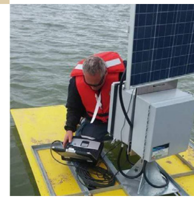
CAMP

Coordinated Aquatic Monitoring Program



Six Year Summary Report

Technical Document 7: Churchill River Diversion Region

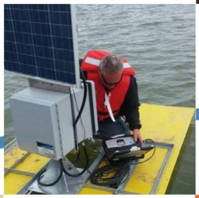
2008-2013

Submitted to:
Manitoba/Manitoba Hydro MOU Working Group

2017

Report Citation:

Coordinated Aquatic Monitoring Program (CAMP). 2017. Six Year Summary Report (2008-2013). Report prepared for Manitoba/Manitoba Hydro MOU Working Group by North/South Consultants Inc., Winnipeg, MB.



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SIX YEAR SUMMARY REPORT (2008-2013)

Technical Document 7:

Churchill River Diversion Region Results

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2017

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ABBREVIATIONS AND ACRONYMS

3PT	Threepoint Lake
APU	Apussigamasi Lake
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
CL	Confidence limit
CPUE	Catch-per-unit-effort
CRD	Churchill River Diversion
CRDR	Churchill River Diversion Region
CS	Control structure
DL	Detection limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon
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
FOOT	Footprint Lake
ISQG	Interim sediment quality guideline
K_F	Condition Factor
KHLP	Keeyask Hydropower Limited Partnership
LEFT	Leftrook Lake
LEL	Lowest effect level
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
MYN-CEN	Central Mynarski Lake
n_F	Number of fish
NTG	Notigi Lake
NTG - E	Notigi Lake - East
NTG - W	Notigi Lake - West
n_Y	Number of years sampled
PAL	Protection of aquatic life
PEL	Probable effect level
ppm	Parts per million
PSA	Particle size analysis
Q (OW)	Average discharge during the open water period
Q (GN)	Average discharge during the gillnetting program

RAT	Rat Lake
RCEA	Regional cumulative effects assessment
SAC	Sediment alert concentration
SE	Standard error of the mean
SEL	Severe effect level
SQG	Sediment quality guideline
TDS	Total dissolved solids
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 Churchill River Diversion Region (CRDR). As described in Technical Document 1, Section 2.6.1, the CRDR is composed of the portion of the Churchill River Diversion (CRD) that extends from the man-made outlet of Southern Indian Lake at South Bay, through the Rat/Burntwood river system to First Rapids on the Burntwood River, approximately 20 km upstream of Split Lake. The region also includes Leftrook Lake, an off-system lake, located on the Footprint River system.

Waterbodies and sites monitored in this region over this period included six on-system lakes and one off-system lake as follows:

- Rat Lake;
- Central Mynarski Lake;
- Notigi Lake;
- Threepoint Lake;
- Footprint Lake;
- Apussigamasi Lake; and
- Leftrook Lake (off-system).

Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.6. 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 waterbody or river reach 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 at some waterbodies and on a three-year rotation at other sites. Components monitored in the CRDR over this time period include hydrology, water quality, sediment quality, phytoplankton, benthic macroinvertebrates (BMI), fish community, mercury in fish, and aquatic habitat. Sampling in this region was not initiated until 2009.

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. An aquatic habitat survey of Apussigamasi Lake was completed during the Pilot Program in 2010 and results are reported in the previous CAMP summary report (CAMP 2014).

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 Churchill River Diversion 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**
Rat Lake	RAT	X			X			X			X
Central Mynarski Lake	MYN-CEN	X			X				X		
Notigi Lake	NTG	X			X		X			X	
Threepoint Lake	3PT	X		X			X	X	X	X	X
Footprint Lake	FOOT	X			X			X			X
Apussigamasi Lake	APU	X			X		X			X	
Leftrook Lake	LEFT		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.

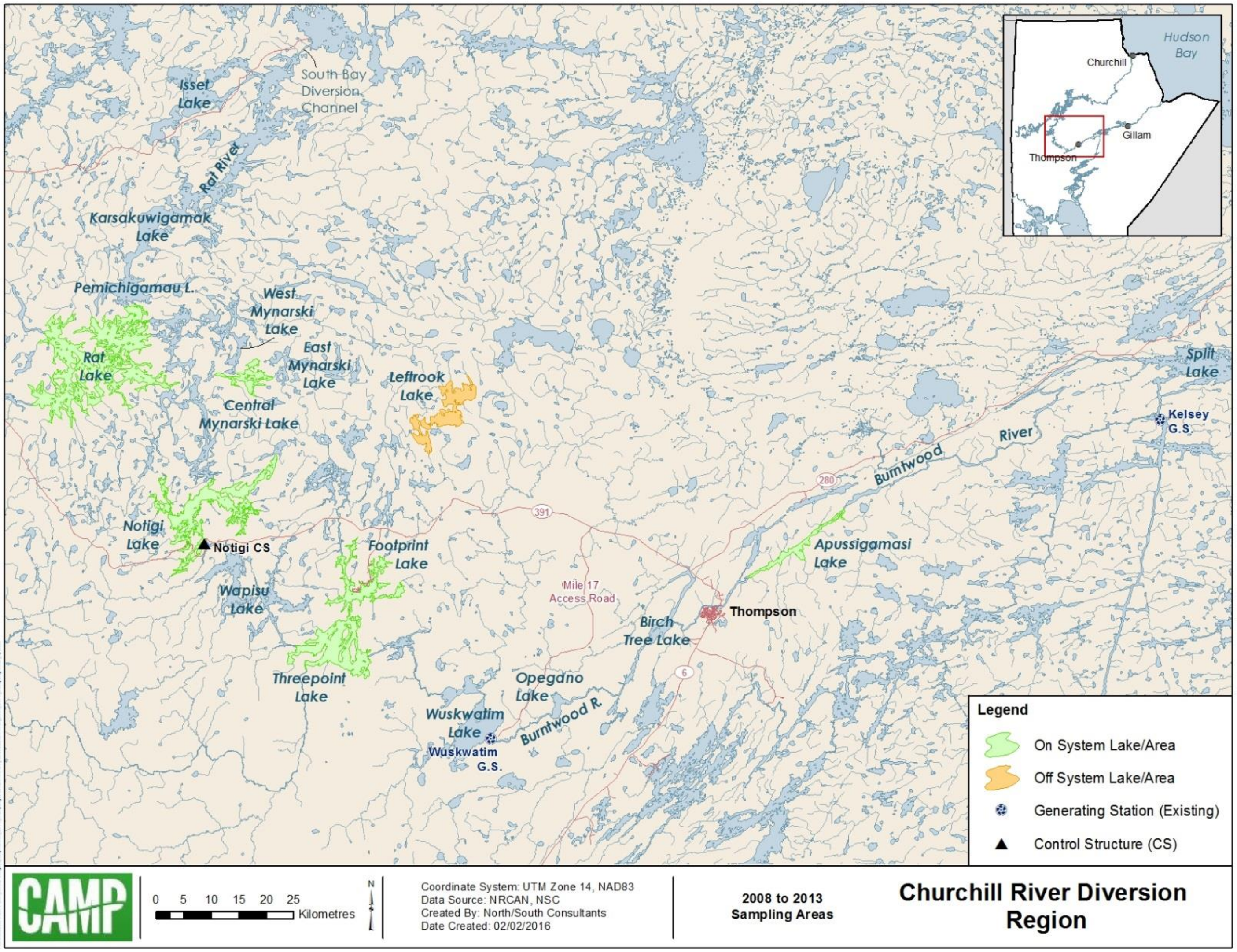


Figure 1-1. On-system and off-system waterbodies and river reaches sampled under CAMP in the Churchill River Diversion Region: 2008/2009-2013/2014.

2.0 HYDROLOGY

CRD improves downstream hydropower generation by transferring the majority of the water flow from the Churchill River to the Nelson River via the Rat River and the Burntwood River. The amount of water diverted to the Nelson River is regulated by the Notigi Control Structure (CS) while Southern Indian Lake is used as a reservoir. Local inflows also contribute to the total water flowing from the Burntwood River into the Nelson River. CAMP water level monitoring in the Churchill River Diversion Region occurred on Rat Lake, Notigi Lake (Notigi forebay), Threepoint Lake, Footprint Lake, Apussigamasi Lake, and the off-system Leftrook Lake. Flows for this region were monitored at the Notigi CS.

Notigi CS flow releases between 2008 and 2013 were generally at the *Water Power Act* licensed maximum during the winter months. Flow releases were more variable during the open-water period, depending on precipitation conditions in the upper Churchill River basin as well as flow conditions on the lower Nelson River. Flow releases were reduced to near or below the lower quartile during the open-water season for parts of each year from 2008 to 2011. These reductions occurred to avoid aggravating flood conditions on the lower Nelson River. Open-water flow releases were above average in general in 2012 and 2013 but were reduced to near average for part of each year (Figure 2-1).

Rat Lake and the Notigi forebay are controlled reservoirs with water levels typically following a similar pattern each year. In spring, water levels typically rise because of both increased inflow with the spring freshet and reduced outflows at the Notigi CS as energy demand is lower. Summer outflows at the Notigi CS are managed depending on precipitation conditions and inflows such that water levels peak in late summer/fall each year. Rat Lake and the Notigi forebay water levels then typically decline steadily through the winter as inflows drop off and Notigi CS outflows are maximized to meet Manitoba’s higher winter energy requirements.

From 2008 to 2013, water levels generally followed this typical trend, with the exception that levels remained at near record highs through the winters of 2009/2010 and 2012/2013. This occurred because of high precipitation in the upper Churchill River basin late in the preceding year despite maintaining outflows at the Notigi CS at the *Water Power Act* licensed maximum. Water levels also climbed and refilled Rat Lake and the Notigi forebay earlier than normal in the spring of 2012 and later than normal in the spring of 2008. In early 2014, water levels declined but remained above the upper quartile from January through March (Figures 2-2 and 2-3).

Water levels on Footprint Lake, Threepoint Lake, and Apussigamasi Lake generally followed a similar pattern to the Notigi CS flow releases from 2008 to 2013. Water levels were generally highest and close to average during the winter months. Water levels were more variable during the open-water period as decisions regarding operation of the Notigi CS were made considering precipitation conditions in the upper Churchill River basin as well as flow conditions on the lower Nelson River. Flow reductions at the Notigi CS led to water levels being near or below the lower quartile during the open-water season for parts of each year from 2008 to 2011. These reductions occurred to avoid aggravation of flood conditions on the lower Nelson River. Record low water levels on each of these lakes were reached for part of the 2011 open-water season. Summer water levels were above average in general in 2012 and 2013 but were reduced to near or below average for part of both years (Figures 2-4 to 2-6).

Leftrook Lake water levels were not monitored in 2009 when water quality and biological monitoring on this lake was initiated. Based on the limited available data from 2010 to 2013, water levels appear to have been below average during the 2010 open-water season, above average during the 2012 open-water season, and above average in late 2013 into early 2014 (Figure 2-7).

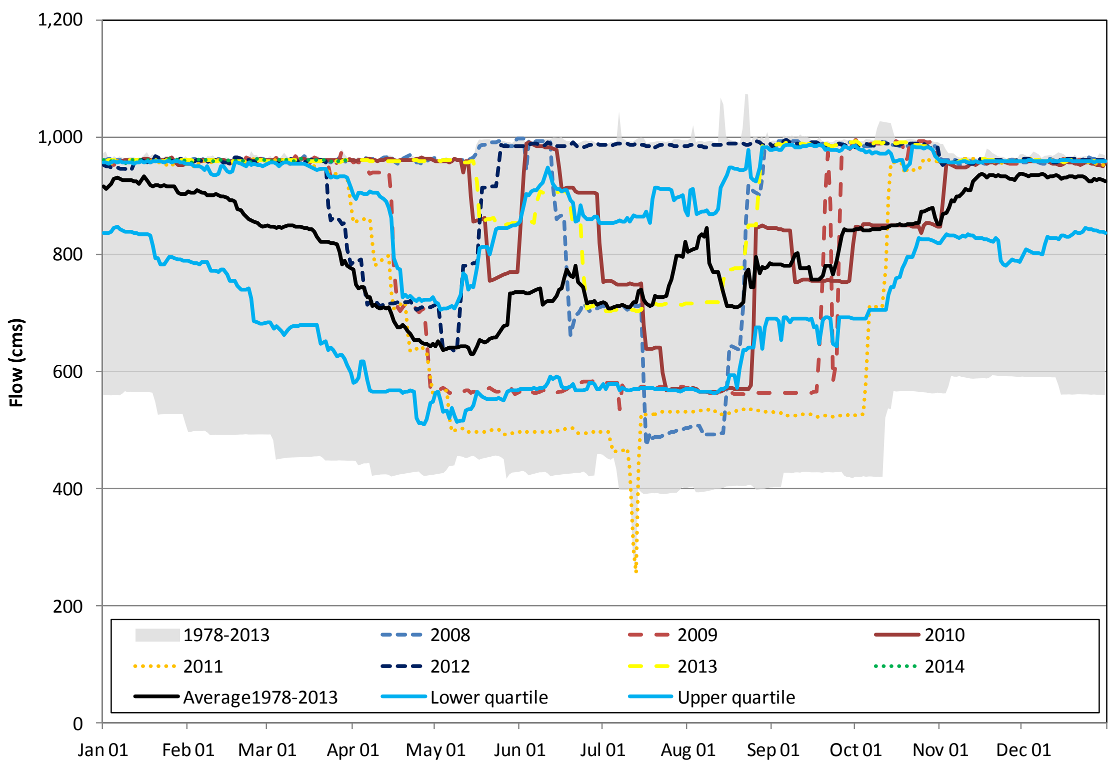


Figure 2-1. 2008-2013 Churchill River Diversion flow at the Notigi Control Structure.

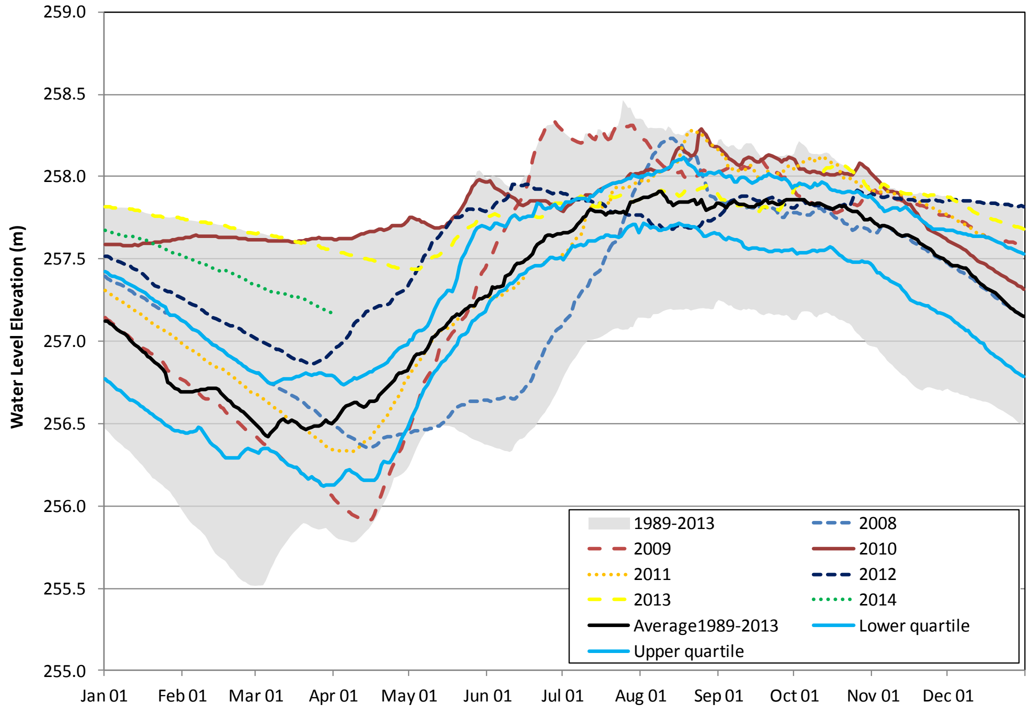


Figure 2-2. 2008-2013 Rat Lake (05TF004) water level elevation.

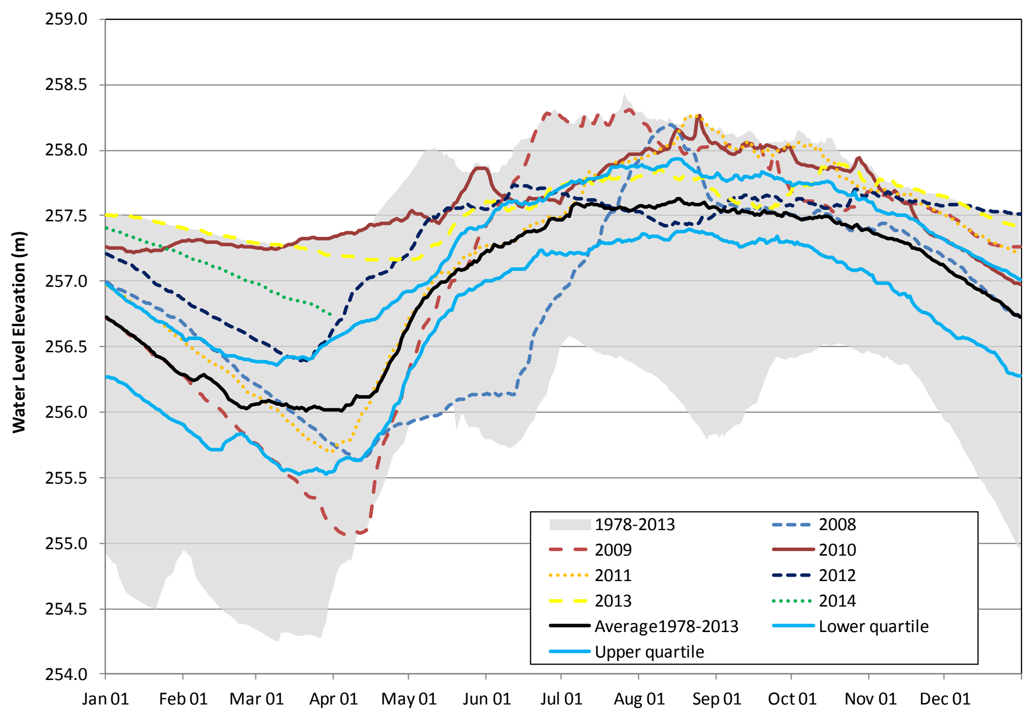


Figure 2-3. 2008-2013 Notigi Control Structure Forebay water level elevation.

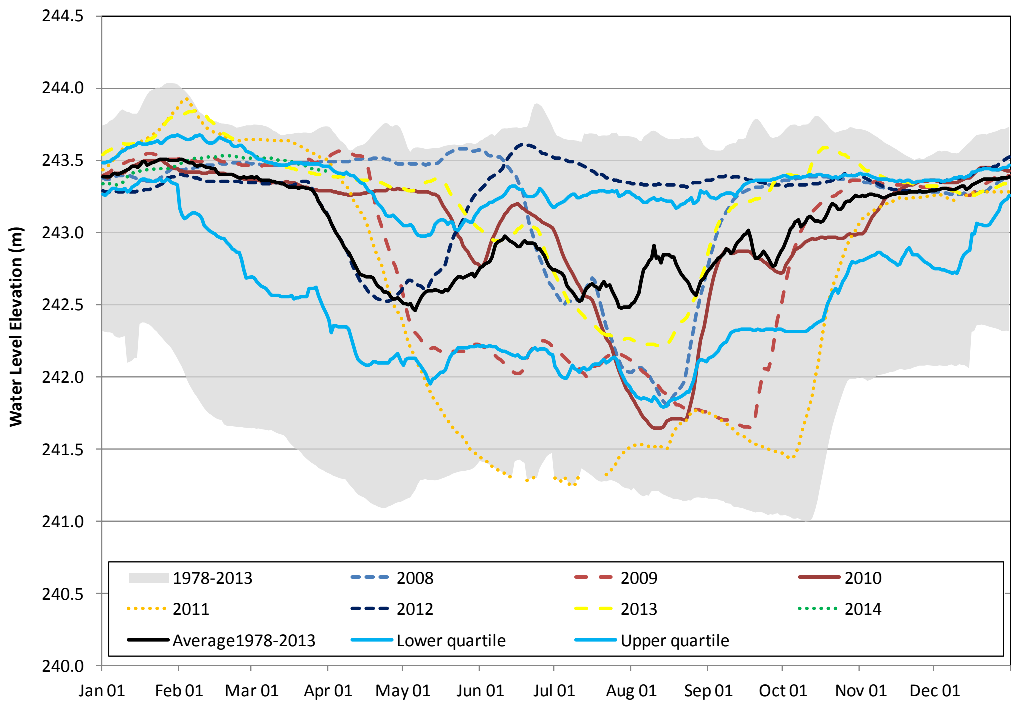


Figure 2-4. 2008-2013 Footprint Lake (05TF001) water level elevation.

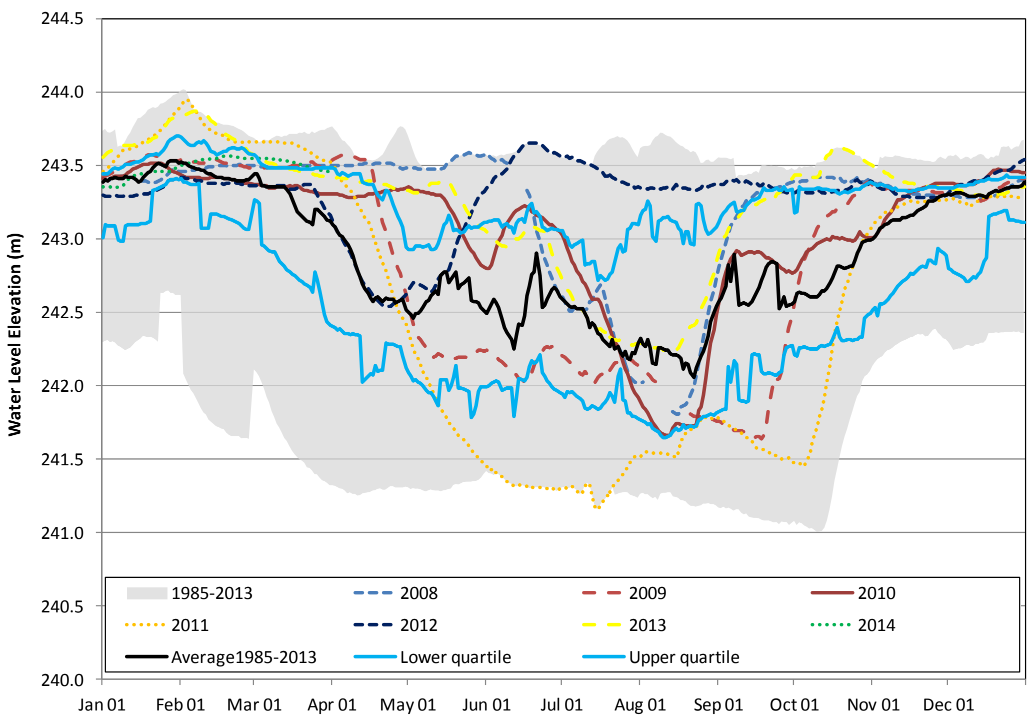


Figure 2-5. 2008-2013 Threepoint Lake (05TF703) water level elevation.

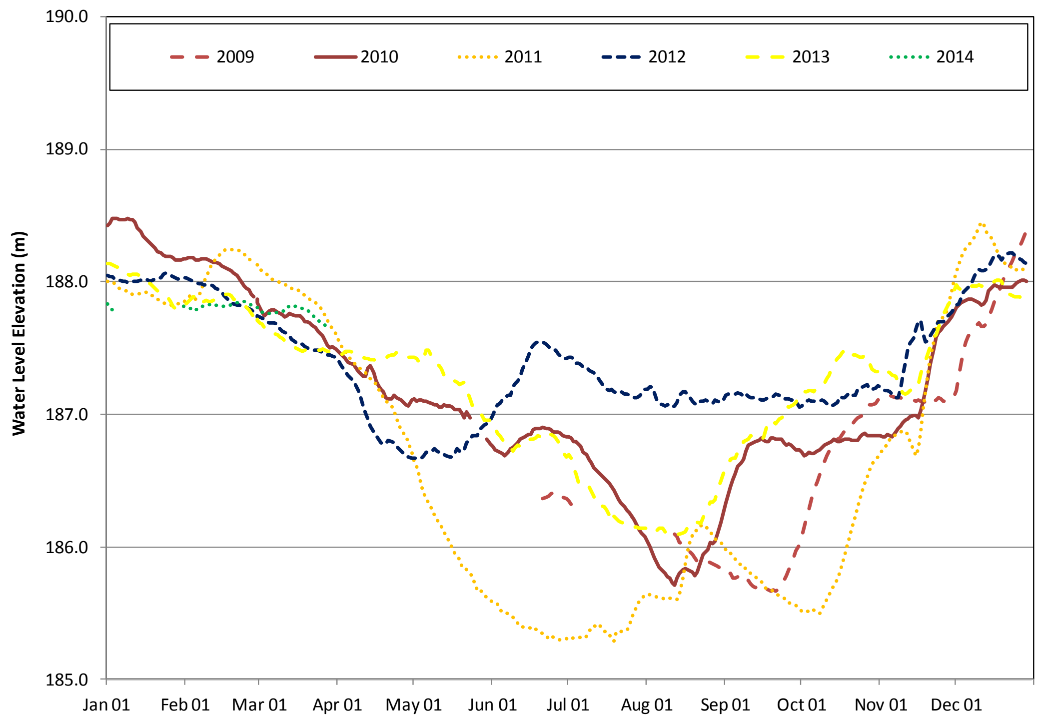


Figure 2-6. 2009-2013 Apussigamasi Lake (05TG712) water level elevation.

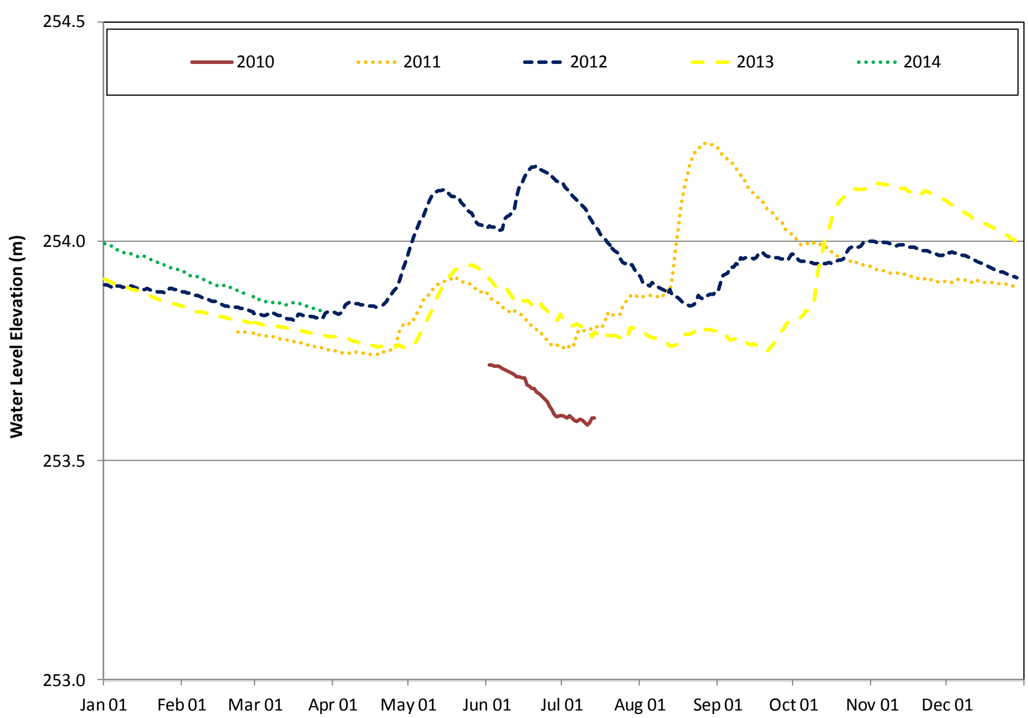


Figure 2-7. 2010-2013 Leftrook Lake (05TF784) water level elevation.

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 CRDR. Waterbodies sampled annually for water quality included one on-system (Threepoint Lake) and one off-system (Leftrook Lake) lake (Table 3-1; Figure 3-1). Five additional on-system lakes (Rat, Central Mynarski, Notigi, Footprint, and Apussigamasi lakes) were sampled on a rotational basis (Table 3-1; Figure 3-1). With one exception, all sampling was completed as intended. Sampling at Apussigamasi Lake could not be completed in winter 2012/2013 due to poor ice conditions.

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 lake. The exception for the CRDR is that water quality is monitored at two sites in Notigi Lake (Notigi Lake – West and Notigi Lake – East).

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 to 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 sites monitored annually. 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 (flow and water level) and water quality metrics to evaluate correlations.

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 CRDR in the following present data in an upstream to downstream direction. Site abbreviations applied in tables and figures are defined in Table 1-1.

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.

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 Churchill River Diversion

Most lakes monitored along the Churchill River Diversion were periodically stratified during the monitoring period. The exceptions were Threepoint and Apussigamasi lakes which were isothermal throughout the sampling program (Table 3-2; Figures 3-2 to 3-8).

Stratification was observed at Notigi Lake in spring and summer of each year of monitoring (Figures 3-4 and 3-5). Although different thermal profiles were recorded at the eastern and western sites, a stronger thermocline (i.e., change of > 2°C difference in 1 m of water) was observed at both sites in 2009 than 2012. A deeper spring thermocline was also observed at each site in 2009 (> 11 m) compared to 2012 (0-2 m), though sampling occurred two weeks later in 2012. In contrast, summer sampling in 2009 and 2012 occurred on approximately the same dates but water temperature was notably higher (>3 °C) in 2012 than 2009. However, only the shallower eastern site stratified during that period. The stronger, deeper thermocline and lower water temperatures in 2009 occurred under higher water levels in the lake and lower discharge at the Notigi CS, relative to 2012 (see Section 2.0).

In contrast to Notigi Lake, Rat Lake was isothermal in 2010 when water levels were near the upper quartile (see Section 2.0). Stratification events in this lake were observed during summer and winter 2013/2014 (thermocline at 13-15 m) when water levels were near average (Figure 3-6).

Pronounced thermal stratification was observed in Central Mynarski Lake throughout the open-water season when it was sampled in 2011 (thermocline at 7-8 m in spring and summer, and 1-2 m in fall; Figure 3-7). There are no hydrologic records for this lake in 2011.

Spring stratification was noted at Footprint Lake during both years that sampling occurred (2010 and 2013), and the depth of the thermocline (6-8 m) was similar between years (Figure 3-8). Concurrent stratification events in the off-system lake (Leftrook Lake) during spring 2010 and 2013, summer 2011 and 2012, and the winter of 2009/2010 (Figure 3-9) also suggests that regional influences (e.g., climatological conditions) may have contributed to the pattern of stratification events observed at on-system lakes.

Relatively shallow lakes with low residence times (i.e., Threepoint and Apussigamasi lakes) located along the main flow of the Rat/Burntwood River system were isothermal (Table 3-2; Figures 3-2 and 3-3) and well-oxygenated (Figures 3-10 and 3-11) during all sampling periods.

Deeper lakes with longer residence times experienced periods of lower DO conditions, particularly in the hypolimnion, and concentrations were occasionally below PAL objectives. This included sites located on the main flow path of the Rat/Burntwood River system, as well as lakes more isolated from the main flow of the river.

DO concentrations in the hypolimnion of Notigi Lake – West (in 2012) and Rat Lake (in 2013) in summer were below the PAL objectives for cold-water (6.5 mg/L) and cool-water (6.0 mg/L) aquatic life, respectively (Figures 3-12 and 3-13).

With the exception of Notigi Lake – East, DO concentrations measured at off-current locations (i.e., Central Mynarski and Footprint lakes) in the CRD region were more frequently depleted at depth than at the on-current sites. DO in Central Mynarski Lake declined across the water column and fell below the PAL objective for cool-water species (6.0 mg/L) during spring, summer, and fall[1] in the year it was sampled (2011), concurrent with pronounced thermal stratification (Figure 3-14). Concentrations at Footprint Lake during the spring[1] and summer of 2013 were also below the cool-water PAL objective at depth; whereas, concentrations in Notigi Lake – East consistently remained above the most stringent PAL objectives (Figures 3-15 and 3-16).

For comparison, DO concentrations in the off-system Leftrook Lake fell below the cool-water PAL objective during spring or summer each year between 2010 and 2013 (Figure 3-17; Section 3.2.1.2). DO concentrations measured in the region during the open-water season of 2009 were removed from the analysis because of a meter malfunction.

Dissolved oxygen concentrations in all lakes in the region remained above the most stringent cool- and cold-water objectives (5.5 and 9.5 mg/L, respectively) during the ice-cover seasons when sampling occurred (Figures 3-10- to 3-16). However, DO measured during the winters of 2011/2012 and 2013/2014 were removed from the analysis due to issues with the water quality meters. DO conditions in Apussigamasi Lake in the winter of 2012/2013 are unknown as sampling could not be completed during this period; however, the lake was well oxygenated during all other sampling periods. These observations contrast with results from the off-system Leftrook Lake where DO concentrations fell below the cool-water PAL objective during both winters for which data are available (2010/2011 and 2012/2013; Section 3.2.1.2).

[1] DO may be overestimated at depth.

Surface DO concentrations were similar across sites in the region during each the open-water and ice-cover seasons and there is no indication of spatial trends over the first six years of CAMP (Figure 3-18).

3.2.1.2 Off-system Waterbody: Leftrook Lake

Leftrook Lake was thermally stratified during some spring (2010 and 2013) and summer (2011 and 2012) monitoring periods (Figure 3-9). During each open-water season stratification event, DO decreased across the water column and concentrations fell below the most stringent Manitoba PAL objectives for cool-water species (6.0 mg/L; Figure 3-17). Notigi Lake – West and Mynarski, Rat, and Footprint lakes also experienced periods of oxygen depletion during these open-water periods (Table 3-2).

In contrast to most on-system sites, Leftrook Lake was thermally stratified during winter of 2009/2010 (Figure 3-9). DO concentrations declined to levels below the PAL objective for cool-water species (5.5 mg/L) during the 2010/2011 and 2012/2013 ice-cover periods (Figure 3-17).

3.2.1.3 Temporal Comparisons and Trends

Examination of data for the annual on-system monitoring site (Threepoint Lake) and the annual off-system site (Leftrook Lake) indicates that open-water season DO (surface measurements) did not vary significantly between years at either location (Figures 3-19). 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 TSS, 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 Churchill River Diversion

Mean TSS concentrations were low to moderate across most of the CRD route, with annual averages measuring less than 10 mg/L at all sites except Apussigamasi Lake (Table 3-2; Figure 3-20). Apussigamasi Lake, the most downstream site, was characterized by higher TSS concentrations, and higher inter-annual variability in concentrations, than other sites.

Turbidity levels (Figure 3-21) and Secchi disk depths (Figure 3-22) indicated Based on turbidity levels (Figure 3-21) and Secchi disk depths (Figure 3-22) water clarity at Threepoint and Apussigamasi lakes was lower than at the other sites. Open-water season mean Secchi disk depths were near 0.5 m in Threepoint Lake and 0.3 m in Apussigamasi Lake, compared to approximately 1 m at all other lakes (Figure 3-22).

TSS and turbidity were notably higher and Secchi disk depth was lower at the most downstream sites (Threepoint and Apussigamasi lakes) compared to the other waterbodies (Figure 3-23).

3.2.2.2 Off-system Waterbody: Leftrook Lake

TSS concentrations in the off-system Leftrook Lake were low (annual means < 5 mg/L) and similar to those measured at the most upstream lakes along the Churchill River Diversion (Table 3-2; Figure 3-20). Conversely, turbidity (Figure 3-21) and Secchi disk depth (Figure 3-22) measurements in Leftrook Lake were lower and higher, respectively, compared to conditions in the on-system lakes. 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.

3.2.2.3 Temporal Comparisons and Trends

Statistical analysis indicates that water clarity metrics measured during the open-water season did not differ significantly between years at the annual on-system site (Threepoint Lake) and visual examination of the data for the six-year period does not suggest increasing or decreasing trends in these metrics.

In contrast, open-water TSS measured in the off-system Leftrook Lake was significantly lower in 2010/2011 compared to 2013/2014 and mean concentrations visually appeared to increase through time in conjunction with concurrent qualitative decreases in Secchi disk depth (Figure 3-24). However, there were no significant inter-annual differences or overall trends in turbidity levels in Leftrook 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 Churchill River Diversion

Lakes located along the Churchill River Diversion were mesotrophic to meso-eutrophic on the basis of mean open-water season TP concentrations, and oligotrophic to mesotrophic based on TN (Table 3-3 and Figures 3-25 and 3-26). In terms of mean chlorophyll *a* concentrations, Notigi Lake - West, Notigi Lake - East, and Rat, Threepoint, and Apussigamasi lakes were oligotrophic to mesotrophic, Footprint Lake was mesotrophic to eutrophic, and Central Mynarski Lake was eutrophic (Figure 3-27).

On average, TP concentrations were below the Manitoba narrative nutrient guideline (0.025 mg/L for lakes, reservoirs and streams near the inflows to waterbodies; MWS 2011) in Rat and Central Mynarski lakes and both sites in Notigi Lake during each year of monitoring. In contrast, mean annual TP concentrations at the downstream waterbodies (i.e., Threepoint, Footprint, and Apussigamasi lakes), occasionally exceeded this guideline (Figure 3-28). Exceedance of the guideline for individual samples also occurred more frequently at the downstream lakes; no individual samples from Central Mynarski or Notigi lakes exceeded the guideline, though exceedances occurred in Rat (25% of samples), Threepoint (45% of samples), Footprint (50% of samples), and Apussigamasi (75% of samples) lakes. Exceedances of the annual mean TP concentrations and individual samples occurred in the off-system Leftrook Lake at a similar rate as on-system waterbodies.

All but two samples collected at sites along the CRD route were below the CAMP trigger of 10 µg/L for chlorophyll *a* (indicating the presence of an algal bloom) during the open-water season (Table 3-3). The two exceptions occurred at Central Mynarski Lake in fall 2011 and Footprint Lake in summer 2013; as such, 33 and 17% of all samples from these sites, respectively, exceeded the trigger. By comparison, 53% of samples collected in Leftrook Lake had chlorophyll *a* concentrations in excess of the trigger.

Neither TP nor TN was significantly correlated to chlorophyll *a* in Threepoint Lake based on the first six years of monitoring data (Figure 3-29). This suggests that nutrients are not the primary factor limiting phytoplankton growth and/or that bioavailability of these nutrients to algae is limited. However, lack of significant correlations may also be a reflection of the relatively limited amount of data. Most on-system waterbodies sampled annually under CAMP showed either a lack of, or a weak, correlation between nutrients and chlorophyll *a* for the six year monitoring period.

The ratio of chlorophyll *a* to total phosphorus - an indicator of the efficiency of assimilating phosphorus into algae - indicated relatively low chlorophyll *a* production per unit of phosphorous at on-system sites. With the exception of Central Mynarski Lake, TP assimilation efficiency at sites along the Rat/Burntwood River system ranged from a mean of 0.086 in Apussigamasi Lake to 0.310 in Footprint Lake; higher mean chlorophyll *a*:TP ratios were measured in Central Mynarski Lake (0.717) and the off-system Leftrook Lake (0.480; Figure 3-30).

Examination of the first six years of monitoring data suggests that TN and chlorophyll *a* were higher in Central Mynarski and Footprint lakes compared to the other sites along the Churchill River Diversion, while mean TP concentrations increased with distance downstream of Notigi Lake. These patterns are evident both when considering annual means for specific years when each site was sampled (Figures 3-25 to 3-27) and for overall means of pooled data (Figure 3-31).

3.2.3.2 Off-system Waterbody: Leftrook Lake

On average, Leftrook Lake had a similar trophic status (i.e., mesotrophic based on mean open-water TN and mesotrophic to eutrophic in terms of TP and chlorophyll *a*) as the lakes along the Churchill River Diversion (Table 3-2 and Figures 3-25 to 3-27); however, mean chlorophyll *a* concentrations were higher than at the on-system sites. Mean annual TP concentrations in Leftrook Lake also occasionally exceeded the Manitoba narrative nutrient guideline (0.025 mg/L for lakes, reservoirs and streams near the inflows to waterbodies; MWS 2011), and the frequency of exceedance of individual samples (25%) was similar to that observed for Rat Lake (Table 3-2; Figure 3-28).

In contrast to Threepoint Lake, TN and TP were both significantly correlated with chlorophyll *a* (Figure 3-29) and the TP to chlorophyll *a* ratio was moderate in Leftrook Lake.

3.2.3.3 Temporal Comparisons and Trends

No statistically significant inter-annual differences for TN, TP, or chlorophyll *a* were found for the annual on-system (Threepoint Lake) or off-system (Leftrook Lake) monitoring sites (Figure 3-25 to 3-27). No increasing or decreasing trends were observed for TN at either site over the five year monitoring period. However, mean open-water TP and chlorophyll *a* concentrations at Threepoint Lake decreased and increased, respectively, between 2010 and 2013. Chlorophyll *a* concentrations also qualitatively increased in the off-system Leftrook Lake between 2009 and 2013, and Secchi disk depth decreased concurrently (Figure 3-24). Additional data are required to truly determine if these observations reflect inter-annual, or short-term variability, relative to long-term trends.

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. A number of parameters measured at Threepoint Lake were lowest during the open-water season of 2010, including total alkalinity, bicarbonate alkalinity, specific conductance, hardness, major ions (calcium, chloride, and sodium) and some metals (strontium and uranium; Figures 3-32 to 3-40). Although specific trends vary for each parameter, levels were also often low in 2009 and high in 2012 and 2013.

A slightly different pattern was evident at the annual off-system monitoring site (Leftrook Lake); sodium, strontium, and uranium concentrations measured in 2009 were significantly lower than those measured in either 2011 or 2013, and magnesium qualitatively increased between 2009 and 2013 (Figures 3-38 to 3-41). However, there was no indication of increasing or decreasing trends over the six year period for non-key metrics.

pH, ammonia, and nitrate remained within PAL guidelines/objectives at all sites and times, both on- and off-system. Additionally, most metals measured in the CRDR were consistently within Manitoba water quality PAL objectives and guidelines; exceptions occurred for aluminum, iron, lead, and silver. Aluminum was above the PAL guideline (0.1 mg/L) in 75-100% of samples from the Churchill River Diversion sites (Table 3-4). Iron also frequently (75-90% of samples) exceeded the PAL guideline (0.3 mg/L) in Rat, Threepoint and Apussigamasi lakes although lower frequencies of exceedance (0-25%) were also observed in Central Mynarski, Notigi-West, Notigi-East, and Footprint lakes. Lead marginally exceeded the PAL objective in one sample collected at Notigi Lake-West in summer 2009 (Table 3-4). Silver marginally exceeded the PAL guideline (0.0001 mg/L) in one sample collected in spring 2009 at Notigi Lake - West; however, the analytical detection limit was equivalent to the PAL guideline. Measurements that are at or near the DL are associated with relatively high uncertainty and there is low confidence that an actual exceedance of a PAL guideline has occurred when the measurement is near a DL. No exceedances of PAL objectives or guidelines for these metals were found in the off-system Leftrook Lake (Table 3-4); however, elevated levels 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 [KHLP] 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 guideline (128-309 mg/L; Meays and Nordin 2013) at all on- and off-system sites monitored in this region.

3.4 RELATIONSHIPS WITH HYDROLOGICAL

Statistically significant inter-annual differences in water quality were observed for the annual on-system site (Threepoint Lake) and results indicated that alkalinity, specific conductance, hardness, and major ions (calcium, sodium, and chloride) were lower in 2010 than 2011. A number of these parameters were also higher in 2012 and 2013 than 2009. Total phosphorous and chlorophyll *a* concentrations also qualitatively decreased and increased, respectively, in Threepoint Lake after 2010.

Water level and discharge in the open-water season were generally lower in 2009-2011 (and notably low in 2011) and higher in 2012 and 2013 (notably for a portion of 2012; see Section 2.0 for details), which suggests a possible linkage between some water quality conditions and hydrology. To provide a preliminary exploration of potential correlations, statistical analyses were conducted between water quality metrics at Threepoint Lake and hydrological metrics including daily and weekly mean water level (Threepoint Lake) and discharge (Notigi CS discharge)[2]. This analysis, found no significant correlations for the available data set. The lack of significant relationships, however, may reflect the relatively limited quantity of data.

3.5 SUMMARY

Most water quality metrics were within objectives and guidelines for the protection of aquatic life, and the few metrics that exceeded these benchmarks in this region (notably TP, aluminum, and iron) are commonly above these benchmarks in northern Manitoba lakes and rivers, including off-system sites monitored under CAMP.

Some differences in water quality and limnological conditions were observed across waterbodies monitored in the CRDR. Relatively shallow lakes with low residence times (i.e., Threepoint and Apussigamasi lakes) located along the main flow of the Rat/Burntwood River system were isothermal and well-oxygenated during all sampling periods. Conversely, the most pronounced stratification and DO depletion occurred in deeper lakes with longer residence times located both on and off the main flow path of the Rat/Burntwood River system (i.e., Central Mynarski, Rat, Footprint, and Notigi lakes). DO concentrations were lower than the benchmarks for the protection of aquatic life in the lower portion of the water column at the latter sites during at least one monitoring period. Stratification was also observed at the off-system Leftrook Lake and oxygen concentrations near the bottom of the water column were also below benchmarks for the protection of aquatic life during those open-water periods.

[2] Water residence time of Threepoint Lake estimated as approximately 3.4 days based on a volume of 285 million m^3 (Technical Document 1, Table 2-1) and a median discharge of 980 m^3/s (Manitoba Hydro and Nisichawayasihk Cree Nation 2003).

Water clarity in the region ranged from low to high across sites located along the CRD route; Central Mynarski Lake, located off of the main flow path of the Rat/Burntwood River was notably clearer, and the most downstream lakes (Threepoint and Apussigamasi lakes) were more turbid than the other on-system sites.

Lakes located along the Churchill River Diversion were mesotrophic to meso-eutrophic on the basis of mean open-water season TP concentrations, and oligotrophic to mesotrophic based on TN. Concentrations of chlorophyll *a* varied across sites and some lakes fell in the oligotrophic to mesotrophic range (Notigi Lake-West, Notigi Lake-East, and Rat, Threepoint, and Apussigamasi lakes), one ranged between mesotrophic and eutrophic (Footprint Lake), and one (Central Mynarski Lake) was eutrophic. Trophic status of the off-system Leftrook Lake was similar to that of the on-system sites, though nutrient concentrations were somewhat higher and Leftrook Lake supported higher levels of algae (measured as chlorophyll *a*); conditions in this lake were most similar to the on-system Central Mynarski Lake.

Total phosphorus and chlorophyll *a* concentrations appear to have undergone decreasing and increasing trends, respectively, in Threepoint Lake since 2010. Chlorophyll *a* followed a similar increasing trend in the off-system Leftrook Lake. Additional data are required to determine if these preliminary observations reflect inter-annual, or short-term variability, relative to long-term trends.

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

Waterbody/Area	**Site Abbreviation**	**Site ID**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
							2008/09	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**
Rat Lake	RAT	TFS 005	X			X			X			X
Central Mynarski Lake	MYN-CEN	TFS 019	X			X				X		
Notigi Lake-West	NTG-W	TFS 015	X			X		X			X	
Notigi Lake-East	NTG-E	TFS 016	X			X		X			X	
Threepoint Lake	3PT	TFS 017	X		X			X	X	X	X	X
Footprint Lake	FOOT	TFS 010	X			X			X			X
Apussigamasi Lake	APU	TGS 014	X			X		X			X [1]	
Leftrook Lake	LEFT	TFS 018		X	X			X	X	X	X	X

[1] Apussigamasi Lake was not sampled in winter 2012/13 due to thin ice conditions.

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

Metric		**Waterbody**							
		RAT	**MYN**	**NTG-W**	**NTG-E**	**3PT**	**FOOT**	**APU**	**LEFT**
Years Sampled		2010/11, 2013/14	2011/12	2009/10, 2012/13	2009/10, 2012/13	2009/10-2013/14	2010/11, 2013/14	2009/10, 2012/13	2009/10-2013/14
TP	(mg/L)	0.0202	0.0160	0.0165	0.0171	0.0220	0.0235	0.0321	0.0247
	Trophic Status	Meso-eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic
TN	(mg/L)	0.30	0.50	0.35	0.32	0.33	0.46	0.39	0.59
	Trophic Status	Oligotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
TKN	(mg/L)	0.28	0.48	0.34	0.31	0.32	0.43	0.38	0.55
Chlorophyll *a*	(µg/L)	1.77	8.23	2.16	2.06	2.27	4.40	2.36	10.1
	Trophic Status	Oligotrophic	Eutrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Eutrophic
TN:TP	-	35	74	49	44	36	60	28	60
DOC	(mg/L)	7.1	8.8	7.7	7.8	7.8	9.1	8.1	8.7
Nitrate/nitrite	(mg N/L)	0.0184	0.0186	0.0174	0.0165	0.0194	0.0221	0.0163	0.0325
Ammonia	(mg N/L)	0.009	0.005	0.006	0.006	0.011	0.025	0.024	0.015
Dissolved Phosphorus	(mg/L)	0.009	0.009	0.009	0.009	0.011	0.008	0.012	0.010
DO Lower than MWQSOGs for PAL	(Y/N)	Yes (summer 2013)	Yes (spring, summer, and fall 2011)	Yes (summer 2012)	No	No	Yes (spring and summer 2013)	No	Yes (spring 2010 and 2013, summer 2011 and 2012,and winter 2010/2011 and 2012/2013)
DO - open-water season (surface)	(mg/L)	9.38	9.53	8.97	9.05	9.67	9.61	10.2	9.35
DO - open-water season (bottom)	(mg/L)	8.39	3.68	8.50	9.53	9.62	8.62	10.1	6.81
DO - ice-cover season (surface)	(mg/L)	13.8	n/r	13.6	13.5	15.7	n/r	17.2	n/r
DO - ice-cover season (bottom)	(mg/L)	13.0	n/r	13.2	11.4	15.5	n/r	16.5	n/r
Thermal Stratification	(Y/N)	Yes (summer 2013, and winter 2013/2014)	Yes (spring, summer and fall 2011)	Yes (spring 2009 and 2012, and summer 2009)	Yes (spring 2009 and 2012, and summer 2012)	No	Yes (spring 2010 and 2013)	No	Yes (spring 2010 and 2013, summer 2011 and 2012, and winter 2009/2010)
Secchi Disk Depth	(m)	0.93	1.27	1.02	1.23	0.58	1.16	0.36	1.57
TSS	(mg/L)	3.1	3.8	1.9	1.8	6.2	5.0	14.7	2.9
Turbidity	(NTU)	8.51	4.71	7.63	7.00	14.3	8.34	26.0	3.19
True Colour	(TCU)	14.8	12.2	14.7	16.1	27.4	14.1	55.0	12.8
Conductivity	(µmhos/cm)	105	174	104	108	112	178	121	198
TDS	(mg/L)	65.9	97.0	69.9	71.4	89.8	119	88.9	133
Hardness	(mg/L)	49.0	99.4	49.3	52.0	54.1	90.3	62.4	107.4
Hardness Category	-	Soft	Moderately Soft/Hard	Soft	Soft	Soft	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard
pH	-	7.99	8.28	7.86	7.91	8.00	8.19	8.10	8.31
Total Alkalinity	(mg/L)	49.7	94.8	51.1	52.5	54.4	88.6	58.4	105.1
Metals > MWQSOGs for PAL	-	Al, Fe	Al	Al, Fe, Pb, Ag	Al, Fe	Al, Fe	Al, Fe	Al, Fe	-
Aluminum	(mg/L)	0.520	0.175	0.285	0.313	0.628	0.460	0.886	0.027
Iron	(mg/L)	0.394	0.110	0.256	0.265	0.525	0.317	0.850	0.065
Mercury (26 ng/L DL only)	(mg/L)	1.2	-	<20	<20	<20	<20	<20	<20
Mercury (1 ng/L DL only)	(mg/L)	1.2	-	<1.0	<1.0	<1.0	<1.0	1.2	1.4
Calcium	(mg/L)	12.5	28.9	12.9	13.6	14.1	25.7	16.7	30.6
Magnesium	(mg/L)	4.31	6.36	4.19	4.38	4.58	6.28	5.04	7.55
Potassium	(mg/L)	1.31	1.19	1.26	1.29	1.35	1.34	1.48	1.23
Sodium	(mg/L)	3.19	2.42	3.10	3.22	3.27	3.27	3.93	3.00
Chloride	(mg/L)	0.97	0.62	1.14	1.15	1.04	1.08	1.46	0.73
Sulphate	(mg/L)	2.35	2.00	3.82	4.03	3.20	2.43	4.42	2.95

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

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

Indicator	Metric		Unit	Waterbody: RAT	MYN	NTG-W	NTG-E	3PT	FOOT	APU	LEFT
Nutrients	TP	Mean	(mg/L)	0.0200	0.0165	0.0154	0.0166	0.0209	0.0221	0.0325	0.0277
		Trophic Status	-	Mesotrophic/ Meso-eutrophic boundary	Mesotrophic	Mesotrophic	Mesotrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic
	TN	Mean	(mg/L)	0.26	0.51	0.35	0.30	0.32	0.47	0.37	0.59
		Trophic Status	-	Oligotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
	Chlorophyll *a*	Mean	(µg/L)	2.26	10.5	2.80	2.66	2.93	5.77	2.73	13.1
		Trophic Status	-	Oligotrophic	Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Eutrophic
	TN:TP	Mean	-	33	75	51	43	38	69	26	52
	Nutrient Limitation	Nutrient	-	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation
	Chlorophyll *a*:TP	Mean	-	0.270	0.717	0.179	0.164	0.184	0.310	0.086	0.480
	Chlorophyll *a*:TN	Mean	-	0.027	0.018	0.009	0.009	0.011	0.015	0.008	0.021
	Algal Bloom Frequency (Chlorophyll *a* >10 µg/L)	-	(%)	0	33	0	0	0	17	0	53
Dissolved Oxygen	DO Lower than MWQSOGs for PAL	-	(Y/N)	Yes (summer 2013)	Yes (spring, summer, and fall 2011)	Yes (summer 2012)	No	No	Yes (spring and summer 2013)	No	Yes (spring 2010 and 2013, and summer 2011 and 2012)
	DO	Surface Mean	(mg/L)	9.38	9.53	8.97	9.05	9.67	9.61	10.2	9.35
		Bottom Mean	(mg/L)	8.39	3.68	8.50	9.53	9.62	8.62	10.1	6.81
	Thermal Stratification	-	(Y/N)	Yes (summer 2013)	Yes (spring, summer and fall 2011)	Yes (spring 2009 and 2012, and summer 2009)	Yes (spring 2009 and 2012, and summer 2012)	No	Yes (spring 2010 and 2013)	No	Yes (spring 2009 and 2013, and summer 2011 and 2012)
Water Clarity	Secchi Disk Depth	Mean	(m)	0.93	1.27	1.02	1.23	0.58	1.16	0.36	1.57
	TSS	Mean	(mg/L)	3.3	4.7	2.0	2.1	7.5	5.9	15.6	3.5
	Turbidity	Mean	(NTU)	8.77	5.68	8.07	7.23	15.73	6.82	28.02	3.95

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 Churchill River Diversion 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*	Molybdenum	Nickel	Selenium	Silver	Thallium	Uranium	Zinc	Chloride	Sulphate
Objective or Guideline (mg/L)		0.1	0.15	1.5	0.000133 - 0.000355	0.0394 - 0.1162	0.00412 - 0.01274	0.3	0.000941 - 0.00506	0.000026	0.073	0.0232 - 0.071	0.001	0.0001	0.0008	0.015	0.0533 - 0.163	120	128 - 309
Rat Lake	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**6**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**75**	0	0	0	0	0	0	0	0	0	0	0
Mynarski Lake	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	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**75**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notigi Lake-West	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**2**	**1**	0	0	0	0	**1**	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**25**	**13**	0	0	0	0	**13**	0	0	0	0	0
Notigi Lake-East	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**13**	0	0	0	0	0	0	0	0	0	0	0
Threepoint Lake	n	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	# Exceedances	**20**	0	0	0	0	0	**18**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**90**	0	0	0	0	0	0	0	0	0	0	0
Footprint Lake	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**25**	0	0	0	0	0	0	0	0	0	0	0
Apussigamasi Lake	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
Leftrook Lake	n	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	# 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.

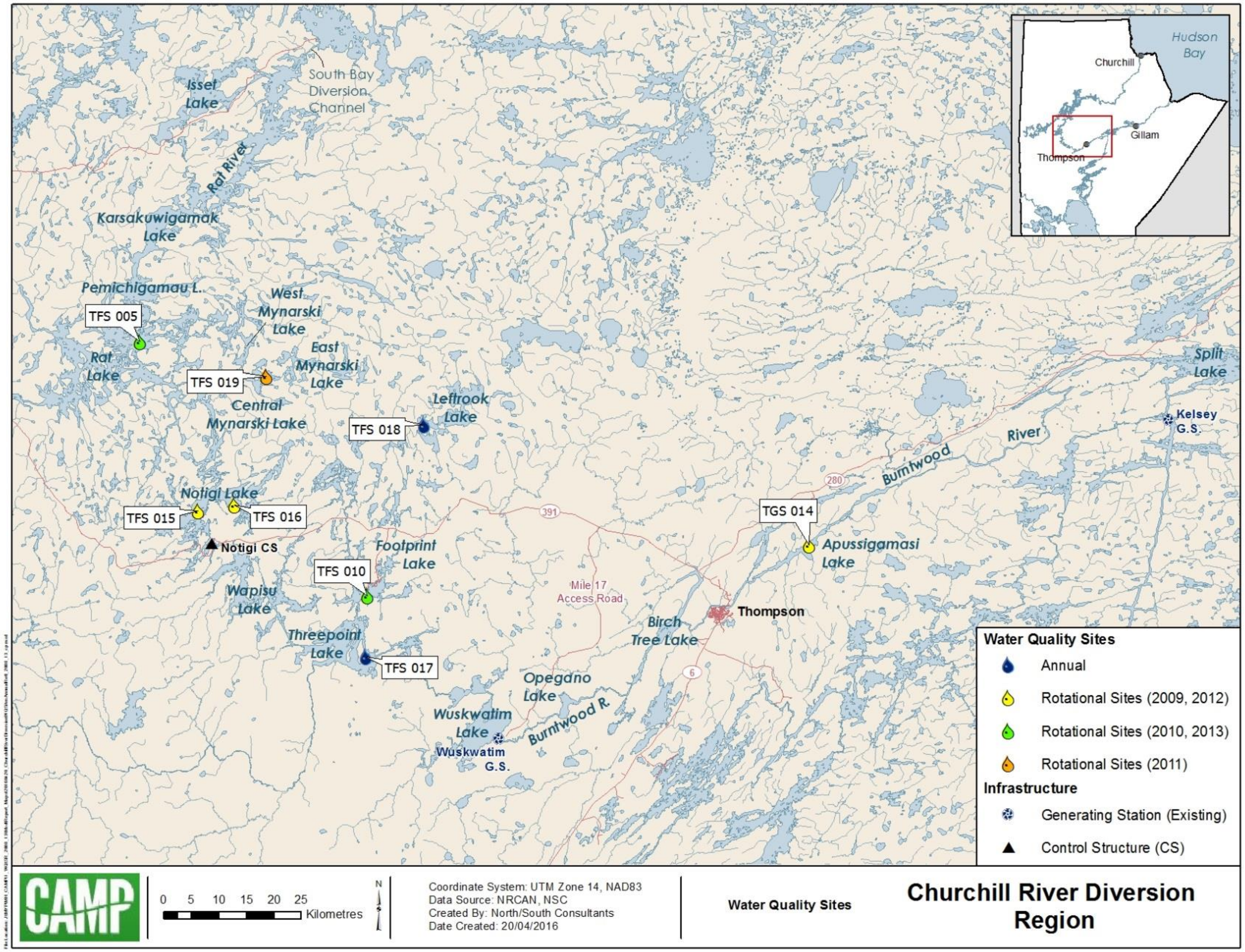


Figure 3-1. Water quality sampling sites in the Churchill River Diversion Region: 2008/2009-2013/2014.

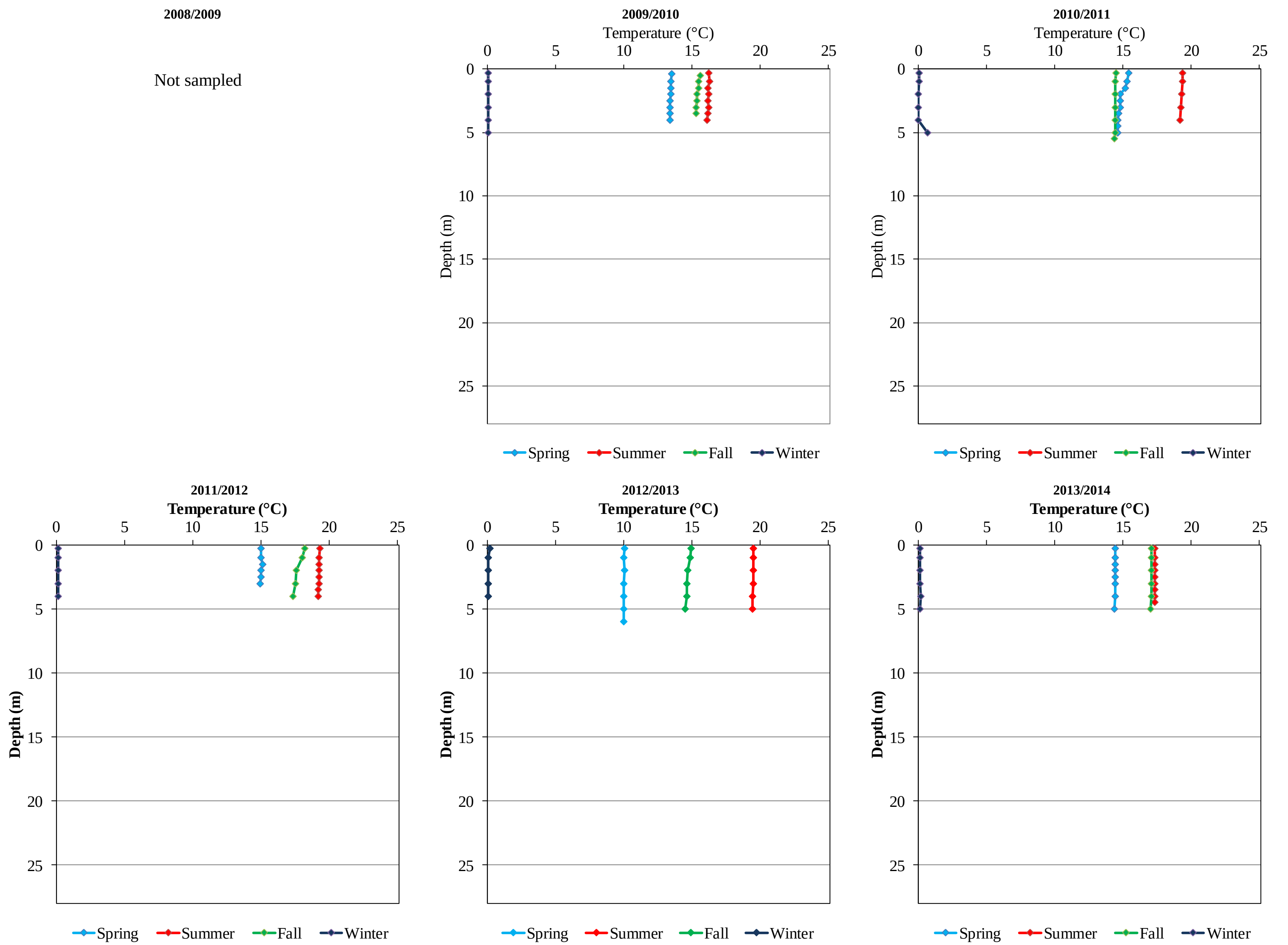


Figure 3-2. Temperature depth profiles in Threepoint Lake: 2008/2009-2013/2014.

