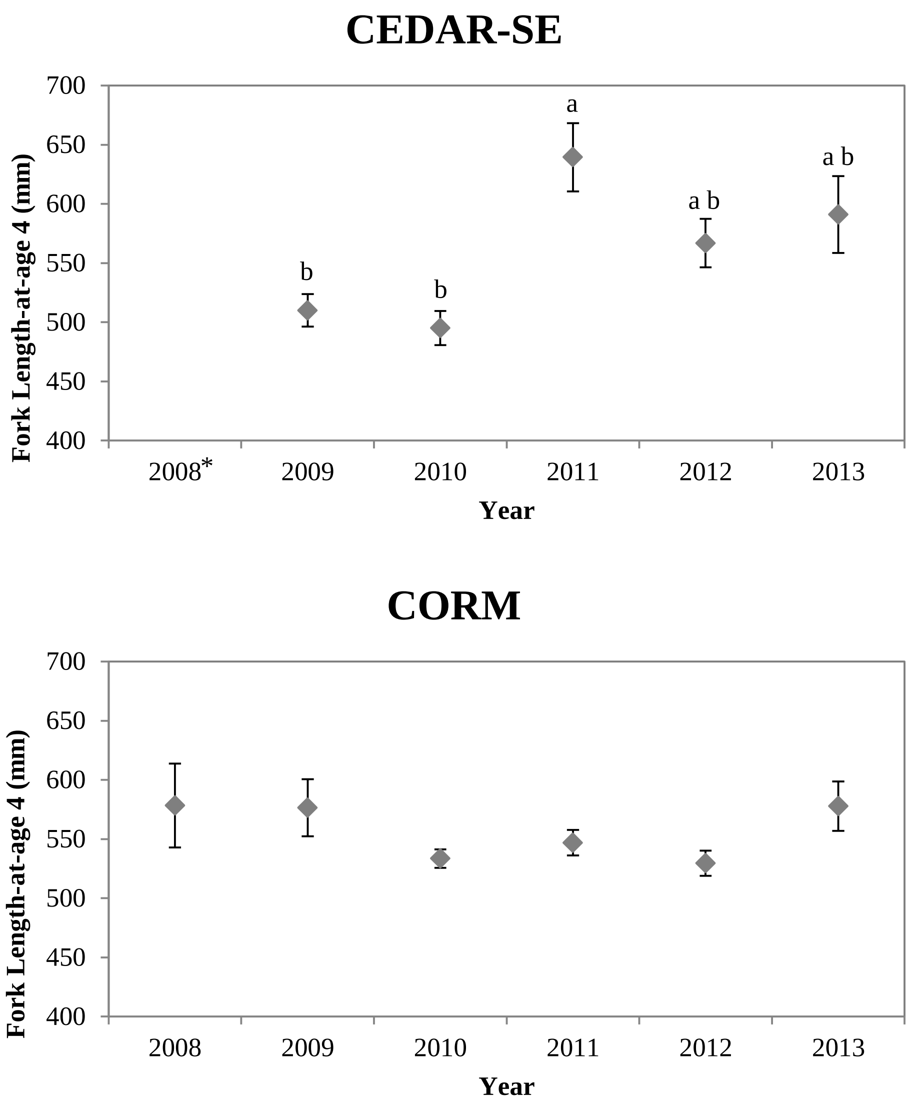
*Too few age-3 fish were captured at SASK in all years and at CEDAR-SE in 2010.

Figure 6-28. Annual mean length-at-age 3 (mm) of Walleye captured in gill nets set in Saskatchewan River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 3-year-old fish captured over the 6-year sampling period is shown above the box for each waterbody.



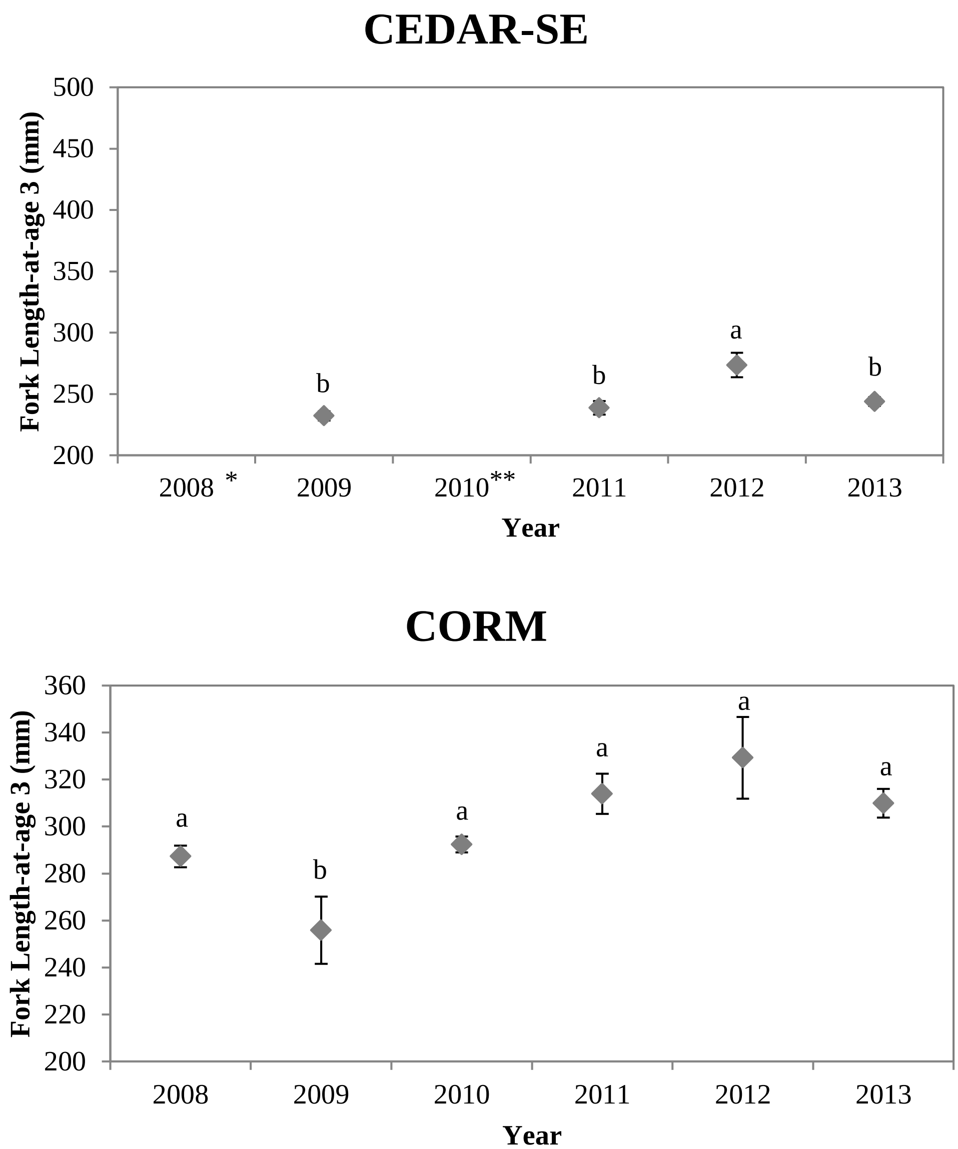
* Too few fish.

Figure 6-29. Fork length-at-ages 4 (top) and 5 (bottom; mean ± SE) of Lake Whitefish captured at Cormorant Lake. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



* Not sampled.

