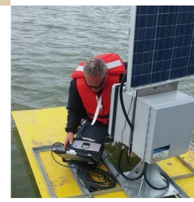
CAMP

Coordinated Aquatic Monitoring Program



Six Year Summary Report

Technical Document 6:
Lower Churchill River Region

2008-2013

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Introduction, Background, and Methods

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- Sampling and laboratory methods
- Reporting approach and data analysis methods

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- Hydrology
- Water quality
- Sediment quality
- Benthic macroinvertebrates
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- Mercury in fish

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SIX YEAR SUMMARY REPORT (2008-2013)

Technical Document 6:

Lower Churchill River Region Results

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ABBREVIATIONS AND ACRONYMS

ASL	Above sea level
BCMOE	British Columbia Ministry of Environment
BIL	Billard Lake
BMI	Benthic macroinvertebrate(s)
CAMP	Coordinated Aquatic Monitoring Program
CCME	Canadian Council of Ministers of the Environment
CL	Confidence limit
CPUE	Catch-per-unit-effort
CRD	Churchill River Diversion
CS	Control structure
DL	Detection limit
DO	Dissolved oxygen
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)
FID	Fidler Lake
FL	Fork length
FL-at-age	Fork-length-at age
GAU	Gauer Lake
GS(s)	Generating station(s)
HAYES	Hayes River
ISQG	Interim sediment quality guideline
K_F	Condition Factor
KHLP	Keeyask Hydropower Limited Partnership
LCR-LiCR	Lower Churchill River at t Little Churchill River
LCR-RHR	Lower Churchill River at Red Head Rapids
LCRR	Lower Churchill River Region
LEL	Lowest effect level
LNRR	Lower Nelson River Region
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
n_F	Number of fish
n_Y	Number of years sampled
NIL	Northern Indian Lake
PAL	Protection of aquatic life
PBL	Partridge Breast Lake
PEL	Probable effect level
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 (OW)	Average water level during the open water period
WL (GN)	Average water level during the gillnetting program
WSL	Water surface level

1.0 INTRODUCTION

The following presents a description of results of monitoring conducted under the Coordinated Aquatic Monitoring Program (CAMP) for years 1 through 6 (i.e., 2008/2009 through 2013/2014) in the Lower Churchill River Region (LCRR). As described in Technical Document 1, Section 2.5.1, the LCRR extends from the outlet of Southern Indian Lake (i.e., the Missi Falls Control Structure [CS]) to the mouth of the river at the Town of Churchill on Hudson Bay. Waterbodies and riverine sites monitored in this region over this period included one off-system waterbody and six on-system waterbodies or river reaches as follows (listed in an upstream to downstream direction):

- Partridge Breast Lake;
- Northern Indian Lake (NIL);
- Fidler Lake;
- Billard Lake;
- Lower Churchill River at the Little Churchill River;
- Lower Churchill River at Red Head Rapids; and
- Gauer Lake (off-system).

Monitoring results for an off-system river reach (i.e., the Hayes River) are also considered in the following presentation of results; while the Hayes River is formally considered part of the Lower Nelson River Region (LNRR) under CAMP, this site is intended to provide contextual information for the interpretation of monitoring results for both the LNRR and the LCRR.

Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.5. 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 LCRR over this time period include hydrology, aquatic habitat, water quality, sediment quality, phytoplankton, benthic macroinvertebrates (BMI), fish community, and mercury in fish.

Results presented below include a discussion of hydrology, water quality, sediment quality, BMI, fish community, and fish mercury for key metrics, as described in Technical Document 1. Observations of note for additional metrics are also provided in the following for the water quality, BMI, and fish community components. Results of aquatic habitat surveys completed in the LCRR over years 1 to 3 of CAMP, including the west basin of Northern Indian and Billard lakes (surveyed in 2010) are presented in CAMP (2014). No additional aquatic habitat surveys were completed between 2011 and 2013 in this region.

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

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

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

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

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

Waterbody/Area	Site Abbreviation	On-sy stem	Off-sy stem	Annual	Rotational	Sampling Years [1]					
						2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Partridge Breast Lake	PBL	X			X		X			X	
Northern Indian Lake	NIL	X		X		X	X	X	X	X	X
Fidler Lake	FID	X			X				X		
Billard Lake	BIL	X			X			X			X
Lower Churchill River at Little Churchill River	LCR-LiCR	X		X		X	X	X	X	X	X
Lower Churchill River at Red Head Rapids [2]	LCR-RHR	X			X				X		
Gauer Lake	GAU		X	X		X	X	X	X	X	X
Hayes River [3]	HAYES		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 moved to the lower Churchill River at the Churchill Weir in 2014.
[3] Site formally included in the Lower Nelson River Region; included here for discussion of results for the LCRR.

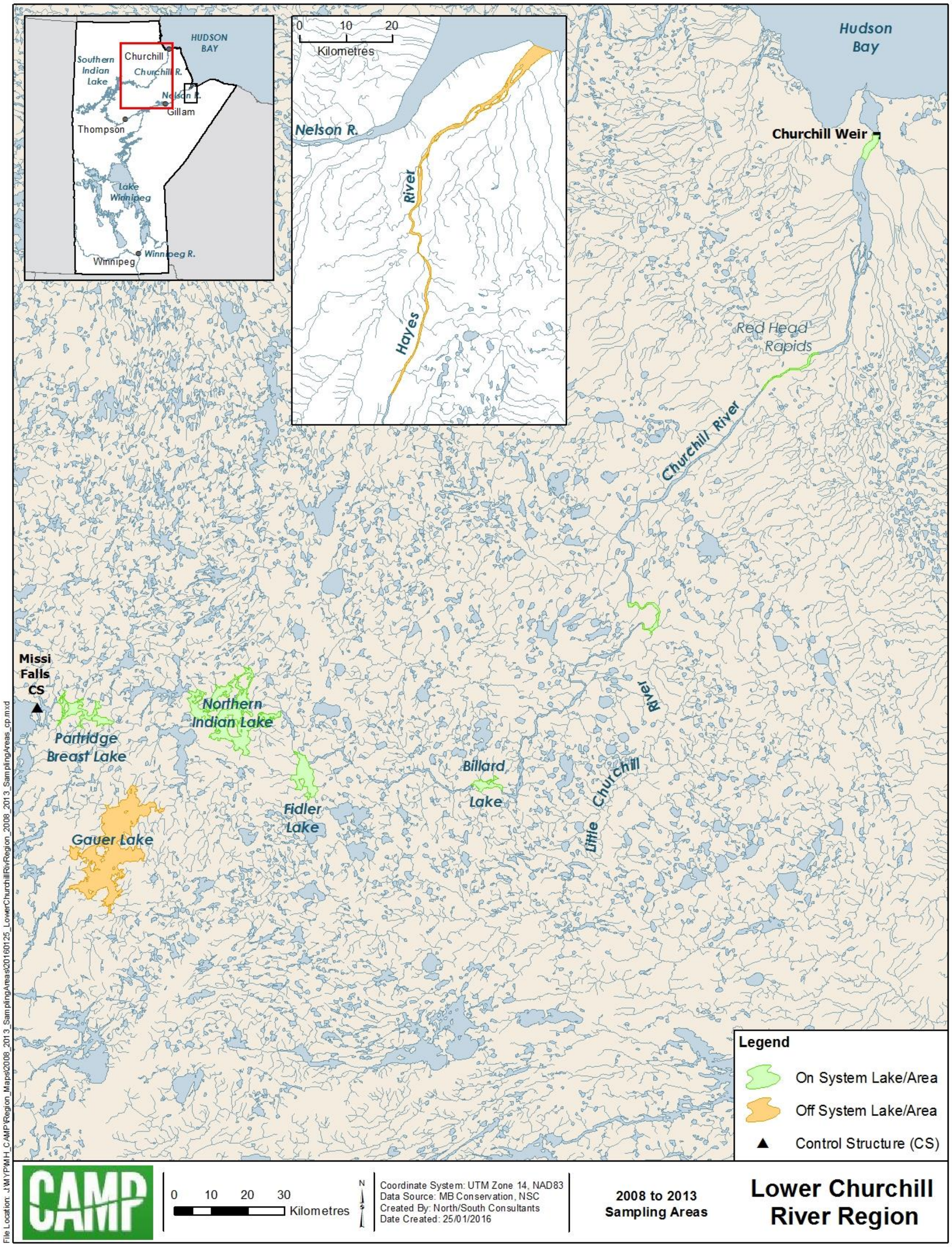


Figure 1-1. On-system and off-system waterbodies and river reaches sampled under CAMP in the Lower Churchill River Region: 2008/2009-2013/2014.

2.0 HYDROLOGY

Flows along the lower Churchill River have been modified as a result of the Churchill River Diversion (CRD) which diverts the majority of the upper Churchill River flow through the Rat-Burntwood River system to the Nelson River for power production. The Missi Falls CS releases the remaining portion of the upper Churchill River flow from Southern Indian Lake into the lower Churchill River. The lower Churchill River flows through a number of lakes where discharge is augmented by local inflows and inflows from tributaries along the way to the Churchill River Estuary at Hudson Bay. Between 2008 and 2013, CAMP monitoring occurred in Partridge Breast, Northern Indian, Fidler, and Billard lakes, and in the lower Churchill River at the confluence with the Little Churchill River. Flows for this region are monitored at the Missi Falls CS and on the lower Churchill River below Fidler Lake and above Red Head Rapids. Gauer Lake was also monitored as the off-system water body for this region. Gauer Lake levels were inferred from Gauer River flows.

With the exception of a short peak in August 2008, Missi Falls CS outflows were generally close to average from the start of 2008 to mid-2009, and well above average from mid-2009 to the end of 2009. Missi Falls CS outflows are driven by snowpack and precipitation in the upper Churchill River Basin, available storage in Southern Indian Lake and flows in the Nelson River. In 2010, Missi Falls CS outflows remained close to average for most of the year except for a short peak above the upper quartile from late-August to mid-October. At this time, high Nelson River flow resulted in less than maximum diversion flows through the Notigi CS and consequently, higher flows through the Missi Falls CS. In 2011, Missi Falls CS outflows remained close to average from January to late July. Flows were then increased to near record high by early September before being reduced back to near average by the end of the year. The high flow in 2011 was the result of very high precipitation in the basin and reduced flows out of the Notigi CS for most of the open-water season because of a record flood on the Nelson River. In 2012, Missi Falls CS outflows remained close to average from January to late May and then there were periods of above average outflow in parts of the rest of the year. This was mainly due to a lack of storage on Southern Indian Lake which was not drawn down in the winter of 2011/2012 because of high inflow conditions in late 2011. Missi Falls CS outflows remained close to average for most of 2013 except for a short peak in October-November because of high fall precipitation in the basin. Outflows remained close to average in early 2014 (Figure 2-1).

Between 2008 and early 2014, flows on the lower Churchill River below Fidler Lake and above Red Head Rapids and water levels on Partridge Breast, Northern Indian, and Billard lakes, and on the Churchill River above Swallow Rapids (near the confluence with the Little Churchill River) generally followed a similar trend to the Missi Falls CS outflows (Figures

2-2 to 2-7). In 2010, a very low snowpack resulted in flows being at record lows from June to mid-August.

Between 2008 and 2014, Gauer River flows were generally close to average during the winter months and increased each year in late-April to May because of runoff from snow melt. The exception was 2010 when a very low snowpack resulted in little to no spring freshet and flows being at record low from late-May to mid-August. Flows then increased rapidly in mid-August 2010 to reach near record highs by September before declining for the winter. Late summer/fall flow peaks also occurred in 2009 and 2011. Flows on the Gauer River are unregulated and respond to local precipitation and Gauer Lake levels (Figure 2-8).

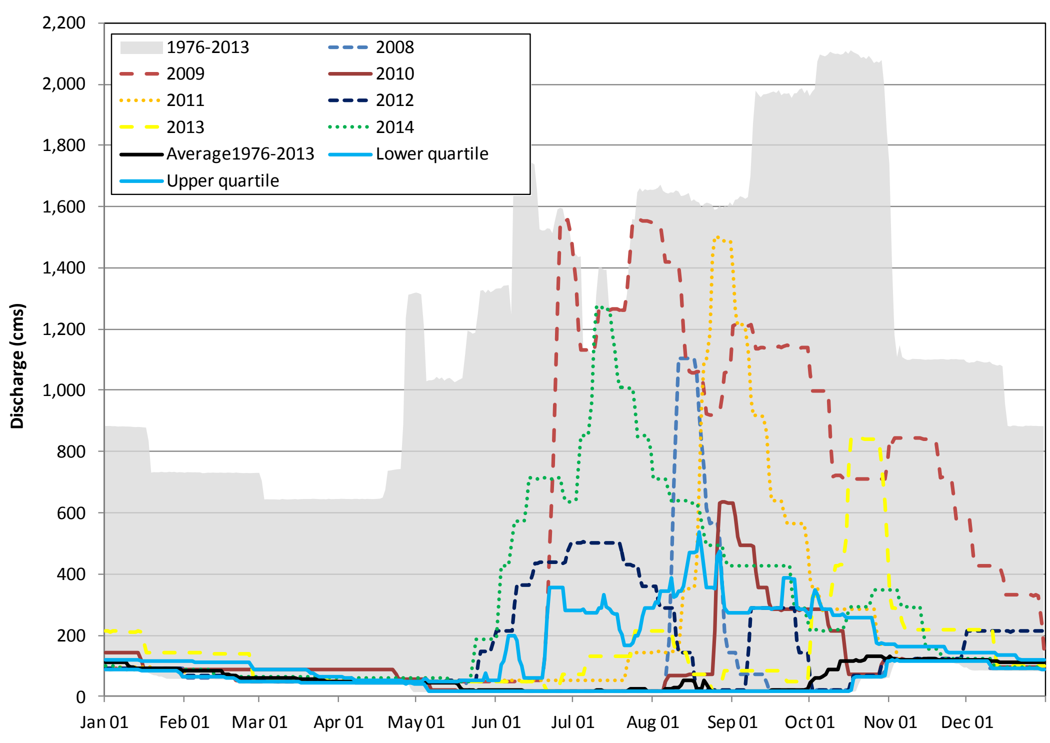


Figure 2-1. 2008-2014 Missi Falls Control Structure flow.

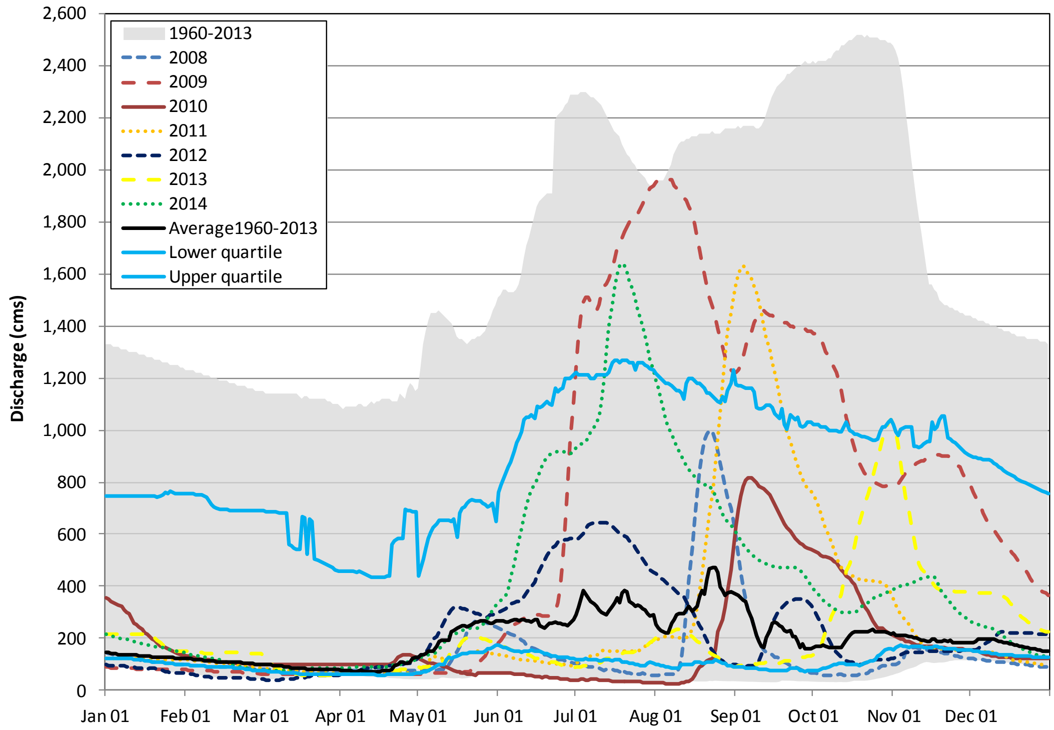


Figure 2-2. 2008-2014 Churchill River below Fidler Lake (06FB001) flow.

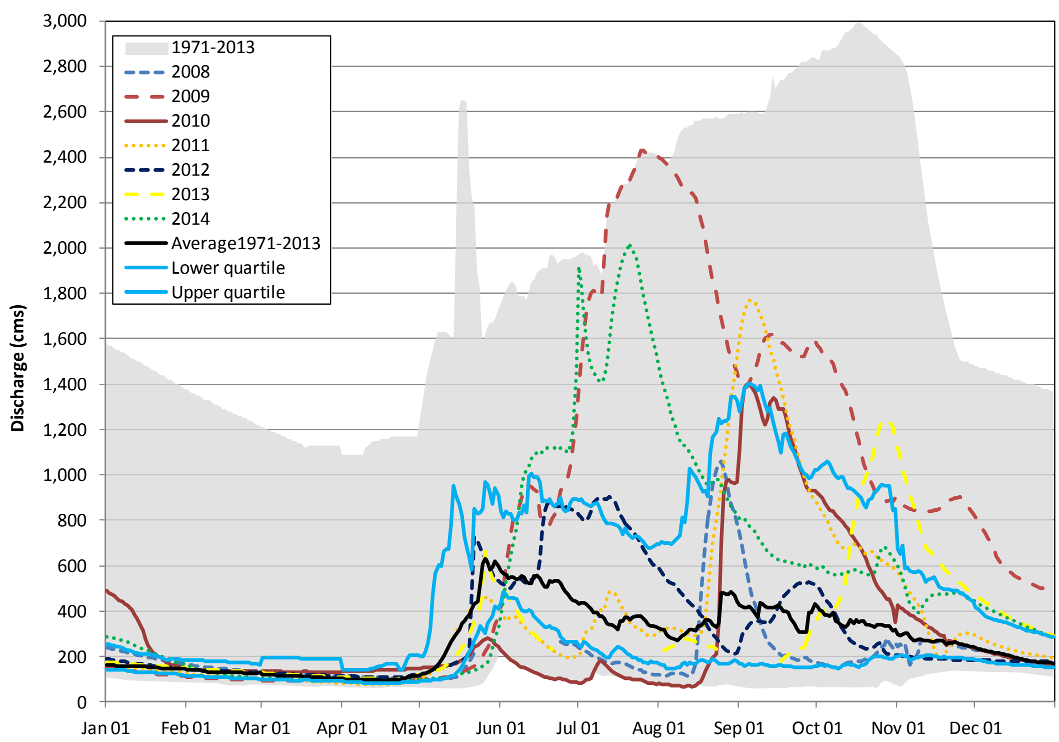


Figure 2-3. 2008-2014 Churchill River above Red Head Rapids (06FD001) flow.

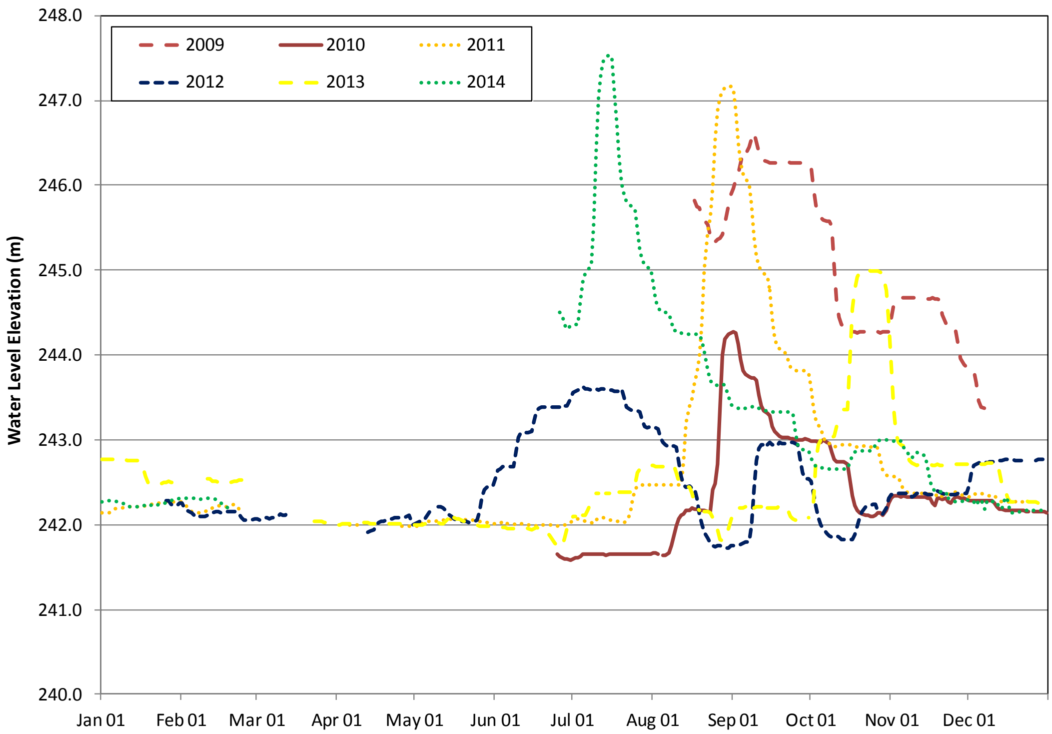


Figure 2-4. 2009-2014 Partridge Breast Lake (06FA703) water level elevation.

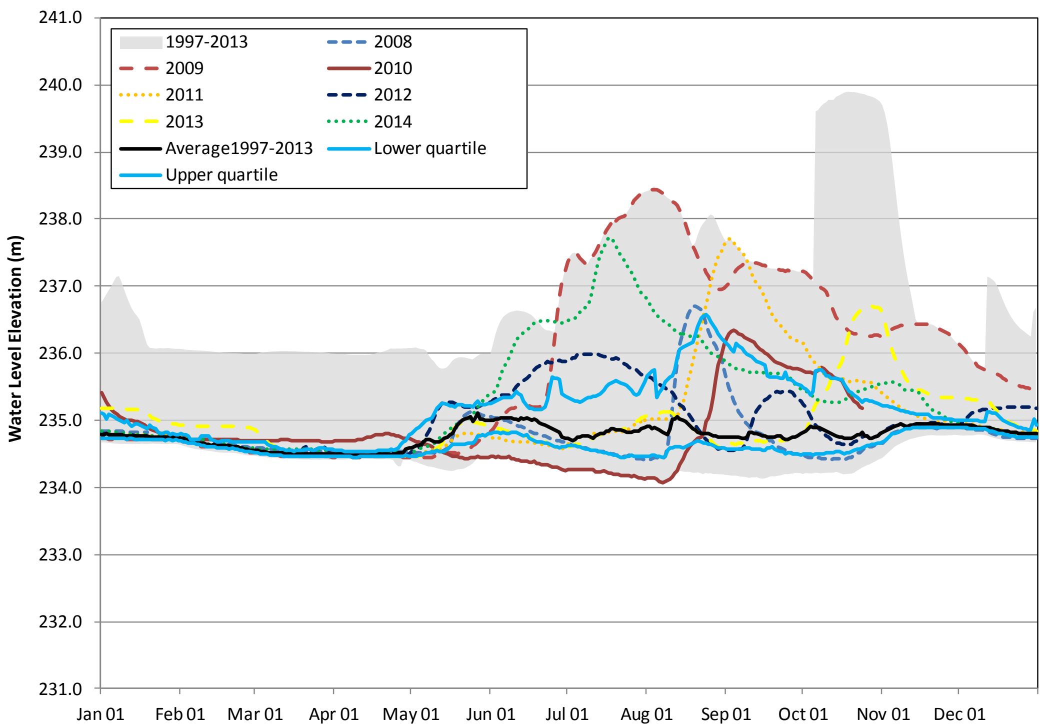


Figure 2-5. 2008-2014 Northern Indian Lake (06FA701) water level elevation.

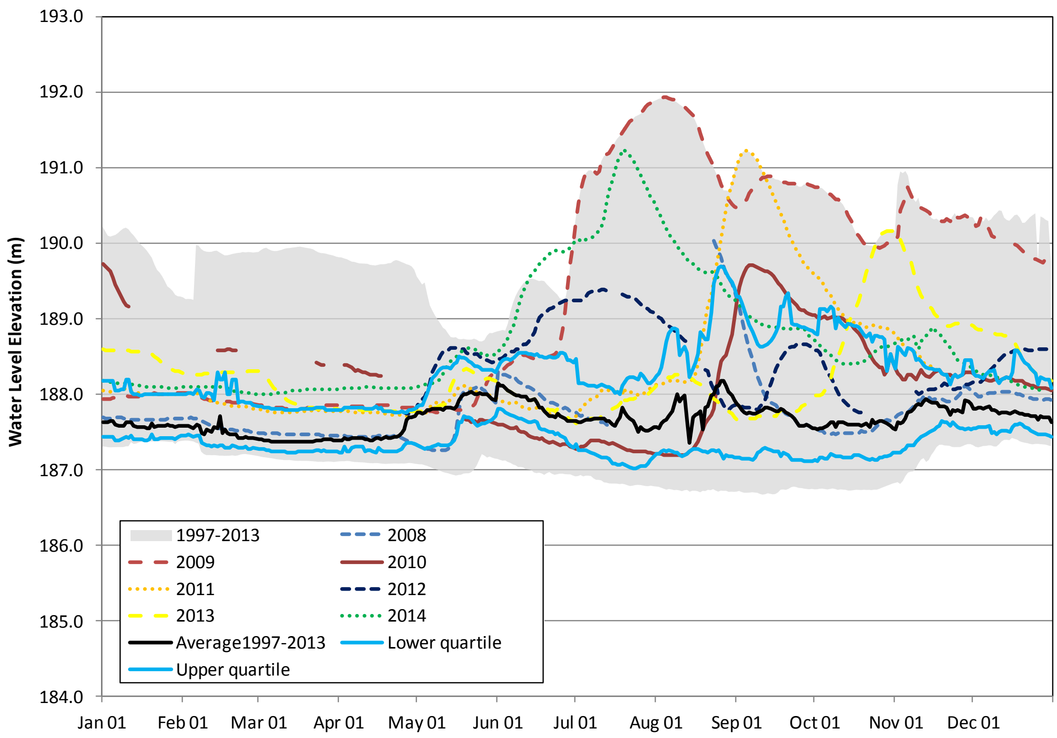


Figure 2-6. 2008-2014 Billard Lake (06FB702) water level elevation.

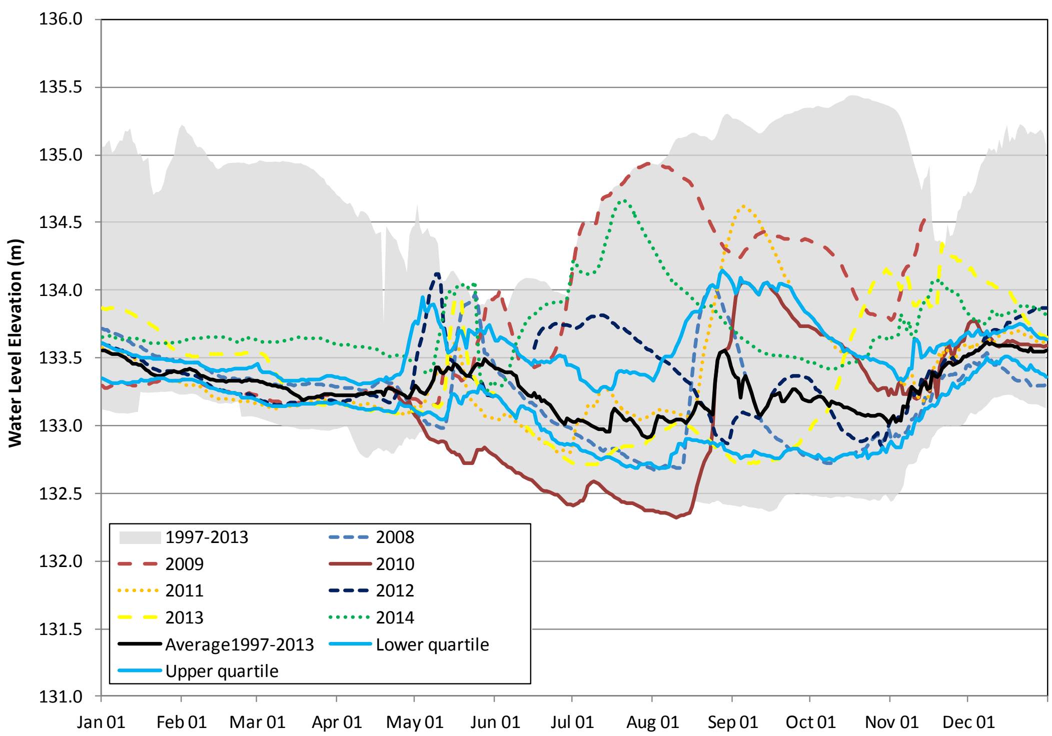


Figure 2-7. 2008-2014 Churchill River above Swallow Rapids (06FD702) water level elevation.

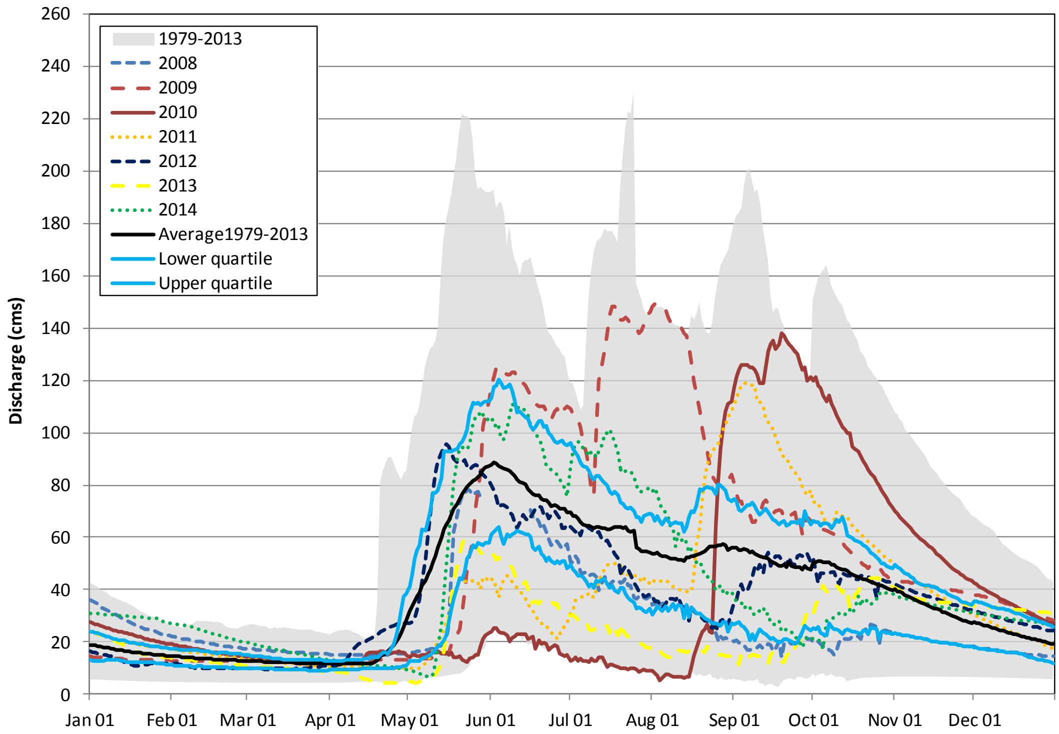


Figure 2-8. 2008-2014 Gauer River (06FA001) flow.

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 LCRR. Waterbodies/river reaches sampled annually included two on-system sites (Northern Indian Lake and the lower Churchill River at the Little Churchill River) and one off-system lake (Gauer Lake). Four additional on-system waterbodies or river reaches were sampled on a rotational basis including Partridge Breast, Billard, and Fidler lakes and the lower Churchill River at Red Head Rapids (Table 3-1; Figure 3-1). While formally part of the LNNR under CAMP, results for the off-system Hayes River were also considered in the interpretation of water quality data for the LCRR.

Sampling in winter was not completed at the lower Churchill River at the Little Churchill River site in 2009/2010 due to ice conditions and in 2013/2014 due to an inability to locate sufficient water for sampling. Sampling was also not completed at Red Head Rapids in spring 2011 due to low water levels which prevented site access with a fixed wing aircraft.

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

3.1.1 Objectives and Approach

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

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

The first objective was addressed through comparisons 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 statistical analysis of hydrological and water quality metrics to evaluate correlations between flow and water level and water quality metrics. Statistically significant relationships between hydrological (discharge) and water quality metrics (total suspended solids [TSS], turbidity, alkalinity, hardness, conductivity, magnesium and calcium) were observed in Manitoba Hydro and the Province of Manitoba's (2015) recent regional cumulative effects assessment (RCEA) for the pre-CRD and, notably, post-CRD periods at Red Head Rapids.

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 LCRR 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*, TSS, turbidity, and Secchi disk depth. A detailed description of key indicators is provided in Technical Document 1, Section 4.3.1.

Manitoba Hydro and the Province of Manitoba's (2015) recent RCEA identified several effects of CRD on water quality in the lower Churchill River. Long-term (i.e., permanent) effects included increases in alkalinity, conductivity (a measure of the amount of dissolved substances in water), hardness, and calcium and decreases in potassium. Effects were due to reduced inputs of the Churchill River via the Missi Falls CS. As noted above, these metrics were also correlated to discharge, including discharge of the upper Churchill River upstream of Southern Indian Lake. However, the analysis indicated that key CAMP indicators were largely unaffected by CRD. Therefore, 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 Lower Churchill River

Most of the lakes monitored under CAMP on the lower Churchill River are isothermal (Table 3-2; Figures 3-2 to 3-5). However, occasional thermal stratification was observed at Northern Indian Lake (spring 2008; thermocline at 8-9 m, and summer 2013; thermocline at 0-1 m; Figure 3-3). Stratification was also observed in spring 2008 upstream in Southern Indian Lake (Technical Document 5, Section 3.2.1.1), and in spring 2008 and summer 2013 at the off-system Gauer Lake (Figure 3-6), indicating these occurrences may have been related to regional influences (e.g., climatological conditions).

All lakes and river reaches were well-oxygenated year-round and DO concentrations consistently exceeded the most stringent Manitoba PAL objectives for cool-water and cold-water aquatic life

(5.5 and 9.5 mg/L, respectively) across the water column over the six years of monitoring (Figures 3-7 to 3-12). No DO data are available for the winter of 2013/2014 at any site due to a malfunction of the water quality meter. Additionally, DO conditions in the lower Churchill River at the Little Churchill River in the winter of 2009/2010 are unknown as sampling could not be completed at this site due to ice conditions. However, lakes sampled during this period were well-oxygenated. DO conditions were similar across the lower Churchill River sites and there is no indication of spatial trends along the length of the river over the first six years of CAMP (Figure 3-13).

3.2.1.2 Off-system Waterbodies: Gauer Lake and the Hayes River

Gauer Lake was thermally stratified at the same approximate times (spring 2008 and summer 2013; Figure 3-6) as the on-system Northern Indian Lake (Figure 3-3). With one exception (winter 2008/2009), Gauer Lake was well-oxygenated across depth and DO concentrations exceeded the most stringent Manitoba PAL objectives for cool-water and cold-water aquatic life (5.5 and 9.5 mg/L, respectively; Figure 3-14).

DO may decrease in north temperate ecosystems that experience long periods of ice cover due to the lack of an oxygen source from the atmosphere (i.e., no or minimal reaeration due to ice). In winter 2008/2009 DO concentrations decreased across the water column and concentrations dropped below the PAL objective for cold-water species at approximately 3 m from the surface, and the PAL objective for cool-water species at approximately 6 m from the surface, in Gauer Lake. This is in contrast to lakes located along the lower Churchill River where DO was consistently within PAL objectives over the first six years of CAMP. Because sampling conducted in Gauer Lake in winters other than 2008/2009 was done at shallower depths, it is unknown if DO depletion may have occurred at deeper sites in other winters.

The Hayes River was well-oxygenated during all sampling periods and all DO concentrations were within the Manitoba PAL objectives for cool-water and cold-water aquatic life (Figure 3-15).

3.2.1.3 Temporal Comparisons and Trends

There were no statistically significant differences in concentrations or percent saturation of DO (open-water season) between years at the two on-system monitoring sites sampled annually (Northern Indian Lake and the lower Churchill River at the Little Churchill River) or at the off-system Gauer Lake. Some inter-annual differences in percent saturation were observed for the Hayes River site (see Technical Document 9, Section 3.2.1.3), though saturation exceeded 90% on average in each open-water season indicating sites were well-oxygenated. There was no indication of an increasing or decreasing trend in oxygen conditions over the six year monitoring period at any of the annual monitoring 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 Lower Churchill River

TSS concentrations are relatively low in this region (i.e., annual means typically < 5 mg/L) and TSS was below the analytical detection limit (DL) of 2 mg/L in approximately 25-37% of samples collected at on-system sites over the six years of monitoring. Concentrations of TSS (Figures 3-16 and 3-17) increased slightly with distance downstream but a clear spatial pattern was not evident for turbidity (Figures 3-17 and 3-18). Secchi disk depths (measured at lake sites only) were greater than 1 m on average, with notable inter-annual variability (annual means measured at Northern Indian Lake ranged from 1.30 to 2.35 m; Figure 3-19).

3.2.2.2 Off-system Waterbodies: Gauer Lake and the Hayes River

Turbidity (Figure 3-17) was lower in the off-system Gauer Lake than lakes along the lower Churchill River. Conversely, TSS (Figure 3-16) and Secchi disk depth (Figure 3-20) measurements in Gauer Lake were similar to conditions measured in lakes along the lower Churchill River. TSS and turbidity were notably higher in some years in the off-system Hayes River than either lake or river sites on the lower Churchill River (Figures 3-16 and 3-17). However, as discussed in Technical Document 1, Section 1.2.2.1, it is recognized that off-system waterbodies monitored under CAMP may fundamentally differ from on-system waterbodies and would not necessarily be expected to exhibit similar chemical or biological characteristics.

3.2.2.3 Temporal Comparisons and Trends

Statistical comparisons of water clarity metrics between years at the annual on-system sites (Northern Indian Lake and the lower Churchill River at the Little Churchill River) indicate no significant differences between years and visual examination of the data for the six-year period does not suggest increasing or decreasing trends in these metrics. The same observations apply for the two off-system sites (Gauer Lake and the Hayes River).

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 Lower Churchill River

Lakes located along the lower Churchill River were mesotrophic on the basis of mean open-water season TP concentrations, and oligotrophic to mesotrophic based on TN and chlorophyll *a* (Table 3-2 and Figure 3-21). Riverine sites ranked as mesotrophic to meso-eutrophic based on mean open-water season TP, but ranked lower (oligotrophic) on the basis of TN and chlorophyll *a* concentrations (Table 3-2 and Figure 3-22); the lower trophic ranking based on TN and chlorophyll *a* for the riverine sites relative to lakes reflects differences in trophic categorization schemes for lakes and rivers, rather than lower concentrations of TN or chlorophyll *a*.

On average, TP concentrations were below the Manitoba narrative nutrient guideline (0.025 mg/L for lakes, reservoirs and streams near the inflows to waterbodies and 0.050 mg/L for streams; MWS 2011) in each year of monitoring at all sites on the lower Churchill River (Figure 3-23). However, occasional exceedances were observed at Northern Indian Lake (8% of samples) and Partridge Breast Lake (13% of samples). With the exception of a single sample collected from the lower Churchill River at the Little Churchill River (6% frequency of exceedance; Table 3-3), chlorophyll *a* was less than 10 µg/L (the level identified under CAMP as indicative of an algal bloom) in the open-water seasons at sites along the lower Churchill River.

Neither TP nor TN was significantly correlated to chlorophyll *a* in Northern Indian Lake or in the lower Churchill River near the Little Churchill River based on the first six years of monitoring data (Figure 3-24). This suggests that nutrients are not the primary factor limiting phytoplankton growth or that bioavailability of nutrients is limited, but may also be a reflection of the relatively limited amount of data. Most on-system waterbodies sampled annually under CAMP showed either a weak or lack of a correlation between nutrients and chlorophyll *a* for the six year monitoring period. The ratio of chlorophyll *a* to TP (which ranged from 0.23-0.26 in this region) - an indicator of the efficiency of assimilating phosphorus into algae - indicates lakes along the lower Churchill River produce a relatively low amount of chlorophyll *a* per unit phosphorus, and ratios were lower than the off-system Gauer Lake (mean ratio of 0.42; Figure 3-25).

There is no spatial pattern evident along the length of the Churchill River for TN, TP, or chlorophyll *a* for the six years of monitoring (Figure 3-26), though mean chlorophyll *a* was somewhat higher at Red Head Rapids in the year it was sampled (6.02 µg/L in 2011) relative to other sites sampled concurrently (means ranging from 3.44 µg/L at Fidler Lake to 4.9 µg/L at the lower Churchill River at the Little Churchill River; Figures 3-21 and 3-22).

3.2.3.2 Off-system Waterbodies: Gauer Lake and the Hayes River

On average, Gauer Lake has a similar trophic status (i.e., mesotrophic based on mean open-water TP, TN, and chlorophyll *a*) compared to lakes on the lower Churchill River (Table 3-2 and Figure 3-26). Trophic status of the Hayes River was also similar to that of the lower Churchill River; the Hayes River was, on average, mesotrophic on the basis of TP but oligotrophic based on TN and chlorophyll *a* concentrations (Table 3-2 and Figure 3-27). TN and TP were not correlated to chlorophyll *a* in Gauer Lake or the Hayes River (Figure 3-29). As noted in Section 3.2.3.1, this may indicate factors other than nutrients are limiting to phytoplankton growth or that bioavailability of nutrients is limited, but may also reflect the relatively limited data.

None of the samples collected from the Hayes River exceeded the Manitoba narrative nutrient guideline for TP for streams and rivers (0.050 mg/L). Three (approximately 13%) samples collected in Gauer Lake (in three different years) exceeded the guideline for lakes and reservoirs (0.025 mg/L), which is similar to the frequency of exceedance observed for the lower Churchill River lakes.

3.2.3.3 Temporal Comparisons and Trends

Chlorophyll *a* was lowest in the open-water season of 2010 at the annual sampling sites on the lower Churchill River, in the nearby off-system Gauer Lake, and the more distant off-system Hayes River (Figure 3-29). However, inter-annual differences were only statistically significant at two of these sites (Northern Indian Lake and the Hayes River). Chlorophyll *a* was not measured at the Hayes River site in summer 2010 which may have, at least in part, contributed to the lower mean concentration observed in that year. There were no significant inter-annual differences for TN or TP at any of the annual monitoring sites and none of the metrics appeared to experience an increasing or decreasing trend over the six years of monitoring.

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. No overt temporal trends were evident for the lower Churchill River and no unusual conditions were observed for other water quality metrics measured over the period of 2008-2013 (see Technical Document 1, Section 3.3 for a list of additional metrics).

pH, ammonia, and nitrate remained within PAL guidelines and objectives at all sites, both on- and off-system, and times. Additionally, most metals were consistently within Manitoba water quality PAL objectives and guidelines. Exceptions included aluminum, iron, and selenium. Aluminum was above the PAL guideline (0.1 mg/L) in 67-100% of samples from the lower Churchill River sites (Table 3-4). Exceedances of this metal were also observed in the off-system Hayes River but not in Gauer Lake. Other PAL guideline exceedances included occasional exceedances of the iron PAL guideline (0.3 mg/L) at several sites on the lower Churchill River and one exceedance of the PAL guideline for selenium at Partridge Breast Lake (Table 3-4). These observations and conditions are common in northern Manitoba lakes and rivers and are also observed in lakes and rivers unaffected by hydroelectric development (Ramsey 1991; Keeyask Hydropower Limited Partnership [KHLP] 2012; Manitoba Hydro and the Province of Manitoba 2015), including off-system CAMP waterbodies.

Chloride was within the Canadian Council of Ministers of the Environment (CCME 1999; updated to 2017) PAL guideline and sulphate remained within the British Columbia Ministry of the Environment (BCMOE) PAL guideline (218-429 mg/L; Meays and Nordin 2013) at all on- and off-system sites monitored in this region.

3.4 RELATIONSHIPS WITH HYDROLOGICAL METRICS

Exploratory analyses of potential relationships between river discharge and water quality metrics indicated several statistically significant relationships for the lower Churchill River at the Little Churchill River for the open-water season (Table 3-5; Figures 3-30 to 3-32). The strongest correlations occurred for TP (Figure 3-30), TSS (Figure 3-31), and turbidity (Figure 3-32), each of which was positively correlated to river discharge. Similar observations (i.e., significant relationships and direction of correlations) were identified based on analysis of a long-term water quality dataset collected at Red Head Rapids (Manitoba Hydro and the Province of Manitoba 2015). Positive correlations between TSS and turbidity and discharge are frequently observed in aquatic systems and may reflect rainfall/runoff events, snowmelt, erosion, sediment resuspension and/or changes in sediment transport and deposition with changes in flow. Nutrients also commonly increase with discharge for similar reasons and TP is frequently associated with TSS. Concentrations of TP are higher in Lake Winnipeg, for example, during wet years and are also increased by sediment resuspension in the lake (Environment Canada [EC] and MWS 2011).

3.5 SUMMARY

Lakes and river reaches along the lower Churchill River were well-oxygenated year-round and typically well-mixed. Water clarity was relatively high in this region and concentrations of TSS were below the analytical detection limit of 2 mg/L in 25-37% of samples collected at on-system sites over the six years of monitoring.

Lakes located along the lower Churchill River were mesotrophic on the basis of mean open-water season TP concentrations, and oligotrophic to mesotrophic based on TN and chlorophyll *a*. Riverine sites ranked as mesotrophic to meso-eutrophic based on mean open-water season TP, but ranked lower (oligotrophic) on the basis of TN and chlorophyll *a* concentrations; the lower trophic ranking based on TN and chlorophyll *a* for the riverine sites relative to lakes reflects differences in trophic categorization schemes for lakes and rivers, rather than lower concentrations of TN or chlorophyll *a*.

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

None of the metrics appear to have undergone an increasing or decreasing trend over the six year period, though some significant inter-annual variability was observed for some metrics (e.g., chlorophyll *a*). Preliminary analyses of correlations between water quality metrics and hydrological conditions (i.e., discharge) indicated some significant relationships occurred in the six year monitoring period. Similar observations (i.e., significant relationships and direction of correlations) were identified based on a long-term water quality dataset collected at Red Head Rapids (Manitoba Hydro and the Province of Manitoba 2015). These relationships will be further explored as additional data are acquired through CAMP.

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

Waterbody/Area/River Reach	**Site Abbreviation**	**Site ID**	**On-syst em**	**Off-syst em**	**Annual**	**Rotational**	**Sampling Years**					
							2008/09	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**
Partridge Breast Lake	PBL	FAS 009	**X**			**X**		**X**			**X**	
Northern Indian Lake	NIL	FAS 008	**X**		**X**		**X**	**X**	**X**	**X**	**X**	**X**
Fidler Lake	FID	FBS 004	**X**			**X**				**X**		
Billard Lake	BIL	FBS 003	**X**			**X**			**X**			**X**
Lower Churchill River at Little Churchill River	LCR-LiCR	FDS 004	**X**		**X**		**X**	**X**	**X**	**X**	**X**	**X**
Lower Churchill River at Red Head Rapids	LCR-RHR	FDS 003	**X**			**X** [1]				**X**		
Gauer Lake	GAU	FAS 007		**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**
Hayes River [2]	HAYES	ABS 002		**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**

[1] Site was subsequently moved to the lower Churchill River at the Churchill Weir in 2014.

[2] Site formally included in the LNRR; included here for discussion of results.

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

Metric		**Waterbody**							
		PBL	**NIL**	**FID**	**BIL**	**LCR-LiCR**	**LCR-RHR**	**GAU**	**HAYES**
Years Sampled		2009/10, 2012/13	2008/09-2013/14	2011/12	2010/11, 2013/14	2008/09-2013/14	2011/12	2008/09-2013/14	2008/09-2013/14
TP	(mg/L)	0.0153	0.0158	0.0134	0.0151	0.0154	0.0134	0.0171	0.0163
	Trophic Status	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
TN	(mg/L)	0.29	0.33	0.45	0.29	0.38	0.46	0.42	0.44
	Trophic Status	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic
TKN	(mg/L)	0.27	0.31	0.44	0.27	0.37	0.43	0.40	0.41
Chlorophyll *a*	(µg/L)	2.79	3.00	3.20	2.87	3.14	4.11	5.30	2.07
	Trophic Status	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic
TN:TP	-	46	51	76	47	60	90	60	70
DOC	(mg/L)	6.5	7.4	6.9	7.9	7.6	8.3	8.6	9.6
Nitrate/nitrite	(mg N/L)	0.0129	0.0191	0.0130	0.0235	0.0184	0.0279	0.0206	0.0244
Ammonia	(mg N/L)	0.014	0.010	0.005	0.012	0.011	0.005	0.008	0.010
Dissolved Phosphorus	(mg/L)	0.008	0.007	0.008	0.006	0.007	0.005	0.007	0.006
DO Lower than MWQSOGs for PAL	(Y/N)	N	N	N	N	N	N	Yes (Winter 200/2009)	N
DO - open-water season (surface)	(mg/L)	10.74	9.95	9.75	10.31	10.32	9.90	10.01	10.11
DO - open-water season (bottom)	(mg/L)	10.23	9.44	9.67	10.04	10.34	8.90	9.84	10.36
DO - ice-cover season (surface)	(mg/L)	15.78	14.94	-	13.73	15.02	-	14.15	13.02
DO - ice-cover season (bottom)	(mg/L)	15.46	13.75	-	13.05	14.33	-	11.23	12.05
Thermal Stratification	(Y/N)	N	Yes (spring 2008, summer 2013)	N	N	N	N	Yes (spring 2008, summer 2013)	N
Secchi Disk Depth (open-water season)	(m)	1.13	1.57	1.58	1.46	1.77	-	1.87	1.43
TSS	(mg/L)	3.4	2.9	3.5	3.9	5.3	8.5	2.6	12.9
Turbidity	(NTU)	6.25	3.86	3.54	4.06	4.18	5.39	1.64	7.06
True Colour	(TCU)	22.3	17.7	15.4	14.4	20.3	26.2	19.2	28.4
Specific Conductance	(µmhos/cm)	125	135	128	141	134	145	156	156
Total Dissolved Solids	(mg/L)	83.6	88.2	80.5	88.6	86.1	92.0	101.8	101.5
Hardness	(mg/L)	63.6	68.2	70.8	69.4	70.3	78.3	83.4	87.6
Hardness Category	-	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard	Moderately Soft/Hard
pH	-	8.14	8.04	8.05	8.15	8.15	8.11	8.14	8.14
Total Alkalinity	(mg/L)	62.5	67.9	66.6	69.9	68.4	78.5	81.5	81.8
Metals > MWQSOGs for PAL	-	Al, Fe, Se	Al, Fe	Al	Al	Al, Fe	Al		Al, Cu, Ag
Aluminum	(mg/L)	0.306	0.173	0.193	0.219	0.166	0.179	0.021	0.149
Iron	(mg/L)	0.181	0.126	0.099	0.123	0.132	0.190	0.041	0.248
Mercury (<26 ng/L DL only)	(ng/L)	<20	<20	-	2.6	<20	-	<20	<20
Mercury (≤1 ng/L DL only)	(ng/L)	<1	1.1	-	2.6	1.2	-	1.0	1.9
Calcium	(mg/L)	17.2	19.2	19.8	19.5	19.7	22.5	24.0	26.5
Magnesium	(mg/L)	5.00	4.94	5.22	5.03	5.11	5.38	5.68	5.18
Potassium	(mg/L)	1.127	0.976	0.991	0.978	0.931	0.824	0.770	0.602
Sodium	(mg/L)	2.72	2.14	2.25	2.24	2.15	2.20	1.59	1.90
Chloride	(mg/L)	0.96	0.94	0.81	0.86	0.96	1.00	0.72	1.11
Sulphate	(mg/L)	3.14	2.55	1.70	1.98	2.32	1.60	1.92	1.59

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

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

Indicator	**Metric**		**Units**	**Waterbody**							
				PBL	**NIL**	**FID**	**BIL**	**LCR-LiCR**	**LCR-RHR**	**GAU**	**HAYES**
Nutrients	TP	Mean	(mg/L)	0.0148	0.0162	0.0146	0.0153	0.0164	0.0165	0.0184	0.0184
		Trophic Status	-	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
	TN	Mean	(mg/L)	0.25	0.30	0.50	0.25	0.39	0.51	0.41	0.44
		Trophic Status	-	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic
	Chlorophyll *a*	Mean	(µg/L)	3.62	3.62	3.44	3.36	3.77	6.02	6.68	2.58
		Trophic Status	-	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic
	TN:TP	Mean	-	39	46	78	41	54	78	53	58
		Nutrient Limitation	-	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation
	Chlorophyll *a*:TP	Mean	-	0.25	0.25	0.26	0.23	0.24	0.44	0.42	0.15
	Chlorophyll *a*:TN	Mean	-	0.022	0.015	0.007	0.017	0.011	0.012	0.019	0.006
	Algal Bloom Frequency (Chlorophyll *a* >10 µg/L)	-	(%)	0	0	0	0	6	0	22	0
Dissolved Oxygen	DO Lower than MWQSOGs for PAL	-	(Y/N)	N	N	N	N	N	N	N	N
	DO	Surface Mean	(mg/L)	10.74	9.95	9.75	10.31	10.32	9.90	10.01	10.11
		Bottom Mean	(mg/L)	10.23	9.44	9.67	10.04	10.34	8.90	9.84	10.36
	Thermal Stratification	-	(Y/N)	N	Yes (spring 2008, summer 2013)	N	N	N	N	Yes (spring 2008, summer 2013)	N
Water Clarity	Secchi Disk Depth	Mean	(m)	1.13	1.57	1.58	1.46	1.77	-	1.87	1.43
	TSS	Mean	(mg/L)	4.1	3.5	4.3	4.8	6.3	12.2	3.1	16.2
	Turbidity	Mean	(NTU)	6.21	3.84	3.72	4.11	4.51	7.00	1.95	8.72

Table 3-4. Frequency of exceedances of objectives and guidelines for PAL for metals measured in the Lower Churchill River Region: 2008-2013. Values in red indicate exceedances occurred at a given site.

Waterbody		**MWQSOGs PAL (mg/L)**																**CCME PAL Chloride (mg/L)**	**BCMOE PAL Sulphate (mg/L)**
		Aluminum	**Arsenic**	**Boron**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Mercury**[1]	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Uranium**	**Zinc**		
Objective or Guideline		0.1	0.15	1.5	0.000174 – 0.000283	0.0531 – 0.0904	0.00562 – 0.00981	0.3	0.001497 – 0.00343	0.000026	0.073	0.0316 – 0.0548	0.001	0.0001	0.0008	0.015	0.0725 – 0.126	120	218-309
Partridge Breast Lake	n	8	8	8	8	8	8	8	8	4	8	8	8	8	8	8	8	8	8
	# Exceedances	**7**	0	0	0	0	0	**2**	0	0	0	0	**1**	0	0	0	0	0	0
	% Exceedance	**88**	0	0	0	0	0	**25**	0	0	0	0	**13**	0	0	0	0	0	0
Northern Indian Lake	n	24	24	24	24	24	24	24	24	8	24	24	24	24	24	24	24	24	24
	# Exceedances	**19**	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**79**	0	0	0	0	0	**8**	0	0	0	0	0	0	0	0	0	0	0
Fidler Lake	n	4	4	4	4	4	4	4	4	0	4	4	4	4	4	4	4	4	4
	# Exceedances	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Billard Lake	n	8	8	8	8	8	8	8	8	4	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower Churchill River at the Little Churchill River	n	22	22	22	22	22	22	22	22	7	22	22	22	22	22	22	22	22	22
	# Exceedances	**15**	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**68**	0	0	0	0	0	**5**	0	0	0	0	0	0	0	0	0	0	0
Lower Churchill River at Red Head Rapids	n	3	3	3	3	3	3	3	3	0	3	3	3	3	3	3	3	3	3
	# Exceedances	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gauer Lake	n	24	24	24	24	24	24	24	24	8	24	24	24	24	24	24	24	24	24
	# Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hayes River	n	23	23	23	23	23	23	23	23	8	23	23	23	23	23	23	23	23	23
	# Exceedances	**13**	0	0	0	0	**1**	**7**	0	0	0	0	0	**1**	0	0	0	0	0
	% Exceedance	**57**	0	0	0	0	**4**	**30**	0	0	0	0	0	**4**	0	0	0	0	0

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

Table 3-5. Linear regressions between water quality and discharge in the lower Churchill River at the Little Churchill River site for the open-water season. Values in red indicate significant correlations.

Metric	Units		R^2	p-value	Direction
Dissolved Phosphorus	(mg/L)	Log	**0.301**	**0.018**	+
Total Phosphorus	(mg/L)	Log	**0.441**	**0.003**	+
Total Suspended Solids	(mg/L)	Log	**0.457**	**0.002**	+
Turbidity	(NTU)	Log	**0.601**	**0.0002**	+
In Situ Turbidity	(NTU)	Log	**0.565**	**0.001**	+
Laboratory Conductivity	(µS/cm)	Log	**0.278**	**0.024**	−
In Situ Specific Conductance	(µS/cm)		**0.398**	**0.005**	−
Total Alkalinity as $CaCO_3$	(mg/L)	Log	**0.269**	**0.027**	−
Potassium	(mg/L)		**0.333**	**0.012**	+

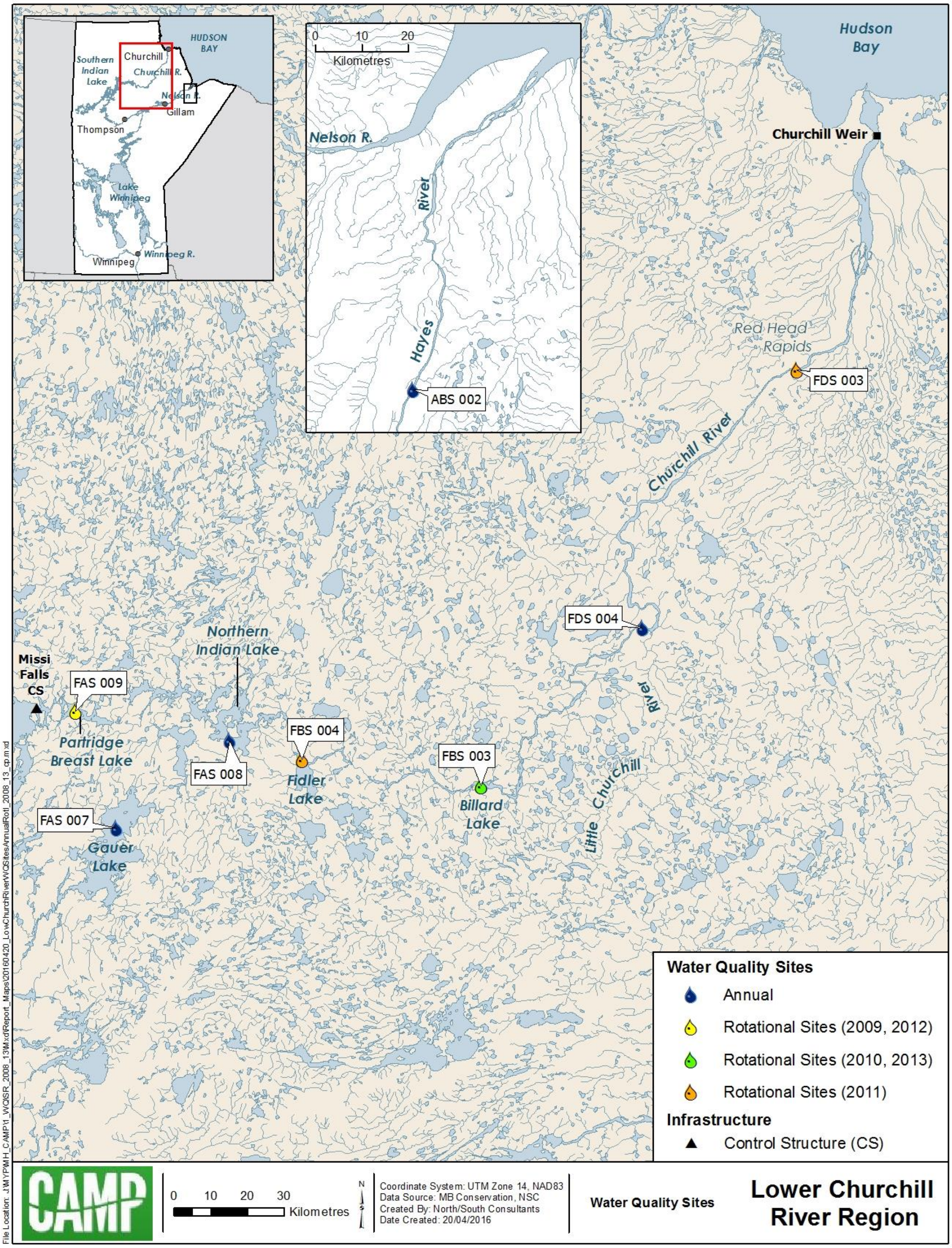
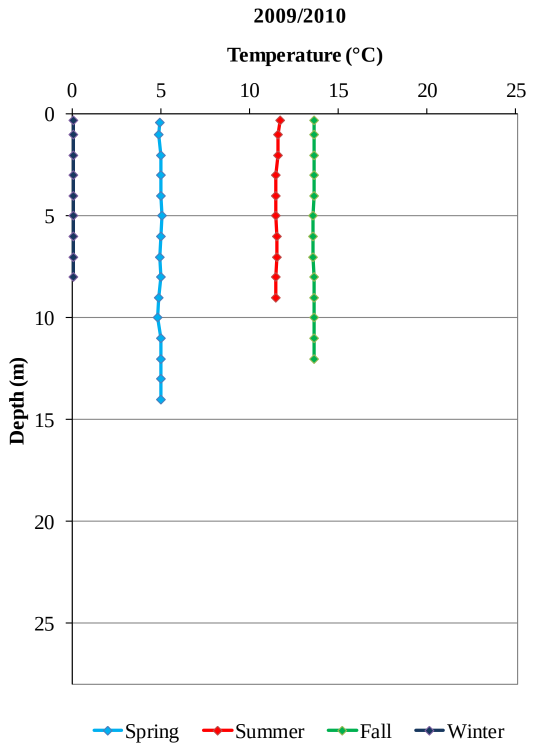


Figure 3-1. Water quality sampling sites in the Lower Churchill River Region: 2008/2009-2013/2014.



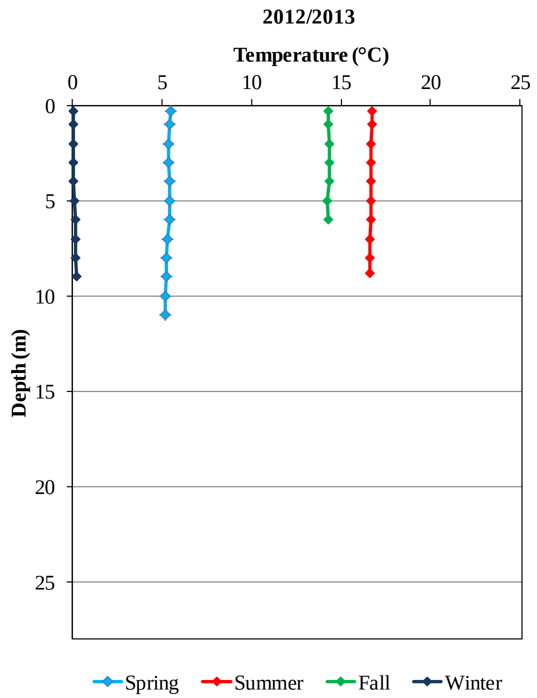


Figure 3-2. Temperature depth profiles in Partridge Breast Lake: 2008/2009-2013/2014.

