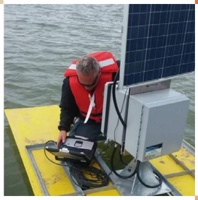
Coordinated Aquatic Monitoring Program



Six Year Summary Report

Technical Document 8: Upper Nelson River Region

2008-2013

Submitted to:
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- Sampling and laboratory methods
- Reporting approach and data analysis methods

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SIX YEAR SUMMARY REPORT (2008-2013)

Technical Document 8:

Upper Nelson River Region Results

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ABBREVIATIONS AND ACRONYMS

2M-IN	Two-Mile Channel Inlet
2M-OUT	Two-Mile Channel Outlet
ASL	Above sea level
BCMOE	British Columbia Ministry of Environment
BMI	Benthic macroinvertebrate(s)
CAMP	Coordinated Aquatic Monitoring Program
CCME	Canadian Council of Ministers of the Environment
CL	Confidence limit
CPUE	Catch-per-unit-effort
CROSS	Cross Lake
DL	Detection Limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EC	Environment Canada
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
EPT:C	Ratio of the combined abundances of Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) to the abundance of Chironomidae (non-biting midges)
FL	Fork length
GS	Generation station
ISQG	Interim sediment quality guideline
K_F	Condition Factor
KHLP	Keeyask Hydropower Limited Partnership
LEL	Lowest effect level
LSSEP	Lake Sturgeon Stewardship Enhancement Program
LPLAYG	Little Playgreen Lake
LWR	Lake Winnipeg Regulation
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
n_F	Number of fish
NR-WL	Nelson River near Warren Landing
n_Y	Number of years sampled
PAL	Protection of aquatic life
PEL	Probable effect level
PLAYG	Playgreen Lake
ppm	Parts per million
Q (OW)	Average discharge during the open water period
Q (GN)	Average discharge during the gillnetting program
RCEA	Regional cumulative effects assessment
SAC	Sediment alert concentration
SE	Standard error of the mean

SEL	Severe effect level
SET	Setting Lake
SIP	Sipiwesk Lake
SQG	Sediment quality guideline
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
UNR	Upper Nelson River upstream of the Kelsey GS
UNRR	Upper Nelson River Region
WL (OW)	Average water level during the open water period
WL (GN)	Average water level during the gillnetting program
WLKR	Walker Lake
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 Upper Nelson River Region (UNRR). As described in Technical Document 1, Section 2.7.1, the UNRR is composed of the Nelson River extending from the outlet of Lake Winnipeg, including Two-Mile Channel, to the Kelsey Generating Station (GS) near Split Lake. The region also includes two off-system lakes: Setting Lake located on the Grass River system; and Walker Lake. As noted in Section 2.0, Walker Lake water levels are periodically affected by a backwater effect from the Nelson River when water levels at Cross Lake exceed about 207.6 m.

Waterbodies and sites monitored in this region over this period included two off-system waterbodies and seven on-system waterbodies or river reaches as follows:

- upper Nelson River at Warren Landing (water quality only);
- Two-Mile Channel (water quality only);
- Playgreen Lake;
- Little Playgreen Lake;
- Cross Lake – west basin;
- Sipiwesk Lake;
- upper Nelson River upstream of the Kelsey GS;
- Walker Lake (off-system); and
- Setting Lake (off-system).

Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.4. 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 UNRR 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 UNRR over years 3 to 6 of CAMP, including the west basin of Cross Lake (surveyed in 2011) and Playgreen Lake (surveyed in 2012), are also provided below.

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 were 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 Upper Nelson River Region: 2008/2009-2013/2014.

Waterbody/Area	**Site Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years [1]**					
						2008/09	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**
Upper Nelson River near Warren Landing	NR-WL	**X**		**X** [2]						**X**	**X**
Two-Mile Channel (inlet and outlet)	2M-IN /2M-OUT	**X**		**X** [2]							**X**
Playgreen Lake	PLAYG	**X**			**X**		**X**			**X**	
Little Playgreen Lake	LPLAYG	**X**			**X**			**X**			**X**
Cross Lake - West Basin	CROSS	**X**		**X**		**X**	**X**	**X**	**X**	**X**	**X**
Sipiwesk Lake	SIP	**X**			**X**				**X**		
Upper Nelson River upstream of the Kelsey GS	UNR	**X**			**X**				**X**		
Walker Lake	WLKR		**X**		**X**			**X**			**X**
Setting Lake	SET		**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] Sites sampled for water quality only.

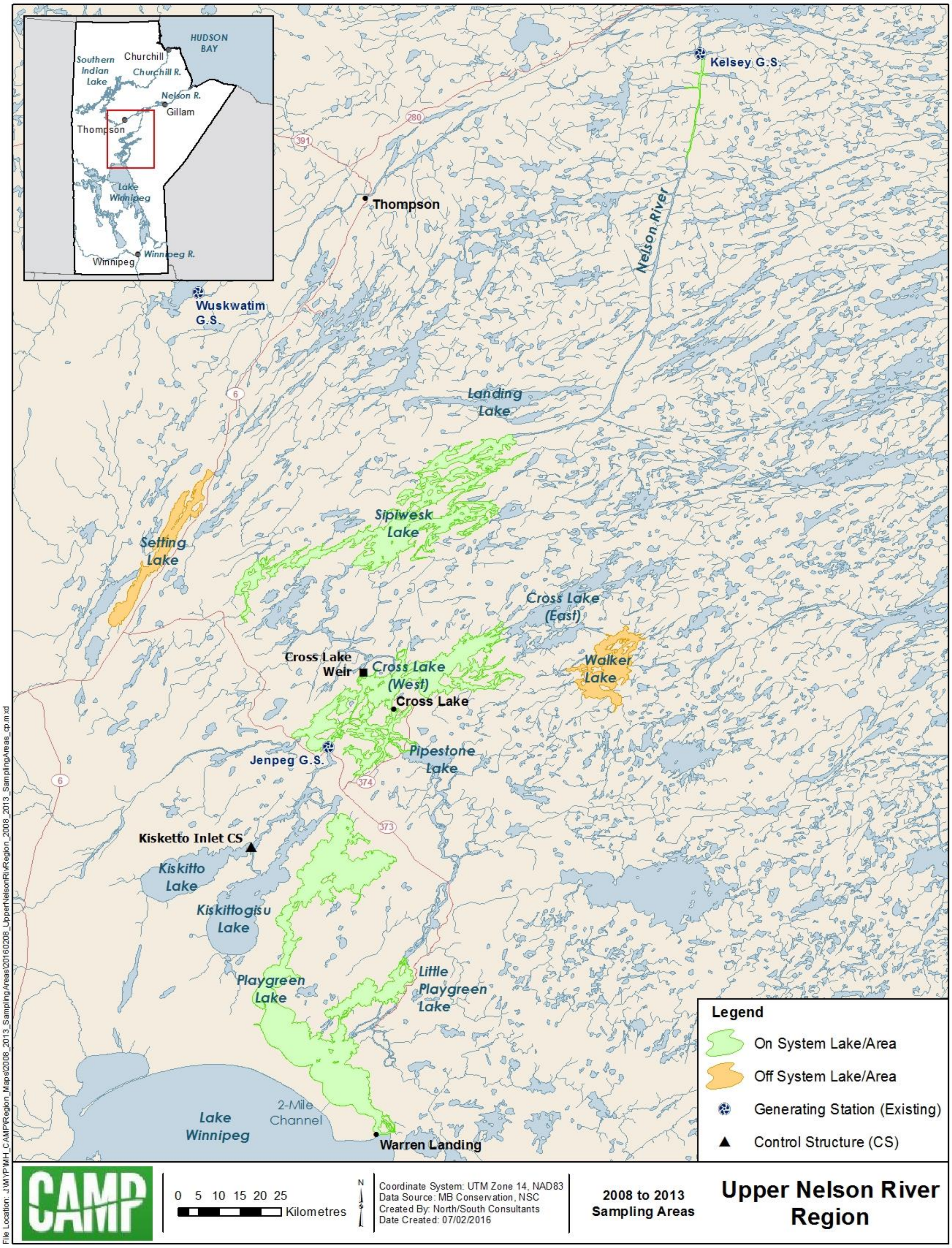


Figure 1-1. On-system and off-system waterbodies and river reaches sampled under CAMP in the Upper Nelson River Region: 2008/2009-2013/2014.

2.0 HYDROLOGY

The majority of Lake Winnipeg's discharge flows through the upper Nelson River's West Channel, which is regulated by operations at the Jenpeg GS for power production purposes and for flood and drought support on Lake Winnipeg. The East Channel is un-regulated and accounts for roughly 15 percent of the total flow. CAMP monitoring occurs on Playgreen Lake, which is the first lake downstream from Lake Winnipeg, and on Little Playgreen Lake, downstream from Playgreen Lake on the upper Nelson River's East Channel. Monitoring also occurs on Cross Lake, which is directly downstream from the Jenpeg GS, Sipiwesk Lake, downstream of Cross Lake, and the upper Nelson River upstream of the Kelsey GS, and at two off-system lakes - Walker Lake which flows to the west basin of Cross Lake and Setting Lake. Although considered off-system, Walker Lake water levels are periodically affected by levels at Cross Lake when water levels exceed about 207.6 m.

Flows for this region are monitored at the Jenpeg and Kelsey GSs. Upper Nelson River flows at the Kelsey GS between 2008 and 2013 were generally above average due to above average precipitation in the Lake Winnipeg drainage basin which led to high inflows and lake levels on Lake Winnipeg. As a result, discharge out of Lake Winnipeg was maximized for flood reduction purposes during portions of the open water season in 2008-2011 and 2013. Flows reached record highs in early-July 2009 and again from October to the end of the year in 2010. Flows then reached new record highs for most of 2011. The exceptions to the high flow trend included brief periods in spring of 2008 and 2010 when below average snowpack led to lower early summer flows. Flows in 2012 were closer to the long-term average, alternating above and below average for much of the year (Figure 2-1).

Playgreen Lake water levels were generally above average and near upper quartile for much of 2008-2013. Record highs were reached at the end of 2010 and for much of 2011. Below average levels occurred in early 2012 and spring 2013 (Figure 2-2). Little Playgreen Lake followed the same trend as Playgreen Lake with levels remaining above average except for a brief period in May 2013 (Figure 2-3). Record highs were not reached on Little Playgreen Lake because it has a longer period of record, indicating that Playgreen Lake would likely have reached higher levels historically than in recent years.

Cross Lake water levels were above average for almost all of 2008 to 2013, falling below average only briefly in the spring of 2010 and for most of 2012. Record highs were reached in late 2010 and for much of 2011 (Figure 2-4).

Sipiwesk Lake water levels were above average for almost all of 2008 to 2013, falling below average only briefly in the springs of 2008, 2010 and 2012. Record highs were reached in late 2010 and for much of 2011 (Figure 2-5).

For most part of the open-water seasons from 2008 to 2013, the Kelsey GS forebay was maintained below the maximum licence forebay elevation of 605 ft. Water levels were drawn down each year during late-November early-December to temporarily increase power production, with the forebay being re-filled in late-December when power demand is reduced. Similarly, water levels were also drawn down each year typically between January and March with the forebay being re-filled between April and June. Temporary drawdown also occurred during June 2010 and early July 2013 (Figure 2-6).

Walker Lake water levels were above average for most of 2008 to 2013 except for the spring of 2008 and 2013 and all of 2012, which remained near the lower quartile from May through December. Record highs were also reached from October to December 2010 and from mid-May to mid-September 2011. Walker Lake levels were close to average from January to March 2014 (Figure 2-7). High Walker Lake levels are influenced by a backwater effect from Cross Lake when Cross Lake levels exceed 207.6 m. Cross Lake levels exceeded 207.6 m for much of the period from 2008-2013. Cross Lake was below 207.6 m from mid-April to mid-June in 2008, mid-March to mid-June in 2010, mid-February through June and September through October 2012, and parts of April, May, and June 2013.

As part of the CAMP program, a water level gauge was established on the off-system Setting Lake in late 2008. Based on the limited data available it appears that 2010 and 2013 were lower water level years during the summer season with water levels increasing in the late fall due to precipitation events. Water levels in 2009, 2011 and 2012 all peaked at nearly the same level but at different times during the season (Figure 2-8).

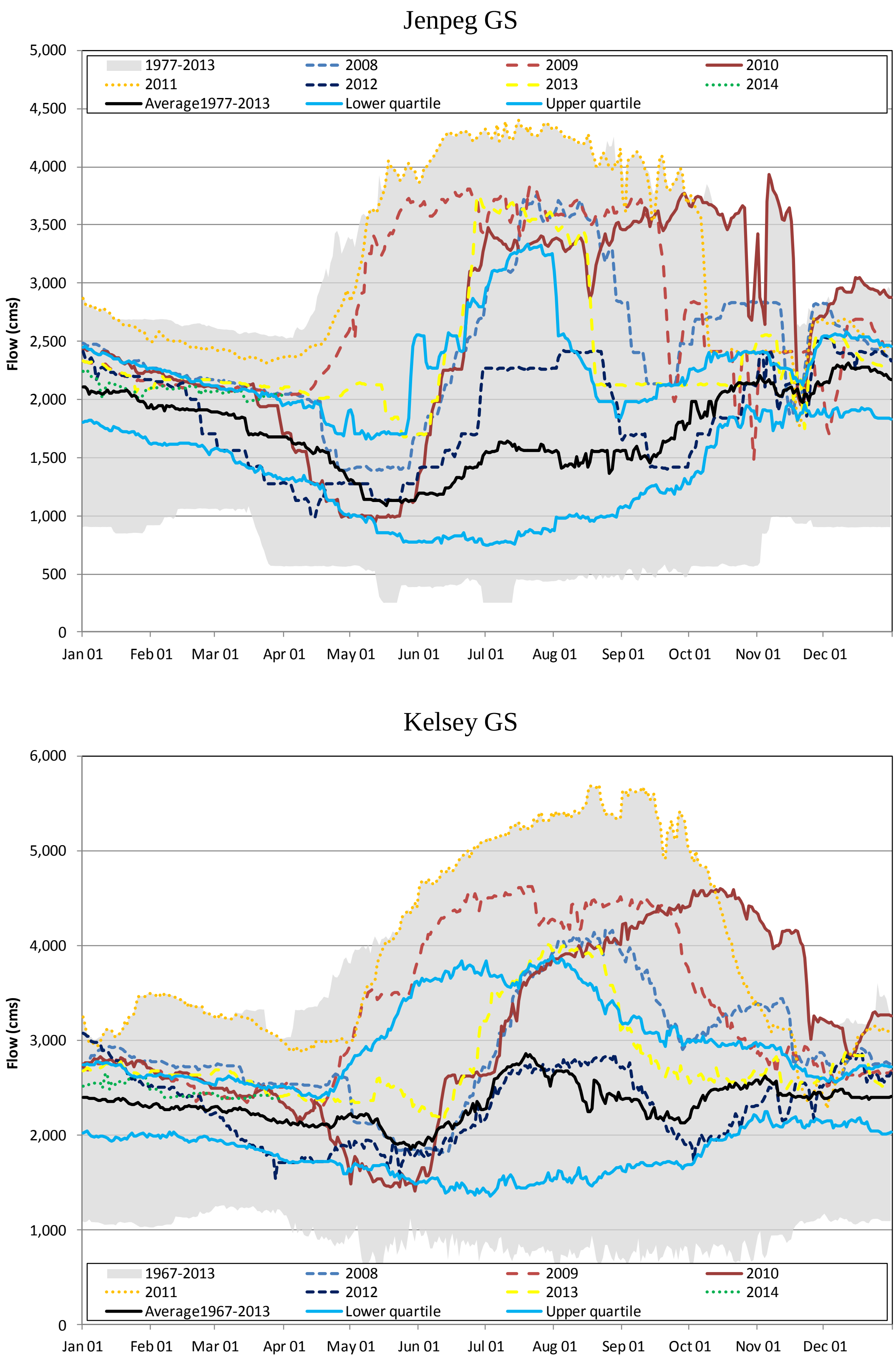


Figure 2-1. 2008-2013 Jenpeg and Kelsey generating station outflows.

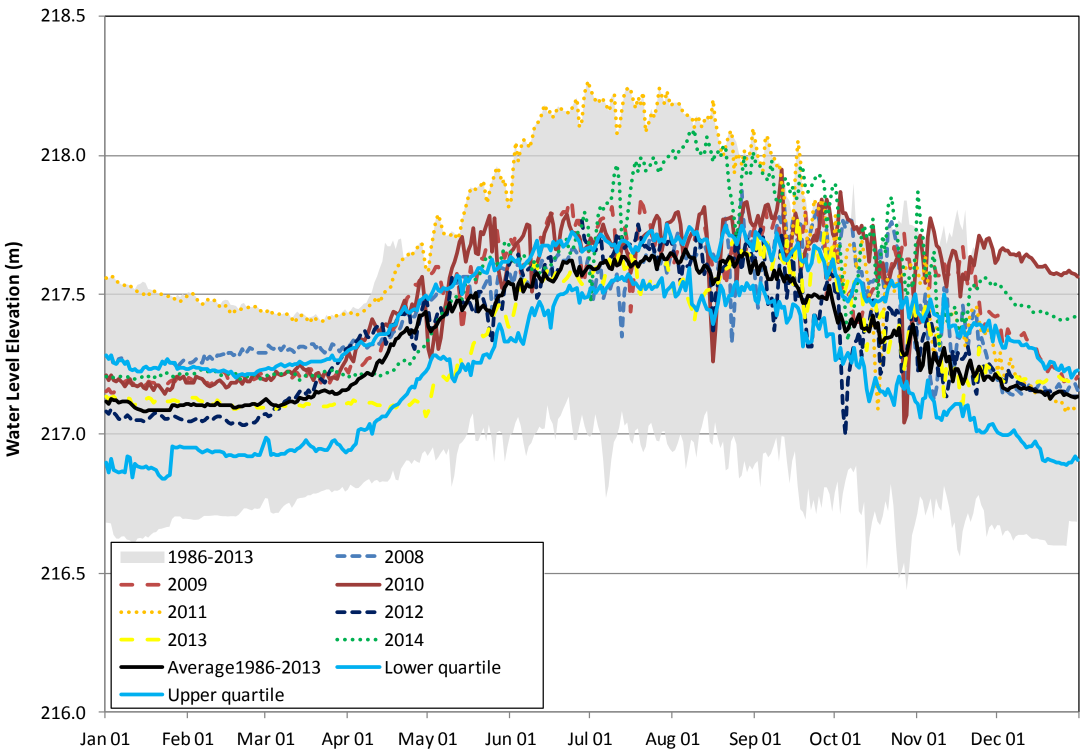


Figure 2-2. 2008-2013 Playgreen Lake (05UB005) water level elevation.

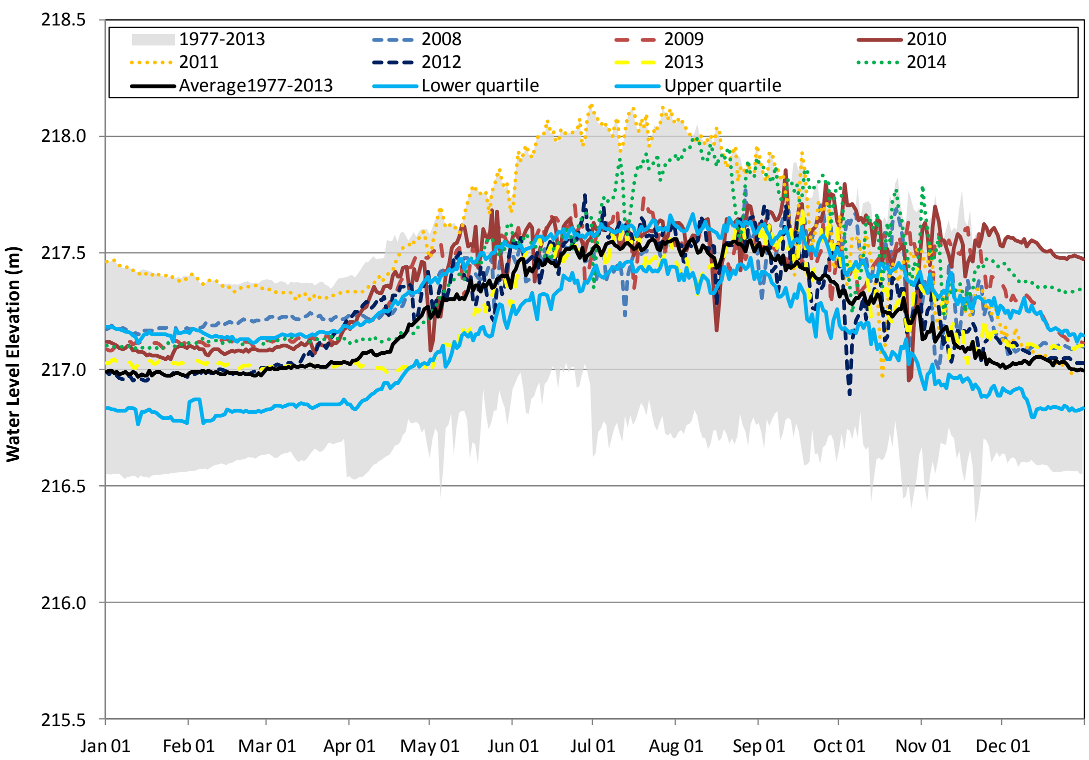


Figure 2-3. 2008-2013 Little Playgreen Lake (05UB001) water level elevation.

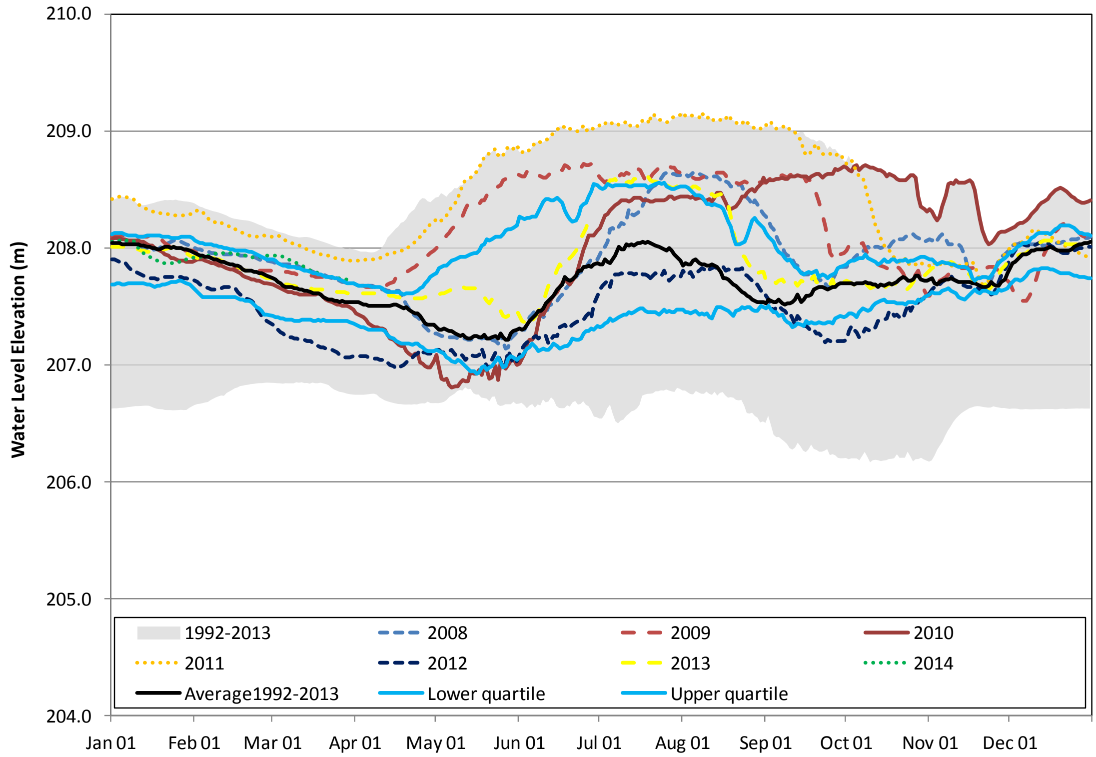


Figure 2-4. 2008-2013 Cross Lake (05UD001) water level elevation.

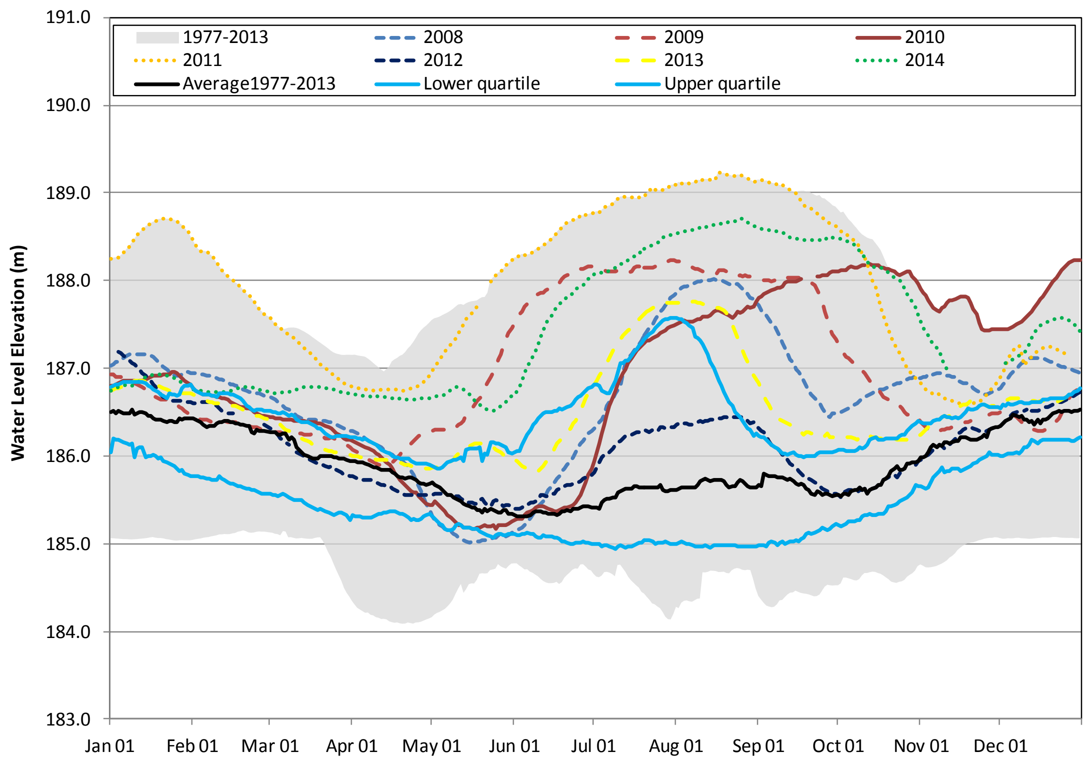


Figure 2-5. 2008-2013 Sipiwesk Lake (05UD006) water level elevation.

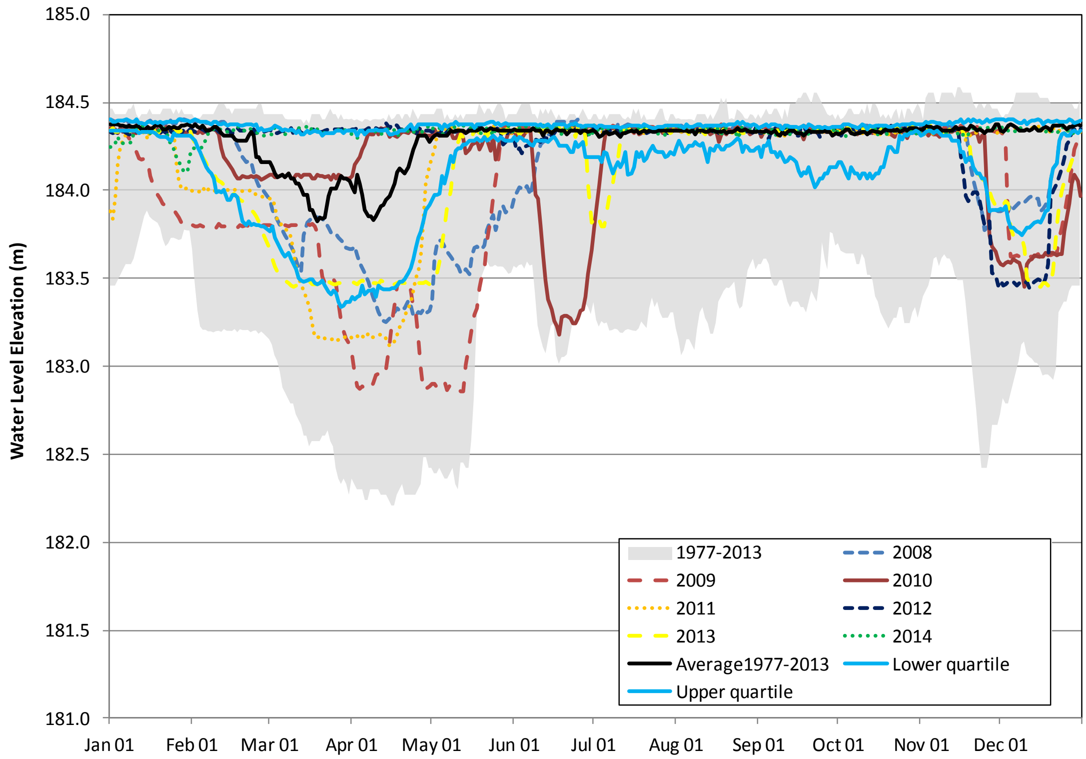


Figure 2-6. 2008-2013 Kelsey generating station forebay water level elevation.

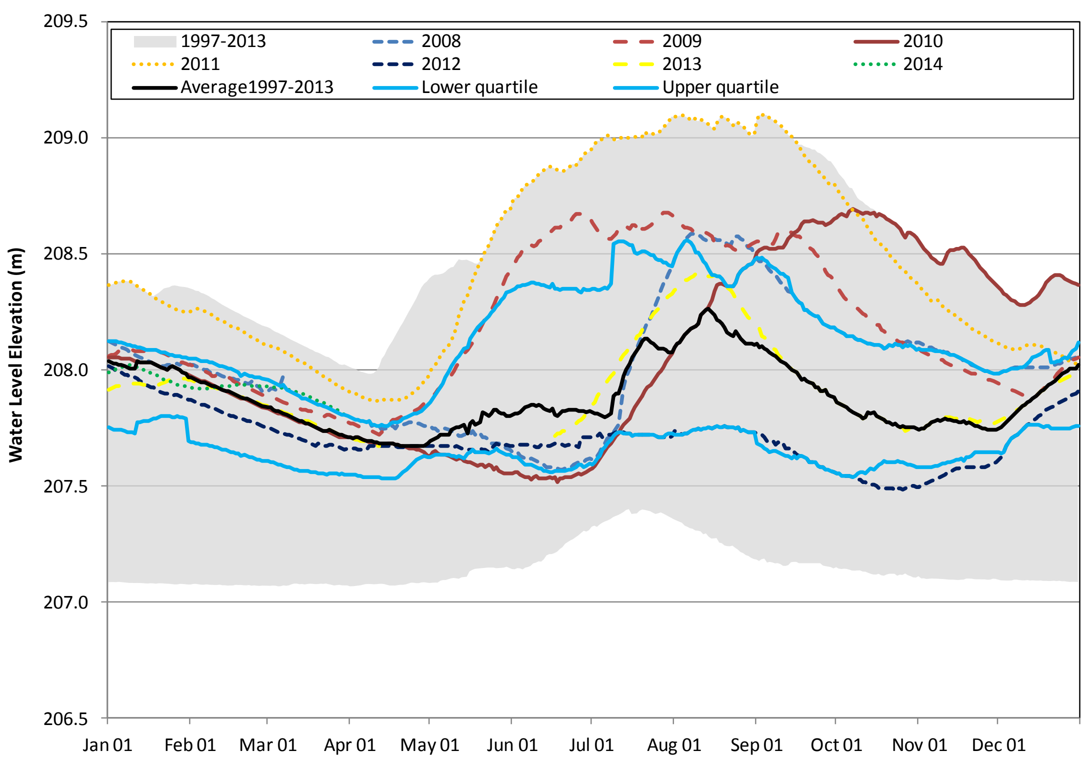


Figure 2-7. 2008-2013 Walker Lake (05UD704) water level elevation.

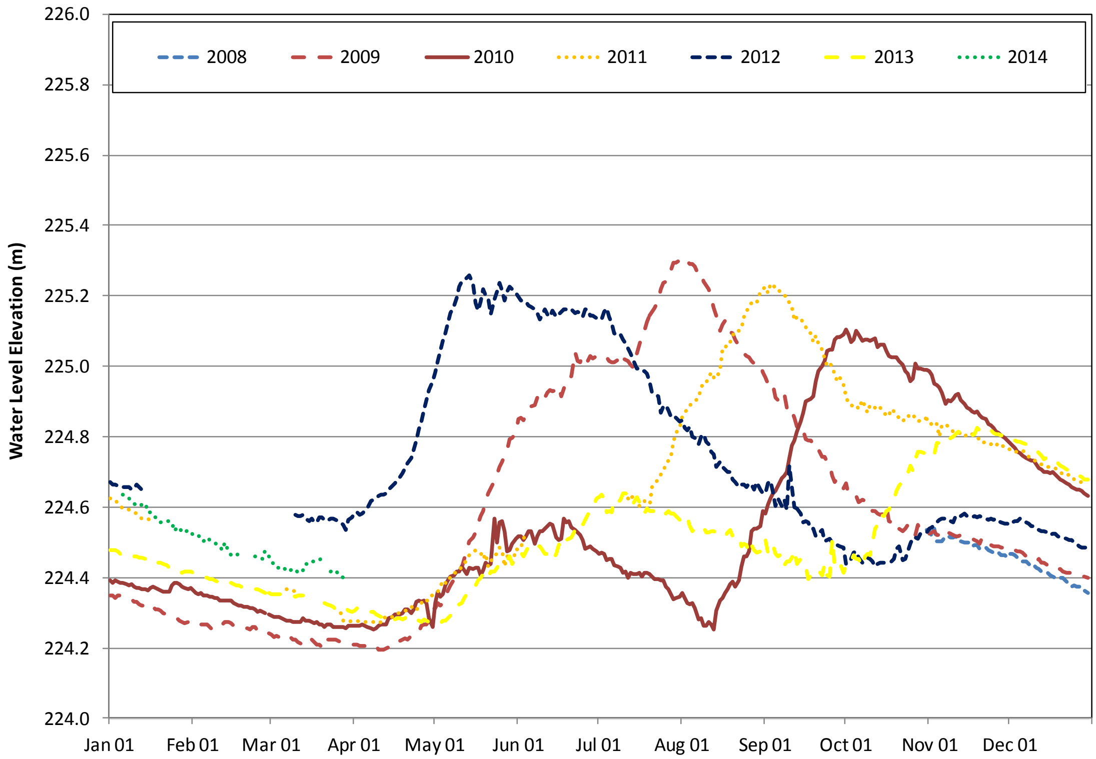


Figure 2-8. 2008-2013 Setting Lake (05TC701) water level elevation.

3.0 WATER QUALITY

3.1 INTRODUCTION

The following provides an overview of water quality conditions for key metrics measured over years 1-6 of CAMP in the UNRR. Waterbodies/river reaches sampled annually for water quality included one on-system lake (Cross Lake) and two off-system lakes (Setting and Walker lakes; Table 3-1; Figure 3-1). Four additional on-system waterbodies or river reaches were sampled on a rotational basis including Playgreen, Little Playgreen, and Sipiwesk lakes and the upper Nelson River upstream of the Kelsey GS. Annual sampling was initiated in 2012 and 2013 in the Lake Winnipeg outflows: the upper Nelson River at Warren Landing (2012), Two-Mile Channel Inlet (2013), and Two-Mile Channel Outlet (2013). Sampling was completed at all locations and sampling periods as planned. Winter sampling is not conducted under CAMP at the Lake Winnipeg outflow sites.

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

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

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

3.1.2 Indicators

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

Manitoba Hydro and the Province of Manitoba’s (2015) recent regional cumulative effects assessment (RCEA) identified few effects of Lake Winnipeg Regulation (LWR), the Kelsey GS, and/or the Cross Lake Weir on water quality of the upper Nelson River. The analysis also indicated that water quality does not change notably along the length of the upper Nelson River; rather conditions generally reflect the water quality of the Lake Winnipeg outflow. However, analysis of the long-term data sets suggested potential recent increases in some water quality metrics (i.e., total phosphorus, alkalinity, hardness, specific conductance, and some major ions) in this region. Based on the conclusions of the RCEA, results for metrics other than key metrics were also reviewed and summarized below where of particular note (e.g., where there was evidence of temporal trends and/or where a metric did not meet MWQSOGS for PAL).

3.2 KEY INDICATORS

3.2.1 Dissolved Oxygen

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

3.2.1.1 Upper Nelson River

Most of the lakes monitored under CAMP on the upper Nelson River are isothermal (Table 3-2; Figures 3-2 to 3-4); weak and transient thermal stratification was only observed at Cross Lake in spring 2012 (thermocline at 1-1.5 m; Figure 3-3). Stratification was also observed during the same sampling period in the nearby off-system Setting Lake (Figure 3-4).

In general, lakes and river reaches were well-oxygenated year-round and, with one exception, 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) across the water column over the six years of monitoring (Figures 3-5 to 3-10). The exception occurred at Cross Lake in the winter of 2008/2009 when DO was below the instantaneous minimum objective for cold-water aquatic life (8.0 mg/L) across the 1 m of the water column where measurements were collected, and just below the most stringent objective for cool-water aquatic life (5.5 mg/L) at 1 m below the ice surface (Figure 3-8). This is in contrast to the off-system Setting Lake where DO concentrations were below PAL objectives in some open-water and all ice-cover seasons (see Section 3.2.1.2). 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).

DO conditions were similar across the upper Nelson River sites and there is no indication of spatial trends over the first six years of CAMP (Figure 3-11).

3.2.1.2 Off-system Waterbodies: Walker and Setting Lakes

Setting Lake was thermally stratified on a number of occasions over the first six years of CAMP, including the spring sampling period in each year and in two summers (2008 and 2009; Figure 3-4). The lake was well-oxygenated during most open-water sampling periods across depth (Figure 3-12). However, DO concentrations were below PAL objectives in the hypolimnion in both summers when stratification was observed.

Oxygen depletion is more likely to develop in lakes during long periods of stratification, notably near the bottom of the water column over winter. DO was lower at depth, and concentrations were below the most stringent DO objective (9.5 mg/L for cold-water aquatic life), below depths of approximately 13-15 m in each winter in Setting Lake (Figure 3-12). Although the lake was not thermally stratified, there was a notable increasing temperature gradient across the water column in winter.

Like Setting Lake, Walker Lake was thermally stratified in the spring of both sampling years (Figure 3-2). DO was near the most stringent PAL objective (6.0 mg/L) in summer of 2010 at the bottom of the water column and was below the most stringent objective (9.5 mg/L) in winter of 2014 at depths greater than 5 m (Figure 3-13); no DO data are available for the winter of 2011 due to a meter malfunction.

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 Cross Lake or the off-system Setting Lake. In addition, there was no indication of an increasing or decreasing trend in oxygen conditions over the six year monitoring period at either site.

3.2.2 Water Clarity

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

3.2.2.1 Upper Nelson River

With the exception of Two-Mile Channel, TSS concentrations were moderate (annual means of approximately 8 to 21 mg/L) in this region and TSS was above the analytical detection limit of 2 mg/L in 75-100% of samples collected at on-system sites over the six years of monitoring. Lakes and riverine sites on the upper Nelson River had similar concentrations of TSS

(Figure 3-14) and turbidity levels (Figure 3-15) during most sampling periods. Annual average TSS concentrations were typically greater than 5 but less than 15 mg/L, though notably higher concentrations were observed on occasion at the inlet and outlet of Two-Mile Channel (fall 2013) and Playgreen Lake (fall 2012; Figure 3-16). Available information is insufficient to identify the potential source or spatial extent of these spikes in TSS in this area.

Sediment plumes are known to originate along the northern shoreline of Lake Winnipeg near Two-Mile channel. These plumes extend into Playgreen Lake while traveling along the banks of Two-Mile Channel, and become increasingly sediment-laden due to shoreline erosion and sediment re-suspension. The CAMP sampling sites in this area may have been affected by plumes during some or all sampling periods. Furthermore, sampling at the Two-Mile Channel Inlet site in fall 2013 was conducted northwest of the target sampling location (due to high velocities near the inlet) and more distant from the inlet than in previous sampling periods. This relocation may have, in part, contributed to the high TSS observed at this time (228 mg/L), as it is well established that sediment plumes occur off of the north shore of Lake Winnipeg. However, that TSS and turbidity were also notably elevated near the outlet of Two-Mile Channel at this time (147 mg/L) suggests that the increase may have extended downstream and may not have been isolated to Lake Winnipeg; however, that TSS was concurrently high at the inlet and outlet of Two-Mile Channel does not eliminate the possibility that the high TSS at the outlet site was caused by local erosion and/or resuspension.

Subsequent monitoring conducted in Two-Mile Channel in 2014 and 2015 under CAMP suggests that TSS and turbidity are typically higher in the fall near the inlet to Two-Mile Channel. Environment Canada (EC) and Manitoba Water Stewardship (EC and MWS 2011) reported that based on monitoring conducted over the period of 1999-2007, TSS was typically highest in both basins of Lake Winnipeg in the fall; it was suggested that this seasonality reflected the higher frequency and duration of high wind events in fall, notably for the south basin (EC and MWS 2011). The general increase in TSS in fall in the north basin is a function of wind-induced erosion and sediment resuspension, transfer of TSS from the south basin over the open-water season, and phytoplankton growth over summer. Higher TSS in shallow (< 12 m depth) areas in the north basin of Lake Winnipeg were believed to reflect littoral erosion and bottom resuspension associated with high wind events in fall. McCullough et al. (2001) concluded that antecedent winds were the most significant factor contributing to TSS dynamics in Lake Winnipeg, and the relationship between antecedent winds and TSS was stronger for the north basin (notably along the eastern shore) than the south basin.

TSS concentrations were relatively similar in the Lake Winnipeg outflows (excluding outliers) and Playgreen, Little Playgreen, and Cross lakes indicating that the major origin of suspended solids is Lake Winnipeg. However, omitting the three outliers discussed above (228 mg/L and 147 mg/L at Two-Mile Inlet and Outlet, respectively, in fall 2013 and 95 mg/L in Playgreen Lake in fall 2012), available data suggest that TSS and, notably, turbidity increase slightly on average downstream of Cross Lake (Figure 3-17). This may indicate local inputs (e.g., erosion, resuspension) of sediments in these areas. Flows and water levels were at record highs in 2011 when Cross and Sipiwesk lakes and the upper Nelson River upstream of the Kelsey GS were sampled concurrently and water quality conditions measured in that year may not be representative of conditions under lower flows. Furthermore, with only a single year of data for the downstream sites, any conclusions based on these limited data are associated with relatively high uncertainty.

Secchi disk depths (measured at lake sites only) were typically less than 1 m on average, with notable inter-annual variability (Figure 3-18).

3.2.2.2 Off-system Waterbodies: Walker and Setting Lakes

TSS (Figure 3-14) and turbidity (Figure 3-15) were lower and Secchi disk depth (Figure 3-18) was higher in the off-system Walker and Setting lakes than lakes along the upper Nelson River. 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. Off-system lakes located off of the main flow of the large river systems had, in general, higher water clarity than on-system lakes, likely reflecting inherent differences in hydrology and drainage basin characteristics.

3.2.2.3 Temporal Comparisons and Trends

Statistical comparisons of water clarity metrics between years at the annual on-system site (Cross Lake) indicate no significant differences over the six year period. Furthermore, qualitative examination of the data does not suggest increasing or decreasing trends in these metrics over the six year monitoring period. The same observations were found for the annual off-system waterbody (i.e., Setting Lake). As noted in Section 3.2.2.1, there may be seasonal differences for water clarity metrics at some locations along the upper Nelson River, notably immediately downstream of Lake Winnipeg. As more data are acquired, future analyses of temporal trends would benefit from considering seasons separately.

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 Upper Nelson River

Lakes, forebays, and riverine sites near inflows to these waterbodies along the upper Nelson River were eutrophic on the basis of mean open-water season TP concentrations (Table 3-3; Figure 3-19), though conditions varied from meso-eutrophic to eutrophic between years at some sites (i.e., Cross and Little Playgreen lakes; Figure 3-20). On-system lakes had a similar, but somewhat lower, trophic status based on TN (mesotrophic[1] on average; Table 3-3; Figure 3-19) and chlorophyll *a* (mesotrophic to eutrophic on average; Table 3-3; Figure 3-19), though conditions also varied notably between years in some waterbodies (Figures 3-21 and 3-22). Of the three metrics, chlorophyll *a* was the most variable.

Neither TP nor TN was significantly correlated to chlorophyll *a* in Cross Lake based on the first six years of monitoring data (Figure 3-23). This suggests that nutrients are not the primary factor limiting phytoplankton growth and/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 lack of, or a weak, correlation between nutrients and chlorophyll *a* for the six year monitoring period.

On average, TP concentrations were in excess of the Manitoba narrative nutrient guideline for lakes, ponds, and reservoirs and streams near the point of entry to these waterbodies (0.025 mg/L) in each year of monitoring at all on-system sites on the upper Nelson River (Figure 3-24). This occurrence was observed in other CAMP regions and is commonly observed in other more southern lakes and streams in Manitoba, including Lake Winnipeg (EC and MWS 2011). However, TP concentrations were higher along the Nelson River than most other river systems monitored under CAMP which reflects the conditions upstream in Lake Winnipeg.

The ratio of chlorophyll *a* to total phosphorus (which ranged from 0.07-0.25 in this region) – an indicator of the efficiency of assimilating phosphorus into algae – indicates lakes along the upper Nelson River produce a relatively low amount of chlorophyll *a* per unit phosphorus and values are generally lower than the off-system Setting Lake (mean ratio of 0.28; Table 3-3).

[1] Excluding one outlier (14.5 mg/L TN) measured in Playgreen Lake in August 2012.

Occasional high concentrations of TP and TN were observed in the upstream end of the UNRR. Specifically, high TP concentrations were observed in fall 2012 in Playgreen Lake (0.096 mg/L), in summer 2012 in the upper Nelson River at Warren Landing (0.364 mg/L), and in fall 2013 at the inlet (0.222 mg/L) and outlet to Two-Mile Channel (0.118 mg/L; Figure 3-25). High TN concentrations were observed in Playgreen Lake in summer 2012 (14.5 mg/L), in fall 2010 at Little Playgreen Lake (1.07 mg/L), and in fall 2013 at the inlet to Two-Mile Channel (3.10 mg/L; Figure 3-25). Some of these occurrences coincided with unusually high TSS concentrations, whereas the high TP at Warren Landing in summer 2012 and the high TN in Playgreen Lake in summer 2012 and Little Playgreen Lake in fall 2010 did not. As discussed in Section 3.2.2, the Two-Mile Channel Inlet monitoring site may have been influenced by sediment plumes during some or all of the monitoring periods which may have contributed to periodically high measurements of TSS and associated parameters such as total nutrients. Chlorophyll *a* was also relatively high in fall 2013 at the inlet (15.1 µg/L) and outlet (10.1 µg/L) of Two-Mile Channel, which may have contributed to higher TSS and, potentially nitrogen; *Aphanizomenon*, a type of algae that has the ability to fix atmospheric nitrogen, was relatively abundant at that time.

Excluding outliers, there was no clear spatial pattern evident along the length of the upper Nelson River for TP, TN, or chlorophyll *a* for the six years of monitoring (Figure 3-19). Rather, nutrients and chlorophyll *a* were relatively similar across sites in the UNRR which suggests that the major factor affecting these metrics in this region is the upstream inflow (i.e., outflow from Lake Winnipeg), rather than local influences. This suggestion is in agreement with the conclusions of Manitoba Hydro/Manitoba’s RCEA (MH and the Province of Manitoba 2015).

3.2.3.2 Off-system Waterbodies: Walker and Setting Lakes

On average, the off-system Walker and Setting lakes had a similar trophic status based on TN and chlorophyll *a* (i.e., mesotrophic) than lakes on the upper Nelson River (Tables 3-2 and 3-3; Figures 3-21 to 3-22). Conversely, both off-system lakes had lower concentrations of TP and ranked with a lower overall trophic status (mesotrophic and meso-eutrophic) than on-system waterbodies based on this nutrient (Table 3-3; Figure 3-20).

Like the on-system Cross Lake, TN and TP were not correlated to chlorophyll *a* in the off-system Setting Lake (Figure 3-23). As previously noted, the lack of a significant correlation 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 available for examination of inter-relationships between metrics.

On average TP concentrations were below the Manitoba guideline for TP for lakes (0.025 mg/L) in both Walker and Setting lakes, however occasional exceedances were observed (Figure 3-24).

Two samples (approximately 8%) collected in Setting Lake and three samples (approximately 38%) from Walker Lake exceeded the guideline for lakes and reservoirs (0.025 mg/L). This occurrence was observed in other CAMP regions and is commonly observed in other more southern lakes and streams in Manitoba, including Lake Winnipeg (EC and MWS 2011).

3.2.3.3 Temporal Comparisons

There were no statistically significant inter-annual differences for nitrogen, phosphorus, or chlorophyll *a*. None of the metrics appeared to experience an increasing or decreasing trend over the six years of monitoring in Cross or Setting lakes.

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. Several non-key water quality metrics indicate a potential increasing trend over the period of 2008-2013 at the annual on-system site (Cross Lake) monitored in this region including:

- total alkalinity (Figure 3-26);
- hardness (Figure 3-27);
- specific conductance (Figure 3-28);
- major cations (calcium and sodium; Figure 3-29; magnesium and potassium; Figure 3-30); and
- chloride and sulphate (Figure 3-31).