Figure 6-30. Fork length-at-age 4 (mean ± SE) of Northern Pike captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



*Not sampled.
**Too few fish

Figure 6-31. Fork length-at-age 3 (mean ± SE) of Walleye captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

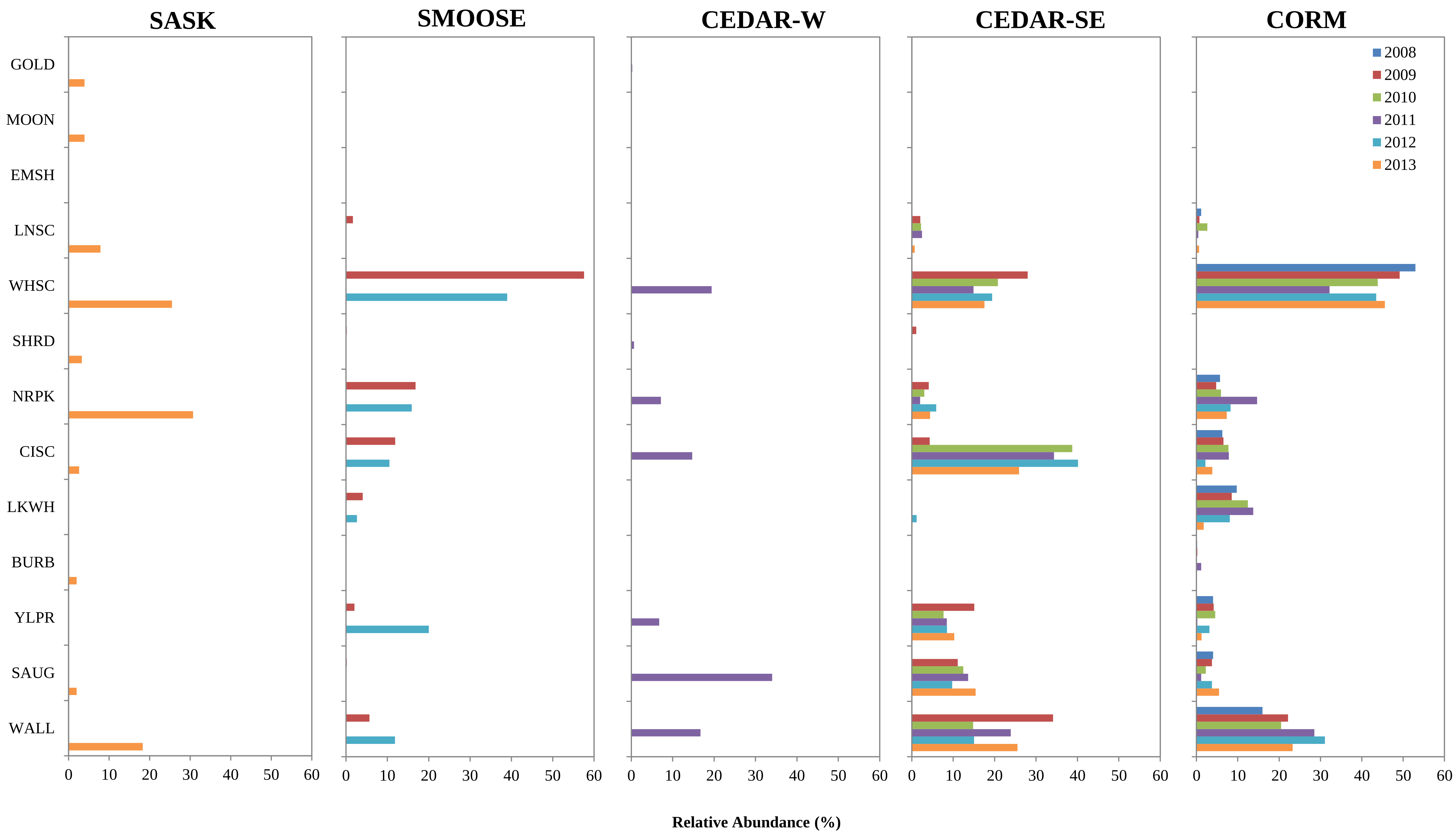


Figure 6-32. Relative abundance of fish species captured in standard gang index gill nets in Saskatchewan River Region waterbodies, 2008-2013.

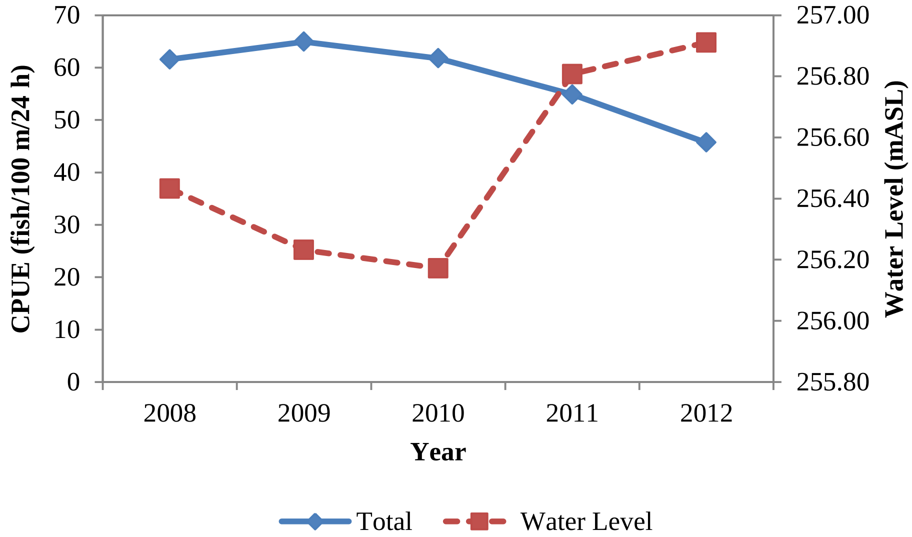


Figure 6-33. Abundance of total catch in gill nets in Cormorant Lake as measured by CPUE in relation to the average water level at the same location during the gillnetting period: 2008-2013.

7.0 FISH MERCURY

7.1 INTRODUCTION

The following provides an overview of the results of fish mercury monitoring conducted in the SRR under CAMP in the first six years of the program. Fish mercury sampling was conducted on a three-year rotation (2010 and 2013) in Cedar Lake - Southeast and the off-system Cormorant Lake.

A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 4.7. In brief, fish mercury was analysed in the trunk muscle of pike, whitefish, and walleye selected from a range of fork lengths. Sampling also targeted capture of 1-year-old Yellow Perch for analysis of mercury in the whole carcass with the head, pelvic girdle, pectoral girdle, and caudal fin removed. The latter are included in CAMP as a potential early-warning indicator of changes in mercury in the food web.

7.1.7 Objectives and Approach

The key objectives of the analysis of CAMP fish mercury data were to:

- evaluate the suitability of fish for domestic, recreational and commercial fisheries; and
- evaluate whether there are indications of temporal differences in fish mercury concentrations.

The first objective was addressed through comparisons to the Health Canada standard for commercial marketing of freshwater fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011) for the three target species (Lake Whitefish, Northern Pike, and Walleye).

The second objective (temporal differences) was addressed through statistical comparisons between years for a given waterbody or riverine area where more than one year of data were available. Trend analysis and assessment of potential relationships with hydrological metrics could not be undertaken for fish mercury because only two years of monitoring data were available for this region.

A detailed description of the approach and methods applied for analysis and reporting is provided in Technical Document 1, Section 4.7. Site abbreviations applied in tables and figures are defined in Table 1-1.

7.1.8 Indicators

Results presented below focus upon one key indicator (fish mercury concentrations) and two key metrics: absolute or arithmetic mean mercury concentrations; and length-standardized mean mercury concentrations (also referred to as "standard mean(s)"). Fish mercury concentrations are typically positively correlated to fish length and standardization to a single fish length for a given species is commonly done to enable comparisons among waterbodies and over time. As CAMP targets a specific age class of perch, fish captured for this component are inherently of a limited size range; therefore, length-standardization for this species was not undertaken.

7.2 KEY INDICATOR: MERCURY CONCENTRATIONS IN FISH

7.2.1 Saskatchewan River

A total of 137 fish were analyzed for mercury from Cedar Lake - Southeast (Table 7-1). The target sample size of 36 fish was obtained, or nearly obtained, for Walleye in both years, Northern Pike in 2010, and perch (n = 25) in 2010. Only small numbers of Lake Whitefish (2010 and 2013) and Yellow Perch (2013) were captured during the fish community monitoring program and none were analyzed for mercury.

Mean length-standardized concentrations for all species analyzed for mercury in 2010 and 2013 were substantially lower than the 0.5 parts per million (ppm) Health Canada standard for commercial marketing of fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011; Table 7-1).

All of the pike, Walleye, and perch from Cedar Lake had mercury concentrations lower than 0.5 ppm, reaching maximum concentrations of 0.39 ppm, 0.28 ppm, and 0.03 ppm, respectively (Figures 7-1 and 7-2). Concentrations of both species were notably lower in Cedar Lake than the off-system Cormorant Lake (Table 7-1).

7.2.2 Off-system Waterbody: Cormorant Lake

A total of 237 fish were analyzed for mercury from Cormorant Lake (Table 7-1). Sample sizes for Northern Pike and Walleye in both years and whitefish in 2010 were at or near the target of 36 fish. Yellow Perch were at or near their target sample size of 25 fish in both years.

Mean length-standardized concentrations of mercury were lower than the 0.5 ppm Health Canada standard for commercial marketing of fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011) for all species sampled, including pike, Walleye, and whitefish, during all years of monitoring (Table 7-1).