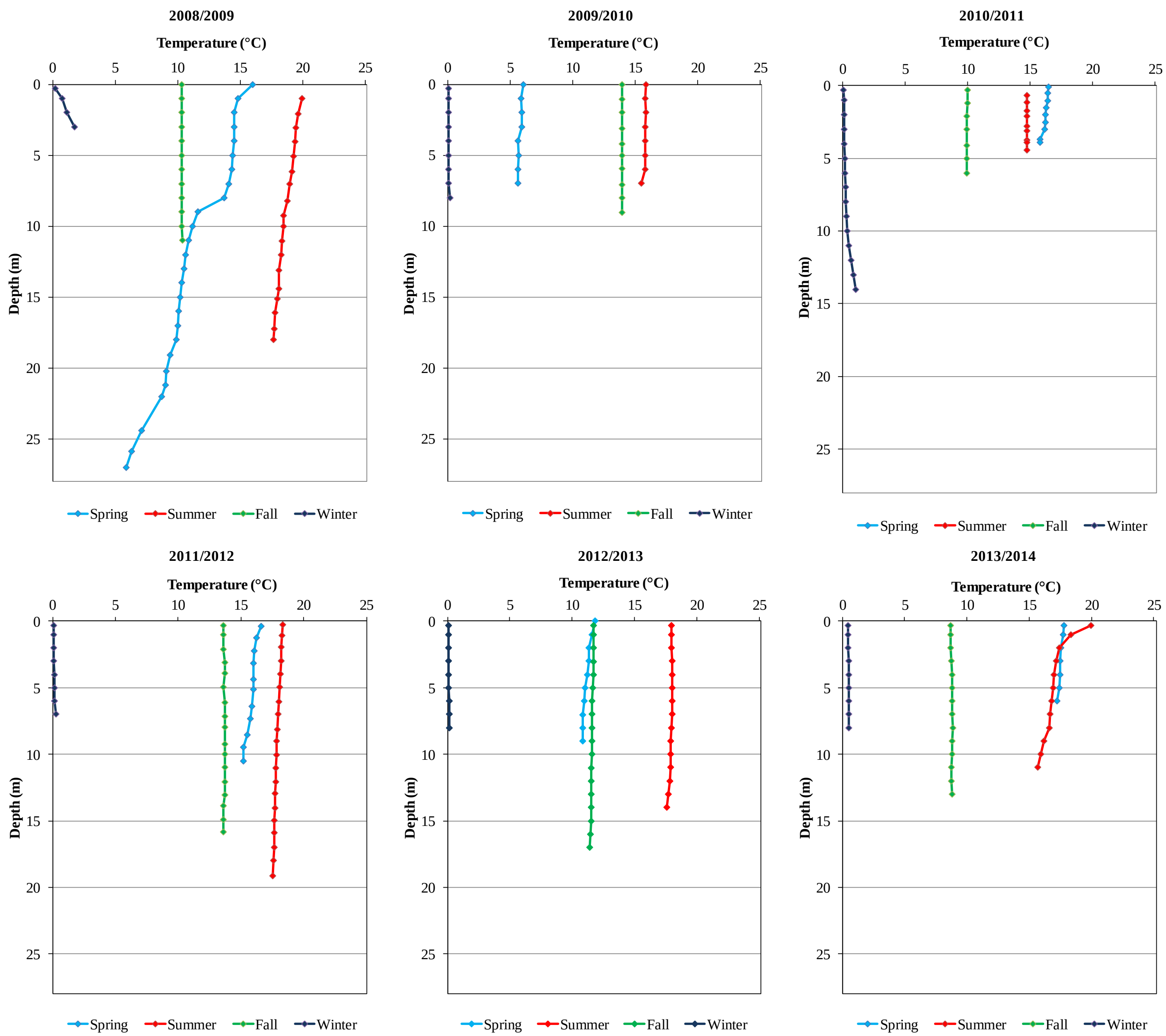


Figure 3-3. Temperature depth profiles in Northern Indian Lake: 2008/2009-2013/2014.

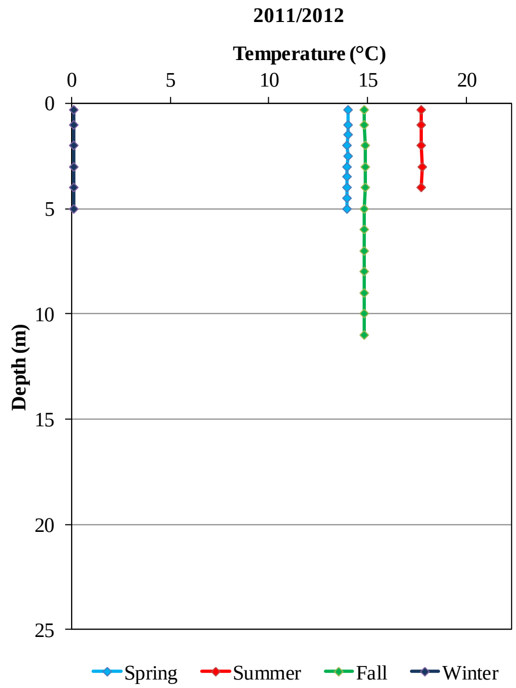
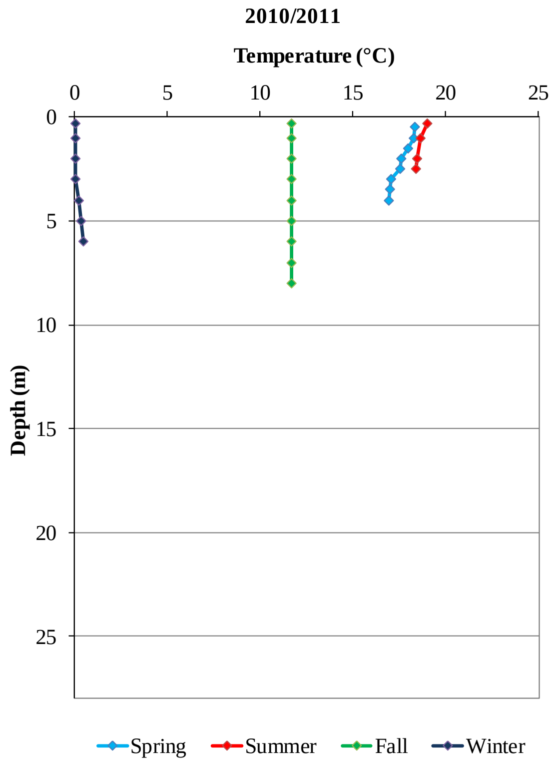


Figure 3-4. Temperature depth profiles in Fidler Lake: 2008/2009-2013/2014.



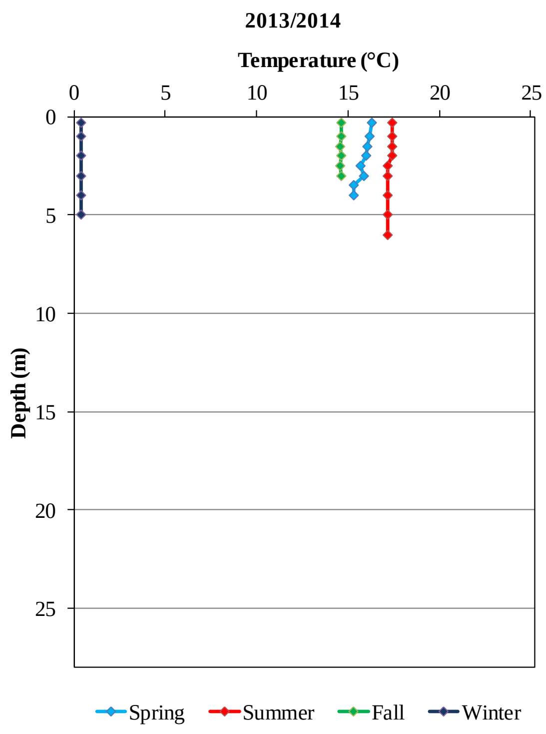


Figure 3-5. Temperature depth profiles in Billard Lake: 2008/2009-2013/2014.

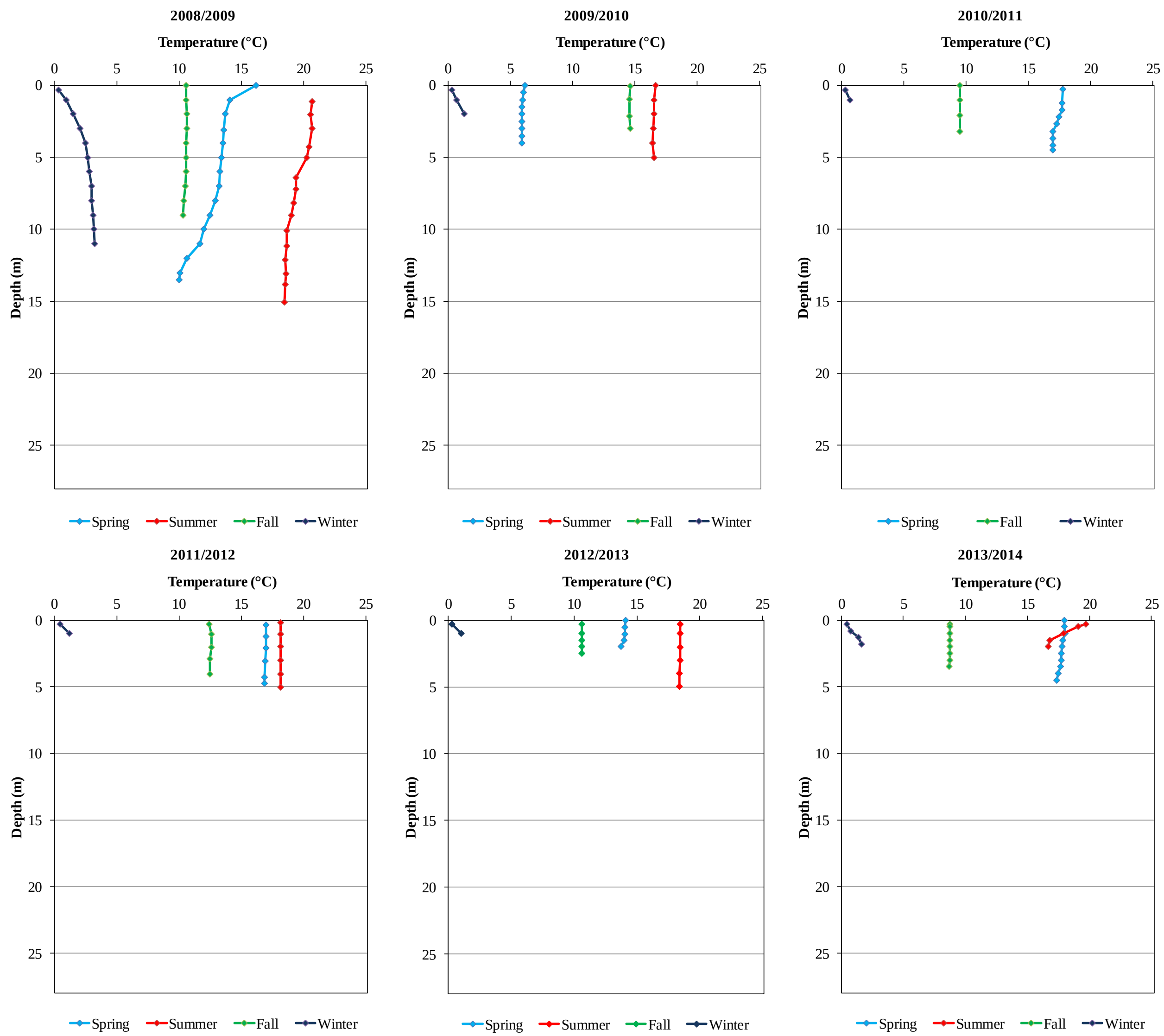
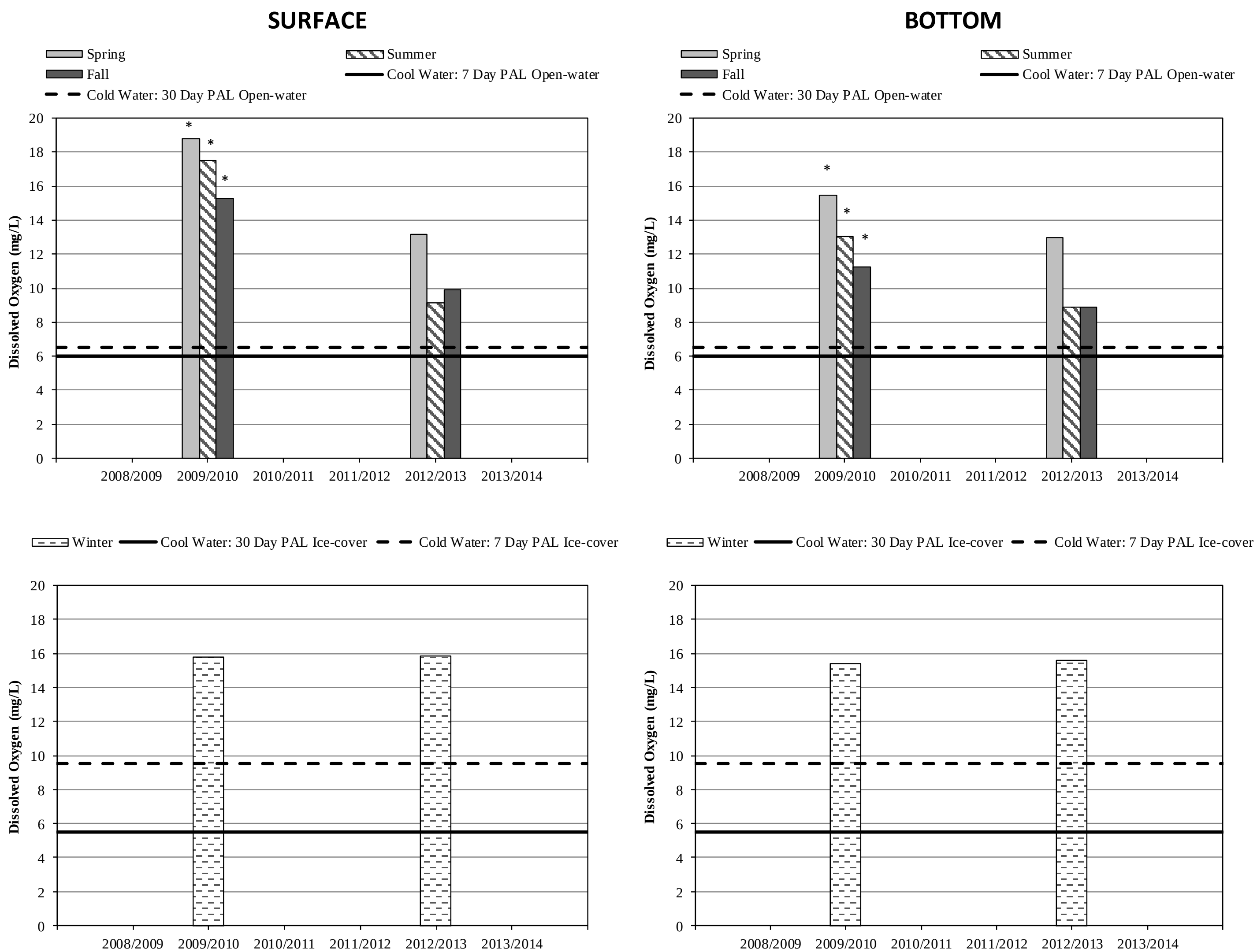


Figure 3-6. Temperature depth profiles in the off-system Gauer Lake: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations likely overestimated.

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

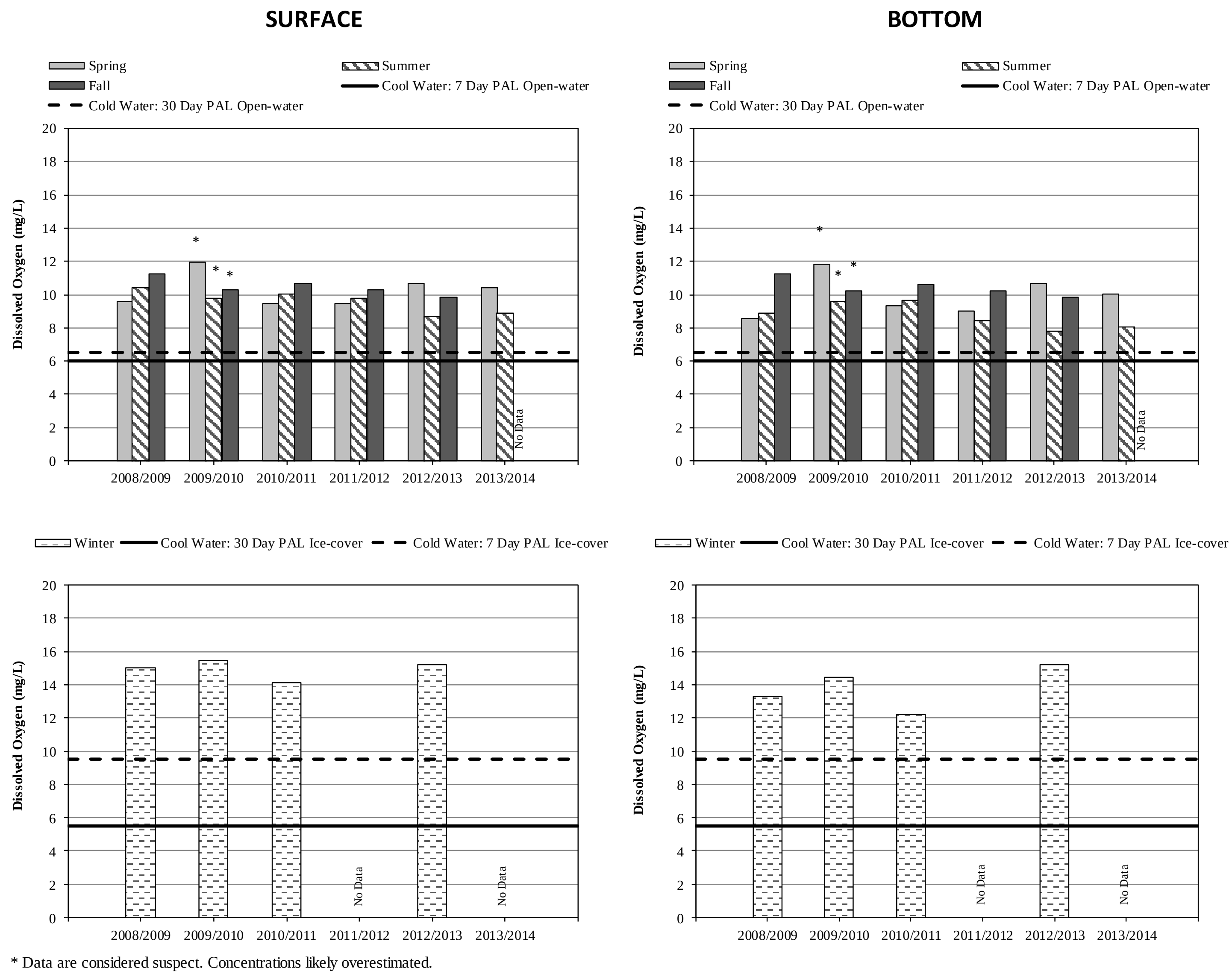


Figure 3-8. Dissolved oxygen measured near the surface and bottom of the water column in Northern Indian Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

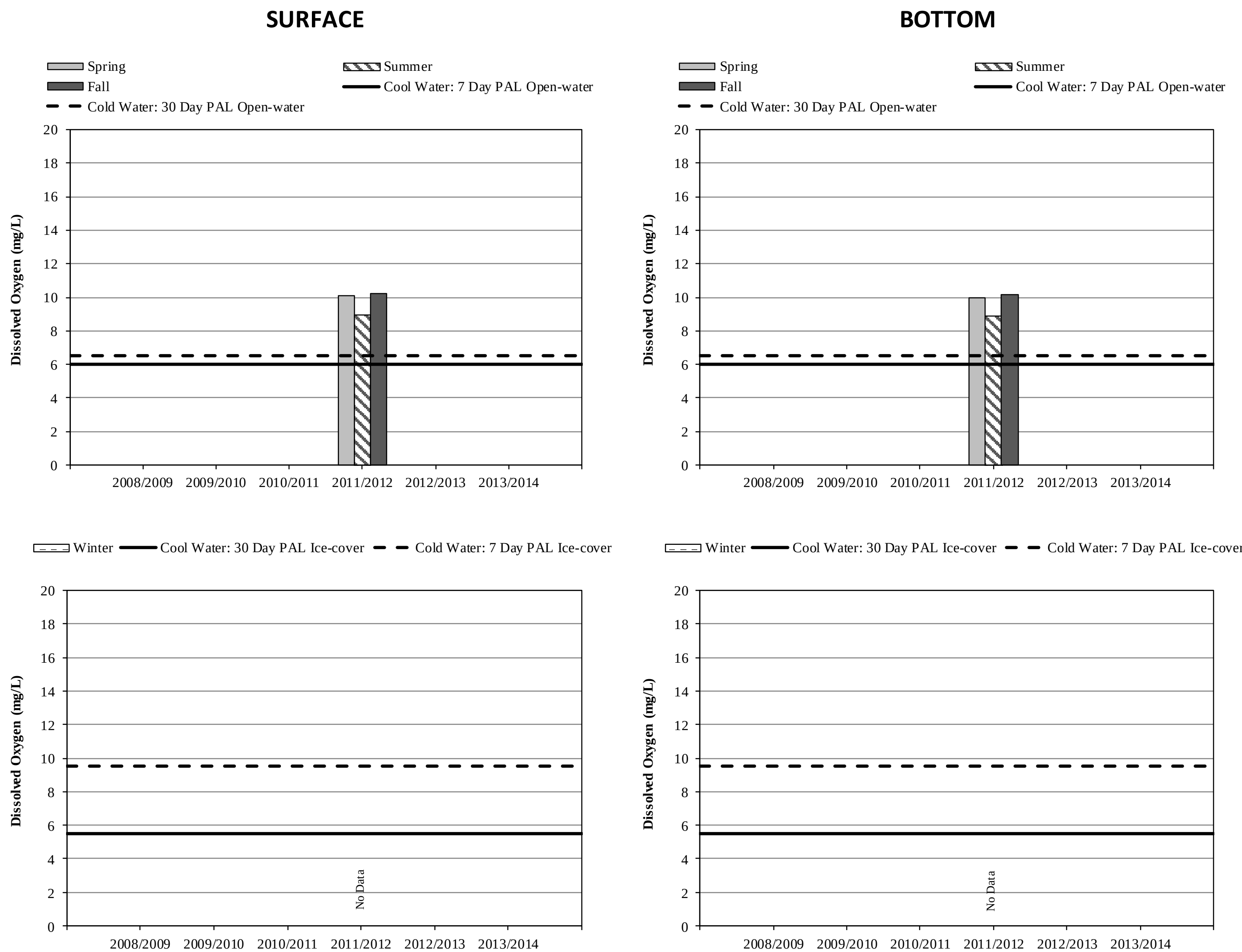


Figure 3-9. Dissolved oxygen measured near the surface and bottom of the water column in Fidler Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

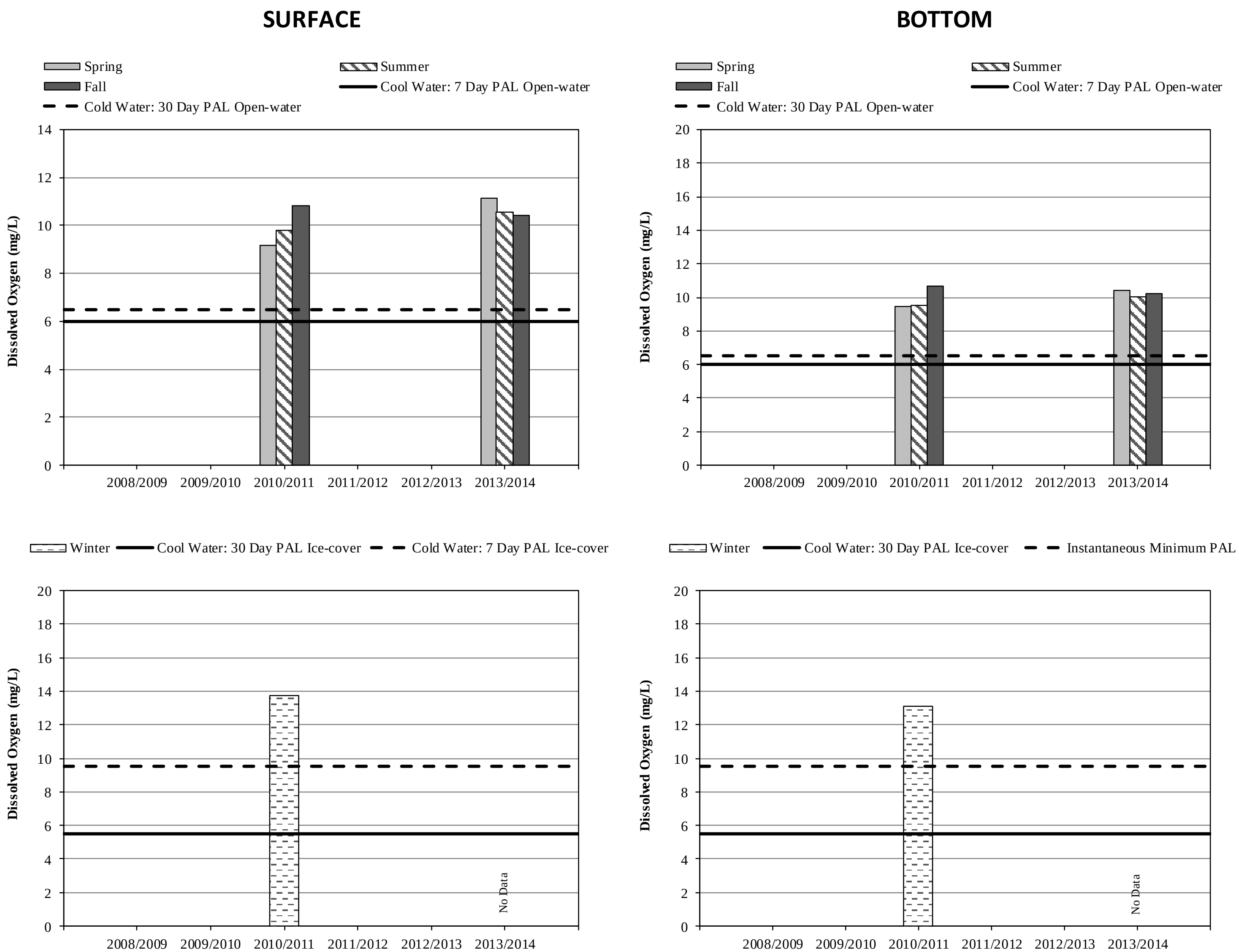


Figure 3-10. Dissolved oxygen measured near the surface and bottom of the water column in Billard Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

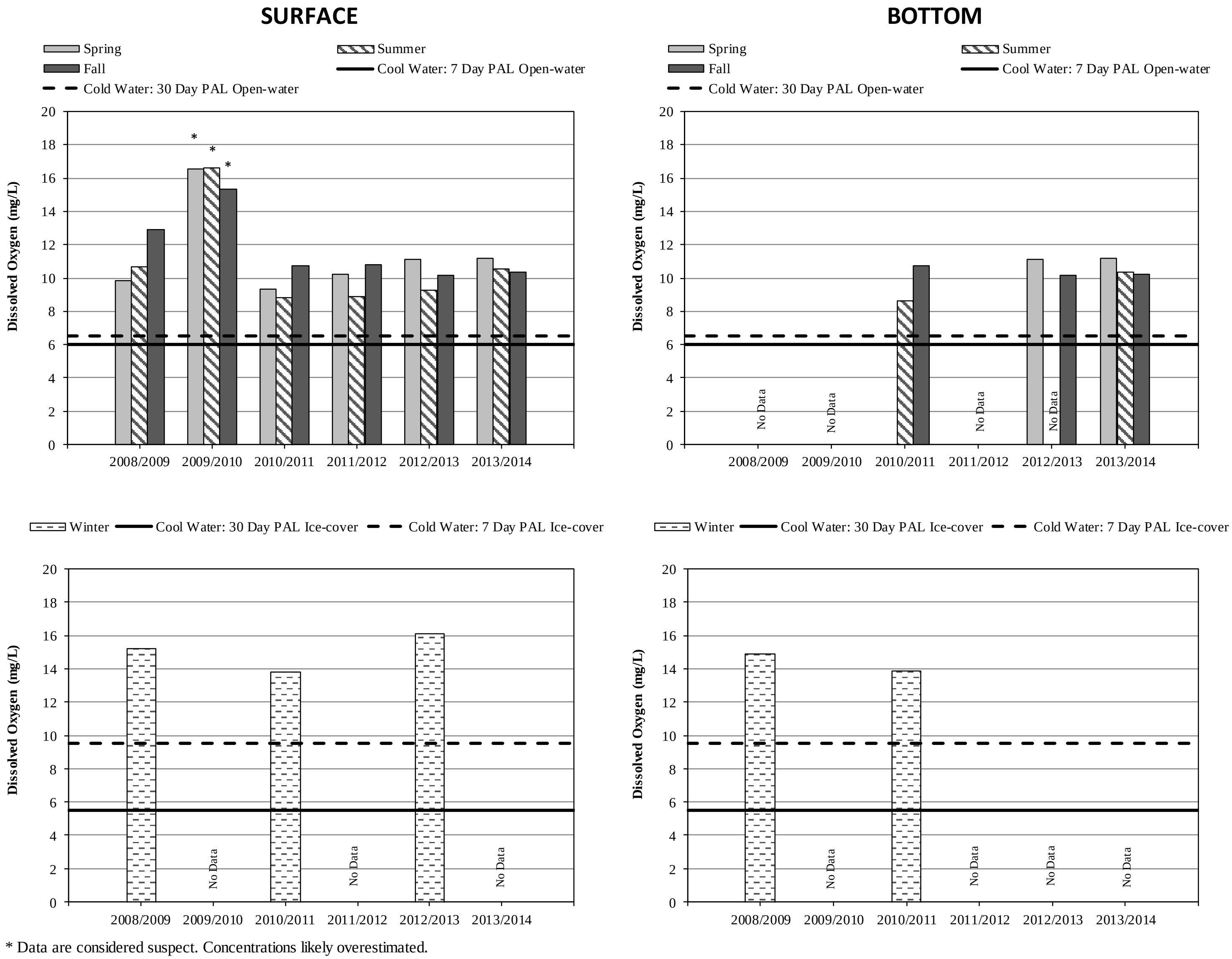


Figure 3-11. Dissolved oxygen measured near the surface and bottom of the water column in the lower Churchill River near the Little Churchill River and comparisons to MB PAL objectives: 2008/2009-2013/2014.

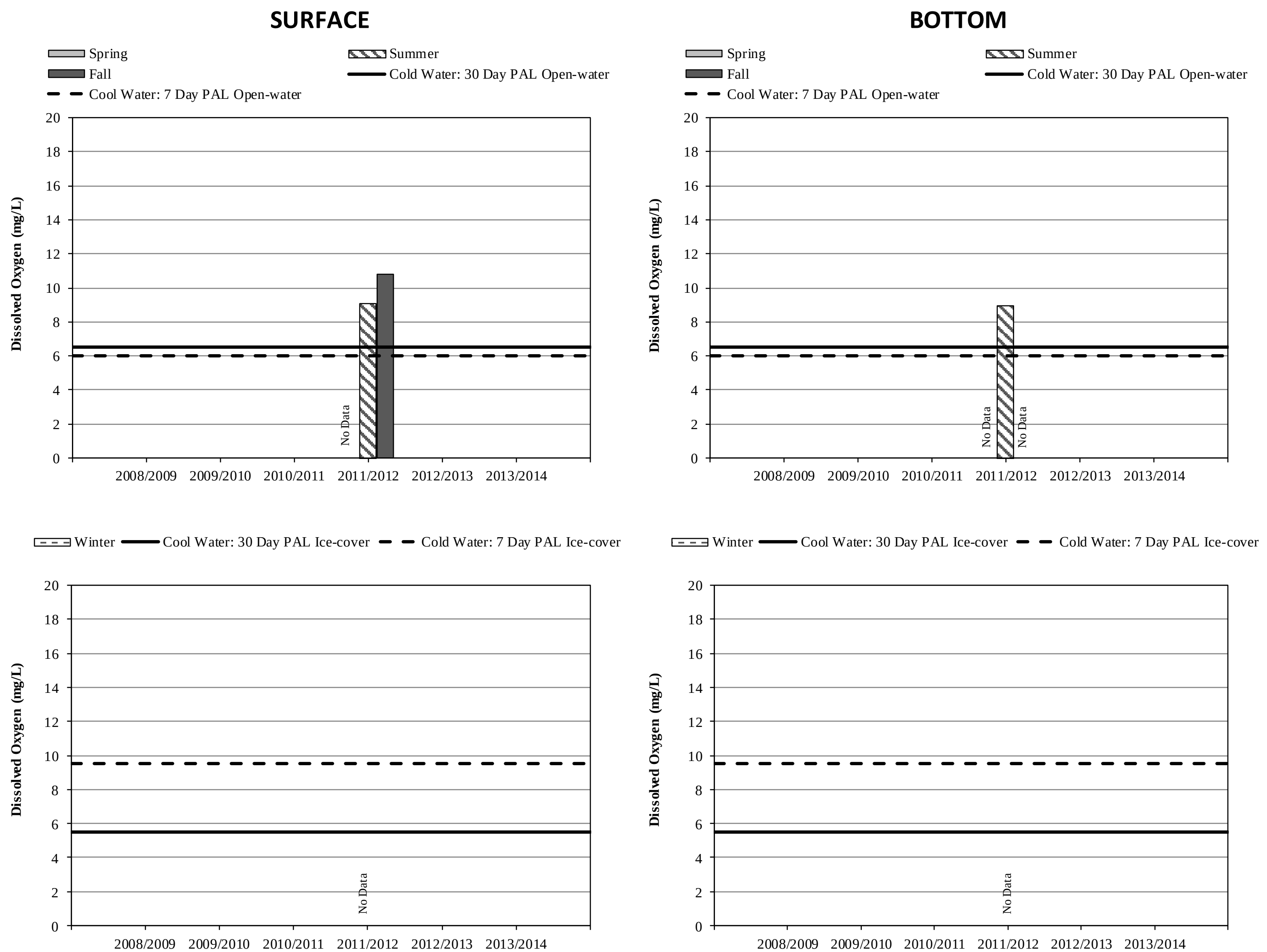


Figure 3-12. Dissolved oxygen measured near the surface and bottom of the water column in the lower Churchill River at Red Head Rapids and comparisons to MB PAL objectives: 2008/2009-2013/2014.

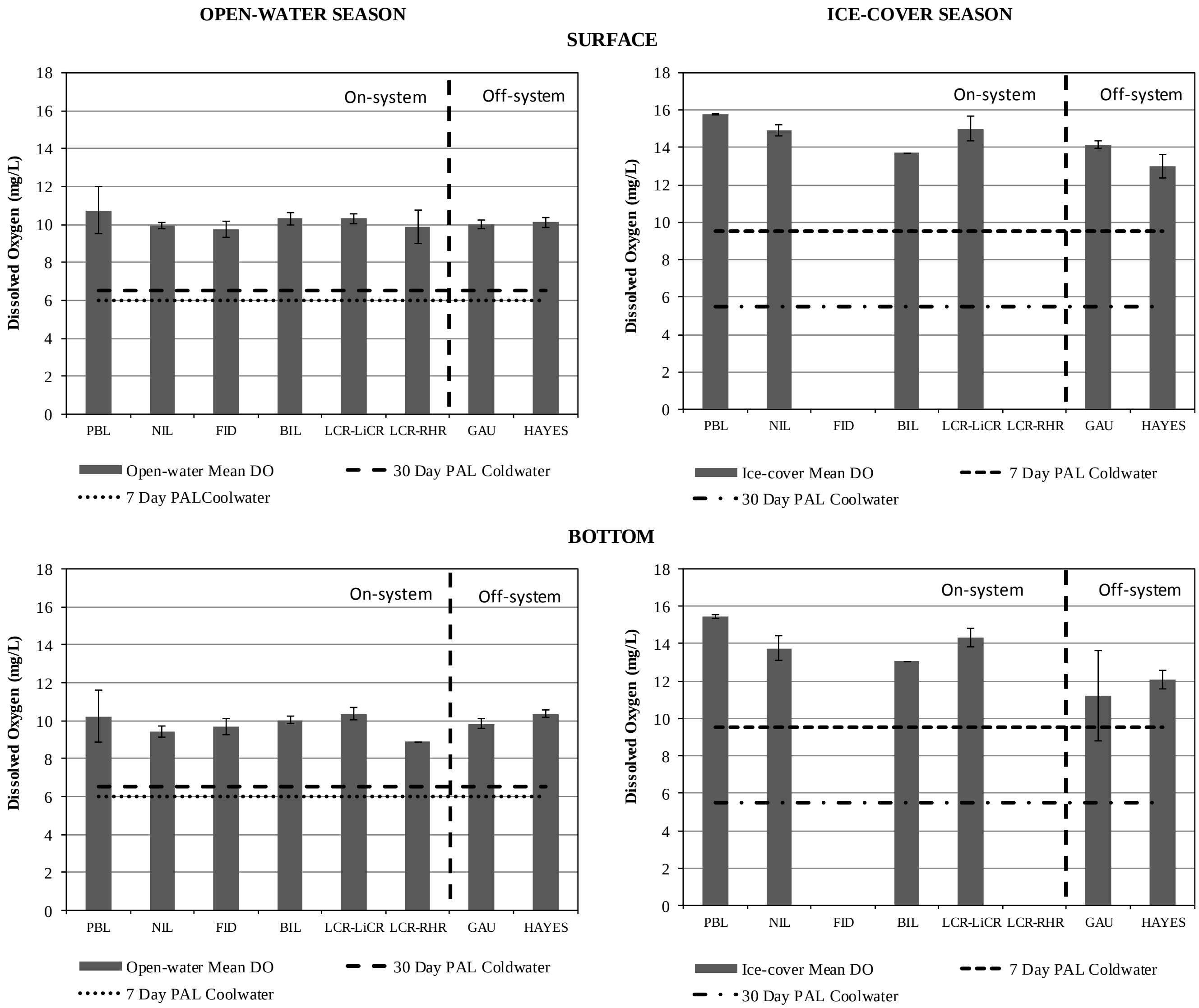


Figure 3-13. Dissolved oxygen (mean±SE) measured near the surface and bottom of the water column in the lower Churchill River and off-system waterbodies: 2008/2009-2013/2014.

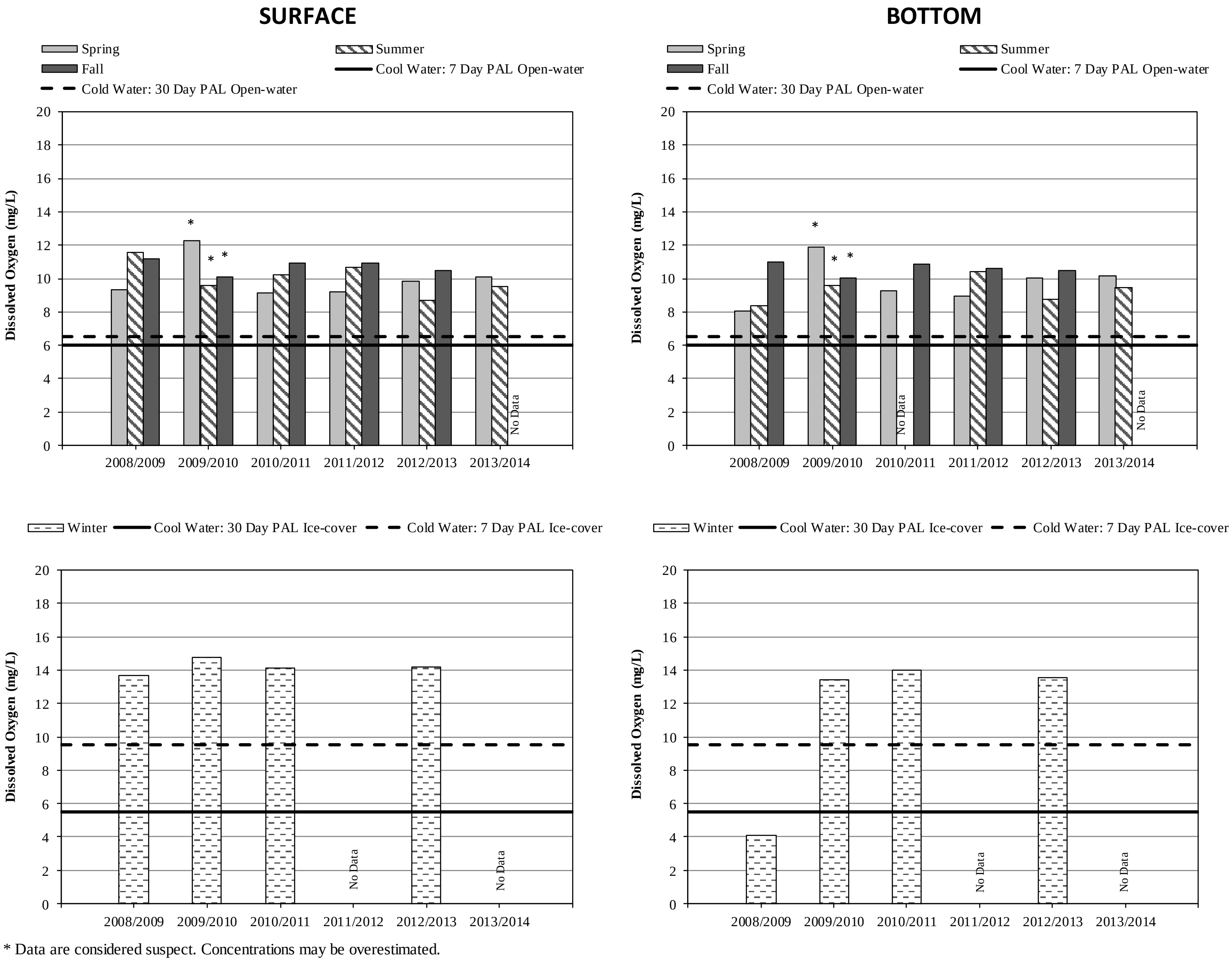


Figure 3-14. Dissolved oxygen measured near the surface and bottom of the water column in the off-system Gauer Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

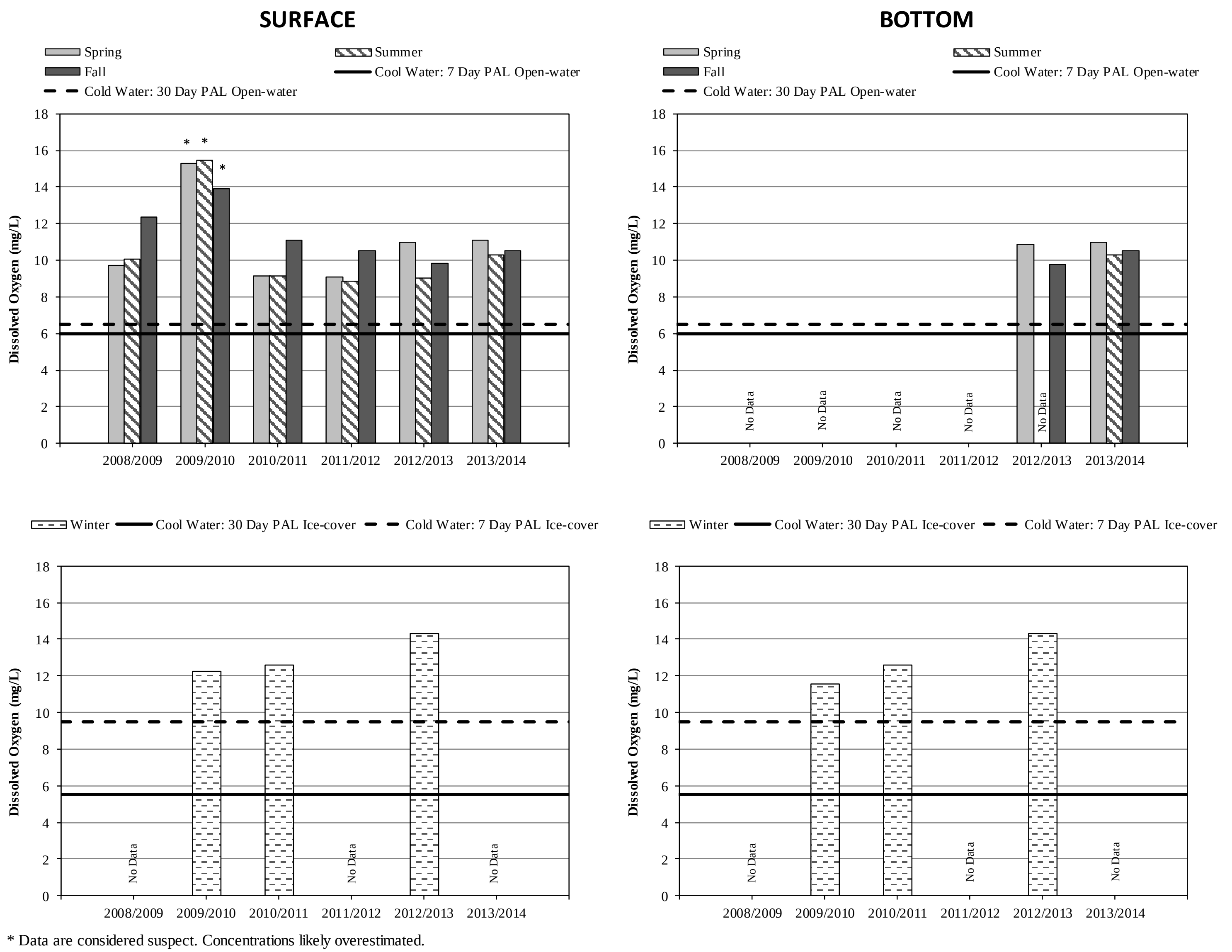
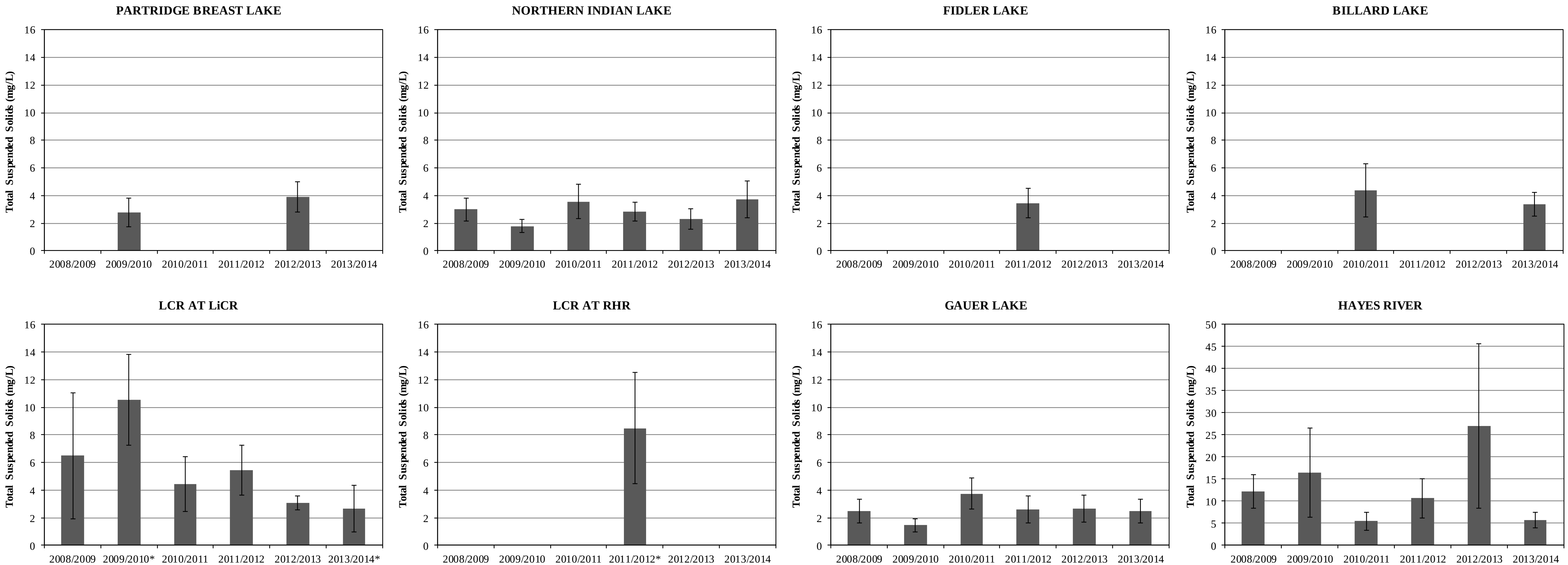


Figure 3-15. Dissolved oxygen measured near the surface and bottom of the water column in the off-system Hayes River and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Samples not collected in: winter 2009/2010 or 2013/2014 at LCR-LiCR and spring at LCR-RHR.

Figure 3-16. Total suspended solids (mean±SE) measured in the lower Churchill River and off-system waterbodies: 2008/2009-2013/2014.

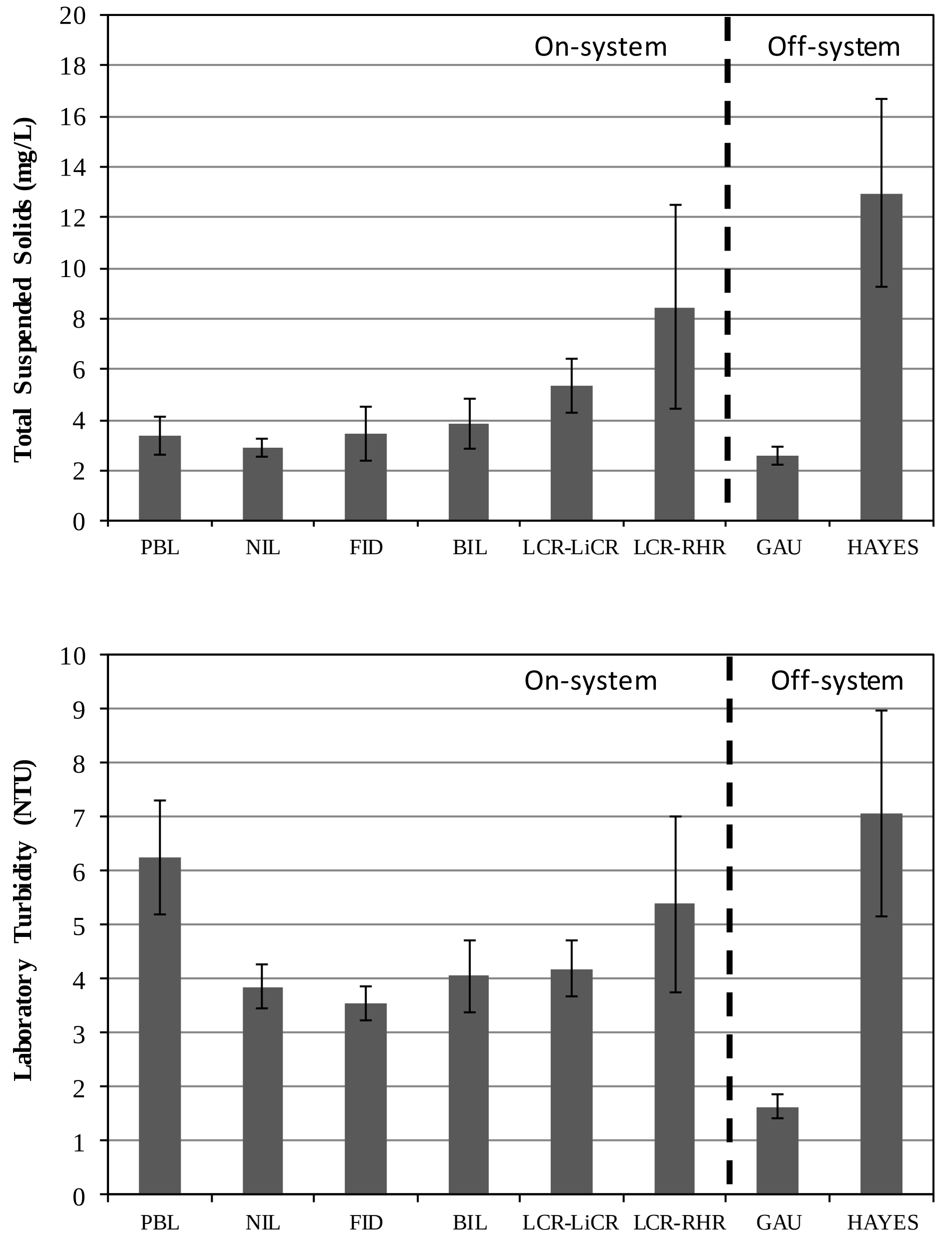
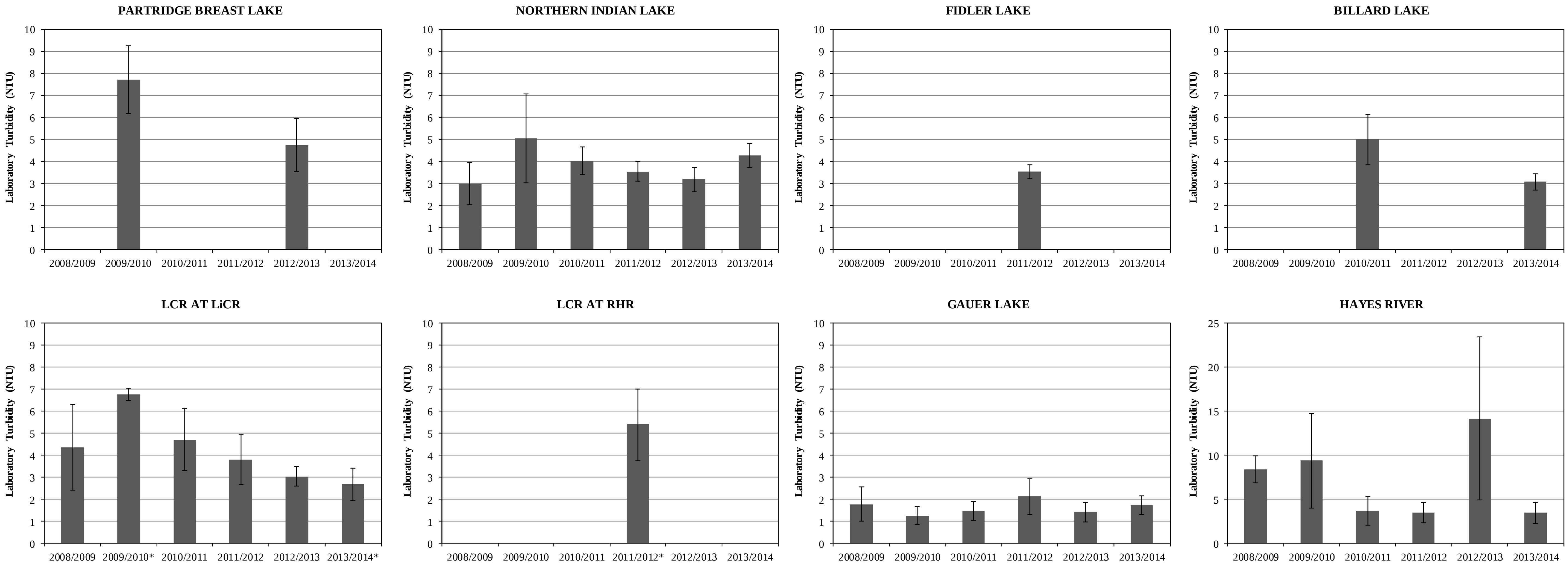


Figure 3-17. TSS and laboratory turbidity (mean±SE) measured in the lower Churchill River and off-system waterbodies: 2008/2009-2013/2014.



* Samples not collected in: winter 2009/2010 or 2013/2014 at LCR-LiCR and spring at LCR-RHR.

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

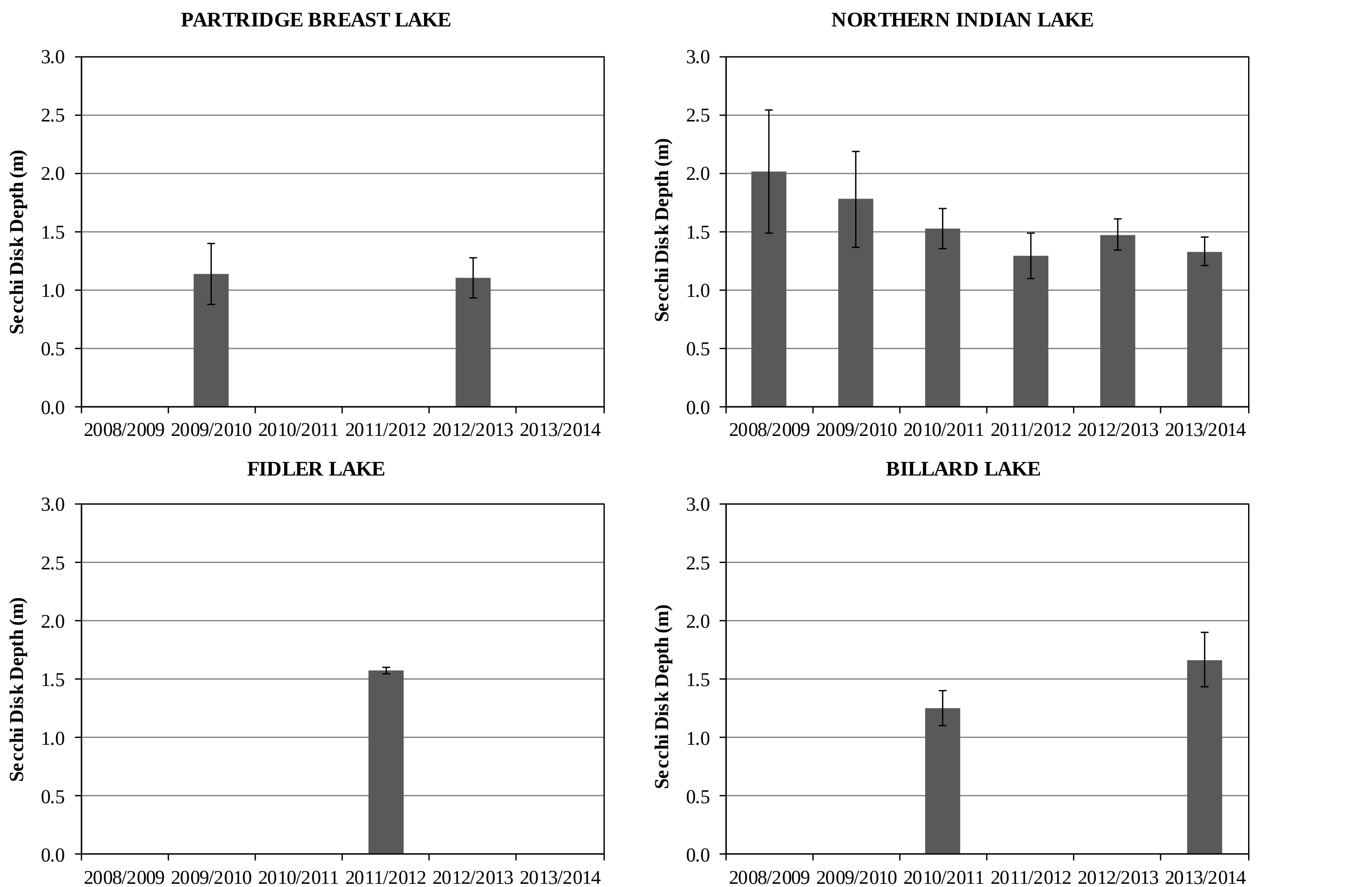


Figure 3-19. Secchi disk depths (mean±SE) measured in lower Churchill River lakes: 2008/2009-2013/2014 (open-water season).

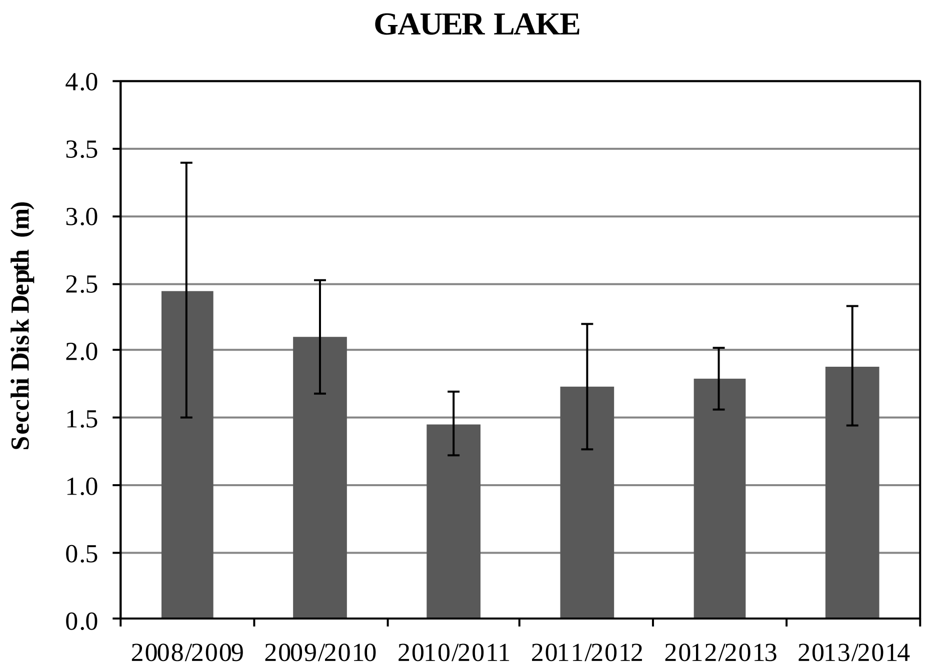


Figure 3-20. Secchi disk depths (mean±SE) measured in the off-system Gauer Lake: 2008/2009-2013/2014 (open-water season).

