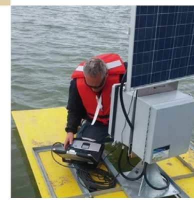
CAMP

Coordinated Aquatic Monitoring Program



Six Year Summary Report

Technical Document 2: Winnipeg River Region

2008-2013

Submitted to:
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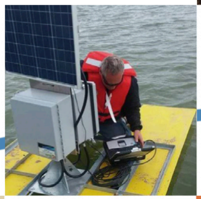

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SIX YEAR SUMMARY REPORT (2008-2013)

Technical Document 2:

Winnipeg River Region Results

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ABBREVIATIONS AND ACRONYMS

ASL	Above sea level
BCMOE	British Columbia Ministry of Environment
BMI	Benthic macroinvertebrate(s)
CAMP	Coordinated Aquatic Monitoring Program
CCME	Canadian Council of Ministers of the Environment
CL(s)	Confidence limit(s)
CPUE	Catch-per-unit-effort
DL	Detection limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EAGLE	Eaglenest Lake
EC	Environment Canada
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
EPT:C	Ratio of the combined abundances of Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) to the abundance of Chironomidae (non-biting midges)
FL	Fork length
FL-at-age	Fork-length-at age
GS(s)	Generating station(s)
ISQG	Interim sediment quality guideline
K_F	Fulton's Condition Factor
KHLP	Keeyask Hydropower Limited Partnership
LDB	Lac du Bonnet
LEL	Lowest effect level
MANIG	Manigotagan Lake
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
n_F	Number of fish
n_Y	Number of years sampled
NS	Not significant
PAL	Protection of aquatic life
PDB	Pointe du Bois Forebay
PEL	Probable effect level
PFF	Pine Falls Forebay
ppm	Parts per million
PSA	Particle size analysis
Q (OW)	Average discharge (cms) during the open-water period
Q (GN)	Average discharge (cms) during the gillnetting program
RCEA	Regional cumulative effects assessment
SAC	Sediment alert concentration
SE	Standard error of the mean

SEL	Severe effect level
SQG	Sediment quality guideline
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
WL (GN)	Average water level during the gillnetting program
WRR	Winnipeg River Region

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 Winnipeg River Region (WRR). As described in Technical Document 1, Section 2.7.1, the WRR is composed of Winnipeg River from the Manitoba-Ontario border downstream to the mouth of the river at Traverse Bay on Lake Winnipeg. Waterbodies and sites monitored in this region over this period included two off-system waterbodies and three on-system waterbodies or river reaches as follows (upstream to downstream direction):

- Eaglenest Lake (off-system);
- the Pointe du Bois Forebay;
- Lac du Bonnet;
- the Pine Falls Forebay; and
- Manigotagan Lake (off-system).

Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.1. 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 river reaches and on a three-year rotation at other sites. Components monitored in the WRR over this time period included hydrology, aquatic habitat, water quality, sediment quality, phytoplankton, benthic macroinvertebrates (BMI), fish community, and mercury in fish.

Results presented below include a discussion of hydrology, water quality, sediment quality, BMI, fish community, and fish mercury for key metrics, as described in Technical Document 1. Observations of note for additional metrics are also provided in the following for the water quality, BMI, and fish community components.

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 Winnipeg River Region: 2008/2009-2013/2014.

Site	Site Abbreviation	On-system	Off-system	Annual	Rotational	Sampling Years [1]					
						2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Eaglenest Lake	EAGLE		X		X			X			X
Pointe du Bois Forebay	PDB	X		X		X	X	X	X	X	X
Lac du Bonnet	LDB	X		X		X	X	X	X	X	X
Pine Falls Forebay	PFF	X			X				X		
Manigotagan Lake	MANIG		X	X		X	X	X	X	X	X

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

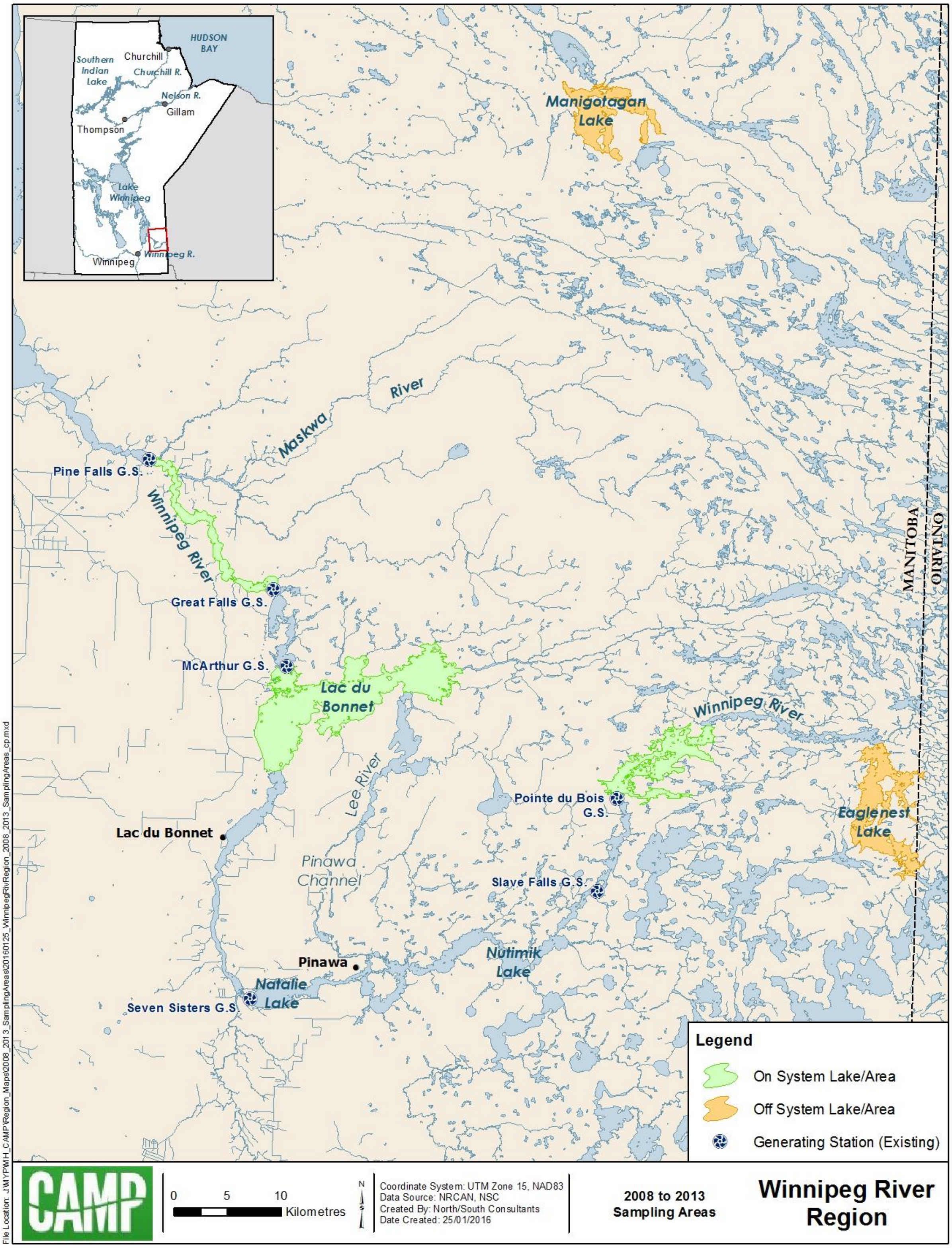


Figure 1-1. On-system and off-system waterbodies and river reaches sampled under CAMP in the Winnipeg River Region: 2008/2009-2013/2014.

2.0 HYDROLOGY

Although river flows are primarily determined by precipitation within the river's drainage basin, a major influence on Winnipeg River flows is releases from upstream storage reservoirs in Ontario, which are regulated by the Lake of the Woods Control Board considering the interest of all users. Outflows from Lake of the Woods on the Winnipeg River and Lac Seul on the English River combine at Boundary Falls just east of the Manitoba-Ontario border.

Six Manitoba Hydro generating stations (GSs) along the Winnipeg River create upstream impoundments of fairly stable water levels under almost all flow conditions. CAMP monitoring occurred in the Pointe du Bois GS Forebay, the McArthur Falls GS Forebay (Lac du Bonnet), and the Pine Falls GS Forebay. Flows for the entire reach are reported based on outflows from the Slave Falls GS since it has the longest and most reliable record along the Winnipeg River. Flows also do not change significantly from the Slave Falls GS to Lake Winnipeg.

From 2008 to 2013, flows varied considerably from near record lows in parts of some years to near record highs in other years. Flow started out very high in 2008 but dropped in spring due to a very low snowpack, before rising to record highs in August because of above average precipitation. A very high snowpack in 2009 then led to a rapid increase in spring flows peaking at a near record high in July, while average precipitation sustained flows above average most of the year. A very low snowpack led to a rapidly declining flow in the spring of 2010, which rebounded to well above the upper quartile in August because of very high summer precipitation. The snowpack leading into 2011 was slightly above average leading to high spring flows, which were followed by a rapid decline to near record low flows by September through the end of the year because of very low summer precipitation. A below average snowpack kept flows very low until briefly rising above average in the summer of 2012 before returning to lower quartile flows. Below average snowpack in 2013 led to lower quartile flows in spring followed by a rapid increase above the upper quartile due to very high precipitation in May. Flows then returned to average by the end of 2013 and stayed close to average into early 2014 (Figure 2-1).

Pointe du Bois Forebay water levels are controlled within a narrow range between 299.0 and 299.1 m, typically fluctuating by less than 0.1 metres. Water levels between 2008 and 2013 generally remained within this range (Figures 2-2).

Lac du Bonnet water levels are controlled within a narrow range between 254.8 and 255.0 m, typically fluctuating by less than 0.2 metres. Water levels in each year from 2008 to 2013 were generally very near the average (Figure 2-3).

Pine Falls Forebay water levels are controlled within a narrow range between 229.0 and 229.2 m, typically fluctuating by less than 0.2 metres. Water levels in each year from 2008 to 2013 were generally very near the average (Figure 2-4).

Manigotagan and Eaglenest lakes are the off-system waterbodies for this region. Although there are no direct water level data for Eaglenest Lake, relative lake levels can be inferred from Winnipeg River flows presented above. Similarly, there are no direct water level data for Manigotagan Lake and relative lake levels must be inferred from Manigotagan River flows. Water Survey of Canada measured Manigotagan River flows from 1913 to 1996 when monitoring of the gauging station was discontinued. No data were collected in either 2008 or 2009 however the gauge was re-established in late 2010 by Water Survey of Canada in order to provide data for CAMP. In late fall 2010, Manigotagan River flows were the highest on record indicating that Manigotagan Lake levels were likely the highest on record for that time of year and remained above average for the remainder of the year. Flows peaked above the upper quartile in the spring of 2011 before declining to lower quartile from September through December. Flows remained low through the spring of 2012 before peaking at record high in late-June to early-July and again at the end of the year. In 2013, flows were generally close to average and flows remained close to average in early 2014 (Figure 2-5).

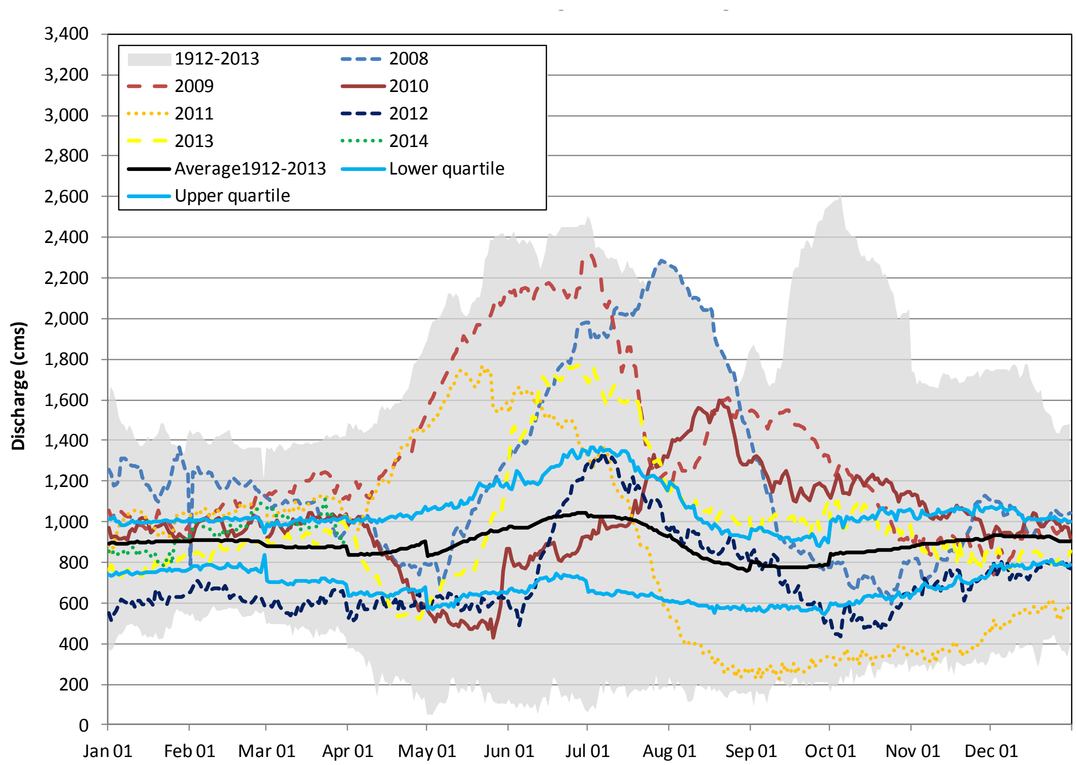


Figure 2-1. 2008-2013 Winnipeg River flow at the Slave Falls GS.

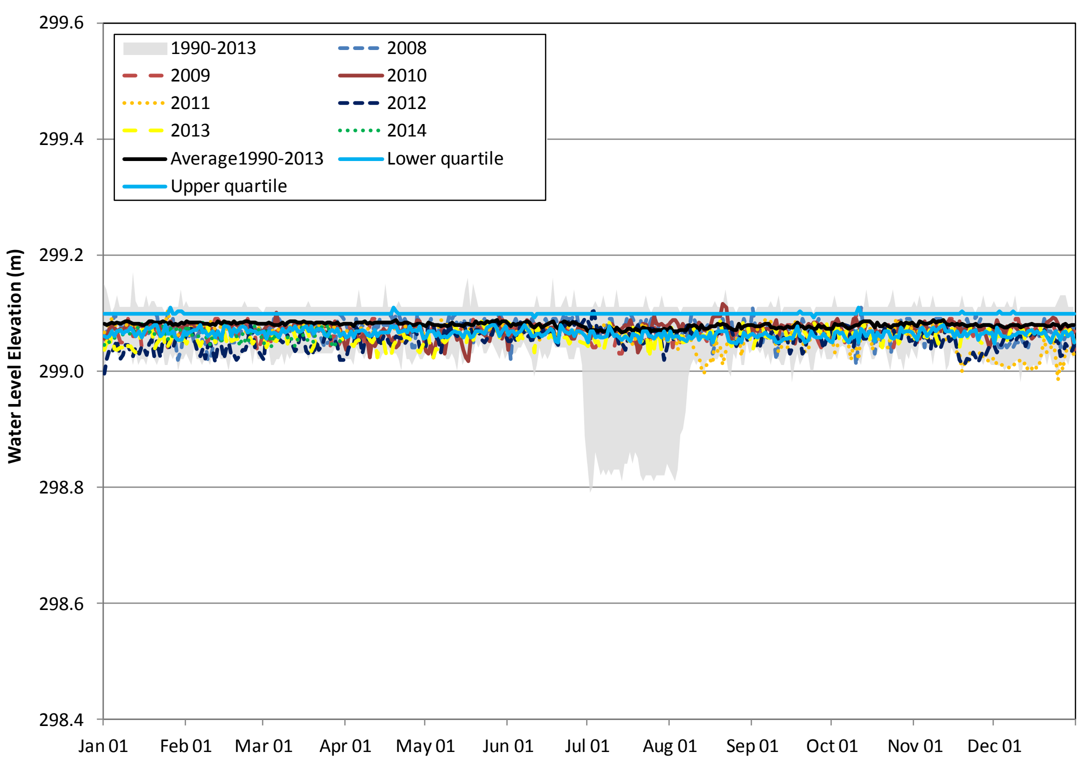


Figure 2-2. 2008-2013 Pointe du Bois Outer Forebay water level elevation.

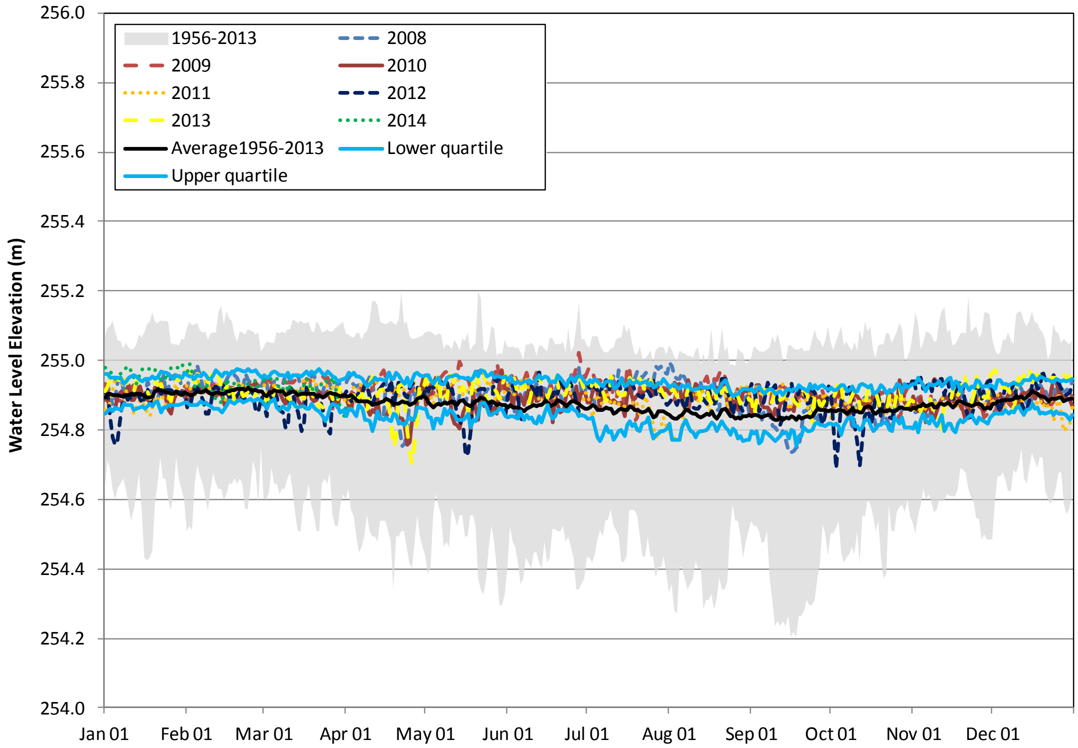


Figure 2-3. 2008-2013 Lac du Bonnet (05PF062) water level elevation.

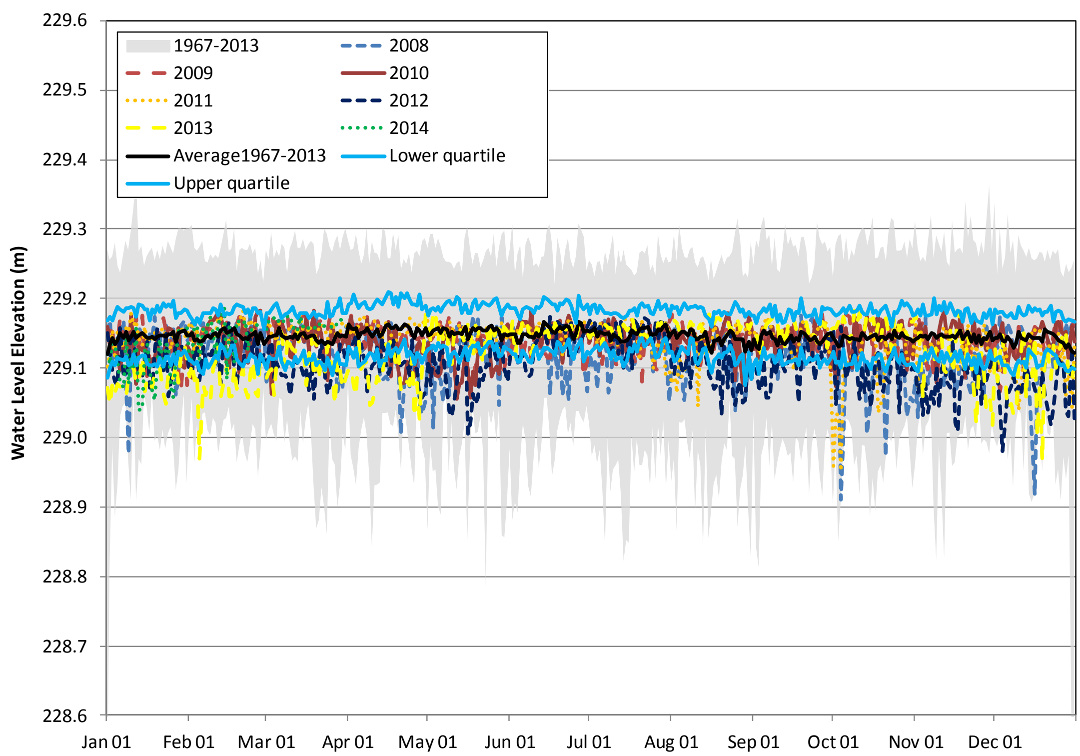


Figure 2-4. 2008-2013 Pine Falls Forebay water level elevation.

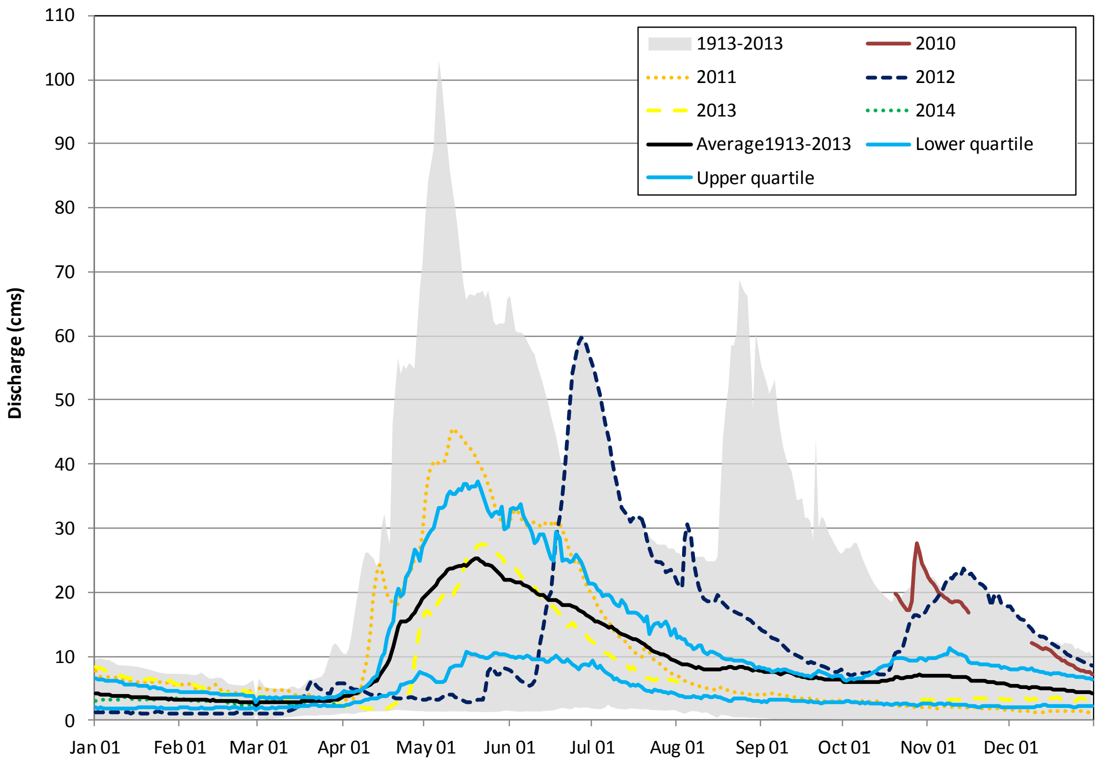


Figure 2-5. 2010-2013 Manigotagan River flow.

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 WRR. Waterbodies/river reaches sampled annually for water quality included two on-system sites (the Pointe du Bois Forebay and Lac du Bonnet) and one off-system lake (Manigotagan Lake; Table 3-1; Figure 3-1). Two additional on-system waterbodies (Eaglenest Lake and the Pine Falls Forebay) were sampled on a rotational basis.

A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 3.3. In brief, the CAMP water quality program includes four sampling periods per year (referred to as spring, summer, fall, and winter) at a single location within each monitoring waterbody or area of a waterbody/river reach. The exception occurred in the winter of 2009/2010 when sampling could not be completed at the Pointe du Bois Forebay due to thin ice.

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 sites monitored annually; 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 qualitative comparison of hydrological and water quality metrics to evaluate correlations between flow and water level and water quality metrics.

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

A detailed description of the approach and methods applied for analysis and reporting is provided in Technical Document 1, Section 4.3. Figures illustrating results for all sites sampled in the WRR 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. Results for parameters in addition to the key metrics were also reviewed and summarized in Section 3.3 where of particular note (e.g., where there was evidence of temporal trends or where a metric did not meet MWQSOGs for PAL).

3.2 KEY INDICATORS

3.2.1 Dissolved Oxygen

Concentrations of DO 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 Winnipeg River

With one exception, the lakes and forebays monitored on the Winnipeg River under CAMP were isothermal during each sampling period (Table 3-2; Figures 3-2 to 3-5). Weak/transient thermal stratification was observed in Eaglenest Lake in spring 2010 (thermocline at 0-1 m; Figure 3-2). In contrast, the off-system Manigotagan Lake was stratified during most open-water periods (Figure 3-6), likely reflecting differences in hydrology and water residence times.

Though DO conditions are not known for all sampling periods over the six years of monitoring (i.e., sampling was not completed at the Pointe du Bois Forebay in the winter of 2009/2010 and concentrations measured in the region in summer 2009, winter 2010/2011, and spring 2013 were removed from the analysis due to issues with the water quality meter), available data indicate all lakes and forebays were well-oxygenated year-round and DO concentrations across the water column consistently exceeded the most stringent Manitoba PAL objectives for cool-water and cold-water aquatic life during the open-water and ice-cover seasons (i.e., 6.5 and 9.5 mg/L, respectively; Table 3-2; Figures 3-7 to 3-10). This again contrasts with the off-system Manigotagan Lake, where DO concentrations fell below the PAL objectives during at least one season every year of the six year monitoring program (Figure 3-11). Overall, DO conditions were similar across the Winnipeg River sites and there is no indication of spatial trends along the length of the river over the first six years of CAMP (Figure 3-12).

3.2.1.2 Off-system Waterbody: Manigotagan Lake

Manigotagan Lake was thermally stratified during most open-water sampling events conducted over the six years of monitoring (Figure 3-6). Specifically, stratification was observed during all open-water sampling periods in 2008 and 2010, summer and fall 2009, 2011 and 2013, and summer 2012 (Table 3-2). During approximately half of the stratification events and some winter periods, DO concentrations in Manigotagan Lake also fell below the most stringent Manitoba PAL objectives for cool-water and cold-water aquatic life (5.5 and 9.5 mg/L, respectively) near the bottom of the water column (Figure 3-11).

DO may decrease at depth in ecosystems that experience thermal stratification due to the development of thermally distinct layers of water and the lack of wind-induced mixing of the lower layer with the oxygenated surface layer. During late summer or fall of each year, DO concentrations decreased across the water column in Manigotagan Lake to levels below one or more of the PAL objective for cold-water and cool-water species (6.5 and 6.0 mg/L, respectively) at approximately 14 m from the surface (Figure 3-11). This is in contrast to lakes located along the Winnipeg River, where DO exceeded PAL objectives during all sampling events over the first six years of CAMP.

DO may decrease in winter in north temperate ecosystems that experience long periods of ice cover due to the lack of an oxygen source from the atmosphere (i.e., no or minimal reaeration due to ice). Though the lake was isothermal during each ice-cover season, DO concentrations in Manigotagan Lake decreased across the water column in 2012/2013 and 2013/2014 and dropped below the PAL objective for cold-water species (9.5 mg/L) at approximately 18 m from the surface (Figure 3-11). Concentrations in the bottom 3 m of lake also fell below the PAL objective for cool-water species (5.5 mg/L) in winter 2009/2010. This contrasts conditions in the lakes located along the Winnipeg River, where winter DO consistently exceeded PAL objectives.

3.2.1.3 Temporal Comparisons and Trends

Examination of data for the two annual on-system monitoring sites (the Pointe du Bois Forebay and Lac du Bonnet) indicates open-water season DO did not vary significantly between years at either site along the Winnipeg River; a lack of significant inter-annual variability was also observed at the off-system Manigotagan Lake (Figure 3-13). Additionally, there was no indication of an increasing or decreasing trend in oxygen conditions over the six year monitoring period at either on- or off-system sites.

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 Winnipeg River

Water clarity was relatively high in this region over the six years of monitoring. Specifically, annual averages of TSS were less than 5 mg/L at each site, with detectable concentrations observed during most periods (TSS concentrations were below the analytical detection limit [DL] of 2 mg/L in a maximum of 37% of samples; Table 3-2; Figure 3-14). Mean annual turbidity was less than 6 NTU (Table 3-2; Figure 3-15). Secchi disk depths also indicated high water clarity, with open-water means typically exceeding 1 m at each site (Figure 3-16).

TSS, turbidity, and Secchi disk depths all decreased with increasing distance down the Winnipeg River (Figure 3-17).

3.2.2.2 Off-system Waterbody: Manigotagan Lake

TSS and turbidity were lower, and Secchi disk depth was higher, in the off-system Manigotagan Lake than in lakes along the Winnipeg River (Figures 3-14 to 3-17). The majority of TSS measurements in Manigotagan Lake were less than the 2 mg/L detection limit.

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 sites (Lac du Bonnet and the Pointe du Bois Forebay) and visual examination of the data for the six-year period does not suggest increasing or decreasing trends in these metrics. The off-system site (Manigotagan Lake) indicated relatively consistent turbidity and TSS but a potential increasing trend in Secchi disk depth. However, the lack of trends may reflect the relatively limited quantity of data and/or temporal period.

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 (TP and TN) 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 Winnipeg River

Lakes and forebays along the Winnipeg River were mesotrophic to meso-eutrophic on the basis of mean open-water season TP concentrations, mesotrophic based on TN, and mesotrophic to eutrophic based on chlorophyll *a* (Table 3-3 and Figures 3-18 to 3-20). One exception occurred in 2010/2011, when the mean TN concentration in the Pointe du Bois Forebay was within the oligotrophic range.

Annual mean open-water TP concentrations were typically below the Manitoba narrative nutrient guideline (0.025 mg/L for lakes, reservoirs and streams near the inflows to waterbodies; MWS 2011) over the six years of monitoring (Figure 3-21). However, TP concentrations exceeded the narrative guideline in some samples and, on average, in some years of monitoring; between 22 and 58% of samples collected within each waterbody exceeded the guideline. This occurrence was observed in other CAMP regions and is commonly observed in other more southern lakes and streams in Manitoba, including Lake Winnipeg (Environment Canada [EC] and MWS 2011).

On one or two occasions in the open-water season in each lake, chlorophyll *a* concentrations exceeded 10 µg/L – the trigger applied under CAMP as indicative of an algal bloom (Table 3-3); all instances occurred either in spring 2011 or spring 2013.

Neither open-water season TP nor TN was significantly correlated to chlorophyll *a* in the Pointe du Bois Forebay or Lac du Bonnet, based on the first six years of monitoring data (Figure 3-22). This suggests that nutrients are not the primary factor limiting phytoplankton growth and/or that bioavailability of nutrients is limited; however, lack of significant correlations may also be a reflection of the relatively limited amount of data and/or small range of conditions encountered over the monitoring period. Most on-system waterbodies sampled annually under CAMP showed either the lack of a, or a weak, correlation between nutrients and chlorophyll *a* for the six year monitoring period; the exception was Lake Winnipeg (see Technical Document 4, Section 3.2.3.1).

The ratio of chlorophyll *a* to TP (which ranged from a mean of 0.25 to 0.47 in this region; Table 3-3) - an indicator of the efficiency of assimilating phosphorus into algae — indicates lakes along the Winnipeg River produce a low to moderate amount of chlorophyll *a* per unit phosphorus. Assimilation efficiency in Eaglenest Lake, the Pointe du Bois Forebay, and Lac du Bonnet was low and similar to that of the off-system Manigotagan Lake (mean ratio of 0.28), while the efficiency for the Pine Falls Forebay was higher (0.47), though based on a single year of sampling (Figure 3-23).

Spatial patterns for nutrients and chlorophyll *a* in the Winnipeg River differ by parameter. There was no apparent pattern for TP, though there is some indication of a slight increase in mean TN at the furthest downstream site (i.e., the Pine Falls Forebay; Figure 3-24). Mean chlorophyll *a* was similar between the upstream sites but the mean concentration was somewhat higher in the Pine Falls Forebay (Figures 3-24). Although the latter site was only sampled in one of the six years, in the year it was sampled (2011/2012), the annual mean chlorophyll *a* was higher than conditions measured concurrently at the other sites (Figure 3-20).

3.2.3.2 Off-system Waterbody: Manigotagan Lake

On average, Manigotagan Lake had a similar trophic status (i.e., mesotrophic to meso-eutrophic based on mean open-water TP, TN, and chlorophyll *a*) compared to lakes and forebays on the

Winnipeg River (Tables 3-2 and 3-3 and Figures 3-18 to 3-20). TP in Manigotagan Lake was not significantly correlated to chlorophyll *a* during the open-water season, although there was a weak, positive relationship between TN and chlorophyll *a* for this site (Figure 3-22). As noted in Section 3.2.3.1, the absence of strong nutrient-algal relationships may indicate that factors other than nutrients are limiting to phytoplankton growth and/or that bioavailability of nutrients is limited, but may also reflect the relatively limited data acquired over the monitoring period.

The annual mean TP in Manigotagan Lake only exceeded the Manitoba narrative nutrient guideline for TP for lakes, reservoirs and streams near the inflows to waterbodies (0.025 mg/L) on one occasion (2010/2011; Figure 3-21). However, approximately 33% of samples (all from winter and the following spring) were above the guideline, which is similar to the frequency of exceedance observed for the on-system sites.

3.2.3.3 Temporal Comparisons and Trends

There were no statistically significant inter-annual differences for open-water TN, TP, or chlorophyll *a* at any of the annual monitoring sites. Additionally, none of the metrics exhibited an increasing or decreasing trend over the six years of monitoring in the Pointe du Forebay, Lac du Bonnet, or Manigotagan Lake.

3.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

Other water quality metrics measured under CAMP, as described in Technical Document 1, Section 3.3.1, were also reviewed to assess trends and to compare to water quality objectives and guidelines for the protection of aquatic life. Water quality metrics were relatively consistent over the six year monitoring period in the Winnipeg River and no trends were evident.

Ammonia, nitrate/nitrite, and pH remained within PAL objectives and guidelines at all sites and times, both on- and off-system. Additionally, most metals were consistently within Manitoba water quality PAL objectives and guidelines. Exceptions included aluminum, copper, iron, selenium, and silver (Table 3-4). Aluminum was above the PAL guideline (0.1 mg/L; MWS 2011) in 96-100% of samples from the Winnipeg River sites; exceedance of this metal was also observed in 29% of samples from Manigotagan Lake. Iron concentrations occasionally exceeded the PAL guideline (0.3 mg/L) and copper exceeded the site-specific objectives in one sample from each of Eaglenest Lake, Lac du Bonnet, and the Pine Falls Forebay. In addition, one sample from the Pine Falls Forebay and one sample from Lac du Bonnet was marginally above the guideline for selenium (0.001 mg/L) and silver (0.0001 mg/L), respectively. However, the analytical detection limits for these metals were equivalent to the PAL guidelines. Measurements that are at or near the detection limit 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 detection limit. Elevated levels of aluminum and iron, and occasional exceedances of PAL objectives and guidelines for other metals, are common in Manitoban 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).

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 (309-429 mg/L; Meays and Nordin 2013) at all on- and off-system sites monitored in this region.

3.4 RELATIONSHIPS WITH HYDROLOGICAL METRICS

As water quality conditions were relatively consistent in the Winnipeg River over the six year monitoring period, statistical comparisons between hydrological and water quality metrics were not conducted. Qualitatively, there were no indications of relationships between water quality metrics and hydrological conditions. As described in Section 2.0, water levels on the Winnipeg River fluctuated over a small range (i.e., generally by less than 0.2 m over 2008-2013) and relationships between water level and water quality would therefore not be expected. Conversely, discharge (as measured at the Slave Falls GS) varied substantively between seasons and years, with high flows (i.e., near record flows) in 2008 and 2009 over the open-water season monitoring period and relatively low (near average) flows in the open-water season monitoring period in 2012. That water quality conditions were relatively consistent, or at a minimum did not appear to follow the discharge patterns, suggests that discharge was not a major factor affecting water quality in this region over the six year monitoring period.

3.5 SUMMARY

Lakes and reservoirs along the Winnipeg River were well-oxygenated, relatively clear (i.e., TSS and turbidity were low), and the water column was well-mixed (i.e., on-system sites generally do not stratify). In contrast, the off-system Manigotagan Lake stratified in the open-water-seasons – meaning the water column was not mixed – and lower DO levels were observed in the lower part of the water column.

The Winnipeg River was moderately to highly nutrient-rich, with moderate to high concentrations of chlorophyll *a* (i.e., indicator of algal abundance). Lakes located along the Winnipeg River were mesotrophic to eutrophic based on nitrogen, phosphorus, and chlorophyll *a*. While many water quality metrics were similar along the length of the Winnipeg River, three key metrics (TSS, turbidity, and nitrogen) increased slightly with increasing distance downstream.

Most water quality metrics measured in the WRR were within objectives and guidelines for the protection of aquatic life, and the few metrics that exceeded these benchmarks with a relatively high frequency (total phosphorous, aluminum, and iron) are commonly above these benchmarks in other Manitoba lakes and rivers, including off-system sites monitored under CAMP.

There was no indication of an increasing or decreasing trend for water quality metrics, including key metrics, despite relatively large variations in river discharge experienced over the six year monitoring period. That water quality conditions were relatively consistent over this period, and did not appear to follow the discharge patterns, suggests that within the confines of conditions encountered in the six year monitoring period, discharge was not a major factor affecting water quality in this region.

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

Waterbody/Area	Site Abbreviation	Site ID	On-system	Off-system	Annual	Rotational	Sampling Years[1]					
							2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Eaglenest Lake	EAGLE	PFS 097		X		X			X			X
Pointe du Bois Forebay	PDB	PFS 094	X		X		X	X[2]	X	X	X	X
Lac du Bonnet	LDB	PFS 093	X		X		X	X	X	X	X	X
Pine Falls Forebay	PFF	PFS 098	X			X				X		
Manigotagan Lake	MANIG	RAS 155		X	X		X	X	X	X	X	X

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

[2] Site was not sampled in winter 2009/2010 due to thin ice conditions.

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

Metric		**Waterbody**				
		EAGLE	**PDB**	**LDB**	**PFF**	**MANIG**
Years Sampled		2010/11, 2013/14	2008/09-2013/14	2008/09-2013/14	2011/12	2008/09-2013/14
TP	(mg/L)	0.024	0.023	0.026	0.022	0.022
	Trophic Status	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic
TN	(mg/L)	0.40	0.46	0.50	0.49	0.54
	Trophic Status	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
TKN	(mg/L)	0.36	0.41	0.45	0.45	0.47
Chlorophyll *a*	(µg/L)	4.2	5.2	4.9	7.6	4.2
	Trophic Status	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
TN:TP	-	38.0	46.1	43.3	53.1	60.0
DOC	(mg/L)	10.3	10.2	10.3	10.5	13.1
Nitrate/nitrite	(mg N/L)	0.048	0.050	0.052	0.040	0.067
Ammonia	(mg N/L)	0.009	0.010	0.011	0.008	0.009
Dissolved Phosphorus	(mg/L)	0.014	0.014	0.017	0.016	0.015
DO Lower than MWQSOGs for PAL	(Y/N)	No	No	No	No	Yes (summer 2012; fall 2008, 2009, 2010, 2011, 2013; winter 2009/10, 2012/13, 2013/14)
DO - open-water season	(mg/L)	9.66	10.0	10.1	8.54	9.75
DO - open-water season	(mg/L)	9.63	9.88	9.87	8.53	7.36
DO - ice-cover season	(mg/L)	13.7	13.0	14.6	13.7	14.0
DO - ice-cover season	(mg/L)	13.3	12.9	14.3	13.7	8.50
Thermal Stratification	(Y/N)	Yes (spring 2010)	No	No	No	Yes (spring 2008 and 2010; summer 2008-2013; and, fall 2008, 2009, 2010, 2011 and 2013)
Secchi Disk Depth (open-water season)	(m)	1.7	1.5	1.1	1.2	1.9
TSS	(mg/L)	2.4	3.4	4.4	4.9	1.3
Turbidity	(NTU)	3.4	4.1	5.4	5.6	1.9
True Colour	(TCU)	32.1	34.1	33.8	32.3	55.4
Specific Conductance	(µmhos/cm)	98.7	97.9	101	99.7	72.5
Total Dissolved Solids	(mg/L)	69.7	66.6	69.1	64.7	55.5
Hardness	(mg/L)	46.2	47.1	48.8	54.0	37.8
Hardness Category	-	Soft	Soft	Soft	Soft	Soft
pH	-	7.84	7.88	7.91	7.94	7.79
Total Alkalinity	(mg/L)	42.4	43.2	44.6	45.0	33.9
Metals > MWQSOGs for PAL	-	Al, Cu, Fe	Al, Fe	Al, Cu, Fe, Ag	Al, Cu, Fe, Se	Al, Se
Aluminum	(mg/L)	0.229	0.233	0.256	0.268	0.086
Iron	(mg/L)	0.209	0.215	0.251	0.238	0.156
Mercury (<26 ng/L DL only)	(ng/L)	2.9	<20	<20	-	<20
Mercury (≤1 ng/L DL only)	(ng/L)	2.9	1.4	2.3	-	1.9
Calcium	(mg/L)	12.5	12.7	13.1	14.5	9.65
Magnesium	(mg/L)	3.62	3.72	3.92	4.33	3.33
Potassium	(mg/L)	0.93	0.94	0.96	1.01	0.80
Sodium	(mg/L)	2.51	2.58	2.61	2.78	1.03
Chloride	(mg/L)	1.54	1.60	1.63	1.55	0.55
Sulphate	(mg/L)	3.73	4.19	4.44	3.50	2.92

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

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

Indicator	**Metric**		**Units**	**Waterbody**				
				EAGLE	**PDB**	**LDB**	**PFF**	**MANIG**
Nutrients	TP	Mean	(mg/L)	0.023	0.022	0.026	0.022	0.020
		Trophic Status	-	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic
	TN	Mean	(mg/L)	0.37	0.44	0.46	0.48	0.53
		Trophic Status	-	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
	Chlorophyll *a*	Mean	(µg/L)	5.6	6.5	6.2	9.6	5.2
		Trophic Status	-	Mesotrophic	Mesotrophic	Mesotrophic	Eutrophic	Mesotrophic
	TN:TP	Mean	-	37	46	41	55	64
		Nutrient Limitation	(mg/L)	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation
	Chlorophyll *a*:TP	Mean	-	0.26	0.30	0.25	0.47	0.28
	Chlorophyll *a*:TN	Mean	-	0.015	0.016	0.014	0.020	0.010
	Algal Bloom Frequency (Chlorophyll *a* >10 µg/L)	-	(%)	17	11	11	33	0
Dissolved Oxygen	DO Lower than MWQSOGs for PAL	-	(Y/N)	No	No	No	No	Yes (summer 2012; fall 2008, 2009, 2010, 2011, 2013)
	DO	Surface Mean	(mg/L)	9.66	10.0	10.1	8.54	9.75
		Bottom Mean	(mg/L)	9.63	9.88	9.87	8.53	7.36
	Thermal Stratification	-	(Y/N)	Yes (spring 2010)	No	No	No	Yes (spring 2008 and 2010; summer 2008-2013; and, fall 2008, 2009, 2010, 2011 and 2013)
Water Clarity	Secchi Disk Depth	Mean	(m)	1.7	1.5	1.1	1.2	1.9
	TSS	Mean	(mg/L)	2.6	3.8	5.4	5.9	1.4
	Turbidity	Mean	(NTU)	3.21	4.11	5.87	5.86	2.09

Table 3-4. Frequency of exceedances of MWQSOGs for PAL for metals measured in the Winnipeg River Region: 2008-2013. Values in red indicate exceedances occurred at a given site.

		MWQSOGs PAL																CCME PAL	BCMOE PAL
Waterbody		**Aluminum**	**Arsenic**	**Boron**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Mercury[1]**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Uranium**	**Zinc**	**Chloride**	**Sulphate**
Objective or Guideline Value (mg/L)		0.1	0.15	1.5	0.000118 – 0.000181	0.0345 – 0.0551	0.00359 – 0.00585	0.3	0.000767 – 0.00159	0.000026	0.073	0.0203 – 0.0329	0.001	0.0001	0.0008	0.015	0.0465 – 0.075	120	309-429
Eaglenest 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	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	**13**	**13**	0	0	0	0	0	0	0	0	0	0	0
Pointe du Bois Forebay	n	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
	# Exceedances	**23**	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**17**	0	0	0	0	0	0	0	0	0	0	0
Lac du Bonnet	n	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	# Exceedances	**23**	0	0	0	0	**1**	**6**	0	0	0	0	0	**1**	0	0	0	0	0
	% Exceedance	**96**	0	0	0	0	**4**	**25**	0	0	0	0	0	**4**	0	0	0	0	0
Pine Falls Reservoir	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	# Exceedances	**4**	0	0	0	0	**1**	**1**	0	0	0	0	**1**	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	**25**	**25**	0	0	0	0	**25**	0	0	0	0	0	0
Manigotagan Lake	n	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	# Exceedances	**7**	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0
	% Exceedance	**29**	0	0	0	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0

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

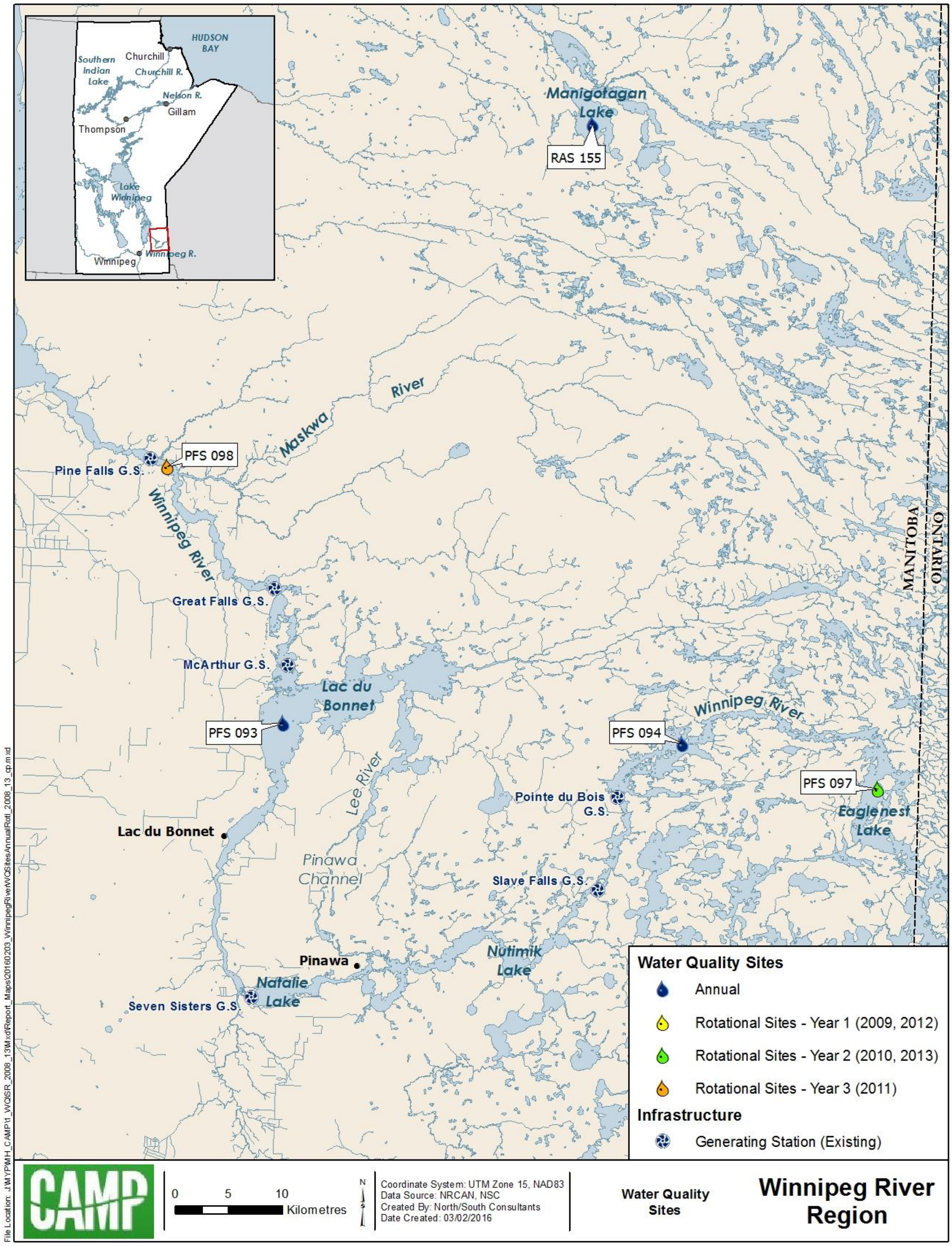


Figure 3-1. Water quality sampling sites in the Winnipeg River Region: 2008/2009-2013/2014.

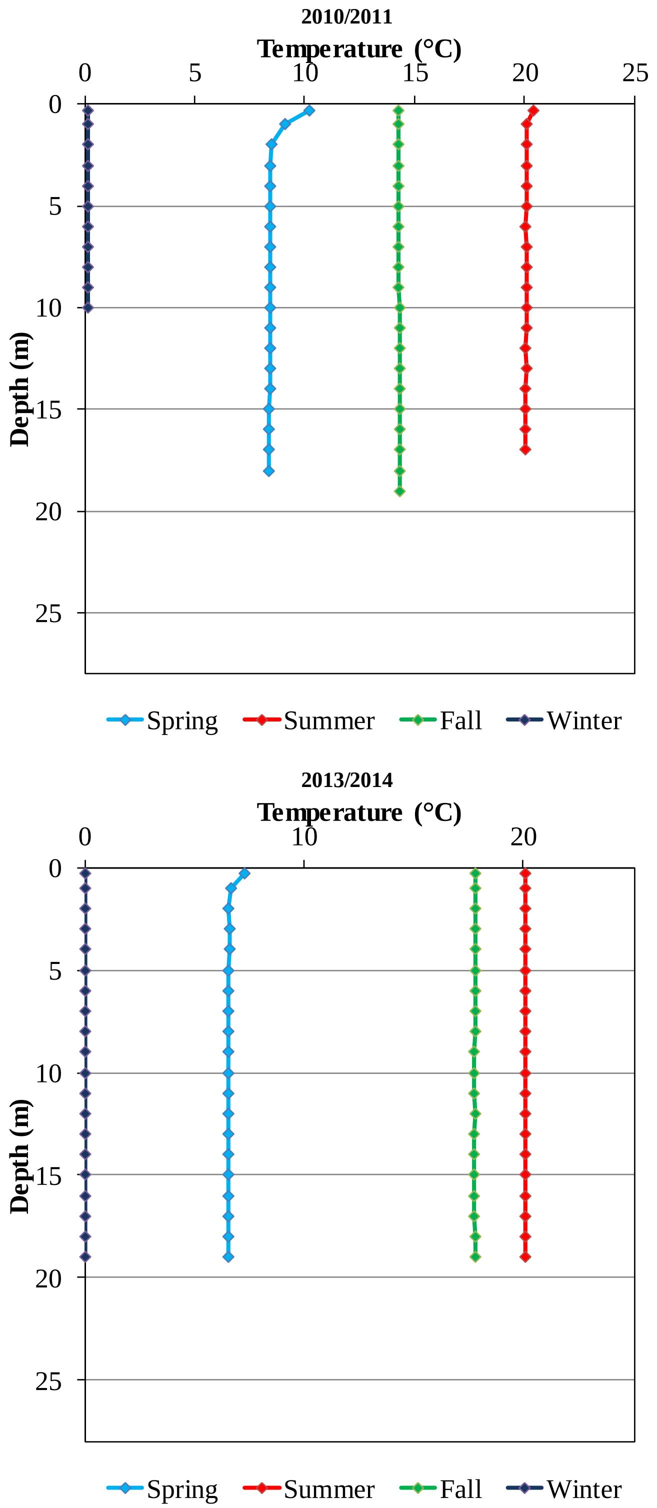


Figure 3-2. Temperature depth profiles in Eaglenest Lake: 2008/2009-2013/2014.