Unlike the on-system Cedar Lake where no exceedances were observed, mercury concentrations in individual fish from all sampling years, 24% of the pike (approximately equal proportions each year) and 1% of the Walleye (a single fish from 2010), from Cormorant Lake exceeded the Health Canada standard (Figure 7-1). This difference between the on- and off-system site may be due in part to the larger size of fish collected from Cormorant Lake (Table 7-2); however, that length-standardized concentrations were higher in Cormorant Lake suggests that size differences are not the only potential causal factor. None of the whitefish or perch had mercury concentrations approaching 0.5 ppm, with maximum concentrations of 0.25 ppm (Figure 7-1) and 0.05 ppm (Figure 7-2), respectively.

7.2.3 Temporal Comparisons

There were no significant inter-annual differences in length-standardized mercury concentrations for any species captured in Cedar or Cormorant lakes (Figure 7-3).

7.3 SUMMARY

Mean length-standardized mercury concentrations of all species in Cedar and Cormorant lakes were well below the 0.5 ppm Health Canada standard for commercial marketing of fish (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011). Based on concentrations in individual fish, approximately 25% of the pike and a single Walleye from Cormorant Lake exceeded the standard. No individual fish from Cedar Lake exceeded the standard in any year and no significant differences between years were observed.

Table 7-1. Arithmetic mean (±SE) and length-standardized (95% confidence limits [CL]) mercury concentrations (ppm) for Lake Whitefish, Northern Pike, Walleye, and Yellow Perch captured in the Saskatchewan River Region: 2010-2013.

Waterbody	Year	Species	n	Mercury Concentration (ppm)			
				Arithmetic Mean	**SE**	**Standard Mean**	**95% CL**
Cedar Lake - Southeast	2010	Pike	31	0.116	0.011	0.105	0.090 - 0.121
		Walleye	36	0.106	0.010	0.107	0.095 - 0.120
		Perch	25	0.016	0.001	-	-
	2013	Pike	12	0.122	0.030	0.118	0.100 - 0.138
		Walleye	33	0.116	0.009	0.130	0.117 - 0.144
Cormorant Lake	2010	Pike	36	0.407	0.029	0.304	0.256 - 0.360
		Walleye	36	0.224	0.019	0.202	0.185 - 0.221
		Whitefish	35	0.058	0.007	0.047	0.041 - 0.055
		Perch	25	0.033	0.001	-	-
	2013	Pike	36	0.319	0.030	0.264	0.238 - 0.292
		Walleye	37	0.209	0.010	0.194	0.182 - 0.207
		Whitefish	14	0.090	0.018	NS	-
		Perch	18	0.024	0.003	-	-

NS = Not significant

Table 7-2. Mean (±SE) fork length, round weight, condition (K_F), and age of Lake Whitefish, Northern Pike, Walleye, and Yellow Perch sampled for mercury from the Saskatchewan River Region: 2010-2013.

Waterbody	Year	Species	n	Length (mm)	Weight (g)	K_F	Age (years)
Cedar Lake - Southeast	2010	Pike	31	549.2 ± 18.4	1436.1 ± 133.0	0.79 ± 0.01	5.3 ± 0.3
		Walleye	36 [1]	377.3 ± 15.6	798.8 ± 107.7	1.20 ± 0.02	7.0 ± 0.4
		Perch	25	106.3 ± 4.0	19.5 ± 2.1	1.44 ± 0.03	1.6 ± 0.1
	2013	Pike	12	525.2 ± 47.2	1452.9 ± 500.9	0.74 ± 0.02	3.3 ± 0.7
		Walleye	33	352.4 ± 15.7	563.5 ± 69.3	1.05 ± 0.02	6.1 ± 0.5
Cormorant Lake	2010	Pike	36 [2]	608.5 ± 11.0	1776.3 ± 115.8	0.75 ± 0.01	6.5 ± 0.4
		Walleye	36 [3]	415.3 ± 16.7	925.7 ± 116.3	1.05 ± 0.02	6.1 ± 0.5
		Whitefish	35 [2]	360.8 ± 12.0	690.9 ± 63.2	1.29 ± 0.02	11.5 ± 1.0
		Perch	25 [4]	108.8 ± 2.4	16.7 ± 1.1	1.26 ± 0.02	1 – 3 [6]
	2013	Pike	36	560.3 ± 13.4	1317.9 ± 103.2	0.71 ± 0.01	5.0 ± 0.4
		Walleye	37	422.3 ± 13.8	843.1 ± 78.5	0.99 ± 0.01	6.0 ± 0.3
		Whitefish	14	405.4 ± 15.3	892.9 ± 88.4	1.27 ± 0.03	13.6 ± 1.7
		Perch	18 [5]	75.1 ± 1.8	5.2 ± 0.4	1.20 ± 0.02	1 - 2 [6]

[1] n=32 for age; [2] n=34 for age; [3] n=35 for age; [4] n=12 for age; [5] n=7 for age; [6] range of ages presented.

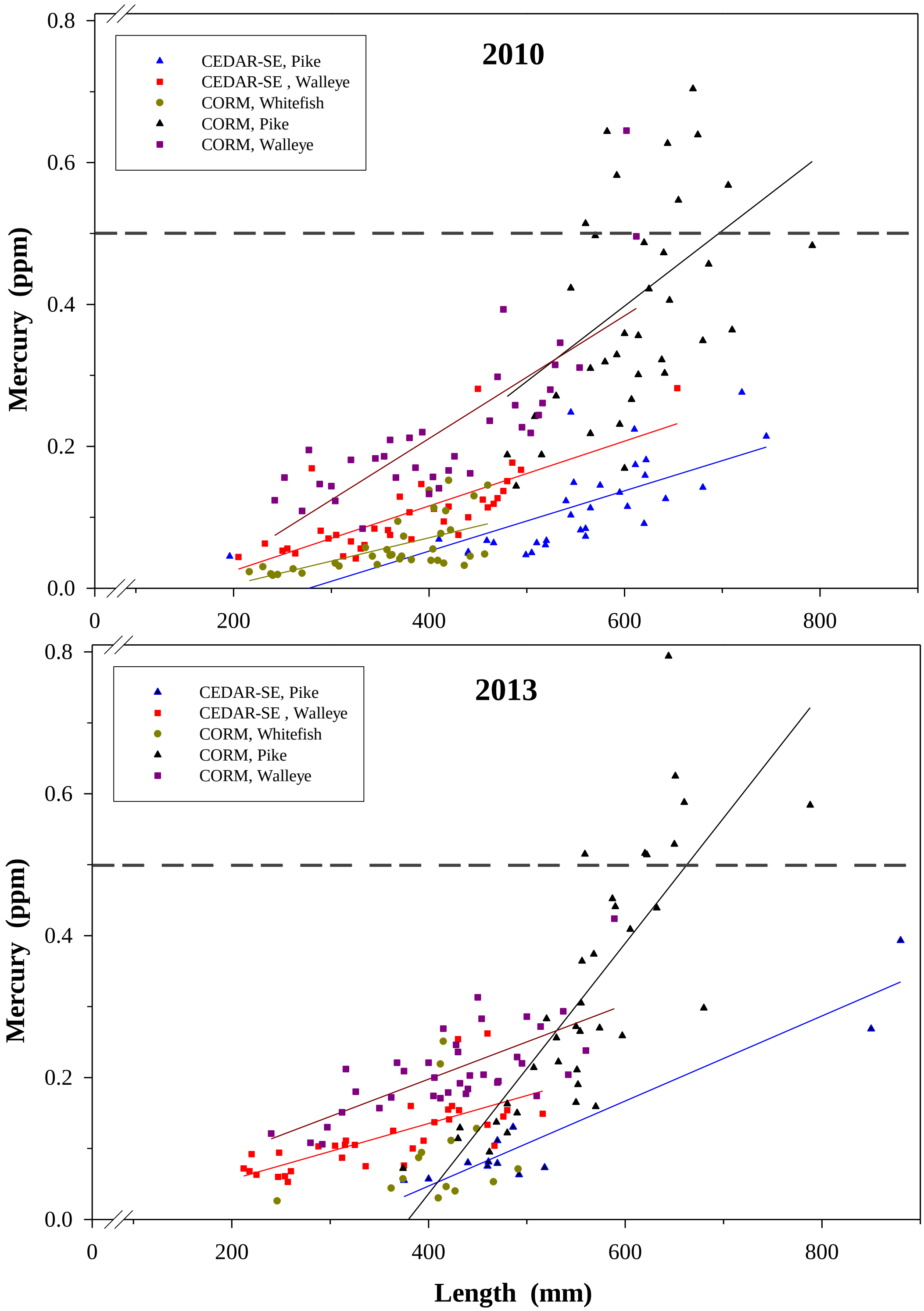


Figure 7-1. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from the Saskatchewan River Region in 2010 and 2013. Significant linear regression lines are shown. Dashed lines represent the 0.5 ppm standard for retail fish.