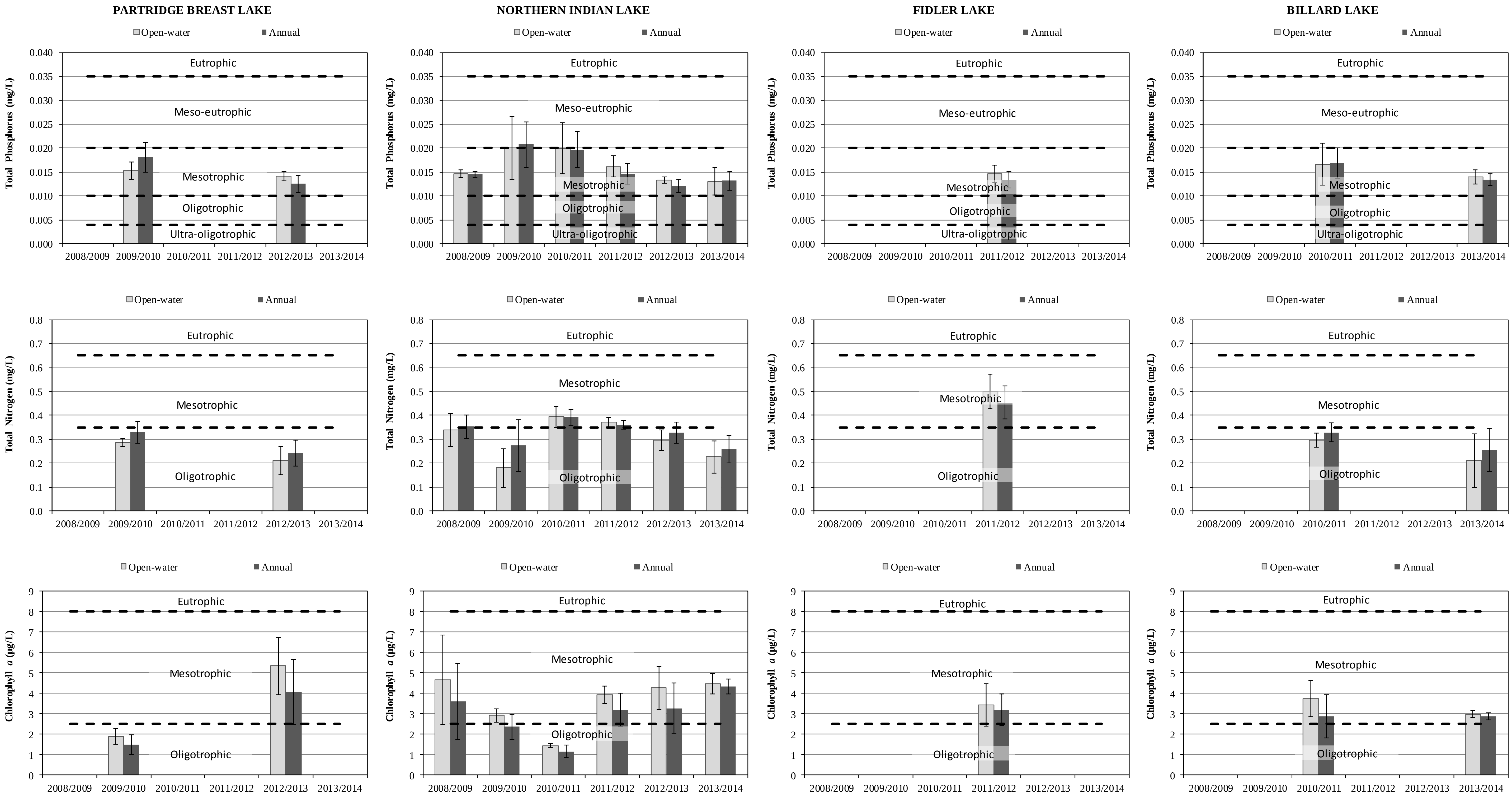
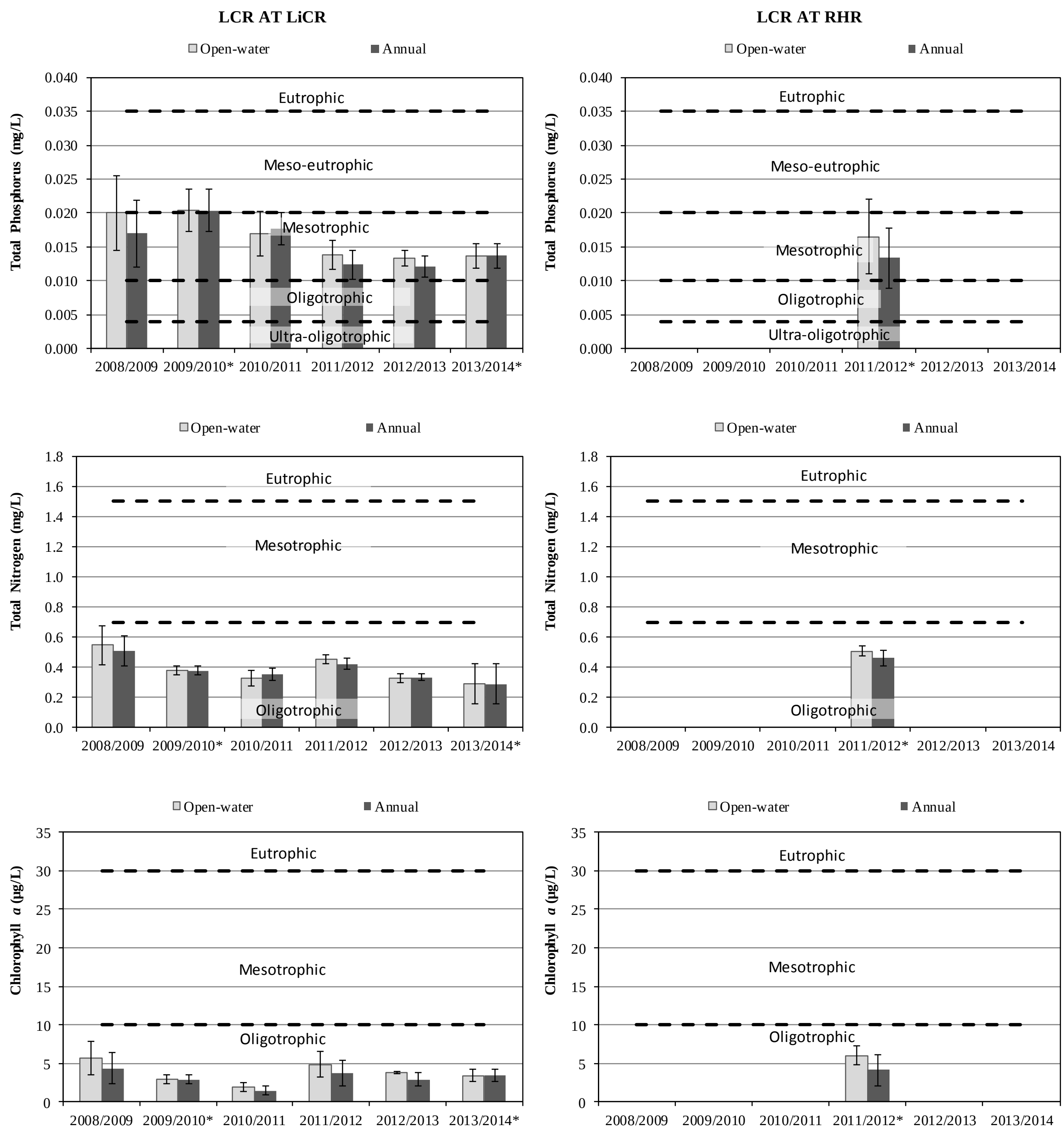
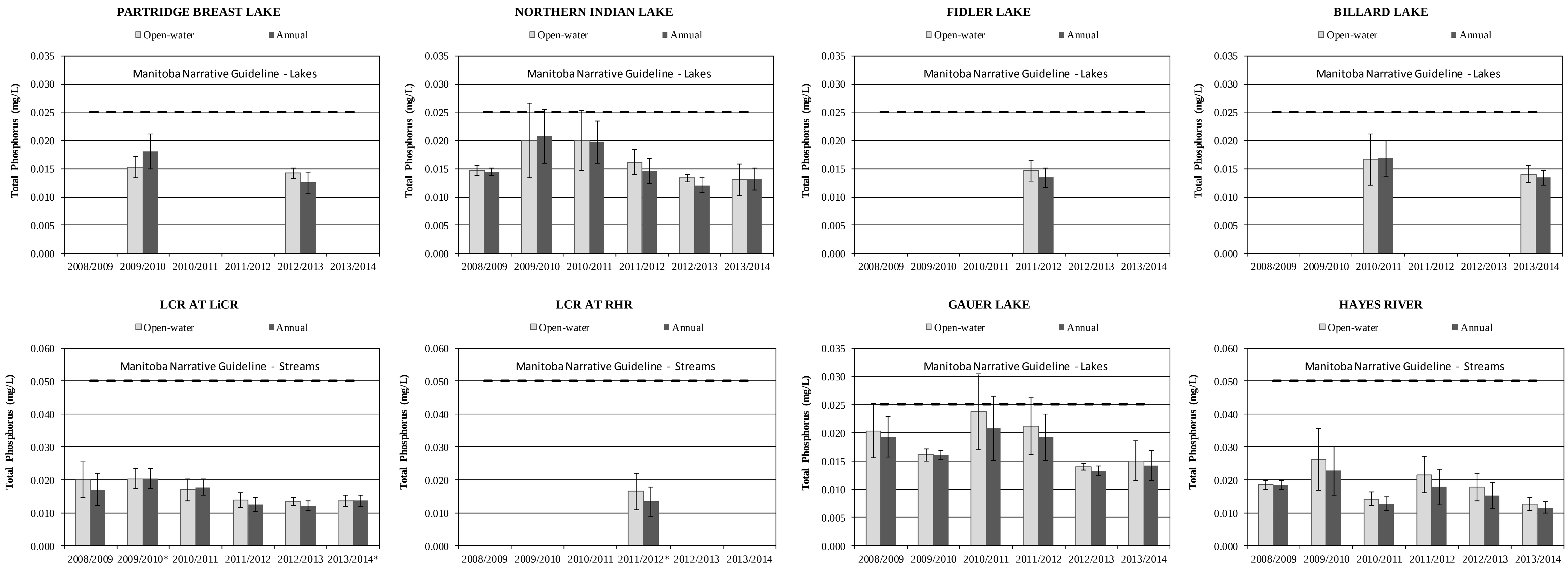


Figure 3-21. Total phosphorus, total nitrogen, and chlorophyll *a* (mean±SE) measured in the lower Churchill River lakes and comparison to trophic categories: 2008/2009-2013/2014.



* Samples not collected in: winter 2009/2010 or 2013/2014 at LCR-LiCR and spring at LCR-RHR.

Figure 3-22. Total phosphorus, total nitrogen, and chlorophyll *a* (mean±SE) measured at riverine sites on the lower Churchill River and comparison to trophic categories: 2008/2009-2013/2014.



* Samples not collected in: winter 2009/2010 or 2013/2014 at LCR-LiCR and spring at LCR-RHR.

Figure 3-23. Total phosphorus (mean±SE) measured at on-system sites on the lower Churchill River lakes and off-system sites and comparison to the Manitoba narrative nutrient guidelines: 2008/2009-2013/2014.

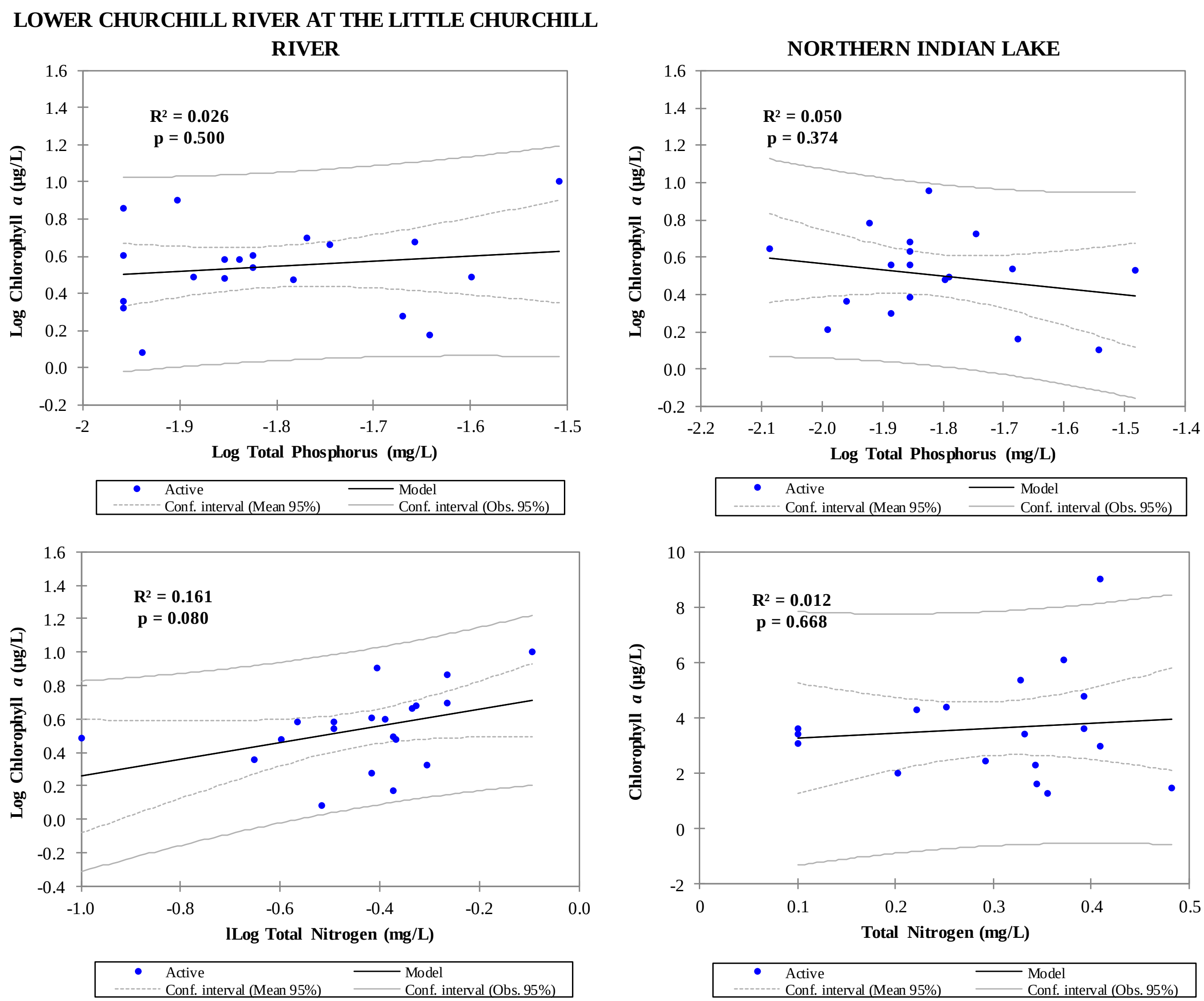


Figure 3-24. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* in Northern Indian Lake and the lower Churchill River at the Little Churchill River: open-water seasons 2008-2013.

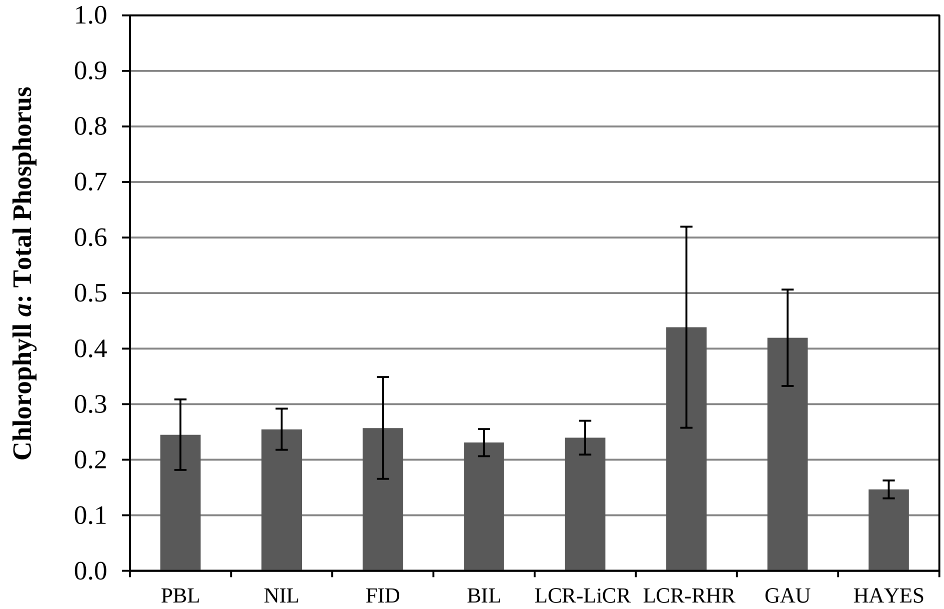


Figure 3-25. Chlorophyll *a* to total phosphorus ratios (mean±SE) measured in the lower Churchill River and off-system waterbodies: open-water seasons 2008-2013.

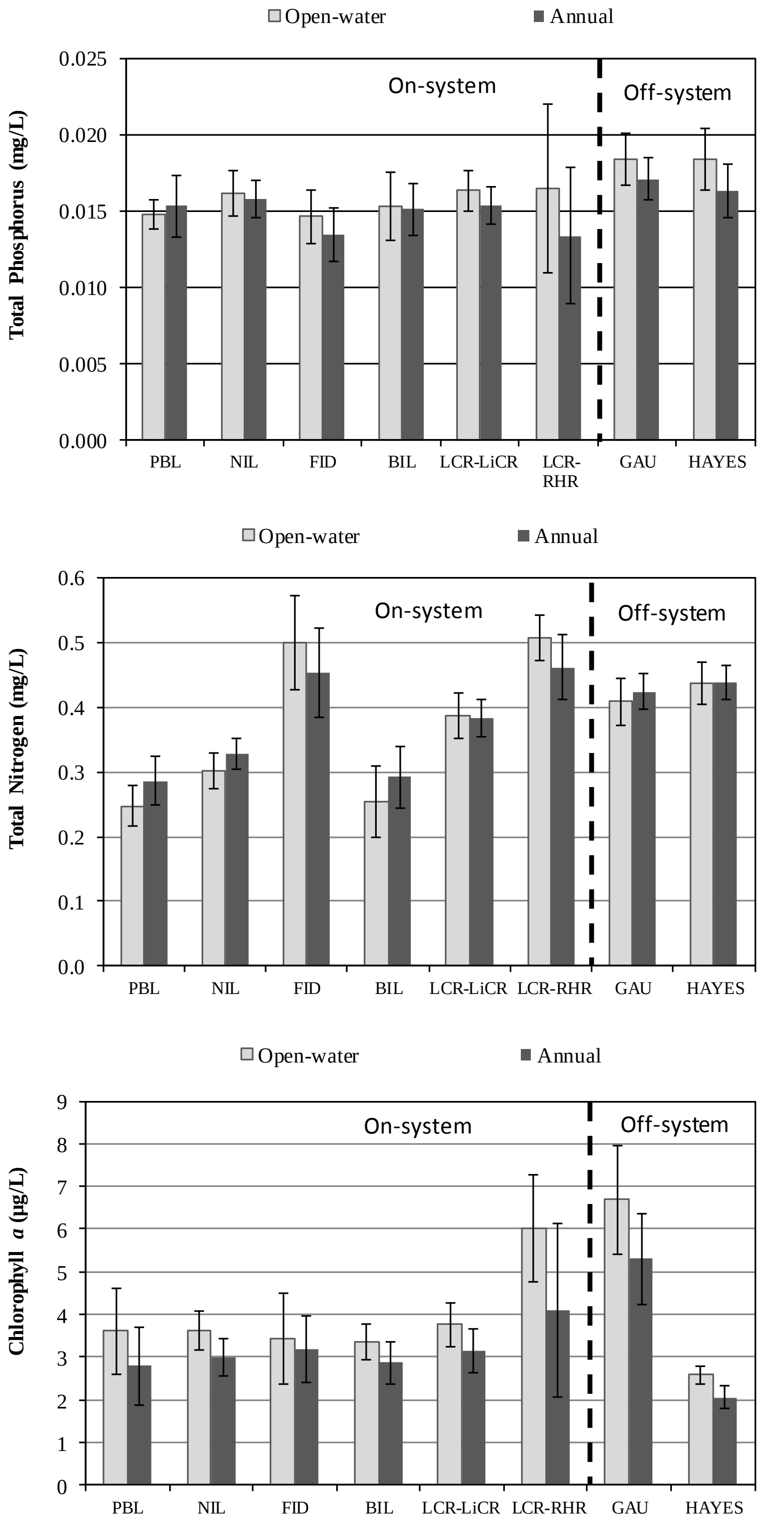


Figure 3-26. Total phosphorus, total nitrogen, chlorophyll *a* (mean±SE) measured in the lower Churchill River and off-system waterbodies: 2008/2009-2013/2014.

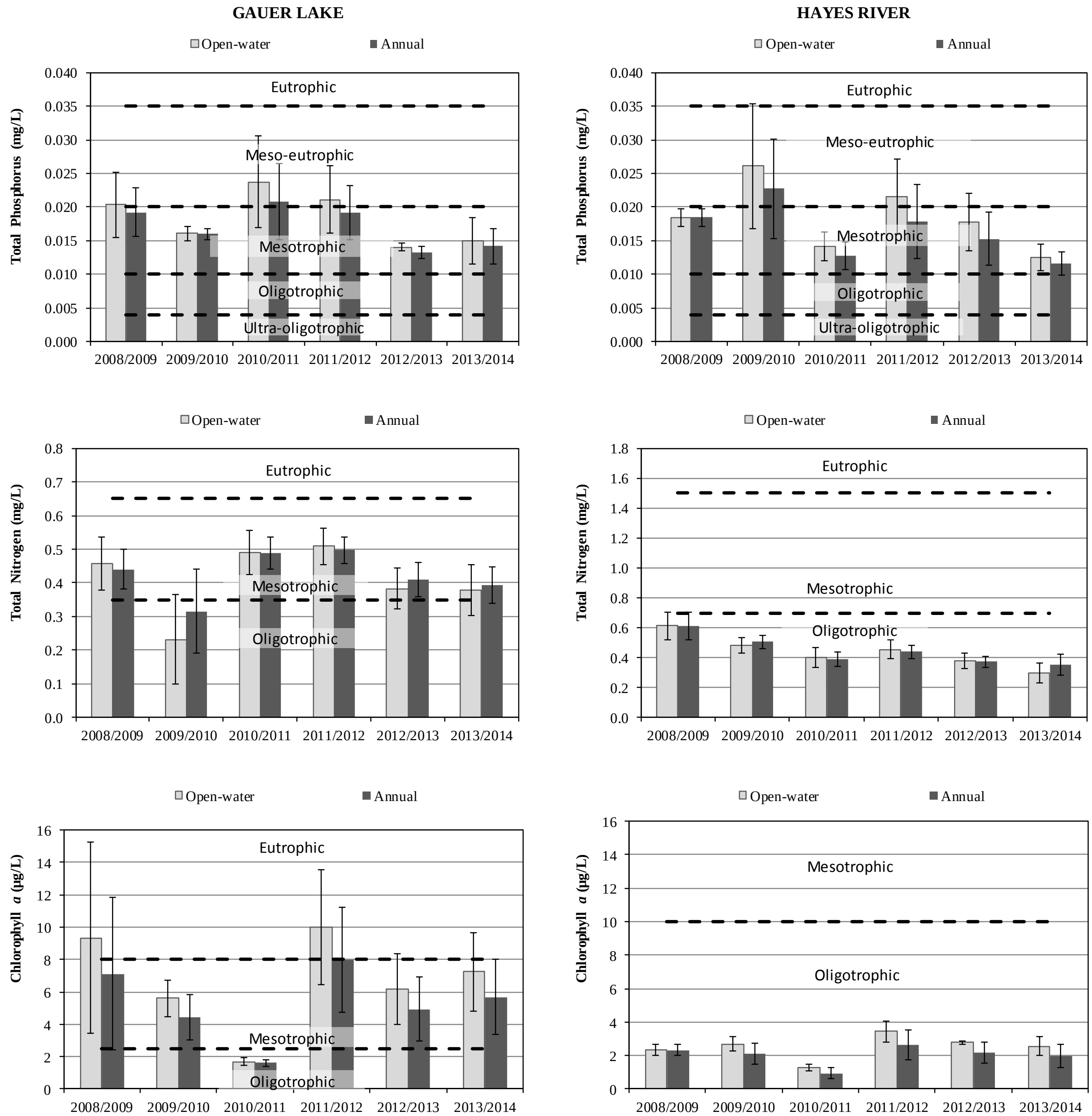


Figure 3-27. Total phosphorus, total nitrogen, and chlorophyll *a* (mean±SE) measured at the off-system Gauer Lake and the Hayes River and comparison to trophic categories: 2008/2009-2013/2014.

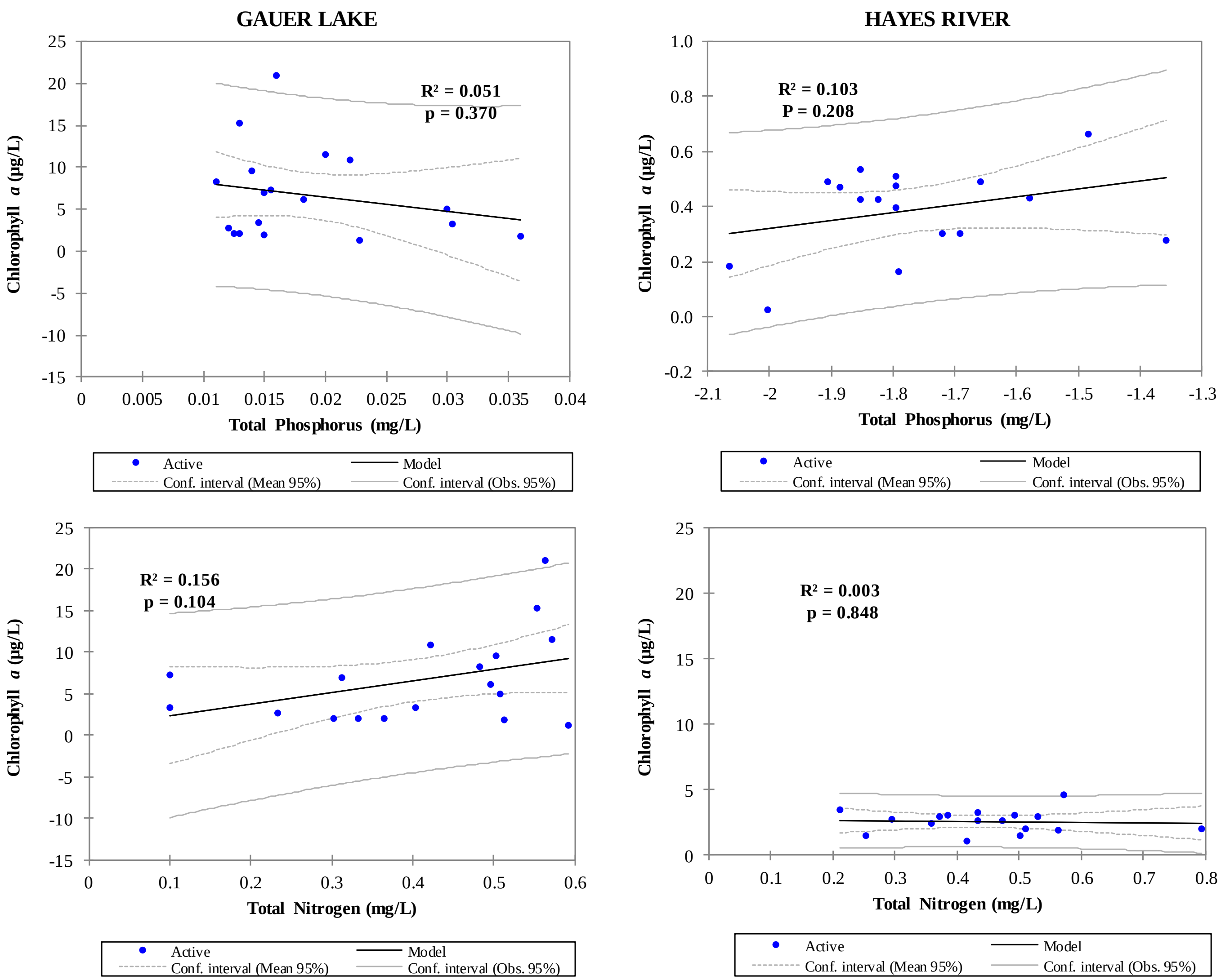
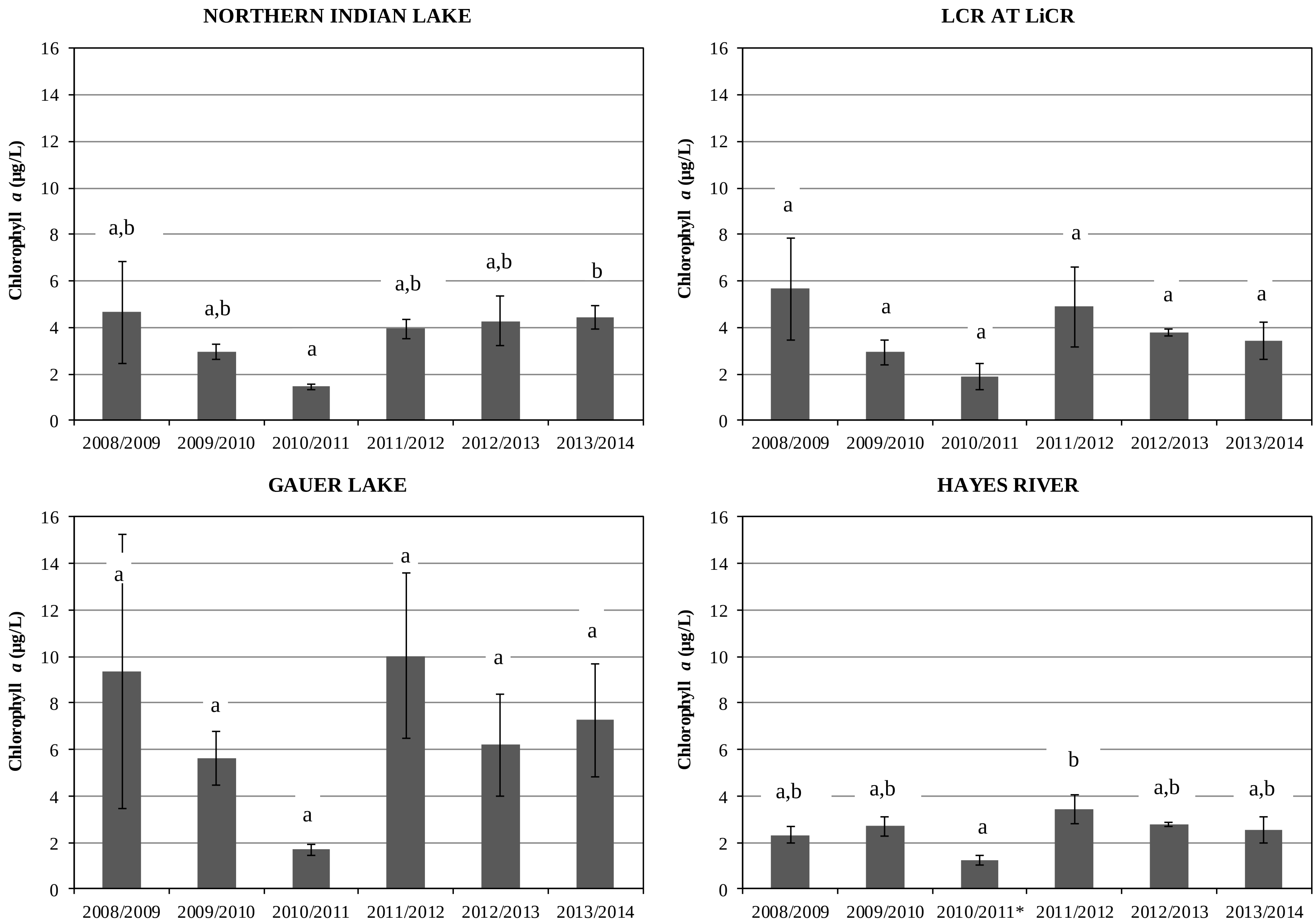


Figure 3-28. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* in the off-system Gauer Lake and the Hayes River: open-water seasons 2008-2013.



No sample collected in summer period.

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

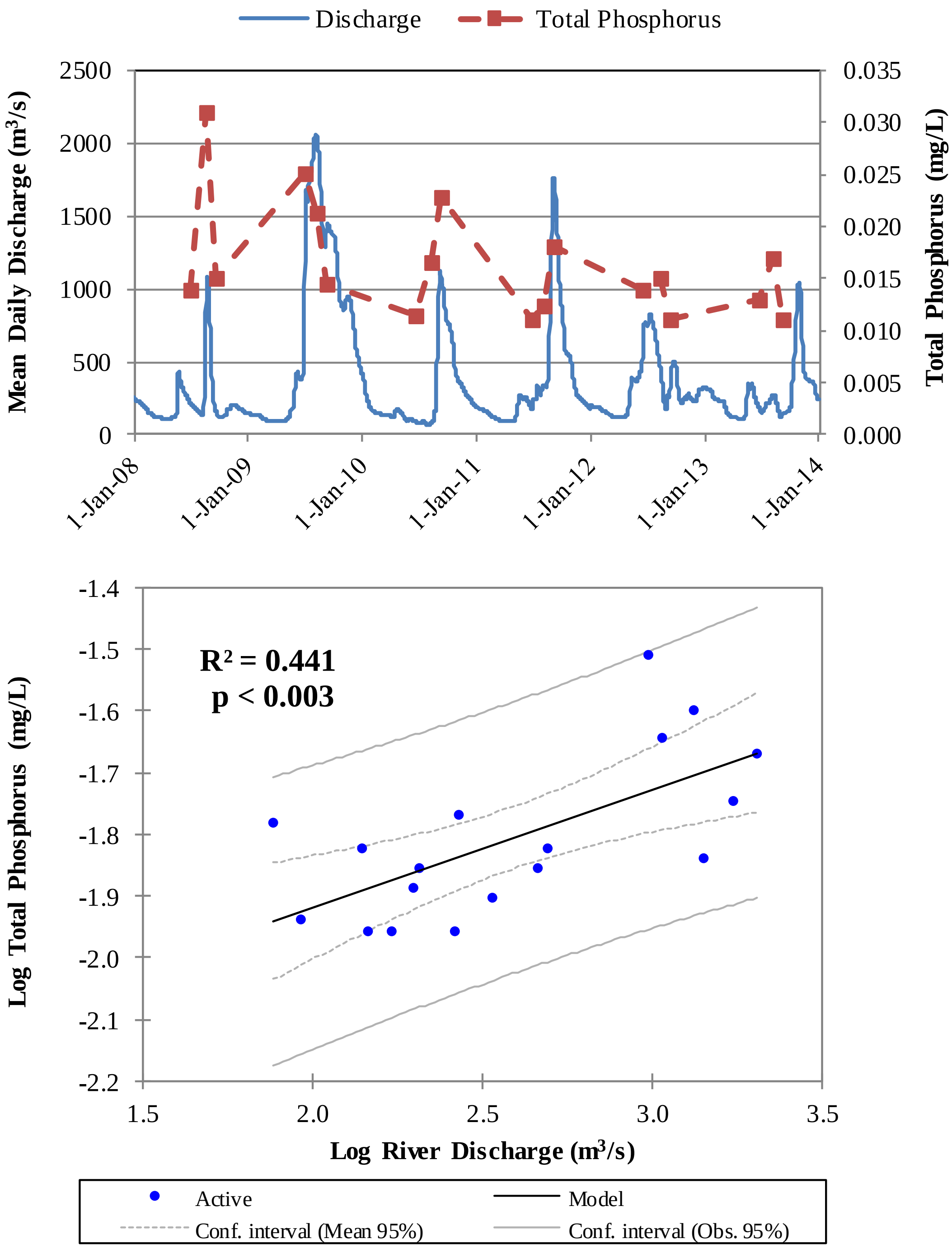


Figure 3-30. Open-water season total phosphorus versus discharge at the lower Churchill River at the Little Churchill River.

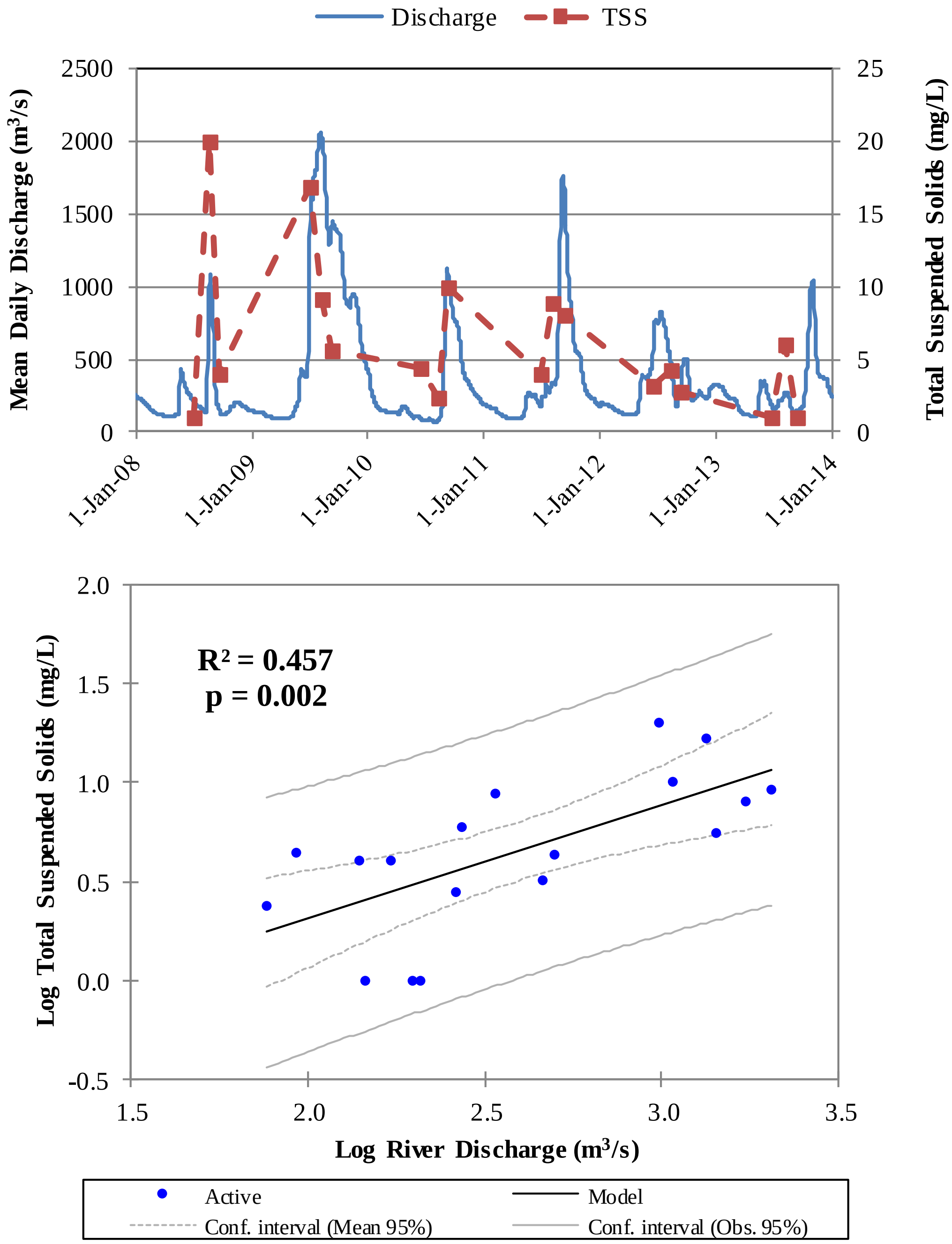
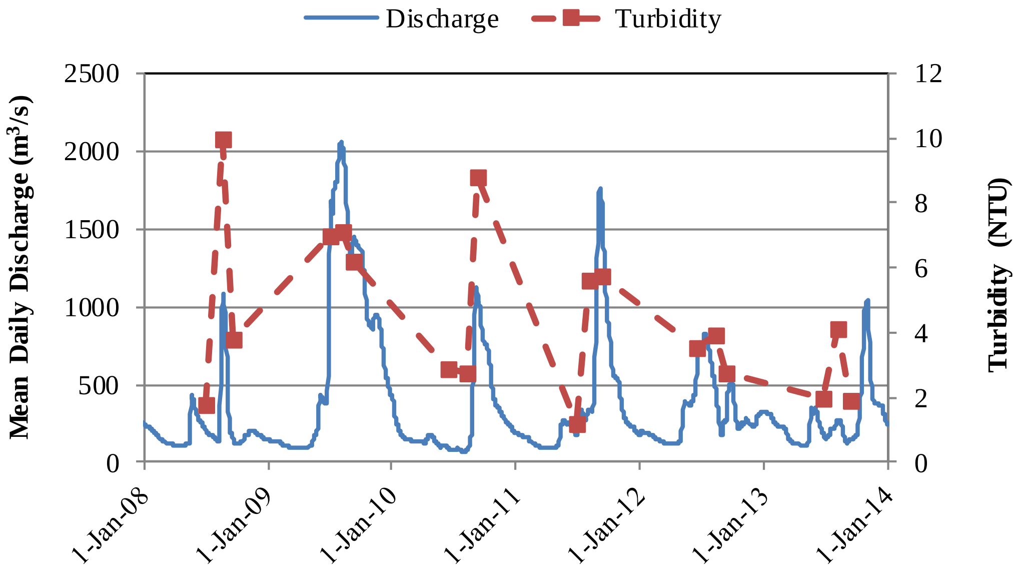


Figure 3-31. Open-water season total suspended solids versus discharge at the lower Churchill River at the Little Churchill River.



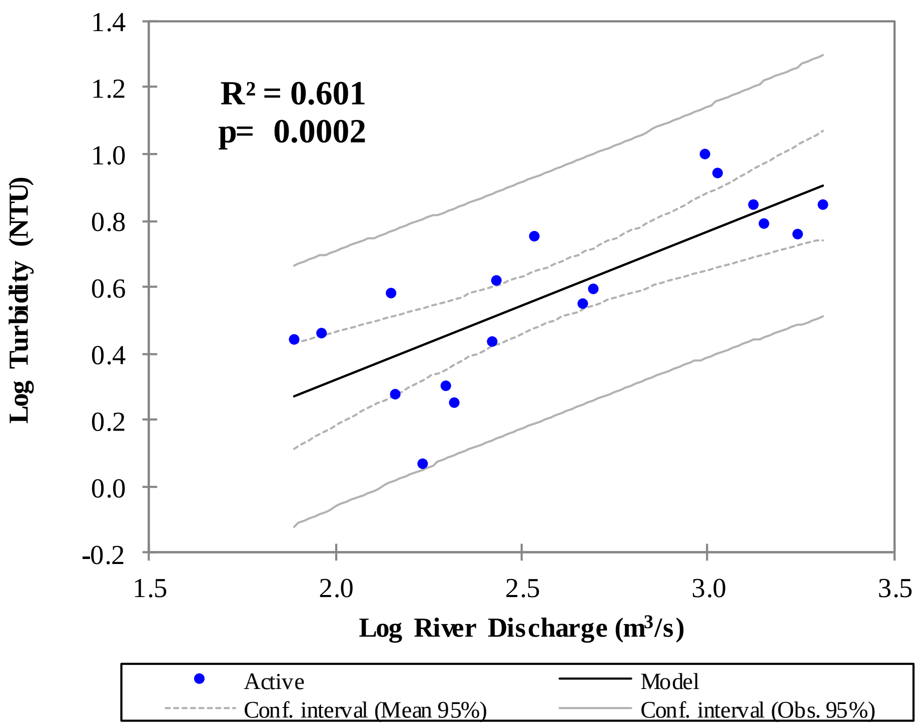


Figure 3-32. Open-water season turbidity versus discharge at the lower Churchill River at the Little Churchill River.

4.0 SEDIMENT QUALITY

4.1 INTRODUCTION

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

Sediment quality was measured in 2011 in Northern Indian Lake (on-system site) and Gauer Lake (off-system site; Figure 4-1). Samples from two areas (one predominantly sand and the other predominantly silt/clay) were collected and analysed from Gauer Lake. An additional sample was collected because the target site was comprised predominantly of sand, whereas the on-system sediment quality site was comprised predominantly of finer substrate; this was done to provide a more comparable sample as the chemical composition of sediments varies according to particle size (e.g., metals are typically present in higher concentrations in fine textured sediments). There is generally a strong positive correlation between the fraction of silt/clay and metal concentrations (e.g., Horowitz 1985; Table 4-1). Samples could not be retrieved from the lower Churchill River at the confluence with the Little Churchill River or from the off-system Hayes River because of rocky substrates.

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 LOWER CHURCHILL RIVER

Surficial sediment samples from Northern Indian Lake were dominated by silt/clay (96%; Table 4-2; Figure 4-2) and had moderate levels of total organic carbon (TOC; Figure 4-3). The particle size and TOC content were similar to that observed at the fine texture sediment sampling site in the off-system Gauer Lake, indicating that this site is the most comparable in terms of basic substrate characteristics (see Section 4.3).

Total organic carbon (Figure 4-3), TP (Figure 4-4), and total Kjeldahl nitrogen (TKN; Figure 4-5) exceeded the Ontario LEL, but were below the SEL in Northern Indian Lake; results were generally similar to those observed at the fine texture sediment sampling site in the off-system Gauer Lake.

All but one metal (chromium), including arsenic, cadmium, copper, lead, mercury, and zinc, were on average within the Manitoba SQGs (Figures 4-6 to 4-12). Chromium exceeded the Manitoba SQG but not the PEL in Northern Indian Lake; a similar average concentration was also observed in the off-system Gauer Lake at the fine texture sediment sampling site (Figure 4-8).

Iron (Figure 4-13) and nickel (Figure 4-14) exceeded the Ontario LEL but not the SEL, and manganese exceeded the SEL (Figure 4-15), in Northern Indian Lake. Both iron and manganese concentrations were higher than, but nickel was similar to, concentrations measured at the fine texture sediment sampling site in the off-system Gauer Lake.

Selenium was not detected in surficial sediments from Northern Indian Lake (Figure 4-16) and the analytical detection limit (0.5 µg/g) was below the BC SAC and the AB ISQG (2.0 µg/g). Results for other metals are presented in Table 4-3.

4.3 OFF-SYSTEM WATERBODY: GAUER LAKE

Particle size, nutrients, and metals were notably higher at the fine texture sampling site in Gauer Lake, and were more similar to the composition of sediments collected from Northern Indian Lake, than the site composed predominantly of sand (Figures 4-2 to 4-16). Correlation analysis indicates that key sediment quality metrics for samples collected in the LCRR are strongly positively correlated to the fraction of clay and TOC (Table 4-1).

Concentrations of nutrients and metals were generally low at the site composed predominantly of sand and all parameters excepting TKN, which marginally exceeded the Ontario LEL, were within the sediment quality benchmarks.

Exceedances of sediment quality benchmarks at the fine texture sampling site in Gauer Lake were generally similar to those observed in Northern Indian Lake. TP and TOC exceeded the Ontario LEL and TKN, which was notably higher than Northern Indian Lake, exceeded the Ontario SEL. Similar to Northern Indian Lake, all metals excepting chromium (which exceeded the SQG) were within the Manitoba SQGs, and iron, manganese and nickel exceeded the Ontario LEL but not the SEL. Selenium was marginally above the analytical detection limit but well below the BC SAC and the AB ISQG at the fine texture site.

4.4 SUMMARY

Approximately half of the sediment quality parameters for which there are applicable benchmarks were within benchmarks in the LCRR. 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 4-2).

Table 4-1. Spearman rank correlations for selected sediment quality metrics based on means obtained from all sites. Where presented, numbers indicate correlation coefficients for statistically significant ($p < 0.05$) correlations.

Metrics	Silt	Clay	Silt+Clay	TOC
TKN	-	0.705	0.508	0.983
Total Phosphorus	-	0.548	-	0.583
Aluminum	-	0.841	0.674	0.645
Antimony	-	0.799	0.511	0.590
Arsenic	-	0.548	-	0.439
Barium	-	0.680	0.507	0.496
Beryllium	-	0.590	-	0.508
Bismuth	-	0.720	0.526	0.661
Boron	-	0.723	0.733	0.478
Cadmium	-	0.734	0.534	0.659
Calcium	-	-	-	-
Cesium	-	0.664	0.599	0.560
Chromium	-	0.771	0.663	0.562
Cobalt	-	0.608	0.497	-
Copper	-	0.903	0.776	0.748
Iron	-	0.614	0.485	-
Lead	-	0.834	0.595	0.609
Magnesium	-	-	0.497	-
Manganese	-	-	-	-
Mercury	-	-	-	-
Molybdenum	-	0.628	-	0.651
Nickel	-	0.833	0.731	0.577
Potassium	-	0.756	0.679	0.552
Rubidium	-	0.719	0.611	0.567
Selenium	-	0.505	0.543	0.541
Silver	-	0.785	0.689	-
Sodium	-	-	-	-
Strontium	-	-	0.520	-
Sulfur	-	-	-	-
Tellurium	-	-		-
Thallium	-	0.767	0.617	0.644
Tin	-	-	-	-
Titanium	-	-	-	-
Tungsten	-	-	-	-
Uranium	-	-	-	0.620
Vanadium	-	0.715	0.540	0.492
Zinc	-	0.938	0.723	0.721
Zirconium	0.523	0.558	0.564	-

Table 4-2. 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 4-3. 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).

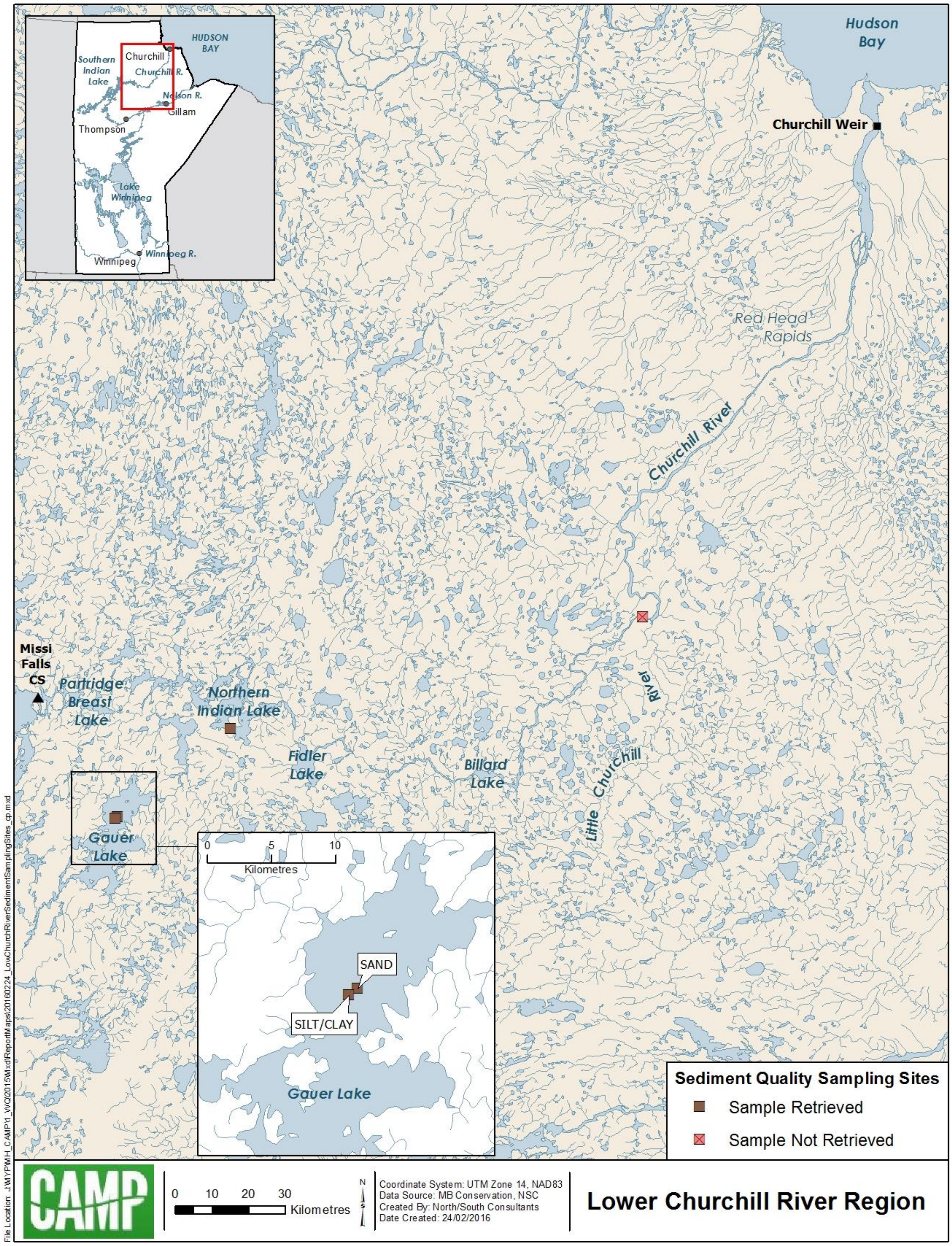


Figure 4-1. Sediment quality sampling sites in the Lower Churchill River Region: 2008-2013.

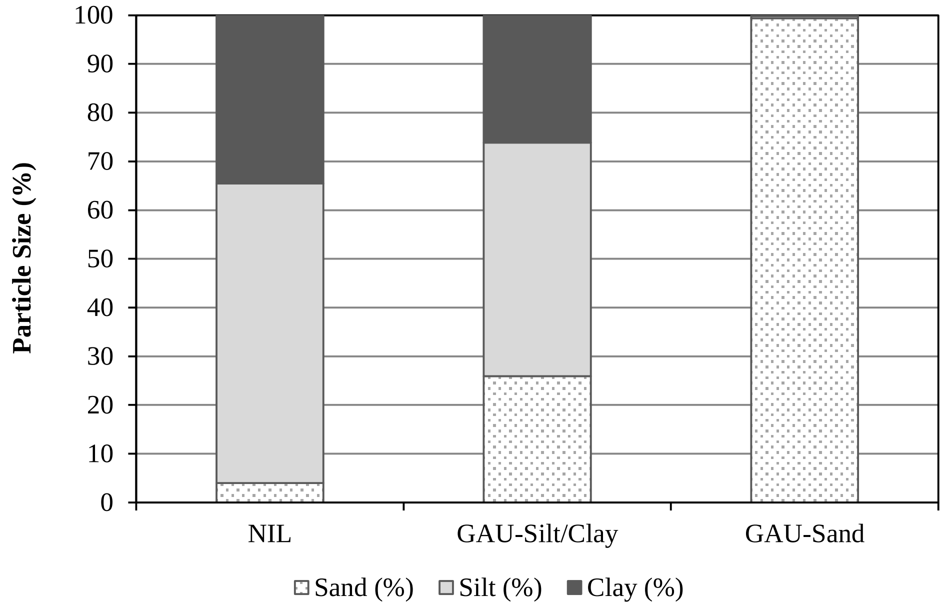


Figure 4-2. Particle size of surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU).

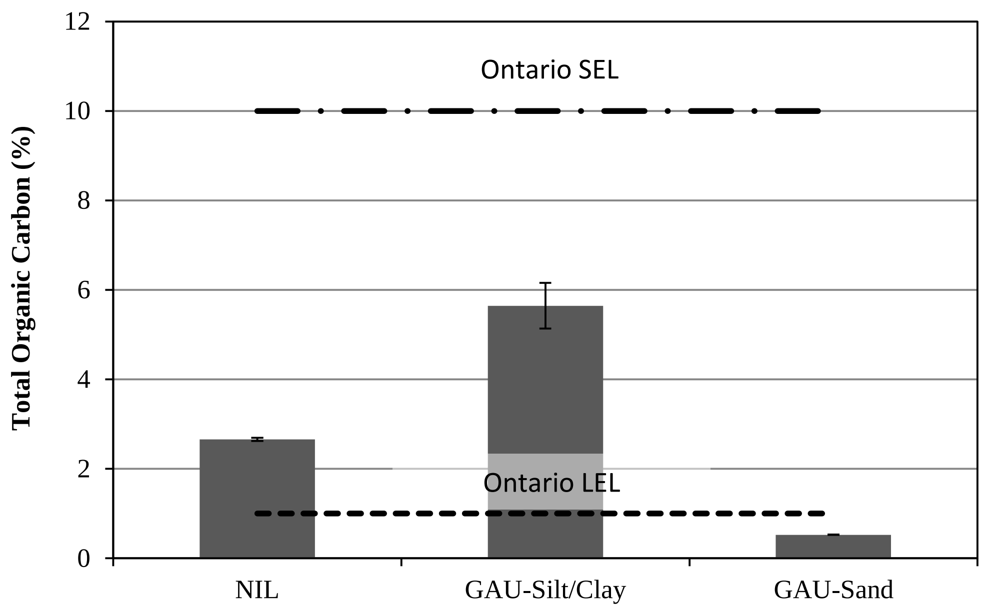


Figure 4-3. Percentage of total organic carbon in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Ontario sediment quality guidelines.

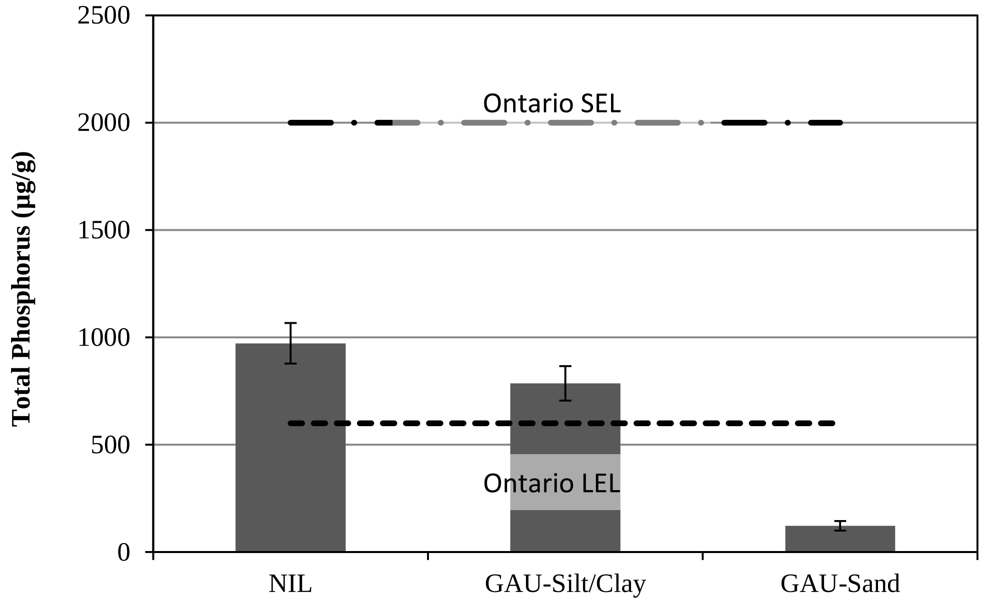


Figure 4-4. Mean (±SE) concentrations of total phosphorus in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Ontario sediment quality guidelines.

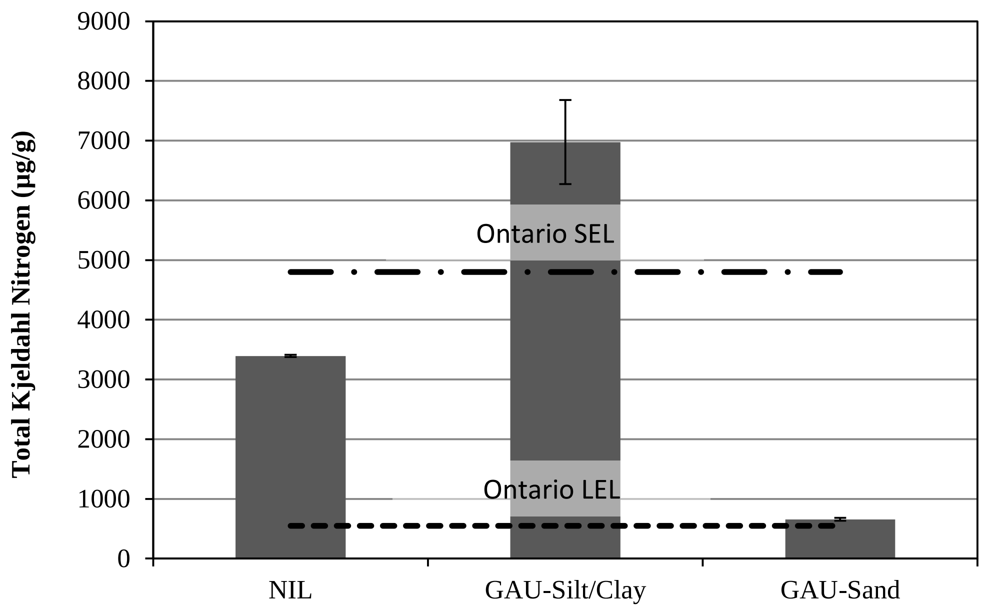


Figure 4-5. Mean (±SE) concentrations of total Kjeldahl nitrogen in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Ontario sediment quality guidelines.

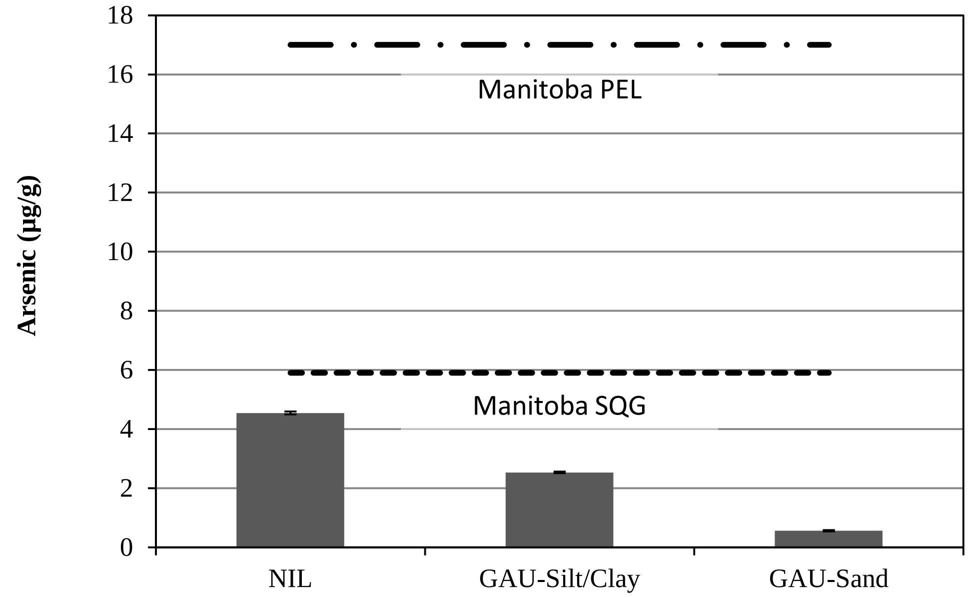


Figure 4-6. Mean (±SE) concentrations of arsenic in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines.

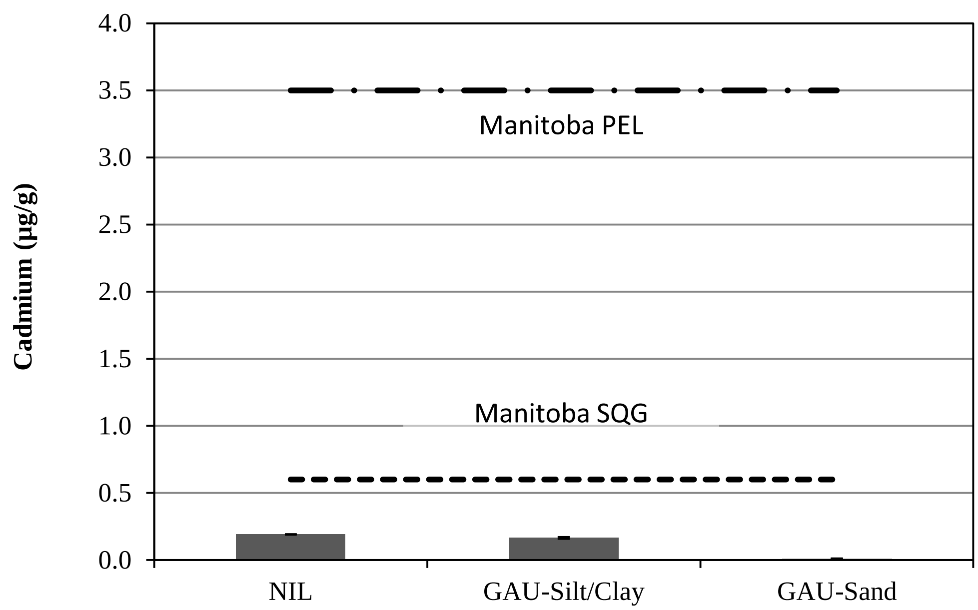


Figure 4-7. Mean (±SE) concentrations of cadmium in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines. Means indicated in light grey were below the analytical detection limit.