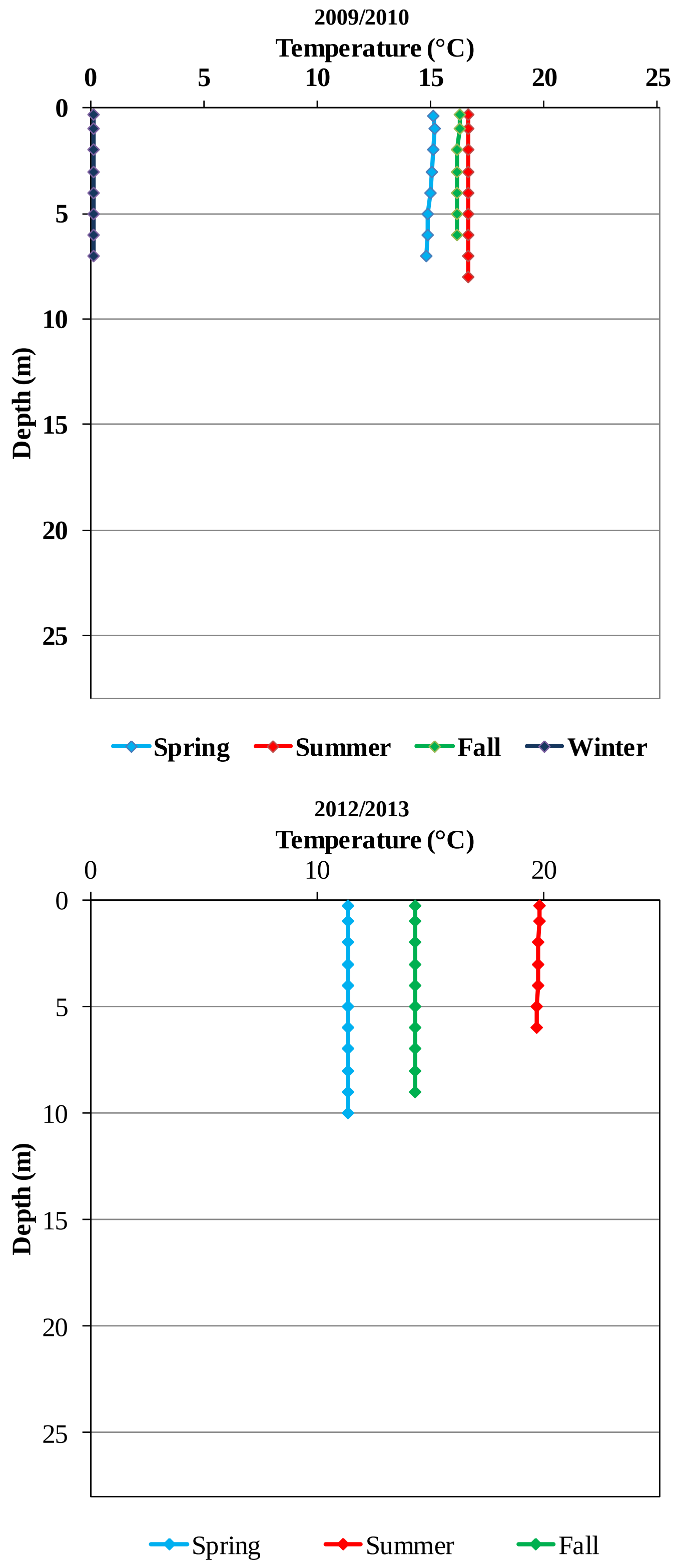
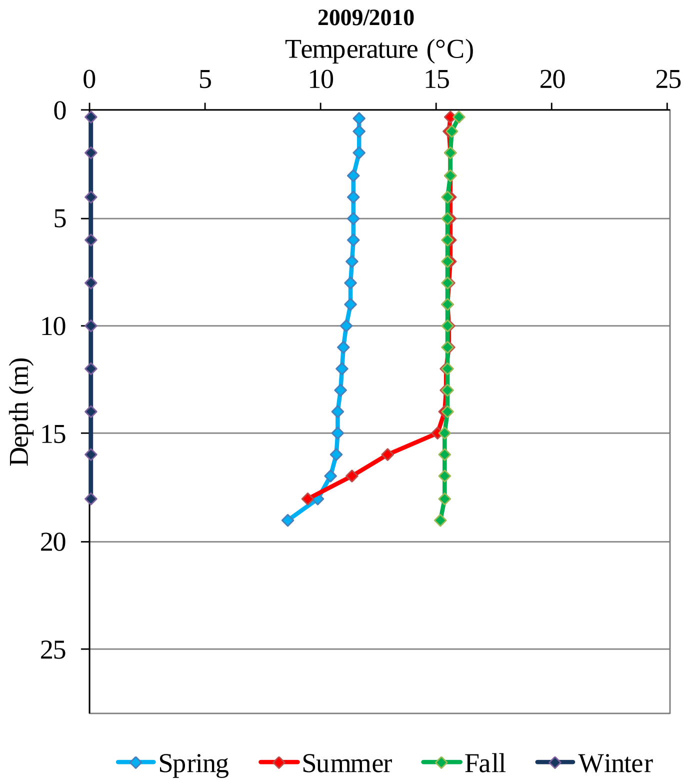


Figure 3-3. Temperature depth profiles in Apussigamasi Lake: 2008/2009-2013/2014.



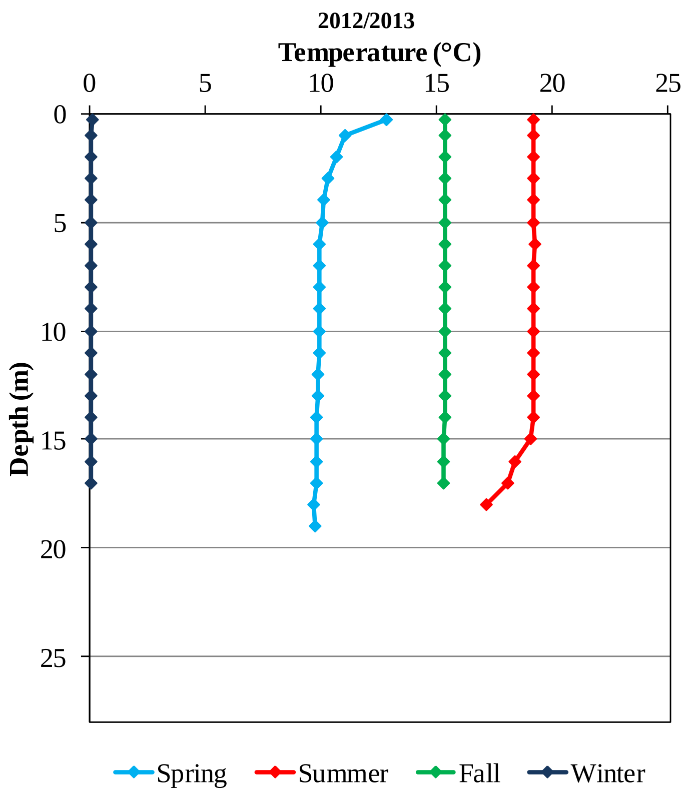
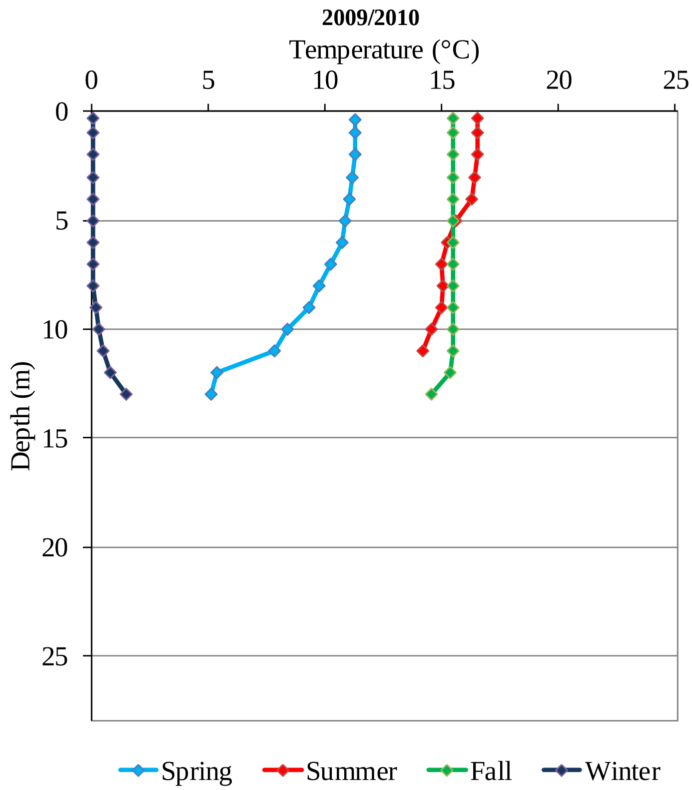


Figure 3-4. Temperature depth profiles in Notigi Lake-West: 2008/2009-2013/2014.



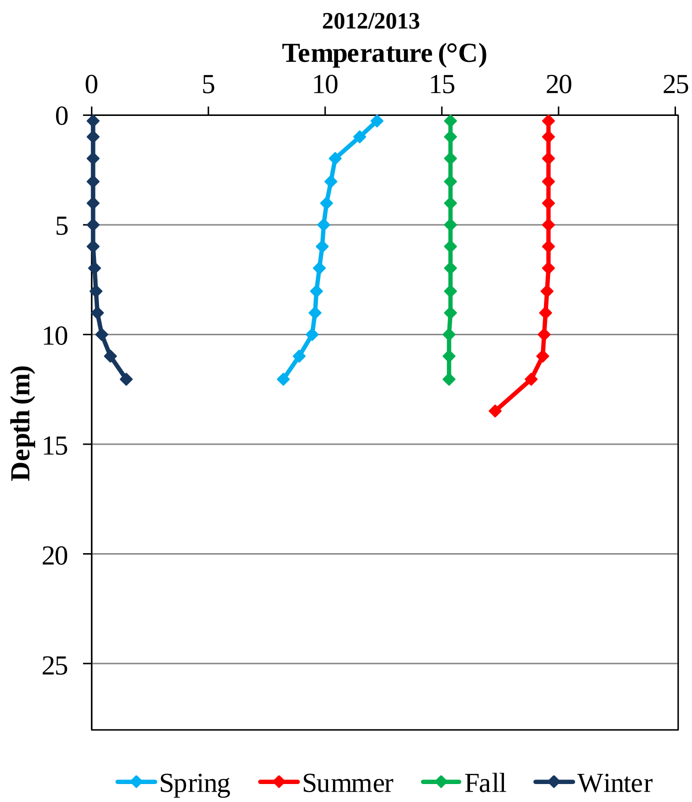
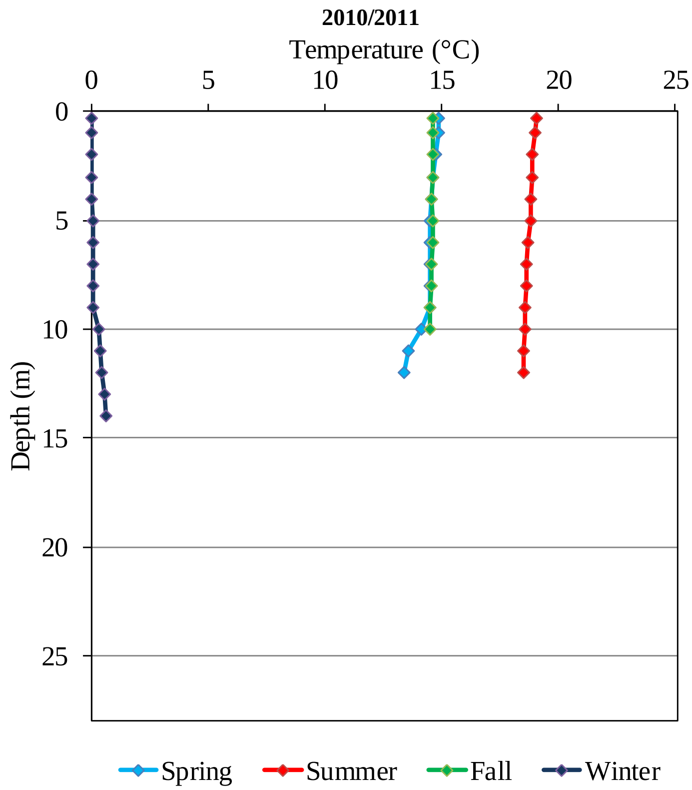


Figure 3-5. Temperature depth profiles in Notigi Lake-East: 2008/2009-2013/2014.



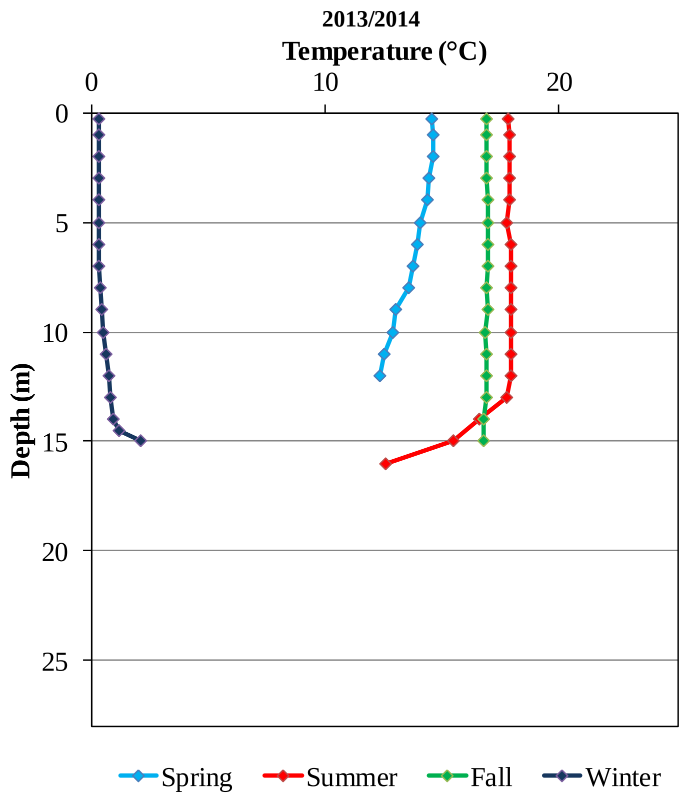


Figure 3-6. Temperature depth profiles in Rat Lake: 2008/2009-2013/2014.

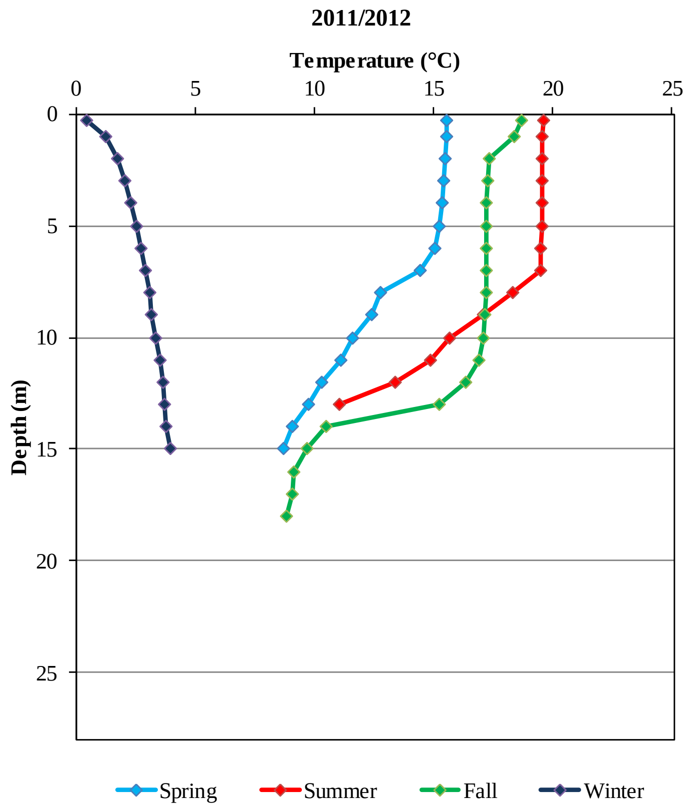


Figure 3-7. Temperature depth profiles in Central Mynarski Lake: 2008/2009-2013/2014.

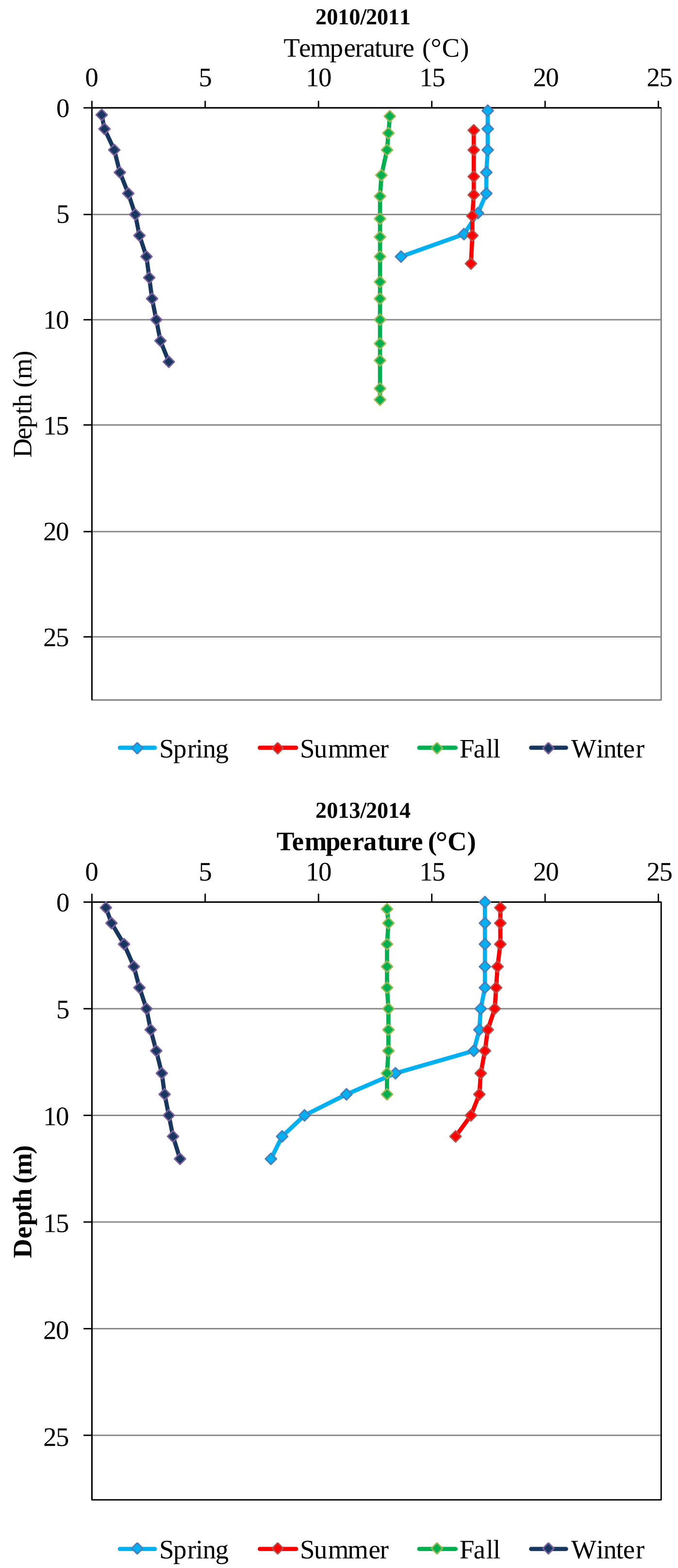


Figure 3-8. Temperature depth profiles in Footprint Lake: 2008/2009-2013/2014.

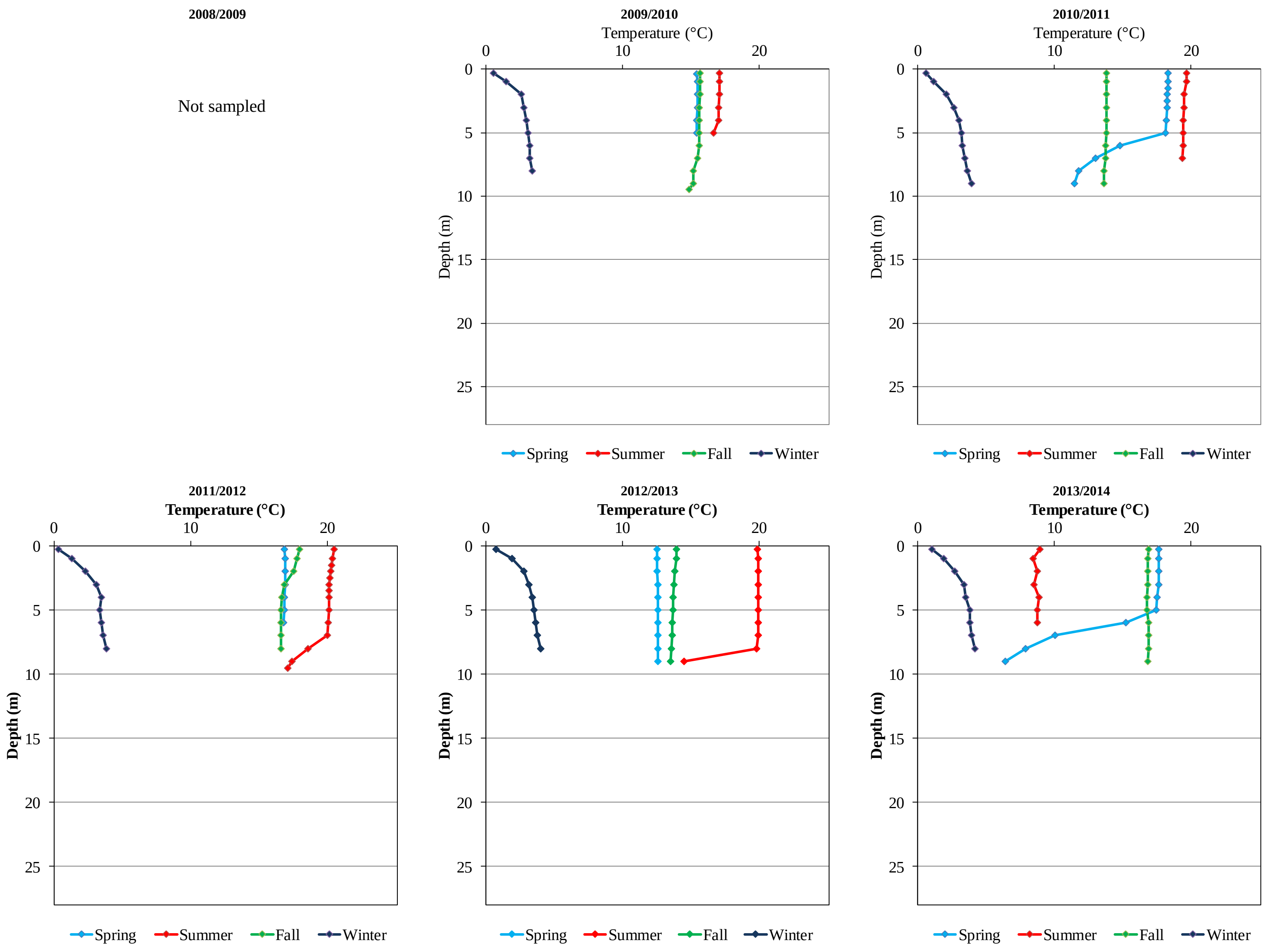
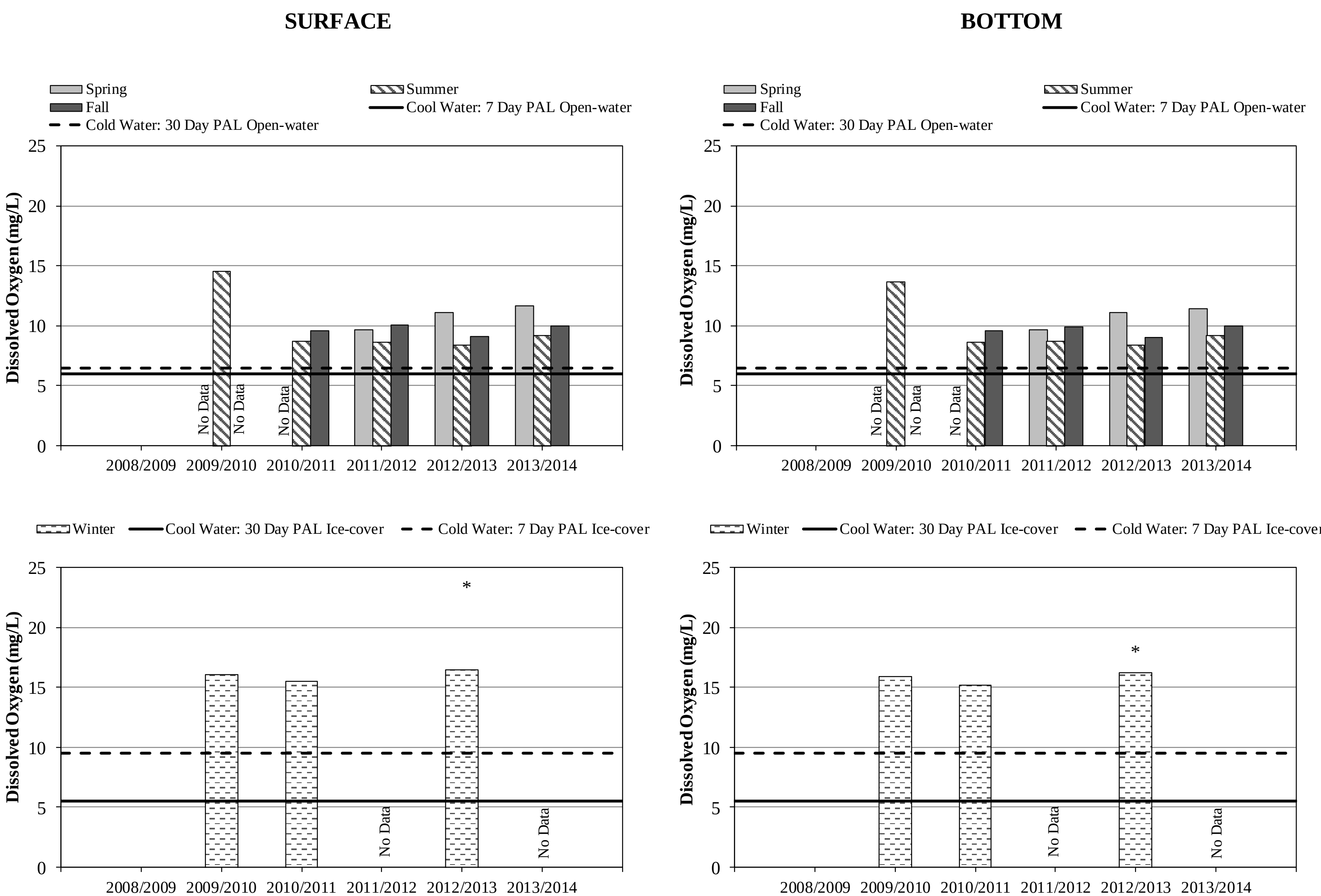
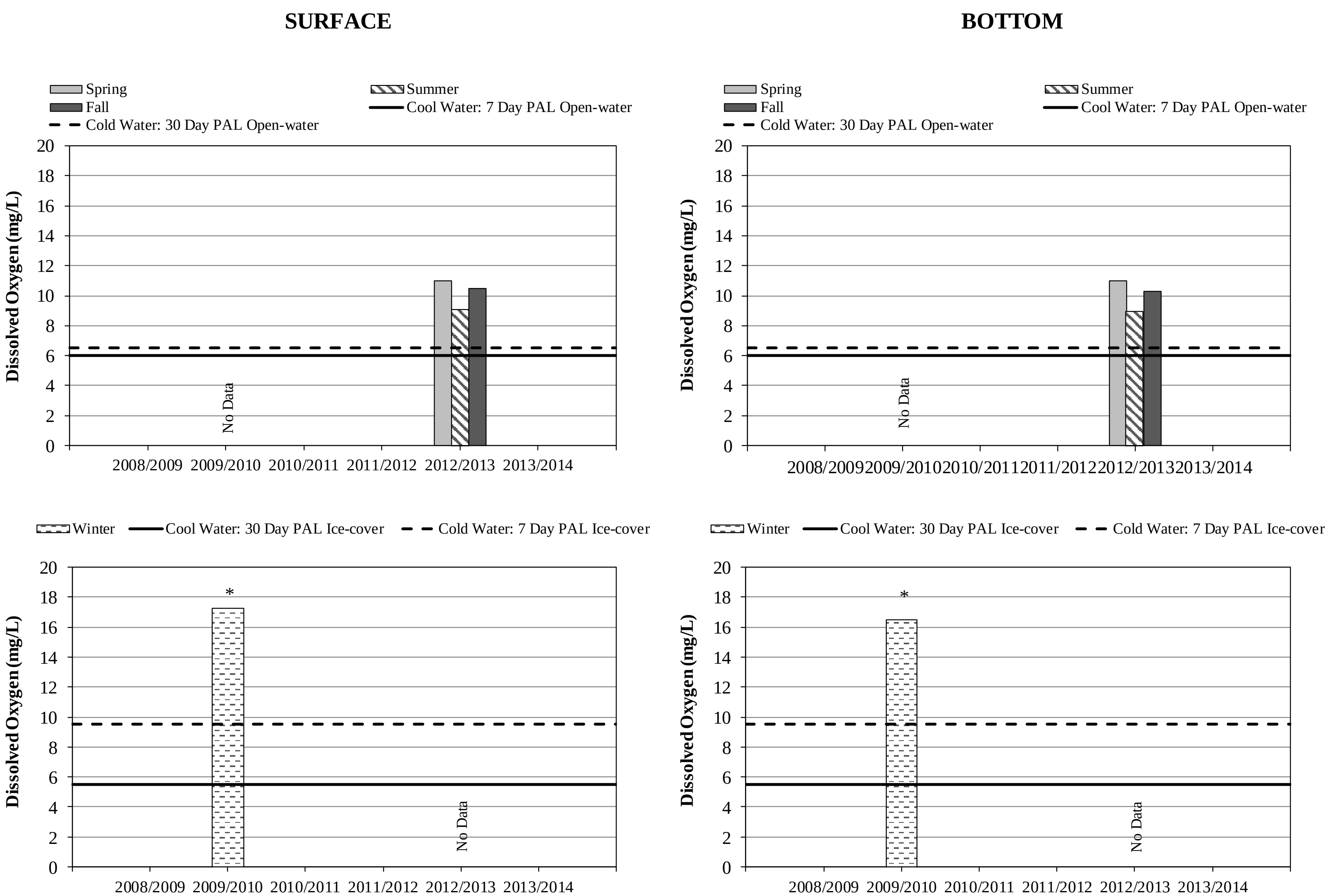


Figure 3-9. Temperature depth profiles in the off-system Leftrook Lake: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations may be overestimated.

Figure 3-10. Dissolved oxygen measured near the surface and bottom of the water column in Threepoint Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations may be overestimated.

Figure 3-11. Dissolved oxygen measured near the surface and bottom of the water column in Apussigamasi Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

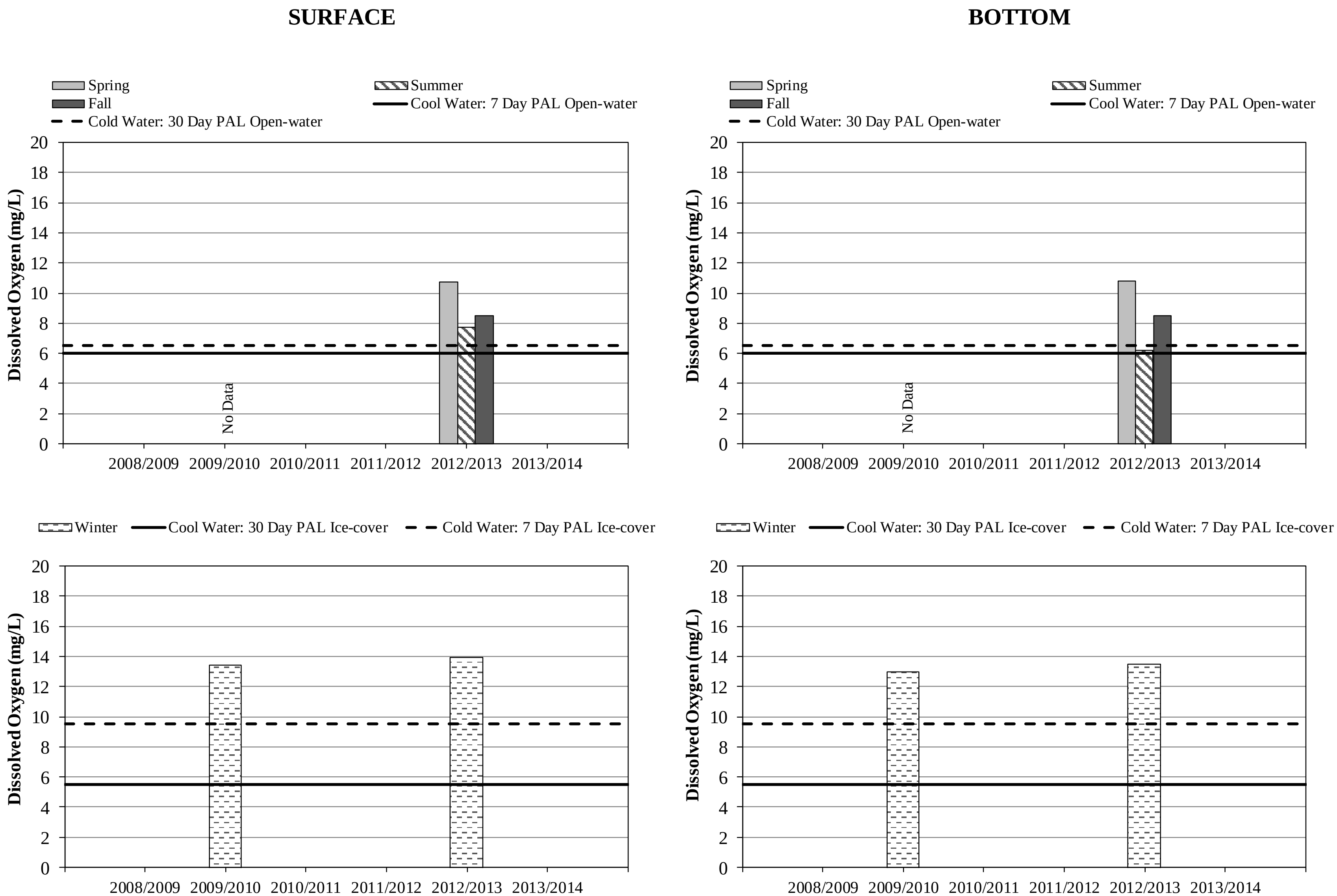


Figure 3-12. Dissolved oxygen measured near the surface and bottom of the water column in Notigi Lake-West and comparisons to MB PAL objectives: 2008/2009-2013/2014.

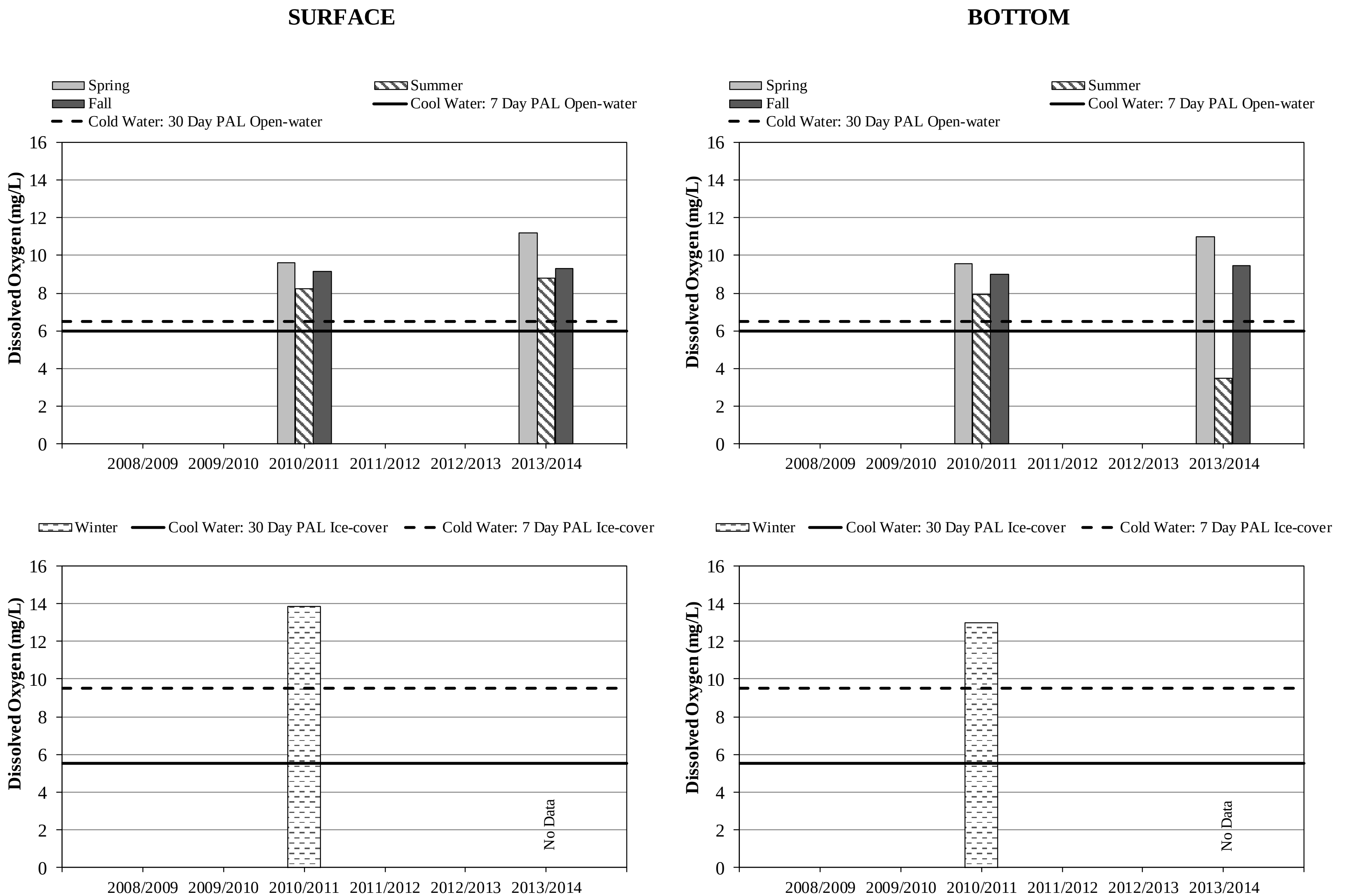
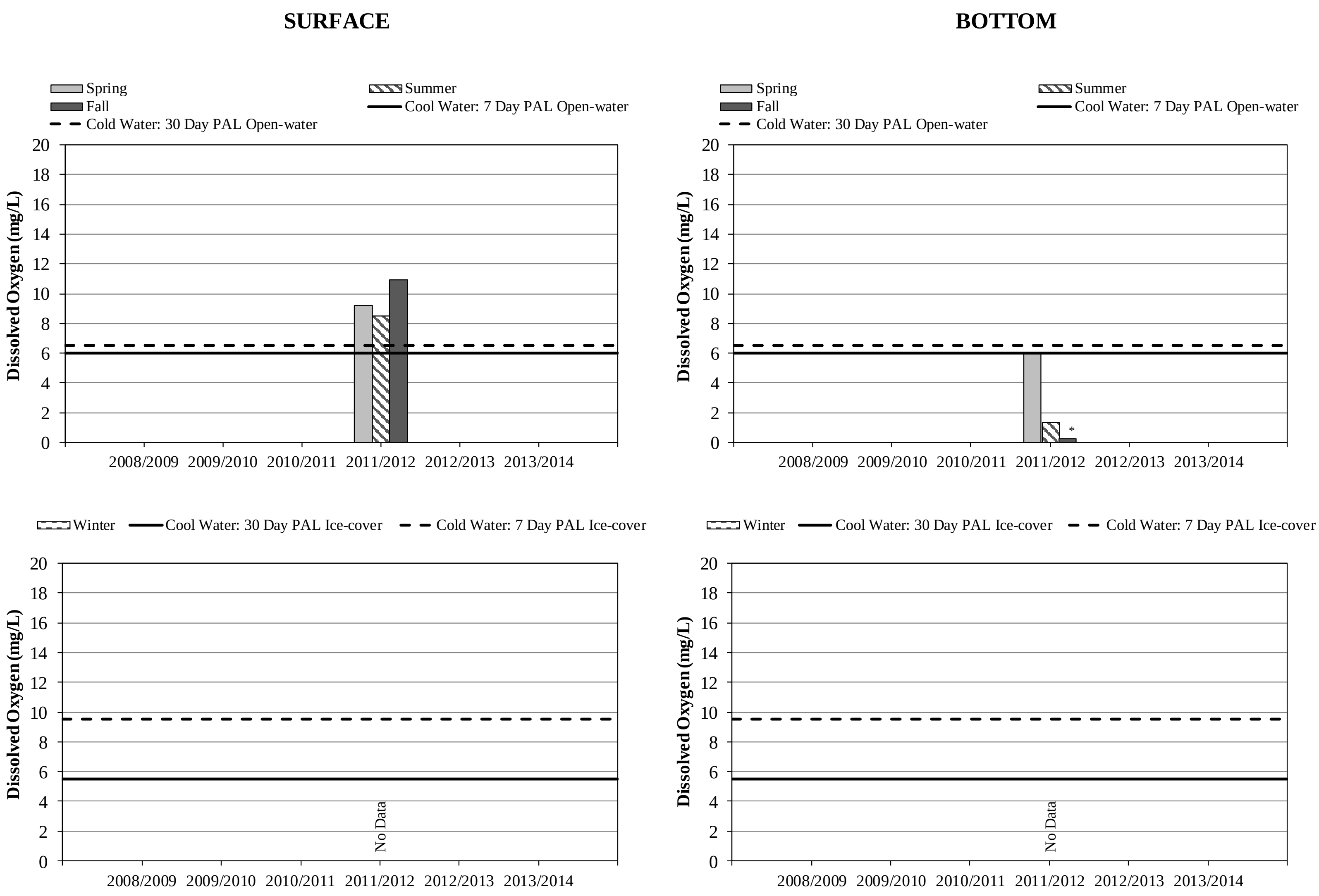
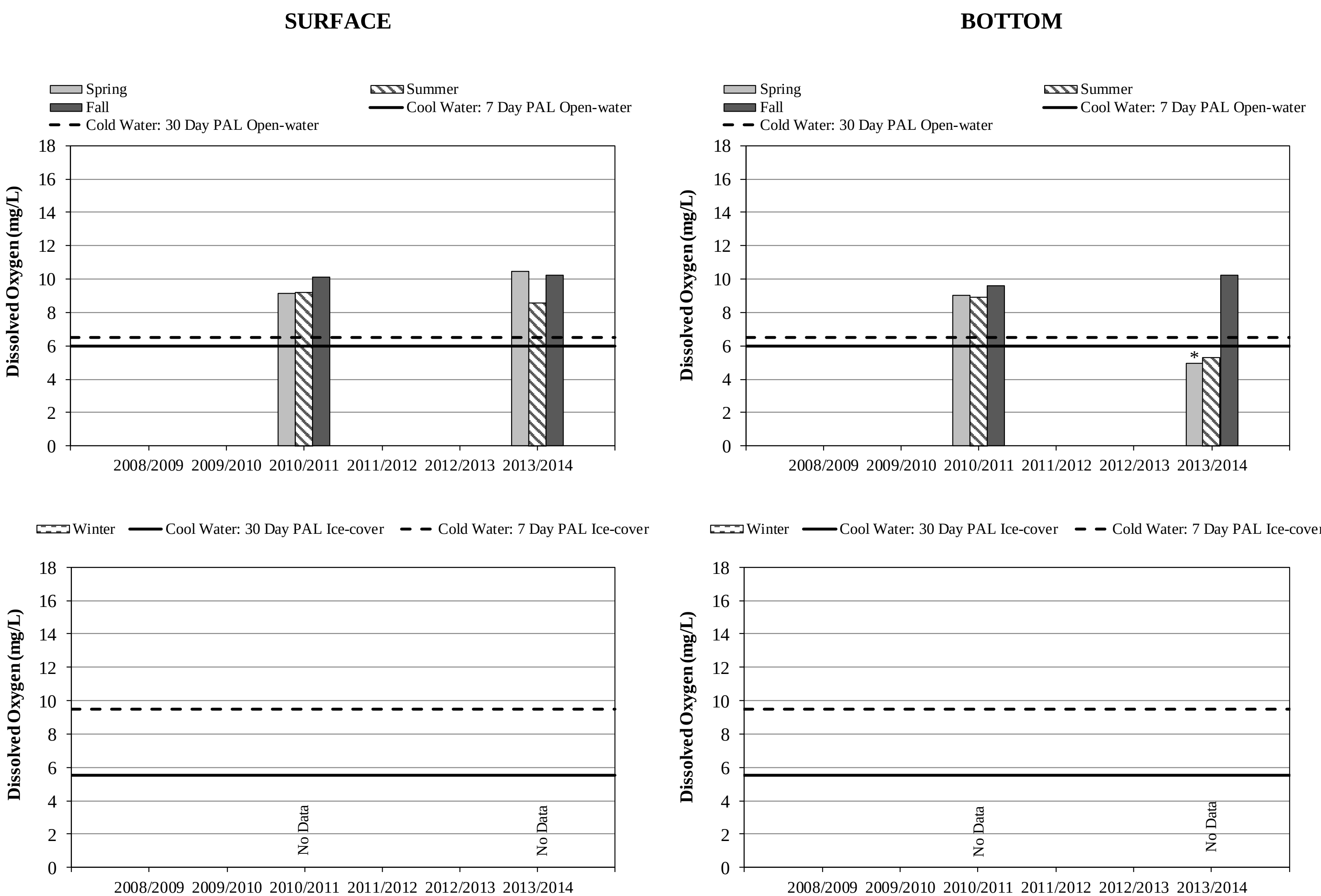


Figure 3-13. Dissolved oxygen measured near the surface and bottom of the water column in Rat Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations may be overestimated.

Figure 3-14. Dissolved oxygen measured near the surface and bottom of the water column in Central Mynarski Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations may be overestimated.

Figure 3-15. Dissolved oxygen measured near the surface and bottom of the water column in Footprint Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

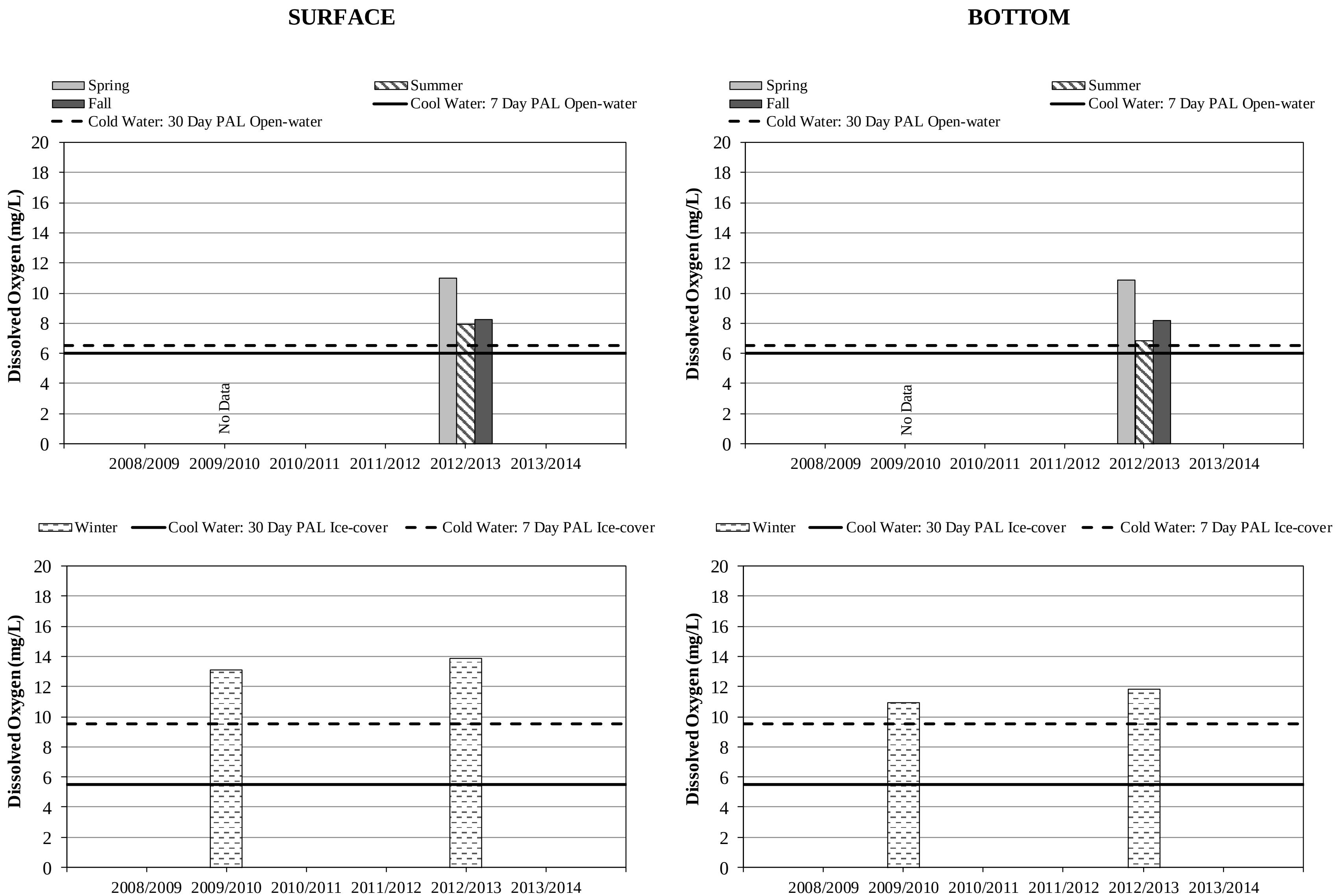
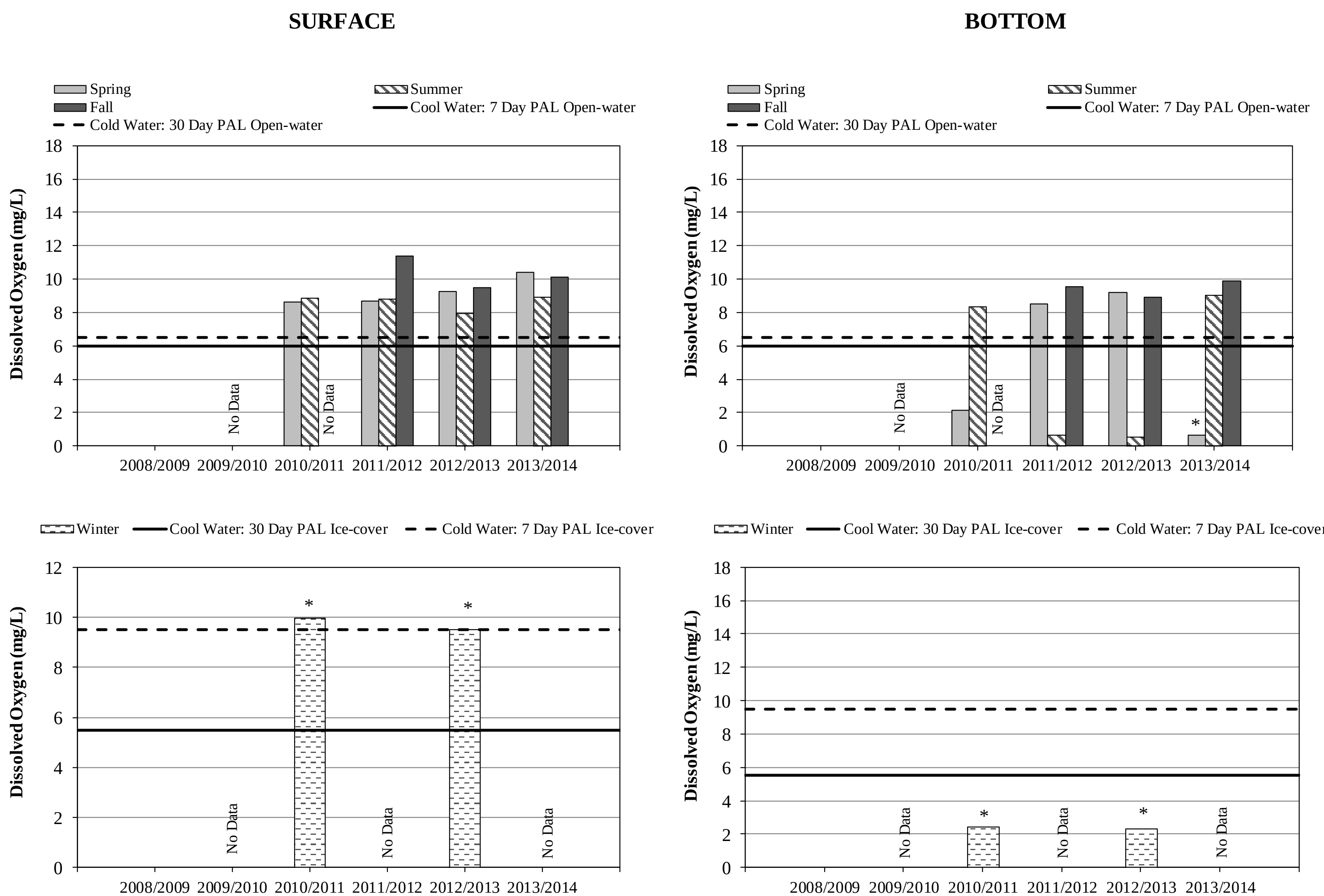


Figure 3-16. Dissolved oxygen measured near the surface and bottom of the water column in Notigi Lake-East and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations may be overestimated.

Figure 3-17. Dissolved oxygen measured near the surface and bottom of the water column in the off-system Leftrook Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

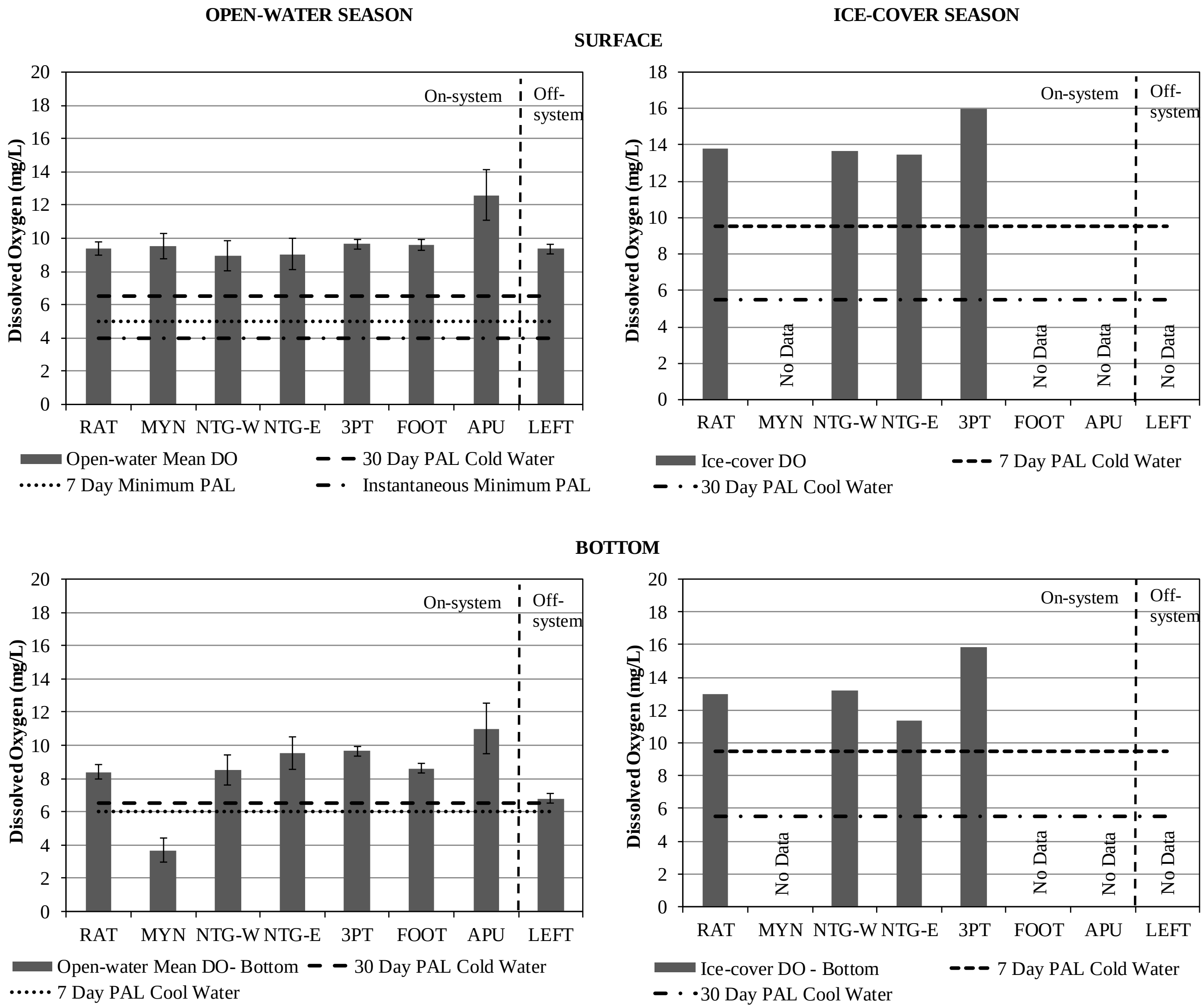


Figure 3-18. Dissolved oxygen (mean±SE) measured near the surface and bottom of the water column in the Churchill River Diversion and off-system waterbodies: 2008/2009-2013/2014.

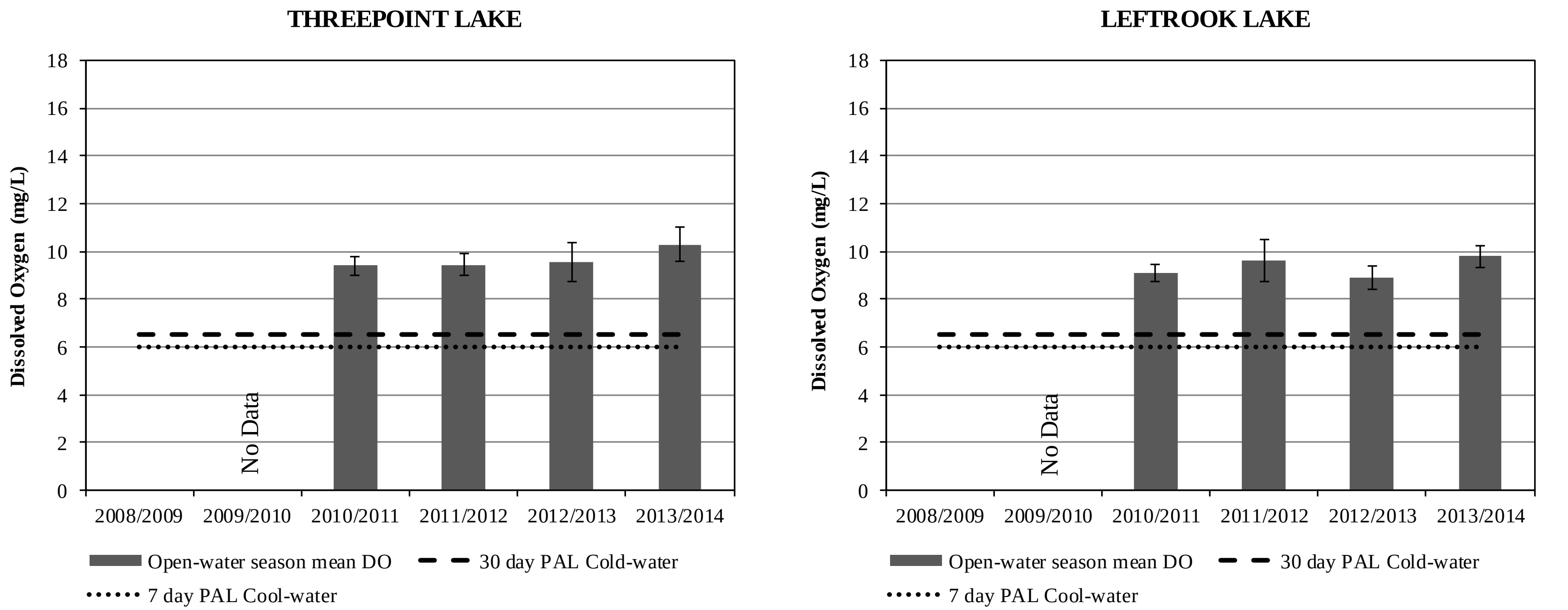
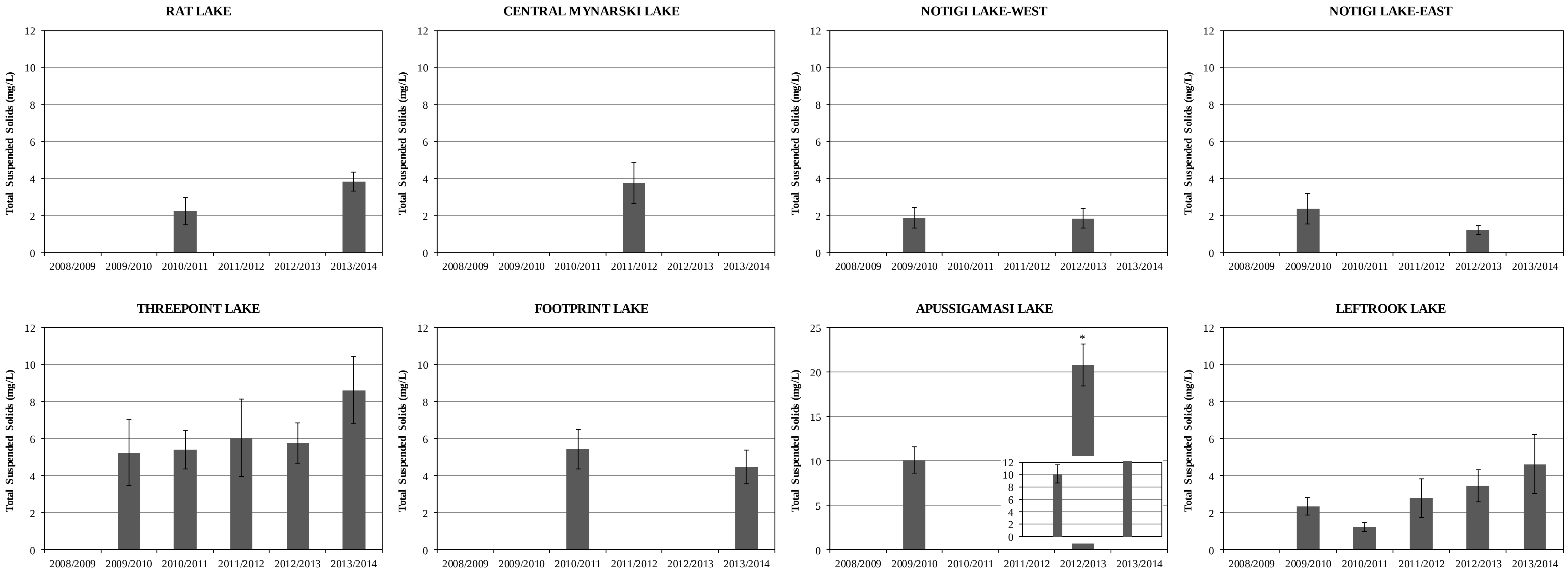
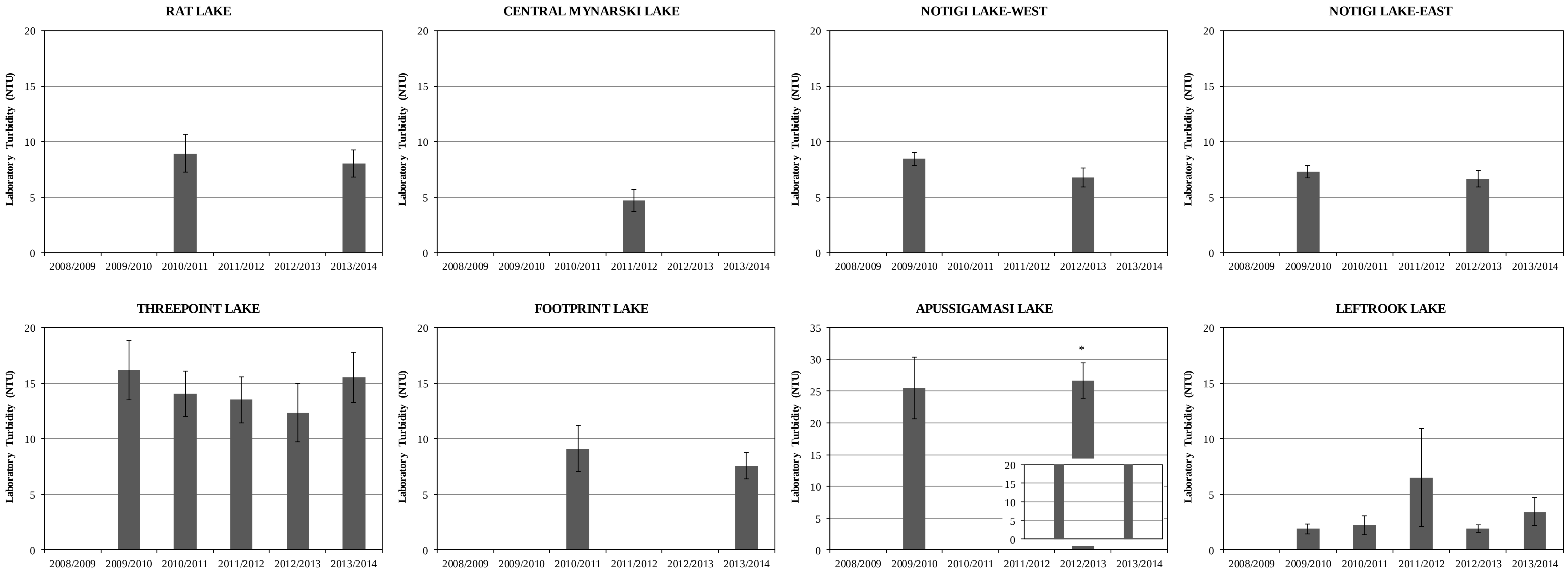


Figure 3-19. Open-water season dissolved oxygen concentrations (mean±SE) measured in the annual monitoring sites. No significant differences were found between years.