Concentrations of these metrics were higher in the open-water seasons of 2012 and, notably, 2013 in Cross Lake. No trends were evident for the annual off-system monitoring site (Setting Lake). Though this may suggest a trend has recently begun to develop in Cross Lake since the inception of CAMP (i.e., since 2008), additional data are required to determine if these observations reflect inter-annual, or short-term variability, relative to long-term trends.

Though several of the metrics indicated above were found to be negatively correlated to water level and/or discharge for the 2008-2013 monitoring period (see Section 3.4), which may suggest the observed potential trends were a reflection of variability of local hydrological conditions, observations made using larger datasets suggest that at least some metrics were notably high in 2013 relative to the long-term record. Further, considering that water level and discharge measured in the UNRR in 2013 were well within the ranges measured for the post-LWR or post-Cross Lake Weir periods, suggests that factors other than local hydrological conditions, such as changes in the upstream environment (i.e., Lake Winnipeg drainage) may have caused or contributed to this condition.

An analysis of long-term post-LWR data for Cross Lake conducted as part of Manitoba Hydro and the Province of Manitoba’s (2015) RCEA indicated that alkalinity, hardness, specific conductance, and most of the major ions exhibited increases since approximately 2008. These recent increases were also observed at sites located upstream and downstream on the upper Nelson River. Collectively, these observations were deemed indicative that water quality conditions along the upper Nelson River are defined primarily by the inflowing water (i.e., Lake Winnipeg outflow) rather than local influences. Further, the temporal patterns and concentrations observed at Cross Lake for these metrics were similar to those observed upstream along the upper Nelson River near Norway House.

Several of the metrics that were highest in Cross Lake in 2013 were also highest at the Lake Winnipeg CAMP site including alkalinity, specific conductance, hardness, and sulphate (see Technical Document 3, Section 3.3). This suggests these potential trends or recent increases observed in the UNRR for at least some metrics may be driven by changes upstream.

Ammonia and pH remained within PAL guidelines/objectives at all sites and times, both on- and off-system. A single measurement of nitrate/nitrite (13.7 mg N/L), which was comprised primarily of nitrate (13.5 mg N/L), from Playgreen Lake in August, 2012 exceeded the PAL guideline of 2.93 mg N/L by a notable margin. This measurement has been identified as suspect based on other nitrogenous parameters being within ranges typically measured in the UNRR in the same sample and because concentrations of nitrate/nitrite are typically very low and well within the PAL guideline in northern Manitoba in general.

Most metals, excepting aluminum, iron, and mercury, were also consistently within Manitoba water quality PAL objectives and guidelines in the UNRR. Aluminum was above the PAL guideline (0.1 mg/L) in 96-100% of samples from on-system sites in the UNRR (Table 3-4). Exceedances of this metal were also observed in the off-system Setting Lake (71%) but not in Walker Lake. The iron PAL guideline (0.3 mg/L) was exceeded between 33 and 75% of samples collected at on-system sites (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. Total mercury also slightly exceeded the PAL guideline (26 ng/L) in winter 2013/2014 at both Little Playgreen (27.2 ng/L) and Cross lakes (34.0 ng/L); no other on-system sites were monitored in that year and it is not known if these exceedances extended further downstream. However, an exceedance was concurrently observed in the nearby off-system Setting Lake and Lake Winnipegosis which suggests potential sample contamination.

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 guidelines (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

Significant relationships were observed between some water quality metrics at Cross Lake and water discharge (measured at the Jenpeg GS) or level (measured in Cross Lake) for the open-water period over the six years of monitoring (Table 3-5). All significant relationships were negative (i.e., water quality metrics were lower under high water level and/or discharge conditions) and included measures of alkalinity (Figures 3-32 and 3-33), inorganic carbon (Figure 3-34), water clarity (TSS [Figure 3-35] and turbidity [Figures 3-36 and 3-37]), specific conductance (Figures 3-38 and 3-39) and total dissolved solids (TDS; Figure 3-40), and two major ions (chloride [Figure 3-41] and sodium [Figure 3-42]). The highest coefficients of determination occurred for TSS (R^2 = 0.484), bicarbonate alkalinity (R^2 = 0.428), chloride (R^2 = 0.415), and *in situ* specific conductance (R^2 = 0.407) in relation to water level. With the possible exception of water clarity metrics, metrics that were significantly correlated to water level or discharge were lowest in 2011, when water level was at a record high.

Similar relationships, and direction of relationships, were also observed for the CAMP water quality site in the north basin of Lake Winnipeg (see Technical Document 4, Section 3.4). Several metrics including specific conductance, TDS, and magnesium were negatively correlated to annual mean water level.

The results of this analysis for Cross Lake are largely, but not entirely, in agreement with past studies for sites in the UNRR. Ramsey (1991) reported that pH, alkalinity, hardness, specific conductance, TDS, most major ions, ammonia, nitrate/nitrite, and dissolved inorganic carbon were negatively correlated with Nelson River discharge (Norway House area) over the period of 1987-1989. Duncan and Williamson (1988) noted that post-LWR (period of approximately 1977-1984), alkalinity, calcium, magnesium, total inorganic carbon, and conductivity decreased, while pH and turbidity increased, with increased discharge at Norway House. Conversely, Duncan and Williamson (1988) reported positive relationships between discharge and alkalinity, magnesium, hardness, potassium, sodium, and chloride and negative relationships for pH and TSS at Cross Lake. Differences in the conclusions between this and previous studies may reflect differences in the quantity and/or quality of data analysed (e.g., changes in analytical sensitivities), differences in the range of water levels and flows for the various study periods, and/or potentially changes over time.

In addition, that several of water quality metrics appeared to have undergone an increase over the latter period of the six years of monitoring, as discussed in Section 3.3, while water level and flow conditions did not follow this same pattern, suggests that factors other than local hydrological conditions may have caused or contributed to temporal patterns in water quality observed in this region.

3.5 SUMMARY

Overall, analysis of the six years of CAMP monitoring data collected in the UNRR indicated that most water quality metrics were within PAL objectives and guidelines and metrics that exceeded PAL guidelines in this region are commonly above these benchmarks in northern Manitoba lakes and rivers. Lakes and riverine areas were generally well-oxygenated year-round; off-system lakes (Walker and Setting lakes) were more prone to thermal stratification and developed oxygen deficits during some periods, notably during periods of stratification or near the end of the ice-cover season.

CAMP data indicate a potential recent increasing trend for several non-key indicators of water quality (total alkalinity, hardness, specific conductance, and major cations and anions). Although many of these same metrics were found to be negatively correlated to water level and flow at Cross Lake, available information collectively suggests that the recent increases, notably those observed in 2013, may reflect changes upstream (i.e., Lake Winnipeg drainage basin). Relationships with hydrological metrics and evaluation of longer-term patterns in the data (i.e., trend analysis) will be further explored as additional data are acquired through CAMP.

Water quality conditions along the upper Nelson River are relatively similar and available information indicates that conditions are largely defined by the conditions of the major inflow (i.e., outflow from Lake Winnipeg), rather than local influences.

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

Waterbody/Area	Site Abbreviation	Site ID	On-system	Off-system	Annual	Rotational	Sampling Years [1]					
							2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Upper Nelson River near Warren Landing	NR-WL	UBS 010	X		X [2]						X	X
Two-Mile Channel Inlet	2M-IN	UBS 020	X		X [2]							X
Two-Mile Channel Outlet	2M-OUT	UBS 021	X		X [2]							X
Playgreen Lake	PLAYG	UBS 015	X			X		X			X	
Little Playgreen Lake	LPLAYG	UBS 019	X			X			X			X
Cross Lake - West Basin	CROSS	UDS 004	X		X		X	X	X	X	X	X
Sipiwesk Lake	SIP	UDS 021	X			X				X		
Upper Nelson River upstream of the Kelsey GS	UNR	UFS 017	X			X				X		
Walker Lake	WLKR	UDS 020		X		X			X			X
Setting Lake	SET	TCS 006		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] Sites sampled for water quality only.

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

Metric		Waterbody									
		NR-WL	**2M- IN**	**2M- OUT**	**PLAYG**	**LPLAY**	**CROSS**	**SIP**	**UNR**	**WLKR**	**SET**
Years Sampled		2012, 2013	2013	2013	2009/10, 2012/13	2010/11, 2013/14	2008/09-2013/14	2011/12	2011/12	2010/11, 2013/14	2008/09-2013/14
TP	(mg/L)	0.0952	0.0977	0.0623	0.0430	0.0373	0.0412	0.0513	0.0470	0.0219	0.0208
	Trophic Status	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Meso-eutrophic	Meso-eutrophic
TN	(mg/L)	0.49	1.24	0.50	2.23 (0.48 without outlier)[1]	0.61	0.57	0.51	0.54	0.51	0.53
	Trophic Status	Oligotrophic	Mesotrophic	Oligotrophic	Eutrophic (Mesotrophic without outlier)[1]	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
TKN	(mg/L)	0.48	1.23	0.48	0.50	0.55	0.52	0.45	0.47	0.49	0.50
Chlorophyll *a*	(µg/L)	6.69	6.62	4.77	5.38	3.94	6.77	6.53	3.27	4.31	3.73
	Trophic Status	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
TN:TP	-	24	23	20	155 (30 without outlier)[2]	36	36	23	26	56	134
DOC	(mg/L)	8.1	7.8	7.7	8.4	8.8	9.8	8.6	8.4	9.7	13.1
Nitrate/nitrite	(mg N/L)	0.0128	0.0072	0.0155	1.73 (0.0209 without outlier)[3]	0.0601	0.0562	0.0694	0.0742	0.0246	0.0287
Ammonia	(mg N/L)	0.007	0.012	0.013	0.010	0.018	0.015	0.020	0.017	0.021	0.011
Dissolved Phosphorus	(mg/L)	0.017	0.019	0.019	0.019	0.021	0.023	0.027	0.031	0.007	0.012
DO Lower than MWQSOGs for PAL	(Y/N)	No	No	No	No	No	Winter (2008/2009)	No	No	Summer (2010); winter (2013/2014)	Yes (summer 2008 and 2009; winter 2008, 2009, 2011-2013)
DO - open-water season (surface)	(mg/L)	8.64	9.28	9.52	10.54	9.70	9.47	9.07	8.73	9.60	9.47
DO - open-water season (bottom)	(mg/L)	-	-	-	10.27	9.47	9.06	8.98	8.70	8.93	8.16
DO - ice-cover season (surface)	(mg/L)	-	-	-	14.46	13.11	11.93	13.82	-	13.30	13.99
DO - ice-cover season (bottom)	(mg/L)	-	-	-	14.40	12.90	11.50	14.82	-	6.85	6.93
Thermal Stratification	(Y/N)	No	No	No	No	No	Yes (spring 2012)	No	No	Yes (spring 2010 and 2013)	Yes (spring 2008-2013; summer 2008 and 2009)
Secchi Disk Depth	(m)	0.88	0.53	0.35	0.69	0.94	0.82	0.40	0.45	2.40	1.77
TSS	(mg/L)	11.4	81.5	53.5	20.5	8.9	7.7	11.0	13.6	2.1	2.1
Turbidity	(NTU)	9.90	114	54.0	15.0	8.66	9.64	17.7	20.4	1.55	2.65
True Colour	(TCU)	11.0	9.4	9.1	15.3	15.6	23.7	20.5	17.3	7.3	30.6
Specific Conductance	(µmhos/cm)	380	406	406	346	372	320	275	286	147	160
TDS	(mg/L)	225	271	262	212	221	196	185	191	101	109
Hardness	(mg/L)	155	176	172	143	138	127	127	128	74.7	83.0
Hardness Category	-	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Moderately Soft/Hard	Moderately Soft/Hard
pH	-	8.45	8.35	8.37	8.28	8.28	8.19	8.25	8.20	8.06	8.06
Total Alkalinity	(mg/L)	118	129	125	110	109	102	98.3	99.9	71.3	78.0

Table 3-2. continued.

Metric		Waterbody									
		NR-WL	2M- IN	2M- OUT	PLAYG	LPLAY	CROSS	SIP	UNR	WLKR	SET
Metals > MWQSOGs for PAL	-	Al, Fe, Se, Ag	Al, Fe	Al, Fe	Al, Fe	Al, Fe, Hg	Al, Fe, Hg	Al, Fe	Al, Fe	Al, Fe	Al, Hg
Aluminum	(mg/L)	0.454	2.794	1.674	0.659	0.355	0.395	0.921	0.684	0.006	0.124
Iron	(mg/L)	0.331	2.897	1.653	0.509	0.270	0.314	0.700	0.533	0.063	0.094
Mercury (<26 ng/L DL only)	(ng/L)	<20	<20	<20	<20	7.8	<20	-	-	4.2	<20
Mercury (≤1 ng/L DL only)	(ng/L)	-	-	-	1.3	7.8	5.2	-	-	4.2	7.6
Calcium	(mg/L)	35.2	42.2	40.4	33.1	31.8	29.6	30.3	30.4	21.6	20.2
Magnesium	(mg/L)	16.4	17.2	17.3	14.2	14.2	12.8	12.5	12.7	5.04	7.86
Potassium	(mg/L)	3.66	4.26	3.94	3.24	3.38	2.95	2.91	2.92	0.791	0.979
Sodium	(mg/L)	25.7	25.5	25.2	21.7	23.2	18.9	16.5	15.8	2.18	3.39
Chloride	(mg/L)	26.5	27.0	27.3	21.1	26.2	20.7	18.5	19.4	1.42	2.67
Sulphate	(mg/L)	41.0	43.9	44.3	35.8	37.9	31.3	30.5	29.6	1.82	3.60

[1] Outlier of 14.5 mg/L, August 2012.
[2] Outlier of 1031, August 2012.
[3] Outlier of 13.7 mg N/L, August 2012.
TKN = total Kjeldahl nitrogen; DOC = dissolved organic carbon; DL = detection limit.

Table 3-3. Summary of water quality conditions measured in the UNRR in the open-water season: 2008-2013. Values represent means (outliers removed).

Indicator	Metric		Units	Waterbody									
				NR-WL	**2M- IN**	**2M- OUT**	**PLAYG**	**LPLAY**	**CROSS**	**SIP**	**UNR**	**WLKR**	**SET**
Nutrients	TP	Mean	(mg/L)	0.0414	0.0355	0.0345	0.0362	0.0368	0.0363	0.0500	0.0460	0.0247	0.0186
		Trophic Status	-	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Meso-eutrophic	Mesotrophic
	TN	Mean	(mg/L)	0.49	0.31	0.50	0.45	0.51	0.54	0.49	0.50	0.54	0.50
		Trophic Status	-	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
	Chlorophyll *a*	Mean	(µg/L)	6.69	6.62	4.77	6.91	4.86	8.76	8.60	4.26	5.40	4.72
		Trophic Status	-	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Eutrophic	Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic
	TN:TP	Mean	-	28	19	23	30	33	35	23	25	51	66
		Nutrient Limitation	-	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation
	Chlorophyll *a*:TP	Mean	-	0.16	0.07	0.06	0.20	0.14	0.25	0.19	0.09	0.23	0.28
	Chlorophyll *a*:TN	Mean	-	0.013	0.008	0.008	0.029	0.010	0.016	0.017	0.010	0.010	0.010
	Algal Bloom Frequency (Chlorophyll *a* >10 µg/L)		(%)	33	33	33	33	0	22	33	0	0	0
Dissolved Oxygen	DO Lower than MWQSOGs for PAL		(Y/N)	N	N	N	N	N	Winter (2008/2009)	N	N	Summer (2010); winter (2013/2014)	Yes (summer 2008 and 2009; winter 2008, 2009, 2011-2013)
	DO	Surface	(mg/L)	8.64	9.28	9.52	10.54	9.70	9.47	9.07	8.73	9.60	9.47
		Bottom	(mg/L)	-	-	-	10.27	9.47	9.06	8.98	8.70	8.93	8.16
	Thermal Stratification		(Y/N)	No	No	No	No	No	Spring (2012)	No	No	Yes (spring 2010 and 2013)	Yes (spring 2008-2013; summer 2008 and 2009)
Water Clarity	Secchi Disk Depth		(m)	0.88	0.53	0.35	0.69	0.94	0.82	0.40	0.45	2.40	1.77
	TSS		(mg/L)	11.4	81.5	53.5	26.8	10.4	9.3	14.3	17.7	2.5	2.5
	Turbidity		(NTU)	9.90	113.74	53.97	18.41	8.71	10.31	20.83	24.43	1.73	2.98

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

Waterbody		**MWQSOGs PAL**																**CCME PAL**	**BCMOE PAL**
		Aluminum	**Arsenic**	**Boron**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Mercury[1]**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Uranium**	**Zinc**	**Chloride**	**Sulphate**
Objective or Guideline (mg/L)		0.1	0.15	1.5	0.000206 - 0.000494	0.0639 - 0.1674	0.00683 - 0.01865	0.3	0.001998 - 0.00893	0.000026	0.073	0.0383 - 0.1036	0.001	0.0001	0.0008	0.015	0.0879 - 0.238	120	218 - 429
Nelson River at Warren Landing	n	6	6	6	6	6	6	6	6	6	6	6	5[2]	5[2]	6	6	6	6	6
	# Exceedances	**6**	0	0	0	0	0	**2**	0	0	0	0	0[2]	0[2]	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**33**	0	0	0	0	0[2]	0[2]	0	0	0	0	0
Two-Mile Channel Inlet	n	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	# Exceedances	**3**	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**33**	0	0	0	0	0	0	0	0	0	0	0
Two-Mile Channel Outlet	n	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	# Exceedances	**3**	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**33**	0	0	0	0	0	0	0	0	0	0	0
Playgreen Lake	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**38**	0	0	0	0	0	0	0	0	0	0	0
Little Playgreen Lake	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**4**	0	**1**	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**50**	0	**13**	0	0	0	0	0	0	0	0	0
Cross Lake	n	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	# Exceedances	**23**	0	0	0	0	0	**11**	0	**1**	0	0	0	0	0	0	0	0	0
	% Exceedance	**96**	0	0	0	0	0	**46**	0	**4**	0	0	0	0	0	0	0	0	0
Sipiwesk Lake	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	# Exceedances	**4**	0	0	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**75**	0	0	0	0	0	0	0	0	0	0	0
Upper Nelson River (u/s of Kelsey GS)	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	# Exceedances	**4**	0	0	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**75**	0	0	0	0	0	0	0	0	0	0	0
Walker Lake	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Setting Lake	n	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	# Exceedances	**17**	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0
	% Exceedance	**71**	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	0

[1] Only measurements made with an analytical detection limit of <26 ng/L included.

[2] One measurement with a detection limit above the PAL guideline was excluded.

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

Metric	Units	Water Level vs. Water Quality				Discharge vs. Water Quality			
			R^2	p-value	Direction		R^2	p-value	Direction
Total Alkalinity as $CaCO_3$	(mg/L)	Log	**0.363**	**0.008**	−		**0.284**	**0.023**	−
Bicarbonate Alkalinity as HCO_3	(mg/L)		**0.428**	**0.003**	−		**0.349**	**0.010**	−
Total Inorganic Carbon	(mg/L)		**0.374**	**0.007**	−		**0.266**	**0.028**	−
Total Suspended Solids	(mg/L)		**0.484**	**0.001**	−		**0.325**	**0.013**	−
Laboratory Turbidity	(NTU)		**0.232**	**0.043**	−	Log	0.139	0.127	
In Situ Turbidity	(NTU)		**0.289**	**0.032**	−		0.110	0.209	
Laboratory Specific Conductance	(µmhos/cm)	Log	**0.388**	**0.006**	−		**0.264**	**0.029**	−
In situ Specific Conductance	(µS/cm)	Log	**0.407**	**0.008**	−		0.245	0.051	−
Total Dissolved Solids	(mg/L)	Log	**0.396**	**0.005**	−		**0.288**	**0.022**	−
Chloride	(mg/L)	Log	**0.415**	**0.004**	−		**0.297**	**0.019**	−
Sodium	(mg/L)	Log	**0.233**	**0.043**	−	Log	0.143	0.122	

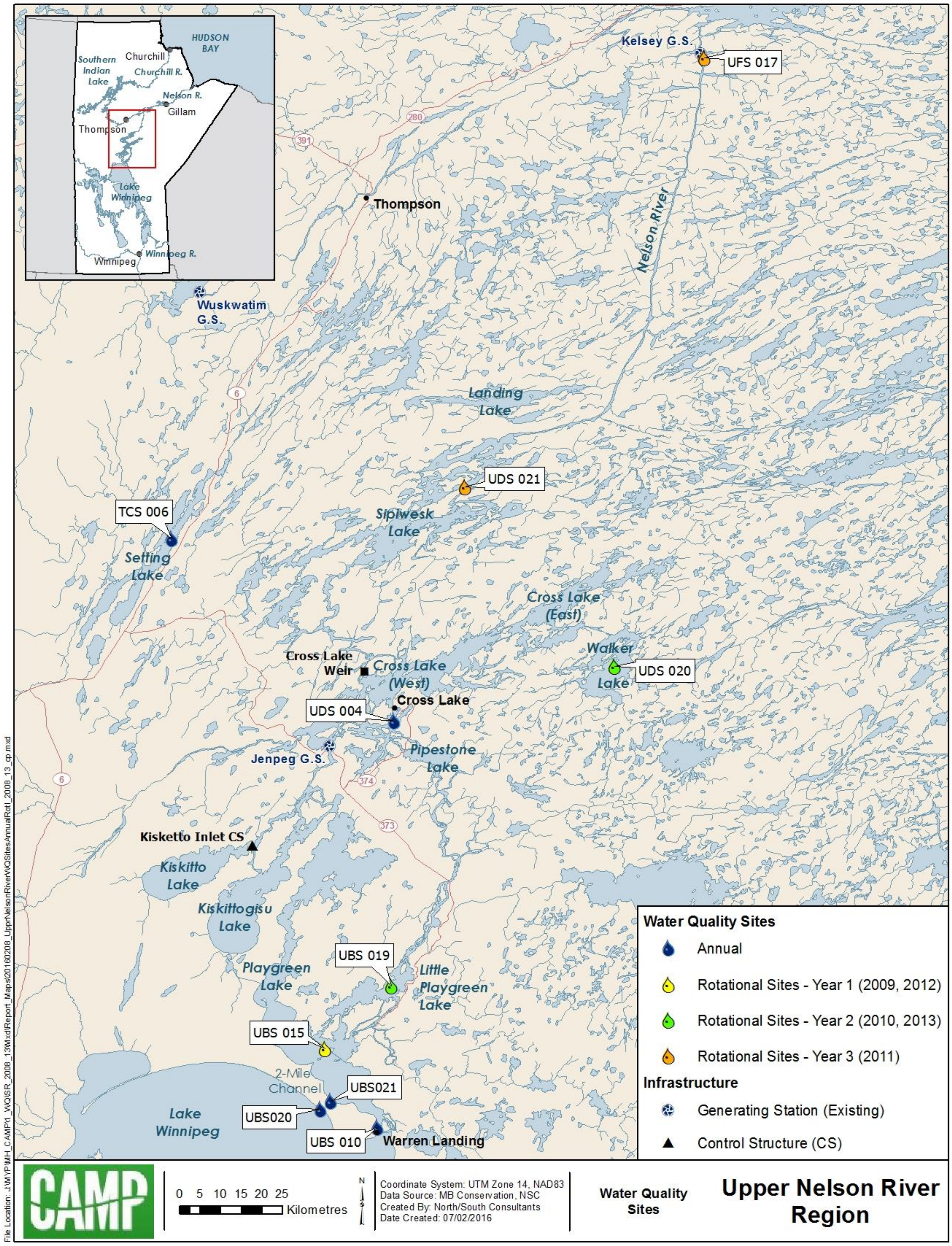


Figure 3-1. Water quality sampling sites in the Upper Nelson River Region: 2008/2009-2013/2014.

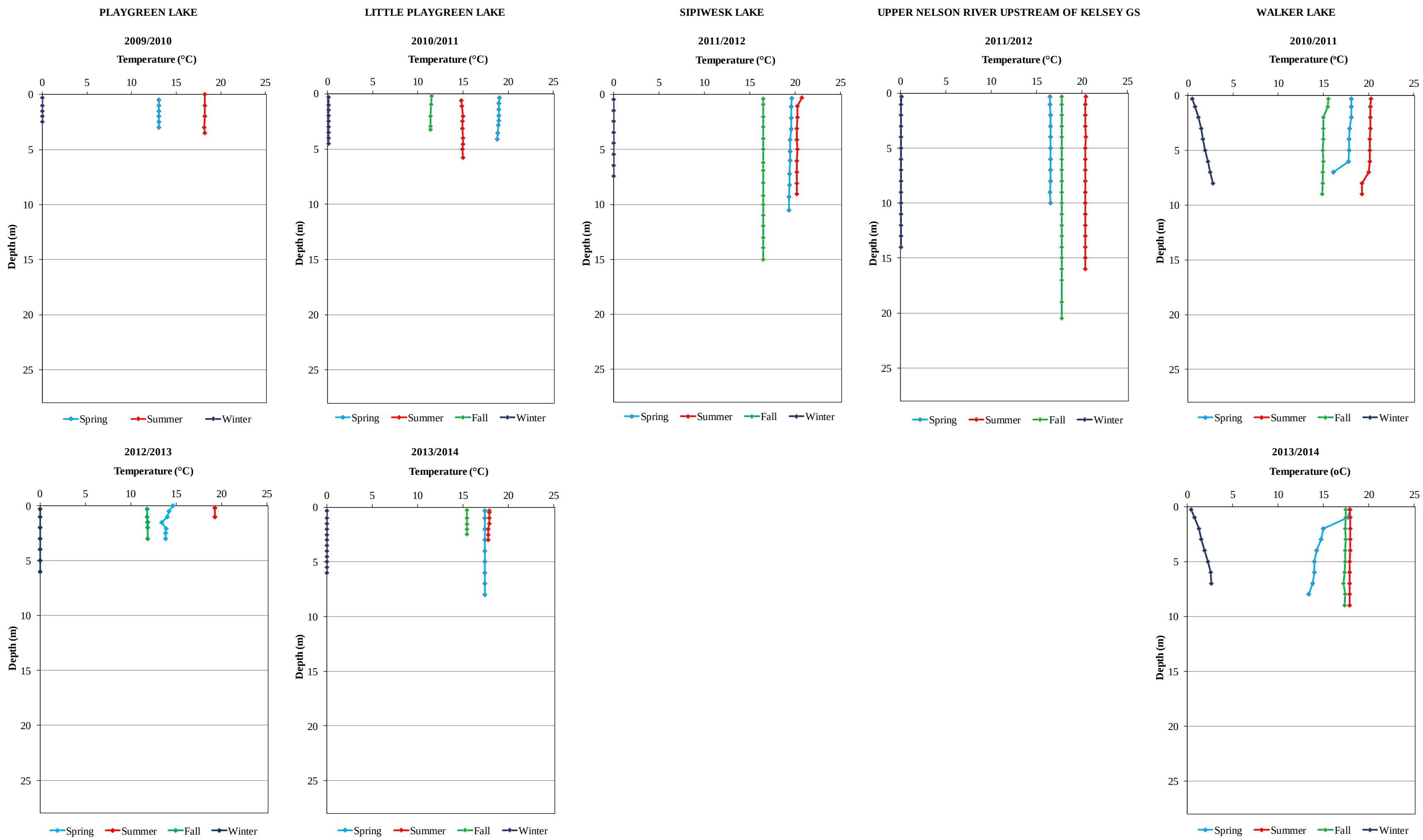


Figure 3-2. Temperature depth profiles in rotational waterbodies in the UNRR: 2008/2009-2013/2014.

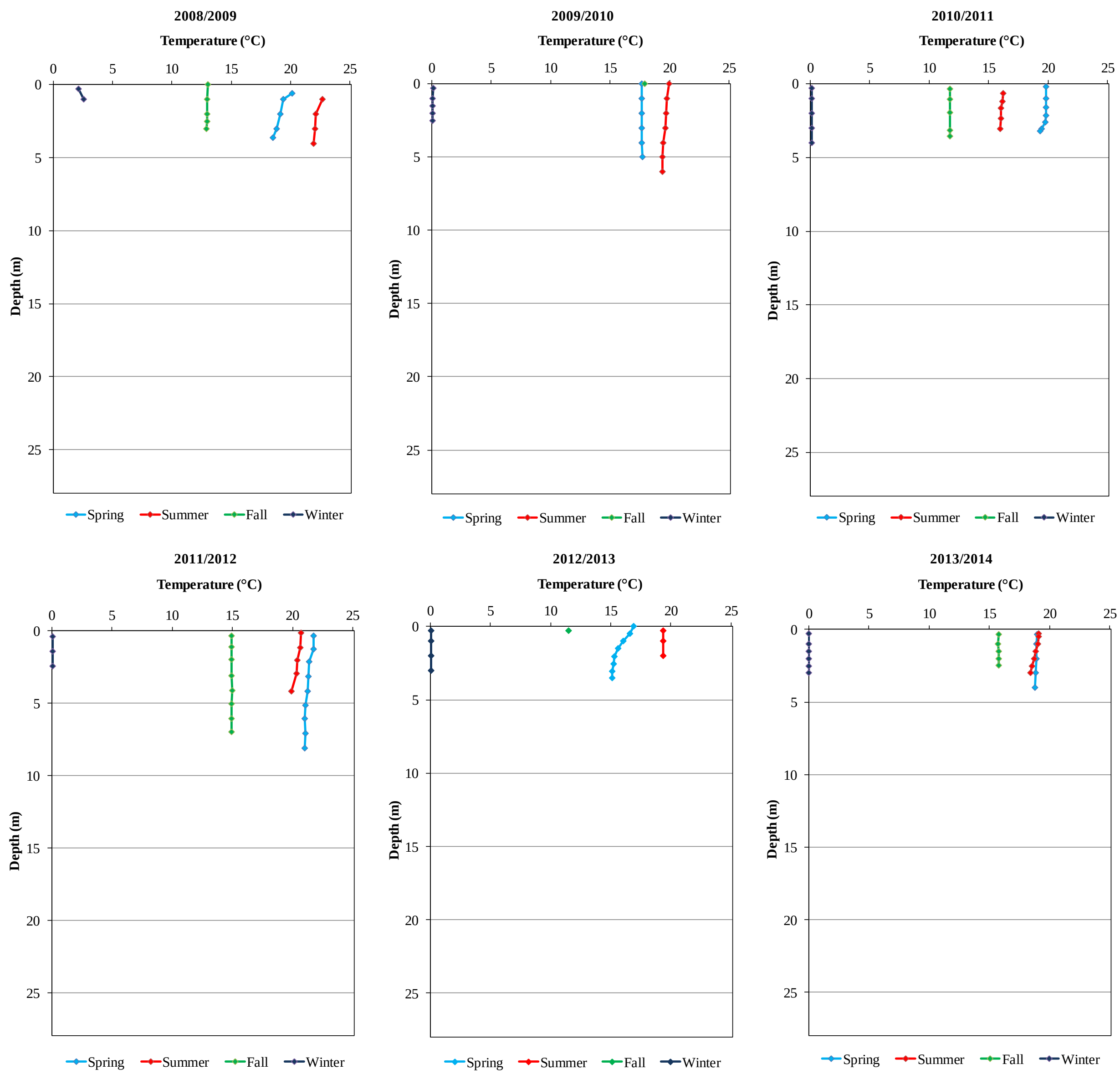


Figure 3-3. Temperature depth profiles in Cross Lake: 2008/2009-2013/2014.

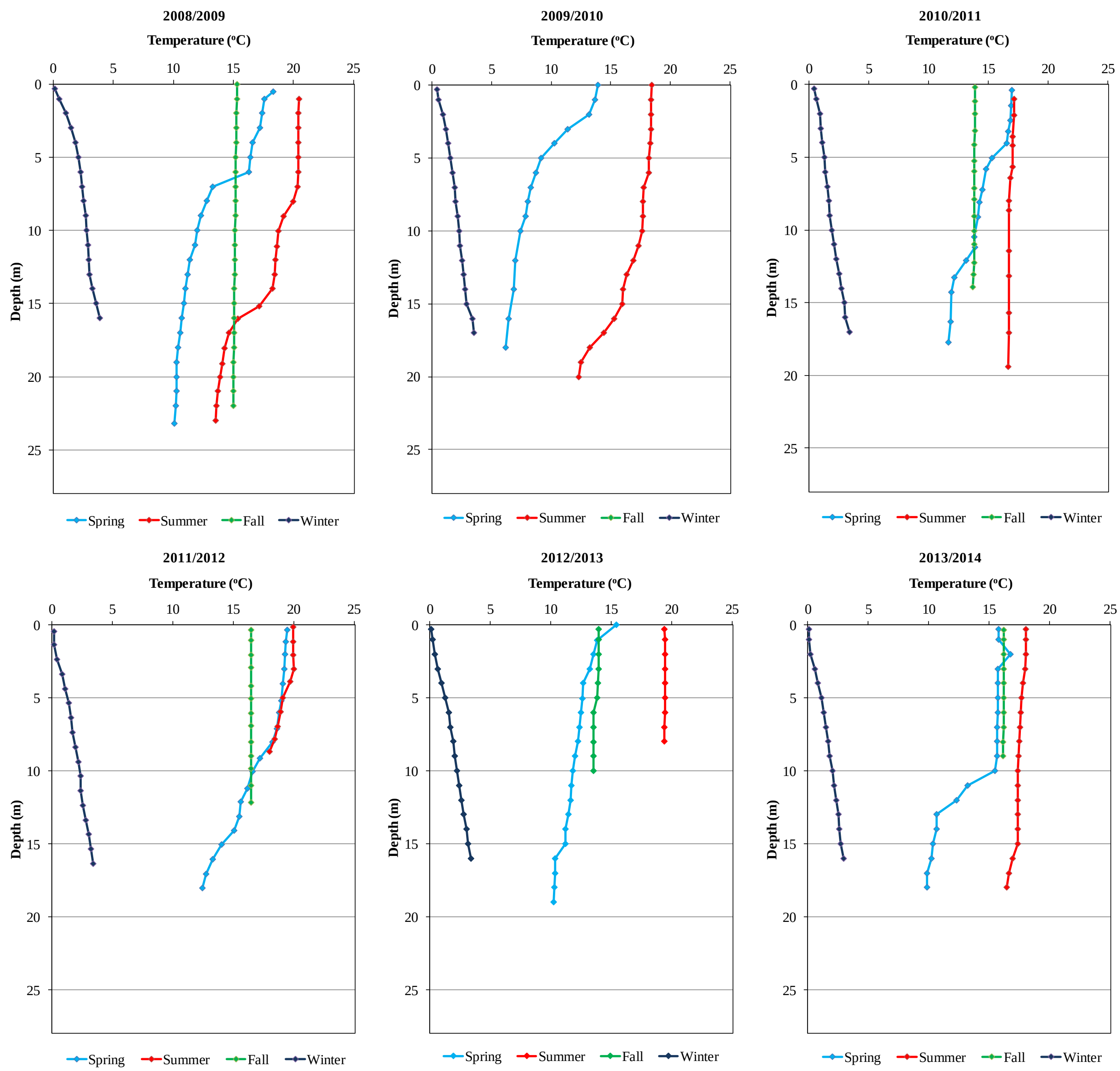


Figure 3-4. Temperature depth profiles in Setting Lake: 2008/2009-2013/2014.

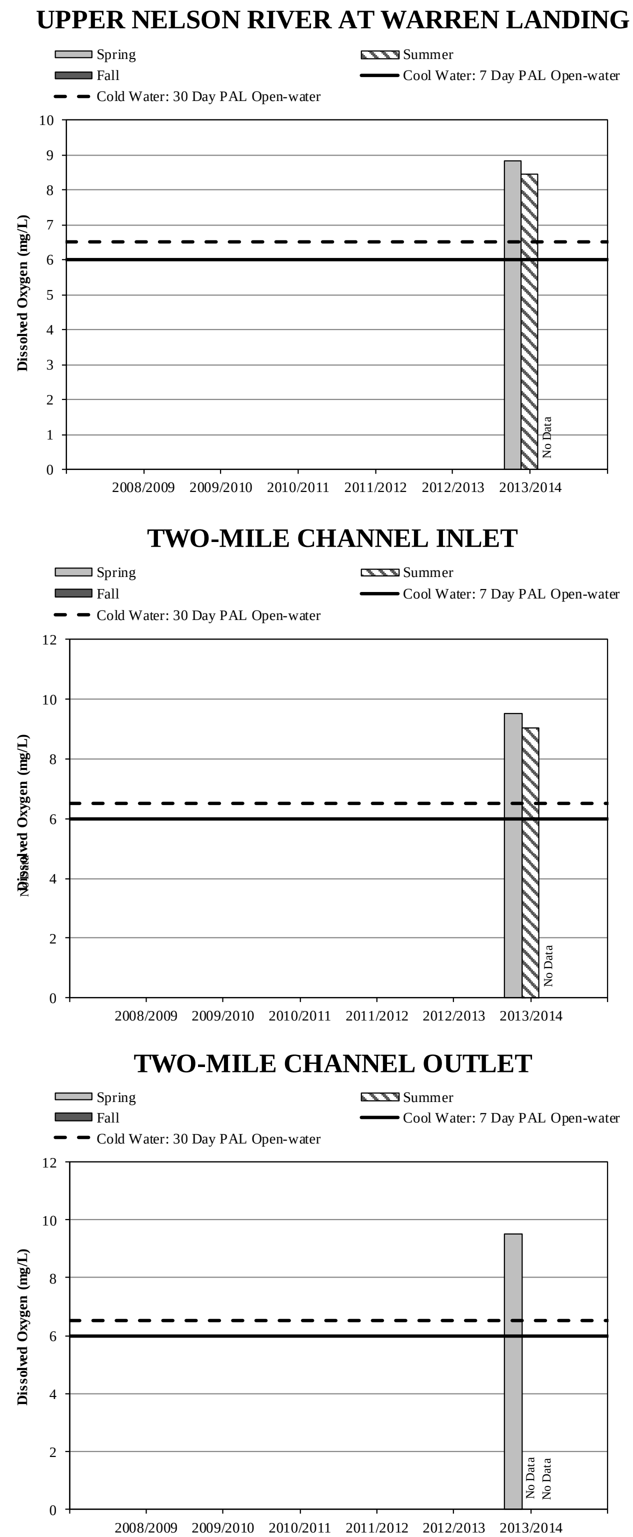
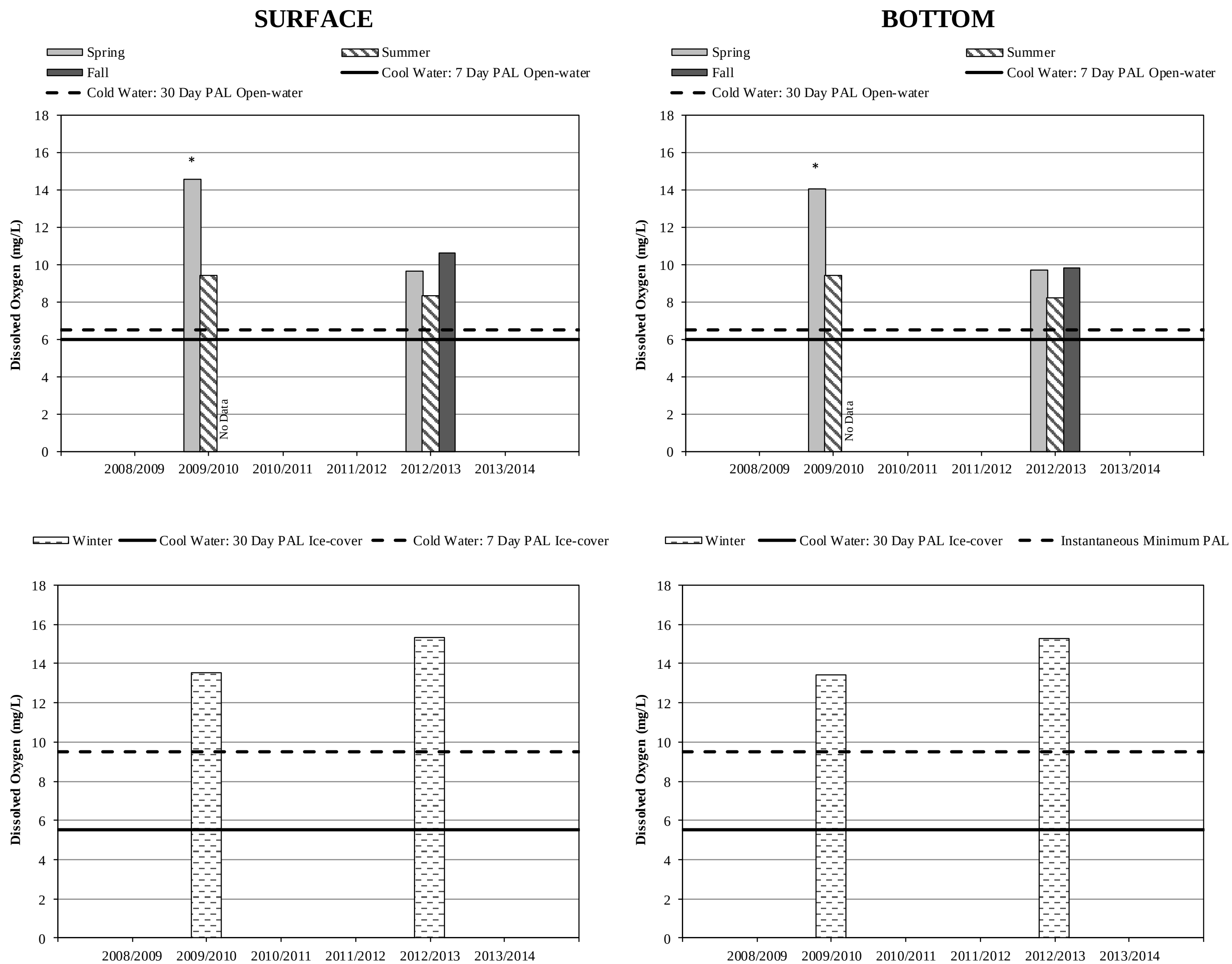


Figure 3-5. Dissolved oxygen measured near the surface of the water column in the upper Nelson River at Warren Landing and the inlet and outlet of Two-Mile Channel and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect. Concentrations may be overestimated.

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

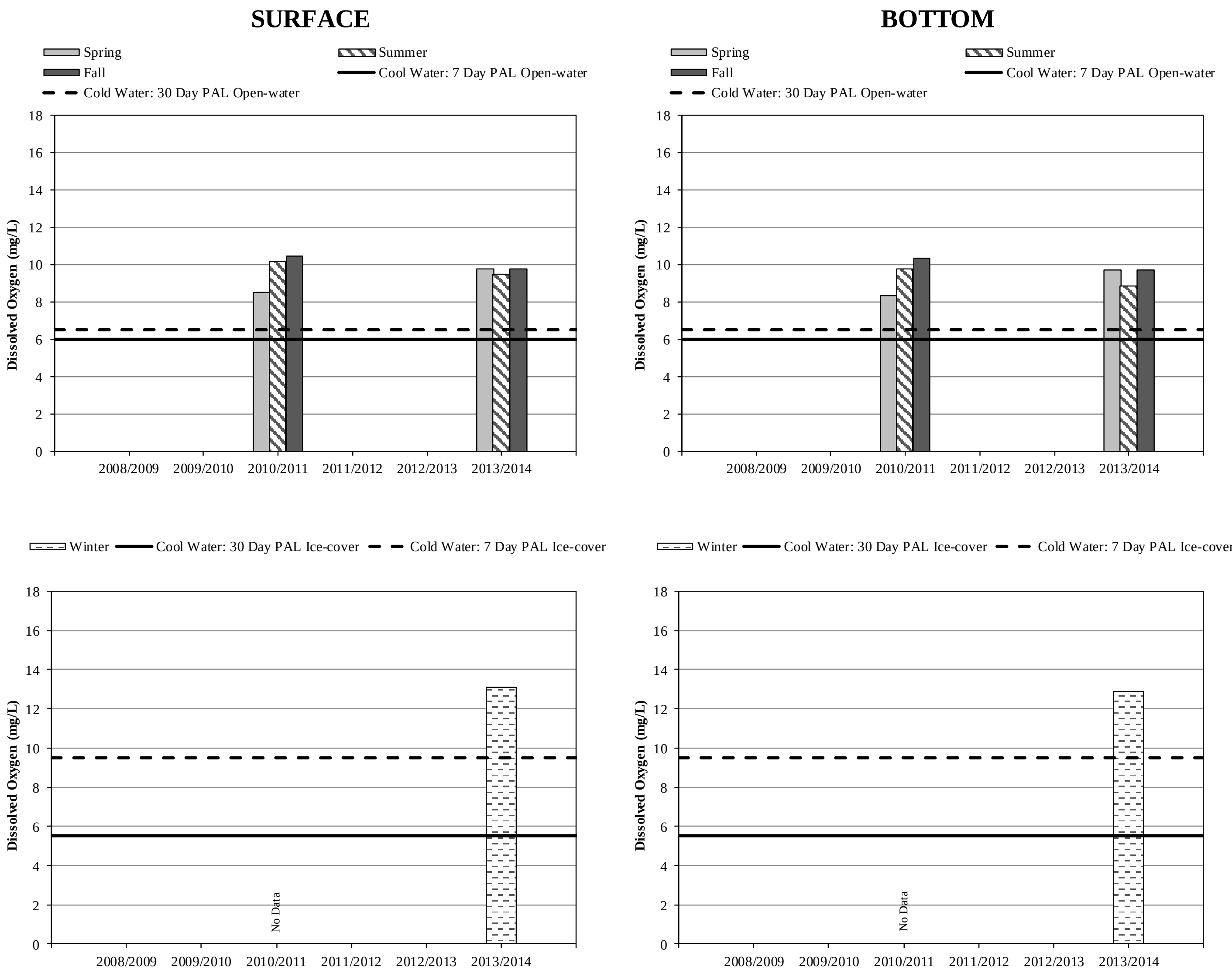


Figure 3-7. Dissolved oxygen measured near the surface and bottom of the water column in Little Playgreen Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

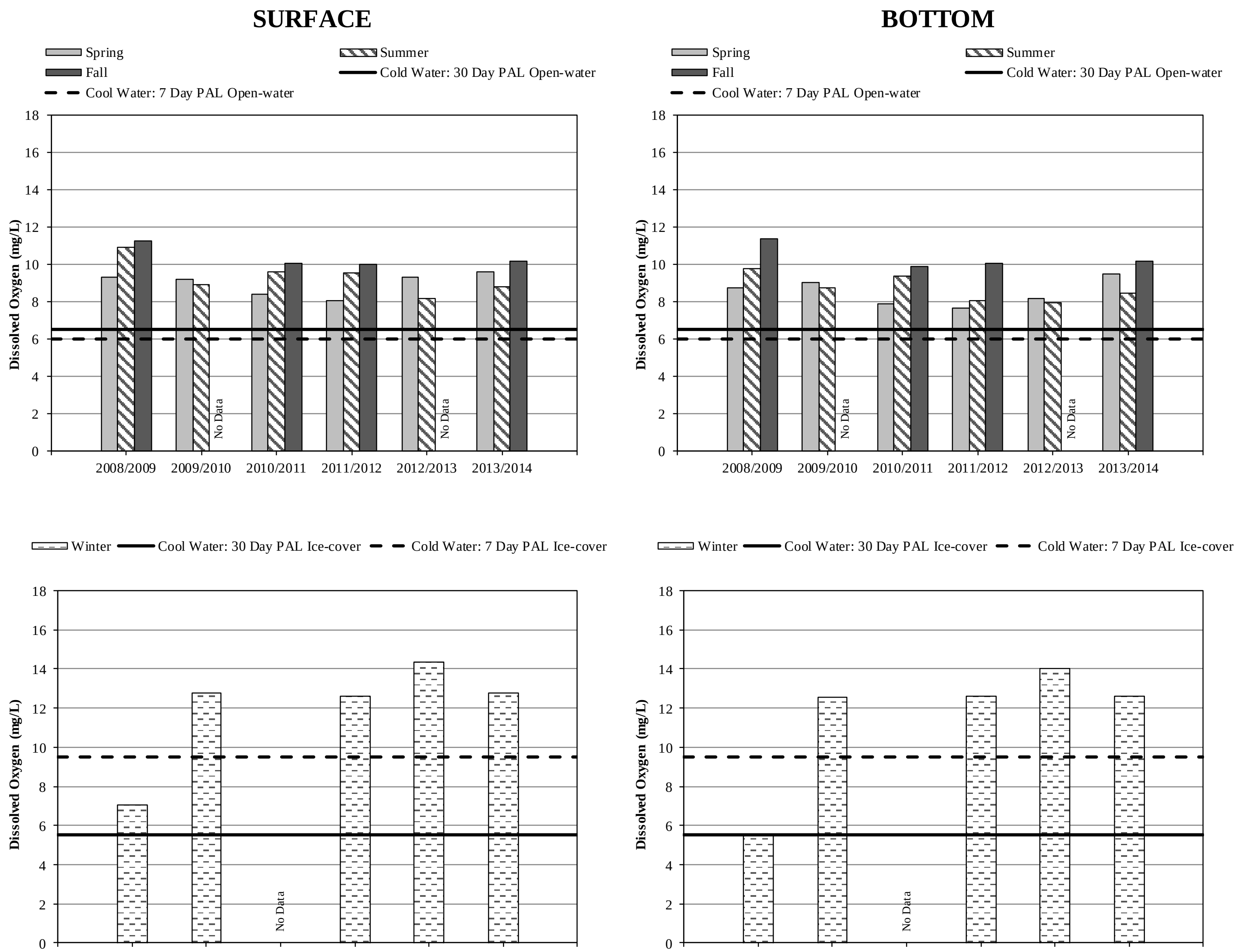


Figure 3-8. Dissolved oxygen measured near the surface and bottom of the water column in Cross Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