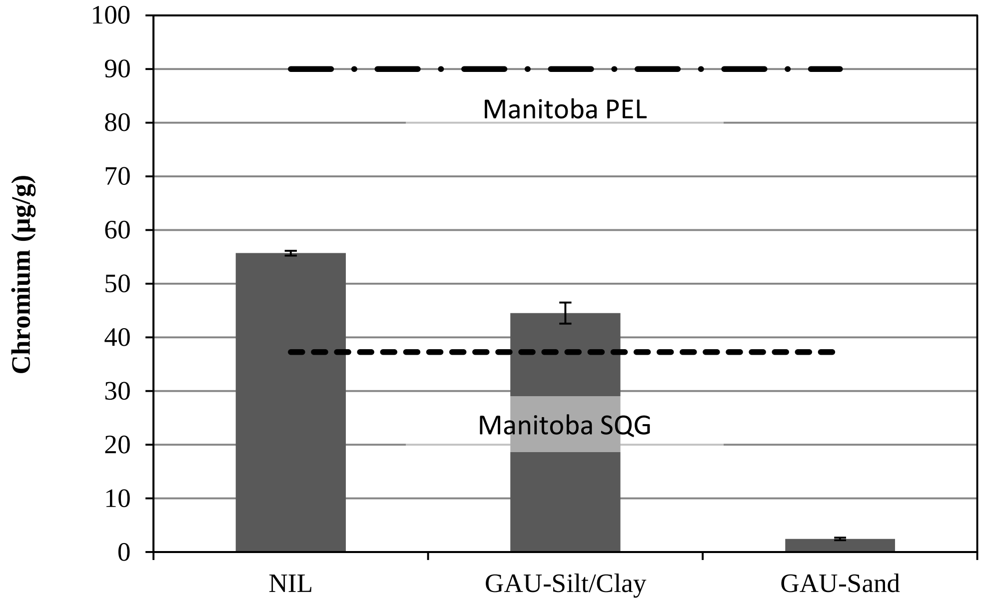


Figure 4-8. Mean (±SE) concentrations of chromium in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines.

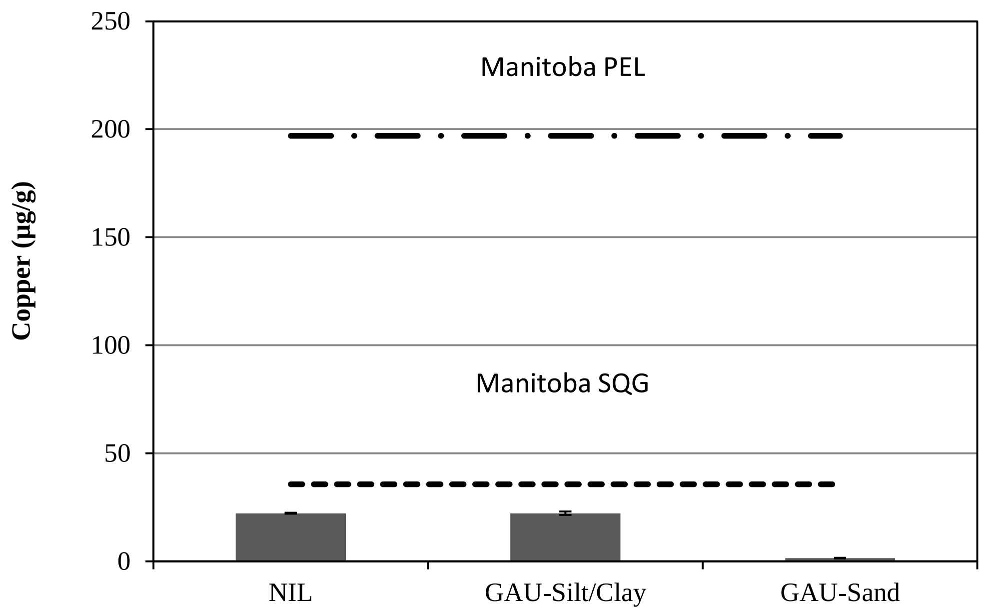


Figure 4-9. Mean (±SE) concentrations of copper in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines.

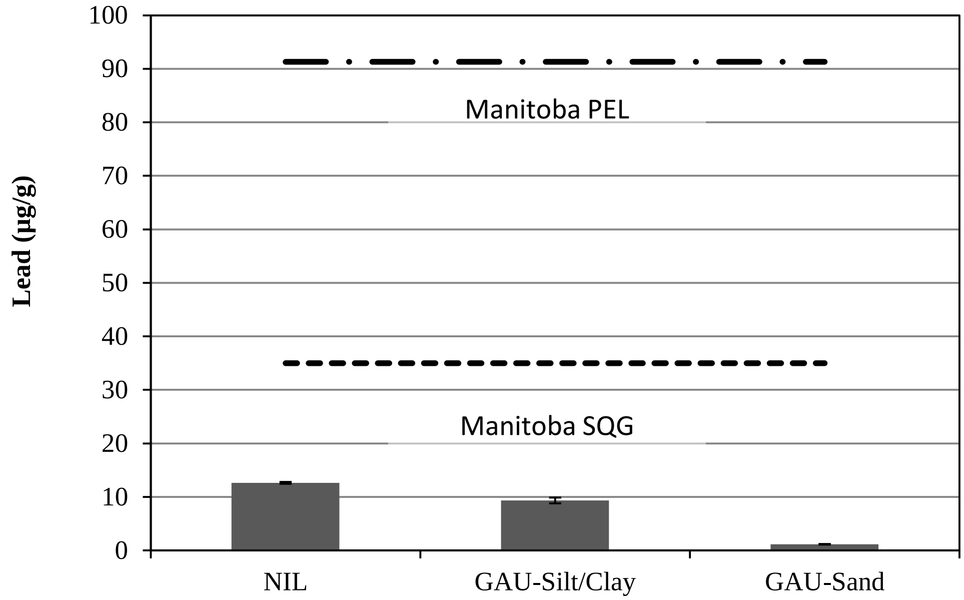


Figure 4-10. Mean (±SE) concentrations of lead in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines.

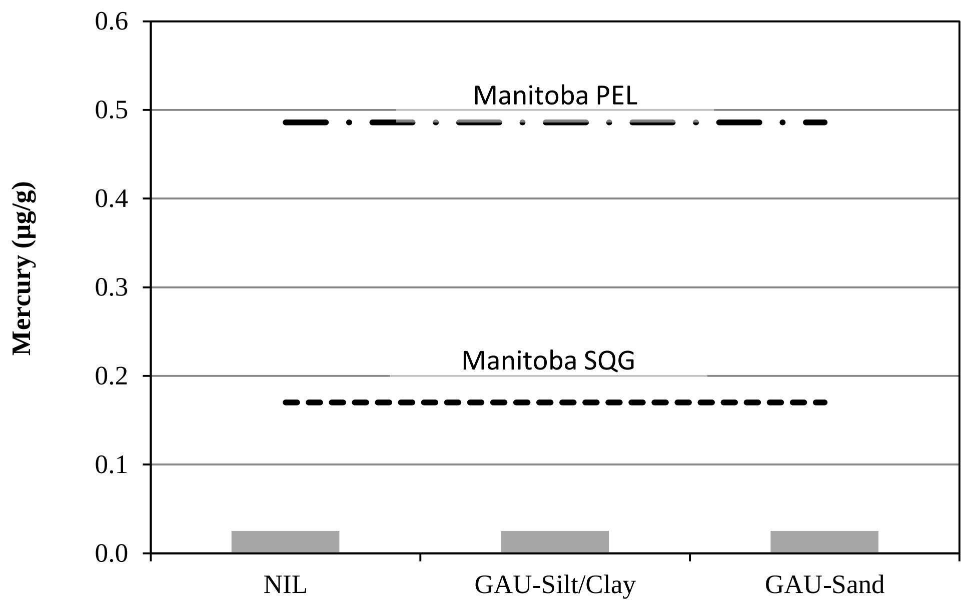


Figure 4-11. Mean (±SE) concentrations of mercury in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines. All measurements were below the analytical detection limit (0.05 µg/g).

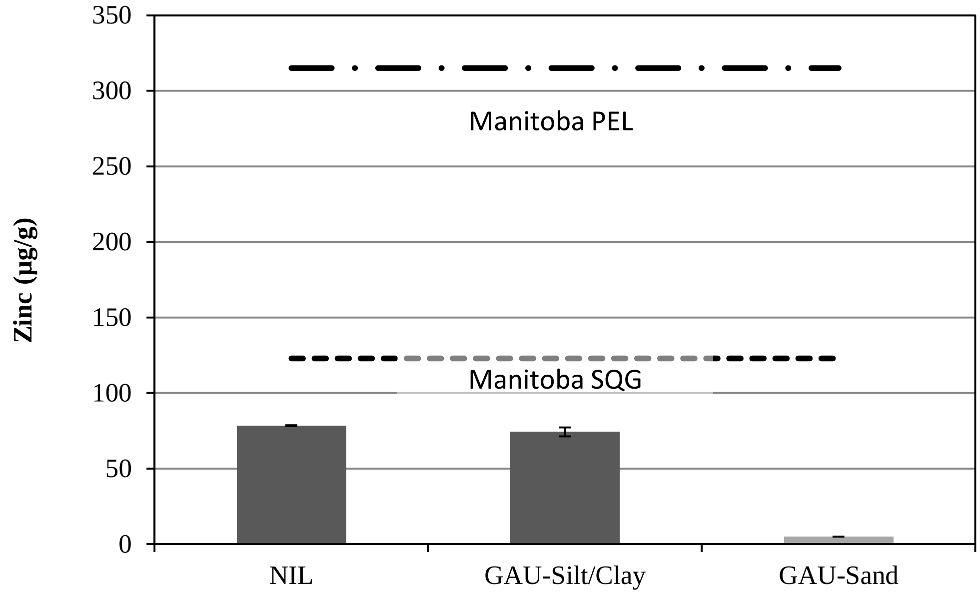


Figure 4-12. Mean (±SE) concentrations of zinc in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Manitoba sediment quality guidelines. Means indicated in light grey were below the analytical detection limit.

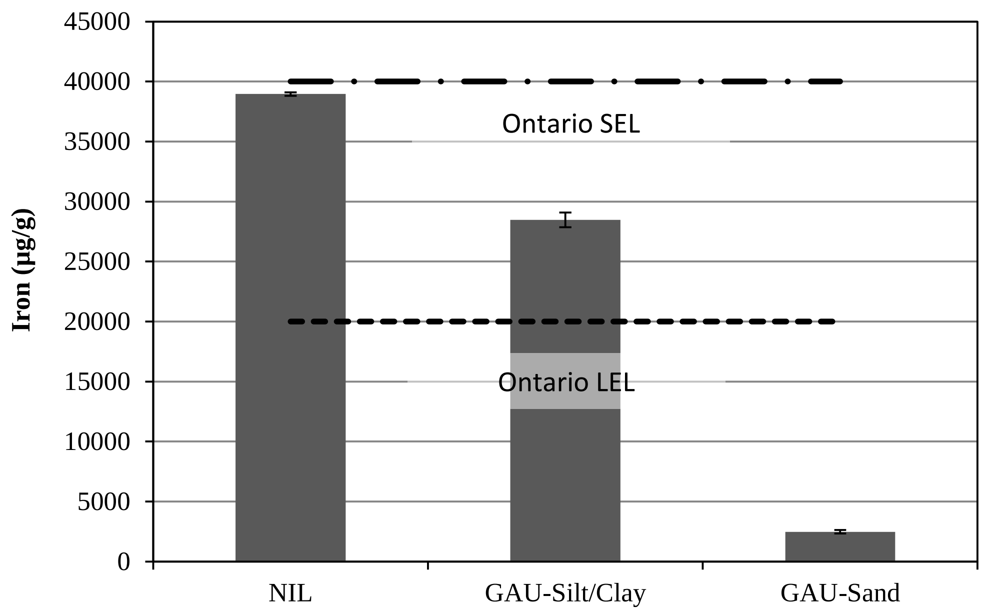


Figure 4-13. Mean (±SE) concentrations of iron in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Ontario sediment quality guidelines.

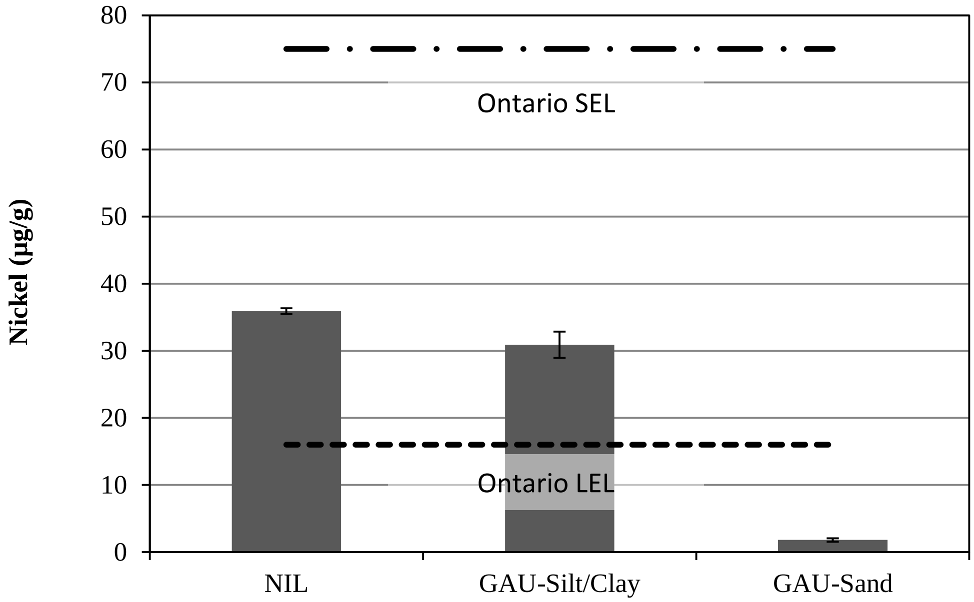


Figure 4-14. Mean (±SE) concentrations of nickel in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Ontario sediment quality guidelines.

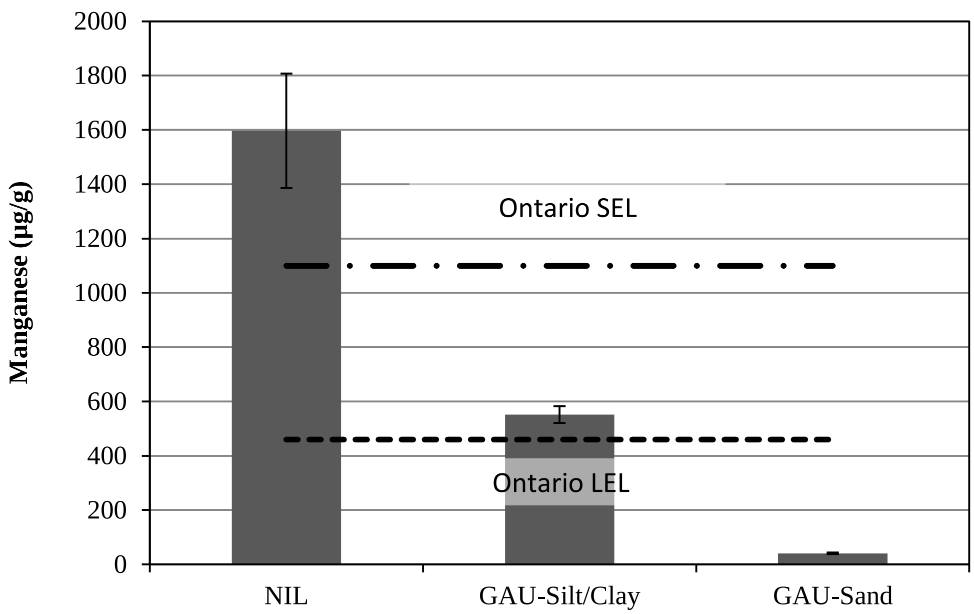


Figure 4-15. Mean (±SE) concentrations of manganese in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to Ontario sediment quality guidelines.

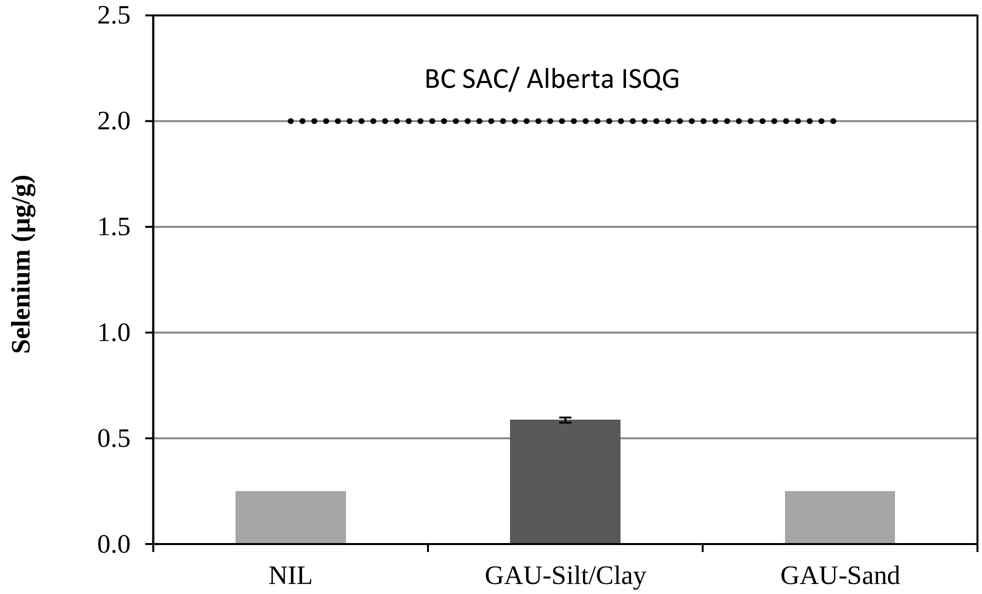


Figure 4-16. Mean (±SE) concentrations of selenium in surficial sediment from Northern Indian Lake (NIL) and two sites in Gauer Lake (GAU) and comparison to the BC SAC and the Alberta ISQG. Means indicated in light grey were below the analytical detection limit.

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 LCRR. Data are restricted to this four-year time period as the sampling design was modified beginning 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/river reaches sampled annually included two on-system sites (Northern Indian Lake and the lower Churchill River at the Little Churchill River) and one off-system lake (Gauer Lake). Four additional on-system waterbodies or areas were sampled on a rotational basis, including Partridge Breast (2012), Fidler (2011), and Billard (2010, 2013) lakes and the lower Churchill River at Red Head Rapids (2011) (Figure 5-1). While formerly part of the LNRR under CAMP, results for the off-system Hayes River (sampled annually) are included in the following discussion to provide context for the LCRR results (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 includes one sampling period in the late summer-fall at nearshore (water depth ≤1 m, sampled with travelling kick/sweep) and offshore (water depth 5-10 m, sampled with Ekman/petite Ponar) habitat sites within each monitoring waterbody (annual and rotational). Due to logistical challenges (hard substrate and higher water velocities), offshore habitat in the lower Churchill River at Red Head Rapids and the Hayes River is not sampled under CAMP.

Depending on the water level at time of sampling, sample collection in the nearshore habitat could include sites that are periodically dewatered, the frequency and duration of dewatering depending on the elevation along the shoreline where samples were collected in relation to the hydrograph. Offshore habitats were always permanently wetted.

5.1.1 Objectives and Approach

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

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

The first objective (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 are also described to aid in the understanding of BMI metrics. It should be noted that four years of data are insufficient to detect trends over time, notably long-term trends, and the assessment was therefore restricted to qualitative assessment of the available data for sites monitored annually. Additionally, any indications of potential trends over the four year period do not necessarily imply a long-term trend is occurring, as apparent trends over this interval may simply reflect the relatively limited time period assessed in conjunction with inter-annual variability in a metric. Consideration of a longer period of record is required to evaluate for long-term trends.

The second objective (linkages with hydrological conditions) was addressed through inspection of differences among key indicators in the nearshore and offshore environments and differences in water levels and flow among sampling years. Statistical analyses were not conducted because the four years of data utilizing a consistent sampling design were 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 presented is provided in Technical Document 1, Section 4.5.1.

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

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

5.2 SUPPORTING HABITAT VARIABLES

Supporting habitat variables consisted of: (i) measures related to water depth to enable calculation of where sampling was conducted in the nearshore zone in relation to the annual cycle of wetting and drying; and (ii) characterization of the substrate (Table 5-1). In 2010, relative benchmarks were established along the shore at each waterbody. The distance from the benchmark along the shore to the water level at time of sampling and the high water mark were recorded; a shorter distance indicates a relatively higher water level at the time of sampling (Table 5-1). Additionally, gauged water levels (i.e., elevations) and discharges were provided by Manitoba Hydro for select locations in the LCRR, for varying periods of time (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 total organic carbon (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 Lower Churchill River

The nearshore habitat of Partridge Breast Lake consisted mainly of coarse, hard substrate (gravel, cobble) and, as such, only one supporting sediment sample was collected that consisted mainly of sand (greater than 90% sand; Figure 5-2). Sediments from Northern Indian Lake and the lower Churchill River at Red Head Rapids contained a greater proportion of silt and clay than other waterbodies, whereas sediments in Billard Lake and the lower Churchill River at the Little Churchill River largely consisted of sand (Figure 5-2). Fidler Lake was characterized as having a moss and vegetation substrate (no sediment samples were collected for analysis of particle size or TOC; Table 5-1). The TOC content of all sediments sampled was low (less than 3 %; Figure 5-3).

The offshore habitat of Partridge Breast Lake and the lower Churchill River at the Little Churchill River consisted mainly of sand, with relatively smaller proportions of silt and clay (Figure 5-4). Northern Indian Lake and Billard Lake sediments had a greater proportion of silt and clay than other waterbodies, whereas Fidler Lake was characterized as having near equal amounts of sand and silt/clay. The TOC of all sediments sampled was low (less than 3%; Figure 5-5).

5.2.2 Off-system Waterbodies: Gauer Lake and the Hayes River

The nearshore habitat of Gauer Lake consisted of mainly large, hard substrate (boulder with cobble); as such, sediment samples were not collected for laboratory analysis (Table 5-1). Hayes River sediments largely consisted of sand (greater than 80%), with the exception of 2013 when no sediment samples were collected for analysis due to the predominance of gravel substrate; TOC of Hayes River sediments was low (less than 0.5%), reflecting the predominance of sand (Figures 5-2 and 5-3).

Similar to Billard Lake, the offshore habitat of Gauer Lake consisted mainly of silt and clay (Figure 5-4); TOC content (7-8%) was higher than on-system lakes (Figure 5-5).

5.3 KEY INDICATORS

5.3.1 Total Number of Invertebrates

Differences in the numbers of organisms are influenced by a variety of physical (e.g., substrate type, flow conditions), biological (e.g., benthic algal biomass), and chemical (e.g., 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 Lower Churchill River

Total invertebrate abundance in nearshore habitat in Northern Indian Lake was extremely variable between years (Figure 5-6). It ranged from 361 invertebrates in 2010 to 7825 invertebrates in 2012 (the lowest and highest nearshore abundance of any on-system LCRR waterbody from 2010-2013, respectively). Numbers of invertebrates collected in 2011 and 2013 were intermediate to these two values, and similar to each other. Species composition was similar in all years except 2010. From 2011-2013, Amphipoda was consistently the dominant non-insect taxon, while Chironomidae was always the dominant insect. In contrast, Tipulidae and Oligochaeta were most abundant in 2010. Samples in 2010 also lacked Trichoptera, and the proportions of Chironomidae and Ephemeroptera were extremely low compared to other years.

At the same time that invertebrate abundance was highest in Northern Indian Lake (2012), it was lowest in the lower Churchill River at the Little Churchill River. Mean abundance for the lower Churchill River at the Little Churchill River in 2011 and 2013 was generally comparable to Northern Indian Lake. Total invertebrate abundance in nearshore habitat on the lower

Churchill River at the Little Churchill River was less variable than Northern Indian Lake, although there were still significantly more invertebrates in 2013 than 2011 or 2012 (Figure 5-6). Insects consistently dominated the samples, although they were most prevalent in 2010 and 2011, when high numbers of Corixidae were collected (comprising approximately 66% of samples in both years). In 2012 and 2013, Ephemeroptera was the dominant taxon. In 2012, Chironomidae and Oligochaeta were also more abundant than other years.

Invertebrate abundance in nearshore habitat on Billard Lake was similar in both years it was sampled (2010 and 2013), but numbers in 2013 were low compared with other on-system waterbodies. In 2010, samples contained more non-insects than insects, and Oligochaeta was the most abundant taxon, accounting for 49% of the sample. Ephemeroptera was the second-most abundant group at 13%. In 2013, nearshore habitat samples contained more insects than non-insects, and Chironomidae (26%) and Ephemeroptera (24%) were the most abundant taxa.

Nearshore habitat in Fidler Lake contained fewer invertebrates than all other LCRR waterbodies sampled in 2011. Based on the qualitative description of substrate, it is likely that the nearshore habitat sampled in Fidler Lake was recently flooded terrestrial habitat (moss, vegetation; Table 5-1; see Section 2.0 for a detailed description of hydrology), which probably contributed to the relatively low mean abundance of BMIs at this site. Samples contained more non-insects than insects, with Gastropoda and Oligochaeta making up the majority (almost 60%) of the sample.

Samples collected from nearshore habitat in Partridge Breast Lake in 2012 contained fewer organisms than samples from Northern Indian Lake, but more than samples from the lower Churchill River at the Little Churchill River. Non-insects were more abundant than insects, and Oligochaeta was the dominant taxon (31%), followed by Ephemeroptera (26%).

Nearshore habitat samples collected from the lower Churchill River at Redhead Rapids in 2011 contained low numbers of invertebrates compared to other LCRR waterbodies, and they were comprised almost entirely of Corixidae (65%) and Oligochaeta (31%). Unlike other on-system sites, nearshore habitat on the lower Churchill River at Redhead Rapids contained no amphipods.

Similar to the nearshore sites in Northern Indian Lake, total abundance at the offshore sites was highest in 2012 (Figure 5-7). Although abundance was more consistent between years in offshore habitat (ranging from 1800-3100 individuals per m^2), abundance in 2011 was still significantly lower than 2012. Insects and non-insects were present in similar proportions in all years and Amphipoda was the dominant taxon in all years except 2013, when Bivalvia was much more abundant than previous years. The higher density in 2012 appears to be due to an increase in Amphipoda and Ephemeroptera in comparison to 2010 and 2011. The dominant insect taxon alternated between Chironomidae (2010 and 2013) and Ephemeroptera (2011 and 2012).

Total invertebrate abundance at offshore sites on the lower Churchill River at the Little Churchill River was more variable than on Northern Indian Lake, and followed a similar pattern to nearshore habitat: the number of invertebrates collected in 2013 was significantly higher than 2012, while intermediate numbers were collected in 2010 and 2011. The higher density in 2013 in the lower Churchill River appears to be due to an increase in Chironomidae and Ephemeroptera compared to preceding sampling years. In all years there were more insects than non-insects, and Chironomidae was the dominant taxon in 2010 and 2013, comprising 91% and 78% of the sample respectively. In 2011 and 2012, when Chironomids accounted for fewer than 30% of sampled organisms, Bivalvia was the dominant taxon. Amphipoda were completely absent from samples in 2011 and 2012, and present in very low numbers in 2010 and 2013. Unique among the offshore LCRR sites, Plecoptera were captured in 2011 and 2012.

In both 2010 and 2013, invertebrate abundance in offshore habitat was higher in Billard Lake than any other on-system LCRR waterbody, but sample composition varied between years. In 2010, Bivalvia was the dominant group, accounting for the majority (68%) of organisms collected. Chironomidae was the most abundant insect taxon in 2010, comprising 20% of the samples. Offshore habitat samples from 2013 contained almost equal amounts of insects and non-insects, and Chironomidae was the most abundant taxon (44%). The dominant non-insect taxa in 2013 were Oligochaeta and Bivalvia, which were present in similar amounts (26% and 24% of the organisms collected, respectively).

The number of invertebrates was not only low in the nearshore habitat of Fidler Lake; the measured density in offshore habitat was also lower than all other LCRR waterbodies in 2011. Samples contained an almost equal proportion of insects and non-insects, and the two most abundant taxa were Amphipoda (28%) and Chironomidae (26%).

Similar to nearshore habitat, offshore habitat in Partridge Breast Lake in 2012 had a lower density of invertebrates than Northern Indian Lake but a higher density than samples from the lower Churchill River at the Little Churchill River. The samples contained more insects than non-insects, and the dominant taxon was Chironomidae, which made up 51% of the sample. Bivalvia was the most abundant non-insect group, accounting for 19% of collected invertebrates.

5.3.1.2 Off-system Waterbodies: Gauer Lake and the Hayes River

Except in 2010, total invertebrate abundance in the nearshore habitat of Gauer Lake was noticeably lower than all the on-system waterbodies in the LCRR (Figure 5-6). The nearshore habitat of Gauer Lake consisted of large, hard substrate (mainly boulder with cobble) in comparison to the on-system lakes (Section 5.2), and total BMI production tends to be relatively low on extremely coarse substrates (e.g., boulder, bedrock; Morin 1997). Nearshore invertebrate abundances in Gauer Lake were comparable in 2010 and 2011, but were lower in 2012 and 2013. Abundance in 2013 was significantly lower than in 2010 and 2011. Insects consistently dominated the nearshore samples. In all years except 2013, Corixidae were extremely abundant; while still present in 2013, they were captured in smaller numbers and the proportion of Trichoptera increased.

Total invertebrate abundance in nearshore habitat on the Hayes River was similar in all four years it was sampled (2010-2013), ranging from a low of 854 invertebrates in 2011 to a high of 1692 invertebrates in 2013. The proportion of insects at this site was also consistently higher than the proportion of non-insects. Corixidae comprised the majority of the catch in 2010, while in the other years Corixidae, together with Chironomidae and Ephemeroptera, were the dominant groups, although Oligochaeta and Bivalvia made up greater than 10% of the fauna in some years.

The mean density of BMIs in offshore habitat in Gauer Lake was notably higher than on-system waterbodies in all years (Figure 5-7). In general, abundance of BMIs increases with the presence of organic matter (i.e., detritus), and the TOC content of offshore sediments in Gauer Lake was higher than any other LCRR waterbody (Section 5.2). In the offshore of Gauer Lake, total density of BMIs was significantly higher in 2013 than in 2011, and densities in 2010 and 2012 were intermediate (Figure 5-7). The proportions of insects and non-insects in offshore samples from Gauer Lake were roughly equal in all years except 2013, when there were slightly more insects. Chironomidae was consistently the most abundant taxon, and the increased density in 2013 appears to be due to a higher abundance of chironomids in comparison to previous sampling years. While the insect composition of samples remained consistent between years, the most abundant non-insect taxon in samples was variable and shifted from Oligochaeta in 2010 and 2011, to Bivalvia in 2012, and back to Oligochaeta in 2013. Similar to the Little Churchill River at the Little Churchill River, Amphipoda were very rarely collected from offshore habitat in Gauer Lake, and were completely absent from 2010 and 2011 samples.

5.3.1.3 Temporal Comparisons and Trends

While invertebrate abundance was variable in on-system waterbodies, there was no indication of increasing or decreasing trends over the four-year sampling period at sites sampled annually (Figures 5-6 and 5-7). Abundance was highest in both nearshore and offshore habitats in Northern Indian Lake in 2012, and second-highest in 2013. In 2012, nearshore abundance was significantly higher than in 2010, while offshore abundance was significantly higher than in 2011. In the lower Churchill River at the Little Churchill River, annual invertebrate abundance followed the same pattern in both the nearshore and offshore environment: it was highest in 2013, second-highest in 2010, followed by 2011 and then lowest in 2012. Nearshore abundance in 2013 was significantly higher than in 2011 and 2012, while offshore abundance in 2013 was only significantly higher than in 2012.

Nearshore habitat in Gauer Lake exhibited a decrease in invertebrate abundance over time, with 2010 counts significantly higher than 2013 counts. In the Hayes River, there was no significant difference in nearshore abundance between years. Invertebrate density in the offshore habitat of Gauer Lake was highest in 2013, and although density was comparable in 2010 and 2012, it was significantly lower in 2011.

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

5.3.2 Ratio of EPT to Chironomidae

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

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

5.3.2.1 Lower Churchill River

The mean ratio of EPT to chironomids in nearshore habitat varied among years and on-system lakes (Figure 5-8). Generally, insects such as ephemeropterans show a preference for shallow waters with gravel or coarse substrates, such as that sampled in the nearshore of Partridge Breast Lake in 2012 (ratio of 3.4; Minshall 1984). The chironomid-dominated nearshore habitat of Fidler Lake (ratio of 0.5) potentially reflects the recently flooded terrestrial habitat that was sampled in 2011 (see Section 2.0 for a detailed description of hydrology). Typically, chironomids (along with oligochaetes) are able to tolerate the conditions of periodic exposure in the upper littoral zone as well as be able to rapidly take advantage of newly wetted habitat, capable of colonizing bare substrates within a month (Fisher and Lavoy 1972; Scheifhacken et al. 2007). The very high ratio of 180.1 observed at Billard Lake in 2013 was due to an abundance of ephemeropterans and absence of chironomids at one replicate station. Ephemeropterans dominated the insect community on the lower Churchill River at the

Little Churchill River and at Red Head Rapids, particularly so at the Little Churchill River, likely due to suitable substrate (Figure 5-8).

The mean EPT:C in offshore habitat varied among years and on-system lakes but was less than 1 in all lakes except in Northern Indian Lake; these results reflect the predominance of chironomids in habitat with a greater amount of fine sediment (Figure 5-9). On the lower Churchill River at the Little Churchill River, mean EPT:C also varied year-to-year and was close to 1 in three of the four years (in 2010 the ratio was 0.1).

5.3.2.2 Off-system Waterbodies: Gauer Lake and the Hayes River

The mean EPT:C in the nearshore habitat of Gauer Lake tended to be somewhat higher than lakes along the lower Churchill River (Figure 5-8). Similar to Partridge Breast Lake, the nearshore of Gauer Lake consisted mainly of boulder with cobble and ephemeropterans tend to prefer this type of substrate (Section 5.2.2). For the Hayes River, mean EPT:C ratio was lower than the lower Churchill River at the Little Churchill River; however, the ratio for the Hayes River was typically greater than 1 indicating a predominance of Ephemeroptera at this site.

Similar to the majority of on-system lakes, the mean ratio of ephemeropterans to chironomids in the offshore habitat of Gauer Lake was less than 1 (Figure 5-9).

5.3.2.3 Temporal Comparisons and Trends

There was a possible increasing trend in the nearshore habitat of Gauer Lake; however, there were no statistically significant differences in EPT:C ratio in the nearshore habitat of on-system waterbodies that were sampled on an annual basis. (Figure 5-8). An opposite pattern was observed on the Hayes River: while the EPT:C ratio was not significantly different from 2010-2012, it decreased annually and in 2013 it was significantly lower than 2010.

In on-system waterbodies that were sampled annually, EPT:C ratios for offshore habitat in 2010 were notably lower than all other years (Figure 5-9). For the offshore of Northern Indian Lake, the EPT:C ratio was lowest in 2010 and highest in 2012 and the difference between these two years was significant (Figure 5-9). The EPT:C ratio in the lower Churchill River at the Little Churchill River offshore habitat followed a similar pattern to that observed in Northern Indian Lake, although it was 2011 was significantly higher than 2010. The EPT:C ratio in the offshore of Gauer Lake was similar among years and no statistically significant differences were observed (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 Lower Churchill River

Total richness of BMIs in the nearshore habitat of Northern Indian Lake increased significantly from 2010 and 2011 to 2012 and 2013 (Figure 5-10). Total richness in the nearshore of the lower Churchill River at the Little Churchill River increased significantly between 2010, 2011, and 2012, although total richness declined somewhat in 2013 (Figure 5-10).

The marginally lower mean total richness in the nearshore habitat of Fidler Lake potentially reflects the recently wetted terrestrial habitat that was sampled in 2011. Total richness on the lower Churchill River at the Little Churchill River was typically higher than upstream on-system lakes; conversely, further downstream at Red Head Rapids, total richness (eight taxa) was considerably lower than both river and lake sites (Figure 5-10).

The mean total richness of BMIs in offshore habitat was very similar among years and on-system lakes (Figure 5-11). Total richness of BMIs in the offshore of Northern Indian Lake was similar among sampling years, with a slight increase in number of taxa observed in 2012 in comparison to other years (Figure 5-11).

On the lower Churchill River at the Little Churchill River, mean total richness in offshore habitat varied among years, but was typically somewhat higher than on-system lakes (Figure 5-11). Similar to the pattern observed for the nearshore, total richness increased over time but was only significantly higher in 2013 than 2010 (Figure 5-11).

5.3.3.2 Off-system Waterbodies: Gauer Lake and the Hayes River

The mean total richness of BMIs in the nearshore habitat of Gauer Lake was typically lower than in lakes along the lower Churchill River (Figure 5-10). Total richness in Gauer Lake was similar in all years except 2011 when it was significantly lower than 2013.

For the Hayes River, mean total richness followed a pattern similar to the lower Churchill River at the Little Churchill River; however, richness was somewhat lower in comparison. Total richness increased between 2010, 2011, and 2012 (statistically significant in 2011 and 2012 compared to 2010) and then declined in 2013 and was significantly lower than 2012.

The mean total richness of BMIs in the offshore habitat of Gauer Lake followed a pattern similar to Northern Indian Lake, but was typically slightly higher than on-system lakes (Figure 5-11).

5.3.3.3 Temporal Comparisons and Trends

An indication of increasing trends over time was observed in the nearshore habitats of Northern Indian Lake and the lower Churchill River at the Little Churchill River and in the offshore habitat of the lower Churchill River at the Little Churchill River.

In the off-system Gauer Lake, total richness was similar among sampling years (Figure 5-11).

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

5.3.4 Ephemeroptera, Plecoptera, and Trichoptera Richness

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

5.3.4.1 Lower Churchill River

The mean EPT richness (family-level) in nearshore habitat of on-system lakes followed the same pattern as total richness (Figure 5-10). Mean EPT richness in the nearshore habitat of Northern Indian Lake was significantly lower than that measured in 2012 (Figure 5-10). Mean EPT richness in the nearshore of the lower Churchill River at the Little Churchill River increased significantly between 2010, 2011, and 2012; EPT richness in 2013 declined and was only statistically significantly higher than that measured in 2010 (Figure 5-10).

The relatively lower mean EPT richness in the nearshore habitat of Fidler Lake potentially reflects the recently flooded terrestrial habitat that was sampled in 2011; however, EPT richness was also relatively lower in Northern Indian Lake in 2010. As for total richness, EPT richness measured for the lower Churchill River at the Little Churchill River was typically higher than on-system lakes; richness was lower further downstream at Red Head Rapids (Figure 5-10).

The mean EPT richness in offshore habitat was very similar among years and on-system lakes, with approximately one family represented in each lake (Figure 5-11). Mean EPT richness in offshore habitat of Northern Indian Lake was similar among sampling years (Figure 5-11). Similar to the pattern observed for the nearshore, EPT richness in the offshore of the lower Churchill River at the Little Churchill River increased over time; however, there were no significant differences among sampling years (Figure 5-11). In Gauer Lake, EPT richness was also similar among sampling years, with the number of EPT taxa observed in 2011 being slightly lower than other years (Figure 5-11).

5.3.4.2 Off-system Waterbodies: Gauer Lake and the Hayes River

The mean EPT richness in the nearshore habitat of Gauer Lake varied among years: it declined between 2010 and 2011, but then increased in each of the subsequent sampling years, and significantly so in 2013 (Figure 5-10). EPT richness in the nearshore of Gauer Lake was typically within the range of the number of taxa observed in on-system lakes (Figure 5-10). For the Hayes River, EPT richness followed a pattern similar to the lower Churchill River at the Little Churchill River; however, richness was marginally higher in comparison, and the only significant difference was that EPT richness was higher in 2012 than 2010.

As for on-system lakes, the mean EPT richness in the offshore habitat of Gauer Lake was comprised of approximately one family (Figure 5-11).

5.3.4.3 Temporal Comparisons and Trends

EPT richness in the nearshore habitat differed among years, but due to high variability, statistical tests indicated no consistent significant differences and increasing or decreasing trends in the nearshore habitat were not obvious (Figure 5-10). EPT richness in the offshore was similar amongst sampling years at the annual lake sites, and appeared to increase slightly over time in the lower Churchill River at the Little Churchill River (Figure 5-11).

In off-system waterbodies, EPT richness appeared to increase from 2011-2013 in the nearshore of Gauer Lake, while consistent values were measured in all years in offshore habitat (Figure 5-10). Similar to the offshore in the lower Churchill River at Little Churchill River, EPT richness in nearshore habitat along the Hayes River increased slightly from 2010-2012 (Figure 5-11).

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

5.3.5 Simpson's Diversity Index

Simpson's Diversity Index is used to quantify the diversity of a habitat and 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).

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

5.3.5.1 Lower Churchill River

Simpson's Diversity Index for the nearshore BMI community varied among years, but minimally among on-system lakes (Figure 5-12). Simpson's Diversity Index in the nearshore habitat of Northern Indian Lake increased over time, and 2013 was statistically significantly higher than in 2010 (Figure 5-12). Diversity index values in the nearshore of the lower Churchill River at the Little Churchill River was similar in 2010 and 2011, and then increased significantly in 2012 and 2013 (Figure 5-12).

In 2010 and 2011, diversity on the lower Churchill River at the Little Churchill River was lower than on-system lakes; however, in 2012 and 2013 diversity was comparable to on-system lakes. Similarly, diversity at Red Head Rapids in 2011 was lower than the upstream lakes.

Similar to nearshore habitat, Simpson's Diversity Index for the offshore BMI community varied among years and on-system lakes (Figure 5-13). No changes in the Simpson's Diversity Index over time in the offshore habitat of Northern Indian Lake were significant (Figure 5-13). The mean Simpson's Diversity Index in the offshore of the lower Churchill River at the Little Churchill River increased over time; however, the diversity index was only significantly higher in 2012 and 2013 in comparison to 2010 (Figure5-13).

In 2010 and 2013, diversity on the lower Churchill River at the Little Churchill River was similar to the nearest upstream lake, Billard Lake; however, in 2011 and 2012 diversity was within the range observed for the other on-system lakes.

5.3.5.2 Off-system Waterbodies: Gauer Lake and the Hayes River

A similar pattern to Northern Indian Lake was observed in the nearshore of the off-system Gauer Lake; however the diversity index decreased between 2010 and 2011 before increasing in each subsequent year; the diversity index in 2013 was statistically significantly higher than that in 2011 and 2012 (Figure 5-12). For the diversity index, no changes over time in the nearshore habitat of the Hayes River were statistically significant (Figure 5-12).

The Simpson's Diversity Index for the nearshore community in Gauer Lake was notably lower than on-system lakes (Figure 5-12). The relatively lower diversity index for the nearshore habitat of Gauer Lake may reflect the predominance of larger, hard substrate (mainly boulder with cobble) with correspondingly lower BMI production in comparison to the on-system lakes (Section 5.3.1). For the Hayes River, diversity in 2010 and 2013 was notably lower than the lower Churchill River at the Little Churchill River; however, in 2011 and 2012 diversity was comparable.

In the offshore habitat of the off-system Gauer Lake, Simpson's Diversity Index was significantly lower in 2013 than in 2011 and 2012. (Figure 5-13). As previously noted, offshore habitat is not sampled in the Hayes River due to the absence of fine substrate. Diversity in the offshore of Gauer Lake was typically within the range observed for on-system lakes (Figure 5-13).

5.3.5.3 Temporal Comparisons and Trends

Simpson's Diversity Index exhibited notable inter-annual variability, including statistically significant differences (Figures 5-12 and 5-13). There were indications of increasing trends over the four-year sampling period in the nearshore habitat of Northern Indian and Gauer lakes; and in the offshore habitat of the lower Churchill River at the Little Churchill River.

5.4 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

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

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

5.4.1 Ephemeroptera Richness

5.4.1.1 Lower Churchill River

Mean Ephemeroptera richness (genus-level) in nearshore habitat varied among years and on-system lakes (Figure 5-14). Ephemeroptera richness in the nearshore habitat of Northern Indian Lake increased significantly from 2010 to 2012 and 2013 (Figure 5-14). Ephemeroptera richness in the nearshore of the lower Churchill River at the Little Churchill River increased significantly between 2010, 2011, and 2012; richness declined somewhat in 2013 and was only statistically significantly higher than that measured in 2010 (Figure 5-14).

The lower mean richness in the nearshore habitat of Fidler Lake potentially reflects the recently flooded terrestrial habitat that was sampled in 2011; however, richness in Northern Indian Lake in 2010 was considerably lower than what was observed in Billard Lake for the same year. Total richness on the lower Churchill River at the Little Churchill River was typically higher than upstream on-system lakes; further downstream at Red Head Rapids, total richness was considerably lower than the upstream river site, but within the range observed for on-system lakes.

Richness of Ephemeroptera in the offshore of Northern Indian Lake was similar among sampling years (Figure 5-15). Ephemeropteran richness in the offshore of the lower Churchill River at the Little Churchill River increased slightly between 2010 and 2011. Richness was notably lower in 2012 before increasing significantly in 2013 (Figure 5-15).

The mean Ephemeroptera richness in offshore habitat was similar among years and on-system lakes (Figure 5-15).

5.4.1.2 Off-system Waterbodies: Gauer Lake and the Hayes River

In the nearshore of the off-system Gauer Lake; richness was comparable in 2010, 2012, and 2013, but notably lower in 2011, however, richness in 2011 was only significantly lower than that in 2013 (Figure 5-14). Ephemeropteran richness in the nearshore of the off-system Hayes River was not statistically significantly different among years (Figure 5-14).

The mean Ephemeroptera richness in the nearshore habitat of Gauer Lake was typically lower than lakes along the lower Churchill River (Figure 5-14). For the Hayes River, mean total richness followed a pattern similar to the lower Churchill River at the Little Churchill River; however, richness was somewhat higher in 2011 and lower in 2013 in comparison.

The mean Ephemeroptera richness in the offshore habitat of Gauer Lake was marginally lower in 2010 and 2011 in comparison to Northern Indian Lake (Figure 5-15).

5.4.1.3 Temporal Comparisons and Trends

Ephemeroptera richness exhibited notable inter-annual variability, including statistically significant differences in the nearshore habitat of all annual sites except for the Hayes River (Figure 5-14). Ephemeroptera richness was less variable among years in the offshore habitat, with statistically significantly inter-annual variability occurring at the lower Churchill River at the Little Churchill River (Figure 5-15). Indications of increasing trends over time were only apparent for the nearshore habitat of Northern Indian Lake.

In the off-system Gauer Lake, richness was also similar among sampling years (Figure 5-15).

5.5 RELATIONSHIPS WITH HYDROLOGICAL METRICS

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

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

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

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

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

Flows in the LCRR are largely controlled by outflows at the Missi Falls CS (Section 2). In 2010 and 2011, flows in spring and early summer were near average before increasing sharply in late summer, concurrent with BMI sampling. In 2012, Missi Falls CS outflows remained close to average until late spring, after which there were periods of increases; in 2013 flows remained close to average through the growing season. These differences in flow directly affected elevations on waterbodies along the LCRR.

The Gauer River is unregulated and flows respond to local precipitation and Gauer Lake water levels. From 2010-2013, Gauer River flows from January to the beginning of August were below average (1979-2013); Section 2.0). In both 2012 and 2013, below-average flow levels persisted through the whole year, but in 2010 and 2011, there was a dramatic increase in discharge in mid-to-late August. There is no information on water levels at the BMI sampling site, but potentially the increased levels in 2010 and 2011 would have resulted in sampling areas that were not wetted throughout the open water season.

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

As noted previously, four years of data are insufficient to support a statistical analysis to determine whether average water levels or discharge during the growing season are related to key benthic invertebrate metrics. However, key metrics in relation to the average water level and discharge during the growing season during a given year at the two annual sites was inspected to determine whether there were any obvious relationships (Table 5-2, Figures 5-16 to 5-18).

Water levels on Northern Indian Lake in 2010 and 2011 increased to above average (1997-2013) from mid-August to early-September, whereas in 2012 and 2013 water levels declined to below average (2012) or remained near average (2013) over that same time period (Section 2.0). Water levels increased in 2010 and 2011 increased near the time of BMI sampling, and nearshore habitat sampled in those years may have been previously dry (or wetted less frequently) earlier in the summer, resulting in relatively lower BMI abundance, richness, and diversity values (Table 5-2). In 2012 and 2013, the nearshore habitat sampled during the BMI program would have been wetted for most of the growing season, resulting in higher abundance, richness and diversity. The difference between 2011 and 2013 is noteworthy as the average water level was the same but in 2013, the nearshore habitat was wetted throughout the growing season, resulting in higher abundance, diversity and richness.

Although abundance was not different, a similar pattern was apparent for richness and diversity on the Churchill River at the Little Churchill, where diversity and richness were markedly lower in 2010 and 2011 than in 2012 and 2013, potentially related to the shorter period of wetting.

As noted above, based on Gauer River discharge, levels in Gauer Lake may have increased in late 2010 and 2011 while levels in 2012 and 2013 would have been more stable. However, assuming that river discharge is directly linked to lake level, inter-annual differences in BMI abundance in the nearshore are not linked to the duration of wetting during the open water season, as abundance was lowest in 2013.

No relationship with water level or discharge was apparent for any of the offshore habitats (Figure 5-16, 5-17 and 5-18).

5.6 SUMMARY

Overall, analysis of the four years of CAMP BMI monitoring data collected in the LCRR indicated that most of the key metrics, and the additional metric Ephemeroptera richness, did not show a consistent increasing or decreasing trend over this time period. Two exceptions occurred in the nearshore habitat of Northern Indian Lake where an increasing trend in Ephemeroptera richness and the diversity index was noted; additionally, an increasing trend in the diversity index in the offshore of the lower Churchill River at the Little Churchill River was observed. As discussed above, these changes over time are likely not trends but related to differences in hydrology between 2010/2011 and 2012/2013. While other temporal trends were not noted, statistically significant inter-annual variability was observed for metrics in both of the habitat types sampled (e.g., total invertebrate abundance in the nearshore habitat of Northern Indian Lake, the lower Churchill River at the Little Churchill River, and Gauer Lake; Simpson’s Diversity Index in the offshore habitat of Gauer Lake).

Water level variation among years influences the extent and duration of the wet/dry cycle of the nearshore habitat and the BMI community. The lower abundance, richness and diversity values may have reflected a relatively recent wetted habitat in the nearshore of Northern Indian Lake in 2010 and 2011; this pattern was subsequently reflected in higher BMI metric values when sampling occurred in habitats that were wetting for much of the growing season in 2012 and 2013. The lower BMI abundance in the nearshore of Fidler Lake in comparison to other LCRR waterbodies may have been due to sampling of recently flooded terrestrial habitat.

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

Waterbody	Date	Nearshore				Offshore				Relative Water Level[3]		Gauged Water Level (daily mean)	
		Water Depth (mean max, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description[1]	Benthic Substrate Texture/Analysis[1, 2]	Water Depth (mean, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description (predominant)[1]	Benthic Substrate Texture/Analysis[1]	Current (m)	High (m)	(WSL m)	(Q m^3/s)
NIL	16-Aug-10	0.3	standing	silt, organic matter	silty clay loam	3.5	standing	clay	silt loam	3.50	n.r.	234.51	--
BIL	16-Aug-10	0.5	standing	cobble, gravel, sand	sand	8.2	standing	clay, organic matter	silty clay loam	5.00	0.34	187.33	--
LCR-LiCR	20-Aug-10	1.0	standing	flooded terrestrial, boulder	--	6.4	low	sand	sand (sandy loam)	1.50	1.92	133.55	--
HAYES	27-Aug-10	1.0	low	sand, gravel, cobble	sand (loamy)	--	--	hard substrate; no benthic grabs	--	0.44	n.r.	22.12	1640.00
GAU	20-Aug-10	0.5	standing	boulder	--	6.2	standing	clay, silt	silty clay loam	1.97	0.95	29.02	24.00
NIL	17-Aug-11	1.0	standing	flooded terrestrial, clay (cobble)	loam (loamy sand)	5.0	standing	clay	silt loam (silty clay loam)	1.96	n.r.	235.59	--
FID	27-Aug-11	0.5	standing	flooded terrestrial, organic matter	--	8.8	low	clay, sand (silt, gravel)	sandy loam (sandy clay loam)	1.52	3.60	28.69	1180.00
LCR-LiCR	18-Aug-11	1.0	standing	boulder, sand (gravel, silt)	sandy loam	6.5	low	sand, cobble, gravel	sand (loamy sand)	3.60	1.37	133.19	--
LCR-RHR	23-Aug-11	1.0	low	cobble	sandy loam	--	--	hard substrate; no benthic grabs	--	1.36	1.20	23.58	800.00
HAYES	17-Aug-11	1.0	low	sand, cobble	loamy sand (sand)	--	--	hard substrate; no benthic grabs	--	1.57	0.21	20.87	772.00
GAU	18-Aug-11	0.8	standing	cobble, boulder	--	6.8	standing	silt, clay	silty clay (silty clay loam)	3.10	2.20	29.37	57.10
PBL	18-Aug-12	0.7	standing	cobble, clay, silt (gravel)	coarse substrate (sand at one replicate station)	5.9	standing	clay, silt, gravel, sand (organic matter)	sandy loam (sandy clay loam)	4.30	1.05	242.31	--
NIL	17-Aug-12	0.5	standing	clay, cobble, organic matter	sandy loam (silt loam)	4.1	standing	clay	silt loam	3.40	2.00	235.10	--
LCR-LiCR	20-Aug-12	1.0	standing	sand, silt, gravel	loamy sand (sand)	5.4	low	sand, gravel	sand	3.10	2.20	133.16	--
HAYES	19-Aug-12	1.0	standing	gravel, cobble (silt)	loamy sand (sand)	--	--	hard substrate; no benthic grabs	--	1.49	n.r.	20.80	733.00
GAU	22-Aug-12	0.8	standing	boulder (cobble, gravel)	--	6.5	standing	silt, clay	silt loam	1.86	n.r.	29.05	28.00
NIL	22-Aug-13	0.5	standing	silt, clay	silty clay loam (sand)	8.2	standing	silt, clay	silty clay loam	3.12	n.r.	234.79	--
BIL	21-Aug-13	1.0	standing	sand	sand	9.1	standing	silt, clay	silt loam (silty clay loam)	4.47	n.r.	188.27	--
LCR-LiCR	19-Aug-13	0.4	standing	sand (gravel)	sand	5.1	standing-low	sand, gravel	sand	4.10	n.r.	132.94	--
HAYES	26-Aug-13	0.4	standing	hard substrate; gravel	--	--	--	hard substrate; no benthic grabs	--	n.r.	n.r.	20.10	410.00
GAU	24-Aug-13	1.0	standing	boulder	--	6.4	standing	silt, clay	silty clay (silty clay loam)	1.25	n.r.	28.95	16.00

[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 Northern Indian Lake, Gauer Lake, and the lower Churchill River at the Little Churchill River in the nearshore and offshore environments, 2010 to 2013.

Northern Indian Lake

Year	Abundance (Number/Kicknet Or Number/m^2)	Richness	Diversity	Water Level (mASL)	Discharge (m^3/s)
Nearshore					
2010	361	13.40	0.70	234.3	45.3
2011	1667	15.20	0.72	234.8	144.8
2012	7825	20.60	0.80	235.7	480.8
2013	2424	20.00	0.86	234.8	154.4
Offshore					
2010	2196	6.80	0.74	234.3	45.6
2011	1774	6.40	0.72	234.9	153.7
2012	3073	7.40	0.66	235.7	480.8
2013	2533	6.40	0.69	234.8	154.4

Gauer Lake

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	541	13.20	0.29	238.9	14.3
2011	541	7.20	0.24	239.2	39.3
2012	332	13.00	0.42	239.3	53.9
2013	126	14.80	0.70	239.0	27.9
Offshore					
2010	3930	8.00	0.75	238.9	14.3
2011	3136	6.40	0.76	239.2	39.3
2012	3780	8.40	0.77	239.3	53.9
2013	5079	8.20	0.70	239.0	27.9

Lower Churchill River at the Little Churchill River

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	1997	12.80	0.52	232.1	113.9
2011	1557	18.80	0.54	232.7	270.0
2012	1293	26.00	0.87	233.4	613.4
2013	2603	23.60	0.86	232.7	225.5
Offshore					
2010	1737	6.20	0.49	232.1	113.9
2011	1291	8.00	0.73	232.7	270.0
2012	487	7.80	0.76	233.4	617.3
2013	3717	12.40	0.76	232.7	225.5

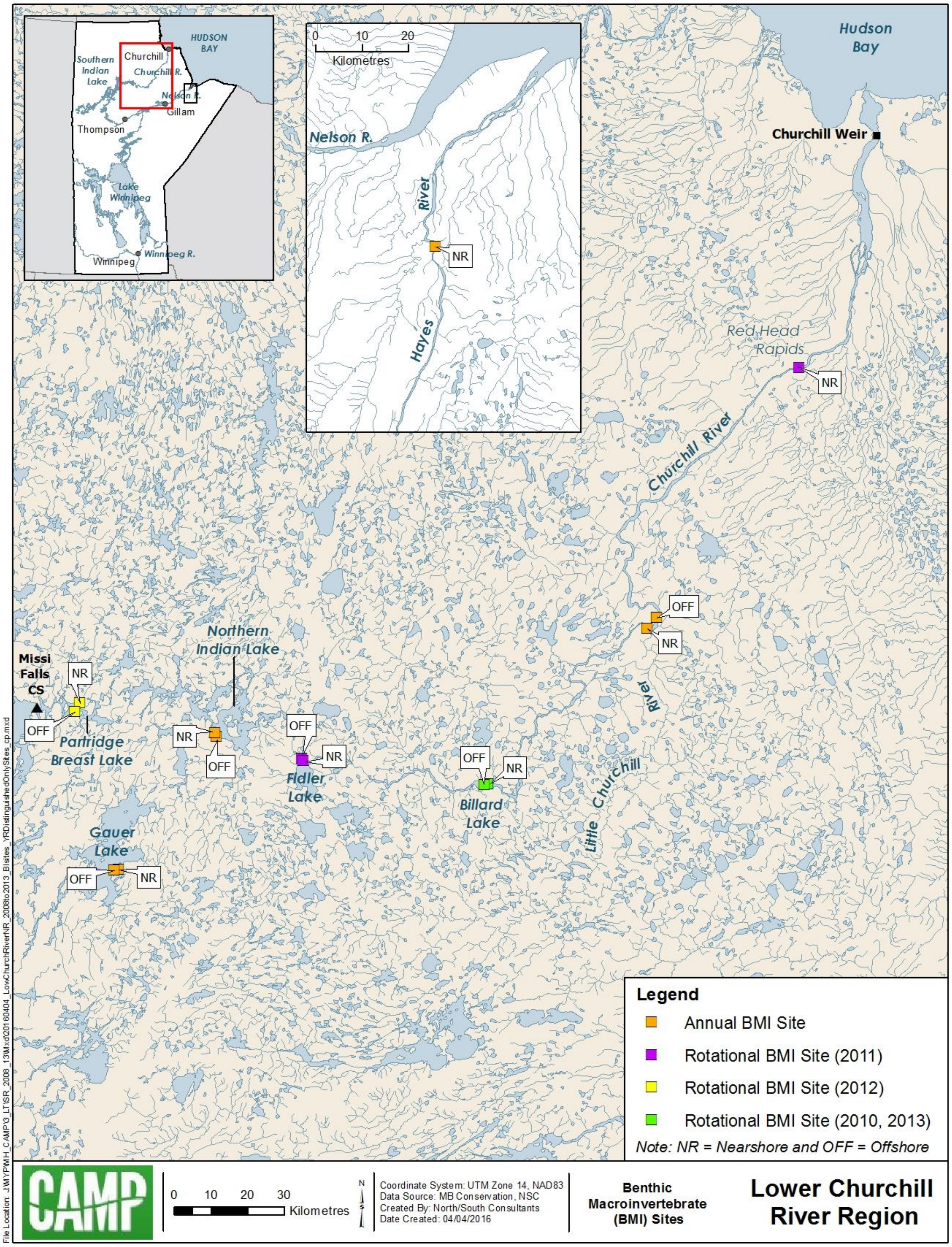
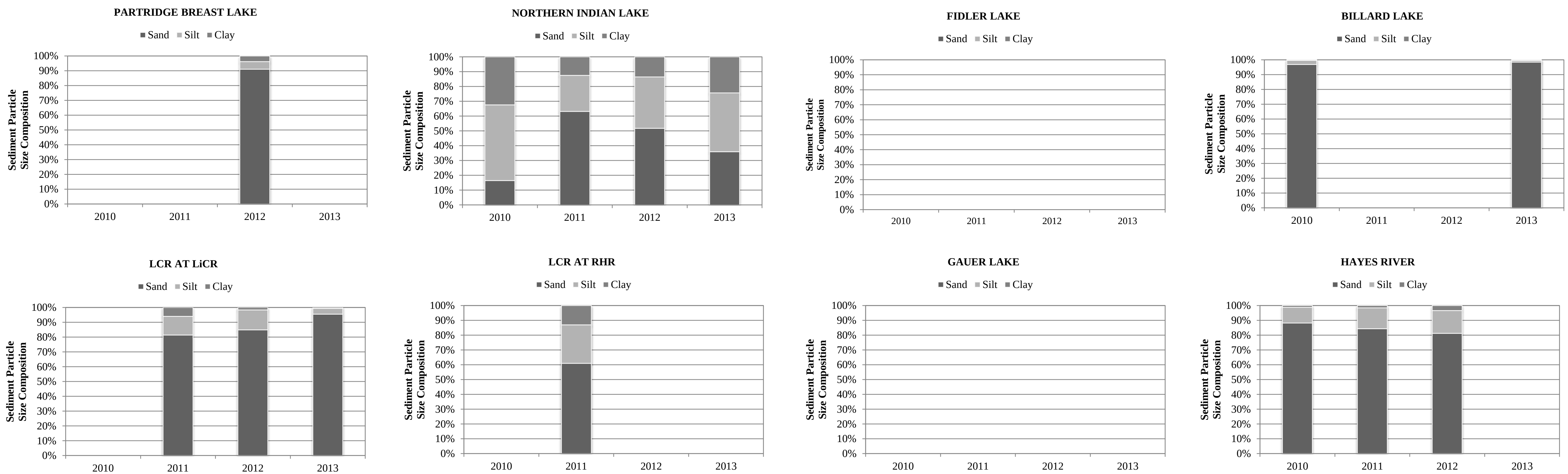


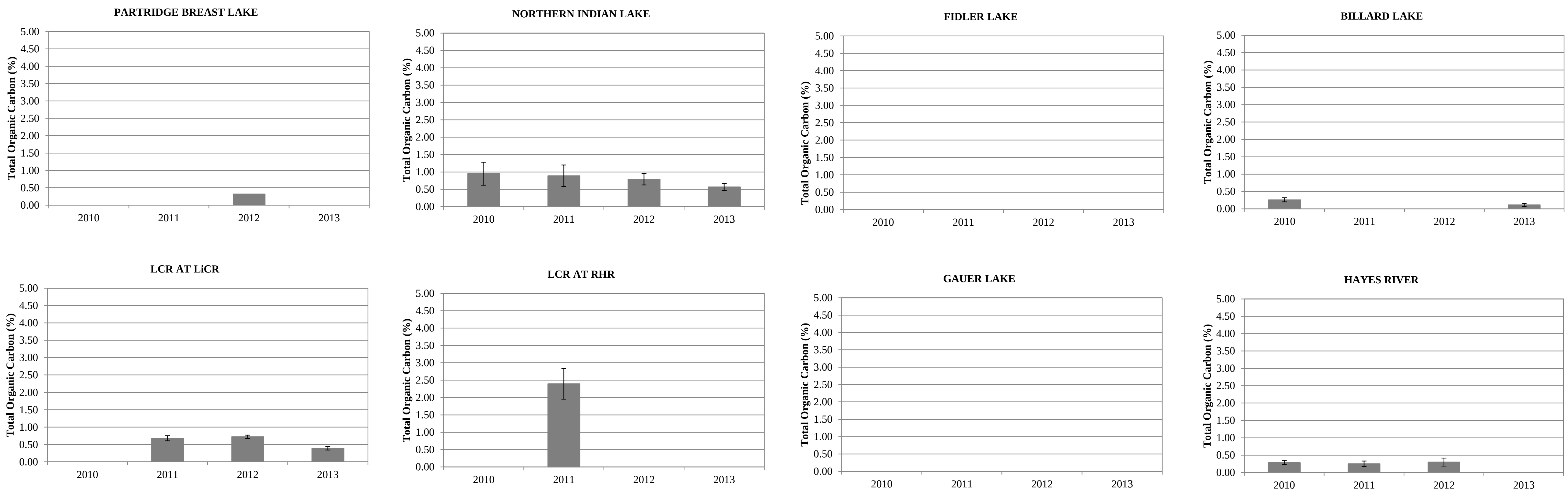
Figure 5-1. Benthic macroinvertebrate sampling sites in the Lower Churchill River Region: 2010–2013.