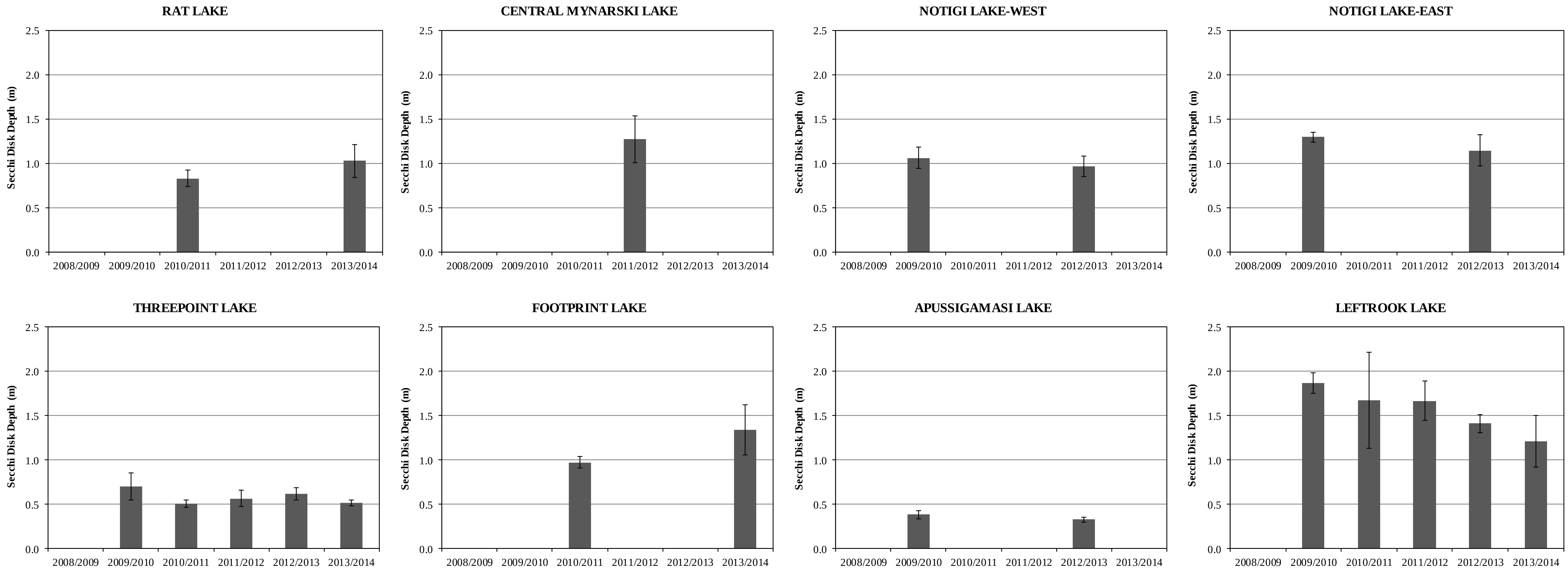
* Samples not collected in winter 2012/2013 at Apussigamasi Lake.

Figure 3-20. Total suspended solids (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake): 2008/2009-2013/2014.



* Samples not collected in winter 2012/2013 at Apussigamasi Lake.

Figure 3-21. Laboratory turbidity (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake): 2008/2009-2013/2014.



* Samples not collected in winter 2012/2013 at Apussigamasi Lake.

Figure 3-22. Secchi disk depths (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake): 2008/2009-2013/2014 (open-water seasons). No significant inter-annual differences were observed at the annual monitoring sites for concentrations measured during the open-water seasons.

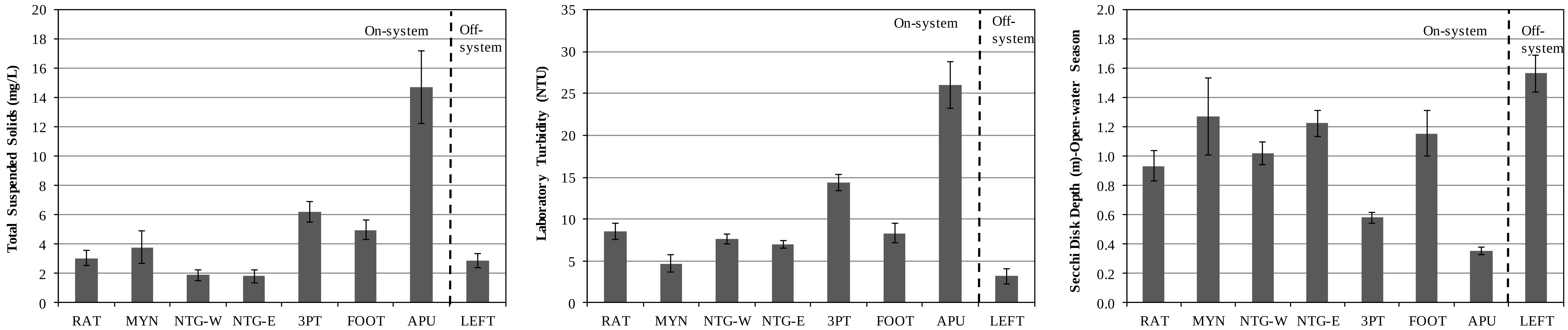


Figure 3-23. TSS, laboratory turbidity, and Secchi disk depths (mean±SE) measured in the Churchill River Diversion and off-system waterbody: 2008/2009-2013/2014.

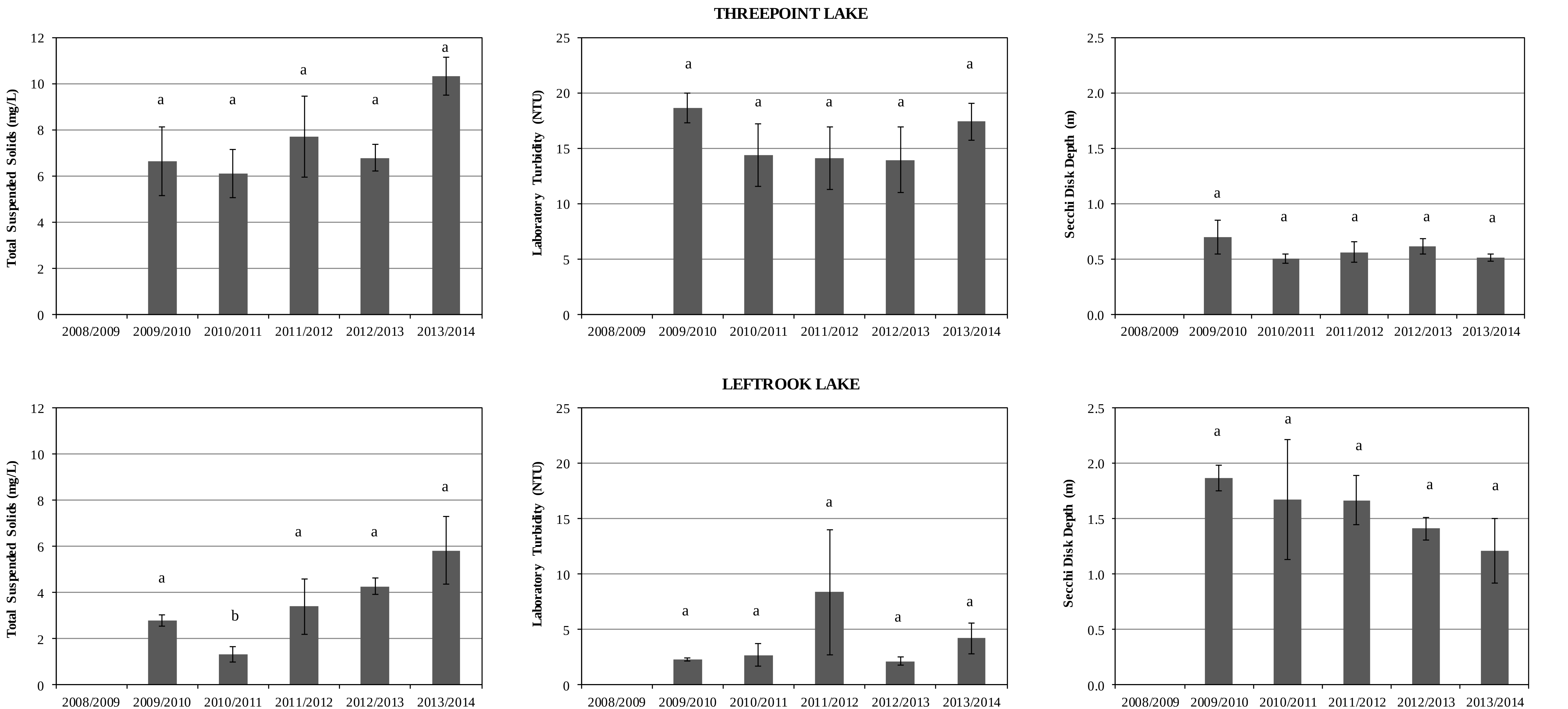


Figure 3-24. Open-water season TSS, turbidity, and Secchi disk depths (mean±SE) measured in the annual monitoring sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

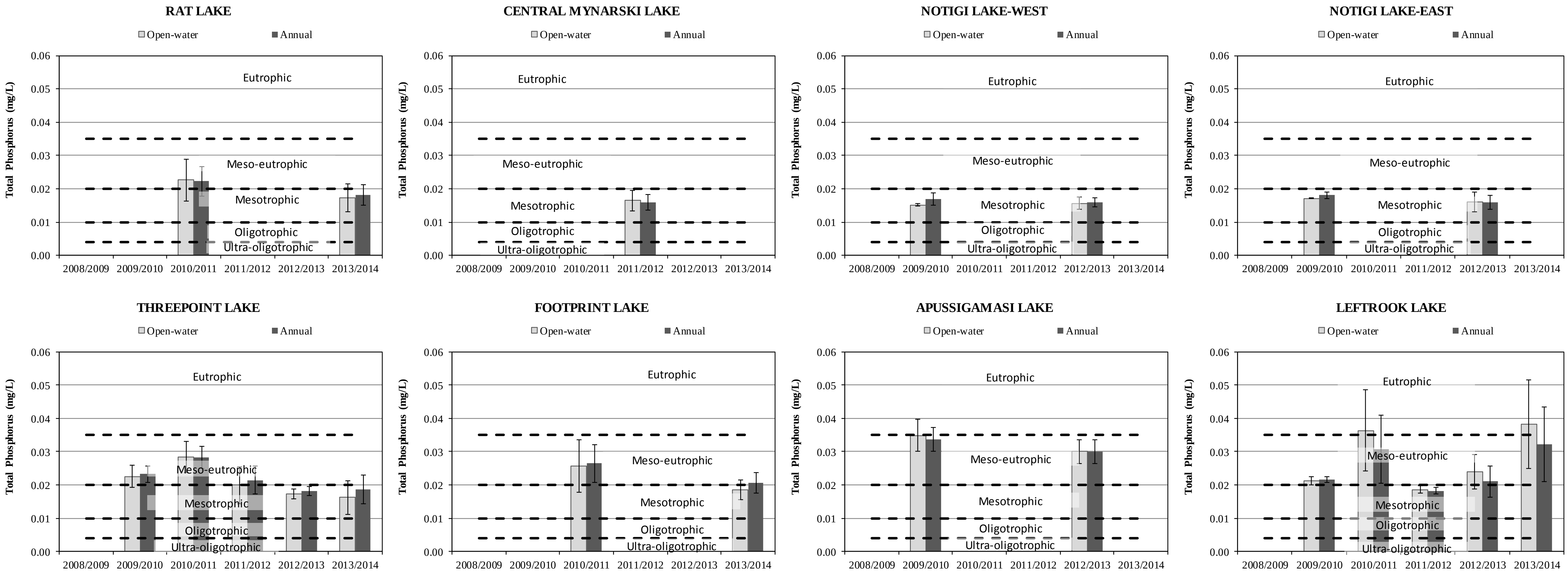


Figure 3-25. Total phosphorus (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake) and comparison to trophic categories: 2008/2009-2013/2014. No significant inter-annual differences were observed at the annual monitoring sites for concentrations measured during the open-water seasons.

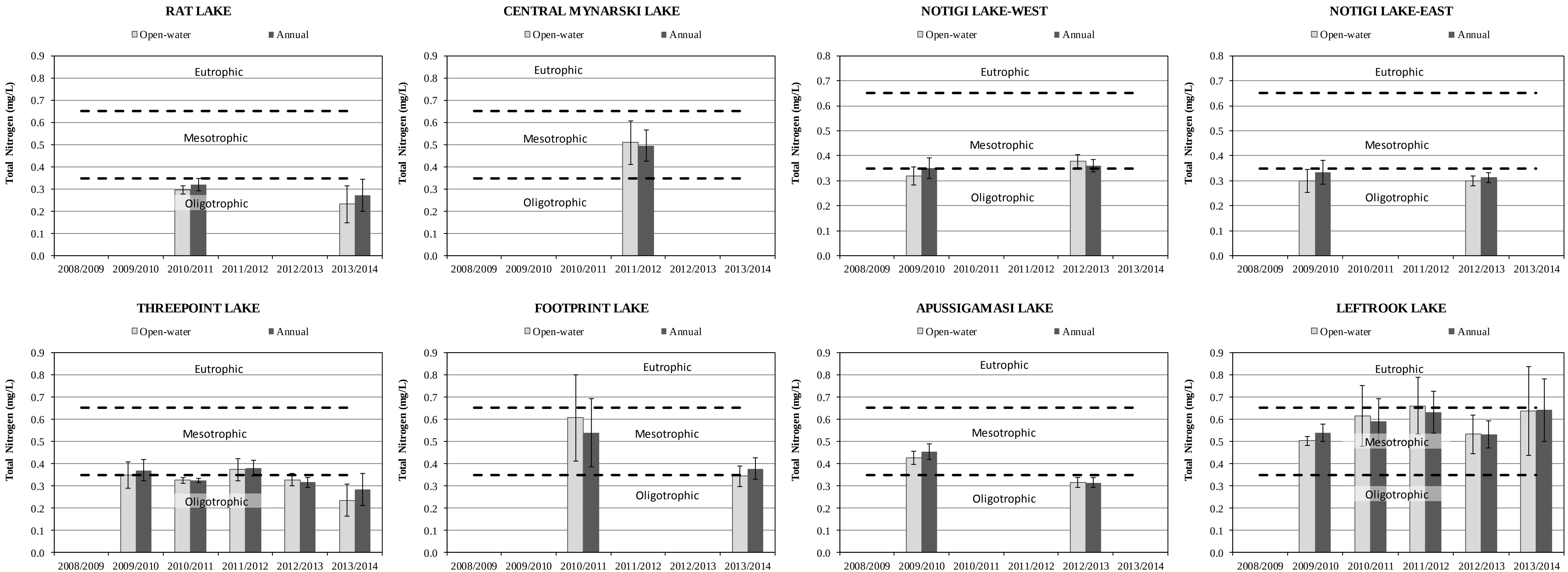


Figure 3-26. Total nitrogen (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake) and comparison to trophic categories: 2008/2009-2013/2014. No significant inter-annual differences were observed at the annual monitoring sites for concentrations measured during the open-water seasons.

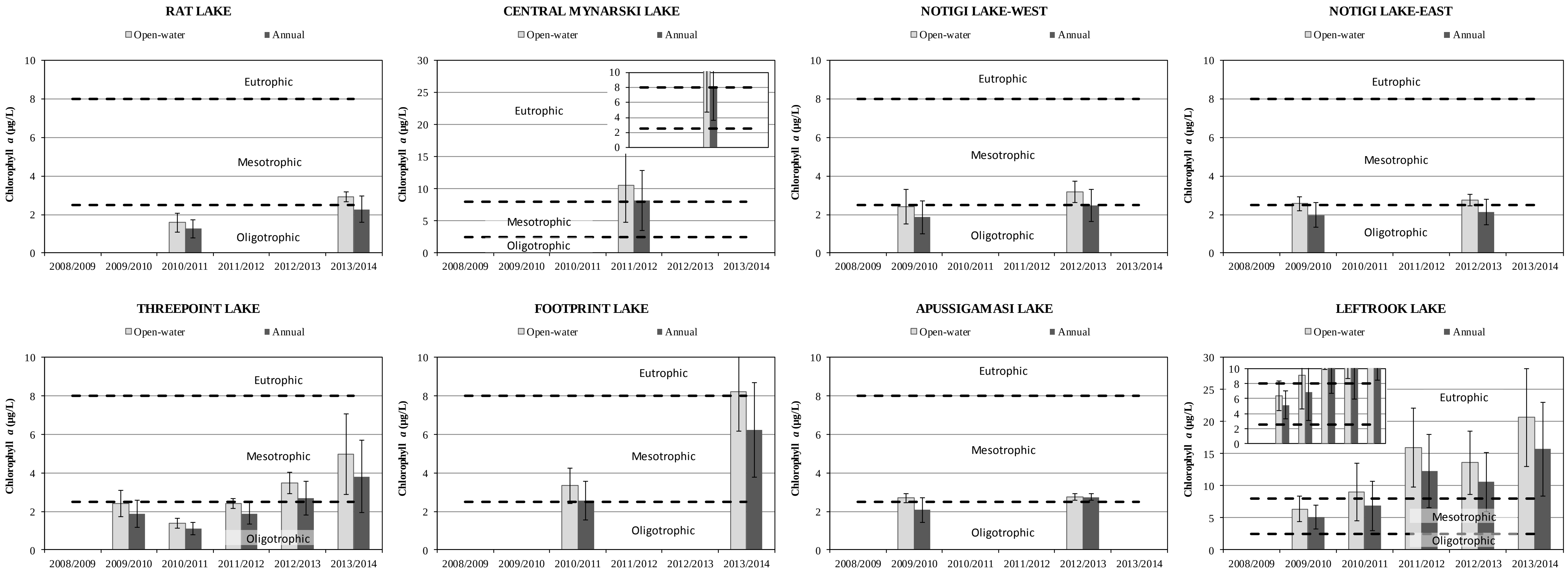


Figure 3-27. Chlorophyll *a* (mean±SE) measured along the Churchill River Diversion and off-system waterbody (Leftrook Lake) and comparison to trophic categories: 2008/2009-2013/2014. No significant inter-annual differences were observed at the annual monitoring sites for concentrations measured during the open-water seasons.

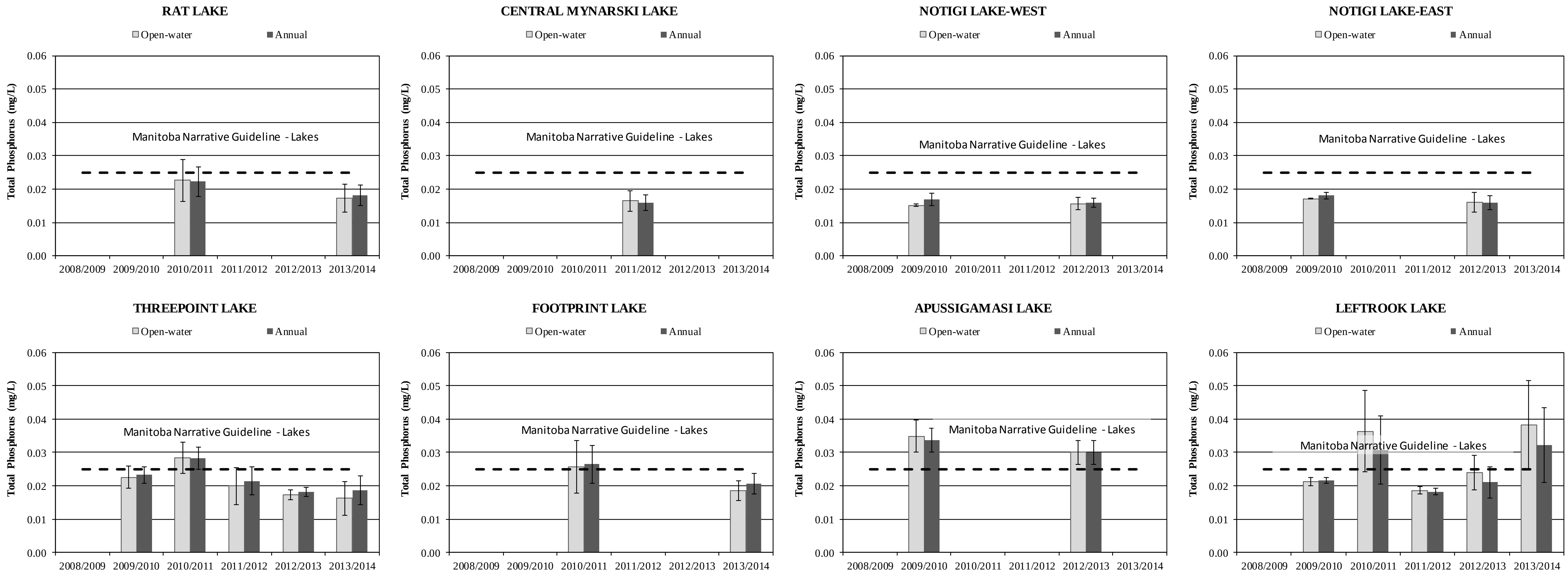


Figure 3-28. Total phosphorus (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake) and comparison to the Manitoba narrative nutrient guidelines: 2008/2009-2013/2014.

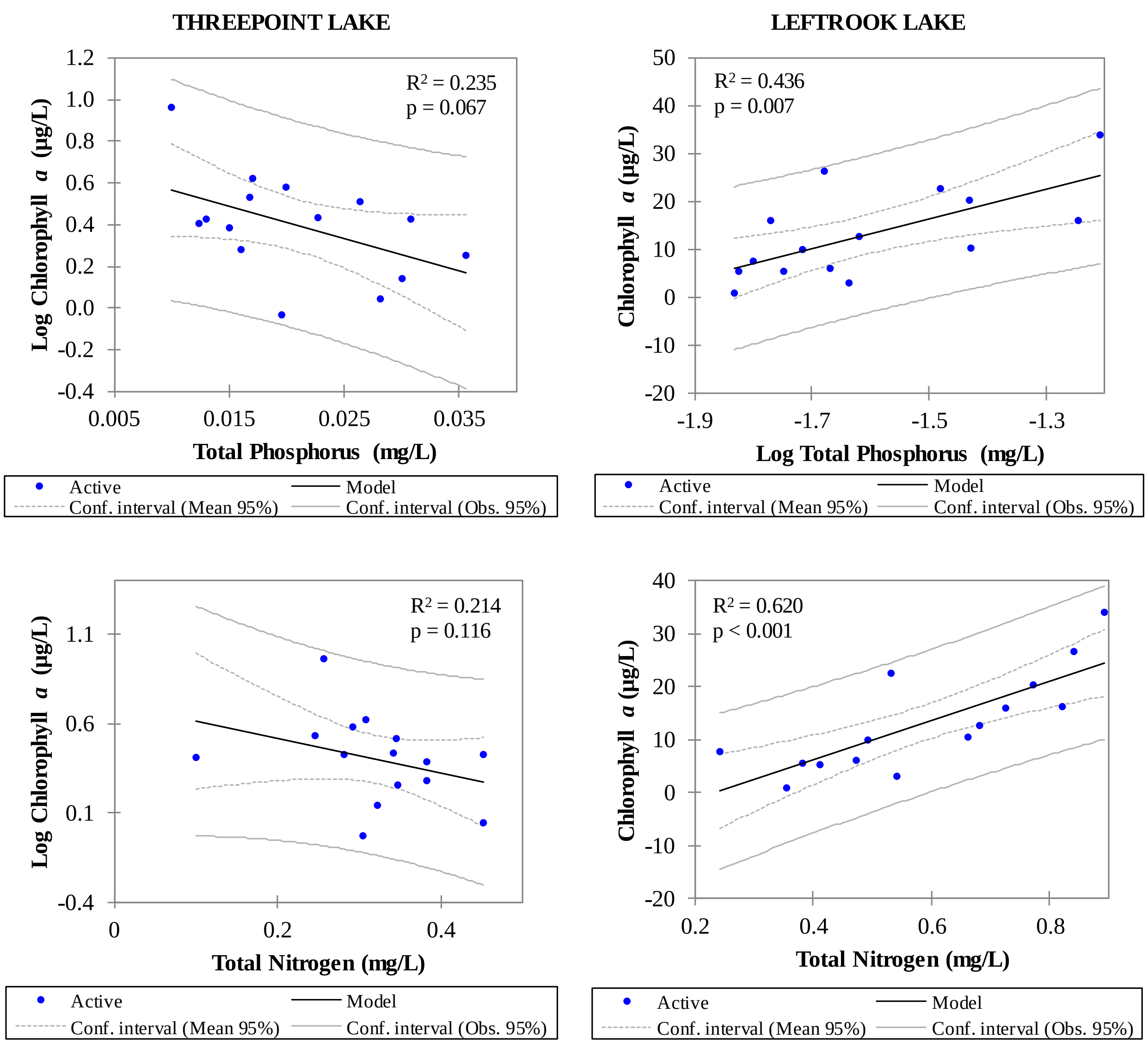


Figure 3-29. Linear regression between total phosphorus or total nitrogen and chlorophyll *a* in Threepoint and Leftrook lakes: open-water seasons 2008-2013.

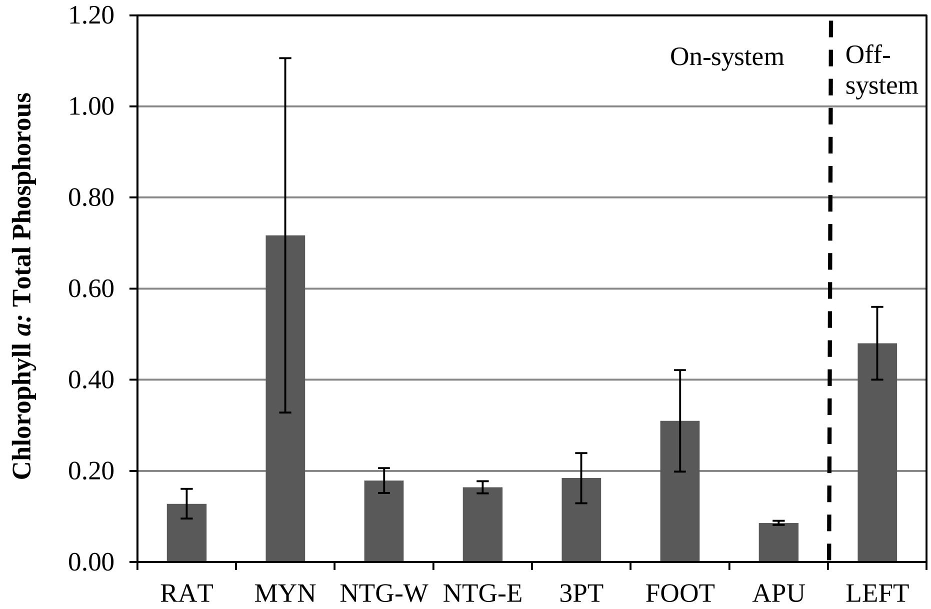


Figure 3-30. Chlorophyll *a* to total phosphorus ratios (mean±SE) measured in the Churchill River Diversion and off-system waterbody: open-water seasons 2008-2013.

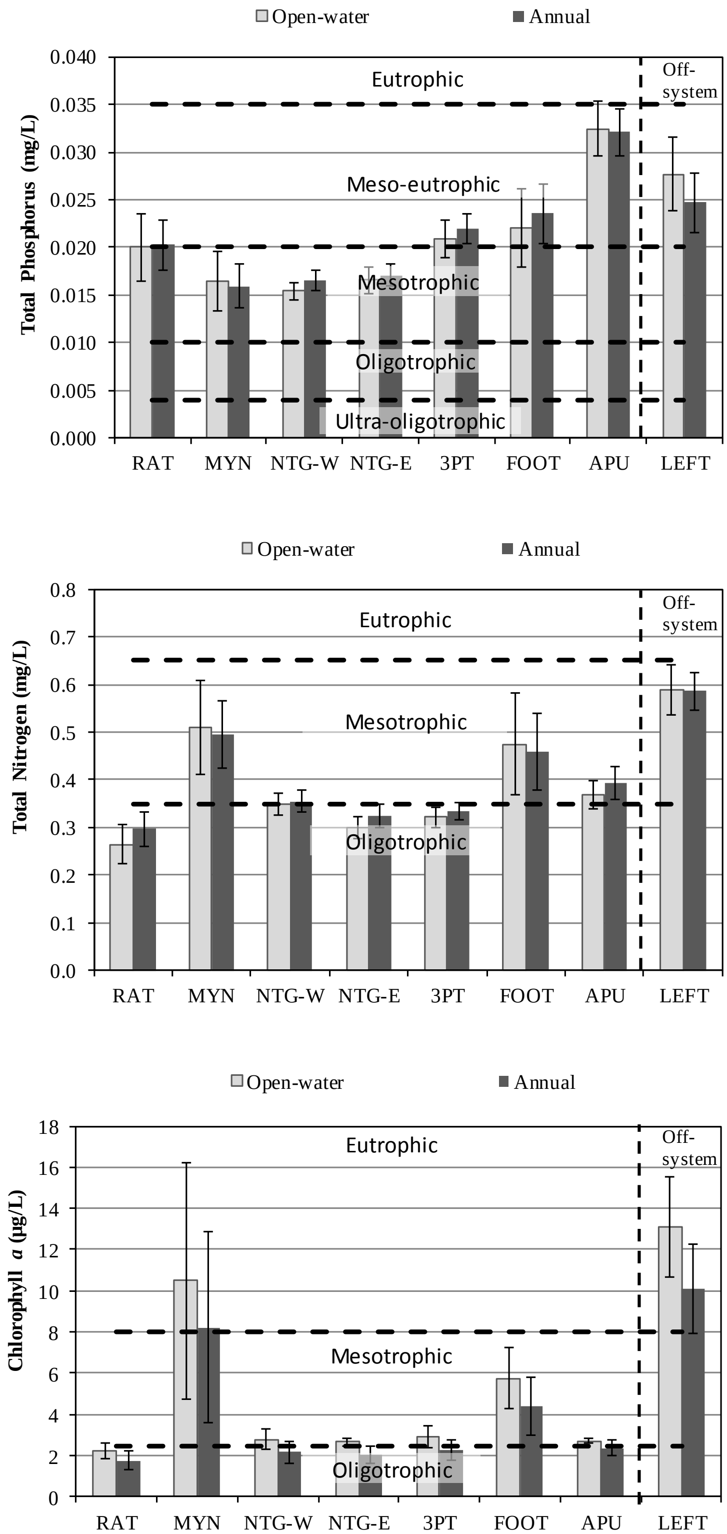
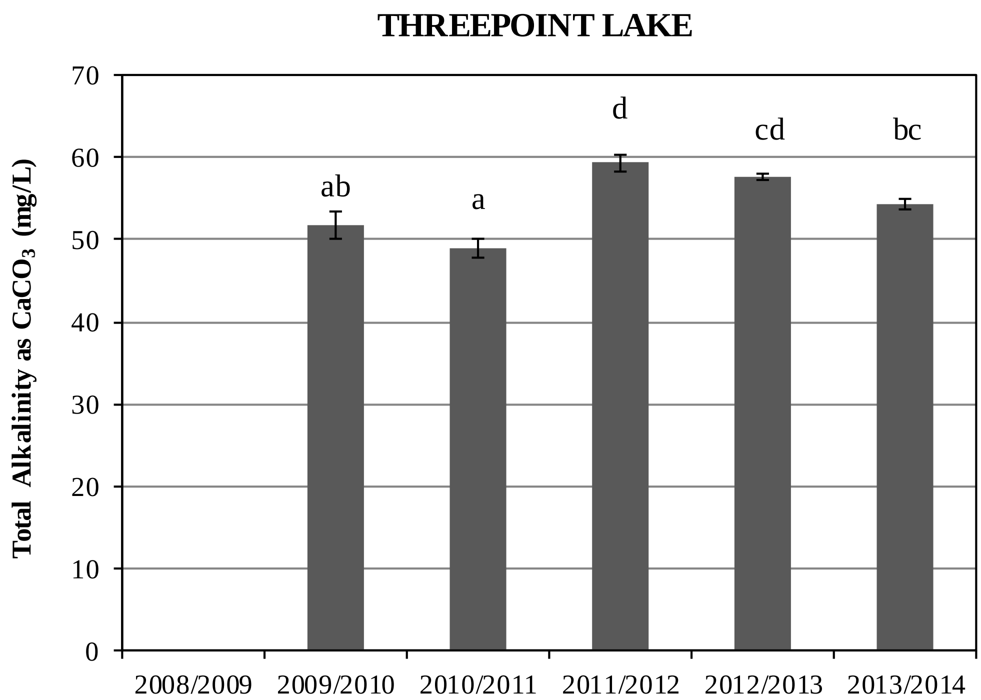
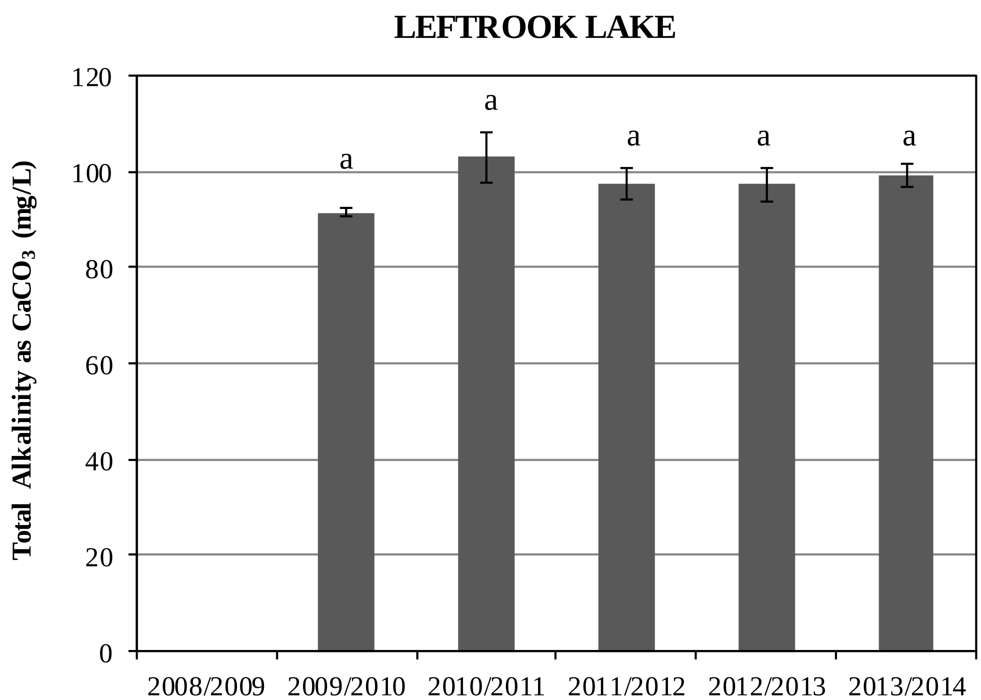


Figure 3-31. Total phosphorus, total nitrogen, and chlorophyll *a* (mean±SE) measured along the Churchill River Diversion and in the off-system waterbody (Leftrook Lake): 2008/2009-2013/2014.





*Note the different scales.

Figure 3-32. Open-water season total alkalinity (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

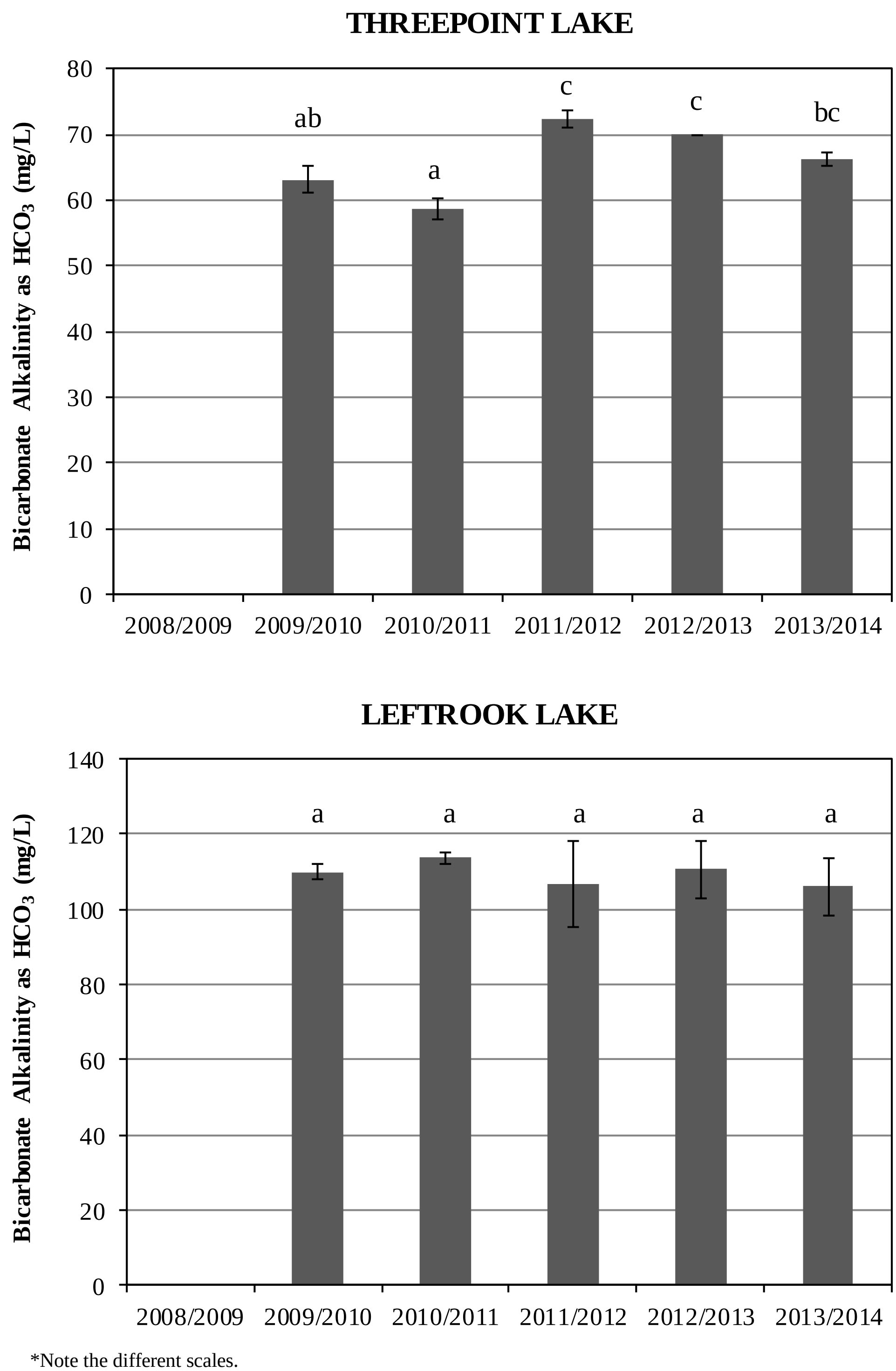
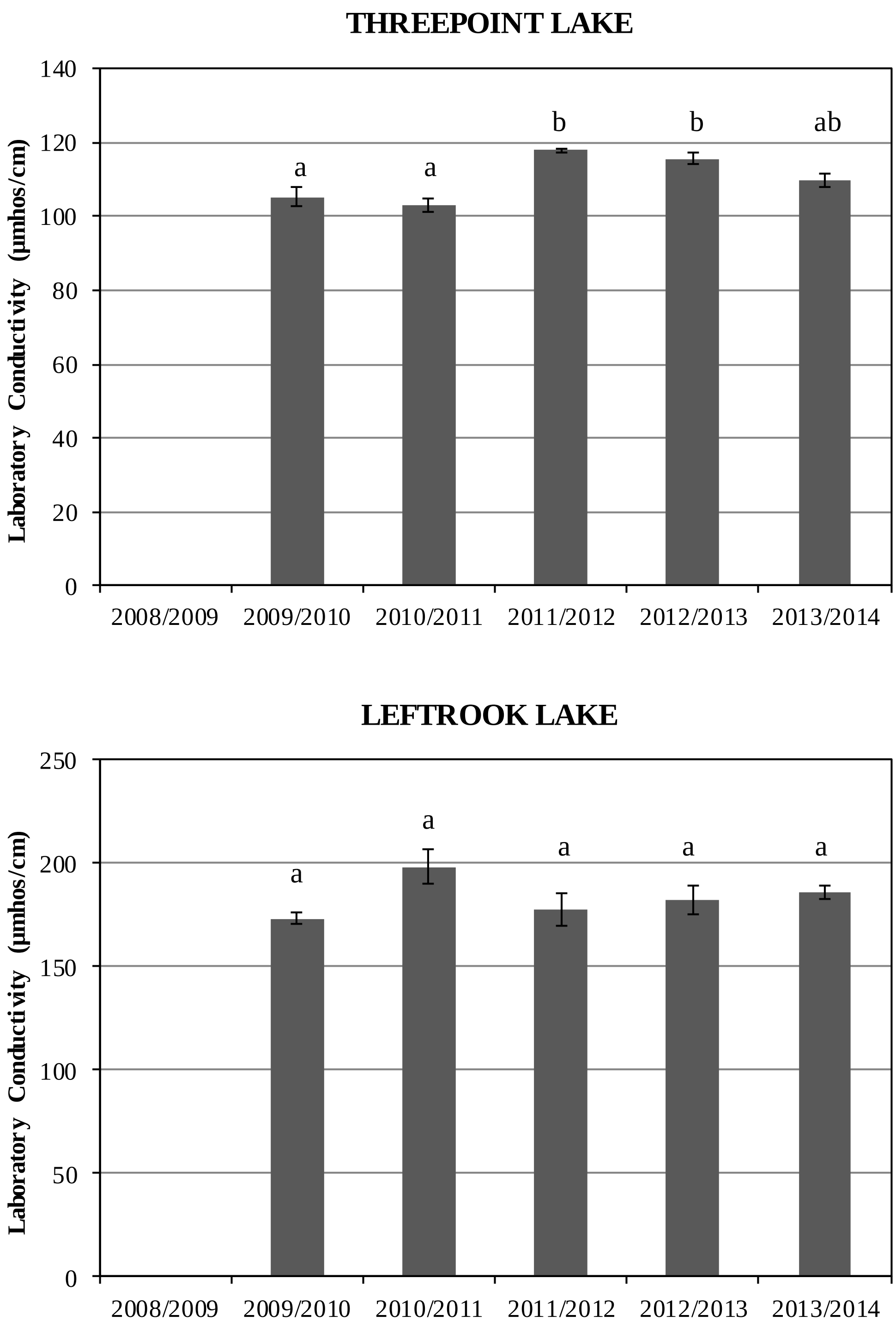
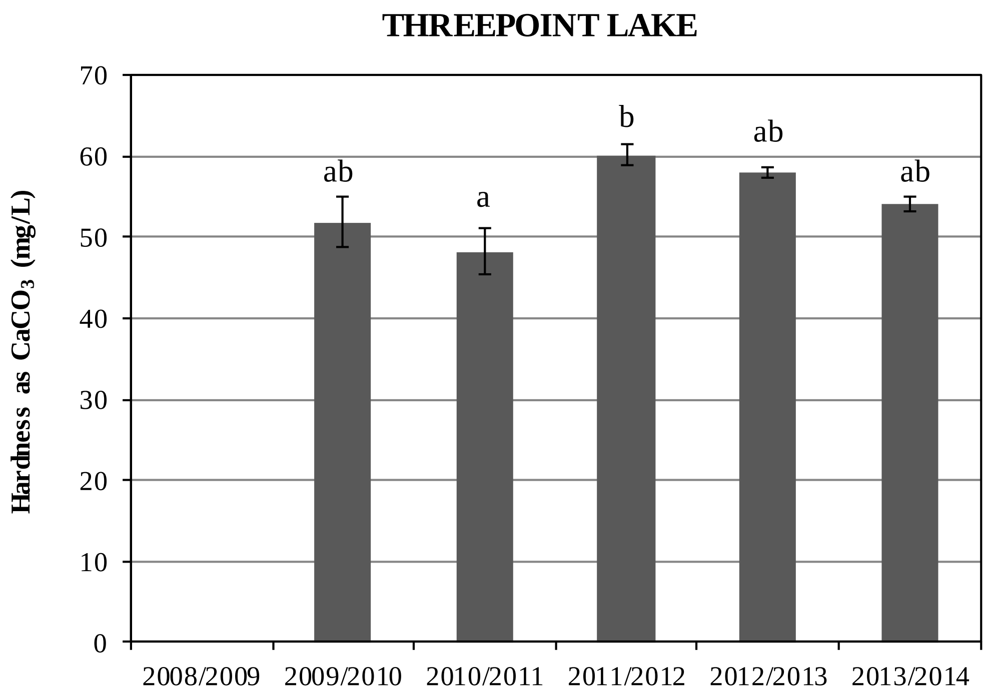


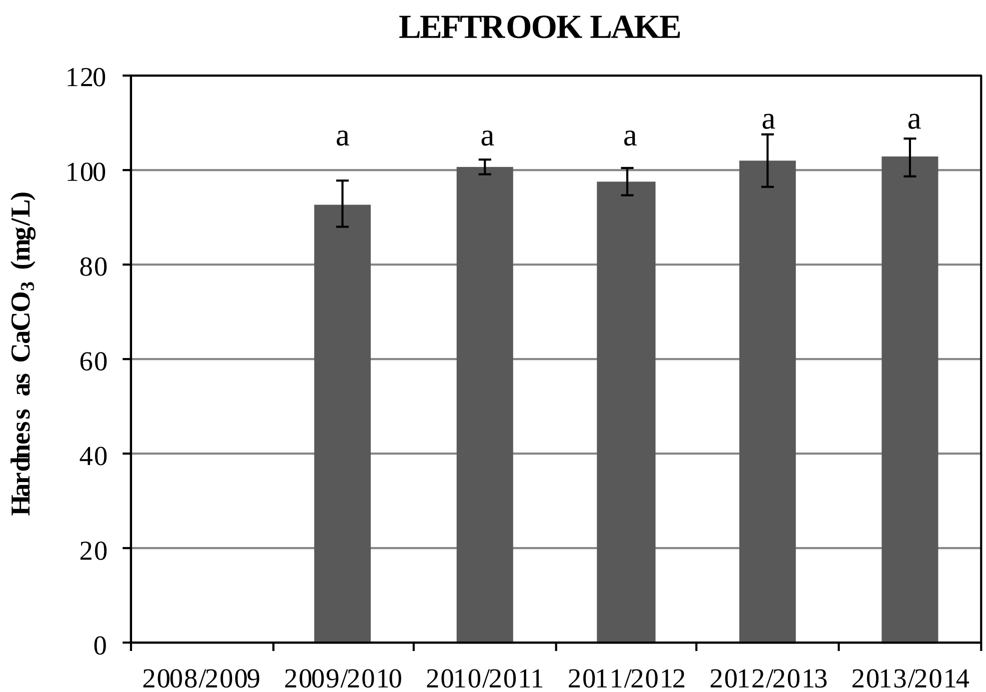
Figure 3-33. Open-water season bicarbonate alkalinity (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



*Note the different scales.

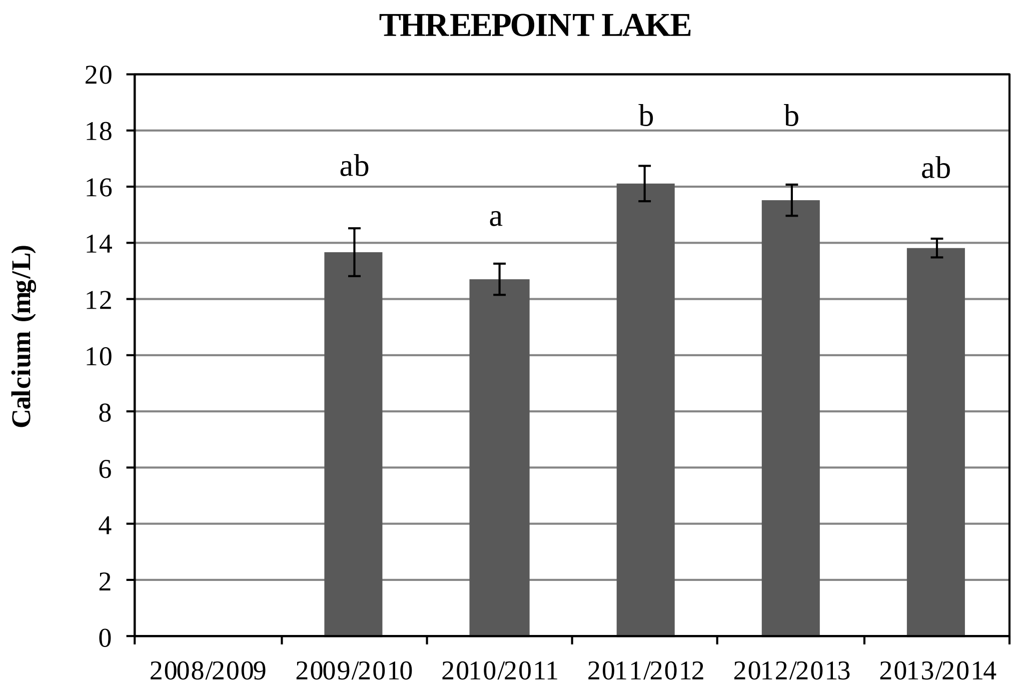
Figure 3-34. Open-water season specific conductance (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

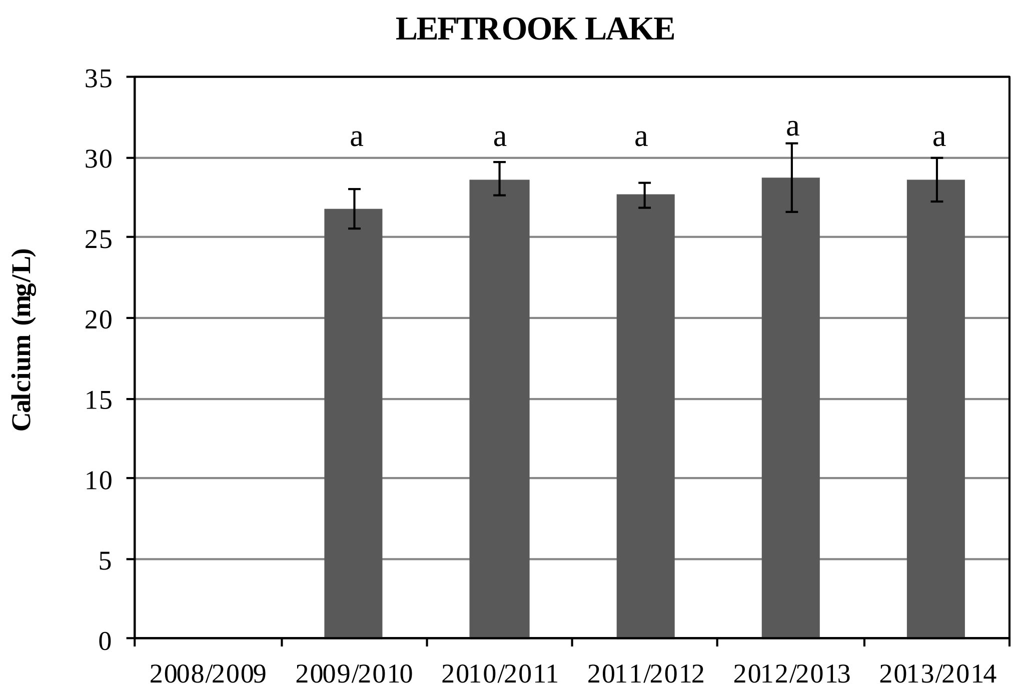




*Note the different scales.

Figure 3-35. Open-water season hardness (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.





*Note the different scales.

Figure 3-36. Open-water season calcium concentrations (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

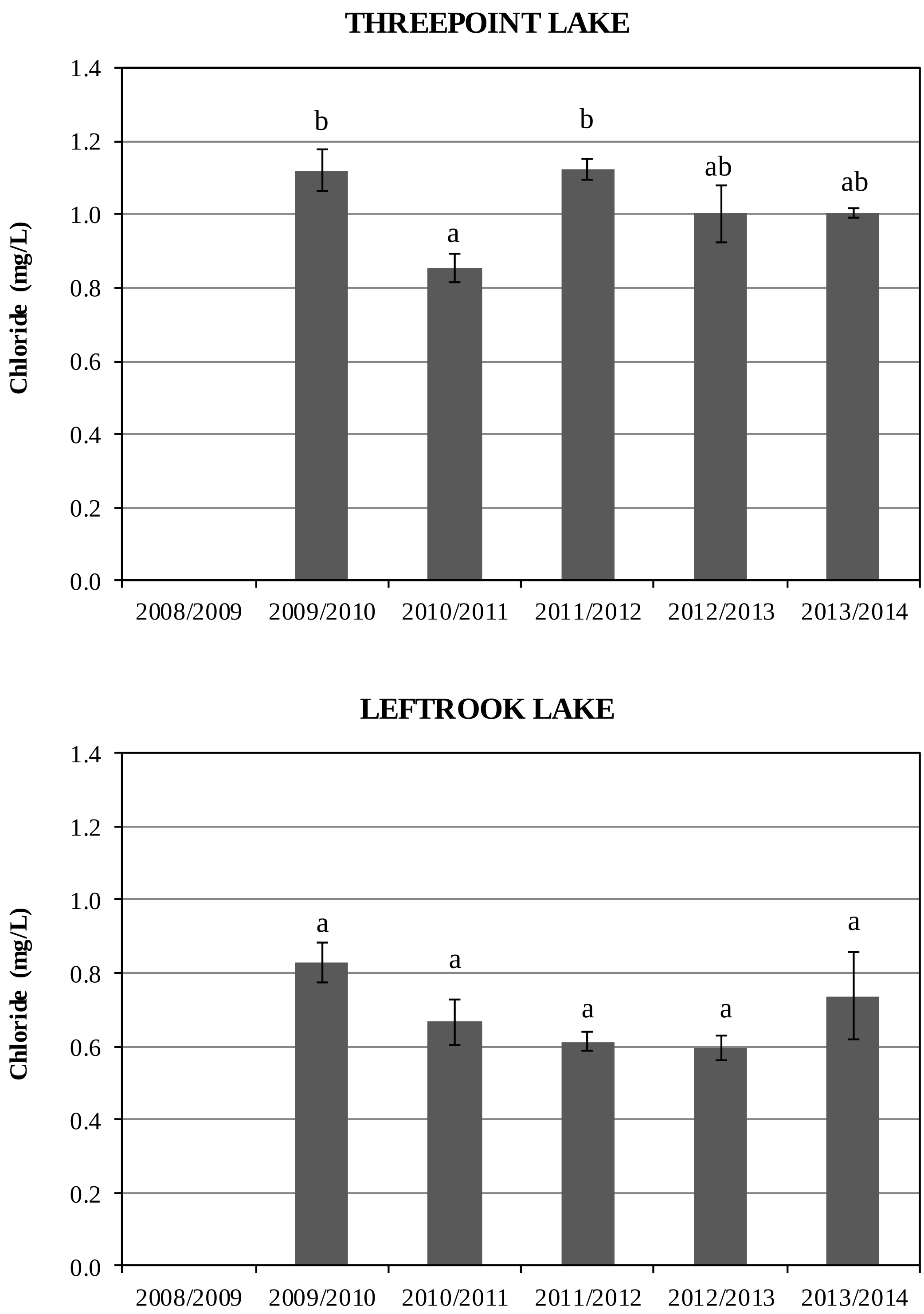
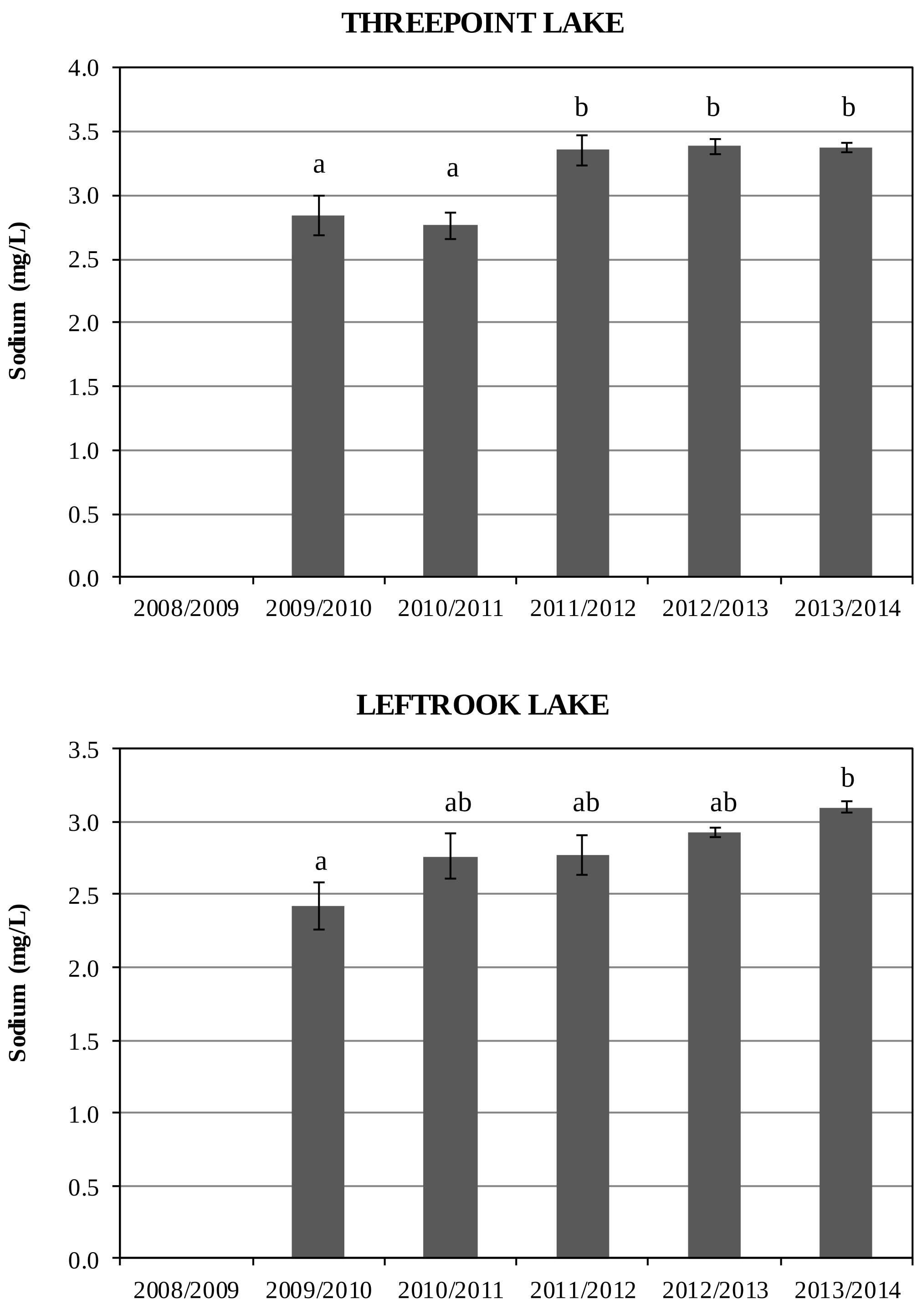
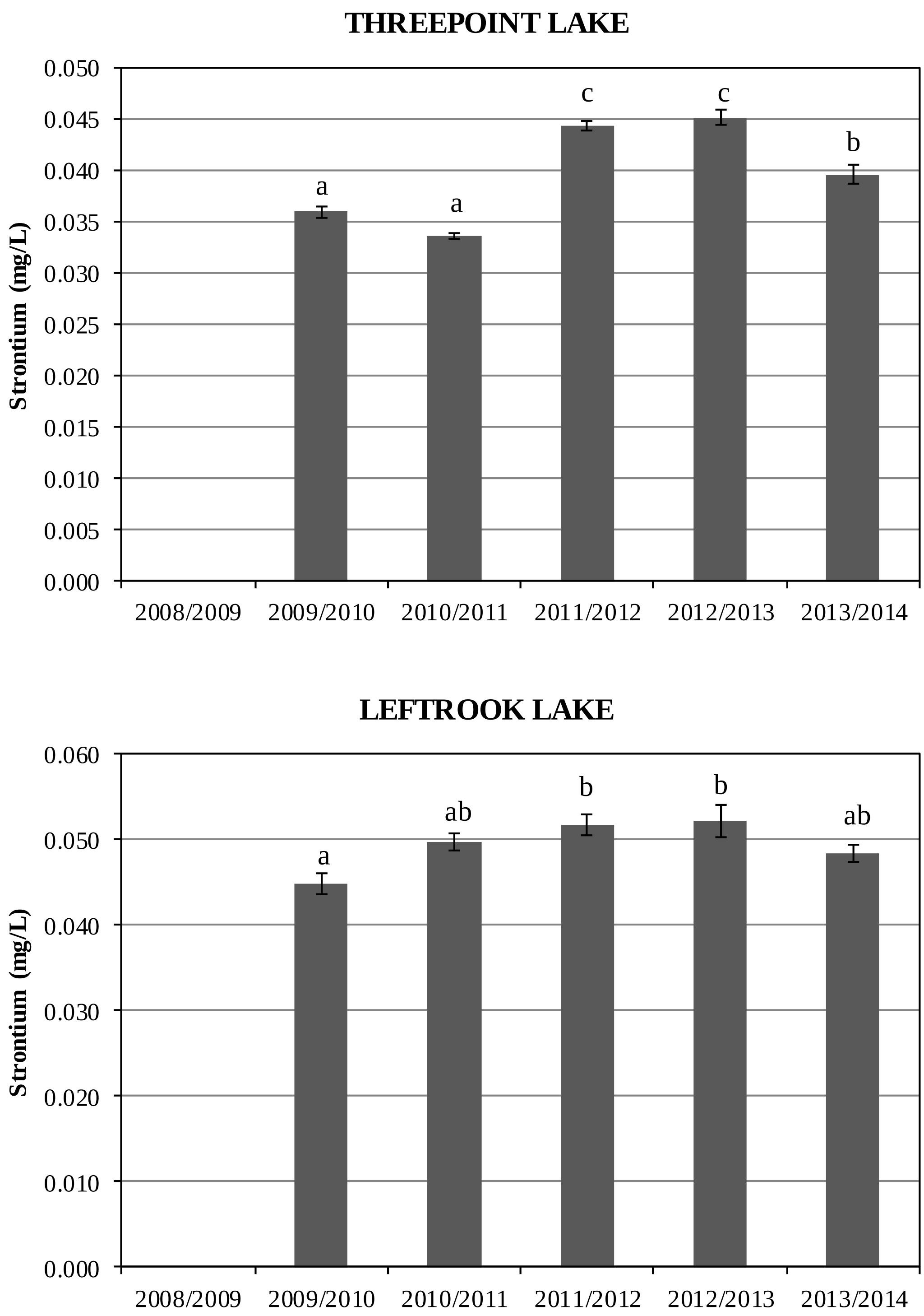


Figure 3-37. Open-water season chloride concentrations (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



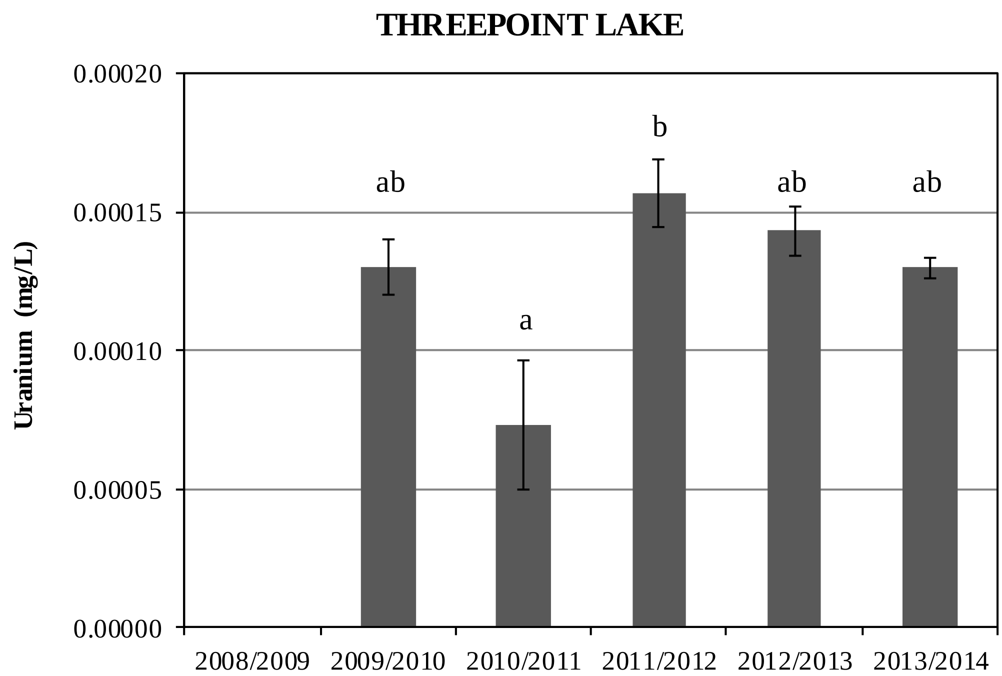
*Note the different scales.