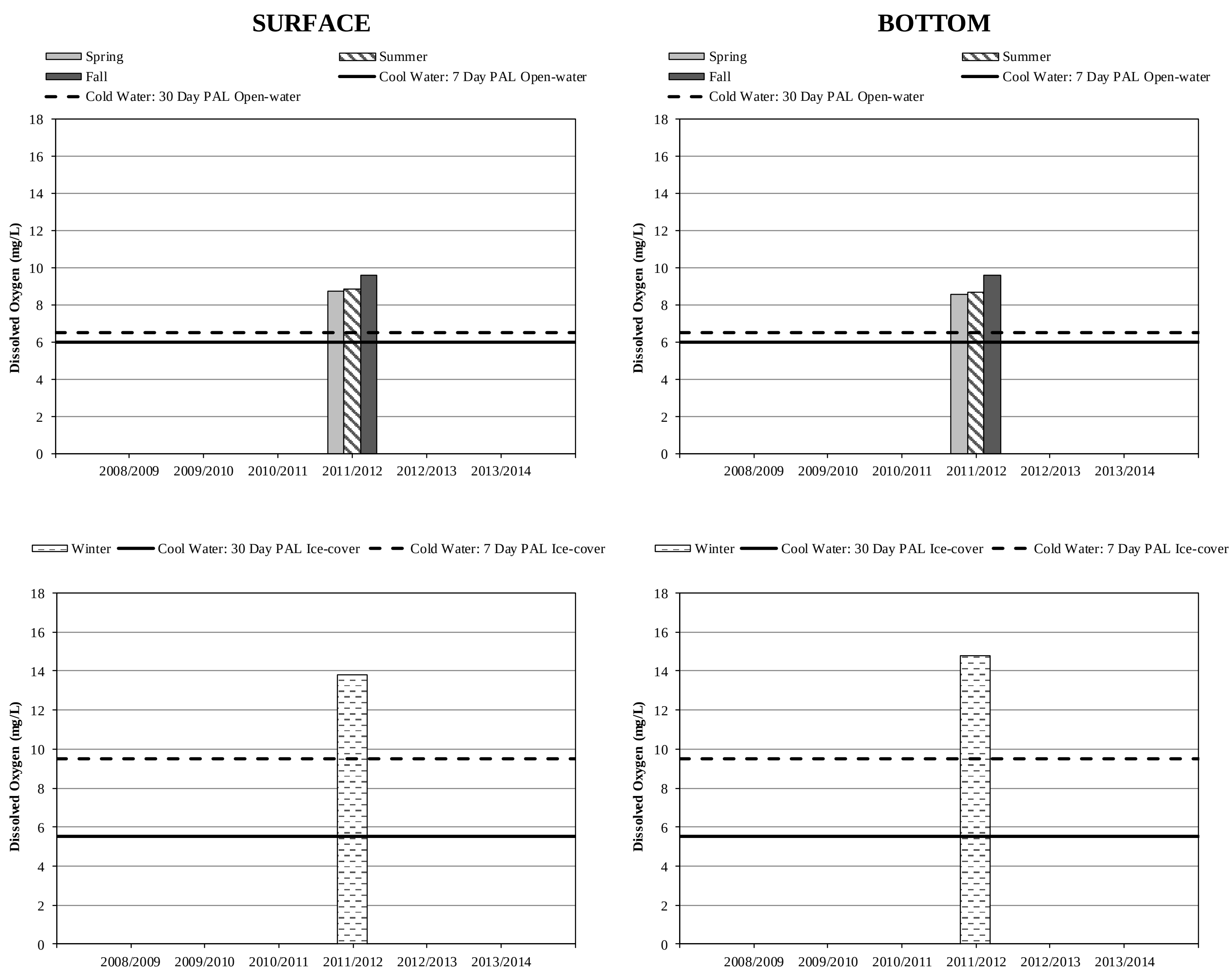


Figure 3-9. Dissolved oxygen measured near the surface and bottom of the water column in Sipiwesk Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

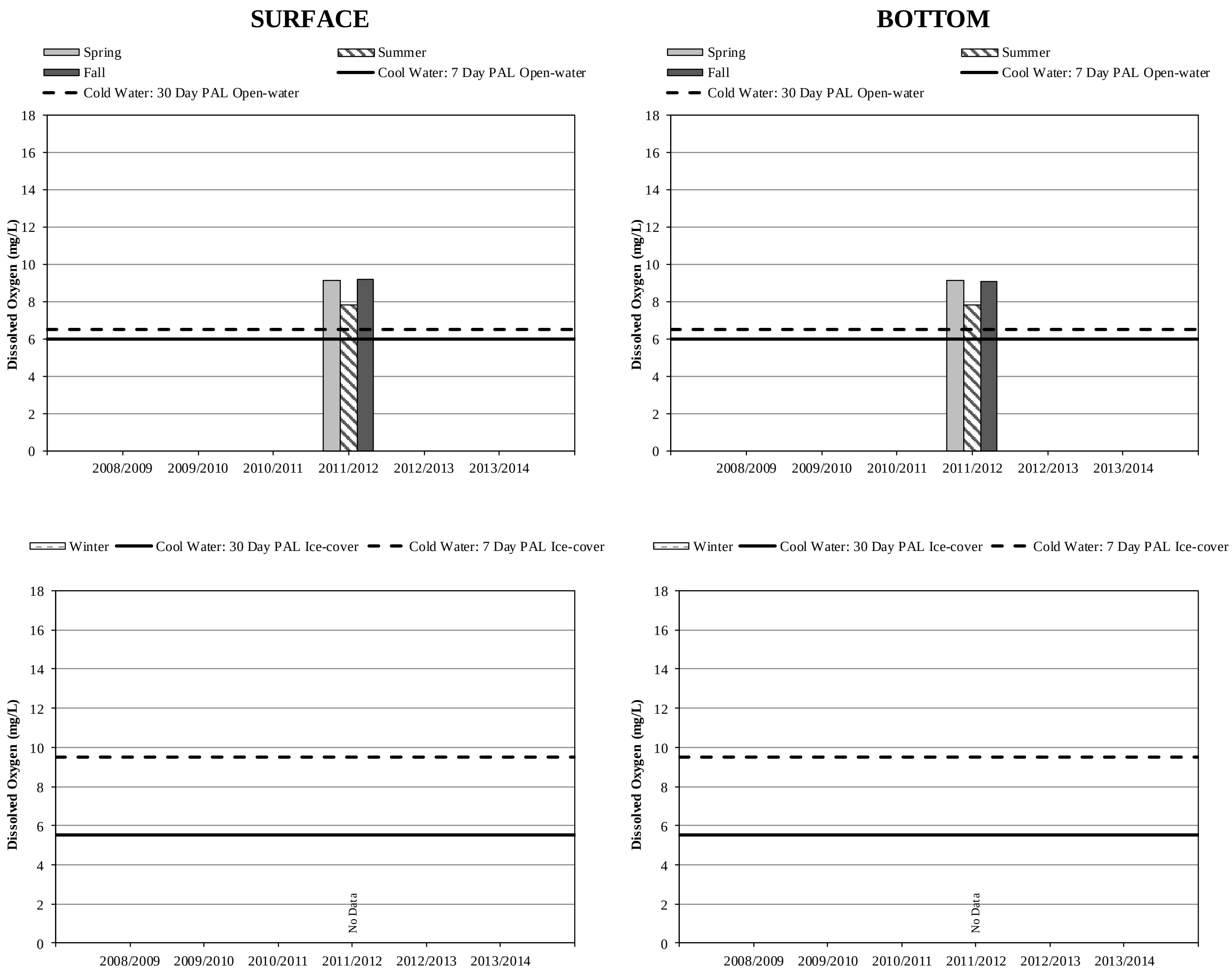


Figure 3-10. Dissolved oxygen measured near the surface and bottom of the water column in the upper Nelson River upstream of the Kelsey GS and comparisons to MB PAL objectives: 2008/2009-2013/2014.

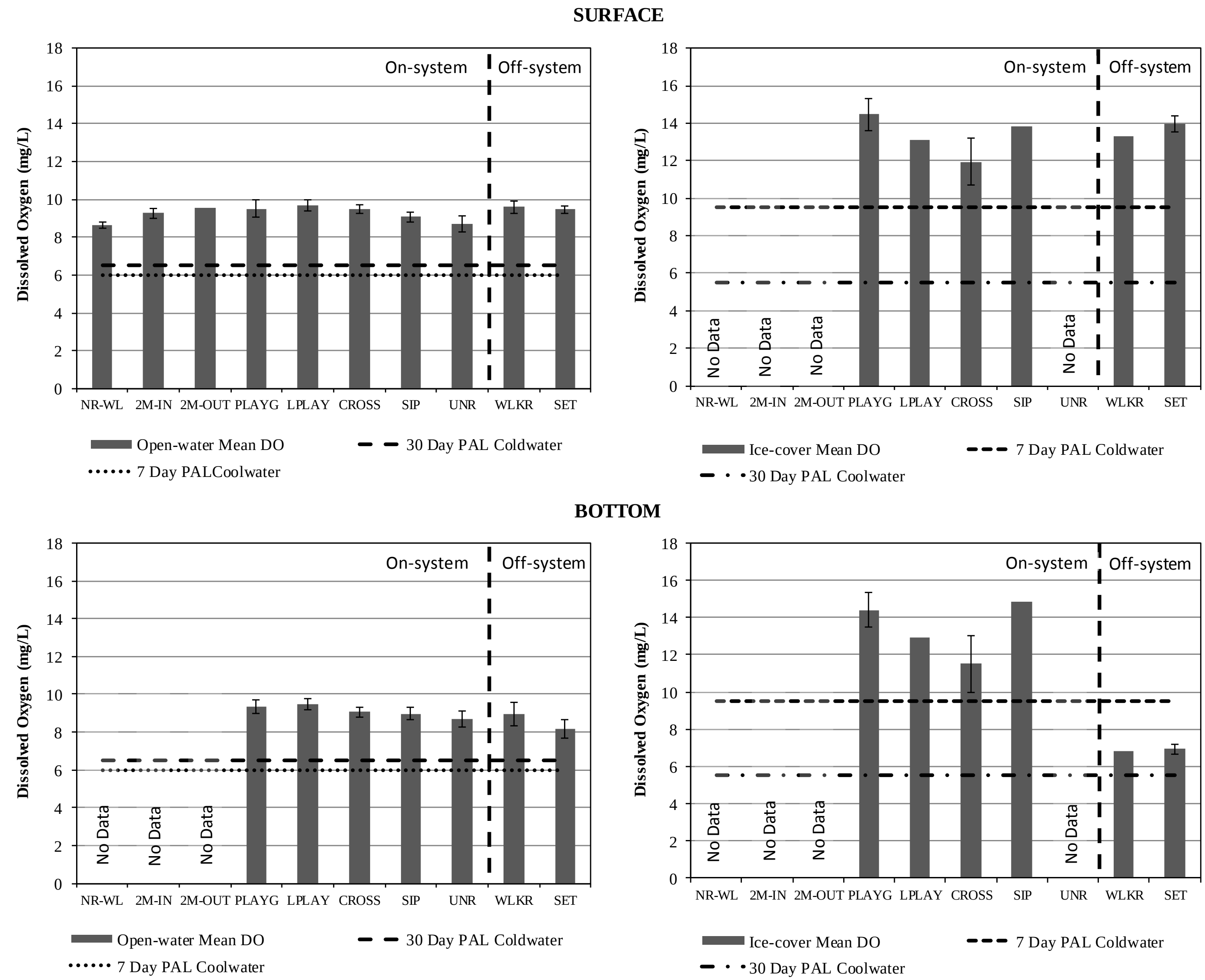


Figure 3-11. Dissolved oxygen (mean±SE) measured in the Upper Nelson River Region in the open-water and ice-cover seasons: 2008/2009-2013/2014.

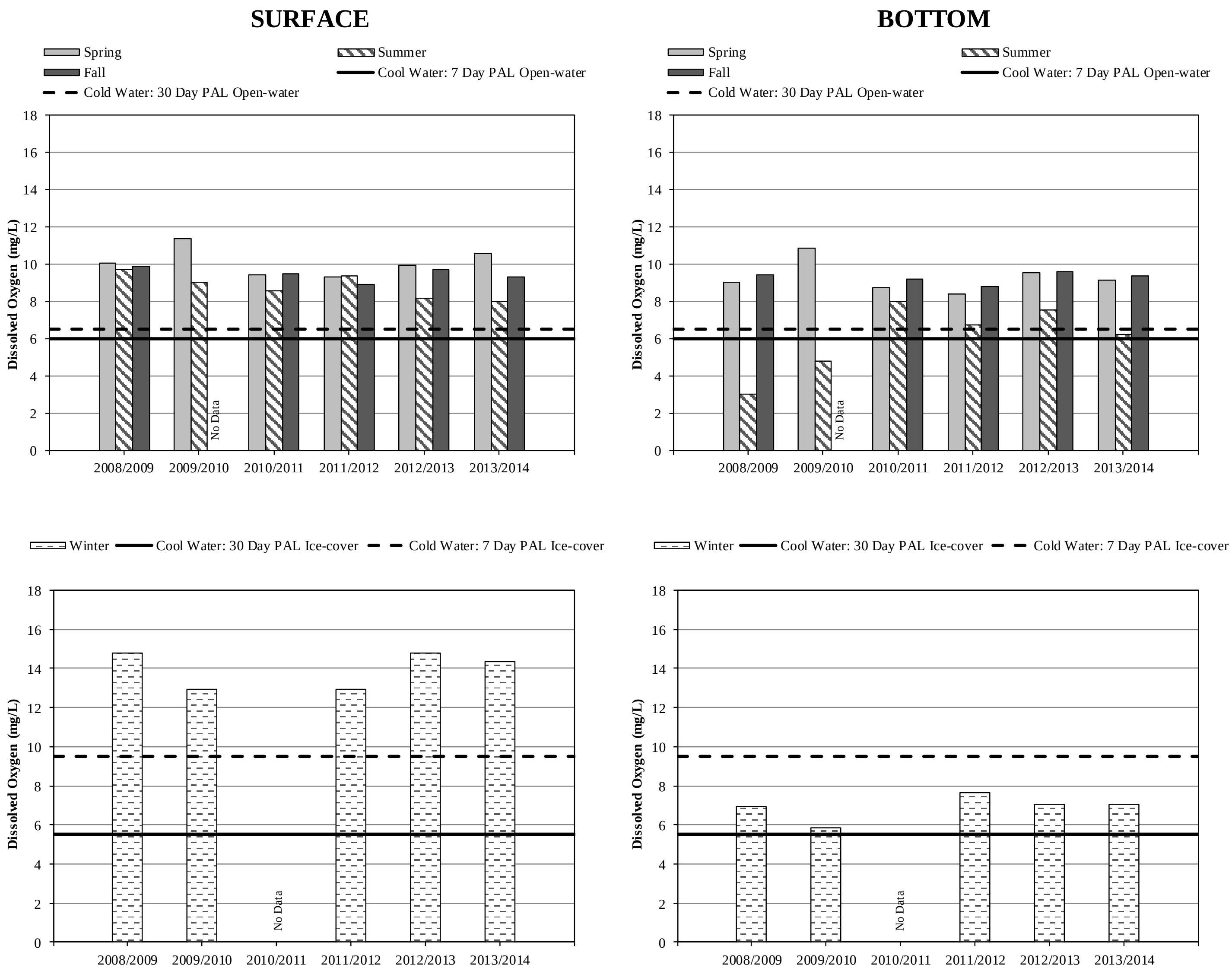


Figure 3-12. Dissolved oxygen measured near the surface and bottom of the water column in Setting Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

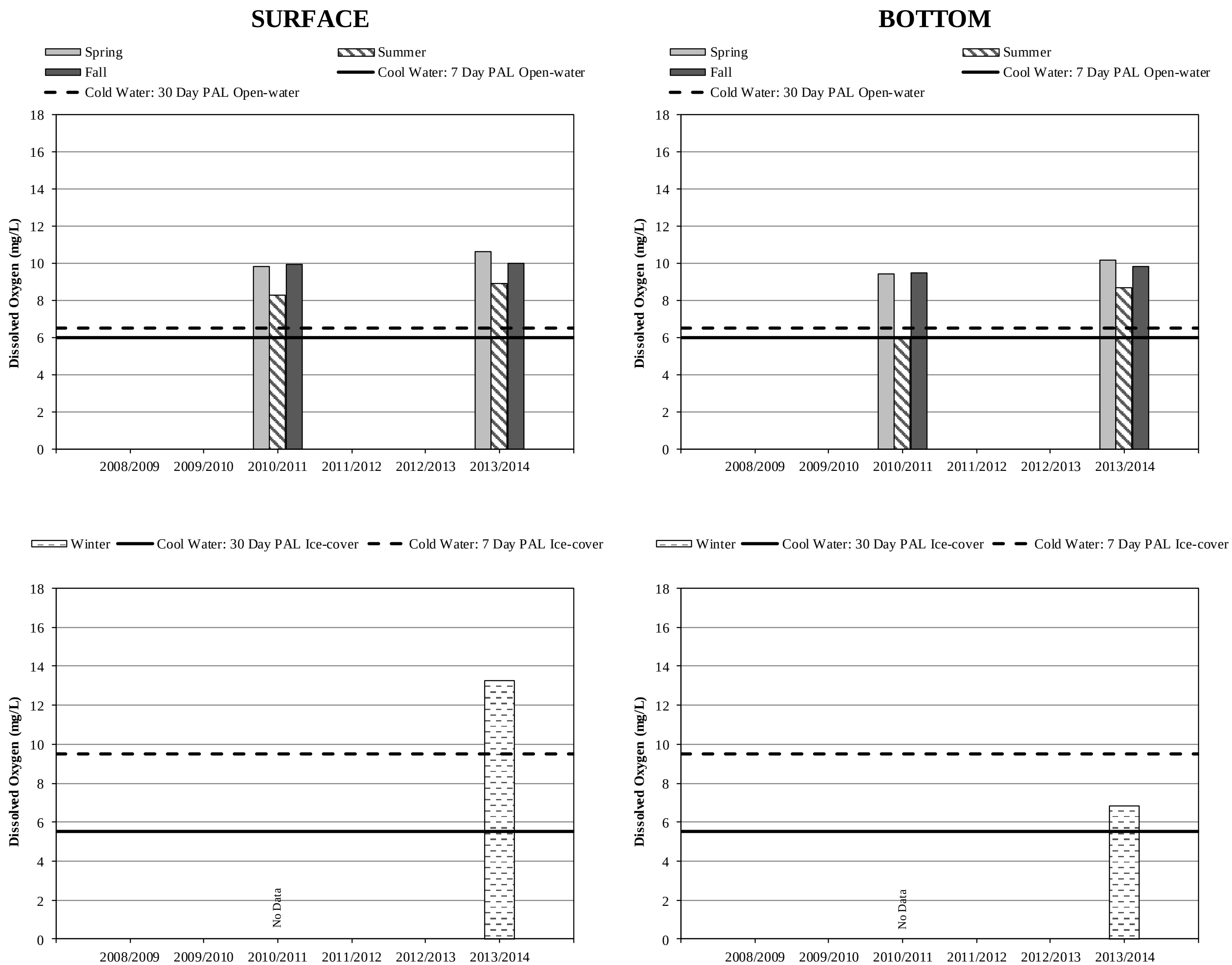


Figure 3-13. Dissolved oxygen measured near the surface and bottom of the water column in Walker Lake and comparisons to MB PAL objectives: 2008/2009-2013/2014.

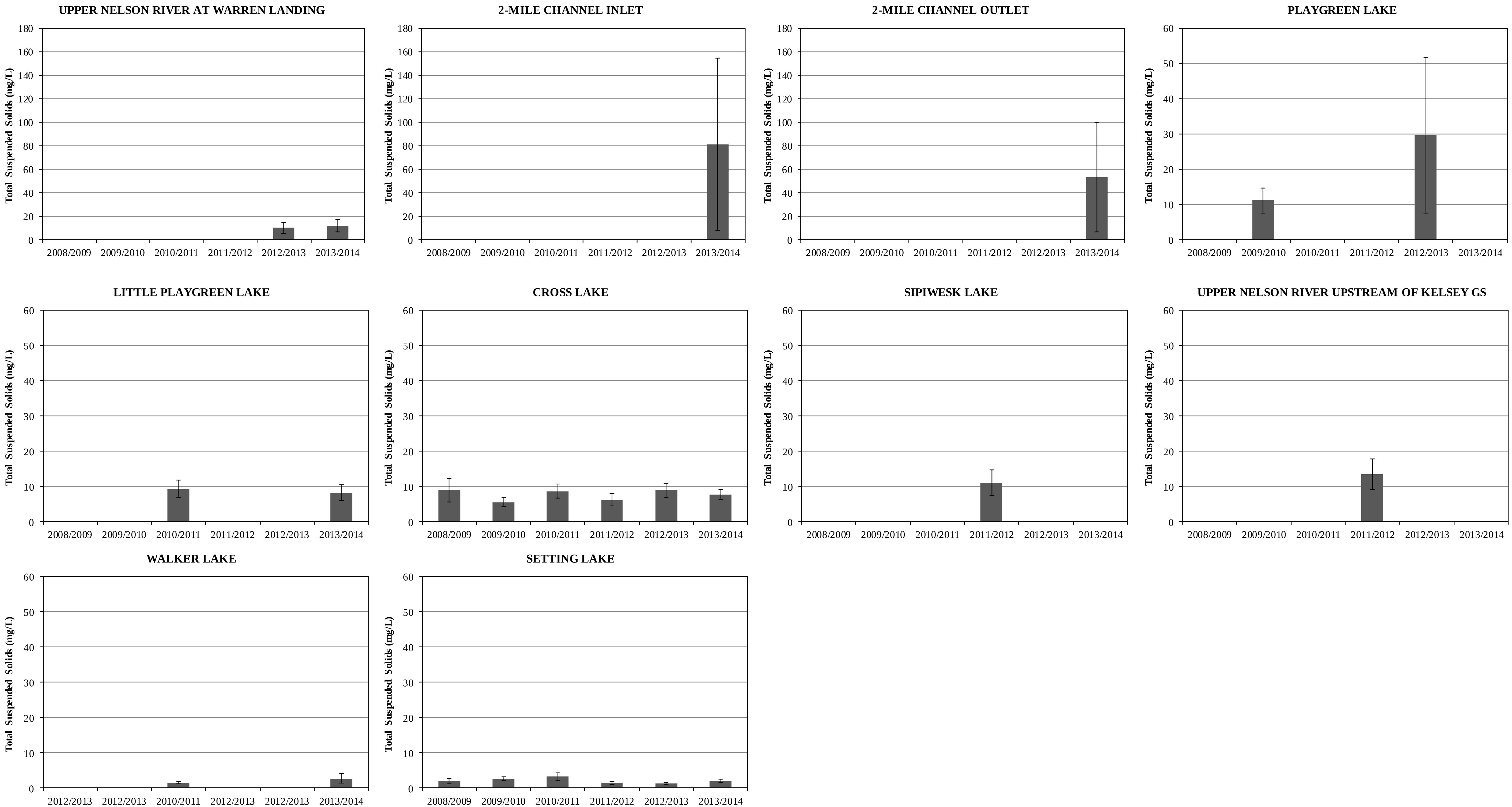


Figure 3-14. Total suspended solids (mean±SE) measured in the Upper Nelson River Region: 2008/2009-2013/2014. Note the difference in scale for the Lake Winnipeg outflow sites.

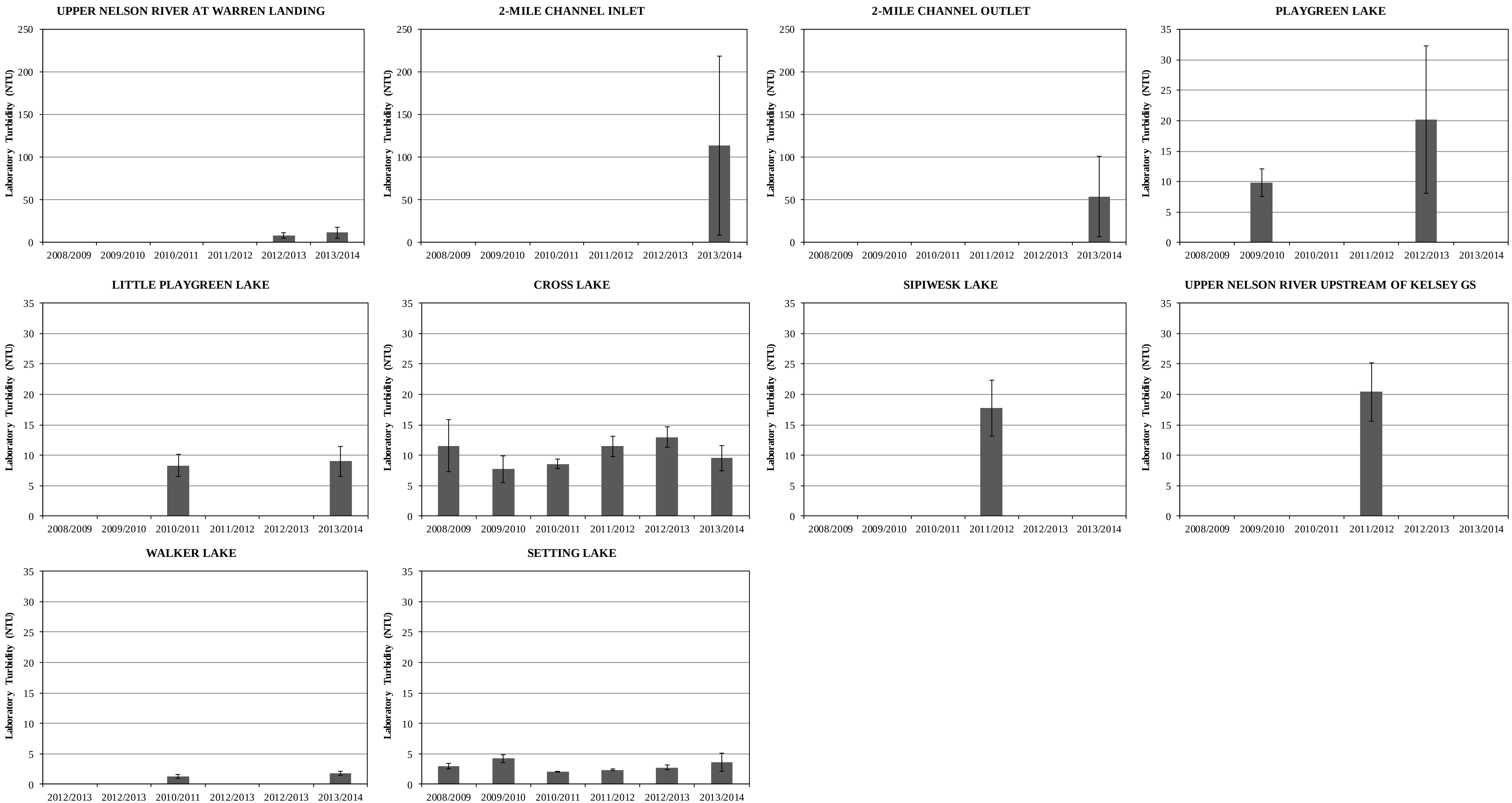
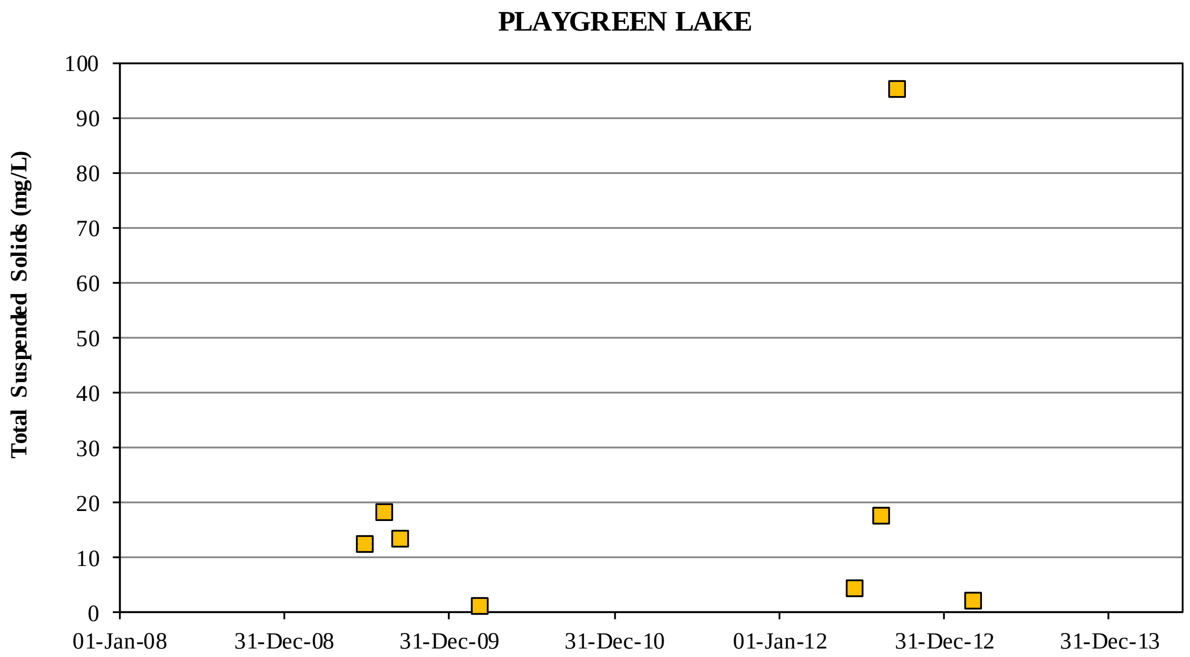


Figure 3-15. Laboratory turbidity (mean±SE) measured in the Upper Nelson River Region: 2008/2009-2013/2014. Note the difference in scale for the Lake Winnipeg outflow sites.



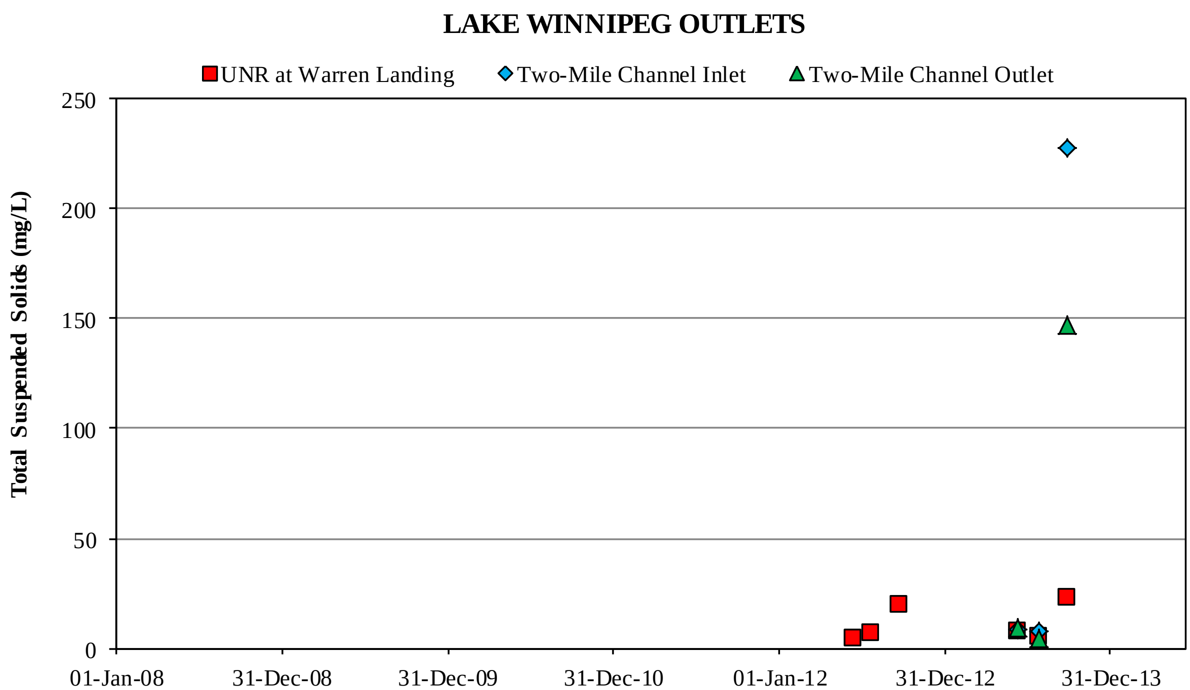


Figure 3-16. Scatterplots of TSS in Playgreen Lake and the outlets of Lake Winnipeg. Note the differences in scale between the figures.

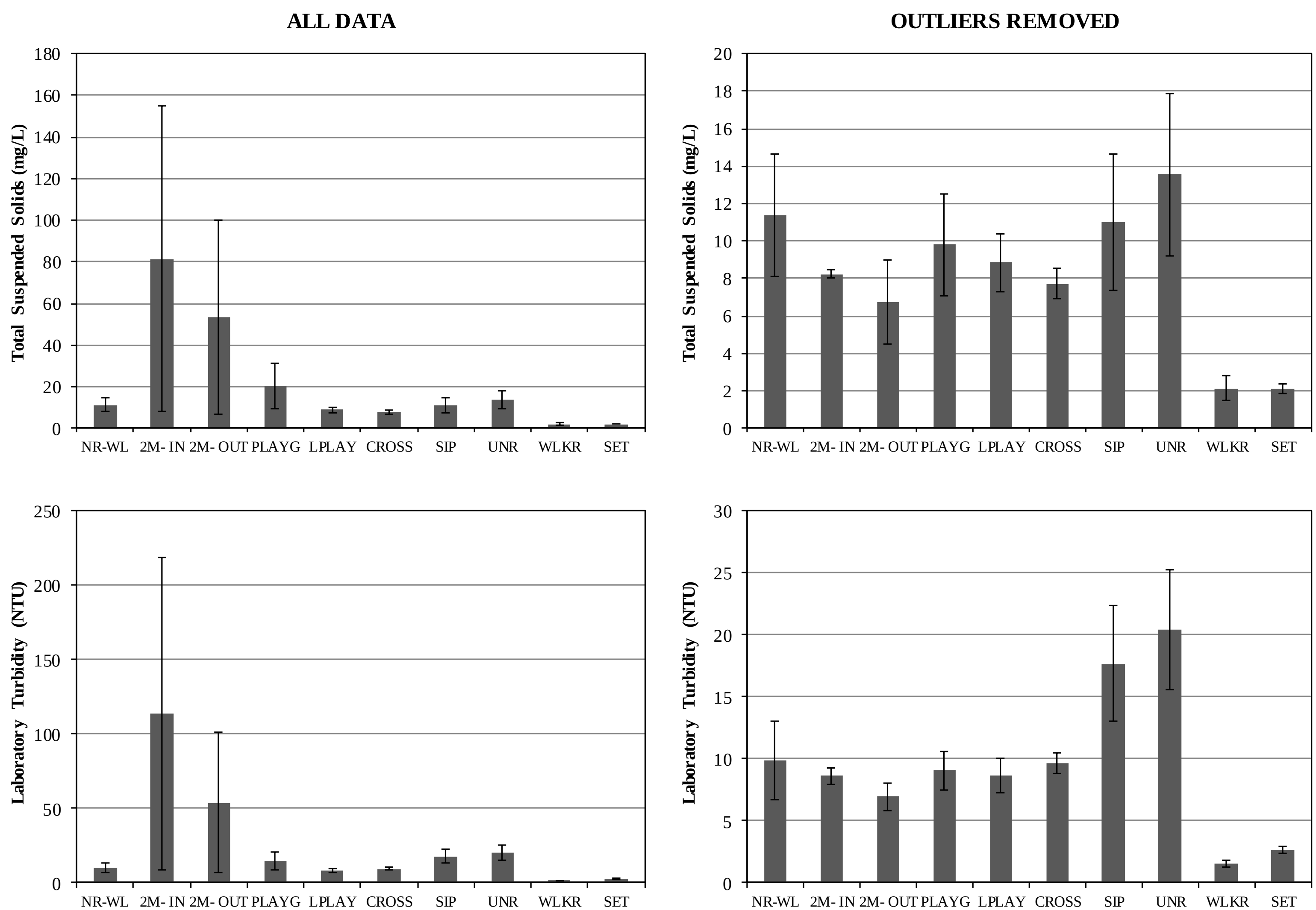


Figure 3-17. TSS and laboratory turbidity (mean±SE) measured in the Upper Nelson River Region: 2008/2009-2013/2014. Figures on the left include all measurements; figures on the right exclude the outliers measured at Playgreen Lake and Two-Mile Channel.

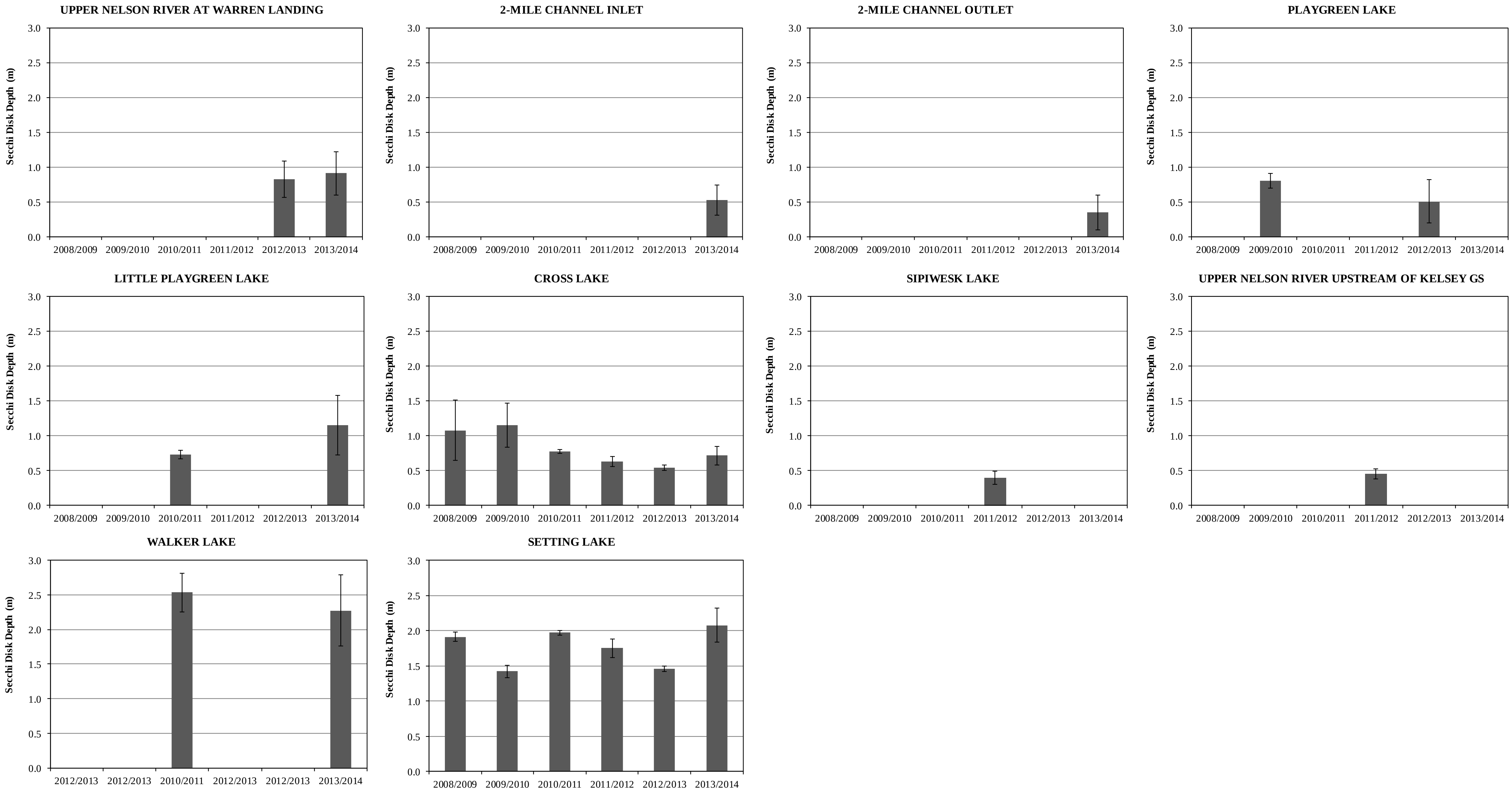


Figure 3-18. Secchi disk depths (mean±SE) measured in Upper Nelson River Region: 2008/2009-2013/2014 (open-water season).

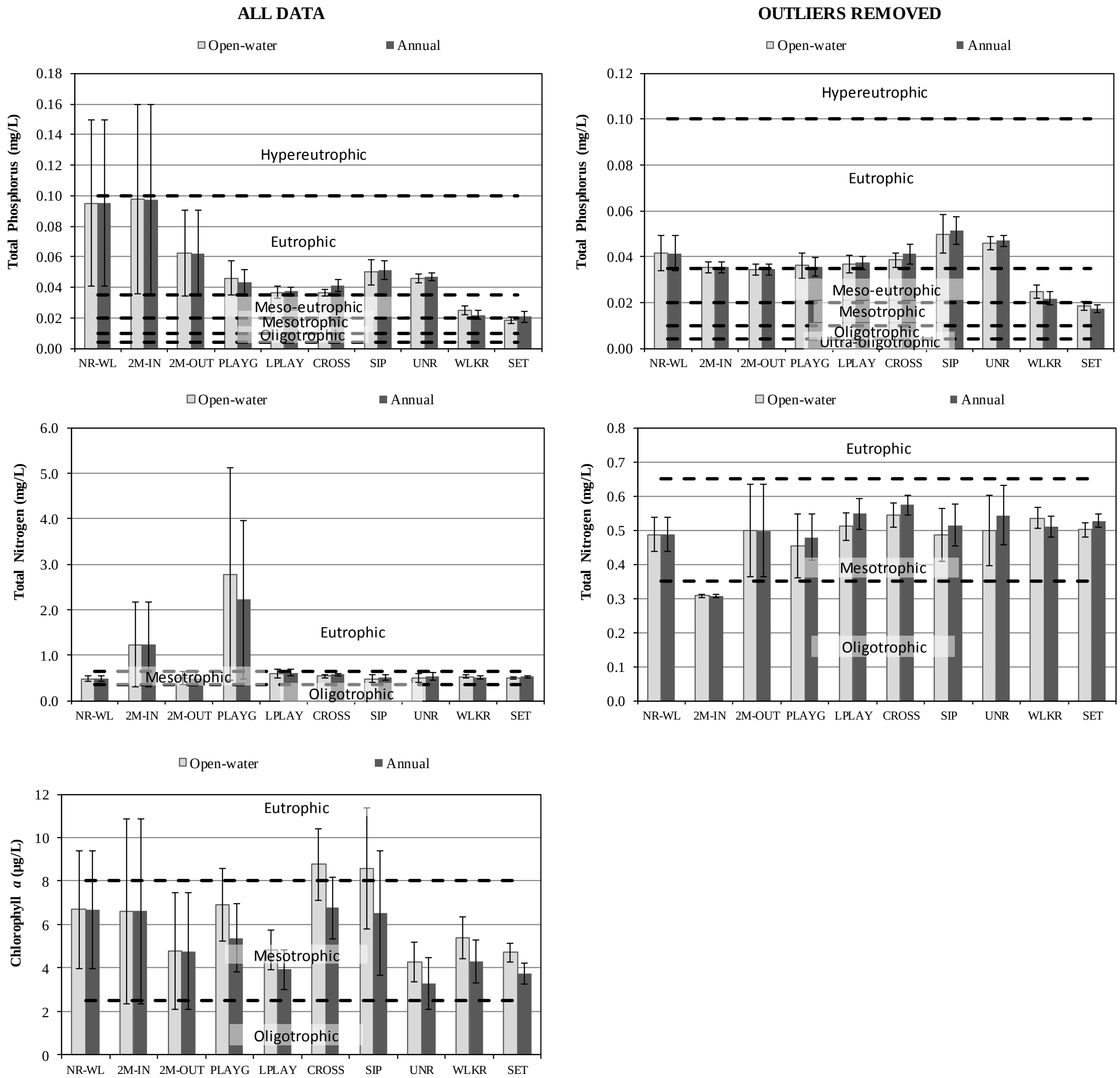


Figure 3-19. TP, TN and chlorophyll *a* (mean±SE) measured in the Upper Nelson River Region: 2008/2009-2013/2014. Figures on the left include all measurements; figures on the right exclude outliers.

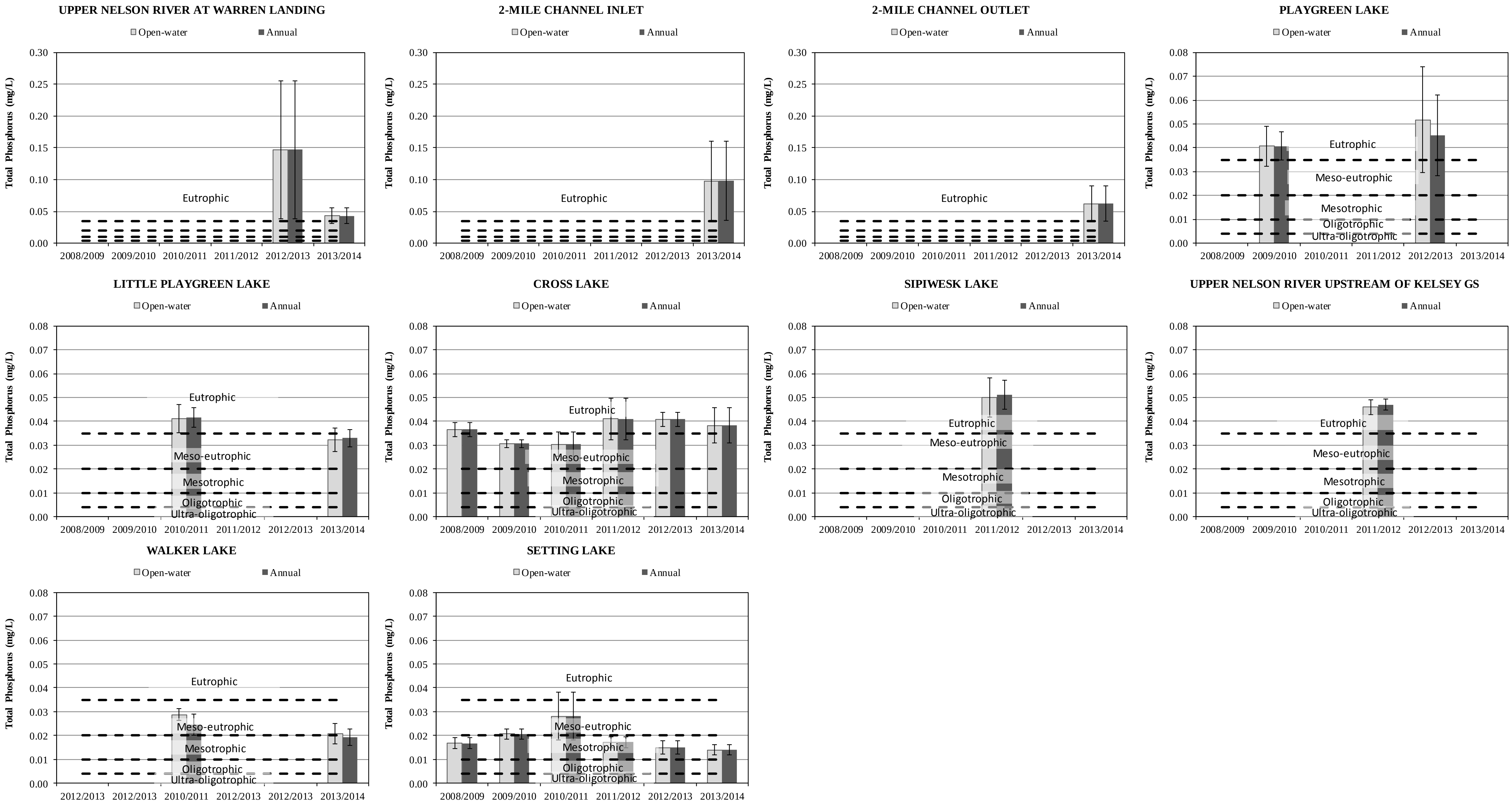
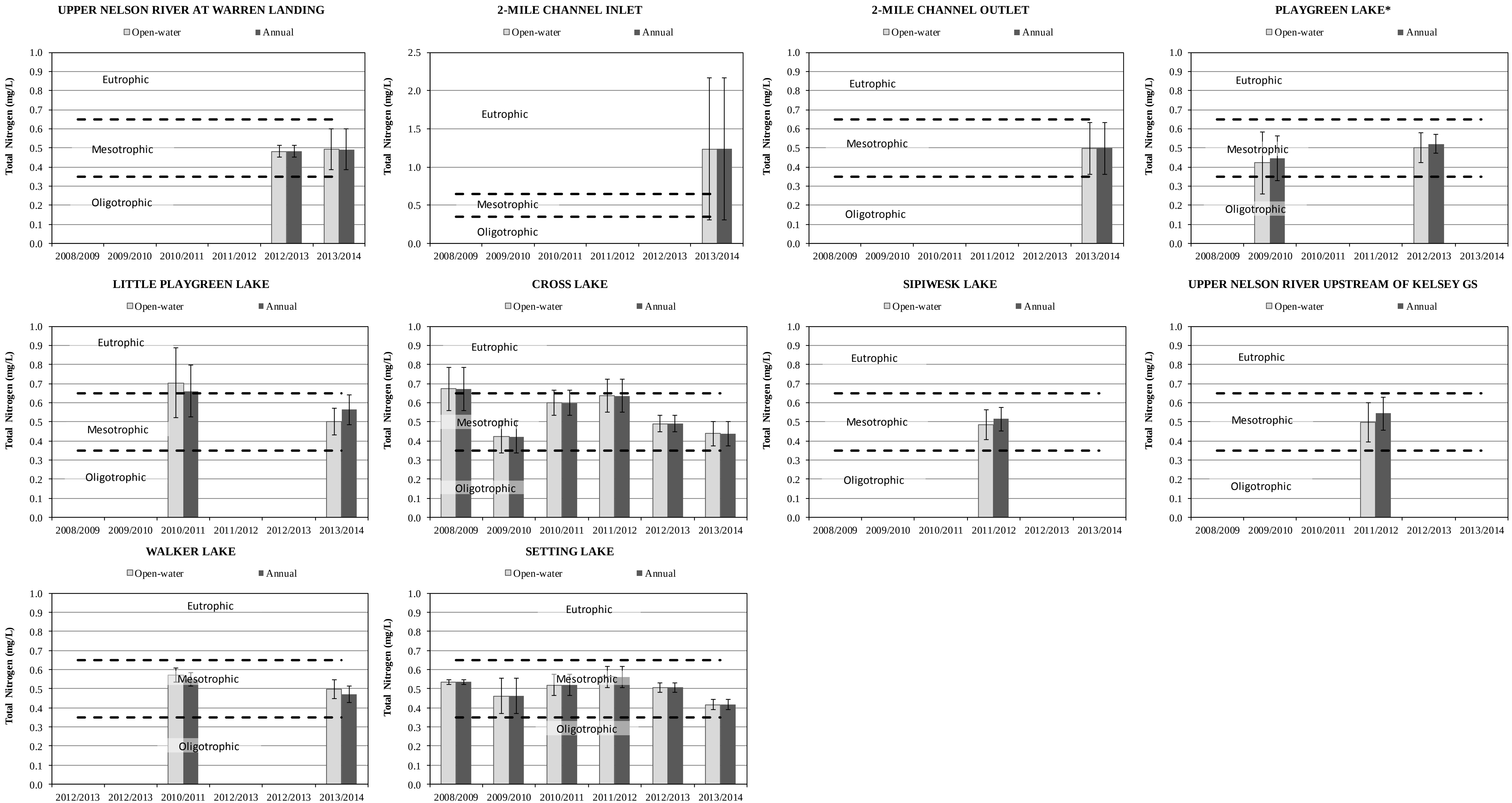


Figure 3-20. Total phosphorus (mean±SE) measured in the Upper Nelson River Region and comparison to trophic categories: 2008/2009-2013/2014.