No sediment samples collected at:

- Partridge Breast Lake (2012) only one sediment sample was collected, majority of shoreline consisted of coarse substrates.
- Fidler Lake (2011) because shoreline was predominantly flooded terrestrial.
- Churchill River at Little Churchill River (2010) because shoreline was predominantly flooded terrestrial.
- Gauer Lake (2010 – 2013) due to predominantly hard substrate.
- Hayes River (2013) due to predominantly hard substrate (gravel).

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



No sediment samples collected at:

- Partridge Breast Lake (2012) only one sediment sample was collected, majority of shoreline consisted of coarse substrates.
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- Churchill River at Little Churchill River (2010) because shoreline was predominantly flooded terrestrial.
- Gauer Lake (2010 – 2013) due to predominantly hard substrate.
- Hayes River (2013) due to predominantly hard substrate (gravel).

Figure 5-3. Total organic carbon (mean % ± SE) in the nearshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Northern Indian Lake, lower Churchill River at Little Churchill River and Hayes River).

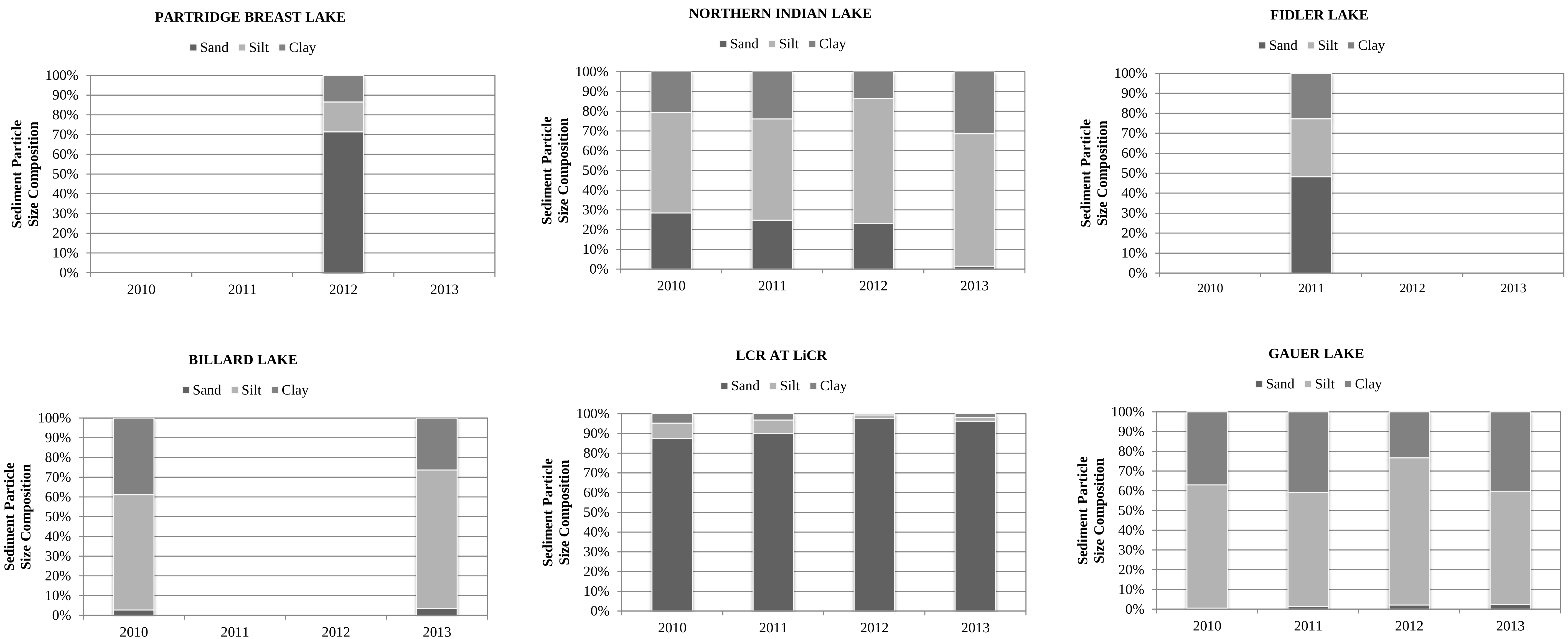


Figure 5-4. Sediment particle size composition (mean % of sand, silt, clay) in the offshore habitat of the Lower Churchill River Region, by year: 2010 – 2013.

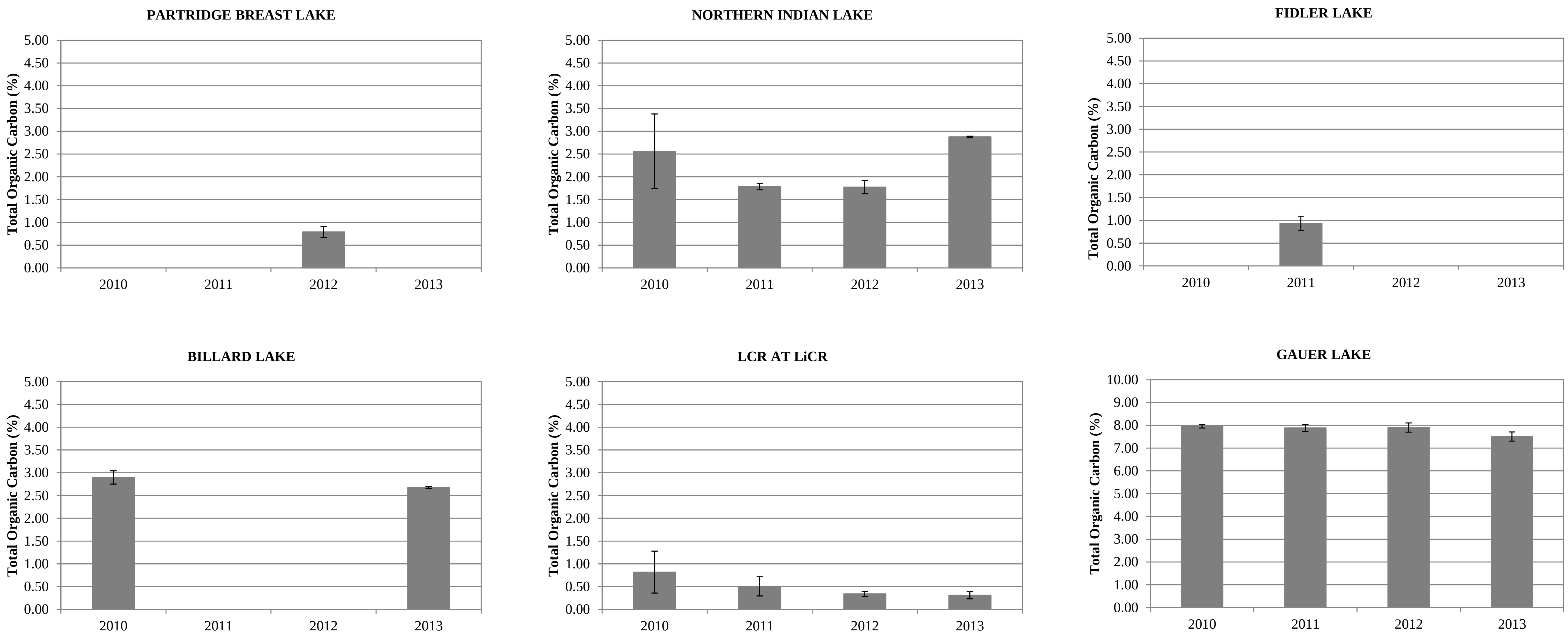


Figure 5-5. Total organic carbon (mean % ± SE) in the offshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Northern Indian Lake, lower Churchill River at Little Churchill River and Gauer Lake).

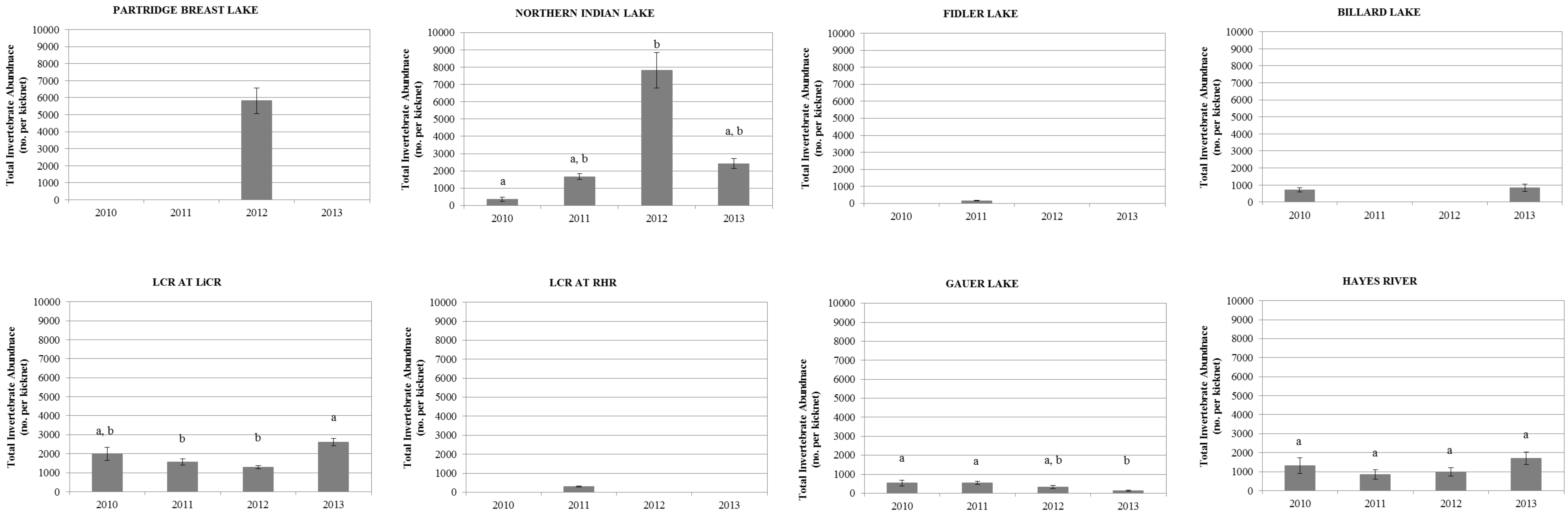


Figure 5-6. Total invertebrate abundance (mean ± SE) in the nearshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

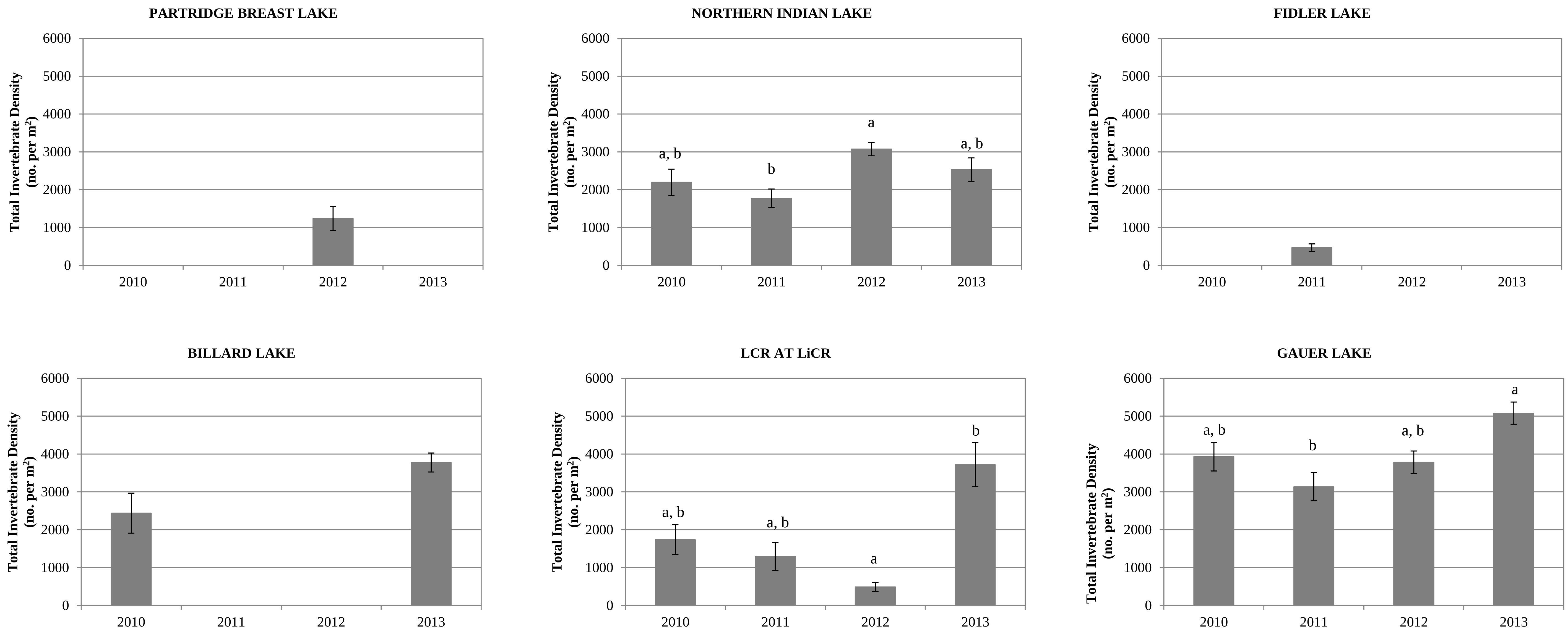


Figure 5-7. Total invertebrate density (mean ± SE) in the offshore of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

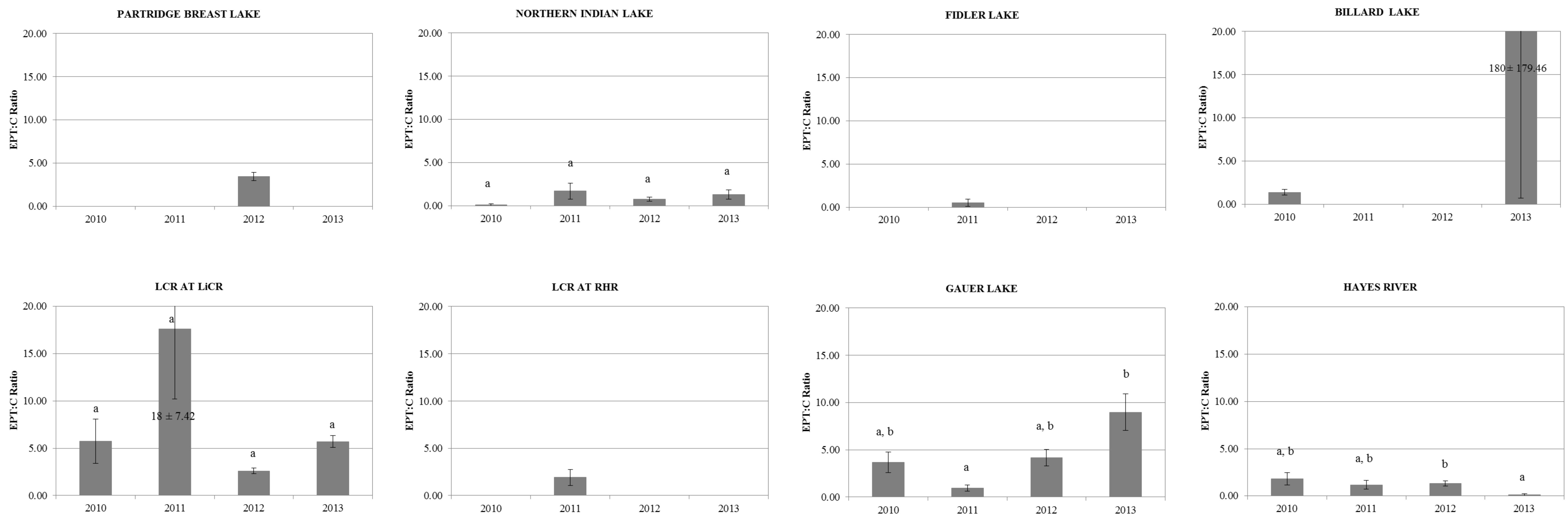


Figure 5-8. EPT:C ratio (mean ± SE) in the nearshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

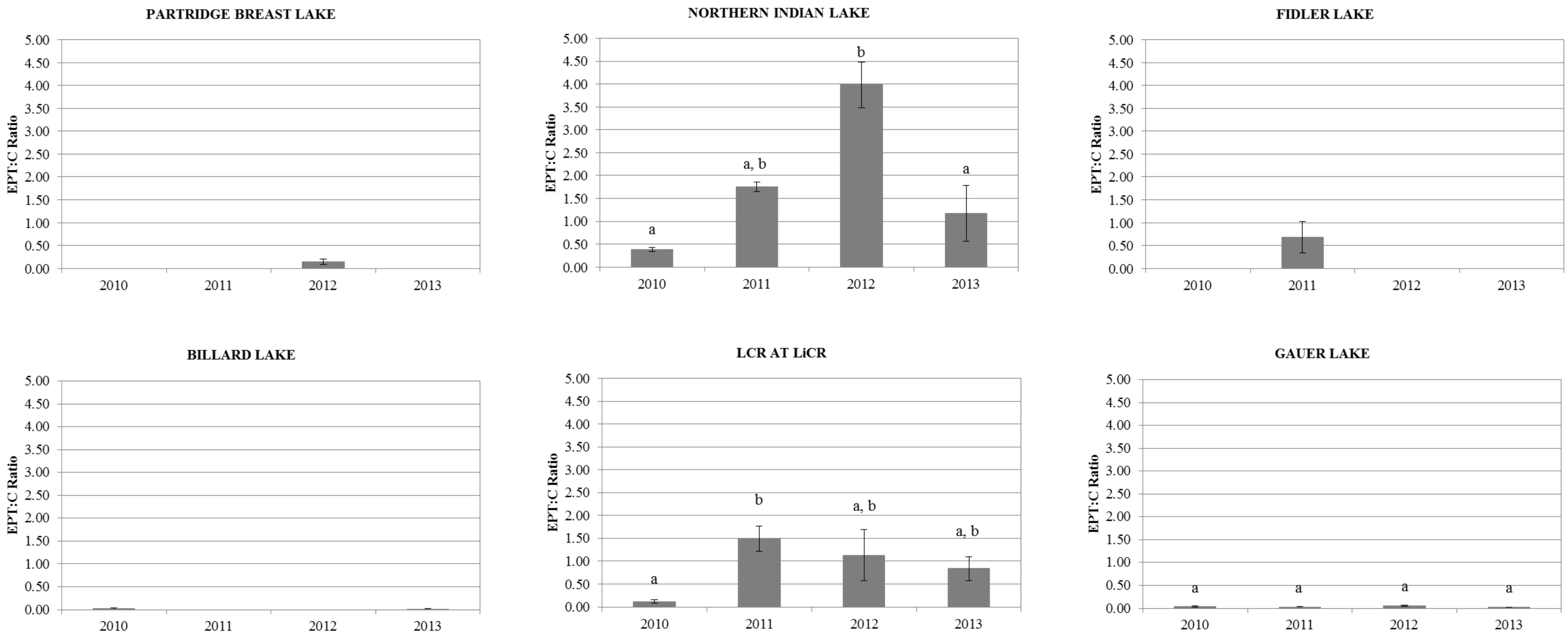


Figure 5-9. EPT:C ratio (mean ± SE) in the offshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

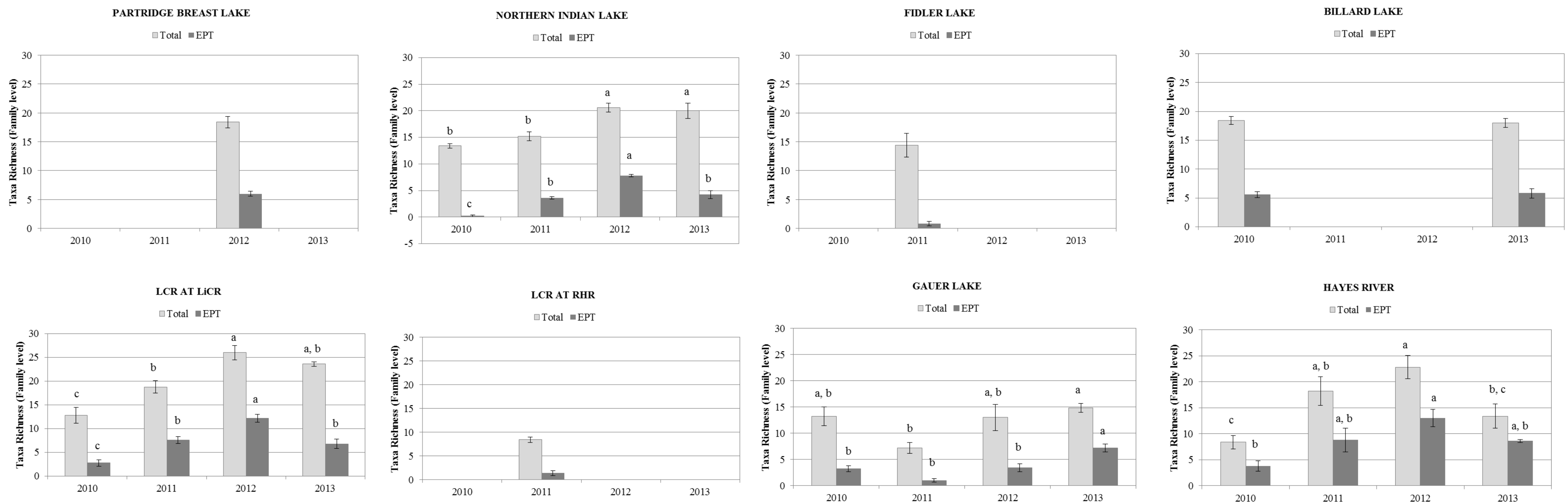


Figure 5-10. Taxonomic richness (total and EPT to family level; mean ± SE) in the nearshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote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

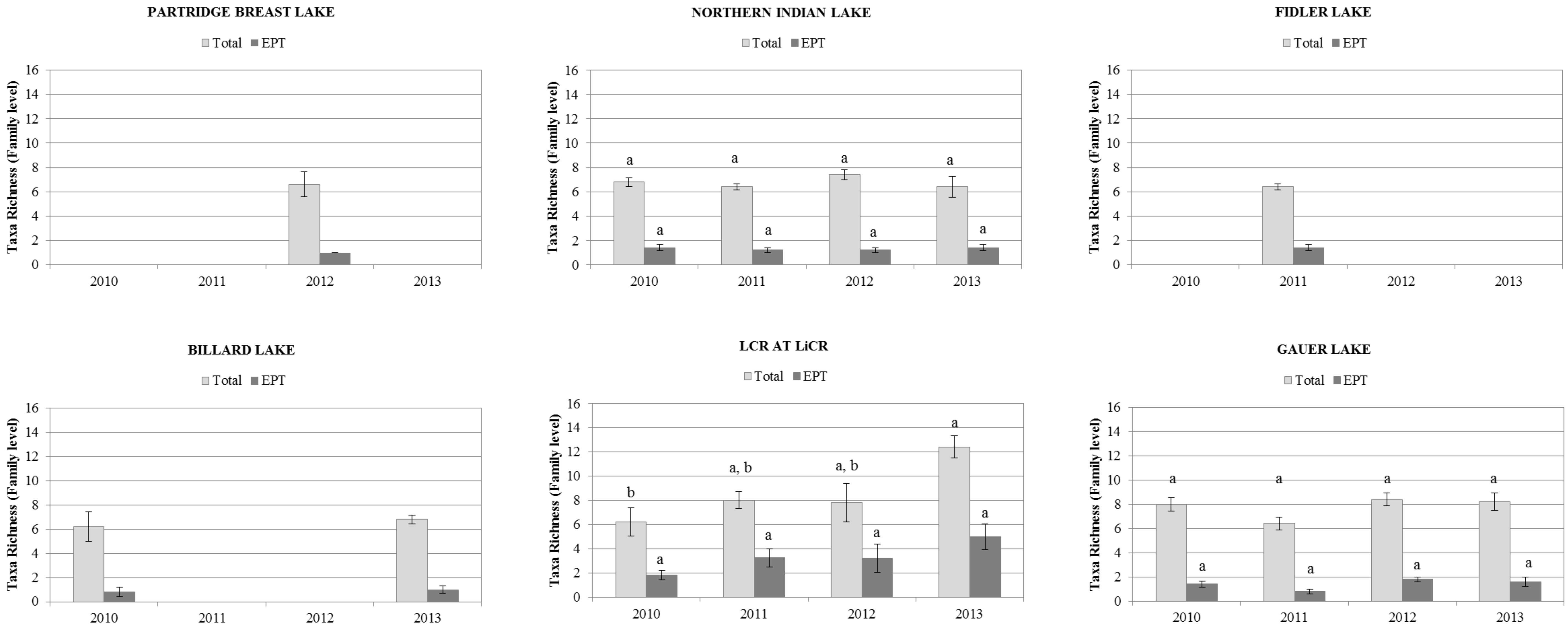


Figure 5-11. Taxonomic richness (total and EPT to family level; mean ± SE) in the offshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote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

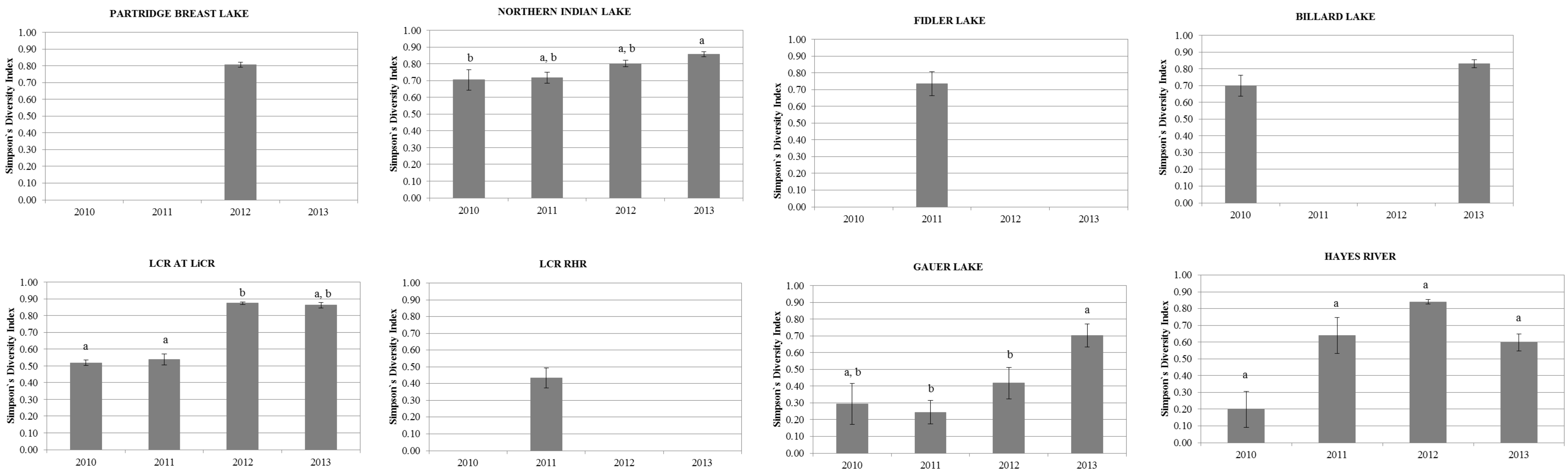


Figure 5-12. Simpson's Diversity Index (mean ± SE) in the nearshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

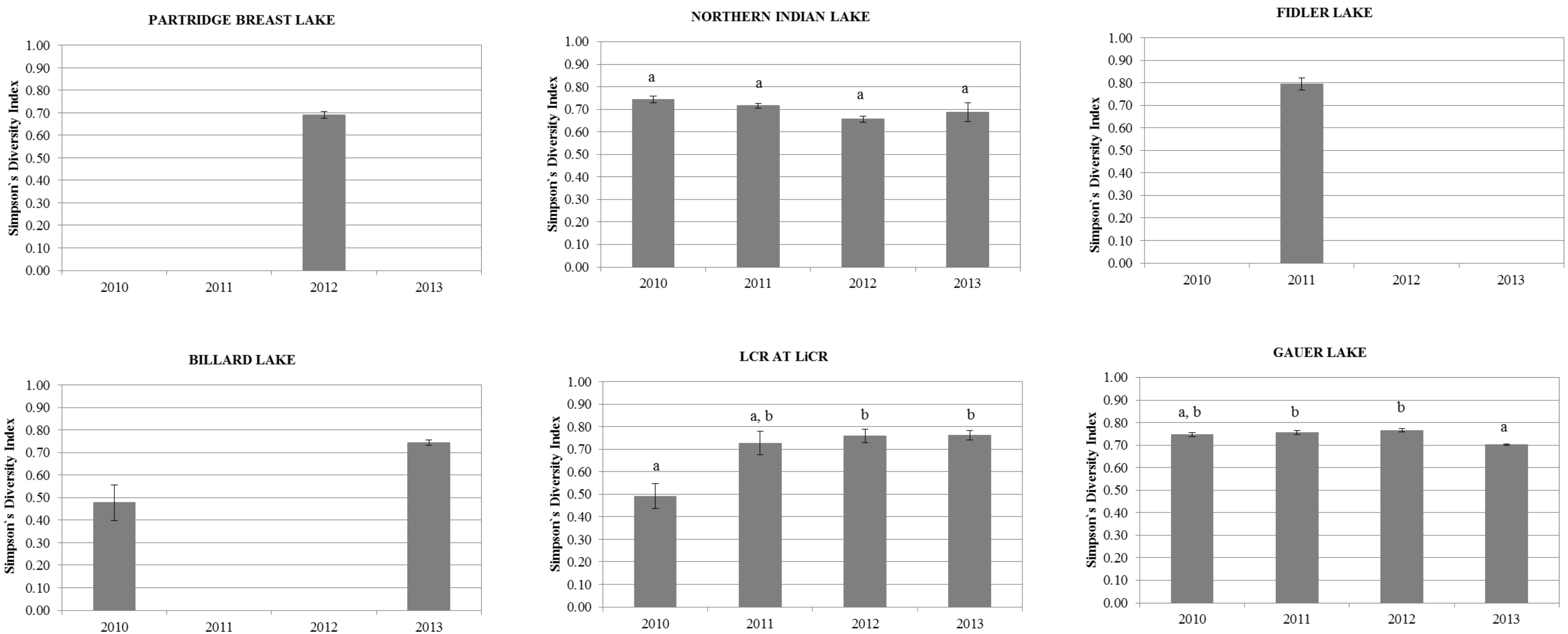


Figure 5-13. Simpson's Diversity Index (mean ± SE) in the offshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

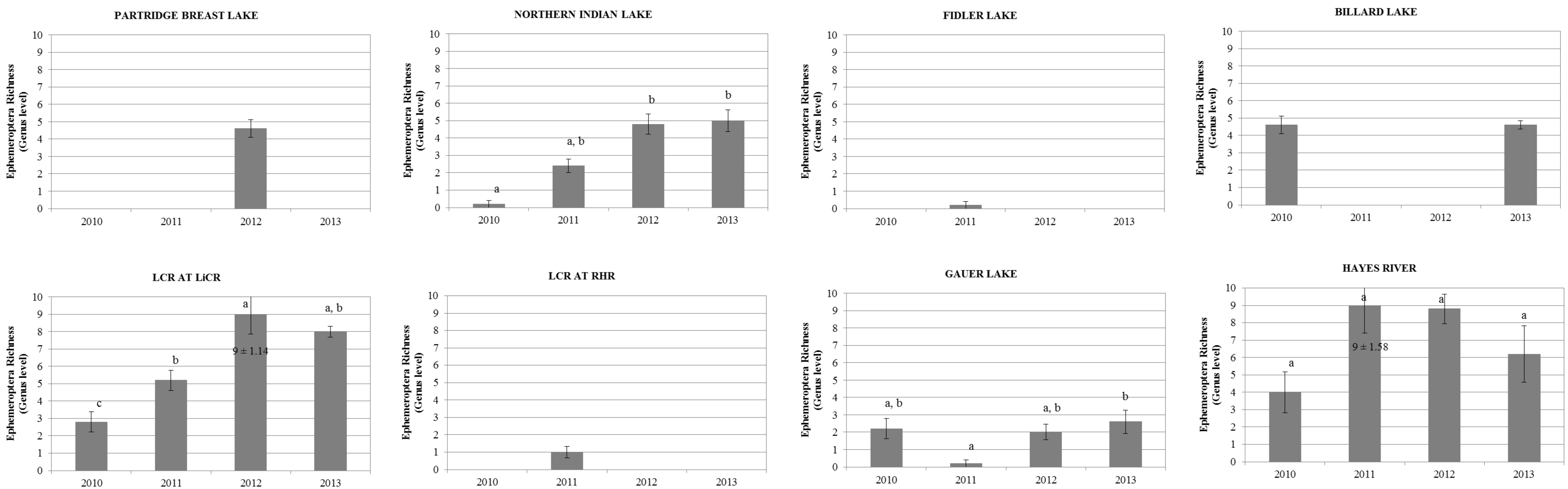


Figure 5-14. Ephemeroptera richness (genus level; mean ± SE) in the nearshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

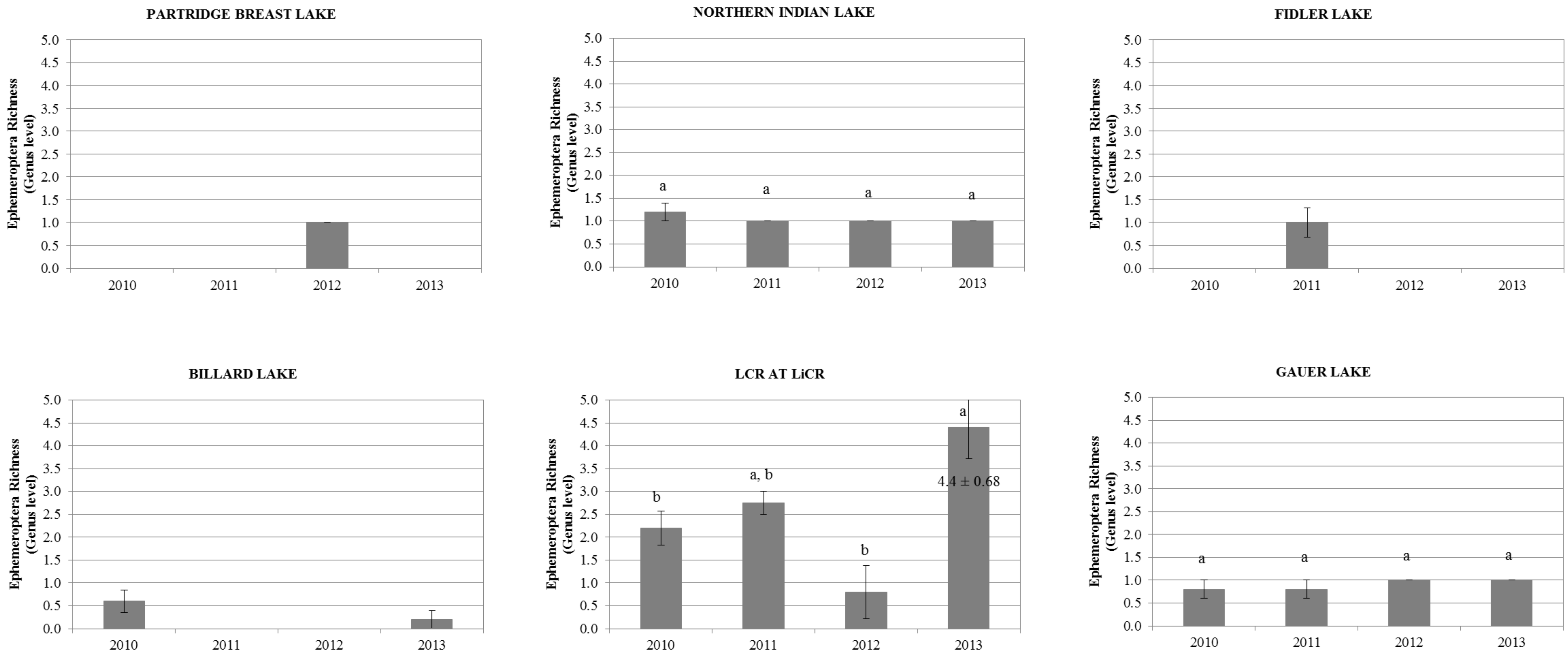


Figure 5-15. Ephemeroptera richness (genus level; mean ± SE) in the offshore habitat of the Lower Churchill River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

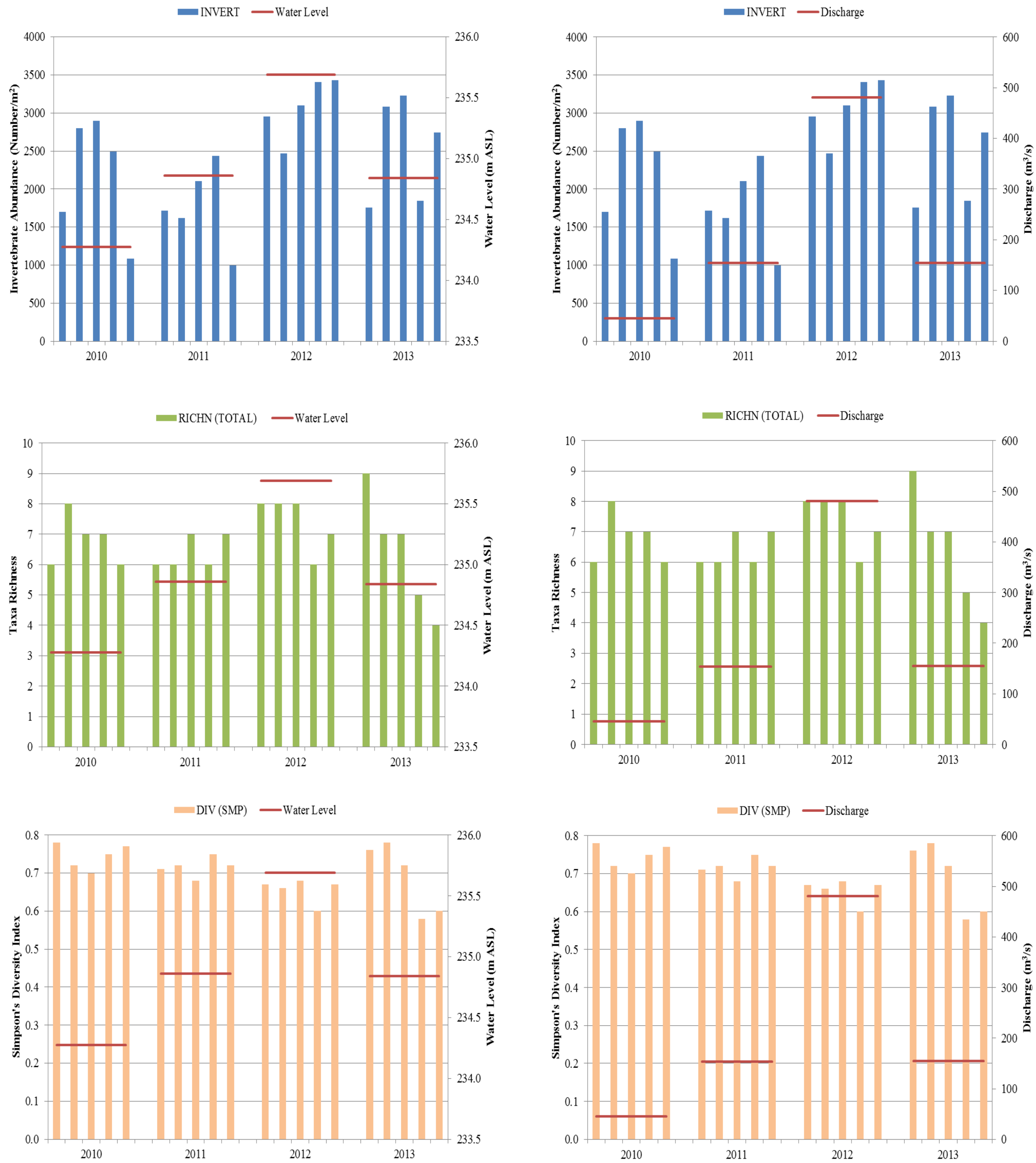


Figure 5-16. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Northern Indian Lake site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

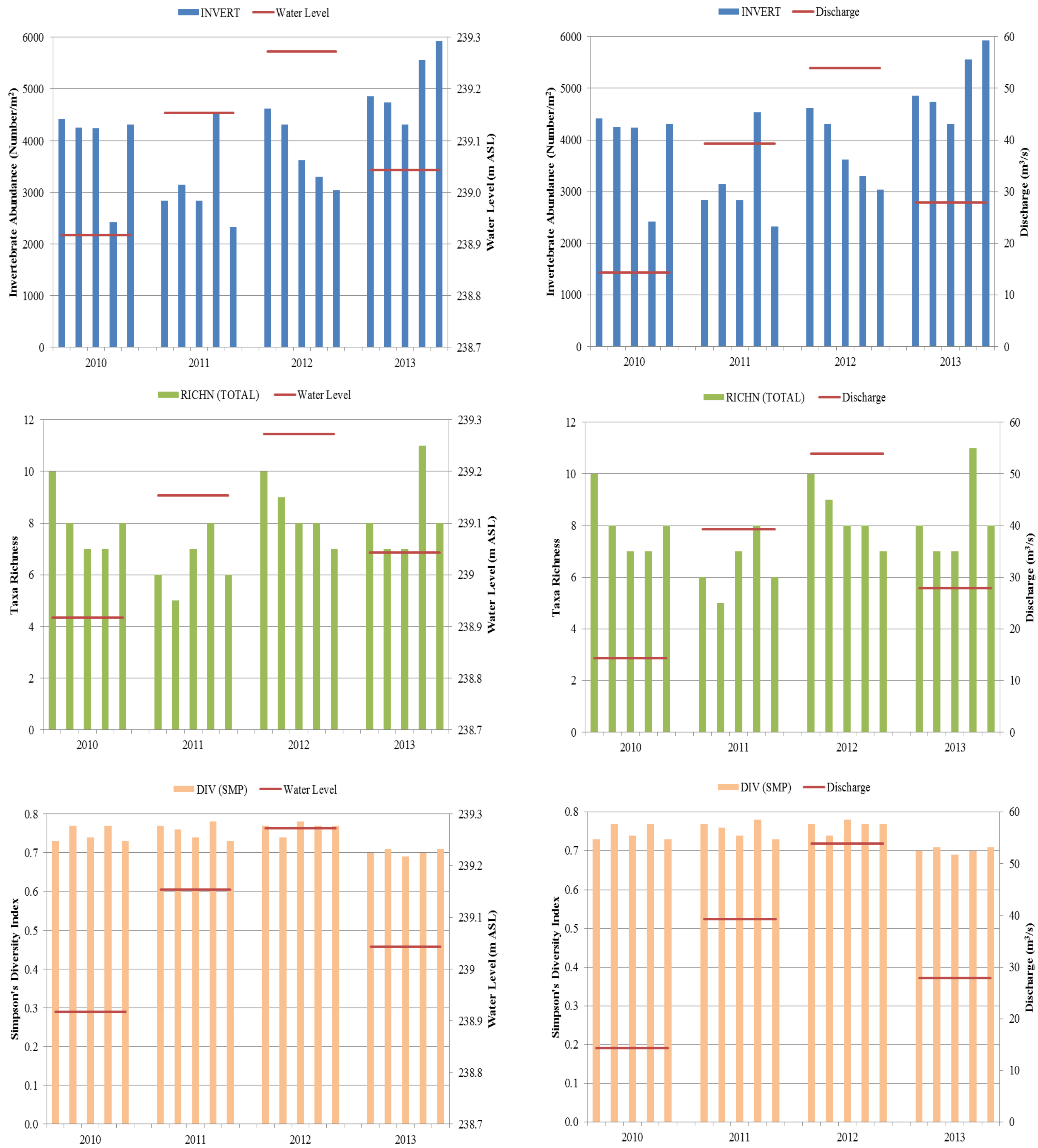


Figure 5-17. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Gauer Lake site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

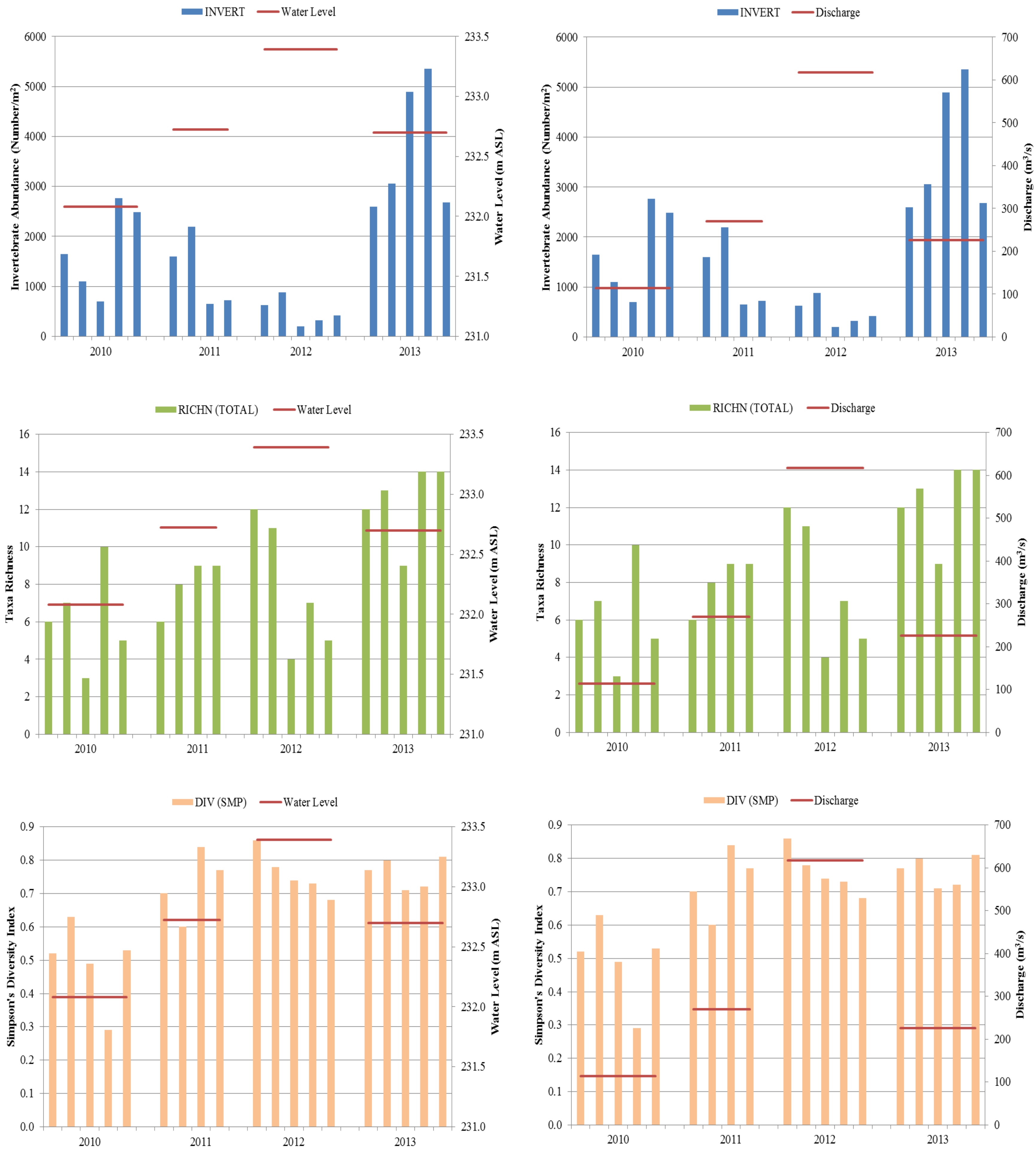


Figure 5-18. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore lower Churchill River at Little Churchill River site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

6.0 FISH COMMUNITY

6.1 INTRODUCTION

The following provides an overview of the fish community component of CAMP using key metrics measured over years 1 to 6 in the LCRR. As noted in Section 1.0, waterbodies/river reaches sampled annually included two on-system sites (Northern Indian Lake and the lower Churchill River at the Little Churchill River) and one off-system lake (Gauer Lake). Four additional on-system waterbodies or areas were sampled on a rotational basis, including Partridge Breast, Fidler, and Billard lakes and the lower Churchill River at Red Head Rapids (Table 6-1; Figure 6-1). While formally part of the LNRR under CAMP, results for the annual off-system Hayes River are included in the following discussion to provide context for the LCRR results. A discussion of the rationale for the selection of these waterbodies is provided in Technical Document 1 and the site abbreviations used in the tables and figures are 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 methodology is presented in Section 3.6 of Technical Document 1. A complete list of all fish species captured in standard gang and small mesh index gill nets set in LCRR waterbodies, 2008-2013, is presented in Table 6-2.

6.1.1 Objectives and Approach

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

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

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

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

6.1.2 Indicators

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

Manitoba Hydro and the Province of Manitoba's (2015) RCEA identified several effects of hydroelectric development on fish communities along the lower Churchill River and its associated lakes. The principal long-term effect of CRD was a decrease in the amount and productivity of fish habitat due to reductions in flows from the Missi Falls CS. The key conclusion from the RCEA was that reductions in the amount of available aquatic habitat after CRD would likely have caused a reduction in the overall biomass that the area could produce. However, this decrease was not evident in the abundance metric (CPUE), which provides a measure of the rate of capture in a given waterbody, but does not take into account the size of the waterbody and therefore does not provide a measure of total biomass. Since the RCEA indicated the metrics assessed under CAMP were largely unaffected by CRD, additional parameters were also reviewed and summarized in Section 6.3, where of particular note (e.g., where there was evidence of temporal trends).

6.2 KEY INDICATORS

6.2.1 Diversity (Hill's Index)

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

6.2.1.1 Lower Churchill River

The mean Hill's number ranged from a high of 7.5 in Partridge Breast and Northern Indian lakes to a low of 5.4 in Billard Lake (Table 6-3). The mean Hill's number for the 6-year sampling period decreased in a downstream direction in the lakes on the lower Churchill River (Figure 6-2). The mean Hill's value was higher in the lakes closest to the outlet of Southern Indian Lake, Partridge Breast Lake (7.5) and Northern Indian Lake (7.5), and became progressively lower in the lakes farther downstream, Fidler Lake (6.1) and Billard Lake (5.4). The higher Hill's value in the upstream lakes (i.e., Partridge Breast and Northern Indian lakes) was primarily related to a more even representation of several species, with five species each accounting for about 10 to 25% of the catch. In contrast, the catch in the downstream lakes (i.e., Fidler and Billard) was dominated by two species: Lake Whitefish (*Coregonus clupeaformis*) accounted for about 30% of the catch in both lakes, with Walleye (*Sander vitreus*) accounting for 20% of the catch in Billard Lake and Northern Pike (*Esox lucius*) accounting for 25% of the catch in Fidler Lake.

The mean Hill's number was similar in the lower Churchill River at Red Head Rapids (6.7) and in the lower Churchill River at the Little Churchill River (6.6). Although the Hill's number was similar for the two locations, there were considerable differences in the species composition of the catches. About twice as many species were captured in the lower Churchill River at the Little Churchill River (15 species) compared to the lower Churchill River at Red Head Rapids (8 species); however the species composition at the latter site was more even. A greater number of species was well represented at the lower Churchill River at Red Head Rapids, where six species accounted for >10% each, compared to the lower Churchill River at the Little Churchill River, where Walleye (40%) and Lake Sturgeon (*Acipenser fulvescens*; 20%) dominated the catch.

6.2.1.2 Off-system Waterbodies: Gauer Lake and the Hayes River

The mean Hill's number in Gauer Lake (7.7) was similar to that observed in the two most upstream on-system lakes (Table 6-3; Figure 6-2). The mean Hill's value in the Hayes River (6.2) was similar to that observed in the on-system riverine reaches of the lower Churchill River (Table 6-3; Figure 6-2).

6.2.1.3 Temporal Comparisons and Trends

Sites sampled annually (Northern Indian Lake, lower Churchill River at the Little Churchill River, Gauer Lake, and the Hayes River) were examined for temporal trends. The Hill's numbers for waterbodies sampled annually showed variability among sampling years (Figure 6-2). Over the 6-year sampling period, the Hill's number ranged from 6.2 in 2008 to 8.9 in 2011 in Northern Indian Lake and from 6.0 in 2013 to 7.1 in 2008 and 2011 in the lower Churchill River at the Little Churchill River. The increase in the mean Hill's number in Northern Indian Lake in 2010 and 2011 is likely a result of a decrease in the relative abundance of Walleye in the catch; in these years Walleye accounted for only 15% of the catch compared to >25% in other years – resulting in an increase in evenness. The mean Hill's number over the 6-year period was more variable in Northern Indian Lake compared to Gauer Lake, as evidenced by a higher interquartile range, which was 1.3 in the on-system lake and 0.2 in the off-system lake. In comparison, the annual values were more similar at the river locations, where the interquartile range was 1.1 on-system and 0.9 off-system.

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 Lower Churchill River Region

Fish Community

In standard gangs, the mean CPUE ranged from a high of 66 fish/100 m/24 h in Partridge Breast Lake to a low of 9 fish/100 m/24 h in the lower Churchill River at Red Head Rapids (Table 6-3). The most abundant large-bodied species captured in LCRR waterbodies were typically Lake Whitefish, Northern Pike, Walleye, and White Sucker

(*Catostomus commersonii*; Figure 6-3). Lake Sturgeon were also abundant in the lower Churchill River at the Little Churchill River.

In small mesh gangs, the mean CPUE ranged from a high of 148 fish/30 m/24 h in Northern Indian Lake to a low of 6 fish/30 m/24 h in the lower Churchill River at Red Head Rapids (Table 6-3). Small mesh gillnet catches were more variable than in standard gang catches, but the more common small-bodied species included Spottail Shiner (*Notropis hudsonius*), Trout-perch (*Percopsis omiscomaycus*), and Emerald Shiner (*Notropis atherinoides*; Figure 6-3).

The abundance of large-bodied fish appeared to decrease in the on-system lakes in a downstream direction, with a higher mean total CPUE in standard gangs set in Partridge Breast and Northern Indian lakes (66 and 62 fish/100 m/24 h, respectively) compared to Fidler and Billard lakes (47 and 53 fish/100 m/24 h, respectively; Figure 6-4).

The species composition in the standard gangs was generally similar among the lower Churchill River lakes, with the same four species dominating the catch (Figure 6-3). However, there were differences in the abundance of species among lakes, possibly in response to differences in habitat characteristics. The CPUE of Walleye was highest in Northern Indian and Billard lakes; whereas, the CPUE of Northern Pike was highest in Partridge Breast and Fidler lakes. Several species were more abundant in the larger, upstream lakes, including White Sucker, Burbot (*Lota lota*), and Longnose Sucker (*Catostomus catostomus*; only Partridge Breast Lake), while Lake Whitefish were more common in the smaller downstream lakes. Lake Sturgeon were only captured in nets set in Billard Lake, which is the smallest of the lakes sampled in this region and essentially an expansion of the Churchill River.

The abundance of fish in the lower Churchill River at the Little Churchill River (43 fish/100 m/24 h) was in the range observed in the two downstream lakes, but was considerably higher than in the lower Churchill River at Red Head Rapids (9 fish/100 m/24 h; Figure 6-4). The species composition in the lower Churchill River at the Little Churchill River was similar to that in Billard Lake, but fish catches in the riverine location were lower for all species except Lake Sturgeon (Figure 6-3).

Lake Whitefish

Lake Whitefish mean CPUE ranged from a high of 21 fish/100 m/24 h in Fidler Lake to a low of <1 fish/100 m/24 h in the lower Churchill River at Red Head Rapids (Table 6-3). The capture rate of Lake Whitefish was higher in the lakes compared to the riverine locations (Figure 6-5). The downstream lakes (Fidler and Billard lakes), generally produced more Lake Whitefish compared to the more upstream lakes (Partridge Breast and Northern Indian lakes). Lake Whitefish CPUE in the lower Churchill River at the Little Churchill River was considerably higher than in the lower Churchill River at Red Head Rapids.

Northern Pike

Northern Pike mean CPUE ranged from a high of 18 fish/100 m/24 h in Fidler Lake to a low of 3 fish/100 m/24 h in the lower Churchill River at Red Head Rapids (Table 6-3). Similar to Lake Whitefish, Northern Pike CPUE was higher in the lakes than at the riverine locations (Figure 6-6). There was considerable variability in catches of Northern Pike among the lakes. The mean CPUE was highest in Fidler and Partridge Breast lakes, and lower in Billard and Northern Indian lakes. At the riverine locations, Northern Pike catches were higher in the lower Churchill River at the Little Churchill River compared to the lower Churchill River at Red Head Rapids (Figure 6-6).

Walleye

Walleye mean CPUE ranged from a high of 20 fish/100 m/24 h in Northern Indian Lake to a low of 2 fish/100 m/24 h in the lower Churchill River at Red Head Rapids (Table 6-3). There was considerable variation in the capture rate of Walleye in on-system lakes in the lower Churchill River (Figure 6-7). The median CPUE values at Northern Indian and Billard lakes was higher than at Partridge Breast Lake, and the interquartile ranges at Northern Indian and Billard lakes did not overlap with those at Partridge Breast Lake. Walleye abundance in the lower Churchill River at the Little Churchill River was within the range of values found at the on-system lakes, but this species was uncommon in the lower Churchill River at Red Head Rapids (Figure 6-7).

White Sucker

White Sucker mean CPUE in standard gangs ranged from a high of 21 fish/100 m/24 h in Partridge Breast Lake to a low of 2 fish/100 m/24 h in the lower Churchill River at Red Head Rapids (Table 6-3). White Sucker abundance generally decreased in a downstream direction (Figure 6-8). The CPUE in the upstream lakes, Partridge Breast and Northern Indian, was considerably higher than in Fidler and Billard lakes, as evidenced by the separation of the lower quartiles of the box plots for the upstream lakes with the upper quartiles of those for the downstream lakes. The abundance of White Sucker in the downstream lakes was more similar to those of the two riverine locations in the lower Churchill River (Figure 6-8).

6.2.2.2 Off-system Waterbodies: Gauer Lake and the Hayes River

Fish Community

In standard gangs, the mean CPUE was 80 fish/100 m/24 h in Gauer Lake and 10 fish/100 m/24 h in the Hayes River (Table 6-3). The large-bodied fish community in Gauer Lake was dominated by Walleye, White Sucker, and Lake Whitefish, while the most abundant species in the Hayes River were Walleye and Lake Sturgeon (Figure 6-3).

In small mesh gangs, the mean CPUE was 134 fish/30 m/24 h in Gauer Lake and 5 fish/30 m/24 h in the Hayes River (Table 6-3). The small-bodied fish community of Gauer Lake was dominated by Spottail Shiner, with smaller numbers of Trout-perch, Yellow Perch (*Perca flavescens*), and Emerald Shiner (Figure 6-3). Very few fish were captured in small mesh nets set in the Hayes River.

Fish catches at the off-system Gauer Lake were considerably higher than those of any of the on-system lakes, as evidenced by the median CPUE exceeding the upper quartiles of the other lakes (Figure 6-4). The catch in Gauer Lake was characterized by a high abundance of White Sucker and Lake Whitefish, similar to what was observed in Partridge Breast Lake, but, unlike that lake, Gauer Lake had more Walleye than Northern Pike (Figure 6-3).

Fish catches in the Hayes River (10 fish/100 m/24 h) were within the range of those in the lower Churchill River at Red Head Rapids but were less than in the lower Churchill River at the Little Churchill River (Figure 6-4). The abundance of most species in the Hayes River was within the range captured at the two locations on the Churchill River; however, a few species were unique to the Hayes River system and reflect differences in species distributions: Silver Lamprey (*Ichthyomyzon unicuspis*); Shorthead Redhorse (*Moxostoma macrolepidotum*; and Brook Trout (*Salvelinus fontinalis*). Although not captured during the CAMP studies, Brook Trout have been captured in the lower Churchill River system (Bernhardt 1995).

Lake Whitefish

Lake Whitefish had a mean CPUE in standard gangs of 18 fish/100 m/24 h in Gauer Lake and 1 fish/100 m/24 h in the Hayes River (Table 6-3). The CPUE of Lake Whitefish in Gauer Lake was within the range observed at the on-system lakes (Figure 6-5). The capture rate of Lake Whitefish in the Hayes River was comparable to that in the lower Churchill River at Red Head Rapids, but was much lower than in the lower Churchill River at the Little Churchill River (Figure 6-5).

Northern Pike

Northern Pike had a mean CPUE in standard gangs of 11 fish/100 m/24 h in Gauer Lake and 1 fish/100 m/24 h in the Hayes River (Table 6-3). Northern Pike CPUE in the off-system Gauer Lake was in the range observed at the on-system lakes and was most similar to Billard Lake (Figure 6-6). At the riverine locations, Northern Pike catches were higher in the lower Churchill River at the Little Churchill River and the lower Churchill River at Red Head Rapids compared to the off-system Hayes River (Figure 6-6).

Walleye

Walleye had a mean CPUE in standard gangs of 19 fish/100 m/24 h in Gauer Lake and 3 fish/100 m/24 h in the Hayes River (Table 6-3). Walleye CPUE in Gauer Lake was comparable to the on-system lakes, as evidenced by the overlap of the interquartile ranges (Figure 6-7). Compared to the on-system river locations, the CPUE of Walleye in the Hayes River was lower than in the lower Churchill River at the Little Churchill River, but similar to that in the lower Churchill River at Red Head Rapids (Figure 6-7).

White Sucker

White Sucker had a mean CPUE in standard gangs of 21 fish/100 m/24 h in Gauer Lake and 1 fish/100 m/24 h in the Hayes River (Table 6-3). The interquartile ranges of CPUE at Gauer Lake overlapped with those of the upstream on-system lakes, suggesting that White Sucker catches were comparable among these lakes (Figure 6-8). Catches in the off-system Hayes River were also within the range observed at the two riverine sites in the lower Churchill River (Figure 6-8).

6.2.2.3 Temporal Comparisons and Trends

Fish Community

Sites sampled annually (Northern Indian Lake, the lower Churchill River at the Little Churchill River, Gauer Lake, and the Hayes River) were examined for temporal trends. Over the 6-year sampling period, the mean CPUE at on-system sites ranged from 51 fish/100 m/24 h in 2008 to 76 fish/100 m/24 h in 2010 in Northern Indian Lake and from 21 fish/100 m/24 h in 2009 to 59 fish/100 m/24 h in 2010 in the lower Churchill River at the Little Churchill River (Figure 6-4).

The interquartile range for the riverine location was considerably larger (26 fish/100 m/24 h) than at the lacustrine location (11 fish/100 m/24 h). There was a significant difference in total CPUE among years at both annual on-system monitoring sites (i.e., Northern Indian Lake and the lower Churchill River at the Little Churchill River; Figure 6-9). The rate of capture was lowest in 2008 and highest in 2010 in Northern Indian Lake; and lowest in 2009 and 2011 and highest in 2010, 2012, and 2013 in the lower Churchill River at the Little Churchill River. However, there was no indication of an increasing or decreasing trend in CPUE over the six year monitoring period at either location.

Fish catches at the off-system lake (Gauer Lake) also showed considerable variation with a high interquartile range (29 fish/100 m/24 h). The mean CPUE in Gauer Lake ranged from 60 fish/100 m/24 h in 2009 to 98 fish/100 m/24 h in 2013 (Figure 6-4). There was a significant difference in the total CPUE among years. The rate of capture was significantly higher in 2012 and 2013 compared to 2009 and 2010 (Figure 6-9) but no real trend was apparent. The annual CPUE values for the Hayes River were between values at the on-system riverine locations. The means ranged from 6 fish/100 m/24 h in 2009 to 15 fish/100 m/24 h in 2010; the CPUE fluctuated between high and low values in consecutive years over the 6-year period. A significant difference was only observed between two years – catches in 2010 were significantly higher than in 2009 (Figure 6-9).