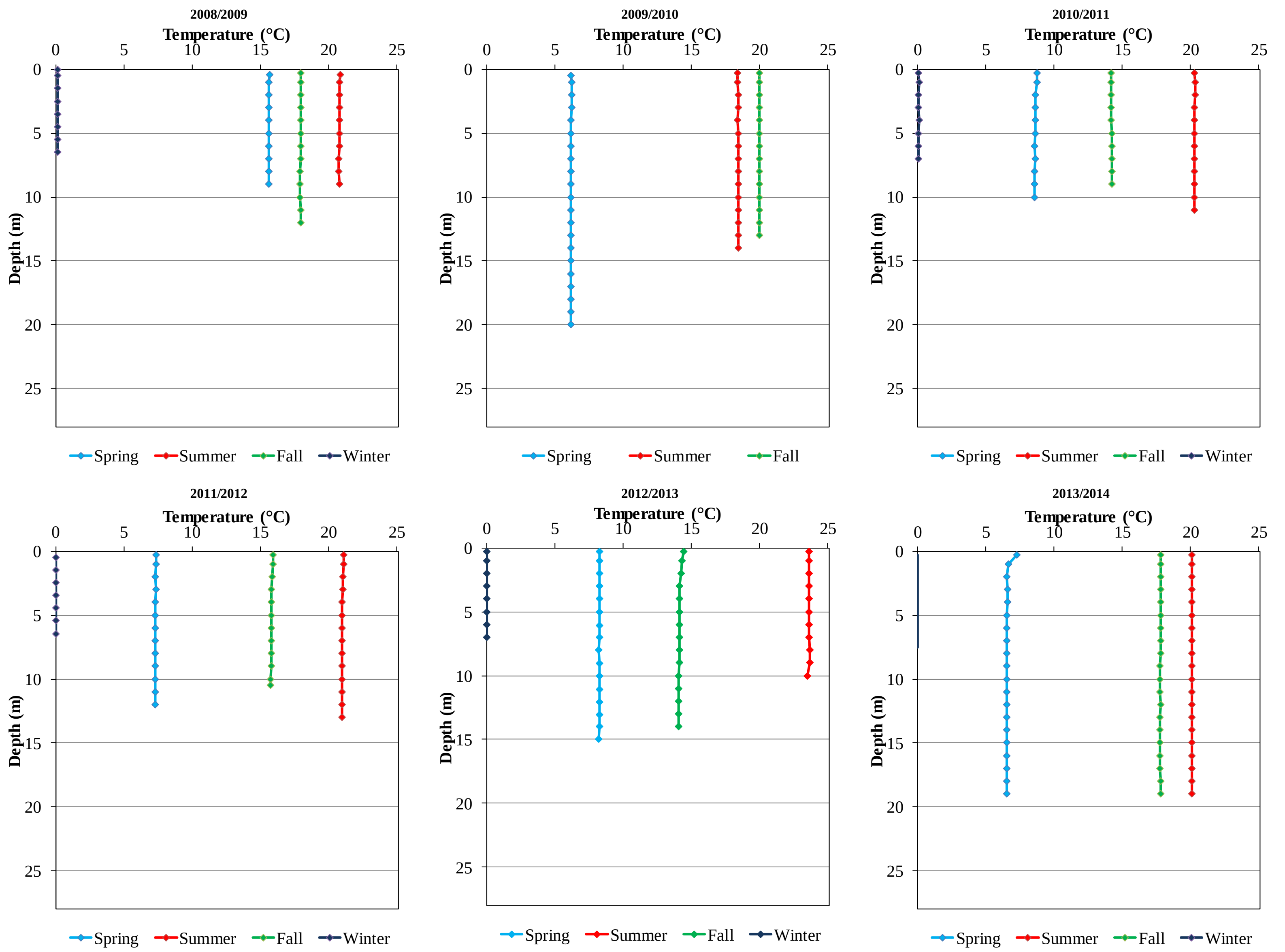


Figure 3-3. Temperature depth profiles in Pointe du Bois: 2008/2009-2013/2014.

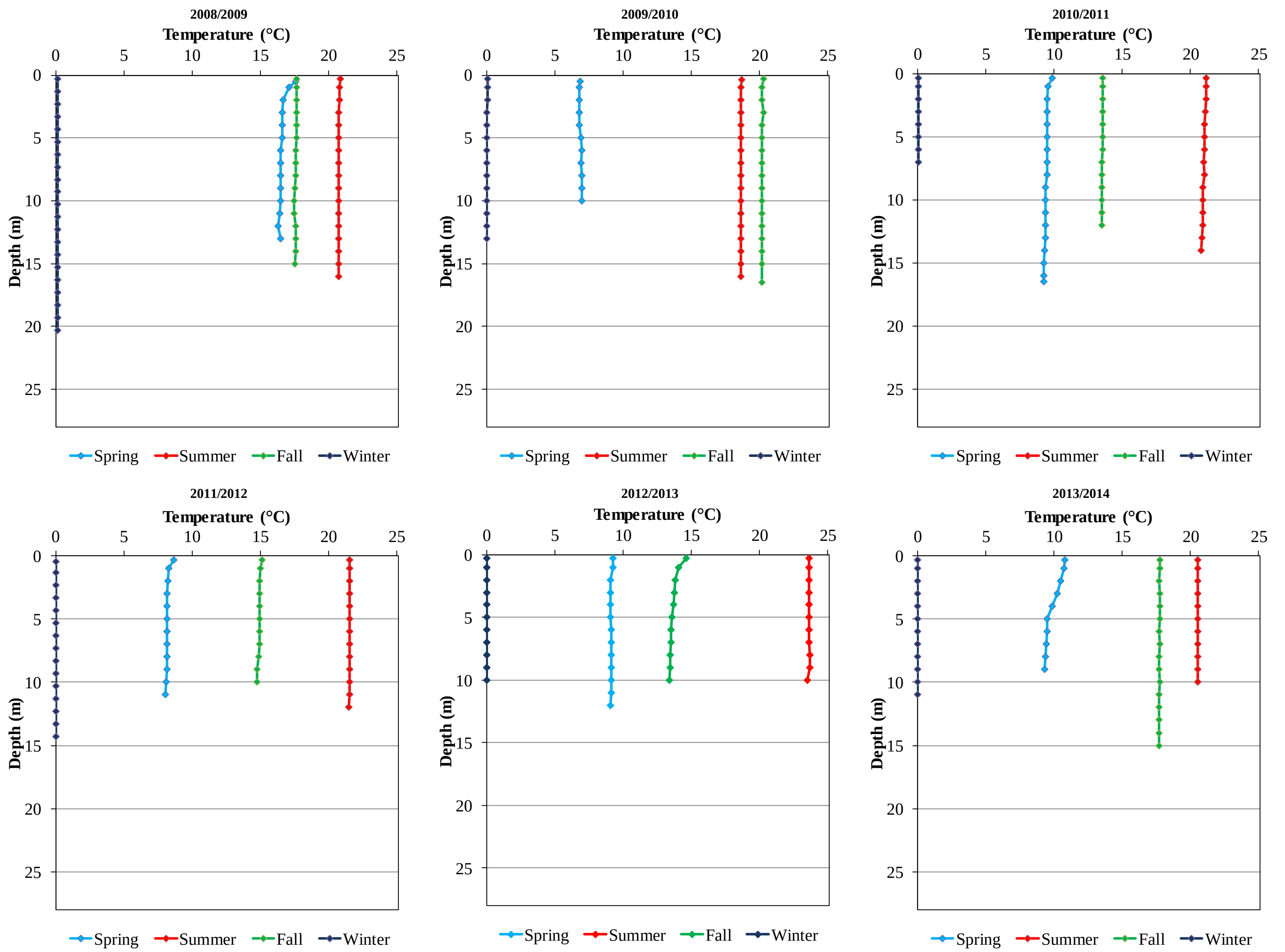


Figure 3-4. Temperature depth profiles in Lac du Bonnet: 2008/2009-2013/2014.

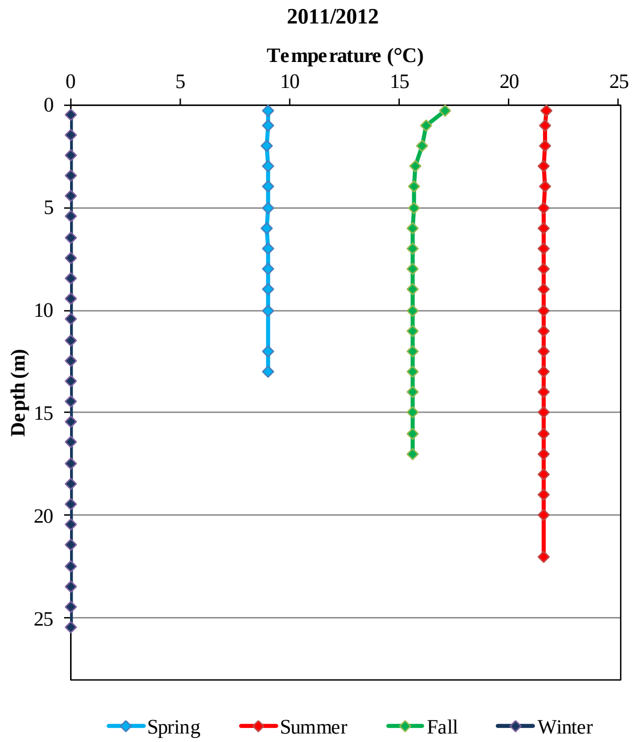


Figure 3-5. Temperature depth profiles in Pine Falls Forebay: 2008/2009-2013/2014.

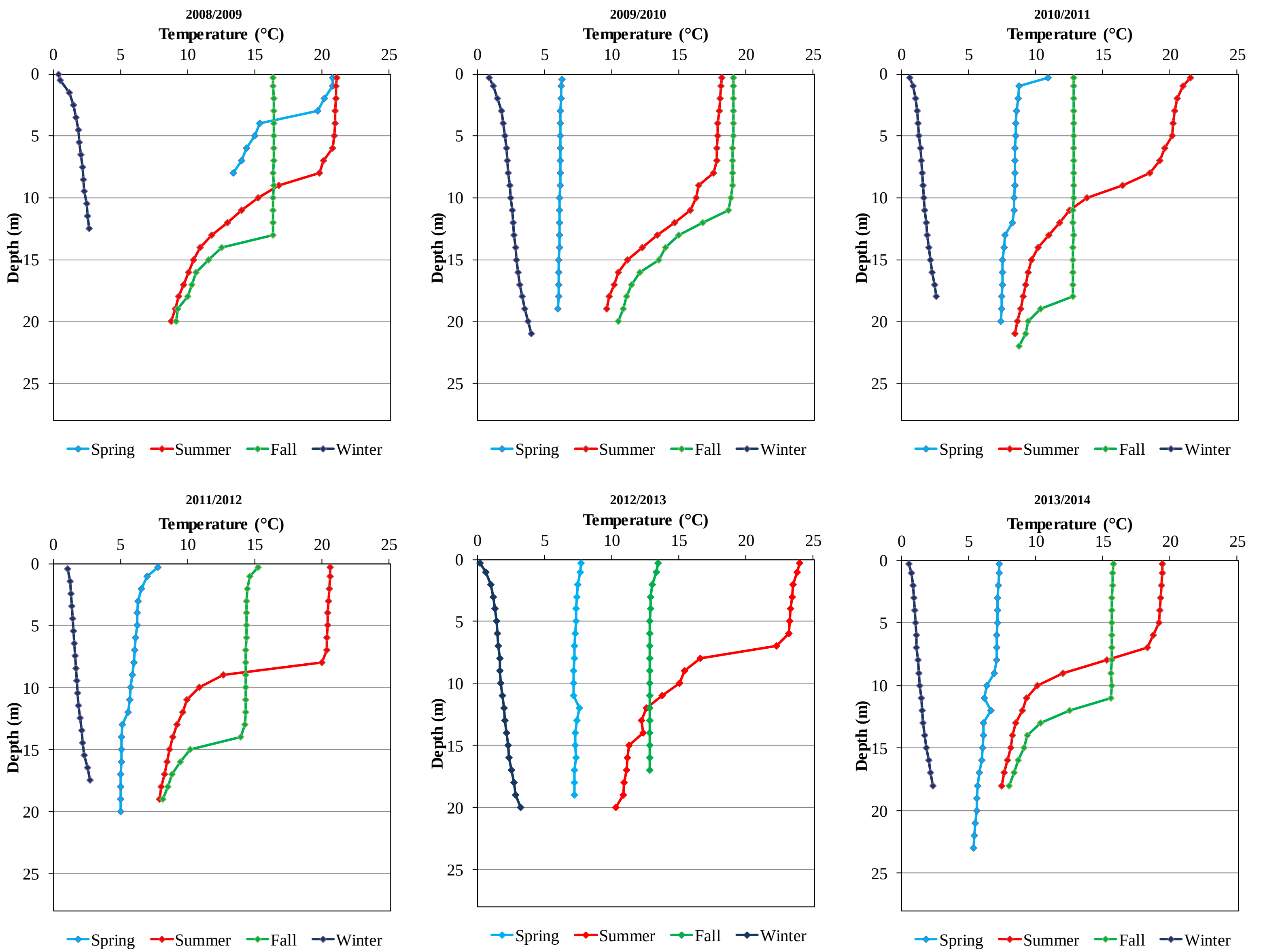


Figure 3-6. Temperature depth profiles in the off-system Manigotagan Lake: 2008/2009-2013/2014.

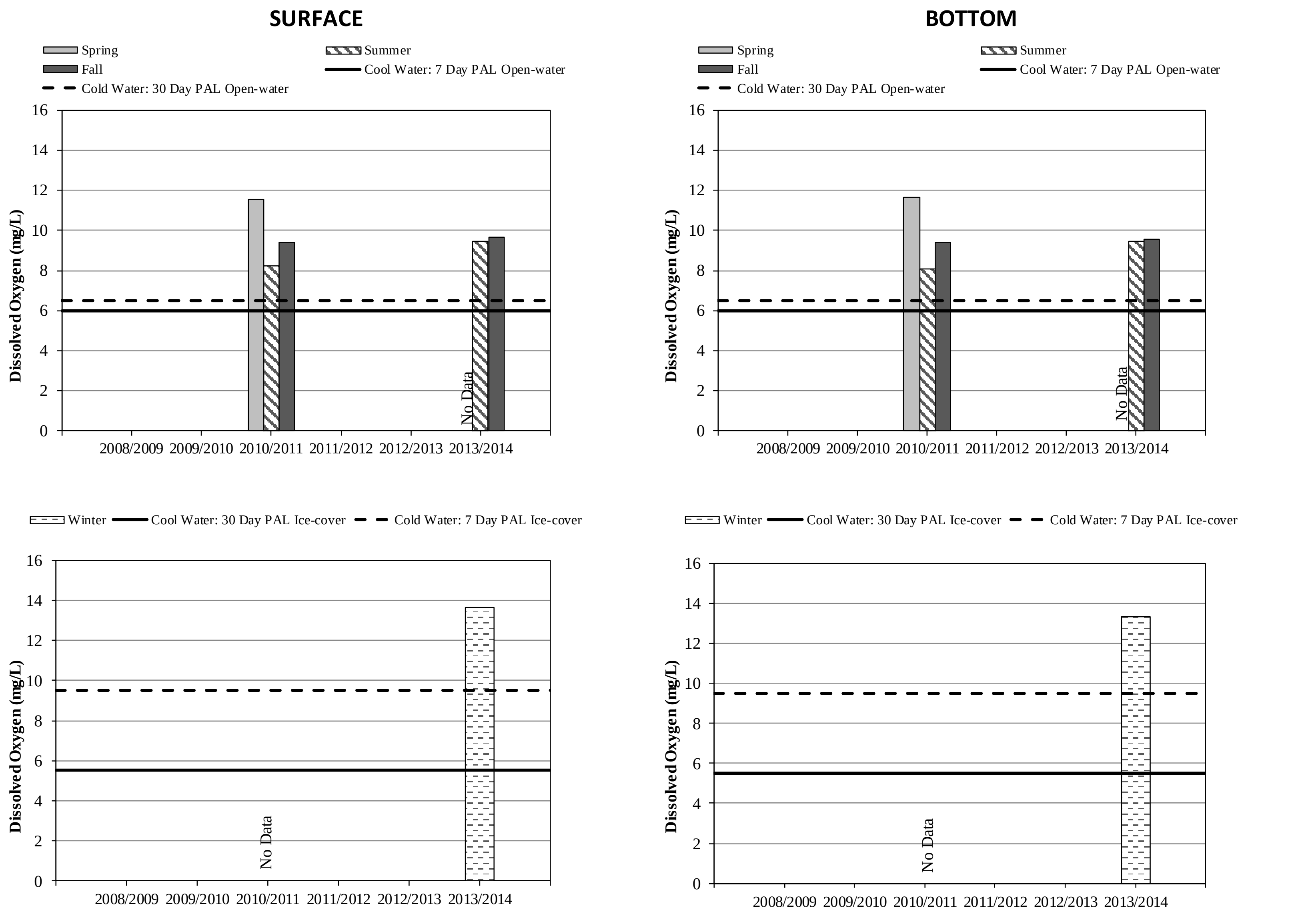


Figure 3-7. Dissolved oxygen measured near the surface and bottom of the water column in Eaglenest Lake and comparison to MB PAL objectives: 2008/2009-2013/2014.

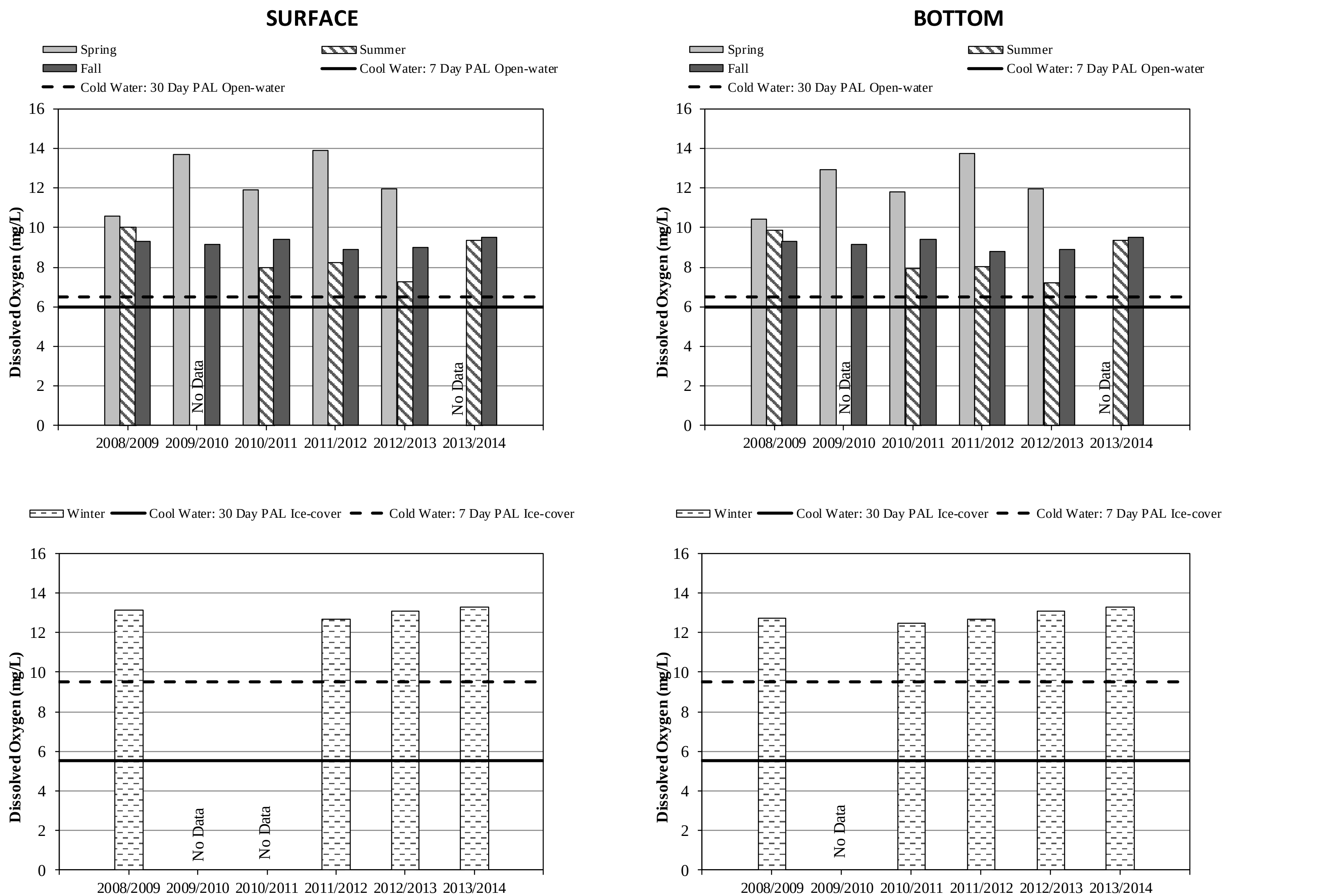


Figure 3-8. Dissolved oxygen measured near the surface and bottom of the water column in the Pointe du Bois Forebay and comparison to MB PAL objectives: 2008/2009-2013/2014.

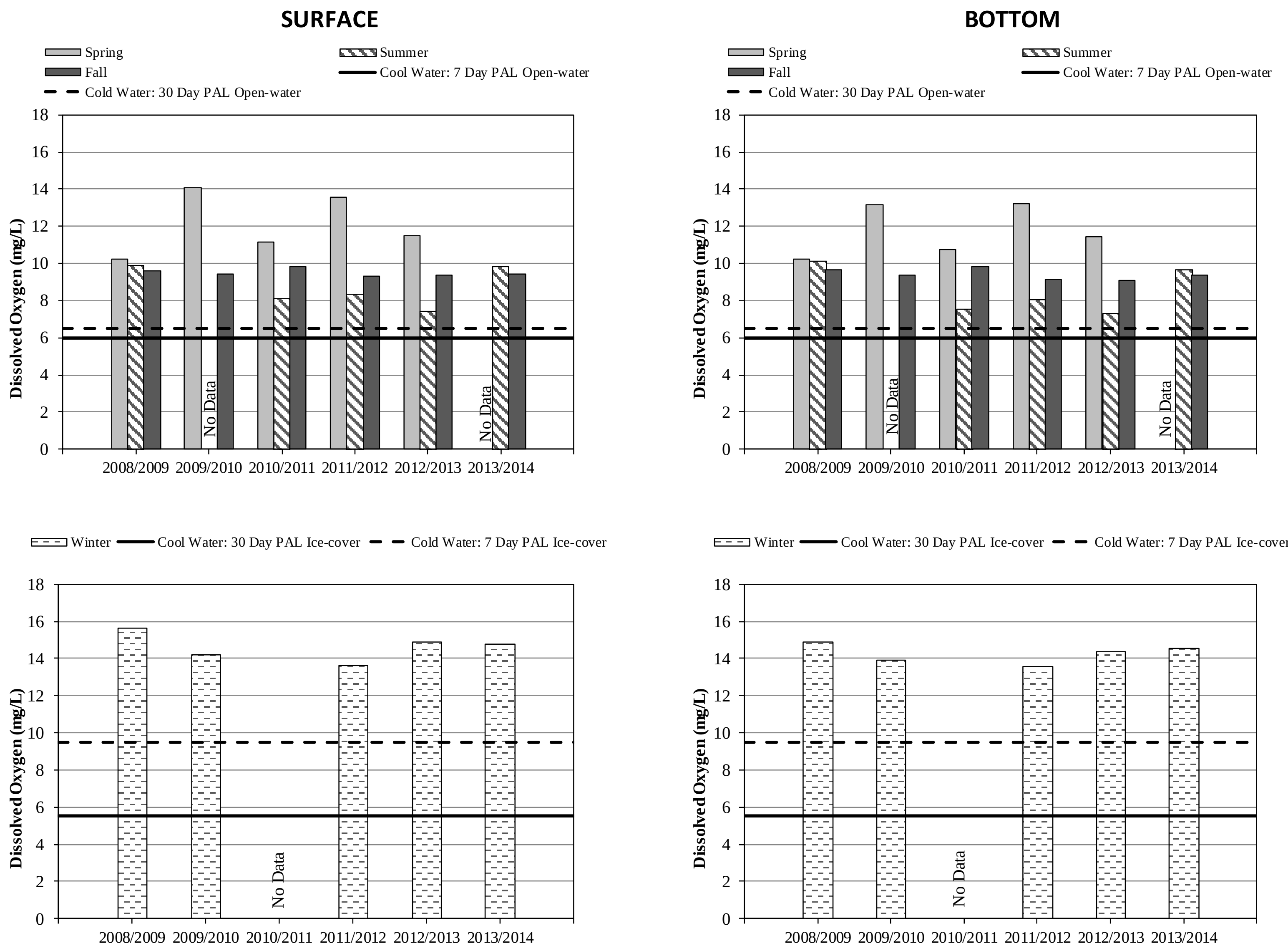
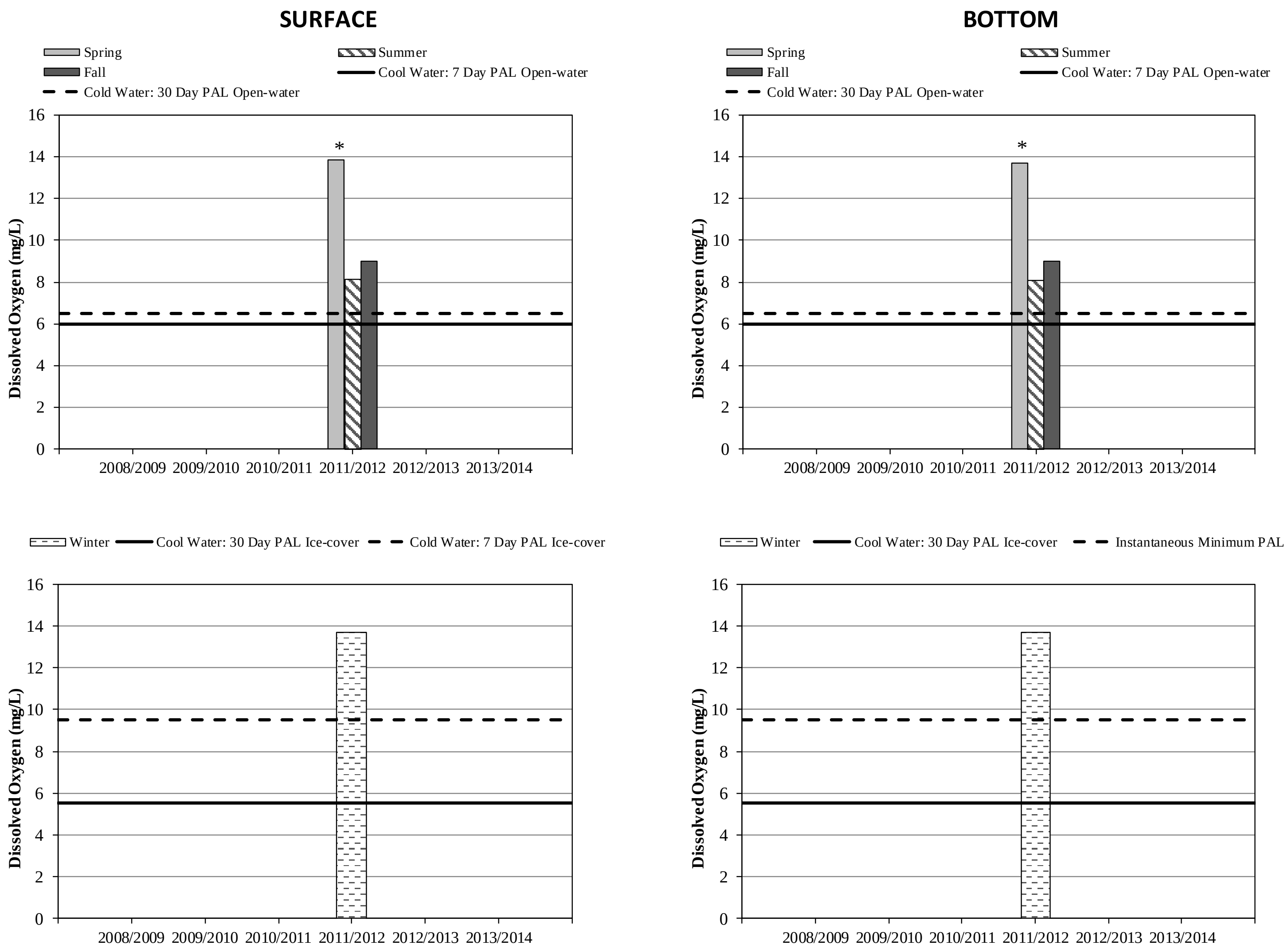


Figure 3-9. Dissolved oxygen measured near the surface and bottom of the water column in Lac du Bonnet and comparison to MB PAL objectives: 2008/2009-2013/2014.



*Values indicated with an asterisk are considered suspect.

Figure 3-10. Dissolved oxygen measured near the surface and bottom of the water column in Pine Falls Forebay and comparison to MB PAL objectives: 2008/2009-2013/2014.

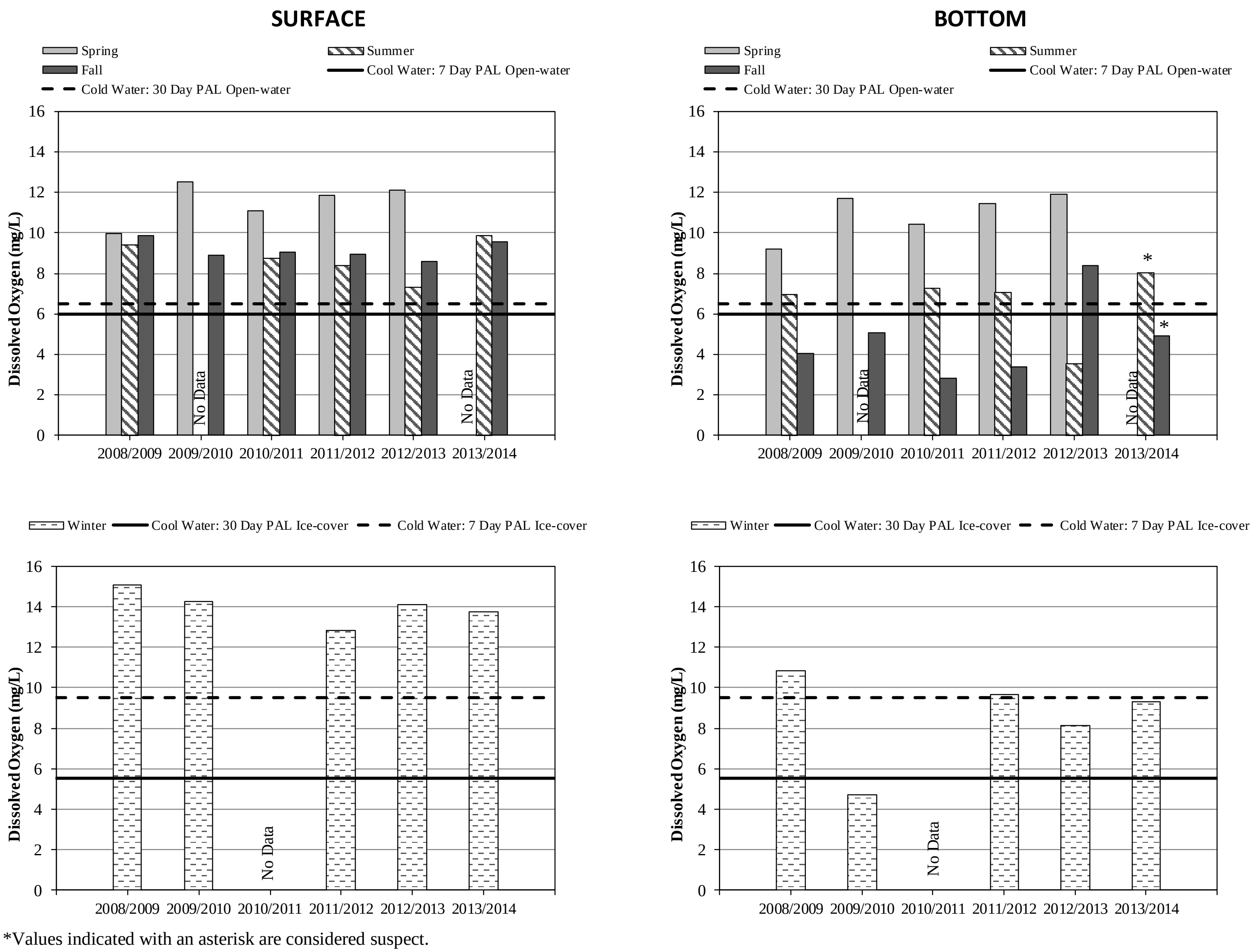


Figure 3-11. Dissolved oxygen measured near the surface and bottom of the water column in the off-system Manigotagan Lake and comparison to MB PAL objectives: 2008/2009-2013/2014. Values indicated with an asterisk are considered suspect.

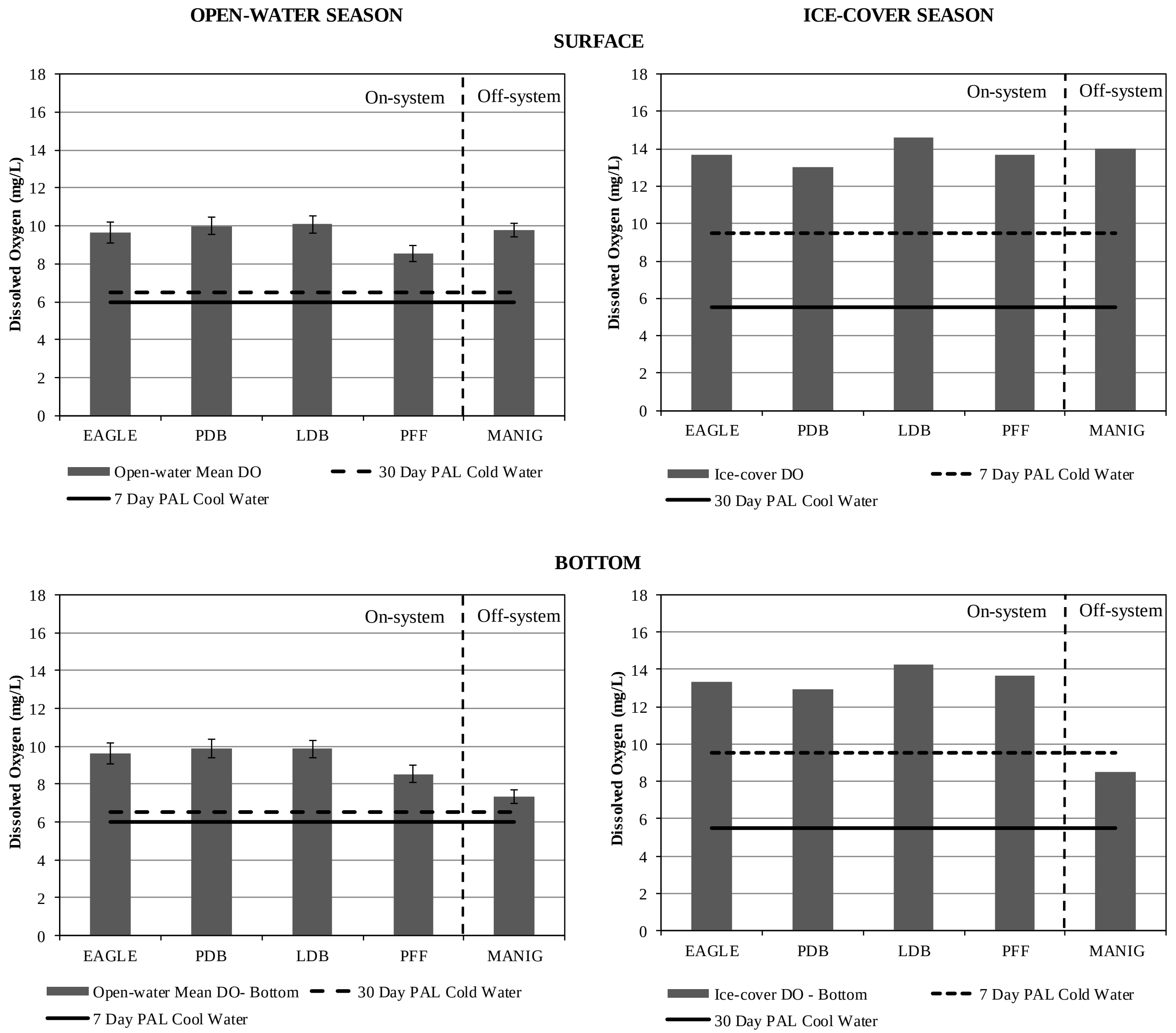


Figure 3-12. Dissolved oxygen (mean±standard error of the mean [SE]) measured near the surface and bottom of the water column in the Winnipeg River and off-system waterbodies: 2008/2009-2013/2014.

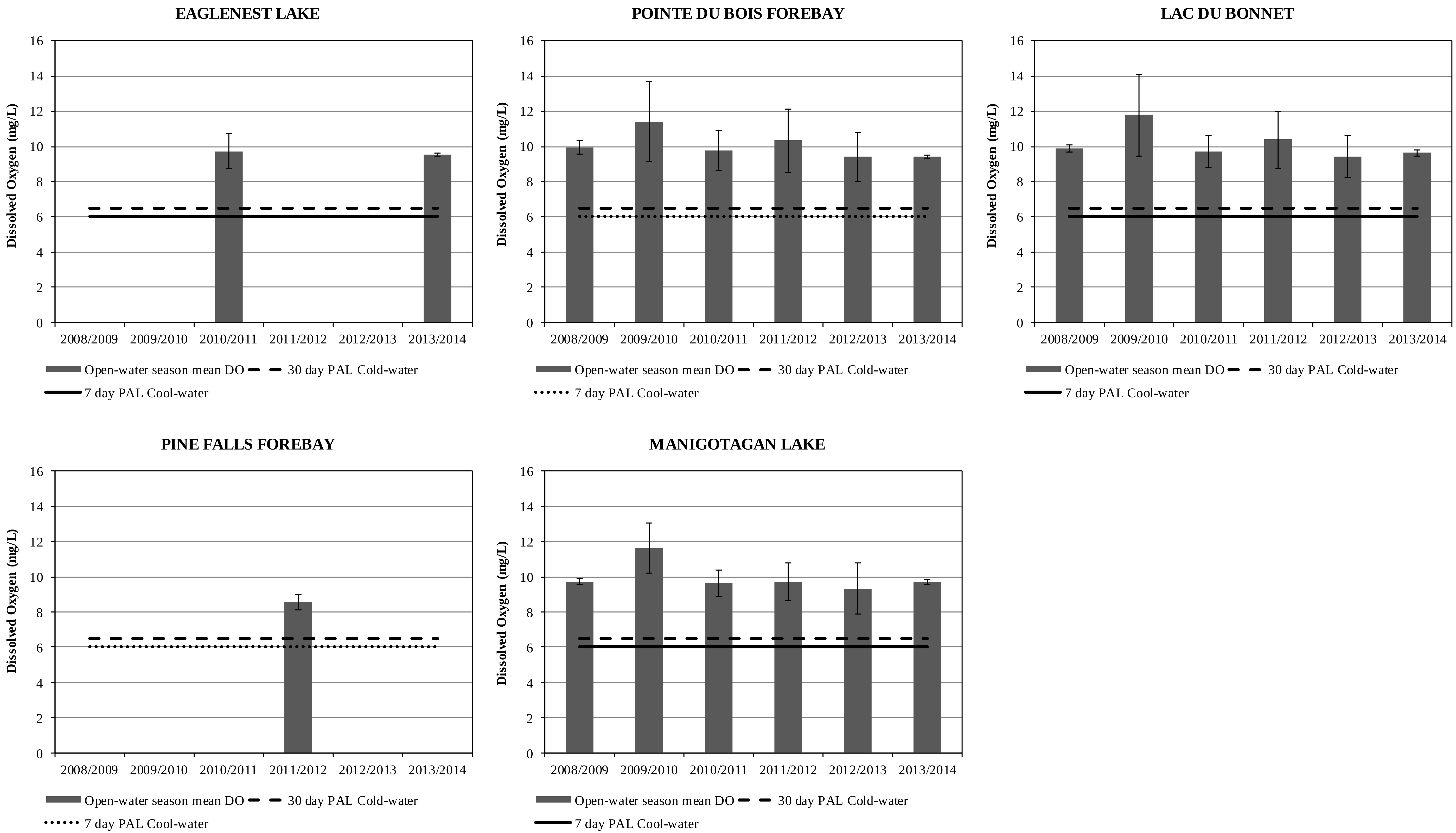


Figure 3-13. Open-water season dissolved oxygen concentrations (mean±SE) in the Winnipeg River and off-system waterbodies. No significant inter-annual differences were observed between the open-water seasons at the annual monitoring sites (PDB, LDB, or MANIG).

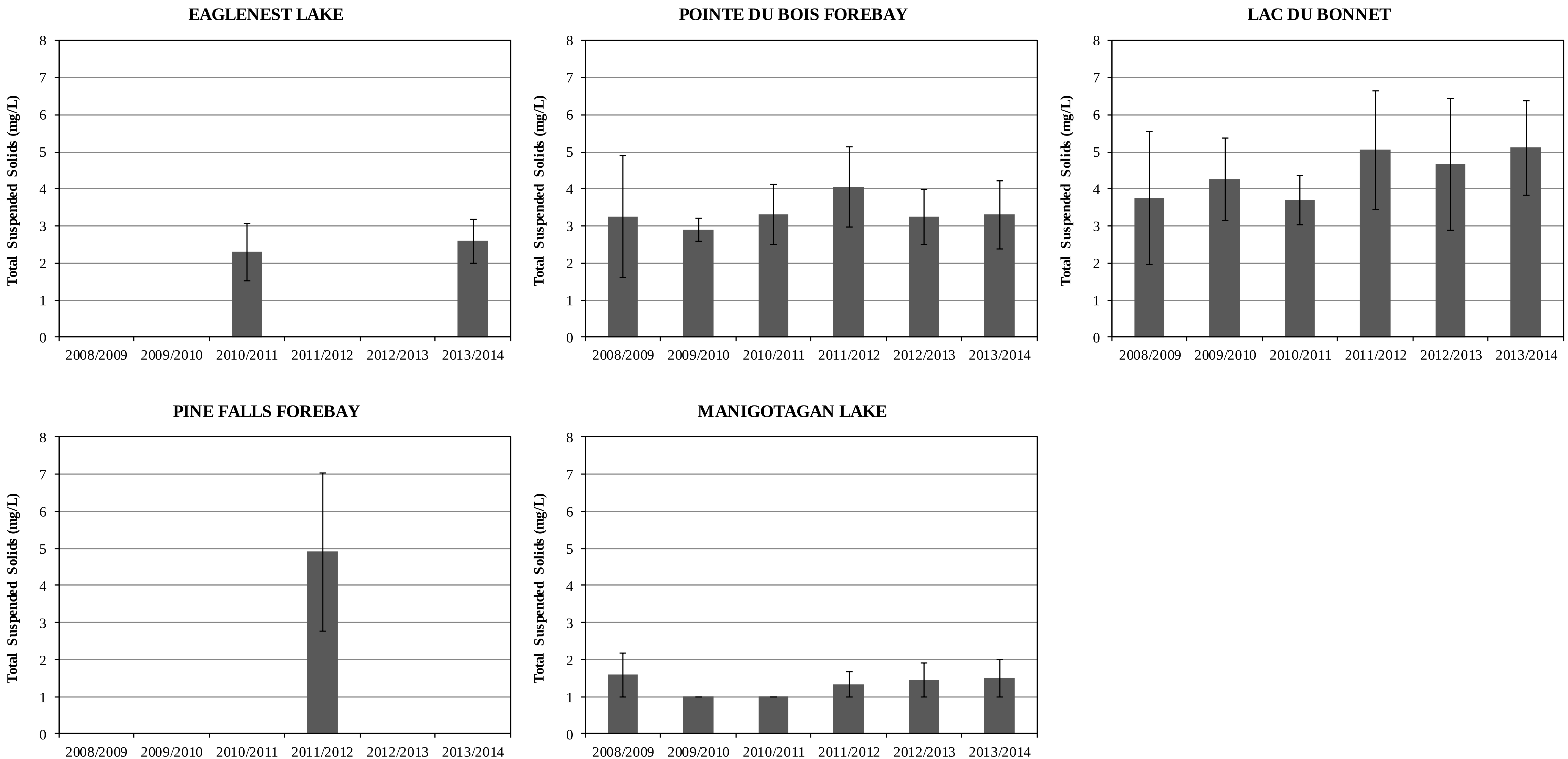


Figure 3-14. Total suspended solids (mean±SE) measured in the Winnipeg River and off-system waterbodies: 2008/2009-2013/2014.

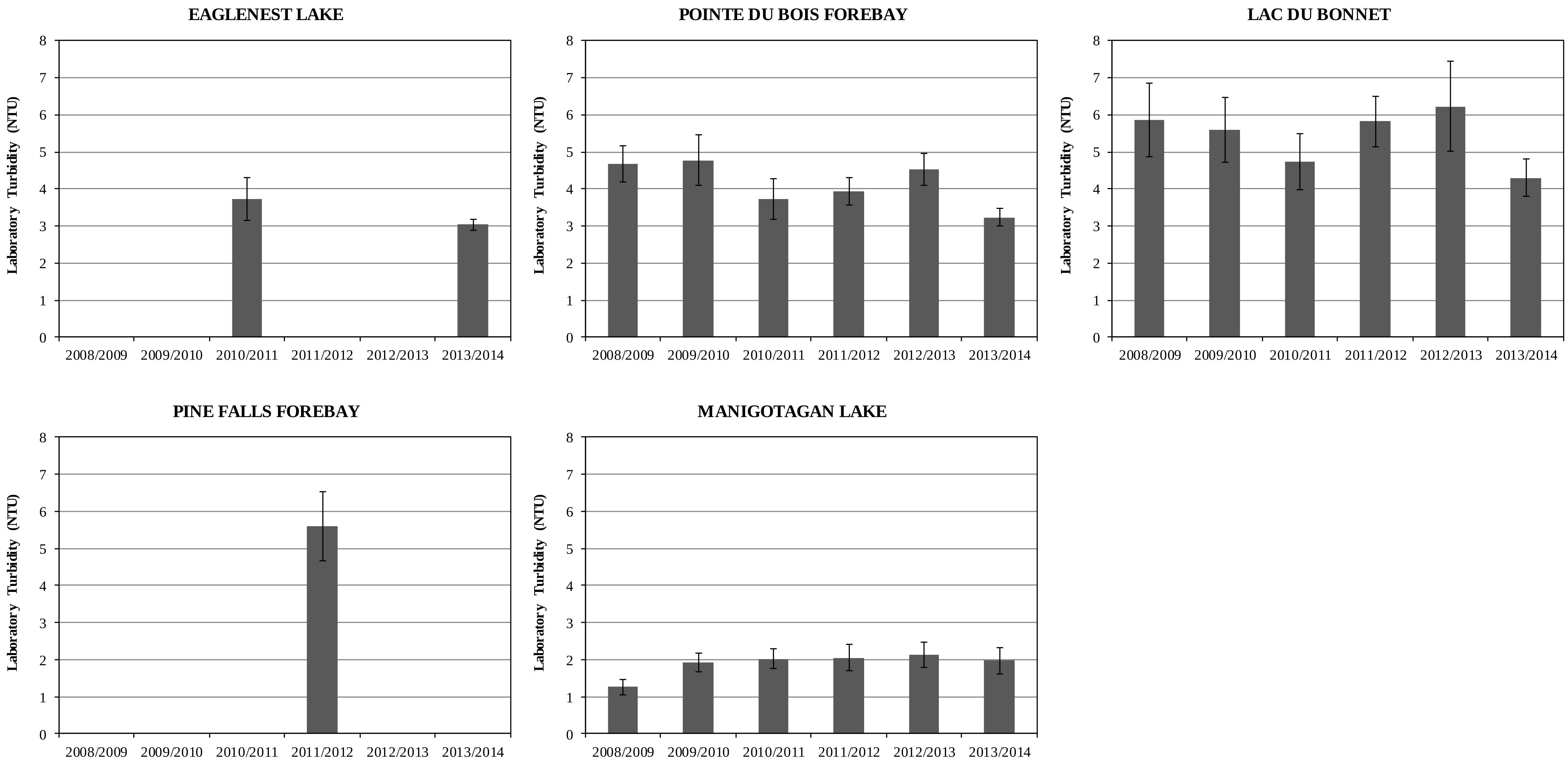


Figure 3-15. Laboratory turbidity (mean±SE) measured in the Winnipeg River and off-system waterbodies: 2008/2009-2013/2014.

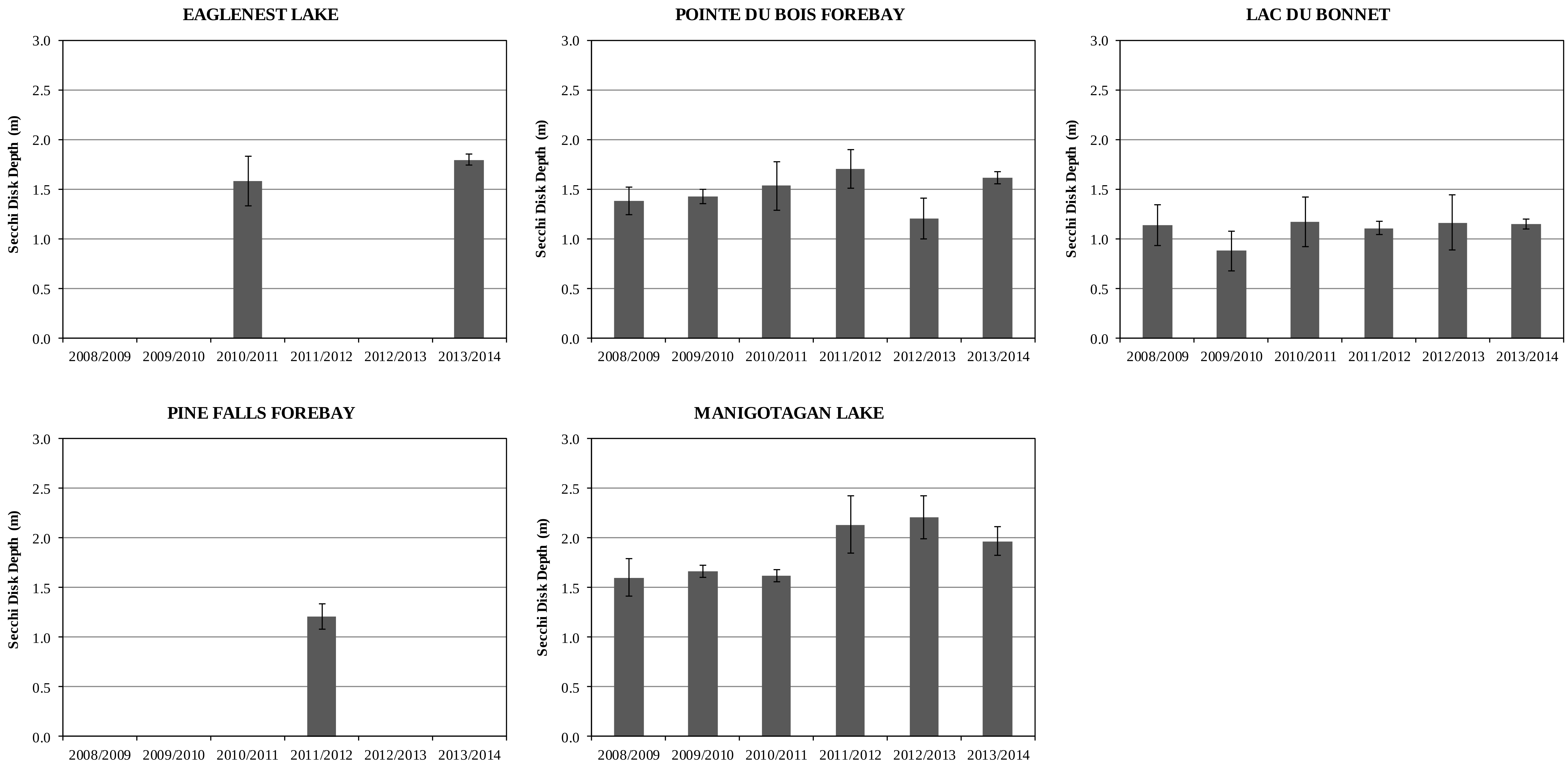


Figure 3-16. Secchi disk depths (mean±SE) measured in Winnipeg River and off-system waterbodies: 2008/2009-2013/2014 (open-water season). No significant inter-annual differences were observed between the open-water seasons at the annual monitoring sites (PDB, LDB, or MANIG).