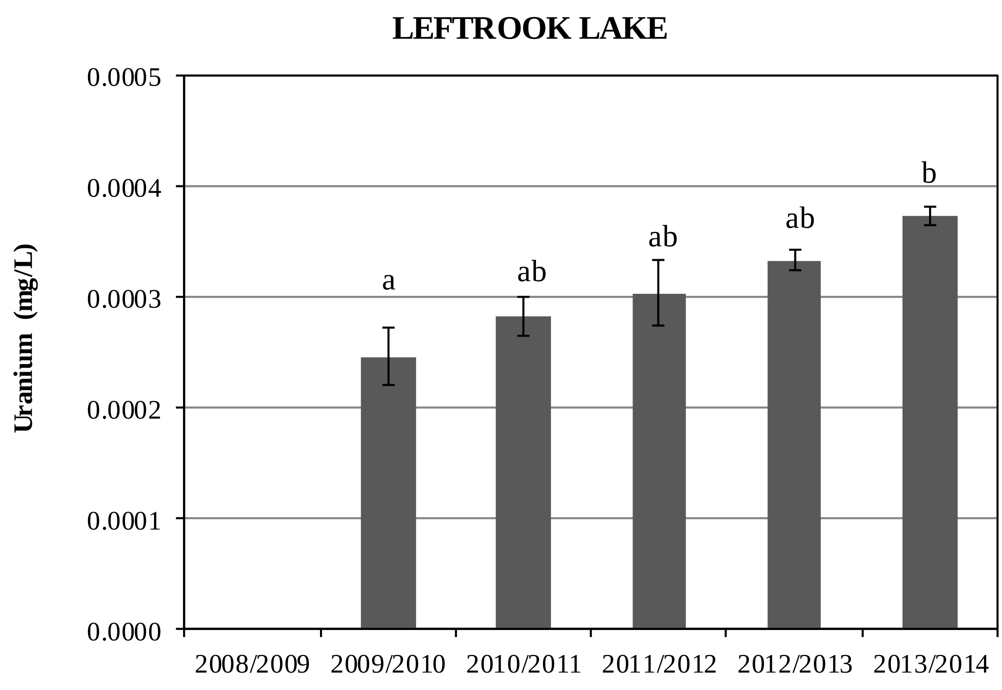
Figure 3-38. Open-water season sodium concentrations (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



*Note the different scales.

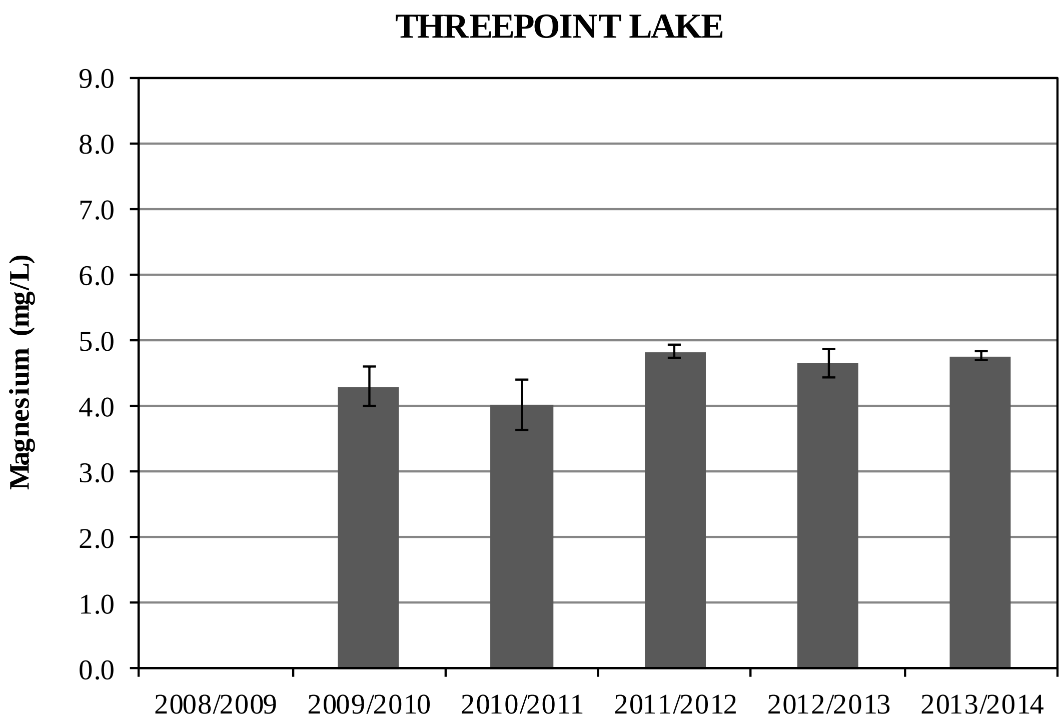
Figure 3-39. Open-water season strontium concentrations (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.





*Note the different scales.

Figure 3-40. Open-water season uranium concentrations (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



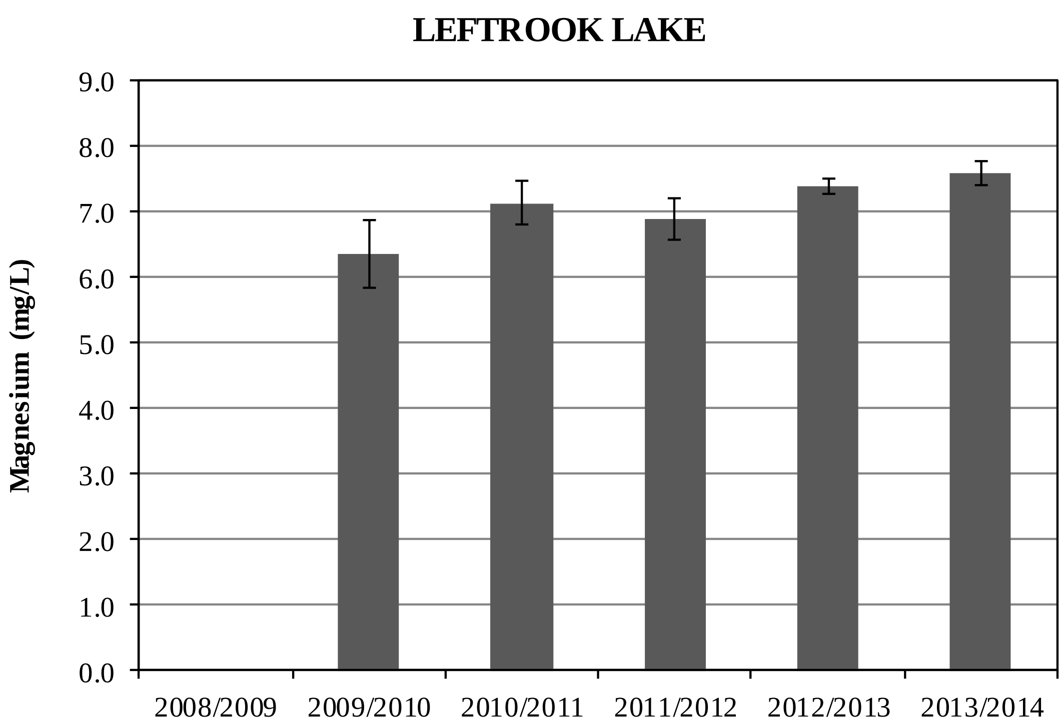


Figure 3-41. Open-water season magnesium concentrations (mean±SE) at the annual on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies.

4.0 SEDIMENT QUALITY

4.1 INTRODUCTION

The following provides an overview of sediment quality conditions measured under CAMP in the CRDR 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 was measured in 2011 in Threepoint (on-system site) and Leftrook lakes (off-system site; 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 CHURCHILL RIVER DIVERSION

Surficial sediment samples from Threepoint Lake were dominated by silt/clay (99%; Figure 4-2) and the composition was similar to the off-system Leftrook Lake. Though relatively low, the mean concentration of total organic carbon (TOC) marginally exceeded the Ontario LEL (Figure 4-3). Leftrook Lake sediments, in contrast, contained notably higher levels of TOC (see Section 4.3).

Both TP (Figure 4-4) and TKN (Figure 4-5) also exceeded the Ontario LELs (TOC also marginally exceeded the LEL) but were below the SELs in Threepoint Lake. Phosphorus concentrations were similar to, but TKN concentrations were substantively lower (approximately 5 times lower) than, those measured in the off-system Leftrook Lake.

All but one metal (chromium), including arsenic, cadmium, copper, lead, mercury, and zinc, were on average within the Manitoba SQGs (Figures 4-6 to 4-12). The concentration of chromium exceeded the Manitoba SQG but not the PEL in Threepoint Lake, but was similar to the average concentration observed in the off-system Leftrook Lake and was within the range observed at other CAMP sites (Figure 4-8; Table 4-1).

Iron (Figure 4-13) and nickel (Figure 4-14) exceeded the Ontario LEL but not the SEL, and manganese exceeded the SEL (Figure 4-15), in Threepoint Lake. Both iron and nickel concentrations were similar to, but nickel was higher than, concentrations measured in the off-system Leftrook Lake. All three metals were within the ranges observed across all CAMP sites; however, manganese was on the upper end of the range measured across sites (Table 4-1). Selenium was not detected in surficial sediments from Threepoint Lake (Figure 4-16) and the analytical detection limit (1.1 µg/g) was below the BC SAC and the AB ISQG (2.0 µg/g). Results for other metals are presented in Table 4-2.

4.3 OFF-SYSTEM WATERBODY: LEFTROOK LAKE

Sediment characteristics in Leftrook Lake were generally similar those of sediments collected from Threepoint Lake (Figures 4-2 to 4-16). TOC and TP exceeded the Ontario LEL, all metals excepting chromium (which exceeded the SQG) were within the Manitoba SQGs, and iron and nickel exceeded the Ontario LEL but not the SEL.

Key differences observed include a lower concentration of manganese, which was within the Ontario LEL, and a notably higher concentration of TOC and TKN, the latter of which exceeded the Ontario SEL, in Leftrook Lake relative to the on-system Threepoint Lake. Leftrook Lake sediments contained the highest concentration of TKN, and the second highest concentration of TOC, of all the CAMP sediment quality monitoring sites (Table 4-1). A strong correlation was observed between TKN and TOC in sediments for all CAMP sites combined ($p < 0.0001$; Spearman correlation coefficient = 0.983); nitrogen has a high association with organic matter in lake sediments (Sondergaard 2007).

4.4 SUMMARY

Half of the key sediment quality metrics were within sediment quality benchmarks in Threepoint Lake and metrics that exceeded the benchmarks were also commonly above these benchmarks in other lakes and rivers monitored under CAMP. Key sediment quality metrics in Threepoint Lake were within the ranges observed across all CAMP monitoring sites and were generally similar to sediments from the off-system Leftrook Lake. However, manganese fell on the upper end of the range of concentrations measured across CAMP sites.

Conversely, TKN and TOC concentrations observed in sediments from the off-system Leftrook Lake were the highest and second highest, respectively, of all the CAMP sites. This co-occurrence is common, as nitrogen is typically strongly associated with organic matter in lake sediments.

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).

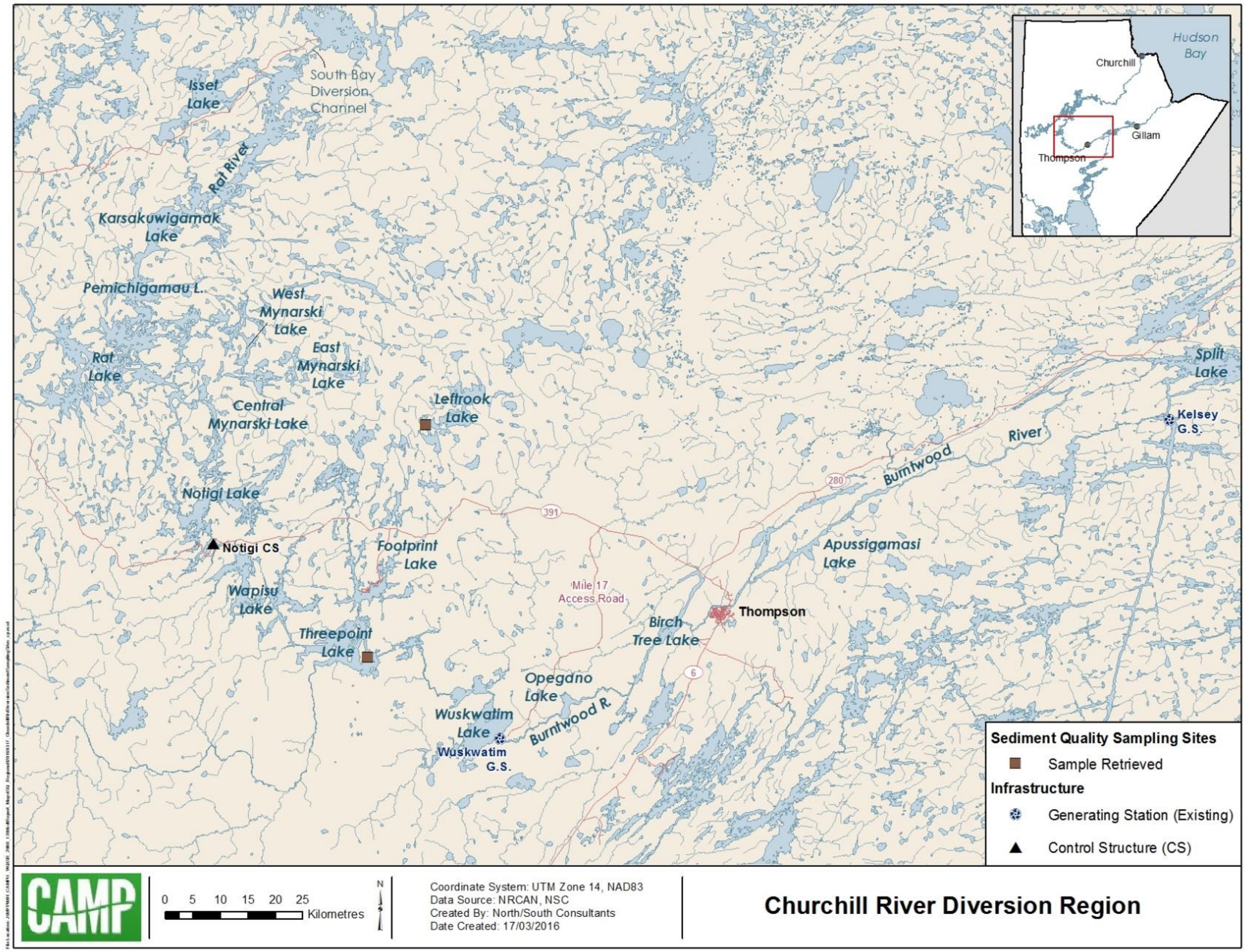


Figure 4-1. Sediment quality sampling sites in the Churchill River Diversion Region: 2008-2013.

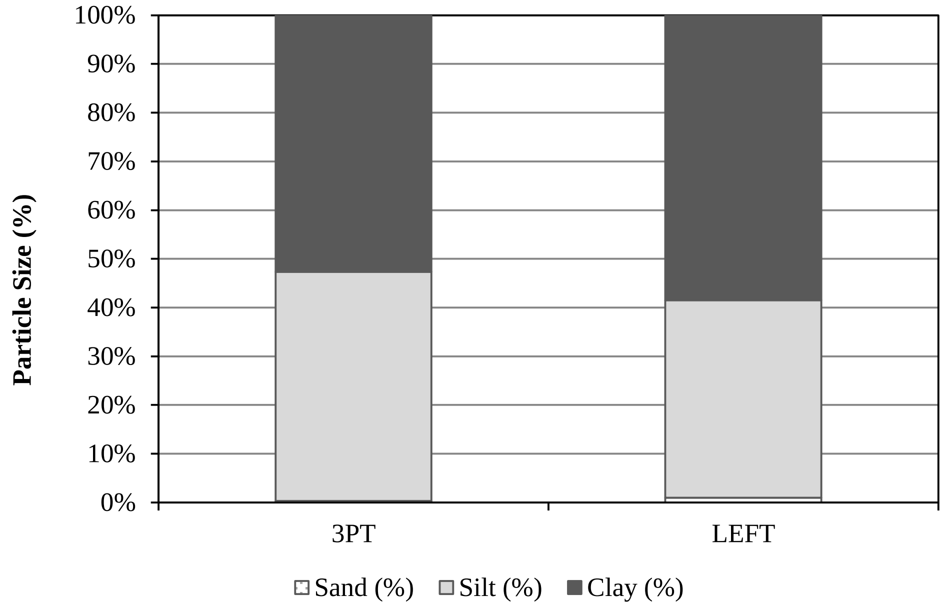


Figure 4-2. Particle size of surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT).

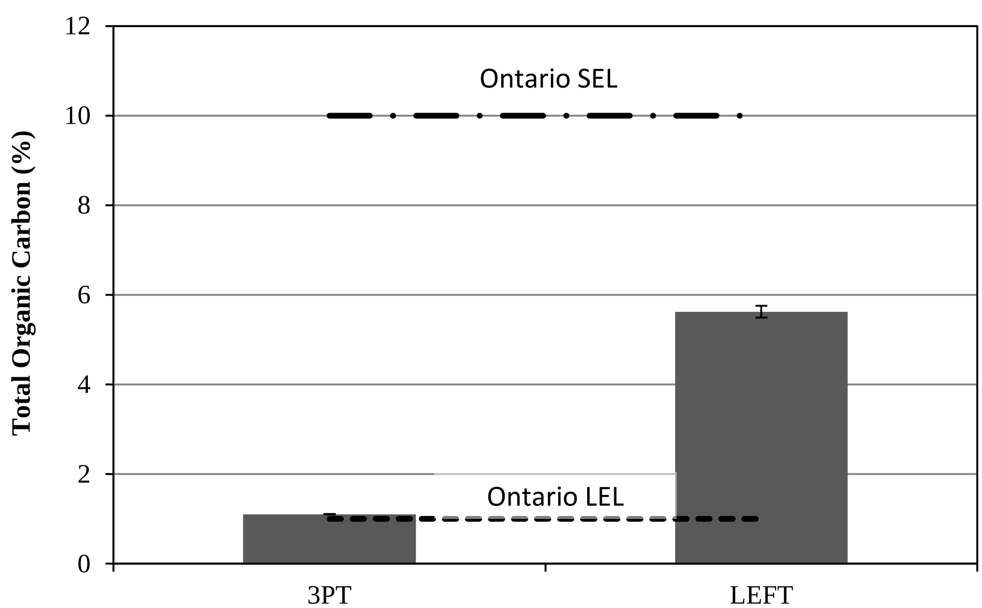


Figure 4-3. Mean (±SE) percentage of total organic carbon in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Ontario sediment quality guidelines.

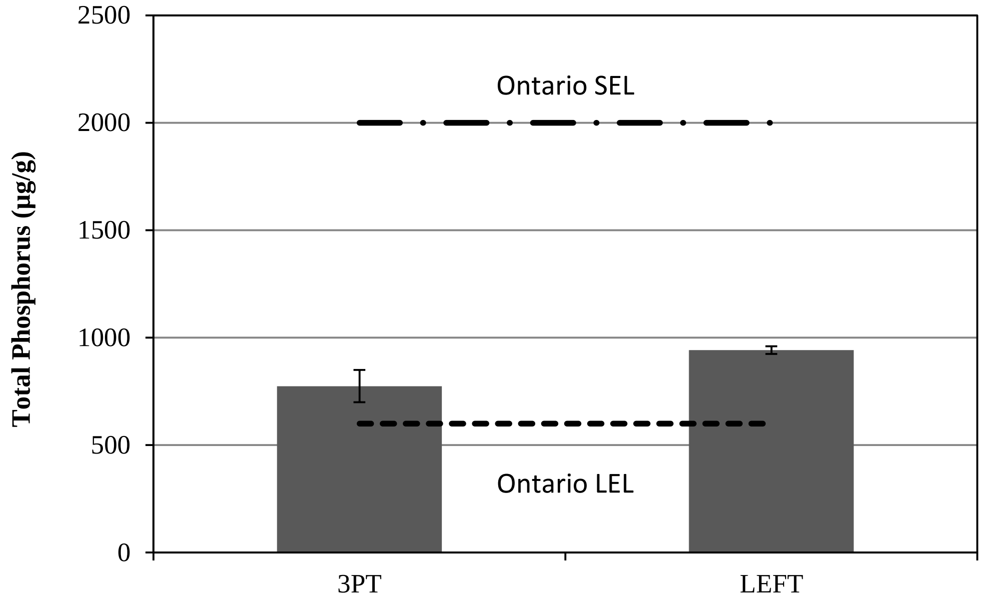


Figure 4-4. Mean (±SE) concentrations of total phosphorus in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Ontario sediment quality guidelines.

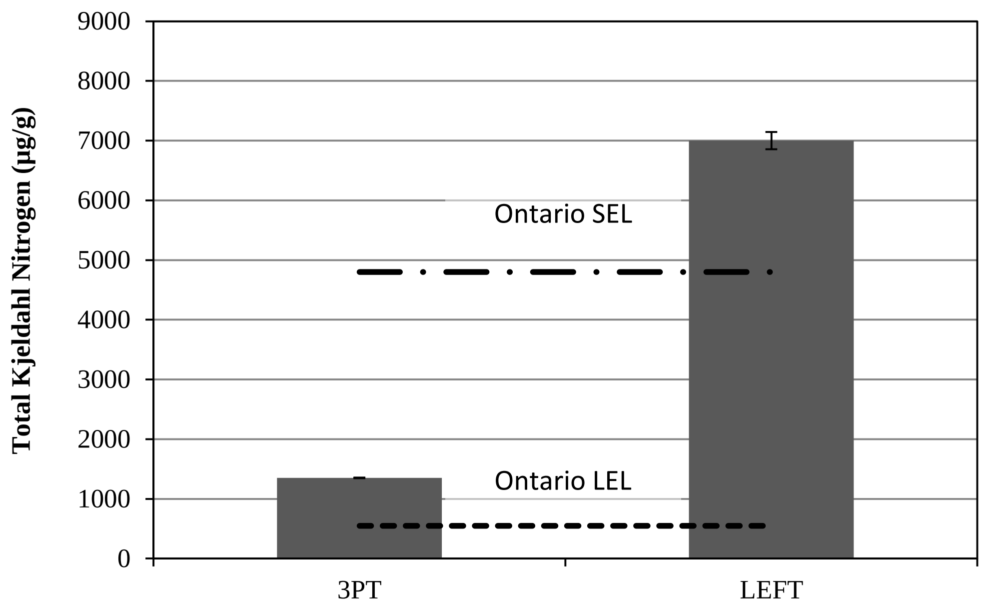


Figure 4-5. Mean (±SE) concentrations of total Kjeldahl nitrogen in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Ontario sediment quality guidelines.

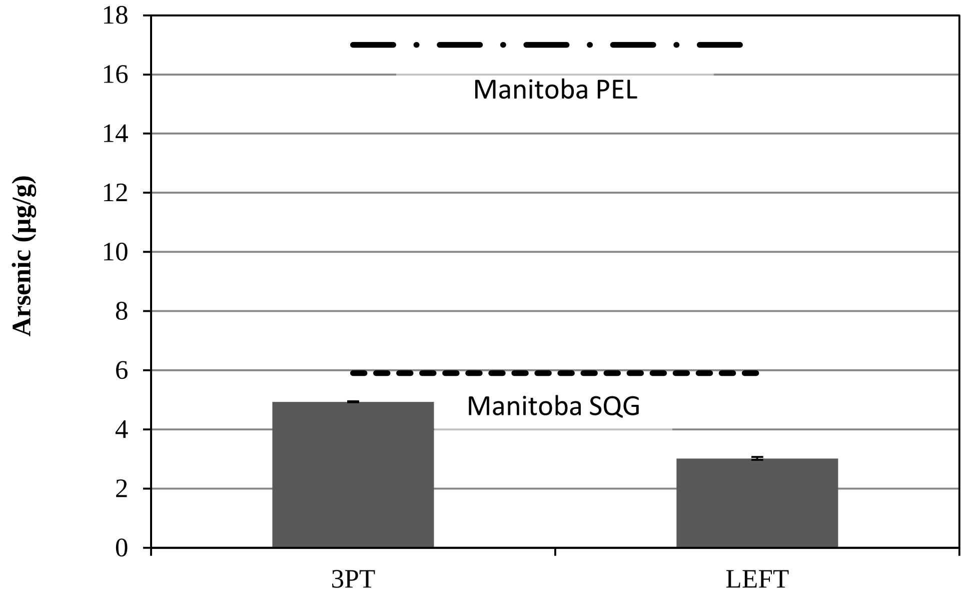


Figure 4-6. Mean (±SE) concentrations of arsenic in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines.

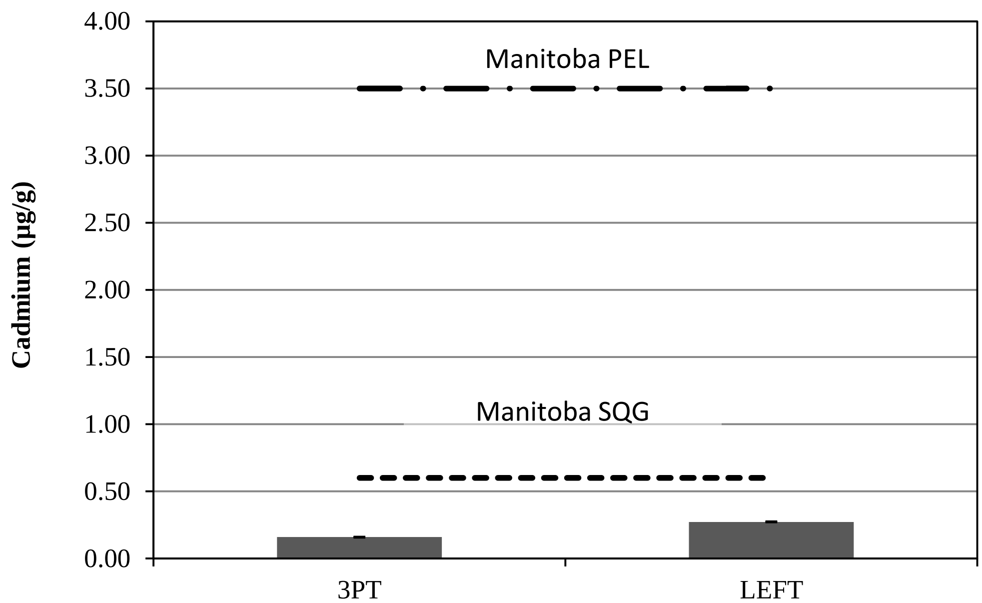


Figure 4-7. Mean (±SE) concentrations of cadmium in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines.

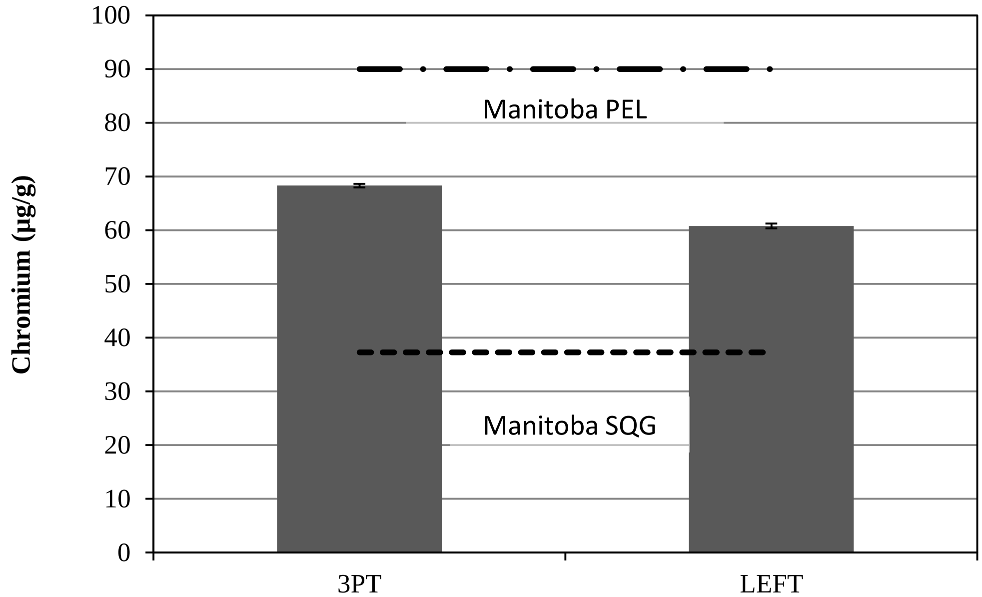


Figure 4-8. Mean (±SE) concentrations of chromium in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines.

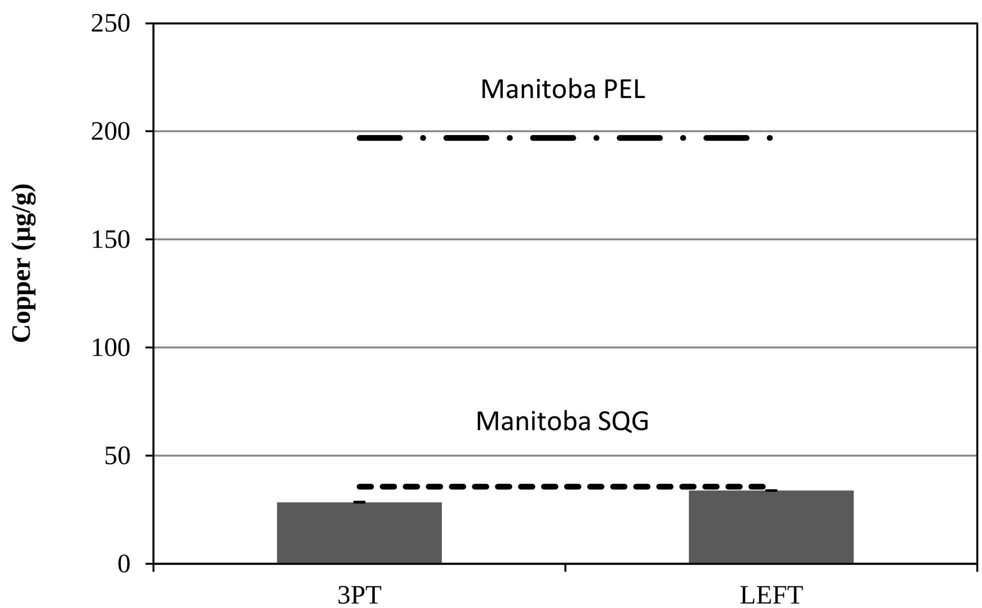


Figure 4-9. Mean (±SE) concentrations of copper in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines.

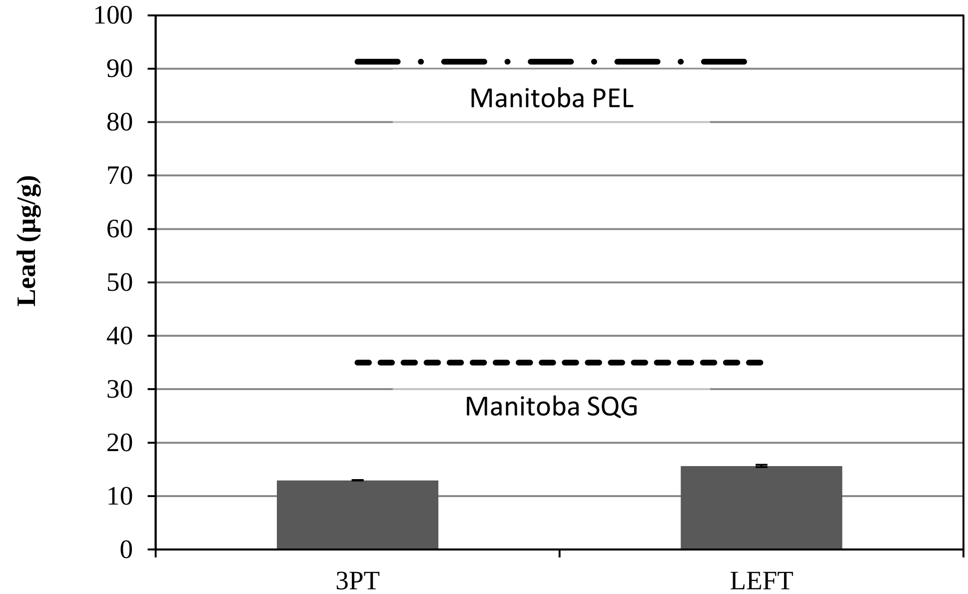


Figure 4-10. Mean (±SE) concentrations of lead in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines.

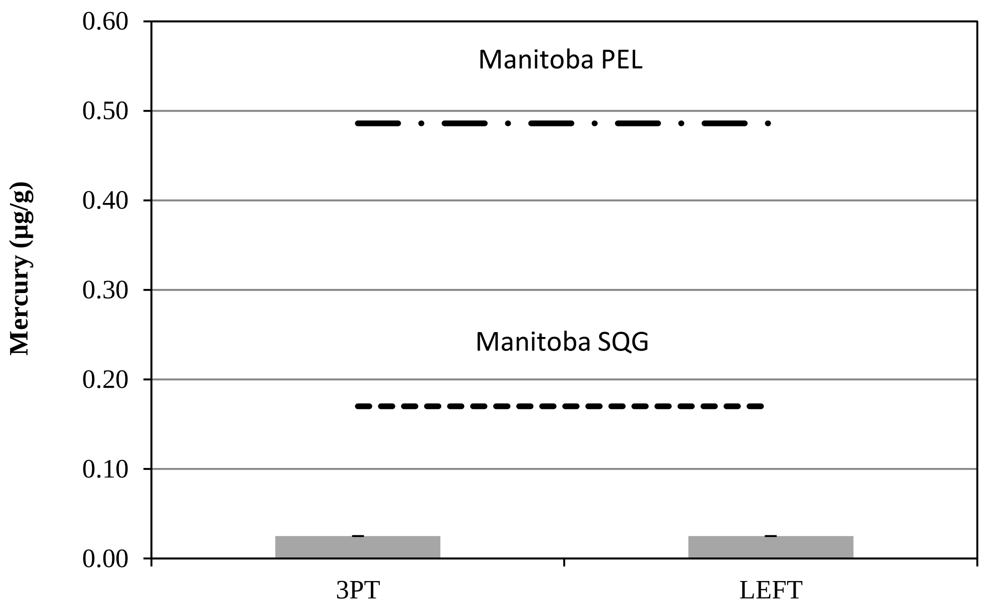


Figure 4-11. Mean (±SE) concentrations of mercury in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines. All measurements were below the analytical detection limit (0.05 µg/g).

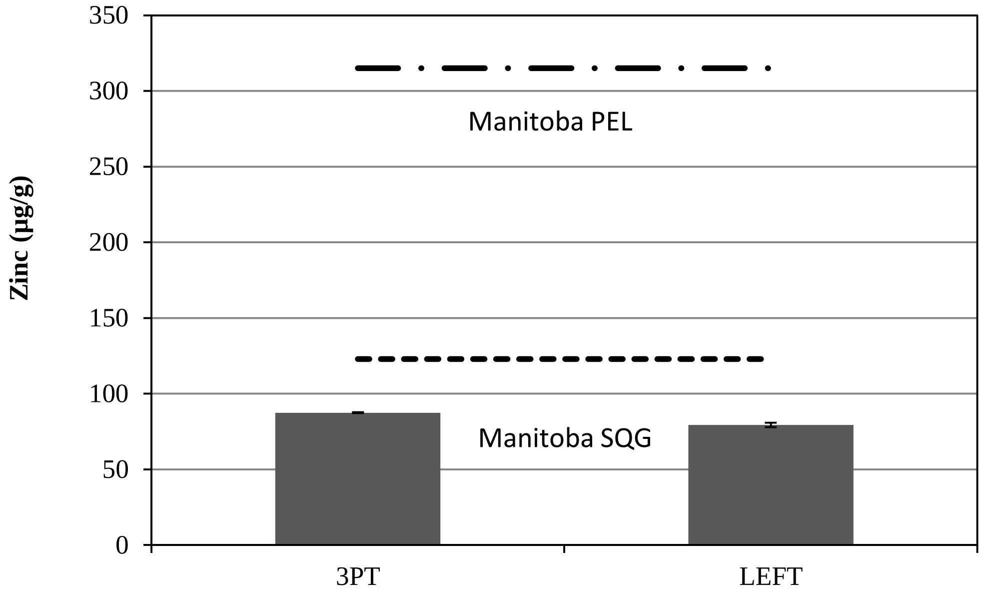


Figure 4-12. Mean (±SE) concentrations of zinc in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Manitoba sediment quality guidelines.

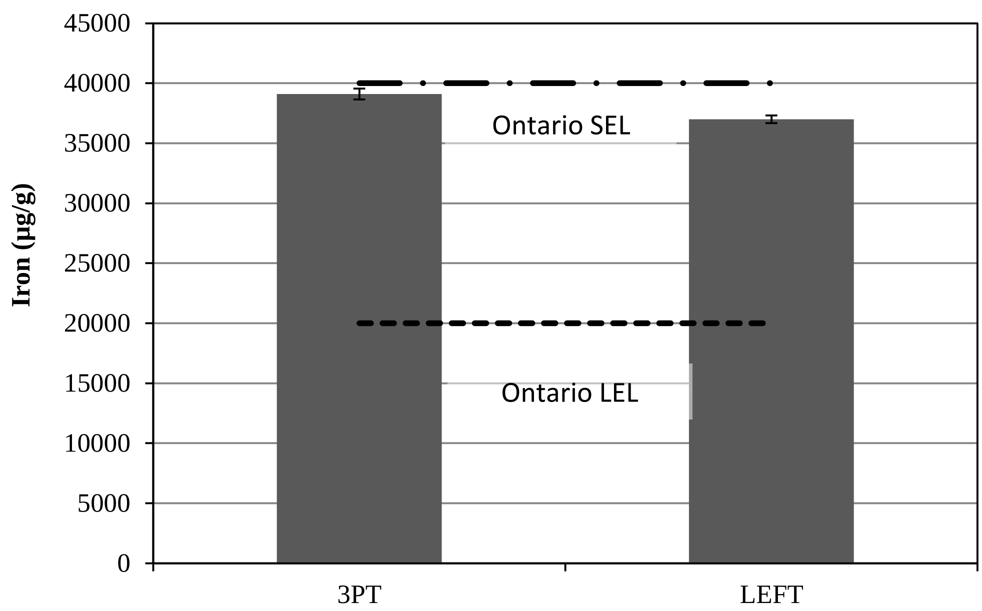


Figure 4-13. Mean (±SE) concentrations of iron in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Ontario sediment quality guidelines.

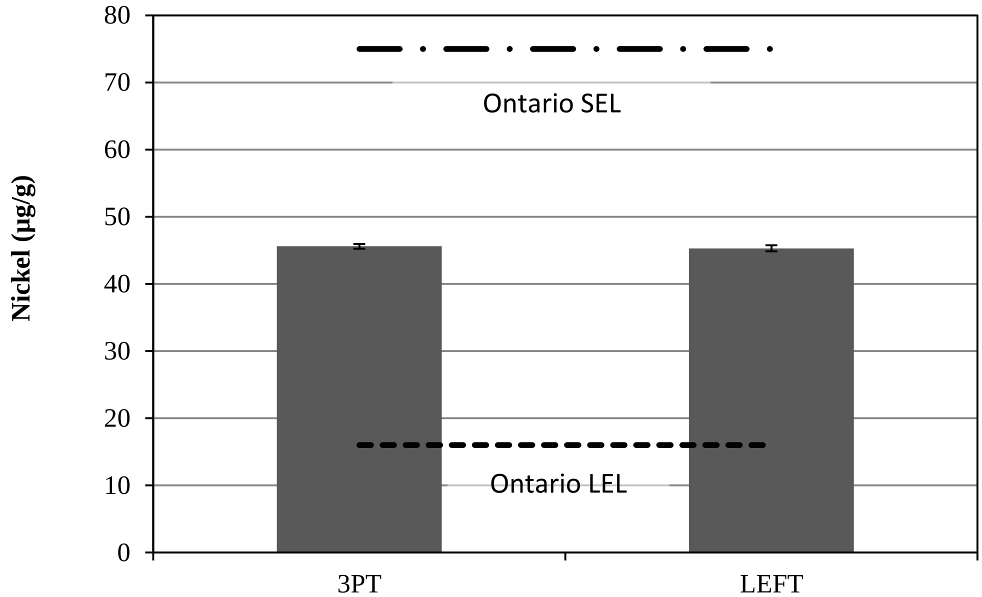


Figure 4-14. Mean (±SE) concentrations of nickel in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Ontario sediment quality guidelines.

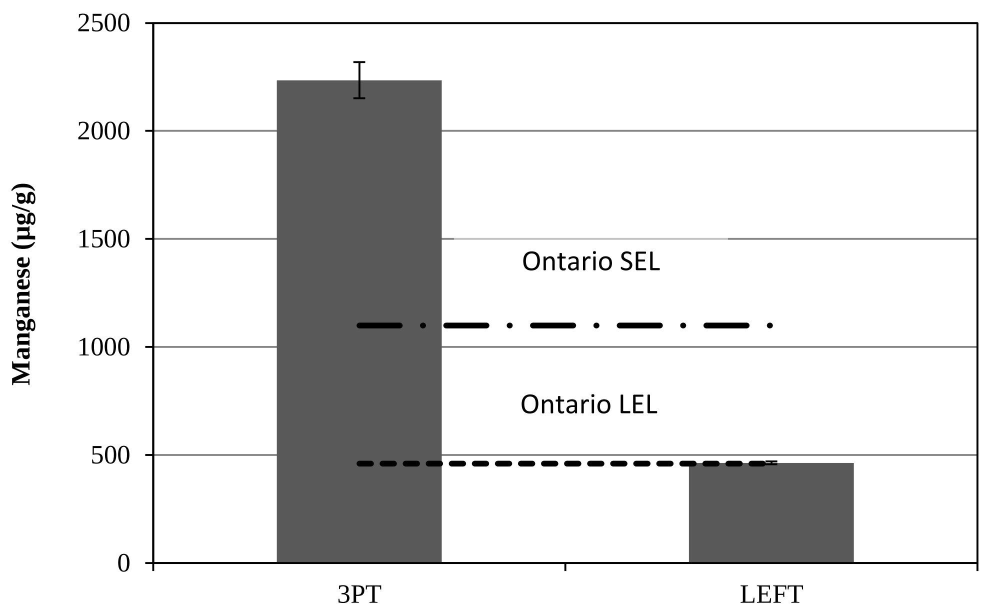


Figure 4-15. Mean (±SE) concentrations of manganese in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to Ontario sediment quality guidelines.

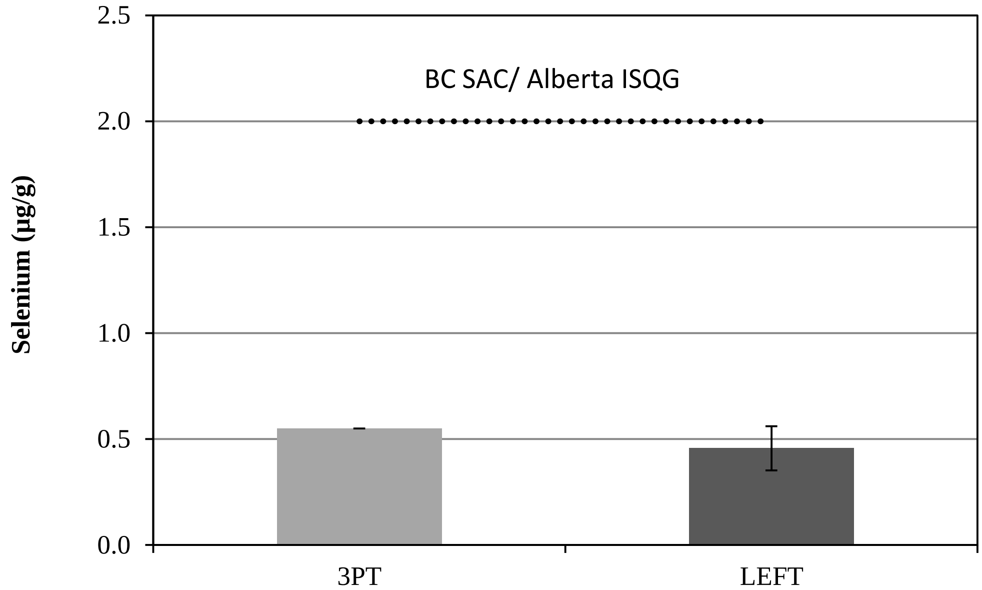


Figure 4-16. Mean (±SE) concentrations of selenium in surficial sediment from Threepoint Lake (3PT) and Leftrook Lake (LEFT) and comparison to the BC sediment alert concentration and the Alberta ISQG. Means indicated in light grey were below the analytical detection limit (DL); the DL for Threepoint Lake (1.1 µg/g) was higher than for Leftrook Lake (0.5 µg/g) due to the requirement for sample dilution.

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 CRDR. 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 (Threepoint Lake) and one off-system lake (Leftrook Lake). Five additional on-system waterbodies or areas were sampled on a rotational basis, including Rat (2010, 2013), Mynarksi (2011), Notigi (2012), Footprint (2010, 2013), and Apussigamasi (2012) lakes (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 net) and offshore (water depth 5-10 m, sampled with Ekman/petite Ponar dredge) habitat sites in the late summer/fall within each monitoring waterbody (annual and rotational). 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, where feasible.

The first objective (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 are 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 available 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 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 CRDR (Section 2.0); relationships between select BMI and hydrology metrics are described in Section 5.5.

Sediment samples were collected at nearshore and offshore replicate stations for particle size analysis (PSA) 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 Churchill River Diversion

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

Sediments sampled in the nearshore habitat of on-system lakes consisted mainly of silt and clay (Figure 5-2). The nearshore of Mynarski Lake consisted of mainly bedrock (Table 5-1); as such only one sediment sample was collected for laboratory analysis (Figure 5-2). Threepoint and Footprint lakes typically had a greater proportion of sand (8-28%) in comparison to other lakes (2-12%; Figure 5-2). With the exception of Rat Lake in 2010 (TOC content 7.8%), the TOC content of all lake sediments sampled was low (less than 2%; Figure 5-3). The somewhat higher TOC content of Rat Lake sediments in 2010 may reflect the abundant woody debris present at this site (Table 5-1).

The offshore habitat of Mynarski (84% sand) and Footprint (40-47% sand) lakes had a much greater proportion of sand when compared to other on-system lakes (Figure 5-4). With the exception of Rat Lake in 2010 (3.9%) and Notigi Lake in 2012 (7.9%), the TOC content of all lake sediments sampled was less than 2% (Figure 5-5). The somewhat higher TOC content of Rat and Notigi lake sediments may reflect the organic matter noted at these sites (Table 5-1).

5.2.2 Off-system Waterbody: Leftrook Lake

The nearshore habitat of Leftrook Lake consisted of mainly large, hard substrate (typically boulder with cobble) and, as such, sediment samples were not collected for laboratory analysis (Table 5-1).

Similar to the majority of on-system lakes, the offshore sediments of Leftrook Lake consisted mainly of silt and clay (Figure 5-4). TOC content of sediments (approximately 5-6%) was higher than on-system lakes, with the exception of Notigi Lake (7.9%; 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 Churchill River Diversion

The mean total abundance of BMIs in nearshore habitat varied somewhat among years at the annual Threepoint Lake although differences were not statistically significant (Figure 5-6). Abundance was lower in comparison to other on-system lakes when sites were sampled in the same year, with the exception of Apussigamasi Lake in 2012.

The composition of the BMI community in the nearshore of Threepoint Lake was relatively consistent between 2010 and 2011; in both years insects comprised an average of 72-74% of the sampled invertebrates and chironomids and corixids were the predominant insect taxa. In 2012 and 2013, the proportion of non-insects was greater and the community was dominated by oligochaetes and amphipods. The insects and non-insects were dominated by herbivores/detritivores and this is likely linked to the suitability of the nearshore habitat, where the silt/clay substrate provides food in the form of detritus.

Rat and Footprint lakes were sampled in 2010 and 2013. In 2010, non-insects comprised 53-60% of the nearshore catch in the two lakes; Amphipoda was the most common non-insect taxon in each lake. In 2013, insects dominated the community sampled in both lakes with Chironomidae, EPT, and Corixidae most relatively abundant in Rat Lake, but only Chironomidae and Corixidae in Footprint Lake.

Mynarski (2011), Notigi (2012), and Apussigamasi (2012) lakes were each only sampled once. Chironomidae and Corixidae dominated the catch in Mynarski Lake. The nearshore of

Mynarski Lake was mainly bedrock. In contrast, non-insects were relatively more abundant in Notigi and Apussigamasi lakes with Oligochaeta and Amphipoda dominating the communities, particularly Amphipoda in Apussigamasi Lake.

In contrast to the nearshore habitat, the mean density of BMIs in the offshore of Threepoint Lake showed greater annual variability and was significantly higher in 2013 compared to 2010 and 2011 (Figure 5-7). Annual density of BMIs in Threepoint Lake was consistently higher than other on-system lakes each year, with the exception of Mynarski Lake in 2011.

Non-insects comprised greater than 70% of the catch each year in the offshore of Threepoint Lake. In all years, the community was dominated by Amphipoda and Bivalvia, despite the fact that bivalves were uncommon in the nearshore. The higher density in 2013 does not appear to be due to an increase in the density of any particular group of invertebrates; all taxa were simply more abundant relative to other sampling years. The relative abundance of groups was quite inconsistent, indicating a high degree of spatial and/or temporal variability.

In 2010 and 2013, offshore habitat samples from Rat and Footprint lakes contained a lower density of invertebrates than Threepoint Lake (Figure 5-7). For both lakes in 2010, insects comprised greater than 80% of the BMI community sampled from the offshore. In Rat Lake, the dominant insect group was Chironomidae (76%), while at 51% of the catch, Chaoboridae was the predominant insect taxon in the Footprint Lake catch. Insects, particularly chironomids, continued to dominate the offshore community of Rat Lake in 2013. In contrast, Amphipoda was the most abundant group (68% of the catch) in the offshore of Footprint Lake in 2013.

The densities of invertebrates in offshore habitat in Mynarski Lake in 2011 and Apussigamasi Lake in 2012 were similar to Threepoint Lake, in the same years, while density in Notigi Lake was lower than Threepoint Lake in 2012 (Figure 5-7). Insects, primarily Chironomidae, dominated the catch in the offshore habitat of Mynarski Lake. Similarly, insects were relatively more abundant in the offshore of Notigi Lake; however, Ephemeroptera comprised a greater proportion of the catch than Chironomidae. In contrast, non-insects were relatively more abundant in Apussigamasi Lake with Amphipoda and Bivalvia dominating the community.

5.3.1.2 Off-system Waterbody: Leftrook Lake

The annual mean abundance of BMIs in the nearshore habitat of Leftrook Lake was within the range of abundances observed for on-system lakes in 2010 and 2012, but was higher in 2011 and, in particular, 2013 (Figure 5-6). The nearshore habitat of Leftrook Lake consisted of mainly large, hard substrate (typically boulder with cobble; Section 5.2). Non-insects were relatively more abundant than insects in all but 2013, when both groups had approximately equal representation. The non-insects were comprised principally of Oligochaeta, Amphipoda, and Gastropoda, though relative abundances were highly variable. Ephemeroptera, Trichoptera, and Chironomidae comprised a substantial portion of the insects in all years, but other insects, specifically Corixidae, also contributed to the community.

With the exception of 2012, the mean density of BMIs in the offshore habitat of Leftrook Lake was higher than on-system lakes (Figure 5-7). In contrast to on-system lakes, the offshore sediments of Leftrook Lake typically had a higher TOC content (Section 5.2) and this may have contributed to the relatively higher mean density of BMIs observed. In addition, Leftrook Lake appeared generally more productive, as indicated by high chlorophyll concentrations (Section 3). Similar to Threepoint Lake, non-insects were consistently more abundant than insects. Bivalvia was dominant in all years, comprising 55-74% of the catch. Similar to the majority of on-system lakes, Chironomidae were relatively the most abundant insect.

5.3.1.3 Temporal Comparisons and Trends

Sites sampled annually (Threepoint and Leftrook lakes) were examined for temporal trends. Abundance of BMIs exhibited inter-annual variability, including statistically significant differences in both the on-system and off-system annual lakes (Figures 5-6 and 5-7). Specifically, abundance in both the nearshore and the offshore in Leftrook Lake and in the offshore in Threepoint Lake was significantly higher in 2013. No obvious increasing or decreasing trends were noted for the annual sites over the four-year sampling period.

The potential 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 chironomids 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 tend to be relatively more abundant on fine textured sediments (e.g., silt/clay, sand) than Ephemeroptera, Plecoptera, and Trichoptera. Fine substrates are often 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 Churchill River Diversion

With the exception of two lakes upstream of the Notigi C.S., Rat and Notigi, the mean ratio of EPT to chironomids (EPT:C) in nearshore habitat of on-system lakes was less than 1 (Figure 5-8). For Rat and Notigi lakes, the EPT:C ratio was between 1.3 and 1.6, indicating that ephemeropterans were somewhat more abundant than chironomids in the nearshore habitat of these two lakes. Typically, chironomids (along with 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, capable of colonizing bare substrates within a month (Fisher and Lavoy 1972; Scheifhacken et al. 2007).

The mean EPT:C in offshore habitat varied among years and on-system lakes, but was consistently less than one in Rat, Mynarski, and Footprint lakes, and greater than one in Notigi, Threepoint (with the exception of 2013), and Apussigamasi lakes (Figure 5-9). The comparatively high mean ratio of 18.8 observed at Apussigamasi Lake in 2012 was due to an absence of chironomids at one replicate station; when that replicate station was removed (Figure 5-9) the ratio (1.8) was comparable to Notigi (1.8) and Threepoint (1.5) lakes.

5.3.2.2 Off-system Waterbody: Leftrook Lake

The mean EPT:C in the nearshore habitat of Leftrook Lake varied among years, but was typically greater than 1 and higher than most on-system lakes (Figure 5-8).

Similar to several on-system lakes, the annual mean ratio of ephemeropterans to chironomids in the offshore habitat of Leftrook Lake was less than one (Figure 5-9). The low ratio (0.04) is indicative of a much greater number of Chironomidae in comparison to Ephemeroptera; this difference may be as a result of critically low dissolved oxygen concentrations at depth overwinter, which Ephemeroptera cannot tolerate (Section 3).

5.3.2.3 Temporal Comparisons and Trends

Sites sampled annually (Threepoint and Leftrook lakes) were examined for temporal trends. The EPT:C ratio in the nearshore habitat of Threepoint Lake varied somewhat over time, but was consistently less than one with no obvious increasing or decreasing trend (Figure 5-8). No changes over time in the nearshore habitat of Threepoint Lake were statistically significant. In the nearshore of the off-system Leftrook Lake, EPT:C also varied over time, but was typically greater than one (Figure 5-8). However, none of these changes were statistically significant.

For the offshore of Threepoint Lake, the EPT:C ratio was consistently greater than one with the exception of 2013 (Figure 5-9), but there was no obvious increasing or decreasing trend. The decline in the EPT:C ratio in 2013 was not statistically significant. The EPT:C ratio in the offshore of Leftrook Lake varied somewhat over time, but was consistently less than one (Figure 5-9). Ratios in 2012 and 2013 were significantly lower than that measured in 2011.

Any 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 Churchill River Diversion

Mean total richness (family-level) in nearshore habitat varied somewhat among on-system lakes, but comparatively less so among years within a waterbody (Figure 5-10). Richness in Threepoint Lake was consistent among years, averaging 11 taxa. Average richness was marginally lower in Apussigamasi Lake (9 taxa) and higher in Footprint (13 taxa) and Notigi (14 taxa) lakes. Richness was greatest in Rat Lake (20 taxa) followed by Mynarski Lake (16 taxa). Variations in diversity are often linked to differences in substrate, but substrates generally were silt/clay. However, shoreline conditions were markedly different. For example, nearshore samples in Rat and Mynarski lakes were collected along a well vegetated riparian shore, while nearshore samples in Threepoint Lake were collected along exposed silt/clay flats with minimal vegetation.

The mean total richness of BMIs in offshore habitat varied among years and on-system lakes, but was generally lower than in the nearshore habitat, likely due to lower habitat diversity in the offshore environment (Figure 5-11). On average, richness in the on-system waterbodies ranged from 6-8 taxa, with the exception of Rat Lake, where average richness was three.

5.3.3.2 Off-system Waterbody: Leftrook Lake

The mean total richness of BMIs in the nearshore habitat of Leftrook Lake was within the range observed for on-system lakes in 2010 and 2013, but somewhat higher in comparison in 2011 and

2012 (Figure 5-10). The larger number of taxa reflects the boulder/cobble substrate and well-vegetated riparian shoreline where samples were collected.

The mean total richness of BMIs in the offshore habitat of Leftrook Lake was within the range observed for on-system lakes in 2010 and 2013, but somewhat lower in comparison in 2011 and 2012 (Figure 5-11).

5.3.3.3 Temporal Comparisons and Trends

Total richness of BMIs in the nearshore habitat of Threepoint Lake showed little variation between 2010 and 2013 (10-12 taxa; Figure 5-10). A similar lack of annual variability was observed in the nearshore of the off-system Leftrook Lake, though richness was higher in comparison to Threepoint Lake, varying from 17 to 19 taxa (Figure 5-10).

Total richness of BMIs in the offshore of Threepoint Lake was greater in 2013 than other years, and the difference between 2011 and 2013 was statistically significant (Figure 5-11). In the off-system Leftrook Lake, total richness was greatest in 2013 and lowest in 2012 but the difference was not were statistically significant (Figure 5-11).

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 Churchill River Diversion

The mean EPT richness (family-level) in nearshore habitat of on-system lakes typically followed a pattern similar to total richness (Figure 5-10).

The mean EPT richness in offshore habitat was very similar among years and on-system lakes, with approximately one to two families usually represented (Figure 5-11).

5.3.4.2 Off-system Waterbody: Leftrook Lake

Mean EPT richness in the nearshore habitat of Leftrook Lake (six taxa) was within the range observed for on-system lakes in 2010 and 2013, but somewhat higher in comparison in 2011 and 2012 (Figure 5-10).

In the offshore habitat of Leftrook Lake, mean EPT richness was within the range observed for on-system lakes with the exception of 2012 when less than one taxon was observed (Figure 5-11).

5.3.4.3 Temporal Comparisons and Trends

Mean EPT richness in the nearshore habitat of Threepoint Lake showed little variation between 2010 and 2012 (two to three taxa) and was marginally higher in 2013 (five taxa) (Figure 5-10). However, no changes over time in richness were statistically significant. EPT richness in the nearshore of the off-system Leftrook Lake varied very little between 2010 and 2013, fluctuating between five and seven taxa (Figure 5-10).