Lake Whitefish

The mean Lake Whitefish CPUE over the 6-year period ranged from 4 fish/100 m/24 h in 2013 to 19 fish/100 m/24 h in 2010 in Northern Indian Lake and from 4 fish/100 m/24 h in 2011 to 11 fish/100 m/24 h in 2008 in the lower Churchill River at the Little Churchill River(Figure 6-5). Statistical comparisons of CPUE at annual on-system locations indicates that there was a statistical difference among sampling years in Northern Indian Lake, but no statistical differences in the annual riverine site (Figure 6-10). The capture rate of Lake Whitefish in Northern Indian Lake was statistically lowest in 2013 and highest in 2010. Visual examination of the data for the 6-year period does not suggest an increasing or decreasing trend for this indicator at either on-system location.

Lake Whitefish catches in Gauer Lake also varied over the 6-year period and had a similar interquartile range (6 fish/100 m/24 h) as in the on-system lake (4 fish/100 m/24 h; Figure 6-5). The mean CPUE in Gauer Lake ranged from 11 fish/100 m/24 h in 2009 to 27 fish/100 m/24 h in 2012 (Figure 6-5) and the difference between values in 2009 and 2012 was significant (Figure 6-10). The mean CPUE for the Hayes River ranged from 0 fish/100 m/24 h in 2013 to 1.4 fish/100 m/24 h in 2008. There were no significant differences in Lake Whitefish catches in the Hayes River among years (Figure 6-10). Visual examination of the data for the 6-year period does not suggest an increasing or decreasing trend for this indicator at either off-system location.

Northern Pike

With the exception of 2008, the CPUE of Northern Pike in Northern Indian Lake, the on-system lake that was monitored annually, has been relatively consistent over the sampling period, ranging from 7 fish/100 m/24 h in 2011 to 10 fish/100 m/24 h in 2009 and 2010 (Figure 6-6). The CPUE was considerably lower in 2008, at 4 fish/100 m/24 h. Annual CPUE has also been generally consistent in the lower Churchill River at the Little Churchill River, ranging from 4 fish/100 m/24 h in 2009, 2011, and 2012 to 7 fish/100 m/24 h in 2008. Statistical comparison of CPUE at annual on-system locations indicates no significant differences and visual examination of the data for the 6-year period does not suggest increasing or decreasing trends in this metric (Figure 6-11).

Fish catches in the off-system waterbodies over the 6-year period have likewise shown little variation. In Gauer Lake, the annual CPUE ranged from 8 fish/100 m/24 h in 2009 to 13 fish/100 m/24 h in 2011 and in the Hayes River from 0.2 fish/100 m/24 h in 2009 to 1 fish/100 m/24 h in 2010 (Figure 6-6). There were no significant differences in Northern Pike catches among years and no apparent increasing or decreasing trend in Northern Pike abundance at either of the off-system locations (Figure 6-11).

Walleye

The mean Walleye CPUE in Northern Indian Lake was lowest in 2010 and 2011 at 15 fish/100 m/24 h and ranged from 20-30 fish/100 m/24 h in other years (Figure 6-7). In the lower Churchill River at the Little Churchill River the CPUE ranged from 5 fish/100 m/24 h in 2009 to 23 fish/100 m/24 h in 2013. There were significant inter-annual differences in CPUE; CPUE was significantly lower in 2009 and 2011 at the annual riverine site and in 2011 at the annual lacustrine site compared to 2013 (Figure 6-12). This metric does not appear to show a consistent increasing or decreasing trend over the six-year sampling period.

Walleye CPUE in Gauer Lake increased over the six-year monitoring period and was statistically highest in 2013 (Figure 6-12). Walleye abundance in the off-system Hayes River has been consistently low, fluctuating between 2 fish/100 m/24 h in 2009 and 2011 and 4 fish/100 m/24 h in 2008, 2010, 2012, and 2013. There were no significant differences in Walleye catches at the riverine location (Figure 6-12).

White Sucker

An increasing trend in White Sucker CPUE was observed in Northern Indian Lake over the first four years (from 11 to 22 fish/100 m/24 h) followed by a decline in the last two years (back to 11 fish/100 m/24 h). Catches in the lower Churchill River at the Little Churchill River were much lower and marked by fluctuations between 2 and 7 fish/100 m/24 (Figure 6-8). There were significant inter-annual differences in CPUE at both locations but a consistent increasing or decreasing trend over the six years of monitoring was not apparent (Figure 6-13). In Northern Indian Lake, CPUE was significantly higher in 2011 than in 2013, while in the lower Churchill River at the Little Churchill River, CPUE was significantly higher in 2010 and 2012 compared to 2008, 2009, and 2011.

A decrease in White Sucker CPUE was observed in Gauer Lake over the first two years (starting at 23 fish/100 m/24 h) followed by an increase over the last four years (from 15 to 29 fish/100 m/24 h). However, these differences were not significant (Figure 6-13) and data were not sufficient to determine if this represents a long-term trend or short-term variation. Catches in the Hayes River were much lower and marked by fluctuations between 0.4 and 3 fish/100 m/24 h (Figure 6-8). There were significant differences in White Sucker catches at the off-system riverine location – catches in 2013 were significantly higher than in 2008 (Figure 6-13).

6.2.3 Condition (Fulton’s Condition Factor)

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

6.2.3.1 Lower Churchill River Region

Lake Whitefish

Mean Fulton’s condition factor for Lake Whitefish between 300 and 499 mm in fork length (FL) from on-system waterbodies was fairly similar, ranging from a high of 1.48 in the lower Churchill River at the Little Churchill River to a low of 1.41 in Northern Indian and Billard lakes (Table 6-3). The condition of Lake Whitefish was generally consistent in the on-system lakes. The condition of Lake Whitefish from the lower Churchill River at the Little Churchill River was similar to those of fish captured in the lakes (Figure 6-14). Too few Lake Whitefish were captured in the lower Churchill River at Red Head Rapids (3 fish) to include in the analysis.

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length from on-system waterbodies was fairly similar among waterbodies, ranging from a high of 0.69 in the lower Churchill River at the Little Churchill River to a low of 0.63 in Northern Indian Lake (Table 6-3). There were insufficient numbers of Northern Pike captured in the lower Churchill River at Red Head Rapids to include in the analysis. The condition of Northern Pike was generally consistent among on-system lakes (Figure 6-15). However, Northern Pike from the riverine location were in slightly better condition than those from the lacustrine locations (Figure 6-15).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from on-system waterbodies ranged from a high of 1.22 in Fidler Lake to a low of 1.07 in Billard Lake (Table 6-3). Insufficient numbers of Walleye were captured in the lower Churchill River at Red Head Rapids to include in the analysis (Table 6-3). The condition of Walleye was generally consistent at the on-system lakes, except in Fidler Lake (Figure 6-16). The spread of annual K_F values for Walleye captured in the lower Churchill River at the Little Churchill River did not overlap with those of the on-system lakes, suggesting there is a difference in condition among the populations; the possible exception is for Fidler Lake where condition was similar to between this site and the riverine location.

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from on-system lakes ranged from a high of 1.51 at Partridge Breast Lake to a low of 1.45 in Billard Lake (Table 6-3). Sufficient numbers of White Sucker were only captured from the lower Churchill River at the Little Churchill River in three years; in these years the mean condition was 1.54 (Figure 6-17). Insufficient numbers were captured at Fidler Lake and the lower Churchill River at Red Head Rapids to include in the analysis (Table 6-3).

6.2.3.2 Off-system Waterbodies: Gauer Lake and the Hayes River

Lake Whitefish

Mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length from Gauer Lake was 1.50 (Table 6-3). Insufficient numbers of Lake Whitefish were captured annually from the Hayes River to include in the analysis. Lake Whitefish from Gauer Lake were in better condition than fish from the on-system lakes, as evidenced by the lower quartile exceeding the upper quartiles of the on-system lakes, and were more similar to those from the lower Churchill River at the Little Churchill River since the box plots overlapped (Figure 6-14).

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length from Gauer Lake was 0.67 (Table 6-3). Insufficient numbers of Northern Pike were captured annually from the Hayes River to include in the analysis. The condition of Northern Pike from Gauer Lake was within the range observed at the on-system lakes, but was lower than those in the lower Churchill River at the Little Churchill River (Figure 6-15).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm from Gauer Lake was 1.13 (Table 6-3). Sufficient numbers of Walleye were captured from the Hayes River in only two years; in these years the mean condition was 1.10 (Figure 6-16). Walleye condition in the off-system waterbodies was within the range observed in the on-system waterbodies (Figure 6-16).

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm from Gauer Lake was 1.54 in the four years sufficient numbers were captured (Figure 6-17). Insufficient numbers of White Sucker were captured annually from the Hayes River to include in the analysis. White Sucker from off-system Gauer Lake were generally in better condition than fish from the on-system lakes, and were more similar to those from the lower Churchill River at the Little Churchill River (Figure 6-17).

6.2.3.3 Temporal Comparisons and Trends

Lake Whitefish

Among the four sites that were sampled annually, there was considerable variability in condition among sampling years (Figure 6-14). At Northern Indian Lake, the mean K_F of Lake Whitefish between 300 and 499 mm was highest at 1.47 in 2009, ranging from 1.37 to 1.43 in the other years. Likewise, Lake Whitefish captured in the lower Churchill River at the Little Churchill River had a particularly high mean K_F in 2009 (1.60) following a particularly low mean K_F the previous year (1.36). After 2009 the mean K_F at this location was more stable, ranging from 1.42 to 1.50. There were statistical differences in the condition of fish among years (Figure 6-18). At both Northern Indian Lake and the lower Churchill River at the

Little Churchill River the condition of Lake Whitefish was statistically higher in 2009 compared to some other years.

The condition of Lake Whitefish at the off-system lake showed a similar range of inter-annual variation (Figure 6-14). Over the 6-year sampling program, fish from Gauer Lake generally had a narrow range of annual K_F values (1.48 to 1.54), with the exception of a particularly low mean K_F in 2010 (1.42) and this difference was significant (Figure 6-18).

While there were some significant inter-annual differences, a consistent increasing or decreasing trend in Lake Whitefish condition was not apparent in either on- or off-system waterbodies over the 6-year sampling period.

Northern Pike

The annual mean condition of Northern Pike between 400 and 699 mm in Northern Indian Lake, the on-system lake that was monitored annually, has been relatively consistent over the 6-year sampling period, ranging from 0.62 to 0.65 (Figure 6-15). The annual mean condition of Northern Pike from the lower Churchill River at the Little Churchill River ranged from 0.67 to 0.71 and showed more variability than at the lacustrine location, as indicated by a larger spread in the data (Figure 6-15). There were no statistical differences in the condition of Northern Pike from either location (Figure 6-19).

At the off-system lake, Gauer Lake, the annual mean K_F ranged from 0.66 to 0.69 (Figure 6-15). There were no significant differences in condition among years (Figure 6-19).

There were no significant inter-annual differences in Northern Pike condition, nor was a consistent increasing or decreasing trend apparent, in either on- or off-system waterbodies over the 6-year sampling period.

Walleye

The condition of Walleye between 300 and 499 mm in Northern Indian Lake has been relatively consistent over the 6-year sampling period, ranging from 1.07 to 1.14 (Figure 6-16). However, the condition was statistically higher in 2012 compared to 2010 (Figure 6-20). As with Northern Pike, the condition of Walleye from the lower Churchill River at the Little Churchill River was more variable than at the lacustrine locations, with a much larger interquartile range (Figure 6-16). The mean condition of Walleye in the lower Churchill River at the Little Churchill River increased from about 1.10 in 2008 and 2009 to about 1.20 after 2010 (Figure 6-16) and this difference was significant (Figure 6-20).

Over the six-year period, the condition of fish from the off-system lake, Gauer Lake, showed an increase in mean K_F values from 1.11 in 2008-2010 to 1.16 in 2012 and 2013 (Figure 6-16). The condition of Walleye captured in 2011-2013 was statistically higher than those captured in 2008-2010 (Figure 6-20).

While there were significant inter-annual differences in Walleye condition, a consistent increasing or decreasing trend was not apparent in either on- or off-system waterbodies over the 6-year sampling period.

White Sucker

The mean condition of White Sucker between 300 and 499 mm in Northern Indian Lake decreased from 1.51 in 2009 to 1.42 in 2011, after which the K_F value increased to 1.50 in 2013 (Figure 6-17). The condition measured in 2009 and 2013 were significantly higher than in the other years (Figure 6-21).

At the off-system lake, the annual mean condition of White Sucker increased from 1.51 in 2009 to 1.56-1.57 in 2012 and 2013 (Figure 6-17).

There were no increasing or decreasing trends apparent in either on- or off-system waterbodies over the 6-year sampling period.

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 Lower Churchill River Region

Lake Whitefish

At the annually sampled on-system waterbodies, older Lake Whitefish were captured from Northern Indian Lake, where fish were aged up to 30 years, compared to the lower

Churchill River at the Little Churchill River where the oldest fish was 24 years (Figure 6-22). At these two locations, most of the Lake Whitefish captured over the 6-year sampling period were between 4 and 10 years of age. Lake Whitefish from the riverine location generally had a larger mean fork length at all ages compared to the lacustrine location.

At age 4, the mean length of Lake Whitefish ranged from a low of 237 mm in Northern Indian Lake to a high of 322 mm in the lower Churchill River at the Little Churchill River (Figure 6-23). The same pattern was observed for 5-year-old Lake Whitefish, with the mean length ranging from a low of 265 mm in Northern Indian Lake to a high of 363 mm in the lower Churchill River at the Little Churchill River (Figure 6-24).

The mean length-at-age of Lake Whitefish was generally comparable in the on-system lakes, except in Northern Indian Lake, where fish were shorter at the selected ages (Figures 6-23 and 6-24). The mean fork length-at-age of fish from Northern Indian Lake was 237 mm at age 4 and 265 mm at age 5, compared to the other lakes where the mean length ranged from 275-311 at age 4 and 319-342 mm at age 5. Lake Whitefish from the lower Churchill River at the Little Churchill River were longer at age, having higher length-at-age at both 4 and 5 years compared to the lakes (341 and 382 mm, respectively).

Northern Pike

Northern Pike captured at the annually sampled on-system waterbodies ranged from 1 to 19 years of age, with most of the fish captured over the 6-year sampling period aged between 5 and 9 years (Figure 6-25). As observed for other target species, Northern Pike from the riverine location generally had a larger mean fork length at all ages compared to the lacustrine location.

Mean fork length for 4-year-old Northern Pike ranged from a low of 446 mm at Northern Indian Lake to a high of 527 mm for the lower Churchill River at the Little Churchill River (Figure 6-26). The length-at-age of Northern Pike was generally consistent among on-system lakes (Figure 6-26). No 4-year-old fish were captured in Fidler Lake. The capture of 4-year-old Northern Pike in only one year from the lower Churchill River at the Little Churchill River precludes a comparison to the lacustrine locations.

Walleye

Walleye captured at the annually sampled on-system sites ranged from 1 to 30 years (Figure 6-27). Most of the catch in Northern Indian Lake was between 6 and 14 years of age, which was somewhat younger than in the lower Churchill River at the Little Churchill River where most of the catch was aged 8 to 15 years. As observed for other target species, Walleye from the riverine location generally had a larger mean fork length at all ages compared to the lacustrine location.

Very few 3-year-old Walleye were captured in the on-system waterbodies (Table 6-3). The mean fork length of 3-year-old Walleye ranged from a low of 237 mm in Northern Indian Lake to a high of 278 mm in Billard Lake and in the lower Churchill River at the Little Churchill River (Figure 6-28).

6.2.4.2 Off-system Waterbodies: Gauer Lake and the Hayes River

Lake Whitefish

Lake Whitefish captured in Gauer Lake ranged from 1 to 30 years, as was observed at the on-system lake (Figure 6-22). However, compared to Northern Indian Lake, younger fish were better represented in the catch, as most of the catch was between 4 and 10 years of age. Lake Whitefish from Gauer Lake generally had similar mean fork lengths (at all ages) to those measured in Northern Indian Lake; the exception was the period of early growth between ages 3 to 6, when fish from Gauer Lake attained a higher mean length.

At age 4, Lake Whitefish in Gauer Lake averaged 272 mm in length (Figure 6-23) and at age 5 they averaged 304 mm (Figure 6-24). The size-at-age 4 and 5 of Lake Whitefish in Gauer Lake was within the range observed in the on-system lakes (Figures 6-23 and 6-24). An insufficient number of 4- and 5-year-old Lake Whitefish were captured in the Hayes River to include in the analysis (Table 6-3).

Northern Pike

Northern Pike from Gauer Lake ranged from 1 to 16 years, representing a younger maximum age than the oldest fish (19 years) observed at the on-system waterbodies (Figure 6-25). Similar to Northern Indian Lake, most of the catch was between 4 and 8 years of age. Mean fork lengths (at all ages) were similar in Gauer and Northern Indian lakes.

At age 4, Northern Pike from Gauer Lake averaged 437 mm in length (Figure 6-26). The size-at-age 4 of Northern Pike from Gauer Lake was within the range observed in the on-system lakes (Figure 6-24). An insufficient number of 4-year-old Northern Pike were captured in the Hayes River to include in the analysis (Table 6-3).

Walleye

Walleye from Gauer Lake ranged from 1 to 20 years, which was a considerably younger maximum age than that observed in the on-system waterbodies (Figure 6-27). Most of the catch was between 5 and 12 years of age. Mean fork lengths (at all ages) were similar in Gauer Lake and Northern Indian Lake.

At age 3, Walleye from Gauer Lake averaged 235 mm in length and those from the Hayes River averaged 288 mm (Figure 6-28). Sufficient numbers of three-year-old Walleye were only obtained in one year (2013) from the Hayes River; lengths of age 3 Walleye were similar to but somewhat larger than those captured in the lower Churchill River at the Little Churchill River.

6.2.4.3 Temporal Comparisons and Trends

Lake Whitefish

The annual mean length-at-age of Lake Whitefish in Northern Indian Lake has been relatively consistent over the 6-year sampling period (Figures 6-23 and 6-24). There were no statistical differences in the length-at-age of either 4- or 5-year-old fish among years in Northern Indian Lake (Figures 6-29 and 6-30).

A sufficient number of Lake Whitefish to calculate length-at-age were not captured at the annual on-system riverine location in every year. However, the mean length of 4- and 5-year-old Lake Whitefish in the lower Churchill River at the Little Churchill River was lower in 2009 (330 and 350 mm, respectively) compared to the other years when sufficient numbers were caught (4 year olds averaged 351 mm in 2008 and 5 year olds averaged 397 mm in 2008 and 400 mm in 2013; Figures 6-23 and 6-24).

The length-at-age of Lake Whitefish has been relatively consistent over the 6-year sampling period at Gauer Lake, with 4 year olds ranging from 262 (in 2011 and 2012) to 287 mm (in 2009), and 5 year olds ranging from 297 mm (in 2011) to 316 mm (in 2008; Figures 6-23 and 6-24). There was no statistical difference in the length-at-age of either 4- or 5-year-old fish among years at Gauer Lake (Figures 6-29 and 6-30).

There were few significant inter-annual differences in the length-at-age of either 4- or 5-year old Lake Whitefish in either on- or off-system waterbodies and no consistent increasing or decreasing trends were apparent over the 6-year sampling period.

Northern Pike

There has been considerable variation in the annual mean length-at-age 4 of Northern Pike in Northern Indian Lake (Figure 6-26). The length-at-age was lower in 2010 and 2011, with means of 406 and 401 mm, respectively, compared to other years when the mean length ranged from 448 to 481 mm. However, the difference in length of 4 year olds among years was not statistically significant (Figure 6-31). Insufficient numbers of 4-year-old Northern Pike to calculate length-at-age were captured at the annual riverine location in all years except 2008, precluding a temporal comparison.

The fork length-at-age of Northern Pike in Gauer Lake showed a similar range of inter-annual variation as in the on-system lake over the 6-year sampling period (Figure 6-26). Four year olds from Gauer Lake ranged from a mean of 390 mm in 2012 to 484 mm in 2008 (Figure 6-26). The length-at-age 4 was statistically lower in 2012 than observed in 2008, 2010, and 2013 (Figure 6-31).

Although there were a few significant inter-annual differences in the length-at-age of 4-year-old Northern Pike, a consistent increasing or decreasing trend was not apparent in either on- or off-system waterbodies over the 6-year sampling period.

Walleye

An insufficient number of 3-year-old Walleye were captured in LCRR waterbodies over the 6-year sampling period to calculate fork length-at-age in most years (Figure 6-28); therefore a temporal comparison and trend assessment were not possible for this species.

6.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

The other fish community metric measured under CAMP, as described in Technical Document 1, Section 4.6, that was reviewed to assess trends was relative abundance. This metric was assessed because the analyses conducted for RCEA on a longer term dataset indicated that a shift in species composition may have occurred in several waterbodies along the lower Churchill River following CRD (Manitoba Hydro and the Province of Manitoba 2015).

The relative abundance of fish species captured in standard gang index gill nets set at CAMP waterbodies from 2008-2013 is shown in Figure 6-32. The same four species dominated catches in standard gangs at on-system lacustrine locations over the 6-year sampling period: Lake Whitefish; Northern Pike; Walleye; and White Sucker. The species composition from the lower Churchill River at the Little Churchill River differed considerably from the lacustrine sites; notably, Lake Sturgeon were present at this location and accounted for a large proportion of the catch.

The same four species dominated the catch in standard gangs set at Gauer Lake, the off-system lake, in all six sampling years. The fish community at the Hayes River, the off-system riverine location, differed considerably from the on-system location in that species such as Brook Trout, Shorthead Redhorse and Silver Lamprey were captured and Yellow Perch were not captured. As with the Churchill River, Lake Sturgeon accounted for a large proportion of the catch in the Hayes River.

6.4 RELATIONSHIPS WITH HYDROLOGICAL METRICS

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

A quantitative consideration of hydrological conditions and fish community metrics for annual sites using water level and discharge data from nearby gauges (and/or simulated discharge data) provided by Manitoba Hydro indicated some statistically significant relationships for Northern Indian Lake, the lower Churchill River at the Little Churchill River and the Hayes River (Table 6-4). Over the 6-year period of record, discharge in the lower Churchill River at the Little Churchill River during the fish community sampling period was highest in 2009 and lowest in 2010 (Section 2.0). Total CPUE in the lower Churchill River at the Little Churchill River showed a statistically significant negative relationship with discharge during the sampling period (Table 6-4; Figure 6-33). The patterns in overall CPUE observed at this location appeared to largely reflect reduced relative abundance of Lake Sturgeon catch success associated with higher flows. In the Hayes River, total CPUE and Northern Pike CPUE and sampling period discharge and water level also showed statistically significant negative relationships (Table 6-4). These relationships were not unexpected as gear effectiveness typically decreases with increasing discharge and/or water level. Total CPUE did not show a relationship with any of the hydrological metrics at either annual lacustrine monitoring site (Northern Indian Lake or Gauer Lake).

The only other quantitative linkage observed for the other CAMP fish community metrics and hydrology was Lake Whitefish condition (Table 6-4). The Fulton’s condition value increased with increases in both water level and discharge during the open-water period at Northern Indian Lake and with increases in water level at the lower Churchill River at the Little Churchill River (Table 6-4). The relationship between Lake Whitefish condition and Northern Indian Lake water level is illustrated in Figure 6-34.

6.5 SUMMARY

Key findings of the six years of CAMP fish community monitoring include:

- The most common large-bodied species in each of the on-system lacustrine waterbodies of the LCRR were Lake Whitefish, Northern Pike, Walleye, and White Sucker. Unlike the lakes, Lake Sturgeon made up a large component of the catches in the lower Churchill River at the Little Churchill River;
- There was evidence for a decreasing trend in the diversity (Hill's index) and abundance (total CPUE) of fish in a downstream direction in the on-system lakes; and
- Lake Whitefish, Northern Pike, and Walleye from the lower Churchill River at the Little Churchill River obtained a larger size-at-age compared to those from Northern Indian Lake (i.e., fish were longer at a standard age).

Analysis of the six years of data has not indicated any obvious temporal trends for the fish community metrics measured over the period of 2008-2013. There has been considerable variability in the metrics among sampling years; however, statistical comparisons between sampling years for the metrics for which analysis was possible revealed few significant differences at the on-system annual sites (Northern Indian Lake and the lower Churchill River at the Little Churchill River). A quantitative consideration of hydrological conditions and fish community metrics indicated that the total CPUE in index gill nets set in the lower Churchill River at the Little Churchill River decreased with increasing flows during the sampling period. The condition of Lake Whitefish from both the lower Churchill River at the Little Churchill River and Northern Indian Lake was positively correlated with discharge and/or water level over the open water period.

Table 6-1. Inventory of fish community sampling completed in the Lower Churchill River Region: 2008-2013.

Location	Site Abbreviation	On-system	Off-system	Annual	Rotational	Sampling Years					
						2008	2009	2010	2011	2012	2013
Partridge Breast Lake	PBL	X			X		X			X	
Northern Indian Lake	NIL	X		X		X	X	X	X	X	X
Fidler Lake	FID	X			X				X		
Billard Lake	BIL	X			X			X			X
Lower Churchill River at Little Churchill River	LCR-LiCR	X		X		X	X	X	X	X	X
Lower Churchill River at Redhead Rapids	LCR-RHR	X			X [1]				X		
Gauer Lake	GAU		X	X		X	X	X	X	X	X
Hayes River [2]	HAYES		X	X		X	X	X	X	X	X

[1] Site was subsequently moved to the lower Churchill River at the Churchill Weir in 2014.

[2] Site formally included in the LNRR; included here for discussion of results.

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

Species	**Abbreviation**	**PBL** n_Y=2	**NIL** n_Y=6	**FID** n_Y=1	**BIL** n_Y=2	**LCR-LiCR** n_Y=6	**LCR-RHR** n_Y=1	**GAU** n_Y=6	**HAYES** n_Y=6
Silver Lamprey	SLLM								X*
Lake Sturgeon	LKST				X*	X			X
Lake Chub	LKCH	X	X		X	X*		X*	X*
Carp	CARP								X*
Northern Pearl Dace	PRDC		X*			X*		X*	
Emerald Shiner	EMSH	X	X	X	X*	X	X	X	
Blacknose Shiner	BLSH		X*						
Spottail Shiner	SPSH	X	X	X	X	X		X	X*
Longnose Dace	LNDC					X*	X		X*
Longnose Sucker	LNSC	X	X	X	X	X	X	X	X
White Sucker	WHSC	X	X	X	X	X	X	X	X
Shorthead Redhorse	SHRD								X
Northern Pike	NRPK	X	X	X	X	X	X	X	X
Cisco	CISC	X	X	X	X*	X		X	X*
Lake Whitefish	LKWH	X	X	X	X	X	X	X	X
Arctic Grayling	ARGR					X*			
Brook Trout	BRTR								X*
Trout-perch	TRPR	X	X	X	X	X		X	X*
Burbot	BURB	X*	X				X	X	X*
Spoonhead Sculpin	SPSC		X*						
Johnny Darter	JHDR								X*
Yellow Perch	YLPR	X	X	X	X*	X*		X	
Logperch	LGPR					X*		X*	
Walleye	WALL	X	X	X	X	X	X	X	X

* species is observed infrequently in catches (i.e., in fewer than 80% of sampling years)
nY = 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 Lower Churchill 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	PBL	2	7.5	0.1	-	-	-	-	-	-	-	-	-
	NIL	6	7.5	0.4	-	-	-	-	-	-	-	-	-
	FID	1	6.1	-	-	-	-	-	-	-	-	-	-
	BIL	2	5.4	0.5	-	-	-	-	-	-	-	-	-
	LCR-LiCR	6	6.6	0.2	-	-	-	-	-	-	-	-	-
	LCR-RHR	1	6.7	-	-	-	-	-	-	-	-	-	-
	GAU	6	7.7	0.2	-	-	-	-	-	-	-	-	-
	HAYES	6	6.2	0.3	-	-	-	-	-	-	-	-	-
Standard gang	PBL	-	-	-	1231	65.5	5.3	-	-	-	-	-	-
	NIL	-	-	-	4214	62.2	3.4	-	-	-	-	-	-
	FID	-	-	-	325	47.2	-	-	-	-	-	-	-
	BIL	-	-	-	886	53.0	2.2	-	-	-	-	-	-
	LCR-LiCR	-	-	-	2109	43.1	6.1	-	-	-	-	-	-
	LCR-RHR	-	-	-	29	8.6	-	-	-	-	-	-	-
	GAU	-	-	-	4710	80.4	6.3	-	-	-	-	-	-
	HAYES	-	-	-	307	10.4	1.4	-	-	-	-	-	-
Small mesh	PBL	-	-	-	634	117.3	2.4	-	-	-	-	-	-
	NIL	-	-	-	3007	148.1	22.8	-	-	-	-	-	-
	FID	-	-	-	275	90.7	-	-	-	-	-	-	-
	BIL	-	-	-	594	106.1	12.5	-	-	-	-	-	-
	LCR-LiCR	-	-	-	1843	127.1	17.9	-	-	-	-	-	-
	LCR-RHR	-	-	-	14	5.7	-	-	-	-	-	-	-
	GAU	-	-	-	2343	133.7	16.0	-	-	-	-	-	-
	HAYES	-	-	-	26	4.5	0.8	-	-	-	-	-	-

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
Lake Whitefish	PBL	-	-	-	241	13.5	4.2	209	1.46	0.05	21	290	8
											23	319	12
	NIL	-	-	-	680	10.3	1.9	478	1.41	0.02	62	237	2
											58	265	3
	FID	-	-	-	147	21.3	-	116	1.44	-	4	275	-
											7	342	-
	BIL	-	-	-	330	18.9	5.3	299	1.41	0.04	30	311	5
											38	338	1
	LCR-LiCR	-	-	-	334	6.7	0.9	299	1.48	0.03	18	322	7
											19	363	5
	LCR-RHR	-	-	-	3	0.9	-	3	1.43	-	-	-	-
	GAU	-	-	-	1085	18.4	2.1	787	1.50	0.02	107	272	2
											134	304	1
	HAYES	-	-	-	29	0.6	0.2	27	1.42	0.04	2	256	27
											3	340	16
Northern Pike	PBL	-	-	-	302	15.8	0.7	276	0.66	0.02	15	460	9
	NIL	-	-	-	543	7.8	0.9	477	0.63	<0.01	45	446	5
	FID	-	-	-	120	17.5	-	101	0.67	-	-	-	-
	BIL	-	-	-	185	11.1	0.2	162	0.64	<0.01	13	476	3
	LCR-LiCR	-	-	-	240	4.8	0.4	142	0.69	0.01	12	500	6
	LCR-RHR	-	-	-	11	3.3	-	11	0.75	-	1	527	-
	GAU	-	-	-	650	10.8	0.6	548	0.67	0.01	64	437	6
	HAYES	-	-	-	32	0.5	0.1	17	0.70	0.02	1	405	-

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	PBL	-	-	-	209	10.5	4.1	182	1.12	0.02	2	304	27
	NIL	-	-	-	1399	20.4	1.7	1209	1.11	0.01	15	237	3
	FID	-	-	-	33	4.7	-	28	1.22	-	-	-	-
	BIL	-	-	-	270	16.9	3.0	138	1.07	0.02	15	278	-
	LCR-LiCR	-	-	-	601	12.7	2.4	379	1.17	0.02	25	239	6
	LCR-RHR	-	-	-	6	1.8	-	4	1.25	-	-	-	-
	GAU	-	-	-	1109	19.2	3.0	999	1.13	0.01	7	221	2
	HAYES	-	-	-	179	3.2	0.4	108	1.09	0.02	14	275	7
White Sucker	PBL	-	-	-	395	21.0	4.0	349	1.51	0.01	-	-	-
	NIL	-	-	-	1149	16.7	1.9	885	1.47	0.02	-	-	-
	FID	-	-	-	17	2.5	-	15	1.39	-	-	-	-
	BIL	-	-	-	79	4.8	0.6	55	1.45	0.01	-	-	-
	LCR-LiCR	-	-	-	192	3.9	0.9	133	1.55	0.02	-	-	-
	LCR-RHR	-	-	-	7	2.0	-	5	1.69	-	-	-	-
	GAU	-	-	-	1247	21.4	1.8	730	1.53	0.01	-	-	-
	HAYES	-	-	-	67	1.1	0.3	52	1.43	0.03	-	-	-

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

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

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

n_Y = number of years sampled

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

SE = standard error

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

Metric	Species	Waterbody	Hydrology Metric	df	F	p	R^2	Direction
CPUE	NRPK	HAYES	Q (GN)	2	48.11	0.02	0.96	-
		HAYES	WL (GN)	2	35.88	0.03	0.95	-
	Total	LCR-LiCR	Q (GN)	4	8.27	0.05	0.67	-
		HAYES	Q (GN)	2	200.16	< 0.01	0.99	-
		HAYES	WL (GN)	2	201.81	< 0.01	0.99	-
K_F	LKWH	LCR-LiCR	WL (OW)	4	12.39	0.02	0.76	+
		NIL	Q (OW)	4	14.12	0.02	0.78	+
		NIL	WL (OW)	4	51.93	0.00	0.93	+

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

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

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

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

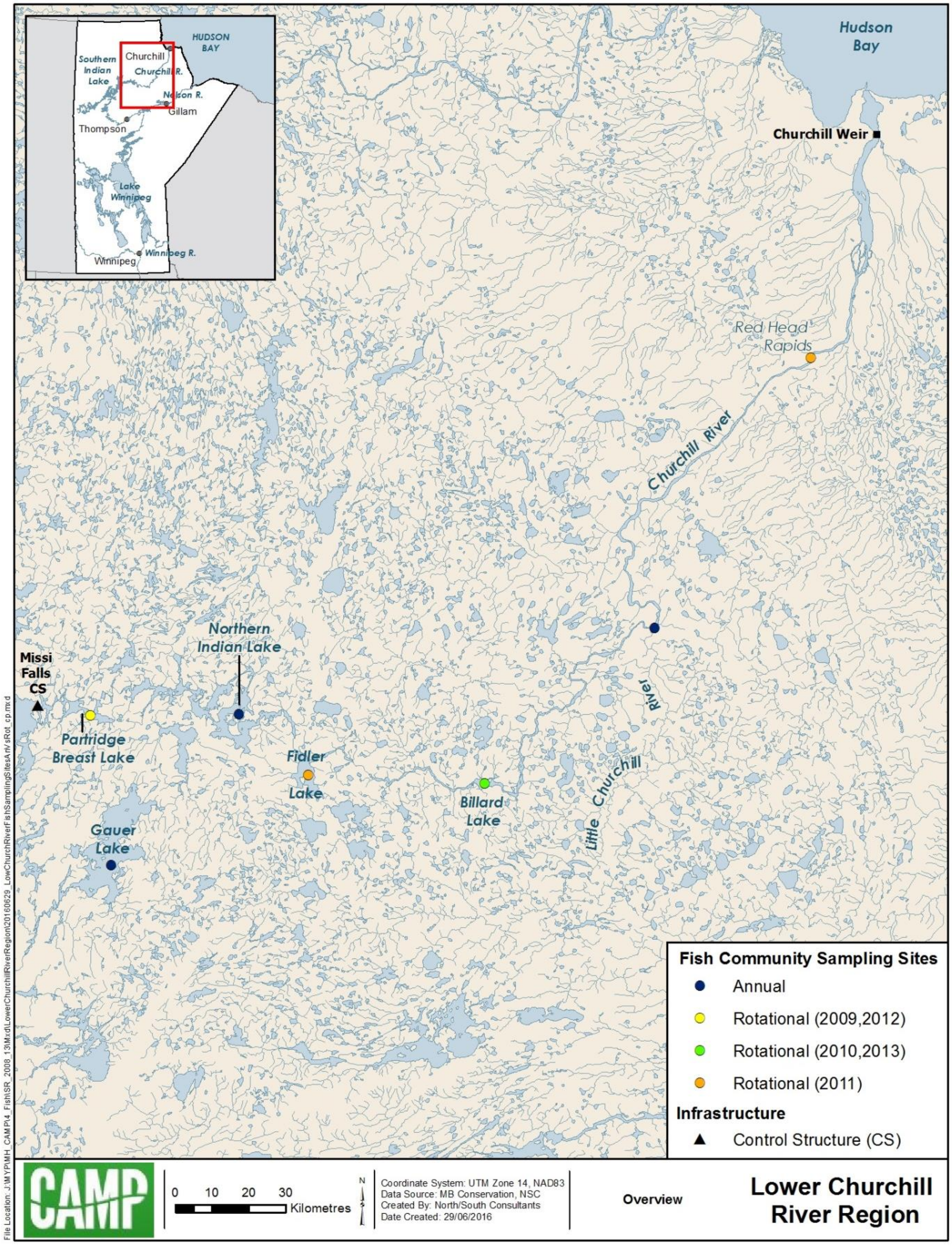


Figure 6-1. Waterbodies sampled in the Lower Churchill River Region: 2008-2013.

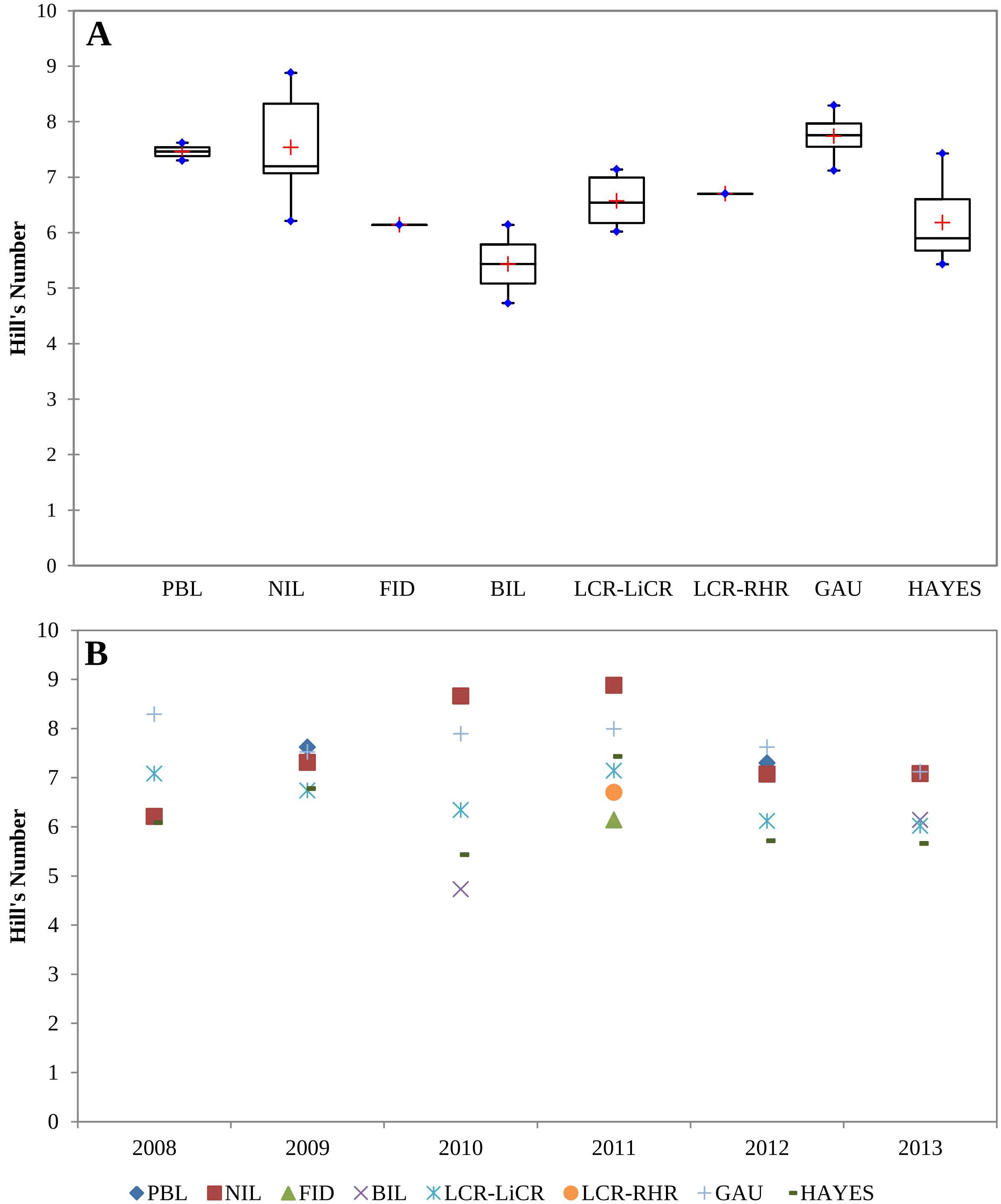


Figure 6-2. Annual mean Hill's effective species richness index (Hill number) for standard gang and small mesh index gill nets set in Lower Churchill River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

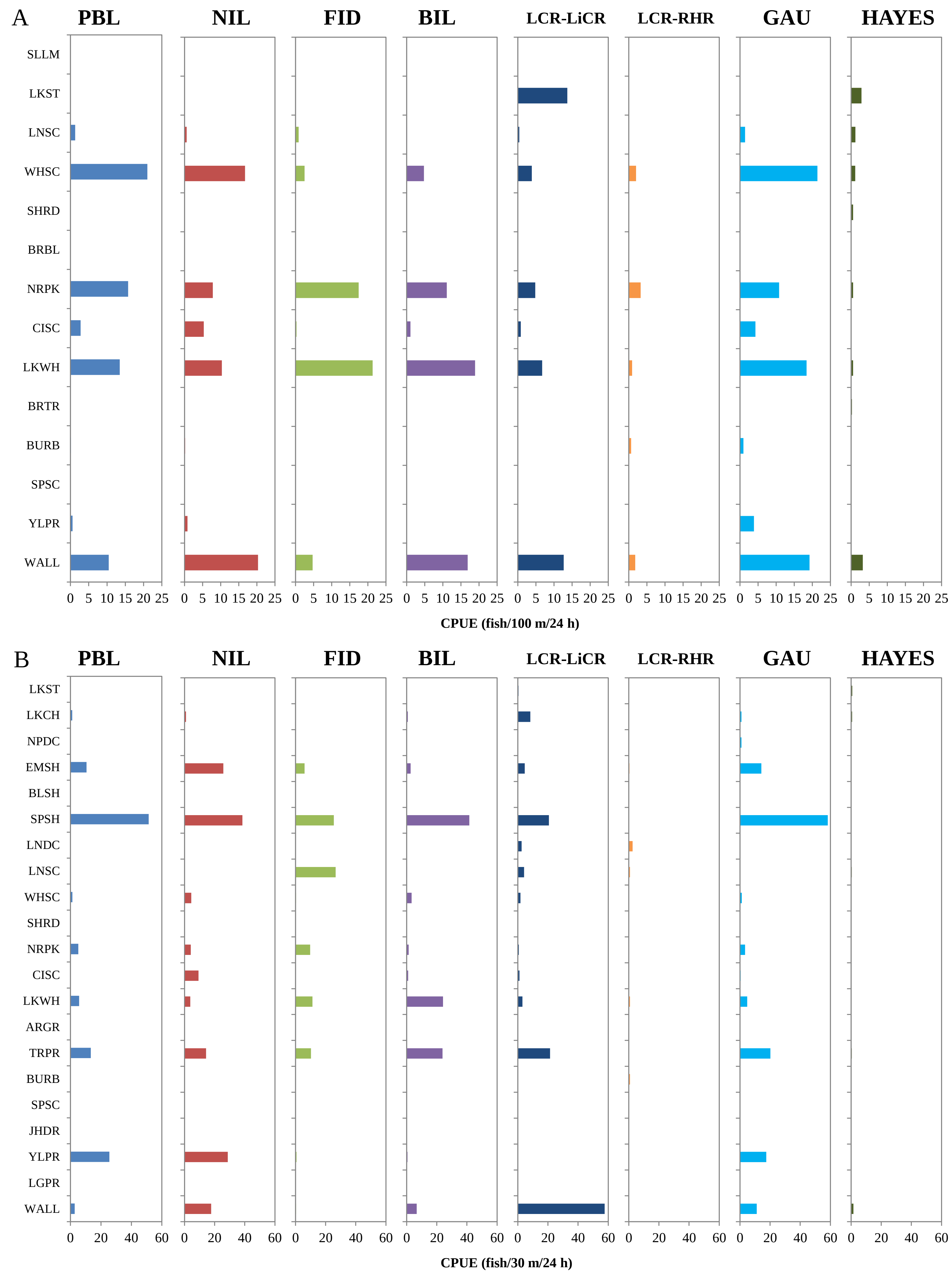


Figure 6-3. Mean catch-per-unit-effort in (A) standard gang (fish/100 m/24 h) and (B) small mesh (fish/30 m/24 h) index gill nets set in Lower Churchill River Region waterbodies: 2008-2013.

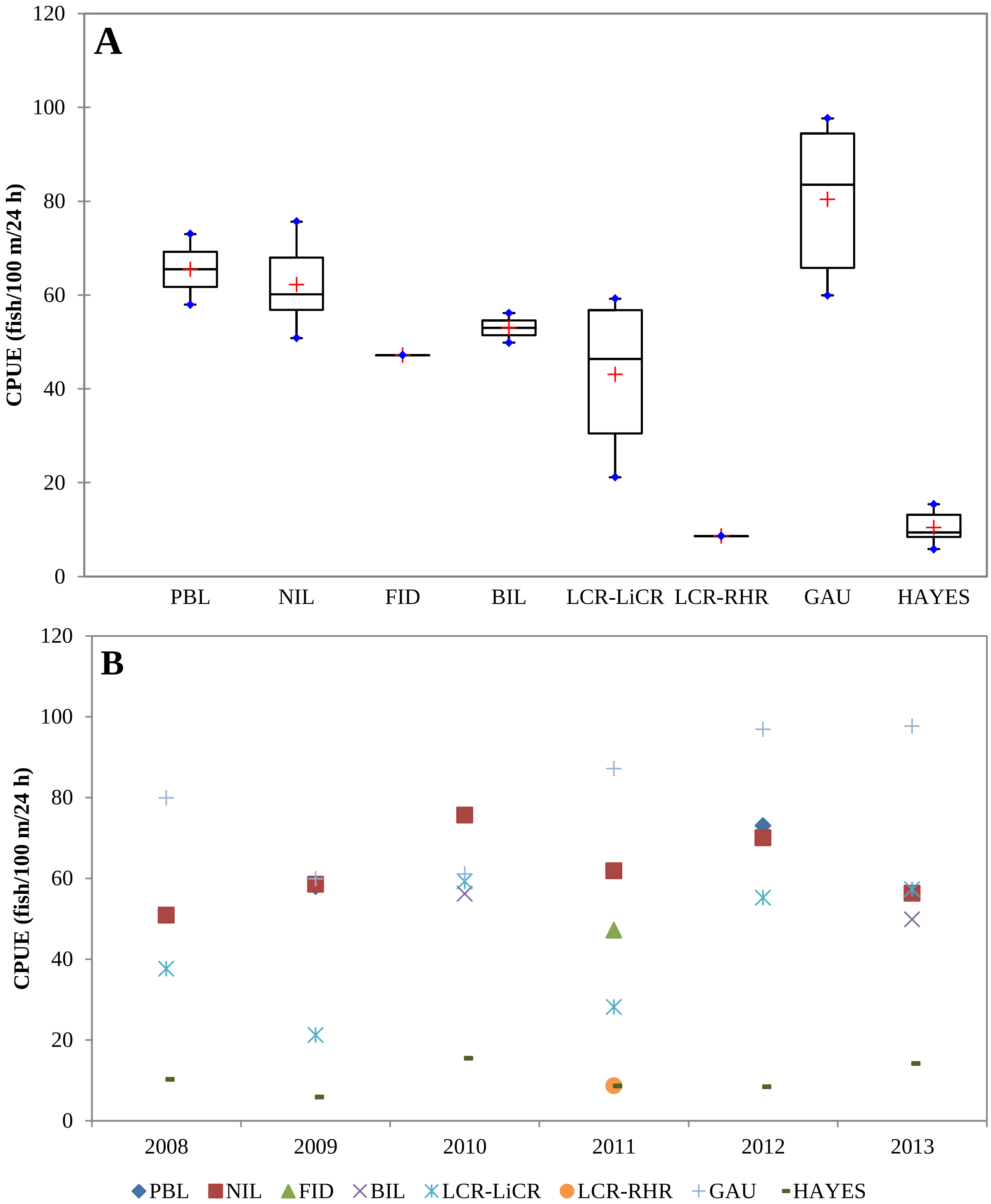


Figure 6-4. Annual mean catch-per-unit-effort (CPUE) calculated for the total catch in standard gang index gill nets set in Lower Churchill River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

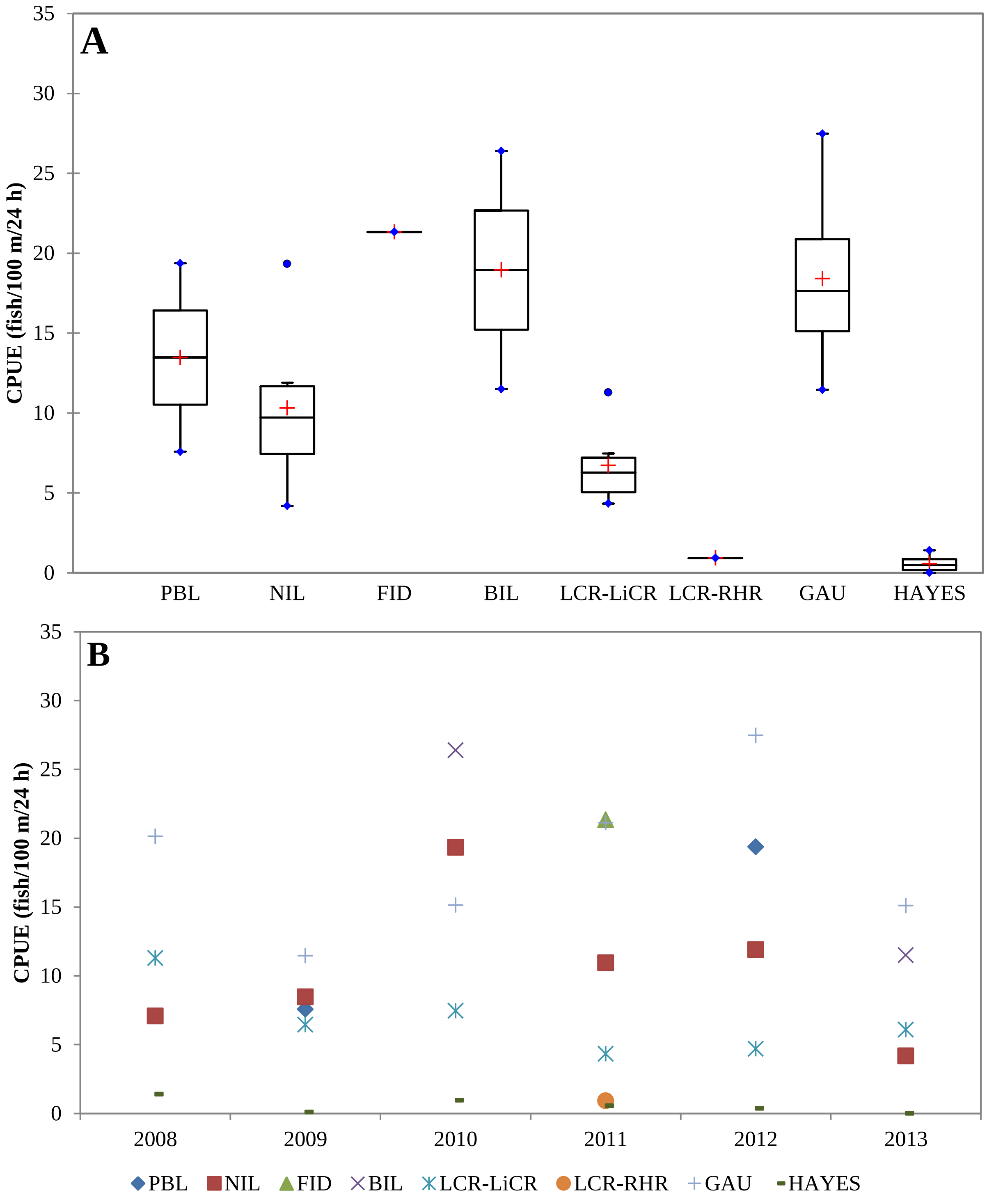


Figure 6-5. Annual mean catch-per-unit-effort (CPUE) calculated for Lake Whitefish captured in standard gang index gill nets set in Lower Churchill River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

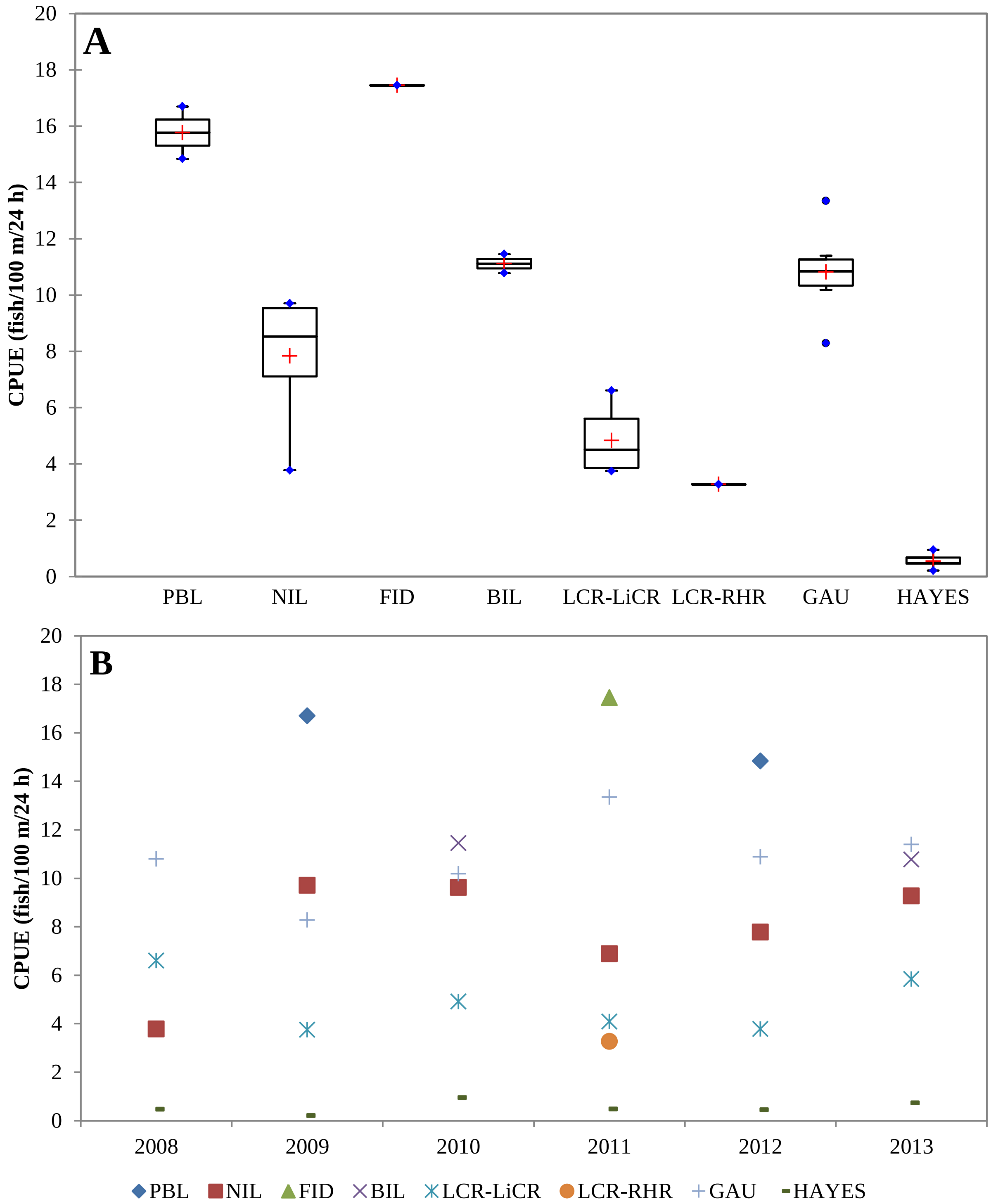


Figure 6-6. Annual mean catch-per-unit-effort (CPUE) calculated for Northern Pike captured in standard gang index gill nets set in Lower Churchill River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

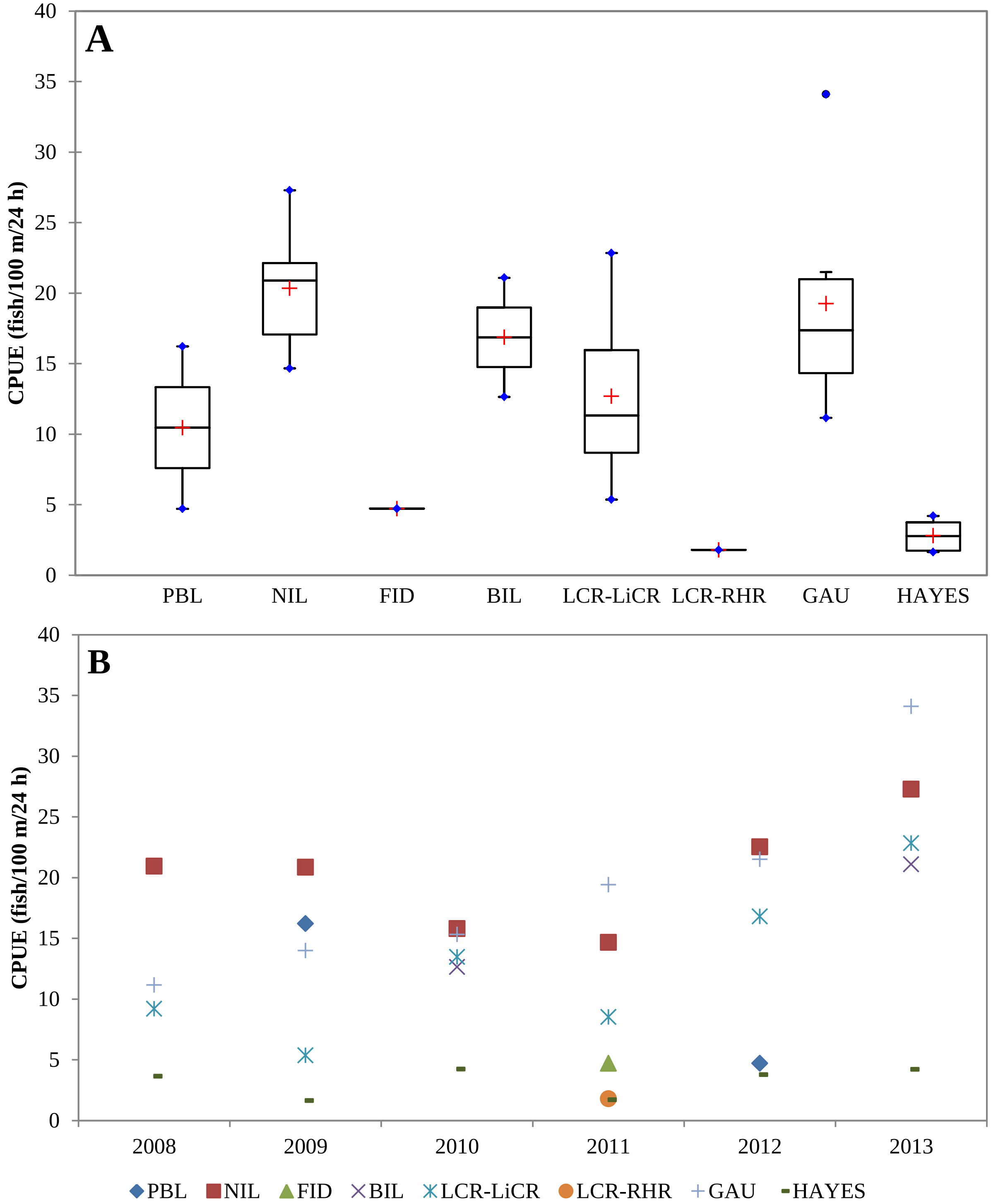


Figure 6-7. Annual mean catch-per-unit-effort (CPUE) calculated for Walleye captured in standard gang index gill nets set in Lower Churchill River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

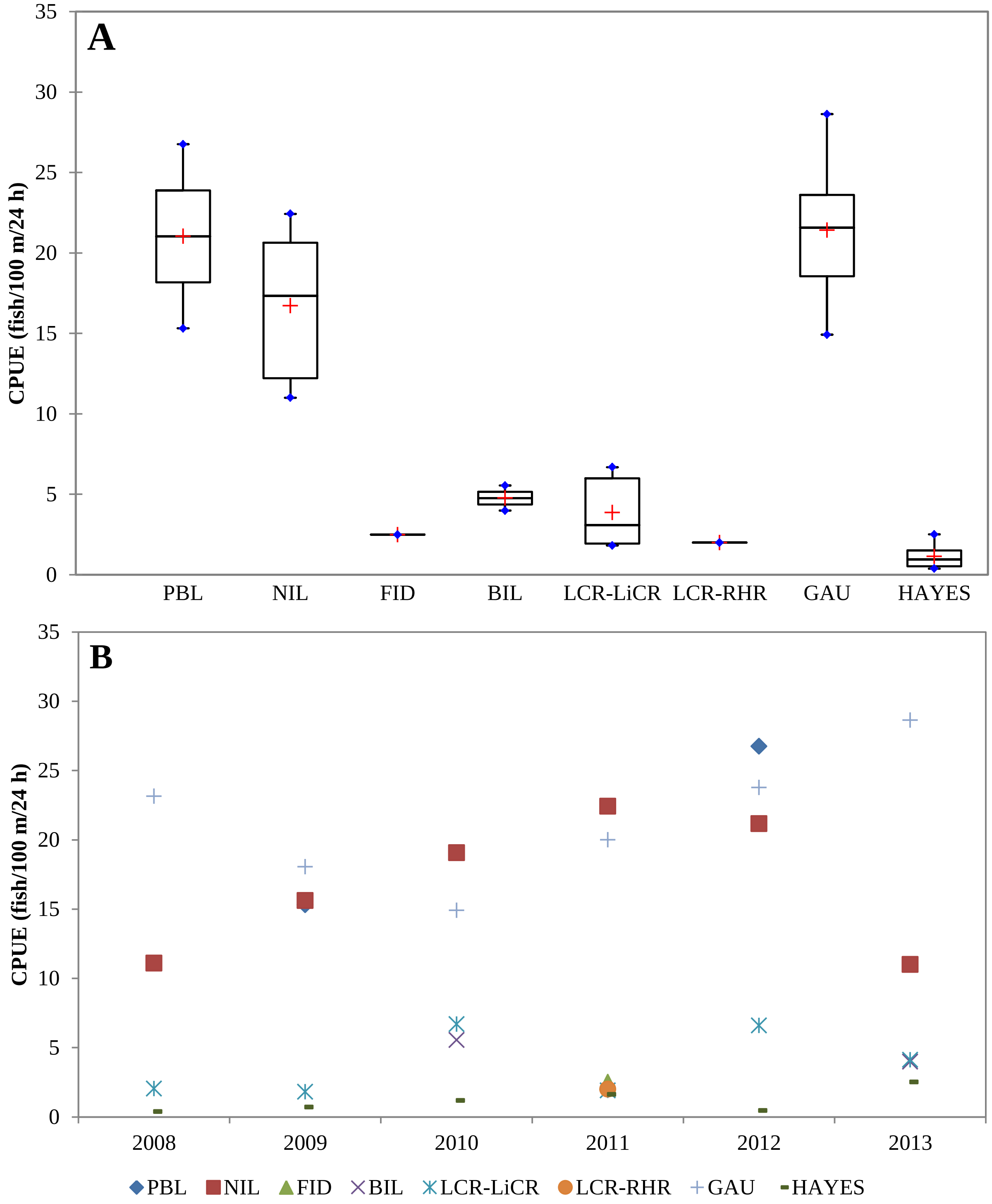


Figure 6-8. Annual mean catch-per-unit-effort (CPUE) calculated for White Sucker captured in standard gang index gill nets set in Lower Churchill River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