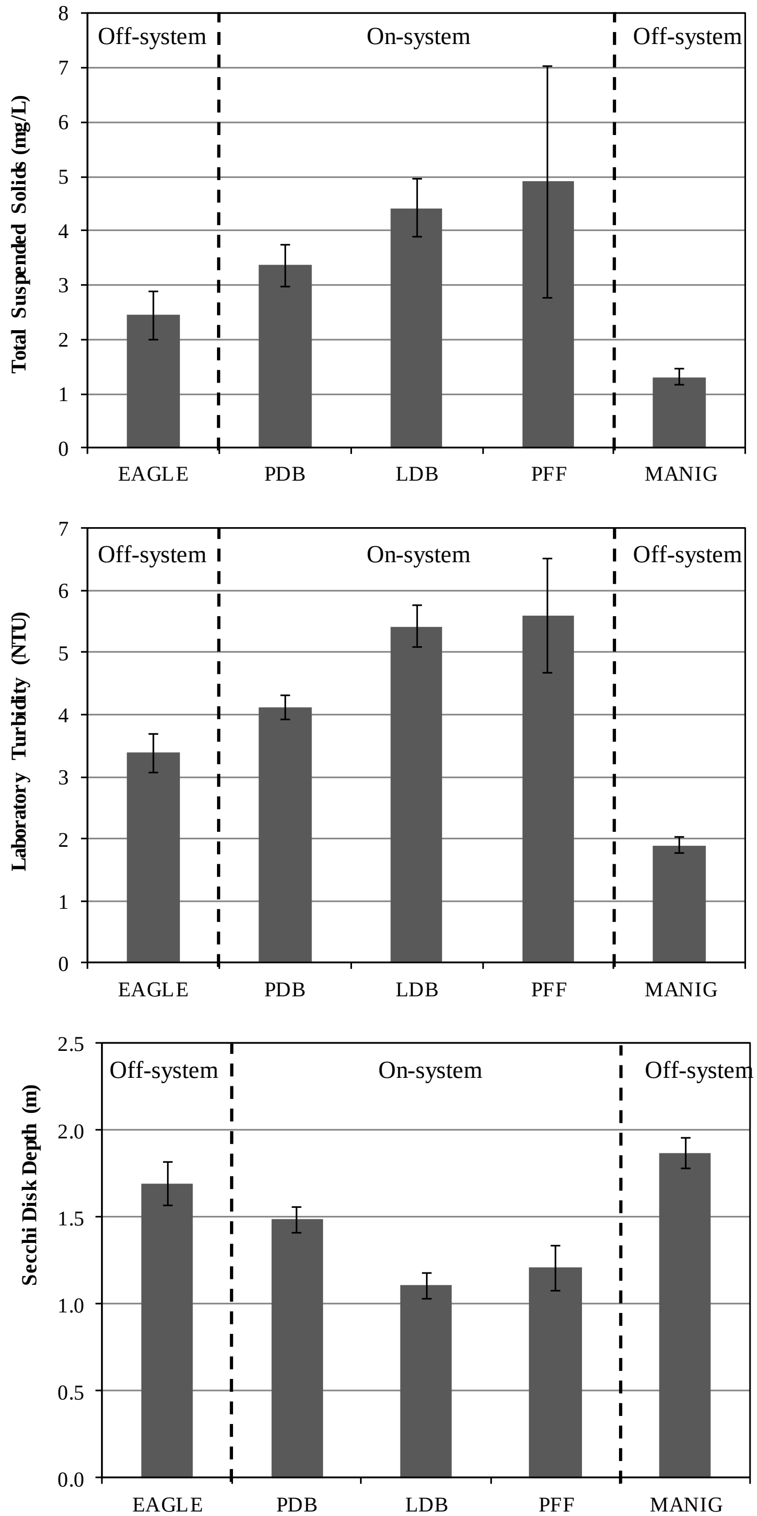


Figure 3-17. Total suspended solids, laboratory turbidity, and Secchi disk depth (mean±SE) measured in the Winnipeg River and off-system waterbodies: 2008/2009-2013/2014.

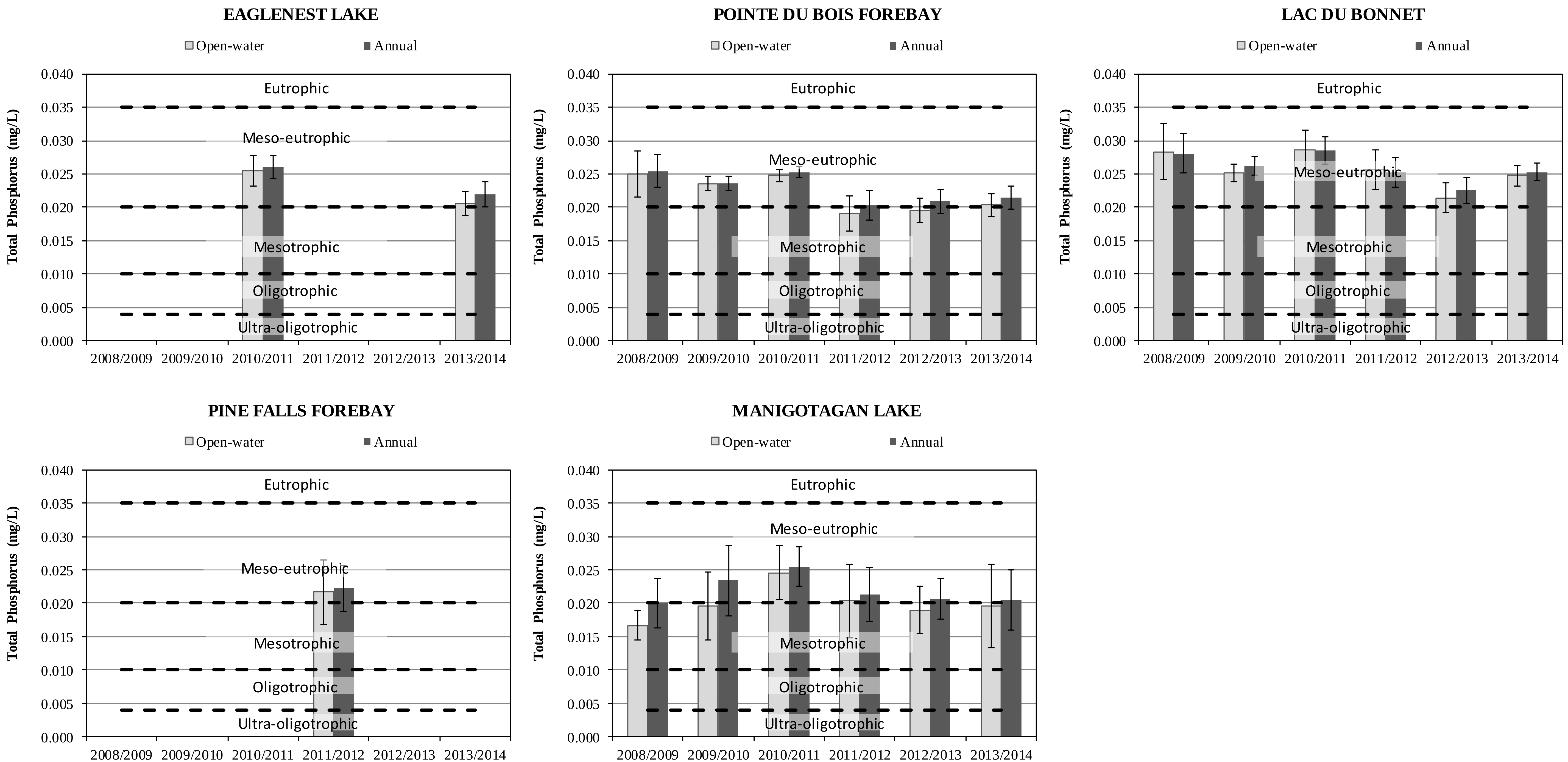


Figure 3-18. Total phosphorus (mean±SE) measured in the Winnipeg River and off-system waterbodies, and comparison to trophic categories: 2008/2009-2013/2014. No significant inter-annual differences were observed between the open-water seasons at the annual monitoring sites (PDB, LDB, or MANIG).

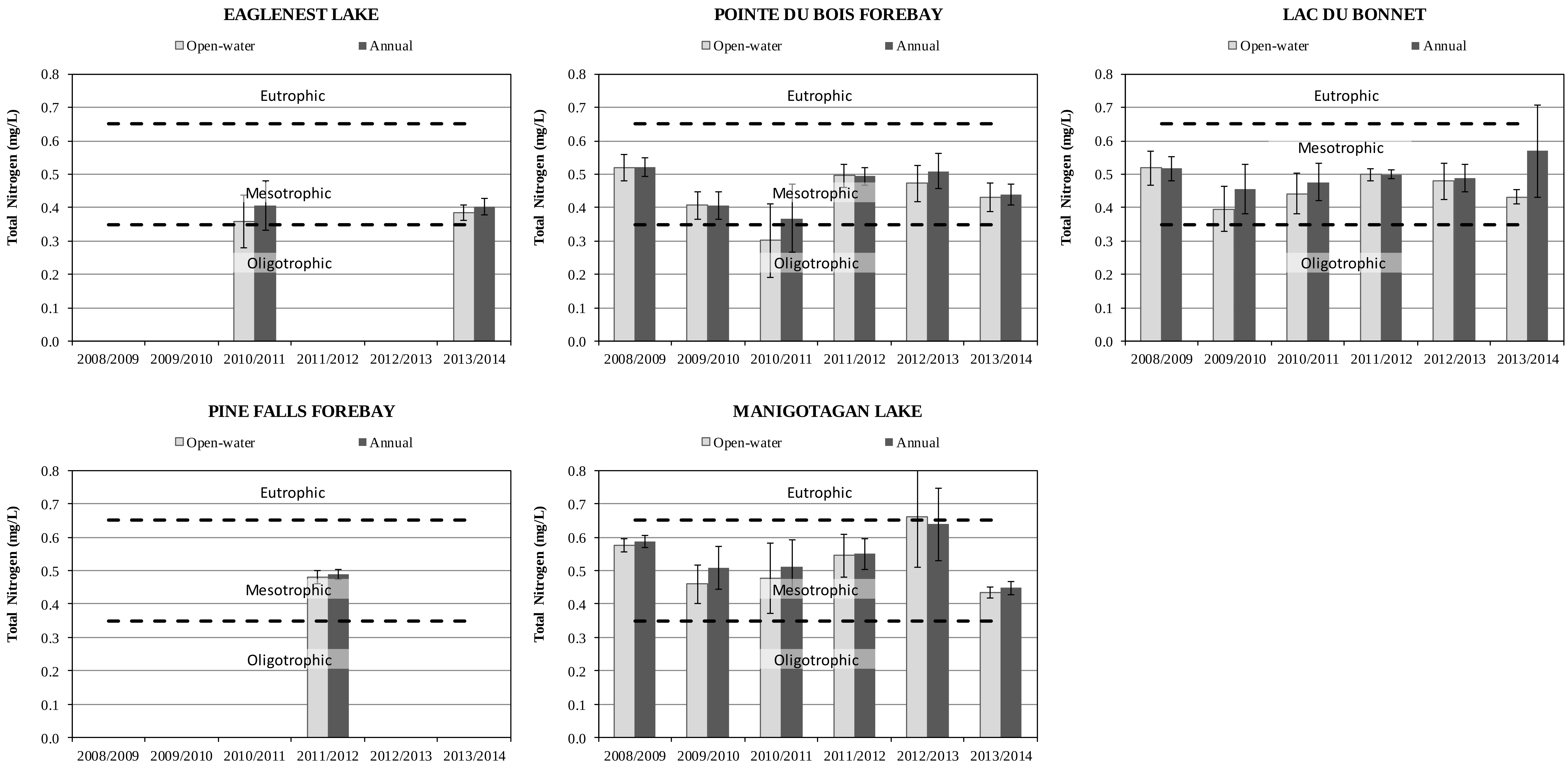


Figure 3-19. Total nitrogen (mean±SE) measured in the Winnipeg River and off-system waterbodies, and comparison to trophic categories: 2008/2009-2013/2014. No significant inter-annual differences were observed between the open-water seasons at the annual monitoring sites (PDB, LDB, or MANIG).

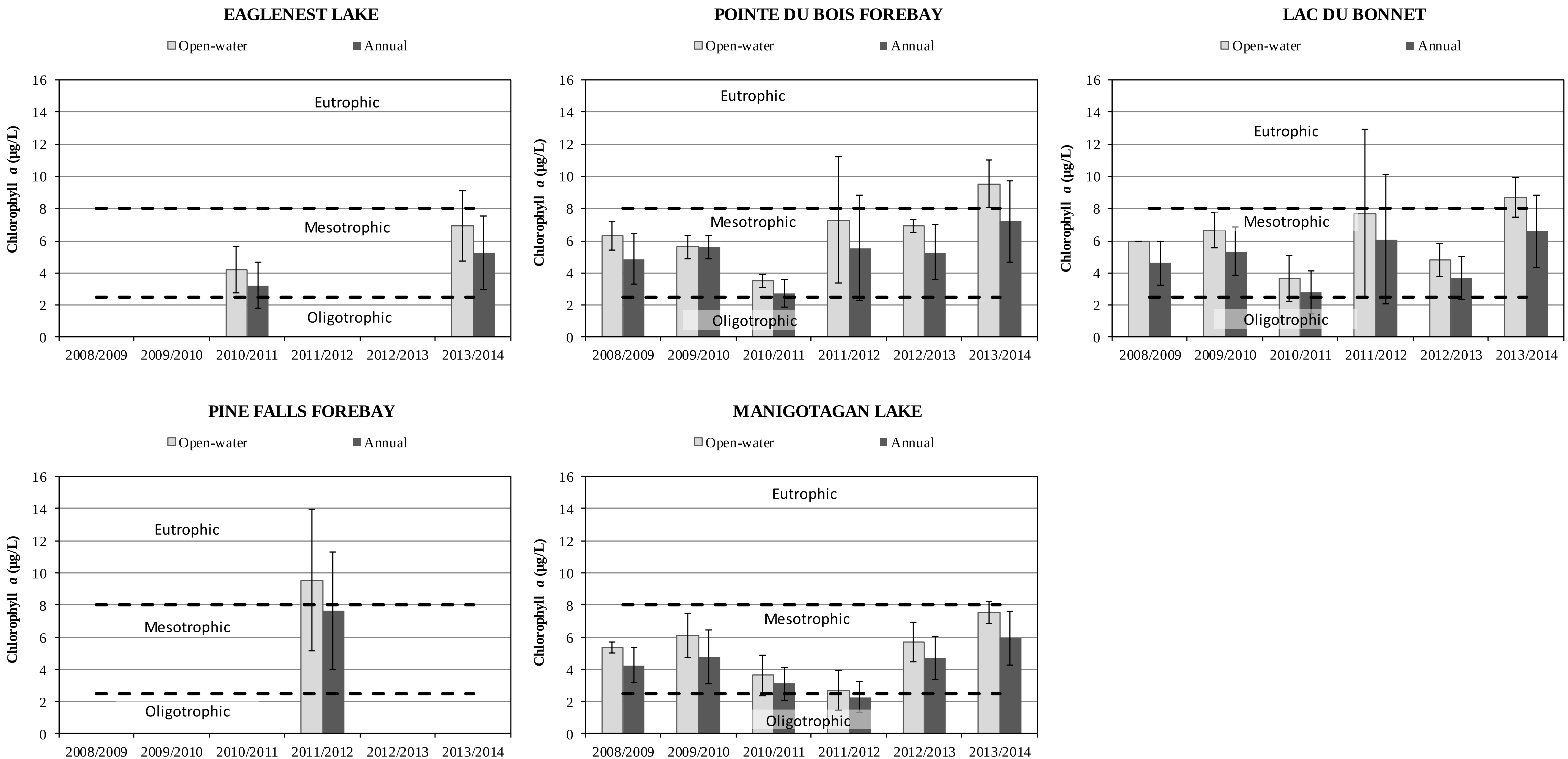


Figure 3-20. Chlorophyll *a* (mean±SE) measured in the Winnipeg River and off-system waterbodies, and comparison to trophic categories: 2008/2009-2013/2014. No significant inter-annual differences were observed between the open-water seasons at the annual monitoring sites (PDB, LDB, or MANIG).

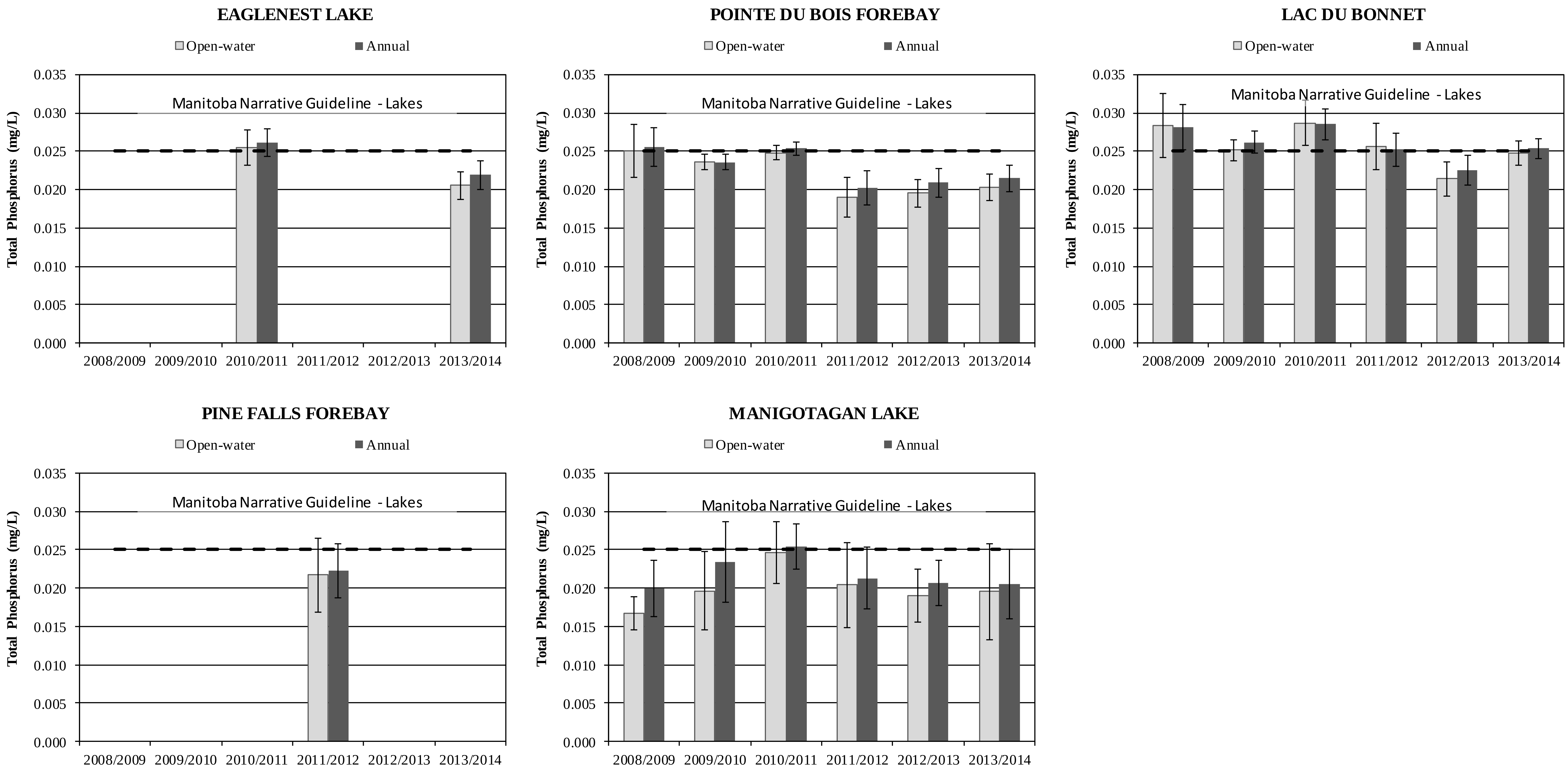


Figure 3-21. Total phosphorus (mean±SE) measured in the Winnipeg River and off-system waterbodies, and comparison to the Manitoba narrative nutrient guideline for lakes: 2008/2009-2013/2014.

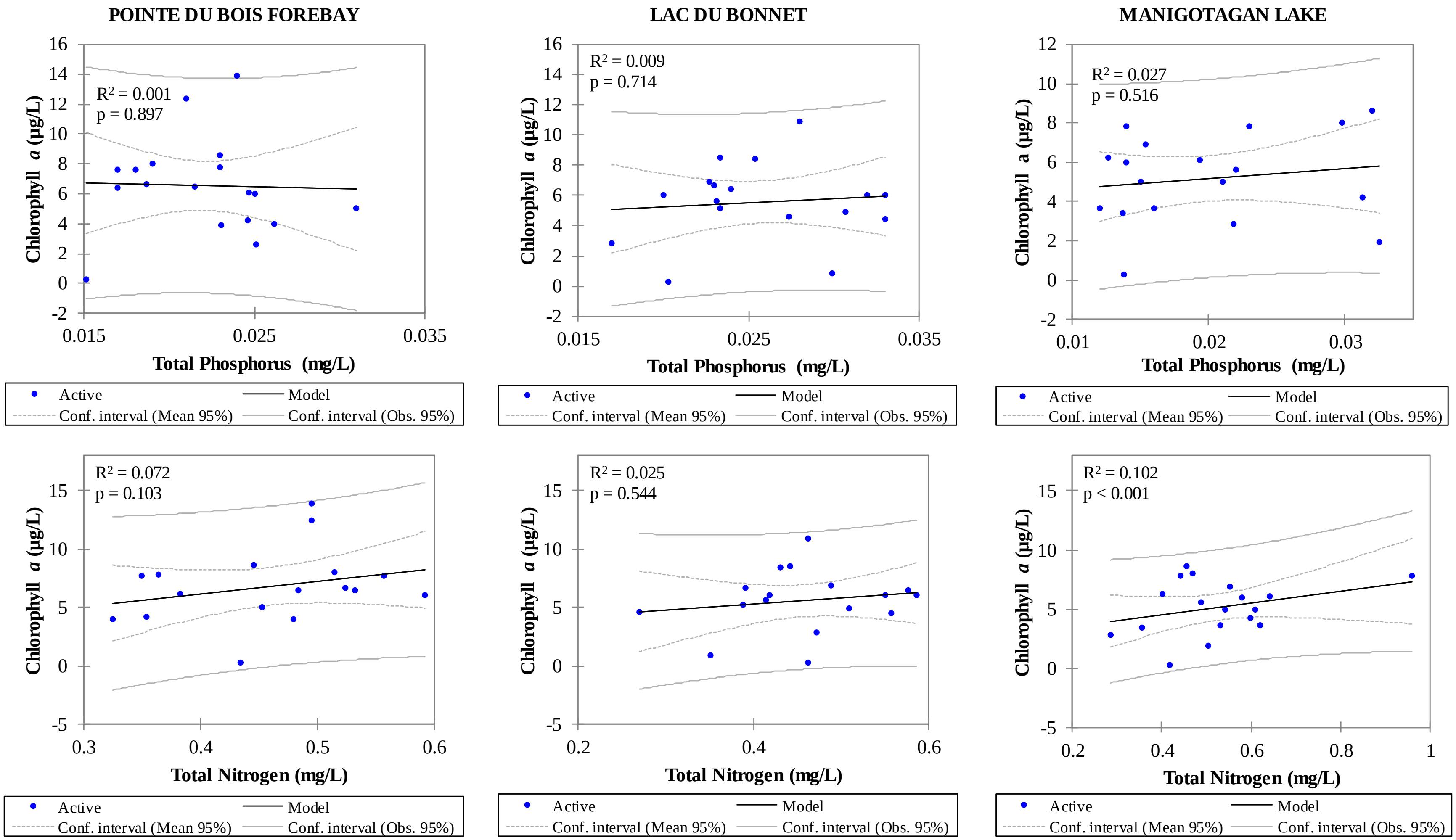


Figure 3-22. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* in the Pointe du Bois Forebay, Lac du Bonnet, and Manigotagan Lake: open-water seasons 2008-2013.

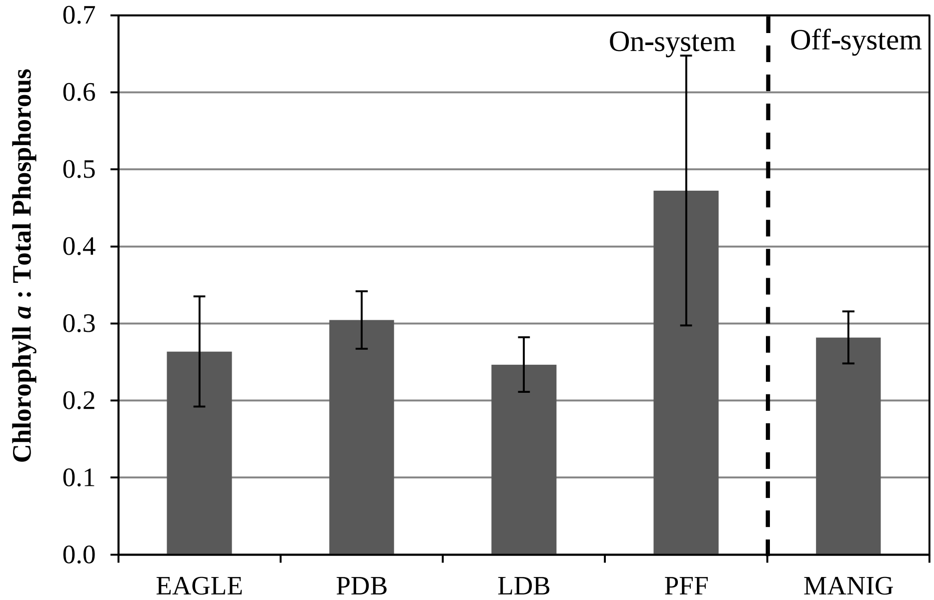


Figure 3-23. Chlorophyll *a* to total phosphorus ratios (mean±SE) measured in the Winnipeg River and off-system waterbodies: open-water seasons 2008-2013.

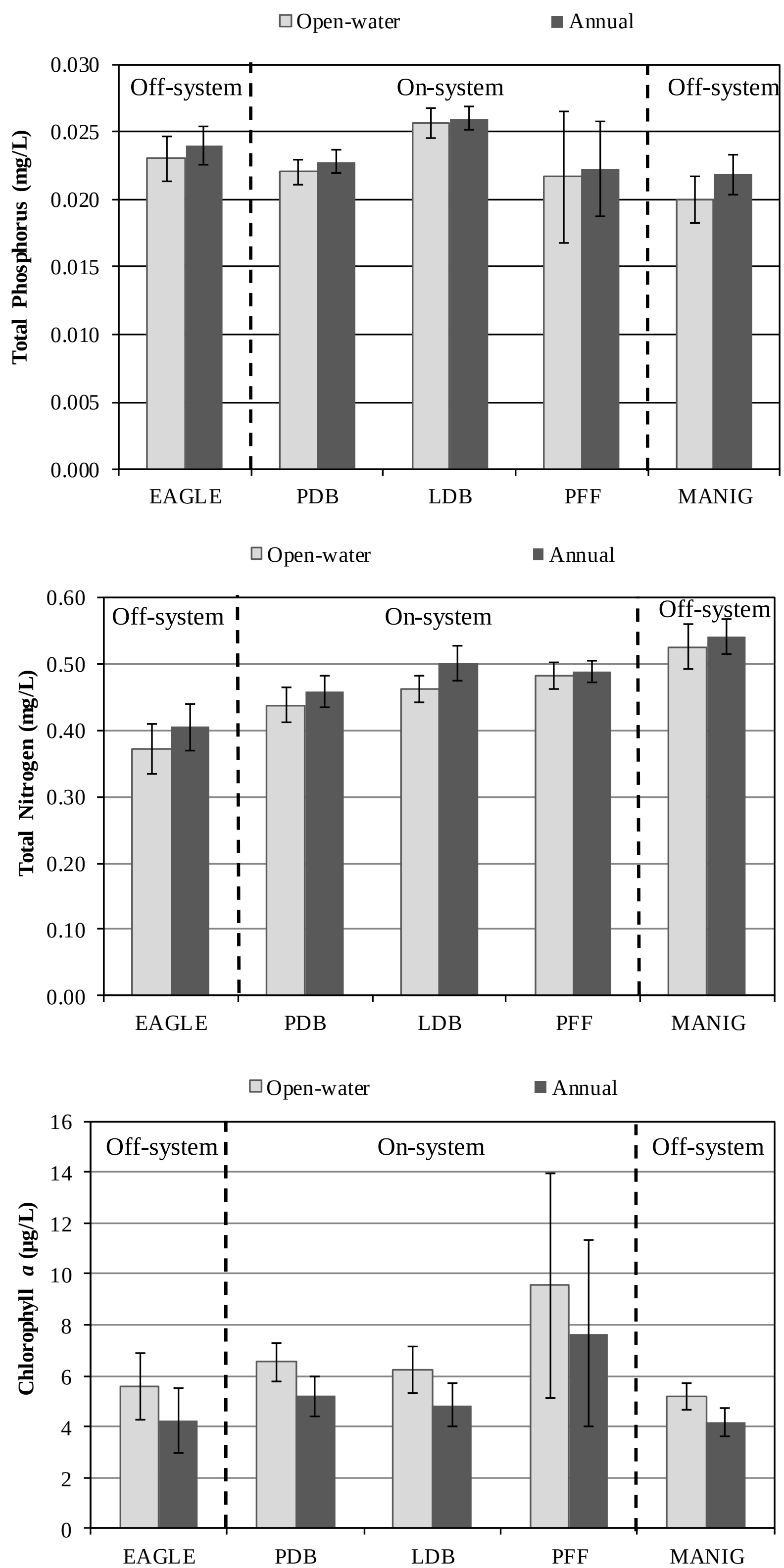


Figure 3-24. Total phosphorus, total nitrogen, chlorophyll *a* (mean±SE) measured in the Winnipeg River and off-system waterbodies: 2008/2009-2013/2014.

4.0 SEDIMENT QUALITY

4.1 INTRODUCTION

The following provides an overview of sediment quality conditions measured under CAMP in the WRR over the period of 2008 through 2013; a description of the sediment quality program sampling methods is provided in Technical Document 1, Section 3.4.1. In brief, sediment quality is monitored in surficial sediments (upper 5 cm) on a six year rotational basis, beginning in 2011, at selected sites under CAMP. Three samples (i.e., a triplicate) were collected at each site. Sediment quality in the WRR was measured in 2011 in the Pointe du Bois Forebay, Lac du Bonnet, and Manigotagan Lake (Figure 4-1).

4.1.1 Objectives and Approach

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

4.1.2 Indicators

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

4.2 WINNIPEG RIVER

Surficial sediment samples from the Pointe du Bois Forebay were dominated by sand (88%) whereas samples from Lac du Bonnet were predominantly composed of silt (67%; Table 4-1 and Figure 4-2). These on-system sites also had low to moderate total organic carbon (TOC) levels, respectively (Figure 4-3). The particle size and TOC content in sediments at the on-system sites both differed from those observed in the off-system Manigotagan Lake (see Section 4.3).

Several parameters exceeded the Ontario LELs including total Kjeldahl Nitrogen (TKN; Figure 4-4), TP (Figure 4-5), TOC (Figure 4-3), manganese (Figure 4-6), and nickel (Figure 4-7) in Lac du Bonnet, but all results remained below the higher benchmarks (i.e., Manitoba PEL and Ontario SEL), which is indicative of an "increased risk of adverse effects to biota". Only one parameter (TKN) exceeded a benchmark (the Ontario LEL) in the Pointe du Bois Forebay. These differences likely reflect the higher fraction of sand, and lower fraction of TOC, present in the Pointe due Bois Forebay sediments. Metals are typically present in higher concentrations in fine textured sediments and there is generally a strong positive correlation between the fraction of silt/clay and metal concentrations (e.g., Horowitz 1985 and references therein).

All metals including arsenic (Figure 4-8), cadmium (Figure 4-9), chromium (Figure 4-10), copper (Figure 4-11), lead (Figure 4-12), mercury (Figure 4-13), and zinc (Figure 4-14), were within the Manitoba SQGs at both sites. These results were generally similar to those observed in the off-system Manigotagan Lake, with the exception that chromium exceeded the Ontario LEL at the latter site (Figure 4-10). Iron was below the Ontario LEL (Figure 4-15) and selenium was below the BC SAC and AB ISQG (Figure 4-16) at both sites. Results for additional metrics are presented in Table 4-2.

4.3 OFF-SYSTEM WATERBODY: MANIGOTAGAN LAKE

Sediments from Manigotagan Lake were dominated by clay (59%) and silt (39%; Figure 4-2), and nutrient and metal concentrations were generally higher than those measured in the on-system waterbodies (Figure 4-3 to 4-16). Exceedances of sediment quality benchmarks in Manigotagan Lake were generally similar to those observed in Lac du Bonnet, where sediments were also composed of a greater proportion of silt/clay than sand. In Manigotagan Lake, TOC (Figure 4-3) and TP (Figure 4-5) exceeded the Ontario LEL and TKN (Figure 4-4) exceeded the Ontario SEL.

Similar to Lac du Bonnet, all metals excepting chromium (which exceeded the SQG; Figure 4-10) were within the Manitoba SQGs. Iron (Figure 4-15), manganese (Figure 4-6), and nickel (Figure 4-7) exceeded the Ontario LEL but not the SEL. Selenium (Figure 4-16) was marginally above the analytical detection limit (0.5 µg/g) but well below the BC SAC and the AB ISQG (2.0 µg/g).

4.4 SUMMARY

The majority of sediment quality metrics for which there are benchmarks were within benchmarks in the WRR and only one metric exceeded a benchmark in the Pointe du Bois Forebay. Differences in sediment quality observed between sites (both between on-system sites and relative to the off-system site) are at least in part attributable to differences in the composition (organic carbon and particle size) of the sediments. Metrics that exceeded sediment quality benchmarks in this region were also commonly above these benchmarks, and concentrations were similar to those observed, in other lakes and rivers monitored under CAMP (Table 4-1).

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).

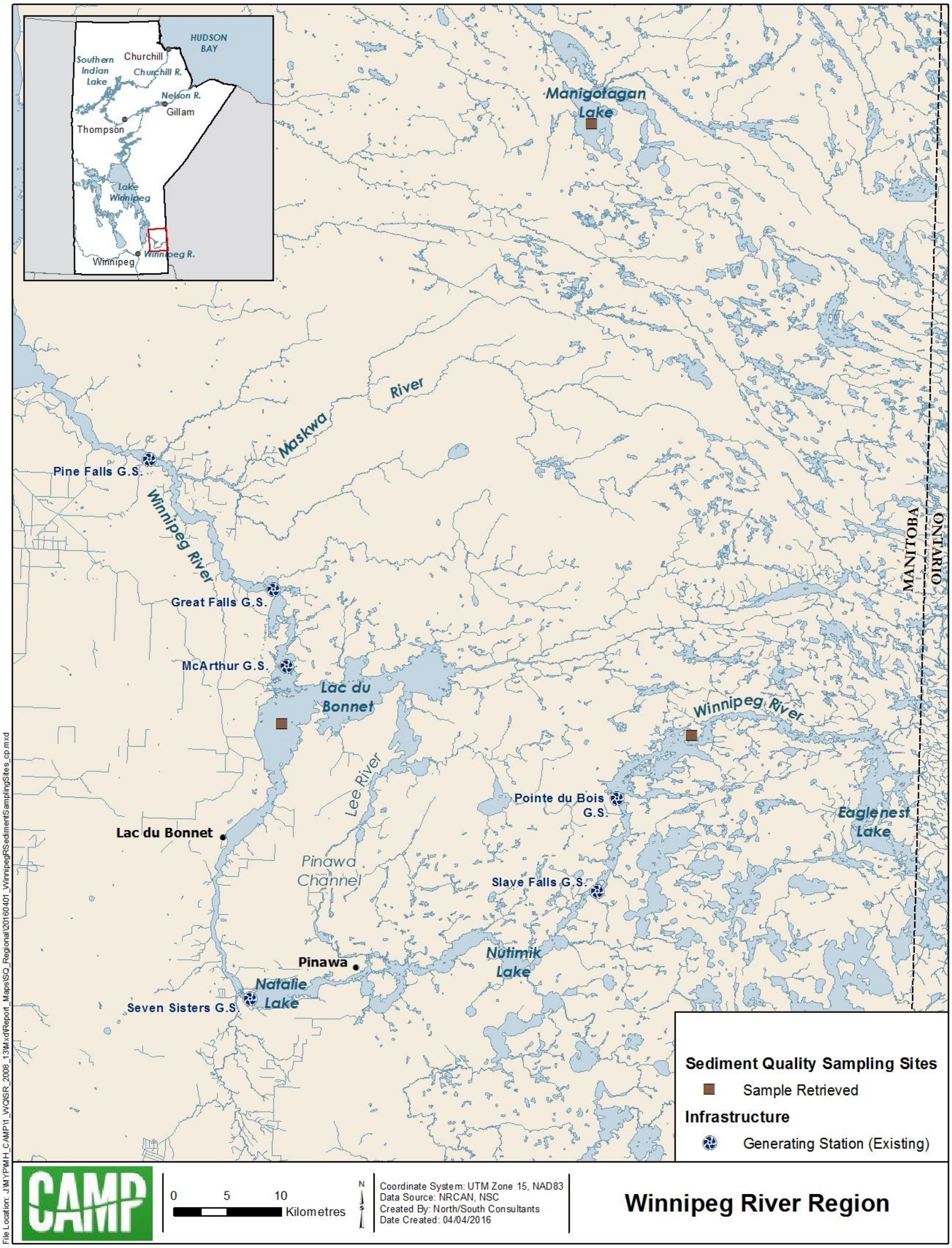


Figure 4-1. Sediment quality sampling sites in the Winnipeg River Region: 2008-2013.

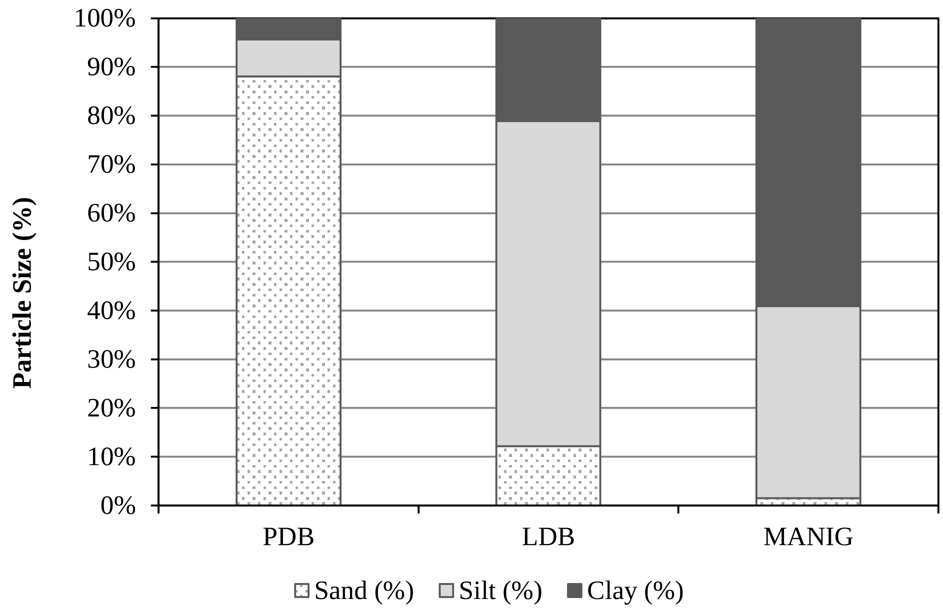


Figure 4-2. Particle size of surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG).

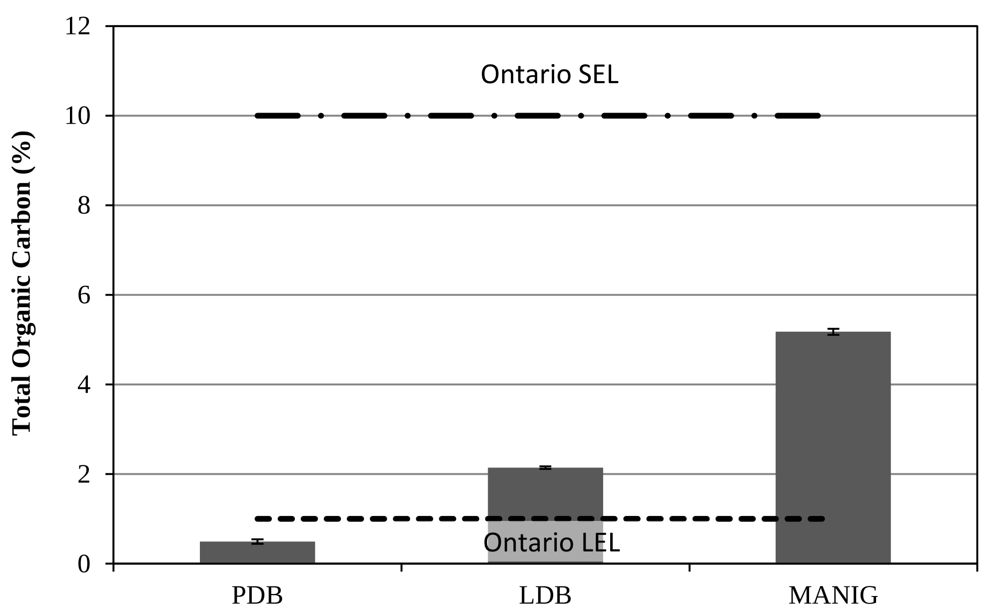


Figure 4-3. Percentage of total organic carbon in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Ontario sediment quality guidelines.

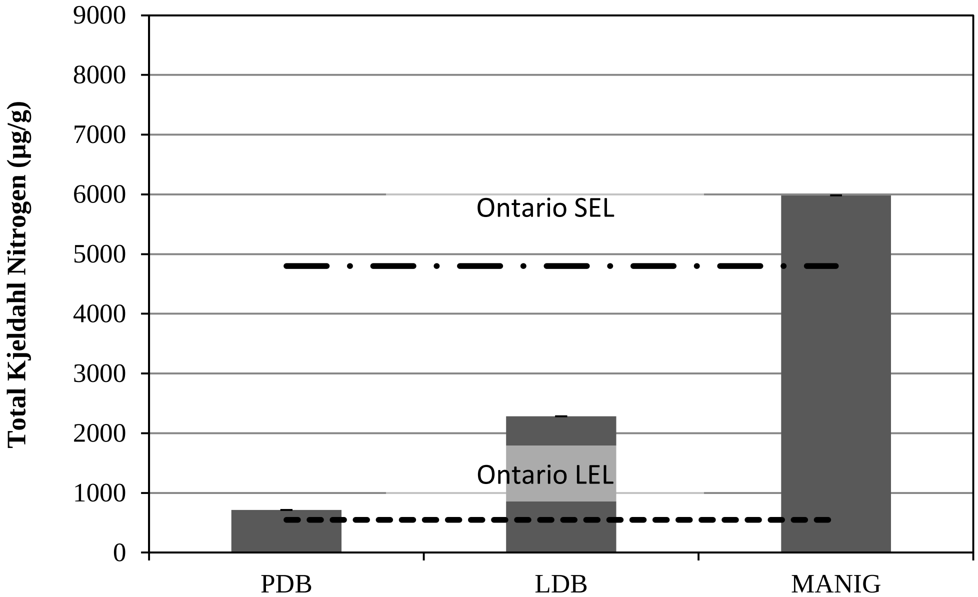


Figure 4-4. Mean (±SE) concentrations of total Kjeldahl nitrogen in surficial sediment from The Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Ontario sediment quality guidelines.

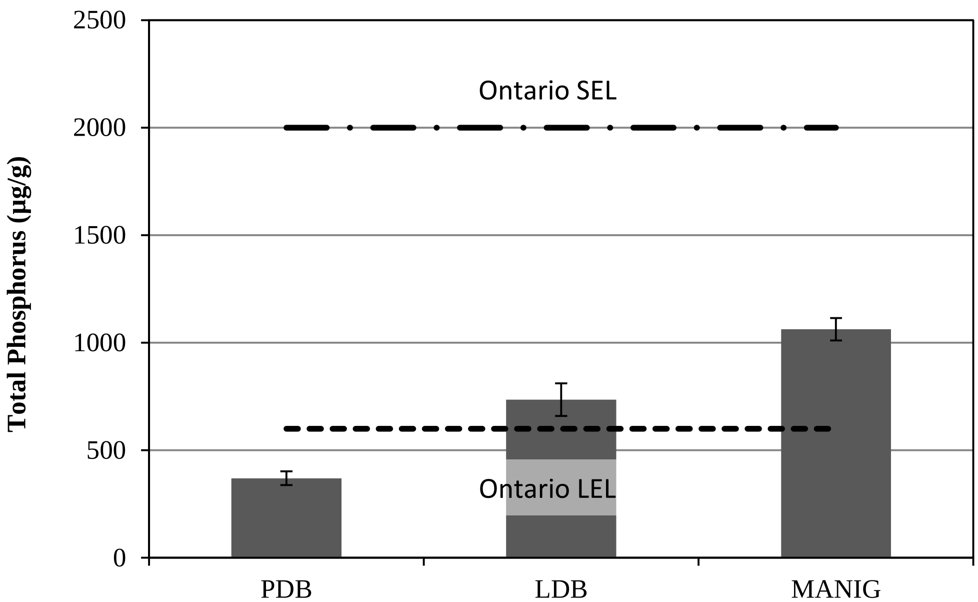


Figure 4-5. Mean (±SE) concentrations of total phosphorus in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Ontario sediment quality guidelines.

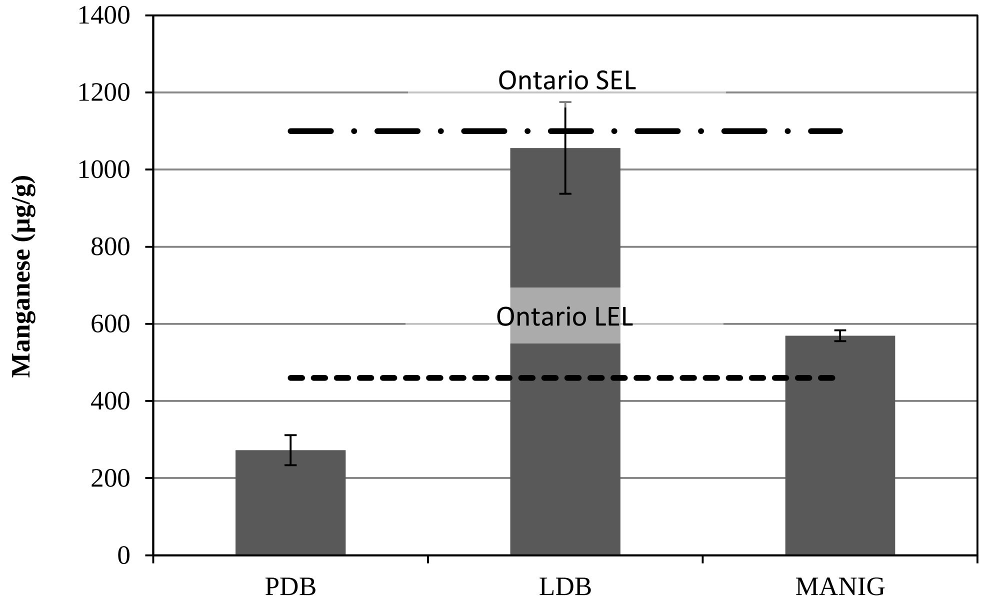


Figure 4-6. Mean (±SE) concentrations of manganese in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Ontario sediment quality guidelines.

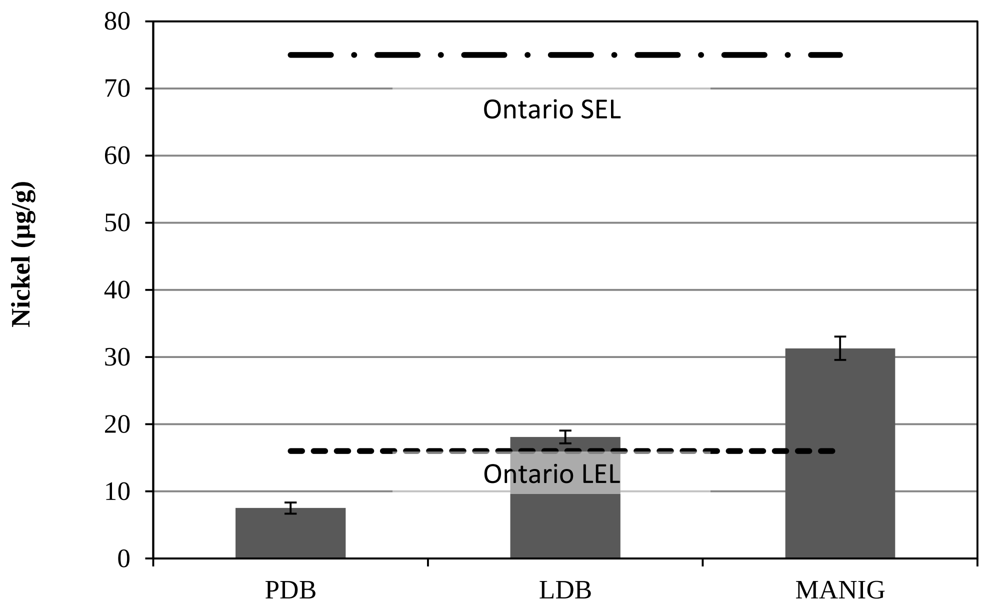


Figure 4-7. Mean (±SE) concentrations of nickel in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Ontario sediment quality guidelines.

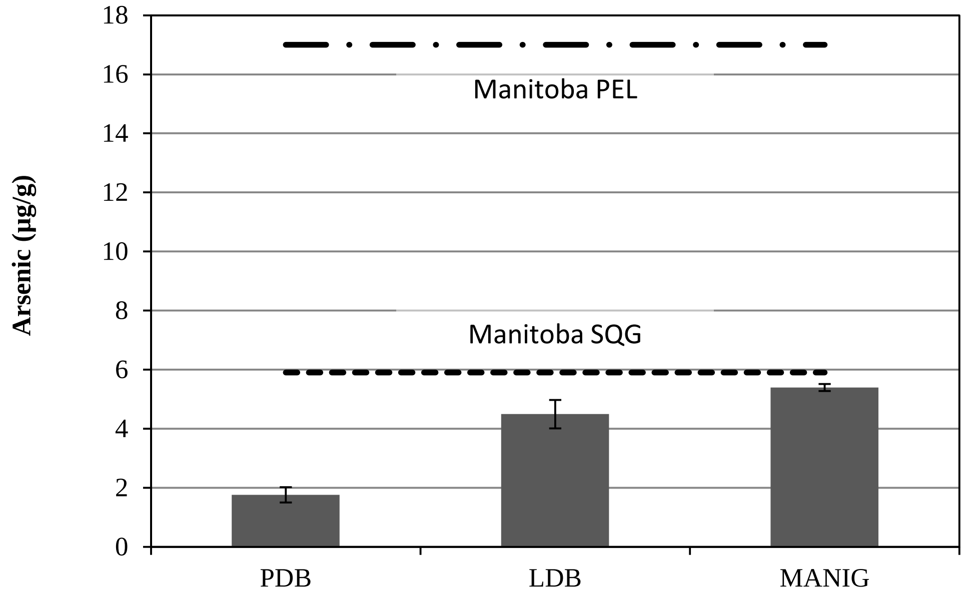


Figure 4-8. Mean (±SE) concentrations of arsenic in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines.

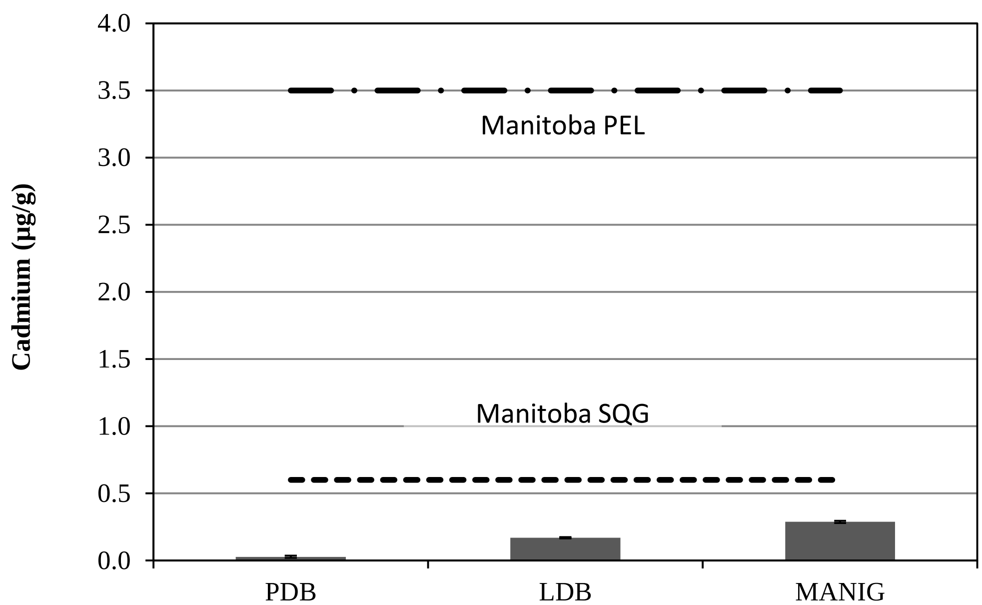


Figure 4-9. Mean (±SE) concentrations of cadmium in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines.

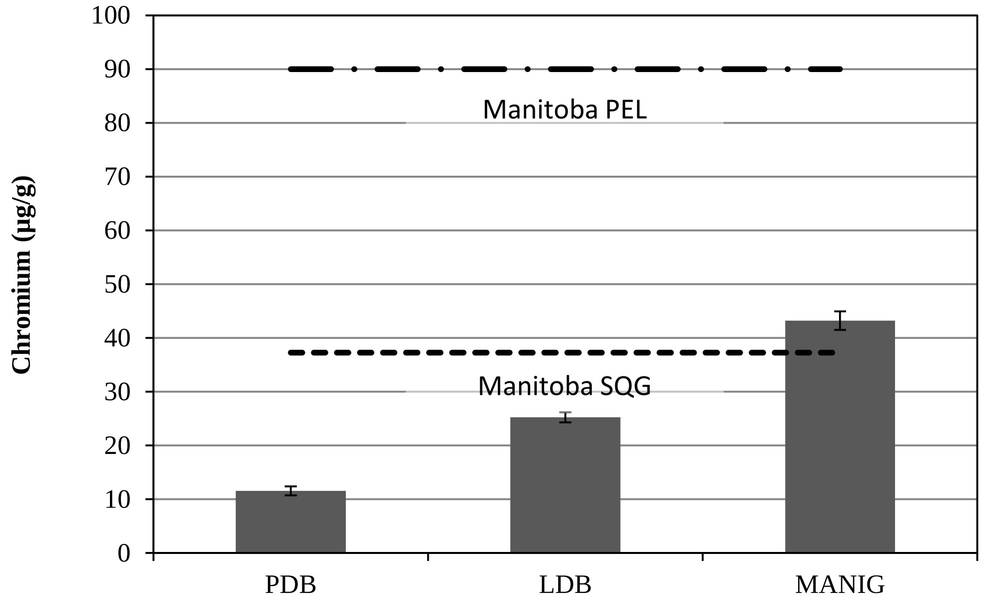


Figure 4-10. Mean (±SE) concentrations of chromium in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines.