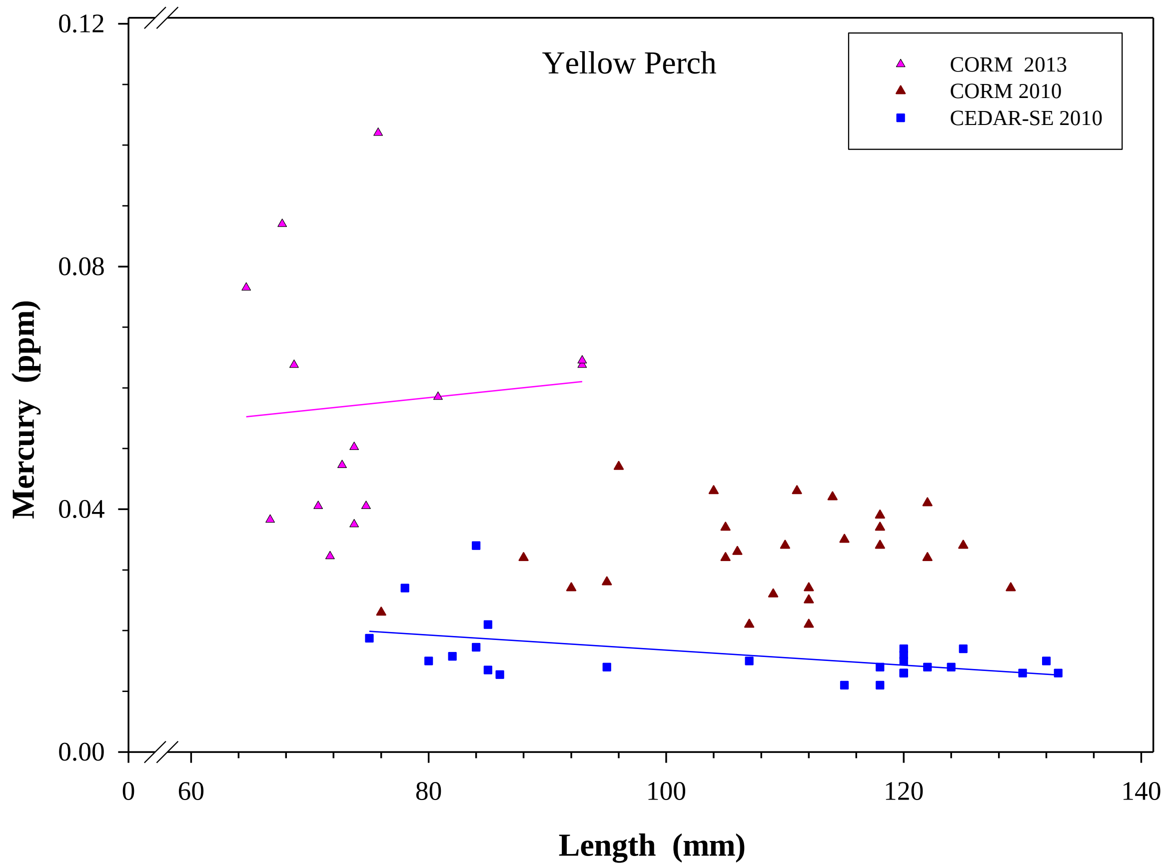
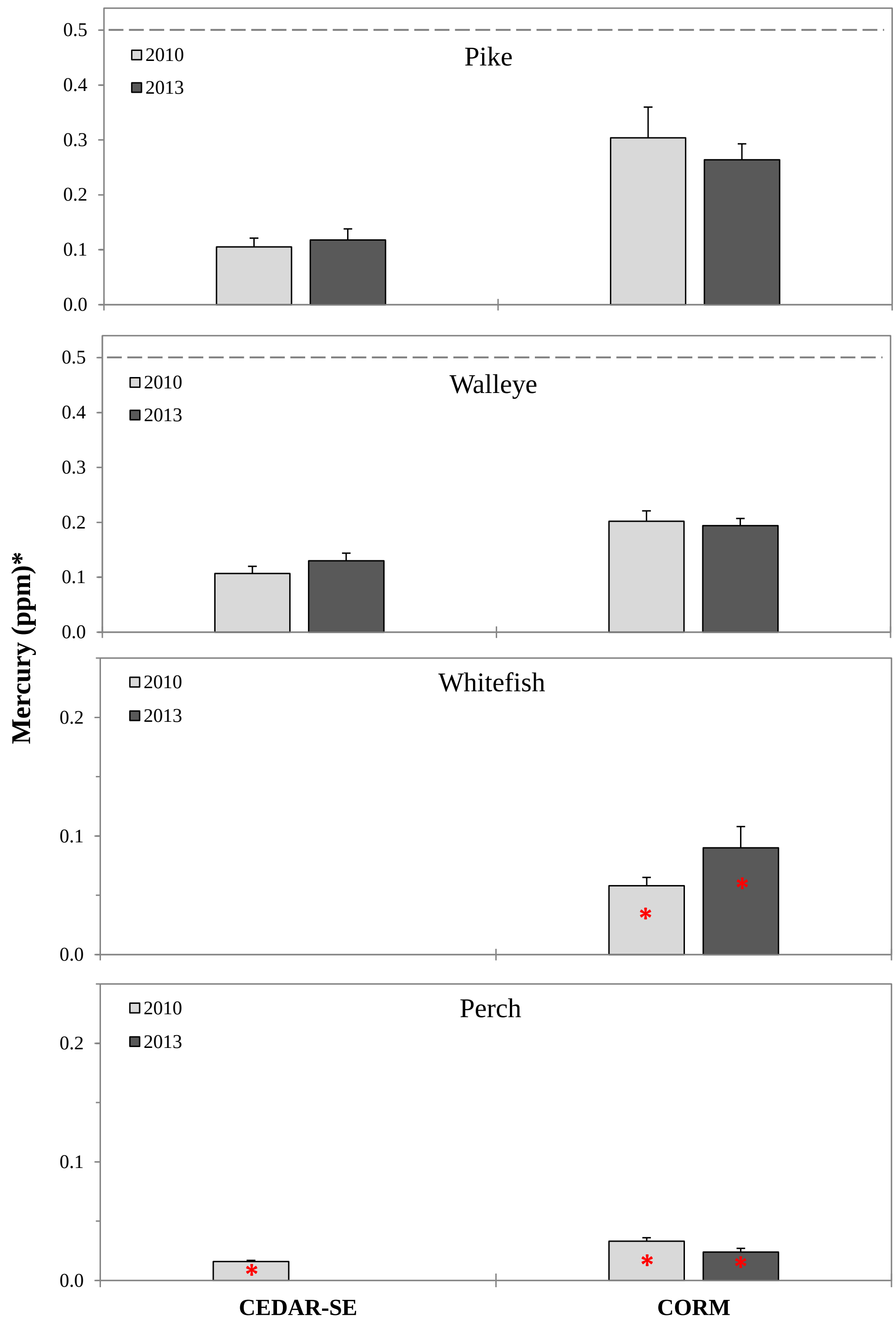


Figure 7-2. Relationship between mercury concentration and fork length for Yellow Perch from Cormorant and Cedar lakes in 2010 and 2013.



* Note differences in mercury scale among species.

Figure 7-3. Standard or arithmetic (asterisk) mean (error bars indicate upper 95% CL) mercury concentrations of Northern Pike, Walleye, Lake Whitefish, and Yellow Perch from the Saskatchewan River Region: 2010-2013. No significant inter-annual differences were observed for any species or waterbody. Dashed lines represent the 0.5 ppm standard for retail fish.

8.0 AQUATIC HABITAT INVENTORY

8.1 INTRODUCTION

The primary objective of the CAMP aquatic habitat inventories is to create depth and substrate distribution maps, which are two common habitat variables used in aquatic habitat assessments. A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 3.2. In brief, the CAMP aquatic habitat inventory component consists of hydroacoustic bottom surveys and collection of physical samples to validate the hydroacoustic data, and data analysis to create habitat maps.

Aquatic habitat inventory surveys were conducted in the Saskatchewan River Region on the west basin of South Moose Lake in June and July of 2011 (Figure 8-1). For ease of reading, 2011 habitat survey results in the following sections pertaining to the west basin of South Moose Lake will be referred to as South Moose Lake. The west basin of South Moose Lake accounts for approximately 41% of the total lake area. The data collected during the surveys were used to produce depth and substrate distribution habitat maps, which were used to describe the depth, substrate, and overall aquatic habitat characteristics of South Moose Lake.