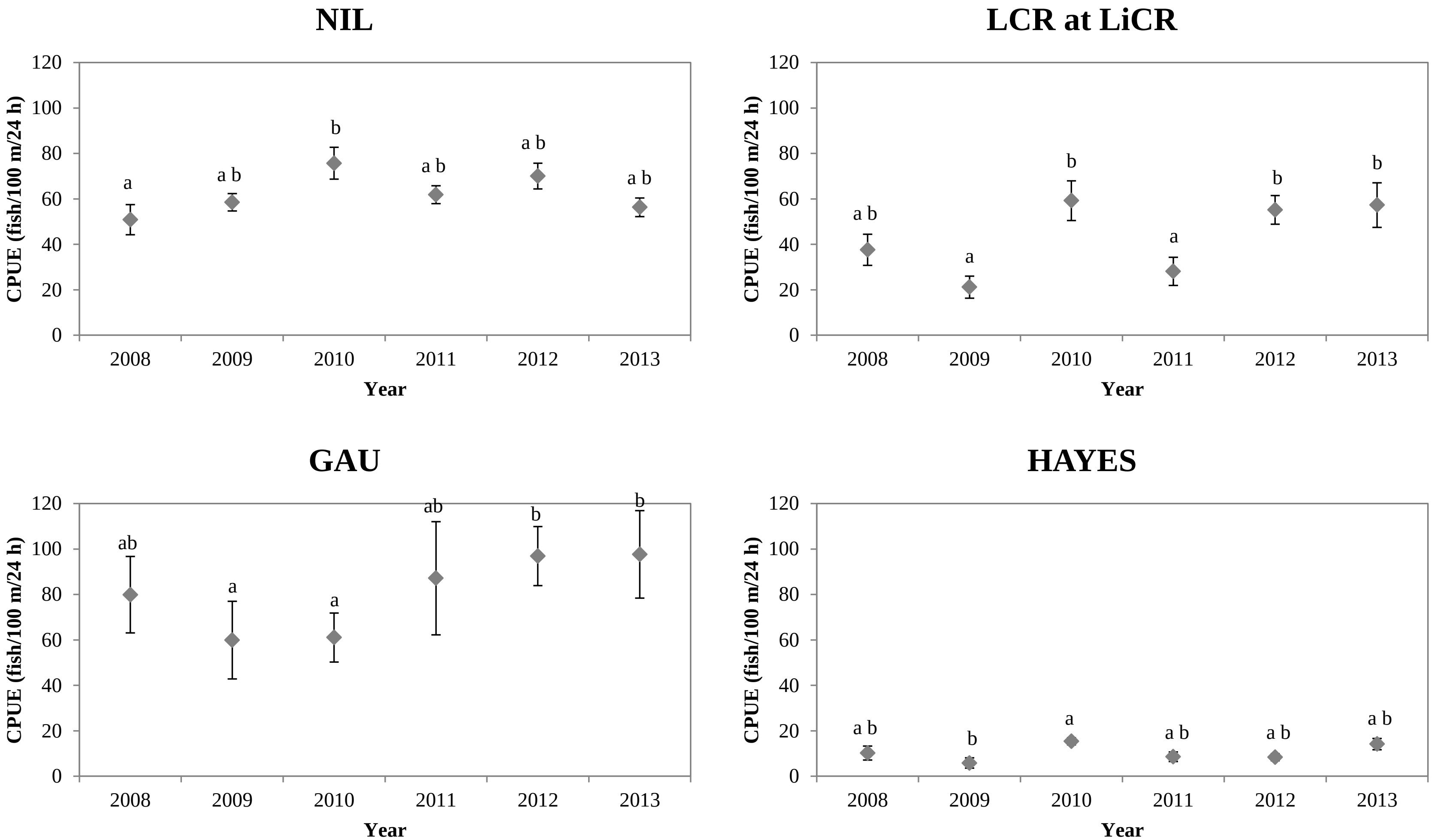


Figure 6-9. Total catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack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

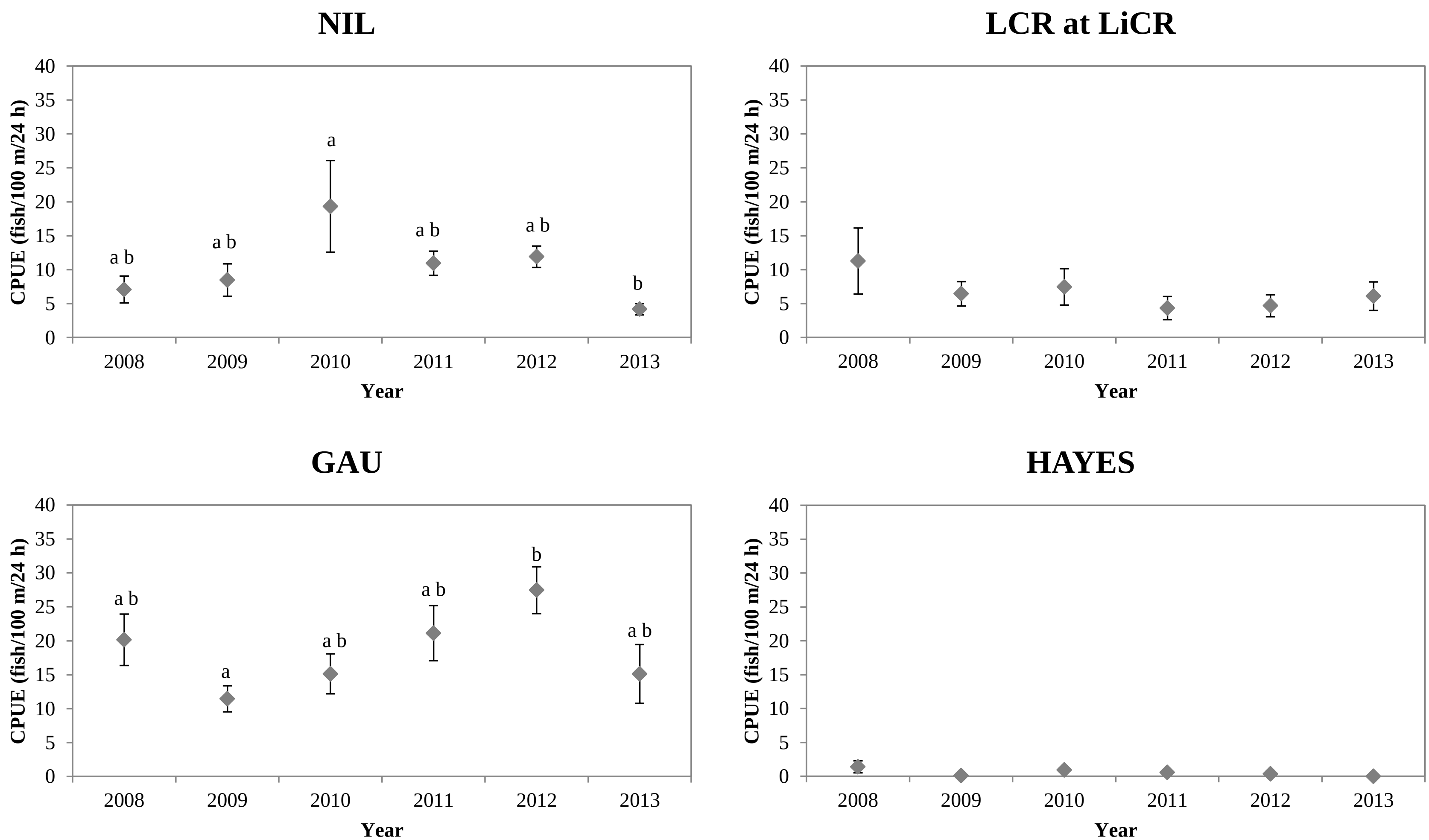


Figure 6-10. Lake Whitefish catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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

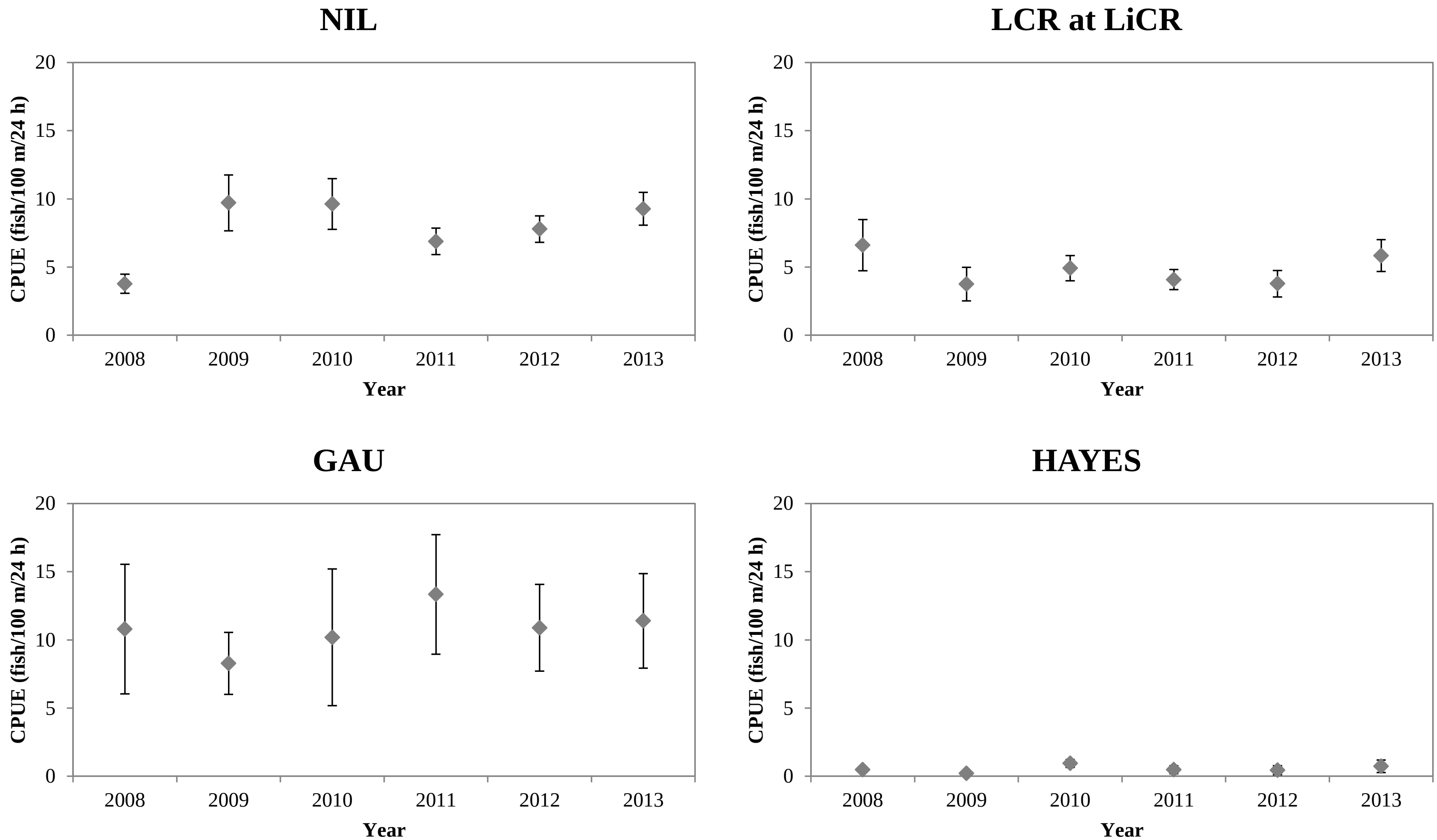


Figure 6-11. Northern Pike catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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

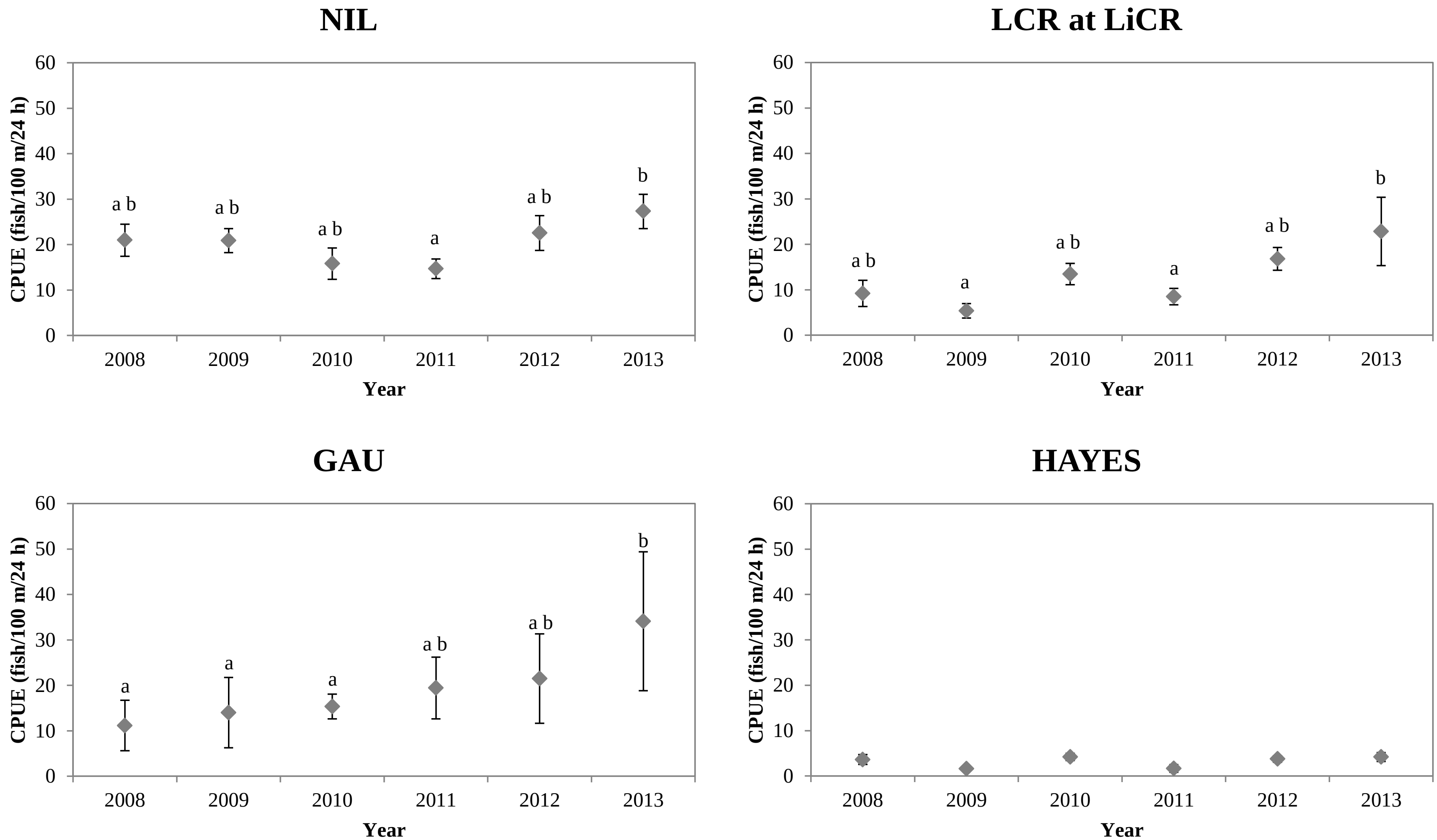


Figure 6-12. Walleye catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or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

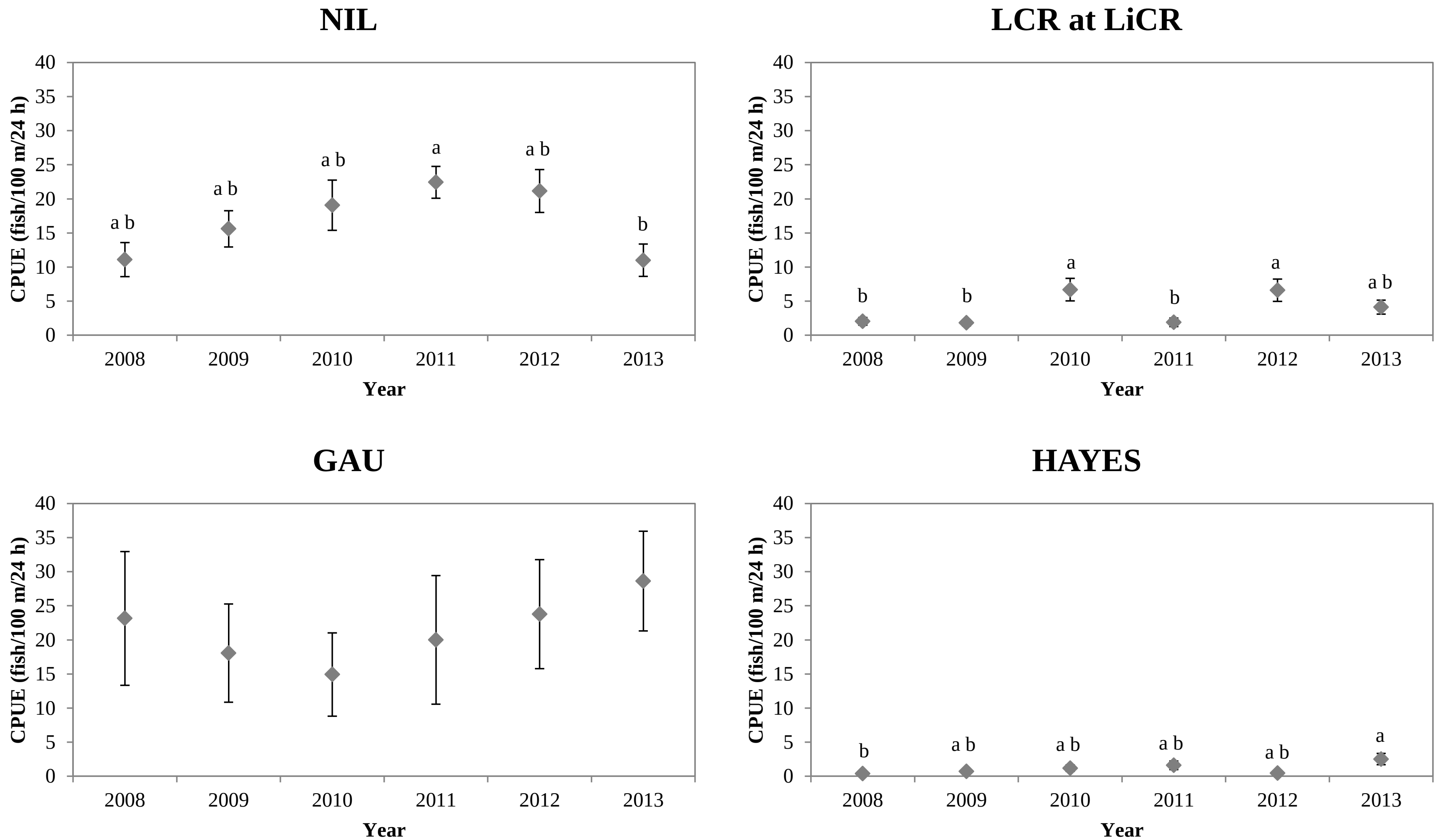
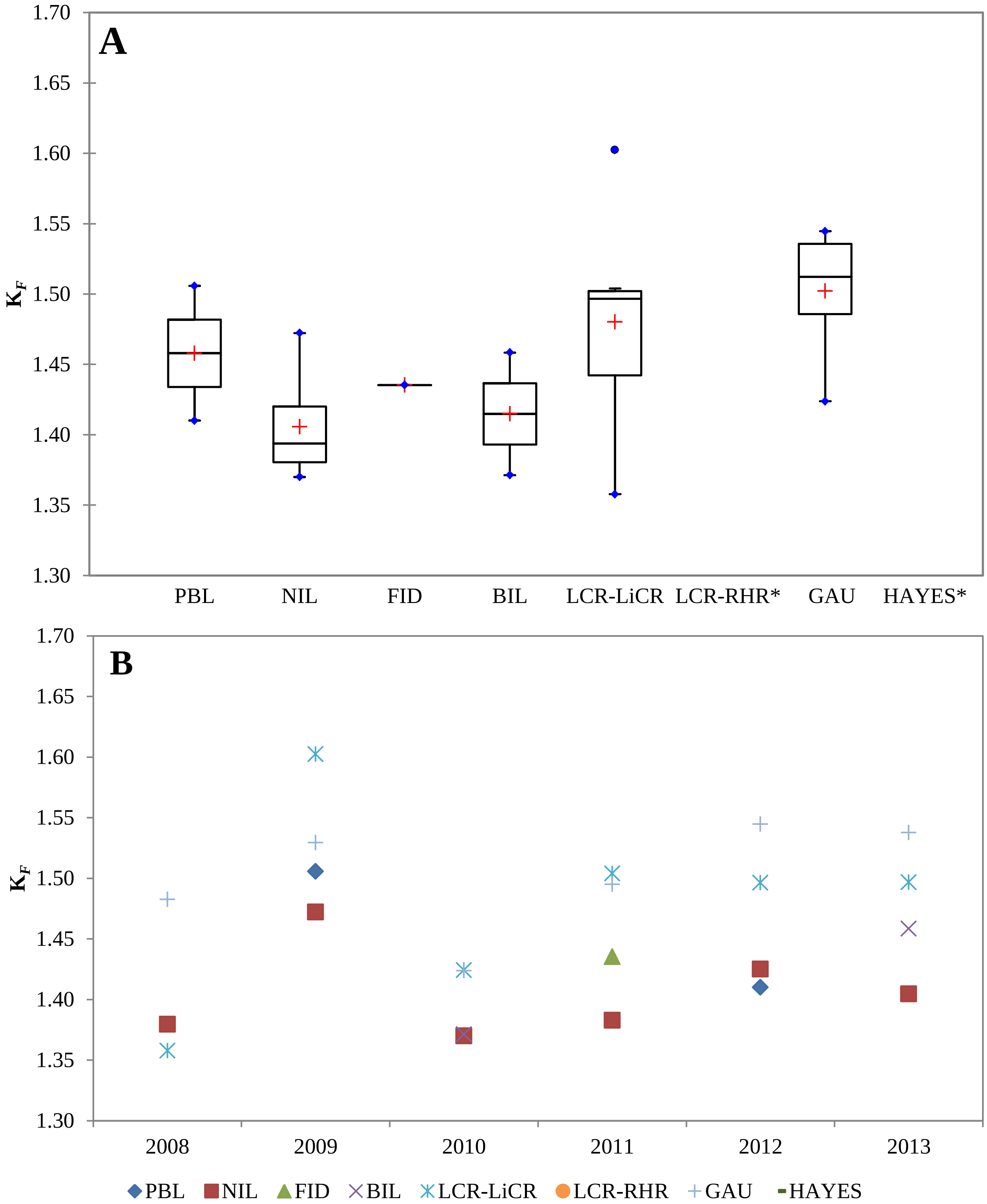
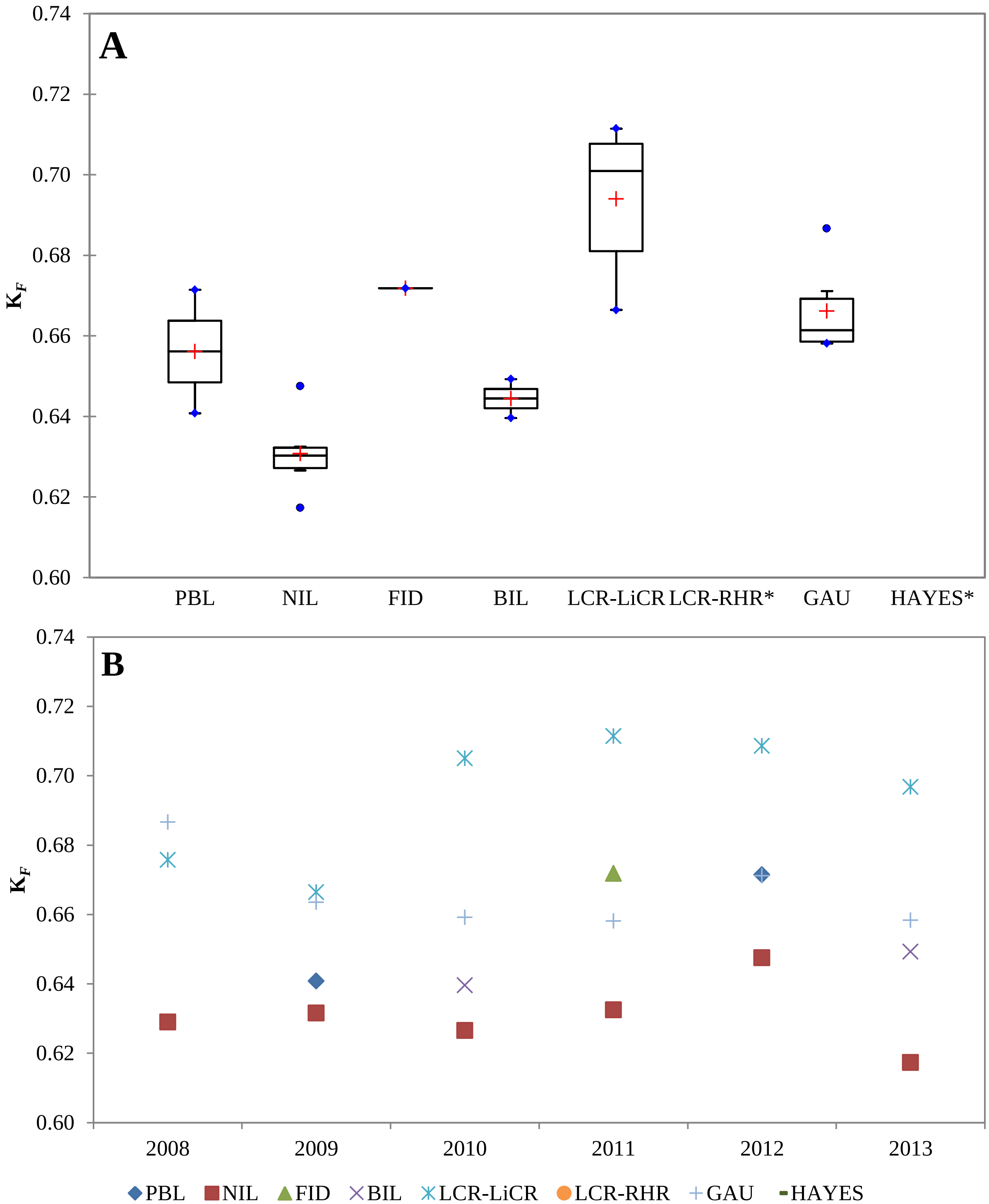


Figure 6-13. White Sucker catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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



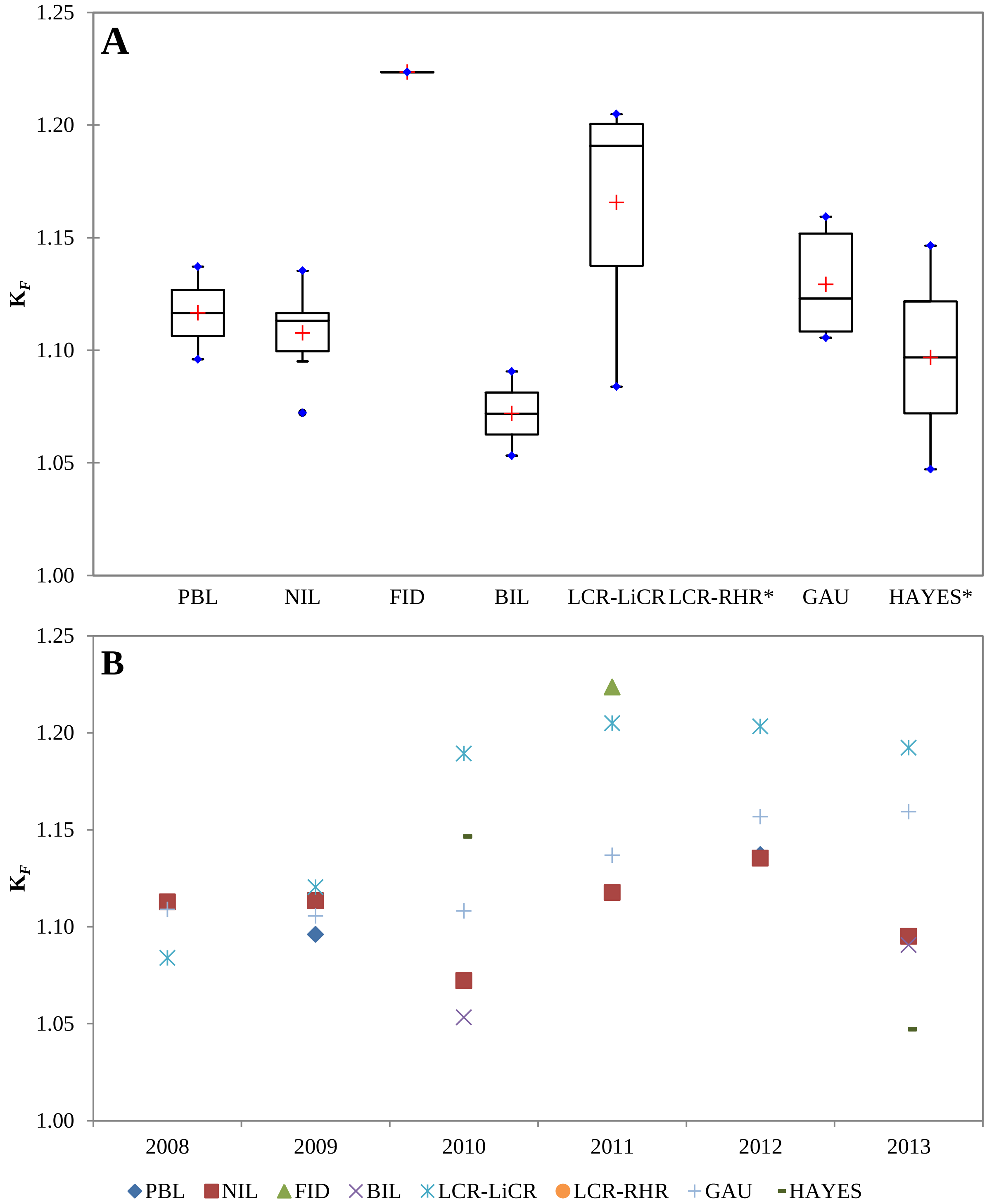
*Too few fish were captured at LCR-RHR and HAYES

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



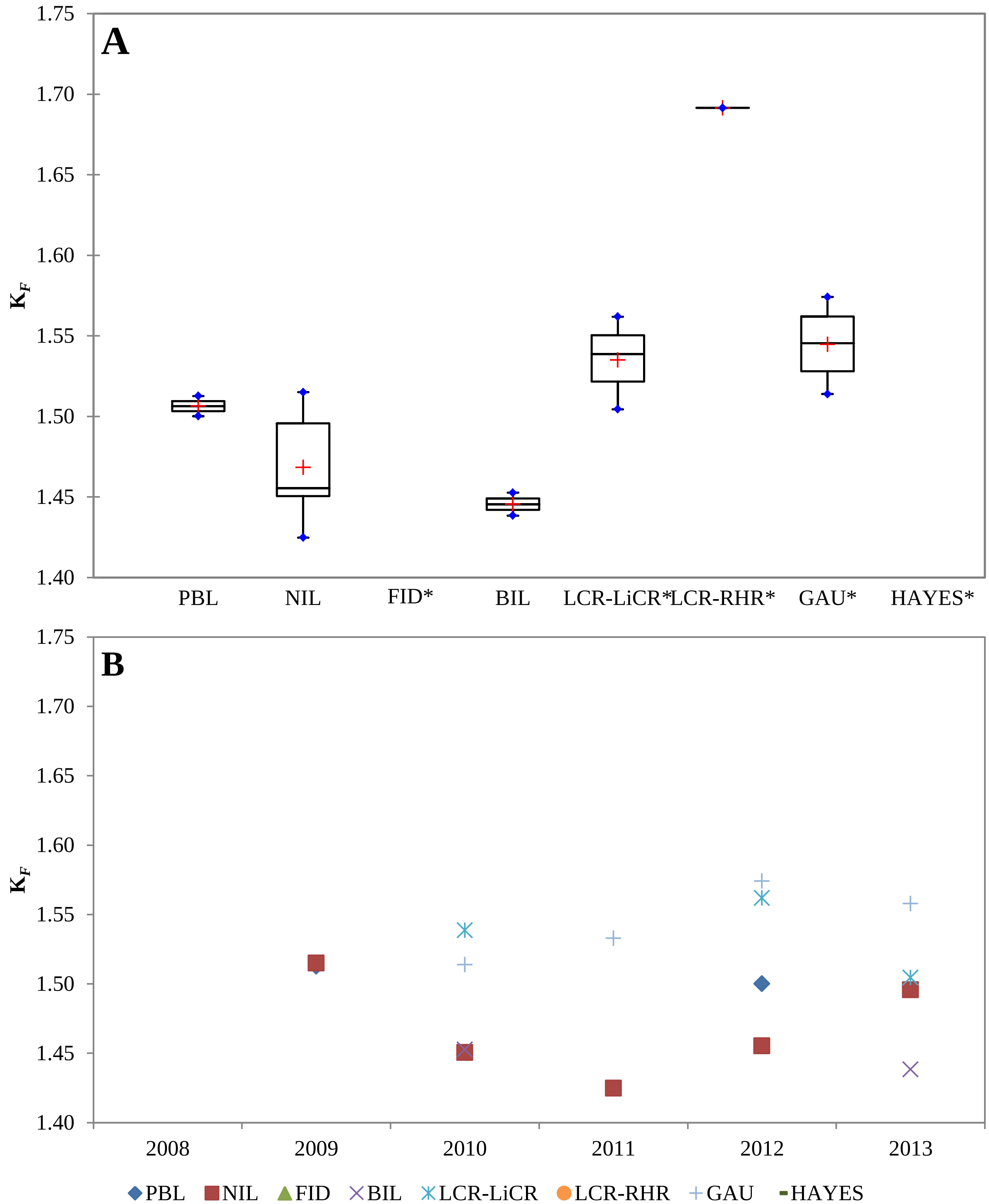
*Too few fish were captured at LCR-RHR and HAYES

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



*Too few fish were captured at LCR-RHR and HAYES in 2008, 2009, 2011, and 2012

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



*Too few fish were captured at LCR-RHR, FID, LCR-RHR, HAYES, and LCR-LiCR in 2009 and 2011, and GAU in 2009; White Sucker were not measured for length in 2008

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

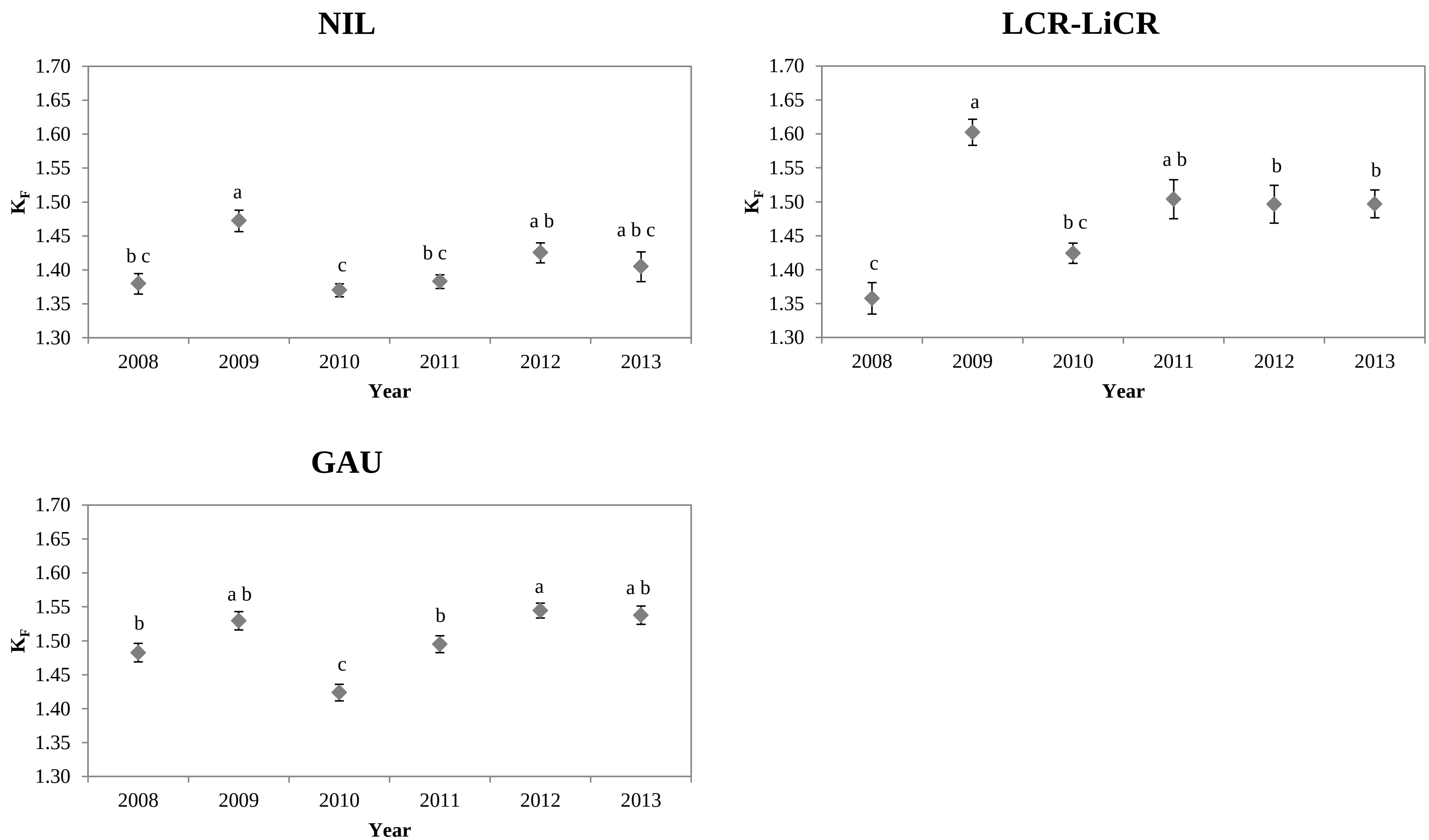


Figure 6-18. Fulton's condition factor (K_F; mean ± SE) of Lake Whitefish between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical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

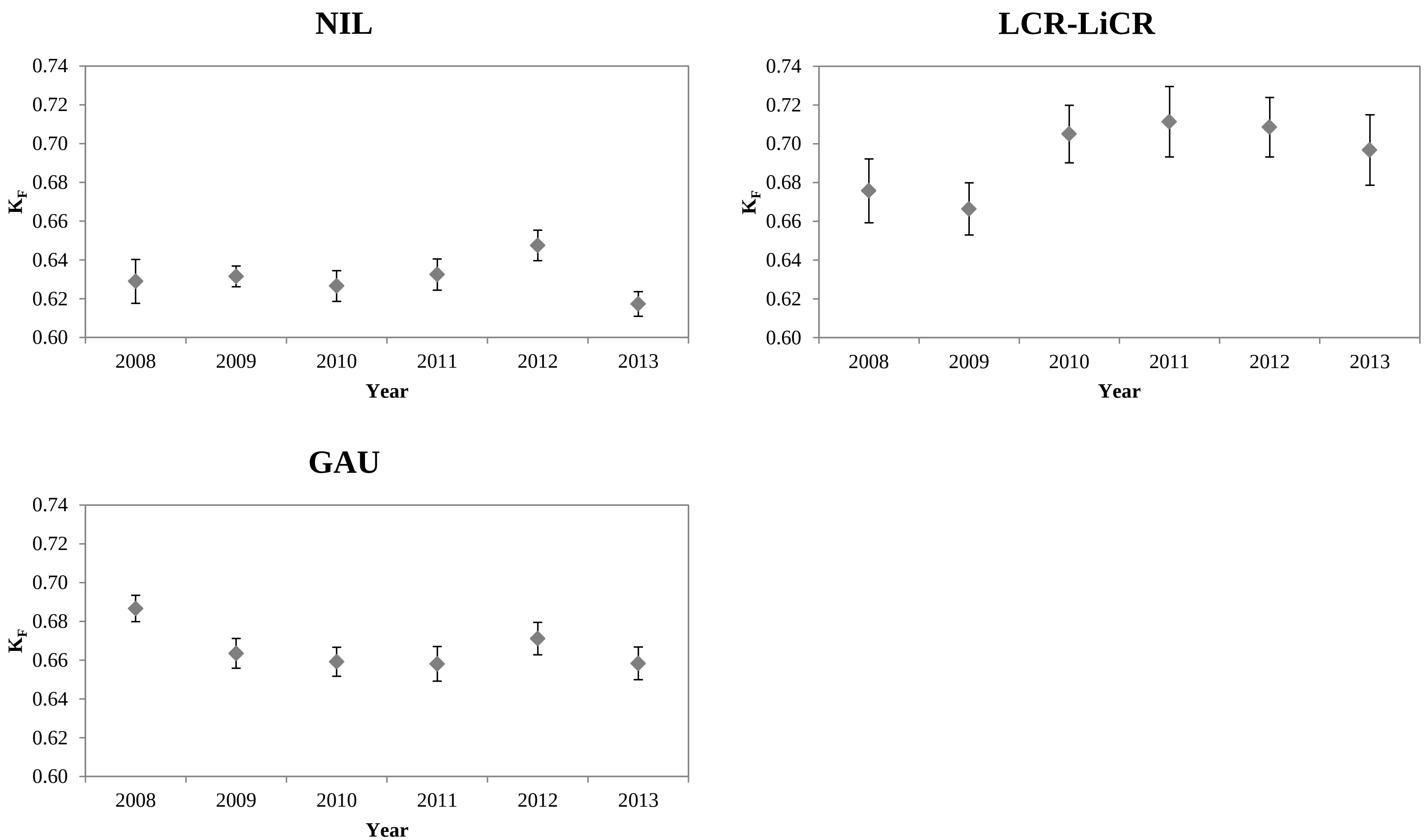


Figure 6-19. Fulton's condition factor (K_F; mean ± SE) of Northern Pike between 400 and 699 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical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

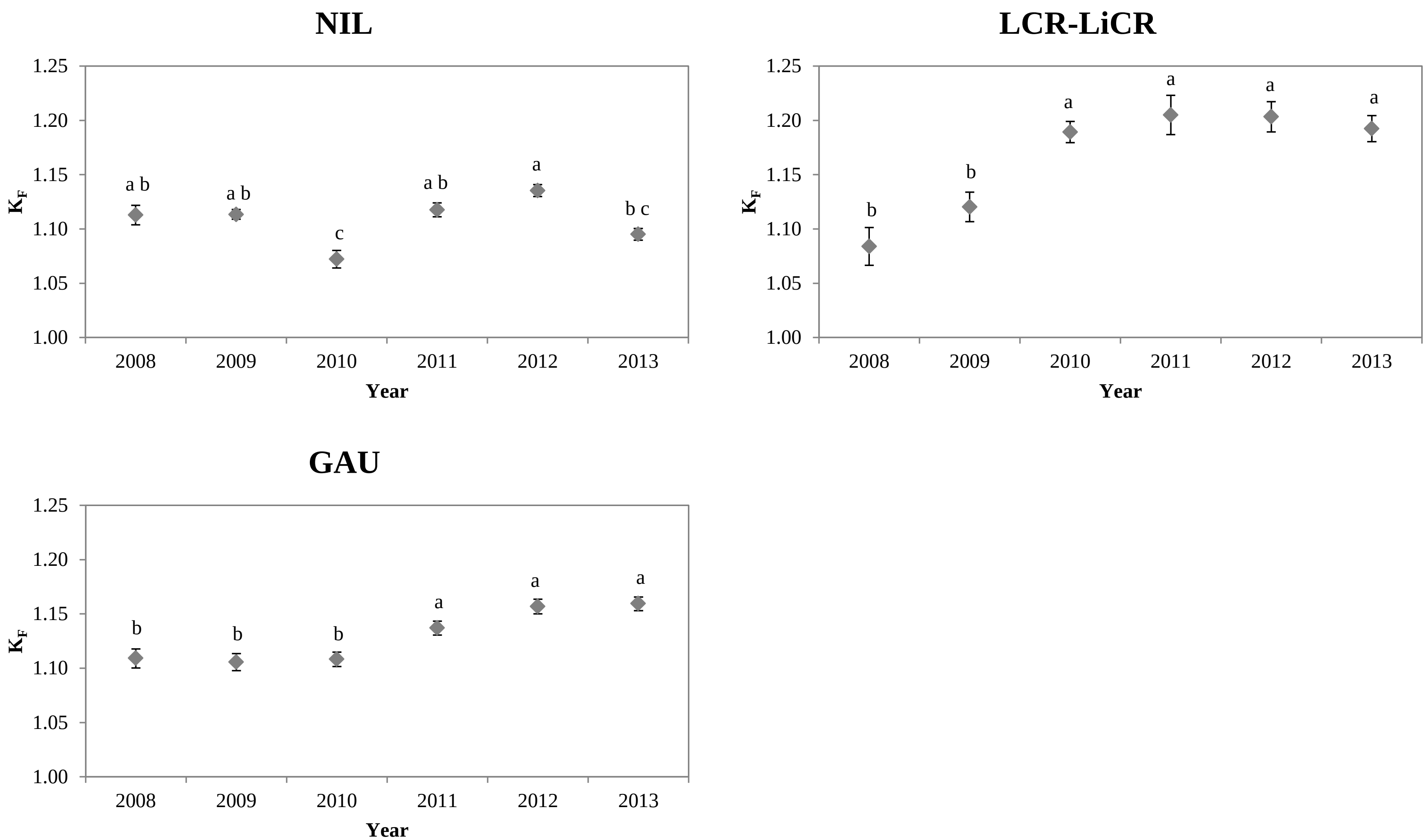


Figure 6-20. Fulton’s condition factor (K_F; mean ± SE) of Walleye between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical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

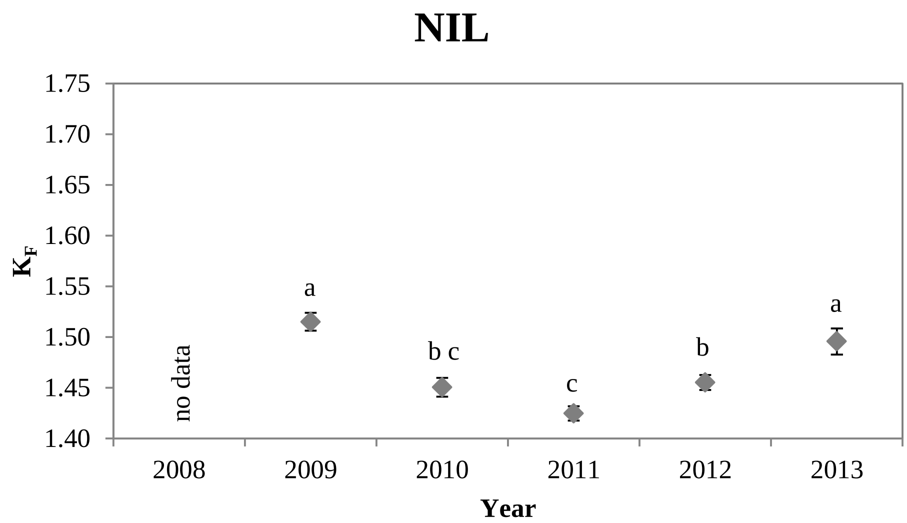


Figure 6-21. Fulton's condition factor (K_F; mean ± SE) of White Sucker between 300 and 499 mm in fork length captured at an annual on-system location. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack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

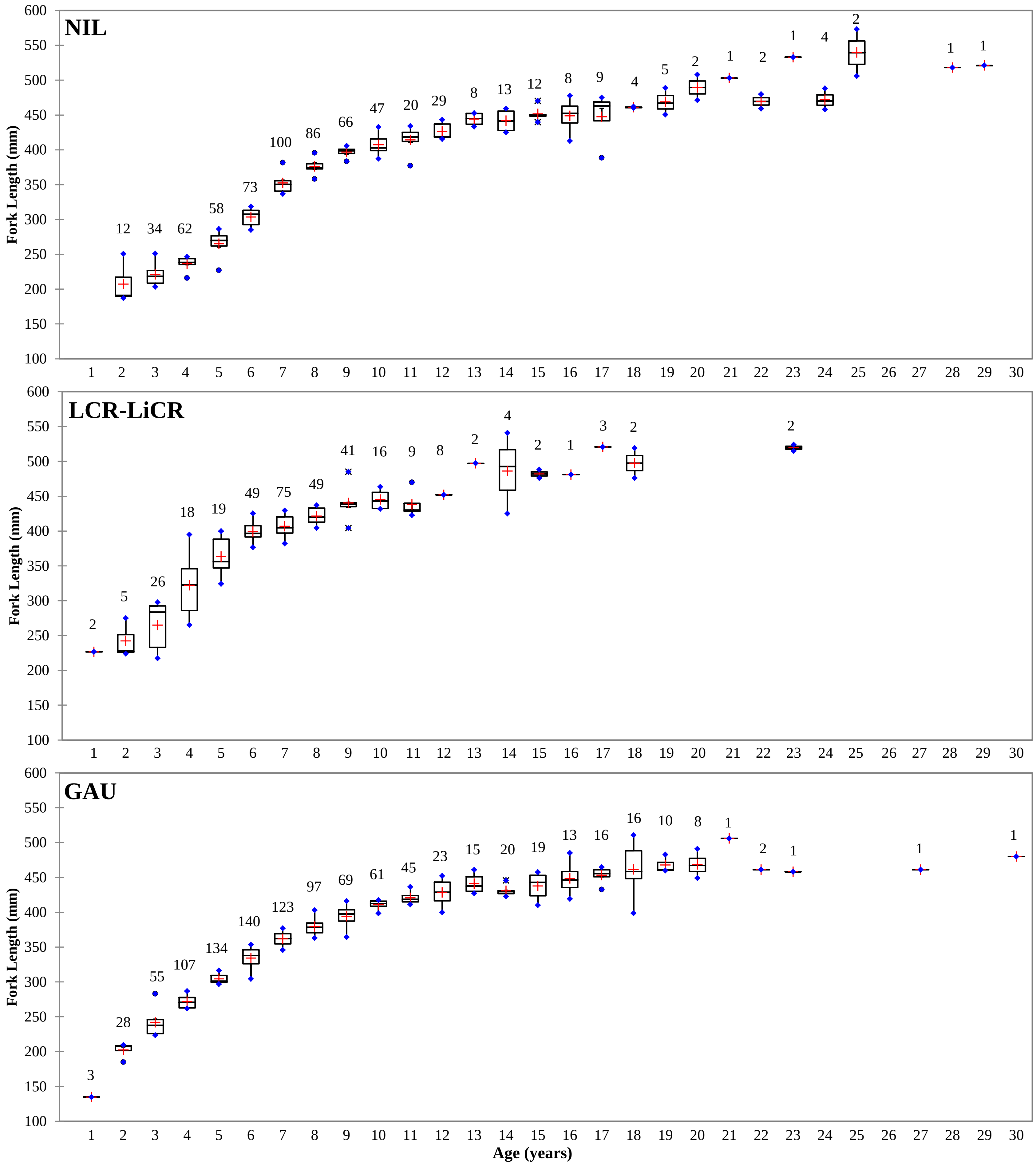
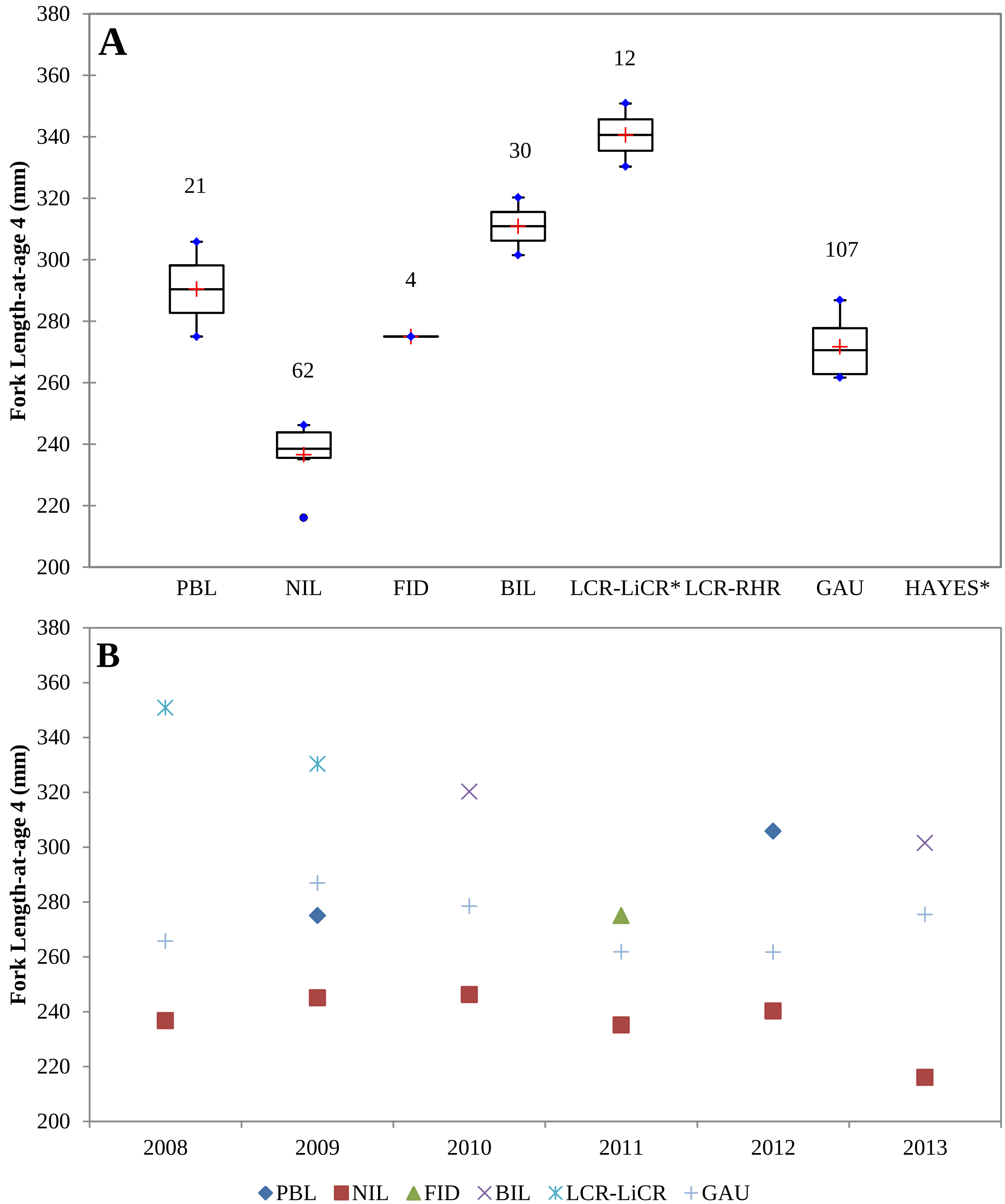
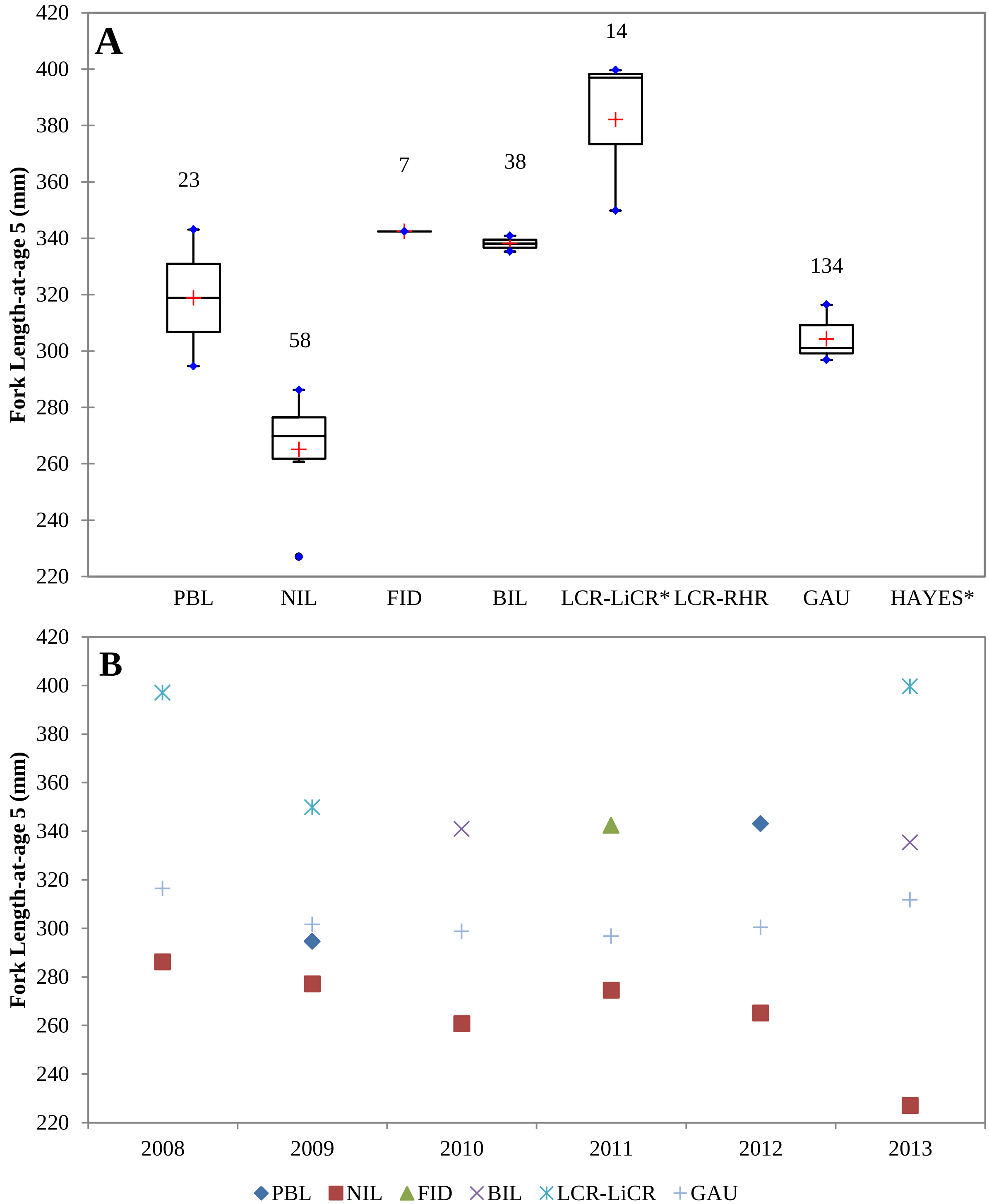


Figure 6-22. Annual mean length-at-age of Lake Whitefish captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Churchill River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



* Too few fish (i.e., 1 or 2 individuals) were captured at several locations in some years to include in the analysis.

Figure 6-23. Annual mean length-at-age 4 of Lake Whitefish captured in standard gang and small mesh index gill nets set in Lower Churchill 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.



* Too few fish (i.e., 1 or 2 individuals) were captured at several locations in some years to include in the analysis.

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

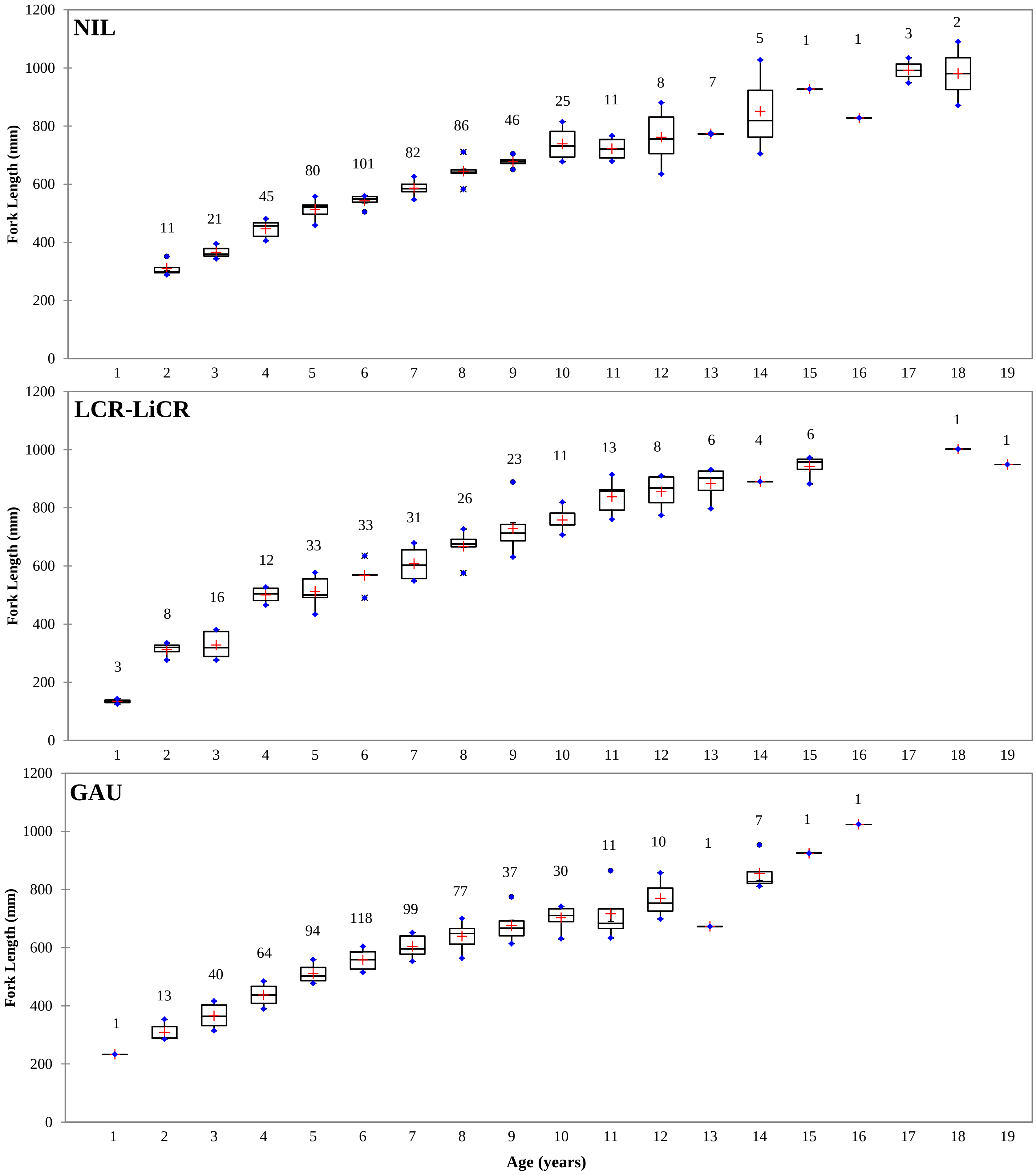
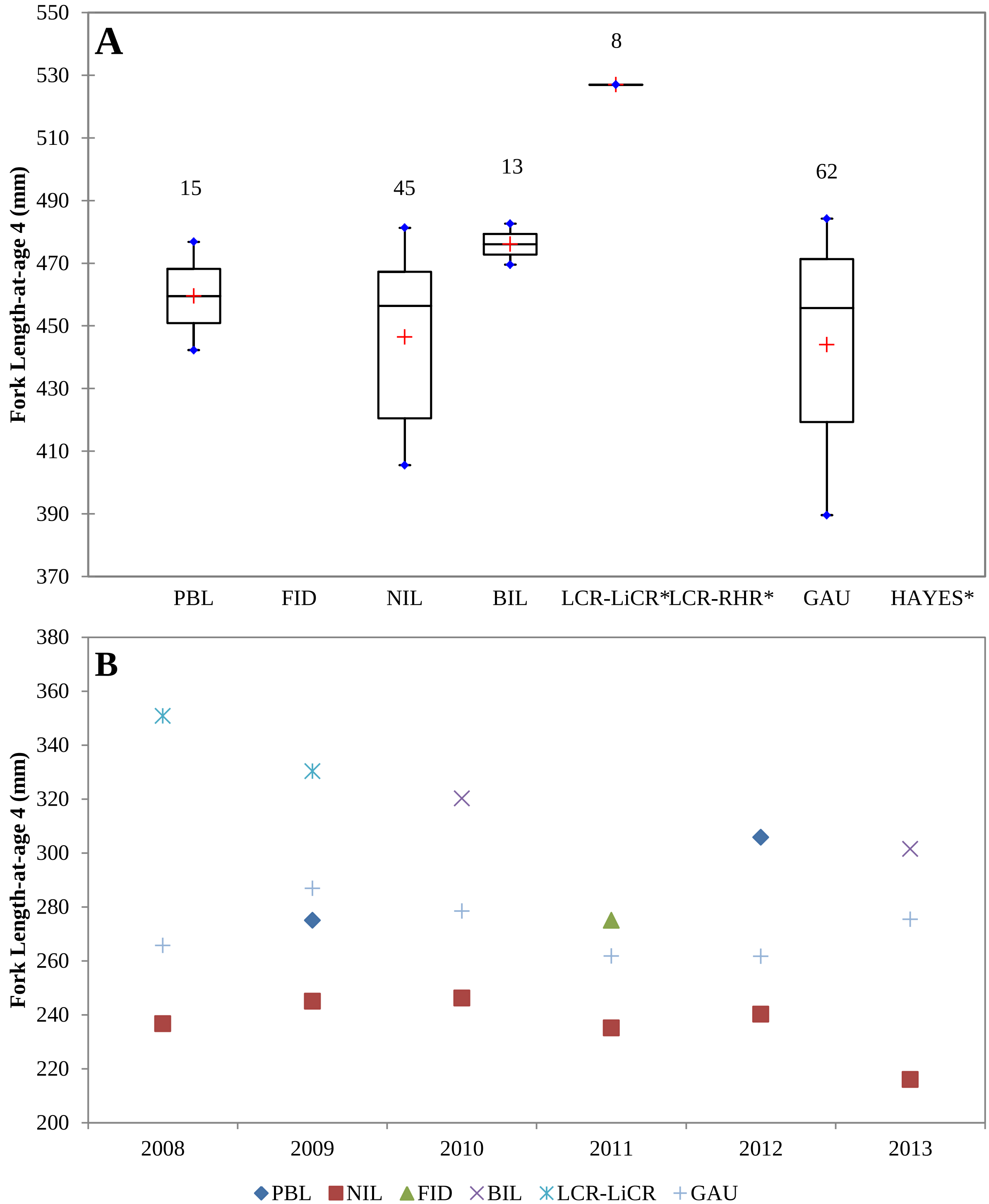


Figure 6-25. Annual mean length-at-age of Northern Pike captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Churchill River Region: 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



*Too few fish (i.e., 1 or 2 individuals) were captured at several locations in some years to include in the analysis.