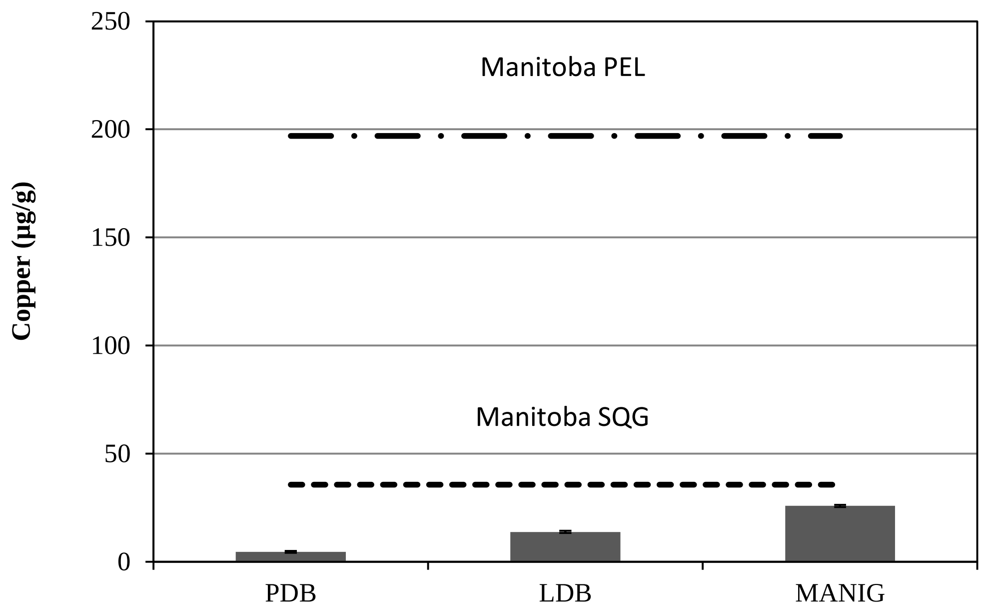


Figure 4-11. Mean (±SE) concentrations of copper in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines.

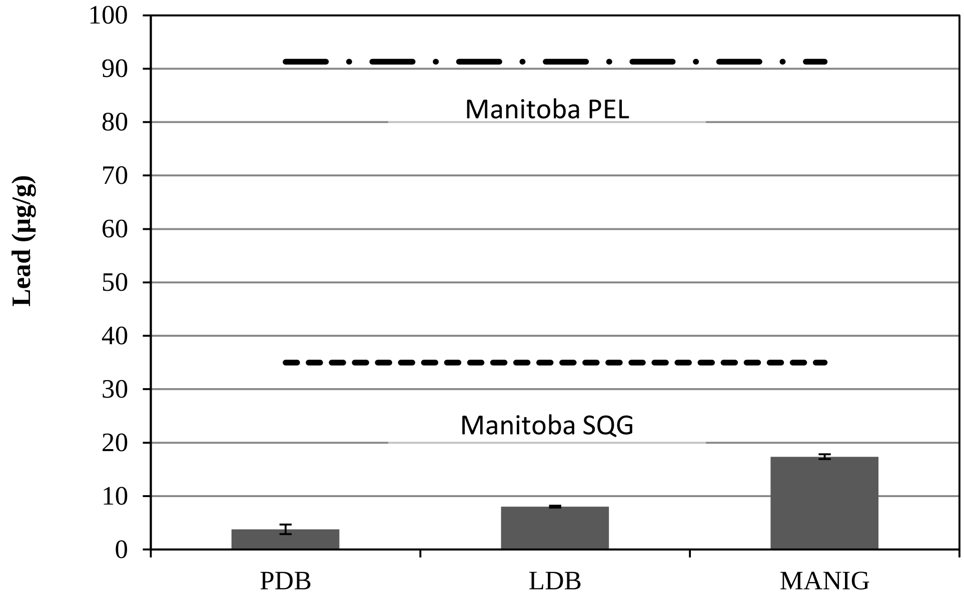


Figure 4-12. Mean (±SE) concentrations of lead in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines.

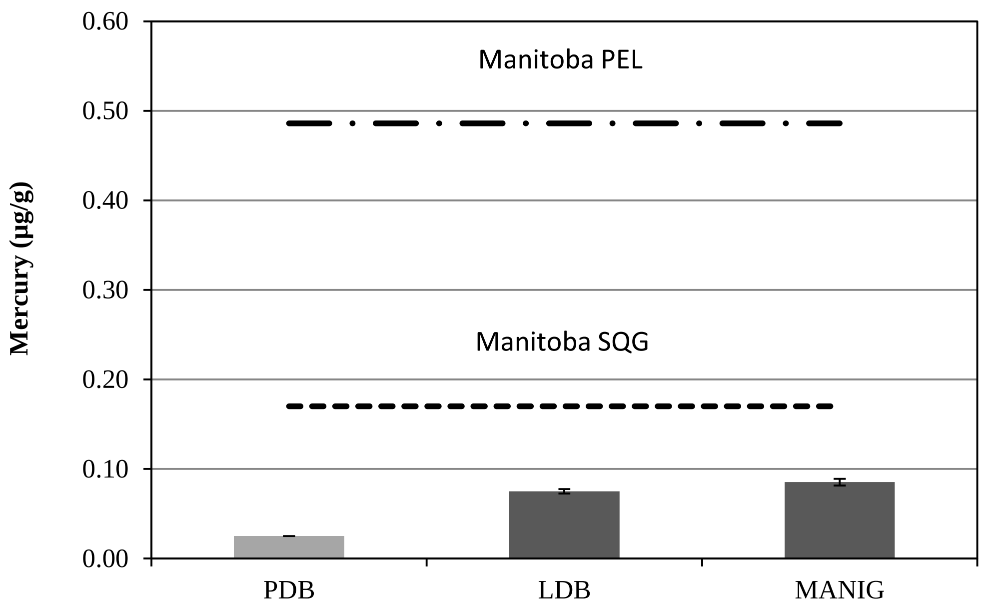


Figure 4-13. Mean (±SE) concentrations of mercury in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines. Means indicated in light grey were below the analytical detection limit.

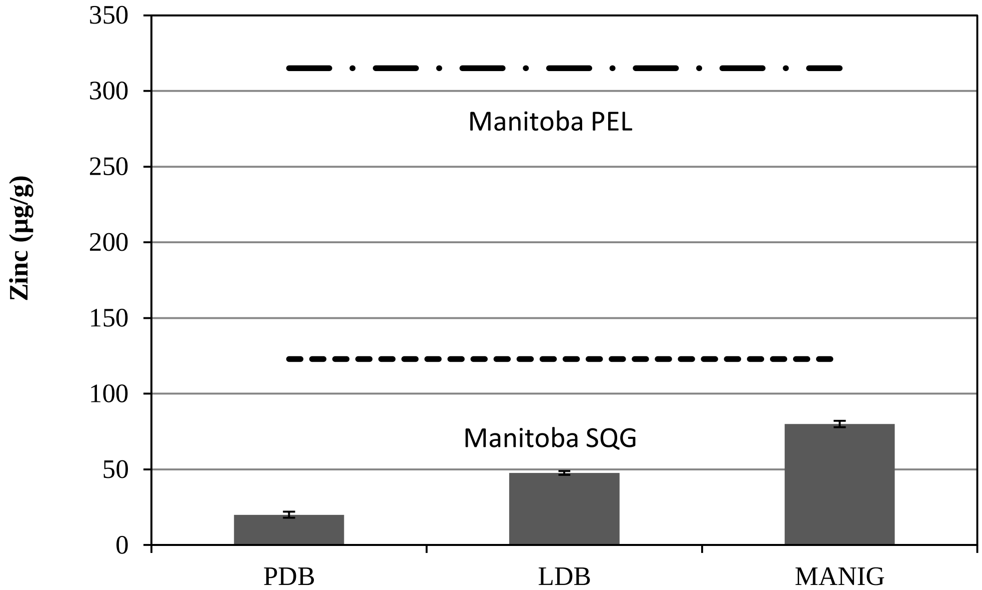


Figure 4-14. Mean (±SE) concentrations of zinc in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Manitoba sediment quality guidelines.

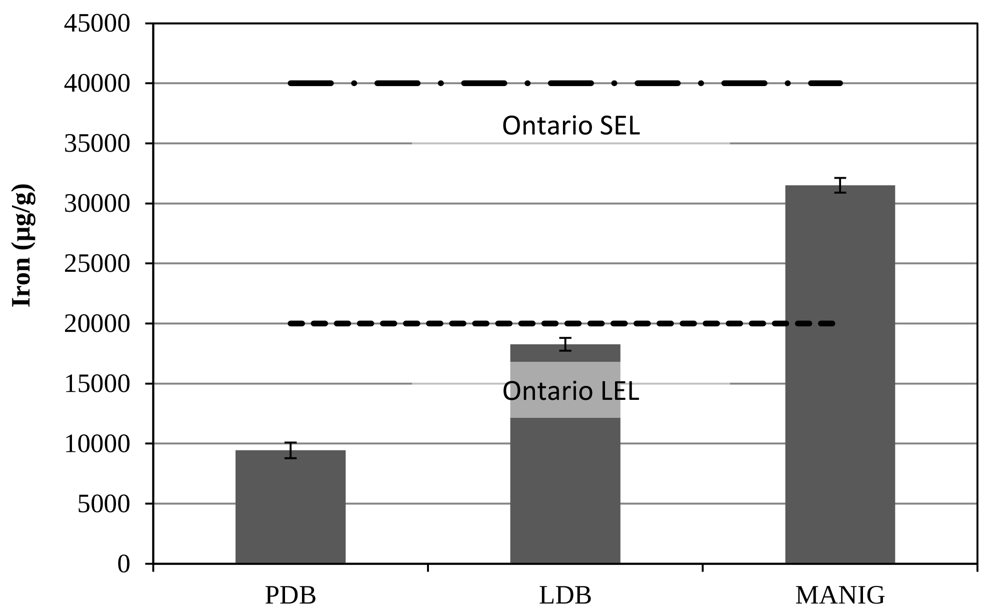


Figure 4-15. Mean (±SE) concentrations of iron in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to Ontario sediment quality guidelines.

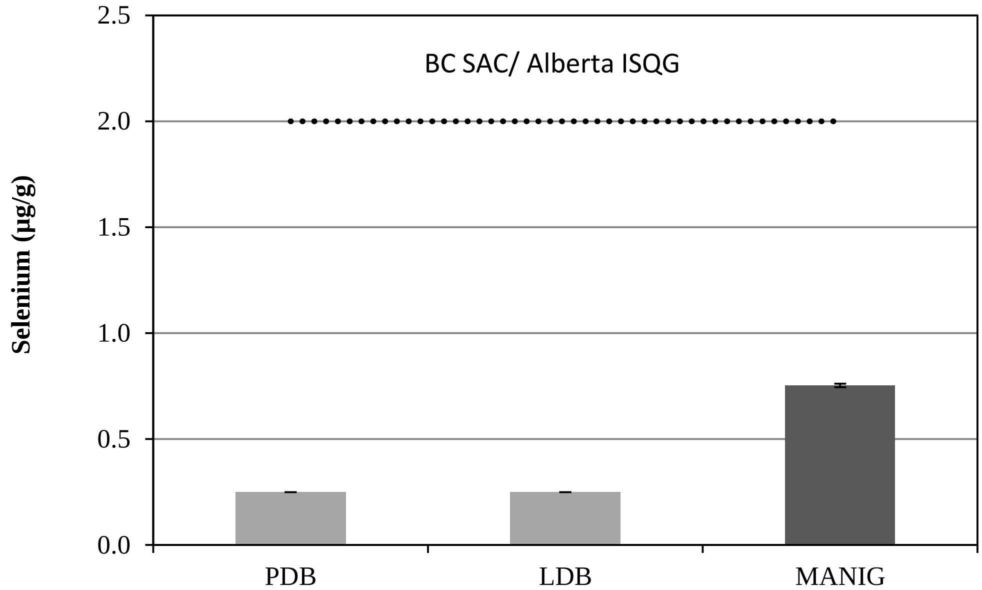


Figure 4-16. Mean (±SE) concentrations of selenium in surficial sediment from the Pointe du Bois Forebay (PDB), Lac du Bonnet (LDB), and Manigotagan Lake (MANIG), and comparison to the BC sediment alert concentration and the Alberta ISQG. Means indicated in light grey were below the analytical detection limit.

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 WRR. 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 two on-system areas (the Pointe du Bois Forebay and Lac du Bonnet) and one off-system lake (Manigotagan Lake). Additional waterbodies sampled on a rotational basis were an off-system area, Eaglenest Lake (2010, 2013), and an on-system area, the Pine Falls Forebay (2011) (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 BMI program is comprised of sample collection at nearshore (water depth ≤1 m, sampled with travelling kick/sweep) and offshore (water depth 5-10m, sampled with Ekman/petite Ponar dredge) habitat sites in the late summer/fall within each monitoring waterbody (annual and rotational). Depending on the water level at time of sampling, sample collection in the nearshore habitat could include sites that are periodically dewatered, the frequency and duration of dewatering depending on the elevation along the shoreline where samples were collected in relation to the hydrograph. Offshore habitats were always permanently wetted.

5.1.1 Objectives and Approach

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

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

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

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

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

5.1.2 Indicators

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

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

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

5.2 SUPPORTING HABITAT VARIABLES

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

Sediment samples were collected at nearshore and offshore replicate stations for particle size analysis (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 Winnipeg River

The nearshore habitat of the on-system Pointe du Bois Forebay, Lac du Bonnet, and the Pine Falls Forebay sites typically was comprised of boulders with varying amounts of finer mineral material and organic matter (Table 5-1). Where sediment samples for particle size analysis could be collected, the substrate was generally predominantly sand (Figure 5-2).

The offshore habitat of Pointe du Bois Forebay and Lac du Bonnet consisted mainly of sand, whereas the Pine Falls Forebay sediment had a greater proportion of clay and silt (Figure 5-4).

The TOC content of sediments in the nearshore and offshore environments was generally low (<2%) (Figures 5-3 and 5-5).

5.2.2 Off-system Waterbodies: Manigotagan and Eaglenest Lakes

As with the on-system waterbodies, the nearshore environments of Eaglenest and Manigotagan lakes were predominantly large hard substrates (Table 5-1). Where material could be collected for particle size analysis, sand was predominant, in particular at the Manigotagan site (Figure 5-2). The offshore habitats of both lakes consisted mainly of sand (Figure 5-4). Overall, organic content of sediments was low (typically <2% (Figures 5-3 and 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., DO 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 Winnipeg River

The mean total abundance of BMIs in nearshore habitat sampled annually varied considerably but high variability among replicates resulted in few statistically significant differences (Figure 5-6). Abundance typically ranged from 500-3000 organisms per sample at all sites and years with the exception of Lac du Bonnet in 2012 when mean abundance was substantially higher. The elevated means were due to exceptionally high numbers in two of five replicates.

In general the nearshore BMI community was comprised of a greater proportion of non-insects than insects, with the former consisting primarily of Amphipoda, with substantial numbers of Oligochaeta in most years. Amphipods generally occur in greater numbers within slower moving water, such as the environments of the Pointe du Bois Forebay, Lac du Bonnet, and the Pine Falls Forebay. Gastropoda comprised greater than 10% of the fauna at Pointe du Bois. Chironomidae and Ephemeroptera (typically Caenidae) comprised the majority of the Insecta, although Trichoptera were also present at most of the Winnipeg River sites. Caenidae (small square gill mayflies) is common in lotic depositional and lentic littoral habitats (Merritt and Cummins 1996). In 2010 and 2011, Corixidae comprised over half the Insecta at Pointe du Bois. The extremely high abundance recorded in the nearshore at Lac du Bonnet in 2012 was due to large numbers of Amphipoda, Oligochaeta and Ephemeroptera (Caenidae).

As in the nearshore environment, the abundance of invertebrates in the offshore varied among years and sites, but high variability again resulted in few statistically significant differences (Figure 5-7). Overall, abundance in Lac du Bonnet tended to be higher than at the other two Winnipeg River on-system sites. The composition of the BMI varied more among years and waterbodies than in the nearshore. At Pointe du Bois, the Insecta dominated the offshore fauna with Ephemeroptera comprising greater than 40% of the sample in all years. At Lac du Bonnet, the composition was variable: in 2010 90% of the fauna was comprised of Oligochaeta and Bivalvia, while in the other years the division was more equal with Oligochaeta and Bivalvia comprising greater than 10% of the faun in most years and Insecta being dominated by variable numbers of Chironomidae and Ephemeroptera. The off shore fauna in the Pine Falls Forebay was dominated by Chironomidae and Ephemeroptera, with the latter group comprising greater than 40% of the total. The predominance of burrowing mayflies at the offshore Winnipeg River sites is likely due to the prevalence of loamy sand bottom sediments (the preferred habitat of *Hexagenia*; Merritt and Cummins 1996).

5.3.1.2 Off-system Waterbody: Manigotagan and Eaglenest Lakes

The mean abundance of BMIs in the nearshore of Eaglenest Lake, which is further upstream on the Winnipeg River, was comparable to that at downstream on-system sites in the same year. However, abundance in Manigotagan Lake, which is not on the Winnipeg River, tended to be lower (Figure 5-6).

BMI composition in Eaglenest Lake was similar to sites further downstream on the Winnipeg River, with the non-insects dominated by Amphipoda, Oligochaeta and Gastropoda. Chironomidae and Ephemeroptera dominated the Insecta, and, in 2012, the numbers of Ephemeroptera (Caenidae) were particularly high. BMI composition in Manigotagan Lake was markedly different from other sites. Numbers of Insecta tended to be equal to or greater than the numbers of non-insects, although the same basic groups dominated (Amphipoda and Oligochaeta in the non-insects and Chironomidae and Ephemeroptera in the Insecta). As in the other waterbodies, particularly large numbers of Ephemeroptera were sampled in 2012 (58% of the total catch); Caenidae was the predominant mayfly family.

As with nearshore habitat, invertebrate abundance in the offshore environment was lowest in Manigotagan Lake. Eaglenest Lake was within the range of other sites on the Winnipeg River. The Insecta (Chironomidae and Ephemeroptera) comprised greater than 80% of the fauna, with Ephemeroptera making up 72% of the sample in 2013. In Manigotagan Lake the numbers of non-insects and insects were generally similar, with the proportion of Oligochaeta, Bivalvia, and Gastropoda varying considerably among years, and Chironomidae generally dominating the Insecta except for in 2013, when there were approximately equal numbers of Chironomidae and Ephemeroptera.

5.3.1.3 Temporal Comparisons and Trends

Despite the large differences in abundance observed between years in the nearshore environments of Lac du Bonnet and Pointe du Bois Forebay, only the difference between 2010 and 2013 in Pointe du Bois was significant (Figure 5-6). The absence of statistically significant differences can be attributed to the high degree of variability in the samples.

Total density of BMIs in the offshore habitat of the Pointe du Bois Forebay was greatest in 2011 and 2013 and was statistically significantly higher in comparison to 2010 and 2012 (Figure 5-7). In Lac du Bonnet densities in 2011 and 2013 were statistically different. In contrast, invertebrate abundance at the off-system Manigotagan Lake site varied little in the nearshore or offshore between years (Figures 5-6 and 5-7).

Neither the on- or off-system sites indicated an obvious increasing or decreasing trend over the four year monitoring period. Total density in the Pointe du Bois Forebay, however, did show what may be the start of an alternating trend related to the life cycle and emergence pattern of *Hexagenia* sp. (Figure 5-7).

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

5.3.2.1 Winnipeg River

The mean ratio of EPT to chironomids in nearshore habitat varied considerably among years and on-system lakes (Figure 5-8). Nearshore habitat in the Winnipeg River at and downstream of the Pointe du Bois Forebay was typically dominated by EPT (ratios ranging between 2.1 to 6.1). The dominant mayfly group at Eaglenest Lake was also Caenidae; however, chironomids were more abundant in comparison to the total number of EPT.

The mean EPT:C in offshore habitat of all sites varied substantially among years (Figure 5-9). The ephemeropterans were the most abundant of the groups considered (Plecoptera, Trichoptera, and Chironomidae). The predominance of burrowing mayflies at the Winnipeg River sites is likely due to the prevalence of loamy sand bottom sediments (the preferred habitat of *Hexagenia*; Merritt and Cummins 1996).

5.3.2.2 Off-system Waterbody: Manigotagan and Eaglenest Lakes

The mean EPT:C ratio in the nearshore habitat of Manigotagan Lake varied among years and compared to on-system lakes (Figure 5-8). In 2012, mean ratio values for Manigotagan Lake (16.0) and Lac du Bonnet (17.6) were similarly high and the result of a few high individual replicate values at both sites (Figure 5-8).

The EPT:C ratio for Manigotagan Lake in 2010 (0.4) indicated a predominance of chironomids, whereas ratios in 2011 (1.2) and 2013 (2.2) indicated the EPT and chironomids were more numerically equivalent. EPT:C ratio in 2012 (16.0) showed a marked increase in the abundance of EPT in comparison to chironomids (Figure 5-8). Relative water levels measured on day of sampling were similar in 2011, 2012, and 2013 (Table 5-1). The higher water level in 2010 may have resulted in higher chironomid abundance because of limited substrate conducive to supporting an EPT community. In 2011 to 2013, when water levels were lower, the nearshore polygon may have shifted into more EPT productive substrate (Table 5-1).

The mean EPT:C ratio in the offshore habitat of Manigotagan Lake was statistically similar among years (Figure 5-9). In 2012 and 2013, ratios for a few individual replicates were higher than the other replicate values, which made the annual means appear considerably different from 2010 and 2011.

5.3.2.3 Temporal Comparisons and Trends

The EPT:C ratio in the nearshore habitat of the Pointe du Bois Forebay was similar among years (Figure 5-8). Conversely, ratios varied among years at Lac du Bonnet, with 2012 being significantly greater than 2010 (Figure 5-8). These differences do not appear related to water level as gauged and relative water levels for the Pointe du Bois Forebay and Lac du Bonnet were similar among years (Table 5-1).

As described in Section 5.3.2.2, the mean EPT:C ratio in the off-system Manigotagan Lake followed a pattern similar to that of Lac du Bonnet; the EPT:C ratio peaked in 2012, but was only statistically significantly higher than 2010 (Figure 5-8).

The mean EPT:C in offshore habitat of the Pointe du Bois Forebay varied to a certain degree among years; the low ratio in 2012 was statistically significantly different than in 2013 (Figure 5-9). A similar degree of variation was found at Lac du Bonnet; although the ratio in 2010 was significantly lower than in 2011 (Figure 5-9).

The EPT:C ratio in the offshore of Manigotagan Lake varied among years but no differences were statistically significant (Figure 5-9).

Neither the on- or off-system sites indicated an obvious increasing or decreasing trend over the four year monitoring period. In the offshore at the Pointe du Bois Forebay and Lac du Bonnet sites, results to date suggest what may be the start of an alternating pattern in the EPT:C metric related to the emergence pattern of *Hexagenia* sp. (Figure 5-9).

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 Winnipeg River

The mean total richness (family-level) of BMIs in nearshore habitat was quite consistent among years and between on-system lakes (Figure 5-10). Total richness in the nearshore of on-system lakes varied from a low of 14 families in Eaglenest Lake (2013) to a high of 25 families in the Pointe du Bois Forebay (2013).

The mean total richness of BMIs in offshore habitat was consistent among years and between on-system lakes, ranging from a low of five taxa in 2012 at the Pointe du Bois Forebay to a high of nine taxa in 2011 and 2012 at Lac du Bonnet (Figure 5-11). Offshore habitat is more homogenous and tends to be less diverse in terms of richness than nearshore habitat.

5.3.3.2 Off-system Waterbody: Manigotagan Lake

The mean total richness of BMIs in the nearshore habitat of the off-system Manigotagan Lake was lower than (2010), and within the range (2011 to 2013) of, richness values observed for on-system lakes along the Winnipeg River (Figure 5-10).

The mean total richness of BMIs in the offshore habitat of Manigotagan Lake was within the range of richness values observed for on-system lakes (Figure 5-11).

5.3.3.3 Temporal Comparisons and Trends

Total richness of BMIs in the nearshore habitat of the Pointe du Bois Forebay appeared to increase over the four year monitoring period from a low of 18 families in 2010 to a higher of 25 in 2013; however, no changes over time were statistically significant (Figure 5-10). Total richness oscillated between years in Lac du Bonnet between 16 (2010), 14 (2011), 22 (2012), and 18 (2013), with 2011 being statistically different from 2012; there was no indication of an increasing or decreasing trend for this site.

No trend was observed in the nearshore of the off-system Manigotagan Lake, though richness changed over time with a high of 24 families in 2011 and a low of 11 families in 2010. Richness in 2011 was only statistically significantly greater than that in 2010 and 2012 (Figure 5-10).

Total richness of BMIs in the offshore of the Pointe du Bois Forebay varied marginally over time from a low of five families in 2012 to a high of eight in 2011; however, no changes in richness over time were statistically significant (Figure 5-11). Total richness at Lac du Bonnet was also consistent amongst sampling years with a low of seven families (2013) to a high nine families (2011 and 2012); all years were statistically similar. Neither site showed evidence of an increasing or decreasing trend.

Similarly, in the offshore of the off-system Manigotagan Lake richness was statistically similar over time ranging between five and six families in each sampling year and there was no indication of a trend over the four year period (Figure 5-11).

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 Winnipeg River

The mean EPT richness (family-level) in nearshore habitat of on-system waterbodies followed a pattern similar to that for total richness (Figure 5-10).The nearshore typically supports a diverse EPT community due to its complex habitat structure with respect to substrate, vegetation, and other abiotic and biotic factors.

The mean EPT richness in offshore habitat varied minimally among years and somewhat between on-system lakes, ranging from a low of one family at Eaglenest Lake (2010) and the Pointe du Bois Forebay (2012) to a high of three families in 2011 at the Pointe du Bois Forebay (Figure 5-11). Low EPT richness is expected as the offshore habitat is typically homogenous and tends to be less diverse in terms of richness.

5.3.4.2 Off-system Waterbody: Manigotagan Lake

In the nearshore of Manigotagan Lake, mean EPT richness was higher than (2011), lower than (2010), and within the range of (2012, 2013) richness values observed for on-system lakes (Figure 5-10).

With the exception of 2013, the mean EPT richness in the offshore habitat of Manigotagan Lake was marginally lower than that for on-system lakes (Figure 5-11).

5.3.4.3 Temporal Comparisons and Trends

Mean EPT richness in the nearshore habitat of both the Pointe du Bois Forebay and Lac du Bonnet were consistent over time (Figure 5-10). All years for both sites were statistically similar.

Conversely, EPT richness varied between years in the nearshore of Manigotagan Lake (Figure 5-10). The low of five families in 2010 was statistically significantly lower than the high of 11 in 2011.

The mean EPT richness in offshore habitat of the Pointe du Bois Forebay varied between years; a count of one family in 2012 was lower than three families in 2011 (Figure 5-11). Richness in Lac du Bonnet was similar among sampling years with only one or two EPT families represented in samples (Figure 5-11).

In the off-system Manigotagan Lake, there were no statistically significant differences in the number of EPT taxa among sampling years (Figure 5-11).

Neither the on- or off-system sites indicated an obvious increasing or decreasing trend over the four year monitoring period.

5.3.5 Simpson's Diversity Index

Simpson's Diversity Index may provide more information about BMI 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).

5.3.5.1 Winnipeg River

Simpson's diversity index for the nearshore BMI community in on-system lakes varied from a low of 0.40 in Lac du Bonnet (2010) to a high of 0.85 in Eaglenest Lake (2012; Figure 5-12). Diversity values were significantly similar among all years at the Pointe du Bois Forebay and significantly different in 2010 and 2012 in Lac du Bonnet.

The on-system lake diversity values are moderate to high indicating that the benthic invertebrate communities are relatively diverse, but lowest at Lac du Bonnet.

Simpson's diversity index in the offshore of on-system lakes varied from a low of 0.21 in the Pointe du Bois Forebay (2013) to a high of 0.74 in Lac du Bonnet (2012; Figure 5-13). Of the on-system lakes, annual diversity values were more variable in the offshore habitat.

The diversity values indicate that the benthic invertebrate community structures in the offshore habitat of the on-system lakes are moderately diverse.

5.3.5.2 Off-system Waterbody: Manigotagan Lake

For nearshore habitat in the off-system Manigotagan Lake, the diversity index was within the range of the on-system lakes in 2010 and slightly higher than in on-system lakes in 2011, 2012, and 2013 (Figure 5-12). The mean diversity value in Manigotagan Lake was 0.80 and indicated that the invertebrate community is relatively diverse.

For the offshore of Manigotagan Lake, the diversity index was somewhat higher than on-system lakes in 2010 and 2013, and within the range of the on-system lakes in 2011 and 2012 (Figure 5-13). The mean diversity in Manigotagan Lake indicated that the benthic community is relatively diverse.

5.3.5.3 Temporal Comparisons and Trends

Simpson's diversity index in the nearshore habitat of the Pointe du Bois Forebay was statistically similar between sampling years (Figure 5-12). The diversity index in Lac du Bonnet varied among years and 2010 and 2012 were statistically different.

In the nearshore of Manigotagan Lake no changes over time were statistically significant (Figure 5-12).

The Simpson's diversity index in the offshore habitat of the Pointe du Bois measured in 2010 and 2012 was statistically significantly higher in comparison to 2011 and 2013 (Figure 5-13).

The diversity index in the offshore of Manigotagan was not statistically significantly different among sampling years.

Neither the on- or off-system sites indicated increasing or decreasing trends over the four year monitoring period.

5.4 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

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

5.4.1 Ephemeroptera Richness

5.4.1.1 Winnipeg River

Mean Ephemeroptera richness (genus-level) in nearshore habitat varied among years and between on-system lakes (Figure 5-14). Richness was greatest in the Pointe du Bois Forebay (2013).

The mean Ephemeroptera richness in offshore habitat was somewhat similar among years and on-system waterbodies with one to two genera represented (Figures 5-15).

5.4.1.2 Off-system Waterbody: Manigotagan Lake

The mean Ephemeroptera richness in the nearshore and offshore habitats of Manigotagan Lake and Eaglenest Lake fell within the range for the on-system waterbodies (Figures 5-14 and 5-15).

5.4.1.3 Temporal Comparisons and Trends

Ephemeroptera richness in the nearshore habitat of the Pointe du Bois Forebay appeared to increase over the four year monitoring period from a low of three genera in 2010 to a high of seven in 2013; however, the number of genera observed was not statistically significantly different among sampling years (Figure 5-14). In Lac du Bonnet, richness, which ranged from three to five genera, was not statistically different between years and no trends over the four year period were evident.

In the nearshore habitat of Manigotagan Lake, ephemeropteran richness ranged from three to seven genera, with 2010 statistically significantly lower than 2011 (Figure 5-14). There was no indication of an increasing or decreasing trend.

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.

Unlike the other regions monitored by CAMP, water levels on the Winnipeg River are regulated to remain within a narrow range and as such variations in water level are small, although discharge can vary considerably.

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

Water levels on the on-system waterbodies (Pine Falls Forebay, Lac du Bonnet and Pointe du Bois Forebay) typically vary by less than 0.2 m annually and water levels during 2010-2013 generally ranged less than this amount. Discharge, however, varied considerably within and between years, ranging from both above upper quartile to below lower quartile (Figure 2-1, Section 2). The is no water level data for Eaglenest Lake, but as it is located on the Winnipeg River system, lake levels likely fluctuated in conjunction with discharge. No water level gauges are present on Manigotagan Lake but based on discharge in the Manigotagan River water levels would have varied considerably among study years.

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

No relationships between water level and discharge are apparent for BMI metrics measured in either the nearshore or offshore environments (Figures 5-16 to 5-18; Table 5-2).

5.6 SUMMARY

BMI abundance and other metrics varied among years, but differences did not appear to be related to variation in discharge. In general the nearshore BMI community was dominated by Amphipoda, with lesser numbers of Oligochaeta. Chironomidae and Ephemeroptera (typically Caenidae) comprised the majority of the Insecta. In the offshore environment, the composition of the BMI community varied considerably among years and sites. At several sites and sampling periods, Ephemeroptera (*Hexagenia*) were very abundant. The alternating approximate 1-2 year life cycle of the burrowing mayfly *Hexagenia* sp. likely contributed to the inter-annual variability observed for several BMI metrics (e.g., density in the Pointe du Bois Forebay offshore; EPT:C ratio in Lac du Bonnet offshore). The predominance of burrowing mayflies in the offshore habitat of WRR sites sampled is likely due to the loamy sand bottom sediments (their preferred habitat).

BMI abundance in Manigotagan Lake, the off-system reference site not located on the Winnipeg River, was lower than the Winnipeg River sites.

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

Waterbody	Date	Nearshore				Offshore				Relative Water Level		Gauged Water Level[3] (daily mean)	
		Water Depth (mean max, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description (predominant)[1]	Benthic Substrate Texture/Analysis[1,2]	Water Depth (mean, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description (predominant)[1]	Benthic Substrate Texture/Analysis[1]	Current (m)	High (m)	(WSL m)	(Q m^3/s)
EAGLE	17-Sep-10	0.9	standing	bedrock (sand, organic matter)	sand, clay, loam	7.0	standing	clay, sand (organic matter)	sand (loamy sand)	1.49	0.91	n.r.	n.r.
PDB	15-Sep-10	0.9	standing	clay, silt (sand, gravel, boulder, woody debris)	silt loam, loamy sand	7.2	standing	clay, sand	loamy sand (sand)	0.96	0.60	299.07	1214.88
LDB	14-Sep-10	0.8	standing	sand, gravel (bedrock, boulder, cobble, woody debris)	sand (loam)	7.0	standing	clay, sand (organic matter)	loamy sand	1.67	1.22	254.86	--
MANIG	21-Sep-10	1.0	standing	boulder, cobble, sand, gravel, (woody debris)	sand (loam)	8.0	standing	clay, sand	sand (loamy sand)	2.28	1.85	--	21.25
PDB	15-Sep-11	0.9	standing	sand, gravel (organic matter, silt, cobble, boulder)	sand (loam)	7.4	standing	clay, sand	sandy loam (sand)	0.93	0.43	299.05	282.88
LDB	18-Sep-11	0.9	standing	clay (sand, boulder, bedrock)	sand (loam)	7.0	standing	clay (sand)	loamy sand (sand)	1.48	1.14	254.88	--
PFF	22-Sep-11	0.7	standing	boulder, gravel, sand (clay)	sand	7.1	standing	clay	clay (silty clay loam)	1.62	1.33	229.14	--
MANIG	20-Sep-11	0.9	standing	boulder, sand (clay)	sand	6.7	standing	clay, sand	sand	3.03	2.09	--	3.35
PDB	10-Sep-12	1.2	standing	sand, gravel, (boulder, organic matter, silt)	sand (loam)	6.8	standing	sand (gravel, silt, clay)	loamy sand, sandy loam	0.62	n.r.	299.06	830.46
LDB	11-Sep-12	1.2	standing	gravel (sand, clay)	--	7.0	standing	silt, sand (clay)	loamy sand, sandy loam	1.52	1.20	254.87	--
MANIG	13-Sep-12	1.1	standing	boulder, cobble (sand, gravel)	--	7.2	standing	sand, gravel (silt, clay)	sand (loamy sand)	3.07	n.r.	--	10.40
EAGLE	16-Sep-13	0.4	standing	bedrock	--	6.8	standing	silt (gravel)	sandy loam (loamy sand)	1.17	0.85	n.r.	n.r.
PDB	17-Sep-13	0.9	standing	silt	sand (sandy clay loam)	7.1	standing	silt	loamy sand	0.63	0.21	299.06	1025.58
LDB	18-Sep-13	0.8	standing	cobble, organic matter (sand)	sand (clay)	7.2	standing	clay (silt, organic matter)	loamy sand	1.50	1.33	254.88	--
MANIG	9-Sep-13	1.1	standing	boulder	--	6.68	standing	sand, silt	sand (loamy sand)	3.42	n.r.	--	4.71

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

Table 5-2. Average abundance, total richness, Simpson's Diversity, water level, and discharge for Pointe du Bois, Lac du Bonnet, and Manigotagan in the nearshore and offshore environments, 2010 to 2013.

Point du Bois

Year	Abundance (Number/Kicknet Or Number/m^2)	Richness	Diversity	Water Level (mASL)	Discharge (m^3/s)
Nearshore					
2010	521	17.60	0.71	299.1	974.7
2011	1247	22.00	0.68	299.1	1073.2
2012	3009	24.00	0.71	299.1	854.9
2013	2723	25.40	0.72	299.1	1153.5
Offshore					
2010	606	5.80	0.65	299.1	974.7
2011	4129	7.80	0.32	299.1	1068.0
2012	932	5.00	0.67	299.1	854.9
2013	3656	6.60	0.21	299.1	1153.5

Lac du Bonnet

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	1669	15.60	0.40	254.9	1004.3
2011	1050	14.40	0.62	254.9	1024.2
2012	6581	21.60	0.71	254.9	885.3
2013	862	17.60	0.51	254.9	1220.0
Offshore					
2010	2765	8.40	0.62	254.9	1004.3
2011	9439	8.80	0.67	254.9	1029.8
2012	3812	8.80	0.74	254.9	885.3
2013	1558	6.80	0.66	254.9	1220.0

Manigotagan

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	no data	no data	no data	no data	no data
2011	506	24.20	0.86	no data	18.8
2012	1257	16.60	0.79	no data	20.4
2013	115	17.60	0.88	no data	16.4
Offshore					
2010	no data	no data	no data	no data	no data
2011	315	4.80	0.66	no data	18.9
2012	387	5.40	0.71	no data	20.4
2013	193	6.00	0.77	no data	16.4

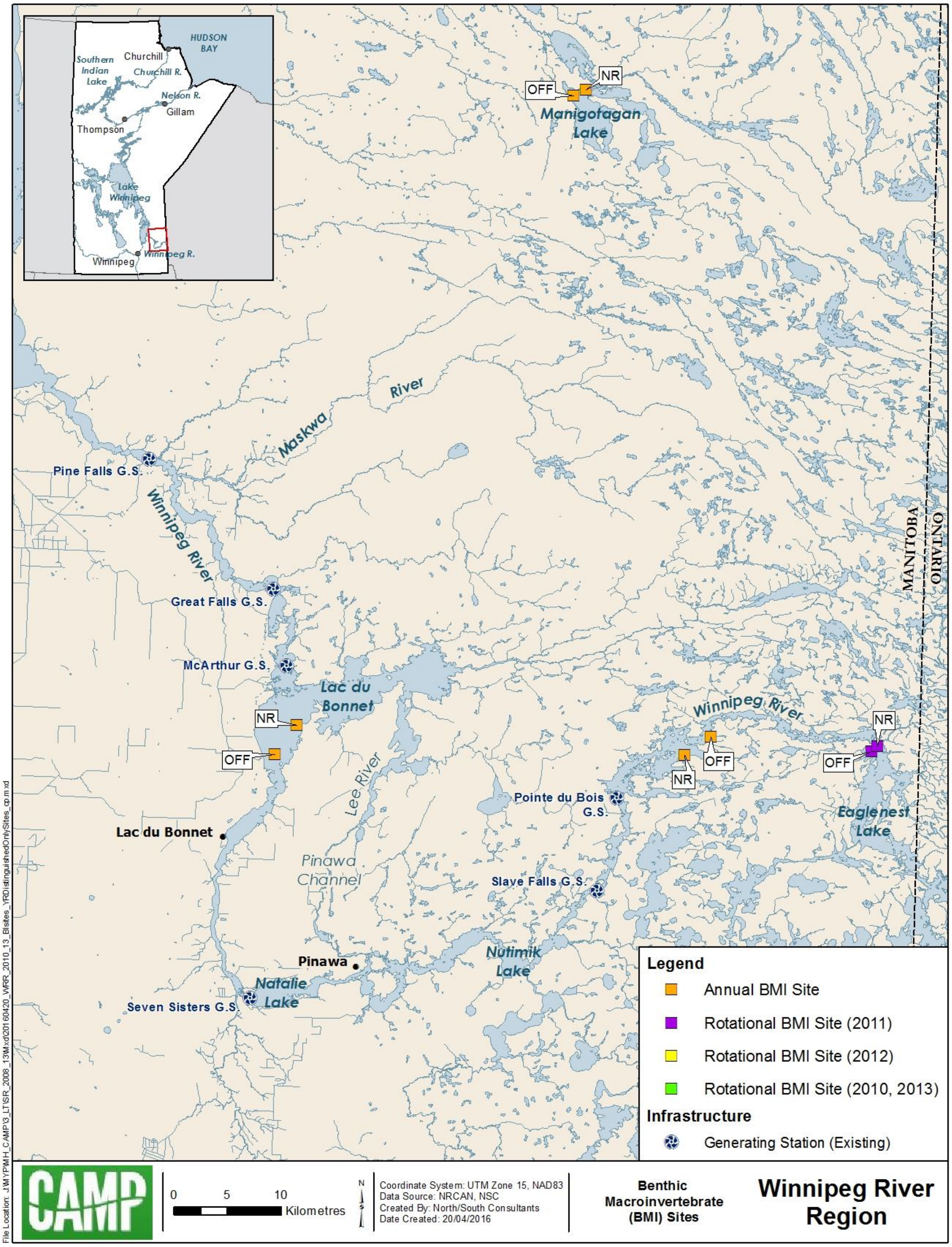


Figure 5-1. Benthic macroinvertebrate sampling sites in the Winnipeg River Region: 2010 – 2013.

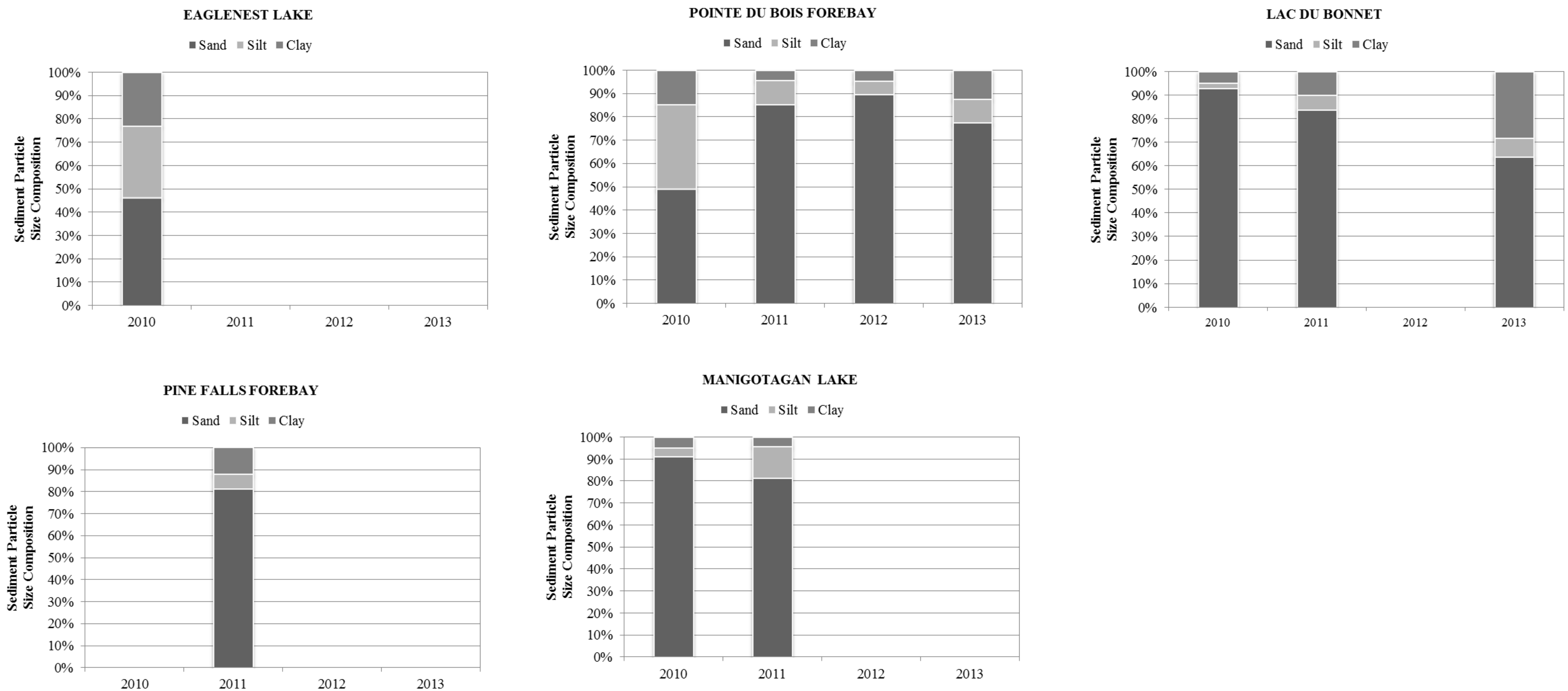


Figure 5-2. Sediment particle size composition (mean % of sand, silt, clay) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013.

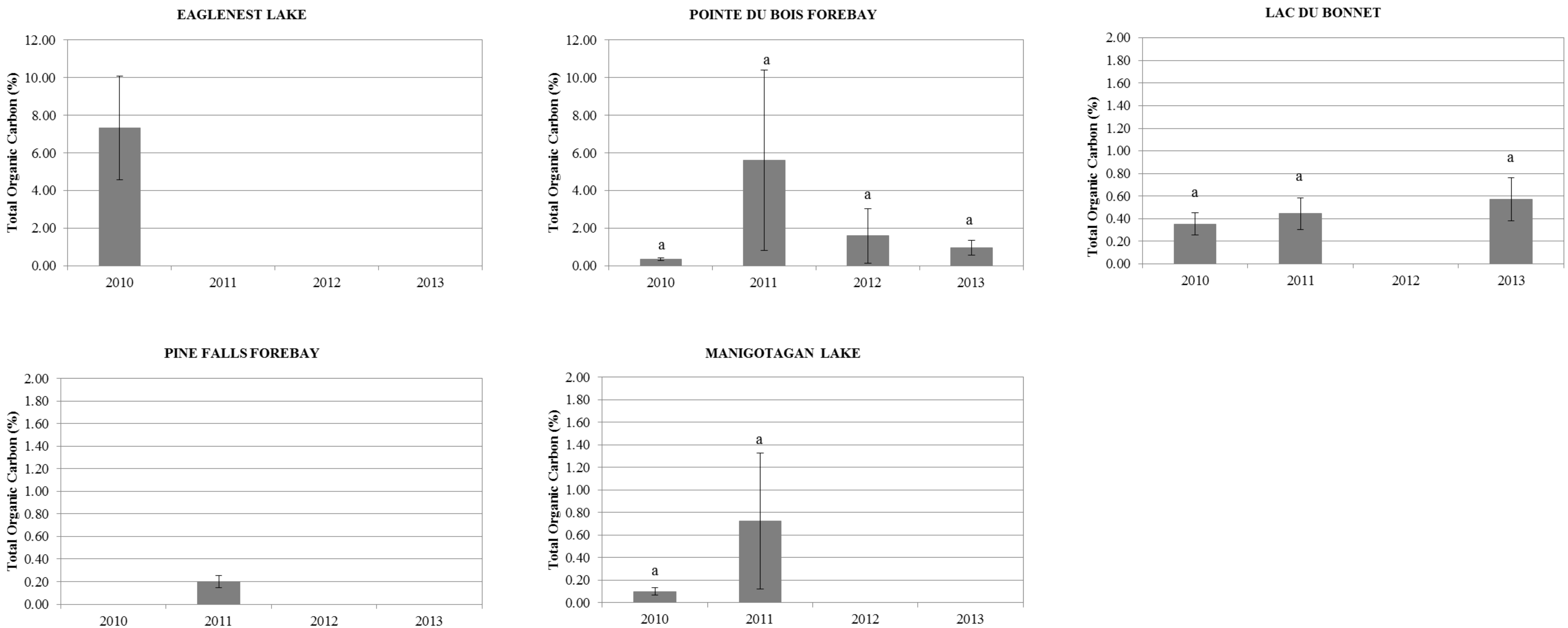


Figure 5-3. Total organic carbon (mean % ± SE) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts indicate significant differences.