8.2 BATHYMETRY

South Moose Lake is a relatively large, flat-bottomed shallow waterbody with over 98% of the lake less than 7 m deep (Figures 8-2 to 8-5). Its mean depth is 4.78 m, and its average bed slope is 0.4 % (Table 8-1). The deepest point in South Moose Lake at the time of survey, when the average water surface elevation was 256.36 m (G.S. of C. Datum, MB Hydro and Provincial Water Resources Extension), was 12.05 m. The waterbody is very shallow throughout its north arm downstream of the Moose Lake Narrows Control Structure. This area is uniformly 2–3 m deep. Depth begins to gradually increase moving south past Bacons Island in to a large very flat circular basin in the middle of the waterbody. In this flat uniform basin, depth is 6-7 metres. Most shores are gradually sloped, which is evident in the south bay between the community of Moose Lake and Big Island. Okaw Narrows, which connects the west basin of South Moose Lake with the central and east basins, has the greatest depth (12.05 m). The maximum slope in the west basin is15% and the total volume of the waterbody is 1,460,003,000 m^3.

8.3 SUBSTRATE

The majority of South Moose Lake has silt/clay substrates (Figure 8-6 to 8-8; Table 8-2). The shore zone is generally rocky with varying degrees of embedded materials between clay and silt/clay substrates. The rock substrates are typically limestone and range from large gravel to boulder-sized material. Rock substrates comprise 3,210 ha (11%) of the substrate in the west basin of South Moose Lake. Silt/clay comprises 27,256 ha (89%) of the total substrate composition. The silt/clay substrates in the North Arm were typically associated with submerged aquatic vegetation. Some of the nearshore bays where silt/clay substrates dominate also contain macrophytes.

8.4 SUMMARY

Habitat in the west basin of South Moose Lake is relatively homogeneous. There are two distinct habitats: shallow rocky nearshore and slightly deeper silt/clay mud-based offshore. Although South Moose Lake is one of the larger CAMP waterbodies it does not have an overly complex shoreline relative to other large CAMP waterbodies. The shorelines were mostly observed to be rocky consisting of either steep limestone cliffs or fragmented limestone and/or till cobble and boulder sized material. It was noted during surveys that the flat shallow North Arm of South Moose Lake contained dense macrophyte beds as did many silt/clay pockets along the shore.

Table 8-1. Summary of depth, slope, and volume statistics of the west basin of South Moose Lake based on aquatic habitat surveys conducted in June and July of 2011.

Waterbody Name	**Area** (ha)	**Maximum Depth** (m)	**Mean Depth** (m)	**Maximum Slope** (%)	**Mean Slope** (%)	**Volume** (m^3)
South Moose Lake (west basin)	30,530	12.05	4.78	15	0.4	1,460,003,000

Table 8-2. Summary of substrate distribution for the west basin of South Moose Lake based on aquatic habitat surveys conducted in June and July 2011.

Substrate	**Area** (ha)	**Total Area** (%)
Cobble/Boulder/ Bedrock	3,210	11
Silt/Clay	27,256	89
Not Classified	63	< 1%
Total	30,530	100

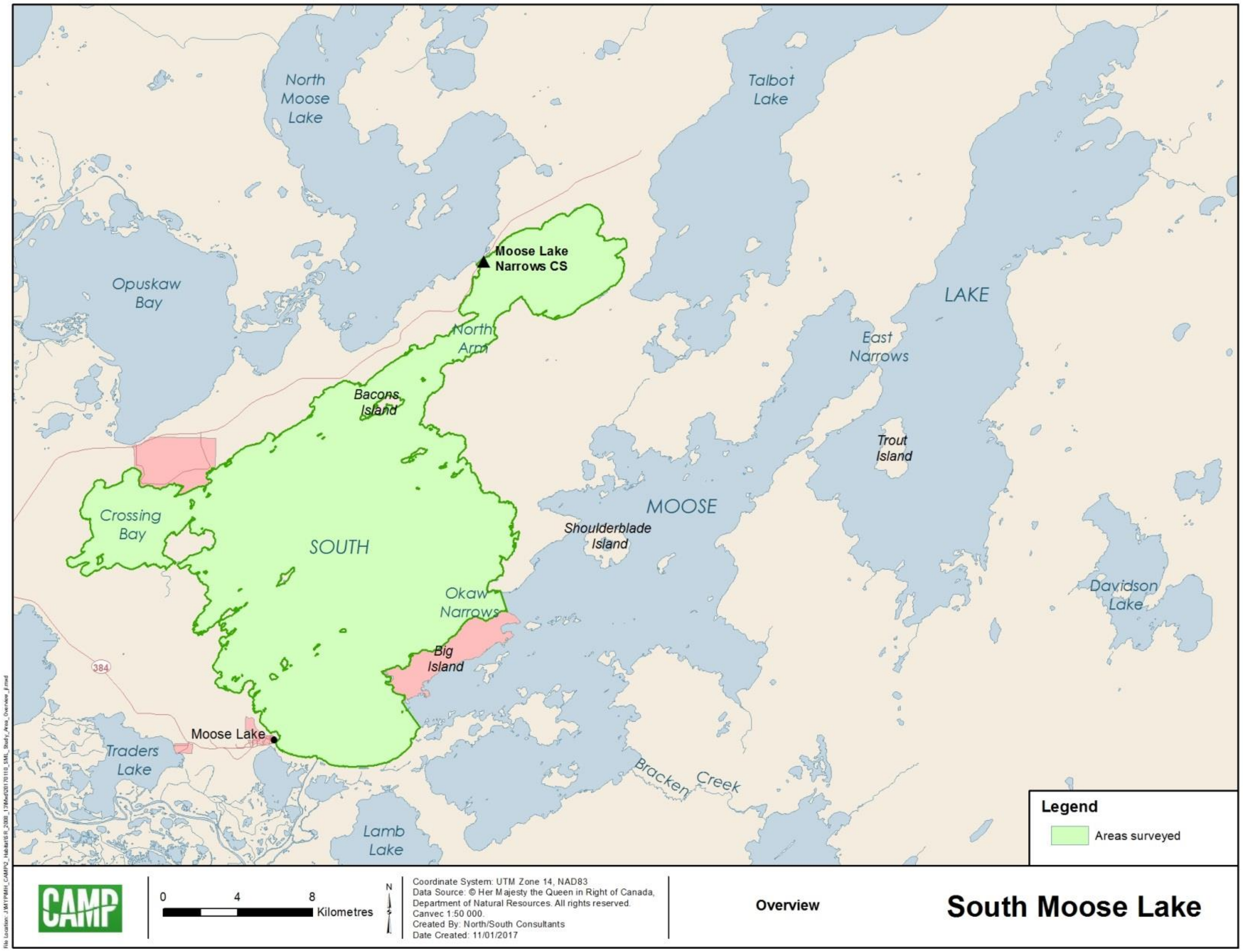


Figure 8-1. Area of habitat surveys on the west basin of South Moose Lake.