*Outlier of 14.5 mg/L (August 2012) removed.

Figure 3-21. Total nitrogen (mean±SE) measured in the Upper Nelson River Region and comparison to trophic categories: 2008/2009-2013/2014.

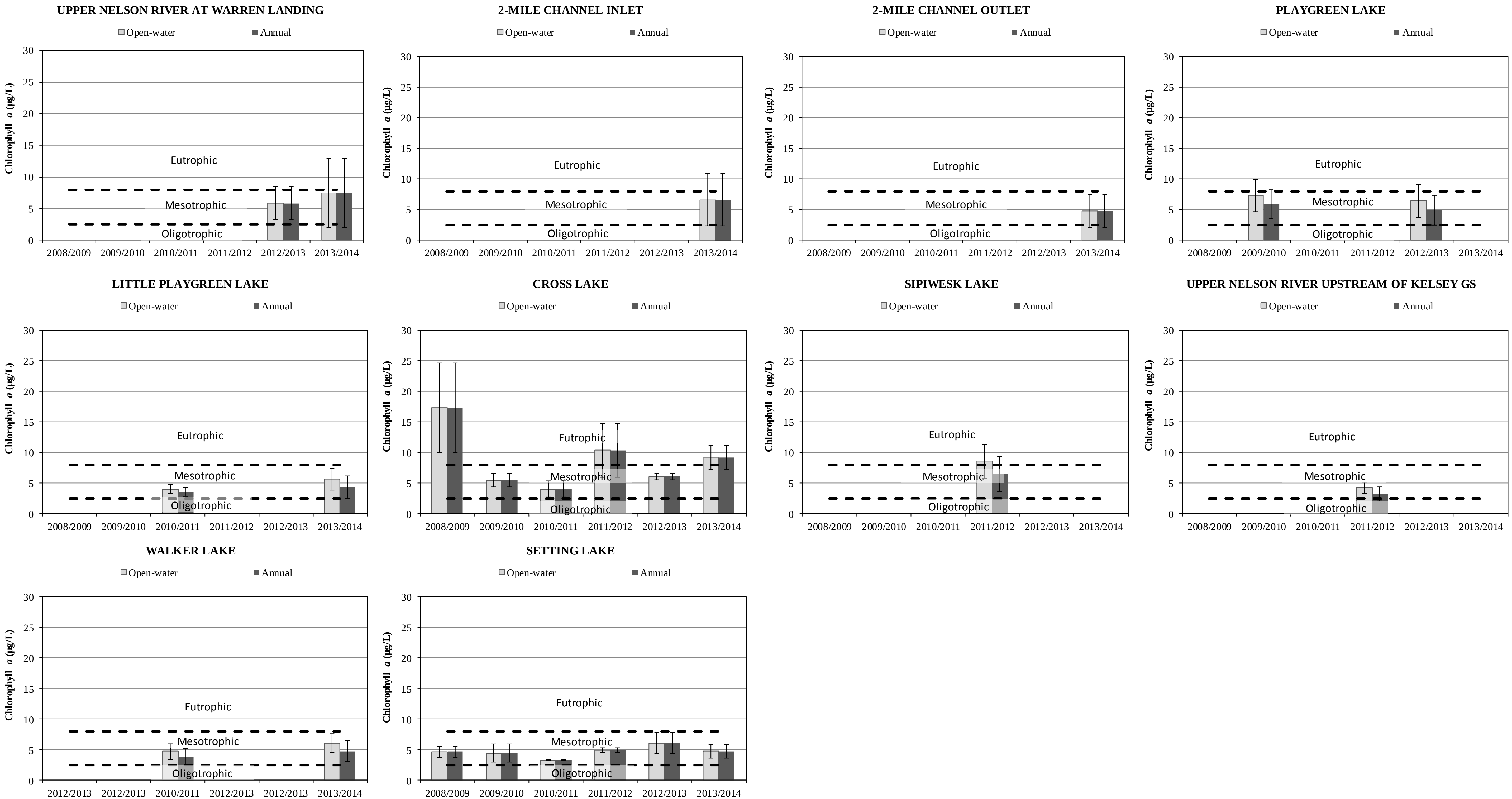


Figure 3-22. Chlorophyll *a* (mean±SE) measured in the Upper Nelson River Region and comparison to trophic categories: 2008/2009-2013/2014.

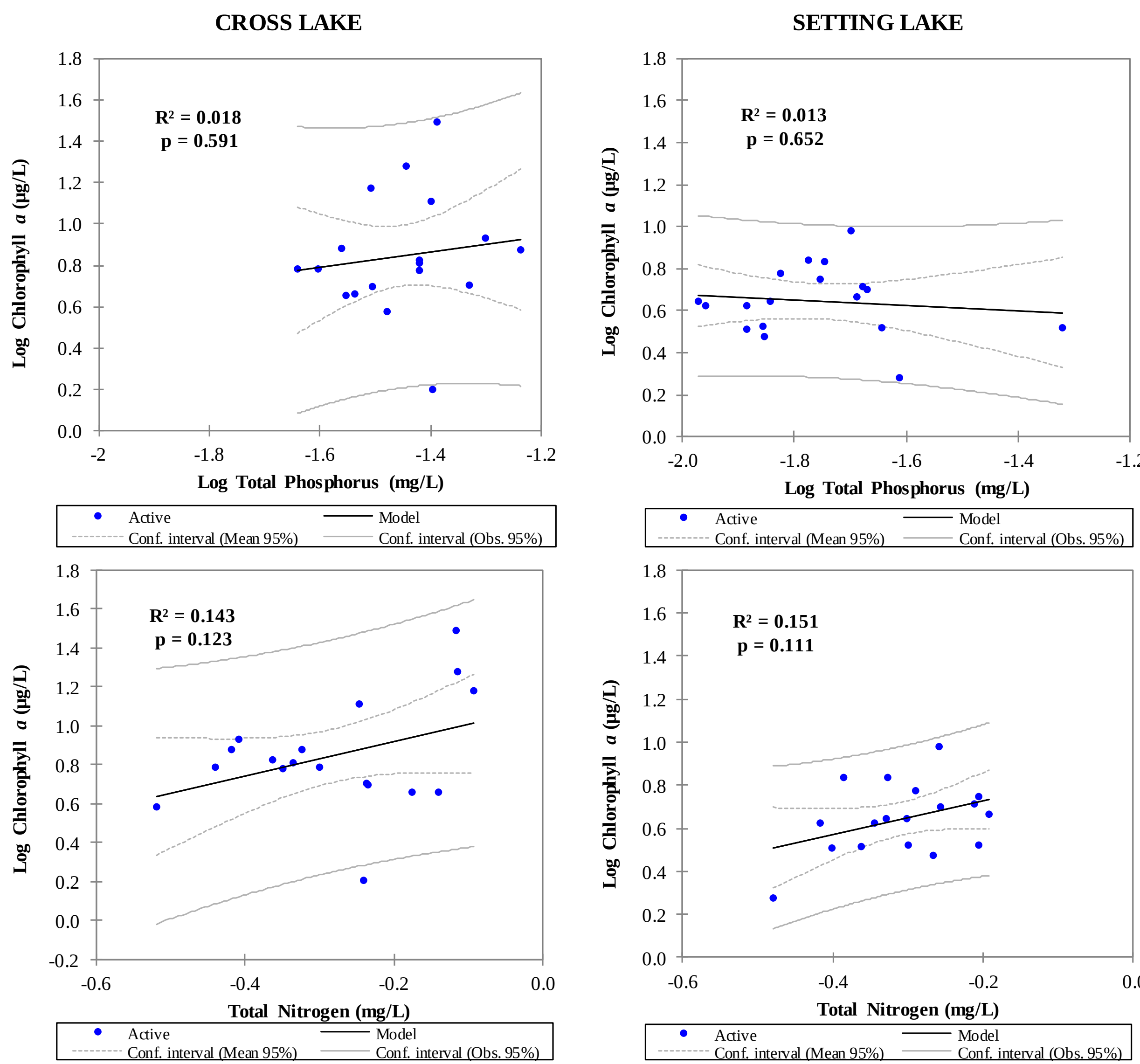


Figure 3-23. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* in Cross Lake (on-system) and Setting Lake (off-system): open-water seasons 2008-2013.

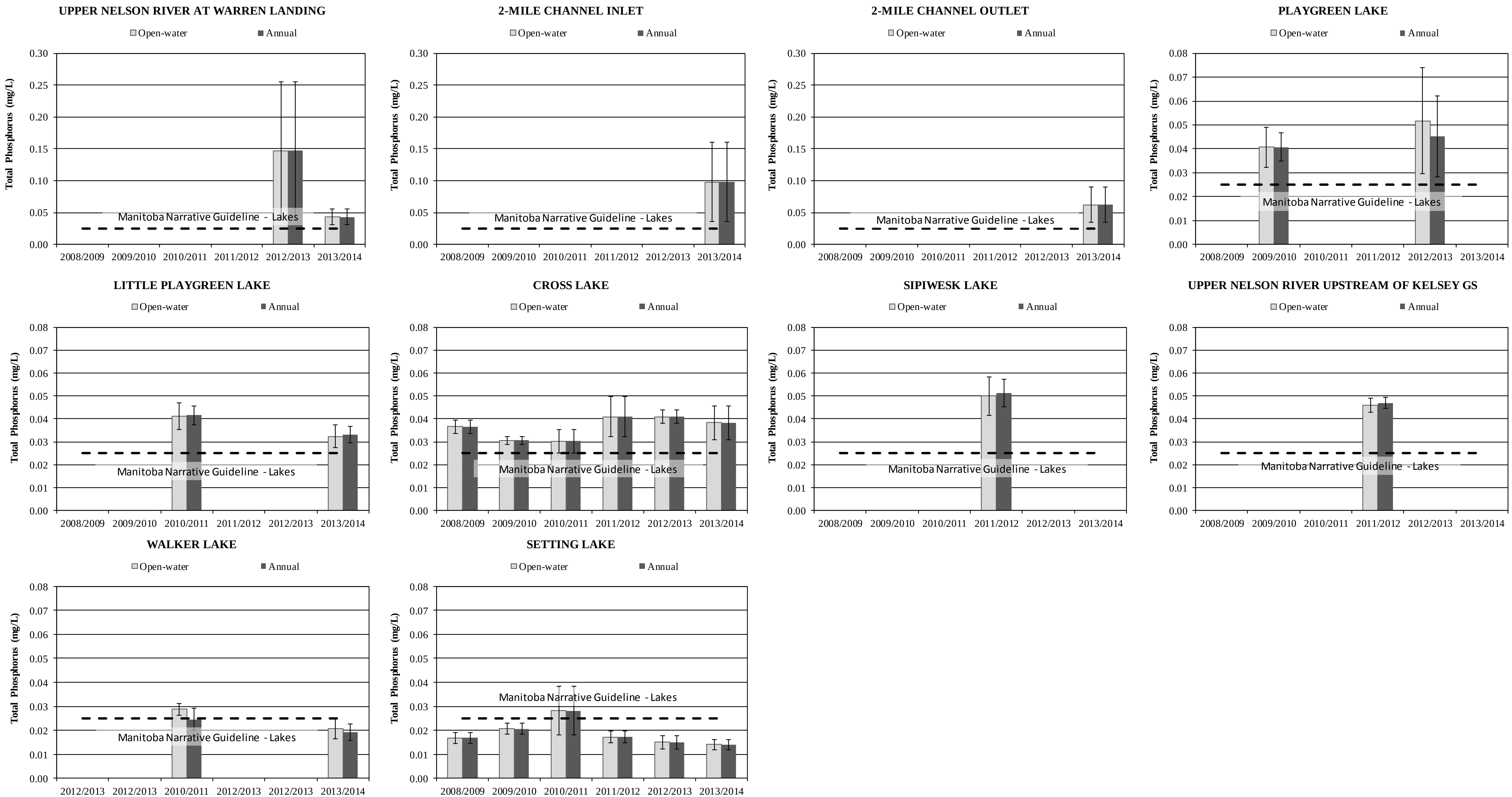


Figure 3-24. Total phosphorus (mean±SE) measured in the Upper Nelson River Region and comparison to the Manitoba narrative nutrient guidelines: 2008/2009-2013/2014.

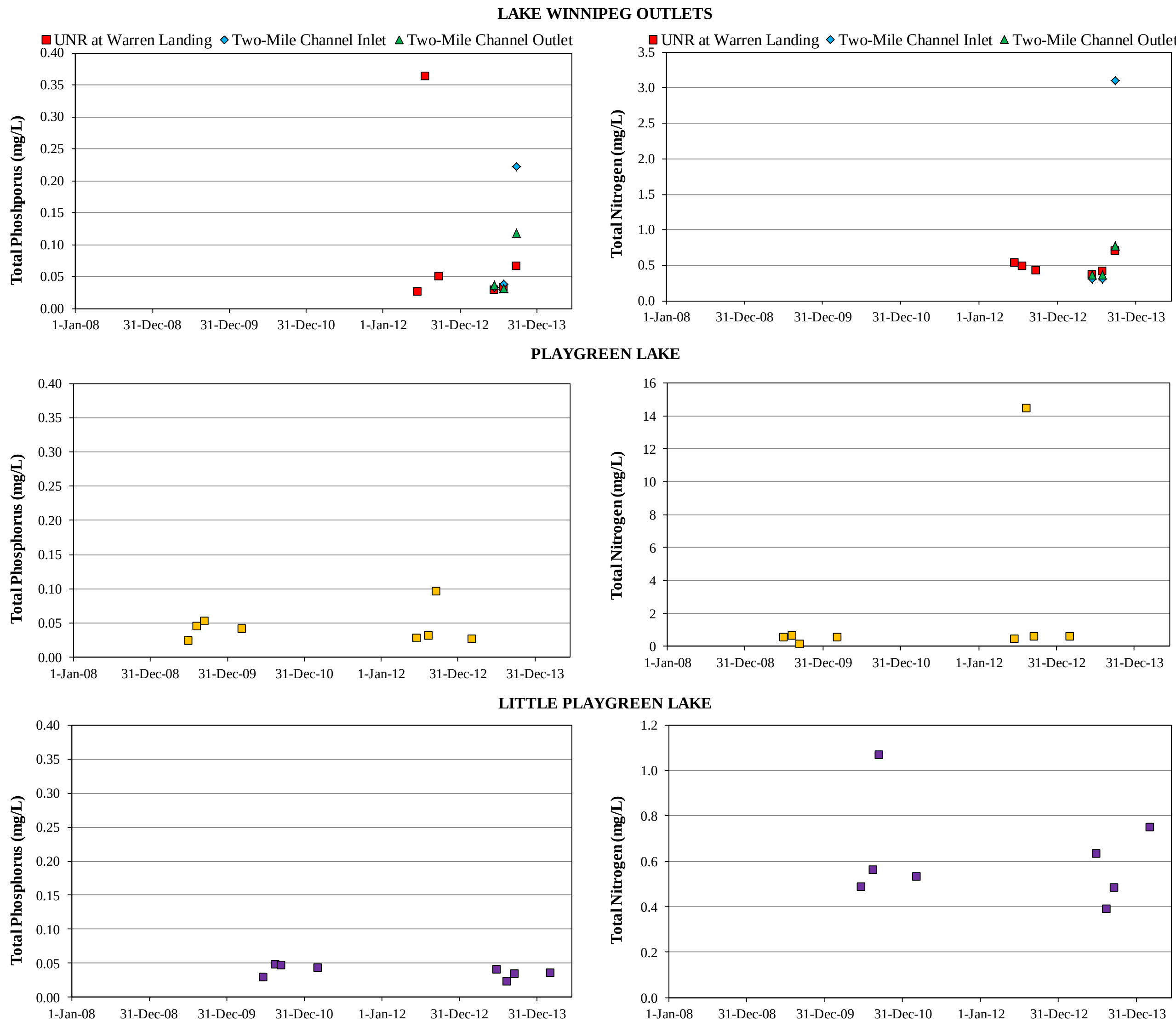
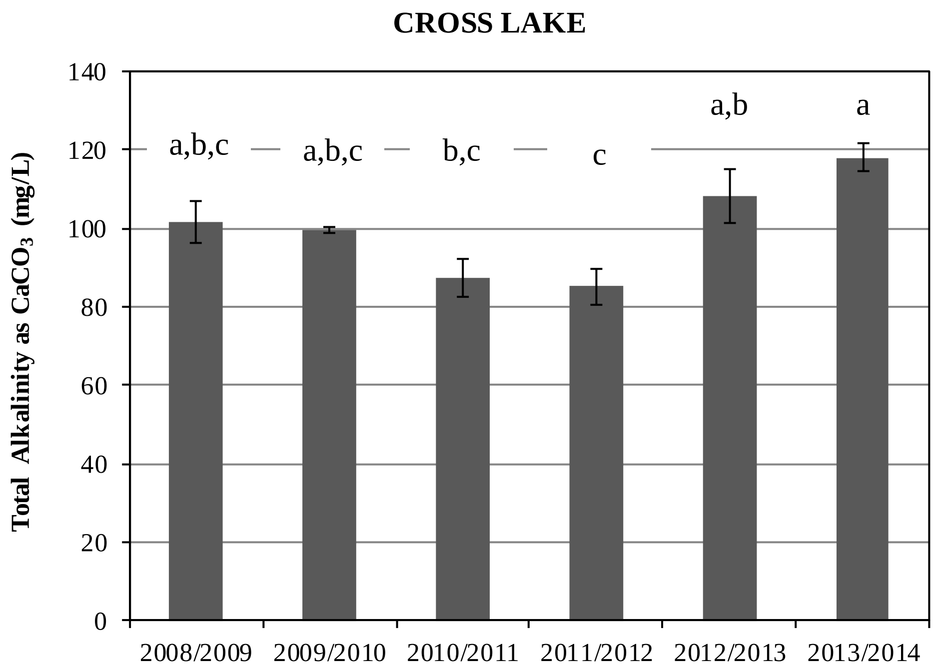


Figure 3-25. Scatterplots of total phosphorus and nitrogen in Little Playgreen Lake, Playgreen Lake and the outlets of Lake Winnipeg.



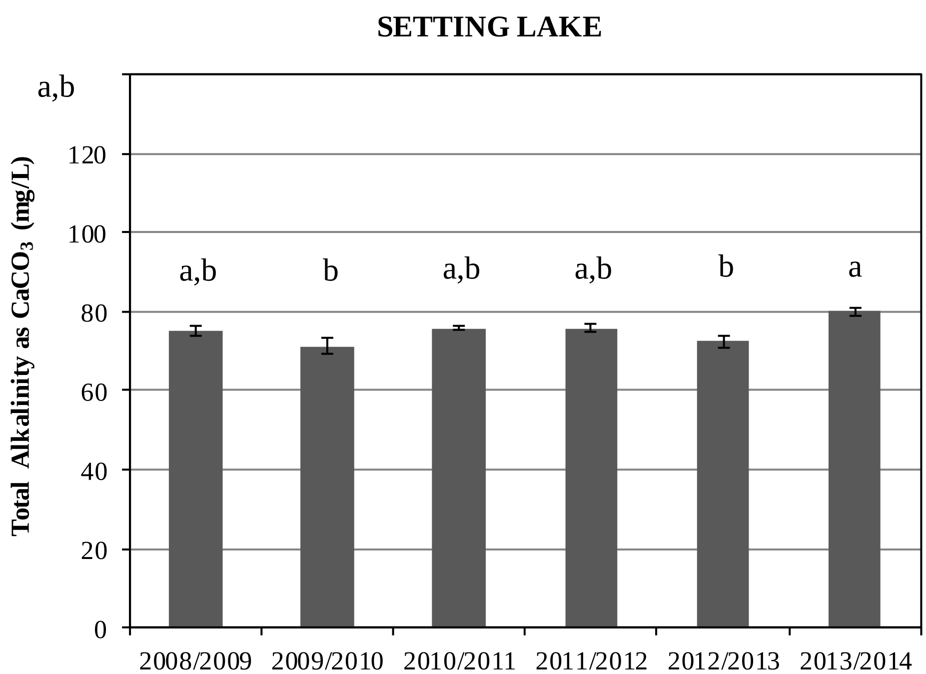


Figure 3-26. Open-water season total alkalinity (mean±SE) at the annual on-system (Cross Lake) and off-system (Setting Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

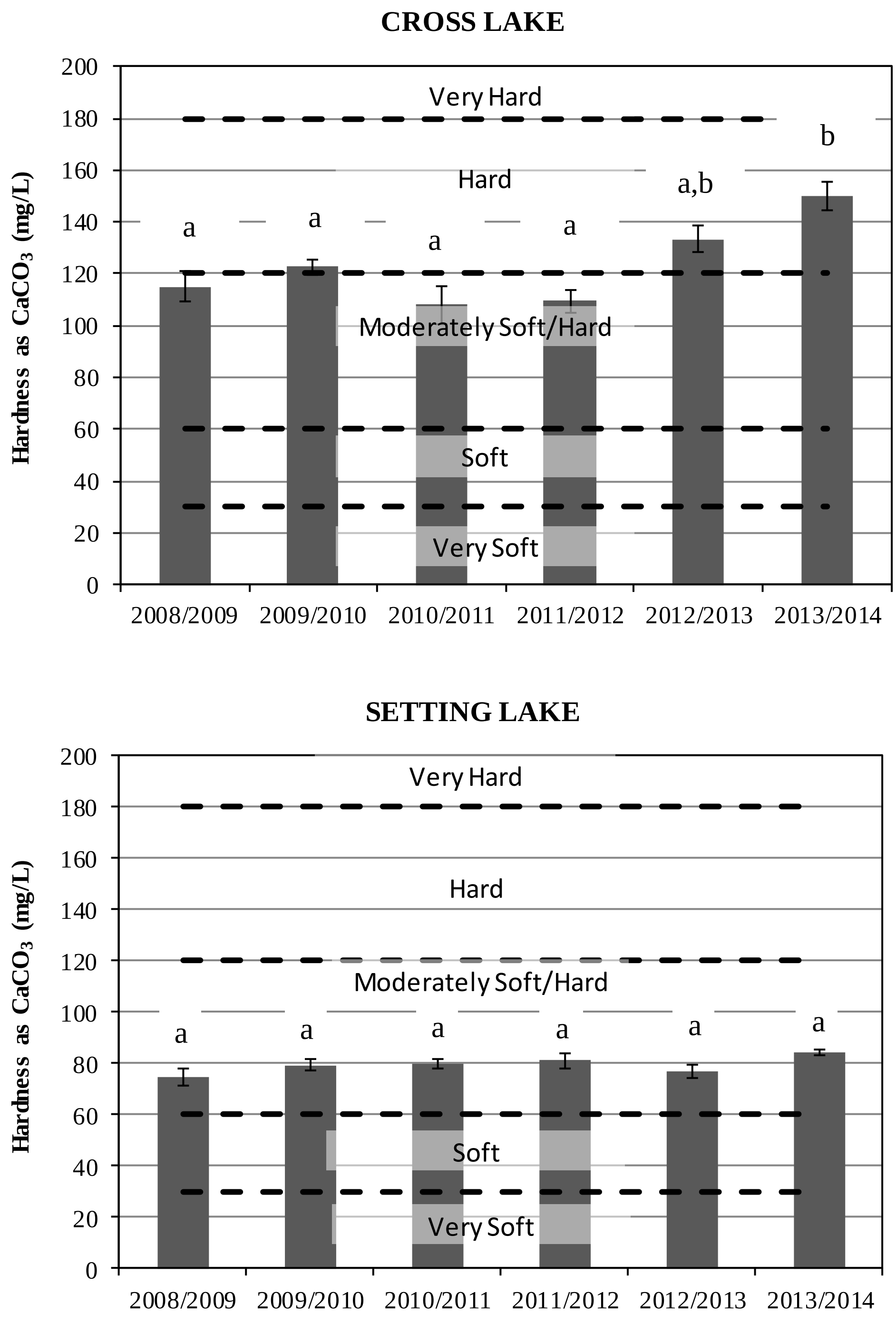
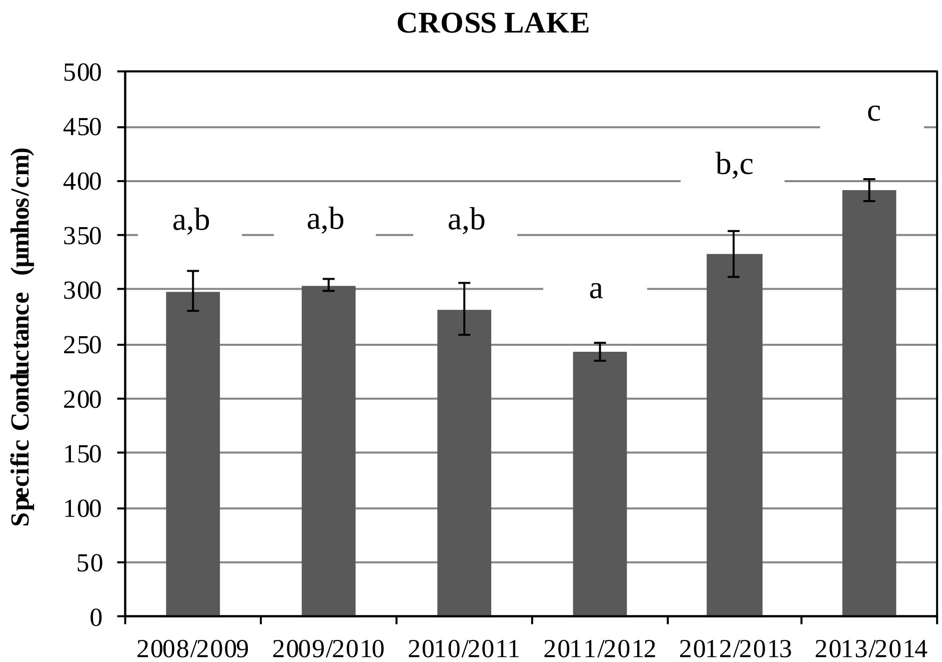


Figure 3-27. Open-water season hardness (mean±SE) at the annual on-system (Cross Lake) and off-system (Setting Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



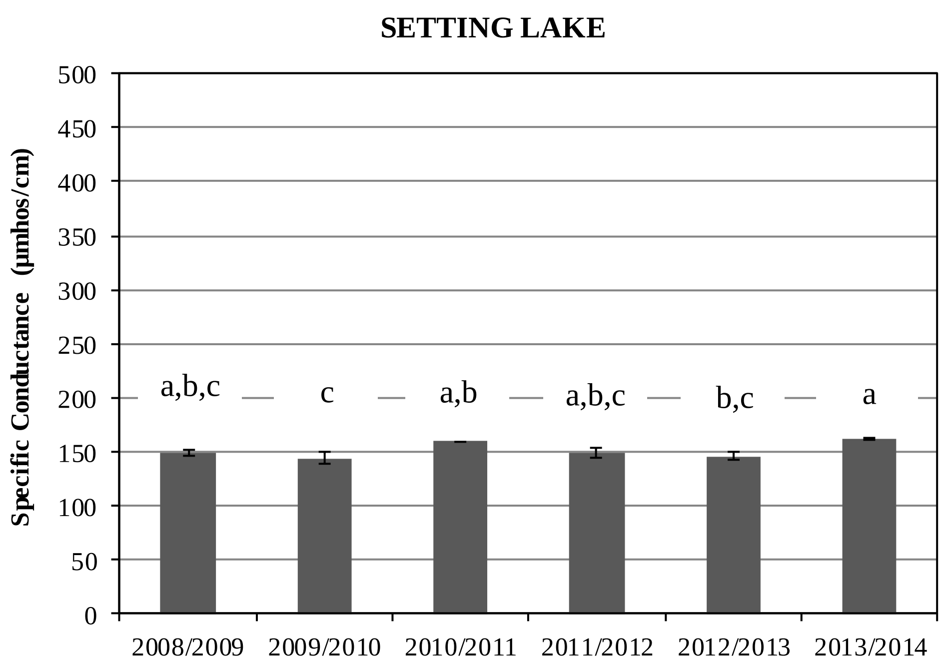


Figure 3-28. Open-water season specific conductance (mean±SE) at the annual on-system (Cross Lake) and off-system (Setting Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

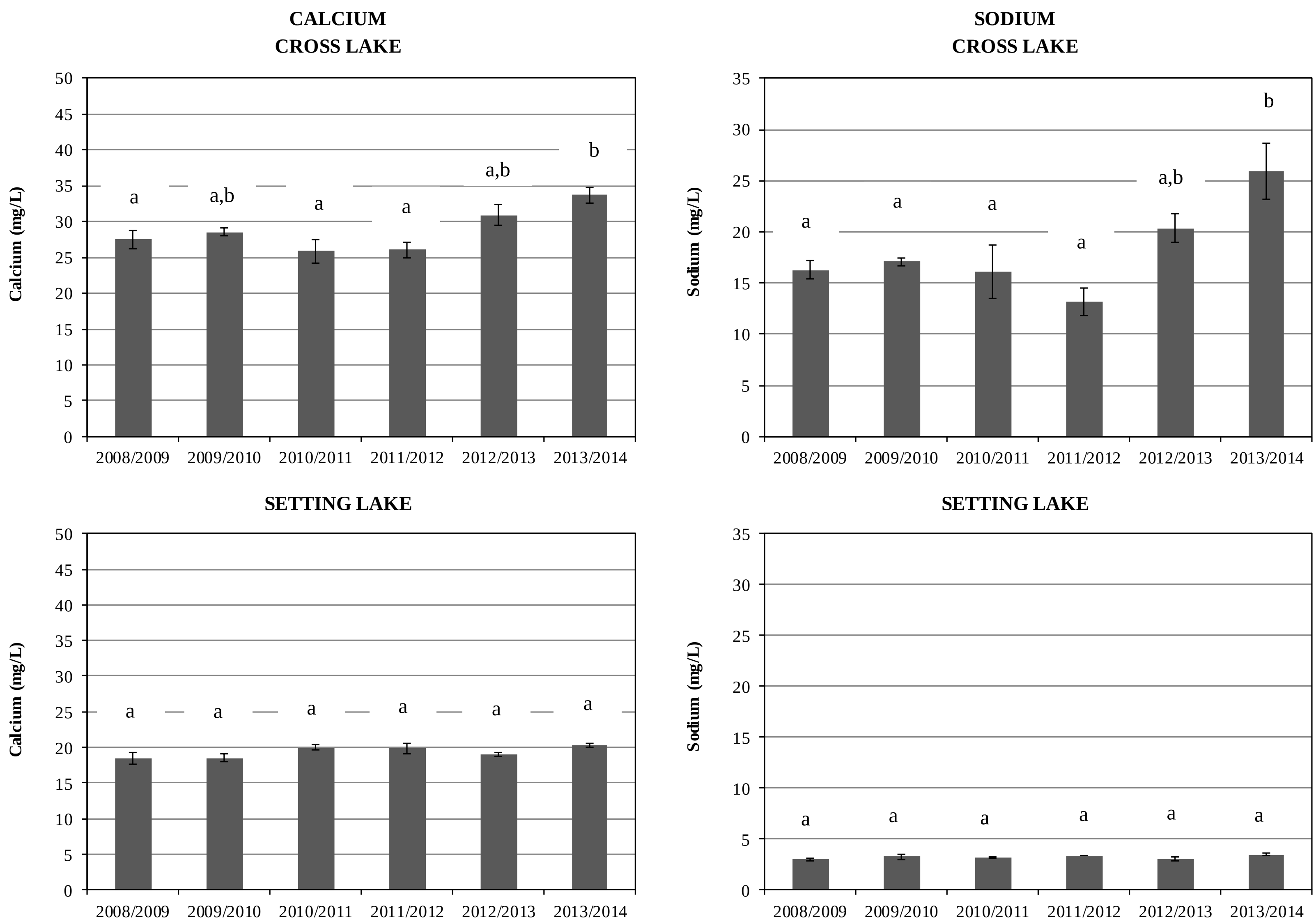


Figure 3-29. Open-water season major cations (calcium and sodium; mean±SE) at the annual on-system (Cross Lake) and off-system (Setting Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

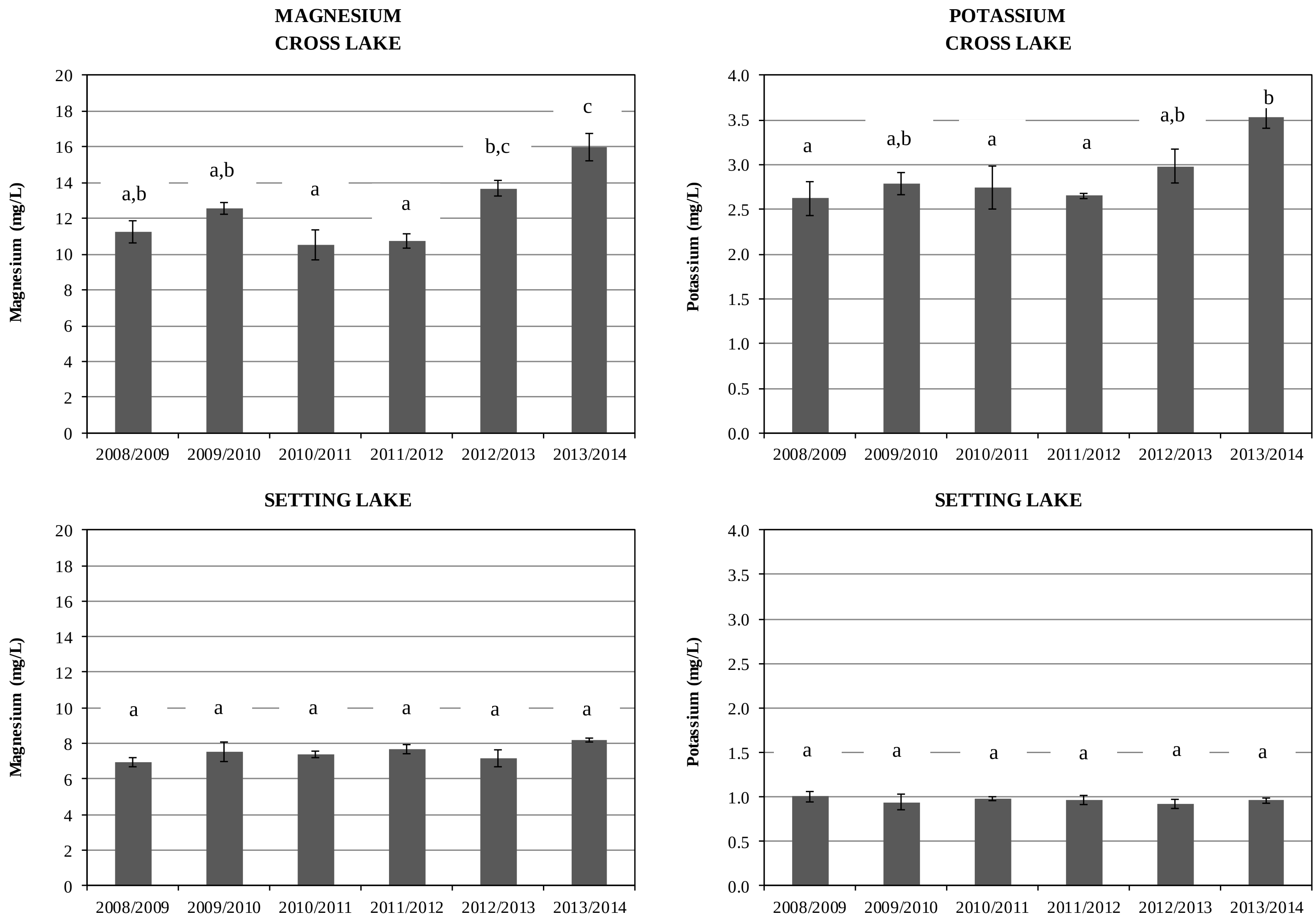


Figure 3-30. Open-water season major cations (magnesium and potassium; mean±SE) at the annual on-system (Cross Lake) and off-system (Setting Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

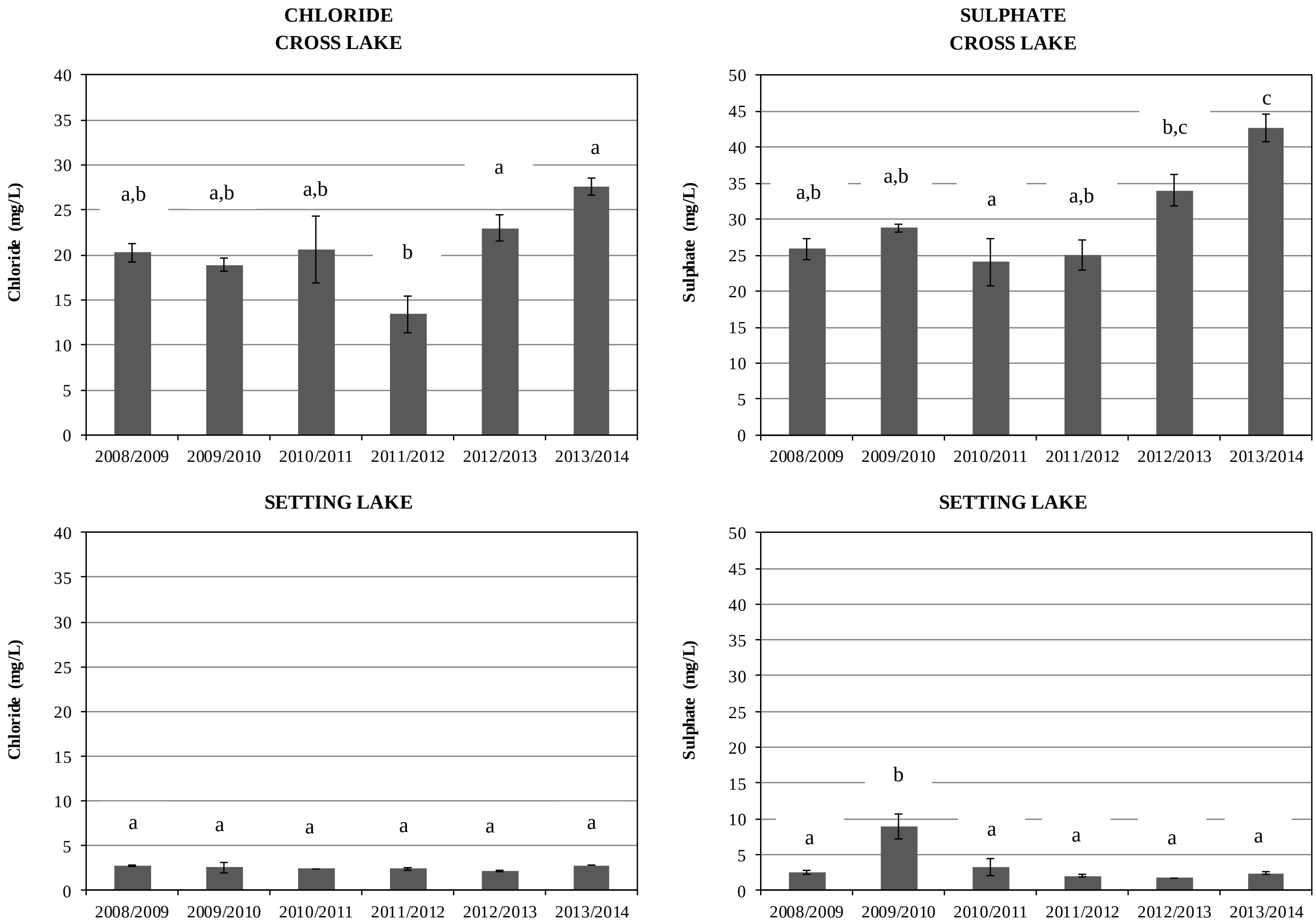
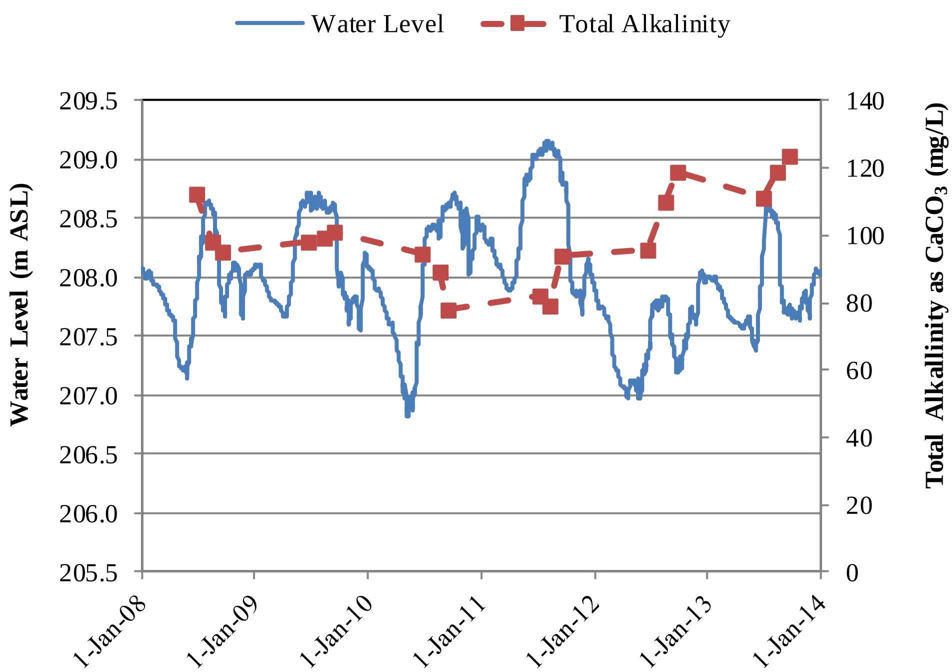


Figure 3-31. Open-water season major anions (chloride and sulphate; mean±SE) at the annual on-system (Cross Lake) and off-system (Setting Lake) sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



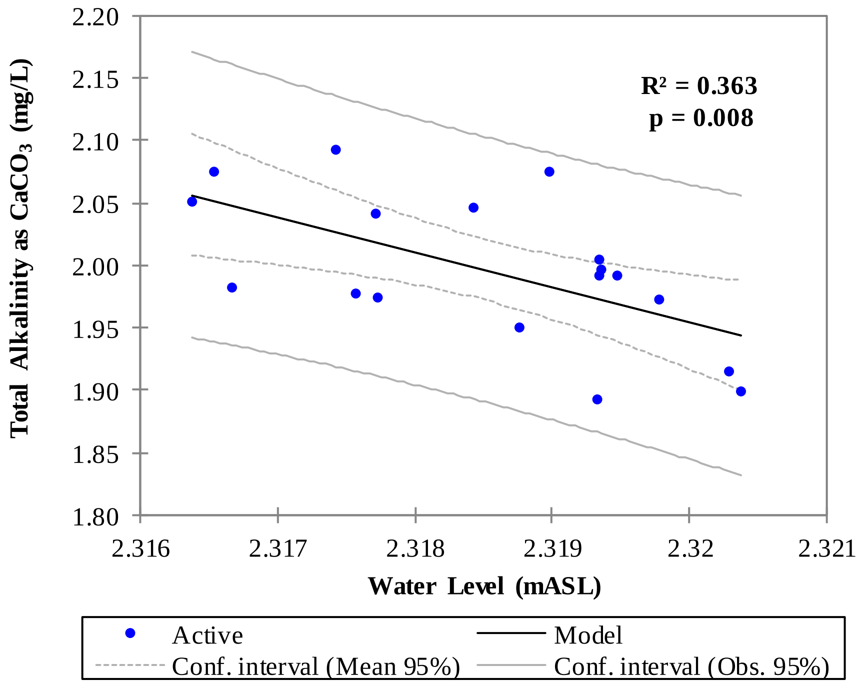


Figure 3-32. Open-water season total alkalinity versus water level in Cross Lake: 2008-2013.

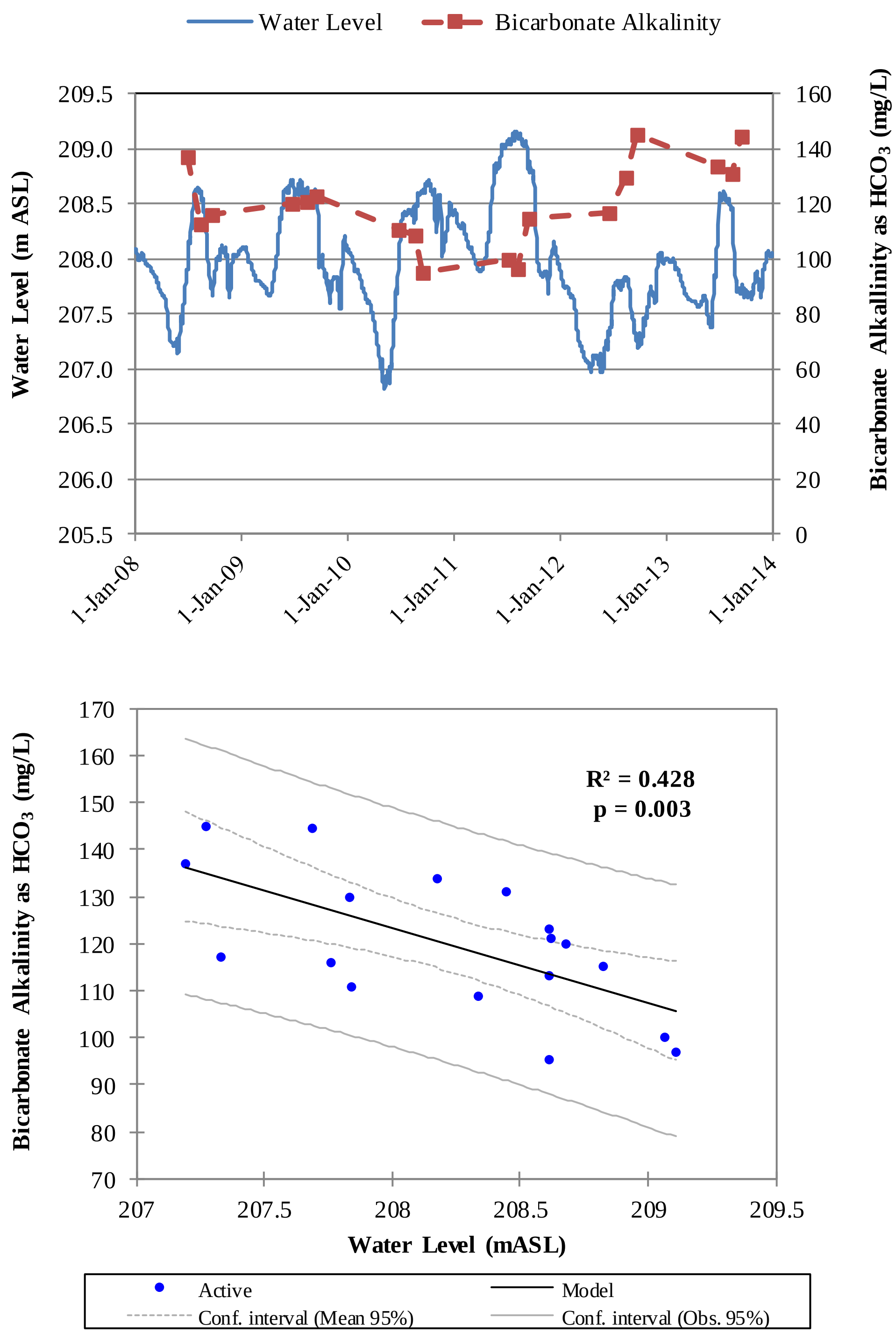


Figure 3-33. Open-water season bicarbonate alkalinity versus water level in Cross Lake: 2008-2013.