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

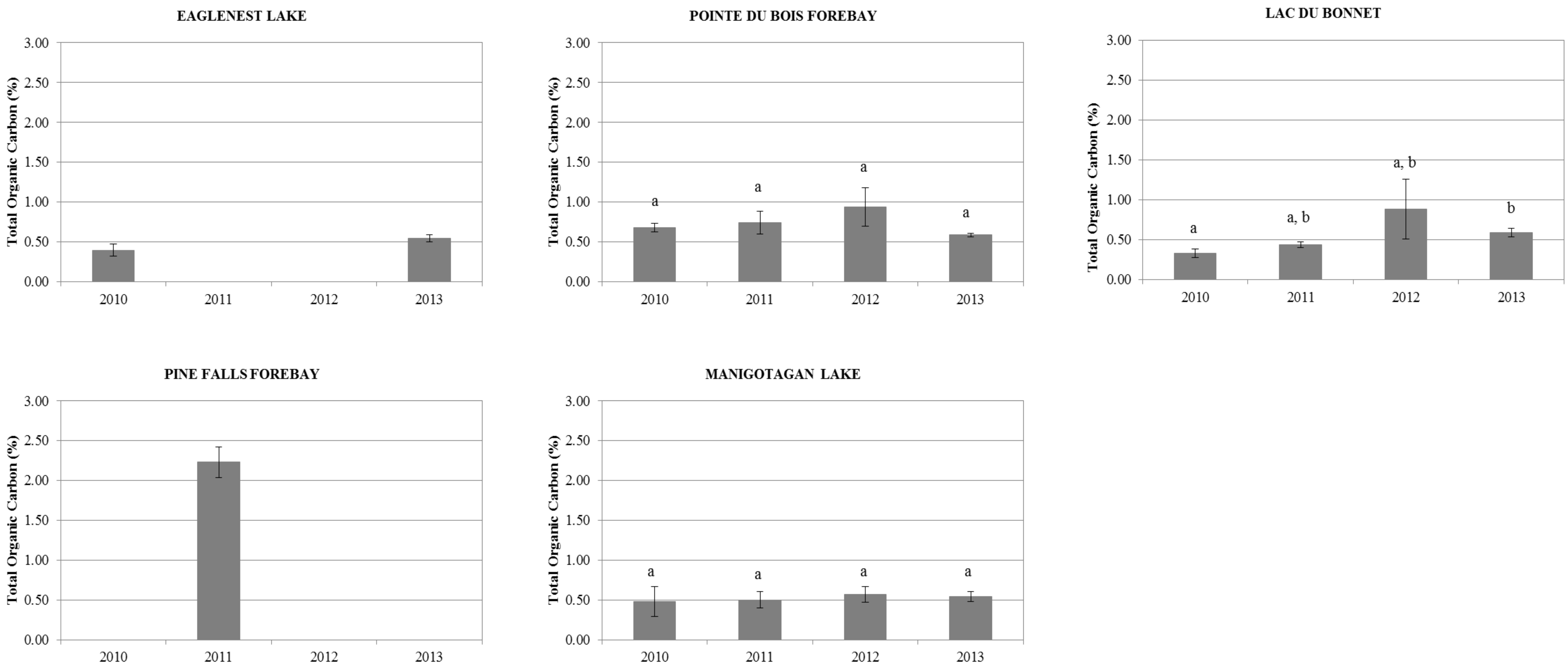


Figure 5-5. Total organic carbon (mean % ± SE) in the offshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

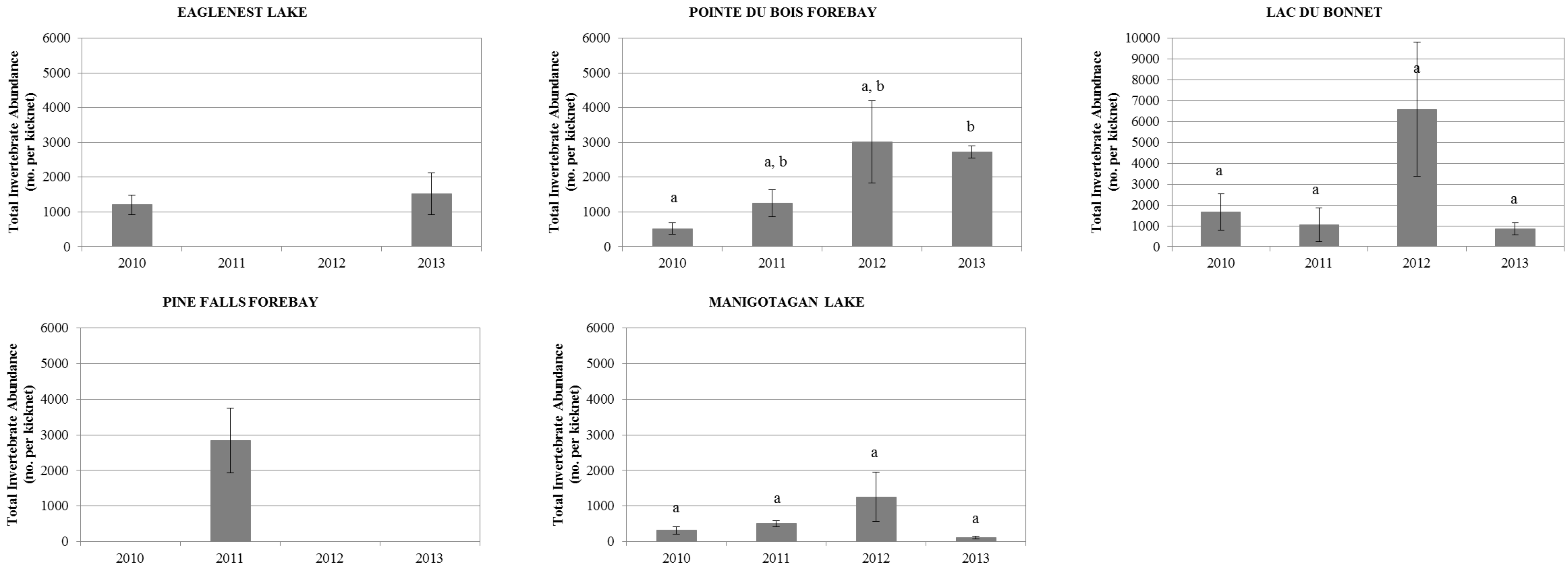


Figure 5-6. Total invertebrate abundance (mean ± SE) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

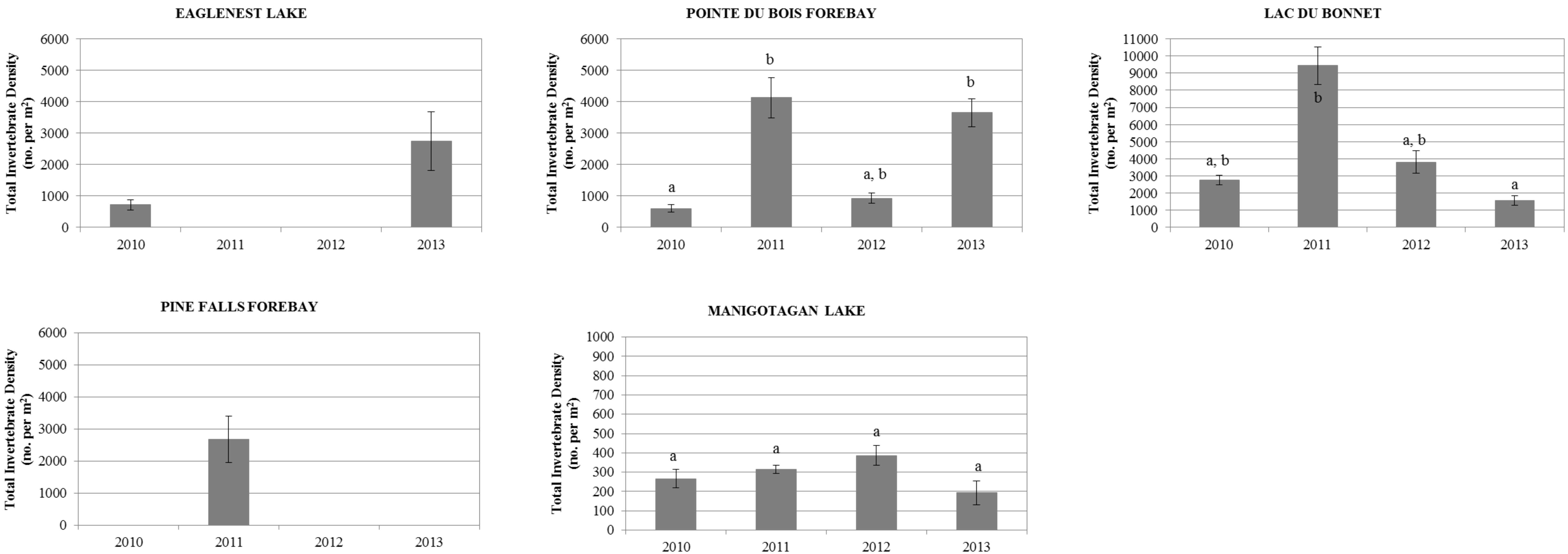


Figure 5-7. Total invertebrate density (mean ± SE) in the offshore of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

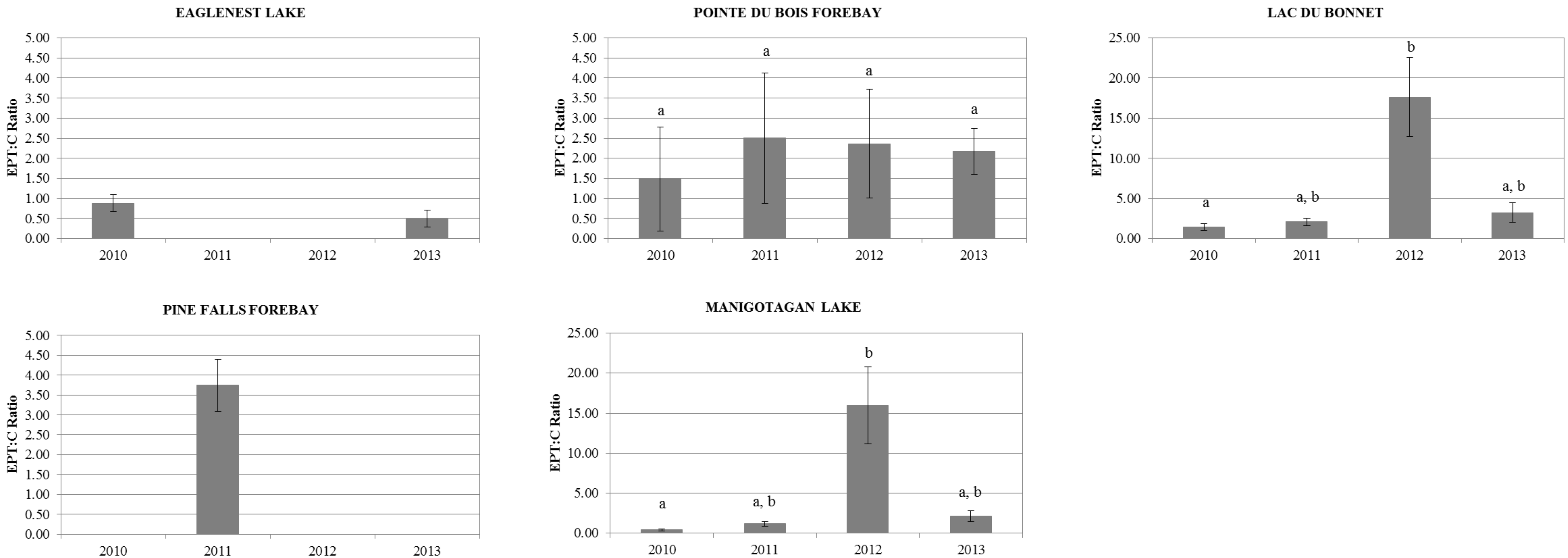


Figure 5-8. EPT:C ratio (mean ± SE) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

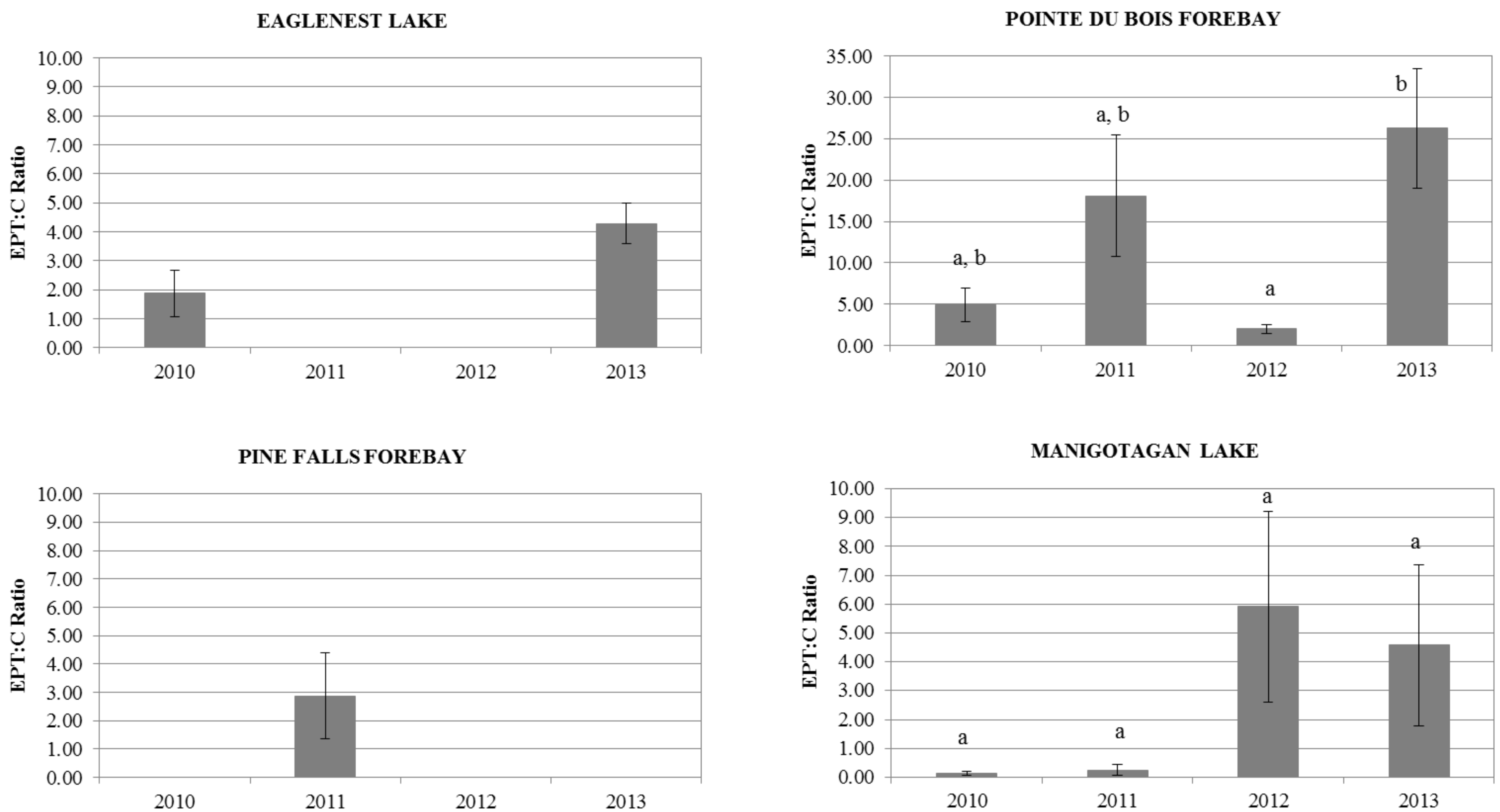


Figure 5-9. EPT:C ratio (mean ± SE) in the offshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

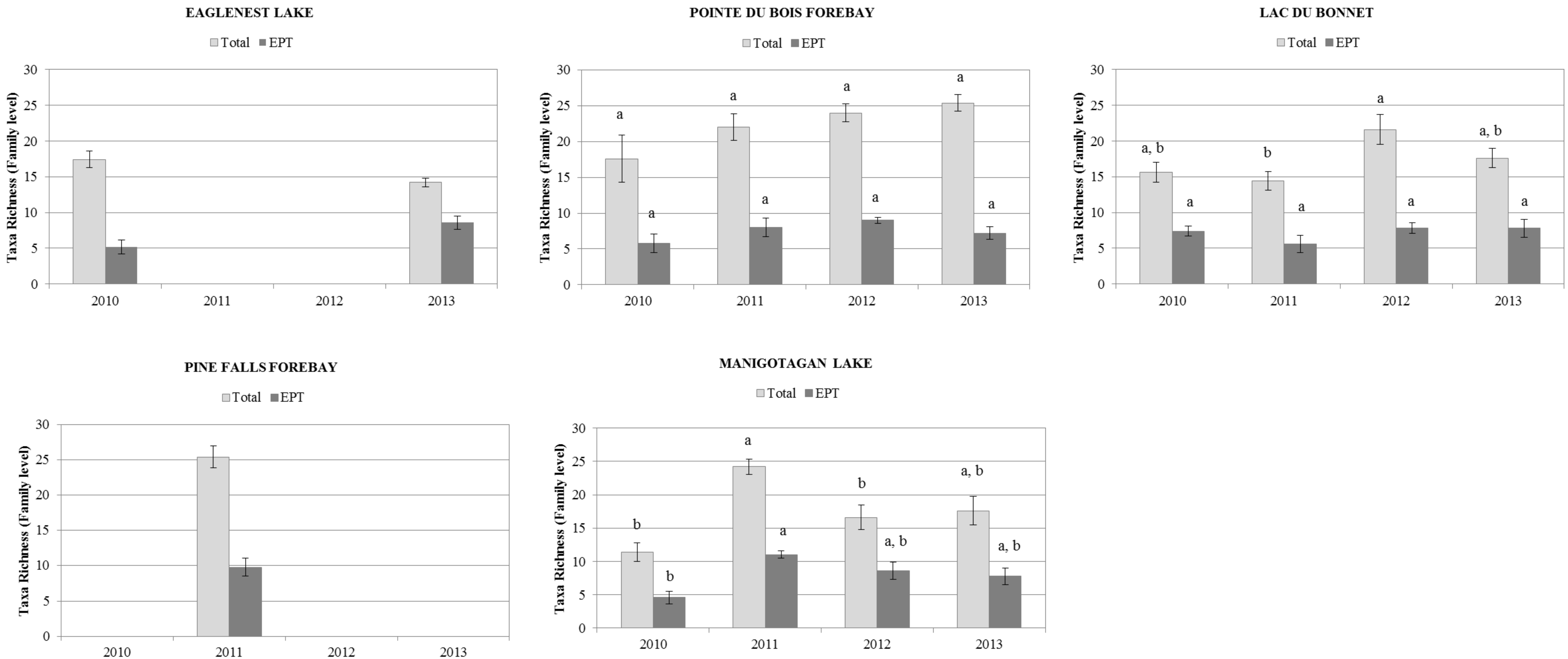


Figure 5-10. Taxonomic richness (total and EPT to family level; mean ± SE) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no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

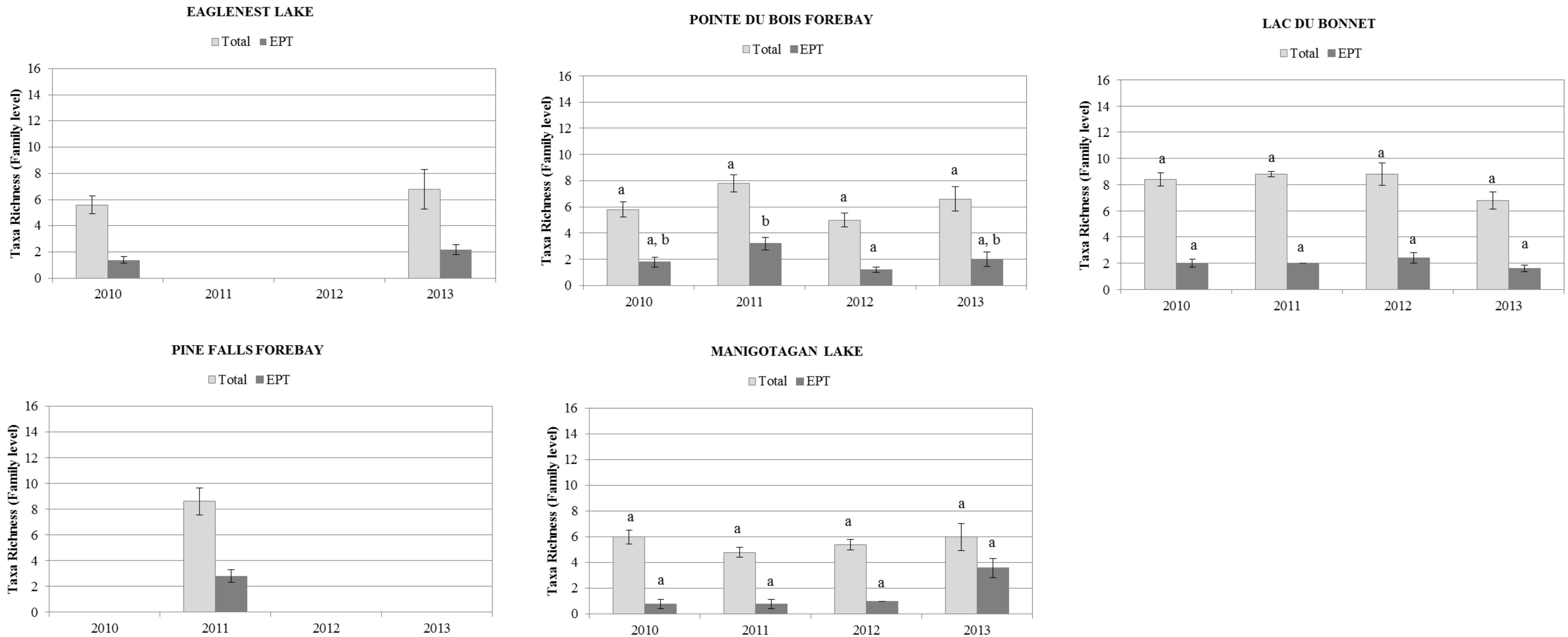


Figure 5-11. Taxonomic richness (total and EPT to family level; mean ± SE) in the offshore habitat of the Winnipeg River Region, by year: 2010 – 2013.Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

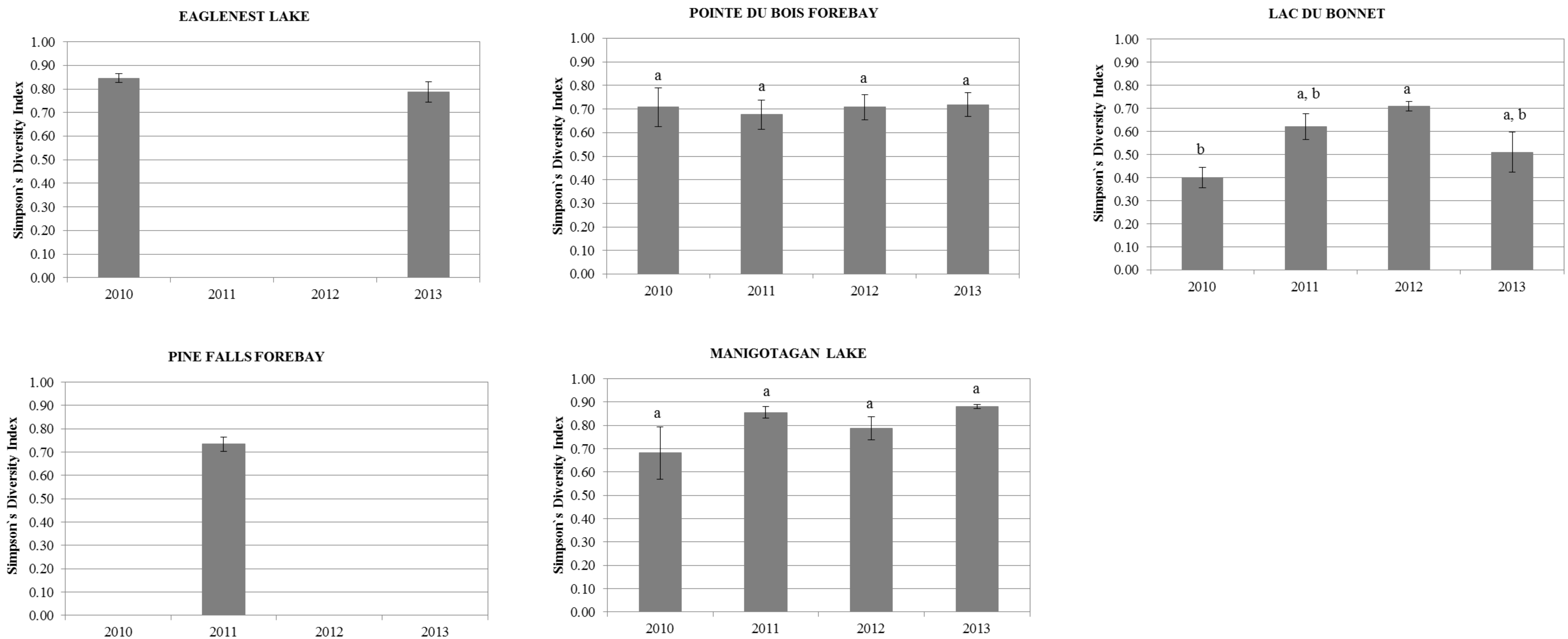


Figure 5-12. Simpson’s Diversity Index (mean ± SE) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

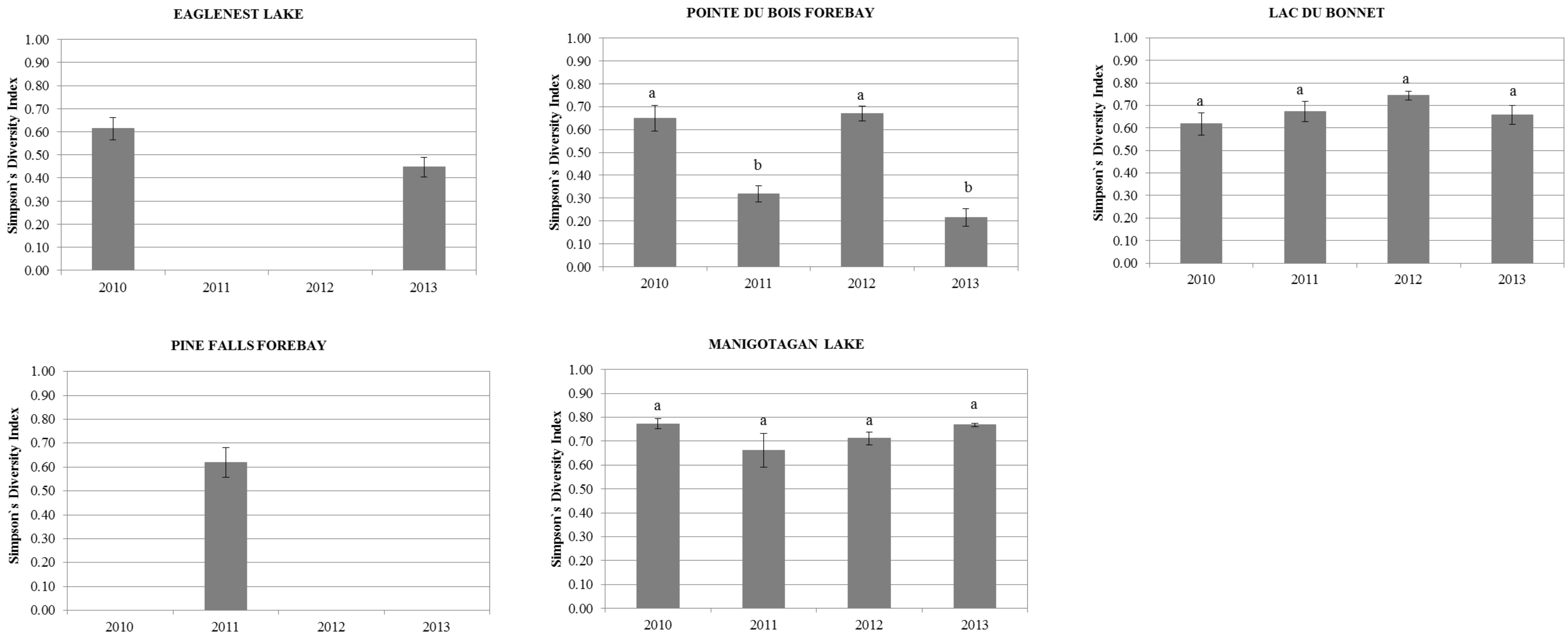


Figure 5-13. Simpson’s Diversity Index (mean ± SE) in the offshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

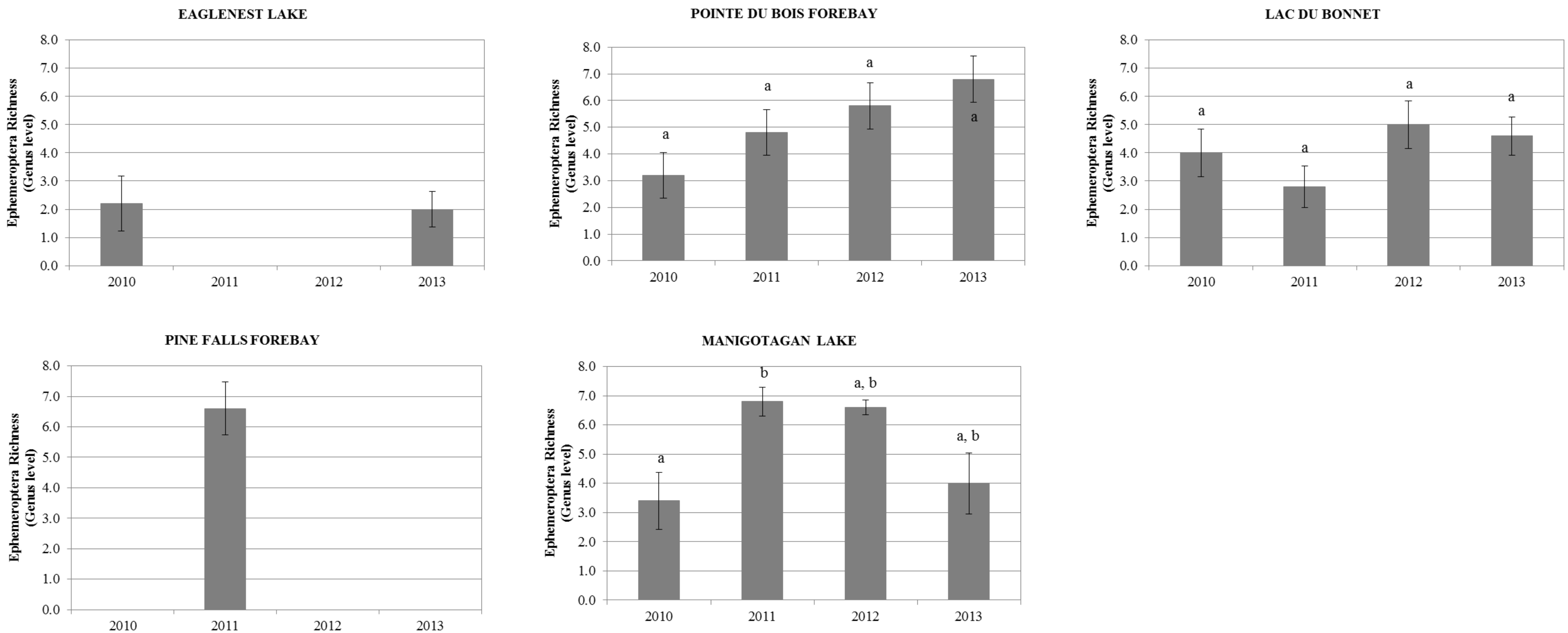


Figure 5-14. Ephemeroptera richness (genus level; mean ± SE) in the nearshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

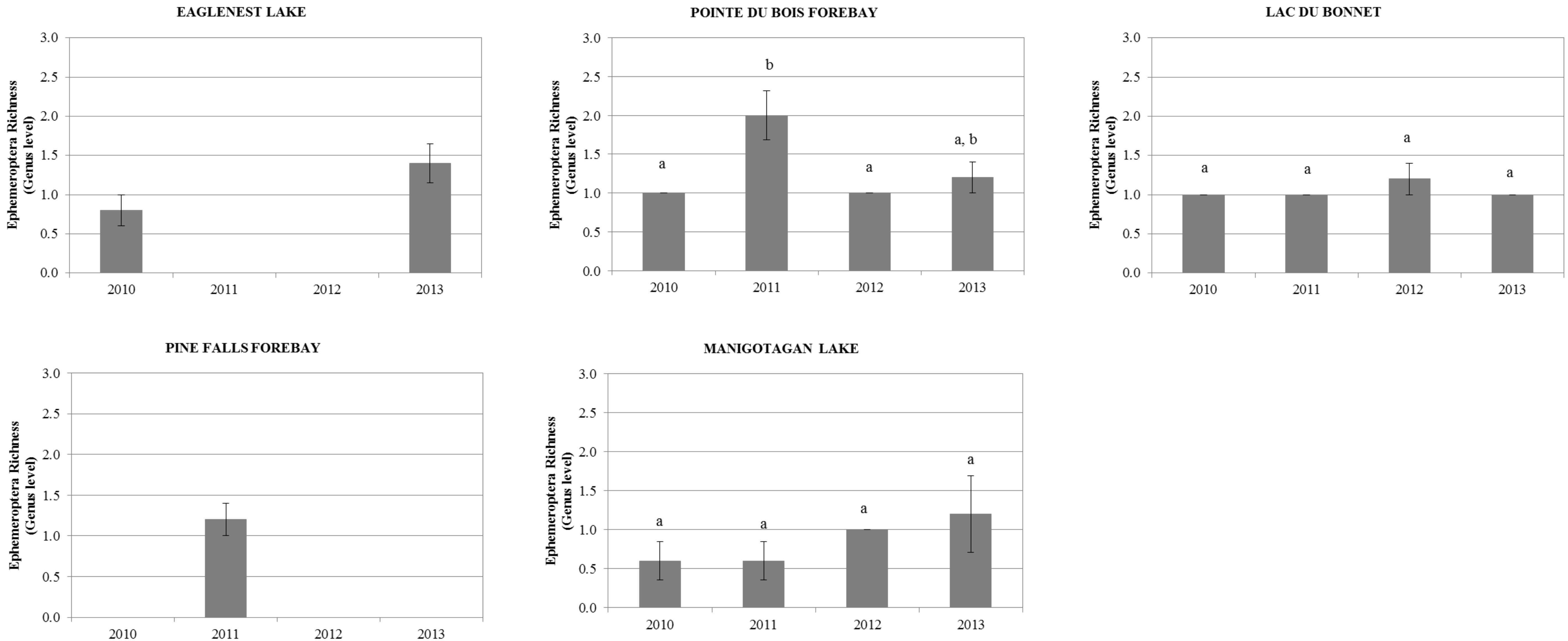


Figure 5-15. Ephemeroptera richness (genus level; mean ± SE) in the offshore habitat of the Winnipeg River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

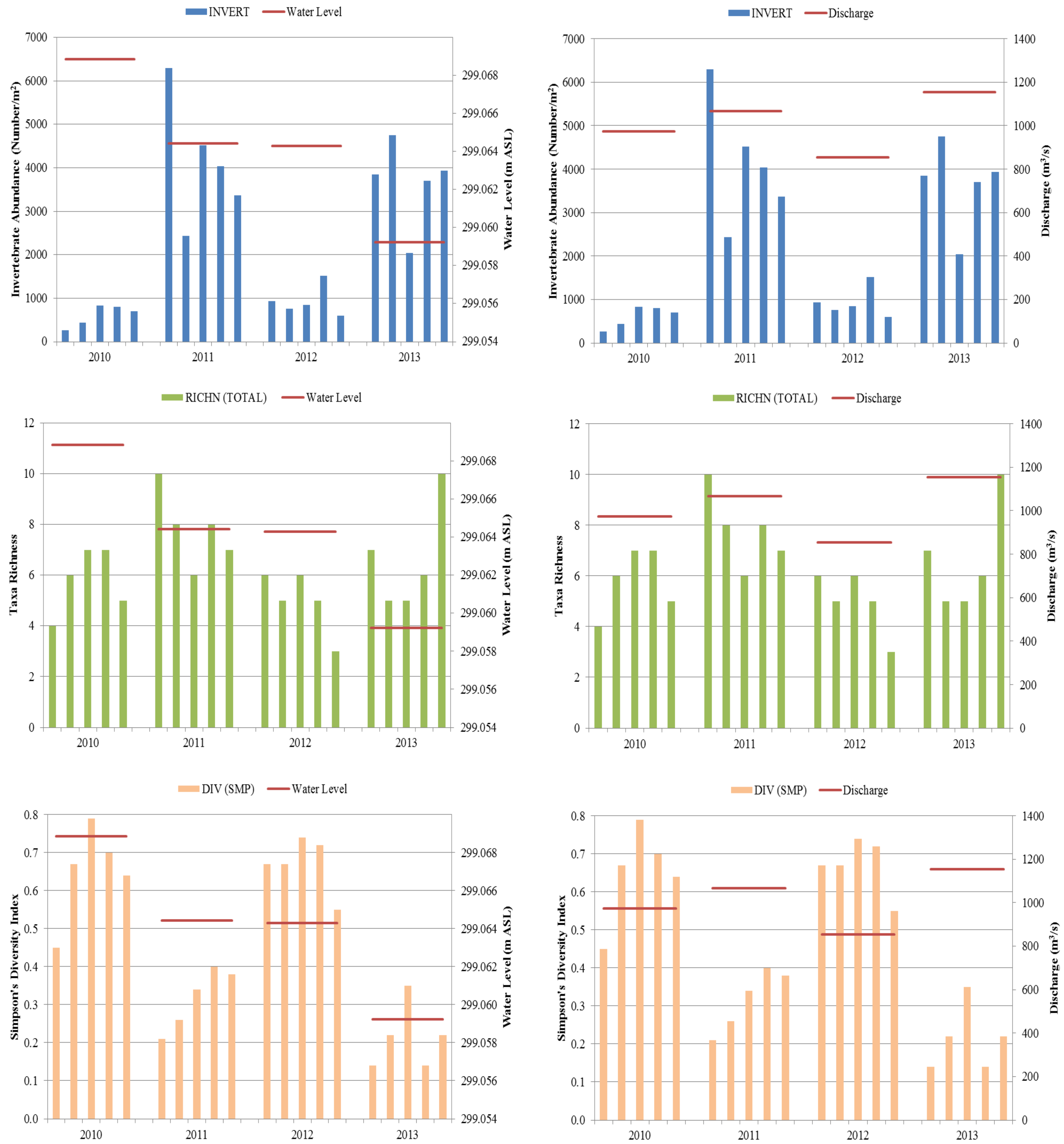


Figure 5-16. Invertebrate abundance, total richness, and Simpson's diversity index for offshore Point du Bois: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

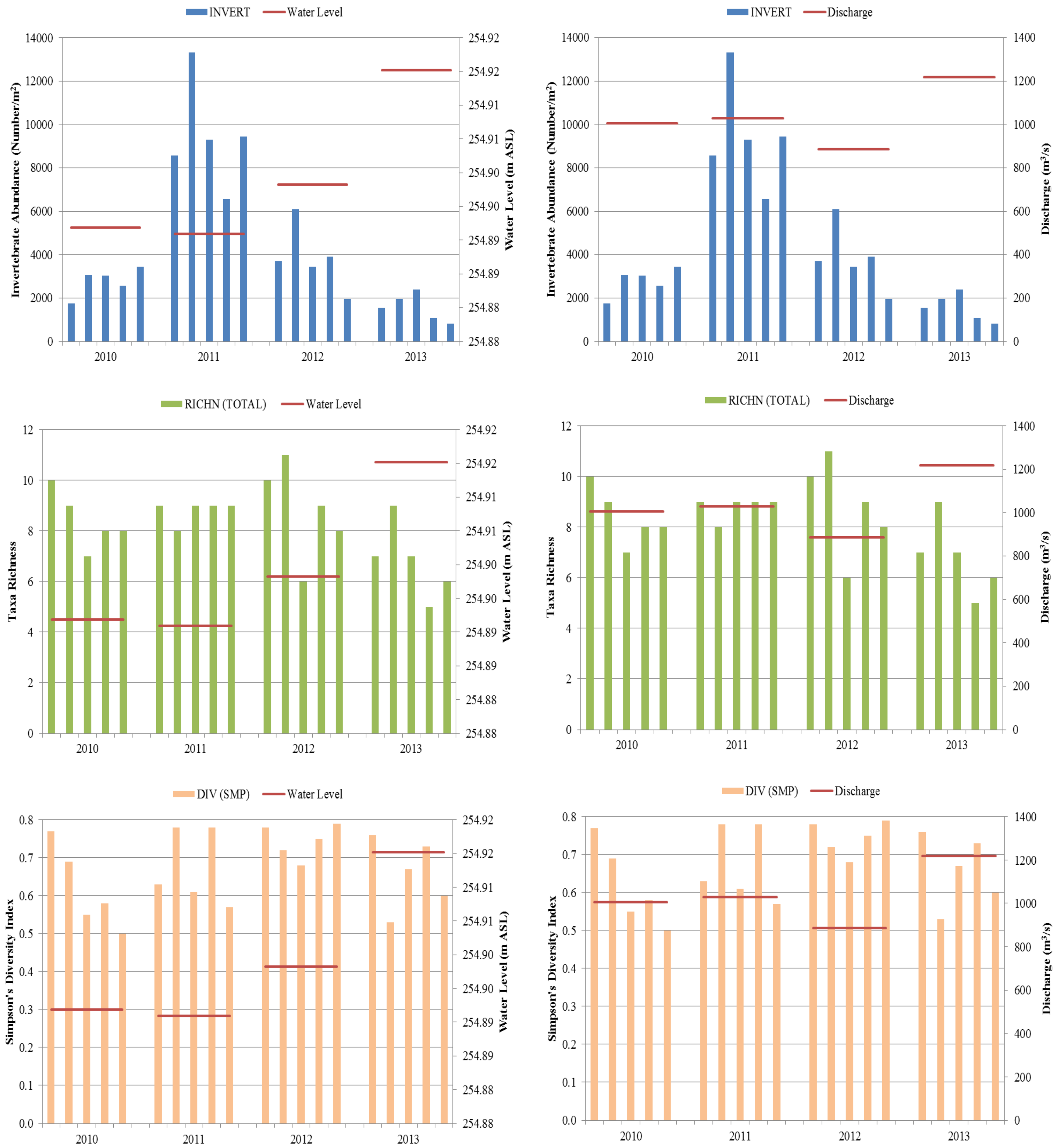


Figure 5-17. Invertebrate abundance, total richness, and Simpson's diversity index for offshore Lac du Bonnet: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

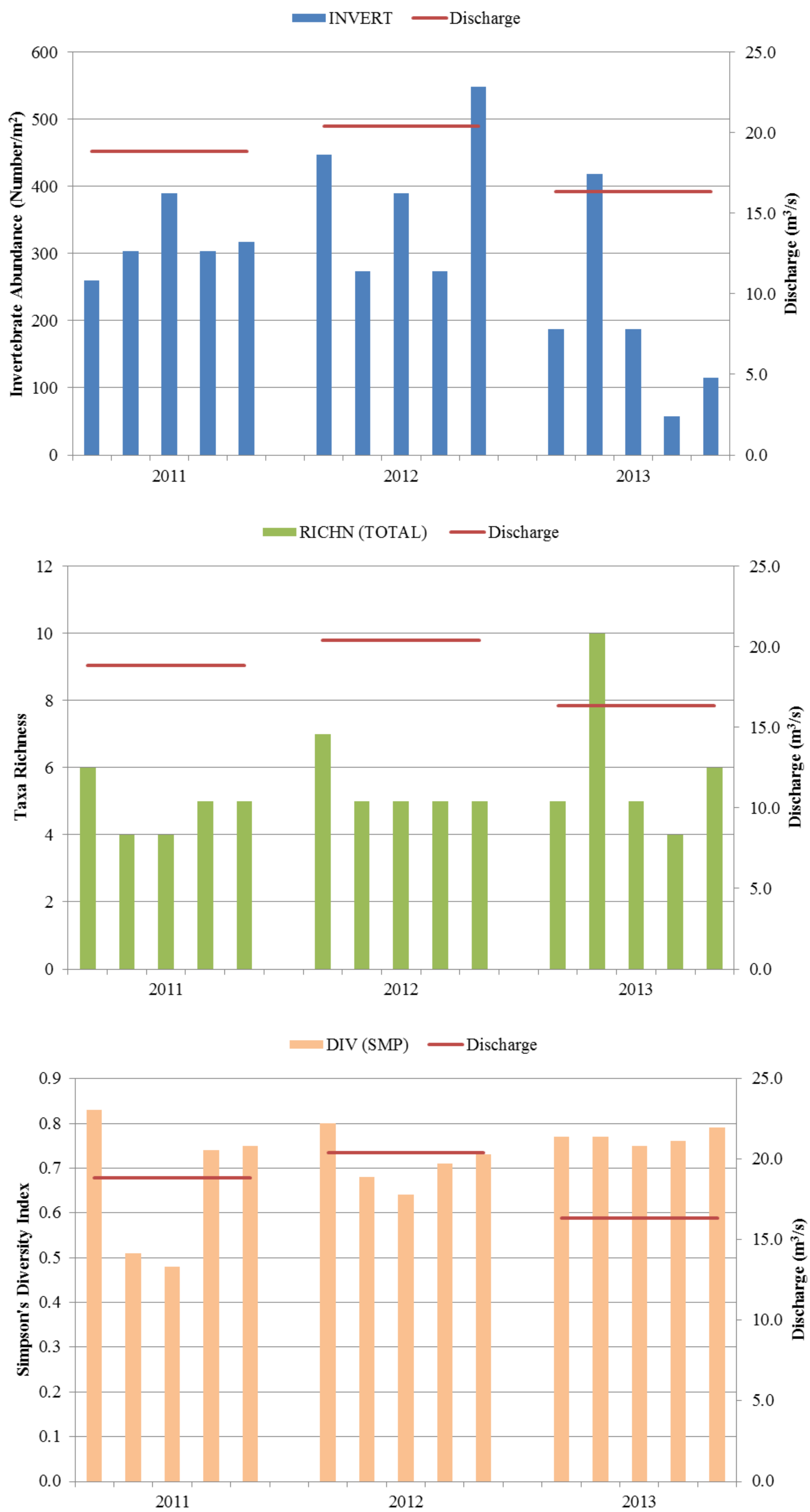


Figure 5-18. Invertebrate abundance, total richness, and Simpson's diversity index for offshore Manigotagan Lake: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

6.0 FISH COMMUNITY

6.1 INTRODUCTION

The following provides an overview of the fish community component of CAMP using key metrics measured over years 1 to 6 in the WRR. As noted in Section 1.0, waterbodies/river reaches sampled annually included two on-system sites (Pointe du Bois Forebay and Lac du Bonnet) and one off-system lake (Manigotagan Lake). Two additional waterbodies were sampled on a rotational basis: Eaglenest Lake (off-system) and Pine Falls Forebay (on-system; Table 6-1; Figure 6-1). A discussion of the rationale for the selection of these waterbodies is provided in Technical Report 1 and the abbreviations for the sampling locations used in the tables and figures are provided in Table 6-1.

All analyses presented below have been conducted on the results of annual or rotational index gillnetting studies. A detailed description of the sampling methods is presented in Section 4.6 of Technical Report 1. A complete list of all fish species captured in standard gang and small mesh index gill nets set in the WRR waterbodies, 2008-2013, is presented in Table 6-2.

6.1.1 Objectives and Approach

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

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

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

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

6.1.2 Indicators

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

6.2 KEY INDICATORS

6.2.1 Diversity (Hill’s Index)

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

6.2.1.1 Winnipeg River

Excluding the Pine Falls Forebay, which was sampled only once, the mean Hill’s number for the two annually sampled on-system waterbodies was 8.1 in Lac du Bonnet and 7.2 in the Pointe du Bois Forebay (Table 6-3). The mean Hill’s number for the 6-year sampling period was generally similar between annual on-system waterbodies, though the interquartile range was much larger for Lac du Bonnet (Figure 6-2). The similarities can be attributed to comparable species compositions and annual diversity in each waterbody, ranging from 16-19 species, while the large interquartile range for Lac du Bonnet is the result of highly variable inter-annual proportions of Spottail Shiner (*Notropis hudsonius*) and Yellow Perch (*Perca flavescens*) in the catches (combined 17-72% of the total catch). Sauger (*Sander canadensis*), Walleye (*Sander vitreus*), White Sucker (*Catostomus commersoni*), and Yellow Perch were all regularly abundant in Lac du Bonnet and the Pointe du Bois Forebay.

The Hill's Index in the one year the Pine Falls Forebay was sampled was 5.4, which was lower than the lowest value at the other two on-system locations. This value was likely the result of the catch being dominated (53%) by one species, Channel Catfish (*Ictalurus punctatus*), which was rare or absent from the other waterbodies.

6.2.1.2 Off-system Waterbodies: Eaglenest and Manigotagan Lakes

The mean Hill's number was 5.3 in Manigotagan Lake and 8.0 in Eaglenest Lake (Table 6-3). The value for Manigotagan Lake was lower than on-system waterbodies due to lower species richness (8-13 species compared to 16-19 species in on-system waterbodies) and reduced evenness with at least 60% of the catch in all but one year being represented by only two species (Cisco [*Coregonus artedi*] and Walleye). Eaglenest Lake, located upstream of the hydraulic zone of influence of Manitoba Hydro's facilities and therefore classified as off-system, is on the Winnipeg River and, as a result, has a similar species composition as that of Lac du Bonnet and the Pointe du Bois Forebay.

6.2.1.3 Temporal Comparisons and Trends

Sites sampled annually (the Pointe du Bois Forebay, Lac du Bonnet, and Manigotagan Lake) were examined for temporal trends. The Hill's numbers for on-system waterbodies sampled annually showed variability among sampling years, but somewhat of a decreasing trend in recent years (Figure 6-2). From 2008 to 2010, the average annual Hill's numbers for the Pointe du Bois Forebay and Lac du Bonnet ranged from 7.5 to 8.0 and 7.4 to 11.4, respectively. Since 2010, the average annual values have decreased to 6.1 to 7.2 in the Pointe du Bois Forebay and 5.5 to 7.3 in Lac du Bonnet. Patterns in the two waterbodies have generally mimicked one another with maximum diversity observed in 2010 and minimum in 2013. Though sampled only twice (2010 and 2013), the higher Hill's number in Eaglenest Lake was also recorded in 2010.

The decrease in Hill's number in on-system waterbodies since 2010 is largely the result of much higher proportions of Spottail Shiner and Yellow Perch captured in small mesh nets. Despite a relatively consistent effort and timing of surveys over the years, the combined proportion of these two species in the total catch (standard and small mesh gangs) from the Pointe du Bois Forebay has increased from 14% in 2008 to more than 50% in 2013. In Lac du Bonnet, the proportion has increased from 17-25% (2008-2010) to more than 70% in 2013. A similar increase in the proportion of these two species was observed between 2010 and 2013 samples in Eaglenest Lake. The difference in the Pointe du Bois Forebay catches may be partially attributed to a change in sampling locations. Site SN-16, which captured most of the Spottail Shiner and Yellow Perch from 2011 to 2013, was not sampled from 2008 to 2010. In Lac du Bonnet, however, the large increase was observed almost exclusively at Site SN-04, which has been sampled annually in late September since 2008.

Average annual Hill's numbers in Manigotagan Lake have shown a small increase since 2010, but there has been no corresponding increase in the number of species captured or a noticeable decrease in the proportion of the catches comprised of Cisco and Walleye. The change can be attributed to more balanced proportions of the remaining species in the recent catches.

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., DO) 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 Winnipeg River

<u>Fish Community</u>

In standard gangs, the mean CPUE ranged from a high of 41 fish/100 m/24 h in Lac du Bonnet to a low of 20 fish/100 m/24 h in the Pine Falls Forebay (Table 6-3), though the latter was sampled only once. The highest catch rates in Lac du Bonnet and the Pointe du Bois Forebay were typically for White Sucker, Yellow Perch, Sauger, and Walleye. Four additional species (Shorthead Redhorse [*Moxostoma macrolepidotum*], Northern Pike [*Esox lucius*], Cisco, and Lake Whitefish [*Coregonus clupeaformis*]) were also relatively common in catches from on-system waterbodies sampled annually. Fall spawning species, such as Cisco and Lake Whitefish, were captured more frequently in Lac du Bonnet than in other on-system waterbodies. This difference may be a function of the timing of the sampling period, which was in late September in Lac de Bonnet and in July in the Pointe du Bois and Pine Falls forebays. This difference in survey timing among waterbodies may also explain some of the variation noted for individual species described below. Unlike other WRR on-system waterbodies, Channel Catfish, which are highly adapted to riverine conditions, were particularly abundant in the Pine Falls Forebay (Figure 6-3).

The total catch rates of large-bodied fish were similar between the Pointe du Bois Forebay and Lac du Bonnet as evidenced by overlapping interquartile ranges (Figure 6-4). The Pine Falls Forebay had a lower mean CPUE than other on-system waterbodies, although it was sampled only once.

In small mesh gangs, the mean CPUE was substantially more variable among on-system waterbodies than in standard gangs, ranging from a high of 167 fish/30 m/24 h in Lac du Bonnet to a low of 12 fish/30 m/24 h in the Pine Falls Forebay (Table 6-3). Despite this variability, Yellow Perch and Spottail Shiner were consistently among the most commonly captured species in small mesh catches from each on-system waterbody (Figure 6-3). Trout-perch (*Percopsis omiscomaycus*) in the Pointe du Bois Forebay and Emerald Shiner in Lac du Bonnet were also relatively abundant.

Northern Pike

Northern Pike mean CPUE in standard gangs in Lac du Bonnet (4 fish/100 m/24 h) was more than double the rate in the Pointe du Bois Forebay (2 fish/100 m/24 h) and more than six times the rate in the Pine Falls Forebay (<1 fish/100 m/24 h) (Table 6-3; Figure 6-5). The mean CPUE in Lac du Bonnet was higher than that in the Pointe du Bois Forebay (i.e., no overlap of interquartile ranges; Figure 6-5).

Sauger

Sauger mean CPUE in standard gangs was 9 fish/100 m/24 h in Lac du Bonnet and 6 fish/100 m/24 h in the Pointe du Bois Forebay (Table 6-3; Figure 6-6). There was only a small amount of overlap between interquartile ranges, suggesting a possible difference in abundance between the two waterbodies (Figure 6-6). As with Northern Pike, differences in catch rates between the two waterbodies may reflect differences in the timing of the monitoring programs (Figure 6-6). Sauger is not a key species for the Pine Falls Forebay.

Walleye

Walleye mean CPUE ranged from a high of 7 fish/100 m/24 h in Lac du Bonnet to a low of 2 fish/100 m/24 h in the Pine Falls Forebay (Table 6-3). There was some variation in the capture rate of Walleye in on-system waterbodies along the Winnipeg River (Figure 6-7). The interquartile ranges for the Pointe du Bois Forebay and Lac du Bonnet did not overlap, suggesting a difference in the abundance of Walleye among the two waterbodies.

White Sucker

White Sucker mean CPUE in standard gangs ranged from a high of 11 fish/100 m/24 h in the Pointe du Bois Forebay to a low of 2 fish/100 m/24 h in the Pine Falls Forebay (Table 6-3). White Sucker abundance appeared to decrease in a downstream direction (Figure 6-8). The CPUE in the Pointe du Bois Forebay was considerably higher than in Lac du Bonnet, as evidenced by the separation of the interquartiles of the box plots (Figure 6-8).

6.2.2.2 Off-system Waterbodies: Eaglenest and Manigotagan Lakes

Fish Community

In standard gangs, the mean CPUE was 38 fish/100 m/24 h in Eaglenest Lake during July and 55 fish/100 m/24 h in Manigotagan Lake during September (Table 6-3). The large-bodied fish community in Eaglenest Lake was dominated by Yellow Perch, Walleye, White Sucker, and Sauger, although no single species had catch rates higher than 13 fish/100 m/24 h. In contrast, the most frequently captured species in Manigotagan Lake were Cisco and Walleye, each with a CPUE greater than 17 fish/100 m/24 h (Figure 6-3). Lake Whitefish were also fairly abundant in Manigotagan Lake. The relatively high catch rates for fall spawning species (i.e., Lake Whitefish, Cisco) in Manigotagan Lake was likely due, at least in part, to the timing of surveys in that waterbody. The only other waterbody sampled during September (Lac du Bonnet) also had higher CPUE for fall spawning species.

Standard gang fish capture rates in Eaglenest Lake were similar to the annually sampled on-system waterbodies (Figure 6-4). In contrast, capture rates in the off-system Manigotagan Lake were higher than in any of the on-system lakes, as shown by the lower quartile CPUE exceeding the upper quartiles of the other waterbodies (Figure 6-4).

In small mesh gangs, the mean CPUE was 56 fish/30 m/24 h in Eaglenest Lake and 37 fish/30 m/24 h in Manigotagan Lake (Table 6-3). The small-bodied fish community of Eaglenest Lake was dominated by Yellow Perch and Trout-perch, though juvenile Sauger were also common, and was generally similar to the small-bodied fish community of Pointe du Bois Forebay (Figure 6-3). Spottail Shiner and juvenile Walleye were most common in Manigotagan Lake small mesh nets.

Northern Pike

Northern Pike had a mean CPUE in standard gangs of approximately 3 fish/100 m/24 h in both Eaglenest and Manigotagan lakes (Table 6-3). Northern Pike CPUE in both off-system waterbodies was within the range observed in the on-system Lac du Bonnet, but was higher than in the Pointe du Bois Forebay, as evidenced by the lack of interquartile overlap (Figure 6-5).

Walleye

Walleye had a mean CPUE in standard gangs of 7 fish/100 m/24 h in Eaglenest Lake and 18 fish/100 m/24 h in Manigotagan Lake (Table 6-3). Walleye CPUE in Eaglenest Lake was somewhat comparable to the on-system lakes (Figure 6-7). However, the CPUE in Manigotagan Lake was considerably higher than in all other waterbodies as evidenced by the lack of interquartile overlap.