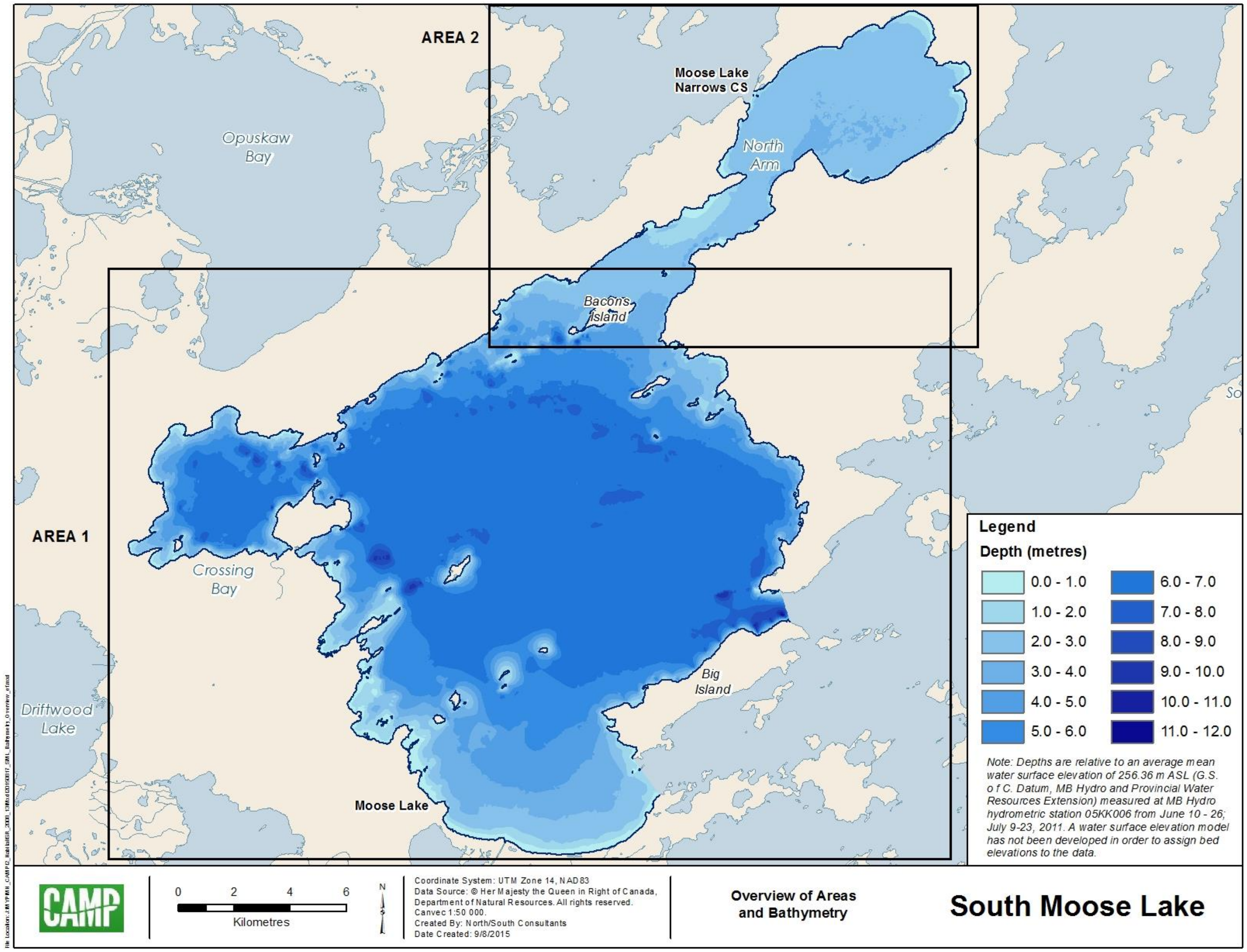


Figure 8-2. Overview bathymetric map of the of South Moose Lake, produced from surveys conducted in June and July of 2011.

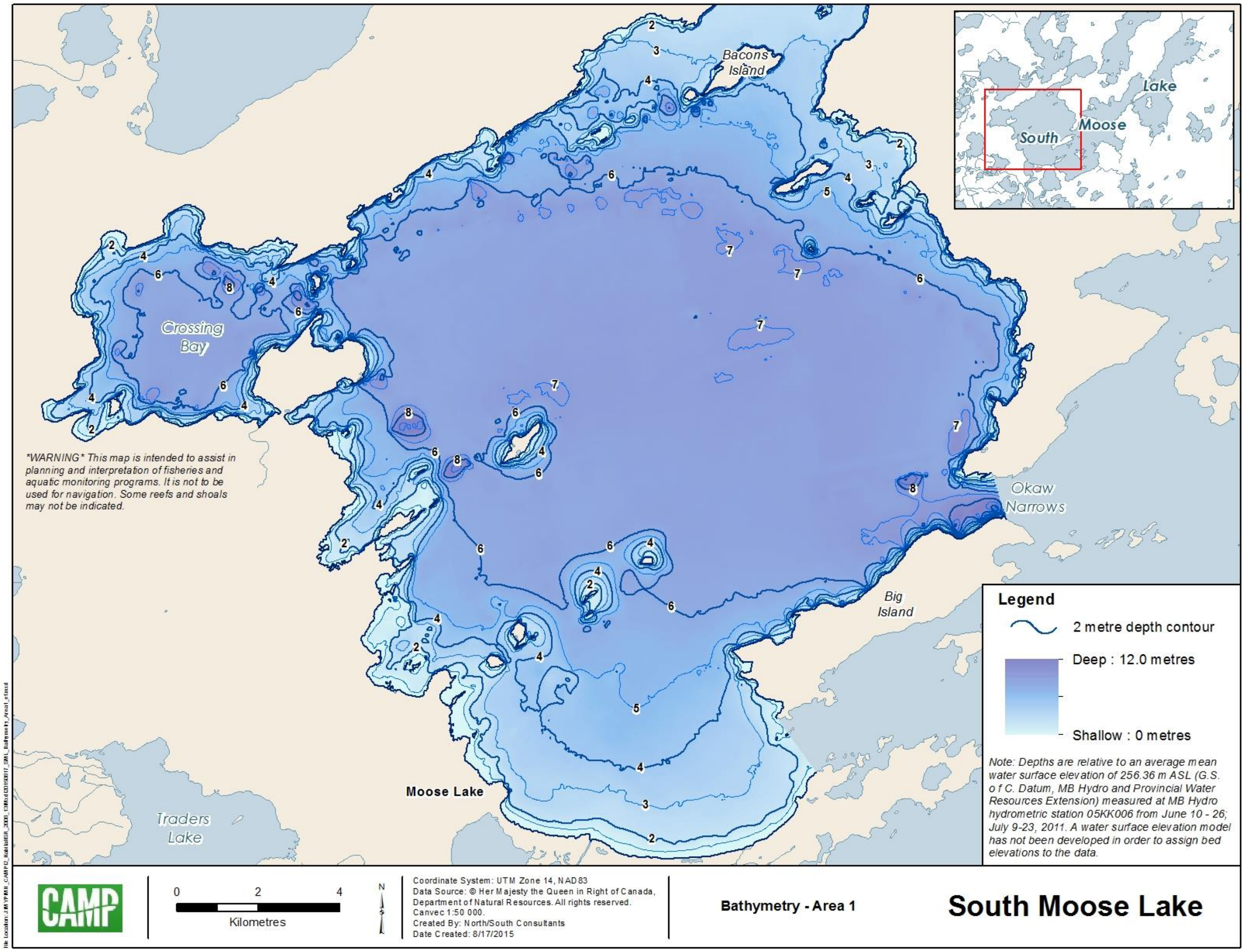


Figure 8-3. Detailed bathymetric map of Area 1 of South Moose Lake.