Similar to the nearshore lake habitat, EPT richness in the offshore of Threepoint Lake showed little variation between 2010 and 2013 (one to two taxa (Figure 5-11). In the off-system Leftrook Lake, offshore EPT richness was low (one taxon) (Figure 5-11).

Potential relation to water levels 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 Churchill River Diversion

Simpson's Diversity Index for the nearshore BMI community varied between approximately 0.7 to 0.9 among years for lakes upstream of the Notigi CS and from 0.6 to 0.8 for lakes downstream of the Notigi CS (Figure 5-12). Diversity in Threepoint Lake was marginally lower than the upstream lakes in all years in which sampling occurred in the same year (Figure 5-12).

In the offshore environment, diversity among on-system lakes was somewhat lower than in the nearshore, and ranged from an average of approximately 0.5 to 0.7, with the exception of Rat Lake, which ranged from an average of approximately 0.3 to 0.5 (Figure 5-13).

5.3.5.2 Off-system Waterbody: Leftrook Lake

Simpson's Diversity Index for the nearshore community in Leftrook Lake was within the range observed for on-system lakes in 2010 and 2013, but slightly higher in comparison for 2011 and 2012 (Figure 5-12).

For the offshore of Leftrook Lake, diversity was within the range observed for on-system lakes with the exception of 2011 when it was much lower in comparison to Mynarski and Threepoint lakes (Figure 5-13).

5.3.5.3 Temporal Comparisons and Trends

Simpson's Diversity Index in the nearshore habitat of both Threepoint Lake and Leftrook Lake was highest in 2013 but there were no significant differences among years in either annually sampled lake (Figure 5-12).

In the offshore of Threepoint Lake, the diversity index varied, but with no obvious increasing or decreasing trend (Figure 5-13). Diversity in 2011 was highest, and was significantly greater than in 2012. In the off-system Leftrook Lake, 2011 was lowest and significantly less than 2012 and 2013.

Potential relation to water levels is discussed in Section 5.5.

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.

Ephemeroptera richness for all sites and years for the nearshore environment are provided in Figure 5-14. Results for the offshore are provided in Figure 5-15.

5.4.1 Ephemeroptera Richness

5.4.1.1 Churchill River Diversion

Mean Ephemeroptera richness (genus-level) in nearshore habitat varied among years and on-system lakes, ranging from about 1-5 genera (Figure 5-14). Too few genera were present and variation among years was too great to provide comparative information among sites (e.g., in Rat Lake, there were two genera in 2010 and five in 2013).

The mean Ephemeroptera richness in offshore habitat was very similar among years and on-system lakes with typically one genus represented (Figure 5-15).

5.4.1.2 Off-system Waterbody: Leftrook Lake

The mean Ephemeroptera richness in the nearshore habitat of Leftrook Lake ranged from about 1.5-3.0 genera (Figure 5-14). The mean Ephemeroptera richness in the offshore habitat of Leftrook Lake was typically one genus (Figure 5-15).

5.4.1.3 Temporal Comparisons and Trends

Too few genera were present to provide a meaningful analysis of trends.

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 CRDR Waterbodies, 2010-2013

Rat and Notigi lakes are controlled reservoirs and water levels are managed such that they peak in late summer/fall each year. During years when sampling was conducted, the nearshore in Notigi Lake (2012) and Rat Lake (2013) would have been wetted for the entire growing season, while in Rat Lake (2010) a substantial portion would only have been wetted later in the growing season. Downstream of the Notigi CS, water levels in the open water season are much more variable. Sampling in the nearshore in Threepoint Lake in 2012 was conducted at a very high elevation; water levels in 2010, 2011 and 2013 were lower and therefore sampling was conducted at a lower elevation along the shoreline (Table 5-1). In all years except 2011, most of the nearshore would have been wetted; in the 2011 a substantial portion of the nearshore habitat was dewatered for the first month of the open water season (see Figure 2-5 in Section 2.0). Water levels n Footprint Lake are the same as in Threepoint; therefore, sampling in 2010 and 2013 was conducted in nearshore habitat that had been wetted through the open water season.

In Leftrook Lake, the nearshore habitat sampled was wetted the entire growing season in 2010, 2012 and 2013 but was partially exposed in early 2011.

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

Data collected to date indicate that the nearshore BMI community of the CRDR is adapted to at least some of the major hydrological effects of flow regulation. In particular, the nearshore habitat in the lakes upstream of the Notigi CS is completed dewatered during winter, but the BMI community is comparable in abundance (excluding the high abundance in 2013), richness and diversity to off-system Leftrook Lake when sampling was conducted in late summer.

Downstream of the Notigi CS, the water regime may be somewhat less favorable to the nearshore community, although during the sampling period there was not a direct relationship to dewatering (most of the nearshore was wetted during the study years). When comparing the nearshore habitat of on-system lakes, it was noted that total abundance, total and EPT richness, and diversity tended on the whole to be slightly higher for lakes upstream of the Notigi C.S. (Rat, Mynarski, and Notigi lakes) in comparison to those downstream (Threepoint, Footprint, and Apussigamasi lakes) (Figure 5-6, 5-10, and 5-12). This may in part be due to the greater stability of water levels during the growing season in the upstream lakes than in the downstream lakes. The longer period of wetting and the greater diversity of habitat could both contribute to higher numbers of invertebrates as well as greater taxonomic richness and diversity. For example, the riparian vegetation in Rat and Mynarski lakes is better developed than in Threepoint Lake.

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, available data for Threepoint Lake were inspected to determine whether there were any obvious relationships (Table 5-2, Figure 5-16). No relationship was observed with respect to the nearshore (Table 5-2) or offshore habitat (Table 5-2, Figure 5-16), despite the wide range of water levels and flows that occurred during this period (Section 2.0). As additional data are collected during future years of monitoring, a relationship may become apparent.

5.6 SUMMARY

The BMI communities of the CRDR lakes was generally dominated by chironomids, corixids, oligochaetes, and amphipods in the variable nearshore habitat (silt/clay and bedrock substrates), and primarily oligochaetes, amphipods, bivalves, chironomids, and ephemeropterans in the fine-textured sediments (silt/clay, sand) of the offshore habitat. Non-insects were often relatively more abundant that insects. BMI abundance at the off-system Leftrook Lake was often higher than the on-system lakes. However, the same major BMI groups dominated and non-insects tended to be relatively more abundant than insects.

Data collected to date indicate that the BMI community of the CRDR is likely adapted to at least some of the major hydrological effects of flow regulation. In particular, the BMI community in lakes upstream of the Notigi CS seems to be adapted to overwinter dewatering of the nearshore habitat, and abundance, richness and diversity are generally comparable to off-system Leftrook Lake. The nearshore zone downstream of the Notigi CS appears to be more adversely affected by the regulated water regime, possibly due to the wide range in water levels typically experienced during the open water season.

Differences in water regime may affect the quality of the nearshore habitat. Riparian vegetation at sampling sites in lakes upstream of the Notigi CS tends to be better developed than downstream of the Notigi CS, where the shoreline is largely devoid of vegetation, presumably due to the large water level changes during the growing season. These differences, in conjunction with substrate type, affect the abundance, richness and diversity of the nearshore BMI community. For example, lower total and EPT richness in the nearshore of Threepoint Lake in comparison to Leftrook Lake may reflect the predominance of silt and clay along its sampled shoreline area. In contrast, the shoreline area sampled in Leftrook Lake had greater habitat heterogeneity, with a mainly boulder and cobble substrate. Rat Lake also had a silt/clay substrate, but the presence of habitat diversity from riparian vegetation supports species richness comparable to that of Leftrook Lake.

Overall, analysis of the four years of CAMP BMI monitoring data collected in the CRDR did not show a consistent increasing or decreasing trend over this time period. However, abundance in the nearshore and offshore of Leftrook Lake and the offshore of Threepoint Lake was significantly higher in 2013 than other years; this difference was not apparently linked to hydrology or other parameters considered during this study, indicating the complexity of factors influencing the BMI community.

Table 5-1. Supporting variables measured in the nearshore and offshore habitats of the Churchill River Diversion 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)
RAT	18-Aug-10	0.8	standing	woody debris (clay)	clay	7.6	standing	clay, organic matter	clay (silty clay)	0.68	0.68	258.16	--
3PT	18-Aug-10	0.7	standing	clay, organic matter	silty clay (loam)	4.8	medium	clay, sand	silty clay loam	2.55	0.90	241.73	--
FOOT	18-Aug-10	0.6	standing	clay, organic matter (sand, cobble)	silty clay (loam)	6.4	standing	clay, silt	clay loam (silty clay loam)	2.43	1.60	241.71	--
LEFT	22-Aug-10	0.5	standing	boulder, gravel	--	7.9	standing	clay	clay	1.45	0.80	253.65	--
MYN	25-Aug-11	1.0	standing	bedrock (clay, silt, cobble)	clay	6.8	standing	clay, silt, sand	loamy sand, sandy loam	2.10	1.85	258.26	--
3PT	19-Aug-11	0.7	standing	clay	clay	4.2	standing	clay	silty clay loam	2.90	0.63	241.68	--
LEFT	21-Aug-11	0.9	standing	boulder, cobble	--	8.7	standing	silt, clay	clay	1.10	0.88	254.13	--
NTG	20-Aug-12	0.5	standing	silt, clay, organic matter	silt loam (clay)	6.9	standing	organic matter, clay, silt	silty clay (clay)	2.75	0.72	257.44	988.22
3PT	16-Aug-12	0.9	standing	clay, silt	silty clay (loam)	5.9	standing	clay, silt	silty clay loam	1.30	1.15	243.35	--
APU	24-Aug-12	0.8	standing	silt, clay	clay	7.3	standing	clay, silt	silt loam	2.84	2.06	187.10	--
LEFT	23-Aug-12	0.6	standing	boulder (bedrock, cobble, gravel)	--	8.4	standing	silt, clay	clay (silty clay loam)	1.26	n.r.	253.85	--
RAT	29-Aug-13	1.0	standing	silt, clay	clay	7.9	standing	silt, clay	clay	1.15	n.r.	257.92	--
3PT	14-Aug-13	0.9	standing	clay, silt	clay	4.7	standing	clay	silty clay loam	2.07	n.r.	242.26	--
FOOT	17-Aug-13	0.9	standing	clay	clay (sandy clay loam)	6.6	standing	clay (gravel)	clay (loamy sand, sandy clay loam)	2.58	0.64	242.27	--
LEFT	15-Aug-13	1.0	standing	boulder, cobble	--	8.3	standing	clay, silt	silty clay	1.46	n.r.	253.76	--

[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.' data point 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 Threepoint Lake, 2010 to 2013.

Threepoint Lake

Year	Abundance (Number/Kicknet Or Number/m^2)	Richness	Diversity	Water Level (m ASL)	Discharge (m^3/s)
Nearshore					
2010	138	11.60	0.64	242.6	757.8
2011	277	10.40	0.60	241.4	501.9
2012	247	10.60	0.67	243.4	975.7
2013	184	10.80	0.77	242.7	783.8
Offshore					
2010	1065	7.40	0.67	242.6	759.7
2011	848	6.40	0.71	241.4	502.2
2012	2813	8.00	0.57	243.4	975.7
2013	6700	9.60	0.64	242.7	783.8

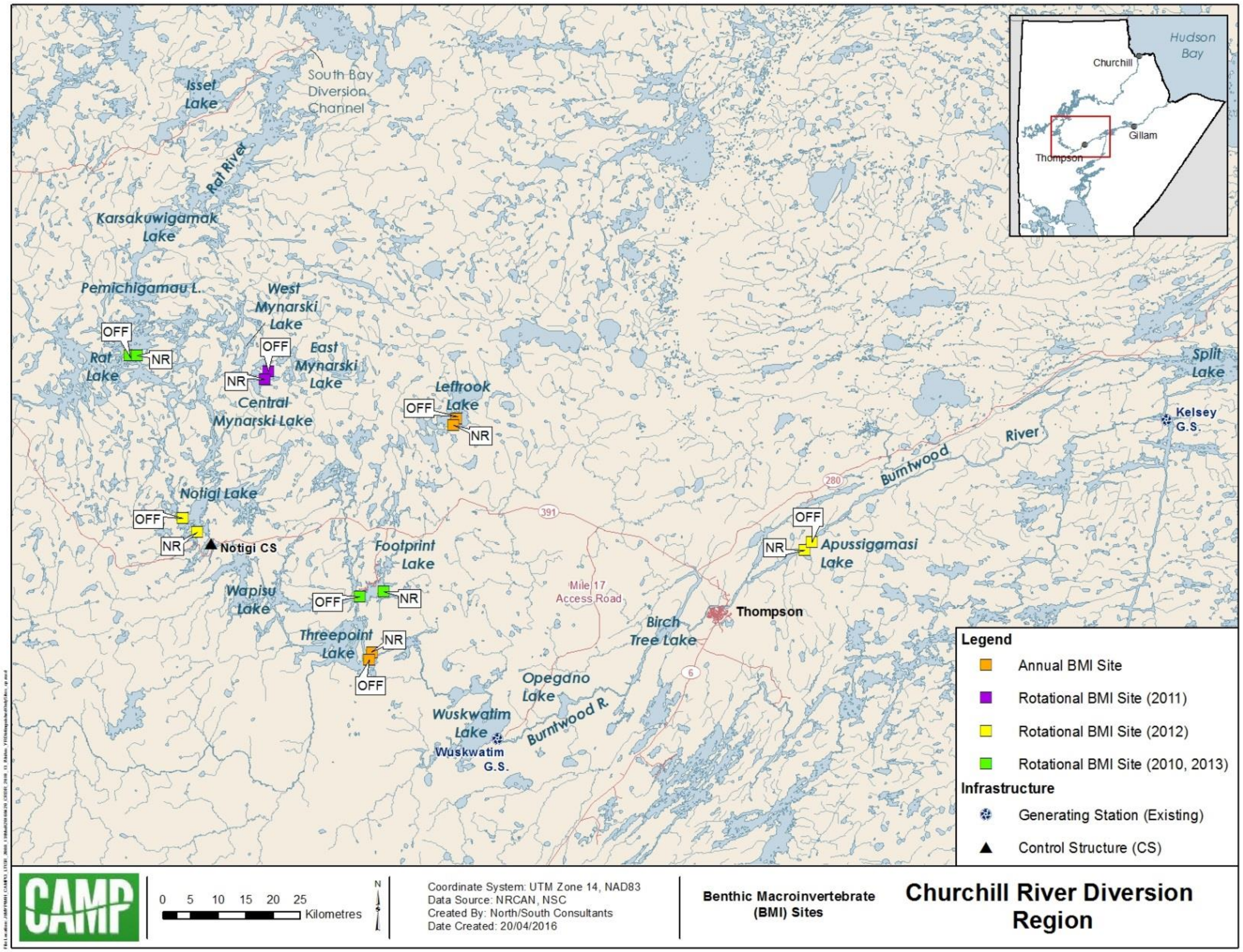
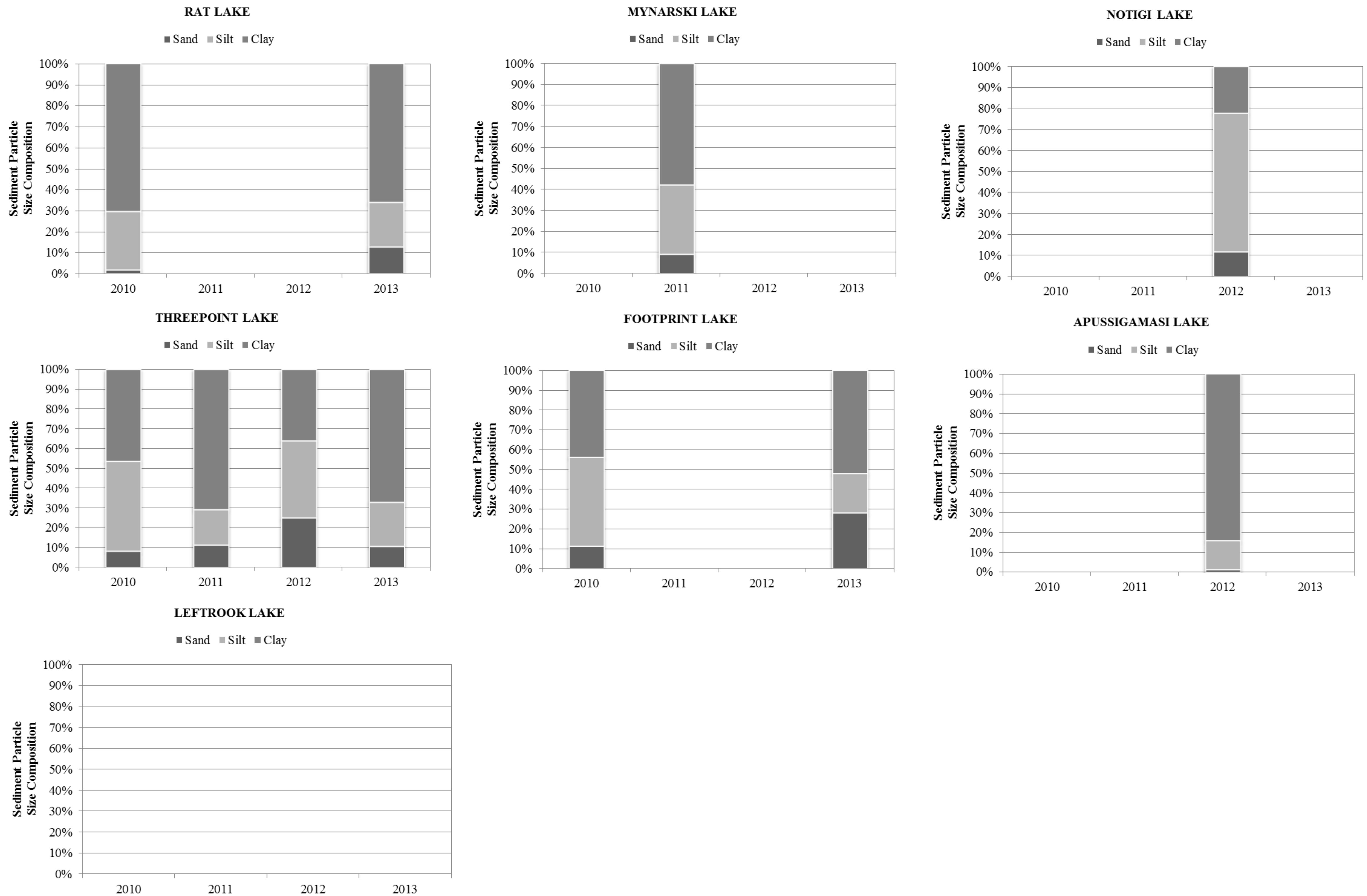


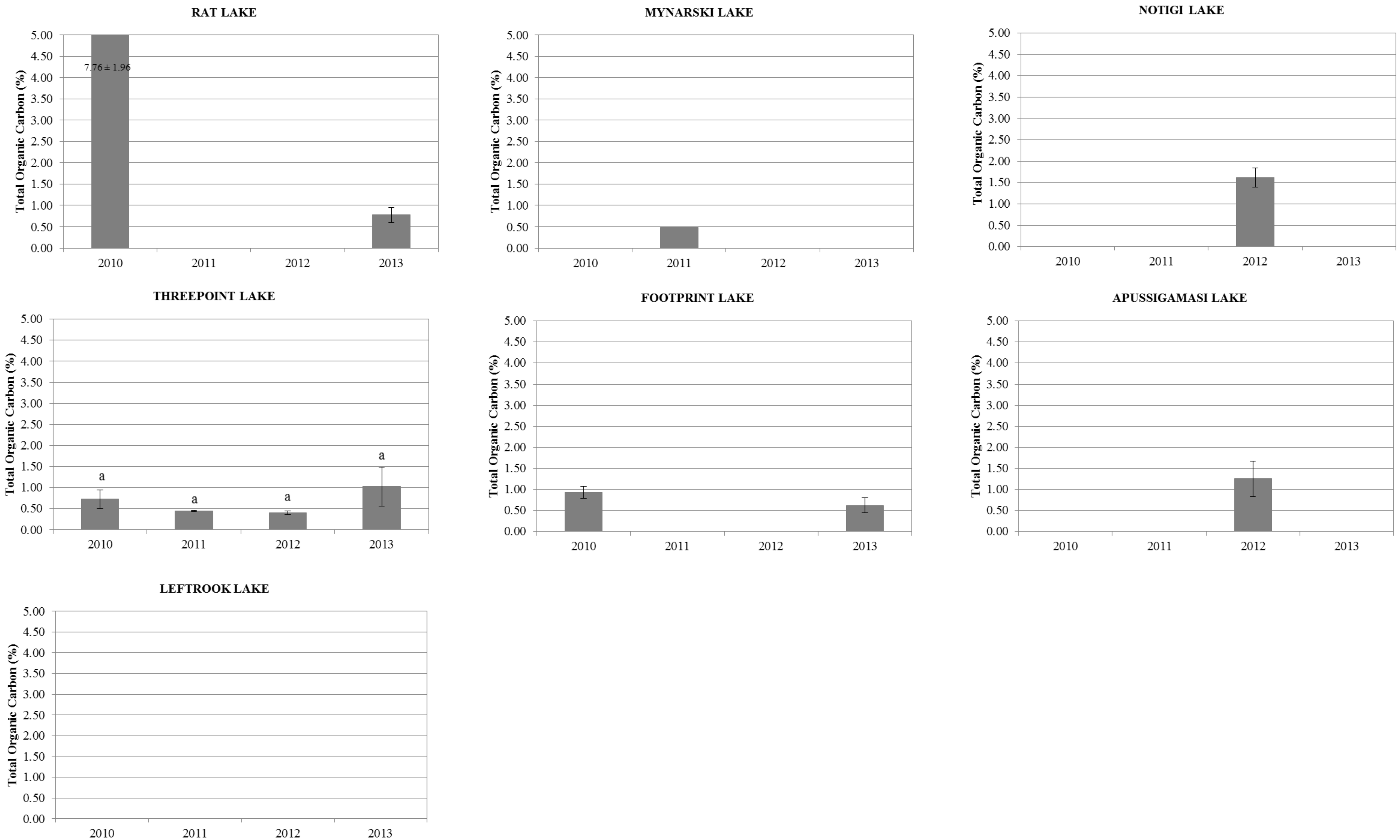
Figure 5-1. Benthic macroinvertebrate sampling sites in the Churchill River Diversion Region: 2010 – 2013.



No sediment samples collected at:

- Leftrook Lake (2010 to 2013) due to predominantly hard substrate.
- Mynarski Lake (2011) only one sediment sample was collected, majority of shoreline consisted of hard substrate.

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



No sediment samples collected at:

- Leftrook Lake (2010 to 2013) due to predominantly hard substrate.
- Mynarski Lake (2011) only one sediment sample was collected, majority of shoreline consisted of hard substrate.

Figure 5-3. Total organic carbon (mean % ± SE) in the nearshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring site (Threepoint Lake).

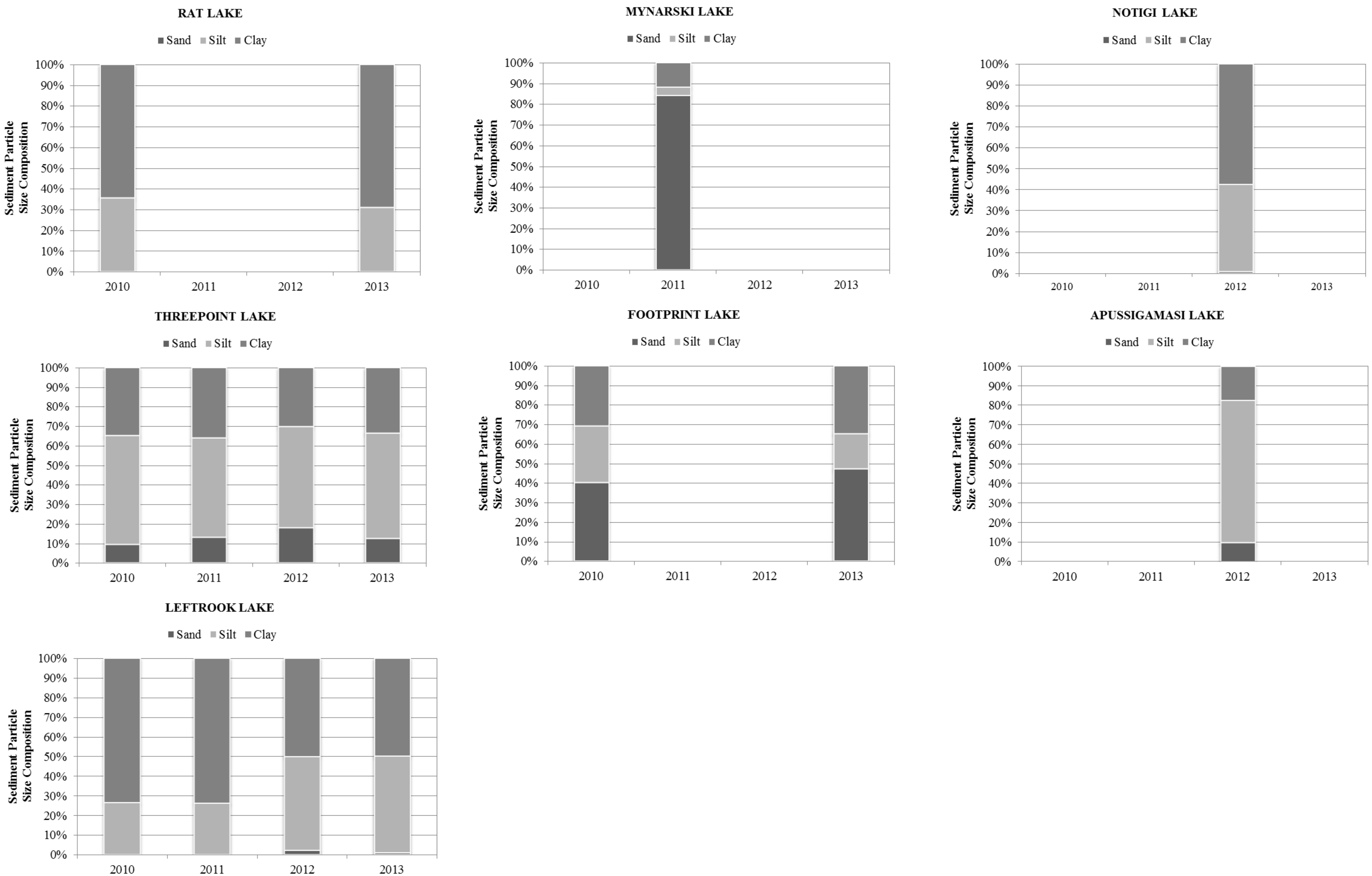


Figure 5-4. Sediment particle size composition (mean % of sand, silt, clay) in the offshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013.

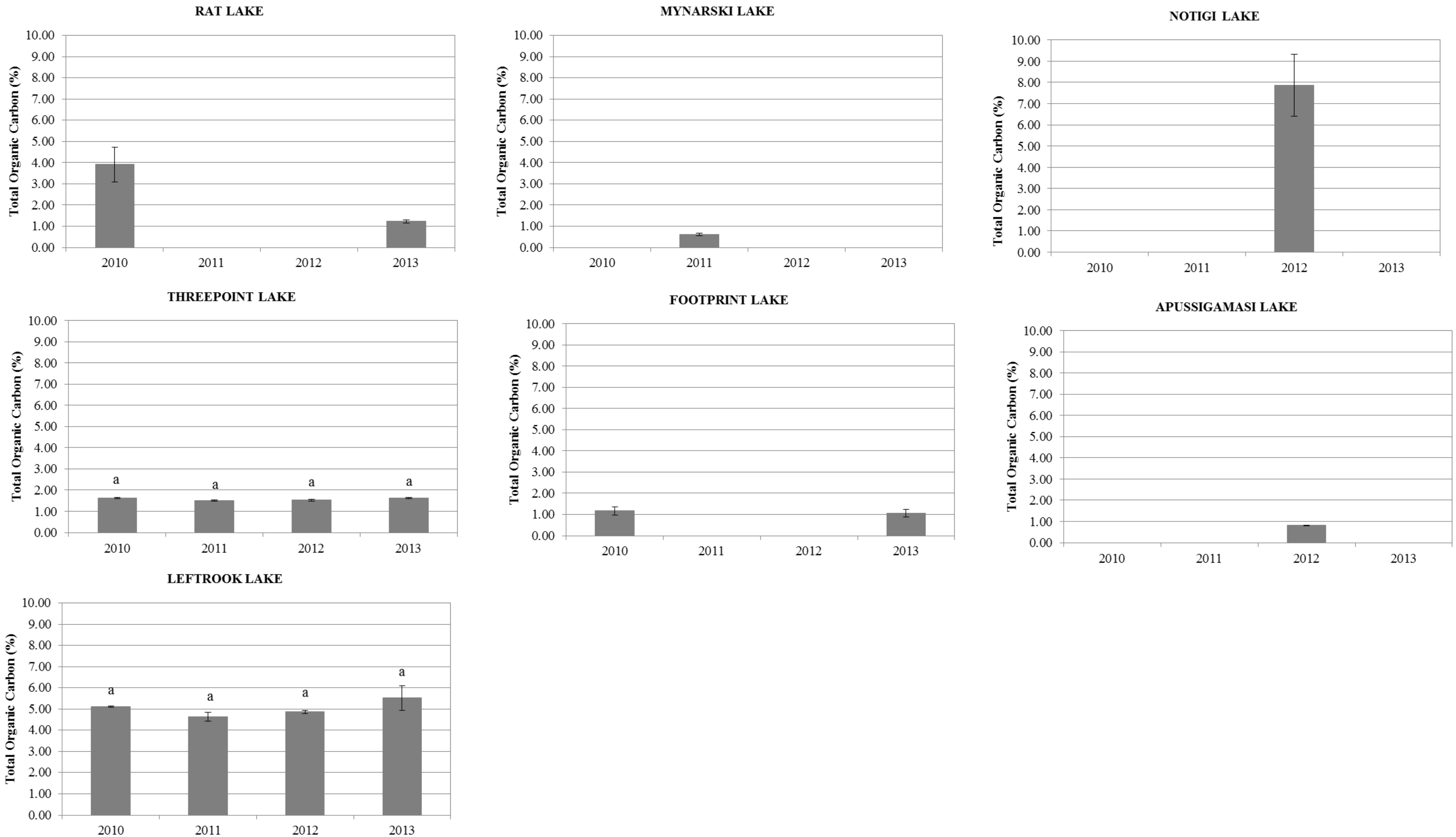


Figure 5-5. Total organic carbon (mean % ± SE) in the offshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Threepoint and Leftrook lakes).

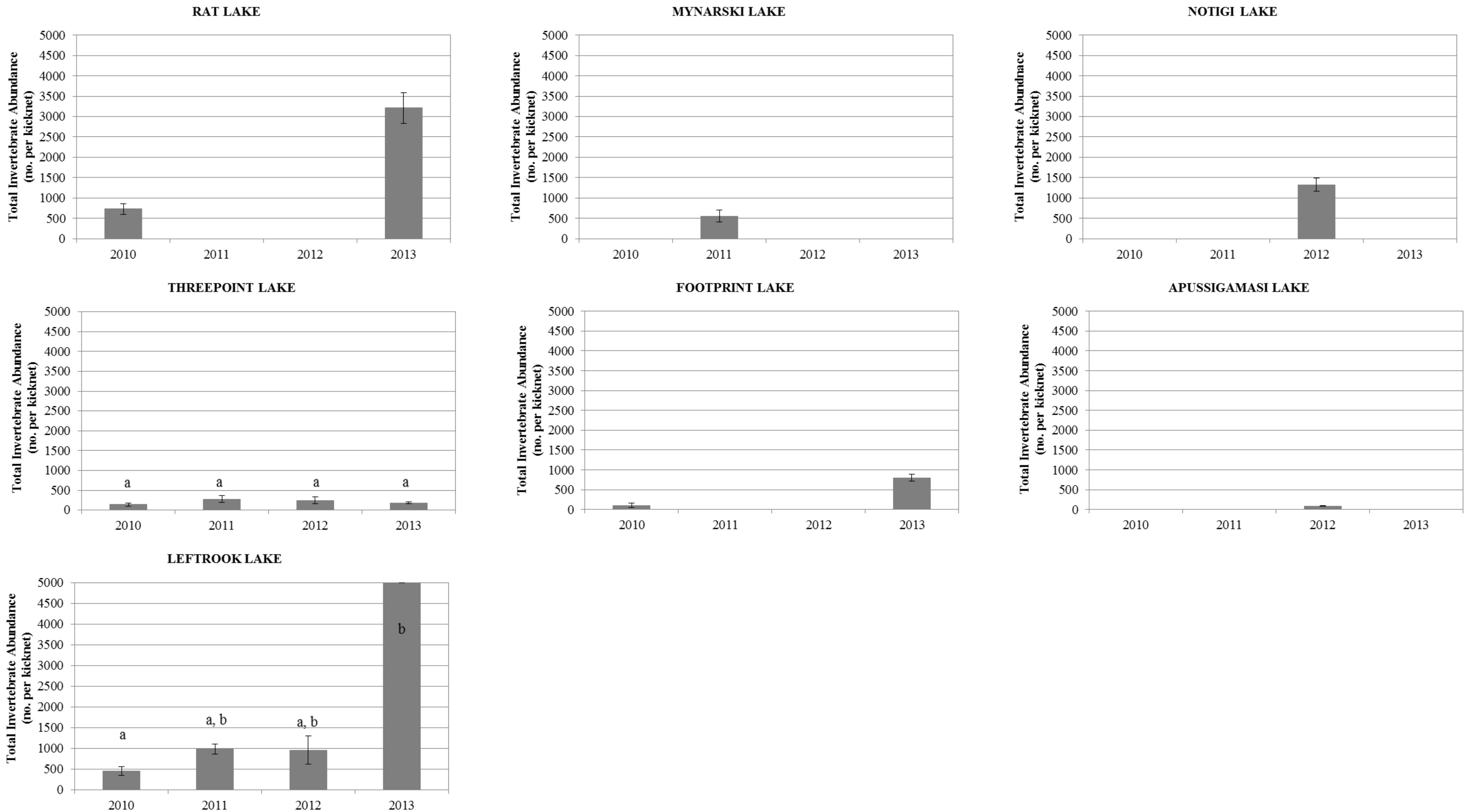


Figure 5-6. Total invertebrate abundance (mean ± SE) in the nearshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

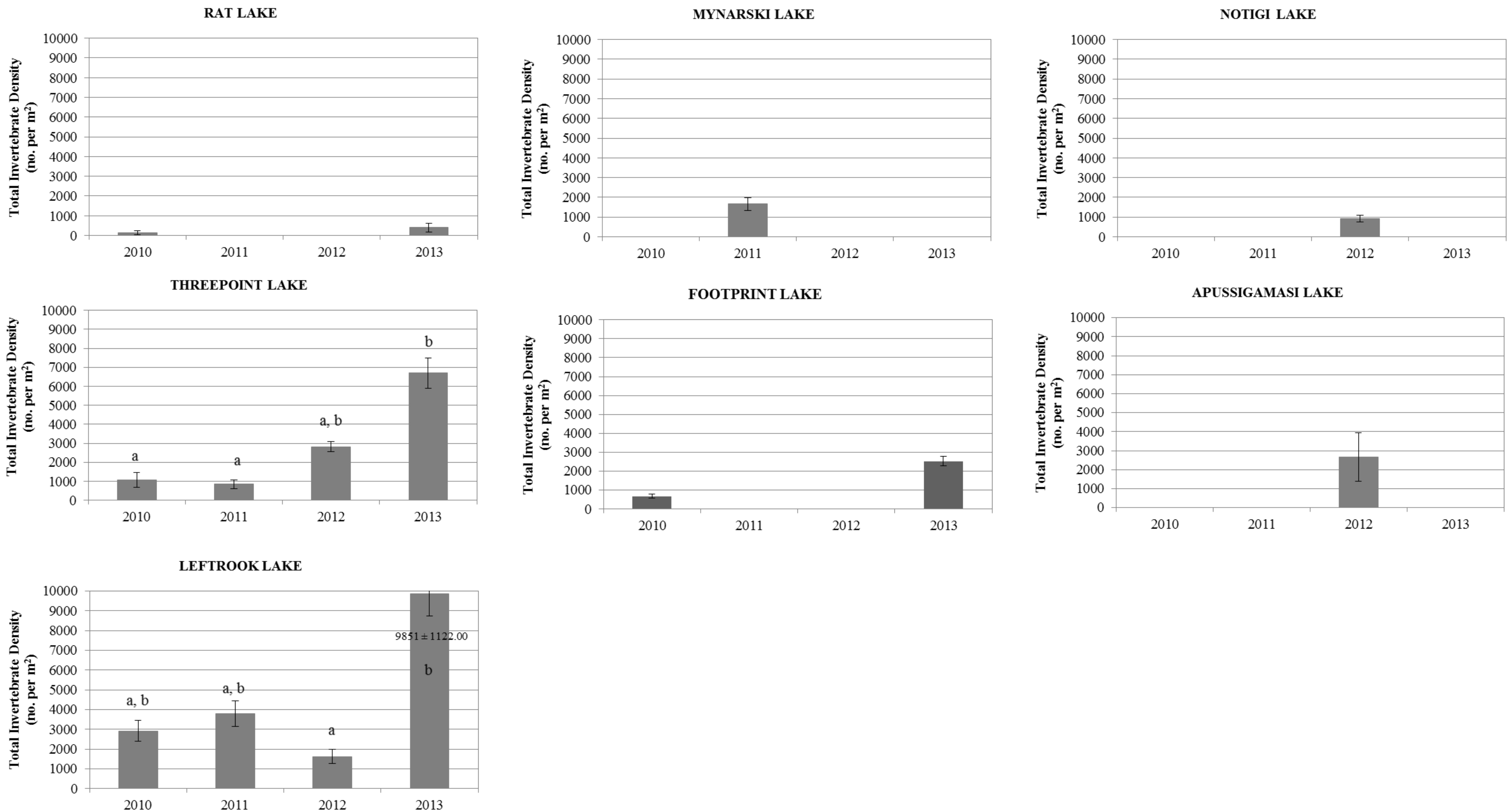


Figure 5-7. Total invertebrate density (mean ± SE) in the offshore of the Churchill River Diversion Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

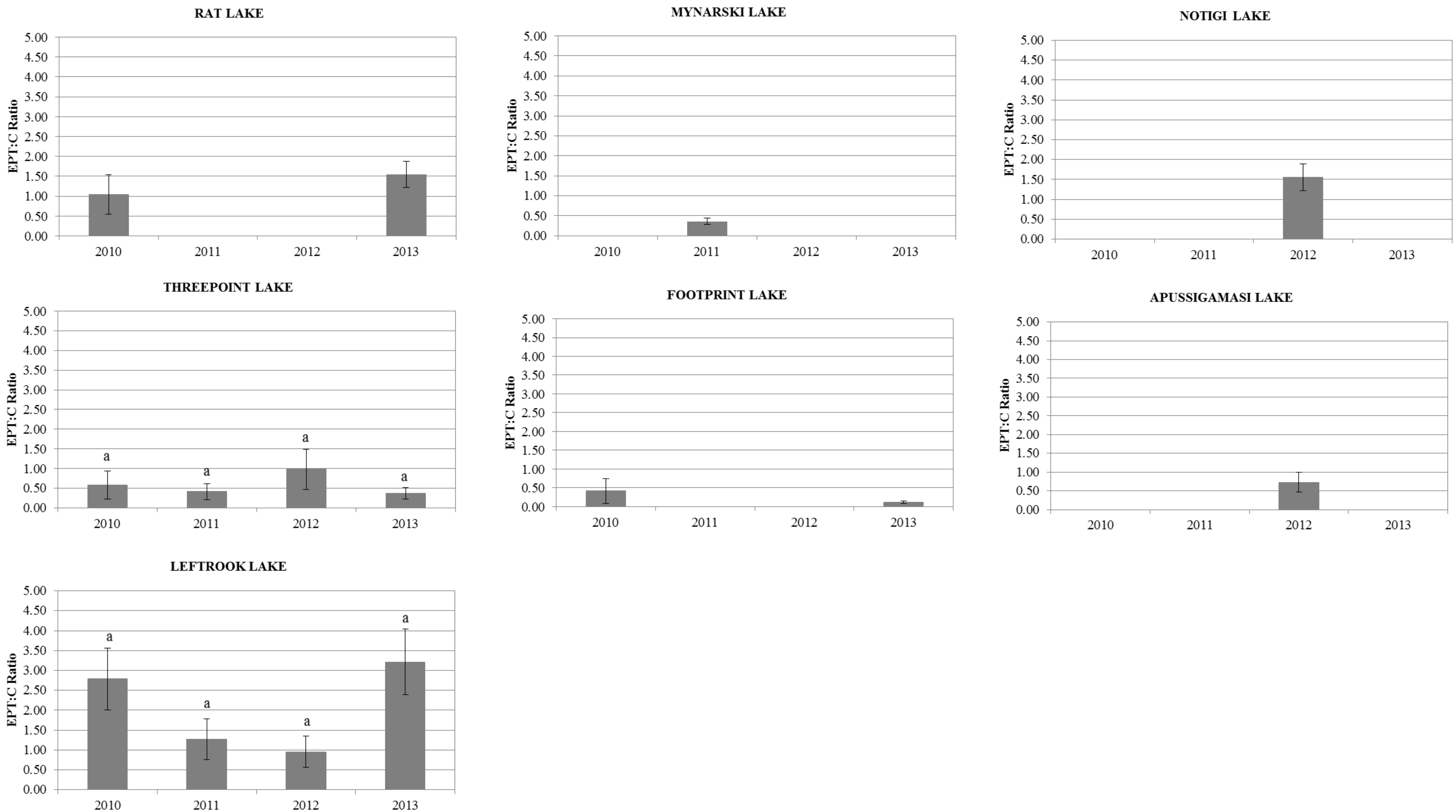


Figure 5-8. EPT:C ratio (mean ± SE) in the nearshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Threepoint and Leftrook lakes).

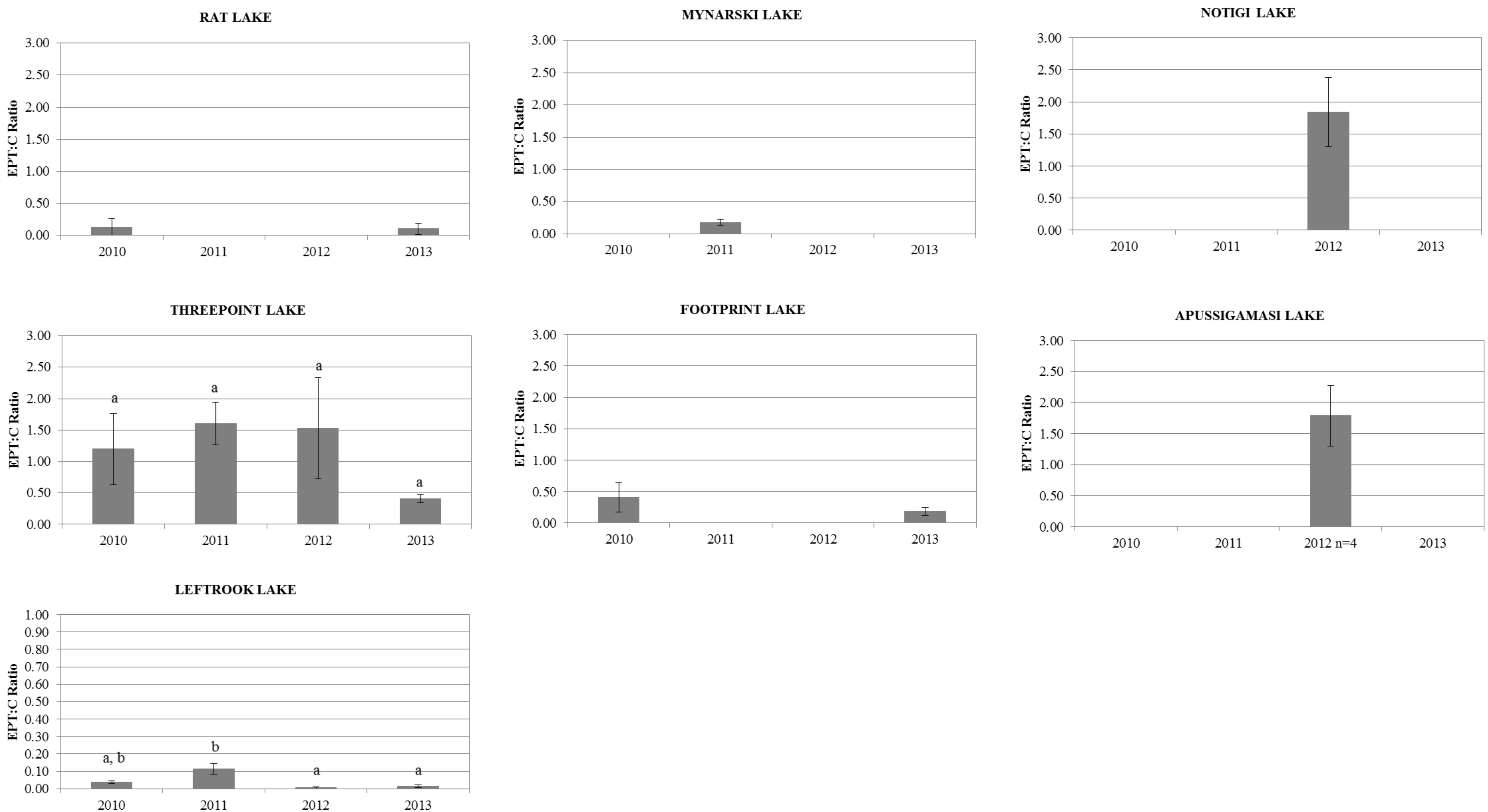


Figure 5-9. EPT:C ratio (mean ± SE) in the offshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. Note different scale used for Leftrook Lake. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

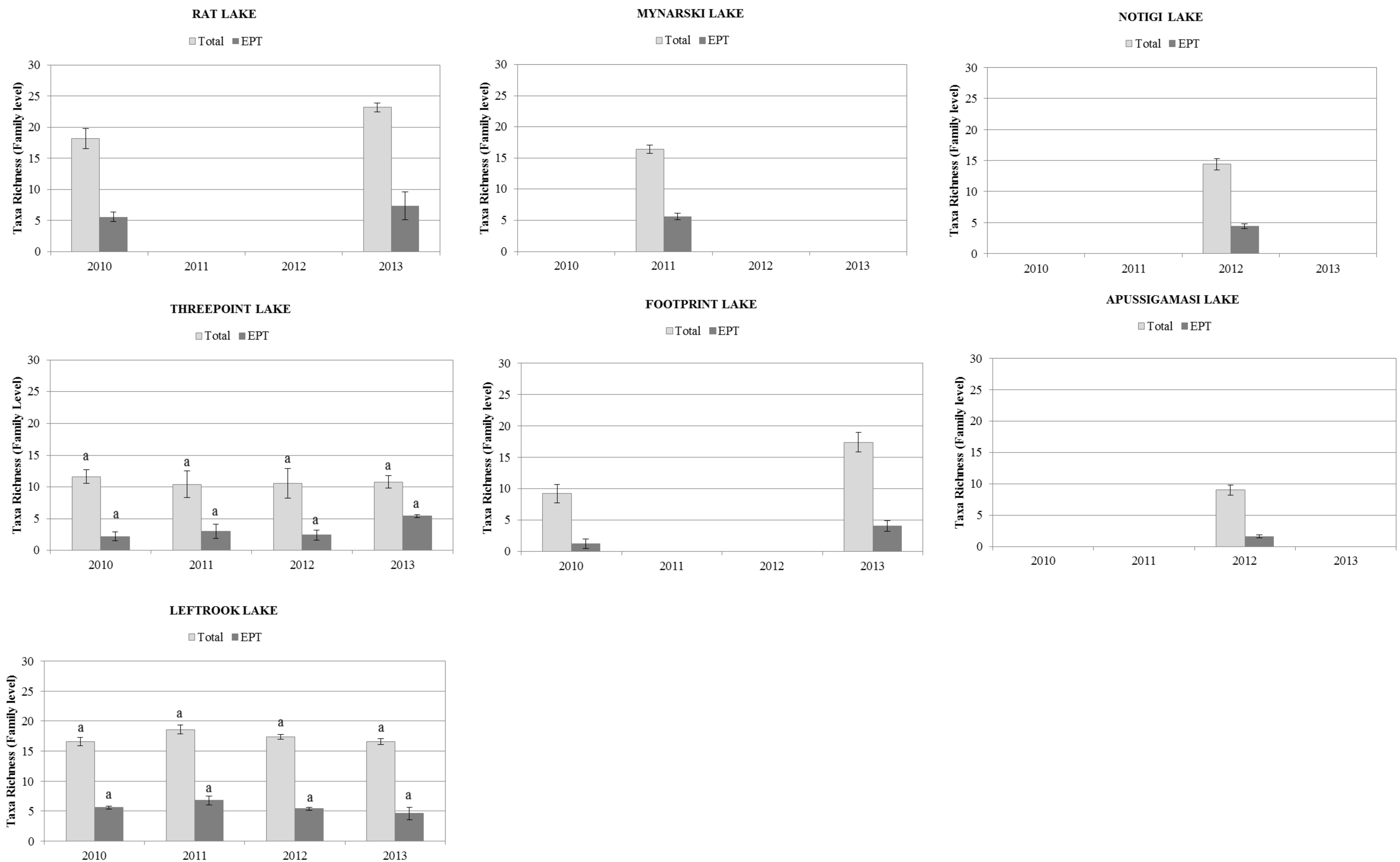


Figure 5-10. Taxonomic richness (total and EPT to family level; mean ± SE) in the nearshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Threepoint and Leftrook lakes).

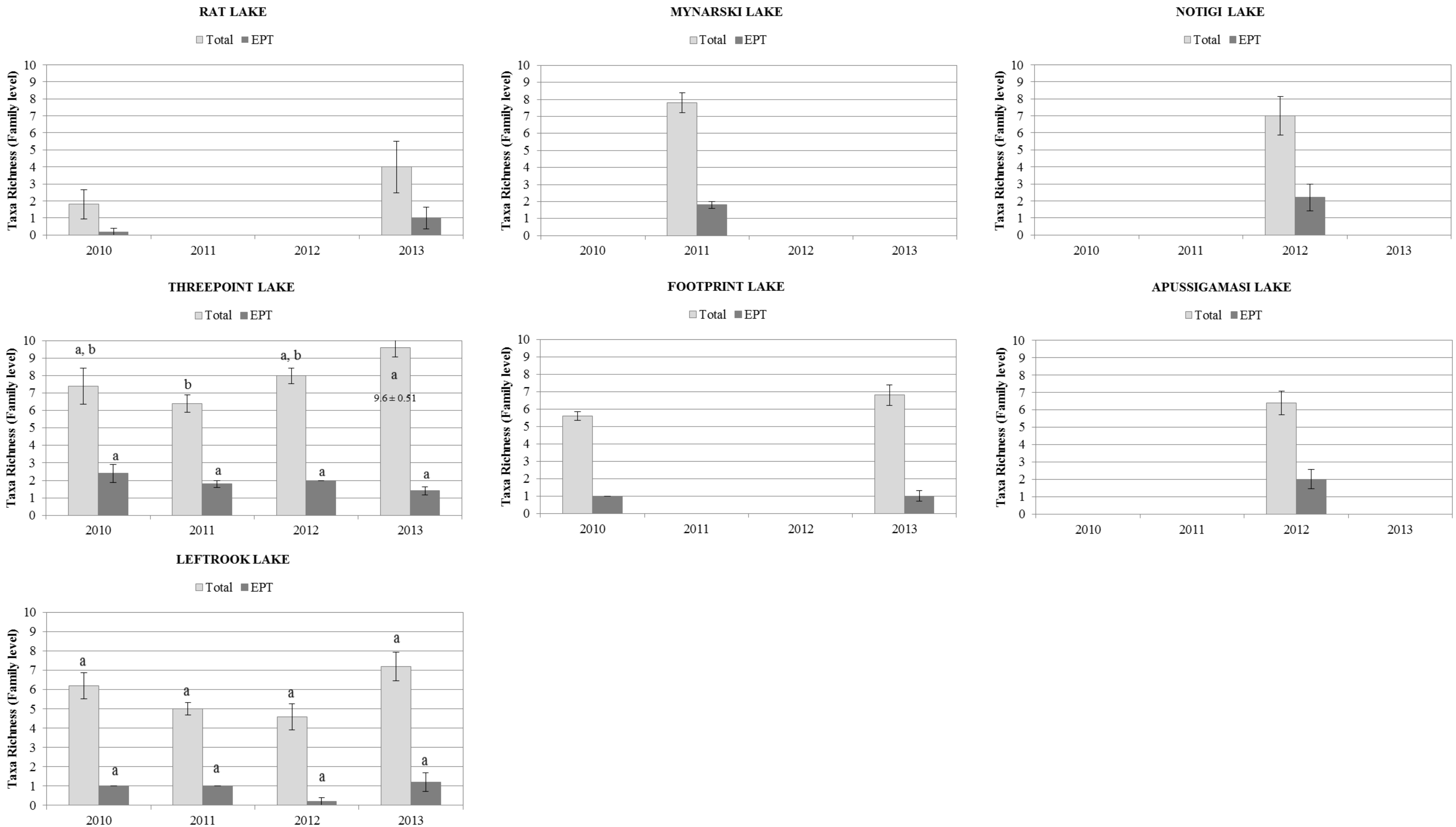


Figure 5-11. Taxonomic richness (total and EPT to family level; mean ± SE) in the offshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts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

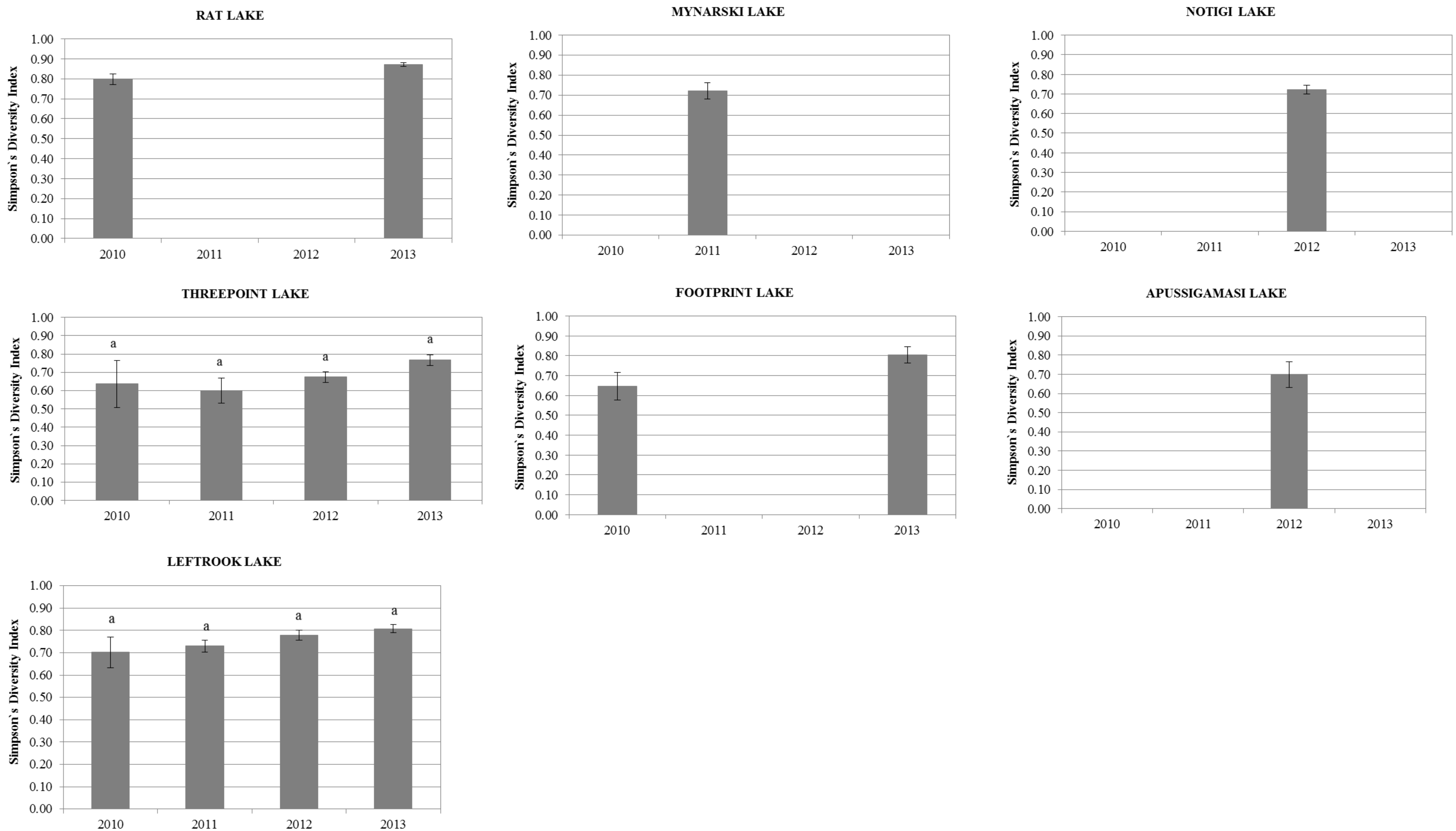


Figure 5-12. Simpson’s Diversity Index (mean ± SE) in the nearshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Threepoint and Leftrook lakes).

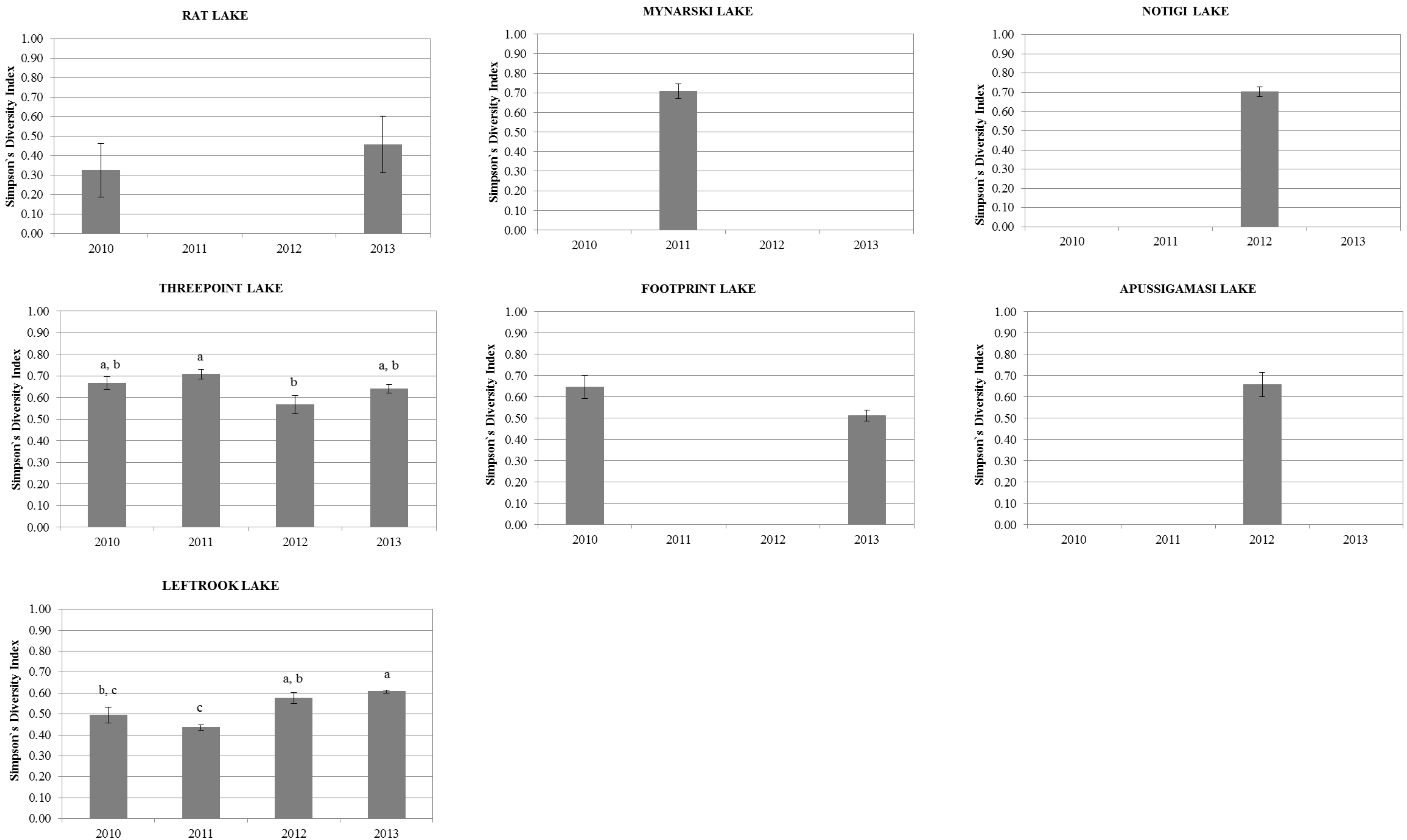


Figure 5-13. Simpson’s Diversity Index (mean ± SE) in the offshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

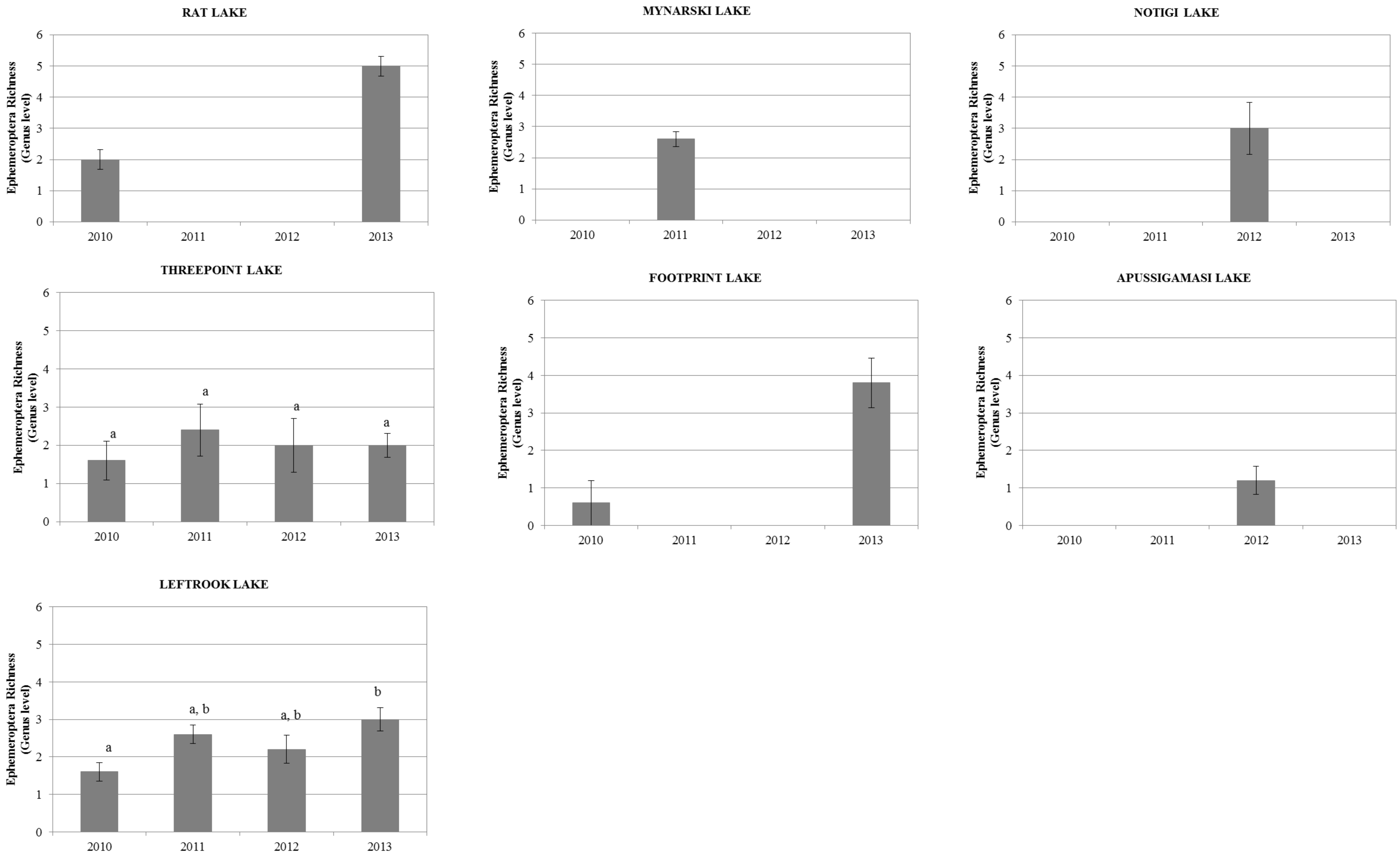


Figure 5-14. Ephemeroptera richness (genus level; mean ± SE) in the nearshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

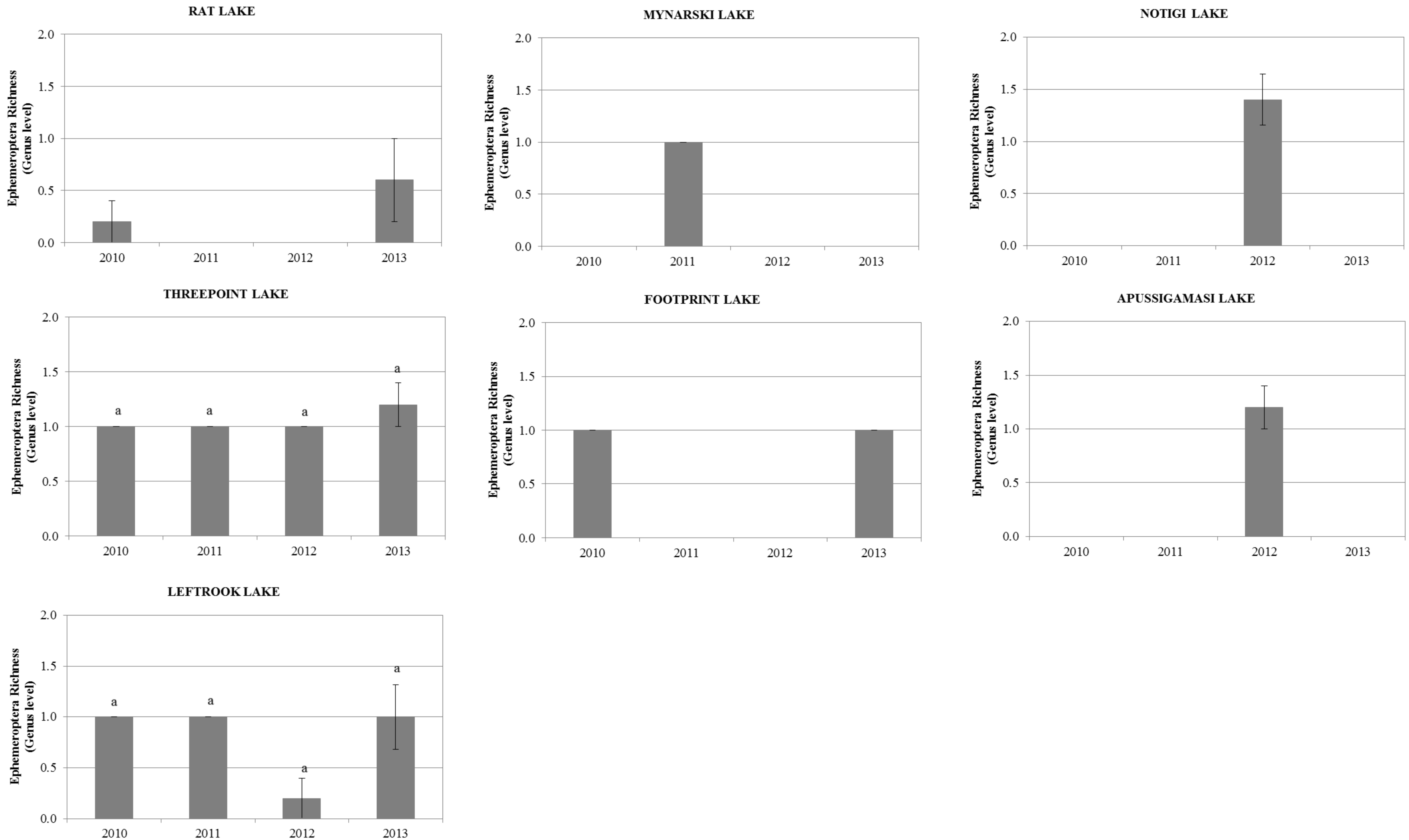


Figure 5-15. Ephemeroptera richness (genus level; mean ± SE) in the offshore habitat of the Churchill River Diversion Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Threepoint and Leftrook lakes).