White Sucker

White Sucker had a mean CPUE in standard gangs of 5 fish/100 m/24 h in Eaglenest Lake and 3 fish/100 m/24 h in Manigotagan Lake (Table 6-3). The interquartile ranges for mean annual CPUE in both off-system lakes overlapped with those of Lac du Bonnet, suggesting that the White Sucker capture rate was comparable among these lakes (Figure 6-8). However, the capture rate in the off-system lakes was considerably lower than in the Pointe du Bois Forebay.

6.2.2.3 Temporal Comparisons and Trends

Fish Community

Sites sampled annually (the Pointe du Bois Forebay, Lac du Bonnet, and Manigotagan Lake) were examined for temporal trends. The mean total CPUE values for annually sampled waterbodies showed variability among years (Figure 6-4). Over the 6-year sampling period, mean total CPUE ranged from 21 fish/100 m/24 h in 2010 to 46 fish/100 m/24 h in 2009 in the Pointe du Bois Forebay, from 32 fish/100 m/24 h in 2008 to 50 fish/100 m/24 h in 2012 in Lac du Bonnet, and from 43 fish/100 m/24 h in 2013 to 68 fish/100 m/24 h in 2008 in Manigotagan Lake (Figure 6-4).

Results from the Pointe du Bois Forebay showed an alternating pattern of high and low CPUE, with no indication of an overall increasing or decreasing trend (Figure 6-4). The CPUE values observed in 2009, 2011, and 2013 were significantly higher than the CPUE values from 2010 and 2012 (Figure 6-9).

Total CPUE in Lac du Bonnet shows a slight increasing trend since 2008, with rates almost 75% higher in 2012 and 2013 than in 2008 (Figure 6-4). The CPUE from 2012 was significantly higher than all years prior to 2011 (Figure 6-9). Similarly, the 2013 CPUE was significantly higher than 2008 and 2010.

There were some fluctuations in fish capture rate in Manigotagan Lake since 2008, with higher CPUE in the even-numbered years than in the odd-numbered years, but the general trend appears to be a decrease in catch rates over time. The 2008 and 2010 CPUE values were significantly higher than those in 2011 and 2013 (Figure 6-9).

Northern Pike

The CPUE of Northern Pike has shown some variation in waterbodies monitored annually, ranging from 1-3 fish/100 m/24 h in Pointe du Bois Forebay, 1-6 fish/100 m/24 h in Lac du Bonnet, and 2-3 fish/100 m/24 h in Manigotagan Lake (Figure 6-5). Statistical comparison of CPUE at annual on-system locations indicates some significant differences (Figure 6-10).

In the Pointe du Bois Forebay, the 2013 CPUE was significantly higher than all other years and the CPUE was significantly higher in 2009 than in 2012; however, no clear trend in abundance over the 6-year period was apparent (Figure 6-10).

In Lac du Bonnet, the catch rate in 2012 was significantly higher than in previous years and was statistically higher in 2013 compared to 2008 and 2009. The higher CPUE values in 2012 and 2013 are suggestive of a potential trend of increasing Northern Pike catches over time in this lake.

Northern Pike catch rates in Manigotagan Lake over the 6-year period have shown a small increase since 2010 (Figure 6-5); however, there are no statistically significant differences among years (Figure 6-10).

Sauger

Sauger mean annual CPUE ranged from 3 fish/100 m/24 h in 2010 to 9 fish/100 m/24 h in 2013 in the Pointe du Bois Forebay and from 6 fish/100 m/24 h in 2010 to 13 fish/100 m/24 h in 2009 in Lac du Bonnet (Figure 6-6). The lowest catch rates for both lakes occurred in 2010 and increased over the period of 2011-2013. In the Pointe du Bois Forebay, the CPUE observed in 2010 was significantly lower than all years but 2011 (Figure 6-11).

Walleye

The CPUE of Walleye in both annually sampled on-system waterbodies typically showed only small variation among years (Figure 6-7). The one exception was 2012 in Lac du Bonnet when CPUE was much higher (12 fish/100 m/24 h) than in other years (5-7 fish/100 m/24 h).

There were some statistical differences in CPUE for the Pointe du Bois Forebay (Figure 6-12), most notably when comparing 2008 and 2009 to 2010, but there was no notable increasing or decreasing trend.

In Lac du Bonnet, CPUE in 2012 was significantly higher than in any other year and catches in all other years were not significantly different from one another (Figure 6-12). No increasing or decreasing trend was apparent.

The mean CPUE in Manigotagan Lake was variable, ranging from 11 fish/100 m/24 h in 2013 to 24 fish/100 m/24 h in 2008 (Figure 6-7). Walleye CPUE in Manigotagan Lake appears to show a downward trend from 2010 to 2013, as was noted for the overall catch, although there were no statistically significant differences in Walleye catch rates among years (Figure 6-12).

White Sucker

In the Pointe du Bois Forebay, CPUE ranged from 8 fish/100 m/24 h in 2012 to 14 fish/100 m/24 h in 2009 (Figure 6-8). Similar to some other species, there was an alternating pattern of high and low White Sucker CPUE values between years that contribute to the pattern observed for total CPUE. Annual White Sucker CPUE in Lac du Bonnet varied only slightly, from 3 fish/100 m/24 h in 2012 to 5 fish/100 m/24 h in 2013 with no obvious trends (Figure 6-8). There were no statistically significant differences in CPUE among years in Lac du Bonnet, but in the Pointe du Bois Forebay, catch rate was significantly lower in 2012 and 2013 compared to 2009 (Figure 6-13).

The mean annual CPUE in Manigotagan Lake varied from 2 fish/100 m/24 h in 2010 and 2011 to 5 fish/100 m/24 h in 2008 (Figure 6-8). The difference between 2008 and 2010/2011 was statistically significant (Figure 6-13) but there was no obvious increasing or decreasing trend apparent over the 6-year period.

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 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 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 Winnipeg River

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length (FL) from on-system waterbodies was higher in Lac du Bonnet (0.73) than in the Pointe du Bois Forebay (0.67; Figure 6-14). However, there were an insufficient number of pike captured (n <20 fish) in most years in all WRR waterbodies to conduct more detailed statistical analyses and comparisons between sites.

Sauger

Mean Fulton's condition factor for Sauger between 200 and 349 mm in fork length was 0.98 in the Pointe du Bois Forebay and 0.93 in Lac du Bonnet (Figure 6-15). Although variation was higher in the Pointe du Bois Forebay, both waterbodies shared overlapping interquartile ranges.

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from on-system waterbodies ranged from 1.09 in the Pine Falls Forebay to 1.16 in Lac du Bonnet (Figure 6-16). The mean condition of Walleye was similar between the Pointe du Bois Forebay and Lac du Bonnet, as indicated by overlap of interquartile ranges (Figure 6-16).

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from on-system waterbodies ranged from a high of 1.59 in Lac du Bonnet to a low of 1.51 in the Pine Falls Forebay (Figure 6-17). Only one year of data are available for both the Pine Falls Forebay and Lac du Bonnet, which is insufficient for detailed comparisons between waterbodies.

6.2.3.2 Off-system Waterbodies: Eaglenest and Manigotagan Lakes

Northern Pike

Mean Fulton's condition factors for Northern Pike between 400 and 699 mm in fork length from Eaglenest Lake and Manigotagan Lake were 0.70 and 0.69, respectively (Table 6-3). As described above, sample sizes were too small in most years to calculate and compare means by waterbody (Figure 6-14).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from Eaglenest Lake was 1.13 and from Manigotagan Lake was 1.07 (Figure 6-16). Walleye condition in Eaglenest Lake showed overlap with the on-system waterbodies, but there was no overlap in interquartile ranges between Manigotagan Lake and any other waterbody (Figure 6-16), suggesting a difference in condition.

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from both Eaglenest and Manigotagan lakes was 1.55 (Figure 6-17). The mean condition of White Sucker from off-system waterbodies was within the range observed in the Pointe du Bois Forebay.

6.2.3.3 Temporal Comparisons and Trends

Northern Pike

There were an insufficient number of years with large enough sample sizes to conduct statistical analyses or assess temporal trends for this species.

Sauger

There was considerable variability in mean condition of Sauger between 200 and 349 mm in fork length among sampling years within on-system waterbodies (Figure 6-15). In the Pointe du Bois Forebay, the mean K_F in 2009 and 2010 (0.87-0.89) was significantly lower than in all other years (1.01-1.05) and the 2013 value was significantly lower than 2008, 2011, and 2012 (Figure 6-18). The mean condition in Lac du Bonnet typically ranged from 0.91 to 0.94 with no significant differences among years with the exception of 2012, when the mean was 1.00, and was significantly higher than all other years (Figure 6-18). There were no obvious increasing or decreasing trends observed in either waterbody.

Walleye

In the Pointe du Bois Forebay, mean condition of Walleye between 300 and 499 mm in fork length ranged from 1.06 in 2010 to 1.21 in 2008 (Figure 6-16). Some statistically significant differences were noted: the mean in 2010 was significantly lower than all years except for 2009; and the mean in 2009 was significantly lower than all years except 2010 and 2013 (Figure 6-19). There were no obvious temporal trends in condition of Walleye captured in the Pointe du Bois Forebay.

Mean condition of Walleye in Lac du Bonnet ranged from 1.14 in 2011 to 1.17 in 2013 (Figure 6-16). There was a small, steady increase in mean condition over time, though there were no significant inter-annual differences (Figure 6-19).

Over the six-year period, the condition of Walleye from the off-system Manigotagan Lake ranged from 1.03 in 2013 to 1.10 in 2012 (Figure 6-16). Statistically significant differences were noted between 2012 and 2010, 2011, and 2013, and between 2009 and 2013, but there were no consistent increasing or decreasing trends over time (Figure 6-19).

White Sucker

In the Pointe du Bois Forebay, mean condition ranged from 1.45 in 2010 to 1.63 in 2011 (Figure 6-17). The 2010 mean condition was significantly lower than all other sampling years (Figure 6-20). No increasing or decreasing trends in White Sucker condition in the Pointe du Bois Forebay were apparent. In Lac du Bonnet, sample sizes in all years except 2010 were insufficient for an analysis of temporal trends.

Over the 4-year period that the condition of White Sucker was measured in Manigotagan Lake, sufficient sample sizes were achieved only in 2012 (1.57) and 2013 (1.53; Figure 6-17). Therefore, there are insufficient data to evaluate inter-annual differences or trends.

6.2.4 Growth (Length-at-age)

Changes in the age or size distribution of a fish population can be caused by changes in growth, adult mortality, or recruitment success. 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 characterized from length-at-age and focused on the length distribution of fish of a given year-class selected for each species based on the following:

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

6.2.4.1 Winnipeg River

Northern Pike

Northern Pike captured in the annually sampled on-system waterbodies ranged from 0 (i.e., young-of-the-year) to 17 years of age, with most of the fish captured over the 6-year sampling period aged between 3 and 7 years (Figure 6-21). In the Pointe du Bois Forebay the fork length-at-age showed a steady increase for ages 0 through 11 years, whereas in Lac du Bonnet initial growth appeared rapid but slowed considerably after age 8.

Mean length of 4-year old Northern Pike from Lac du Bonnet (577 mm) was much larger than from the Pointe du Bois Forebay (439 mm; Table 6-3) as indicated by the lack of overlap among the interquartile ranges (Figure 6-22). As only a single 4-year old pike was captured from the Pine Falls Forebay, no analyses could be undertaken for that waterbody.

Sauger

Sauger captured in the on-system waterbodies sampled annually ranged from 0 to 16 years of age, with most of the fish captured over the 6-year sampling period aged between 2 and 8 years in the Pointe du Bois Forebay and 1 and 7 years in Lac du Bonnet (Figure 6-23). In the Pointe du Bois Forebay, the fork length-at-age showed a period of rapid growth from ages 1-9 years, while in Lac du Bonnet, growth was generally slower after age 3. In addition, Sauger from the Pointe du Bois Forebay reached a larger maximum size than those from Lac du Bonnet.

The mean length of 3-year-old Sauger was 241 mm in Lac du Bonnet and 225 mm in the Pointe du Bois Forebay (Table 6-3). The lack of interquartile overlap suggests that there was a difference in the growth rates of this age class of Sauger between the two waterbodies (Figure 6-24).

Walleye

Walleye captured in the annually sampled on-system waterbodies ranged from 0 to 27 years of age, with most of the fish captured over the 6-year sampling period aged between 2 and 10 years in the Pointe du Bois Forebay and 0 and 7 years from Lac du Bonnet (Figure 6-25). Patterns of growth were generally similar between the two waterbodies.

Mean lengths-at-age 3 for Walleye in Lac du Bonnet and the Pointe du Bois Forebay were 310 mm and 242 mm, respectively (Table 6-3). There was no overlap of interquartile values between lakes (Figure 6-26), suggesting that there is a difference in the growth rates for this age class of Walleye between the two waterbodies. As only a single age-three Walleye from the Pine Falls Forebay was captured, no analyses were undertaken for this waterbody.

6.2.4.2 Off-system Waterbodies: Eaglenest and Manigotagan Lakes

Northern Pike

Northern Pike captured at the annually sampled off-system Manigotagan Lake ranged from 3-13 years of age, with most of the fish captured over the 6-year sampling period aged between 4 and 7 years of age (Figure 6-21). Growth was most rapid between ages 3 and 8.

The mean length-at-age 4 for Northern Pike in Eaglenest and Manigotagan lakes was 395 mm and 471 mm, respectively (Table 6-3). There was no overlap in the interquartile ranges for any of the four sampled on- or off-system waterbodies, suggesting that there were differences in the growth rates of young Northern Pike among waterbodies within the region. Four-year-old Northern Pike from Lac du Bonnet were the largest, followed by those from Manigotagan Lake, the Pointe du Bois Forebay, and Eaglenest Lake (Figure 6-22).

Walleye

Walleye captured in the annually sampled off-system Manigotagan Lake ranged from 0 to 21 years of age, with most of the fish captured over the 6-year sampling period aged between 0 and 6 years of age (Figure 6-25). The pattern of growth was very similar to that observed for Walleye from Lac du Bonnet.

Mean lengths-at age 3 for Walleye from Eaglenest and Manigotagan lakes were 250 mm and 305 mm, respectively (Table 6-3). As observed with Northern Pike, there is likely a difference in the growth rate of young Walleye between Eaglenest and Manigotagan lakes as there is no overlap of the interquartile ranges (Figure 6-26). Furthermore, 3-year-old Walleye from Eaglenest Lake were more similar in length to those from the Pointe du Bois Forebay, while 3-year-old Walleye from Manigotagan Lake were more similar to those from Lac du Bonnet.

6.2.4.3 Temporal Comparisons and Trends

Northern Pike

The annual mean length-at-age 4 for Northern Pike in the Pointe du Bois Forebay ranged from 415 mm in 2013 to 459 mm in 2010 (Figure 6-22) with no significant differences among years (Figure 6-27). No temporal trend in Northern Pike length-at-age 4 was apparent in the Pointe du Bois Forebay. Mean length-at-age 4 in Lac du Bonnet ranged from 509 mm in 2009 to 605 mm in 2013 (Figure 6-22); there were insufficient numbers of 4-year-old fish captured in three of the six survey years from this waterbody and statistical inter-annual comparisons and evaluation of temporal trends could not be performed.

The annual mean length-at-age 4 of Northern Pike from Manigotagan Lake ranged from 459 mm in 2012 to 521 mm in 2008 (Figure 6-22). There were no obvious temporal trends and no statistically significant differences in length among years in which sufficient fish were captured (Figure 6-27).

Sauger

The annual mean length-at-age 3 for Sauger in the Pointe du Bois Forebay had low variability, ranging from 220 mm in 2009 and 2012 to 232 mm in 2008 (Figure 6-24) with no significant differences among years and no apparent trends (Figure 6-28).

The mean length of 3-year-old Sauger from Lac du Bonnet was more variable, ranging from 222 mm in 2010 to 258 mm in 2012 (Figure 6-24). Fish captured in 2012 and 2013 were significantly longer at age 3 than those captured in 2009 and 2010 in this lake (Figure 6-28), and showed some evidence of decreased mean length-at-age 3 from 2008 to 2010 followed by an increase from 2010 to 2012 and 2013.

Walleye

Variability in the annual mean length-at-age 3 for Walleye in the Pointe du Bois Forebay was low, with values ranging from 224 mm in 2008 to 249 mm in 2013 (Figure 6-26), and no significant inter-annual differences were observed (Figure 6-29). No trends in the mean length-at-age 3 for Walleye in the Pointe du Bois Forebay were apparent over the 6-year sampling period.

Mean length-at-age 3 Walleye in Lac du Bonnet ranged from 282 mm in 2010 to 332 mm in 2012 (Figure 6-26). Fish captured in 2012 were significantly longer than those captured in 2009 and 2010 with an overall pattern of decreased mean length-at-age 3 from 2008 to 2010 followed by an increase from 2010 to 2012 (Figure 6-29). This pattern was somewhat similar to that observed for Sauger.

In Manigotagan Lake, the annual mean length-at-age 3 ranged from 267 mm in 2010 to 341 mm in 2008 (Figure 6-26). Statistically significant differences were noted, particularly between 2008 and most other years, and between 2010 and 2012 (Figure 6-29). As in Lac du Bonnet, a similar trend was noted where mean lengths decreased from 2008 to 2010, followed by an increase between 2010 and 2012.

6.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

One additional fish community metric (relative abundance), as described in Technical Report 1, Section 4.6.1.1, was derived to assess trends in the fish community. Information on this metric is included here because the analyses conducted for Manitoba Hydro and the Province of Manitoba's (2015) recent regional cumulative effects assessment (RCEA) on longer-term datasets for other regions indicated that a shift in species composition may have occurred in several hydro-affected waterbodies over time (Manitoba Hydro and the Province of Manitoba 2015). In addition, recent upgrades to the Pointe du Bois GS were predicted to have some small, local residual effects on the fish community that may include changes in species composition near the GS (Manitoba Hydro 2011).

The relative abundance of fish species captured in standard gang index gill nets set at WRR waterbodies between 2008 and 2013 is shown in Figure 6-30. The same four species (White Sucker, Yellow Perch, Sauger, and Walleye) generally dominated catches in Eaglenest Lake, the Pointe du Bois Forebay, and Lac du Bonnet, although the proportion of White Sucker was higher in the Pointe du Bois Forebay catch and the proportion of percids (Yellow Perch, Sauger, Walleye) was higher in Eaglenest Lake and Lac du Bonnet. Lac du Bonnet catches were the most evenly distributed with as many as nine different species representing at least 5% of the total catch in some years (Figure 6-30), indicating a relatively diverse fish community. In contrast, the large-bodied fish community at the Pine Falls Forebay in 2011 was dominated by one species, Channel Catfish (Figure 6-30). The species composition of the off-system Manigotagan Lake differed from waterbodies along the Winnipeg River and was consistently dominated by two species, Cisco and Walleye. Lake Sturgeon (*Acipenser fulvescens*) were captured in the Pointe du Bois Forebay, Lac du Bonnet and the Pine Falls Forebay (one fish captured in small mesh gangs) but represented small proportions of the annual catches (Table 6-2; Figure 6-30).

At least some of the variation observed among waterbodies may be attributed to differences in the timing of the field surveys. For example, Lac du Bonnet and Manigotagan Lake are sampled in September and have greater proportions of fall spawning species (e.g., Cisco and Lake Whitefish) than the other waterbodies which are all sampled in July under CAMP.

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 the Pointe du Bois Forebay and Lac du Bonnet using water level data from gauges on those waterbodies and discharge data from Slave Falls GS that were provided by Manitoba Hydro and fish community metrics indicated only a few statistically significant relationships (Table 6-4). Hydrological data from Manigotagan Lake was only available for part of the 2008-2013 period and, therefore, no attempt was made to relate hydrologic variables to fish community metrics for this waterbody.

The only statistically significant relationships were a positive relationship between Walleye CPUE and discharge during the sampling period in the Pointe du Bois Forebay, a negative relationship between White Sucker CPUE and water level during the sampling period in Lac du Bonnet, and a negative relationship between Northern Pike condition and discharge during the open water period in Lac du Bonnet. The latter two relationships are illustrated in Figure 6-31 and Figure 6-32, respectively.

6.5 SUMMARY

A summary of the key findings of the six years of fish community monitoring include:

- The most common large-bodied species in two of the on-system waterbodies in the WRR (Lac du Bonnet and the Pointe du Bois Forebay) were Sauger, Walleye, White Sucker, and Yellow Perch. The Pine Falls Forebay differed by having a Channel Catfish-dominated catch.
- There was evidence for a decreasing trend in the diversity (Hill's index) of fish in Lac du Bonnet and the Pointe du Bois Forebay between the 2008 to 2010 period and the 2011 to 2013 period, due largely to increases in the proportion of Yellow Perch and Spottail Shiner in the catches.
- Although the total catch was generally similar between Lac du Bonnet and the Pointe du Bois Forebay, there were differences in the abundance of key species: Walleye, Sauger, and Northern Pike were more abundant in Lac du Bonnet; while White Sucker were more abundant in the Pointe du Bois Forebay.
- The condition of Sauger and Walleye in the Pointe du Bois Forebay was generally lower in 2009 and 2010 than in other years. A similar pattern was not noted for other waterbodies.
- The growth rate of young Northern Pike, Sauger, and Walleye was higher in Lac du Bonnet than in Pointe du Bois Forebay.

Statistical analysis of the six years of data identified significant inter-annual differences in many of the fish community metrics over the period of 2008-2013, but few consistent temporal trends. Potential trends that were identified included: alternating high and low total catch CPUE in successive years in the Pointe du Bois Forebay over the six years, driven in part by a similar pattern for White Sucker CPUE; and an increase in Northern Pike CPUE in Lac du Bonnet over the six years.

A quantitative consideration of hydrological conditions and fish community metrics found the following statistically significant relationships: a positive relationship between Walleye CPUE and discharge in Pointe du Bois Forebay; a negative relationship between White Sucker CPUE and water level in Lac du Bonnet; and a negative relationship between Northern Pike condition and discharge in Lac du Bonnet.

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

Location	**Site Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
						2008	**2009**	**2010**	**2011**	**2012**	**2013**
Eaglenest Lake	EAGLE		X		X			X			X
Pointe du Bois Forebay	PDB	X		X		X	X	X	X	X	X
Lac du Bonnet	LDB	X		X		X	X	X	X	X	X
Pine Falls Forebay	PFF	X			X				X		
Manigotagan Lake	MANIG		X	X		X	X	X	X	X	X

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

Species	**Abbreviation**	**PDB** n_Y=6	**LDB** n_Y=6	**PFF** n_Y=1	**EAGLE** n_Y=2	**MANIG** n_Y=6
Silver Lamprey	SLLM	X*	X*		X*	
Lake Sturgeon	LKST	X	X	X		
Mooneye	MOON	X	X	X	X	
Emerald Shiner	EMSH	X*	X*	X		X*
Spottail Shiner	SPSH	X	X	X	X	X*
Longnose Sucker	LNSC	X*	X*			
White Sucker	WHSC	X	X	X	X	X
Golden Redhorse	GLRD	X*				
Shorthead Redhorse	SHRD	X	X	X	X	
Silver Redhorse	SLRD	X	X		X	
Black Bullhead	BLBL		X*		X*	
Channel Catfish	CHCT		X*	X		
Northern Pike	NRPK	X	X	X	X	X
Rainbow Smelt	RNSM	X			X*	
Cisco	CISC	X	X		X	X
Lake Whitefish	LKWH	X	X		X	X
Trout-perch	TRPR	X	X	X	X	X*
Burbot	BURB	X	X*	X		X
Mottled Sculpin	MTSC					X*
Slimy Sculpin	SLSC					X*
Rock Bass	RCBS	X	X	X	X	
Smallmouth Bass	SMBS	X	X		X	X
Black Crappie	BLCR				X	
Yellow Perch	YLPR	X	X	X	X	X
Logperch	LGPR				X	
Sauger	SAUG	X	X	X	X	
Walleye	WALL	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 Winnipeg River Region waterbodies, 2008-2013.

Component	Waterbody	Hill's Index			CPUE [1]			K_F [2]			FL-at-age [3]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
Biodiversity	PDB	6	7.2	0.3	-	-	-	-	-	-	-	-	-
	LDB	6	8.1	0.9	-	-	-	-	-	-	-	-	-
	PFF	1	5.4	-	-	-	-	-	-	-	-	-	-
	EAGLE	2	8.0	0.5	-	-	-	-	-	-	-	-	-
	MANIG	6	5.3	0.2	-	-	-	-	-	-	-	-	-
Standard gang	PDB	-	-	-	3965	36.0	3.8	-	-	-	-	-	-
	LDB	-	-	-	2341	40.6	2.9	-	-	-	-	-	-
	PFF	-	-	-	309	20.0	-	-	-	-	-	-	-
	EAGLE	-	-	-	1098	37.8	3.2	-	-	-	-	-	-
	MANIG	-	-	-	1976	54.5	3.9	-	-	-	-	-	-
Small mesh	PDB	-	-	-	2126	57.0	15.5	-	-	-	-	-	-
	LDB	-	-	-	3263	167.1	57.6	-	-	-	-	-	-
	PFF	-	-	-	57	12.4	-	-	-	-	-	-	-
	EAGLE	-	-	-	531	55.5	11.2	-	-	-	-	-	-
	MANIG	-	-	-	550	37.0	14.6	-	-	-	-	-	-
Northern Pike	PDB	-	-	-	175	1.5	0.8	129	0.66	0.01	48	439	7
	LDB	-	-	-	211	3.6	1.6	131	0.71	0.02	22	577	18
	PFF	-	-	-	7	0.5	-	6	0.67	-	1	428	-
	EAGLE	-	-	-	91	3.1	0.8	55	0.70	0.01	18	395	22
	MANIG	-	-	-	101	2.6	0.6	98	0.63	0.02	20	471	25
Sauger	PDB	-	-	-	705	6.3	0.9	669	0.98	0.03	59	225	2
	LDB	-	-	-	511	8.9	0.8	562	0.93	0.01	102	241	5

Table 6-3. continued.

Component	Waterbody	Hill's Index			CPUE [1]			K_F [2]			FL-at-age [3]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
Walleye	PDB	-	-	-	408	3.7	1.0	200	1.15	0.02	43	242	6
	LDB	-	-	-	398	6.8	2.5	196	1.14	0.01	52	310	10
	PFF	-	-	-	29	1.8	-	21	1.09	-	1	189	-
	EAGLE	-	-	-	201	6.9	< 0.1	128	1.13	0.02	22	250	21
	MANIG	-	-	-	655	17.6	4.1	352	1.07	0.01	85	305	13
White Sucker	PDB	-	-	-	1186	10.9	2.4	662	1.56	0.03	-	-	-
	LDB	-	-	-	251	4.3	0.9	41	1.64	0.03	-	-	-
	PFF	-	-	-	28	1.8	-	27	1.51	-	-	-	-
	EAGLE	-	-	-	156	5.3	0.6	137	1.55	0.05	-	-	-
	MANIG	-	-	-	118	3.2	1.1	69	1.52	0.02	-	-	-

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

[2] Fork lengths analyzed for K_F were 300-499 mm for Walleye and White Sucker, 200-349 mm for Sauger, and 400-699 mm for Northern Pike.

[3] Ages analyzed are 3 years for Walleye and Sauger, and 4 years for Northern Pike.

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 Winnipeg River Region waterbodies sampled annually between 2008 and 2013.

Metric	Species	Waterbody	Hydrology Metric	df	F	p	R^2	Direction
CPUE	WALL	PDB	Q (GN)	4	68.60	0.00	0.94	+
	WHSC	LDB	WL (GN)	4	8.65	0.04	0.68	-
K_F	NRPK	LDB	Q (OW)	4	77.66	< 0.01	0.95	-

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

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

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

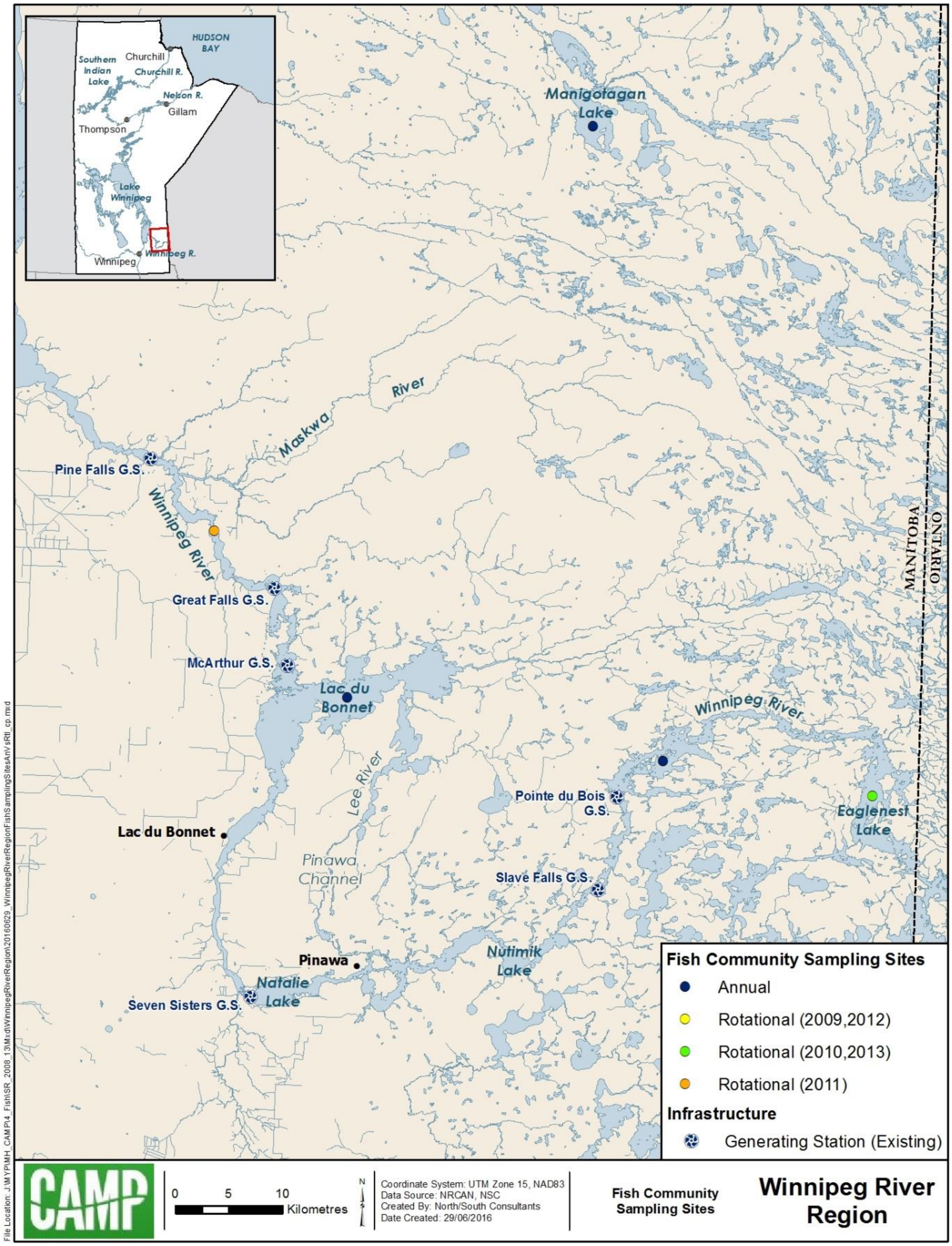


Figure 6-1. Waterbodies sampled in the Winnipeg River Region: 2008-2013.

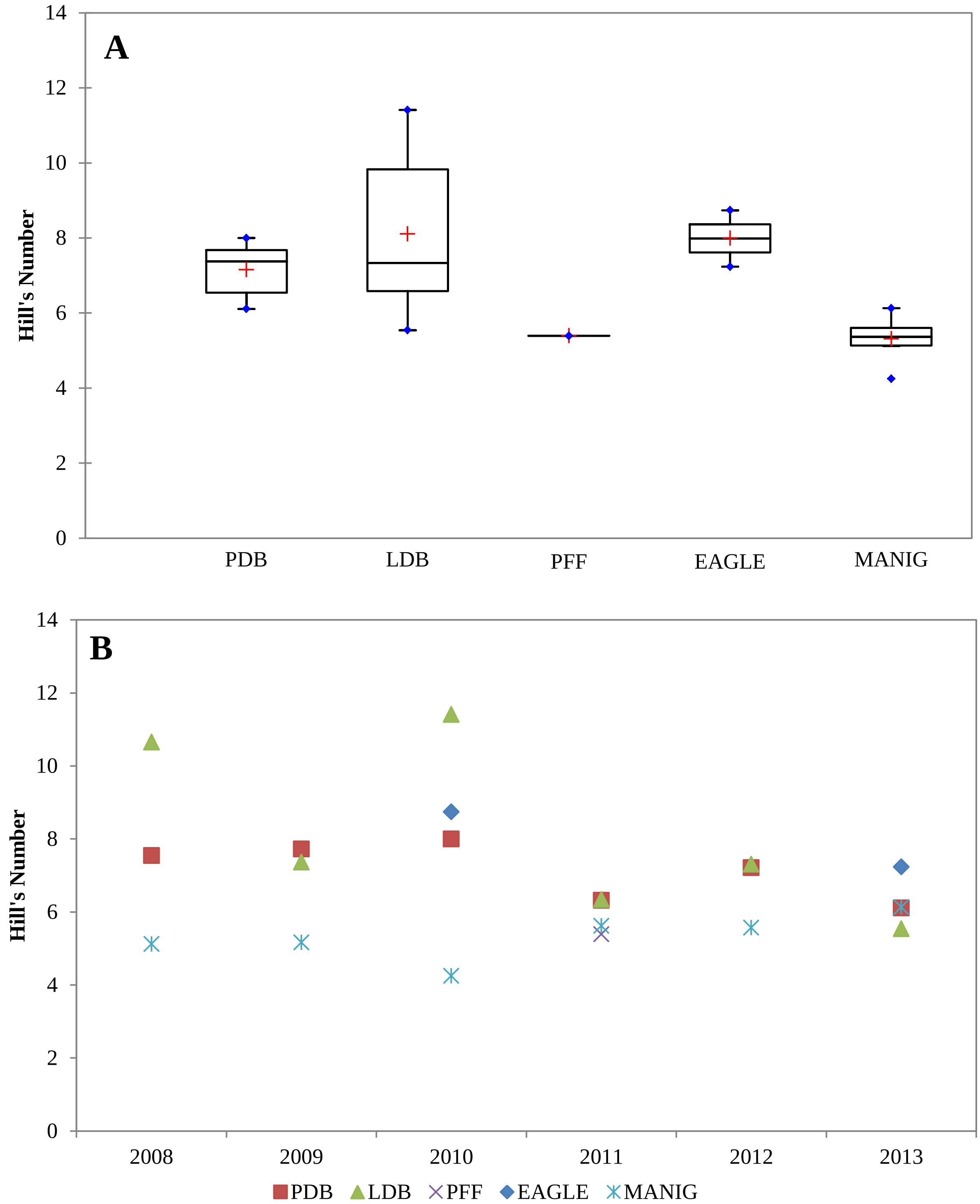


Figure 6-2. Annual mean Hill's effective species richness index (Hill's Number) for standard gang and small mesh index gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

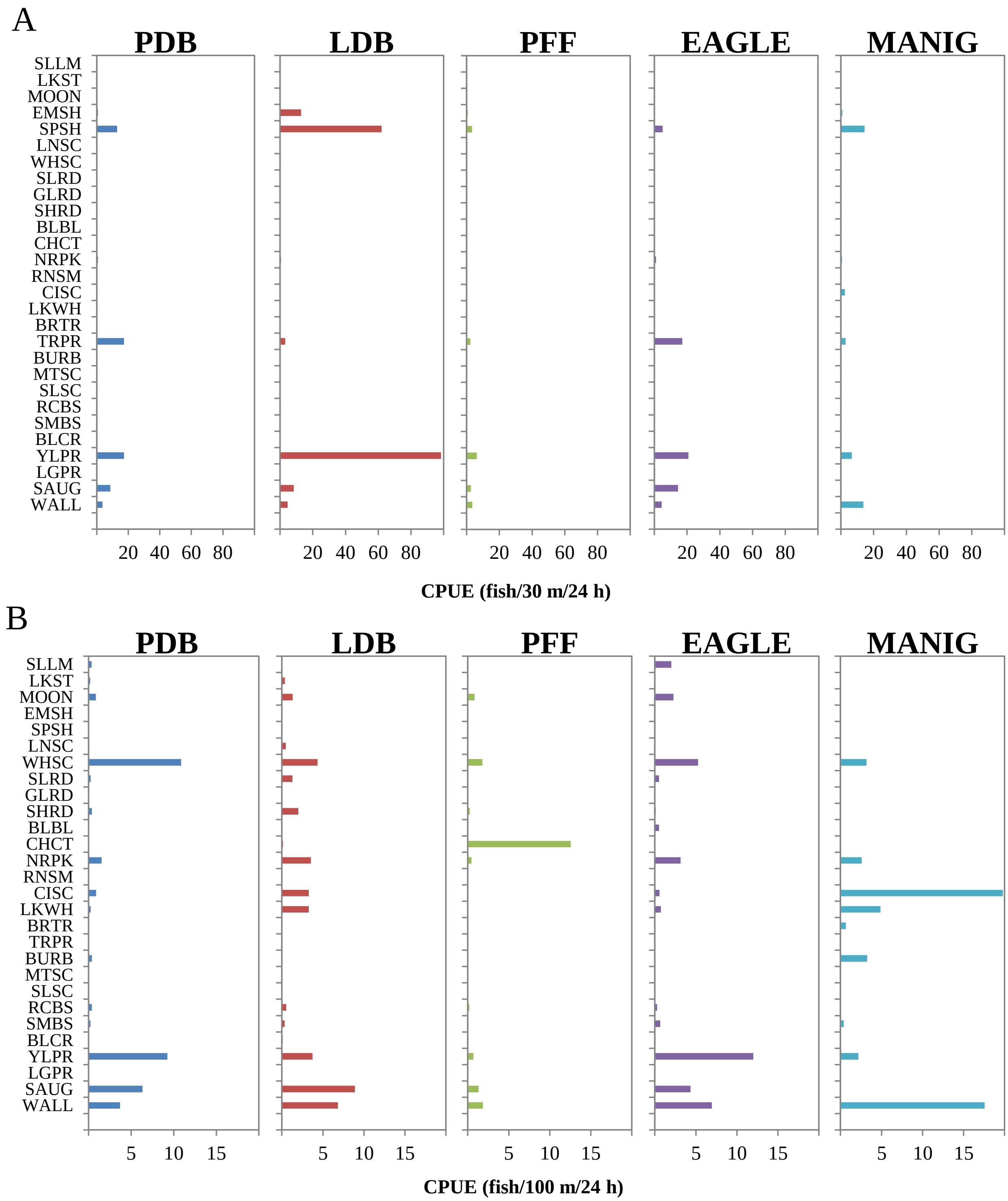


Figure 6-3. Mean catch-per-unit-effort in (A) standard gang (fish/100 m/24 h) and (B) small mesh (fish/30 m/24 h) index gill nets set in Winnipeg River Region waterbodies, 2008-2013.

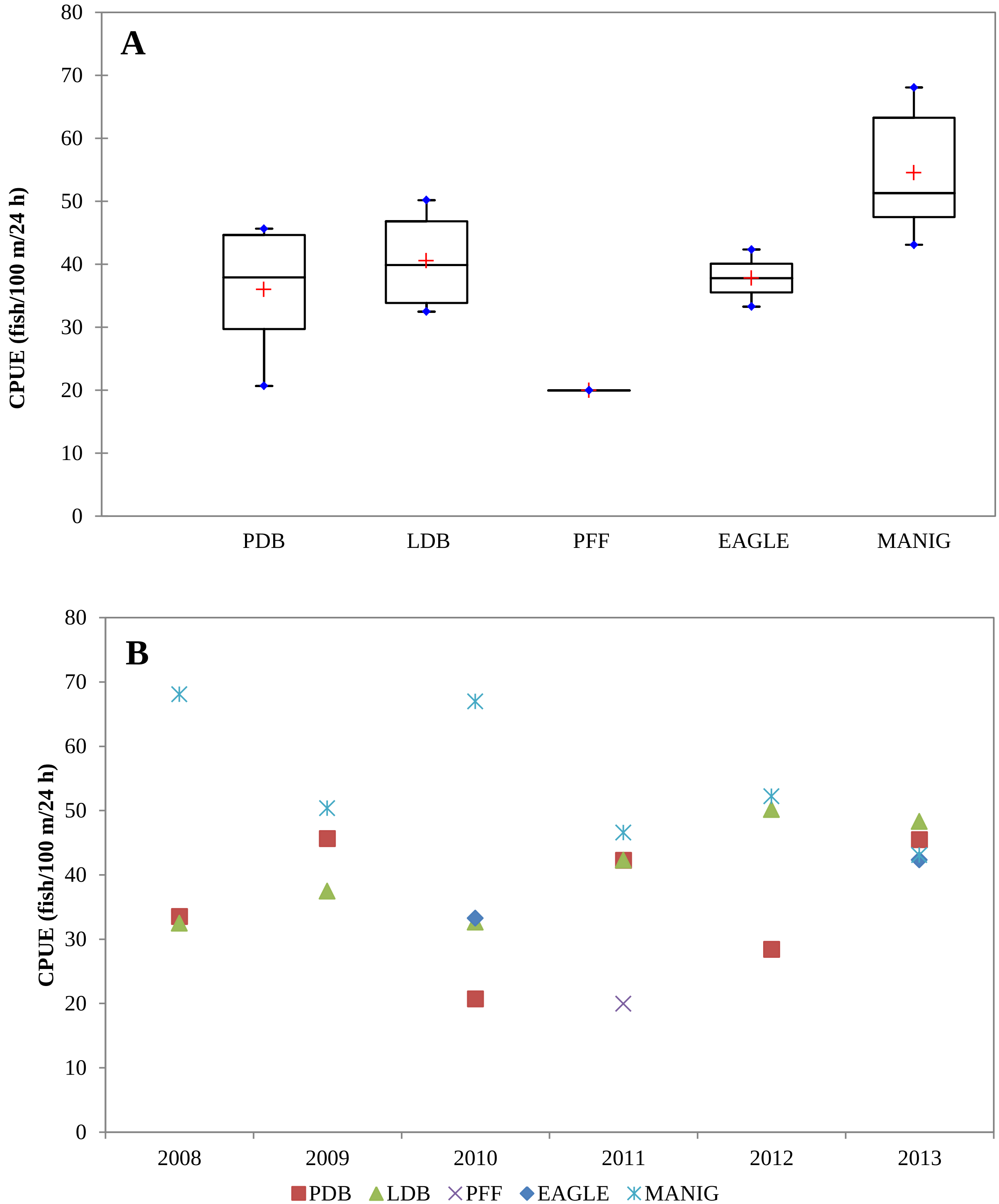


Figure 6-4. Annual mean catch-per-unit-effort (CPUE) calculated for the total catch in standard gang index gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

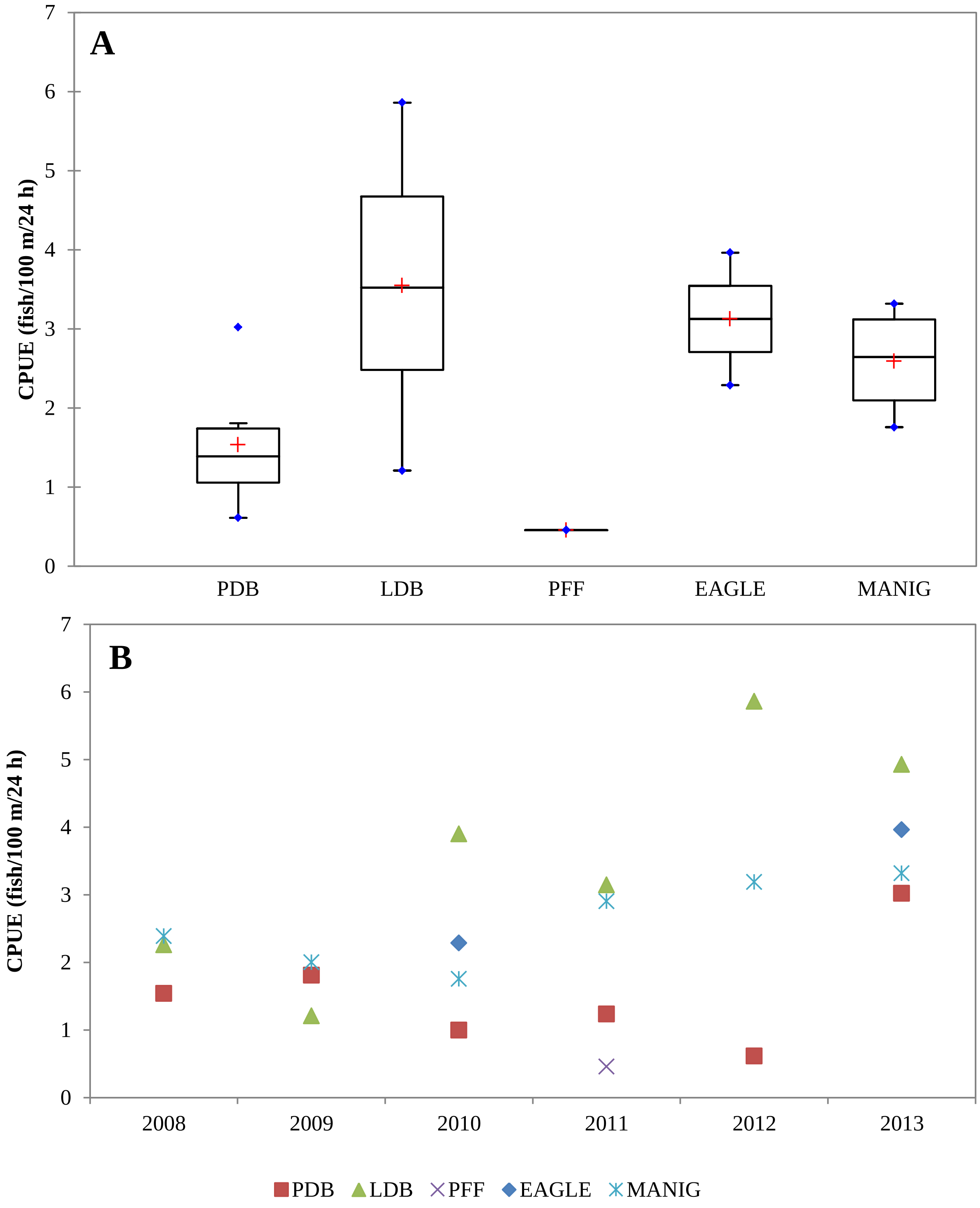


Figure 6-5. Annual mean catch-per-unit-effort (CPUE) calculated for Northern Pike captured in standard gang index gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

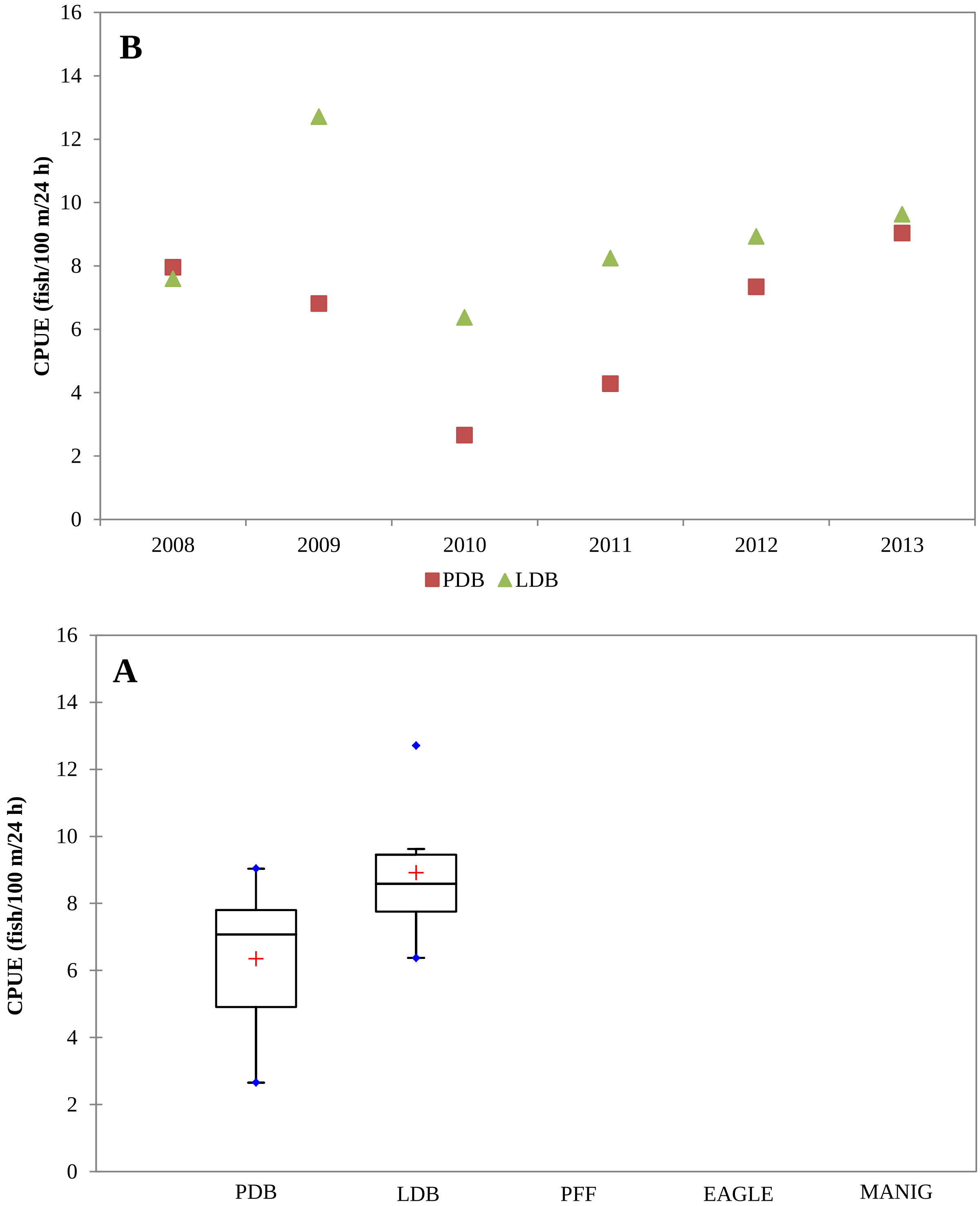


Figure 6-6. Annual mean catch-per-unit-effort (CPUE) calculated for Sauger captured in standard gang index gill nets set in the Pointe du Bois Forebay and Lac du Bonnet, 2008-2013 by waterbody (A) and by year (B).