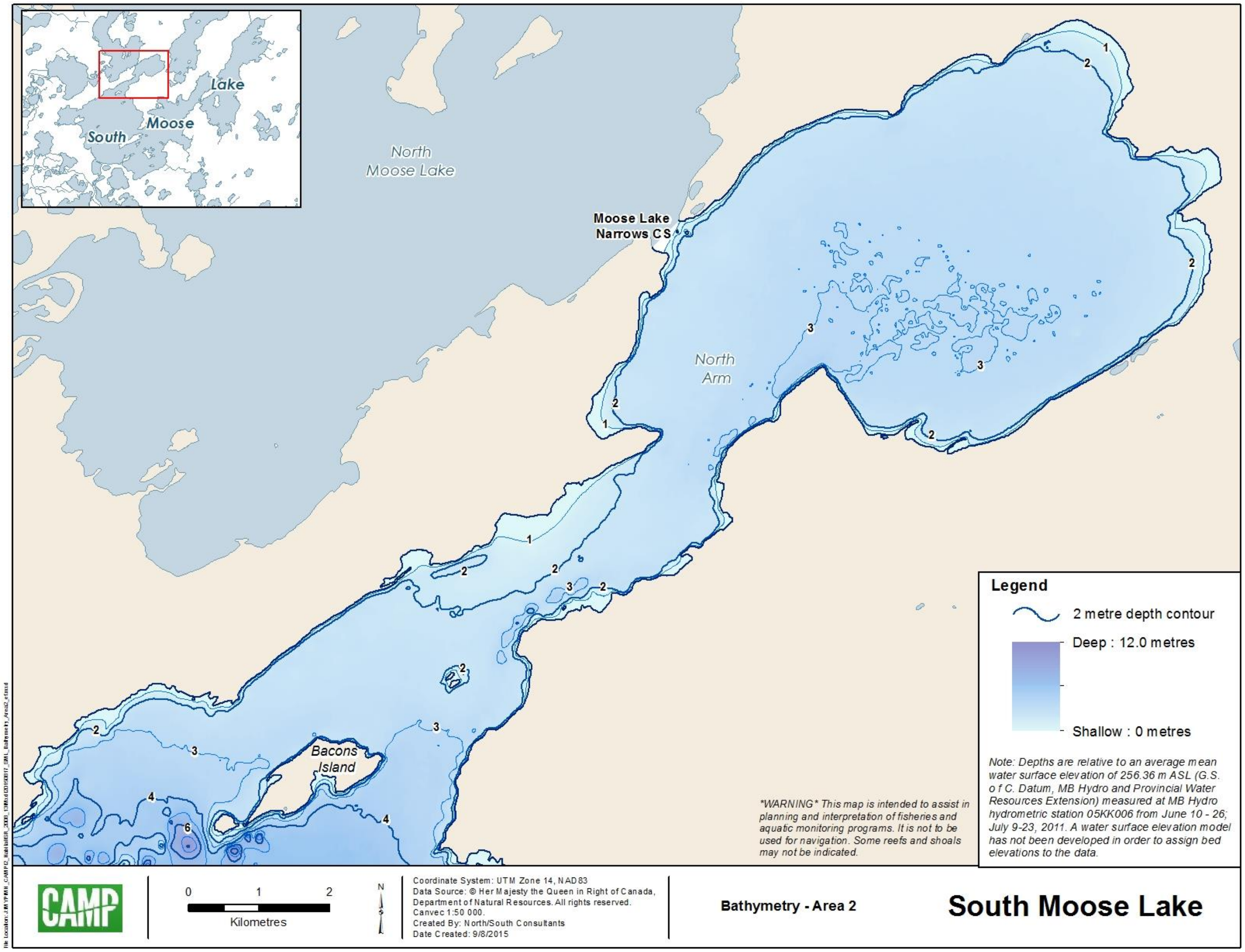


Figure 8-4. Detailed bathymetric map of Area 2 (North Arm) of South Moose Lake.

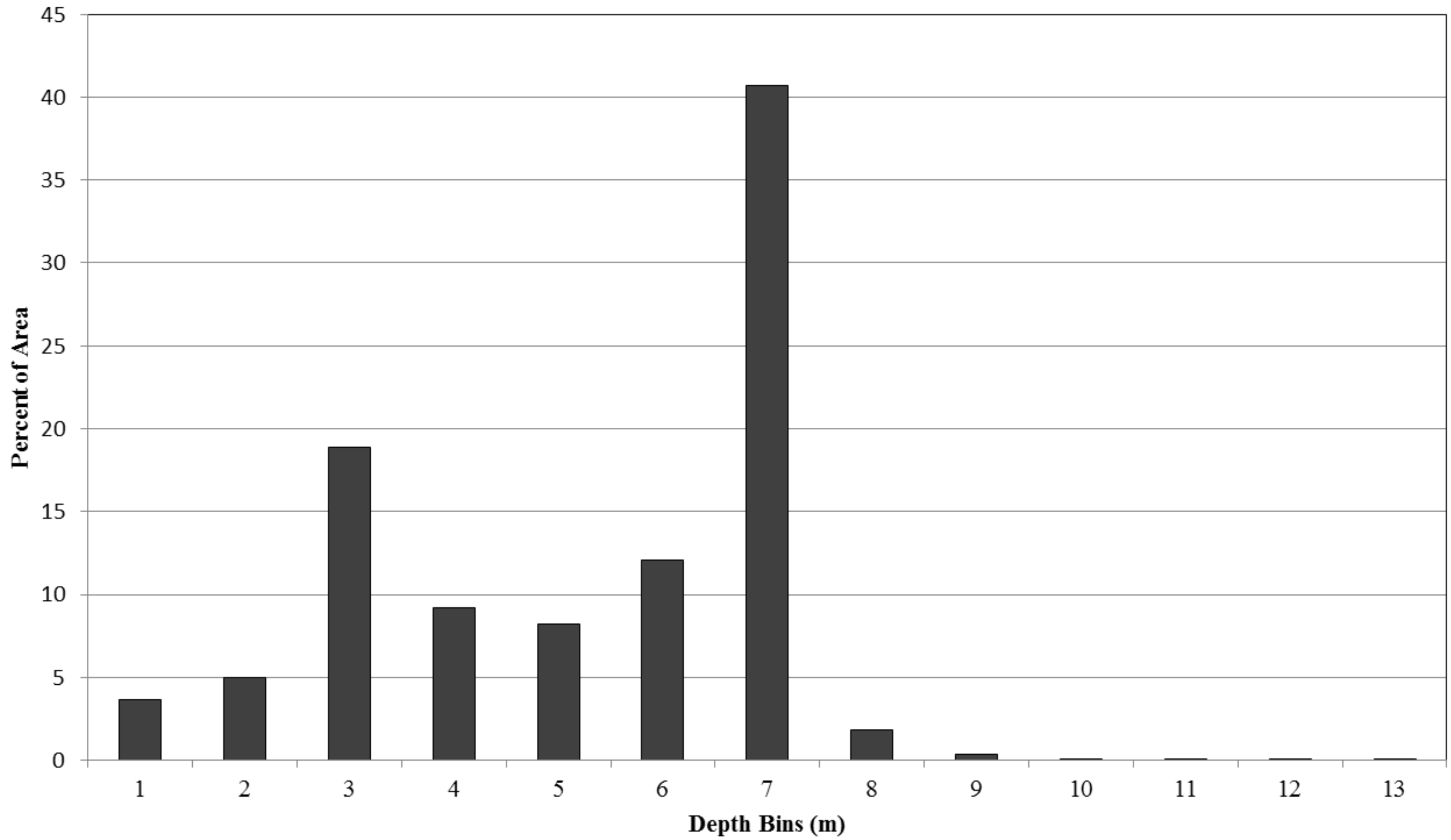


Figure 8-5. Depth distribution histogram depicting 1 m intervals according to the percentage of area of the west basin of South Moose Lake based on the 2011 survey when the mean water surface elevation was 256.36 m (G.S. of C. Datum, MB Hydro and Provincial Water Resources Extension).

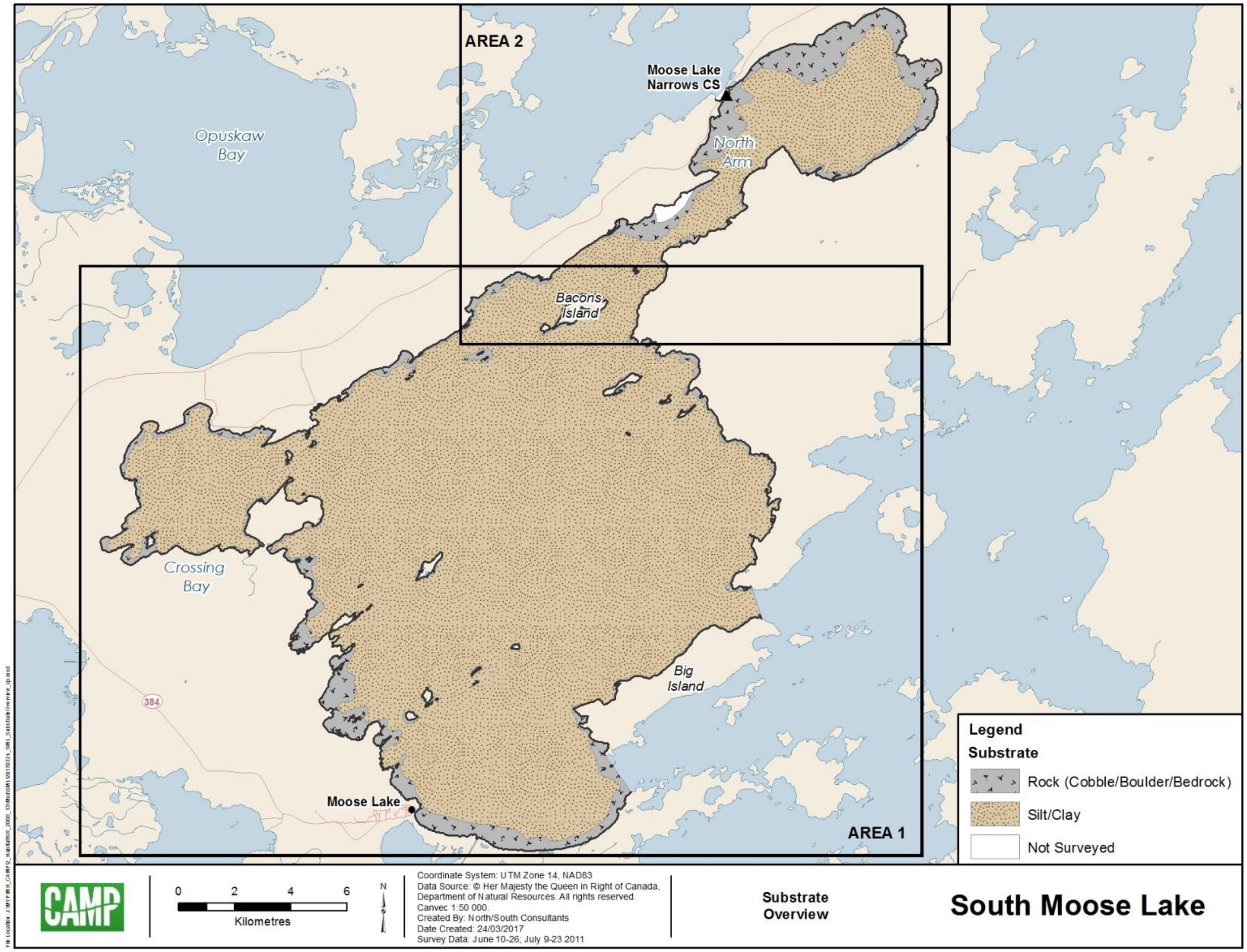


Figure 8-6. Overview substrate map of South Moose Lake produced from the June and July 2011 habitat inventory surveys.