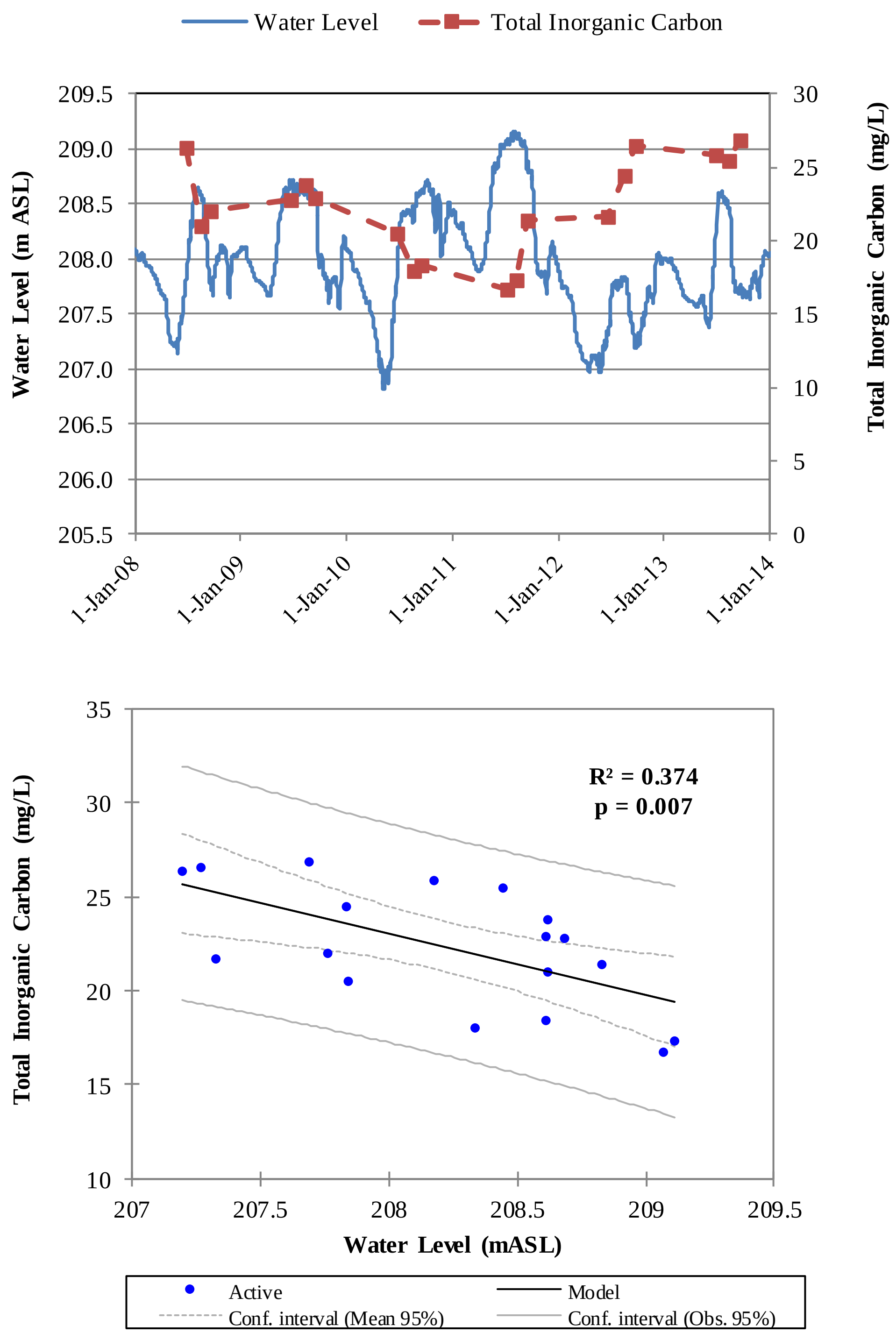


Figure 3-34. Open-water season total inorganic carbon versus water level in Cross Lake: 2008-2013.

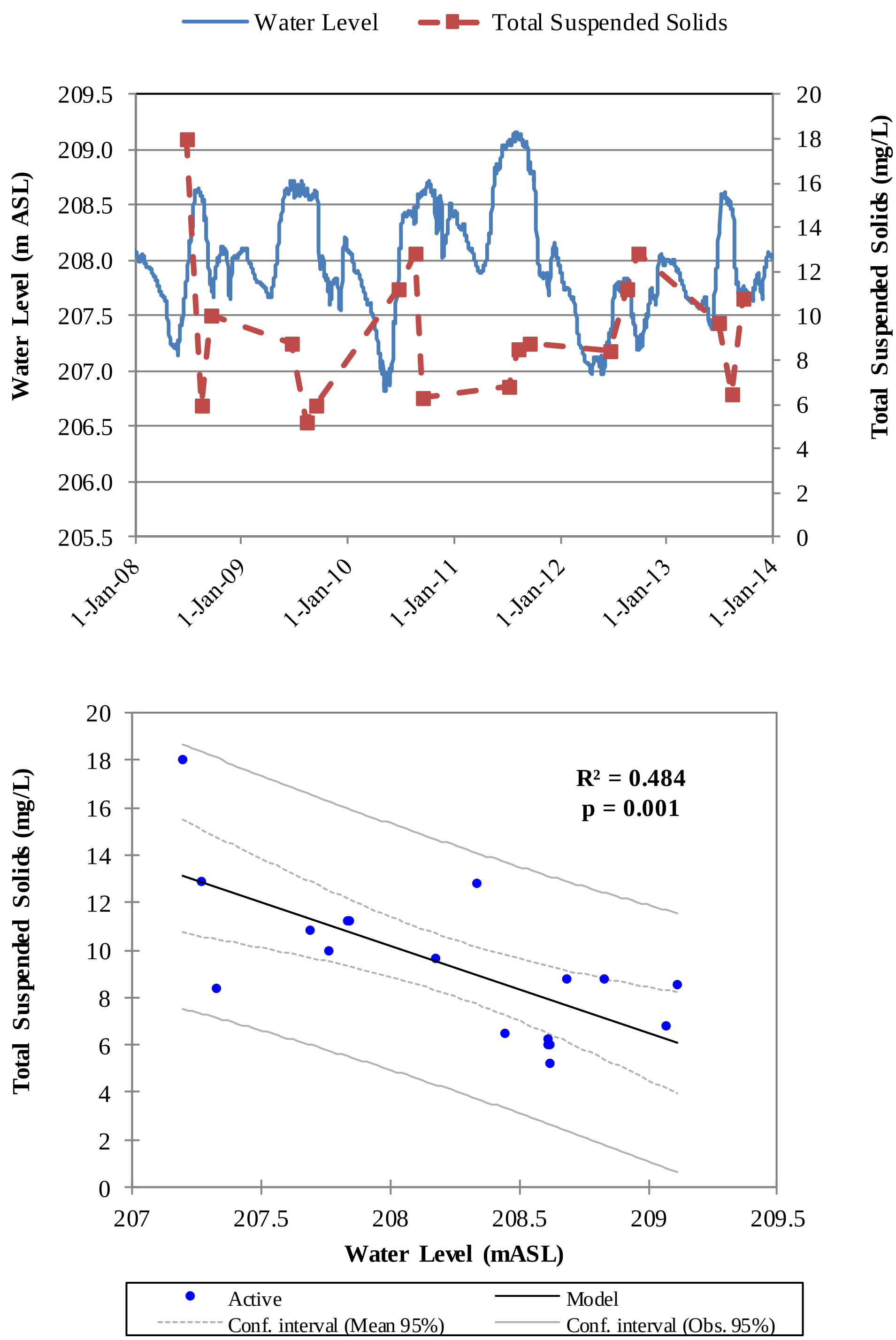


Figure 3-35. Open-water season total suspended solids versus water level in Cross Lake: 2008-2013.

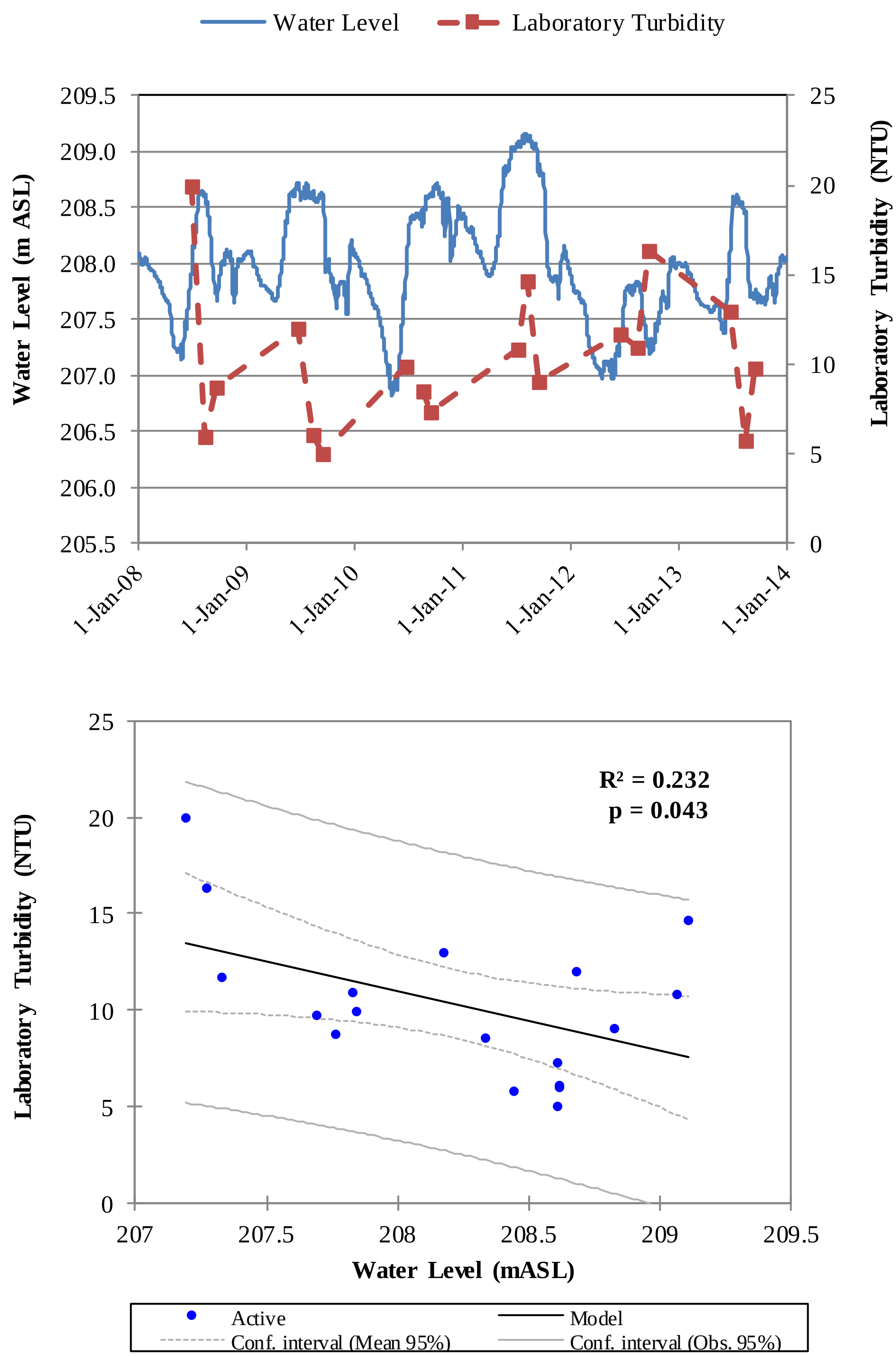
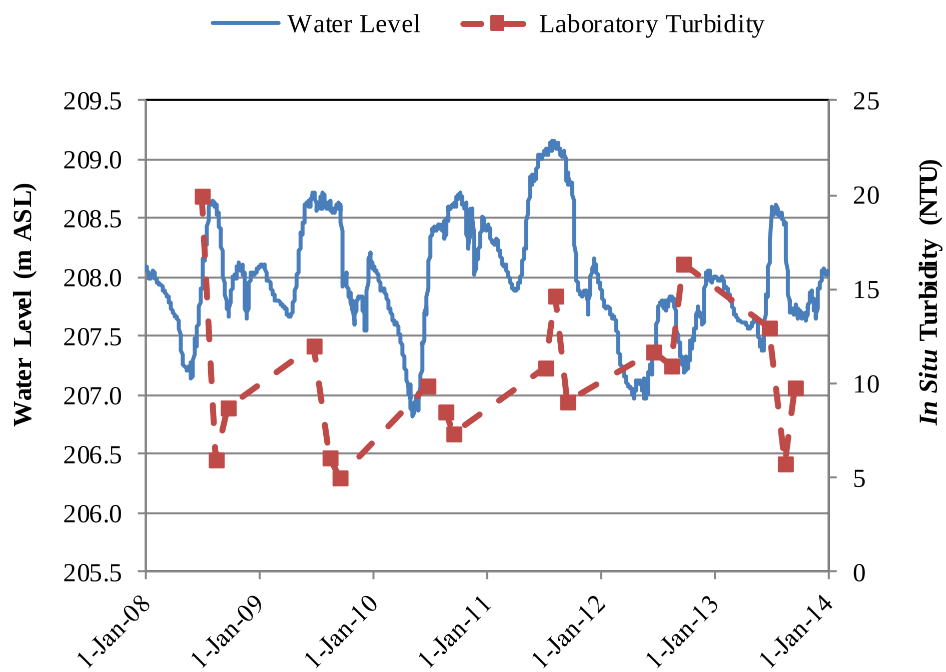


Figure 3-36. Open-water season laboratory turbidity versus water level in Cross Lake: 2008-2013.



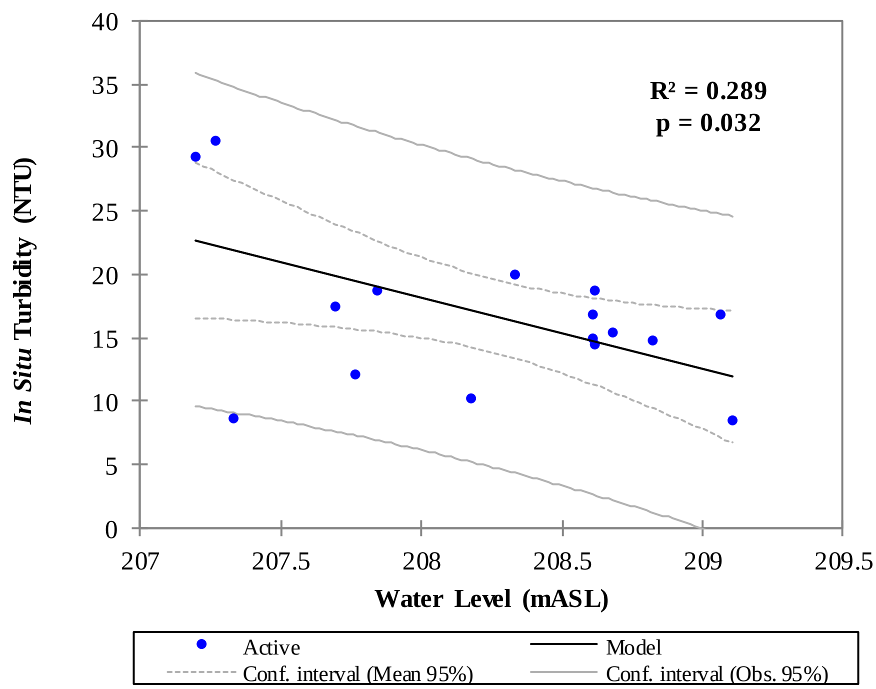


Figure 3-37. Open-water season *in situ* turbidity versus water level in Cross Lake: 2008-2013.

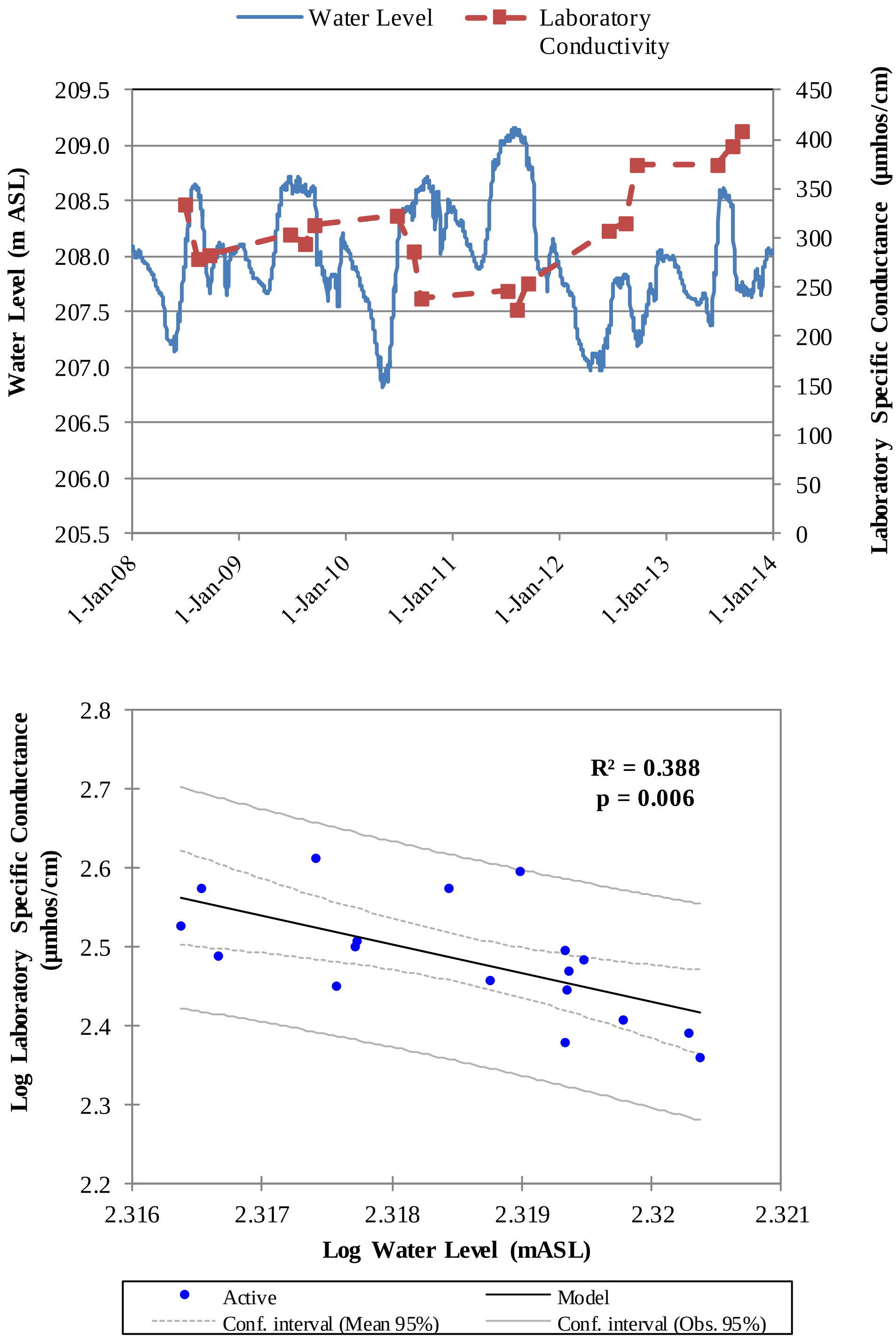


Figure 3-38. Open-water season laboratory specific conductance versus water level in Cross Lake: 2008-2013.

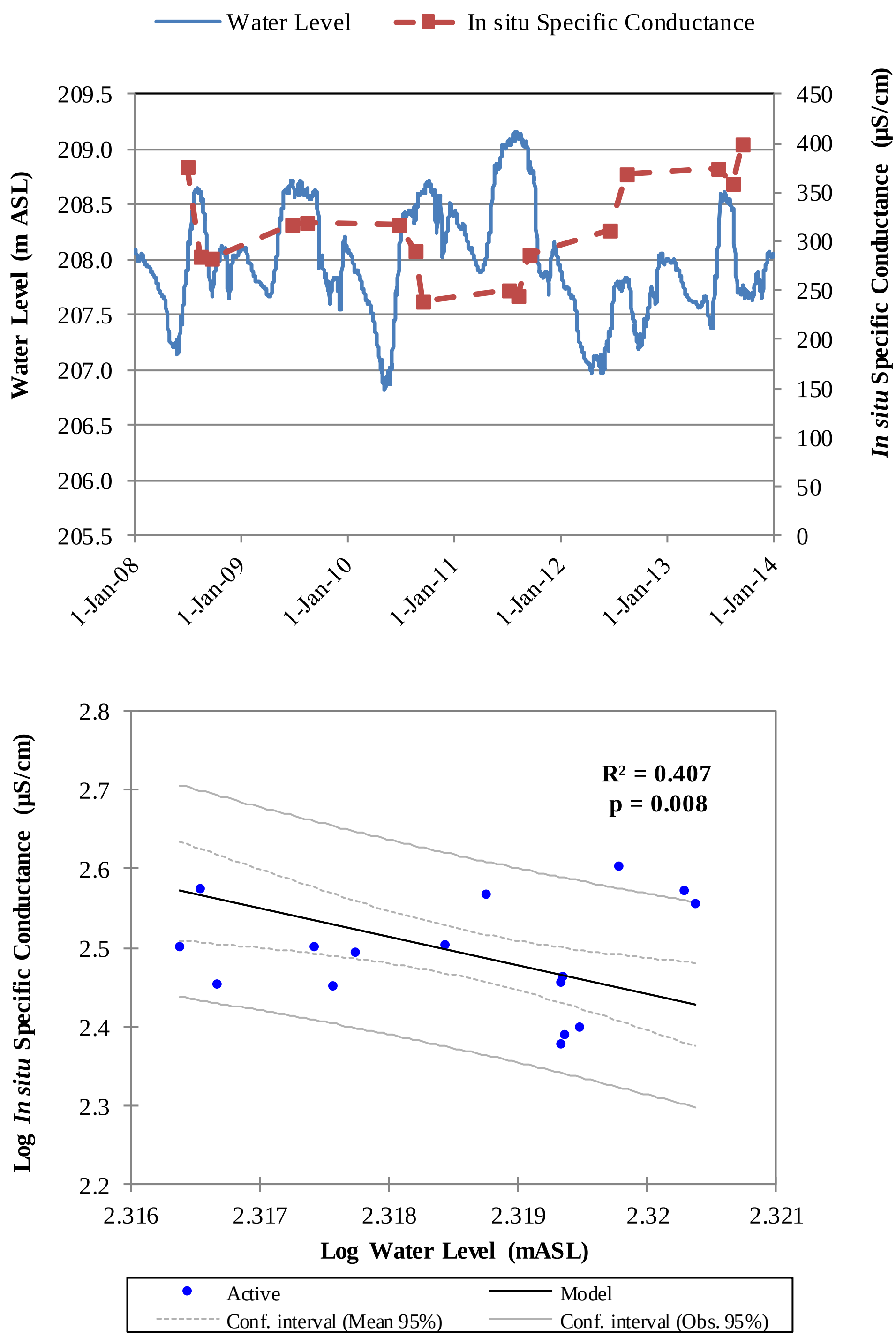
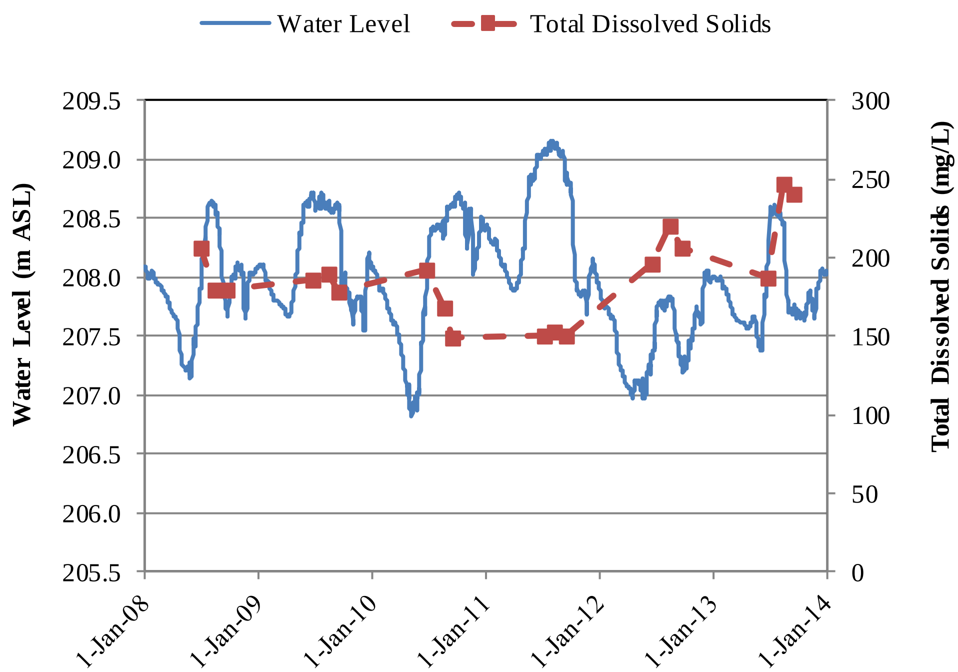


Figure 3-39. Open-water season *in situ* specific conductance versus water level in Cross Lake: 2008-2013.



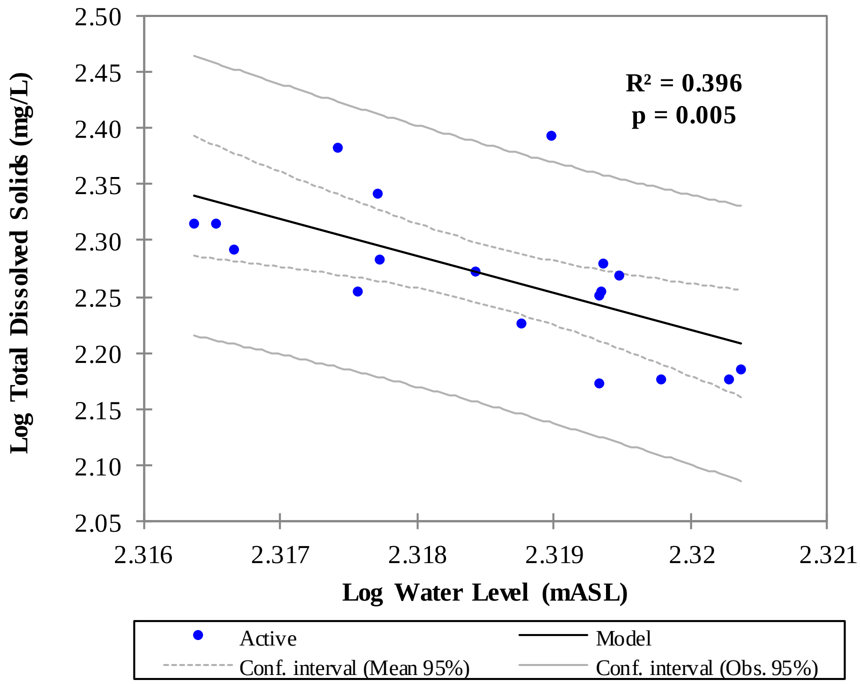


Figure 3-40. Open-water season total dissolved solids versus water level in Cross Lake: 2008-2013.

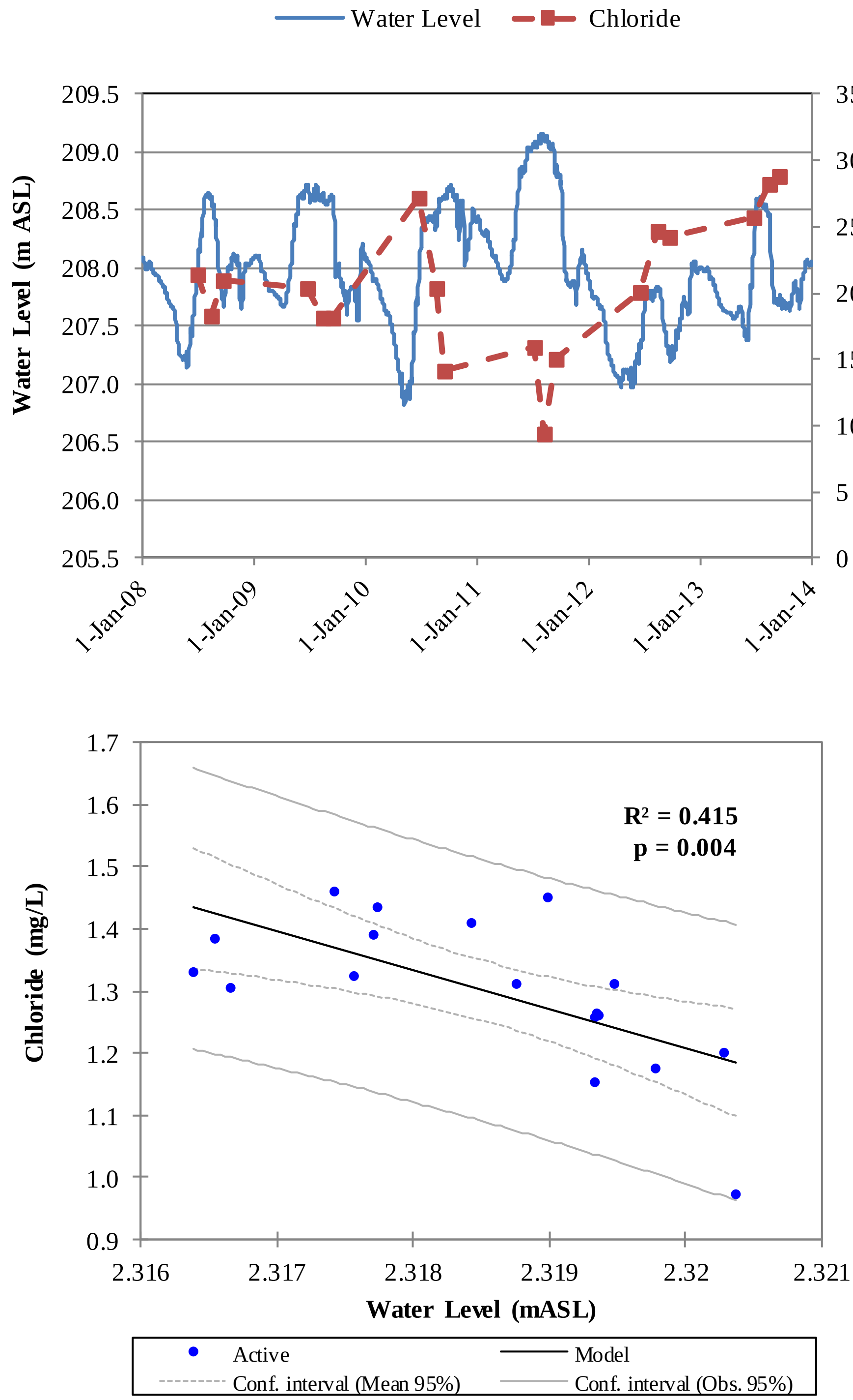


Figure 3-41. Open-water season chloride versus water level in Cross Lake: 2008-2013.

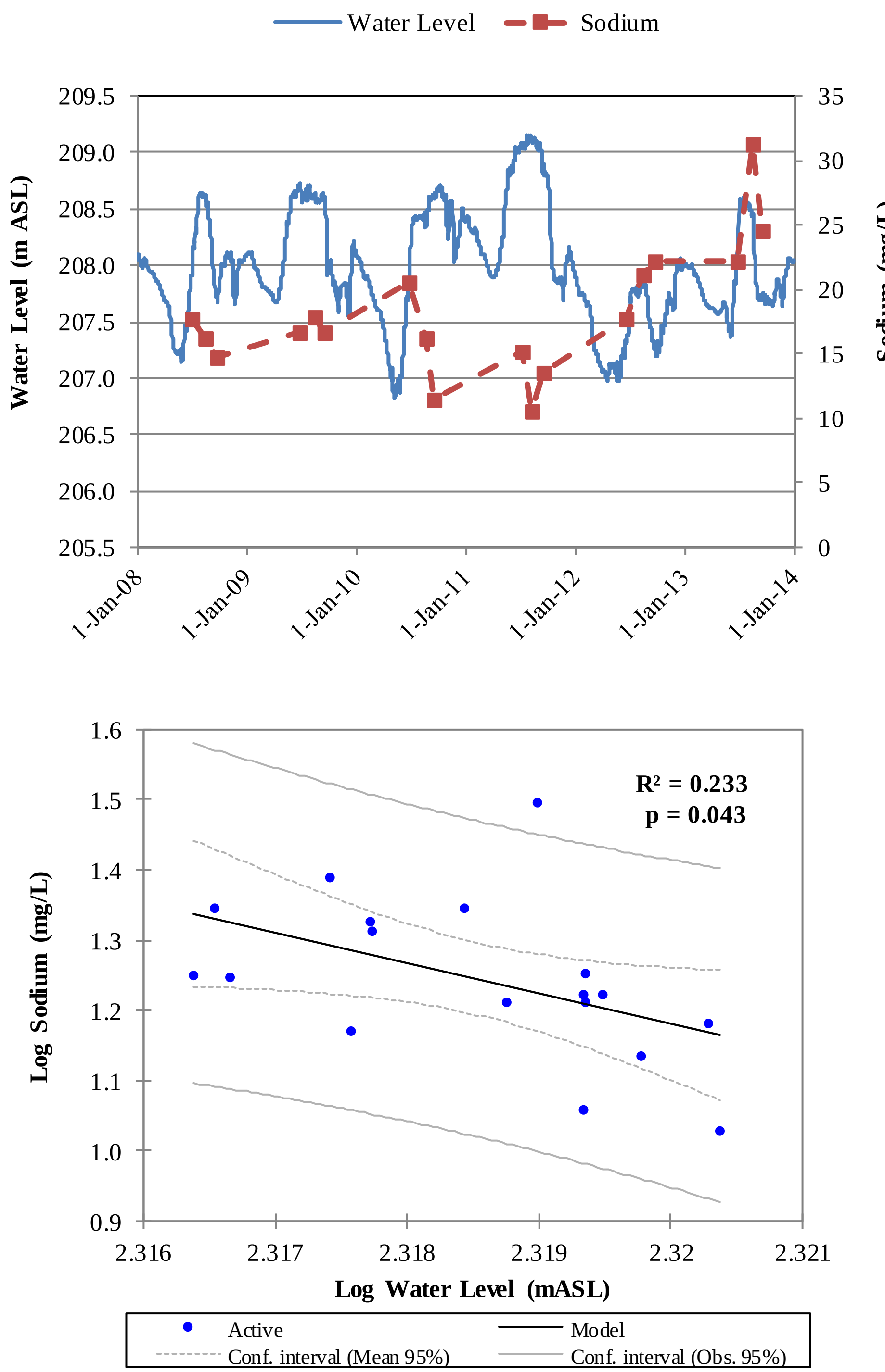


Figure 3-42. Open-water season sodium versus water level in Cross Lake: 2008-2013.

4.0 SEDIMENT QUALITY

4.1 INTRODUCTION

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

4.1.1 Objectives and Approach

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

4.1.2 Indicators

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

4.3 UPPER NELSON RIVER

Surficial sediment samples from Cross Lake were dominated by silt/clay (99%; Figure 4-2) and had moderate levels of total organic carbon (TOC; Table 4-1 and Figure 4-3). Percent silt/clay and TOC content were similar to that observed in the off-system Setting Lake (see Section 4.3), though Cross Lake sediments had a higher proportion of silt and lower proportion of clay than the off-system waterbody.

TOC (Figure 4-3), TP (Figure 4-4), and total Kjeldahl nitrogen (TKN; Figure 4-5) exceeded the Ontario LELs but were below the SELs in Cross Lake; results were generally similar to those observed in the off-system Setting Lake.

All but two metals (arsenic and chromium), including cadmium, copper, lead, mercury, and zinc, were on average within the Manitoba SQGs (Figures 4-6 to 4-12). Arsenic measured in Cross Lake marginally exceeded the Manitoba SQG (Figure 4-6), and chromium exceeded the Manitoba SQG but was below the PEL (Figure 4-8). Relative to the off-system site, the average arsenic concentration in Cross Lake was slightly higher than that measured in Setting Lake, although chromium was lower in Cross Lake than the off-system Setting Lake.

Iron (Figure 4-13), manganese (Figure 4-14), and nickel (Figure 4-15) exceeded the Ontario LELs but not the SELs, in Cross Lake. Concentrations of all these parameters were lower in Cross Lake than in the off-system Setting Lake. Selenium was marginally above the analytical detection limit (0.5 µg/g) in Cross Lake but was well below the BC SAC and the AB ISQG (2 µg/g; Figure 4-16). Results for additional metrics are presented in Table 4-2.

4.4 OFF-SYSTEM WATERBODY: SETTING LAKE

Particle size and nutrient concentrations were generally similar between Cross and Setting lakes, while metal concentrations were similar to or higher in Setting Lake compared to Cross Lake (Figures 4-2 to 4-16). However, exceedances of sediment quality benchmarks were generally similar between the two waterbodies; TOC (Figure 4-3), TP (Figure 4-4), and TKN (Figure 4-5) exceeded the Ontario LELs but not the SELs, and most metals excepting chromium (Figure 4-8) were within the Manitoba SQGs. Unlike Cross Lake, arsenic concentrations (Figure 4-6) in Setting Lake were within the Manitoba guideline. Nickel (Figure 4-15) exceeded the Ontario LEL in both Setting and Cross lakes, but iron and manganese concentrations (Figures 4-13 and 4-14) also exceeded the SEL at the off-system Setting Lake. Selenium was not detected in surficial sediments from Setting 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).

4.5 SUMMARY

Approximately half of the sediment quality parameters for which there are applicable benchmarks were within benchmarks in the UNRR. With one exception, metrics that exceeded sediment quality benchmarks in this region were also commonly above these benchmarks, and concentrations were similar to those observed, in other lakes and rivers monitored under CAMP (Table 4-1). Arsenic marginally exceeded the Manitoba SQG in Cross Lake, which was only exceeded at two other CAMP sites (Cedar Lake – Southeast and Southern Indian Lake – Area 4). However, although slightly higher, the concentration of arsenic in Cross Lake sediments was similar to concentrations measured at numerous other CAMP waterbodies including off-system lakes (Table 4-1).

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

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

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

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

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

Table 4-2. continued.

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

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

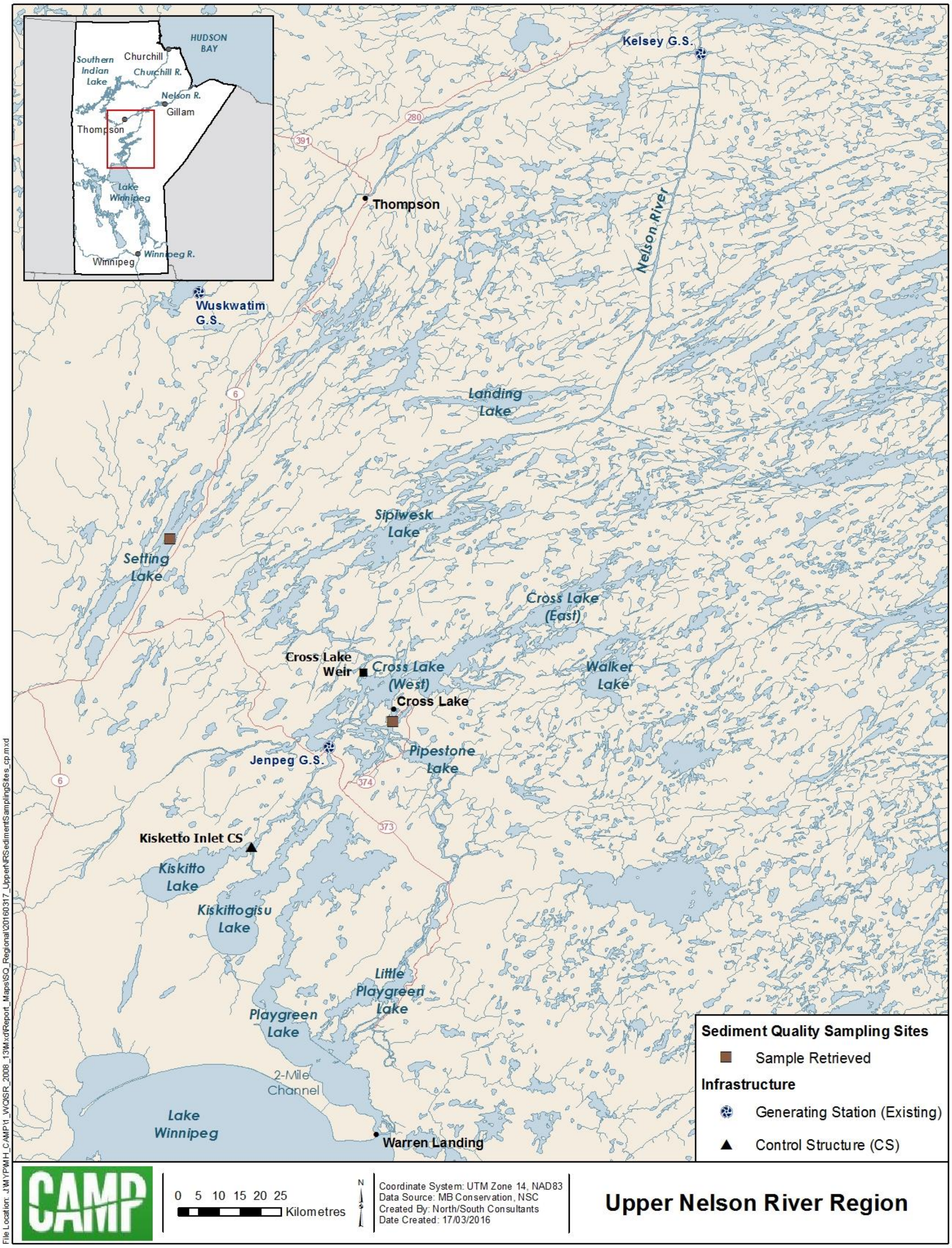


Figure 4-1. Sediment quality sampling sites in the Upper Nelson River Region: 2008-2013.

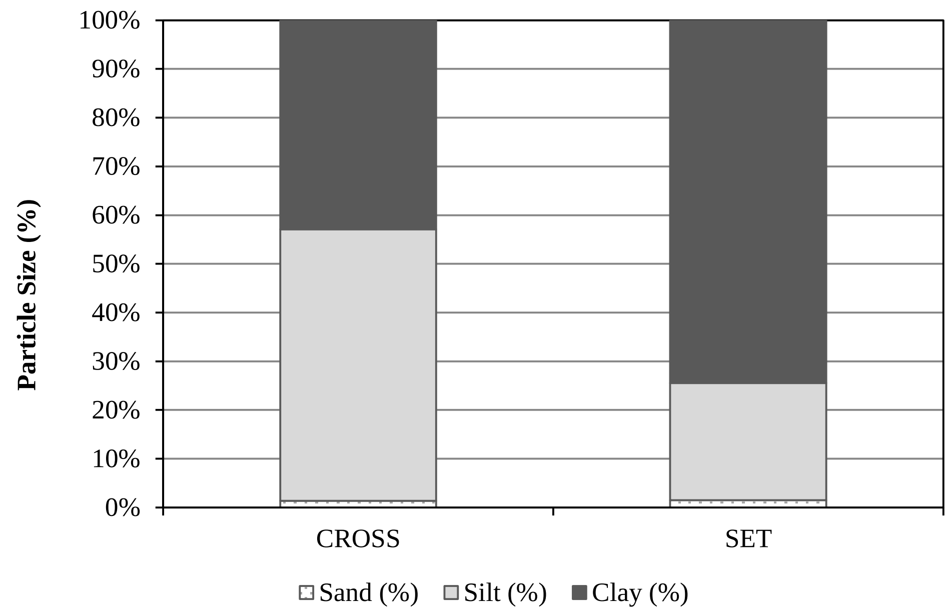


Figure 4-2. Particle size of surficial sediment from Cross (CROSS) and Setting (SET) lakes.

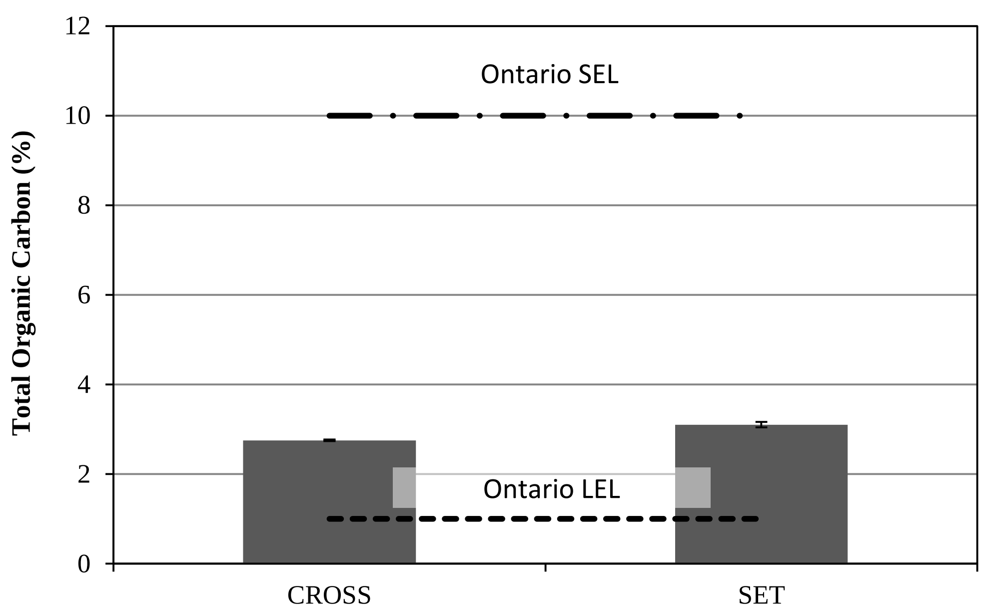


Figure 4-3. Percentage of total organic carbon in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Ontario sediment quality guidelines.

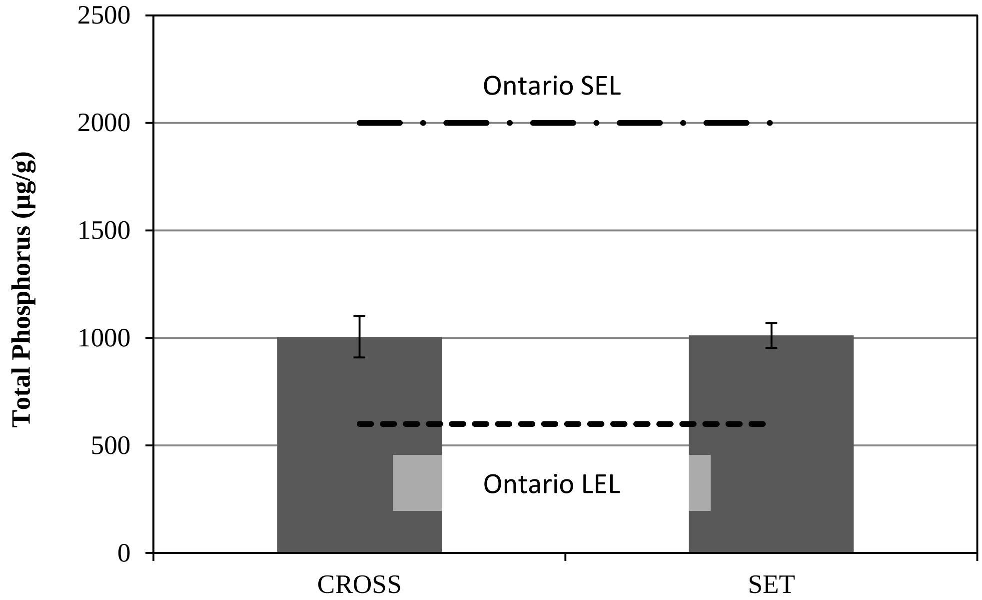


Figure 4-4. Mean (±SE) concentrations of total phosphorus in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Ontario sediment quality guidelines.

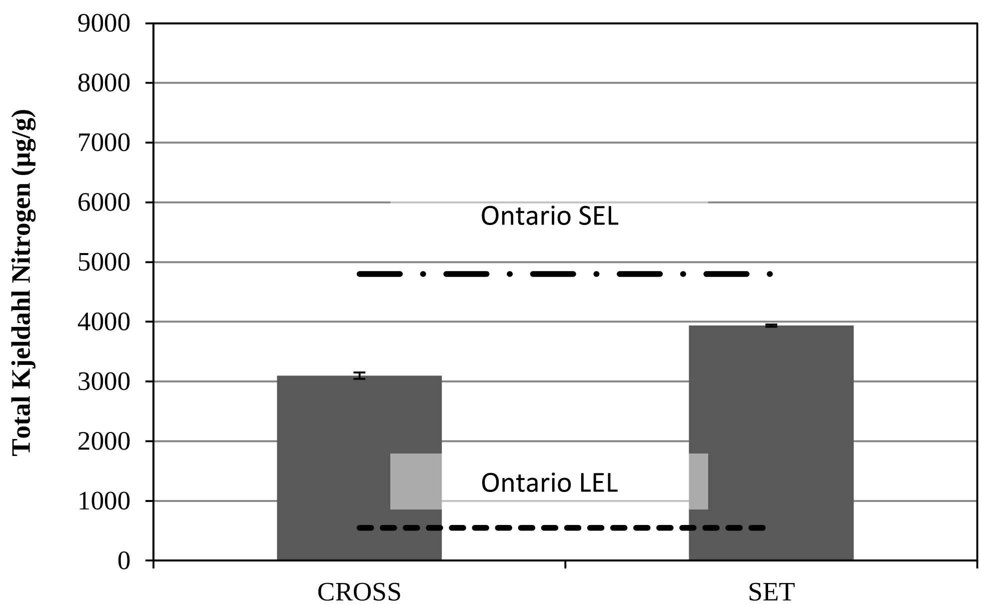


Figure 4-5. Mean (±SE) concentrations of total Kjeldahl nitrogen in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Ontario sediment quality guidelines.