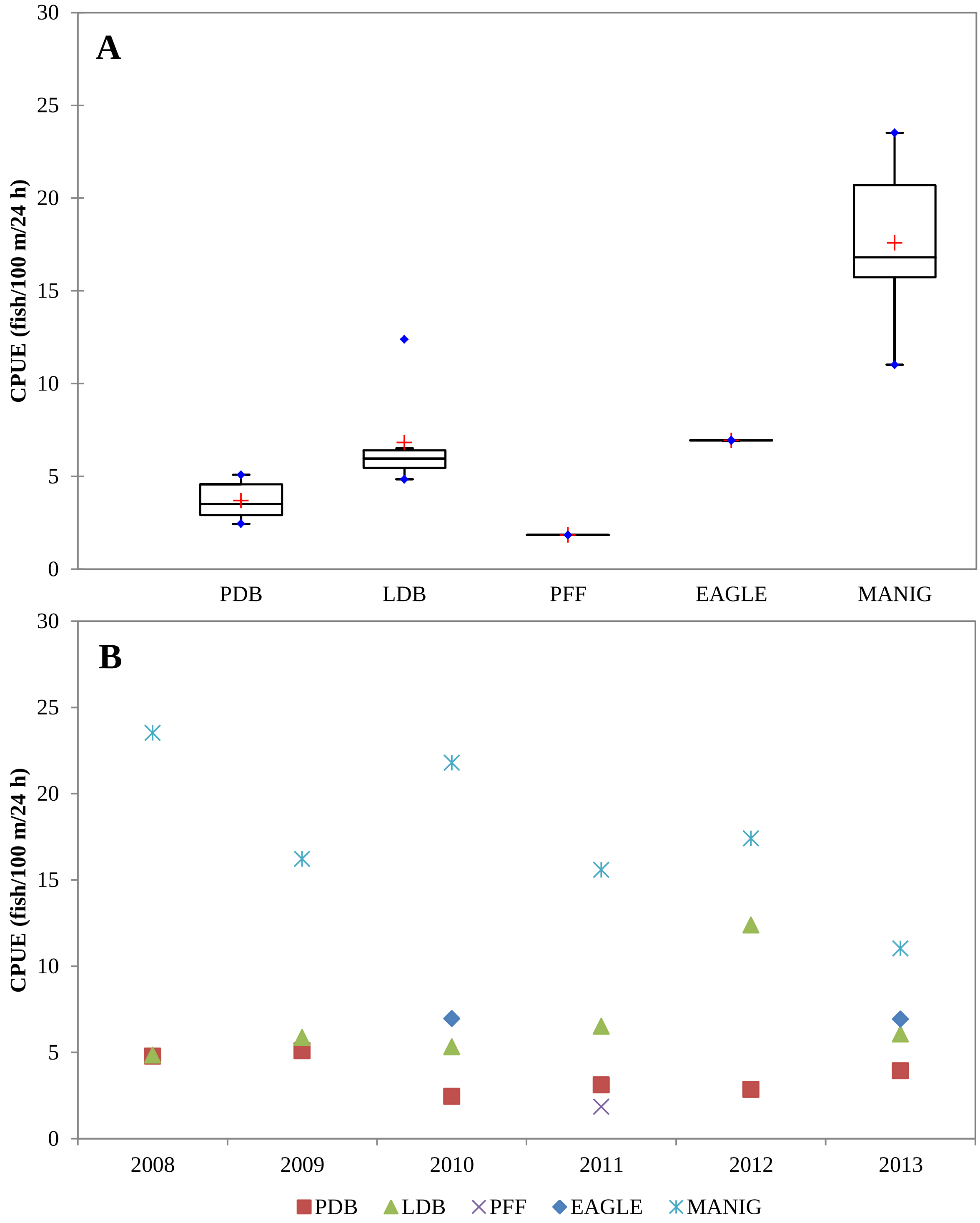


Figure 6-7. Annual mean catch-per-unit-effort (CPUE) calculated for Walleye captured in standard gang index gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

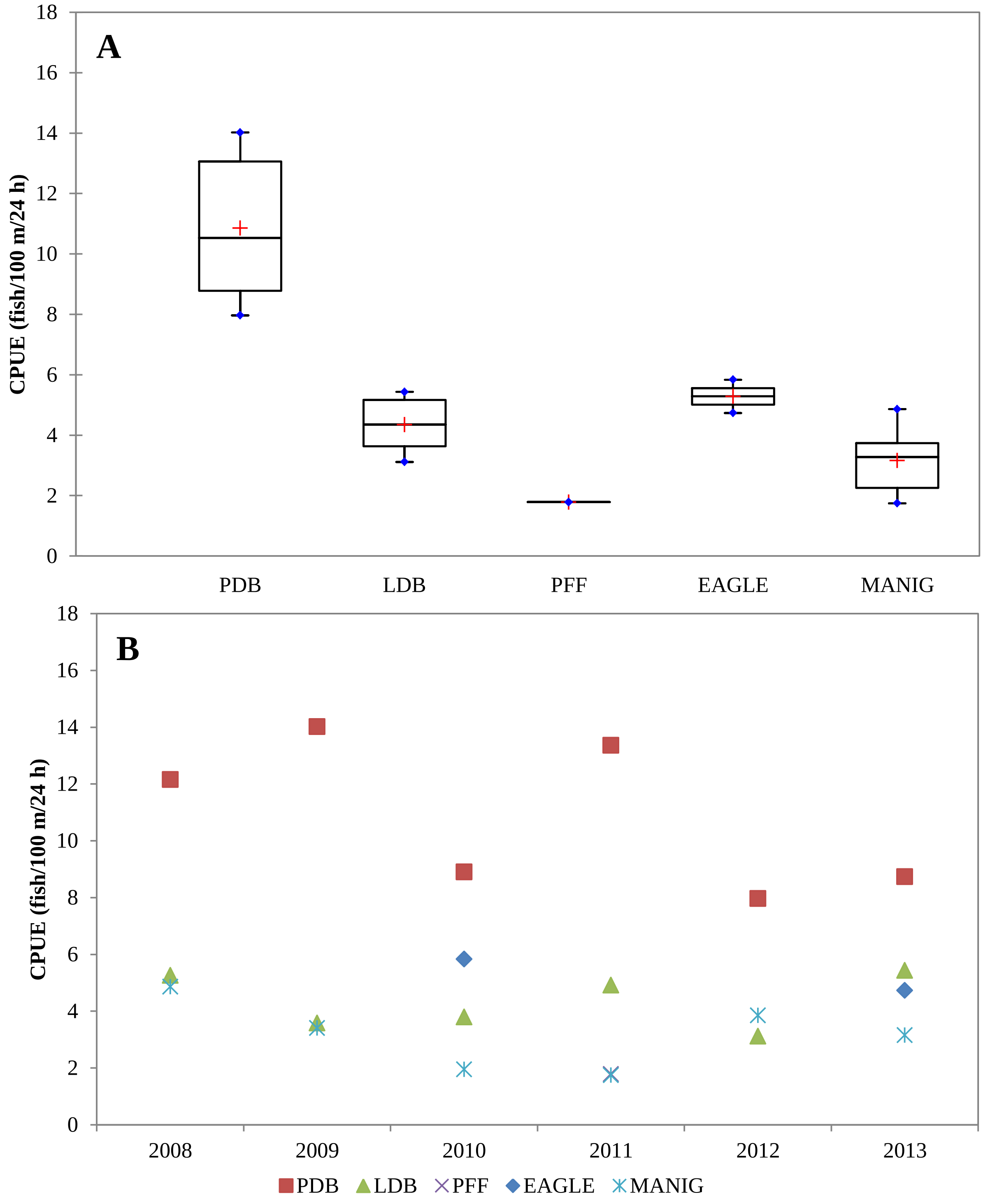


Figure 6-8. Annual mean catch-per-unit-effort (CPUE) calculated for White Sucker captured in standard gang index gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

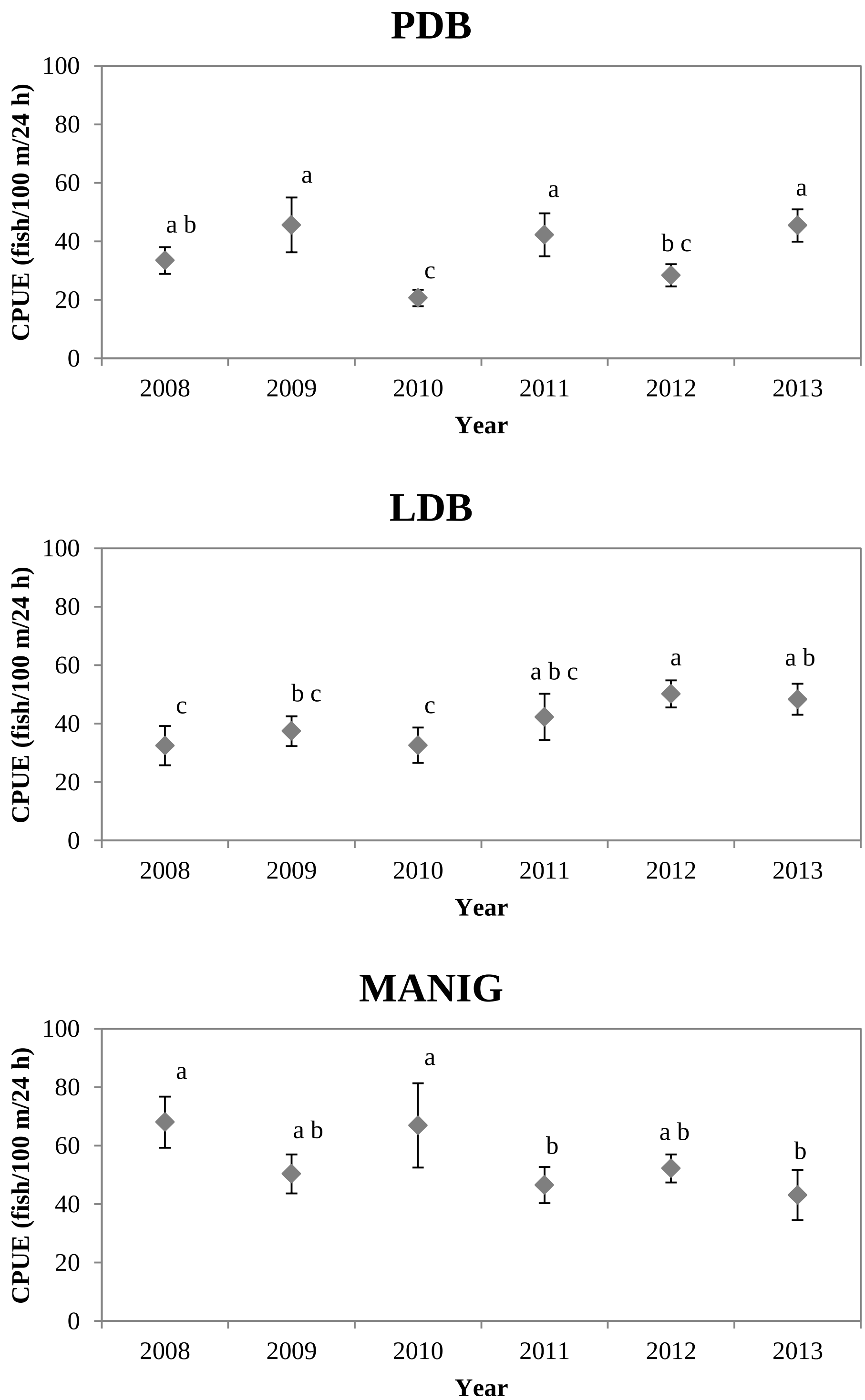


Figure 6-9. Total catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically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

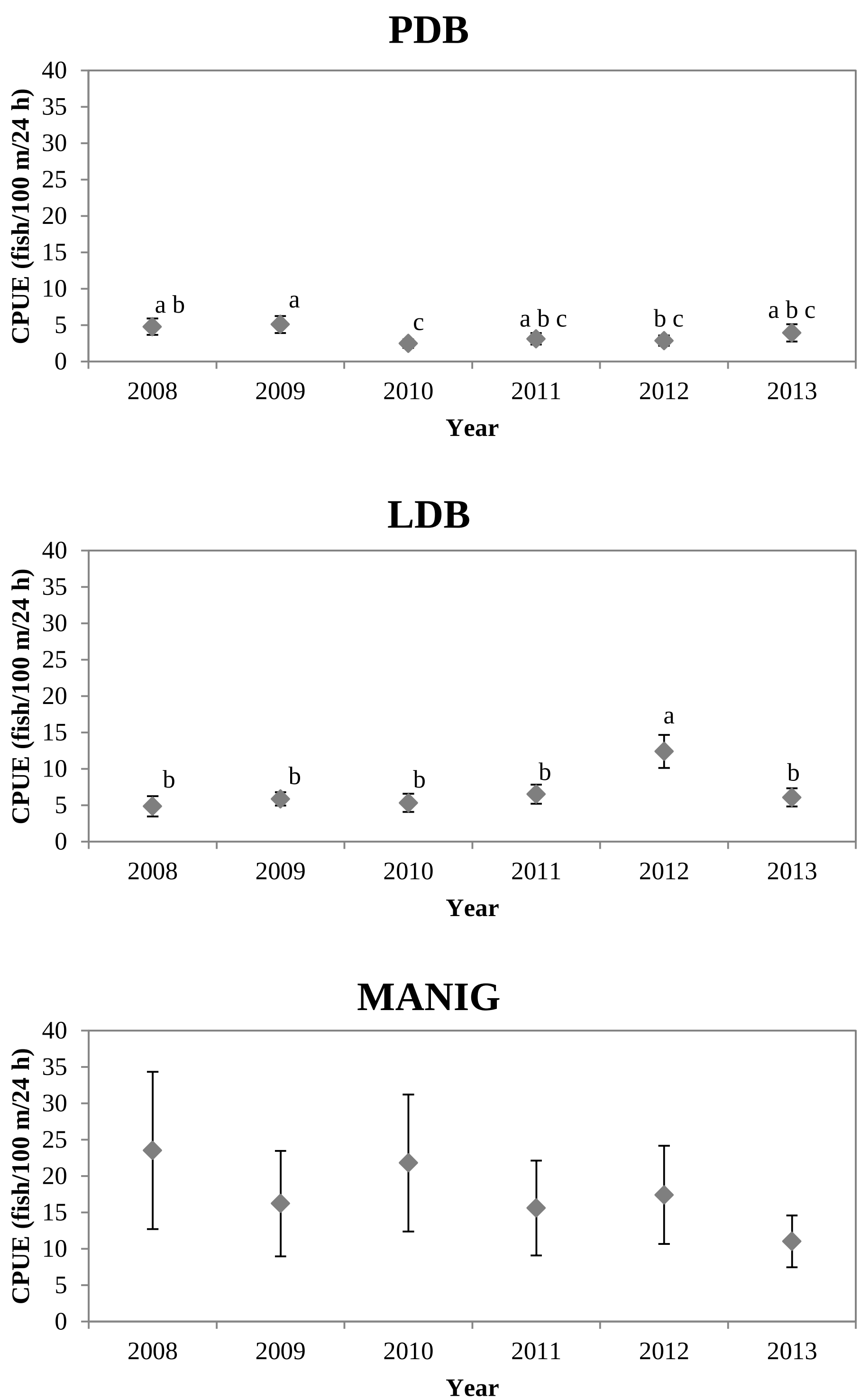


Figure 6-10. Northern Pike catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no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

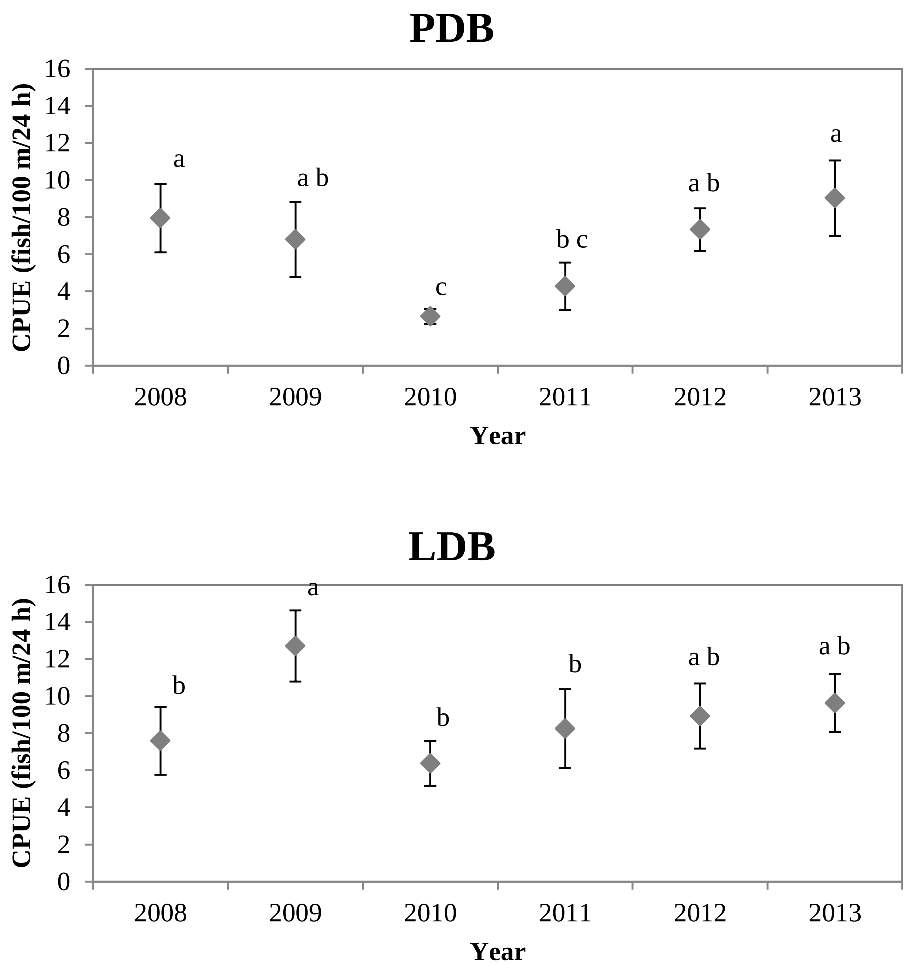


Figure 6-11. Sauger catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically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

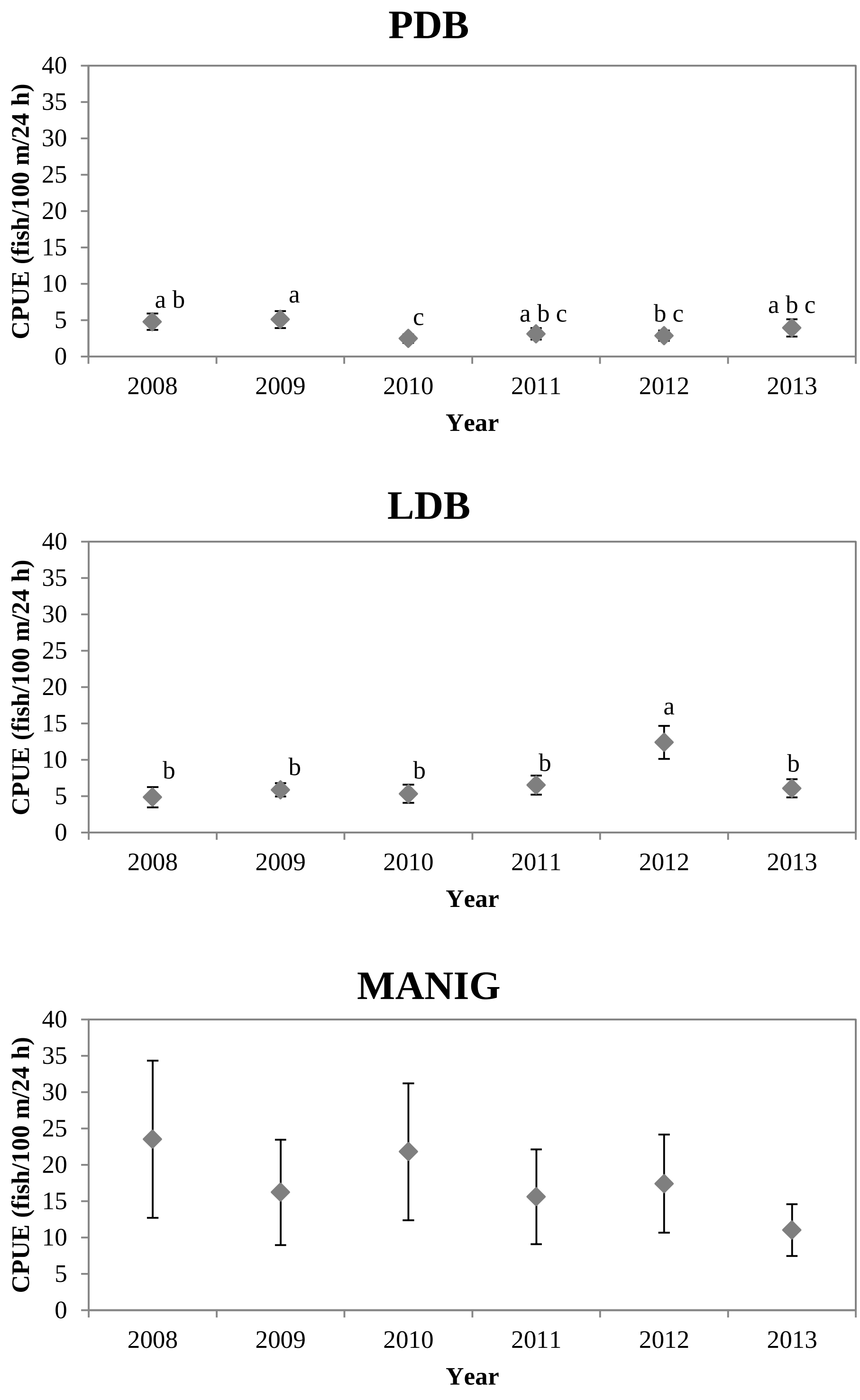


Figure 6-12. Walleye catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically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

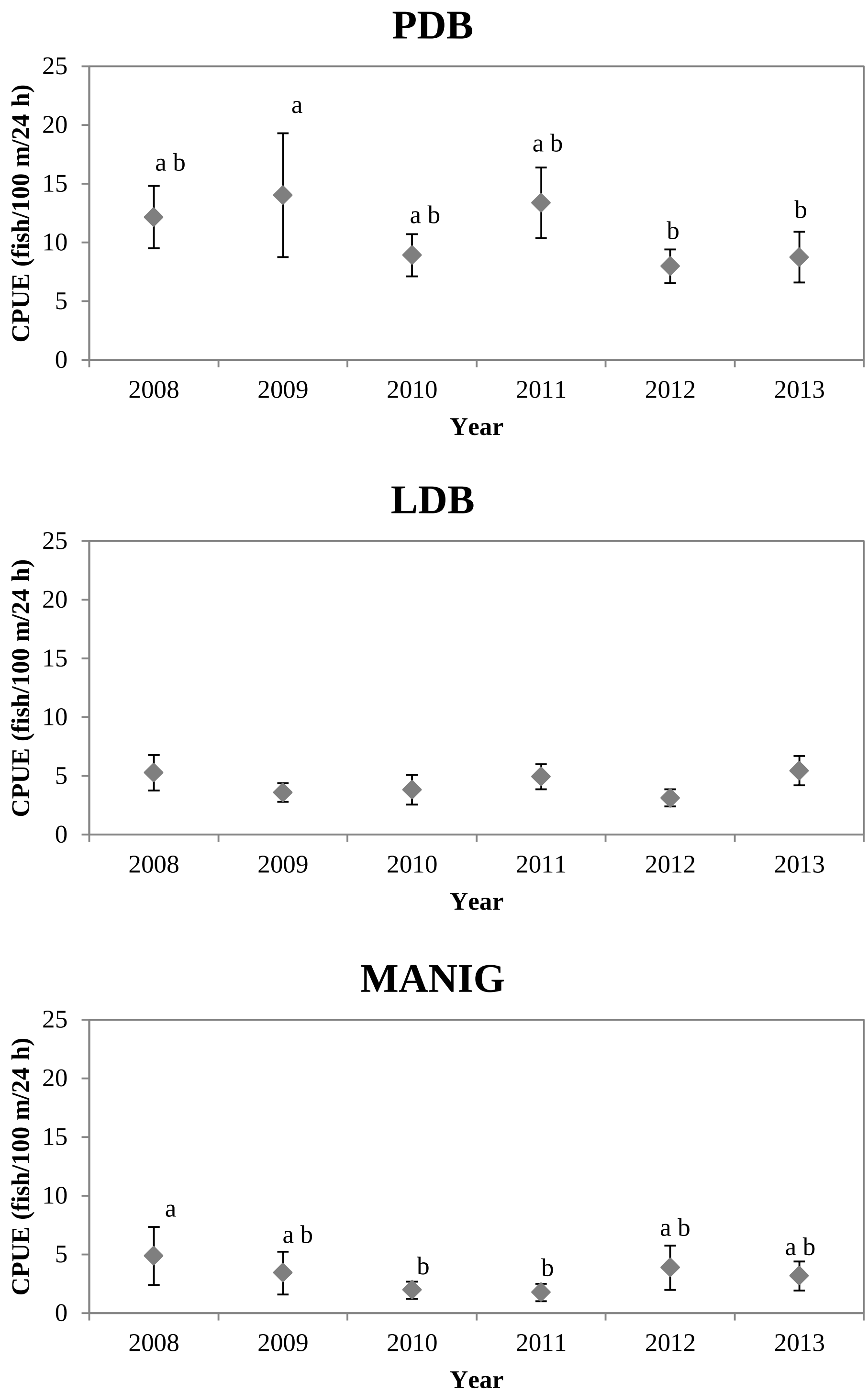
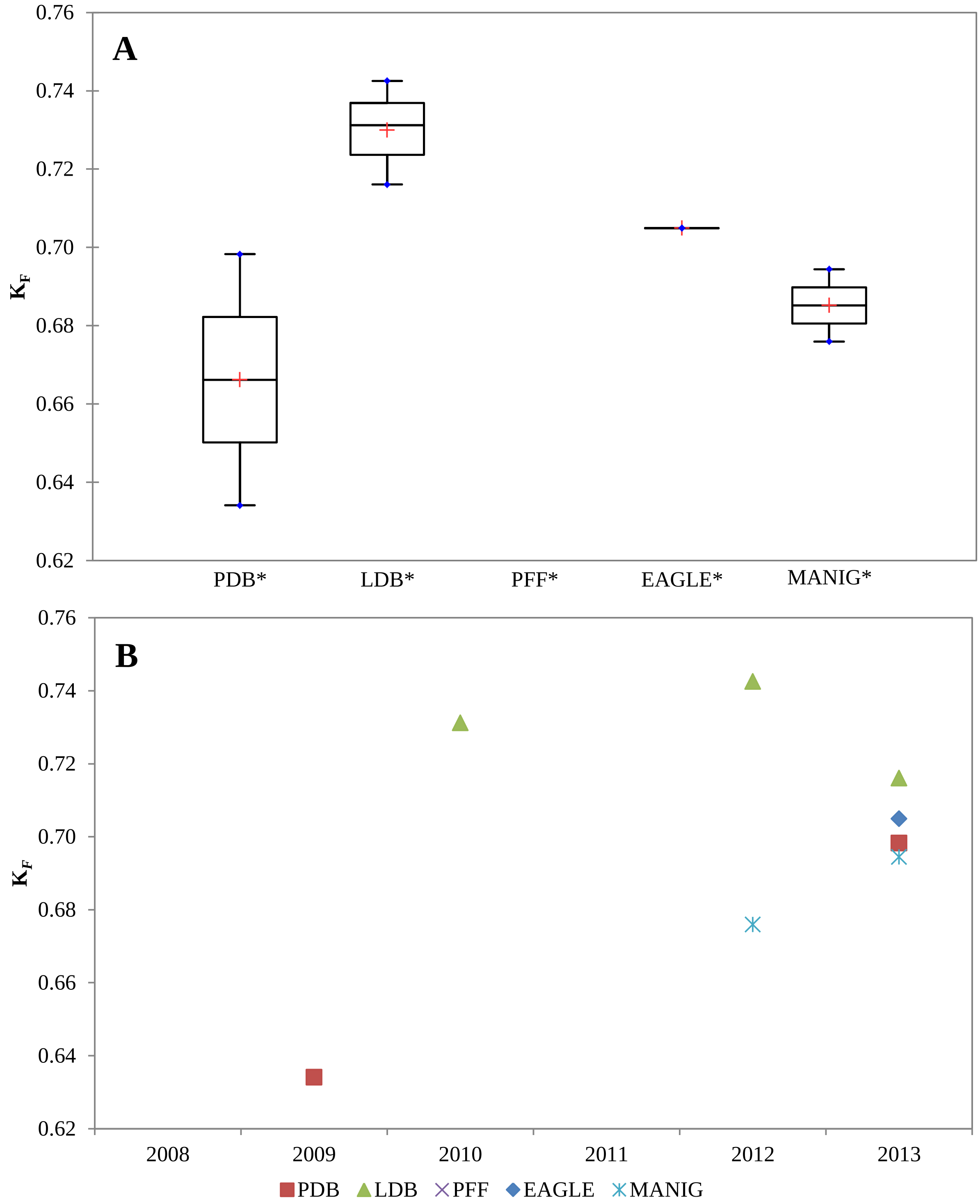


Figure 6-13. White Sucker catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically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



*Too few fish were measured at PDB in 2008, 2010, 2011, and 2012, at LDB in 2008, 2009, and 2011, at PFF in 2011, at EAGLE in 2010, and at MANIG in 2008, 2009, 2010, and 2011.

Figure 6-14. 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 Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

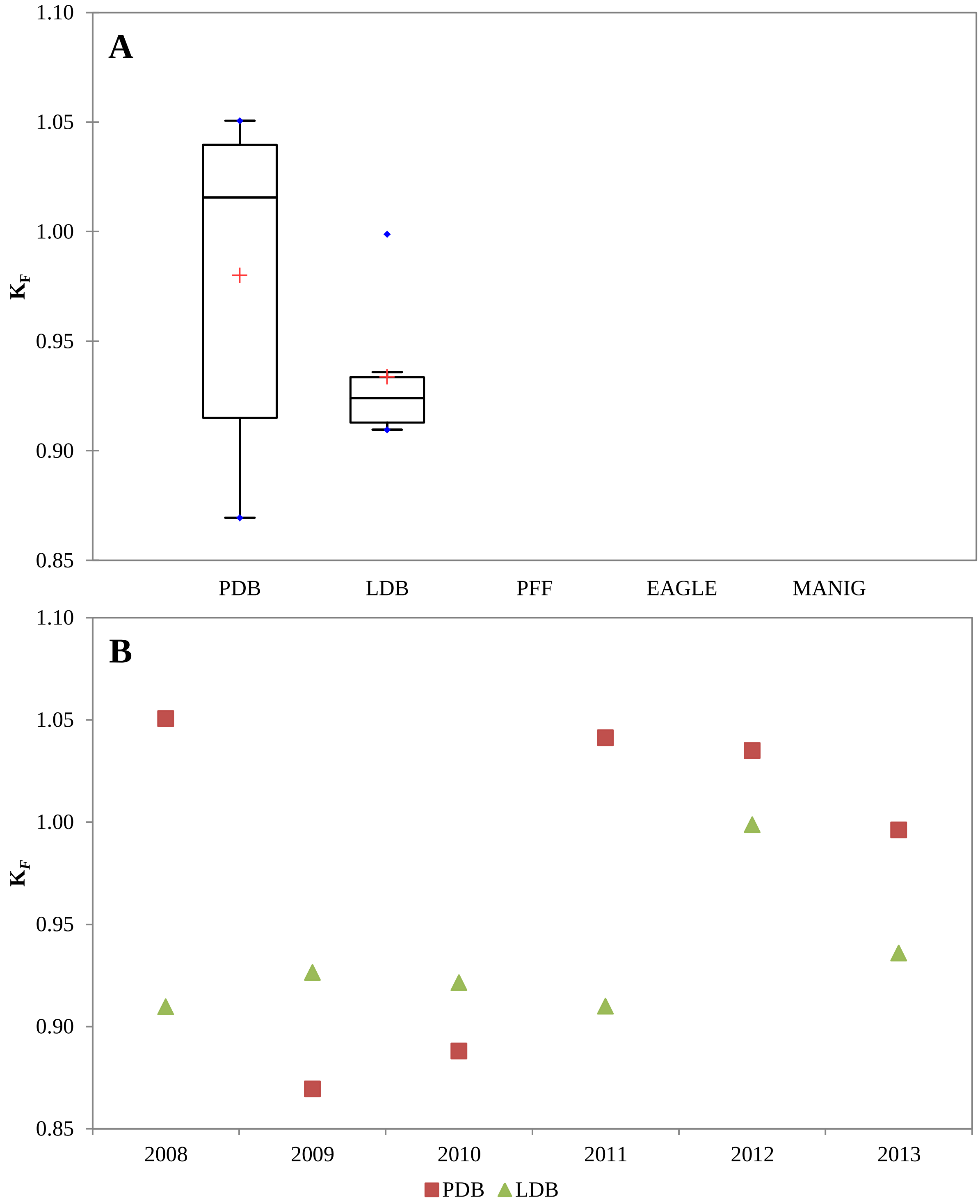
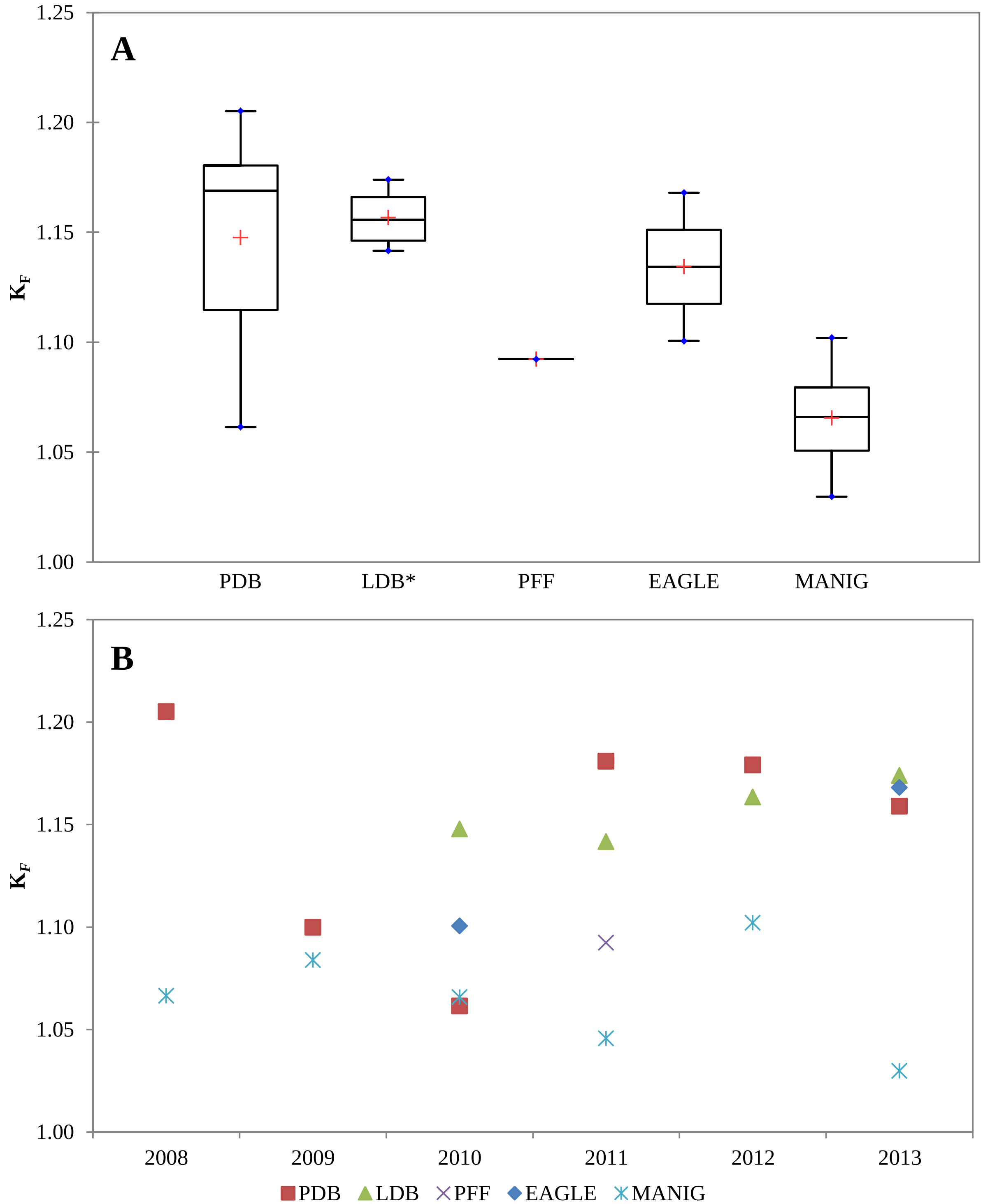
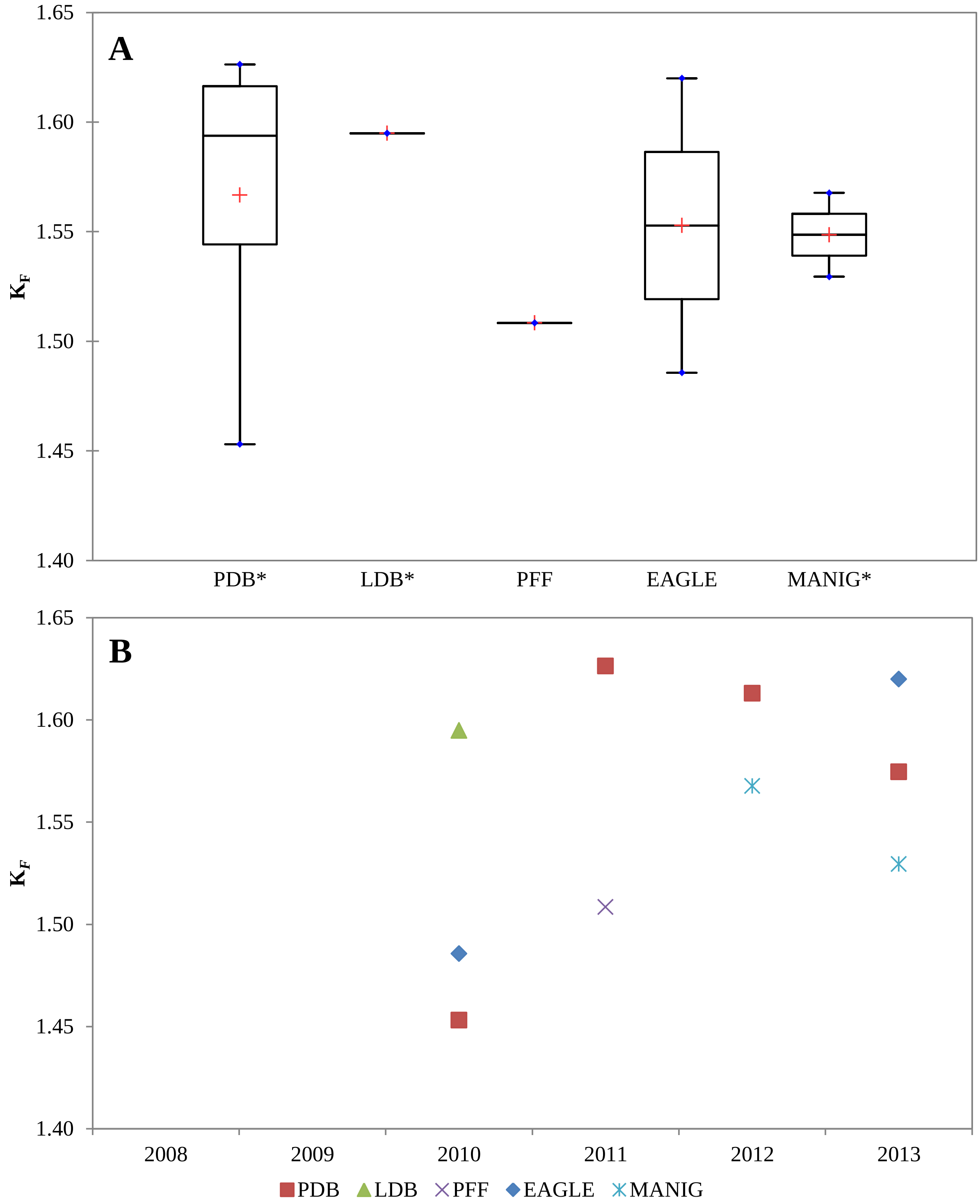


Figure 6-15. Annual mean Fulton's condition factor (K_F) calculated for Sauger between 200 and 349 mm in fork length captured in gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



*Too few fish were measured at LDB in 2008 and 2009.

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 Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



*Too few fish were measured at PDB in 2008, LDB in 2009, 2011, 2012 and 2013, and MANIG in 2008, 2009, 2010 and 2011.

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 Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

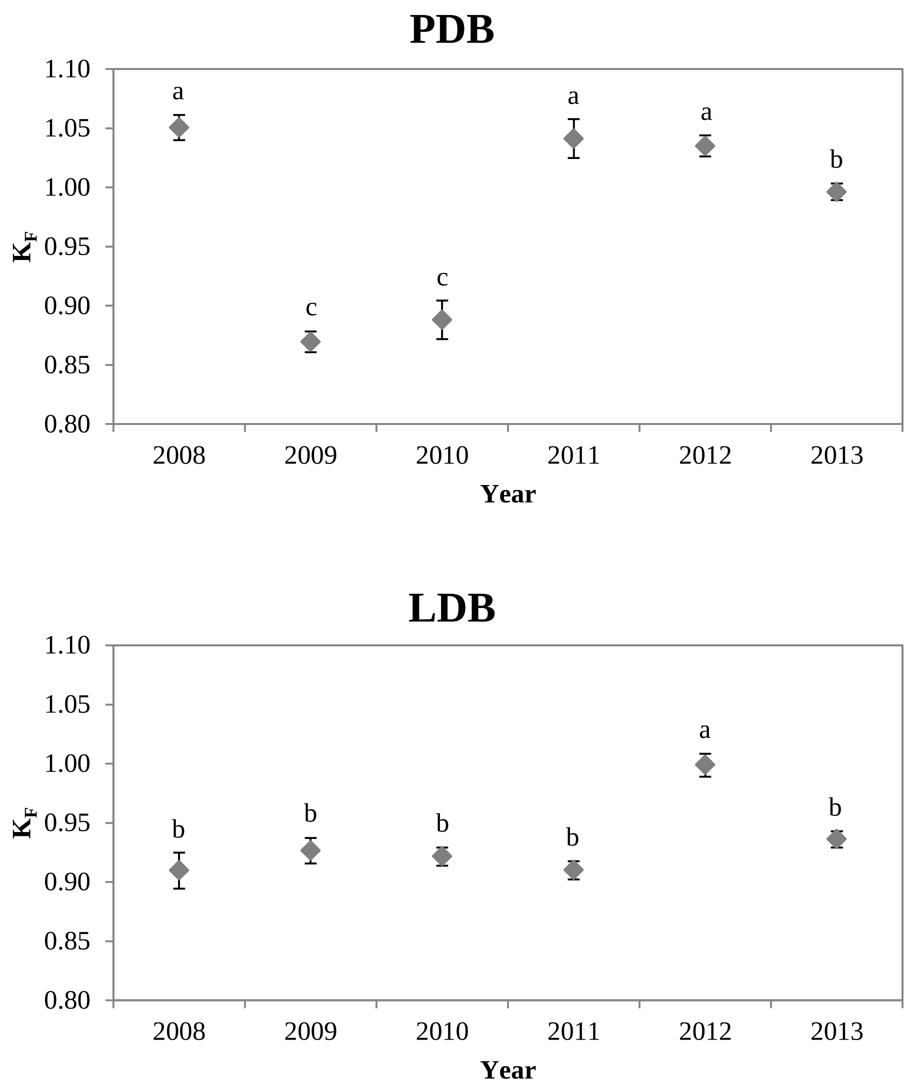


Figure 6-18. Fulton's condition factor (K_F; mean ± SE) of Sauger between 200 and 349 mm in fork length captured at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

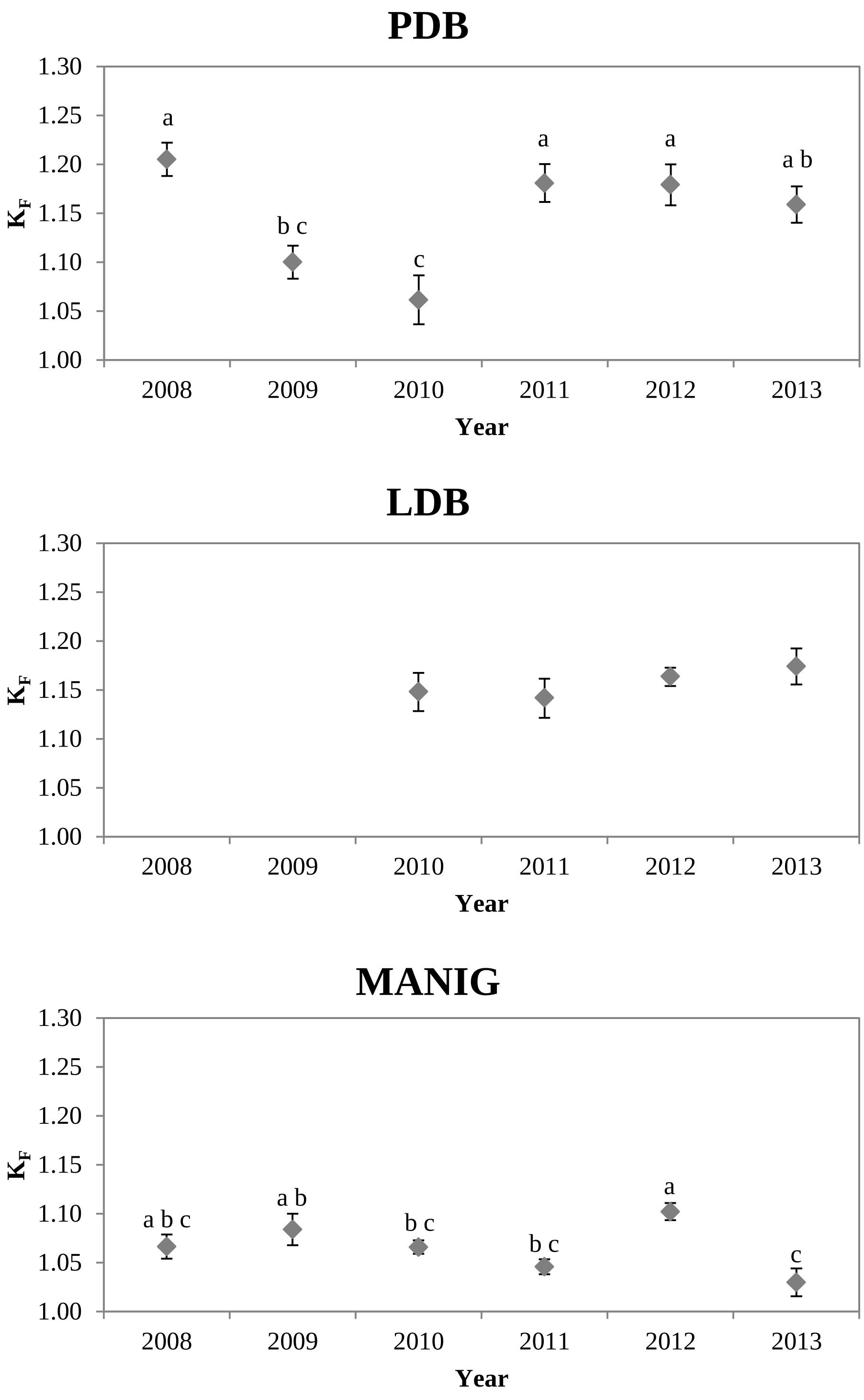


Figure 6-19. Fulton's condition factor (K_F; mean ± SE) of Walleye between 300 and 499 mm in fork length captured at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

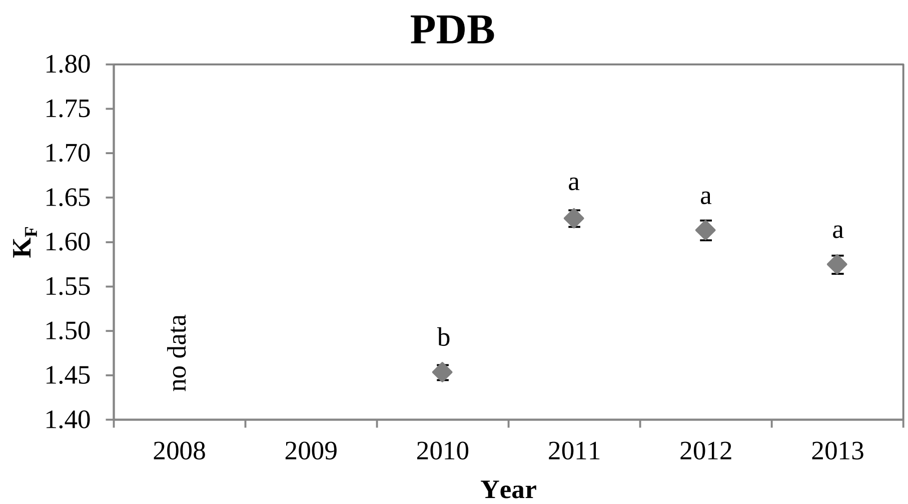


Figure 6-20. Fulton’s condition factor (K_F; mean ± SE) of White Sucker between 300 and 499 mm in fork length captured at the Pointe du Bois Forebay. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

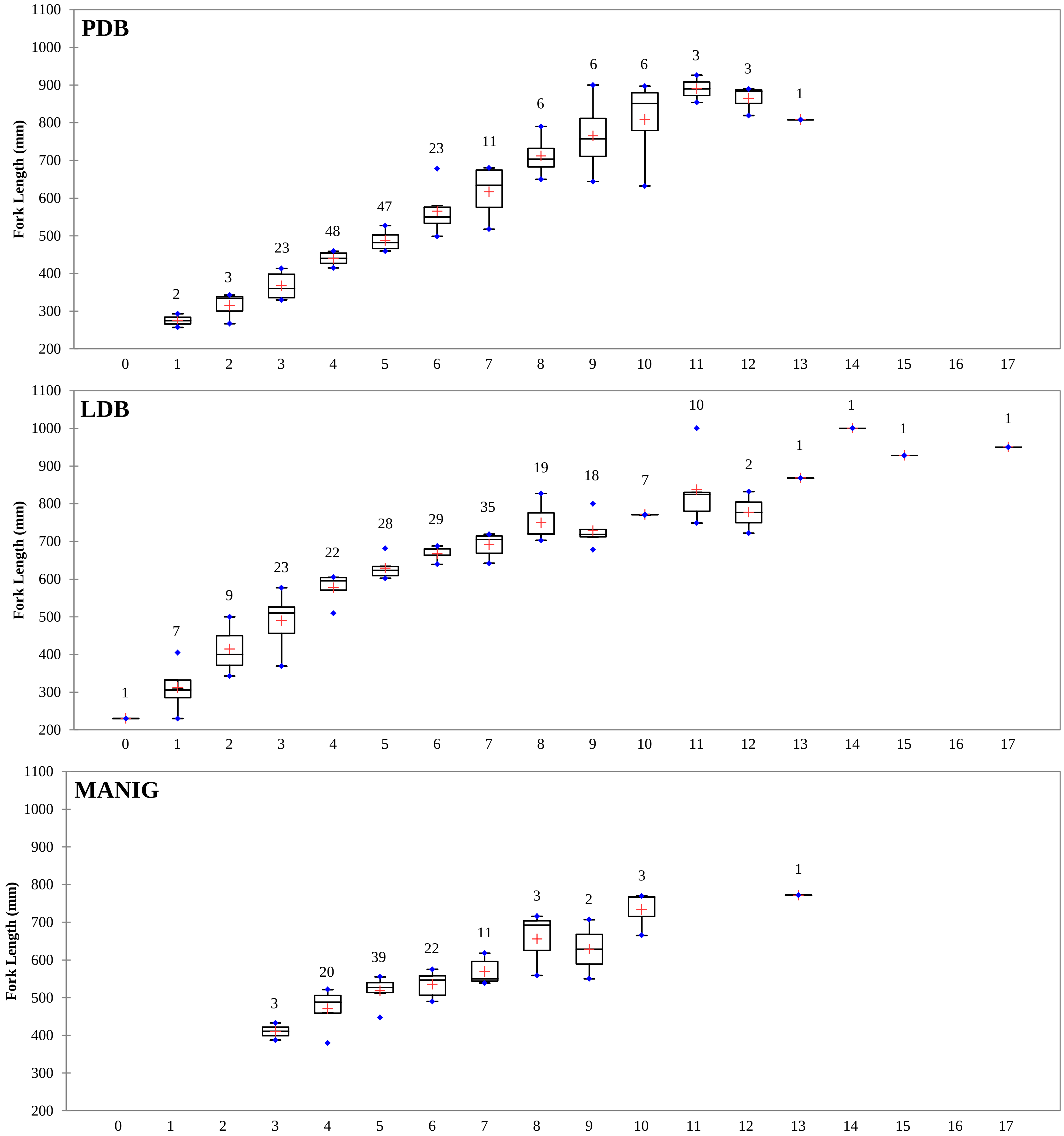
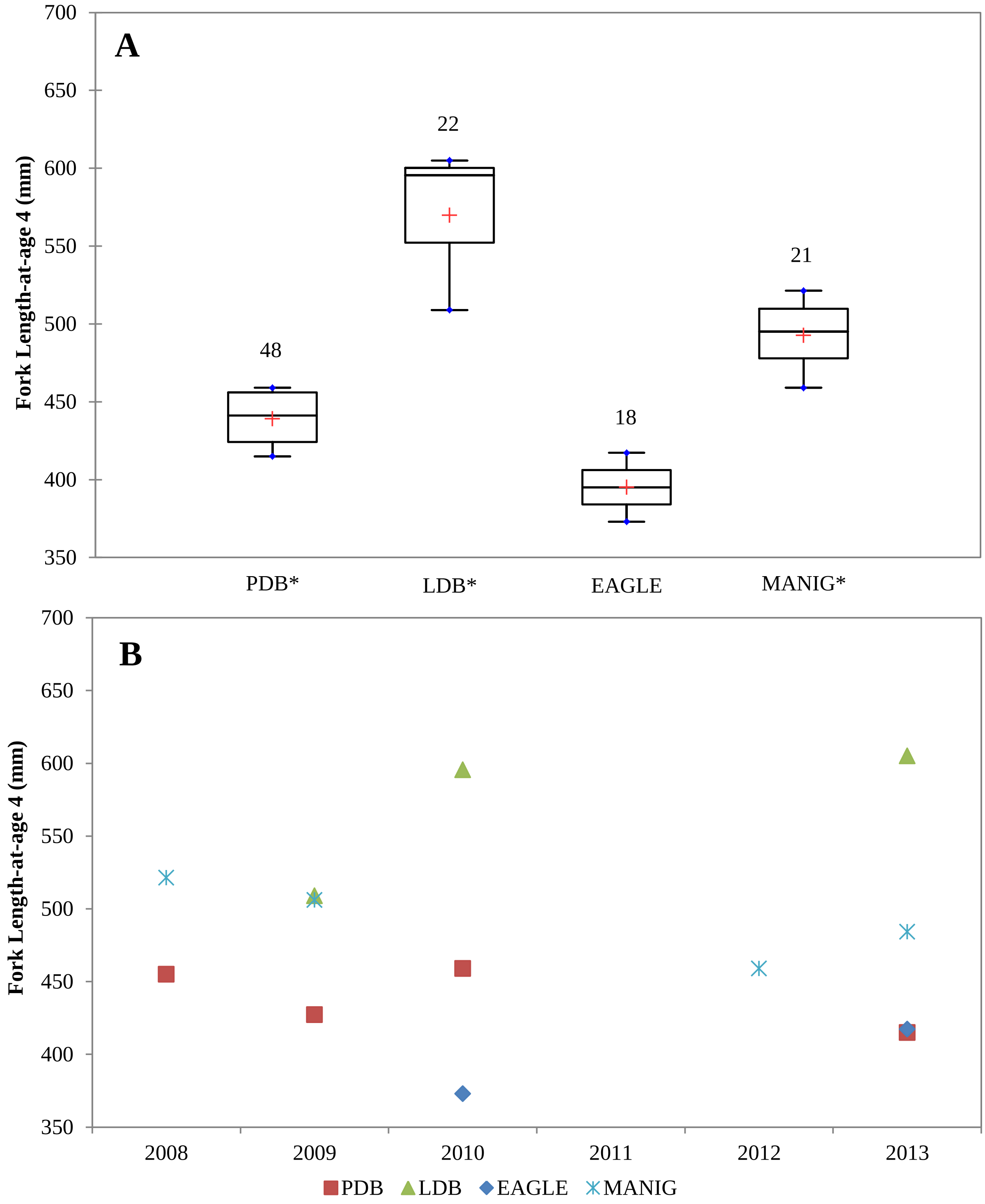


Figure 6-21. Annual mean length-at-age (mm) of Northern Pike captured in gill nets set at annual sampling locations in the Winnipeg River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



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

Figure 6-22. Annual mean length-at-age 4 (mm) of Northern Pike captured in gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 4 year old fish captured over the 6-year sampling period is shown above the box for each waterbody.