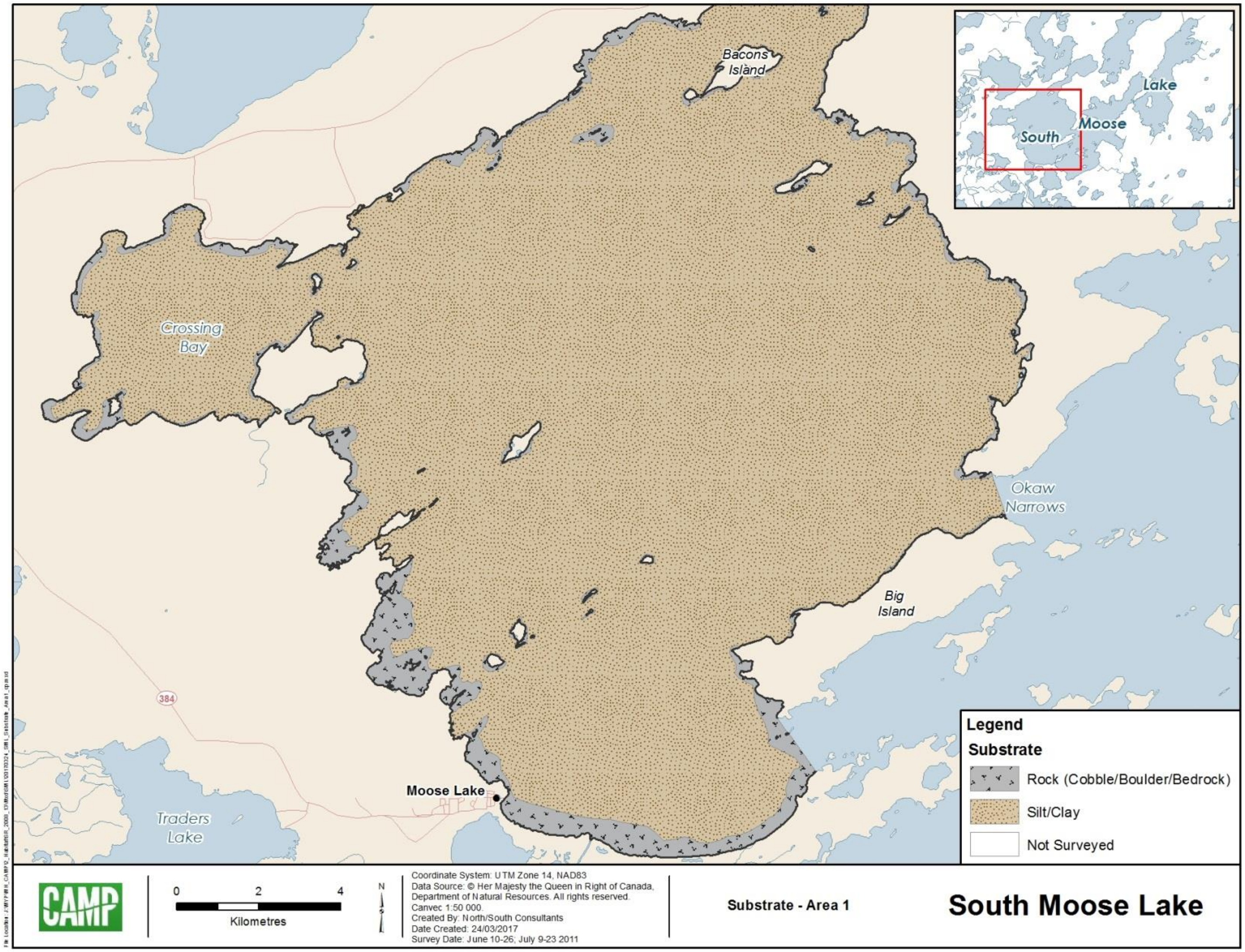


Figure 8-7. Detailed substrate map of Area 1 of South Moose Lake.

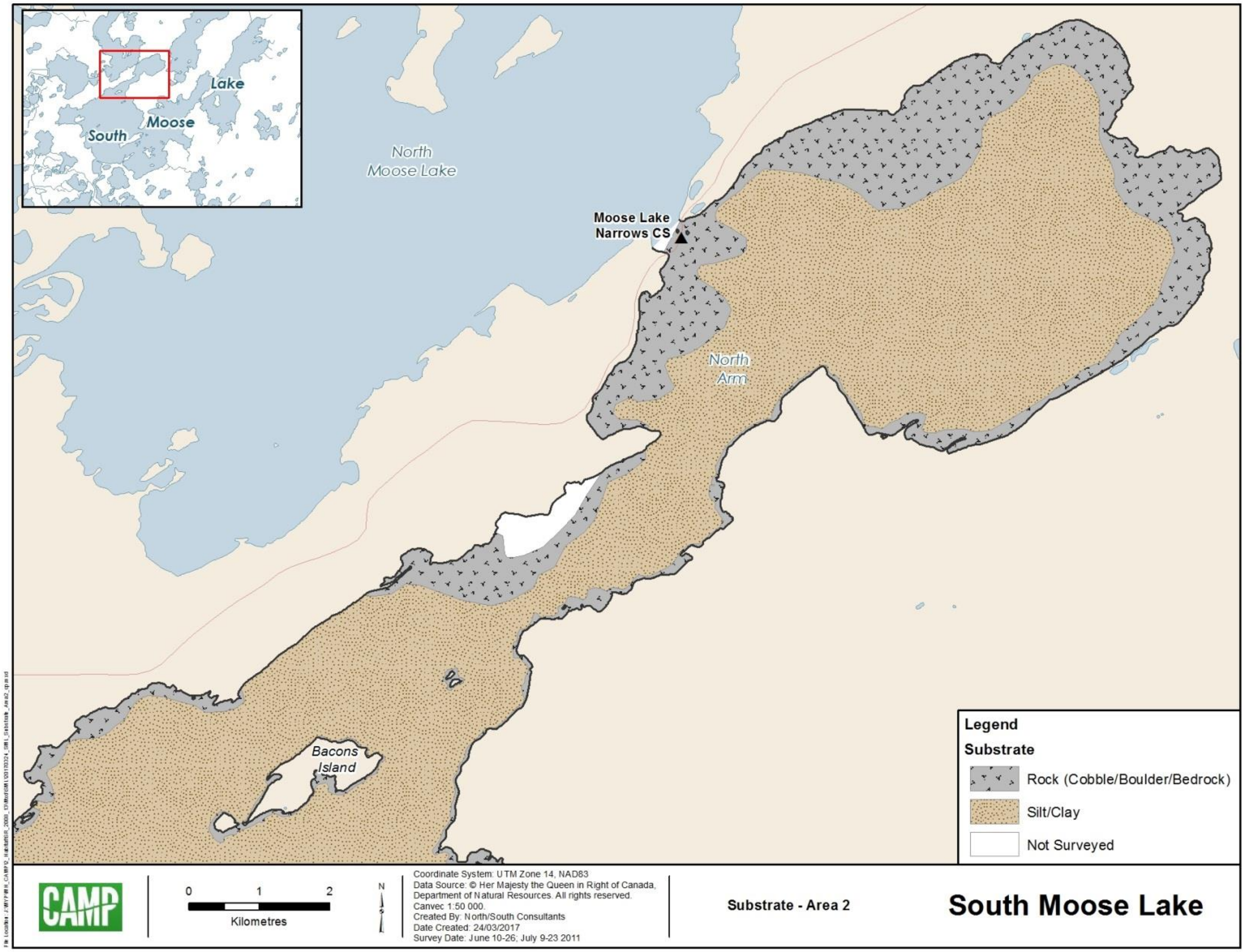


Figure 8-8. Detailed substrate map of Area 2 (North Arm) of South Moose Lake.

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