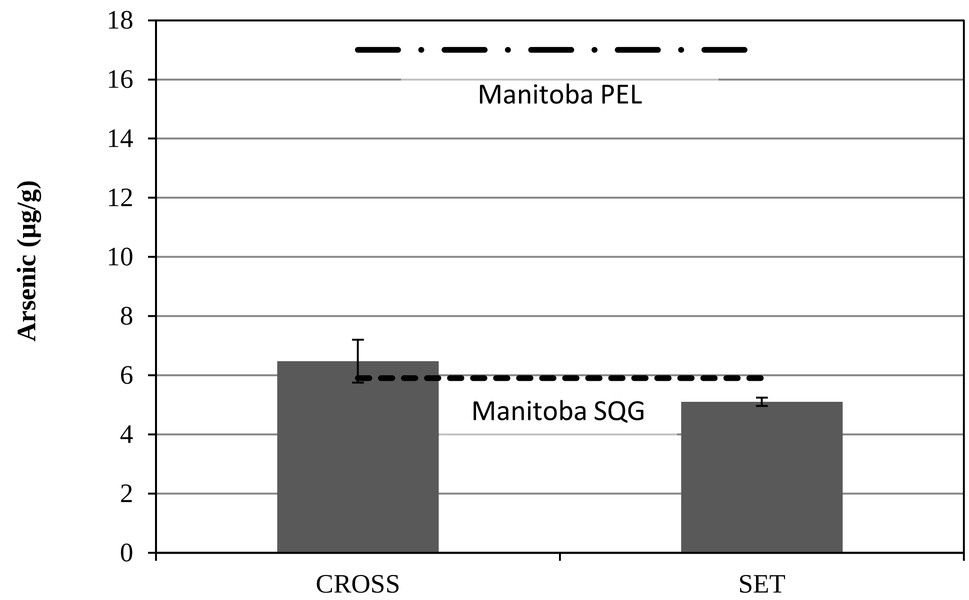


Figure 4-6. Mean (±SE) concentrations of arsenic in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines.

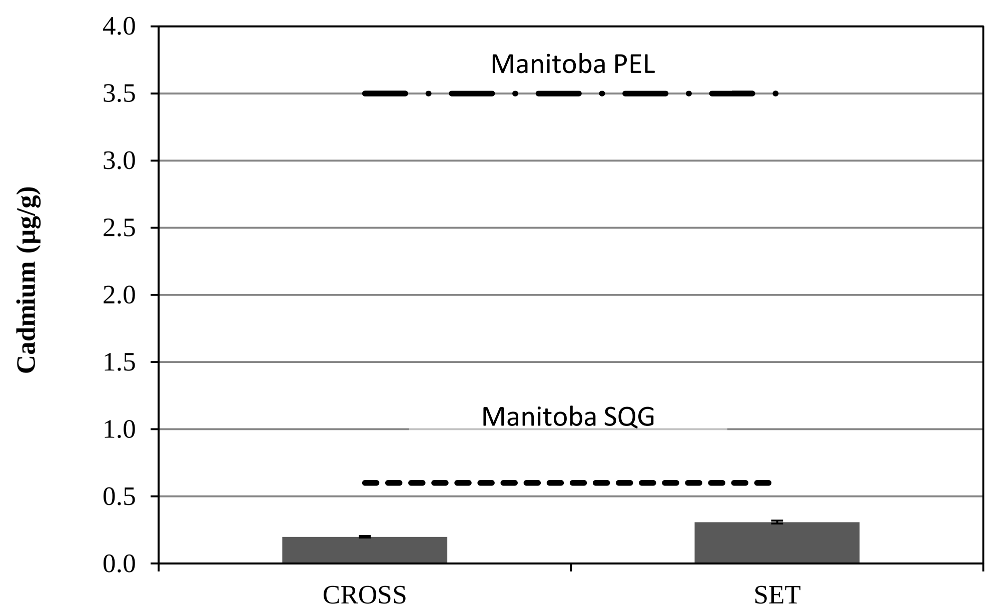


Figure 4-7. Mean (±SE) concentrations of cadmium in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines.

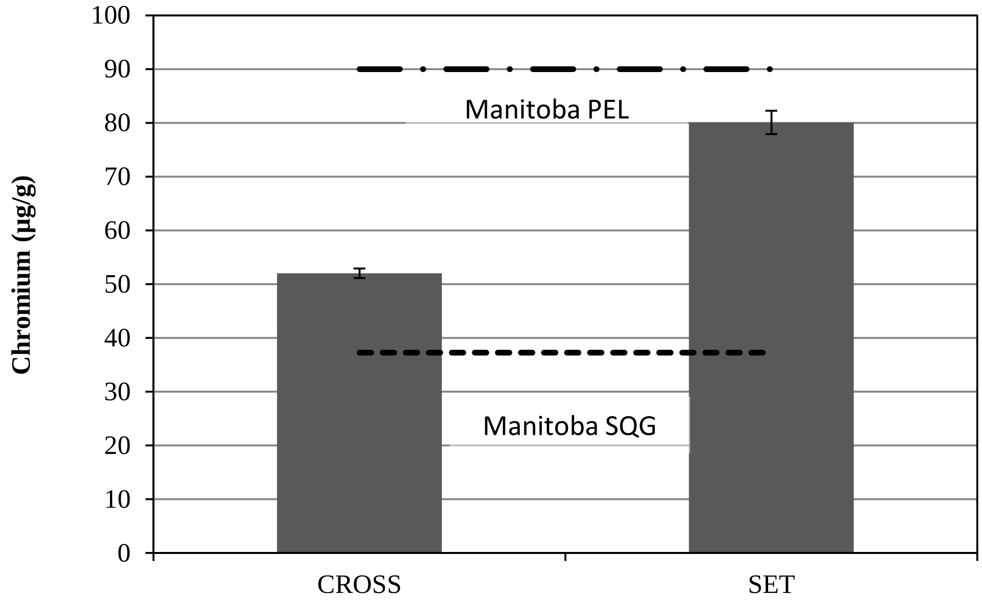


Figure 4-8. Mean (±SE) concentrations of chromium in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines.

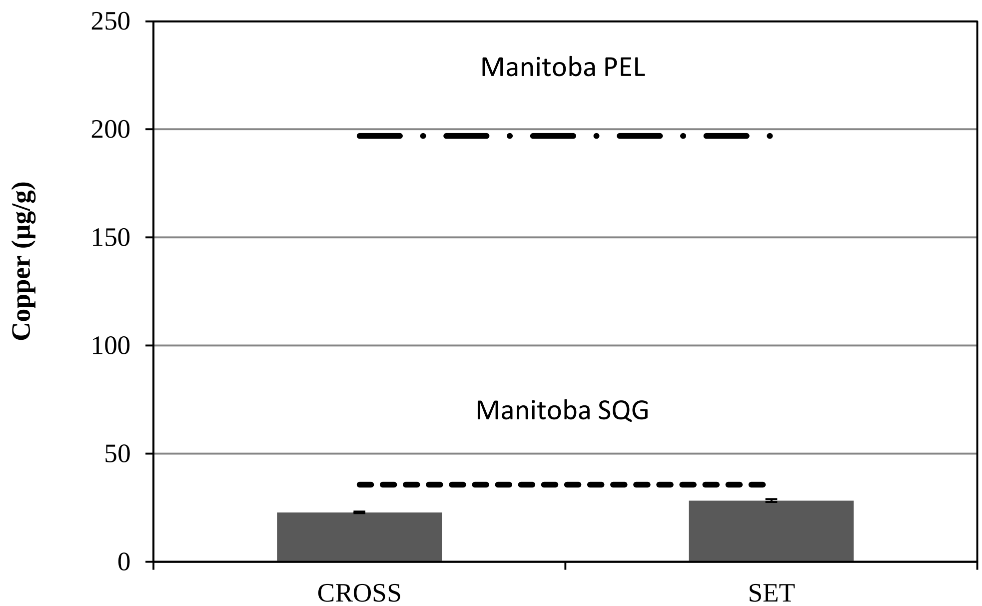


Figure 4-9. Mean (±SE) concentrations of copper in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines.

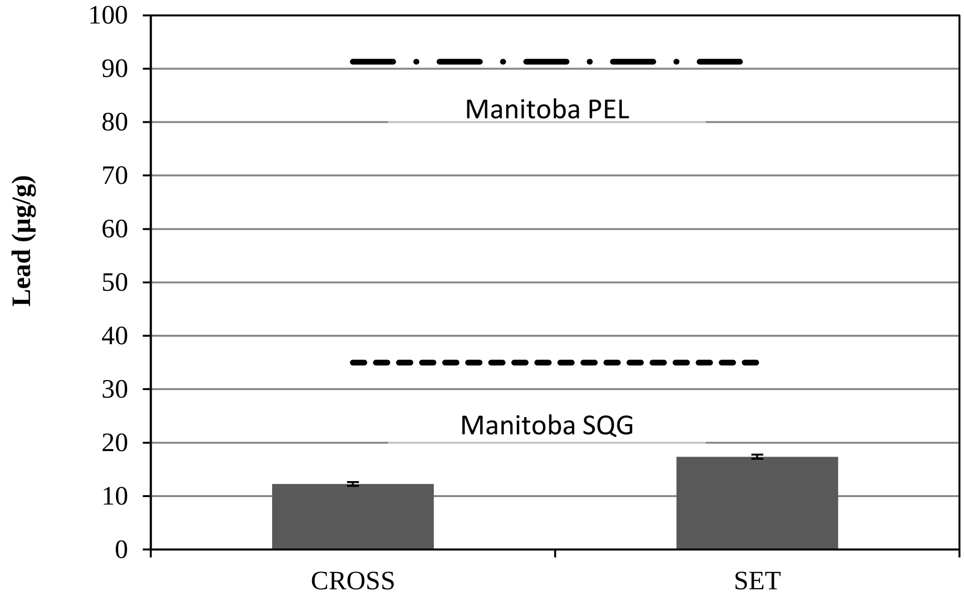


Figure 4-10. Mean (±SE) concentrations of lead in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines.

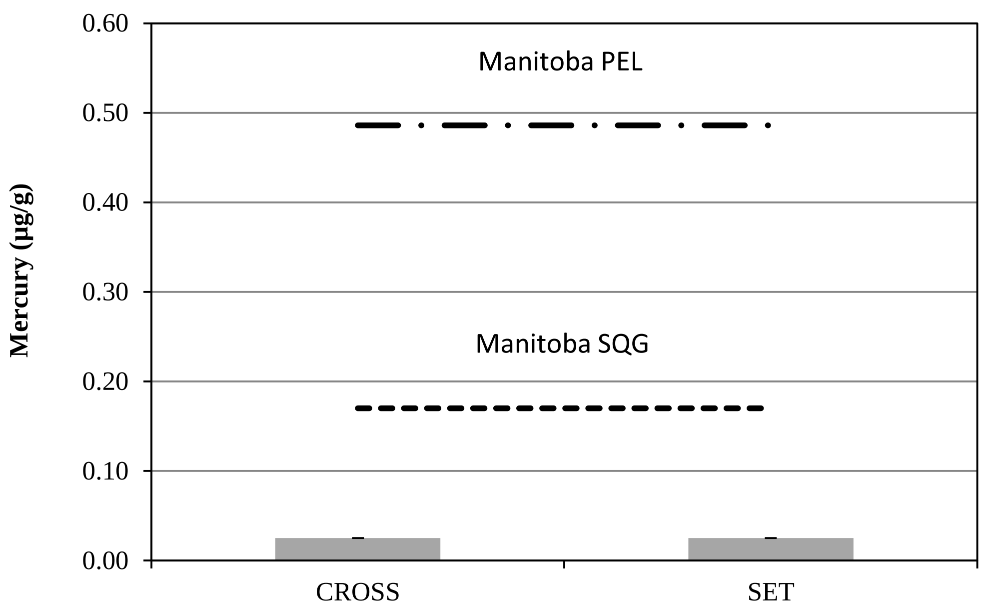


Figure 4-11. Mean (±SE) concentrations of mercury in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines. All measurements were below the analytical detection limit (0.05 µg/g).

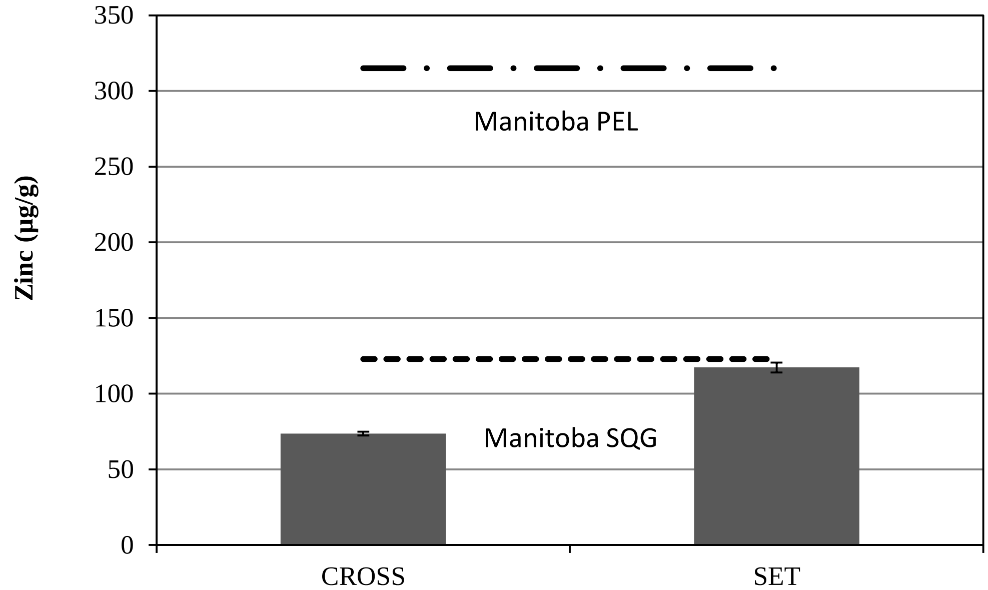


Figure 4-12. Mean (±SE) concentrations of zinc in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Manitoba sediment quality guidelines.

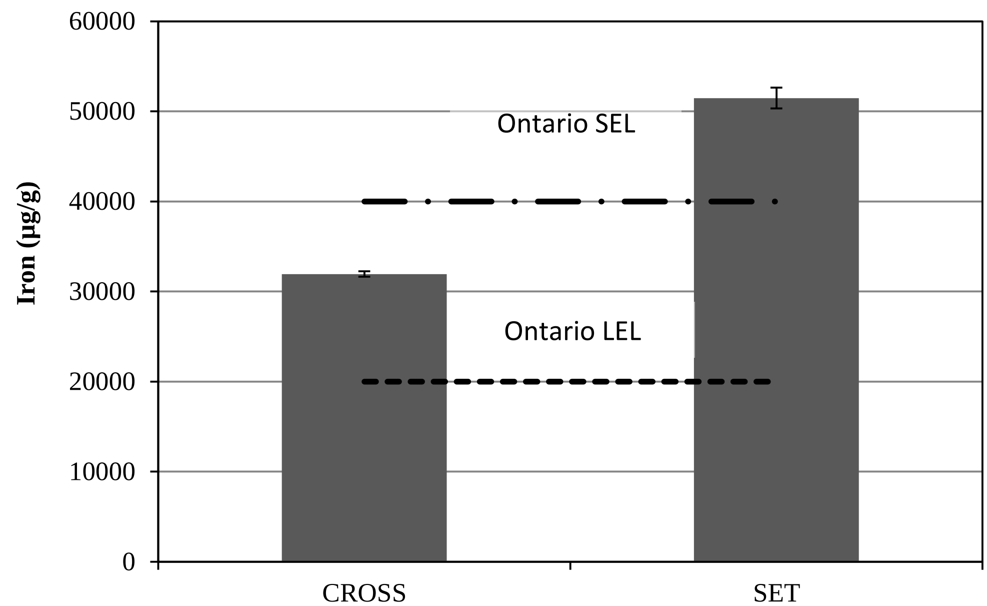


Figure 4-13. Mean (±SE) concentrations of iron in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Ontario sediment quality guidelines.

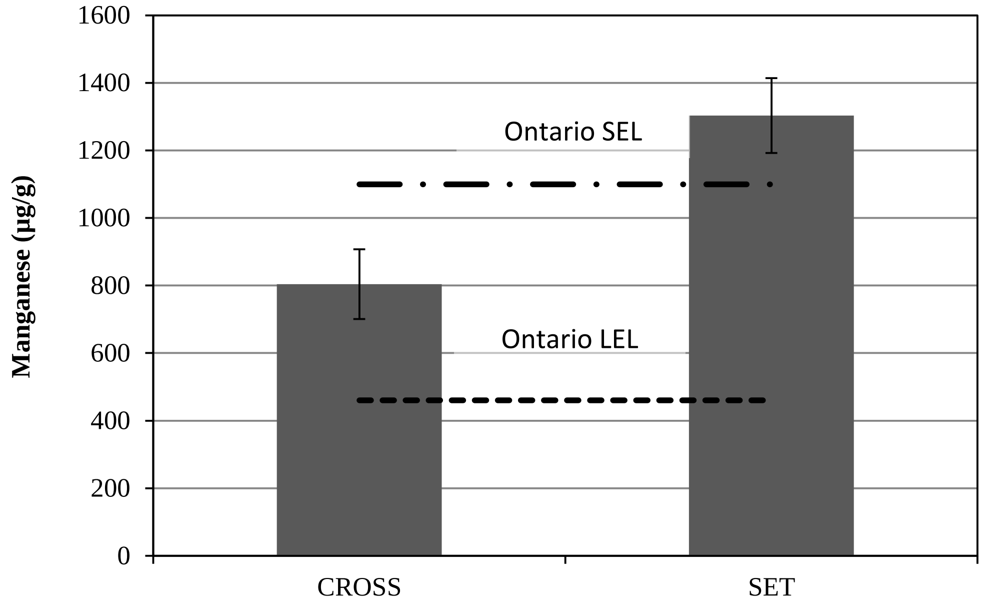


Figure 4-14. Mean (±SE) concentrations of manganese in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Ontario sediment quality guidelines.

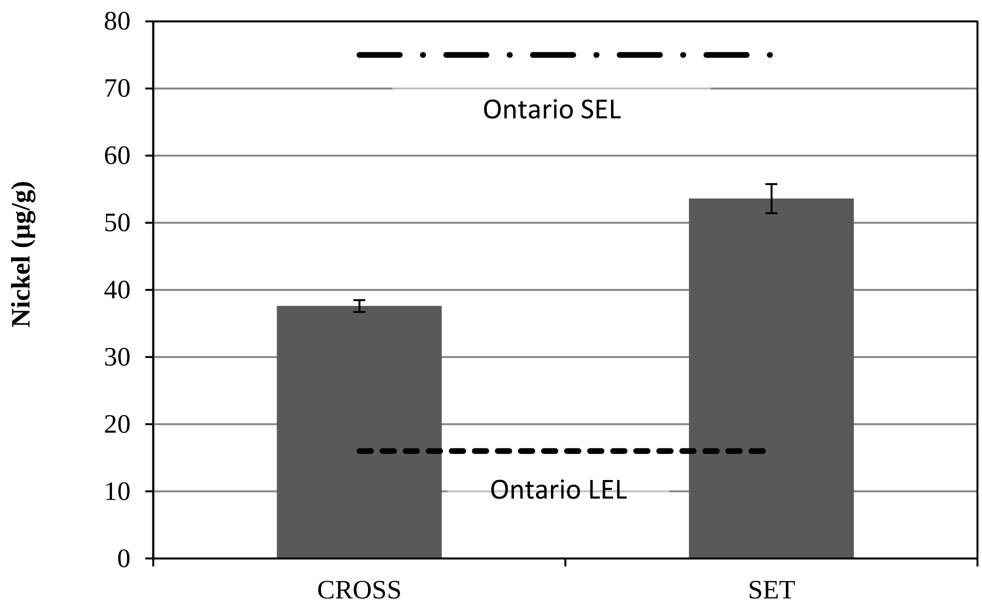


Figure 4-15. Mean (±SE) concentrations of nickel in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to Ontario sediment quality guidelines.

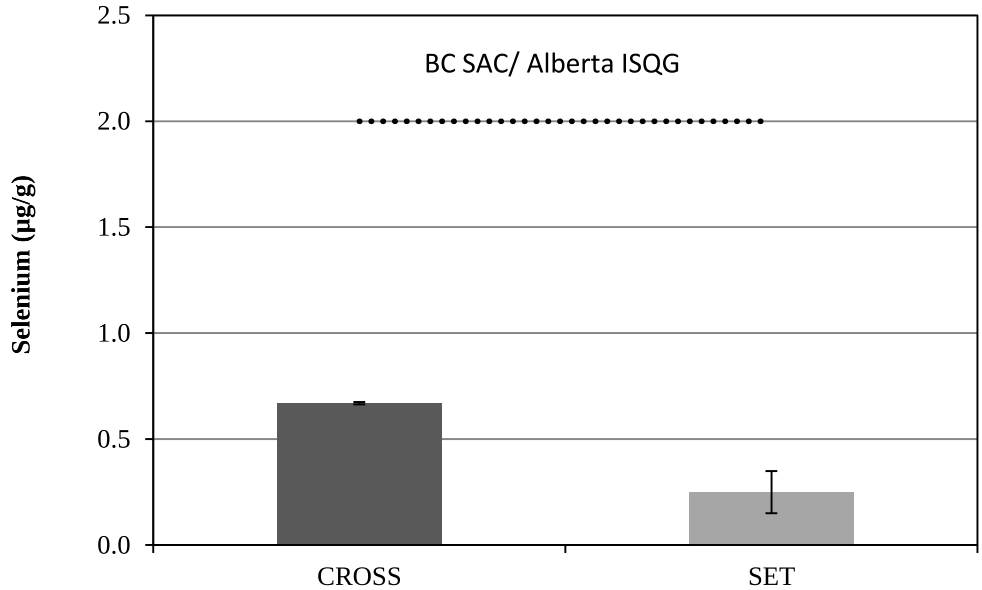


Figure 4-16. Mean (±SE) concentrations of selenium in surficial sediment from Cross (CROSS) and Setting (SET) lakes, and comparison to the BC SAC and the Alberta ISQG. Means indicated in light grey were below the analytical detection limit.

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 UNRR. 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 sampled annually included one on-system lake (Cross Lake – West Basin) and one off-system lake (Setting Lake). Four additional on-system waterbodies or areas were sampled on a rotational basis, including Playgreen (2012), Little Playgreen (2010, 2013), and Sipiwesk (2011) lakes, and the upper Nelson River upstream of the Kelsey GS (2011); the off-system Walker Lake was also sampled on a rotational basis (2010, 2013; Figure 5-1).

A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 3.5. In brief, the CAMP benthic macroinvertebrate program includes one sampling period in the late summer-fall at nearshore (water depth ≤1 m, sampled with travelling kick/sweep) and offshore (water depth 3-10 m, sampled with Ekman/petite Ponar) habitat sites within each monitoring waterbody (annual and rotational).

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

5.1.1 Objectives and Approach

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

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

The first objective (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 each aquatic habitat type sampled for each waterbody. Supporting environmental variables are also described to aid in the understanding of BMI metrics. As noted in Technical Document 1, four 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 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 environmental variables that may aid in the interpretation of BMI metrics.

5.2 SUPPORTING HABITAT VARIABLES

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

5.2.1 Upper Nelson River

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

The nearshore habitat of Playgreen Lake had a greater proportion of sand (99%) than other downstream lakes (Figure 5-2). Little Playgreen Lake consisted mainly of coarser, hard substrate (bedrock, boulder) and, as such, no supporting sediment samples were collected for laboratory analysis (Table 5-1). Cross and Sipiwesk lakes had a greater proportion of silt and clay in comparison to Playgreen Lake. Nearshore sediments from the upper Nelson River upstream of the Kelsey GS largely consisted of silt and clay, with very little sand. The mean TOC content of all lake sediments sampled was low (less than 2%); the TOC content of upper Nelson River sediments (9%) was notably higher than on-system lakes (Figure 5-3).

The offshore habitat of on-system waterbodies consisted mainly of silt and clay; Playgreen and Sipiwesk lakes had a somewhat greater proportion of sand in comparison to other on-system waterbodies (Figure 5-4). Although the TOC of all sediments sampled was low in the offshore (less than 3%), TOC content of Little Playgreen and Cross lakes, and upper Nelson River sediments were slightly higher than other on-system waterbodies (Figure 5-5).

5.2.2 Off-system Waterbodies: Walker and Setting Lakes

The nearshore habitat of Walker and Setting lakes consisted of mainly large, hard substrate (mainly bedrock and boulder with cobble); as such sediment samples were not collected for laboratory analysis (Table 5-1).

In contrast to on-system waterbodies, the offshore sediments of Walker Lake consisted of a greater proportion of sand. Offshore sediments of Setting Lake were more similar to on-system waterbodies, consisting mainly of silt and clay (Figure 5-4). TOC content of sediments was higher for Walker (10%) than Setting Lake (3%) (Figure 5-5).

5.3 KEY INDICATORS

5.3.1 Total Number of Invertebrates

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

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

5.3.1.1 Upper Nelson River

The mean total abundance of BMIs in nearshore habitat varied among years and on-system lakes (Figure 5-6). Total abundance of BMIs in the nearshore habitat in Cross Lake varied among years but differences were not statistically significant (Figure 5-6). In all four years sampled, insects comprised the majority of the catch with Chironomidae outnumbering Ephemeroptera in all years except 2013. Chironomidae comprised between approximately 30% and 55% of the catch in 2010, 2011, and 2012, while Ephemeroptera comprised approximately 46% of the catch in 2013. Amphipoda was consistently the most abundant group of non-insects.

Invertebrate abundance in the nearshore habitat of other on-system sites in the Nelson River were generally within the range observed in Cross Lake, with the exception of Little Playgreen Lake. In both 2010 and 2013 Little Playgreen Lake abundances were more than ten times greater than other lakes (Figure 5-6); Amphipoda and Oligochaeta comprised more than 50% of the fauna in 2010, while chironomids dominated in 2013. Chironomidae accounted for close to 80% of the catch in Playgreen Lake in 2012 with very few ephemeropterans, while in 2011 Corixidae comprised just under half of the insect community in the Nelson River (chironomids dominated) and the majority of the insect community in Sipiwesk Lake.

Abundance varied between waterbodies and years in offshore habitat, with Little Playgreen Lake exhibiting the highest numbers of invertebrates in 2010 (Figure 5-7). Non-insects generally dominated the offshore fauna. In the offshore habitat of Cross Lake, the bivalve Pisidiidae comprised the majority of the non-insect fauna in all years, but their proportion in samples increased annually from 30% in 2010 to 80% in 2013. Amphipoda and Oligochaeta were also consistently present in small numbers, while Gastropoda were generally absent. In all years in Cross Lake, Ephemeroptera and Chironomidae were the dominant insects.

Amphipods was the dominant non-insect invertebrate from the offshore in Sipiwesk Lake and the Nelson River and Ephemeroptera (specifically *Hexagenia sp.*; burrowing mayfly) outnumbered Chironomidae in both waterbodies. Substrate in the Nelson River was identified as silty/clay which is a preferred habitat for burrowing mayflies. In Playgreen Lake, Bivalvia were the dominant group but Amphipoda, Gastropoda, and Oligochaeta were also present. Bivalvia was similarly the dominant taxon in Little Playgreen Lake in 2010, but in 2013 insects (primarily Chironomidae) accounted for more than 70% of the organisms collected, making Little Playgreen Lake different from all the other waterbodies in that year.

5.3.1.2 Off-system Waterbodies: Walker and Setting Lakes

The mean abundance of BMIs in the nearshore habitat of Walker and Setting lakes was typically within the range of abundances observed for on-system waterbodies (Figure 5-6). Insects dominated the fauna in all years except 2011, when Amphipoda, Oligochaeta, and Gastropoda together equaled approximately 60% of the catch. Similar to the on-system waterbodies, in both 2011 and 2012, Ephemeroptera (notably Caenidae) outnumbered Chironomidae.

Total invertebrate abundance was slightly lower in 2013 than in 2010 in the nearshore habitat of Walker Lake. In both 2010 and 2013, non-insects were more dominant than insects, with Acari followed by Amphipoda and Oligochaeta comprising the majority of the fauna. In 2013 Chironomidae accounted for less than ten percent of the fauna and Ephemeroptera were rare.

The mean density of BMIs in the offshore habitat of Walker Lake was lower than on-system lakes, particularly in 2013, whereas the mean density of BMIs in Setting Lake was typically within the range of densities observed for on-system waterbodies (Figure 5-7). In contrast to on-system waterbodies, the offshore sediments of Walker Lake consisted of a greater proportion of sand (Section 5.2). In general, density of BMIs decrease with unstable (i.e., shifting) substrate, such as sand.

Total abundance of BMIs in the offshore of Setting Lake was highest in 2013, followed by 2010, 2012, and 2011 (Figure 5-7). The differences between years in Setting Lake were statistically significant (Figure 5-7). Non-insects dominated the fauna in this waterbody in all four years with Amphipoda comprising the majority of the non-insects. Bivalvia were also present and represented between approximately 11 and 18% of the overall catch, with Oligochaeta and Gastropoda relatively uncommon. Ephemeroptera was present in greater numbers than Chironomidae in 2010, 2011, and 2013.

In 2010 and 2013, Walker Lake was dominated by insects, specifically Chironomidae. Ephemeroptera were also present in very small numbers. Bivalvia and Oligochaeta comprised the non-insect component of the catch, while Amphipoda and Gastropoda were nearly absent and completely absent, respectively. TOC content was notably higher (the majority greater than 12%) in Walker Lake than on-system waterbodies while Setting Lake was also generally higher (greater than 3%).

5.3.1.3 Temporal Comparisons and Trends

Total invertebrate abundance in the nearshore habitat of Cross Lake (on-system) and Setting Lake (off-system) was similar from 2010-2013 with no significant differences between any years (Figure 5-6).

In the offshore environment, abundance in Cross Lake was significantly higher in 2012 than in 2011; differences between 2012 and 2010 and 2013 were of similar magnitude but not statistically significant due to variability in the data. In off-system Setting Lake, numbers in 2013 were significantly higher than in 2011, with 2010 and 2012 being intermediate and not significantly different from any year.

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 Upper Nelson River

With the exception of Cross Lake in 2013 (ratio of 3), the mean ratio of EPT to chironomids in nearshore habitat of on-system waterbodies was less than 1 and generally less than 0.5 (Figure 5-8).

The mean EPT:C in offshore habitat varied among years and on-system lakes and was greater than 1 in all lakes, with the exception of Little Playgreen Lake (0.23; Figure 5-9).

5.3.2.2 Off-system Waterbodies: Walker and Setting Lakes

The mean EPT:C in the nearshore habitat of Walker Lake was near 1, somewhat higher than all but one (Cross Lake) of the on-system waterbodies (Figure 5-8).

Similar to the on-system Little Playgreen Lake, the mean ratio of ephemeropterans to chironomids in the offshore habitat of Walker Lake was considerably less than 1 (0.02; Figure 5-9).

5.3.2.3 Temporal Comparisons and Trends

Despite considerable differences among years (in particular 2013), the high variability of the EPT:C ratio in the nearshore habitat of Cross Lake resulted in no statistically significant differences among years ((Figure 5-8). Similarly, no statistically significant differences were observed in Setting Lake despite apparent differences among years (Figure 5-8).

In the offshore environment, EPT:C in Cross Lake was significantly higher in 2012 than 2010; the differences between 2012 and 2011 and 2013 were of a similar magnitude but were not significant due to the high variability. In Settling Lake, 2012 was also significantly higher than 2010, with the other two years intermediate.

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 Upper Nelson River

The mean total richness (family-level) of BMIs in nearshore habitat varied somewhat among on-system lakes (Figure 5-10). Total richness at the upper Nelson River site in 2011 was higher (14 taxa) than upstream Sipiwesk (eight taxa) and Cross (11 taxa) lakes (Figure 5-10).

The mean total richness of BMIs in offshore habitat varied among years and on-system lakes (Figure 5-11). In contrast to the nearshore habitat, mean total richness in offshore habitat at the upper Nelson River site in 2011 (five taxa) was somewhat lower than upstream Sipiwesk (seven taxa) and Cross (six taxa) lakes (Figure 5-11).

5.3.3.2 Off-system Waterbodies: Walker and Setting Lakes

The mean total richness of BMIs in the nearshore habitat of Walker and Setting lakes was typically higher than that observed for on-system waterbodies (Figure 5-10).

The mean total richness of BMIs in the offshore habitat of Walker and Setting lakes was within the range observed for on-system waterbodies, with the exception of Setting Lake in 2013 (higher total richness; Figure 5-11).

5.3.3.3 Temporal Comparisons and Trends

Total richness of BMIs in the nearshore habitat of Cross and Setting lakes varied little among years and no statistically significant differences were observed (Figure 5-10).

Similar to nearshore lake habitat, total richness of BMIs in the offshore of Cross Lake varied little with no significant differences (Figure 5-11). In the off-system Setting Lake, total richness in 2013 was statistically significantly higher than that in 2011, with 2010 and 2012 intermediate and not significantly different from any year.

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 Upper Nelson River

The mean EPT richness (family-level) in nearshore habitat of on-system lakes followed the same pattern as total richness (Figure 5-10). EPT richness at the upper Nelson River site in 2011 was marginally higher than upstream Sipiwesk Lake, but lower than Cross Lake (Figure 5-10).

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

5.3.4.2 Off-system Waterbodies: Walker and Setting Lakes

With the exception of 2013, the mean EPT richness in the nearshore habitat of Walker and Setting lakes was higher than that observed for on-system waterbodies (Figure 5-10).

The mean EPT richness in the offshore habitat of Walker Lake was less than 1 and lower than the number of taxa observed for on-system waterbodies (Figure 5-11). EPT richness for the offshore of Setting Lake was within the range observed for on-system waterbodies.

5.3.4.3 Temporal Comparisons and Trends

Significant differences among EPT richness followed the same patterns as observed for total richness, with the only statistically significant difference occurring in the offshore habitat of Setting Lake between 2013 and 2011.

5.3.5 Simpson's Diversity Index

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

5.3.5.1 Upper Nelson River

Simpson's diversity index for the nearshore BMI community varied among years and on-system lakes (Figure 5-12). The relatively lower diversity index (0.42) measured for Playgreen Lake in 2012 may have been due in part to the predominance of sand in the nearshore sediments (Section 5.2.1). In general, unstable (i.e., shifting) substrate, such as sand, provides lower quality habitat for BMIs. Mean diversity index for the upper Nelson River in 2011 (0.72) was somewhat higher than at the upstream Cross (0.63) and Sipiwesk lakes (0.67; Figure 5-12).

Similar to nearshore habitat, Simpson's diversity index for the offshore BMI community varied among years and on-system lakes (Figure 5-13). In 2011, diversity on the upper Nelson River was within the range observed for upstream Cross and Sipiwesk lakes.

5.3.5.2 Off-system Waterbodies: Walker and Setting Lakes

Simpson's diversity index for the nearshore community in Walker Lake was within the range observed for on-system lakes in 2010, but somewhat lower in comparison for 2013 (Figure 5-12). In contrast, diversity for the nearshore of Setting Lake was consistently higher than that observed for on-system waterbodies (Figure 5-12).

For the offshore of Walker Lake, diversity was within the range observed for on-system lakes in 2010, but somewhat higher in comparison for 2013 (Figure 5-13). Diversity for the offshore of Setting Lake was within the range observed for on-system lakes in 2010 and 2012; in 2011, diversity in Setting Lake was lower in comparison, whereas in 2013, diversity was higher.

5.3.5.3 Temporal Comparisons and Trends

Simpson's diversity index in the nearshore habitat of Cross Lake varied among years but no differences were statistically significant (Figure 5-12). In Setting Lake, diversity in the nearshore environment was significantly higher in 2010 than 2011, with 2012 and 2013 being intermediate.

In contrast, diversity in the offshore environment in Cross Lake decreased over the four year monitoring period: the diversity index in 2012 was statistically significantly lower than 2010, and diversity in 2013 was significantly lower than 2010, 2011, and 2012. The decline in diversity was due to the increasing dominance of the bivalve Pisidiidae, which by 2013 comprised 80% of the fauna in the samples.

In the offshore habitat of Setting Lake, no significant changes in diversity occurred (Figure 5-13).

5.4 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

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

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 Upper Nelson River

Mean Ephemeroptera richness (genus-level) in nearshore habitat varied among years and on-system lakes (Figure 5-14). Ephemeropteran richness at the upper Nelson River site in 2011 was somewhat lower (1.8) than upstream Sipiwesk Lake (2.2) and more so in comparison to Cross Lake (3.6; Figure 5-14).

The mean Ephemeroptera richness in offshore habitat was very similar among years and on-system waterbodies with typically 1 genus represented (Figure 5-15).

5.4.1.2 Off-system Waterbodies: Walker and Setting Lakes

The mean Ephemeroptera richness in the nearshore habitat of Walker Lake was higher than on-system waterbodies in 2010, but notably lower in comparison in 2013 (Figure 5-14). For Setting Lake, mean Ephemeroptera richness followed a pattern similar to Cross Lake; however, richness was somewhat lower in comparison.

The mean Ephemeroptera richness in the offshore habitat of Walker Lake was less than 1 and less than half of that observed for on-system waterbodies (Figure 5-15). Ephemeroptera richness for the offshore of Setting Lake was identical to the on-system Cross Lake.

5.4.1.3 Temporal Comparisons and Trends

Ephemeroptera richness in the nearshore habitat of Cross Lake in 2013 was statistically significantly higher than in 2011 (Figure 5-14). No significant differences among years were apparent for nearshore Setting Lake or the offshore environment, where typically only one genus was present (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 the UNRR Waterbodies, 2010-2013

Flows in the UNRR were generally above average for the study period (Section 2) and reached record highs for most of 2011. In Cross Lake, water levels during the “growing season” (i.e., from ice off to the time of sampling) generally were low during the first part of the growing season and increased to higher levels in late summer/early fall; under these condition most nearshore sampling occurred in areas that were exposed for at least part of the growing season. Water elevation and duration of wetting varied considerably among the four years of sample collection (Figure 2-4): in 2010, water levels were low in spring and increased to the time of sampling, resulting in areas that were wetted two months or less; in 2011 sampling occurred well above the typical nearshore habitat but in areas wetted for much of the growing season; and in 2012 and 2013 sampling occurred at similar elevations but the duration of wetting in 2012 was much less than in 2013.

A gauge was installed on Setting Lake in 2008; therefore, water elevation cannot be presented in terms of a long term record (Section 2). In 2010 and 2011, sample collection occurred on an ascending hydrograph and much of the nearshore zone would have been exposed during the growing season; in 2012 and 2013 most of the habitat would have been wetted for the growing season (Figure 2-8, Section 2).

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

The BMI community of the nearshore zone of Cross Lake showed remarkably little response to the large differences in the elevation of sample collection and duration of wetting, with no significant inter-annual differences in abundance, richness or diversity despite the differences in water regime described in the preceding section. This is in marked contrast to other regions sampled in CAMP, such as the Lower Nelson River Region. The nearshore community of Setting Lake displayed a similar lack of relationship to differences in water elevation although the high variability may have masked differences.

Although differences were not statistically significant, examination of mean abundance in the nearshore at Cross Lake versus mean water level suggests that higher water elevation may be associated with a lower abundance of invertebrates. No other relationships to richness or diversity were apparent in either the nearshore or offshore environments (Table 5-2; Figure 5-16. A similar lack of relationships was apparent for Setting Lake (Table 5-2; Figure 5-17).

5.6 SUMMARY

The BMI community in the nearshore habitat of Cross Lake was comprised mostly of insects with Chironomidae generally outnumbering Ephemeroptera; Amphipoda was consistently the most abundant group of non-insects. Invertebrate abundance in the nearshore habitat of other on-system sites in the Nelson River was generally within the range observed in Cross Lake, with the exception of Little Playgreen Lake, where invertebrate abundance was more than ten times greater than other lakes.

Abundance varied between waterbodies and years in offshore habitat, with Little Playgreen Lake exhibiting the highest numbers of invertebrates in 2010. Non-insects generally dominated the offshore fauna, and Chironomidae and Ephemeroptera were the dominant insects.

Overall, analysis of the four years of CAMP BMI monitoring data collected in the UNRR indicated few significant inter-annual differences in key metrics in either the nearshore or offshore environments in Cross Lake. High variability may have reduced the potential to identify inter-annual differences.

In the offshore habitat of Cross Lake, there was a consistent decline in diversity during 2010-2013. This decline was as a result of the increasing dominance of a single group of bivalves.

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

Waterbody	Date	Nearshore				Offshore				Relative Water Level		Gauged Water Level (daily mean)	
		Water Depth (mean max, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description[1]	Benthic Substrate Texture/Analysis[1, 2]	Water Depth (mean, m)	Water Velocity (mean, category)	Benthic Substrate Type/Description (predominant)	Benthic Substrate Texture/Analysis[1]	Current (m)	High (m)	(WSL m)	(Q m^3/s)
LPLAY	30-Aug-10	0.7	standing	bedrock, boulder	--	8.0	standing	clay	silty clay loam	1.28	n.r.	217.62	--
CROSS	1-Sep-10	0.9	standing	bedrock, boulder	--	8.0	standing	clay, silt	silty clay loam (silty clay)	1.05	n.r.	208.56	--
WLKR	26-Aug-10	0.9	medium	bedrock, boulder, cobble	--	7.1	medium	silt, organic matter (sand, gravel)	sand, loam (sandy loam)	1.51	n.r.	208.43	--
SET	2-Sep-10	0.8	standing	bedrock, boulder, cobble	--	7.4	standing	clay, silt (sand)	silty clay (sandy clay loam)	1.19	n.r.	224.58	--
CROSS	22-Aug-11	1.0	standing	bedrock, boulder, organic matter	--	7.9	standing	clay	silt	0.55	0.32	209.05	--
SIPI	19-Aug-11	1.0	standing	sand, bedrock, boulder (gravel, silt, clay)	sand (silt, clay, loam)	7.5	standing	silt, clay (sand)	silt loam (sandy loam)	0.94	n.r.	189.22	--
UNR	18-Aug-11	1.0	standing	sand, organic matter (silt, clay)	clay (silt)	8.7	standing	clay, silt	silty clay	1.09	n.r.	184.33	5670.88
SET	17-Aug-11	1.0	standing	cobble, boulder (bedrock)	--	7.8	standing	clay	silty clay	0.85	n.r.	225.05	--
PLAYG	16-Aug-12	1.3	standing	sand, gravel	sand	6.7	standing	clay, silt	silt loam	1.27	n.r.	217.36	--
CROSS	14-Aug-12	1.2	standing	bedrock, cobble, boulder	sandy loam	7.1	standing	clay, organic matter, shells	silt loam (silt)	1.50	n.r.	207.83	--
SET	18-Aug-12	1.2	standing	bedrock, cobble, boulder	--	7.5	standing	clay, silt	silty clay	1.14	n.r.	224.71	--
LPLAY	19-Aug-13	0.8	standing	bedrock	--	7.6	standing	clay	silty clay loam	1.45	0.95	217.49	--
CROSS	27-Aug-13	0.6	standing	bedrock (cobble, gravel, sand)	--	6.7	standing	clay	silt loam	1.75	0.98	207.86	--
WLKR	13-Aug-13	0.9	standing	bedrock	--	7.9	standing	silt, clay	sandy loam (loam)	1.49	n.r.	208.40	--
SET	28-Aug-13	0.8	standing	boulder, cobble (bedrock)	--	7.6	standing	silt	silty clay (silt clay loam)	1.31	n.r.	224.49	--

[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 Cross Lake and Setting Lake in the nearshore and offshore environments, 2010 to 2013.

Cross Lake

Year	Abundance (Number/Kicknet Or Number/m²)	Richness	Diversity	Water Level (m ASL)	Discharge (m³/s)
Nearshore					
2010	745	10.60	0.49	208.0	2701.4
2011	321	11.60	0.73	209.0	4188.3
2012	819	11.60	0.60	207.5	1867.4
2013	483	10.60	0.71	208.1	2841.2
Offshore					
2010	1414	5.00	0.73	207.9	2664.1
2011	1518	6.40	0.60	209.0	4188.3
2012	3359	5.80	0.52	207.5	1867.4
2013	1887	4.80	0.36	208.1	2841.2

Setting Lake

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	993	22.00	0.88	224.4	no data
2011	1542	18.60	0.75	224.7	no data
2012	1179	17.80	0.79	225.0	no data
2013	1497	18.60	0.79	224.5	no data
Offshore					
2010	2796	8.00	0.68	224.4	no data
2011	1723	5.20	0.50	224.7	no data
2012	2409	8.00	0.66	225.0	no data
2013	3757	9.80	0.67	224.5	no data

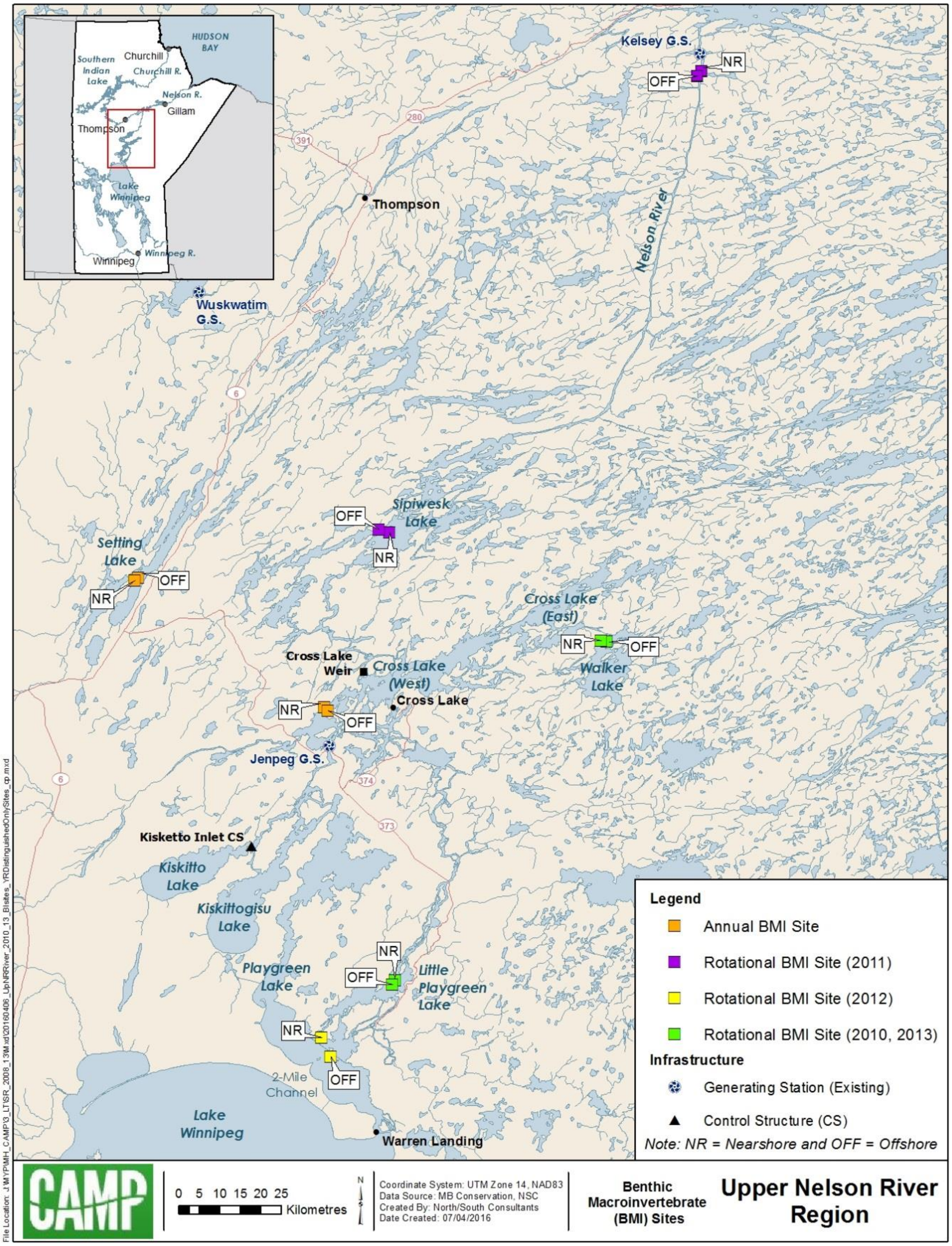
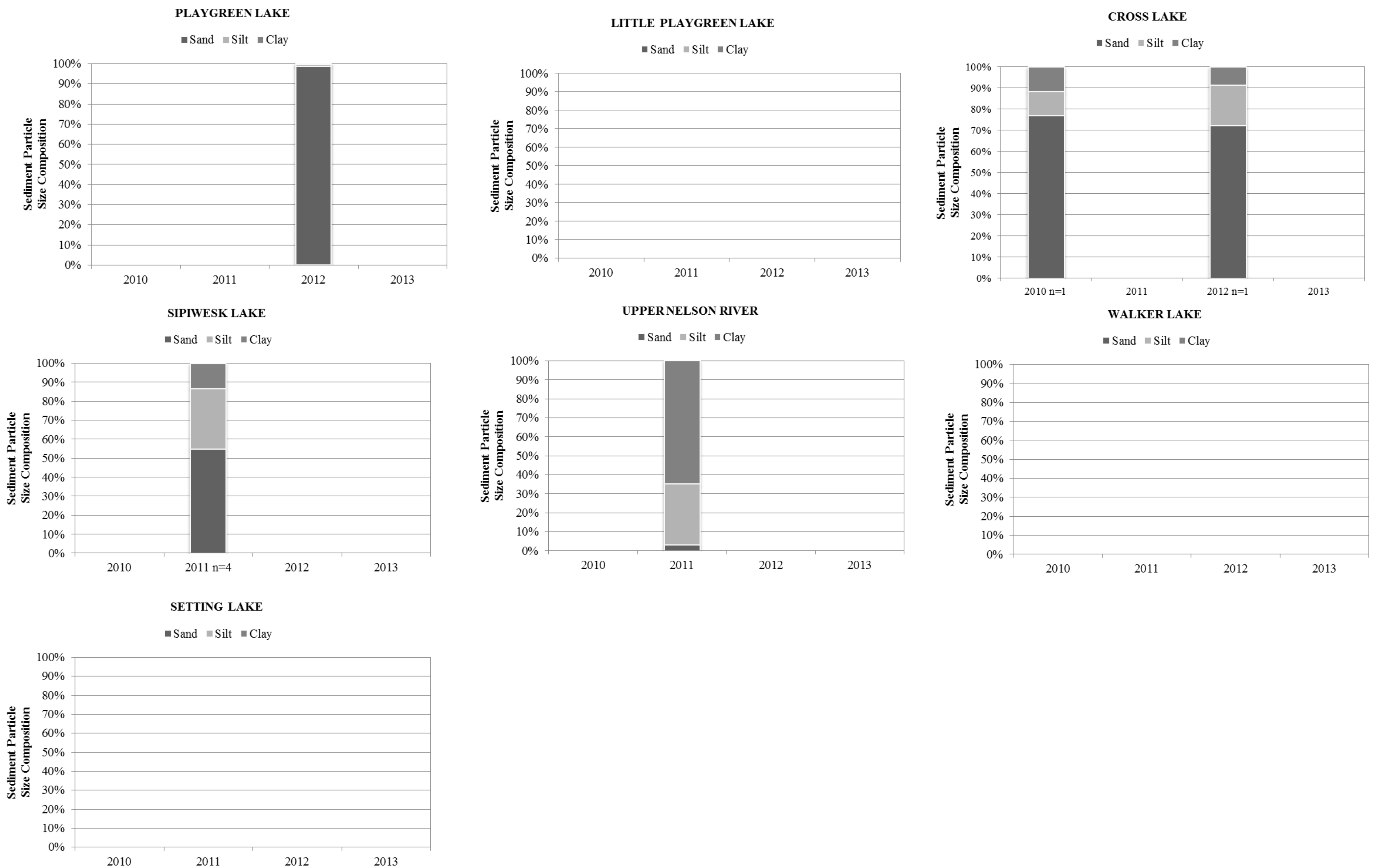


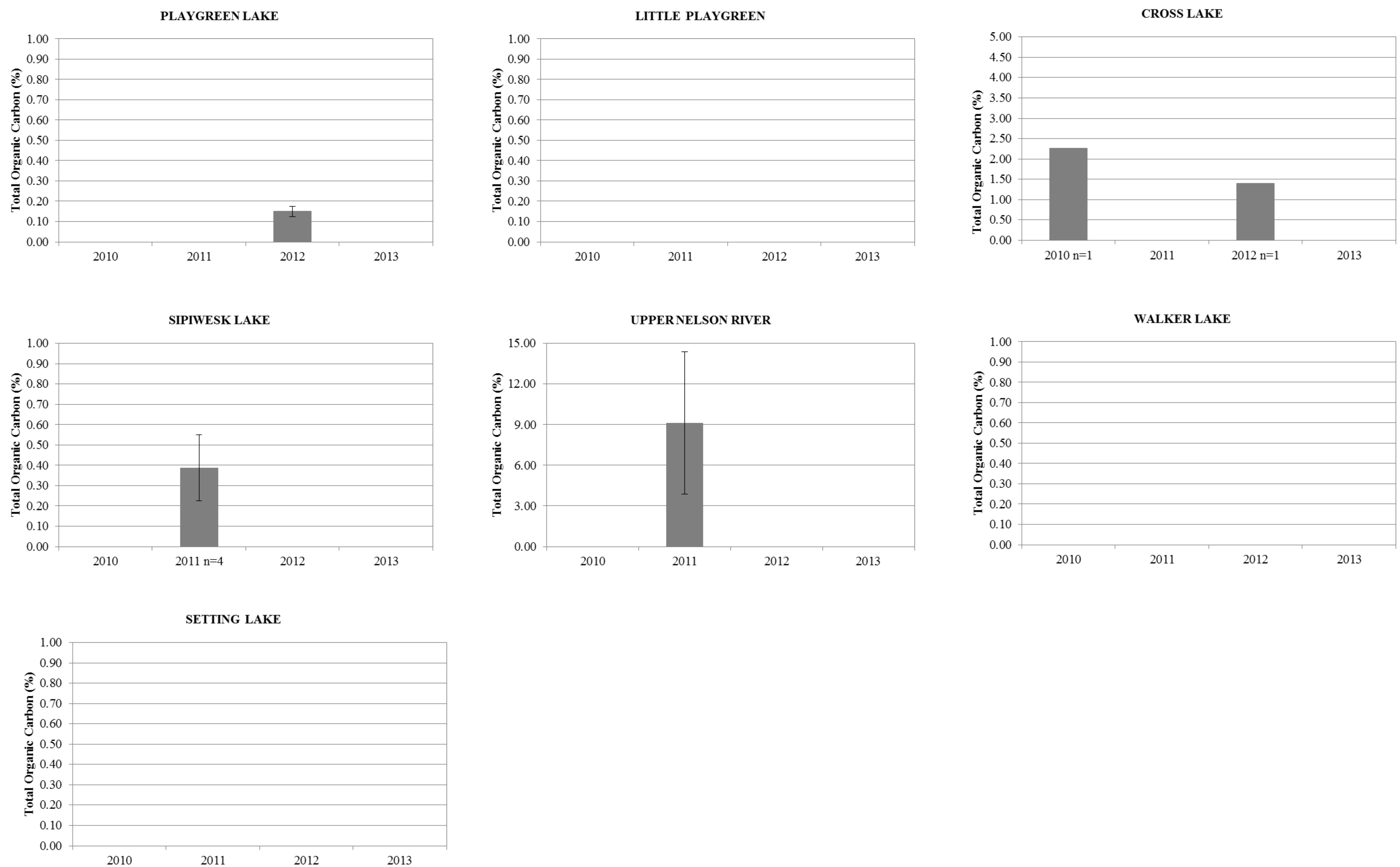
Figure 5-1. Benthic macroinvertebrate sampling sites in the Upper Nelson River Region: 2010 – 2013.