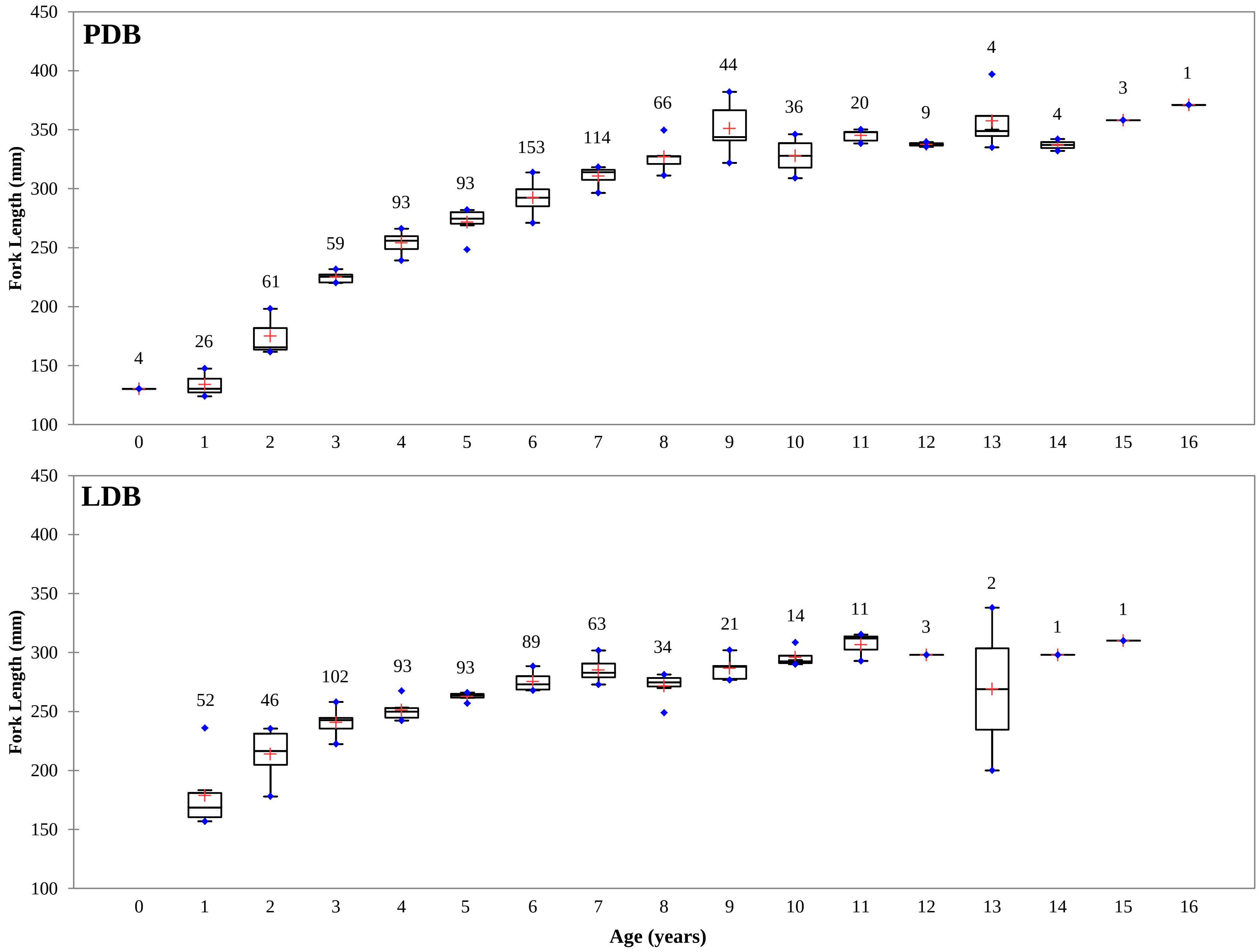
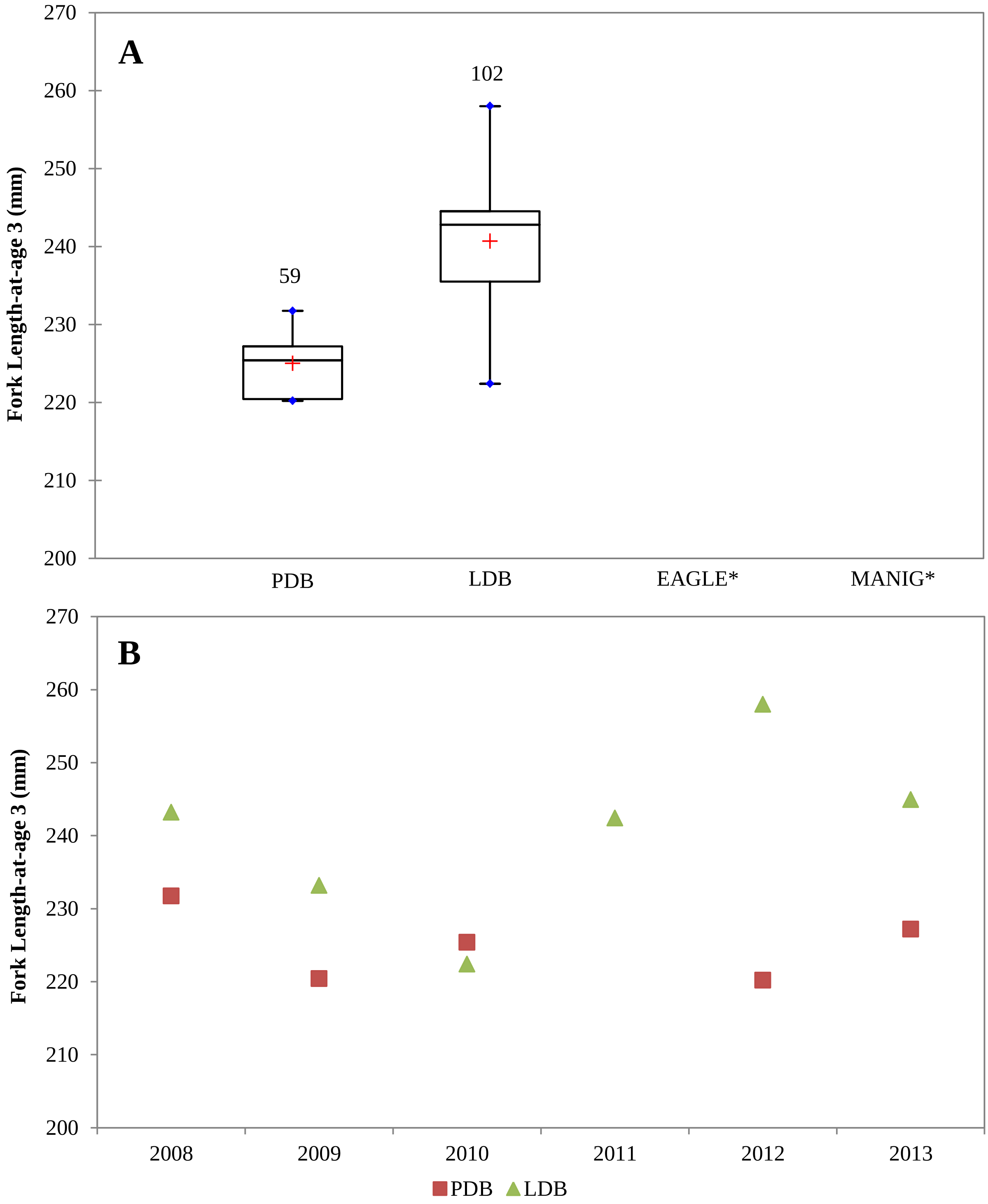


Figure 6-23. Annual mean length-at-age (mm) of Sauger captured in gill nets set at annual sampling locations in the Winnipeg River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



*Not a key species in these waterbodies.

Figure 6-24. Annual mean length-at-age 3 (mm) of Sauger captured in gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 3 year old fish captured over the 6-year sampling period is shown above the box for each waterbody.

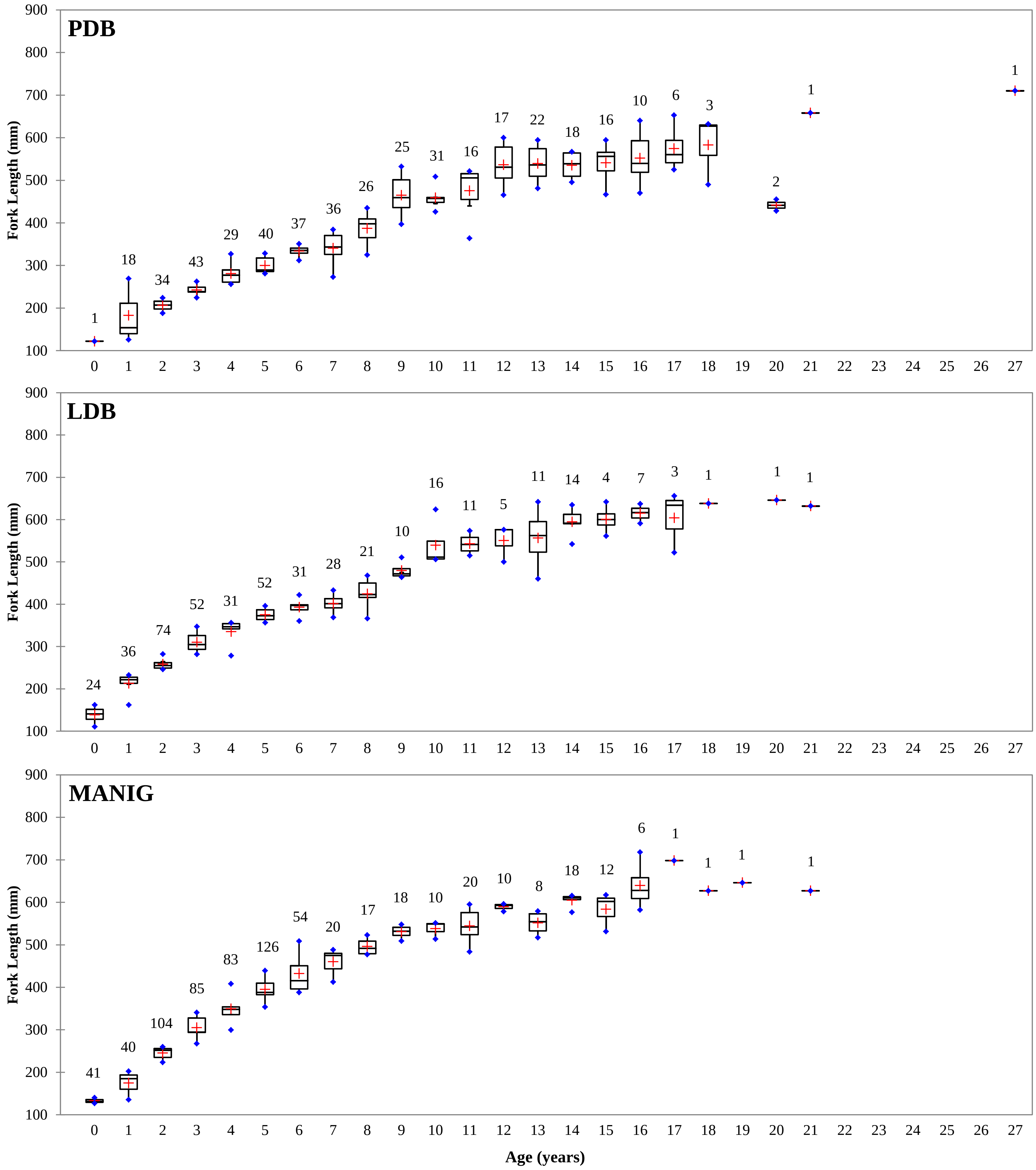
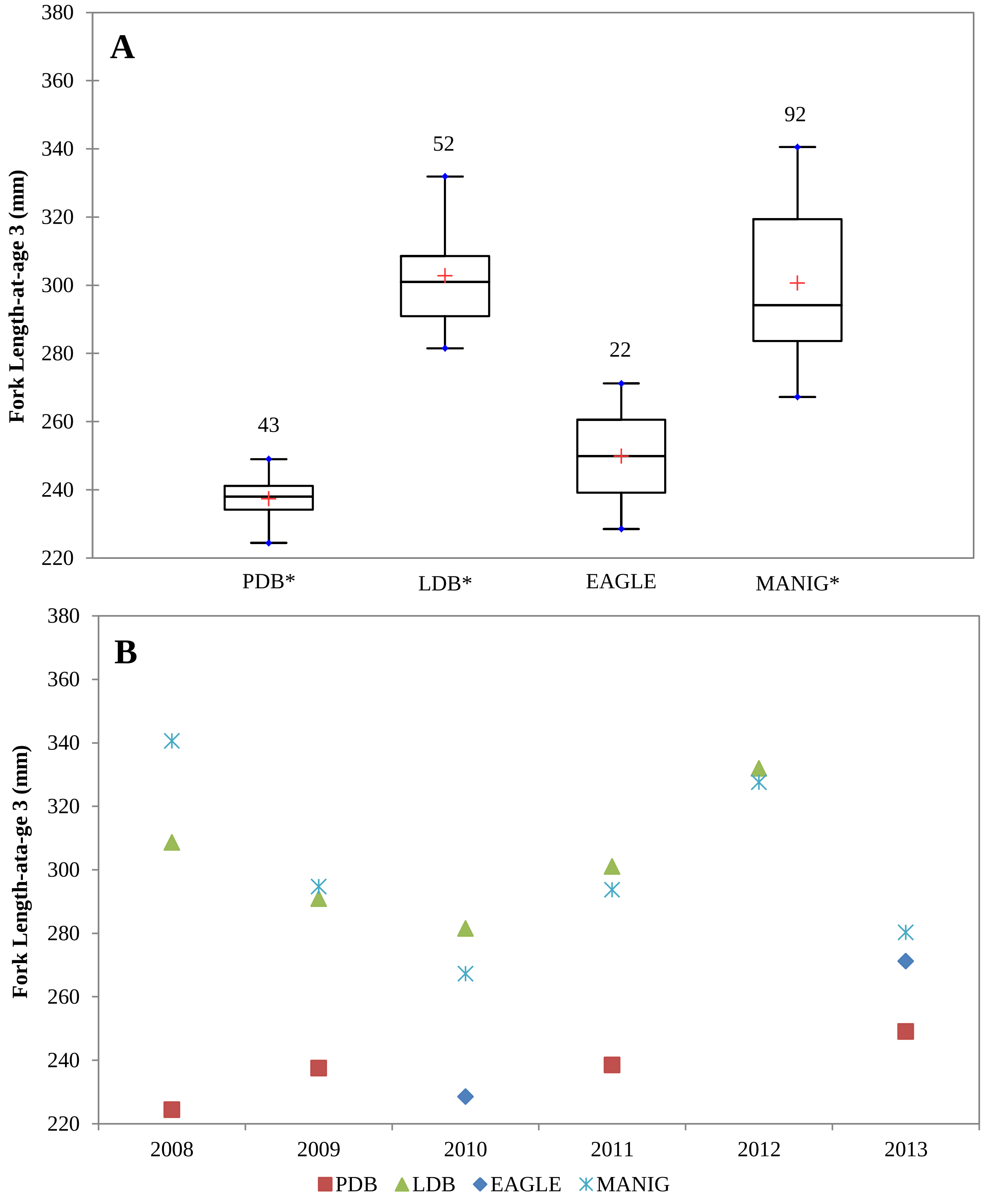
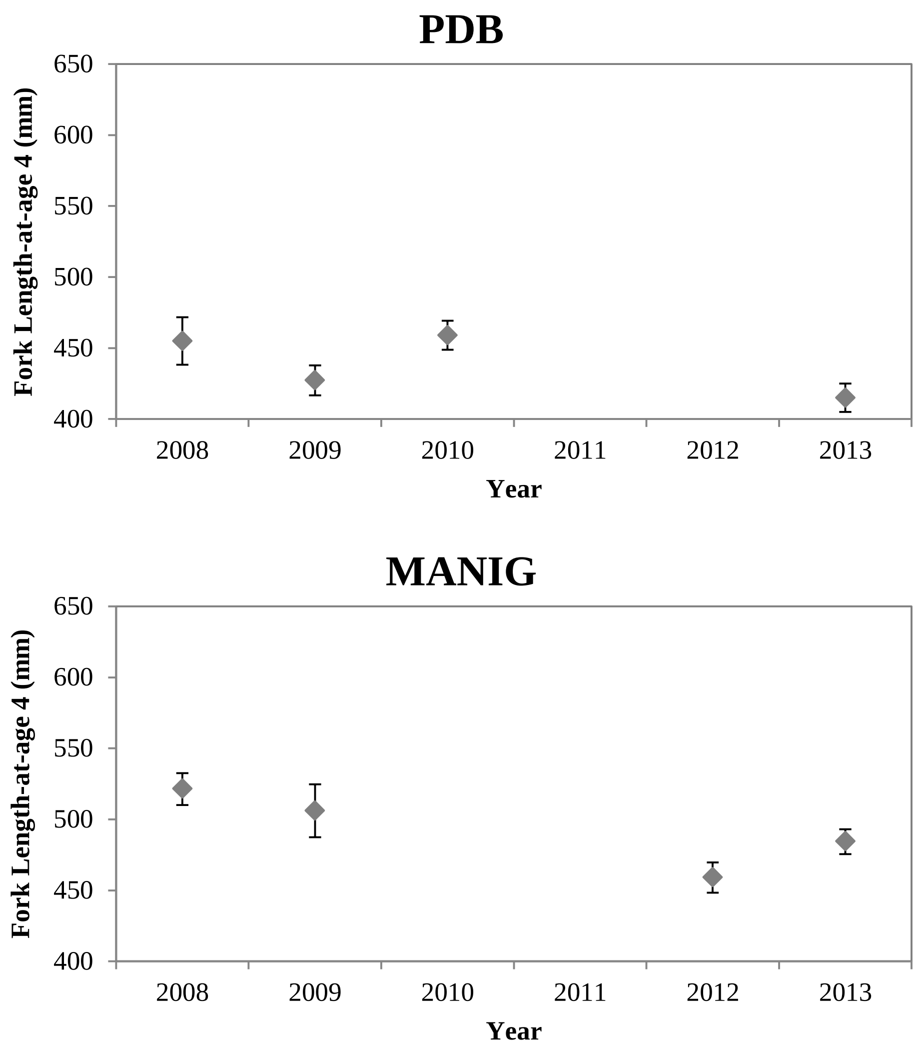


Figure 6-25. Annual mean length-at-age (mm) of Walleye captured in gill nets set at annual sampling locations in the Winnipeg River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



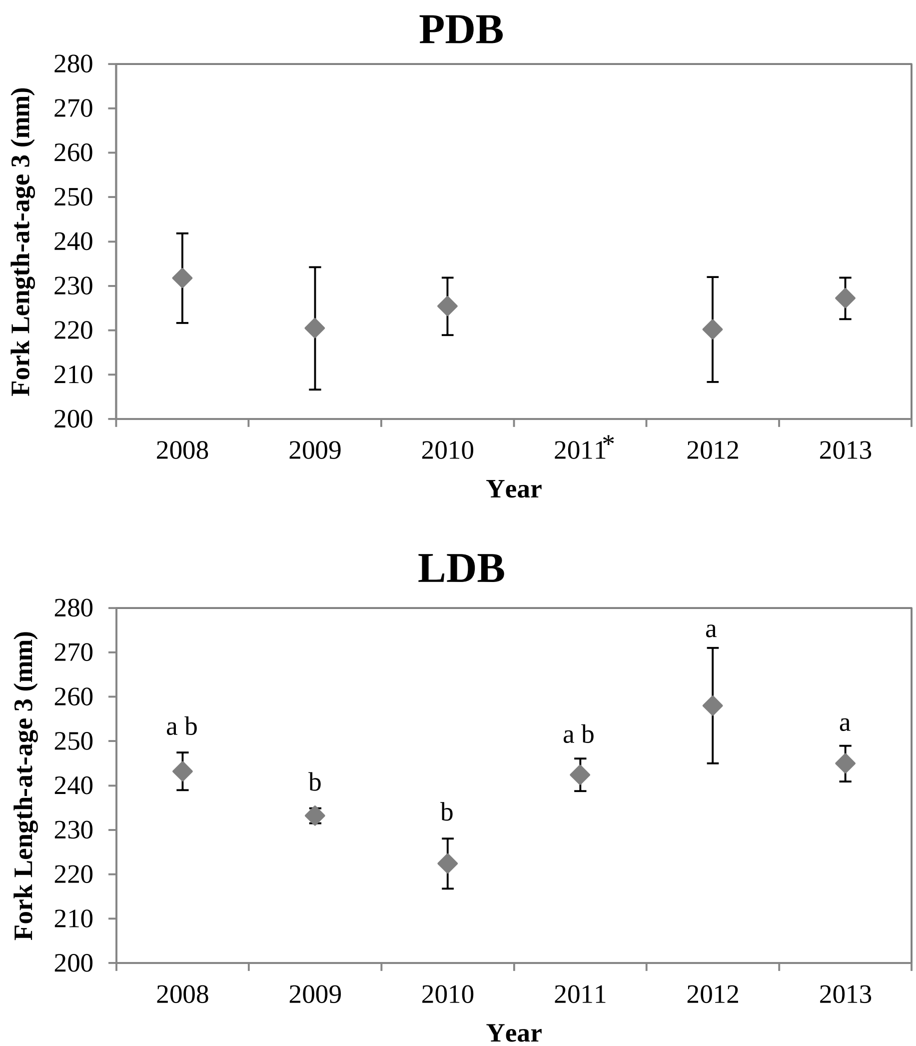
*Years in which 1 or 2 fish were captured were excluded from the analysis.

Figure 6-26. Annual mean length-at-age 3 (mm) of Walleye captured in gill nets set in Winnipeg River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 3 year old fish captured over the 6-year sampling period is shown above the box for each waterbody.



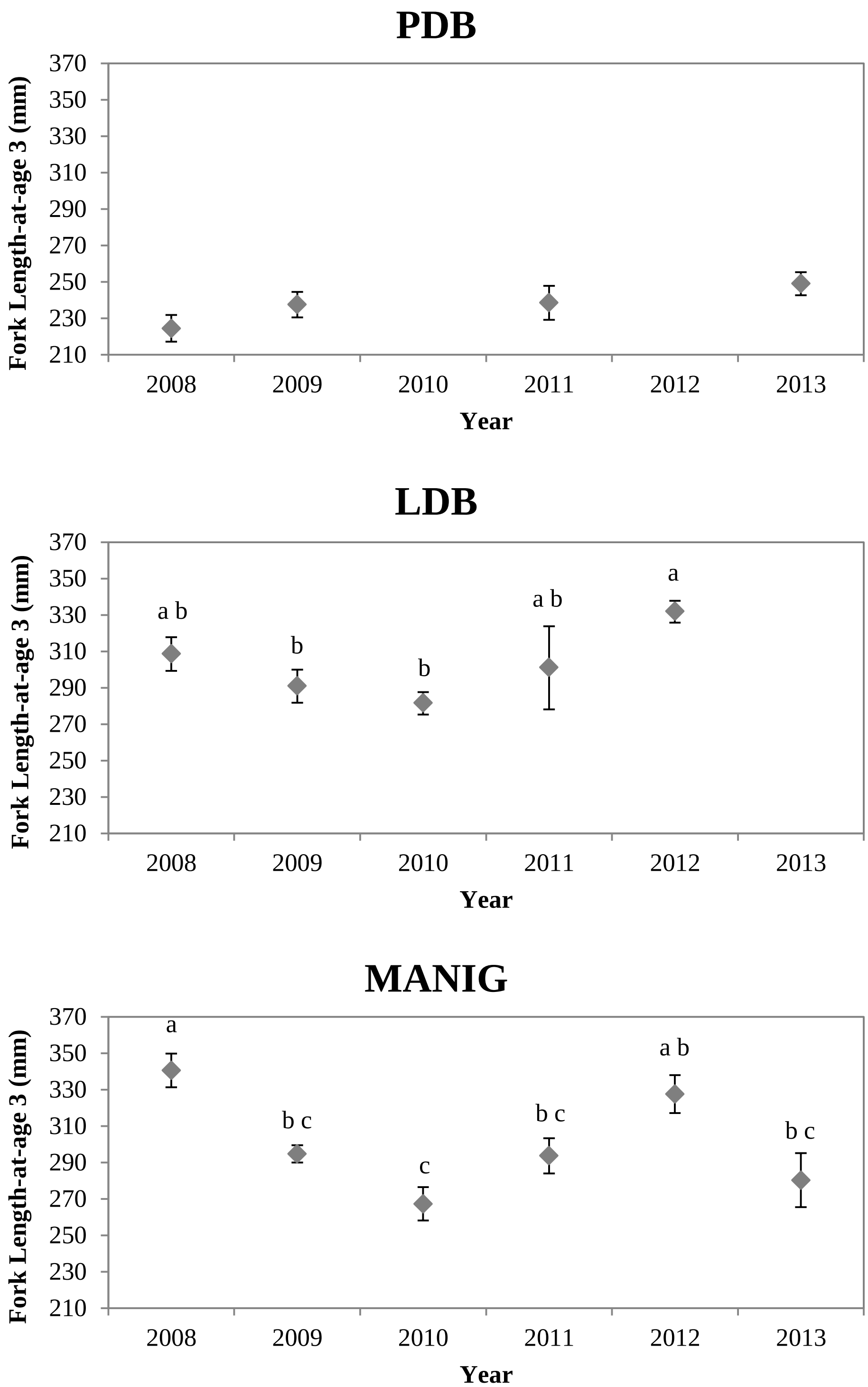
*Too few fish were captured in 2011 and 2012 at PDB, 2008, 2011 and 2012 at LDB, and 2010 and 2011 at MANIG to include in the analysis.

Figure 6-27. Fork length-at-age 4 (mean ± SE) of Northern Pike captured at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



*Too few fish were captured in 2011 at PDB to include in the analysis.

Figure 6-28. Fork length-at-age 3 (mean ± SE) of Sauger captured at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.



*Too few fish were captured in 2010 and 2012 at PDB, and 2013 at LDB to include in the analysis.

Figure 6-29. Fork length-at-age 3 (mean ± SE) of Walleye captured at annual locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

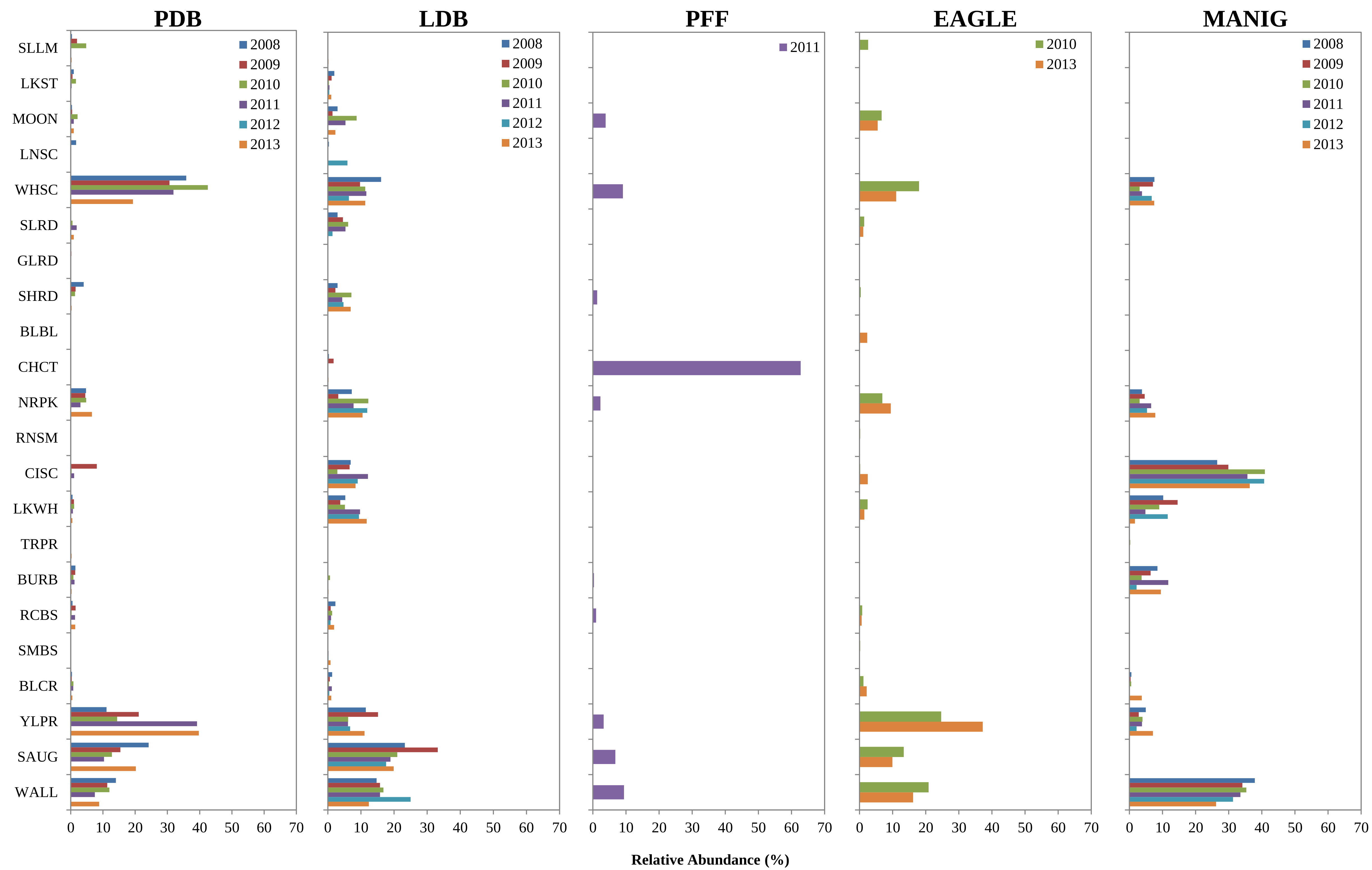


Figure 6-30. Relative abundance of fish species captured in standard gang index gill nets in Winnipeg River Region waterbodies, 2008-2013.

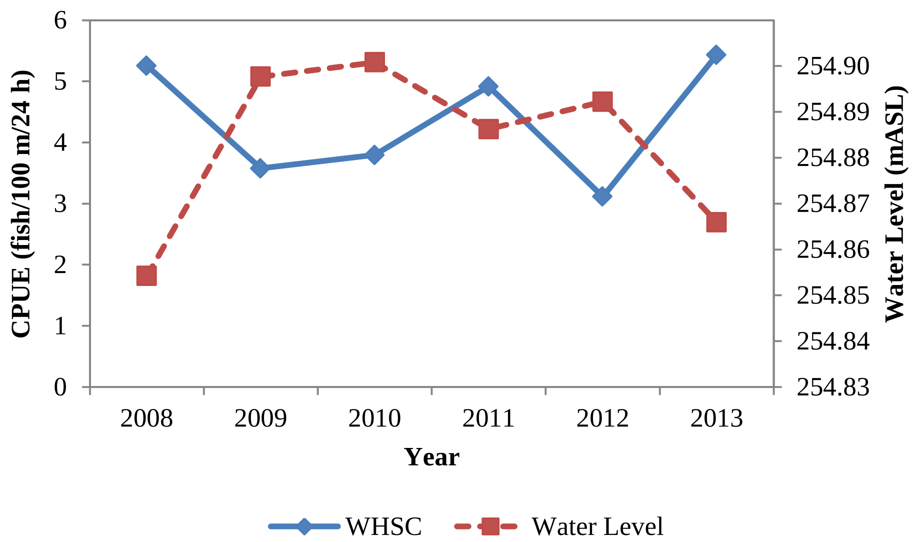


Figure 6-31. Abundance of White Sucker (top) in gillnet catches in Lac du Bonnet as measured by CPUE in relation to the average water level at the same location during the gillnetting period: 2008-2013.

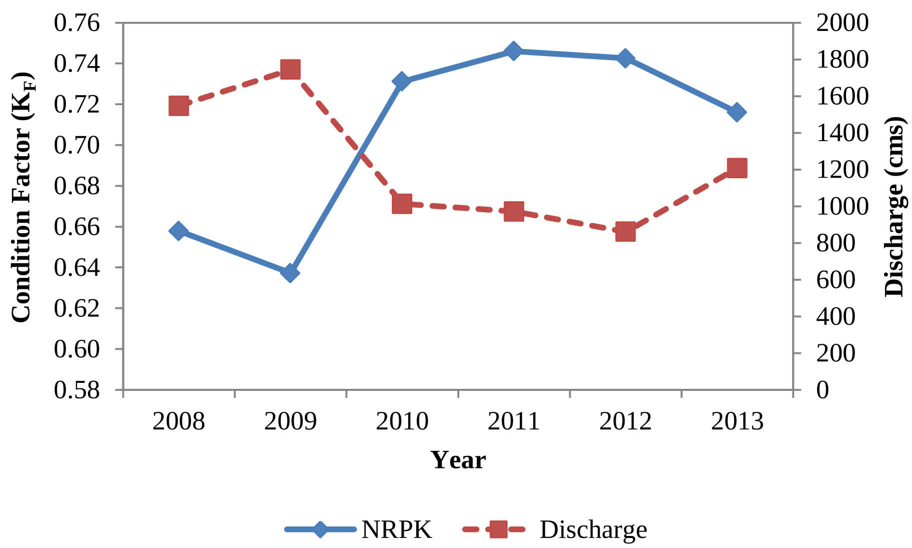


Figure 6-32. Northern Pike condition factor (bottom) in Lac du Bonnet in relation to the average discharge at the same location during the open water period: 2008-2013.

7.0 FISH MERCURY

7.1 INTRODUCTION

The following provides an overview of the results of fish mercury monitoring conducted in the WRR under CAMP in the first six years of the program. Fish mercury sampling was conducted on a three-year rotation (2010 and 2013) in the Pointe du Bois Forebay on the Winnipeg River and in the off-system Manigotagan Lake. Additional sampling was conducted in 2011 for waterbodies where sample sizes obtained in 2010 were substantially below target numbers or a species was not captured at all.

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 for analysis of mercury in the whole carcass with the head, pelvic girdle, pectoral girdle, and caudal fin removed. The latter are included in CAMP as a potential early-warning indicator of changes in mercury in the food web.

7.1.1 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 Winnipeg River

Tissue samples from 172 fish were analyzed for mercury from the Winnipeg River (Table 7-1). Sample sizes varied substantially between species and years. Fish tissue sample sizes varied substantially between species and years and were only consistently close or equal to the target sample size for Walleye. Northern Pike and Yellow Perch reached their respective target sample sizes in 2013 but not for 2010; perch were collected in 2011 because none were captured in 2010. Only 3-4 Lake Whitefish were obtained for analysis in each sampling year.

With the exception of pike (0.56 parts per million [ppm]) and Walleye (0.65 ppm) in 2010, the mean length-standardized concentration for all species for each year of monitoring was below the 0.5 ppm Health Canada standard for commercial marketing of fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011; Table 7-1). Standard mean concentrations were consistently well below the 0.5 ppm standard for whitefish and perch (Table 7-1).

Based on mercury concentrations in individual fish from both sampling years, 23% of the pike and 41% of the Walleye exceeded 0.5 ppm, reaching maximum concentrations of 1.25 ppm and 1.92 ppm, respectively. All of the whitefish (Figure 7-1) and perch (Figure 7-2) from the Pointe du Bois Forebay had mercury concentrations substantially lower than 0.5 ppm, with a maximum concentration of 0.23 ppm for whitefish and 0.03 ppm for perch.

7.2.2 Off-system Waterbody: Manigotagan Lake

A total of 165 fish were analyzed for mercury from Manigotagan Lake (Table 7-1). Sample sizes for Walleye were close to or exceeded the target sample size of 36 fish in both 2010 and 2013. Smaller sample sizes were obtained for all other species. Lake Whitefish were sampled in 2011 due to lack of captures during the 2010 sampling program.

The mean length-standardized mercury concentration for pike from Manigotagan Lake in 2010 (1.012 ppm; Table 7-1) was twice the Health Canada standard for commercial marketing of freshwater fish in Canada (0.5 ppm; Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011). The standard mean concentration in pike from 2013 and from Walleye in both years was near or slightly above the 0.5 ppm standard (Table 7-1). Length-standardized means could not be calculated for Lake Whitefish due to limited sample sizes.

Based on mercury concentrations in individual fish from all sampling years, 38% of pike (including all fish analyzed in 2010) and 30% of Walleye analyzed had mercury concentrations in excess of 0.5 ppm (Figures 7-1 and 7-2). None of the whitefish and perch sampled from Manigotagan Lake exceeded the Health Canada standard (Figures 7-1 and 7-2).

7.2.3 Temporal Comparisons

The length-standardized mean concentration of mercury in Northern Pike and Walleye from the Pointe du Bois Forebay was greater in 2010 than 2013 (Figure 7-3). This temporal difference was also observed for pike, but not walleye, in the off-system Manigotagan Lake. As noted above, length-standardization for Lake Whitefish could not be undertaken due to limited sample sizes and therefore comparisons between years could not be undertaken. Concentrations (not length-standardized) measured in perch from the Pointe du Bois Forebay were similar between years (mean 0.017 ppm in 2011 and 0.018 ppm in 2013); although ages were not obtained for perch in 2011, the mean fork lengths were similar between years.

7.3 SUMMARY

Length-standardized mean mercury concentrations for most species and years were below the 0.5 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). Exceptions included Northern Pike and Walleye sampled from the Pointe du Bois Forebay in 2010; concentrations were also significantly higher in both species in 2010 than 2013. Exceedances of the commercial marketing standard were also observed for the off-system lake (Manigotagan Lake) for both Walleye (2013) and pike (2010), though inter-annual differences were only significant for pike in this waterbody.

Based on mercury concentrations in individual fish from all sampling years, 23% of pike and 41% of Walleye analyzed from the Pointe du Bois Forebay had mercury concentrations in excess of 0.5 ppm. Exceedance frequencies were similar for the off-system Manigotagan Lake where

38% of pike (including all fish analyzed in 2010) and 30% of Walleye sampled exceeded the 0.5 ppm standard.

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

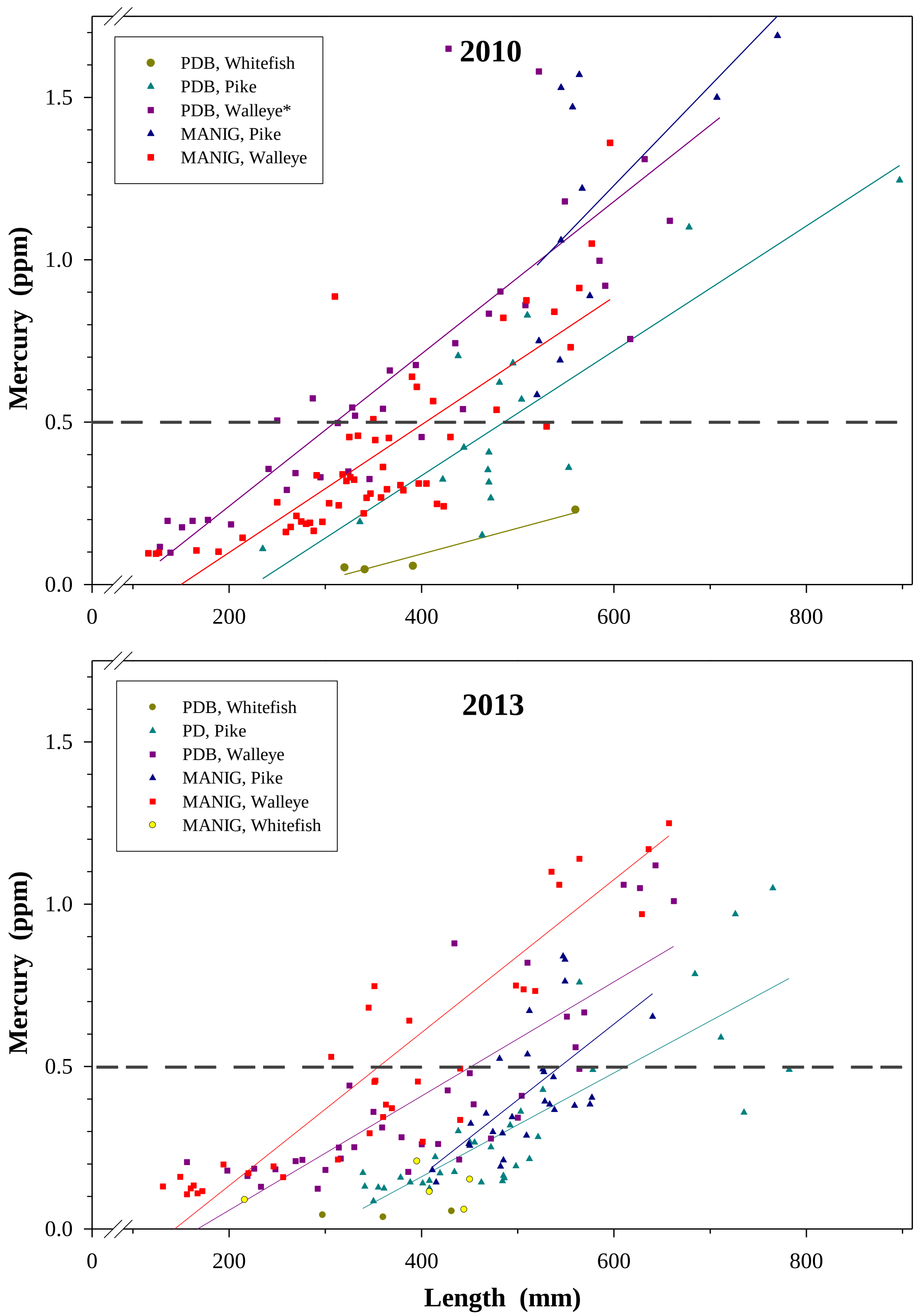
				Mercury Concentration (ppm)			
Waterbody	**Year**	**Species**	**n**	**Arithmetic Mean**	**SE**	**Standard Mean**	**95% CL**
Pointe du Bois Forebay	2010	Pike	17	0.509	0.078	0.559	0.437 - 0.717
		Walleye	36	0.651	0.075	0.648	0.585 - 0.718
		Whitefish	4	0.096	0.045	0.053	0.028 - 0.101
	2011	Perch	15	0.017	0.001	-	-
	2013	Pike	35	0.312	0.042	0.340	0.297 - 0.389
		Walleye	37	0.417	0.048	0.365	0.322 - 0413
		Whitefish	3	0.045	0.005	NS	-
		Perch	25	0.018	0.001	-	0.017 - 0.042
Manigotagan Lake	2010	Pike	11	1.178	0.121	1.012	0.799 - 1.282
		Walleye	53	0.396	0.038	0.429	0.386 - 0.477
	2011	Whitefish	13	0.103	0.005	NS	-
	2013	Pike	28	0.419	0.036	0.494	0.420 - 0.581
		Walleye	36	0.530	0.070	0.522	0.465 - 0.585
		Whitefish	5	0.125	0.026	NS	-
		Perch	19	0.055	0.002	-	-

NS = Not significant.

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

Waterbody	**Year**	**Species**	**n**	**Length (mm)**	**Weight (g)**	**K_F**	**Age (years)**
Pointe du Bois Forebay	2010	Pike	17	490.4 ± 33.5	969.8 ± 292.2	0.62 ± 0.02	4.7 ± 0.4
		Walleye	36	374.8 ± 27.2	891.2 ± 167.6	1.03 ± 0.02	10.7 ± 1.1
		Whitefish	4	403.0 ± 54.4	1096.3 ± 441.4	1.46 ± 0.06	6.5 ± 2.8
	2011	Perch	15	80.4 ± 1.4	7.8 ± 0.5	1.47 ± 0.03	-
	2013	Pike	35[1]	495.0 ± 21.4	1044.8 ± 158.5	0.70 ± 0.01	5.3 ± 0.2
		Walleye	37	404.6 ± 22.5	1045.7 ± 153.6	1.14 ± 0.02	8.1 ± 0.8
		Whitefish	3	362.7 ± 38.7	806.7 ± 307.2	1.57 ± 0.22	-
		Perch	25[2]	80.3 ± 1.2	6.8 ± 0.4	1.29 ± 0.02	1.6 ± 0.2
Manigotagan Lake	2010	Pike	11	583.3 ± 24.1	1270.9 ± 259.9	0.58 ± 0.04	6.4 ± 0.5
		Walleye	53	351.2 ± 15.5	581.5 ± 69.7	1.05 ± 0.01	5.2 ± 0.4
	2011	Whitefish	13[3]	370.6 ± 17.9	669.3 ± 96.9	1.21 ± 0.03	12.5 ± 1.9
	2013	Pike	28	509.3 ± 9.7	941.3 ± 52.4	0.70 ± 0.01	4.7 ± 0.2
		Walleye	36	368.3 ± 26.2	787.9 ± 142.5	0.97 ± 0.02	6.8 ± 0.9
		Whitefish	5	382.6 ± 42.9	840.8 ± 191.8	1.29 ± 0.06	13.2 ± 3.1
		Perch	19[4]	95.7 ± 0.9	10.9 ± 0.3	1.24 ± 0.15	1.8 ± 0.1

[1] n=34 for age; [2] n=8 for age; [3] n=12 for age; [4] n=11 for age.



* One Walleye collected from the Pointe du Bois Forebay in 2010 with a mercury concentration of 1.92 ppm and a length of 710 mm is not shown but was included in the analyses.

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

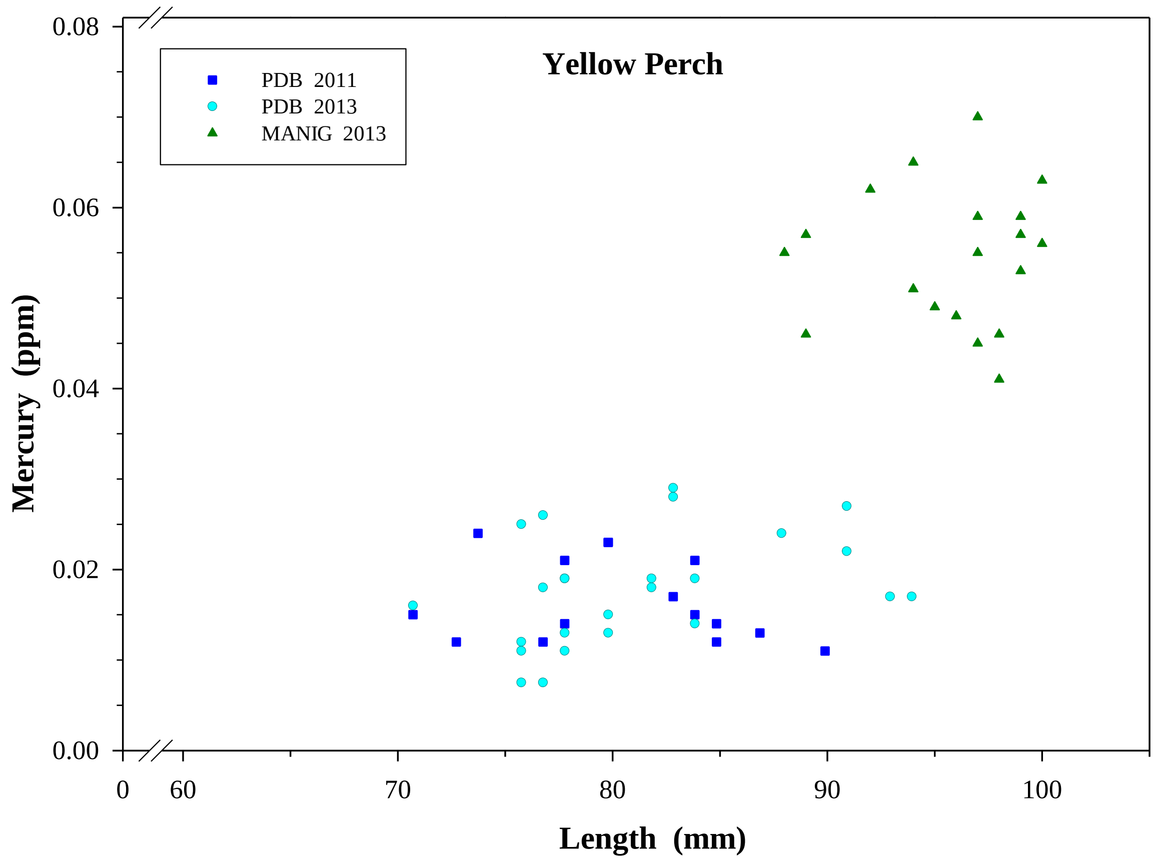
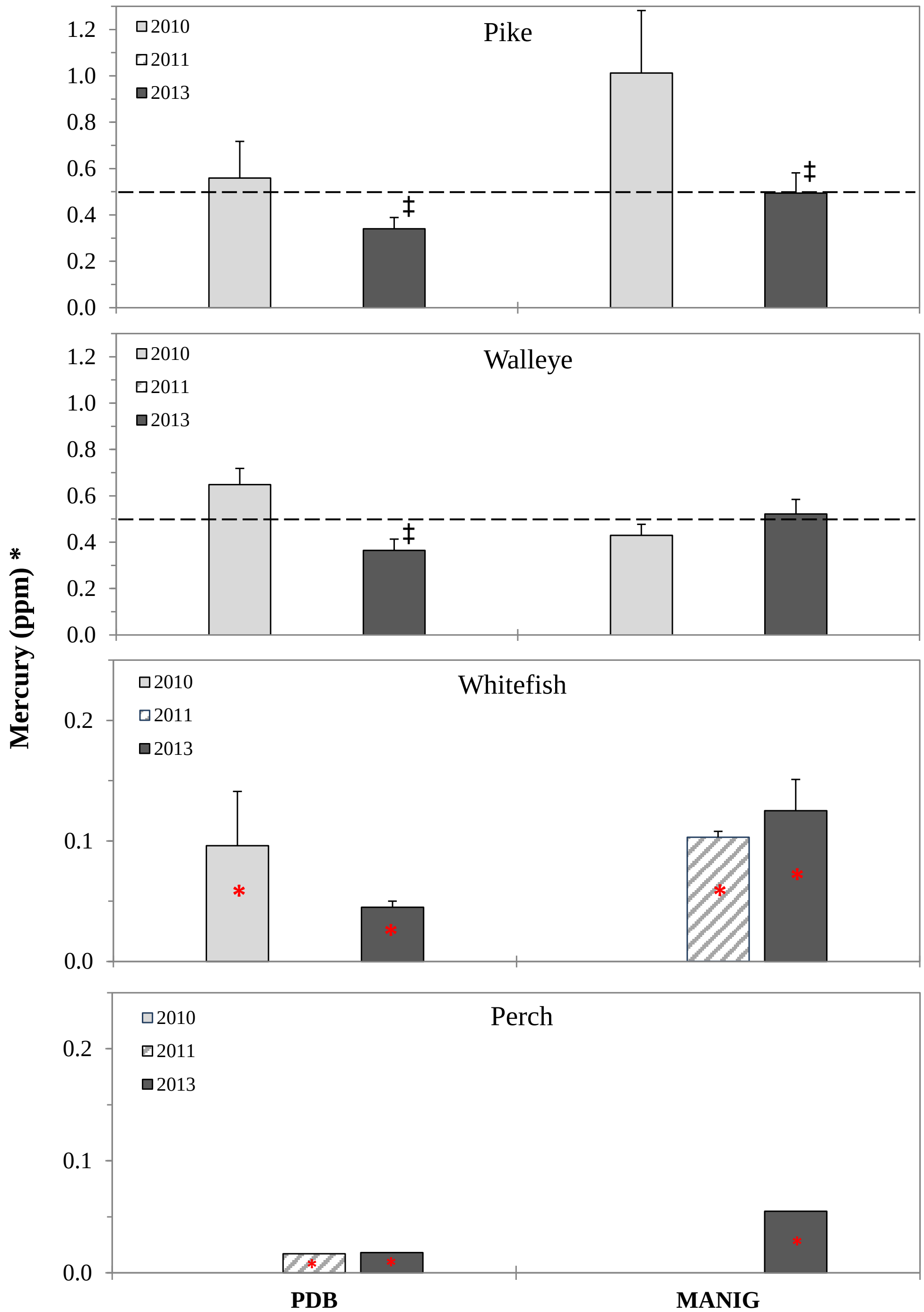


Figure 7-2. Relationship between mercury concentration and fork length for Yellow Perch from the Pointe du Bois Forebay and Manigotagan Lake in 2011 and 2013.



* Note differences in mercury scale among species.

Figure 7-3. Length-standardized (mean+95% CLs) or arithmetic (denoted with an asterisk; mean ± SE) mercury concentrations of Northern Pike, Walleye, Lake Whitefish, and Yellow Perch from the Winnipeg River 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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