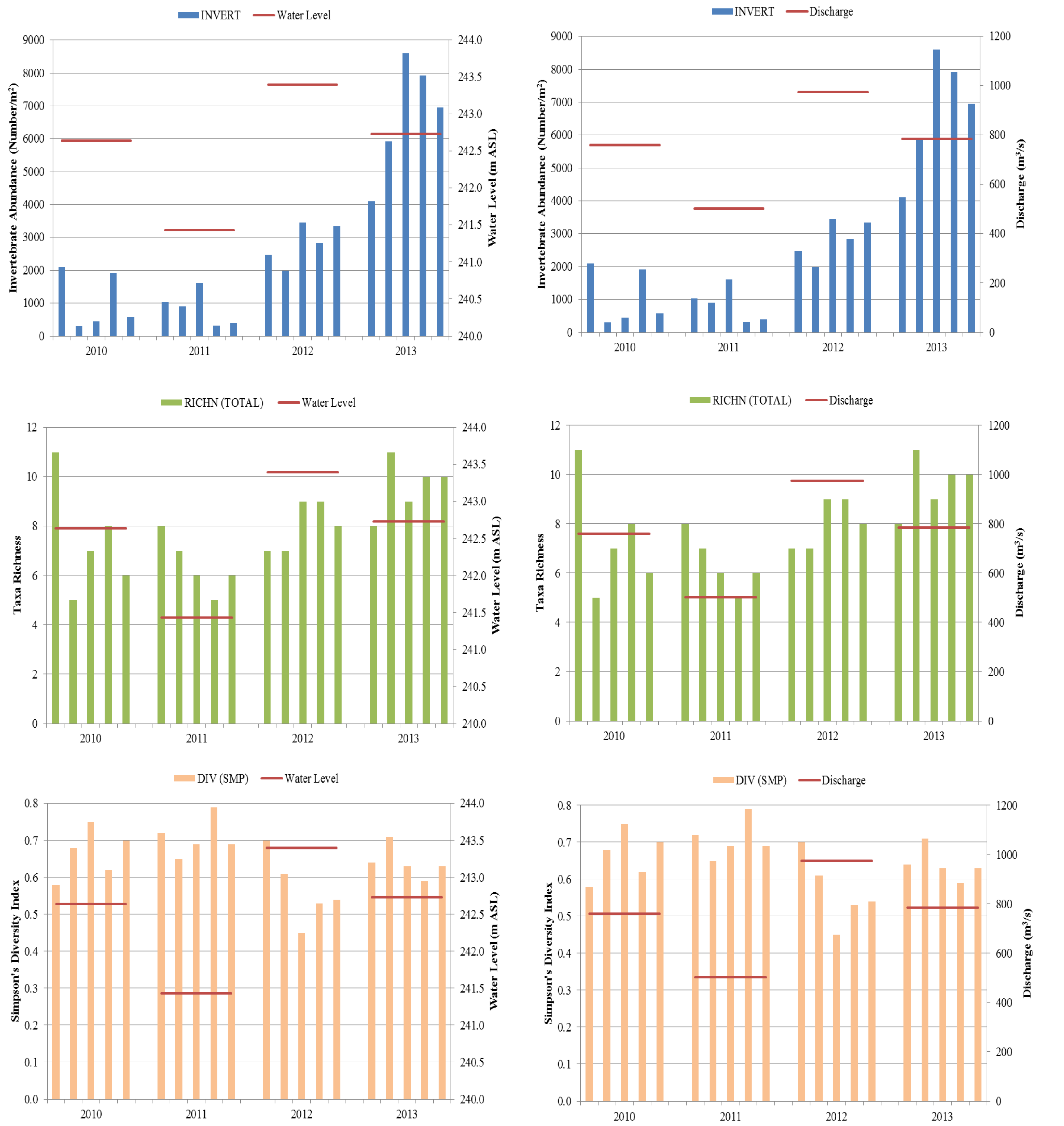


Figure 5-16. Invertebrate abundance, total richness, and Simpson’s diversity index for replicate samples collected at the offshore Threepoint Lake site: 2010 to 2013.The average water level and discharge during the “growing season” are shown.

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 2 to 6 in the CRDR – none of the waterbodies in the CRDR were sampled in 2008. As noted in Section 1.0, waterbodies/river reaches sampled annually included one on-system site (Threepoint Lake) and one off-system lake (Leftrook Lake). Five additional on-system waterbodies were sampled on a rotational basis including Rat, Central Mynarski, Notigi, Footprint, and Apussigamasi lakes (Table 6-1; Figure 6-1). Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.3 and the abbreviations for the sampling locations used in the tables and figures are provided in Table 6-1. Sampling was completed at all locations and sampling periods as intended.

All analyses presented below have been conducted on the results of annual or rotational index gillnetting studies. A detailed description of the sampling methodology 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 CRDR waterbodies, 2009-2013, 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.

Manitoba Hydro and the Province of Manitoba's (2015) regional cumulative effects assessment (RCEA) identified several effects of hydroelectric development on fish communities along the Churchill River Diversion route and its associated lakes, although a lack of pre-CRD data precluded a direct comparison of the key CAMP metrics data collected post-CRD. The principal long-term effect of CRD appeared to be a shift in the species composition in response to increased flows and water levels, particularly in lakes upstream of the Notigi CS where considerable flooding occurred as a result of impoundment. In particular, the abundance of Lake Whitefish (*Coregonus clupeaformis*) and Cisco (*Coregonus artedi*) declined in several of the waterbodies since the 1980s. There is little evidence that the overall abundance metric (CPUE) in many of the lakes along the diversion route has been affected, with the exception of Wuskwatim, Footprint and Threepoint lakes, where there has been a declining trend in CPUE. Key CAMP indicators were largely unaffected by CRD. Therefore the results for parameters in addition to the key metrics were also reviewed and summarized in Section 6.3, where of particular note (e.g., where there was evidence of temporal trends).

6.2 KEY INDICATORS

6.2.1 Diversity (Hill's Index)

Changes in aquatic habitat can result in a shift in the species composition. The Hill's Index is a mathematical measure of species diversity in a community based on how many different species (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 ecosystem health as more diversity increases the ability of the community to respond to environmental stressors.

6.2.1.1 Churchill River Diversion Region

The mean Hill's number ranged from a high of 8.0 in Apussigamasi Lake to a low of 5.7 in Central Mynarski and Footprint lakes (Table 6-3). The mean Hill's number in the lakes on the diversion route was higher (7.0-8.0) for lakes directly on the Rat/Burntwood River flows (i.e., Rat, Threepoint, Notigi and Apussigamasi lakes) and lower (5.7) on tributary lakes (i.e., Central Mynarski and Footprint lakes; Figure 6-2 and Table 6-3). The lower Hill's value in the tributary lakes was primarily related to fewer species being captured at Central Mynarski Lake (10 species compared to ≥12 at the other lakes), and a less even representation of species at Footprint Lake, with Walleye (*Sander vitreus*) accounting for about 40% of the catch.

6.2.1.2 Off-system Waterbodies: Leftrook Lake

The mean Hill's number in Leftrook Lake was 6.8 and was within the range observed in the on-system lakes (Figure 6-2).

6.2.1.3 Temporal Comparisons and Trends

Sites sampled annually (Threepoint and Leftrook lakes) did not exhibit increasing or decreasing trends over the 5 years of monitoring. However, the Hill's numbers for Threepoint Lake showed variability among sampling years (Figure 6-2). Over the 5-year sampling period, the Hill's number ranged from 8.3 in 2011 to 4.9 in 2012. The decrease in Hill's number in 2012 was likely a result of an increase in the relative abundance of three species (Walleye, White Sucker [*Catostomus commersonii*], and Sauger [*Sander canadensis*]) in the catch in standard and small mesh gangs, resulting in a decrease in evenness – in 2012 these species combined accounted for 85% of the catch, compared to an average of 55% in the other years. Hill's number was also variable at Leftrook Lake, which ranged from 6.1 in 2009 and 2012 to 7.9 in 2010.

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 Churchill River Diversion Region

Fish Community

In standard gangs, the mean CPUE ranged from 28 fish/100 m/24 h in Notigi Lake to 60 fish/100m/24 h in Central Mynarski Lake (Table 6-3). The most abundant large-bodied species captured in CRDR waterbodies were typically Walleye and White Sucker (Figure 6-3). The abundance of large-bodied fish was generally higher in tributary waterbodies (i.e., Central Mynarski and Footprint lakes) compared to the lakes on the mainstem of the Rat/Burntwood River. The mean total CPUE in standard gangs set in Rat, Notigi, and Threepoint lakes ranged from 28 to 33 fish/100 m/24 h, compared to 60 and 49 fish/100 m/24 h in Central Mynarski and Footprint lakes, respectively (Figure 6-4). The value in the farthest downstream on-system lake, Apussigamasi Lake, was in between those of tributary and other mainstem waterbodies, averaging 40 fish/100 m/24 h.

The species composition in the standard gangs was generally similar among the diversion route lakes, with the same two species (Walleye and White Sucker) dominating the catch (Figure 6-3). There were differences in the abundance of species among lakes, possibly in response to differences in habitat characteristics. The CPUE of Sauger was highest in the lakes downstream of the Notigi CS (Threepoint, Footprint, and Apussigamasi lakes), while Northern Pike (*Esox lucius*) and Cisco were most abundant in Central Mynarski Lake (Figure 6-3).

In small mesh gangs, the mean CPUE ranged from 22 fish/30 m/24 h in Notigi Lake to 75 fish/30 m/24 h at Central Mynarski Lake (Table 6-3). The more common small-bodied species captured in small mesh nets included Spottail Shiner (*Notropis hudsonius*) and Emerald Shiner (*Notropis atherinoides*; Figure 6-3).

Lake Whitefish

Lake Whitefish mean CPUE ranged from a high of 3 fish/100 m/24 h in Apussigamasi Lake to a low of 0 fish/100 m/24 h in Central Mynarski Lake (Table 6-3). The capture rate of

Lake Whitefish was generally low in all the diversion route lakes (Figure 6-5). CPUE was generally lowest at the tributary lakes (Central Mynarski and Footprint lakes), where the mean CPUE was 0 and <1 fish/100 m/24 h, respectively, compared to most of the lakes on the Rat/Burntwood River mainstem (Notigi, Threepoint, and Apussigamasi lakes), where the mean CPUE ranged from 1 to 3 fish/100 m/24 h. Lake Whitefish were also relatively uncommon in Rat Lake, where the mean CPUE was <1 fish/100 m/24 h.

Northern Pike

Northern Pike mean CPUE ranged from a high of 8 fish/100 m/24 h in Central Mynarski Lake to a low of 1 fish/100 m/24 h in Apussigamasi Lake (Table 6-3). There was considerable variation in the rate of capture of Northern Pike in on-system lakes along the diversion route (Figure 6-6). The median CPUE values were generally lower in the lakes on the mainstem of the diversion route (Rat, Threepoint, and Apussigamasi lakes), compared to tributary lakes (Central Mynarski and Footprint lakes). The exception was Notigi Lake, where the median CPUE was similar to Footprint Lake.

Walleye

There was considerable variation in catches of Walleye in on-system lakes along the CRD route (Table 6-3; Figure 6-7). Upstream of the Notigi CS, Walleye were more abundant in Rat Lake and Central Mynarski Lake, with mean CPUEs of 8 to 13 fish/100 m/24 h compared to Notigi Lake, with a mean of 5 fish/100 m/24 h. Walleye abundance appeared to increase in a downstream direction in lakes on the direct flow of the diversion route from Notigi Lake to Apussigamasi Lake (Figure 6-7). The mean CPUE increased from 5 fish/100 m/24 h in Notigi Lake, to 10 fish/100 m/24 h in Threepoint Lake, to 13 fish/100 m/24 h in Apussigamasi Lake. Walleye catches were higher in Footprint Lake compared to the other lakes, with a mean of 20 fish/100 m/24 h.

White Sucker

White Sucker mean CPUE in standard gangs ranged from a high of 21 fish/100 m/24 h in Central Mynarski Lake to a low of 8 fish/100 m/24 h in Apussigamasi Lake (Table 6-3). With the exception of Central Mynarski Lake, White Sucker catches were generally consistent among on-system lakes with mean CPUE ranging from 8 to 10 fish/100 m/24 h (Figure 6-8).

6.2.2.2 Off-system Waterbodies: Leftrook Lake

Fish Community

In standard gangs, the mean CPUE was 90 fish/100 m/24 h in Leftrook Lake (Table 6-3). The large-bodied fish community was dominated by White Sucker and Walleye (Figure 6-3). Catches in standard gang index gill nets at Leftrook Lake were considerably higher than those of any of the on-system lakes (Figure 6-4). The catch in Leftrook Lake was characterized by a high abundance of White Sucker and Walleye, similar to what was observed in the diversion route lakes, but with higher catches of Lake Whitefish and Northern Pike than the other lakes (Figure 6-3).

In small mesh gangs, the mean CPUE was 189 fish/30 m/24 h in Leftrook Lake (Table 6-3). The small-bodied fish community of the lake was dominated by Spottail Shiner, with smaller numbers of Trout-perch (*Percopsis omiscomaycus*) and Emerald Shiner (Figure 6-3). The same three small-bodied species were common in Threepoint Lake, but the CPUEs were considerably lower (Figure 6-3).

Lake Whitefish

The CPUE of Lake Whitefish in Leftrook Lake (12 fish/100 m/24 h) was considerably higher than observed in the on-system lakes (Figure 6-5).

Northern Pike

Northern Pike catches in Leftrook Lake (11 fish/100 m/24 h) were considerably higher than observed in the on-system lakes (Figure 6-6).

Walleye

Walleye catches in Leftrook Lake (26 fish/100 m/24 h) were higher than in the on-system lakes (Figure 6-7).

White Sucker

The CPUE of White Sucker in Leftrook Lake (31 fish/100 m/24 h) was considerably higher than observed in the on-system lakes (Figure 6-8).

6.2.2.3 Temporal Comparisons and Trends

Fish Community

There was no indication of increasing or decreasing trends in total CPUE in Threepoint or Leftrook lakes over the monitoring period (Figure 6-9). Although there was some limited variability over the 5-year sampling period, the mean CPUE in Threepoint Lake remained within a relatively small range (21 fish/100 m/24 h in 2010 to 36 fish/100 m/24 h in 2009).

Although similar to Threepoint Lake, catches at the off-system Leftrook Lake showed more inter-annual variation, with CPUE ranging from 67 fish/100 m/24 h in 2010 to 114 fish/100 m/24 h in 2012 (Figure 6-4).

Lake Whitefish

Lake Whitefish CPUE in Threepoint Lake showed little variability among sampling years and no increasing or decreasing trends. The mean CPUE over the 5-year period ranged from <1 fish/100 m/24 h in 2010 to 2 fish/100 m/24 h in 2013 (Figure 6-5).

Conversely, Lake Whitefish catches in Leftrook Lake varied considerably over the 5-year period (range of 7 fish/100 m/24 h in 2011 to 18 fish/100 m/24 h in 2012) compared to the on-system lake (Figure 6-5). However, there was no statistical difference in catches among sample years and no apparent increasing or decreasing trends in CPUE (Figure 6-10).

Northern Pike

With the exception of 2009, the CPUE of Northern Pike in Threepoint Lake was relatively consistent over the sampling period, ranging from 2 fish/100 m/24 h in 2012 to 5 fish/100 m/24 h in 2009, and there were no trends evident (Figures 6-6 and 6-11).

Northern Pike catches at the off-system lake were more variable over the 5-year period compared to the on-system lake. At Leftrook Lake, the annual CPUE ranged from 8 fish/100 m/24 h in 2010 to 15 fish/100 m/24 h in 2012 (Figure 6-6). As with the on-system lake, there were no significant inter-annual differences in CPUE in Leftrook Lake and no increasing or decreasing trend was apparent (Figure 6-11).

Walleye

The mean CPUE of Walleye in Threepoint Lake ranged from 7 fish/100 m/24 h in 2010 to 13 fish/100 m/24 h in 2013 (Figure 6-7). There were no significant inter-annual differences and no apparent trends in CPUE over the 5-year sampling period (Figure 6-12).

Like Northern Pike and Lake Whitefish, the CPUE of Walleye in the off-system Leftrook Lake was more variable than at the on-system lake (Figure 6-7). The mean CPUE at Leftrook Lake ranged from 14 fish/100 m/24 h in 2010 to 38 fish/100 m/24 h in 2012 (Figure 6-7).

White Sucker

There were no significant inter-annual differences in White Sucker CPUE and no indications of trends over the monitoring period in Threepoint Lake (Figures 6-8 and 6-13). Mean CPUE in Threepoint Lake was variable, with the lowest value in 2010 (7 fish/100 m/24 h) and the highest value in 2009 (12 fish/100 m/24 h).

The mean CPUE of White Sucker at Leftrook Lake varied little over the 5-year sampling period, fluctuating between 25 fish/100 m/24 h (2010) and 35 fish/100 m/24 h (2011), and there was no indication of increasing or decreasing trends (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 Churchill River Diversion Region

Lake Whitefish

Very few Lake Whitefish between 300 and 499 mm in fork length were captured from on-system waterbodies (Table 6-3). The mean Fulton’s condition factor of Lake Whitefish from Apussigamasi Lake in 2009, the only year where a sufficient number of Lake Whitefish were caught, was 1.74 (Figure 6-14).

Northern Pike

Mean Fulton’s condition factor for Northern Pike between 400 and 699 mm in fork length was similar among on-system waterbodies, ranging from 0.63 in Notigi Lake to 0.68 in Threepoint and Footprint lakes (Figure 6-15). There were insufficient numbers of Northern Pike captured in Rat and Apussigamasi lakes to include in the analysis. The condition of Northern Pike from the lakes upstream of the Notigi CS was generally poorer (i.e., had a lower mean number) compared to those sampled from the downstream lakes (Figure 6-15).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length ranged from 1.04 in Notigi Lake to 1.11 in Apussigamasi Lake (Figure 6-16). There were insufficient numbers of Walleye captured in Rat Lake to include in the analysis. The condition of Walleye from Notigi Lake and Central Mynarski Lake was lower than those from the lakes downstream of the Notigi CS (Figure 6-16). This difference was most notable for Apussigamasi Lake, where Walleye appeared to be in slightly better condition than the other waterbodies downstream of the Notigi CS.

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from on-system waterbodies ranged from 1.47 in Central Mynarski Lake to 1.58 in Rat Lake (Figure 6-17). The condition of White Sucker was generally similar among the on-system lakes (Figure 6-17).

6.2.3.2 Off-system Waterbodies: Leftrook Lake

Lake Whitefish

The mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length from Leftrook Lake was 1.52 (Table 6-3). The condition of Lake Whitefish from Leftrook Lake was lower than observed in Apussigamasi Lake, the only on-system lake where a sufficient sample size was obtained for detailed analysis of this metric (Figure 6-14).

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length from Leftrook Lake was 0.65 (Table 6-3). The condition of Northern Pike from Leftrook Lake was within the range observed in the on-system lakes (Figure 6-15).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from Leftrook Lake (1.04) was similar to the on-system waterbodies located upstream of the Notigi CS, but lower than those located downstream of the CS (Figure 6-16).

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from Leftrook Lake (1.48) was within the range observed at the on-system lakes (Figure 6-17).

6.2.3.3 Temporal Comparisons and Trends

Lake Whitefish

Too few Lake Whitefish were captured in Threepoint Lake in a given year (<20 fish) for statistical analysis of temporal variability of condition or evaluation of trends. In the off-system Leftrook Lake there were significant inter-annual differences in the condition of Lake Whitefish; the statistically highest values occurred in 2009 (1.60) and 2011 (1.59), and the significantly lowest value occurred in 2010 (1.42; Figure 6-18). Although there were some significant inter-annual differences, a consistent increasing or decreasing trend was not apparent in the off-system lake over the 5-year sampling period.

Northern Pike

Too few Northern Pike between 400 and 699 mm in fork length were captured in most years in Threepoint Lake (<20 fish) for statistical analysis or for evaluation of trends. The condition of Northern Pike was statistically higher in 2011 compared to 2009, 2010, and 2013 (Figure 6-19). Although there were some significant inter-annual differences, a consistent increasing or decreasing trend was not apparent in either on- or off-system waterbodies over the 5-year sampling period.

Walleye

There were no increasing or decreasing trends evident for the condition of Walleye from Threepoint Lake. The mean condition of Walleye ranged between 1.10 (2009 and 2013) and 1.00 (2012; Figures 6-16 and 6-20). Walleye condition values in 2009 and 2013 were statistically highest at approximately 1.10, and were statistically higher than values in 2010 and 2011, which were approximately 1.05, and statistically lowest in 2012 at approximately 1.00 (Figure 6-20).

The condition of fish from the annual off-system lake, Leftrook Lake, was variable over the 5-year sampling period, with annual means ranging from 1.01 in 2013 to 1.10 in 2011 (Figure 6-16). Condition was significantly highest in 2011 compared to other years (Figure 6-20). A consistent increasing or decreasing trend was not apparent over the 5-year sampling period.

White Sucker

Although there were no trends apparent over the 5-year monitoring period, the condition of White Sucker varied significantly between years in Threepoint Lake, ranging from 1.47 in 2011 and 2012 to 1.54 in 2010 (Figure 6-17). There were significant inter-annual differences in the K_F, with values measured in 2010 and 2013 being significantly higher than those in 2011 and 2012 (Figure 6-21).

At the annual off-system lake (Leftrook Lake) the condition of fish ranged from a high of 1.51 in 2011 to a low of 1.45 in 2012 (Figure 6-17). Values obtained in 2011 were statistically higher than in 2009, 2010, and 2012, while those in 2012 were also significantly lower than those in 2009 and 2013 (Figure 6-21). There were no trends in White Sucker condition evident for Leftrook Lake.

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. The 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 estimated 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 Churchill River Diversion Region

Lake Whitefish

The few Lake Whitefish captured in the annually sampled on-system lake ranged from 3 to 30 years, with most fish captured over the 5-year sampling period determined to be between 4 and 9 years (Figure 6-22). The mean length increased to age 7 (from 222 mm at age 3 to 400 mm at age 7), after which the mean fork length-at-age fluctuated between 389 and 483 mm (Figure 6-22).

Since very few Lake Whitefish were captured in on-system lakes, there were not many individuals from which to calculate the growth metric (i.e., length-at-age 4 and 5; Table 6-3). The mean length-at-age 4 was 315 mm in Notigi Lake (n = 4 fish) and 321 mm in

Apussigamasi Lake (n = 6 fish; Figure 6-23) and the mean length-at-age 5 was 304 mm in Notigi Lake (n = 4 fish; Figure 6-24). There were insufficient data for this metric for Threepoint, Rat, Central Mynarski, and Footprint lakes (i.e., fewer than 3 fish captured in waterbody per year).

Northern Pike

Northern Pike captured in Threepoint Lake ranged from 1 to 13 years of age, with most of the fish captured over the 5-year sampling period determined to be between 3 and 6 years of age (Figure 6-25). The mean length increased to age 11, from 229 mm at age 1 to 871 mm at age 11.

The mean length of 4-year-old Northern Pike ranged from a low of 385 mm in Threepoint Lake to a high of 394 mm in Footprint Lake (Figure 6-26). There were an insufficient number of 4-year-old pike captured in Apussigamasi Lake to include in the analysis (Table 6-3). The length-at-age 4 of Northern Pike was consistent among on-system lakes, as indicated by the overlap in the box plots among waterbodies (Figure 6-26).

Walleye

Walleye captured in Threepoint Lake ranged from 1 to 22 years, with most of the catch determined to be between 5 and 15 years (Figure 6-27). The mean length increased to age 9, from 137 mm at age 1 to 362 mm at age 9, after which the mean fork length-at-age fluctuated between 359 and 429 mm.

Very few 3-year-old Walleye were captured in the on-system lakes (Table 6-3). The mean length of the few 3-year-old Walleye ranged from a low of 193 mm in Threepoint Lake to a high of 256 mm in Rat Lake (Figure 6-28).

6.2.4.2 Off-system Waterbodies: Leftrook Lake

Lake Whitefish

Similar to what was observed in the on-system lake, Lake Whitefish captured in the annually sampled off-system lake ranged from 3 to 29 years of age, with most of the fish captured over the 5-year sampling period determined to be between 4 and 10 years of age (Figure 6-22). The mean length increased to age 11 (from 315 mm at age 3 to 450 mm at age 11), after which the mean fork length-at-age fluctuated between 444 and 479 mm. Lake Whitefish from Leftrook Lake were generally longer at age than those from Threepoint Lake until about 11 years of age, after which fish from both lakes obtained about the same length-at-age.

Four-year-old Lake Whitefish from Leftrook Lake averaged 335 mm in length and age 5 Lake Whitefish averaged 374 mm (Figures 6-23 and 6-24). Too few 4- and 5-year-old Lake Whitefish were captured in the on-system waterbodies to allow for a comparison to Leftrook Lake (Table 6-3).

Northern Pike

Similar to what was observed in the on-system lake, Northern Pike captured at the annually sampled off-system lake ranged from 1 to 15 years of age, with most of the fish captured over the 5-year sampling period determined to be between 3 and 7 years of age (Figure 6-25). With the exception of 1-year-old fish, the mean length-at-age of Northern Pike increased for every age, from 328 mm at age 2 to 835 mm at age 15. Northern Pike from Leftrook Lake were generally longer than those from Threepoint Lake during the early years (1-5 years), but after age 8, pike from Threepoint Lake obtained a higher mean length-at-age.

The length-at-age 4 of Northern Pike from Leftrook Lake (437 mm) was considerably higher than observed in the on-system lakes (Figure 6-26).

Walleye

Walleye captured in the annually sampled off-system lake ranged from 2 to 28 years, with most of the catch determined to be between 3 and 15 years (Figure 6-27). The mean length increased to age 16 (from 212 mm at age 2 to 398 mm at age 16), after which the fork length fluctuated between 371 and 470 mm. Walleye from Leftrook Lake generally obtained a similar mean fork length-at-age as those from Threepoint Lake.

At age 3, Walleye from Leftrook Lake averaged 221 mm in length (Table 6-3). The length-at-age 3 of Walleye from Leftrook Lake was within the range of the few individuals sampled from the on-system lakes (Table 6-3).

6.2.4.3 Temporal Comparisons and Trends

Lake Whitefish

Insufficient numbers of 4- and 5-year-old Lake Whitefish were captured in Threepoint Lake, the on-system lake that was monitored annually, over the 5-year sampling period to calculate an annual length-at-age 4 and 5.

At the off-system lake (Leftrook Lake), the length-at-age metric for Lake Whitefish was highest in 2012 and 2013 for both 4- and 5-year-olds (Figures 6-23 and 6-24). Four-year-olds averaged 338 mm in 2009, decreased to 315 mm in 2011, after which the mean length increased to

375 mm in 2013. An increasing trend was observed for the length of 5-year-olds from 2010 (349 mm) to 2013 (393 mm). Four-year-old fish were significantly longer in 2013 compared to 2011 and 5-year-old fish were significantly longer in 2012 and 2013 compared to 2010 (Figures 6-29 and 6-30).

Northern Pike

There has been considerable variation in the annual mean length-at-age 4 of Northern Pike in Threepoint Lake, the on-system lake that was monitored annually (Figure 6-26). The length-at-age 4 ranged from a low of 353 mm in 2011 to a high of 411 in 2010. The length of 4-year-old Northern Pike captured in 2010 and 2011 were significantly different from one another although no increasing or decreasing trend was apparent (Figure 6-31).

The fork length-at-age of Northern Pike in the off-system lake showed a similar range of inter-annual variation as in the on-system lake over the 5-year sampling period (Figure 6-26). Four-year-olds from Leftrook Lake ranged from an average of 422 mm in 2012 to 461 mm in 2013 (Figure 6-26). The length-at-age was statistically higher in 2013 compared to 2011 and 2012 although no increasing or decreasing trend in length-at-age 4 was apparent (Figure 6-31).

Walleye

Insufficient numbers of 3-year-old Walleye were captured at Threepoint Lake to calculate an annual length-at-age 3.

At Leftrook Lake, the annual mean fork length-at-age 3 ranged from 191 mm in 2009 to 236 mm in 2013 (Figure 6-28). Three-year-old fish were significantly shorter in 2009 compared to the subsequent sampling years although no increasing or decreasing trend in length-at-age 4 was apparent (Figure 6-32).

6.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

The other fish community metric measured under CAMP, as described in Technical Document 1, Section 4.6, that was reviewed to assess trends was relative abundance. Information on this metric is included here since the analyses conducted for RCEA on a longer term dataset indicated that a shift in species composition may have occurred in several of the hydro-affected waterbodies over time (Manitoba Hydro and the Province of Manitoba 2015).

The relative abundance of fish species captured in standard gang index gill nets set at CAMP waterbodies over the period of 2009-2013 is shown in Figure 6-33. Walleye and White Sucker dominated catches in standard gangs over the 5-year sampling period. Sauger and Northern Pike were also relatively common in most on-system lakes. There were some waterbody-specific differences in species composition: Cisco were generally more abundant in the tributary lakes (Central Mynarski and Footprint lakes); Mooneye (*Hiodon tergisus*) were only observed in Apussigamasi Lake; Shorthead Redhorse (*Moxostoma macrolepidotum*) were only observed in Threepoint and Apussigamasi lakes; and Longnose Sucker (*Catostomus catostomus*) were only observed in lakes on the direct flow of the Rat/Burntwood River. The species composition in Leftrook Lake differed considerably from the on-system lakes in that Lake Whitefish made up a large proportion of the catch and Sauger were not captured.

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 Threepoint Lake using water level data from a gauge on Threepoint Lake and discharge data from Notigi CS that were provided by Manitoba Hydro and fish community metrics indicated no statistically significant relationships (Table 6-4). Hydrologic data from Leftrook Lake was only available for the final four years of the six-year period of record and no attempt was made to relate hydrological variables to fish community metrics for this waterbody.

6.5 SUMMARY

A few of the key findings of the five years of CAMP monitoring in the region include:

- The most common large-bodied species in each of the on-system waterbodies of the CRDR were Walleye and White Sucker;
- The diversity of the fish community, as indicated by the Hill's index, was higher at lakes directly on the Rat/Burntwood River flows (Rat, Notigi, Threepoint, and Apussigamasi lakes) compared to tributary lakes (Central Mynarski and Footprint lakes);
- In contrast, the abundance of large-bodied fish was generally higher in tributary waterbodies compared to the lakes on the mainstem of the Rat/Burntwood River;
- The condition of Northern Pike and Walleye was generally lower in Notigi Lake compared to the lakes downstream of the Notigi CS; and

- The early growth of Northern Pike was generally consistent among diversion route lakes as shown by a similar mean fork length-at-age 4.

Analysis of five years of data has not indicated any obvious temporal trends for the fish community metrics measured over the period of 2009-2013. While there has been considerable variability in the metrics among sampling years, statistical comparisons between sampling years for the metrics for which analysis was possible revealed few significant differences at the on-system annual site.

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

Location	**Site Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
						2008	**2009**	**2010**	**2011**	**2012**	**2013**
Rat Lake	RAT	X			X			X			X
Central Mynarski Lake	MYN	X			X				X		
Notigi Lake	NTG	X			X		X			X	
Threepoint Lake	3PT	X		X			X	X	X	X	X
Footprint Lake	FOOT	X			X			X			X
Apussigamasi Lake	APU	X			X		X			X	
Leftrook Lake	LEFT		X	X			X	X	X	X	X

Table 6-2. Fish species captured in standard gang index and small mesh index gill nets set in Churchill River Diversion Region waterbodies: 2009-2013.

Species	**Abbreviation**	**RAT** n_Y=2	**MYN** n_Y=1	**NTG** n_Y=2	**3PT** n_Y=5	**FOOT** n_Y=2	**APU** n_Y=2	**LEFT** n_Y=5
Goldeye	GOLD						X*	
Mooneye	MOON						X	
Lake Chub	LKCH						X*	
Emerald Shiner	EMSH	X	X	X	X	X	X	X
Spottail Shiner	SPSH	X	X	X	X	X	X	X
Longnose Sucker	LNSC	X		X	X		X	
White Sucker	WHSC	X	X	X	X	X	X	X
Shorthead Redhorse	SHRD				X	X*	X	
Northern Pike	NRPK	X	X	X	X	X	X	X
Cisco	CISC	X	X	X	X	X	X	X
Lake Whitefish	LKWH	X		X	X	X	X	X
Trout-perch	TRPR	X	X	X	X	X	X	X
Burbot	BURB	X	X	X	X	X*	X	X*
Slimy Sculpin	SLSC			X*				
Spoonhead Sculpin	SPSC		X					
Yellow Perch	YLPR	X	X	X	X	X	X	X
Logperch	LGPR			X*				
Sauger	SAUG	X		X	X	X	X	
Walleye	WALL	X	X	X	X	X	X	X

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

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 Churchill River Diversion Region waterbodies, 2009-2013.

Component	Waterbody	Hill's Index			CPUE[1]			K_F			FL_{at-age}[2]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
Diversity	RAT	2	7.5	0.3	-	-	-	-	-	-	-	-	-
	MYN	1	5.7	-	-	-	-	-	-	-	-	-	-
	NTG	2	7.2	0.3	-	-	-	-	-	-	-	-	-
	3PT	5	7.0	0.5	-	-	-	-	-	-	-	-	-
	FOOT	2	5.7	0.3	-	-	-	-	-	-	-	-	-
	APU	2	8.0	0.2	-	-	-	-	-	-	-	-	-
	LEFT	5	6.8	0.3	-	-	-	-	-	-	-	-	-
Standard gang	RAT	-	-	-	570	32.6	6.9	-	-	-	-	-	-
	MYN	-	-	-	575	59.8	-	-	-	-	-	-	-
	NTG	-	-	-	591	28.1	3.3	-	-	-	-	-	-
	3PT	-	-	-	1604	29.2	2.4	-	-	-	-	-	-
	FOOT	-	-	-	1045	49.4	5.2	-	-	-	-	-	-
	APU	-	-	-	806	40.2	3.0	-	-	-	-	-	-
	LEFT	-	-	-	3913	90.4	6.8	-	-	-	-	-	-
Small mesh	RAT	-	-	-	240	48.4	14.6	-	-	-	-	-	-
	MYN	-	-	-	206	74.7	-	-	-	-	-	-	-
	NTG	-	-	-	129	22.0	11.0	-	-	-	-	-	-
	3PT	-	-	-	1299	69.9	16.6	-	-	-	-	-	-
	FOOT	-	-	-	198	33.6	6.2	-	-	-	-	-	-
	APU	-	-	-	304	52.8	7.2	-	-	-	-	-	-
	LEFT	-	-	-	2197	189.1	53.9	-	-	-	-	-	-
Lake Whitefish	RAT	-	-	-	4	0.3	0.1	1	2.02	-	-	-	-
											-	-	-
	MYN	-	-	-	0	0.0	-	-	-	-	-	-	-
											-	-	-
	NTG	-	-	-	23	1.1	0.5	16	1.75	0.20	4	315	-
											4	304	-
	3PT	-	-	-	51	0.9	0.2	45	1.44	0.04	4	286	9
											5	350	7
	FOOT	-	-	-	3	0.2	0.04	1	1.53	-	-	-	-

Table 6-3. continued.

Component	Waterbody	Hill's Index			CPUE[1]			K_F			FL_{at-age}[2]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
											-	-	-
	APU	-	-	-	63	3.1	0.6	46	1.66	0.05	6	321	7
											2	408	-
	LEFT	-	-	-	530	12.1	1.8	513	1.52	0.03	27	335	12
											71	374	8
Northern Pike	RAT	-	-	-	50	2.7	0.3	28	0.63	<0.01	15	389	12
	MYN	-	-	-	72	7.5	-	60	0.64	-	8	393	-
	NTG	-	-	-	105	5.0	0.2	43	0.63	0.01	32	390	3
	3PT	-	-	-	160	2.8	0.5	83	0.66	0.01	43	385	9
	FOOT	-	-	-	99	4.9	0.7	59	0.68	0.01	33	394	17
	APU	-	-	-	27	1.3	0.6	11	0.69	0.04	3	420	4
	LEFT	-	-	-	494	11.1	1.2	458	0.65	0.01	103	437	6
Walleye	RAT	-	-	-	145	8.2	4.0	16	1.07	-	5	238	13
	MYN	-	-	-	128	13.3	-	68	1.05	-	2	200	-
	NTG	-	-	-	114	5.4	0.8	106	1.04	0.01	-	-	-
	3PT	-	-	-	527	9.6	0.9	444	1.06	0.02	8	222	13
	FOOT	-	-	-	419	19.5	3.2	363	1.06	<0.01	16	233	12
	APU	-	-	-	264	13.1	1.8	237	1.11	0.01	11	217	6
	LEFT	-	-	-	1119	26.1	3.6	1036	1.04	0.02	56	221	9
White Sucker	RAT	-	-	-	175	9.7	3.5	165	1.58	<0.01	-	-	-
	MYN	-	-	-	198	20.7	-	181	1.47	-	-	-	-
	NTG	-	-	-	217	10.4	4.5	48	1.58	0.03	-	-	-
	3PT	-	-	-	504	9.3	0.9	365	1.50	0.01	-	-	-
	FOOT	-	-	-	221	10.6	2.8	212	1.50	<0.01	-	-	-
	APU	-	-	-	154	7.8	0.2	131	1.58	0.02	-	-	-
	LEFT	-	-	-	1326	30.5	1.7	1261	1.48	0.01	-	-	-

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

[2] Fork length (FL)s 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 (age 4 is presented above age 5)

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 Churchill River Diversion Region waterbodies sampled annually between 2009 and 2013.

Metric	Species	Waterbody	Hydrology Metric	df	F	p	R^2	Direction
No Significant Results								

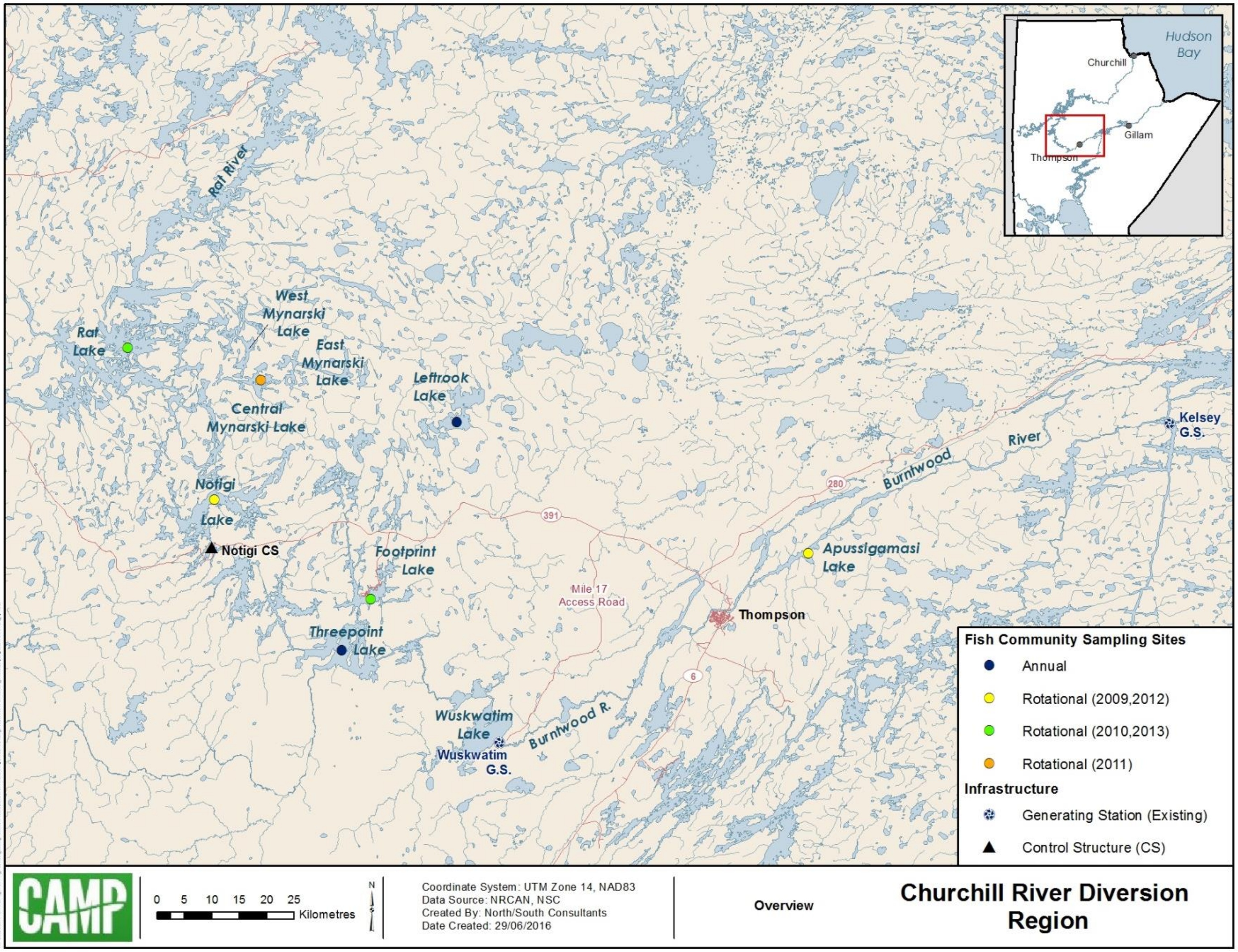
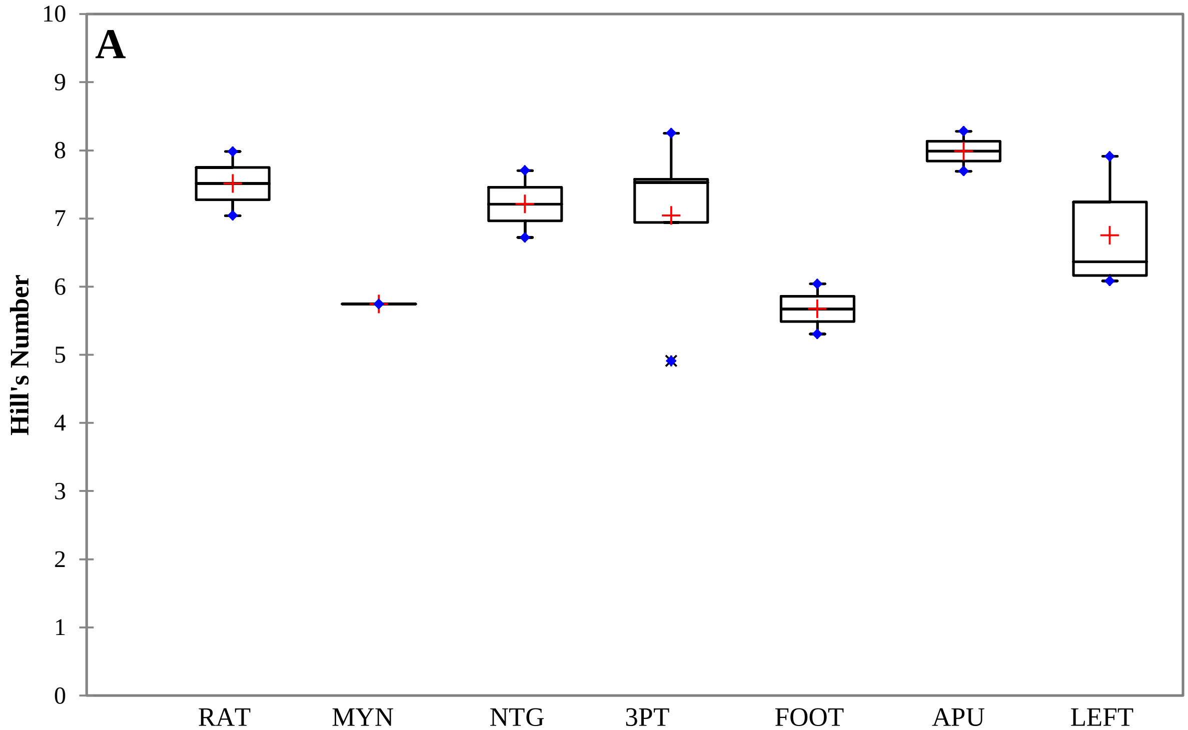


Figure 6-1. Waterbodies sampled along the Churchill River Diversion Route: 2009-2013.



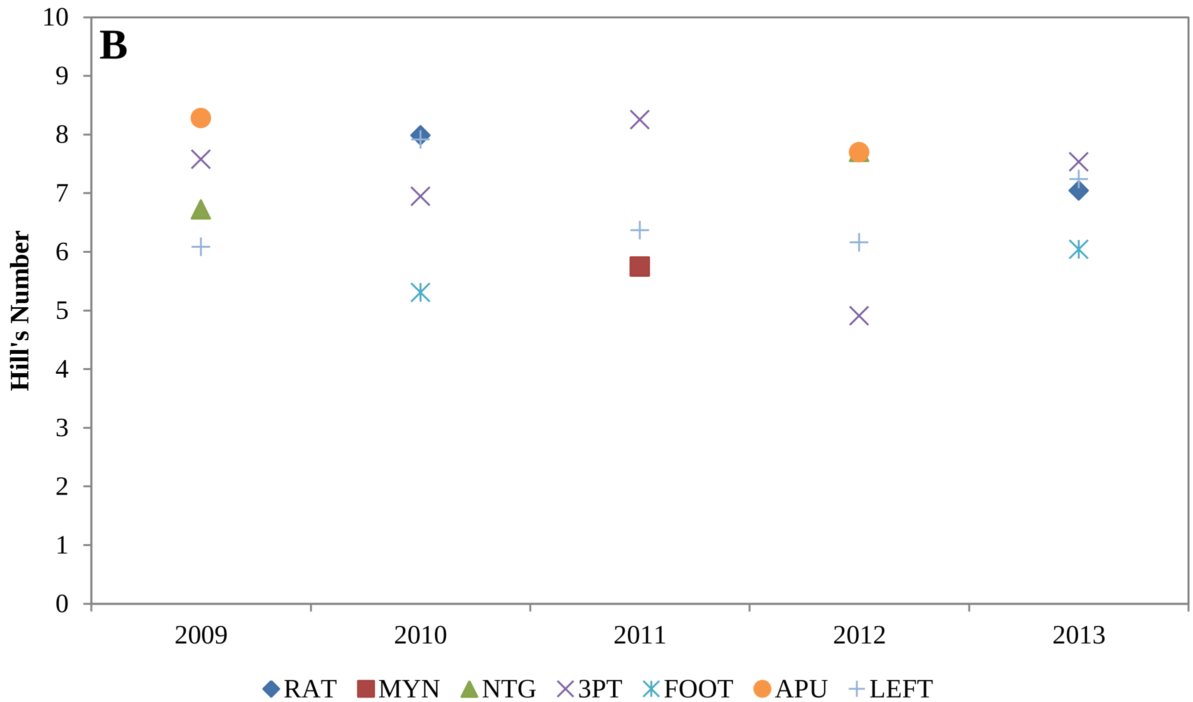


Figure 6-2. Annual mean Hill's effective species richness index (Hill Number) for standard gang and small mesh index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).

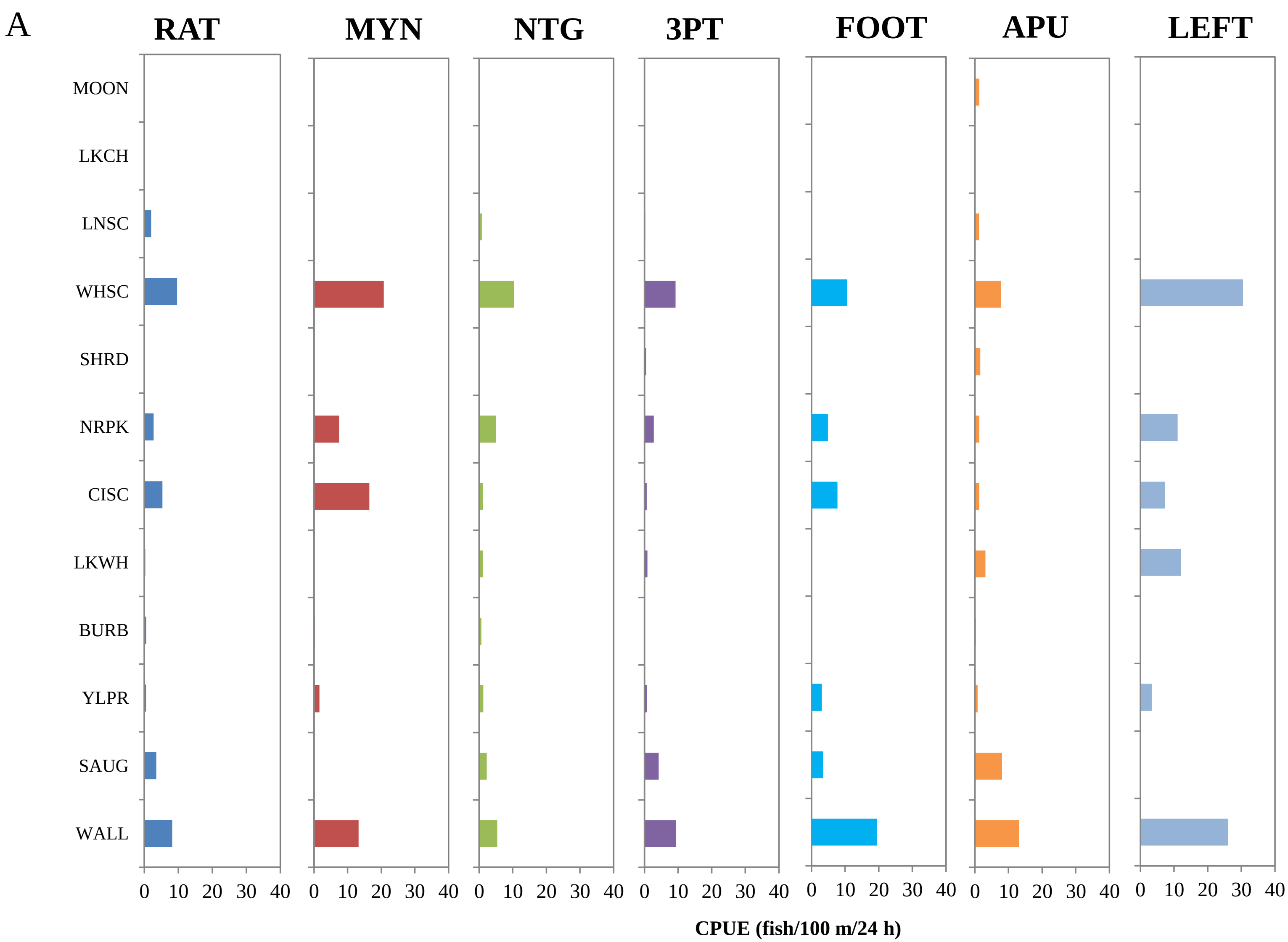


Figure 6-3. Mean catch-per-unit-effort in (A) standard gang (fish/100 m/24 h) and (B) small mesh (fish/30 m/24 h) index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013.

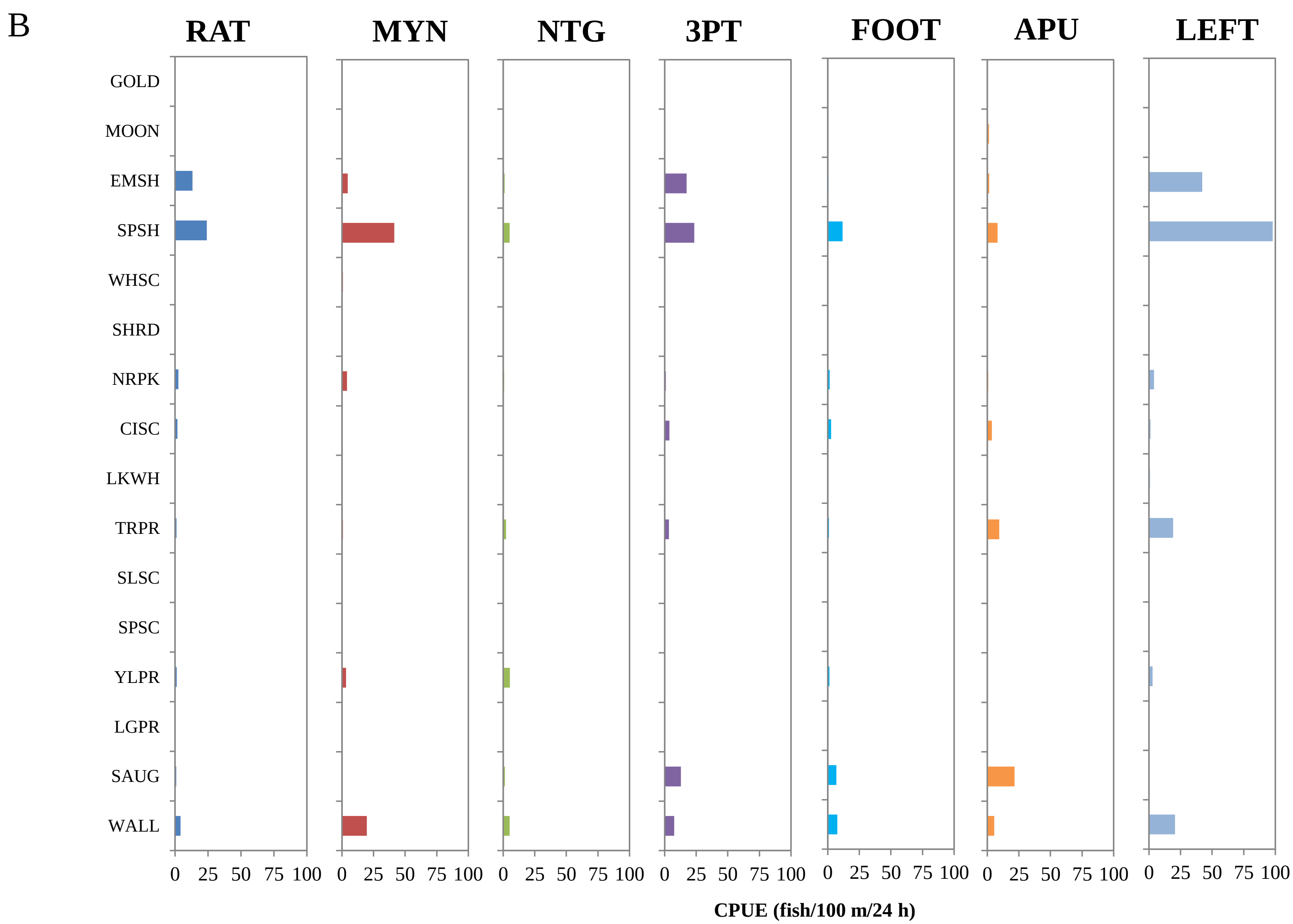


Figure 6-3. continued.

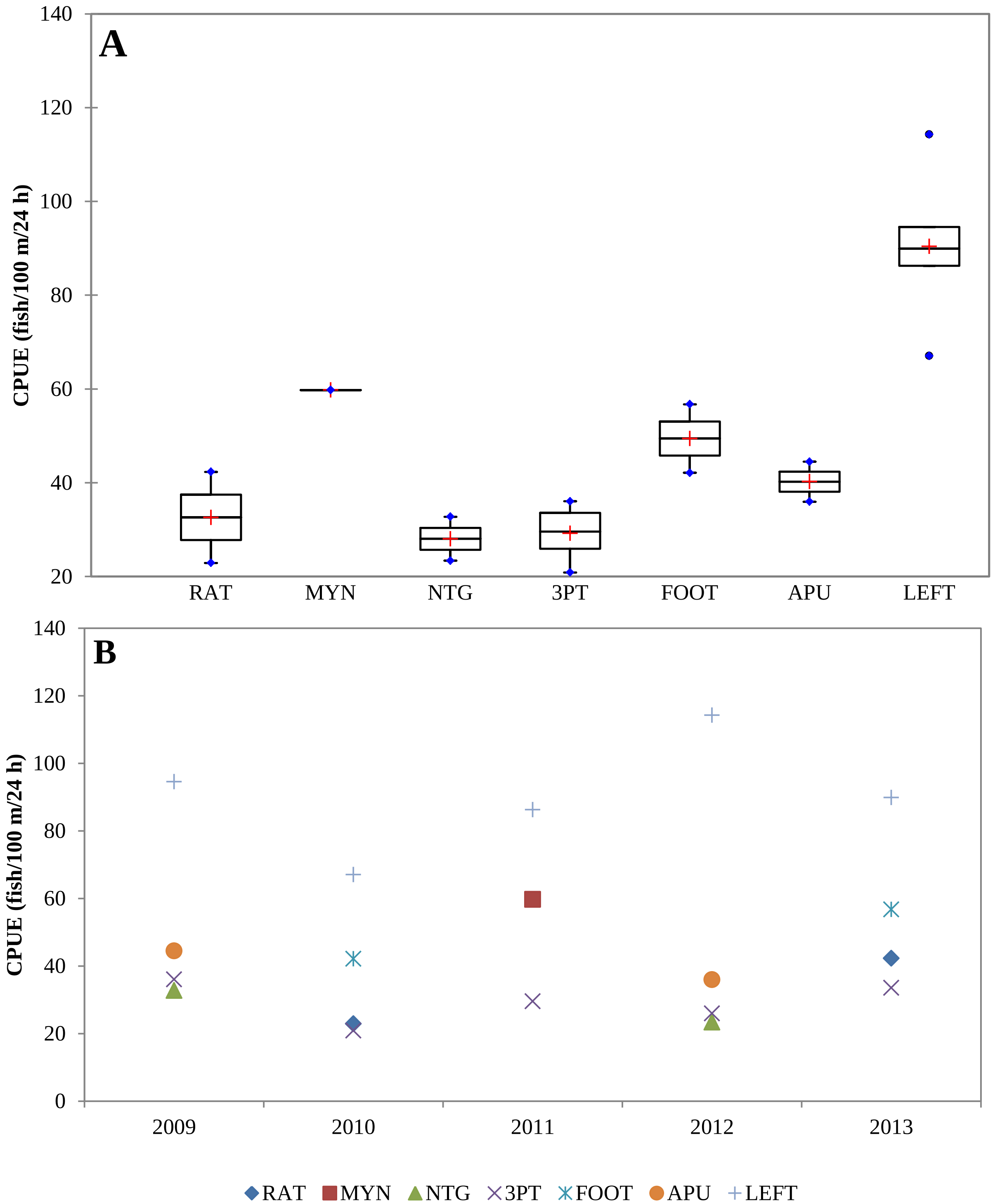


Figure 6-4. Annual mean catch-per-unit-effort (CPUE) calculated for the total catch in standard gang index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).