No sediment samples collected at:

- Little Playgreen, Walker, and Setting lakes due to predominantly hard substrate.
- Cross Lake (2011 and 2013) due to predominantly hard substrate, only one sediment sample collected in each of 2010 and 2012.
- Sipiwesk Lake (2010, 2012, and 2013) due to predominantly hard substrate.

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



No sediment samples collected at:

- Little Playgreen, Walker, and Setting lakes due to predominantly hard substrate.
- Cross Lake (2011 and 2013) due to predominantly hard substrate, only one sediment sample collected in each of 2010 and 2012.
- Sipiwesk Lake (2010, 2012, and 2013) due to predominantly hard substrate.

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

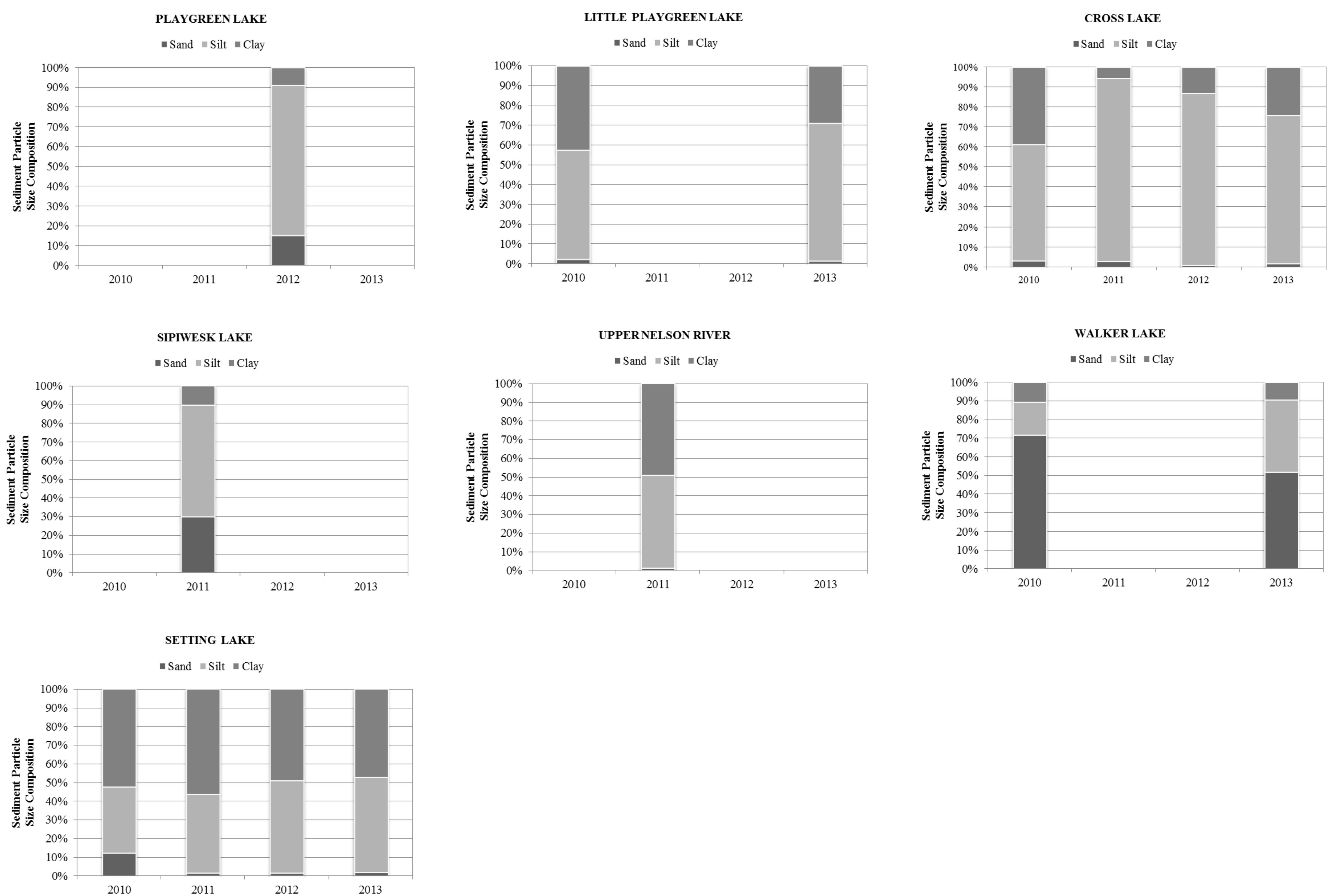


Figure 5-4. Sediment particle size composition (mean % of sand, silt, clay) in the offshore habitat of the Upper Nelson River Region, by year: 2010 – 2013.

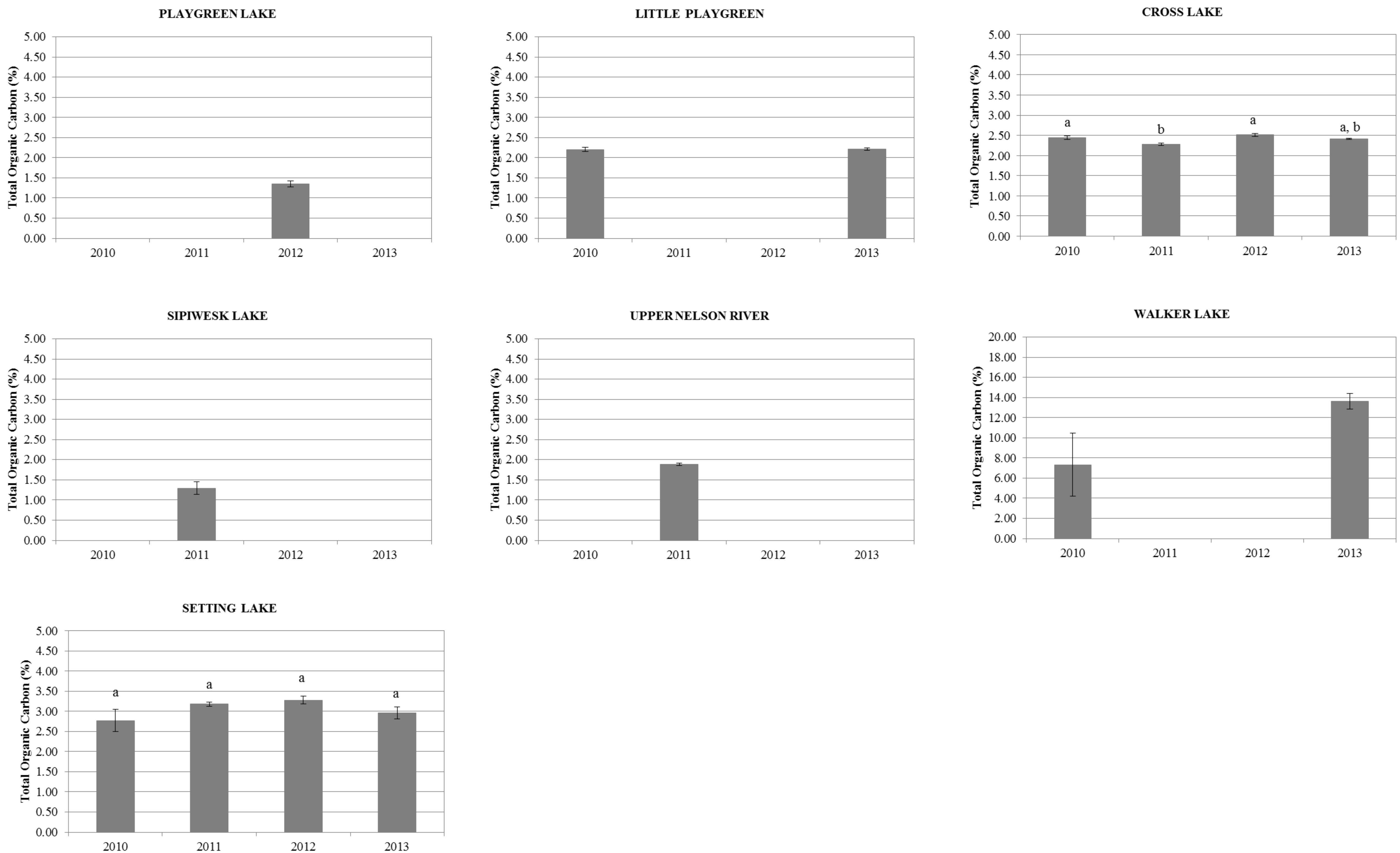


Figure 5-5. Total organic carbon (mean % ± SE) in the offshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

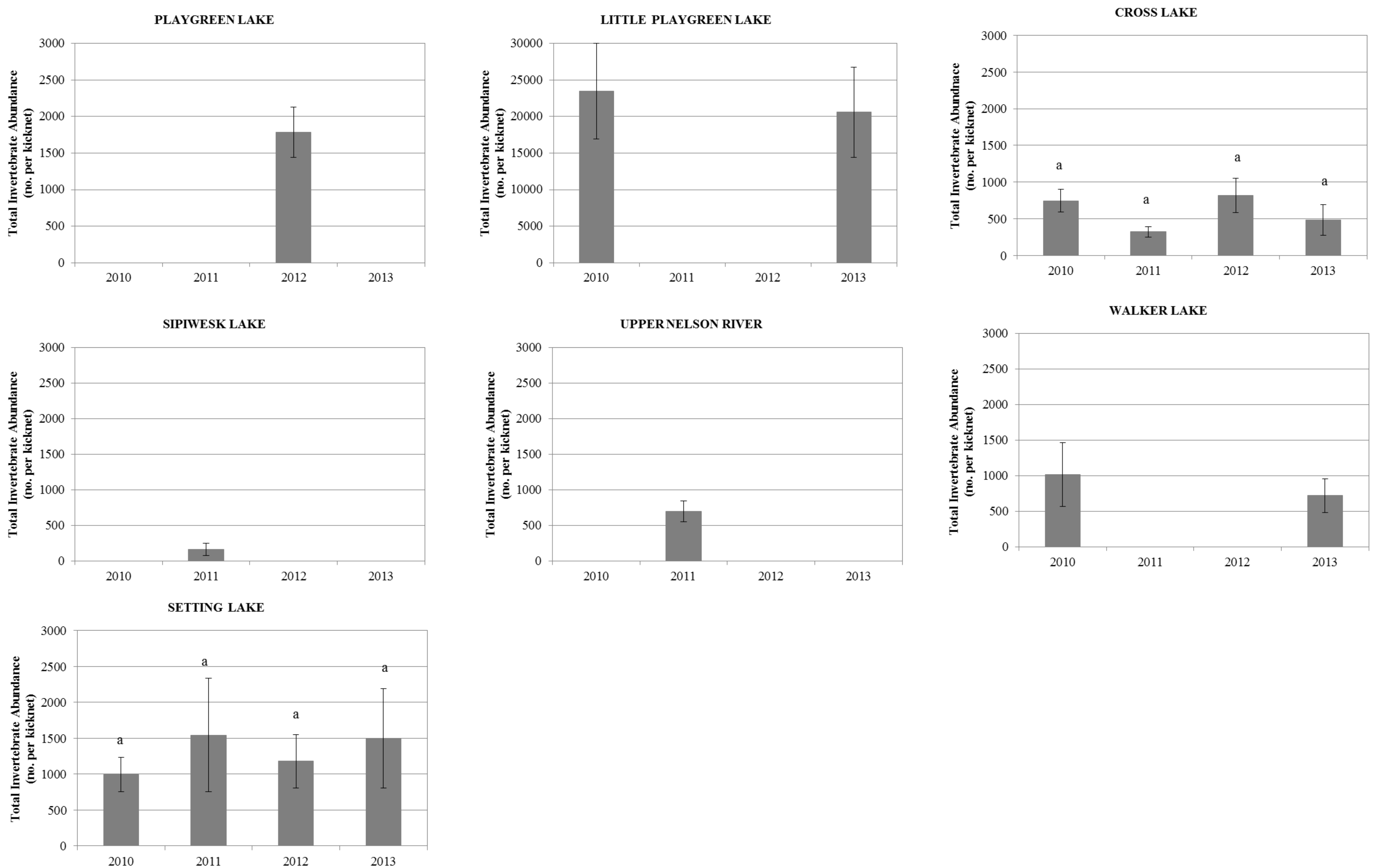


Figure 5-6. Total invertebrate abundance (mean ± SE) in the nearshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Cross and Setting lakes).

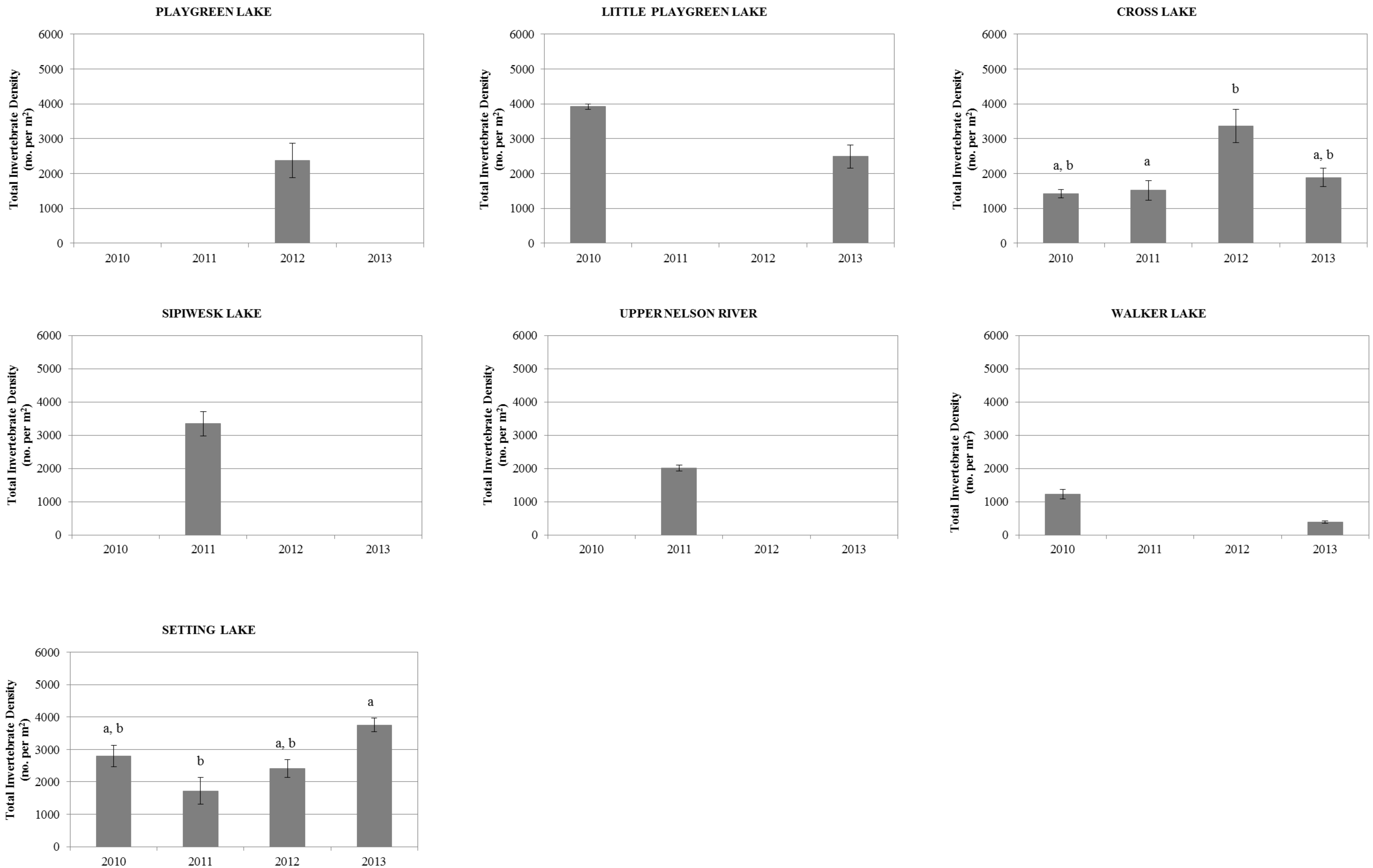


Figure 5-7. Total invertebrate density (mean ± SE) in the offshore of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

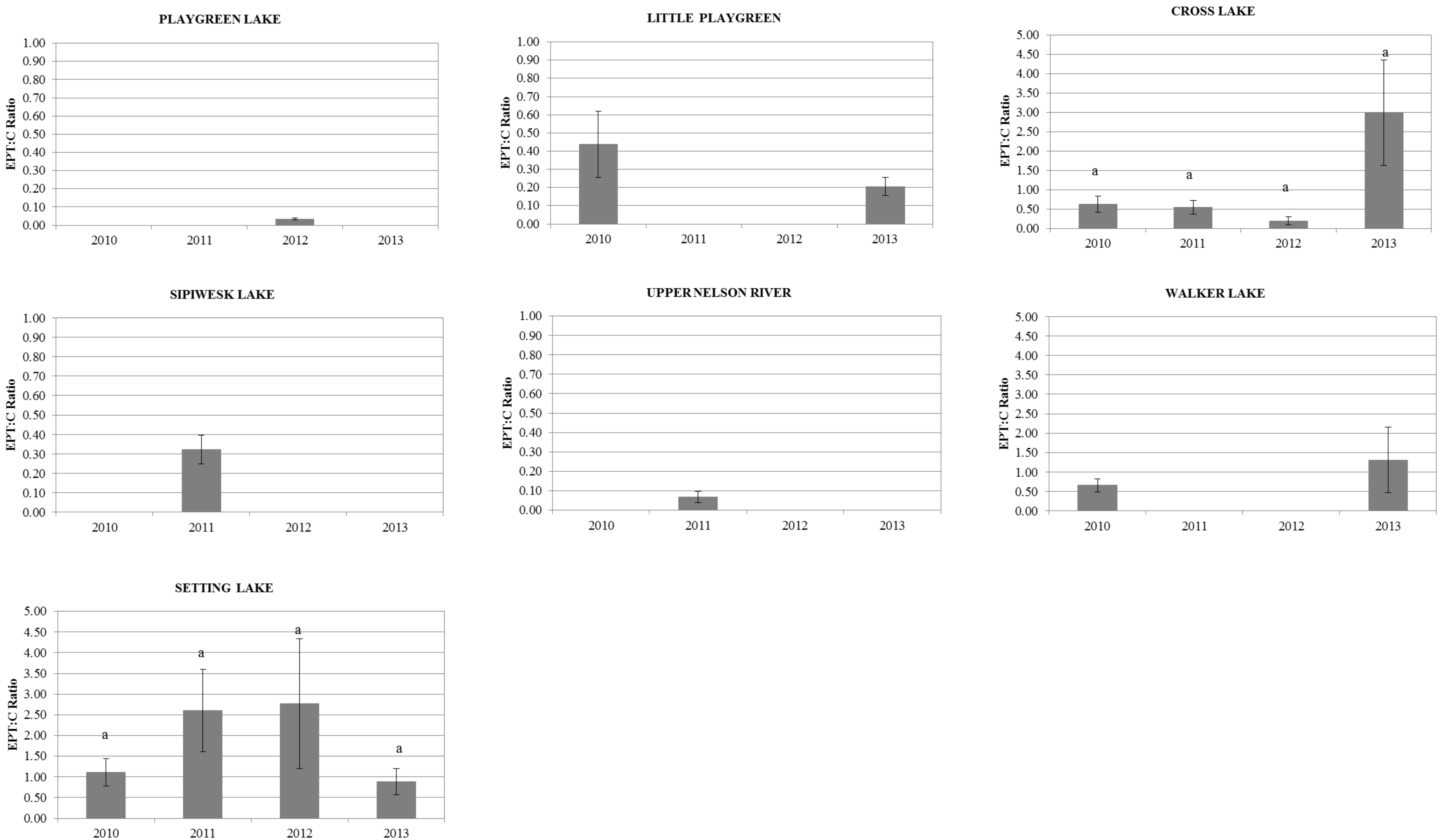


Figure 5-8. EPT:C ratio (mean ± SE) in the nearshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Cross and Setting lakes).Different superscripts indicate significant differences.

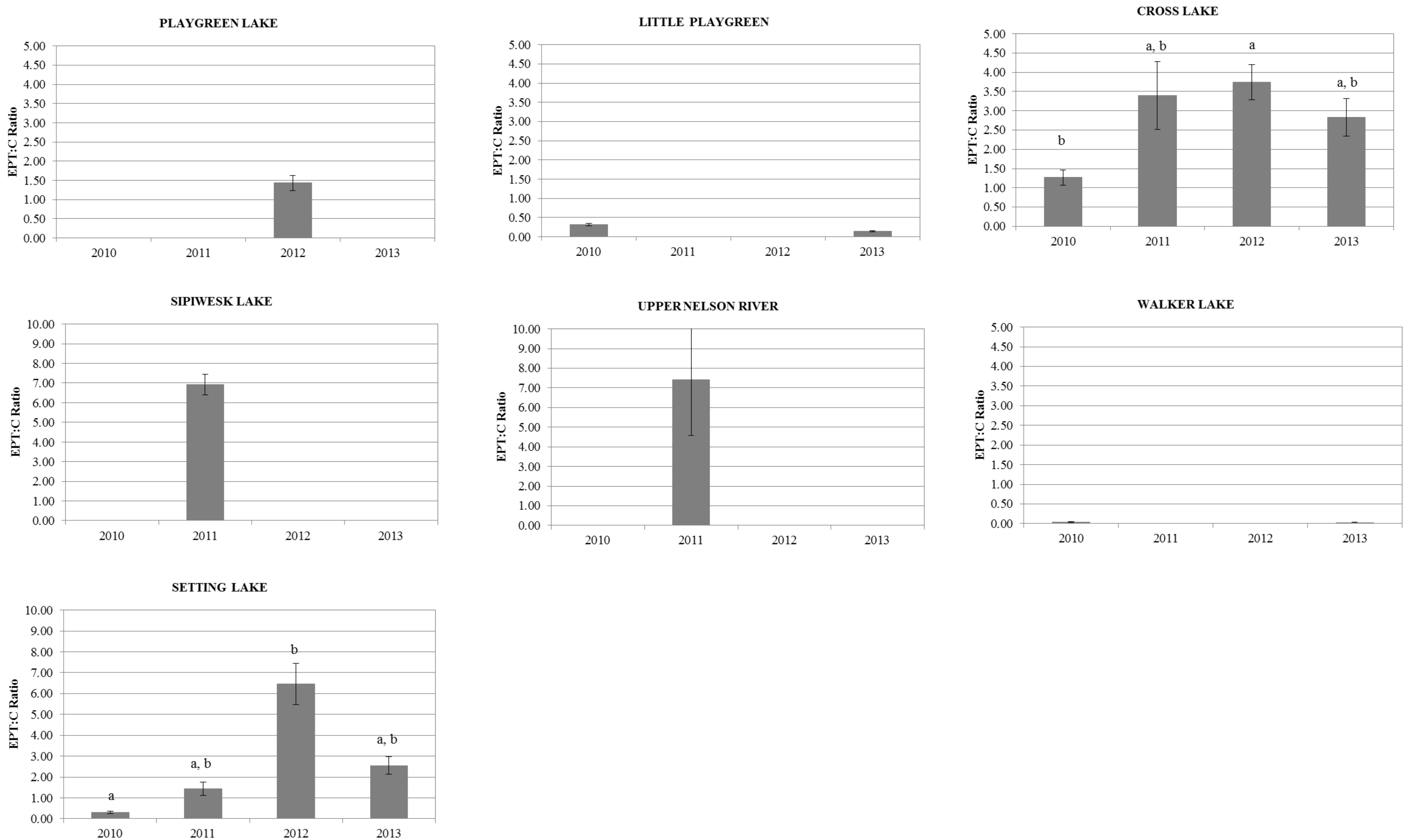


Figure 5-9. EPT:C ratio (mean ± SE) in the offshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

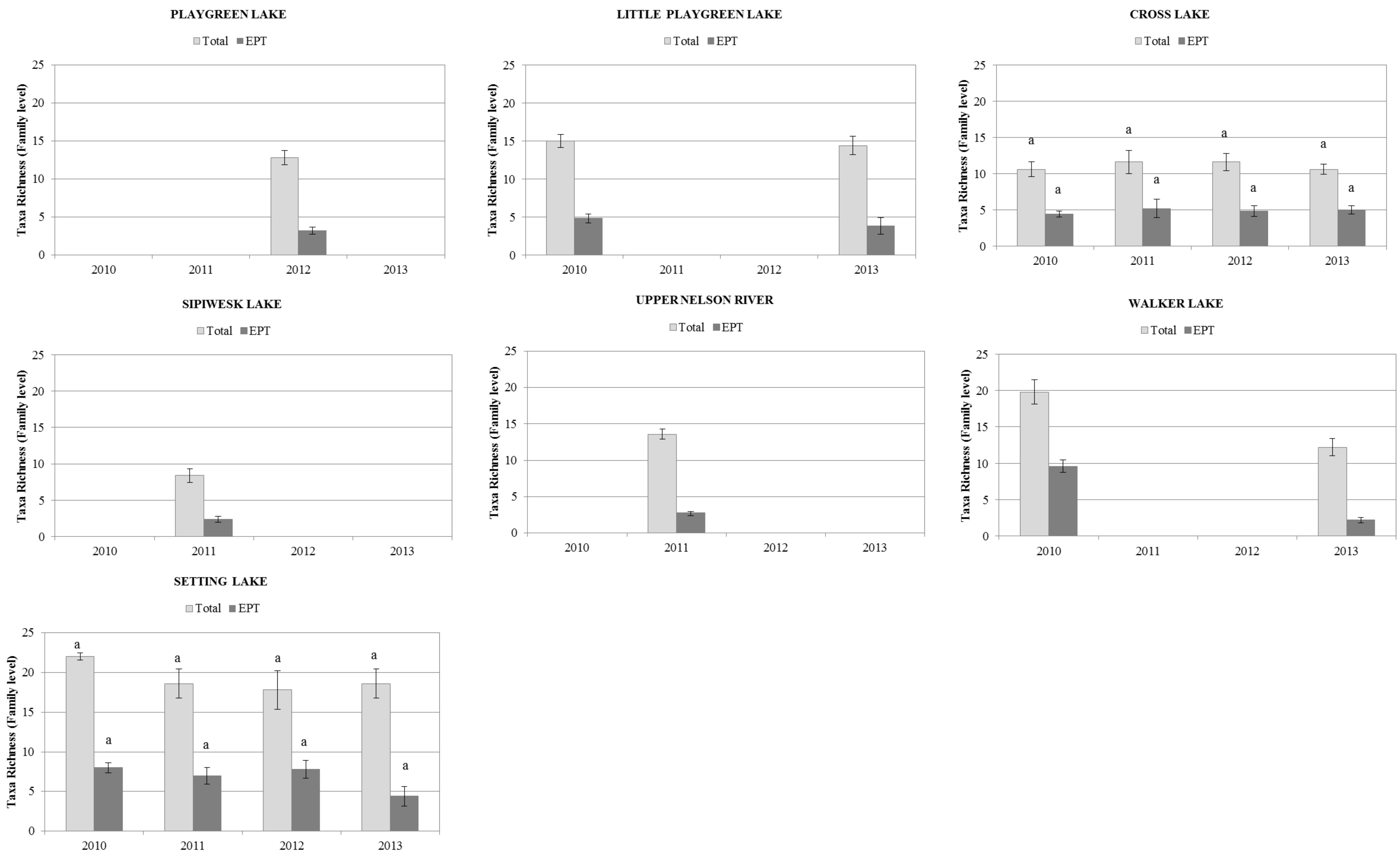


Figure 5-10. Taxonomic richness (total and EPT to family level; mean ± SE) in the nearshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Cross and Setting lakes).

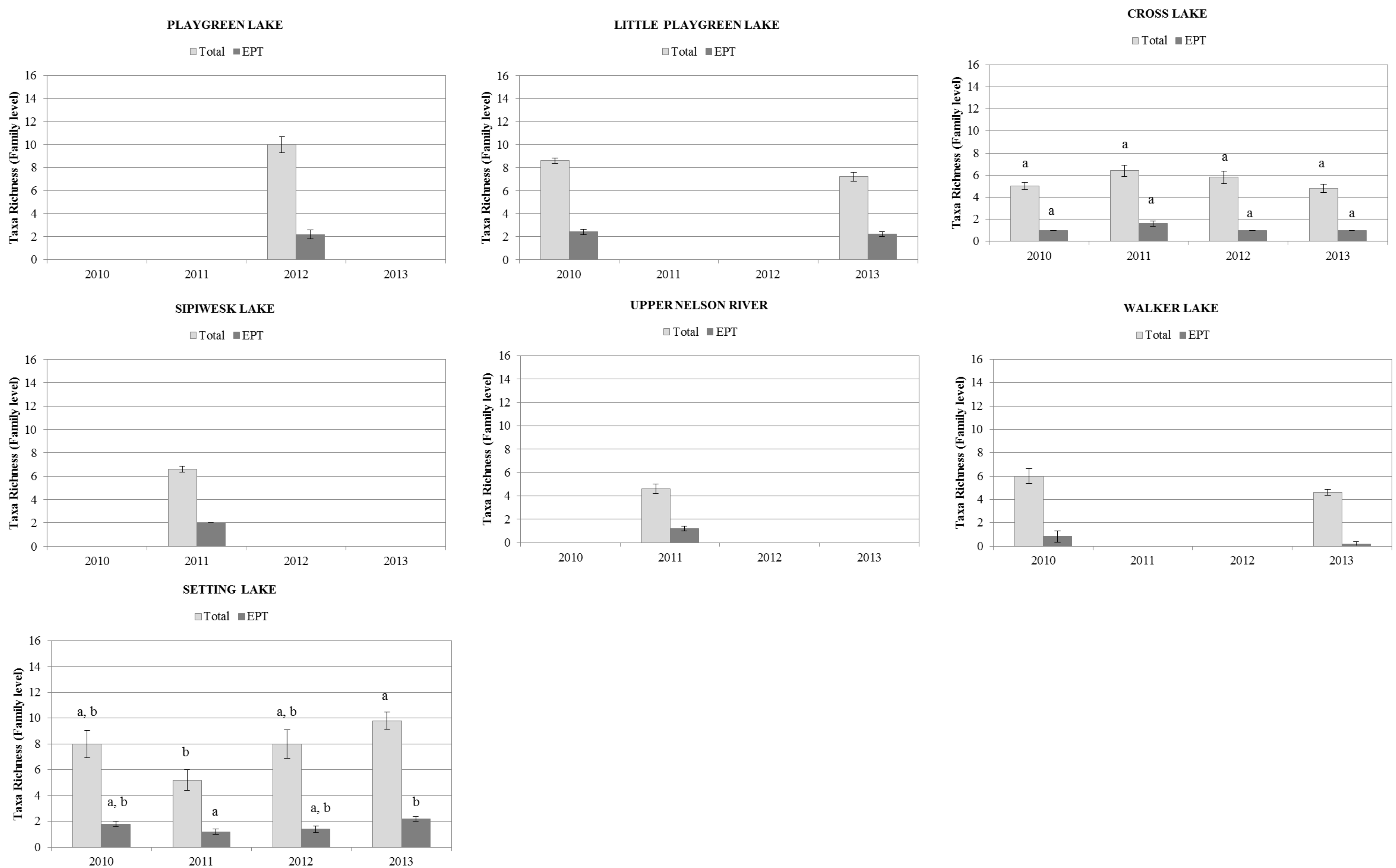


Figure 5-11. Taxonomic richness (total and EPT to family level; mean ± SE) in the offshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote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

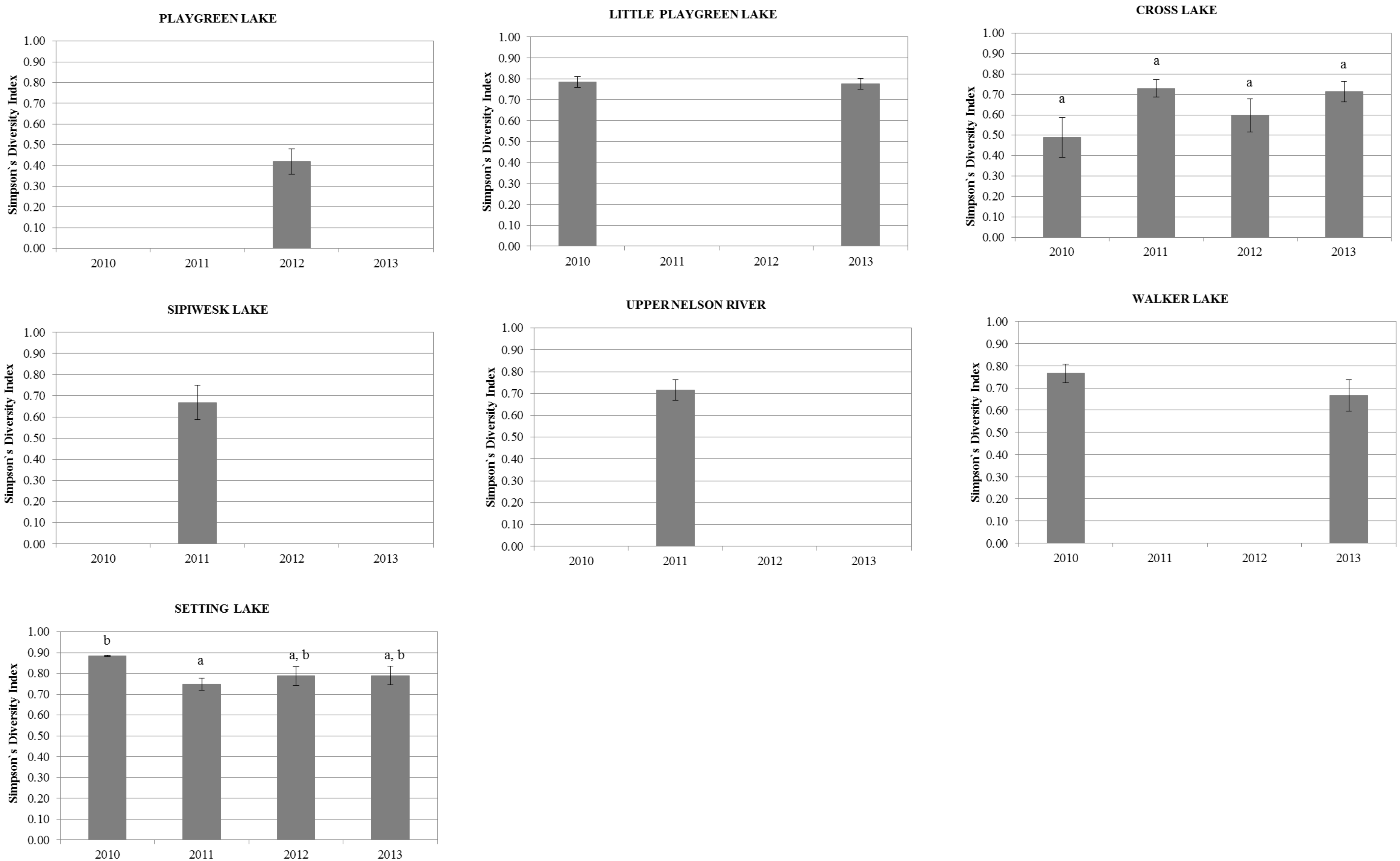


Figure 5-12. Simpson’s Diversity Index (mean ± SE) in the nearshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

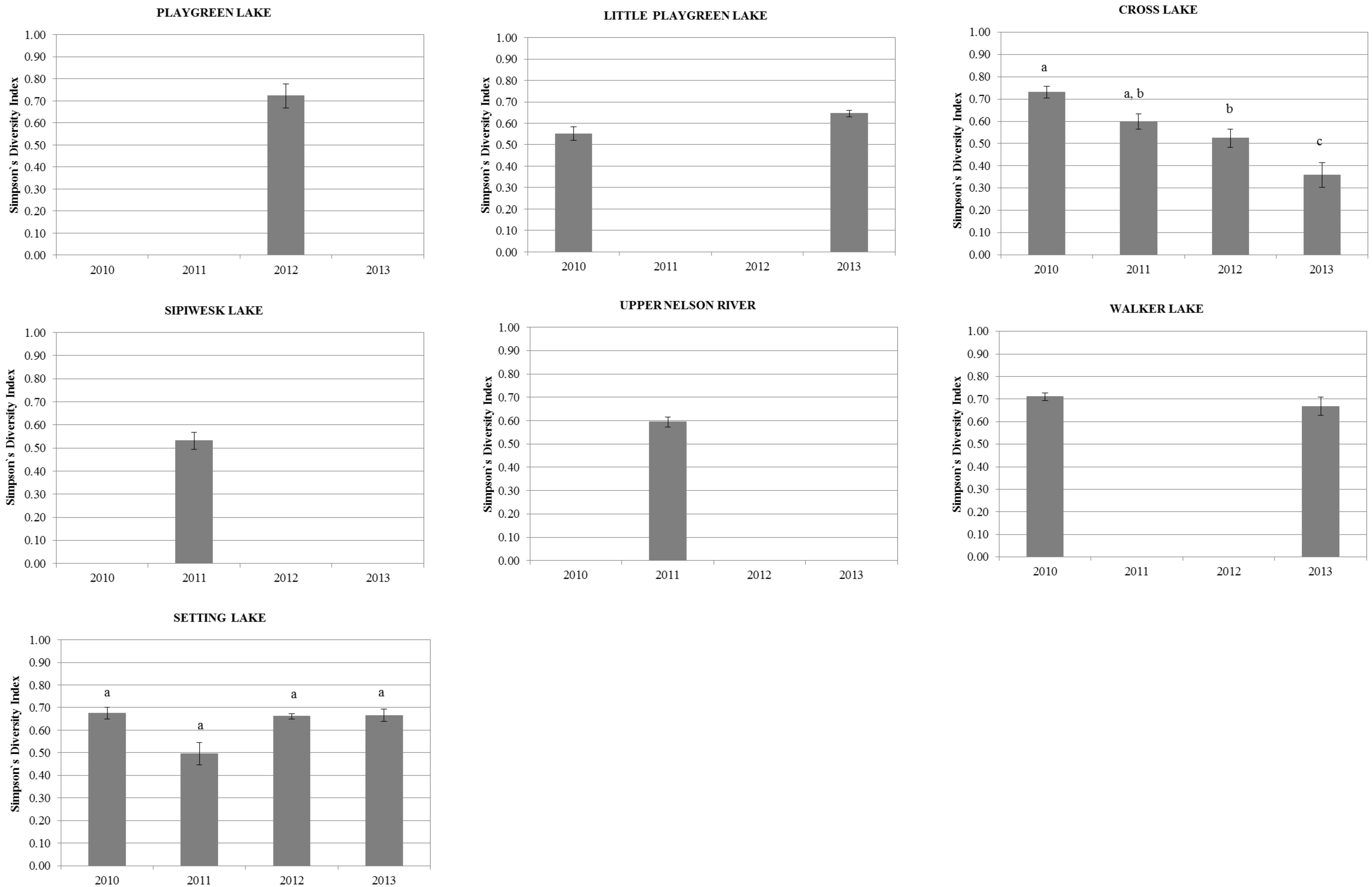


Figure 5-13. Simpson’s Diversity Index (mean ± SE) in the offshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

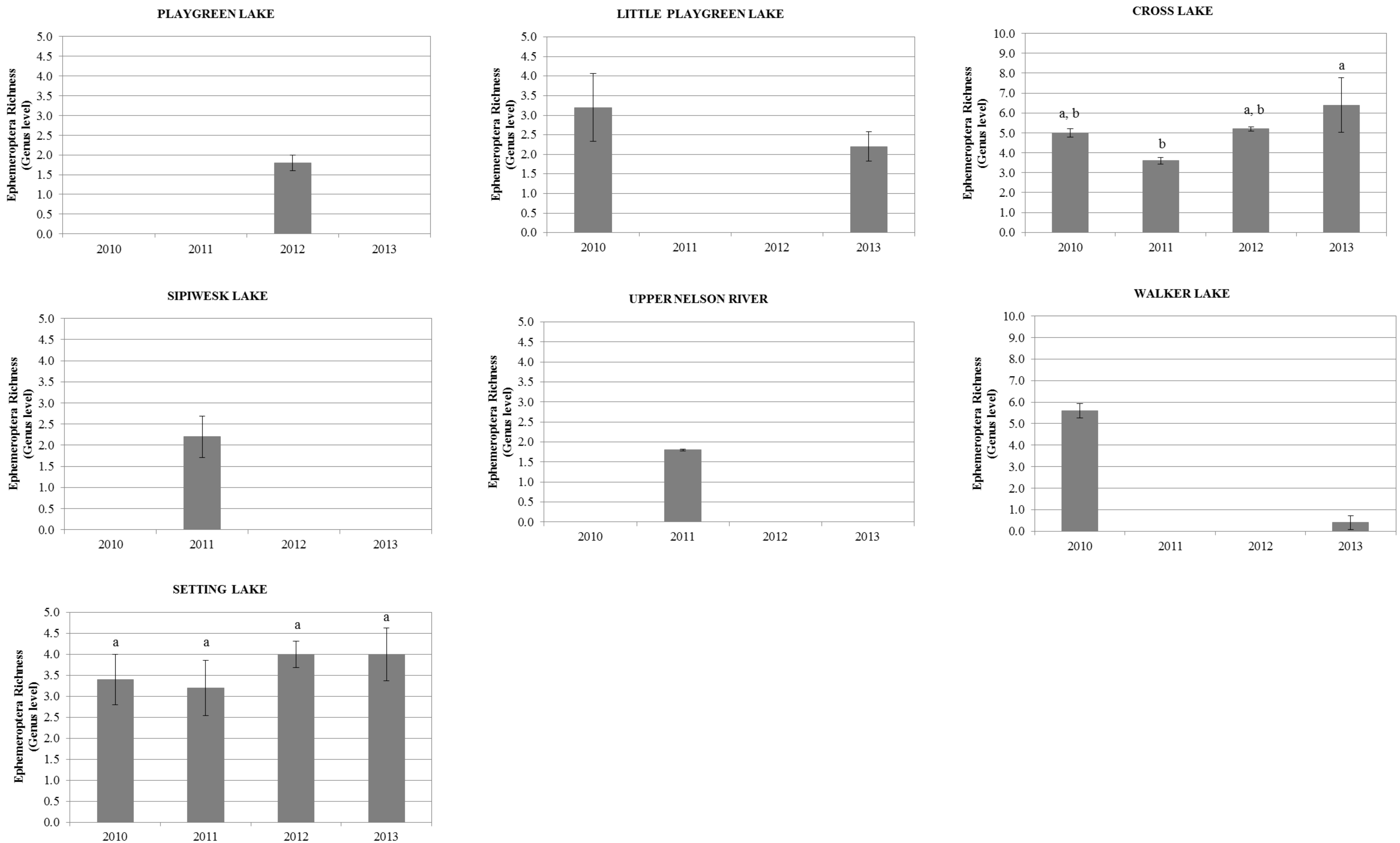


Figure 5-14. Ephemeroptera richness (genus level; mean ± SE) in the nearshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

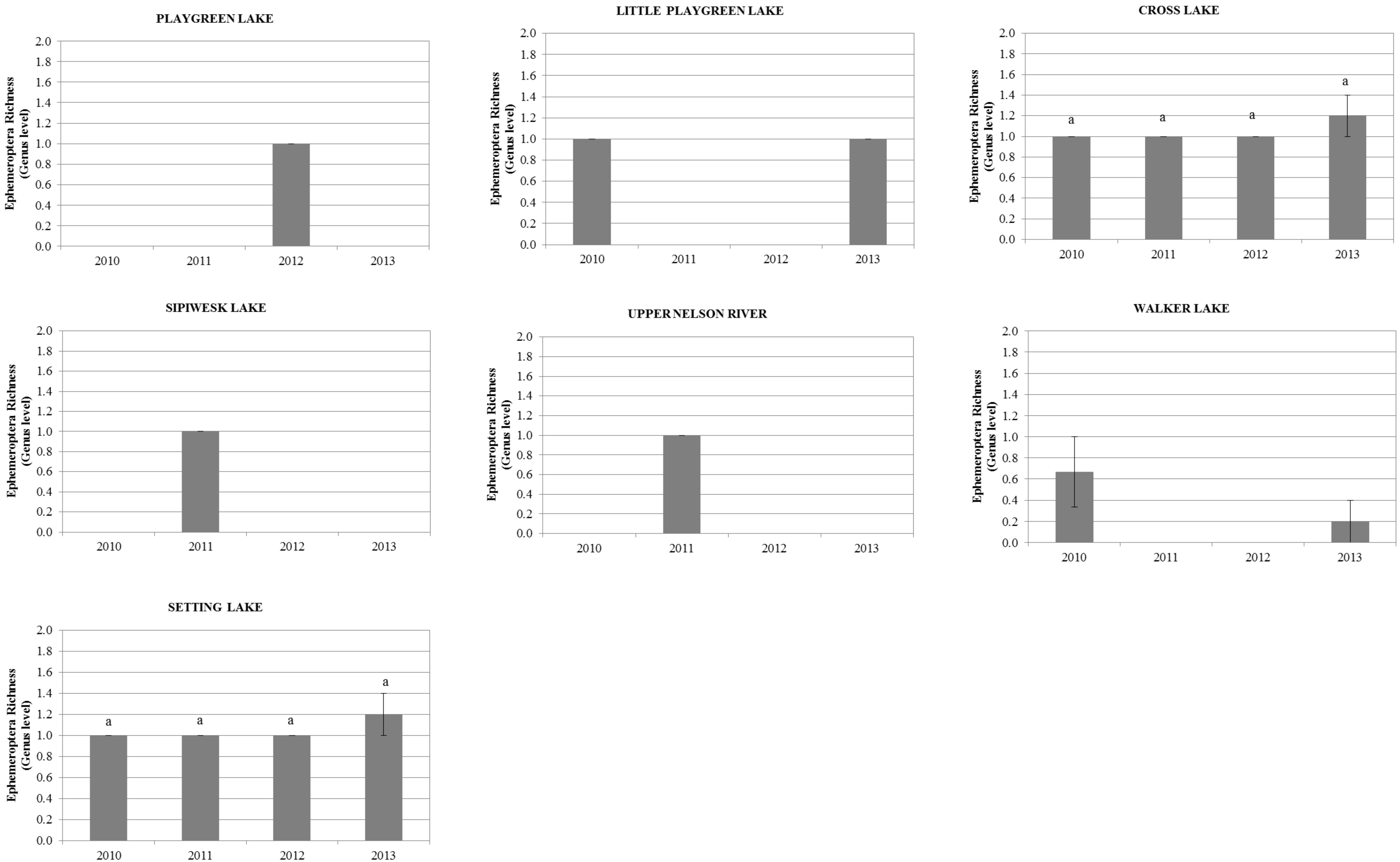


Figure 5-15. Ephemeroptera richness (genus level; mean ± SE) in the offshore habitat of the Upper Nelson River Region, by year: 2010 – 2013. No statistically significant inter-annual differences were observed in the annual monitoring sites (Cross and Setting lakes).