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

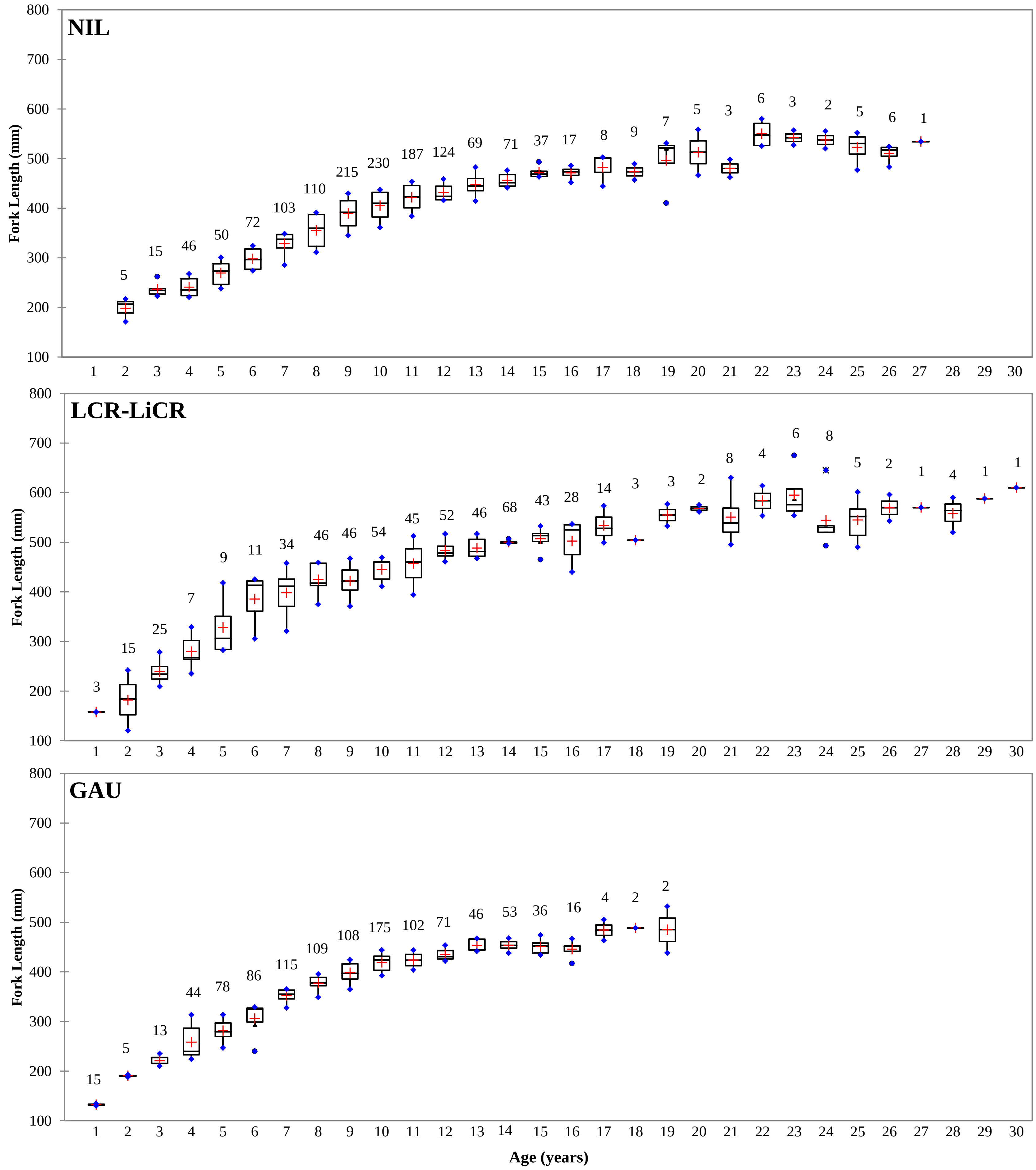
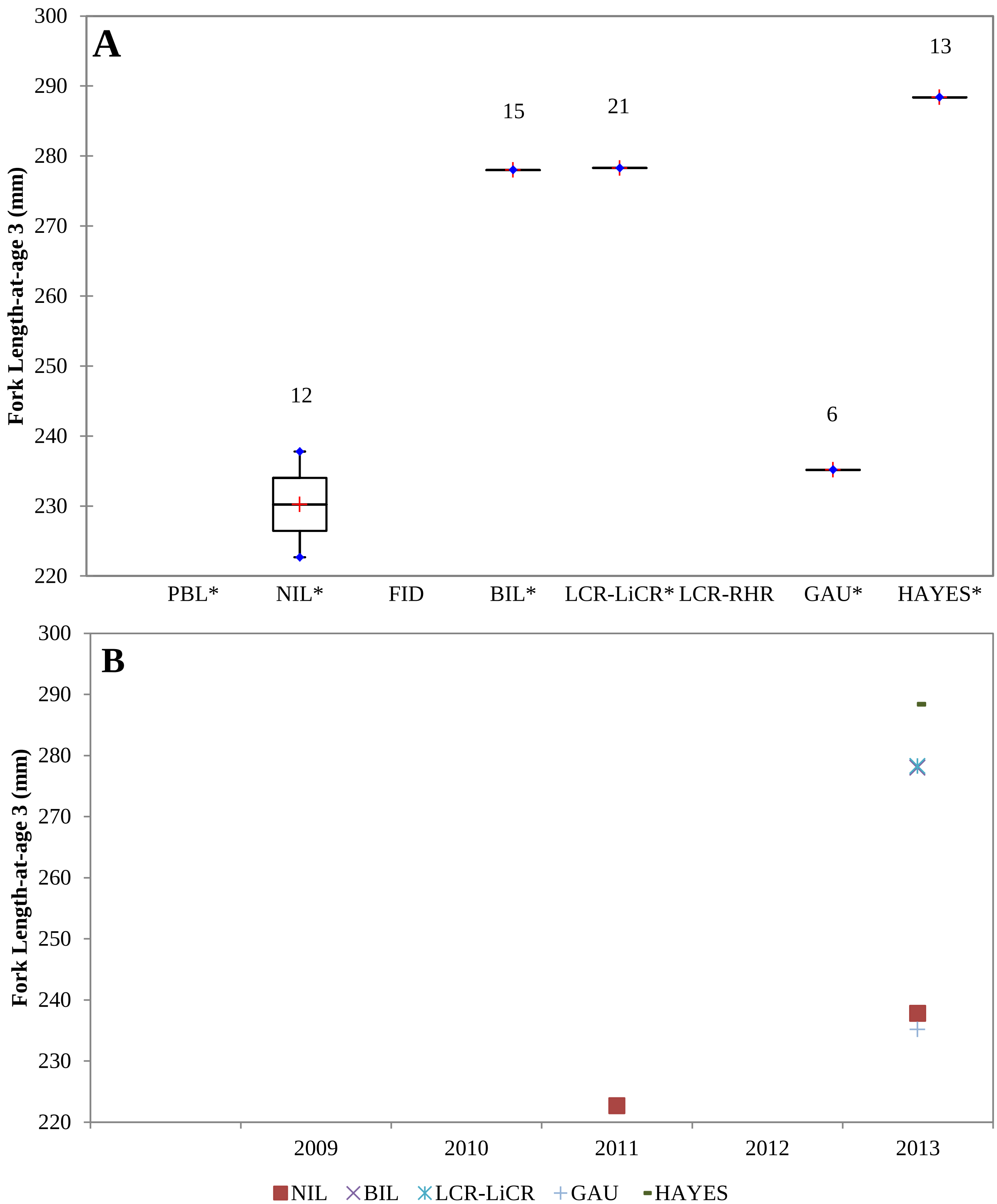


Figure 6-27. Annual mean length-at-age of Walleye captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Churchill River Region: 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



*Too few fish (i.e., 1 or 2 individuals) were captured at several locations in some years to include in the analysis

Figure 6-28. Annual mean length-at-age 3 of Walleye captured in standard gang and small mesh index gill nets set in Lower Churchill 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.

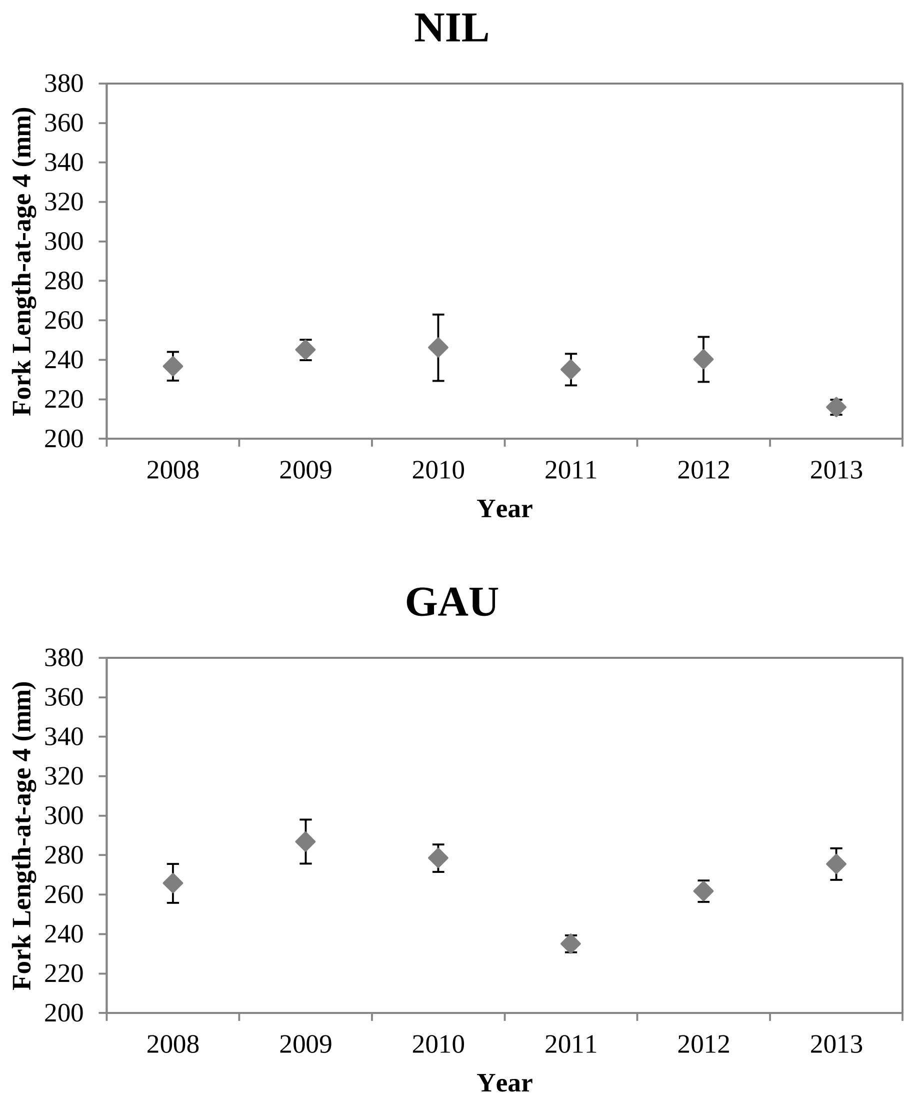


Figure 6-29. Fork length-at-age 4 (mean ± SE) of Lake Whitefish captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote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

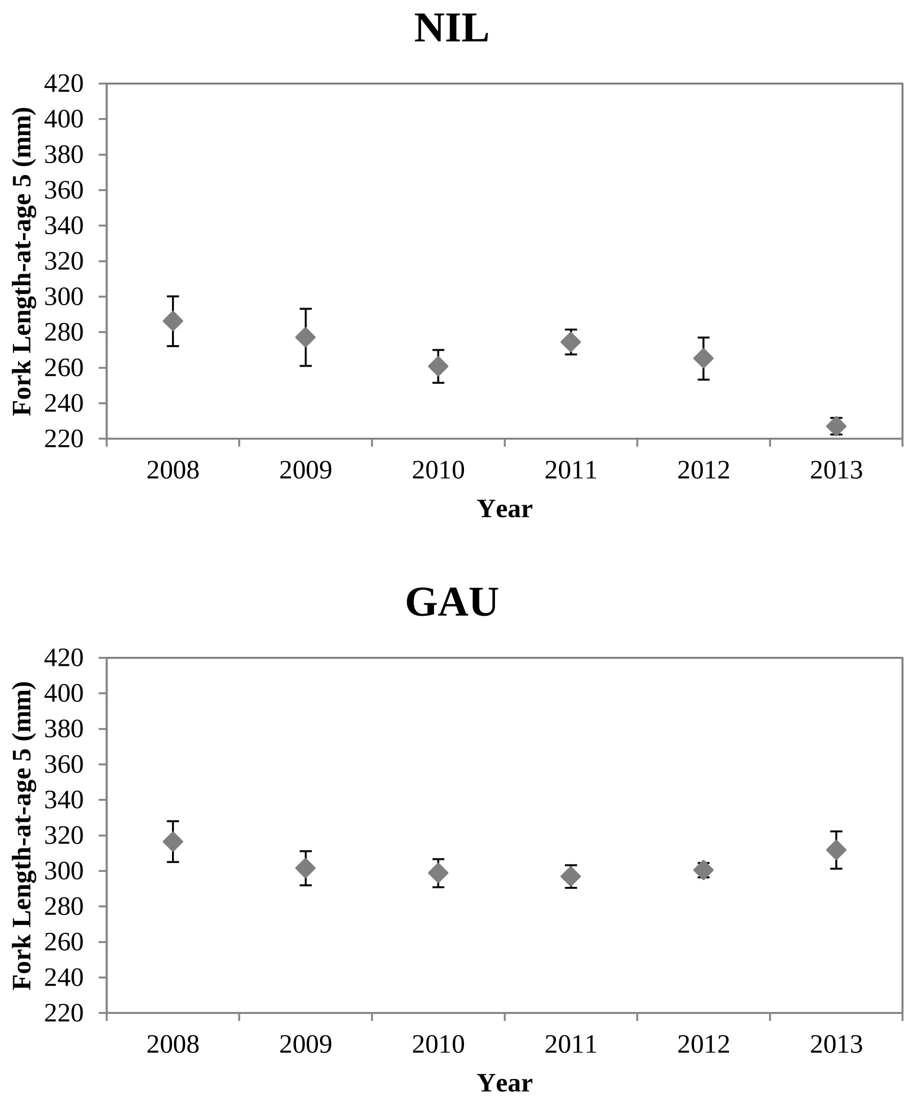


Figure 6-30. Fork length-at-age 5 (mean ± SE) of Lake Whitefish captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote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

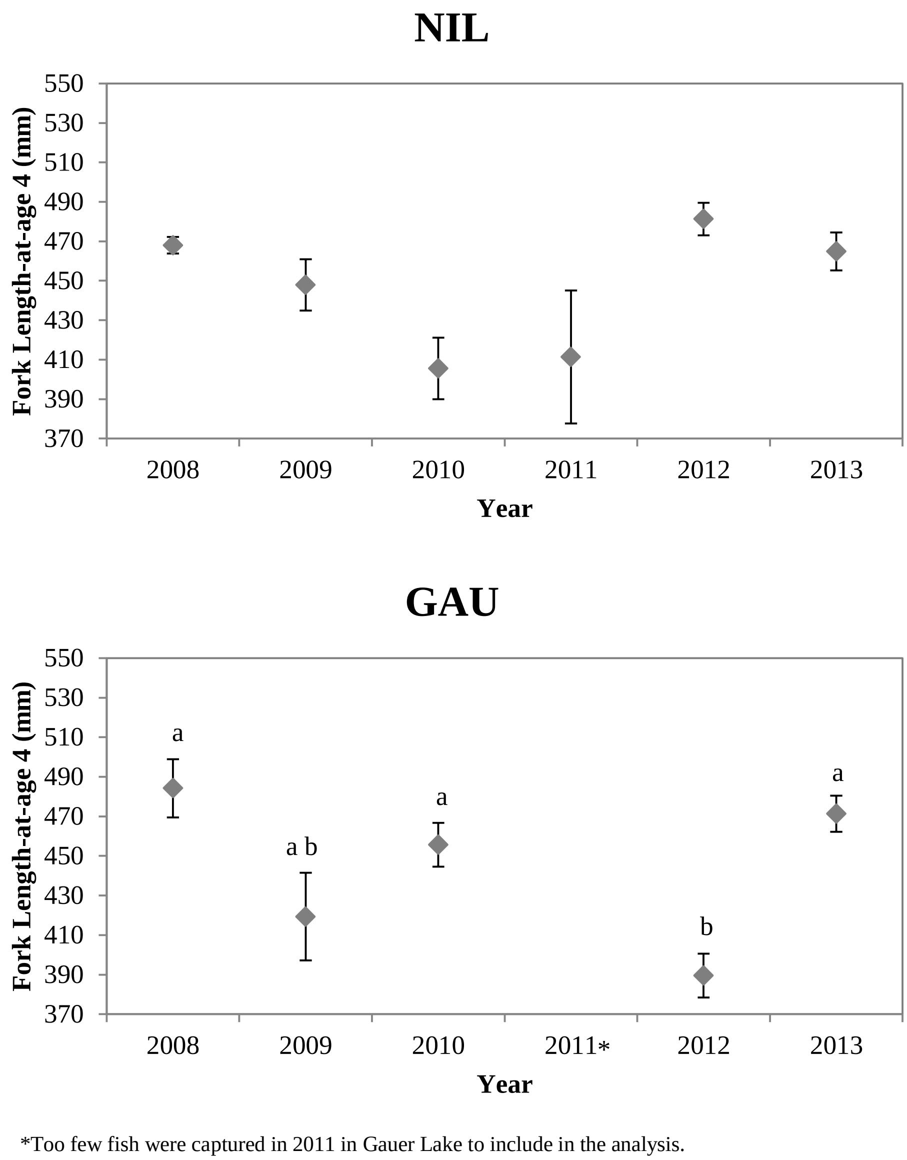


Figure 6-31. Fork length-at-age 4 (mean ± SE) of Northern Pike captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote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

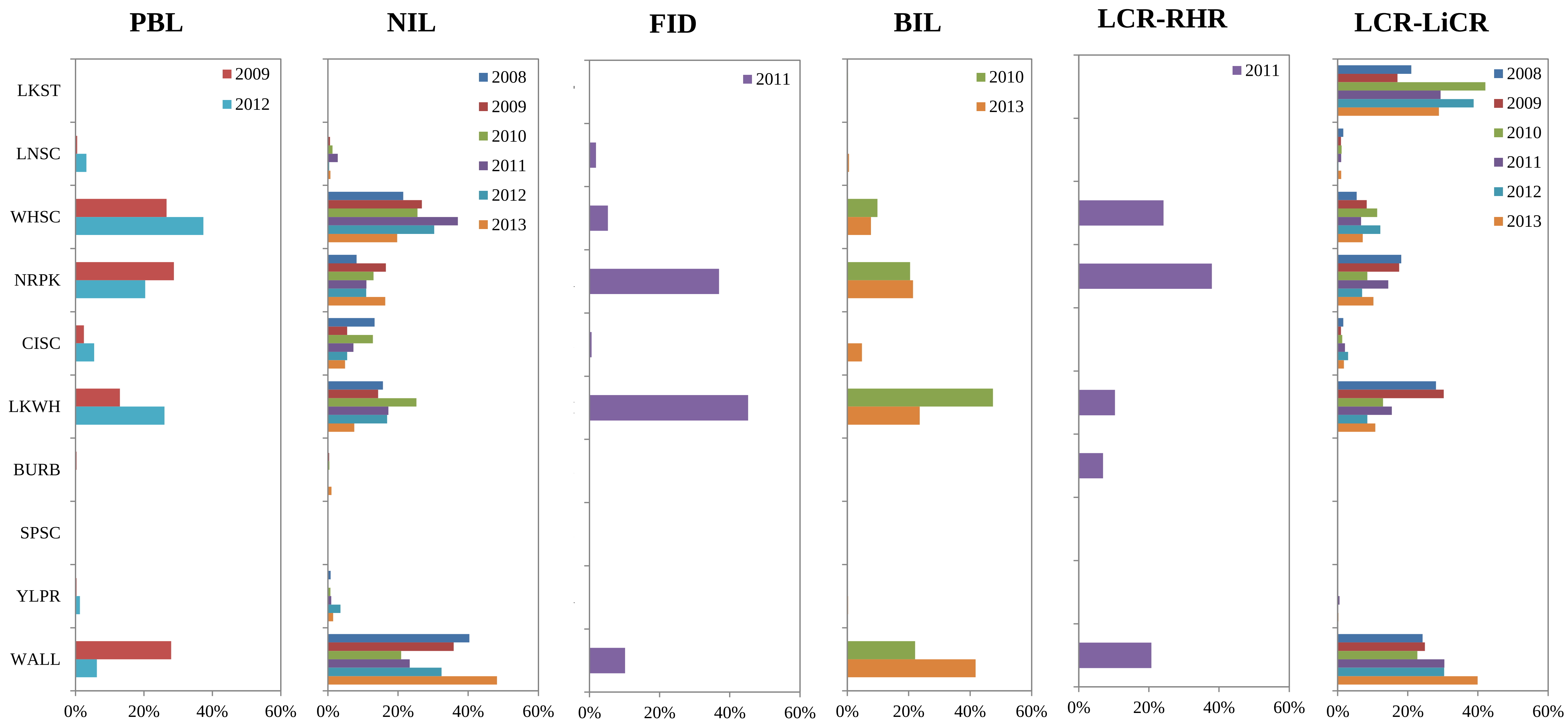
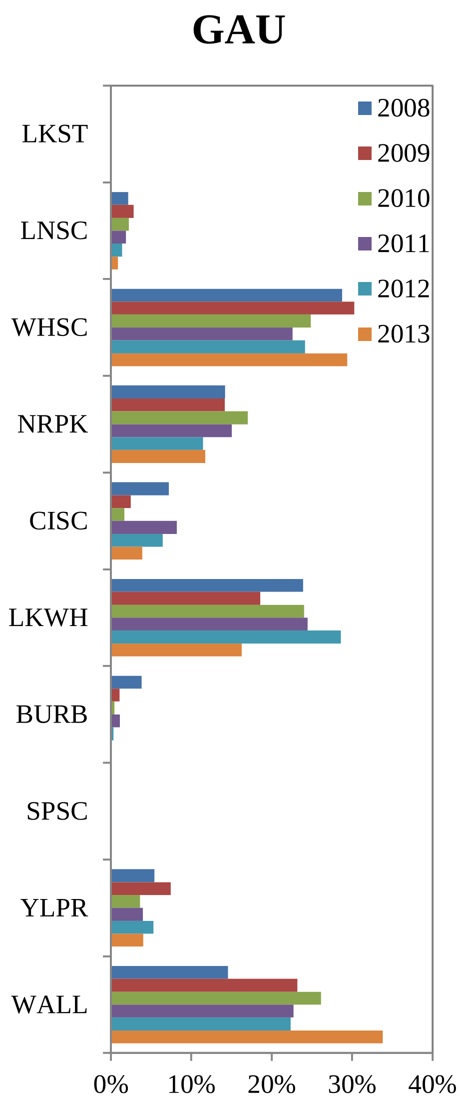


Figure 6-32. Relative abundance of fish species captured in standard gang index gill nets in Lower Churchill River Region waterbodies, 2008-2013.



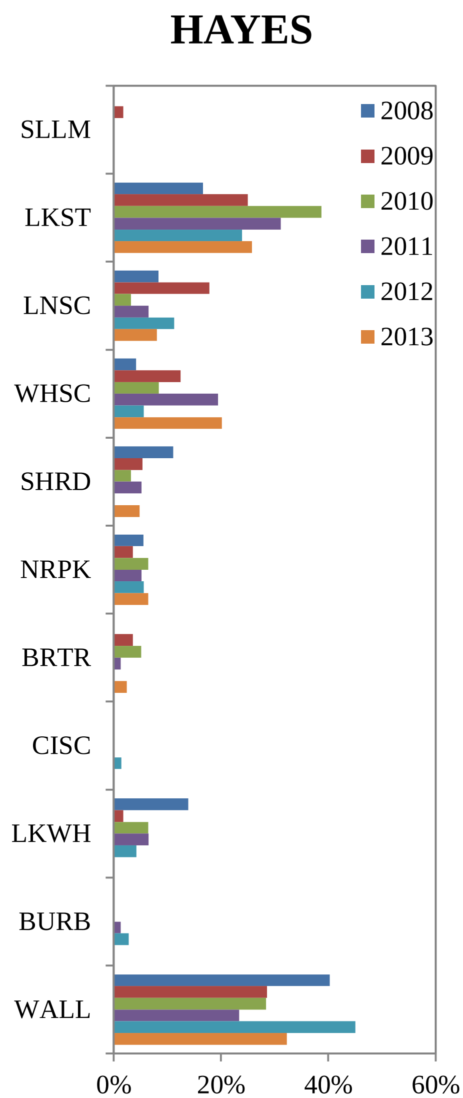


Figure 6-32. continued.

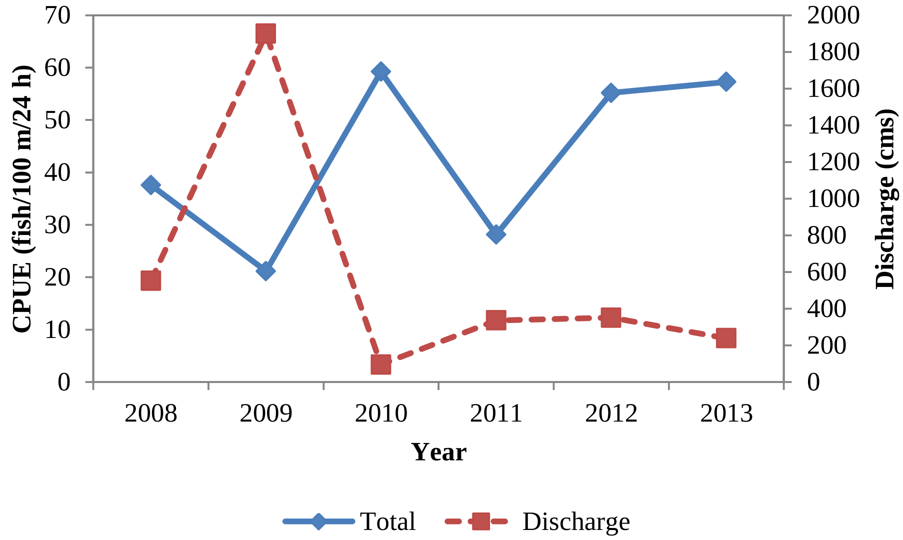


Figure 6-33. Abundance of total catch in gillnet catches in the Lower Churchill River at the Little Churchill River as measured by CPUE in relation to the average simulated water discharge at the same location during the gillnetting period: 2008-2013.

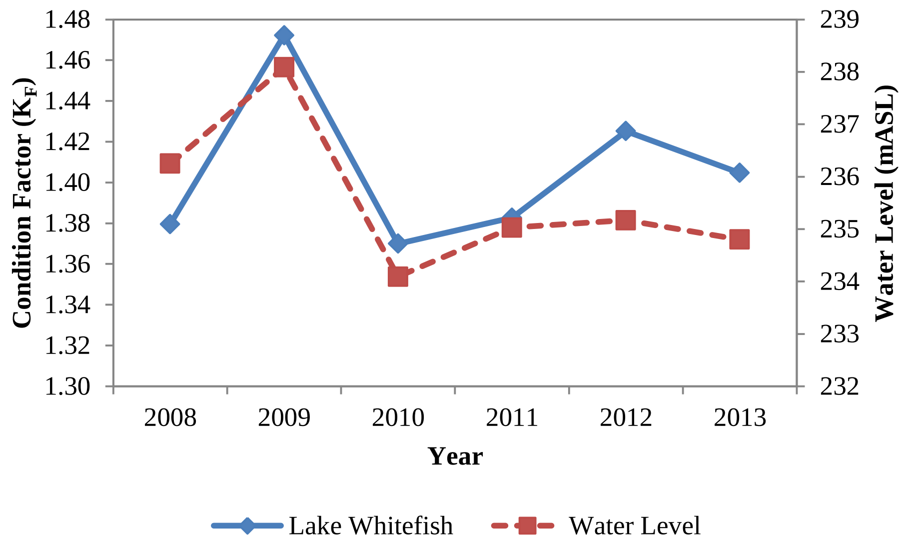


Figure 6-34. Lake Whitefish condition factor in Northern Indian Lake in relation to the water level during the open water period: 2008-2013.

7.0 FISH MERCURY

7.1 INTRODUCTION

The following provides an overview of the results of fish mercury monitoring conducted in the LCRR under CAMP in the first six years of the program. Fish mercury sampling was conducted on a three-year rotation (2010 and 2013) in Northern Indian Lake, the lower Churchill River at the Little Churchill River (hereafter referred to as "lower Churchill River"), and the off-system Gauer Lake. While formally part of the LNRR under CAMP, results for the off-system Hayes River were also considered in the interpretation of fish mercury data for the LCRR.

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 Lower Churchill River

A total of 478 fish were analyzed for mercury from Northern Indian Lake and the lower Churchill River between 2010 and 2013 (Table 7-1). Sample sizes for Lake Whitefish, Northern Pike, Walleye, and Yellow Perch were close or equal to the target sample size. Exceptions included pike and whitefish from Northern Indian Lake in 2013, for which only 20 and 17 of the targeted 36 fish were obtained, respectively (Table 7-1). Mercury samples from 39 Lake Surgeon collected from the lower Churchill River were also analyzed (Table 7-1).

The mean length-standardized mercury concentrations were below the 0.5 parts per million (ppm) Health Canada standard for commercial marketing of fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011) for most target species sampled from Northern Indian Lake and the lower Churchill River (Table 7-1).

Exceptions included pike and Walleye sampled from Northern Indian Lake in 2010; the length-standardized mean concentration was 0.53 ppm for both species (Table 7-1). For both years combined, 55% of individual pike from Northern Indian Lake and 21% from the lower Churchill River exceeded the 0.5 ppm Health Canada standard (Figures 7-1 and 7-2). For Walleye, 31-35% of the individuals from the two on-system waterbodies exceeded the standard for both years combined.

All of the whitefish from both on-system waterbodies (Figures 7-1 and 7-2) and perch (Figure 7-3) from Northern Indian Lake (perch were not captured in the lower Churchill River) had mercury concentrations substantially lower than 0.5 ppm, with maxima of 0.34 ppm and 0.10 ppm, for whitefish and perch, respectively.

Mean length-standardized mercury concentrations measured in incidental sturgeon mortalities from the lower Churchill River were 0.11 in 2010 and 2013 (Table 7-1). Two of the 38 sturgeon from the lower Churchill River had mercury concentrations in excess of 0.5 ppm mercury (Figure 7-4).

7.2.2 Off-system Waterbodies: Gauer Lake and the Hayes River

A total of 353 fish were analyzed for mercury from Gauer Lake and the Hayes River between 2010 and 2013 (Table 7-1). Sample sizes for Lake Whitefish, Northern Pike, and Walleye from Gauer Lake were almost always reached, whereas the number of Yellow Perch analyzed was consistently below the target sample size of 25 for the species. Conversely, the number of fish sampled for all species fell well below the target sample sizes from the Hayes River; only target sample sizes for Walleye were obtained (Table 7-1). Mercury samples from three incidental mortalities of Lake Surgeon collected from the Hayes River were also analyzed (Table 7-1).

Mean length-standardized mercury concentrations were 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) for all species sampled from Gauer Lake and the Hayes River (Table 7-1). Only Walleye captured from the Hayes River in 2010 had a length-standardized mean concentration that approached the 0.5 ppm standard (0.46 ppm; Table 7-1). The higher mean concentration in 2010 may be due in part to the preponderance of larger and older individuals analysed that year (Table 7-2).

Based on mercury concentrations in individual fish, 44% of the Walleye and 10% of the pike from the Hayes River exceeded the 0.5 ppm Health Canada standard for all sampling years combined (Figures 7-1 and 7-2). Only five fish sampled from Gauer Lake during the monitoring period exceeded 0.5 ppm standard. These included four Northern Pike (6%) and one Walleye (1%; Figures 7-1 and 7-2).

None of the whitefish sampled from either the Hayes River or Gauer Lake or perch from Gauer Lake (perch were not captured in the Hayes River) exceeded 0.5 ppm Health Canada standard (Figures 7-1 to 7-2). Similarly, none of the three sturgeon sampled from the Hayes River contained mercury above the 0.5 ppm Health Canada standard (Figure 7-4).

7.2.3 Temporal Comparisons

Statistically significant differences in mercury concentrations between the two sampling years were observed at a minimum of one waterbody for each of the four target species (Figure 7-5). Length-standardized mercury concentrations were lower for pike, Walleye, and perch in 2013 than 2010 in Northern Indian Lake; differences were not significant for whitefish but mean concentrations were lower in 2013 for this species as well. Concentrations of mercury in Walleye were also significantly lower in 2013 at both off-system sites and concentrations were also lower in perch collected in 2013 from Gauer Lake (no perch were captured in the Hayes River). Only whitefish showed significant inter-annual differences for the lower Churchill River at the Little Churchill River, but in this case concentrations were higher in 2013 than 2011.

There was no difference in length-standardized mean mercury concentrations for Lake Sturgeon between years (Table 7-1; Figure 7-6).

7.3 SUMMARY

Mean length-standardized 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) in on-system and off-system waterbodies. Exceptions included pike and Walleye sampled from Northern Indian Lake in 2010, when mean concentrations (0.53 ppm) marginally exceeded the standard. Based on concentrations in individual fish, some of the pike and Walleye from every waterbody exceeded the standard, reaching percentages of up to 44% of the Walleye and 55% of the pike. Significant inter-annual differences were observed for some waterbodies and for most target species. In most instances, means for 2013 were lower compared to 2010.

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

Waterbody	Year	Species	n	Mercury Concentration (ppm)			
				Arithmetic Mean	SE	Standard Mean	95% CL
Northern Indian Lake	2010	Pike	36	0.592	0.050	0.530	0.483 - 0.582
		Walleye	36	0.520	0.042	0.526	0.469 - 0.590
		Whitefish	32	0.126	0.013	0.112	0.100 - 0.125
		Perch	19	0.075	0.004	-	-
	2013	Pike	20	0.463	0.039	0.408	0.350 - 0.475
		Walleye	36	0.418	0.031	0.379	0.339 - 0.425
		Whitefish	17	0.085	0.013	0.073	0.058 - 0.093
		Perch	21	0.039	0.004	-	-
Lower Churchill River	2010	Pike	36	0.472	0.041	0.330	0.292 - 0.371
		Walleye	36	0.481	0.056	0.304	0.227- 0.333
		Whitefish	36	0.117	0.011	0.073	0.062 - 0.085
		Sturgeon	32	0.156	0.023	0.113	0.100 - 0.128
	2013	Pike	37	0.317	0.033	0.269	0.242 - 0.299
		Walleye	40	0.438	0.057	0.362	0.324 - 0.405
		Whitefish	37	0.110	0.009	0.100	0.087 - 0.114
		Sturgeon	7	0.111	0.010	0.107	0.091 - 0.125
Gauer Lake	2010	Pike	36	0.238	0.022	0.202	0.182 - 0.224
		Walleye	33	0.249	0.017	0.246	0.222 - 0.272
		Whitefish	36	0.041	0.003	0.036	0.032 - 0.040
	2011	Perch	15	0.018	0.002	-	-
	2013	Pike	36	0.271	0.026	0.195	0.171 - 0.223
		Walleye	36	0.182	0.016	0.180	0.162 - 0.201
		Whitefish	36	0.033	0.003	0.034	0.030 - 0.037
		Perch	15	0.009	0.001	-	-
Hayes River	2010	Pike	10	0.259	0.029	0.202	0.179 - 0.228
		Walleye	36	0.722	0.060	0.463	0.403 - 0.532
		Whitefish	9	0.063	0.006	0.070	0.064 - 0.077
		Sturgeon	1	0.194	-	-	-
	2011	Pike	3	0.295	0.014	NS	0.234 - 0.356
		Whitefish	5	0.066	0.003	NS	0.058 - 0.074
		Sturgeon	1	0.213	-	-	-
	2013	Pike	8	0.390	0.080	0.171	0.098 - 0.298
		Walleye	38	0.364	0.050	0.290	0.248 - 0.339
		Sturgeon	1	0.176	-	-	-

NS = Not significant.

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

Waterbody	Year	Species	n	Length (mm)	Weight (g)	K_F	Age (years)
Northern Indian Lake	2010	Pike	36	571.9 ± 24.5	1490.6 ± 228.3	0.64 ±	7.0 ± 0.5
		Walleye	36	379.8 ± 13.7	667.9 ± 74.8	1.06 ±	11.2 ± 0.8
		Whitefish	32	352.6 ± 14.8	672.1 ± 72.6	1.32 ±	8.9 ± 0.8
		Perch	19	101.8 ± 1.8	14.3 ± 0.7	1.33 ±	2.1 ± 0.1
	2013	Pike	20[1]	580.5 ± 31.1	1519.0 ± 282.4	0.64 ±	7.0 ± 0.5
		Walleye	36	407.9 ± 12.9	810.8 ± 70.4	1.07 ±	10.1 ± 0.5
		Whitefish	17	352.9 ± 19.3	722.2 ± 106.6	1.40 ±	8.8 ± 1.1
		Perch	21[2]	89.1 ± 2.9	9.0 ± 0.9	1.19 ±	1-2
Lower Churchill River	2010	Pike	36[3]	668.2 ± 27.3	2324.2 ± 277.4	0.74 ±	8.7 ± 0.5
		Walleye	36	442.2 ± 17.8	1194.7 ± 121.2	1.18 ±	13.1 ± 1.1
		Whitefish	36[4]	399.7 ± 9.8	975.3 ± 69.4	1.44 ±	8.7 ± 0.6
		Sturgeon	32[5]	797.6 ± 44.5	2179.8 ± 171.1	0.68 ±	12.1± 0.7
	2013	Pike	37[6]	579.7 ± 32.9	1904.4 ± 279.9	0.70 ±	6.4 ± 0.6
		Walleye	40	396.1 ± 23.4	1016.8 ± 137.4	1.12 ±	9.9 ± 1.3
		Whitefish	37[7]	358.3 ± 18.9	864.1 ± 81.5	1.45 ±	6.1 ± 0.5
		Sturgeon	7[8]	717.0 ± 45.9	2831.4 ± 570.3	0.69 ±	12.3 ± 2.1
Gauer Lake	2010	Pike	36	572.8 ± 20.9	1492.8 ± 234.5	0.68 ±	6.2 ± 0.4
		Walleye	33[9]	390.2 ± 10.2	682.9 ± 49.4	1.08 ±	10.4 ± 0.6
		Whitefish	36[10]	372.7 ± 11.8	824.9 ± 79.6	1.41 ±	10.1 ± 1.1
	2011	Perch	15	78.3 ± 1.8	6.8 ± 0.5	1.39 ±	-
	2013	Pike	36	588.4 ± 22.6	1578.8 ± 176.1	0.68 ±	6.2 ± 0.4
		Walleye	36	381.8 ± 16.4	781.7 ± 86.8	1.15 ±	8.9 ± 0.7
		Whitefish	36[11]	333.1 ± 12.7	658.9 ± 78.7	1.50 ±	7.2 ± 0.8
		Perch	15[12]	75.1 ± 1.4	4.9 ± 0.3	1.15 ±	1
Hayes River	2010	Pike	10	619.8 ± 43.6	1916.0 ± 320.4	0.71 ±	6.5 ± 0.7
		Walleye	36	470.7 ± 16.6	1350.3 ± 140.5	1.15 ±	12.9 ± 0.9
		Whitefish	9[13]	318.1 ± 21.4	517.3 ± 72.8	1.45 ±	5.8 ± 0.4
		Sturgeon	1	664	1998	0.68	13
	2011	Pike	3	728.0 ± 66.4	2903.3 ± 656.7	0.73 ±	9.3 ± 1.5
		Whitefish	5	289.8 ± 22.3	334.6 ± 62.0	1.28 ±	6.4 ± 0.6
		Sturgeon	1	771	2900	0.63	16
	2013	Pike	8	707.1 ± 42.2	2967.5 ± 556.8	0.78 ±	9.4 ± 0.6
		Walleye	38	407.4 ± 21.6	920.0 ± 122.2	1.04 ±	8.7 ± 1.0
		Sturgeon	1	720	2160	0.58	-

[1] n=19 for age; [2] n=13 for age; [3] n=33 for weight and K_F; [4] n=35 for age; [5] n=23 for weight and K_F, n=21 for age
[6] measurements from frozen fish, n=36 for age; [7] n=36 for age; [8] n=6 for age; [9] n=32 for age; [10] n=33 for age; [11] n=34 for age; [12] n=6 for age;
[13] n=8 for age.

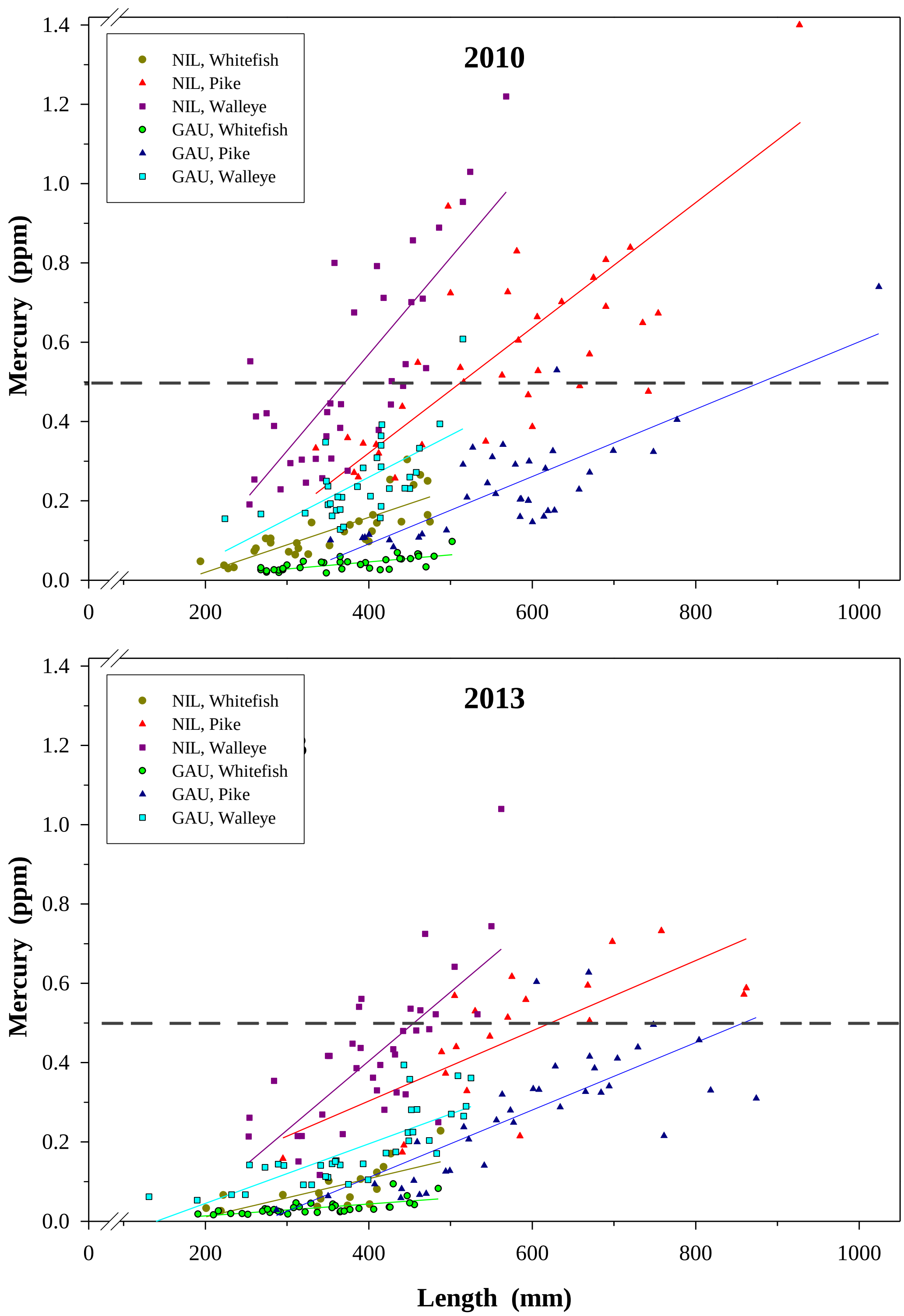


Figure 7-1. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from Northern Indian and Gauer lakes in 2010 and 2013. Significant linear regression lines are shown. Dashed lines represent the 0.5 ppm Health Canada standard for retail fish.

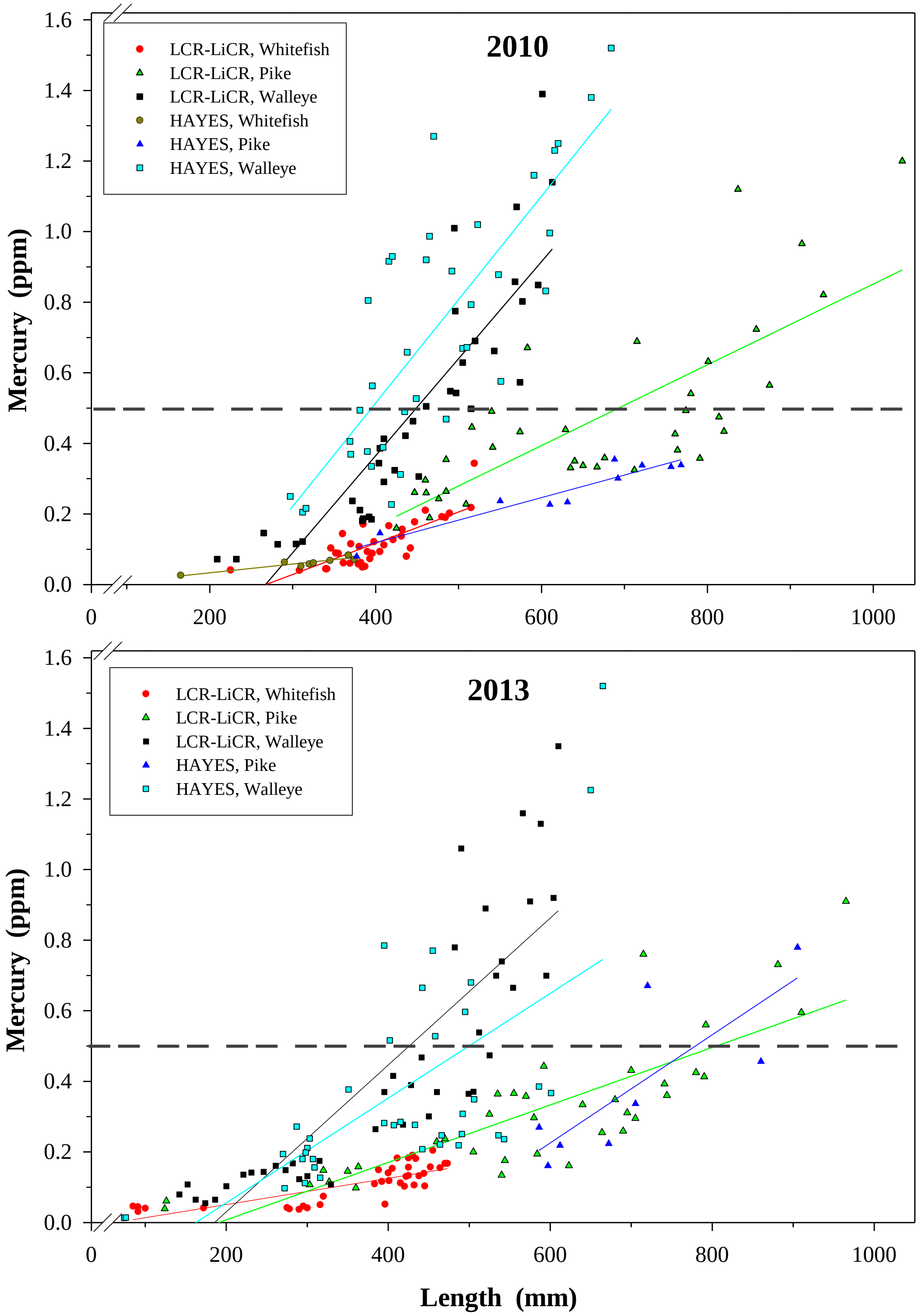


Figure 7-2. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from the lower Churchill River and the Hayes River in 2010 and 2013. Significant linear regression lines are shown. Dashed lines represent the 0.5 ppm Health Canada standard for retail fish.

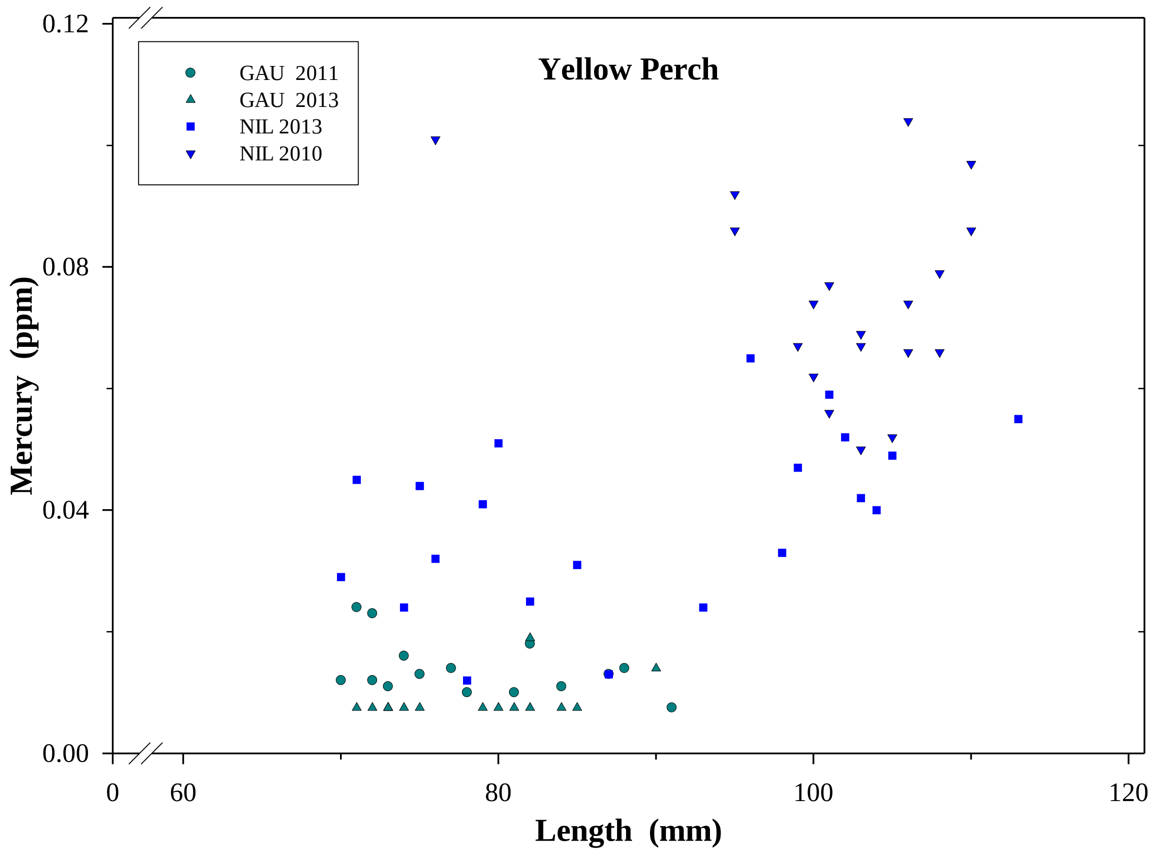


Figure 7-3. Relationship between mercury concentration and fork length for Yellow Perch from Northern Indian Lake and Gauer Lake from 2010-2013.

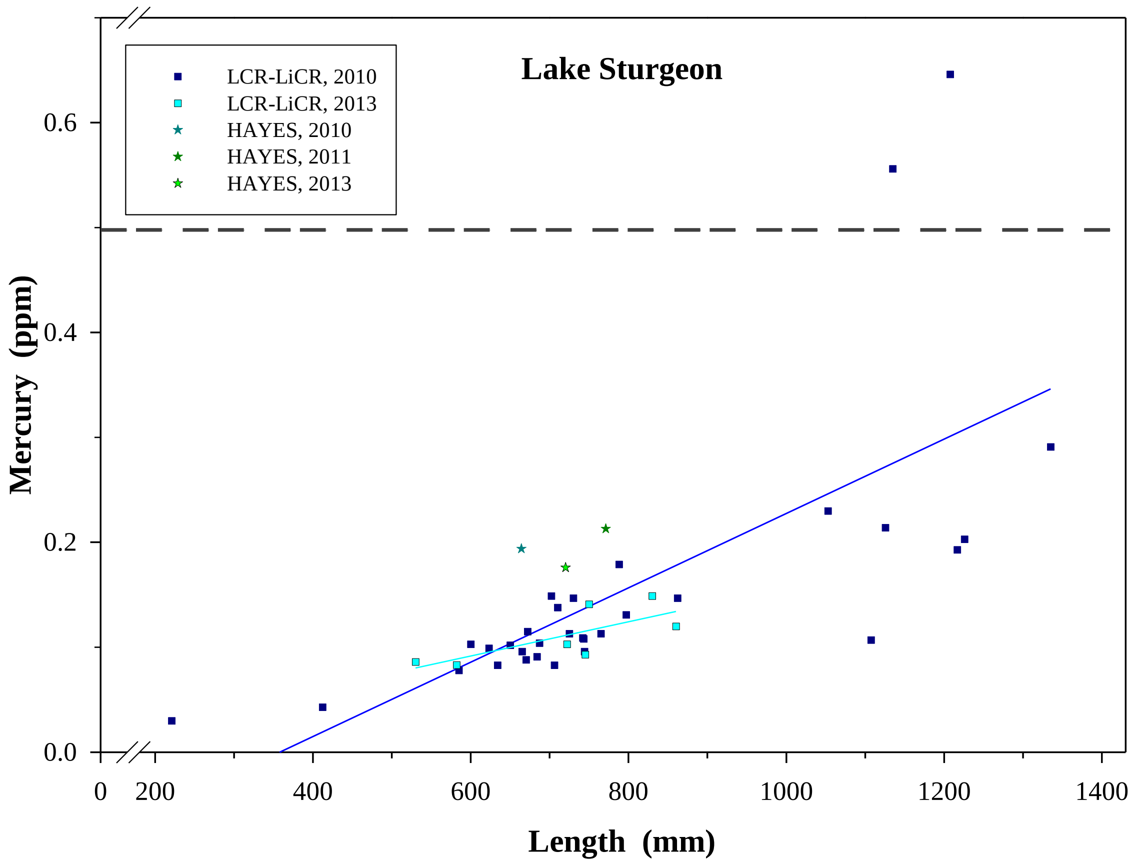
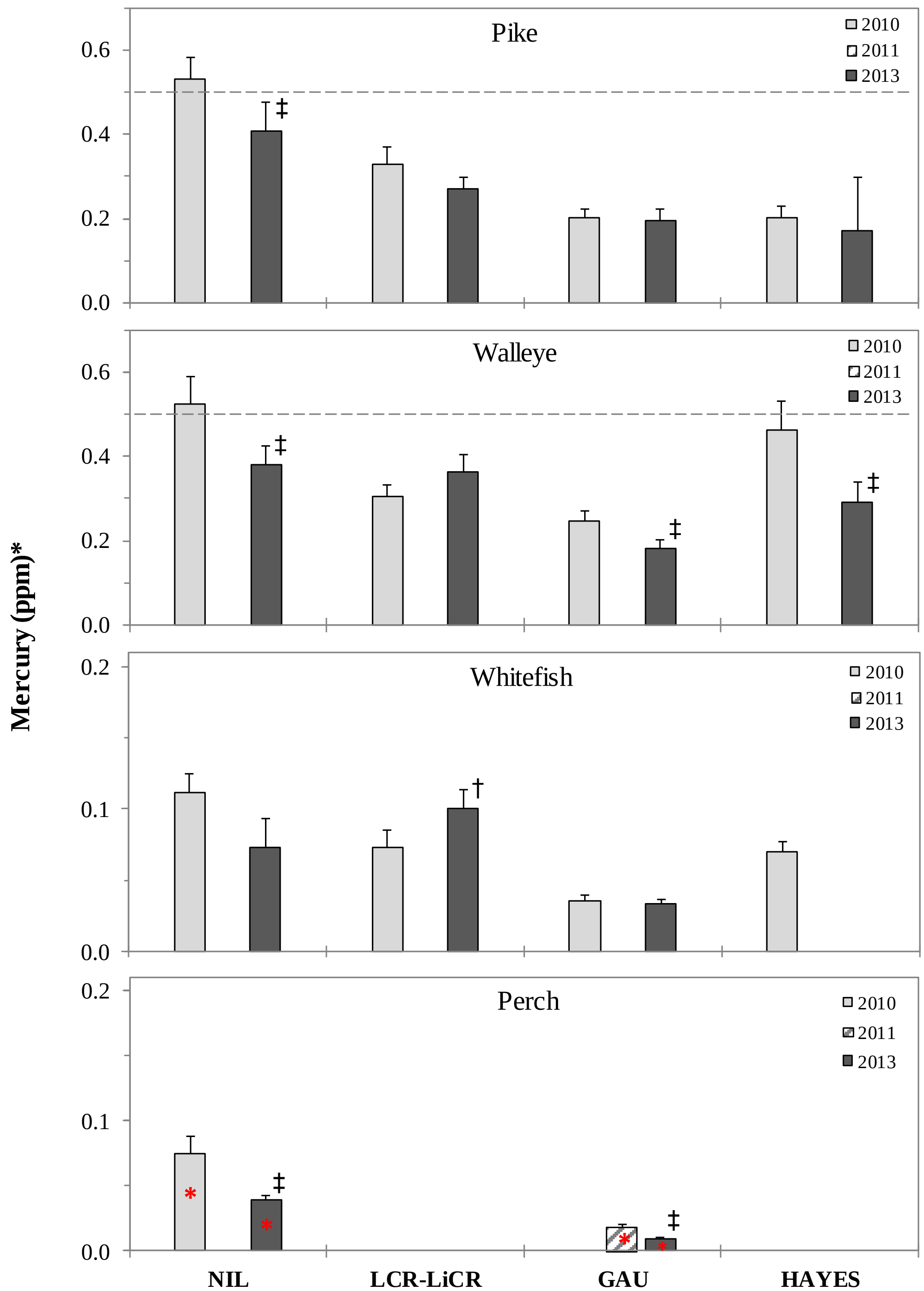


Figure 7-4. Relationship between mercury concentration and fork length for Lake Sturgeon from the lower Churchill River and the Hayes River from 2010-2013. Significant linear regression lines are shown; the dashed line represents the 0.5 ppm Health Canada standard for retail fish.



* Note differences in mercury scale among species.

Figure 7-5. Standard (pike, Walleye, and whitefish) or arithmetic (perch; asterisk) mean (upper 95% CL) mercury concentrations in Northern Pike, Walleye, Lake Whitefish, and Yellow Perch from the Lower Churchill 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.

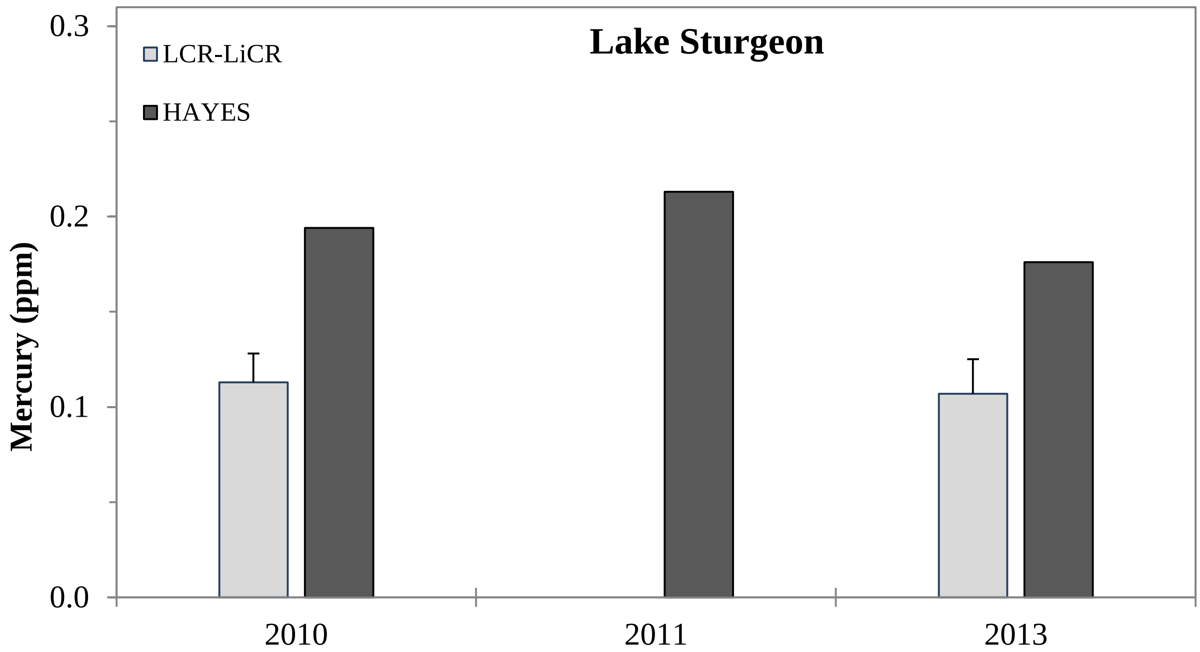


Figure 7-6. Standard mean (error bars indicate upper 95% CL) mercury concentrations of Lake Sturgeon from the Lower Churchill River Region for 2010-2013. Data for the Hayes River represent results from individual fish in each year (i.e., n=1).

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