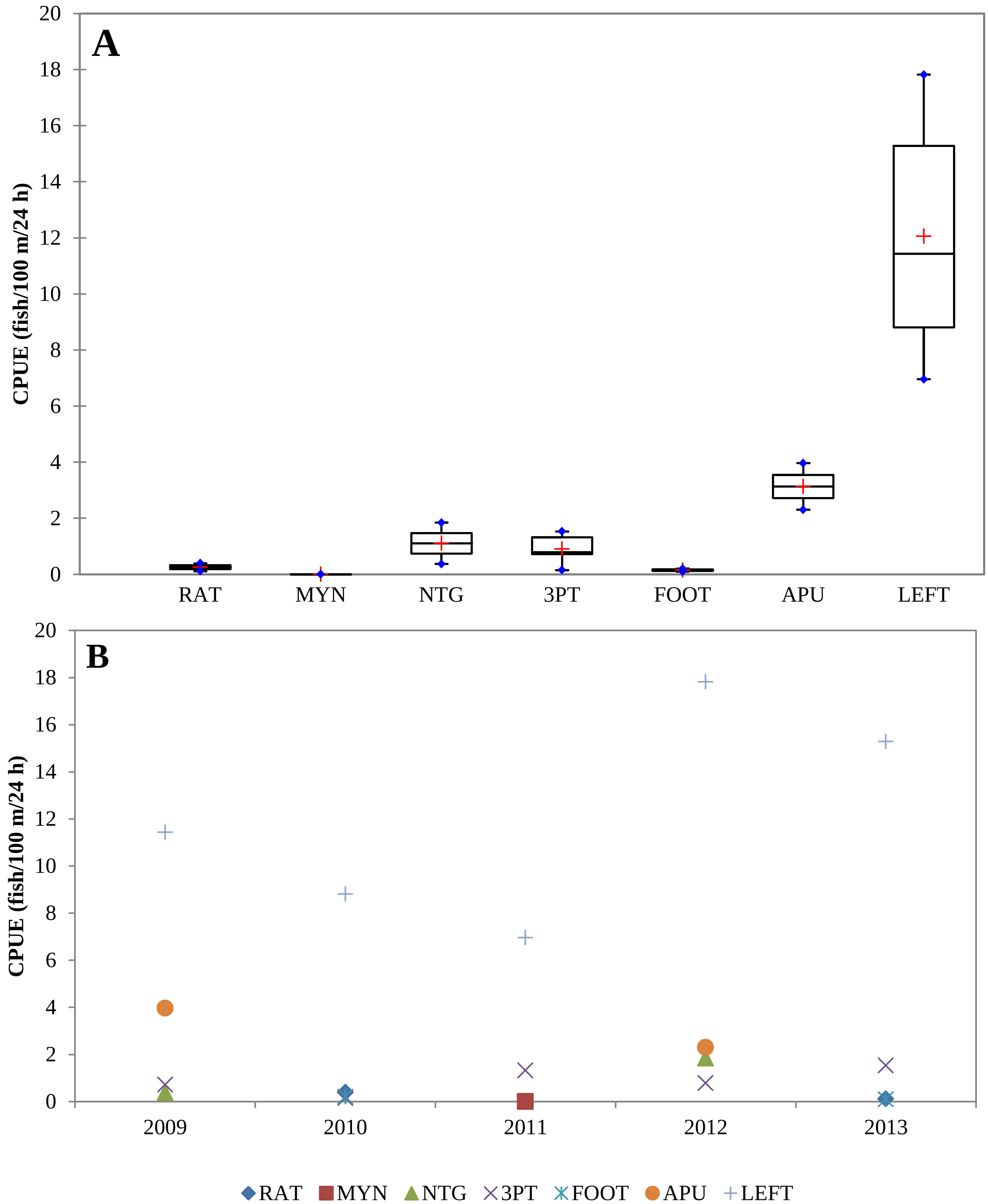


Figure 6-5. Annual mean catch-per-unit-effort (CPUE) calculated for Lake Whitefish captured in standard gang index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).

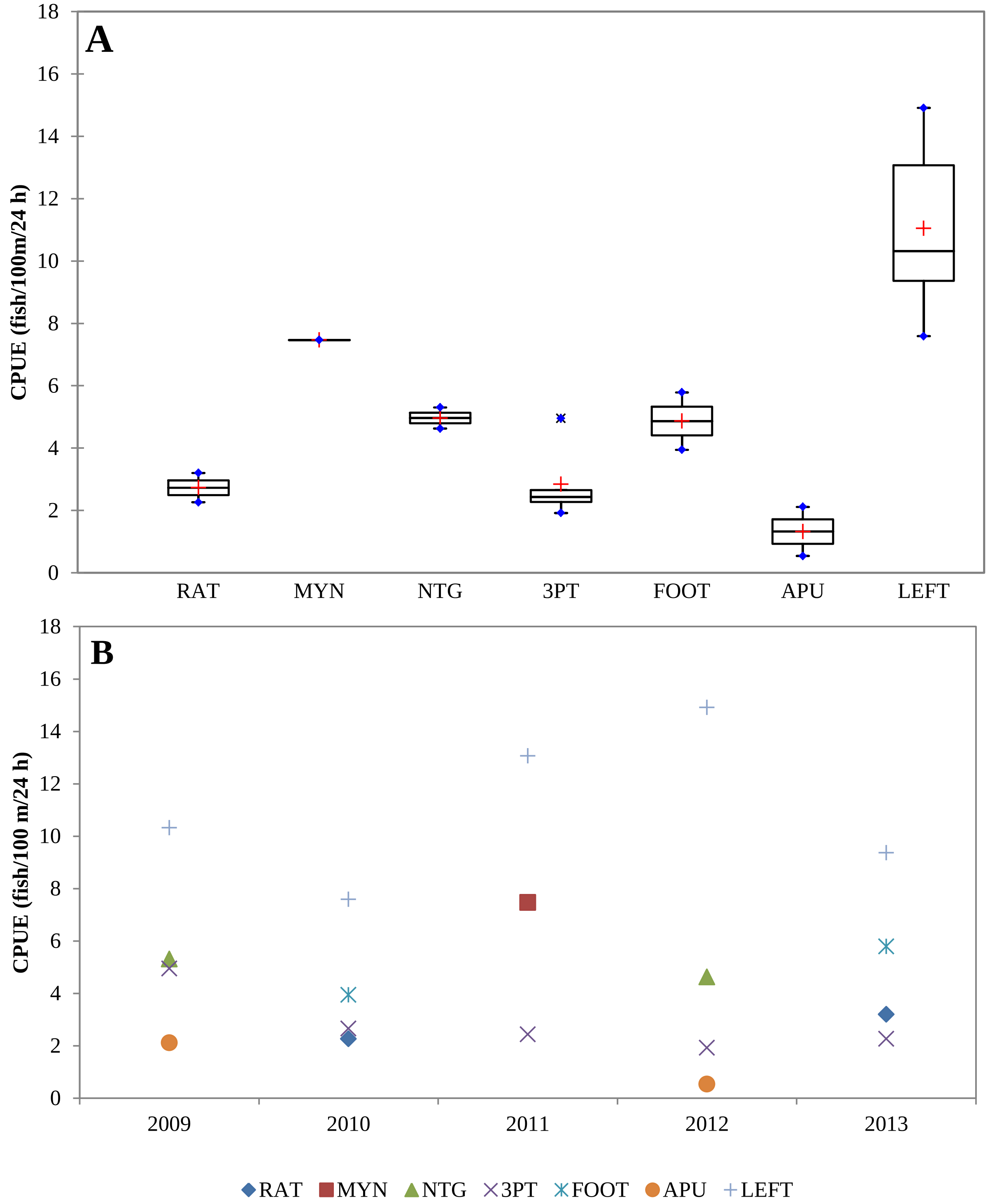


Figure 6-6. Annual mean catch-per-unit-effort (CPUE) calculated for Northern Pike captured in standard gang index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).

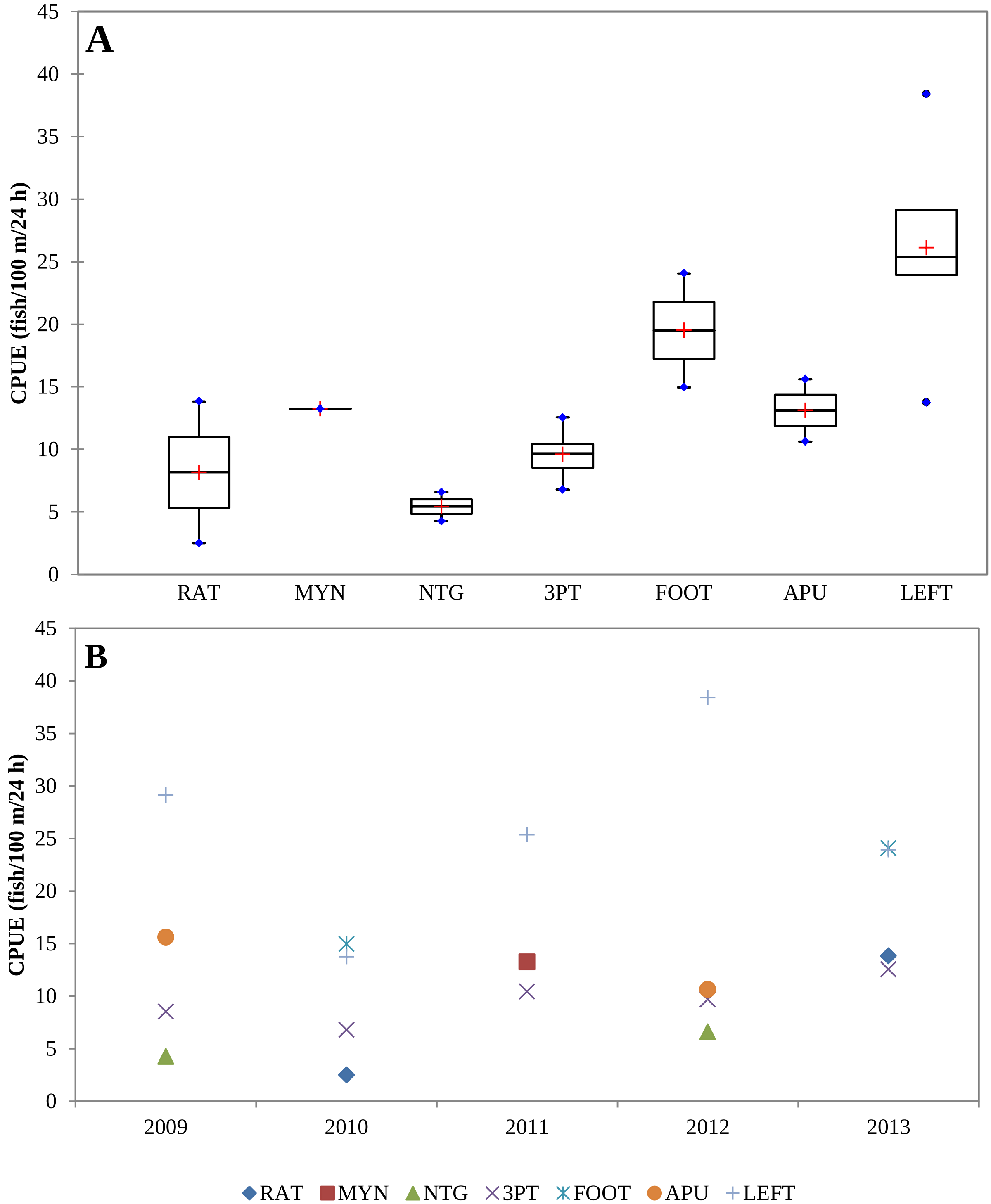


Figure 6-7. Annual mean catch-per-unit-effort (CPUE) calculated for Walleye captured in standard gang index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).

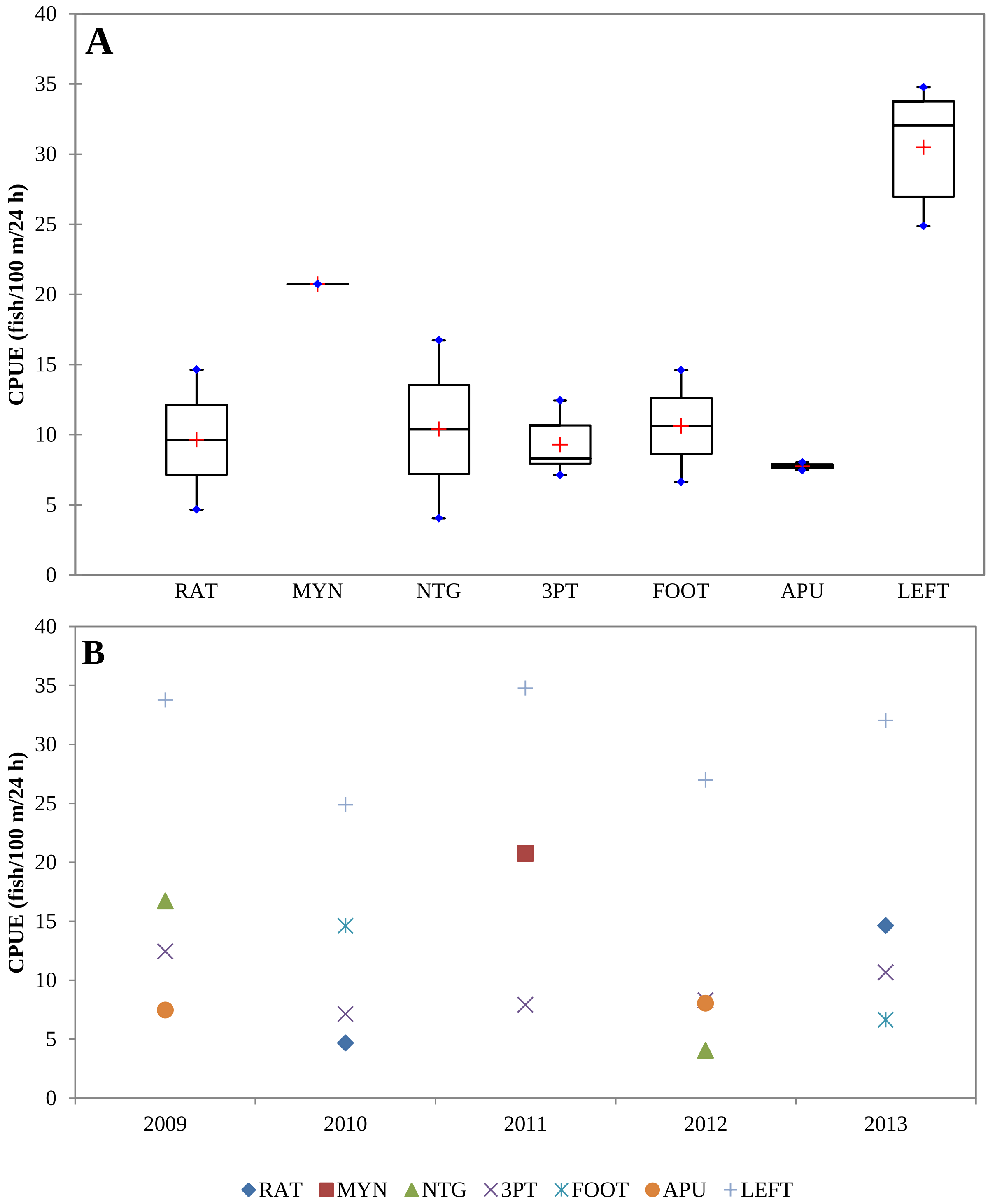
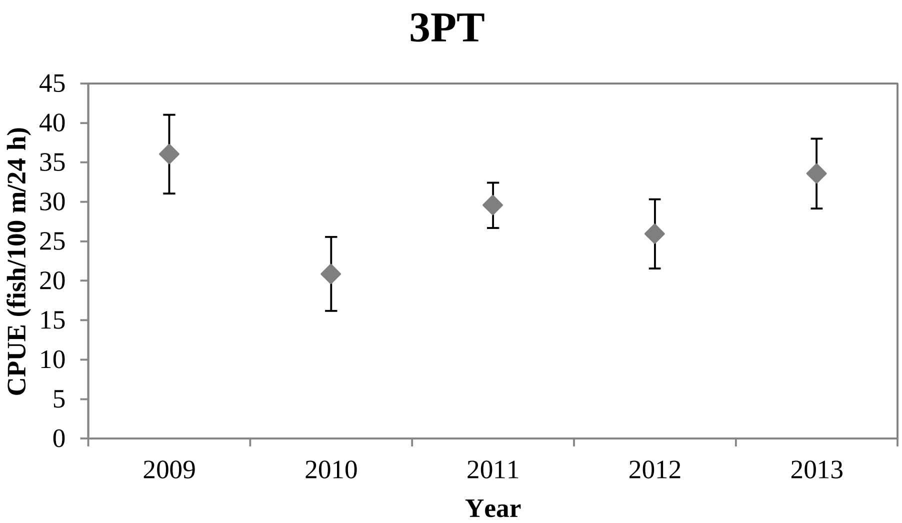


Figure 6-8. Annual mean catch-per-unit-effort (CPUE) calculated for White Sucker captured in standard gang index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).



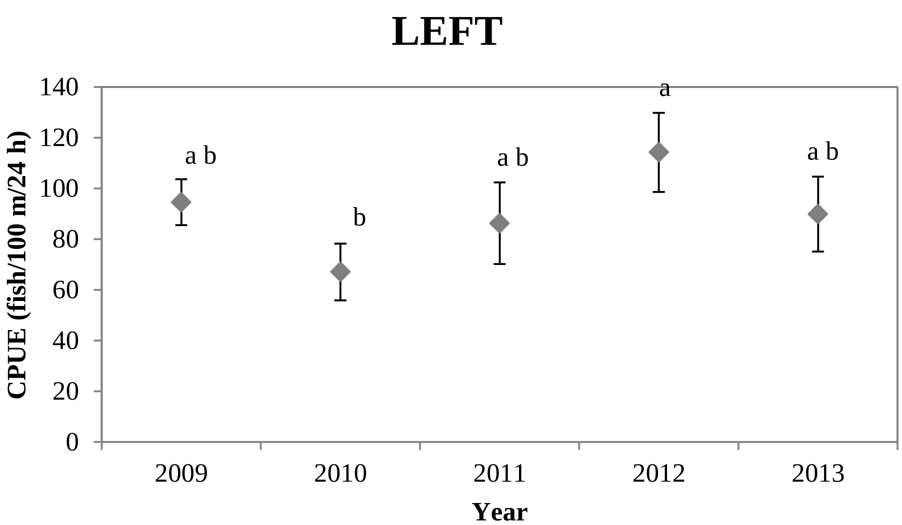
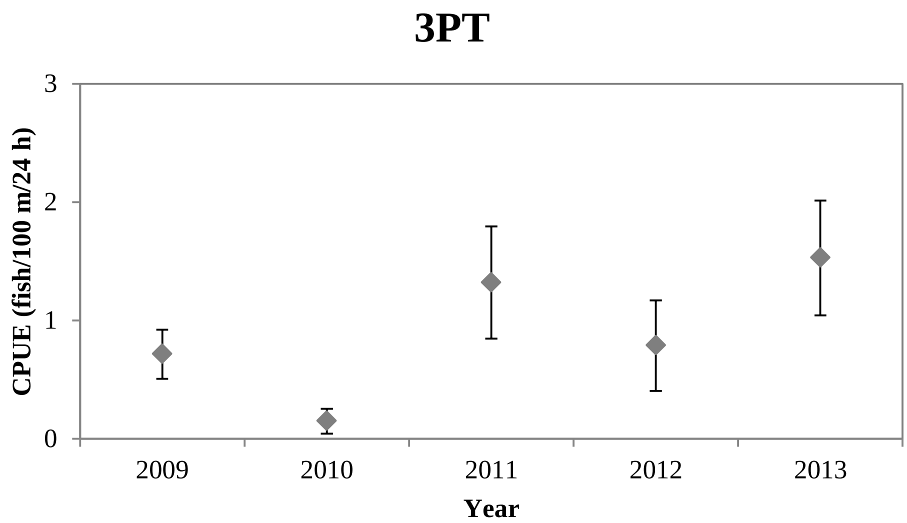


Figure 6-9. Total catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no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



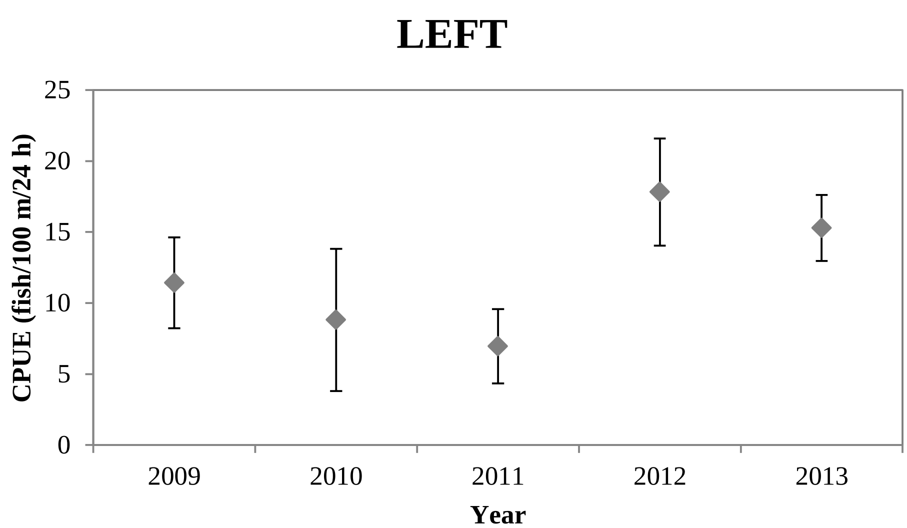


Figure 6-10. Lake Whitefish catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

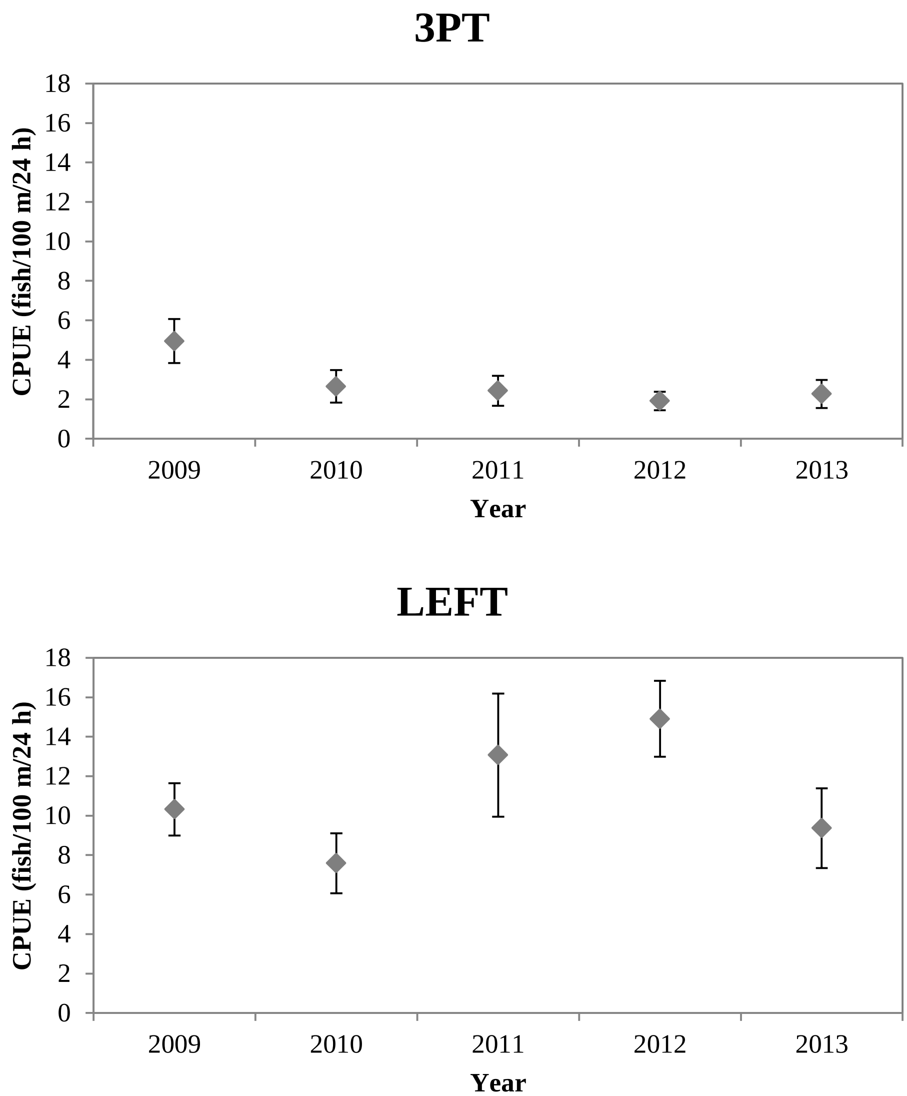


Figure 6-11. Northern Pike catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts,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

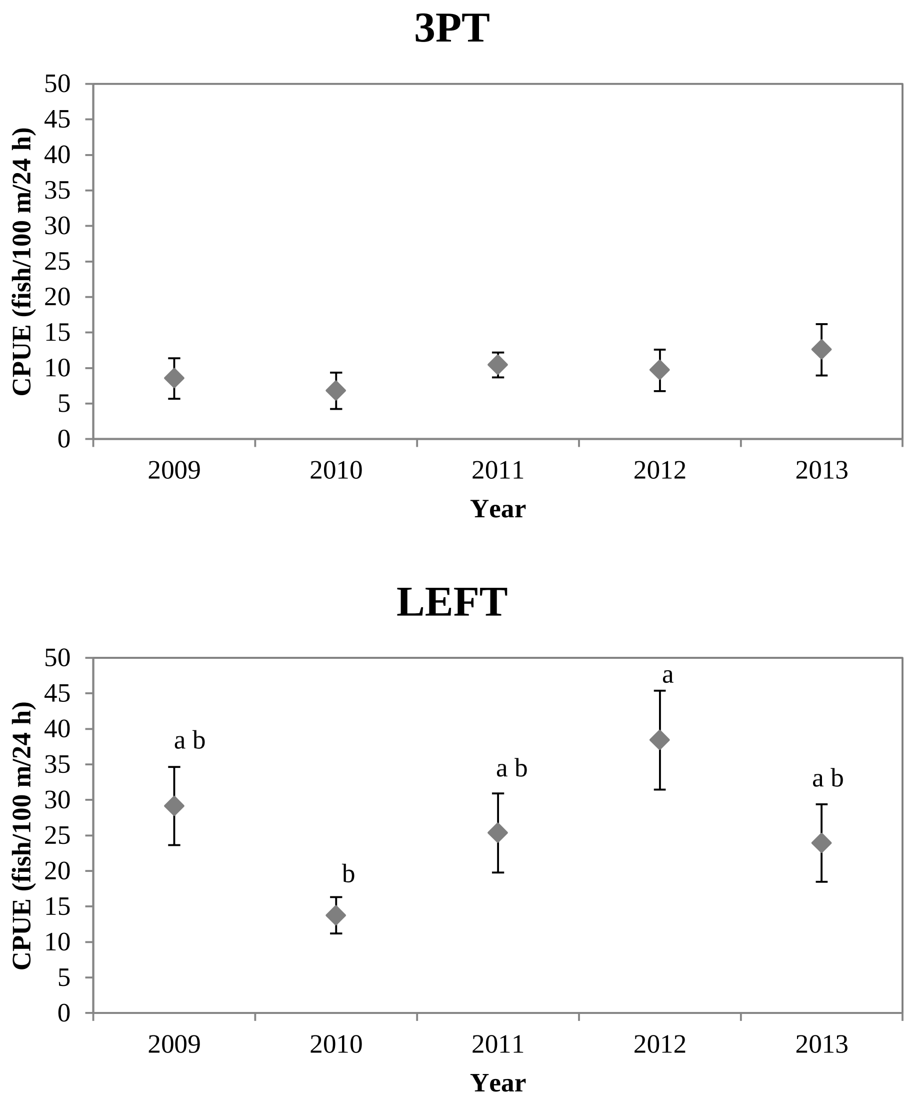
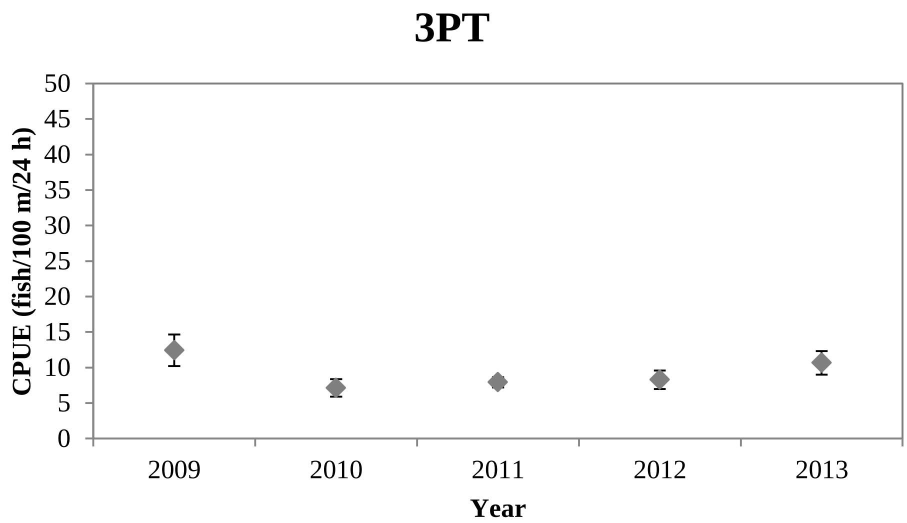


Figure 6-12. Walleye catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote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



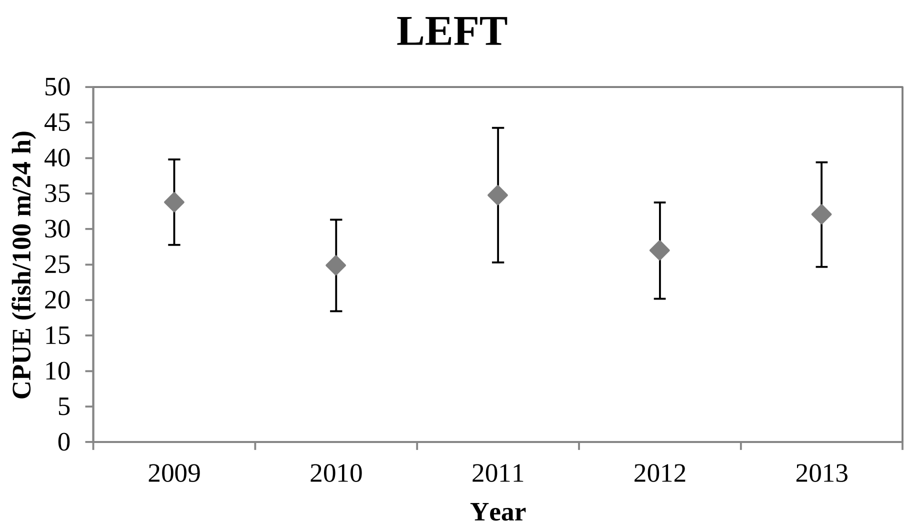
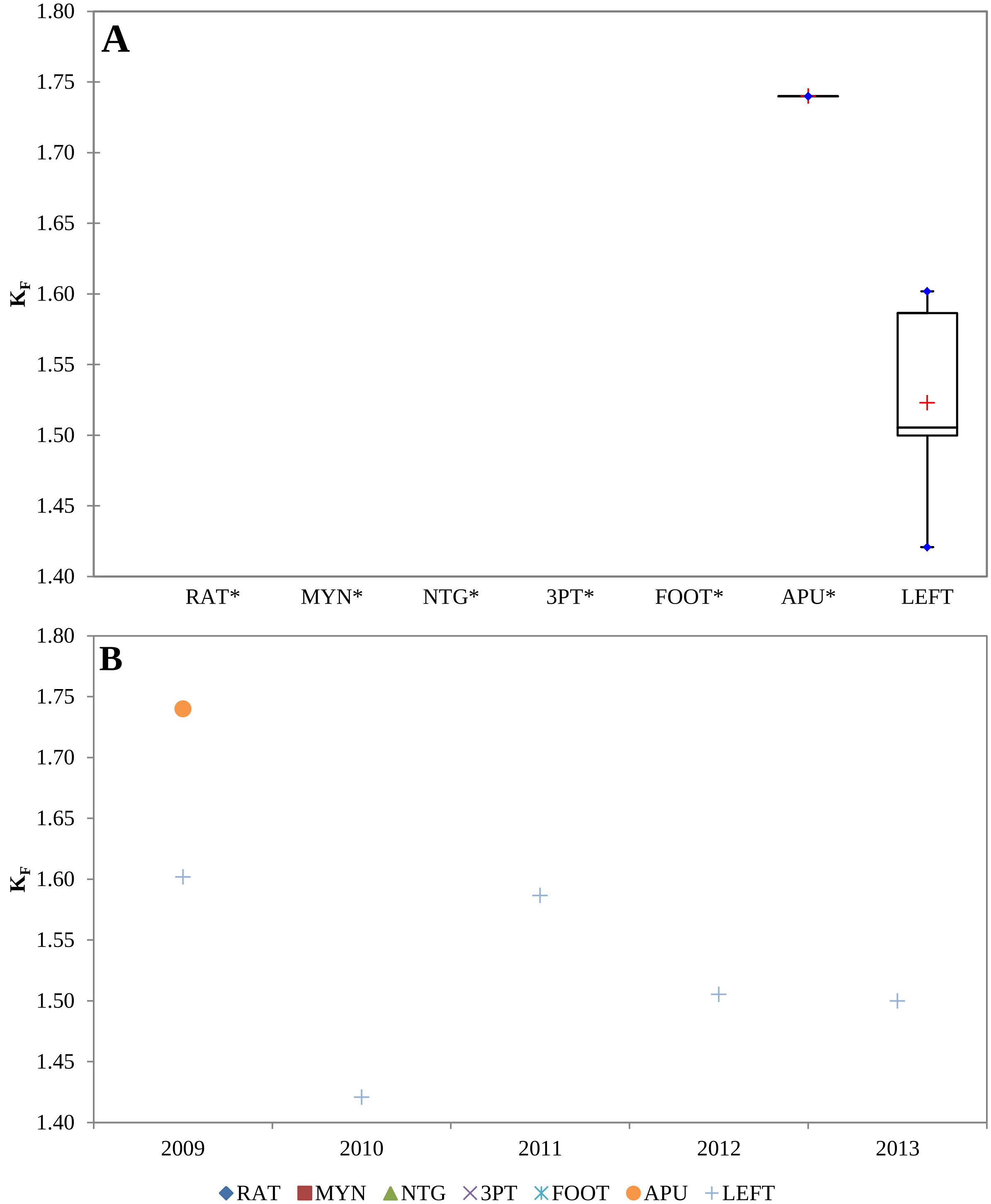
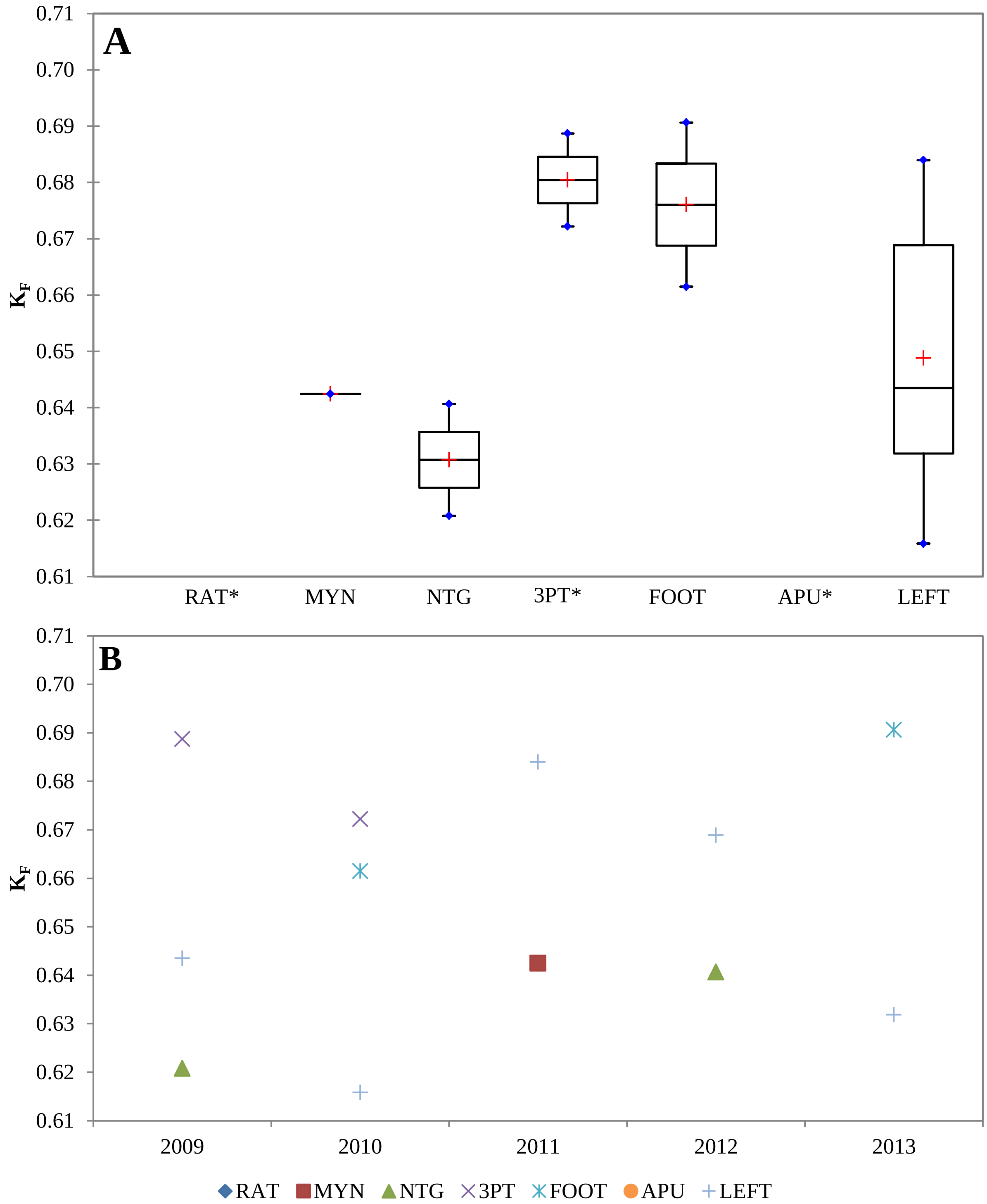


Figure 6-13. White Sucker catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote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



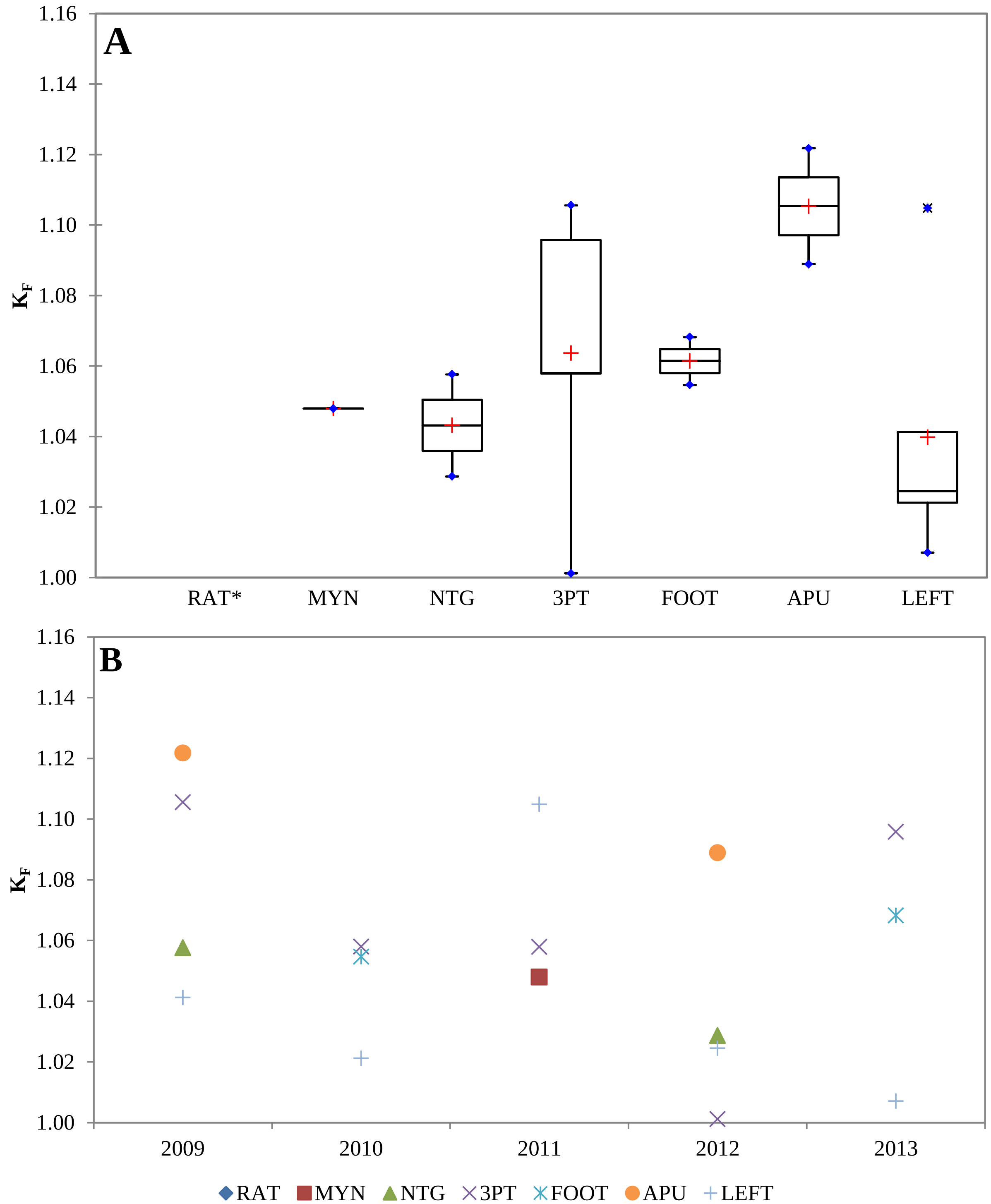
*No or too few fish were captured at RAT, MYN, NTG, 3PT, and FOOT, and too few fish were captured at APU in 2012.

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 Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).



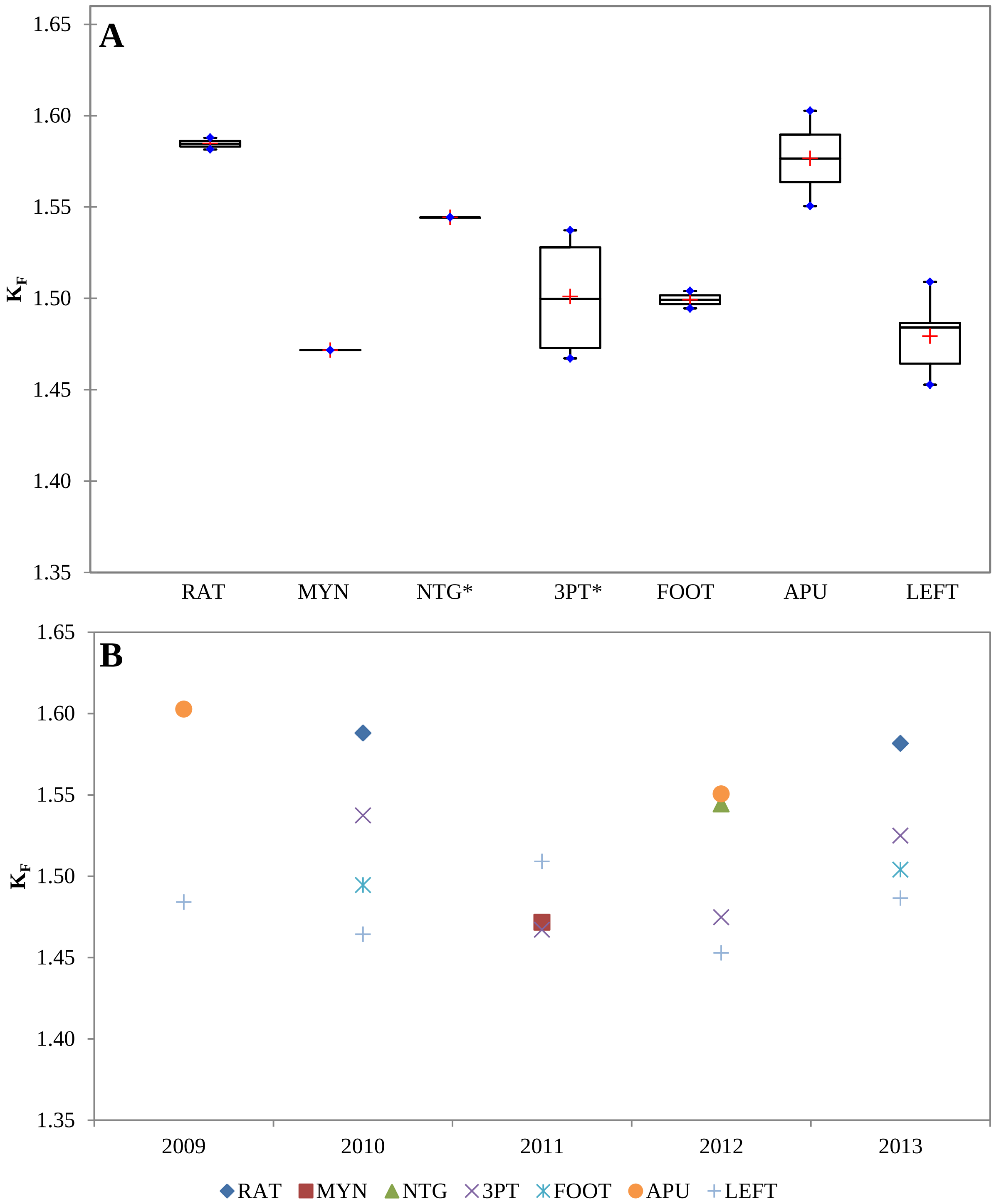
*Too few fish were captured at 3PT in 2011-2013 and RAT and APU in all years.

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 Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).



*Too few fish were captured at RAT in all years.

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 Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).



*Too few fish were measured for fork length at NTG and in 3PT in 2009.

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 Churchill River Diversion Region waterbodies, 2009-2013 by waterbody (A) and by year (B).

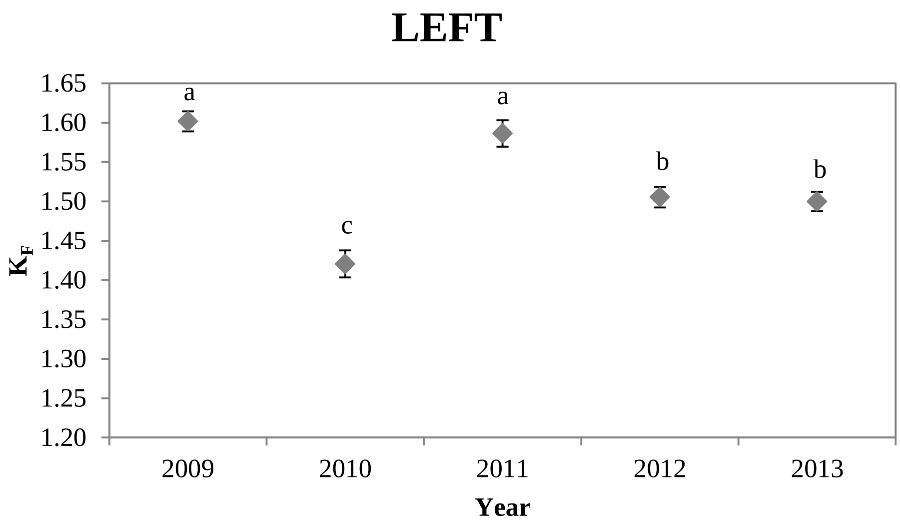


Figure 6-18. Fulton's condition factor (K_F; mean ± SE) of Lake Whitefish between 300 and 499 mm in fork length captured at the annual off-system location. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference. Too few Lake Whitefish were captured in Threepoint Lake to analyze statistically.

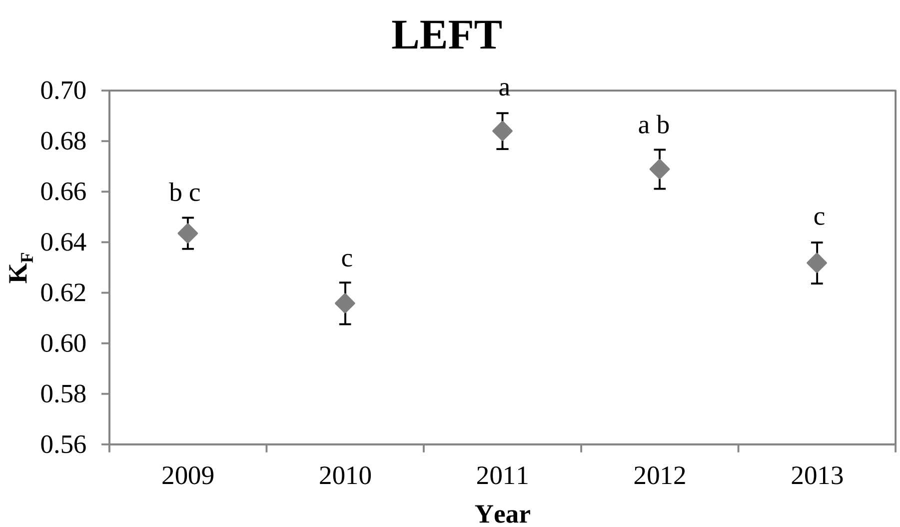


Figure 6-19. Fulton's condition factor (K_F; mean ± SE) of Northern Pike between 400 and 699 mm in fork length captured at the annual off-system location. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack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

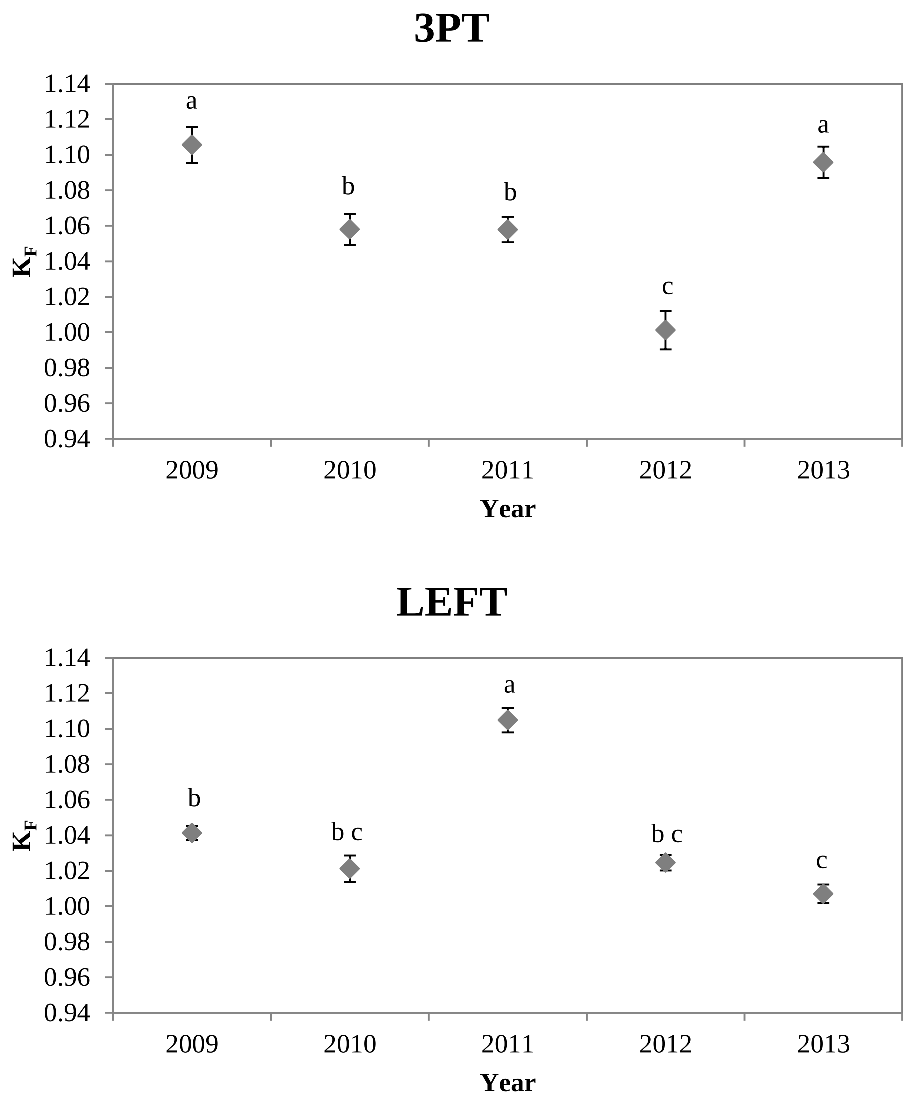


Figure 6-20. Fulton's condition factor (K_F; mean ± SE) of Walleye between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical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

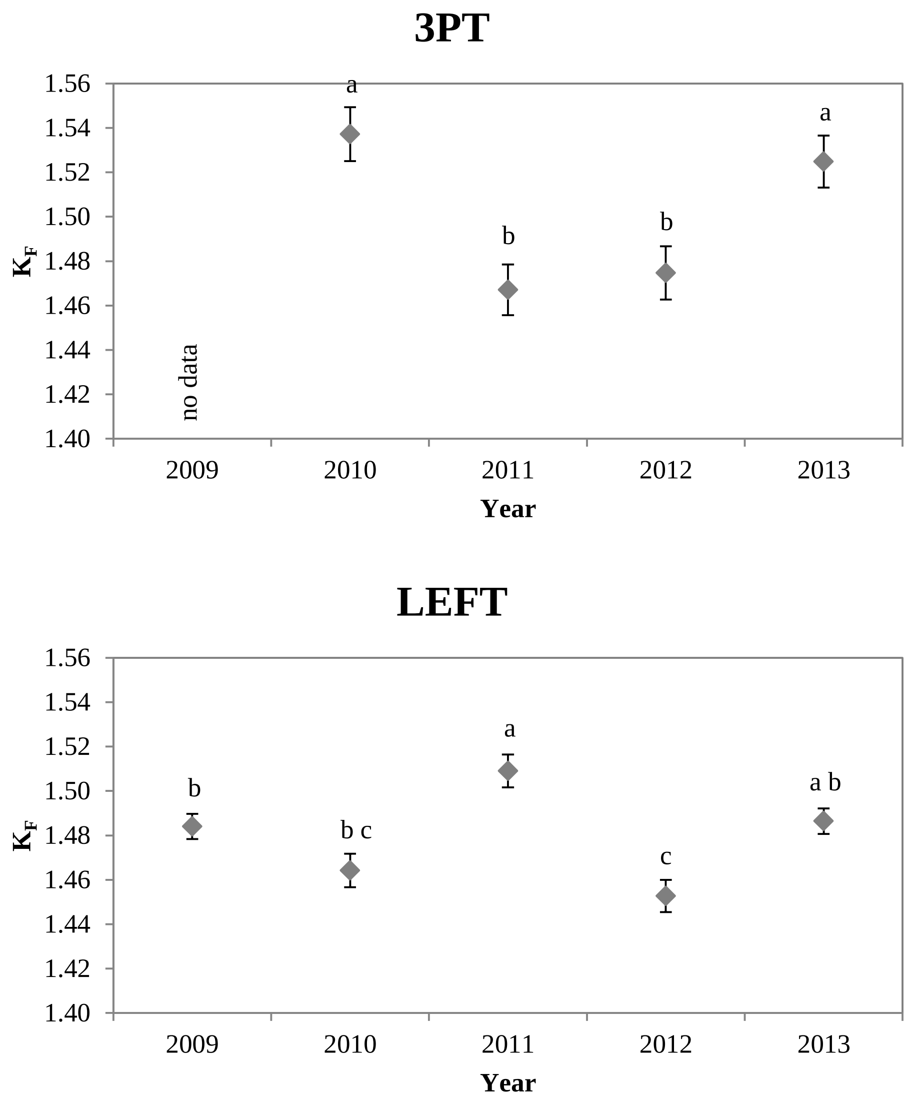


Figure 6-21. Fulton's condition factor (K_F; mean ± SE) of White Sucker between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

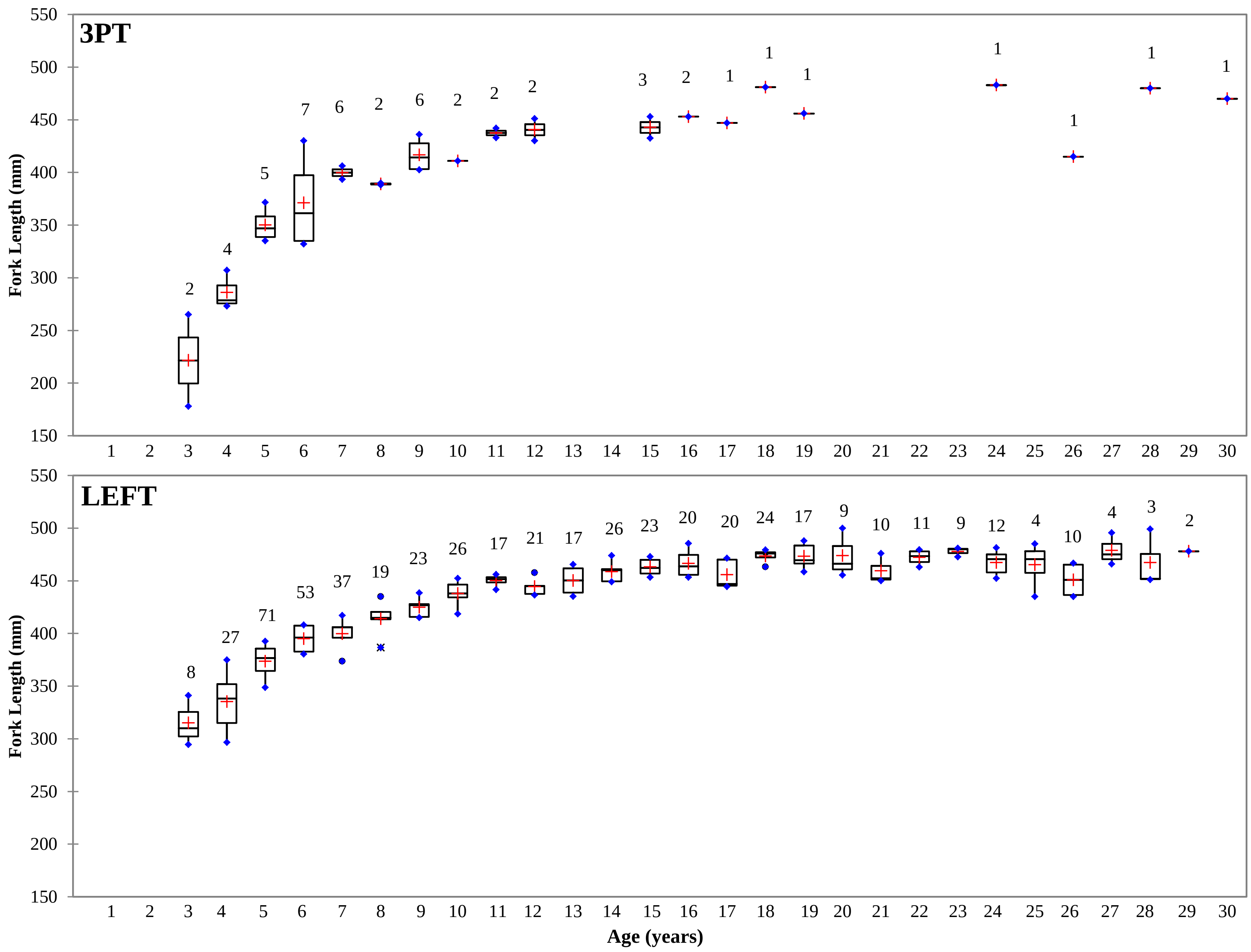
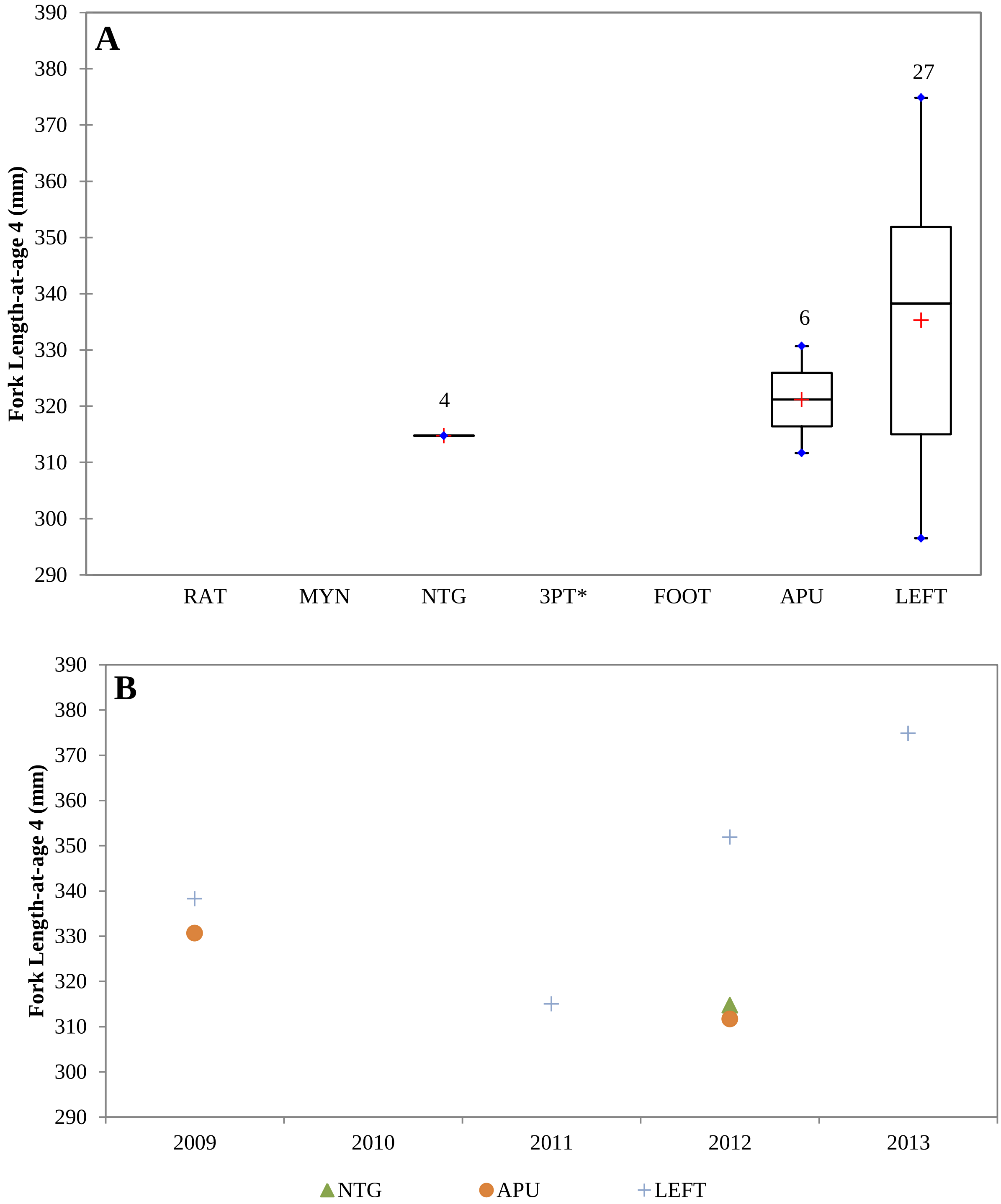
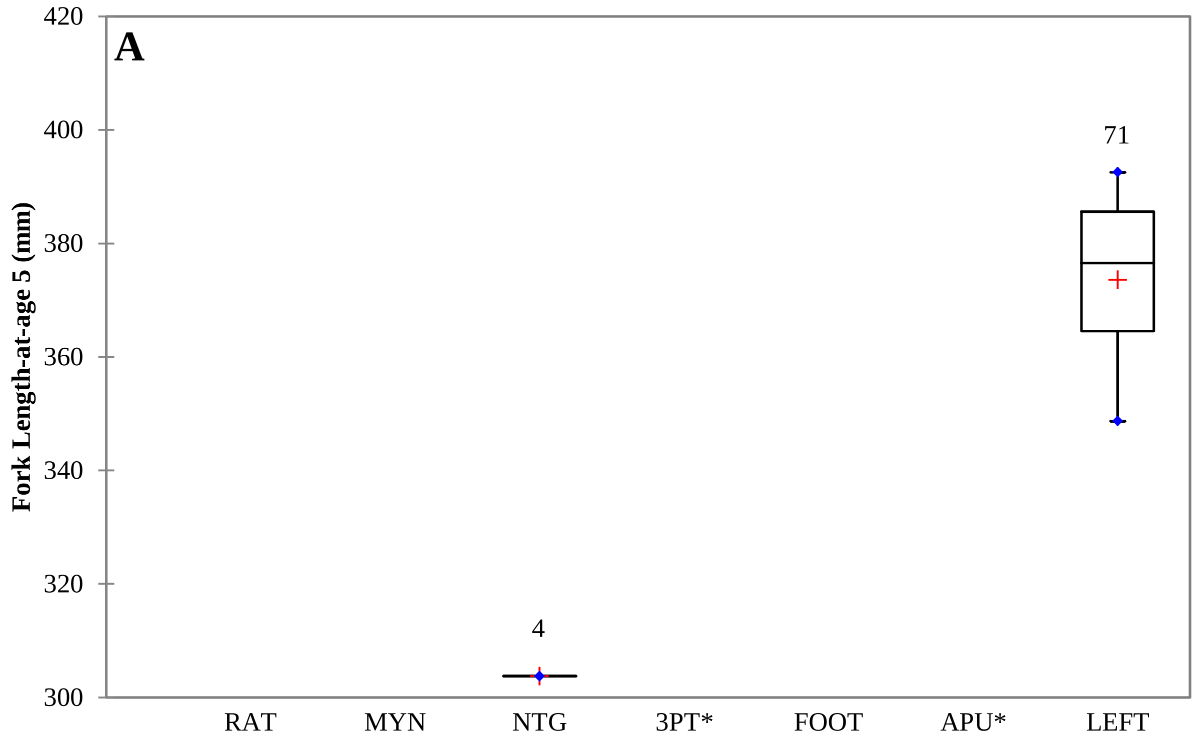


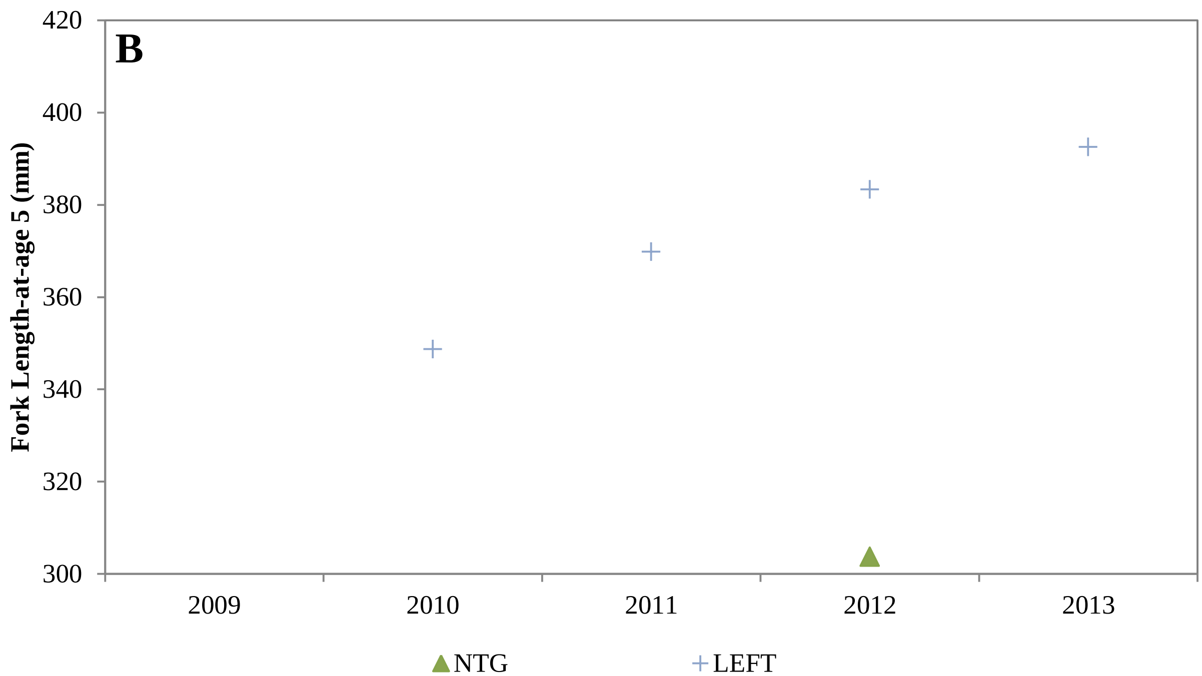
Figure 6-22. Annual mean length-at-age of Lake Whitefish captured in standard gang and small mesh index gill nets set at annual sampling locations in the Churchill River Diversion Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



*Years in which 1 or 2 fish were captured were excluded from the analysis.

Figure 6-23. Annual mean length-at-age 4 of Lake Whitefish captured in standard gang and small mesh index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 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.





*Years in which 1 or 2 fish were captured were excluded from the analysis

Figure 6-24. Annual mean length-at-age 5 of Lake Whitefish captured in gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 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.

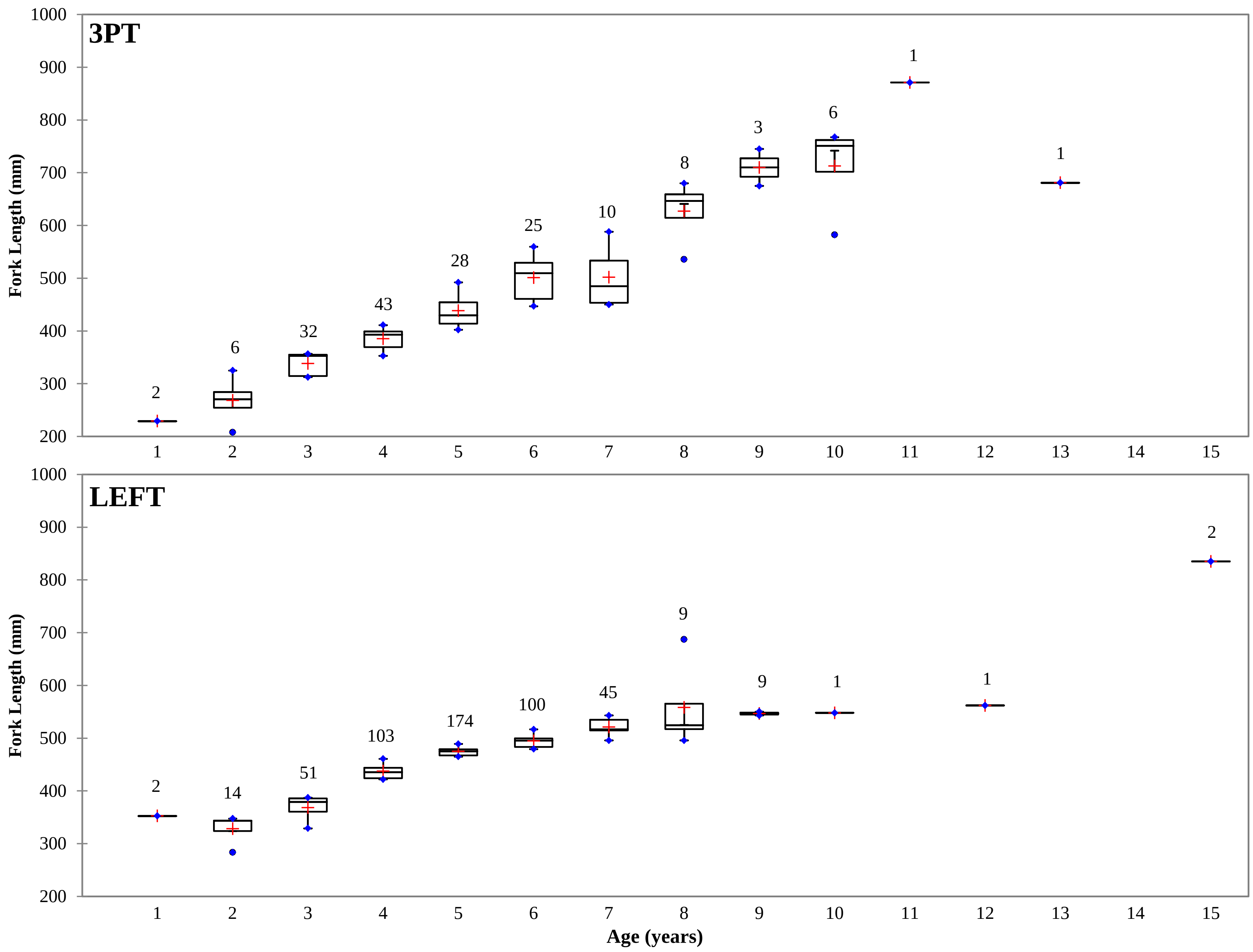
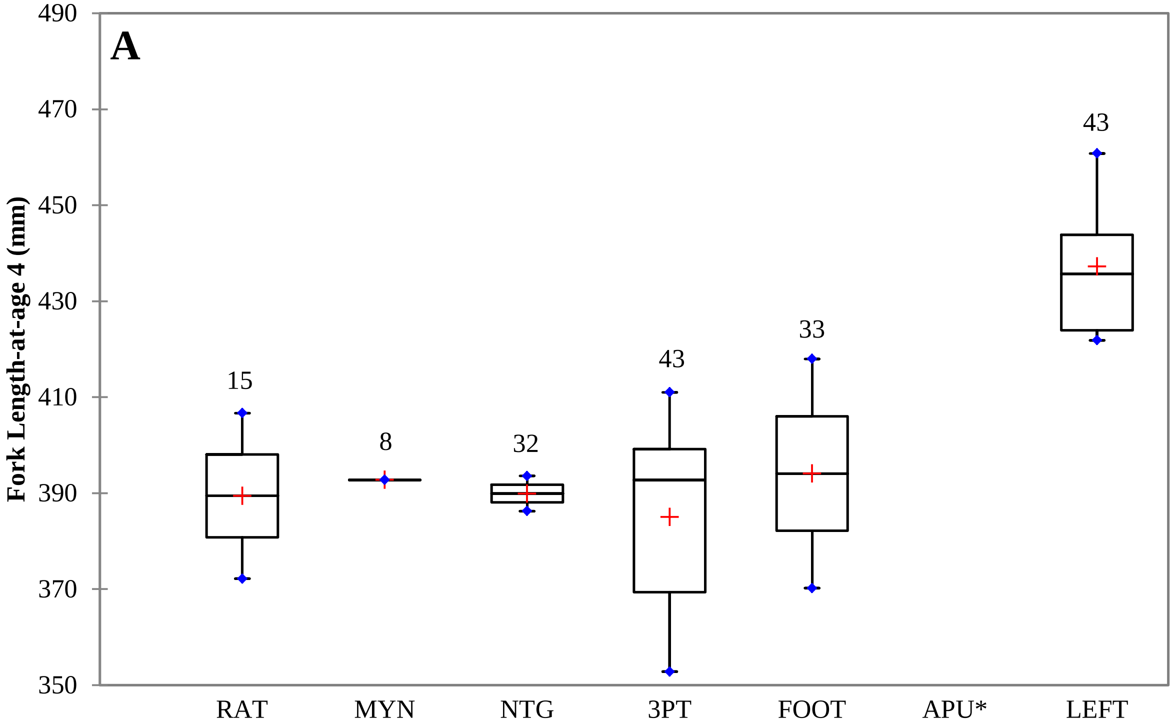
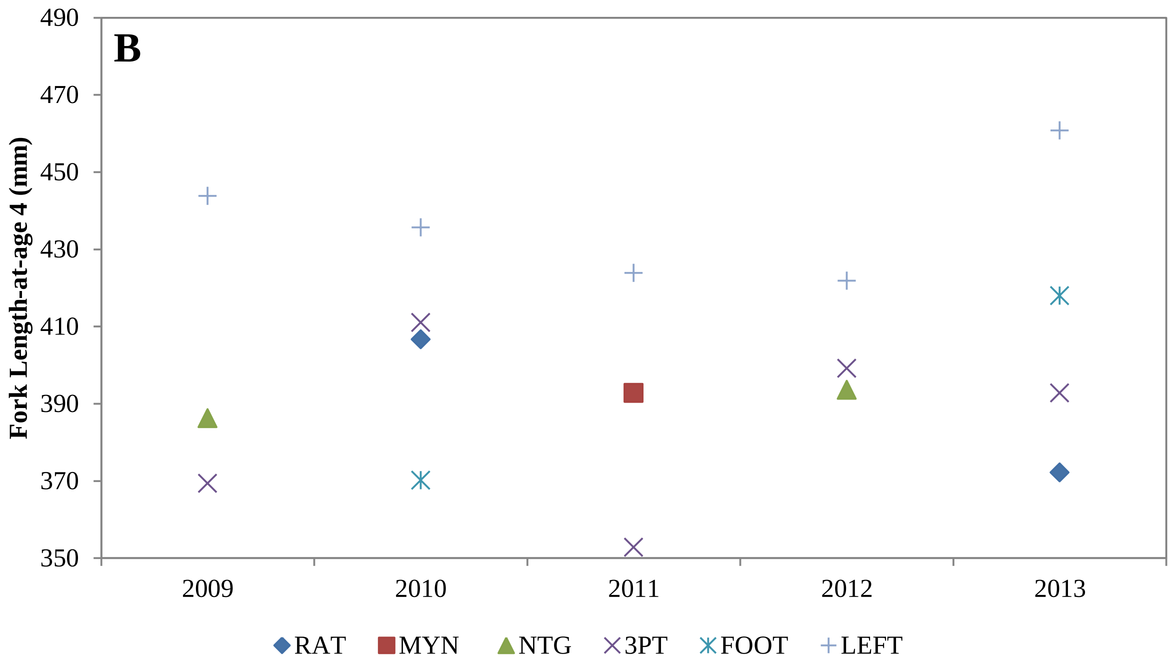


Figure 6-25. Annual mean length-at-age of Northern Pike captured in standard gang and small mesh index gill nets set at annual sampling locations in the Churchill River Diversion Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.





*Years in which 1 or 2 fish were captured were excluded from the analysis.

Figure 6-26. Annual mean length-at-age 4 of Northern Pike captured in standard gang and small mesh index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 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.

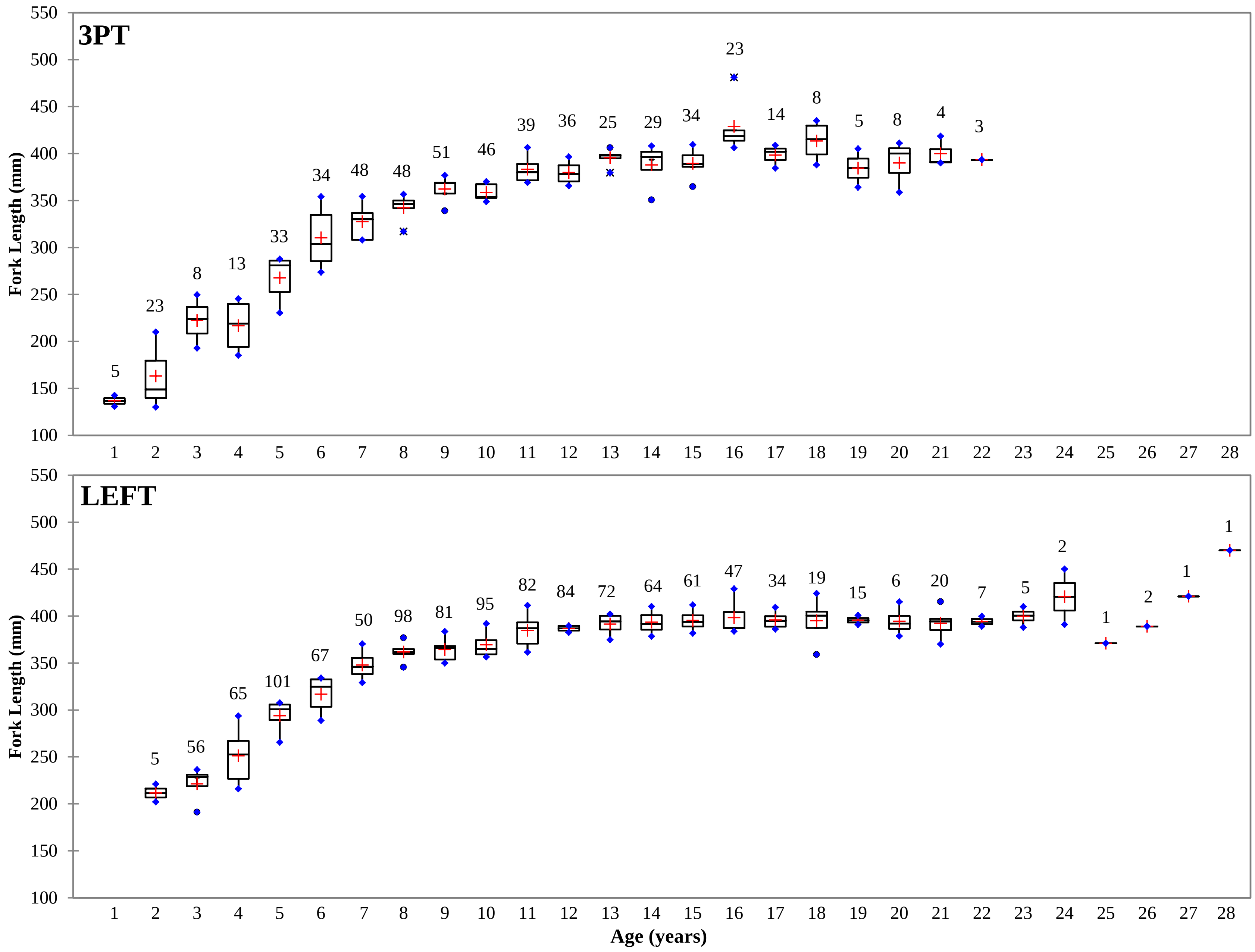
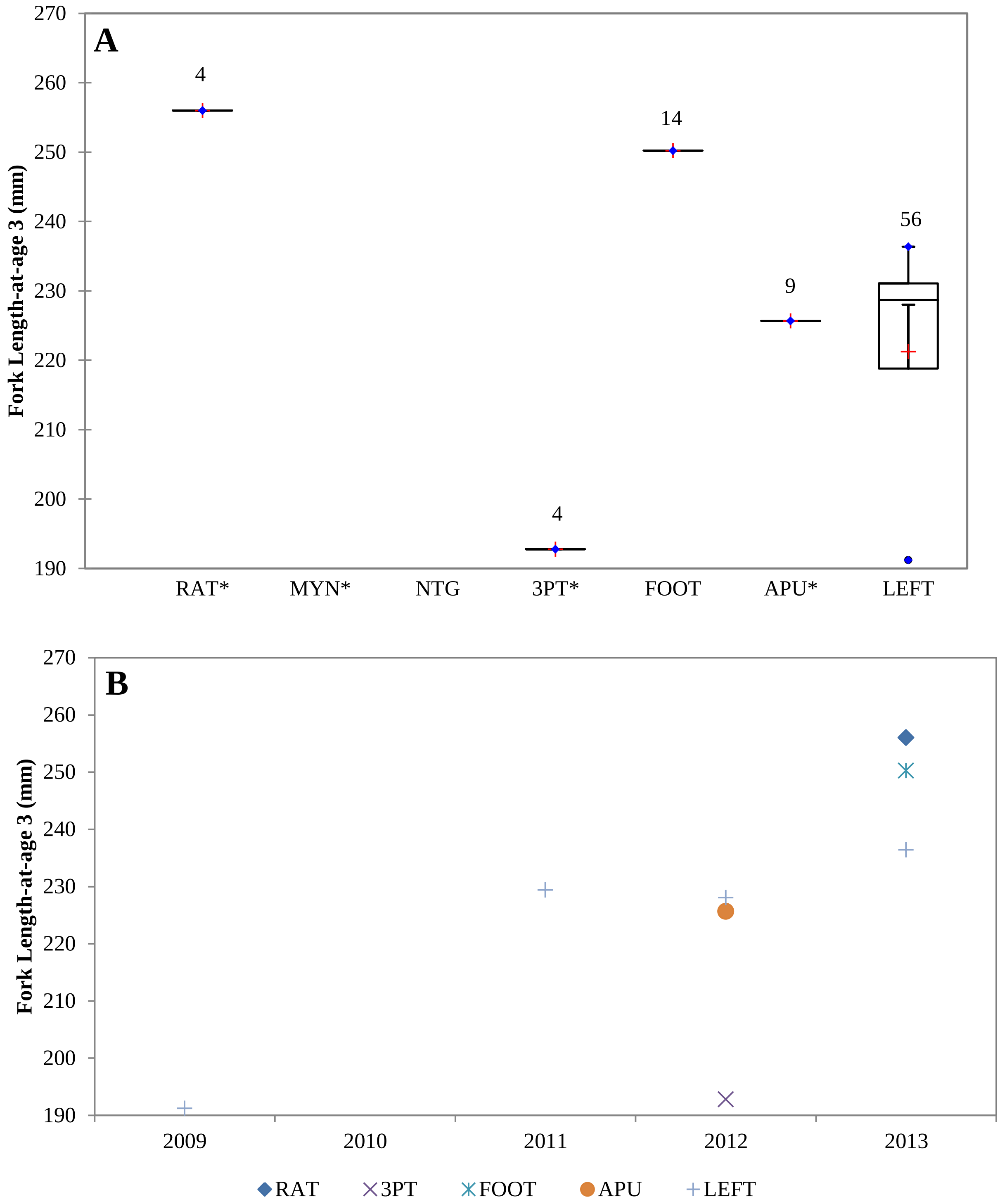
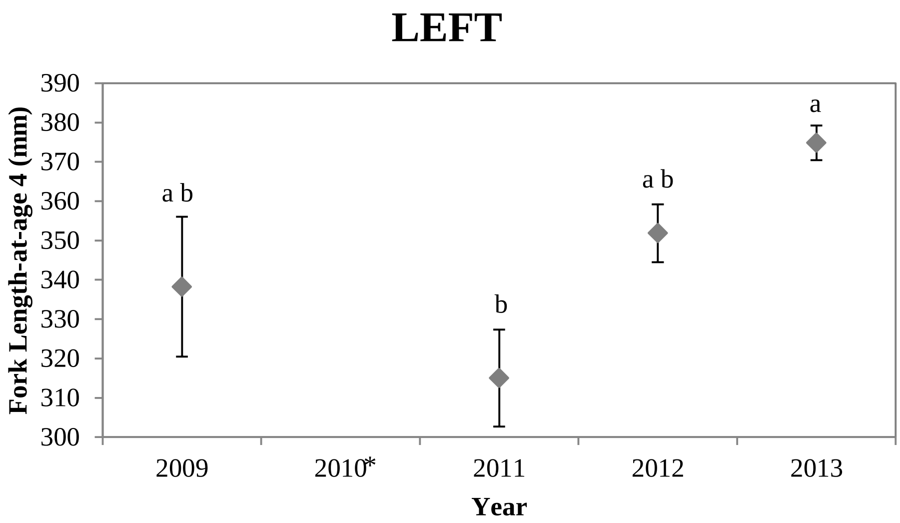


Figure 6-27. Annual mean length-at-age of Walleye captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Churchill River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



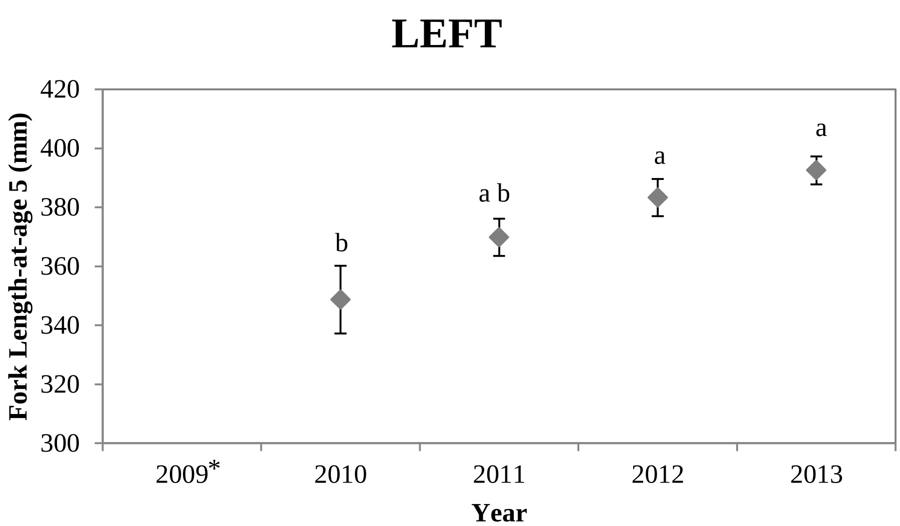
*Years in which 1 or 2 fish were captured were excluded from the analysis.

Figure 6-28. Annual mean length-at-age 3 of Walleye captured in standard gang and small mesh index gill nets set in Churchill River Diversion Region waterbodies, 2009-2013 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 were captured in 2010 to include in the analysis.

Figure 6-29. Fork length-at-age 4 (mean ± SE) of Lake Whitefish captured at the annual off-system location. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



*Too few fish were captured in 2009 to include in the analysis

Figure 6-30. Fork length-at-age 5 (mean ± SE) of Lake Whitefish captured at the annual off-system location. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

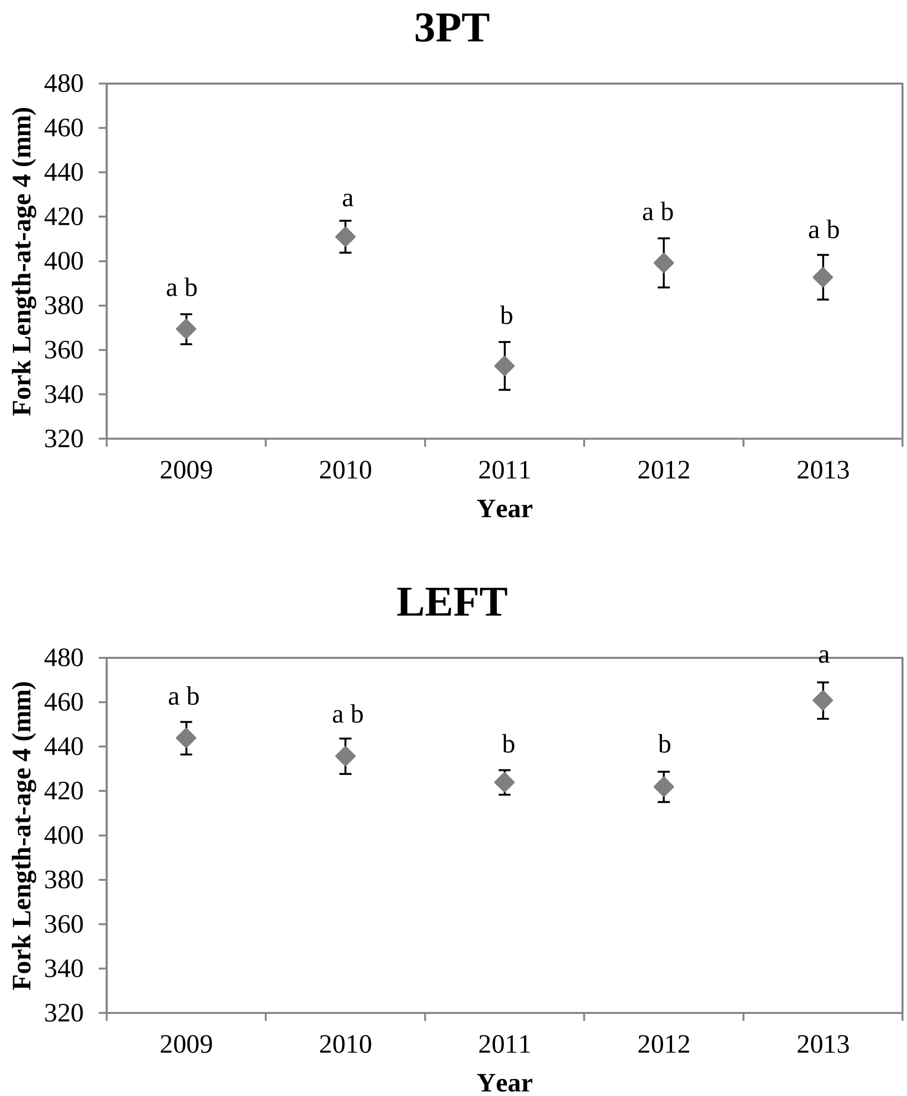


Figure 6-31. Fork length-at-age 4 (mean ± SE) of Northern Pike captured at annual on- (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

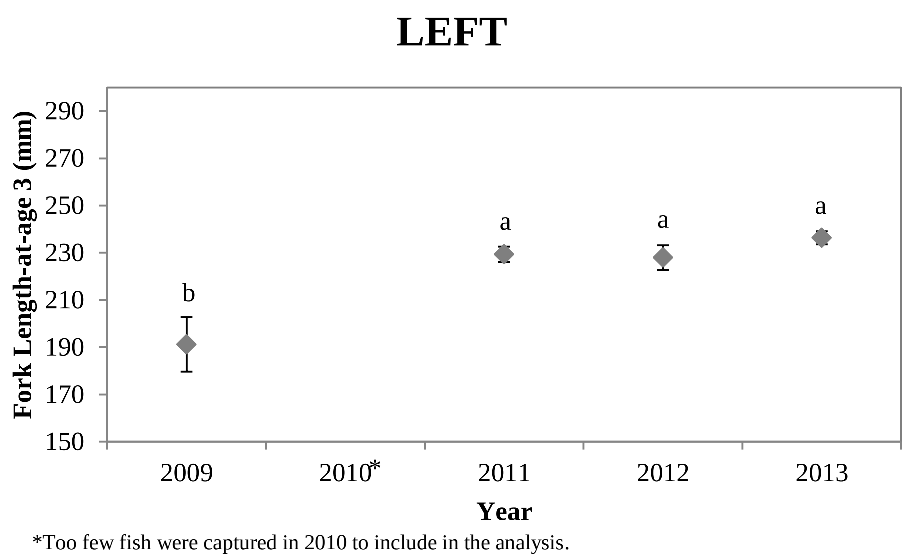


Figure 6-32. Fork length-at-age 3 (mean ± SE) of Walleye captured at the annual off-system location. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

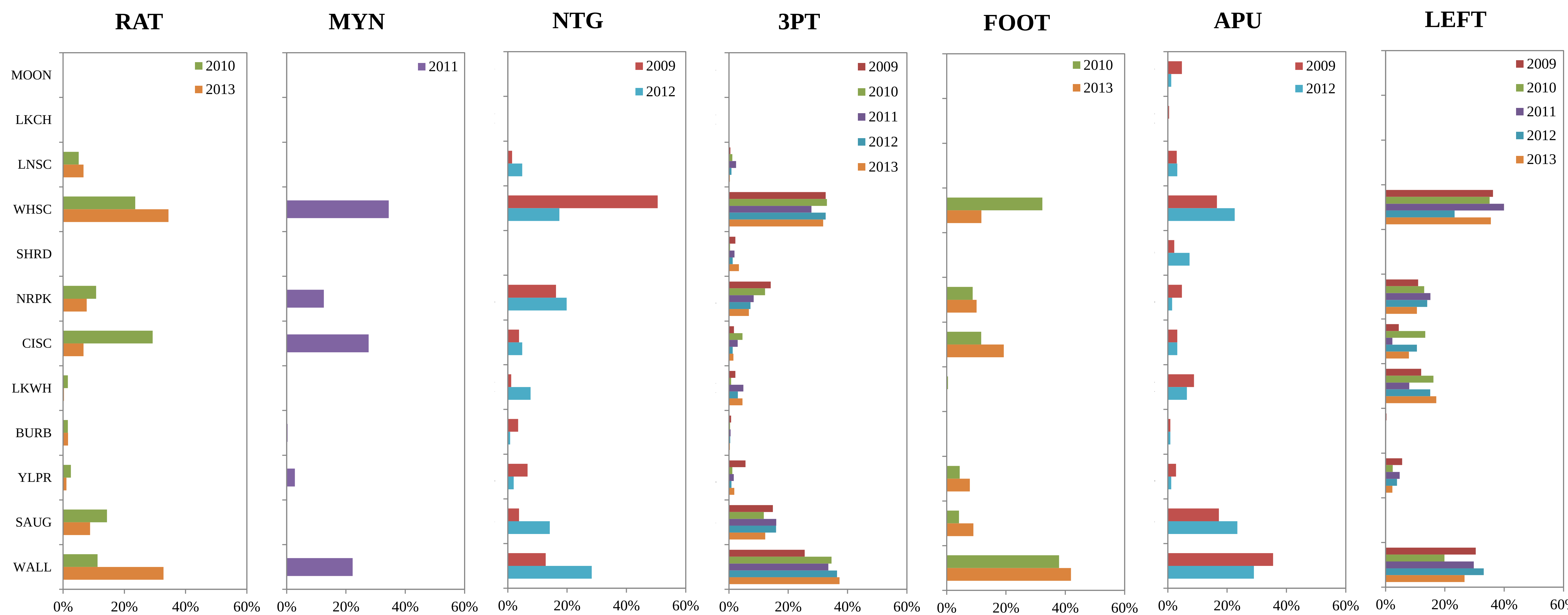


Figure 6-33. Relative abundance of fish species captured in standard gang index gill nets in Churchill River Diversion Region waterbodies, 2009-2013.

7.0 FISH MERCURY

7.1 INTRODUCTION

The following provides an overview of the results of fish mercury monitoring conducted in the CRDR under CAMP in the first six years of the program. Sampling was conducted annually at one on-system (Threepoint Lake) and one off-system lake (Leftrook Lake) and on a three rotation at Rat Lake (2010 and 2013).

A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 4.7. In brief, 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 (*Perca flavescens*) for analysis of mercury in the whole carcass with the head, pelvic girdle, pectoral girdle, and caudal fin removed. Monitoring of perch is included in CAMP as a potential early-warning indicator of changes in mercury in the food web.

7.1.1 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.

7.1.2 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 Churchill River Diversion: Rat and Threepoint Lakes

A total of 431 fish were analyzed for mercury from Rat and Threepoint lakes between 2010 and 2013 (Table 7-1). Though sample sizes varied considerably between species and years, sample sizes for Northern Pike and Walleye met, or were close to, the target sample sizes. Considerably fewer Lake Whitefish and Yellow Perch were captured and sample sizes were frequently insufficient to establish length-standardized mean mercury concentrations (Table 7-1).

Mean length-standardized mercury concentrations for pike and Walleye from both Rat and Leftrook lakes (Table 7-1) were consistently at or slightly above the 0.5 (parts per million) ppm Health Canada standard for commercial marketing of freshwater fish (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011).

Where sample sizes were sufficient to establish length-standardized concentrations, mean concentrations in whitefish from Threepoint Lake were less than 0.5 ppm (Table 7-1). Sample sizes were insufficient to calculate length-standardized mean concentrations for whitefish from Rat Lake (Table 7-1).

Based on mercury concentrations for individual fish sampled from Rat and Threepoint lakes between 2010 and 2013, 21% of pike and 38% of Walleye exceeded 0.5 ppm, reaching maximum concentrations of 1.61 ppm and 0.93 ppm, respectively (Figures 7-1 and 7-2). All of the whitefish (Figures 7-1 and 7-2) and perch (Figure 7-3) from Rat and Threepoint lakes had mercury concentrations substantially lower than the 0.50 ppm standard, with maxima of 0.30 ppm and 0.02 ppm, respectively.

7.2.2 Off-system Waterbody: Leftrook Lake

A total of 464 fish were analyzed for mercury from Leftrook Lake between 2010 and 2013 (Table 7-1). Sample sizes for pike, Walleye, and whitefish reached or exceeded the target sample size of 36 fish in each year. Perch sample sizes were smaller, ranging from 3-15 individuals per year (Table 7-1).

Mean length-standardized mercury concentrations for all species in Leftrook Lake were lower than the 0.5 ppm 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; Table 7-1).

Only 1% of pike and Walleye and none of the whitefish or perch sampled that were analysed from Leftrook Lake exceeded the Health Canada standard (Figures 7-1 to 7-3).

7.2.3 Temporal Comparisons and Trends

Although length-standardized mean concentrations for whitefish, pike and Walleye from all waterbodies sampled in this region have shown some inter-annual variation, no increasing or decreasing trends for Threepoint Lake were evident for the four year monitoring period monitoring (Figure 7-4). Furthermore, no significant inter-annual differences were observed for any species for which length-standardized concentrations could be derived. Insufficient numbers of perch were collected from this lake to examine trends or inter-annual variability.

Only one statistically significant inter-annual difference was observed for any lake or fish species in this region. Length-standardized mercury concentrations in pike were significantly higher in 2010 than any other year (2011-2013) in the off-system Leftrook Lake. Differences in sizes of fish do not appear to be a factor influencing inter-annual differences as the mean size of pike was not highest in 2010 (Table 7-2).

7.3 RELATIONSHIPS WITH HYDROLOGICAL METRICS

There was little variability between years in the length-standardized concentrations of mercury in Lake Whitefish, Northern Pike, or Walleye from Threepoint Lake. Although there was considerable variability in lake water level (see Section 2.0 for details) over the period of monitoring (2010-2013), water levels were relatively high. Collectively, this suggests that in the short-term, hydrological conditions did not have a major influence on mercury concentrations of the large-bodied fish species in this lake. However, the influence of variability in water levels may not manifest in immediate changes in fish mercury concentrations and the available time period may be insufficient to detect any relationships, should they exist. Insufficient catches of 1-year-old Yellow Perch were obtained from this waterbody to facilitate examination of potential more immediate responses in the fish community associated with water level variation.

Hydrological monitoring of Leftrook Lake was relatively limited in 2010, when fish mercury monitoring was initiated under CAMP, and there is no long-term hydrological record for this lake. However, as noted in Section 2.0, water levels appear to have been below average in the open-water season of 2010 which is coincident with the highest mercury concentrations observed in Northern Pike. Whether this co-occurrence reflects a linkage between water level and fish mercury or simply natural variability cannot be determined with the limited amount of available data.

7.4 SUMMARY

Length-standardized mean mercury concentrations for pike and Walleye from both Rat (2010 and 2013) and Threepoint (2010-2013) lakes were at or slightly above the 0.5 ppm Health Canada standard for commercial marketing of freshwater fish. For the two lakes and for all years combined, 21% of pike and 38% of Walleye exceeded the 0.5 ppm standard. Conversely, mean length-standardized mercury concentrations for pike and Walleye were below the 0.5 ppm standard in all sampling years in the off-system Leftrook Lake.

When sufficient numbers of whitefish were obtained from Threepoint or Leftrook lakes to derive length-standardized mercury concentrations, means were below the 0.5 ppm standard. None of the whitefish or perch obtained from any lake over the period of 2010-2013 exceeded 0.5 ppm.

There was no indication of trends over the four year monitoring period for any species in either Threepoint or Leftrook lakes. In addition, there were no statistically significant inter-annual differences in length-standardized mercury concentrations in Lake Whitefish, Northern Pike, or Walleye from Threepoint or Rat lakes. That no differences were observed in Threepoint Lake which was monitored annually, yet lake water levels varied notably over this period, suggests that water level variation had little influence on mercury concentrations in large-bodied fish species in the short-term.

The only significant differences observed between years occurred for Northern Pike in Leftrook Lake, where concentrations were highest in 2010 relative to 2011 through 2013. Potential influence of water levels on these differences is difficult to discern due to the limited data, though the highest concentrations of mercury in pike co-occurred with an assumed low water level period in 2010.

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 from the Churchill River Diversion Region: 2010-2013.

Waterbody	Year	Species	n	Mercury Concentration (ppm)			
				Arithmetic Mean	SE	Standard Mean	95% CL
Rat Lake	2010	Pike	22	0.450	0.065	0.655	0.539 - 0.796
		Walleye	25	0.492	0.030	0.566	0.517 - 0.621
		Whitefish	3	0.063	0.037	NS	-
	2013	Pike	36	0.286	0.023	0.537	0.461 - 0.624
		Walleye	36	0.519	0.032	0.516	0.474 - 0.561
		Whitefish	1	0.064	-	-	-
		Perch	3	0.011	0.003	-	-
Threepoint Lake	2010	Pike	32	0.502	0.039	0.591	0.527 - 0.663
		Walleye	36	0.510	0.036	0.577	0.495 - 0.673
		Whitefish	2	0.082	0.040	NS	-
	2011	Pike	31	0.324	0.036	0.488	0.400 - 0.597
		Walleye	36	0.388	0.028	0.435	0.374 - 0.506
		Whitefish	18	0.087	0.011	0.055	0.043 - 0.070
	2012	Pike	20	0.345	0.046	0.462	0.377 - 0.565
		Walleye	36	0.347	0.038	0.545	0.455 - 0.653
		Whitefish	7	0.118	0.035	0.065	0.035 - 0.120
	2013	Pike	26	0.337	0.057	0.471	0.378 - 0.585
		Walleye	36	0.449	0.044	0.507	0.440 - 0.583
		Whitefish	15	0.099	0.015	0.057	0.048 - 0.069
		Perch	10	0.017	0.001	-	-
Leftrook Lake	2010	Pike	36	0.247	0.017	0.392	0.317 - 0.484
		Walleye	36	0.220	0.017	0.255	0.216 - 0.301
		Whitefish	36	0.044	0.004	0.026	0.022 - 0.031
		Perch	3	0.029	0.007	-	-
	2011	Pike	36	0.205	0.023	0.242	0.214 - 0.273
		Walleye	36	0.185	0.016	0.245	0.216 - 0.277
		Whitefish	36	0.042	0.004	0.026	0.023 - 0.029
		Perch	15	0.008	0.000	-	-
	2012	Pike	36	0.171	0.018	0.248	0.198 - 0.310
		Walleye	38	0.216	0.019	0.273	0.240 - 0.311
		Whitefish	36	0.049	0.005	0.021	0.017 - 0.025
	2013	Pike	38	0.153	0.018	0.229	0.193 - 0.273
		Walleye	36	0.201	0.017	0.234	0.206 - 0.266
		Whitefish	36	0.048	0.004	0.027	0.021 - 0.034
		Perch	10	0.006	0.000	-	-

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 Churchill River Diversion Region: 2010-2013.

Waterbody	Year	Species	n	Length (mm)	Weight (g)	K_F	Age (years)
Rat Lake	2010	Pike	22	421.2 ± 26.8	632.1 ± 191.9	0.64 ± 0.01	4.6 ± 0.4
		Walleye	25 [1]	342.6 ± 16.5	495.4 ± 65.4	1.04 ± 0.02	8.0 ± 0.8
		Whitefish	3 [2]	338.7 ± 101.4	1224.0 ± 102.3	1.68 ± 0.19	-
	2013	Pike	36	389.8 ± 13.5	436.1 ± 49.2	0.66 ± 0.01	4.8 ± 0.4
		Walleye	36	390.3 ± 13.9	716.4 ± 61.4	1.07 ± 0.01	9.1 ± 0.6
		Whitefish	1	470	2100	2.02	7
		Perch	3 [3]	84.0 ± 13.1	12.9 ± 5.3	1.44 ± 0.00	1.5 ± 0.5
Threepoint Lake	2010	Pike	32	483.9 ± 21.8	1046.3 ± 201.6	0.69 ± 0.02	5.2 ± 0.3
		Walleye	36	358.3 ± 8.7	511.5 ± 34.3	1.04 ± 0.01	11.0 ± 0.8
		Whitefish	2	388.5 ± 53.5	889.5 ± 398.5	1.40 ± 0.09	8.0 ± 3.0
	2011	Pike	31 [4]	423.0 ± 18.6	614.8 ± 119.7	0.65 ± 0.01	5.1 ± 0.3
		Walleye	36 [5]	360.8 ± 9.7	526.4 ± 36.4	1.05± 0.01	11.3 ± 0.7
		Whitefish	18	401.7 ± 13.4	939.4 ± 80.0	1.39 ± 0.03	9.7 ± 1.5
	2012	Pike	20	444.0 ± 31.0	786.9 ± 245.8	0.64 ± 0.02	4.8 ± 0.5
		Walleye	36 [5]	286.8 ± 16.6	323.6 ± 44.9	0.95± 0.03	7.5 ± 0.8
		Whitefish	7 [6]	399.3 ± 25.3	936.0 ± 140.1	1.39 ± 0.03	12.3 ± 3.4
	2013	Pike	26 [4]	413.0 ± 28.1	686.6 ± 183.3	0.67 ± 0.02	4.2 ± 0.5
		Walleye	36	353.4 ± 14.1	555.1 ± 52.3	1.07 ± 0.02	10.2 ± 0.8
		Whitefish	15	392.2 ± 13.9	860.3 ± 69.8	1.39 ± 0.03	9.8 ± 1.4
		Perch	10	43.4 ± 0.8	1.0 ± 0.1	1.19 ± 0.03	0
Leftrook Lake	2010	Pike	36	469.8 ± 7.4	645.1 ± 28.3	0.61 ± 0.01	5.1 ± 0.2
		Walleye	36	352.9 ± 0.6	462.6 ± 18.6	1.02 ± 0.01	11.1 ± 0.6
		Whitefish	36 [4]	418.2 ± 10.5	1099.1 ± 74.2	1.41 ± 0.02	13.8 ± 1.2
		Perch	3	78.3 ± 4.4	6.9 ± 1.1	1.42 ± 0.13	1.0 ± 0.0
	2011	Pike	36 [5]	494.3 ± 13.5	967.8 ± 173.8	0.68 ± 0.01	5.8 ± 0.5
		Walleye	36	338.1 ± 11.4	490.0 ± 40.7	1.14 ± 0.02	8.9 ± 0.8
		Whitefish	36	397.1 ± 10.2	1058.3 ± 77.7	1.57 ± 0.02	9.8 ± 1.1
		Perch	15	77.0 ± 2.2	5.9 ± 0.6	1.24 ± 0.03	-
	2012	Pike	36	449.1 ± 16.9	665.6 ± 72.6	0.67 ± 0.01	4.9 ± 0.3
		Walleye	38	341.6 ± 11.3	456.6 ± 39.4	1.03 ± 0.01	9.6 ± 0.8
		Whitefish	36	423.9 ± 9.3	1198.3 ± 82.7	1.48 ± 0.02	11.6 ± 1.0
	2013	Pike	38 [5]	419.7 ± 19.9	590.0 ± 69.6	0.65 ± 0.02	3.9 ± 0.3
		Walleye	36	351.8 ± 12.3	485.3 ± 46.8	0.98 ± 0.01	8.8 ± 0.8
		Whitefish	36	408.5 ± 4.9	1019.7 ± 34.9	1.48 ± 0.02	8.8 ± 0.9
		Perch	10	38.9 ± 1.1	0.7 ± 0.1	1.11 ± 0.05	0

[1] n=16 for age; [2] n=1 for age; [3] n=2 for weight, K_F, and age; [4] n=30 for age; [5] n=35 for age; [6] n=6 for age; [7] n=25 for age.

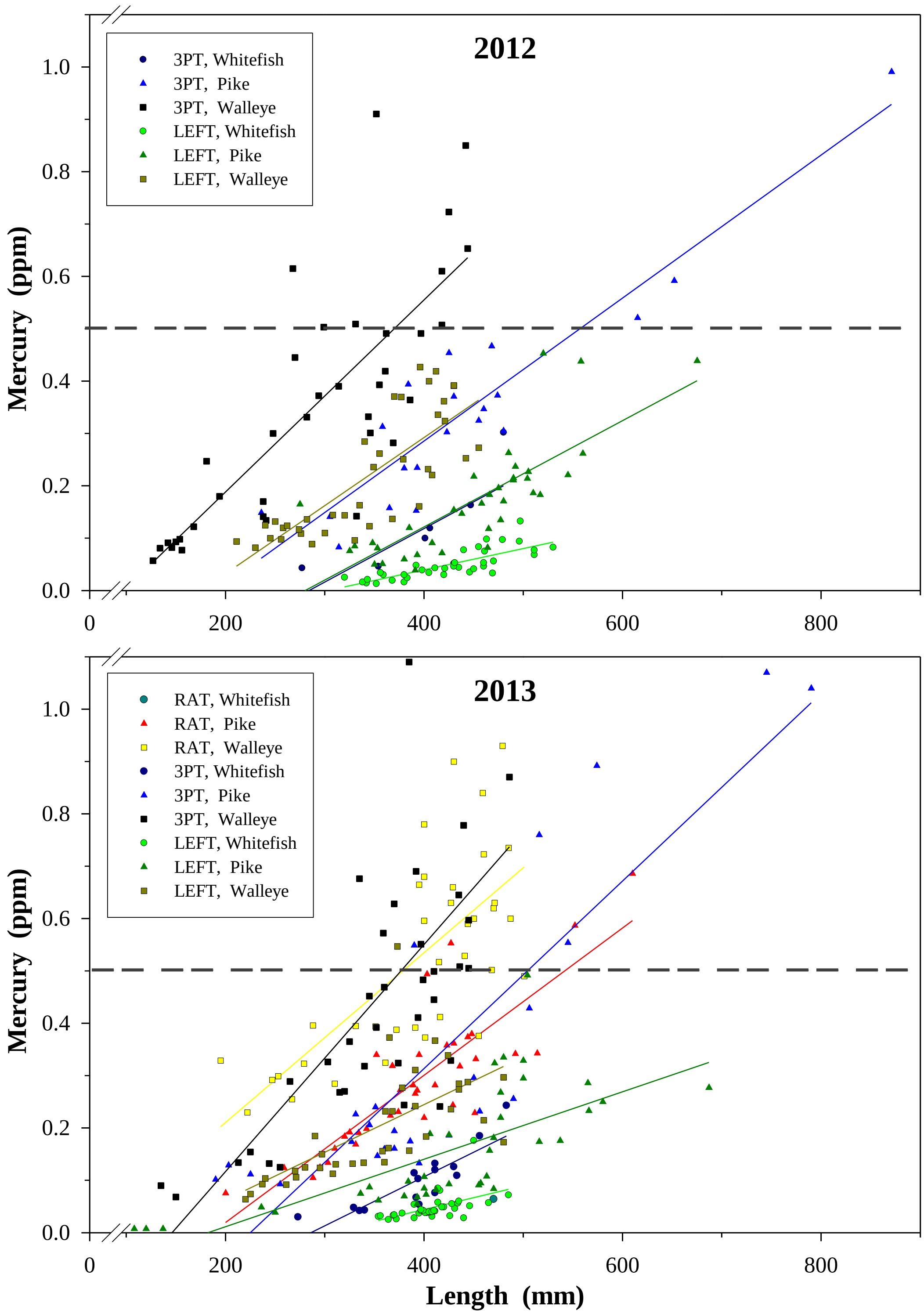
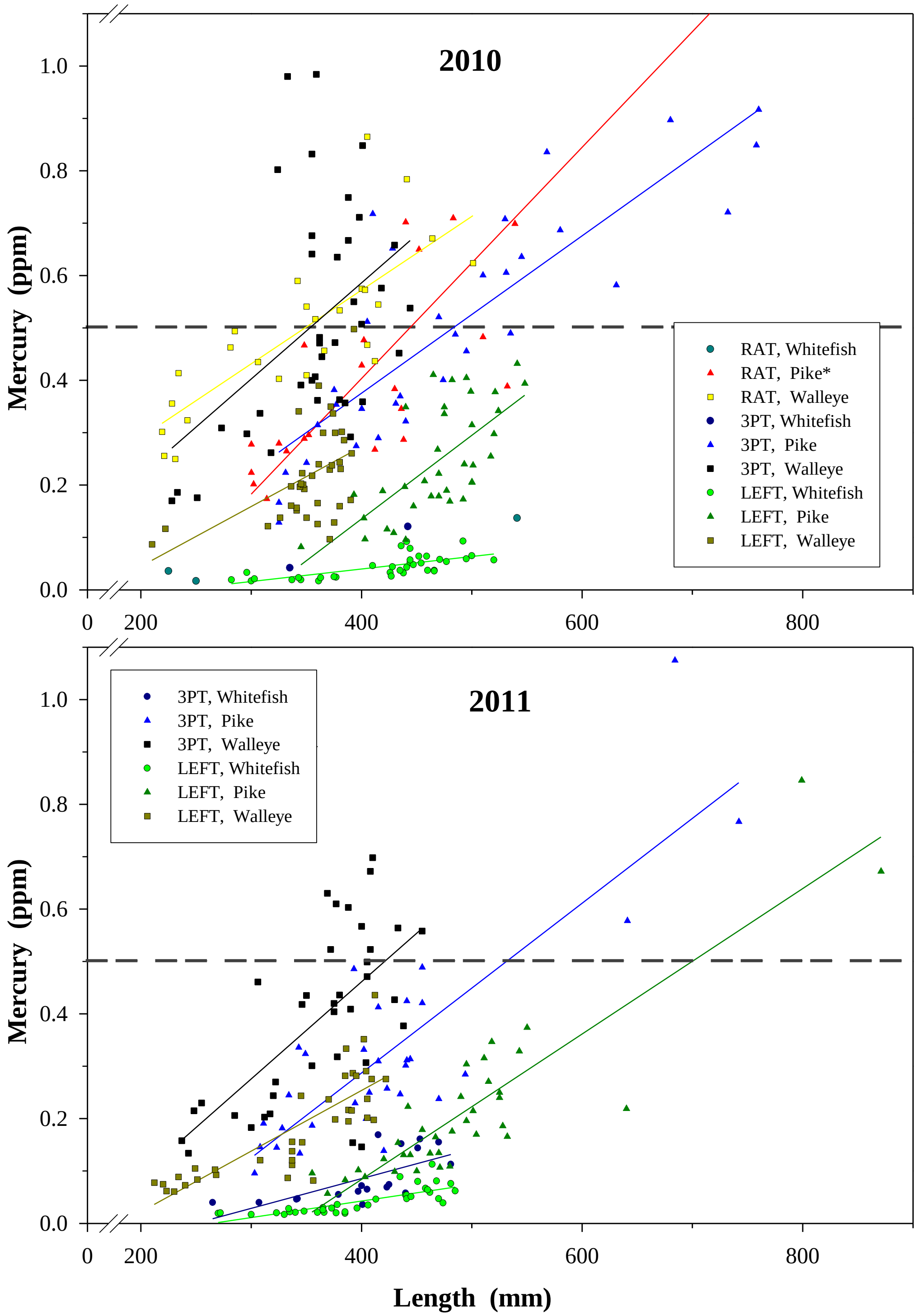


Figure 7-1. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from the Churchill River Diversion Region: 2012-2013. Significant linear regression lines are shown. Dashed lines represent the Health Canada standard for retail fish.



* One pike from Rat Lake in 2010 with a mercury concentration of 1.61 ppm and a length of 871 mm is not shown but was included in all analyses.

Figure 7-2. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from the Churchill River Diversion Region: 2010-2011. Significant linear regression lines are shown. Dashed lines represent the Health Canada standard for retail fish.

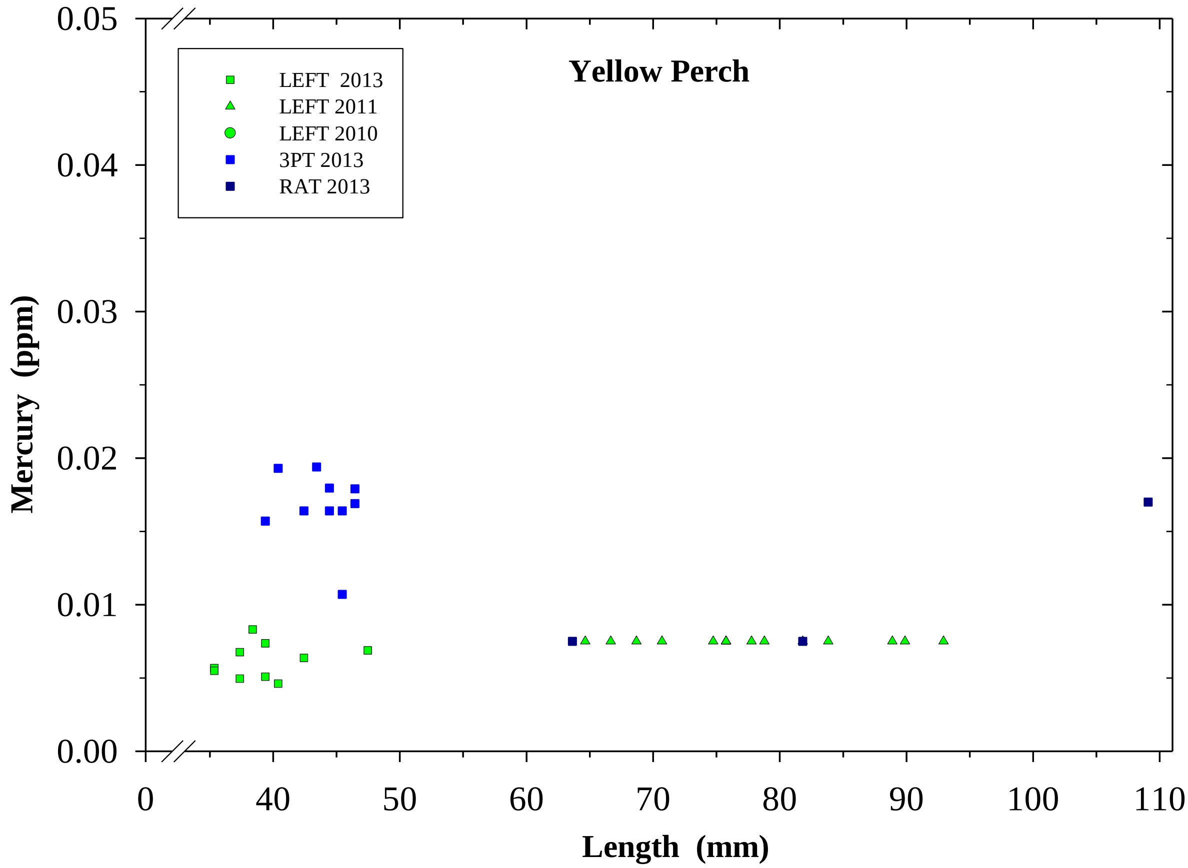
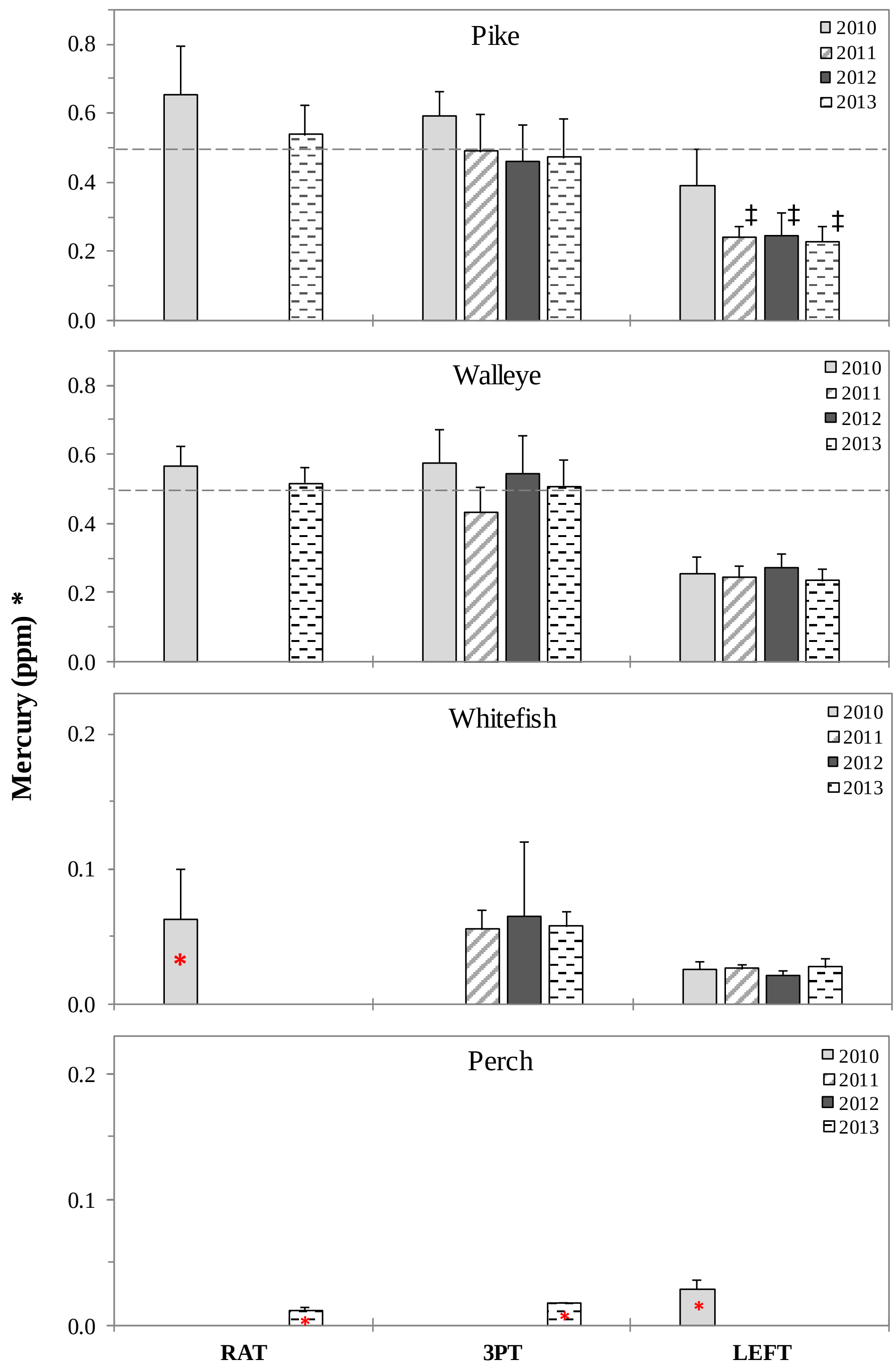


Figure 7-3. Relationship between mercury concentration and fork length for Yellow Perch from the Churchill River Diversion Region: 2010-2013.



*Note differences in mercury scale among species.

Figure 7-4. Standard or arithmetic (asterisk) mean (upper 95% CL) mercury concentrations of Northern Pike, Walleye, Lake Whitefish, and Yellow Perch from the Churchill River Diversion Region: 2010-2013. Significant differences between years are indicated by † (higher than 2010) or ‡ (lower than 2010). Dashed lines represent the 0.5 ppm standard for retail fish.

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