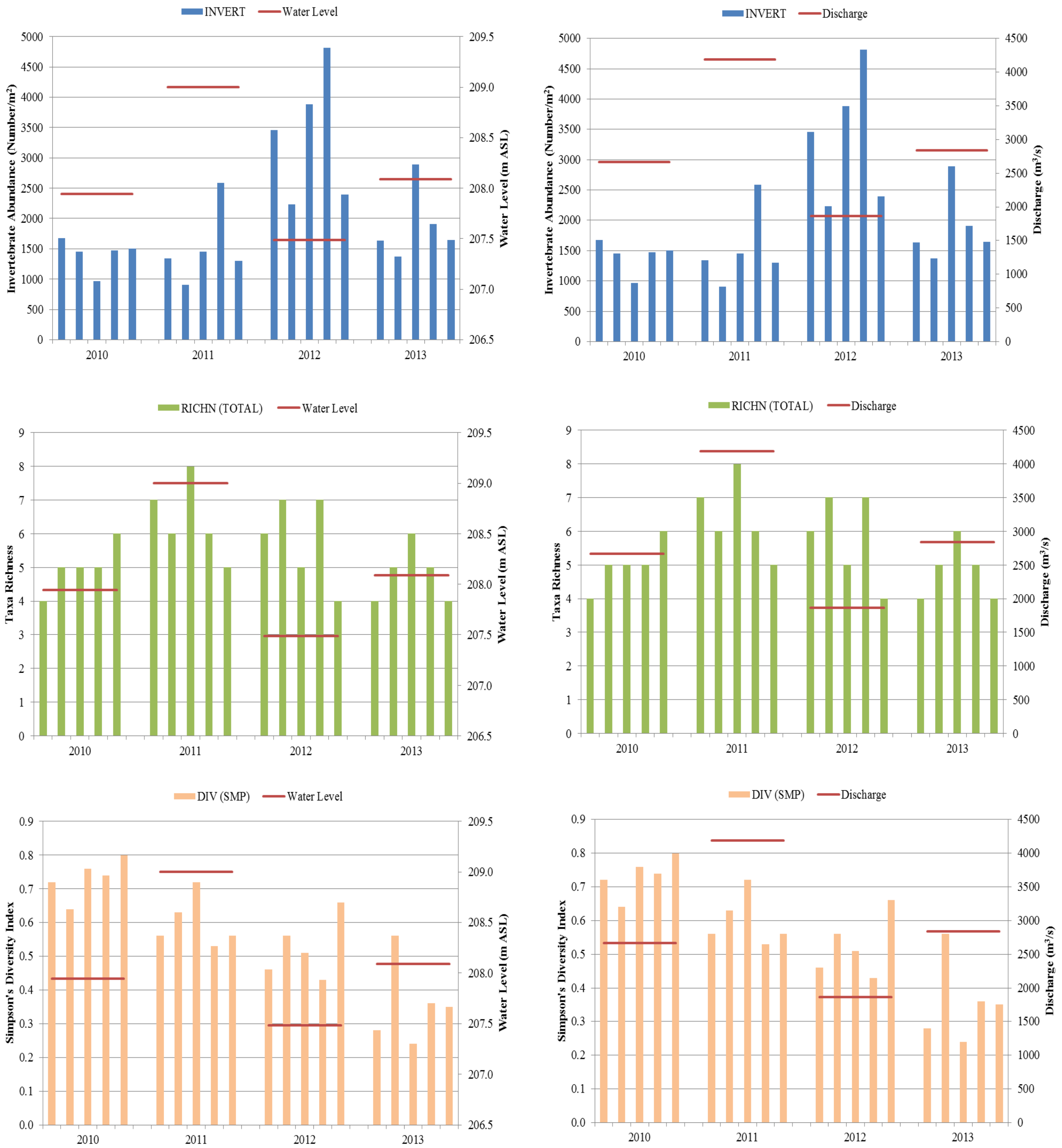


Figure 5-16. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Cross Lake: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

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

6.0 FISH COMMUNITY

6.1 INTRODUCTION

The following provides an overview of the fish community component of CAMP using key metrics measured over years 1 to 6 in the UNRR. As noted in Section 1.0, waterbodies/river reaches sampled annually included one on-system site (Cross Lake – West Basin; herein referred to as Cross Lake) and one off-system lake (Setting Lake). Four additional on-system waterbodies or areas were sampled on a rotational basis, including Playgreen, Little Playgreen, and Sipiwesk lakes and the upper Nelson River (upstream of Kelsey GS), and one off-system waterbody, Walker Lake (Table 6-1; Figure 6-1). A discussion of the rationale for the selection of these waterbodies is provided in Technical Document 1, Section 1.2.2 and the abbreviations for the sampling locations used in the tables and figures is provided in Table 1-1.

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 Technical Document 1, Section 3.6. A complete list of all fish species captured in standard gang and small mesh index gill nets set in UNRR waterbodies, 2008-2013, is presented in Table 6-2.

6.1.1 Objectives and Approach

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

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

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

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

6.1.2 Indicators

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

Manitoba Hydro and the Province of Manitoba's (2015) RCEA identified several effects of hydroelectric development on fish communities along the upper Nelson River and its associated lakes, although a lack of pre-development data precluded a direct comparison of the key CAMP metrics data. The principal long-term effect of the Kelsey GS appeared to be a shift in the species composition in response to changes in aquatic habitat resulting from Kelsey-related flooding in Sipiwesk Lake. There is no evidence that hydrological changes to Sipiwesk Lake under LWR have affected the overall abundance metric (i.e., CPUE), but species such as Lake Whitefish (*Coregonus clupeaformis*), Cisco (*Coregonus artedi*), Mooneye (*Hiodon tergisus*), and Goldeye (*Hiodon alosoides*) have declined. Reductions in fish habitat in Cross Lake under LWR resulted in substantial declines in fish populations, particularly Lake Whitefish. The fish community stabilized following the construction of a weir that reduced water level effects, but Lake Whitefish stocks have not recovered. There is no evidence from the available data for Playgreen and Little Playgreen lakes that there has been an effect to fish stocks attributable to LWR, although there does appear to have been a shift in the species composition of the south basin of Playgreen Lake from a community dominated by Lake Whitefish and Cisco, to one dominated by White Sucker (*Catostomus commersonii*) and Walleye (*Sander vitreus*). Since the RCEA indicated that the metrics assessed as part of CAMP were largely unaffected by

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

6.2.1.1 Upper Nelson River Region

The mean Hill's number ranged from a high of 7.2 in Sipiwesk Lake (based on one year of sampling) to a low of 4.0 in Little Playgreen Lake (Table 6-3). The Hill's value in the lakes in the UNRR were generally similar, with the exception of Little Playgreen Lake (Figure 6-2). The lower Hill's value in Little Playgreen Lake was primarily related to the dominance of two species, White Sucker and Spottail Shiner (*Notropis hudsonius*), which accounted for >60% of the catch in both sample years. In contrast, there was a more even representation of several species in the other on-system lakes, with four or five species each accounting for about 10-30% of the catch.

The mean Hill's number in the upper Nelson River (5.1) was lower than in the lakes, with the exception of Little Playgreen Lake (Figure 6-2). About the same number of species was captured at the riverine location, but the catch consisted primarily of three species: Spottail Shiner; Walleye; and White Sucker. The upper Nelson River was the only waterbody in the region where Lake Sturgeon (*Acipenser fulvescens*) were captured in index gill nets (Table 6-2).

6.2.1.2 Off-system Waterbodies: Walker and Setting Lakes

The mean Hill's number was 6.0 for Walker Lake and 7.7 for Setting Lake (Table 6-3). The mean Hill's value in Walker Lake was in the range of values observed at the on-system lakes (Figure 6-2). The mean Hill's value in Setting Lake was slightly higher than those of the on-system lakes. This difference is likely a function of fewer species captured in Walker Lake (11 species) compared to Setting Lake (15 species). Among the off-system waterbodies, two additional species of sucker (Longnose Sucker [*Catostomus catostomus*] and

Shorthead Redhorse [*Moxostoma macrolepidotum*]) and sculpin (Mottled [*Cottus bairdii*] and Slimy [*Cottus cognatus*]), as well as Burbot (*Lota lota*) were captured in Setting Lake, while Freshwater Drum (*Aplodinotus grunniens*) were only captured in Walker Lake (Table 6-2).

6.2.1.3 Temporal Comparisons and Trends

Sites sampled annually (Cross Lake and Setting Lake) were examined for temporal trends. The Hill's numbers for these waterbodies showed variability among sampling years (Figure 6-2). Over the 6-year sampling period, the Hill's number ranged from a high of 7.8 in 2011 to a low of 6.0 in 2012 in Cross Lake and from 6.7 in 2009 to 8.5 in 2013 in Setting Lake. Species diversity over the 6-year period was about equally variable at Cross Lake and Setting Lake as indicated by the similar size of the interquartile ranges (Figure 6-2).

6.2.2 Abundance (Catch-Per-Unit-Effort)

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

6.2.2.1 Upper Nelson River Region

Fish Community

In standard gangs, the mean CPUE ranged from a high of 74 fish/100 m/24 h in Playgreen Lake to a low of 23 fish/100 m/24 h in the upper Nelson River (Table 6-3). The abundance of large-bodied fish was considerably lower in Cross Lake (38 fish/100 m/24 h) compared to Sipiwesk Lake (47 fish/100 m/24 h) and Playgreen and Little Playgreen lakes (74 and 68 fish/100 m/24 h, respectively; Table 6-3).

In small mesh gangs, the mean CPUE ranged from a high of 770 fish/30 m/24 h in Little Playgreen Lake to a low of 111 fish/30 m/24 h in Sipiwesk Lake (Table 6-3). Small mesh gillnet catches were more variable than standard gang catches, but the more common small-bodied species included Spottail Shiner, Trout-perch (*Percopsis omiscomaycus*), and Emerald Shiner (*Notropis atherinoides*; Figure 6-3).

The species composition in the standard gangs was generally similar among the on-system lakes, with the same three species dominating the catch (Figure 6-3). The most abundant large-bodied species were typically White Sucker, Walleye, and Northern Pike (*Esox lucius*; Figure 6-3). There were differences in the abundance of species among lakes, likely in response to differences in habitat characteristics. The CPUE of Walleye and Yellow Perch (*Perca flavescens*) was lowest in Sipiwesk Lake, where Sauger (*Sander canadense*) were particularly abundant.

The abundance of fish in the upper Nelson River was considerably lower than in the on-system lakes (23 fish/100 m/24 h; Figure 6-4). The species composition in the riverine location was similar to that of the lakes, but fish catches in the river were lower for species such as White Sucker, Northern Pike, and Yellow Perch (Figure 6-3).

Lake Whitefish

Lake Whitefish mean CPUE ranged from a high of 2 fish/100 m/24 h in Playgreen Lake to zero at Sipiwesk Lake and the upper Nelson River (Table 6-3). The capture rate of Lake Whitefish in upper Nelson River on-system waterbodies appeared to decrease in a downstream direction, with mean CPUEs ranging from 2 fish/100 m/24 h in Playgreen Lake, 0.3 fish/100 m/24 h in Little Playgreen Lake, 0.1 fish/100 m/24 h in Cross Lake, to absent from the catches in Sipiwesk Lake and the upper Nelson River (Figure 6-5).

Northern Pike

Northern Pike mean CPUE ranged from a high of 9 fish/100 m/24 h in Playgreen and Little Playgreen lakes to a low of 3 fish/100 m/24 h in the upper Nelson River (Table 6-3). There was considerable within lake variation in the catches of Northern Pike, but the mean CPUE was generally similar among the on-system lakes, ranging from 6-9 fish/100 m/24 h (Figure 6-6). Capture rates were considerably lower at the riverine location (3 fish/100 m/24 h) compared to the lakes (Figure 6-6).

Walleye

Walleye mean CPUE ranged from a high of 12 fish/100 m/24 h in Cross Lake to a low of 2 fish/100 m/24 h in Sipiwesk Lake (Table 6-3). There was considerable variation in the catches of Walleye in on-system lakes within the UNRR (Figure 6-7). The median CPUE values at Cross and Little Playgreen lakes were higher than at Playgreen and Sipiwesk lakes, as evidenced by a lack of overlap in the interquartile ranges. Walleye abundance at the riverine location was within the range of values found at Little Playgreen and Cross Lakes (Figure 6-7).

White Sucker

White Sucker mean CPUE in standard gangs ranged from a high of 38 fish/100 m/24 h in Playgreen Lake to a low of 6 fish in Cross Lake and the upper Nelson River (Table 6-3). There was considerable variation in the catches of White Sucker among on-system waterbodies (Figure 6-8). The CPUE was higher in Playgreen and Little Playgreen lakes (37-38 fish/100 m/24 h), moderate in Sipiwesk Lake (26 fish/100 m/24 h), and lowest in Cross Lake and the upper Nelson River (6 fish/100 m/24 h).

6.2.2.2 Off-system Waterbodies: Walker and Setting Lakes

Fish Community

In standard gangs, the mean CPUE was 31 fish/100 m/24 h in Walker Lake and 74 fish/100 m/24 h in Setting Lake (Table 6-3). Fish capture rates in Walker Lake were similar to those of Cross Lake, while those of Setting Lake were similar to capture rates in Playgreen and Little Playgreen lakes (Figure 6-4).

In small mesh gangs, the mean CPUE was 114 fish/30 m/24 h in Walker Lake and 90 fish/30 m/24 h in Setting Lake (Table 6-3). The small-bodied fish community of Walker and Setting lakes was dominated by Spottail Shiner, with smaller numbers of Emerald Shiner and Trout-perch (Figure 6-3). Rainbow Smelt (*Osmerus mordax*) were not captured in either lake (Table 6-2).

White Sucker, Walleye, and Cisco composed a large proportion of the large-bodied fish community in both off-system lakes (Figure 6-3). The catch in Setting Lake was also characterized by a high abundance of Sauger, similar to what was observed in Sipiwesk Lake (Figure 6-3).

Lake Whitefish

Lake Whitefish had a mean CPUE in standard gangs of 0.1 fish/100 m/24 h in Walker Lake and 1.3 fish in Setting Lake (Table 6-3). The CPUE of Lake Whitefish in Walker Lake was within the range observed in Cross Lake (Figure 6-5). The capture rate of Lake Whitefish in Setting Lake was comparable to that in Playgreen Lake.

Northern Pike

Northern Pike had a mean CPUE in standard gangs of 4 fish/100 m/24 h in both Walker and Setting lakes (Table 6-3). Northern Pike CPUE in both of the off-system lakes was significantly lower than in the on-system lakes as evidenced by the lack of overlap among the interquartile ranges (Figure 6-6).

Walleye

Walleye had a mean CPUE in standard gangs of 6 fish/100 m/24 h in Walker Lake and 16 fish/100 m/24 h in Setting Lake (Table 6-3). Walleye CPUE in Walker Lake was lower than in Cross Lake, as evidenced by a lack of overlap of the interquartile ranges, but was within the range at Playgreen Lake (Figure 6-7). The capture rate of Walleye in Setting Lake exceeded that of all the on-system waterbodies.

White Sucker

White Sucker had a mean CPUE in standard gangs of 13 fish/100 m/24 h in Walker Lake and 12 fish in Setting Lake (Table 6-3). White Sucker catches in the off-system lakes were within the range observed in the on-system lakes (Figure 6-8). There was little variation in the abundance of White Sucker within each off-system lake, as evidenced by the small interquartile ranges.

6.2.2.3 Temporal Comparisons and Trends

Fish Community

Sites sampled annually (Cross Lake and Setting Lake) were examined for temporal trends. The annual total CPUE values for waterbodies sampled annually showed variability among sampling years (Figure 6-4). Over the 6-year sampling period, the mean CPUE ranged from 31 fish/100 m/24 h in 2009 to 47 fish/100 m/24 h in 2008 in Cross Lake and from 68 fish/100 m/24 h in 2009 and 2013 to 83 fish/100 m/24 h in 2010 in Setting Lake. There were no significant differences in total CPUE among years at either the on- or off-system locations (Figure 6-9).

Lake Whitefish

The mean CPUE of Lake Whitefish in Cross Lake was very low over the 6-year period, ranging from 0 fish/100 m/24 h from 2009-2011 to 0.2 fish/100 m/24 h in 2008 and 2013 (Figure 6-5). The mean CPUE of Lake Whitefish in Setting Lake was considerably higher than in Cross Lake, and had a much larger interquartile range (Figure 6-5). The mean CPUE in Setting Lake ranged from <0.1 fish/100 m/24 h in 2008 to 3 fish/100 m/24 h in 2011 (Figure 6-5).

Statistical comparisons of CPUE at the annual locations indicates that there was no statistical difference among sampling years in Cross Lake, but there was a difference among sampling years in Setting Lake (Figure 6-10). The capture rate of Lake Whitefish in Setting Lake was statistically higher in 2011 compared to 2008 and 2009. However, visual examination of the data for the 6-year period does not suggest an increasing or decreasing trend for this metric in either the on- or off-system annual location.

Northern Pike

The CPUE of Northern Pike in Cross Lake has varied considerably over the sampling period (Figure 6-6). Statistical comparison of CPUE at this location indicates there was a significant difference in Northern Pike catches among years (Figure 6-11). CPUE was significantly higher in 2008 compared to 2011, but a visual examination of the data for the 6-year period does not suggest a consistent increasing or decreasing trend in this metric (Figure 6-11).

Fish catches in the off-system lake over the 6-year period have shown little variation in the annual abundance of Northern Pike, where the annual CPUE has consistently ranged from 4-5 fish/100 m/24 h (Figure 6-6) and no statistical difference was detected among years (Figure 6-11).

Walleye

The CPUE of Walleye in both on-system and off-system waterbodies sampled annually has varied over the sampling years. The mean CPUE at Cross Lake ranged from a high of 19 fish/100 m/24 h in 2008 to a low of 8 fish/100 m/24 h in 2009 (Figure 6-7). At Setting Lake, the CPUE ranged from 14 fish/100 m/24 h in 2011 to 17 fish/100 m/24 h in 2009 and 2013 (Figure 6-7). There were significant inter-annual differences in CPUE in Cross Lake, but not in Setting Lake (Figure 6-12). In Cross Lake, CPUE was significantly higher in 2008 compared to 2009, but was similar in the remainder of study years. This metric did not appear to show a consistent increasing or decreasing trend over the six-year sampling period.

White Sucker

The CPUE of White Sucker in both on- and off-system lakes that were sampled annually have shown little variation over the sampling years (Figure 6-8). The mean CPUE in Cross Lake ranged from 5 fish/100 m/24 h in 2009 to 7 fish/100 m/24 h in 2008, 20012, and 2013 (Figure 6-8). In Setting Lake, the CPUE ranged from a high of 14 fish/100 m/24 h in 2008 to 11-12 fish/100 m/24 h in the remaining years (Figure 6-7). There were no significant inter-annual differences in CPUE in either location and there was no evidence of a consistent increasing or decreasing trend over the six years of monitoring (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 Upper Nelson River Region

Lake Whitefish

Too few Lake Whitefish between 300 and 499 mm in fork length were captured at on-system waterbodies to generate a robust mean Fulton's condition factor (Table 6-3).

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length was similar among on-system waterbodies, ranging from 0.82 to 0.84 in Playgreen, Little Playgreen and Sipiwesk lakes (Table 6-3). The exception was Cross Lake, where the mean K_F was 0.74 (Table 6-3). The box plot indicates that the condition of Northern Pike from Cross Lake was lower than in the other on-system lacustrine locations by the lack of overlap in the interquartile ranges (Figure 6-14). There were insufficient numbers of Northern Pike captured in the upper Nelson River to include in the analysis.

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm from on-system waterbodies ranged from 1.20 in Cross Lake to 1.35 in Sipiwesk Lake (Table 6-3). As observed for Northern Pike, the condition of Walleye was generally consistent within the on-system waterbodies, as shown by the overlap in the interquartile ranges for all of the waterbodies, except for Cross Lake (Figure 6-15).

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length was fairly similar among on-system waterbodies, ranging from a high of 1.66 at Little Playgreen Lake to a low of 1.63 at Cross Lake (Table 6-3; Figure 6-16).

6.2.3.2 Off-system Waterbodies: Walker and Setting Lakes

Lake Whitefish

Mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length in Setting Lake was 1.41 (Table 6-3; Figure 6-17). Too few Lake Whitefish were captured in Walker Lake to generate a robust mean.

Northern Pike

Mean Fulton's condition factor for Northern Pike from Walker Lake and Setting Lake was 0.68 and 0.70, respectively (Table 6-3). The mean K_F was lower in the off-system lakes compared to the on-system system waterbodies as shown by a lack of overlap in the interquartile ranges (Figure 6-14).

Walleye

Mean Fulton's condition factor for Walleye from Walker Lake was 1.13 and Setting Lake was 1.14 (Table 6-3). As observed for Northern Pike, the condition of Walleye was lower in the off-system lakes compared to the on-system waterbodies (Figure 6-15).

White Sucker

Mean Fulton's condition factor for White Sucker from Walker Lake was 1.51 and in Setting Lake was 1.59 (Table 6-3). White Sucker from Walker Lake generally had lower condition values than fish from the on-system waterbodies (Figure 6-16). The condition of White Sucker from Setting Lake was similar to those from Cross Lake since the spread of annual mean values overlapped.

6.2.3.3 Temporal Comparisons and Trends

Lake Whitefish

There was an insufficient number of Lake Whitefish between 300 and 499 mm in fork length captured at the on-system waterbodies for a statistical analysis. In Setting Lake, the mean condition of Lake Whitefish captured in 2011 was 1.43 compared to 1.38 in 2013 (Figure 6-17).

Northern Pike

The annual mean condition of Northern Pike between 400 and 699 mm in Cross Lake peaked at 0.78 in 2010 and has shown a decreasing trend in subsequent years to a low of 0.70 in 2013 (Figure 6-14). A similar pattern was observed in the off-system lake, Setting Lake, where the annual K_F ranged from a high of 0.72 in 2010 to a low of 0.67 in 2013. In Cross Lake, the mean K_F was statistically higher in 2008-2011 compared to 2012 and 2013, while in Setting Lake, the mean K_F was statistically higher in 2010 compared to 2013 (Figure 6-18).

Walleye

As observed with Northern Pike, the condition of Walleye in Cross Lake has shown a decreasing trend since 2010 (Figure 6-15). Over the 6-year sampling period, the mean K_F has ranged from a high of 1.26 in 2008 to a low of 1.13 in 2013. There were statistical inter-annual differences in condition – values in 2008 and 2010 were significantly higher than those in 2011, 2012, and 2013 (Figure 6-19). The condition of Walleye from Setting Lake was less variable over time compared to Cross Lake as indicated by the smaller interquartile range (Figure 6-15). The K_F values ranged from a low of 1.12 in 2008 to high of 1.17 in 2009. While there were statistical inter-annual differences, there is no evidence for a consistent trend over time. The K_F values in 2009 and 2013 were significantly higher than those in 2008, 2011, and 2012 (Figure 6-19).

White Sucker

The mean condition of White Sucker in Cross Lake decreased from 1.69 in 2010 to 1.62 in 2011, and to 1.59 in 2012, after which it increased to 1.61 in 2013 (Figure 6-16). The difference between the values recorded in 2010 and 2012 was significant (Figure 6-20). A similar pattern was observed in Setting Lake, where the condition decreased from a high of 1.64 in 2010 to 1.58 in 2011, and to 1.55 in 2012, after which it increased to 1.60 in 2013 (Figure 6-16) and the differences between 2010, 2012, and 2013 were significant (Figure 6-20).

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 Upper Nelson River Region

Lake Whitefish

Very few 4 and 5 year old Lake Whitefish were captured at the on-system locations (Table 6-3), and as such, the results for many locations were excluded from the box plots (Figures 6-21 and 6-22).

Northern Pike

Northern Pike captured at the annually sampled on-system waterbody ranged from 1 to 13 years of age, with most of the fish captured over the 6-year sampling period aged between 3 and 8 years (Figure 6-23). The mean length increased for every age up to 10 years, from 223 mm at age 1 to 831 mm at age 10.

The mean length-at-age of 4 year old Northern Pike ranged from a low of 431 mm in the upper Nelson River to a high of 517 mm in Playgreen Lake (Figure 6-24). The length-at-age of Northern Pike was generally consistent among on-system waterbodies as can be seen by the overlap in the box plots (Figure 6-24). The mean fork length of the five 4-year-old Northern Pike captured in the upper Nelson River in the one year that it was sampled was 431 mm, which is lower than observed in the on-system lakes.

Walleye

Walleye captured in Cross Lake ranged from 1 to 24 years, with most of the catch between 2 and 10 years (Figure 6-25). Walleye increased in mean fork length at every age until age 9, from 192 mm at age 1 to 477 mm at age 9, after which the fork length tended to plateau. The exception was one particularly old Walleye that was considerably longer; it had attained a fork length of 671 mm at 24 years of age (Figure 6-25).

The mean length-at-age 3 was generally similar among the upper lakes in the UNRR, with means of 286 mm in Cross Lake and 296-297 in Playgreen and Little Playgreen lakes (Figure 6-26). Three year old Walleye captured in locations farther downstream appeared longer, with mean fork lengths of 325 mm in the upper Nelson River and 379 mm in Sipiwesk Lake (Figure 6-26); however, these means are based on very small numbers of fish (3-11 fish) and only one year of sampling.

6.2.4.2 Off-system Waterbodies: Walker and Setting Lakes

Lake Whitefish

Four and 5-year-old Lake Whitefish were only captured in Setting Lake in 2011 and 2013 (Figures 6-21 and 6-22). At age 4, Lake Whitefish in Setting Lake averaged 351 mm in length (Figure 6-21) and age 5 Lake Whitefish averaged 361 mm (Figure 6-22). An insufficient number of 4- and 5-year-old Lake Whitefish were captured in Walker Lake to calculate length-at-age.

Northern Pike

Similar to what was observed in Cross Lake, Northern Pike captured in Setting Lake ranged from 1 to 15 years of age, with most of the fish captured over the 6-year sampling period aged between 3 and 8 years (Figure 6-23). The mean length of Northern Pike in Setting Lake increased each year up to age 10, from 309 mm at age 1 to 646 mm at age 10, after which the fork length at age fluctuated. Northern Pike from Setting Lake and Cross Lake were generally similar in fork length at early ages (1-4 years), after which fish from Cross Lake obtained a higher mean length-at-age.

At age 4, Northern Pike from Walker Lake averaged 453 mm in length and those from Setting Lake averaged 468 mm (Figure 6-24). The length-at-age 4 of Northern Pike from the off-system lakes were considerably lower than in Playgreen and Little Playgreen lakes as indicated by the lack of overlap in the spreads, but were within the range observed in Cross Lake (Figure 6-24).

Walleye

Walleye captured in the annually sampled off-system waterbody ranged from 1 to 16 years, with most of the catch between 3 and 8 years (Figure 6-25). The mean length increased for every age until up to age 9, from 176 mm at age 1 to 399 mm at age 9, after which the fork length plateaued. Walleye in Setting Lake generally were shorter at all ages compared to fish in Cross Lake.

At age 3, Walleye in Setting Lake averaged 261 mm in length, which was considerably lower than in the on-system lakes as indicated by the lack of overlap in the spreads of the boxplot (Figure 6-26). No 3-year-old Walleye were captured in Walker Lake, so the length-at-age could not be calculated.

6.2.4.3 Temporal Comparisons and Trends

Lake Whitefish

An insufficient number of 4- and 5-year-old Lake Whitefish were captured in UNRR waterbodies over the 6-year sampling period to calculate fork length-at-age in most years, preventing an evaluation of temporal trends.

Northern Pike

There has been considerable variation in the annual mean length-at-age 4 of Northern Pike in Cross Lake, the on-system lake that was monitored annually, as shown by the wide spread of the box plot (Figure 6-24). The mean length-at-age decreased consistently from 538 mm in 2008 to 437 mm in 2011, after which it increased to 456 mm in 2012 and 508 mm in 2013 (Figure 6-24). There was a statistical difference in the 2008 value compared to values in 2011 and 2012 (Figure 6-27).

The fork length-at-age of Northern Pike captured in Setting Lake showed a smaller range of inter-annual variation compared to the on-system lake over the 6-year sampling period, and the trend was reversed (Figure 6-24). The mean length-at-age increased from 434 mm in 2009 to 498 mm in 2011, after which it decreased to 483 mm in 2012 and 464 mm in 2013 (Figure 6-24). However, there were no statistical differences in the length-at-age among years (Figure 6-27).

Walleye

There has been variation in the annual mean length-at-age 3 of Walleye in Cross Lake, the on-system lake that was monitored annually, over the 6-year sampling period (Figure 6-26). The mean length-at-age ranged from lows of 262 and 268 mm in 2008 and 2011 to a high of 316 mm in 2012. There was a significant difference in the length of 3-year olds in 2011 and 2012 (Figure 6-28).

At Setting Lake, the length-at-age of Walleye was relatively consistent over the first four years of sampling, with 3-year olds ranging in length from 251 mm in 2008 to 258 mm in 2009, followed by an increase to 284 in 2012 and 271 in 2013 (Figure 6-26). There was a statistical difference among sampling years in Setting Lake; the length-at-age was statistically highest in 2012 and lowest in 2008 (Figure 6-28).

6.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

The other fish community metric measured under CAMP, as described in Technical Document 1, Section 4.6.1, that was reviewed to assess trends was relative abundance. Information on this metric is included here since the analyses conducted for RCEA on a longer term dataset indicated that a shift in species composition may have occurred in several of the hydro-affected waterbodies over time (Manitoba Hydro and the Province of Manitoba 2015). The relative abundance of fish species captured in standard gang index gill nets set in CAMP waterbodies 2008-2013 within the UNRR is shown in Figure 6-29. The same three species dominated catches in standard gangs in both lacustrine and riverine locations over the 6-year sampling period: White Sucker, Walleye, and Northern Pike. Species such as Quillback (*Carpiodes cyprinus*) and Rock Bass (*Ambloplites rupestris*) were only observed in lakes upstream of the Jenpeg GS, Lake Sturgeon were only captured at the riverine location, and Rainbow Smelt were not present in the off-system lakes. The species composition at Setting Lake differs considerably from the other lakes in that Longnose Sucker and Sauger made up a large proportion of the catch. Cisco were common in both Setting and Walker lakes, and Sauger were common at Sipiwesk Lake.

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 provided by Manitoba Hydro (using water level data from gauges on Cross Lake and Setting Lake and discharge data from the Jenpeg GS) and fish community metrics indicated very few statistically significant relationships (Table 6-4). The only statistically significant relationship that was found was a negative relationship between White Sucker condition and Setting Lake water level during the open-water period.

6.5 SUMMARY

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

- The most common large-bodied species in each of the on-system waterbodies of the UNRR were White Sucker, Walleye, and Northern Pike.
- The diversity of the fish community was generally similar among the on-system waterbodies as indicated by the Hill's index, with the exception of Little Playgreen Lake, where the predominance of two species resulted in a lower value.

- The total catch (i.e., CPUE) from the lakes upstream of the Jenpeg GS (Playgreen and Little Playgreen lakes) was greater compared to those downstream of the GS (Cross and Sipiwesk lakes). There were differences in the abundance among the species:
  - Lake Whitefish were generally not abundant; however, within the region they were most abundant in Playgreen Lake;
  - Northern Pike were more abundant at the lakes compared to the riverine location;
  - Walleye were most abundant at Little Playgreen and Cross Lakes and were least abundant at Sipiwesk Lake; and
  - White Sucker were most abundant at Playgreen and Little Playgreen lakes and least abundant at Cross Lake and the riverine location.
- The condition of Northern Pike and Walleye was considerably lower in Cross Lake compared to the other on-system waterbodies.
- The early growth rates of Walleye and Northern Pike were generally consistent among the outlet lakes (Playgreen, Little Playgreen, and Cross lakes) as shown by a similar mean fork length-at-age 3 and 4, respectively.

There has been considerable variability in the metrics among sampling years over the period of 2008-2013 and statistical comparisons between sampling years for the metrics for which analysis was possible revealed several significant differences at the on-system annual site (Cross Lake – West Basin). However, consistent increasing/decreasing trends were only observed for condition of Northern Pike and Walleye, which has been decreasing since 2010. Further study will indicate whether this pattern persists.

A quantitative consideration of hydrological conditions and fish community metrics for annual waterbodies (Cross and Setting lakes) found no statistically significant relationships for the on-system waterbody that was examined.

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

Location	**Acronym**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
						2008	**2009**	**2010**	**2011**	**2012**	**2013**
Playgreen Lake	PLAYG	X			X		X	X		X	
Little Playgreen Lake	LPLAY	X			X			X			X
Cross Lake - West Basin	CROSS	X		X		X	X	X	X	X	X
Sipiwesk Lake	SIP	X			X				X		
Upper Nelson River	UNR	X			X				X		
Walker Lake	WLKR		X		X			X			X
Setting Lake	SET		X	X		X	X	X	X	X	X

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

Species	**Abbreviation**	**PLAYG** n_Y=3	**LPLAY** n_Y=2	**CROSS** n_Y=6	**SIP** n_Y=1	**UNR** n_Y=1	**WLKR** n_Y=2	**SET** n_Y=6
Lake Sturgeon	LKST					X		
Goldeye	GOLD		X*	X*				
Mooneye	MOON			X*	X	X		
Emerald Shiner	EMSH	X	X	X	X	X	X*	X
Spottail Shiner	SPSH	X	X	X	X	X	X	X
Quillback	QUIL	X*						
Longnose Sucker	LNSC	X*		X*	X	X		X
White Sucker	WHSC	X	X	X	X	X	X	X
Shorthead Redhorse	SHRD	X	X	X	X	X		X
Northern Pike	NRPK	X	X	X	X	X	X	X
Rainbow Smelt	RNSM	X	X*	X	X	X		
Cisco	CISC	X	X*	X		X	X	X
Lake Whitefish	LKWH	X	X*	X*			X	X
Trout-perch	TRPR	X	X	X	X	X	X	X
Burbot	BURB	X*		X*	X	X		X
Mottled Sculpin	MTSC							X*
Slimy Sculpin	SLSC	X*		X*				X*
Rock Bass	RCBS	X*	X					
Yellow Perch	YLPR	X	X	X	X	X	X	X
Logperch	LGPR	X	X*	X*				
Sauger	SAUG	X	X	X	X	X	X	X
Walleye	WALL	X	X	X	X	X	X	X
Freshwater Drum	FRDR	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 Upper Nelson 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	PLAYG	3	6.9	0.7	-	-	-	-	-	-	-	-	-
	LPLAY	2	4.0	0.7	-	-	-	-	-	-	-	-	-
	CROSS	6	6.9	0.2	-	-	-	-	-	-	-	-	-
	SIP	1	7.2	-	-	-	-	-	-	-	-	-	-
	UNR	1	5.1	-	-	-	-	-	-	-	-	-	-
	WLKR	2	6.0	0.4	-	-	-	-	-	-	-	-	-
	SET	6	7.7	0.2	-	-	-	-	-	-	-	-	-
Standard gang	PLAYG	-	-	-	3065	74.3	6.1	-	-	-	-	-	-
	LPLAY	-	-	-	1316	67.6	8.8	-	-	-	-	-	-
	CROSS	-	-	-	3240	37.8	2.0	-	-	-	-	-	-
	SIP	-	-	-	749	46.8	-	-	-	-	-	-	-
	UNR	-	-	-	199	22.9	-	-	-	-	-	-	-
	WLKR	-	-	-	556	31.3	0.4	-	-	-	-	-	-
	SET	-	-	-	7229	74.2	2.4	-	-	-	-	-	-
Small mesh	PLAYG	-	-	-	3407	358.3	213.1	-	-	-	-	-	-
	LPLAY	-	-	-	3726	769.9	286.7	-	-	-	-	-	-
	CROSS	-	-	-	3856	157.4	10.9	-	-	-	-	-	-
	SIP	-	-	-	441	111	-	-	-	-	-	-	-
	UNR	-	-	-	353	137.3	-	-	-	-	-	-	-
	WLKR	-	-	-	581	113.9	36.9	-	-	-	-	-	-
	SET	-	-	-	1980	90.2	18.6	-	-	-	-	-	-
Lake Whitefish	PLAYG	-	-	-	77	2.0	0.6	32	1.65	0.01	3	344	-
											2	434	11
											1	436	-

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
	LPLAY	-	-	-	5	0.3	0.2	4	1.77	-	-	-	-
	CROSS	-	-	-	7	0.1	<0.1	6	1.72	0.09	1	262	-
											-	-	-
	SIP	-	-	-	0	0	-	0	-	-	-	-	-
											-	-	-
	UNR	-	-	-	0	0	-	0	-	-	-	-	-
											-	-	-
	WLKR	-	-	-	2	0.1	<0.1	2	1.4	-	-	-	-
											2	308	62
	SET	-	-	-	127	1.3	0.4	85	1.41	0.02	41	373	12
											16	387	13
Northern Pike	PLAYG	-	-	-	388	9	0.5	207	0.84	0.02	17	517	13
	LPLAY	-	-	-	179	9.4	2.9	158	0.83	<0.01	28	512	10
	CROSS	-	-	-	696	7.9	0.7	624	0.74	0.01	92	490	14
	SIP	-	-	-	105	6.2	-	86	0.82	-	20	503	-
	UNR	-	-	-	22	2.5	-	19	0.81	-	5	431	-
	WLKR	-	-	-	75	4	1.1	65	0.68	<0.01	21	453	15
	SET	-	-	-	409	4.2	0.2	309	0.7	0.01	62	468	9.7
Walleye	PLAYG	-	-	-	322	7.5	1.1	275	1.33	0.02	17	296	7
	LPLAY	-	-	-	203	10.4	1.3	138	1.31	0.06	20	297	5
	CROSS	-	-	-	1074	12	1.4	976	1.2	0.02	57	290	8
	SIP	-	-	-	26	1.6	-	22	1.35	-	3	379	-
	UNR	-	-	-	94	11.4	-	34	1.3	-	11	325	-
	WLKR	-	-	-	102	5.7	2.4	93	1.13	0.01	-	-	-
	SET	-	-	-	1534	15.7	0.4	1239	1.14	0.01	161	261	5

Table 6-3. continued.

Component	Waterbody	Hill's Index			CPUE[1]			K_F[2]			$FL_{at\ Age}$[3]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
White Sucker	PLAYG	-	-	-	1504	38.1	6.8	948	1.66	<0.01	-	-	-
	LPLAY	-	-	-	717	36.7	3.7	535	1.67	0.01	-	-	-
	CROSS	-	-	-	513	6.1	0.4	362	1.63	0.02	-	-	-
	SIP	-	-	-	407	25.9	-	344	1.64	-	-	-	-
	UNR	-	-	-	56	6.2	-	42	1.64	-	-	-	-
	WLKR	-	-	-	240	13.4	0.5	225	1.51	0.03	-	-	-
	SET	-	-	-	1184	12.2	0.4	750	1.59	0.02	-	-	-

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

[2] Fork lengths analyzed for K_F were 300-499 mm for 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 Upper Nelson River Region waterbodies sampled annually between 2008 and 2013. Gray shading indicates an off-system waterbody.

Metric	**Species**	**Waterbody**	**Hydrology Metric**	**df**	**F**	**p**	**R^2**	**Direction**
K_F	WHSC	SET	WL (OW)	2	26.80	0.04	0.93	-

[1] 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).

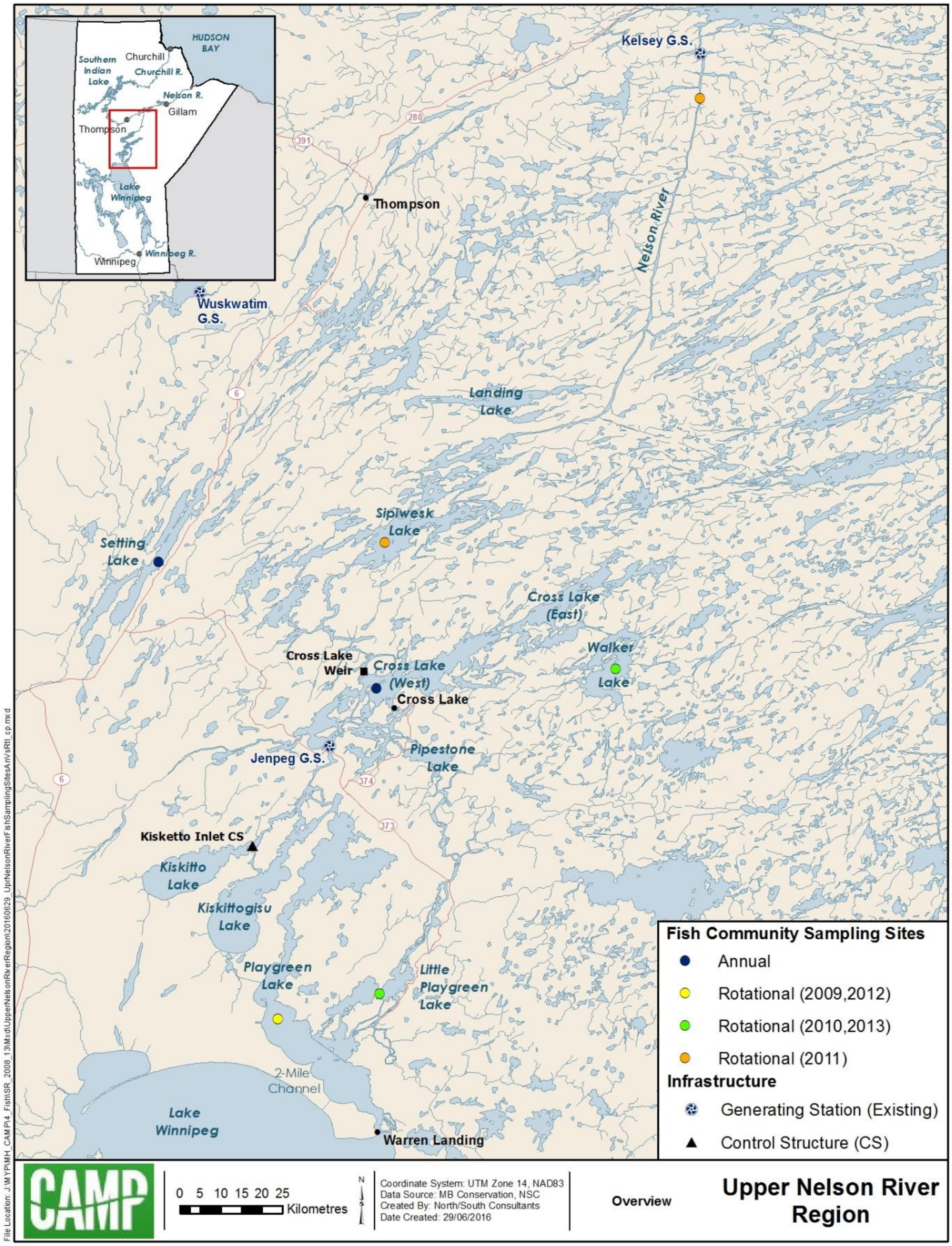


Figure 6-1. Waterbodies sampled in the Upper Nelson River Region: 2008-2013.

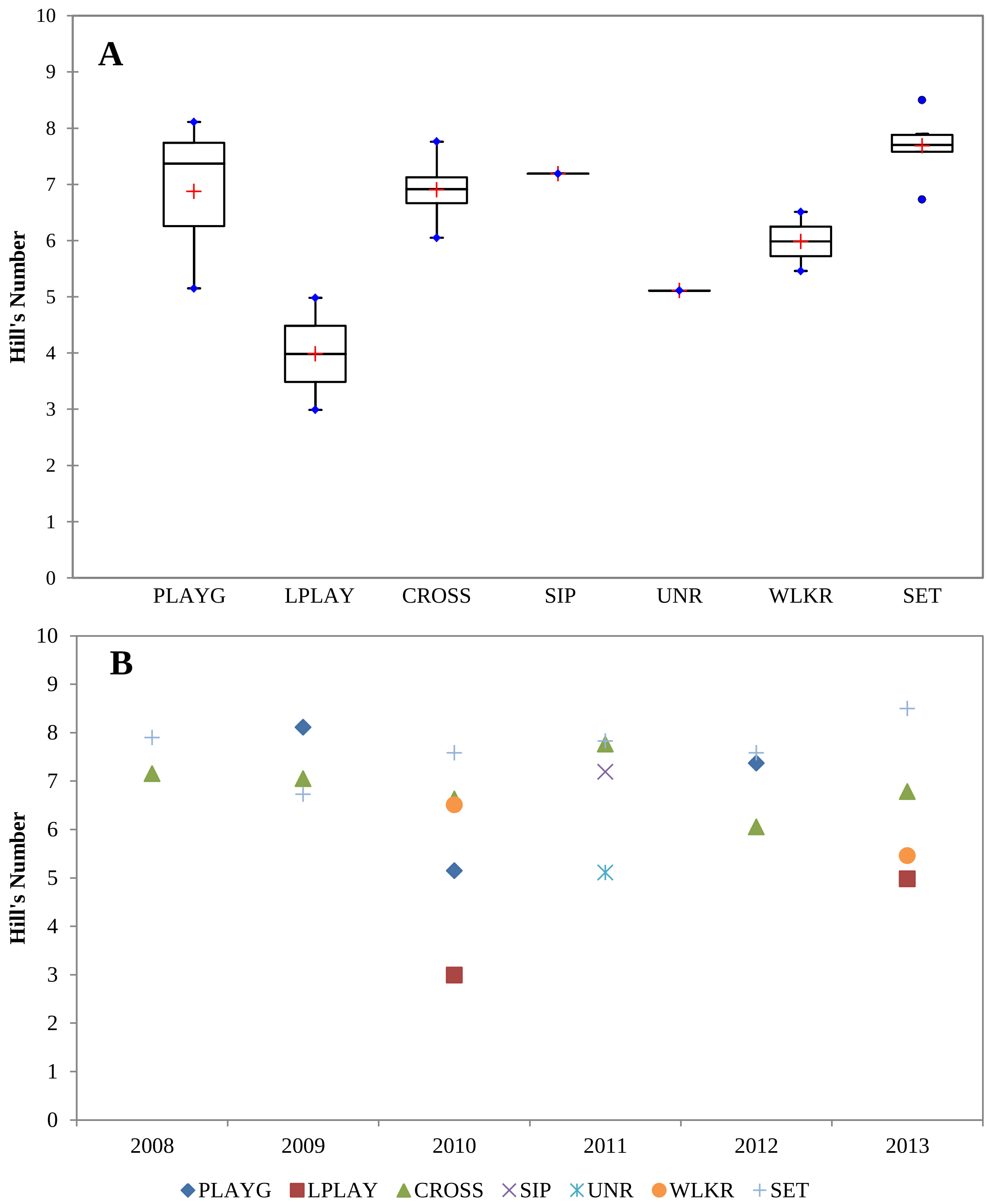


Figure 6-2. Annual mean Hill's effective species richness index (Hill number) for standard gang and small mesh index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

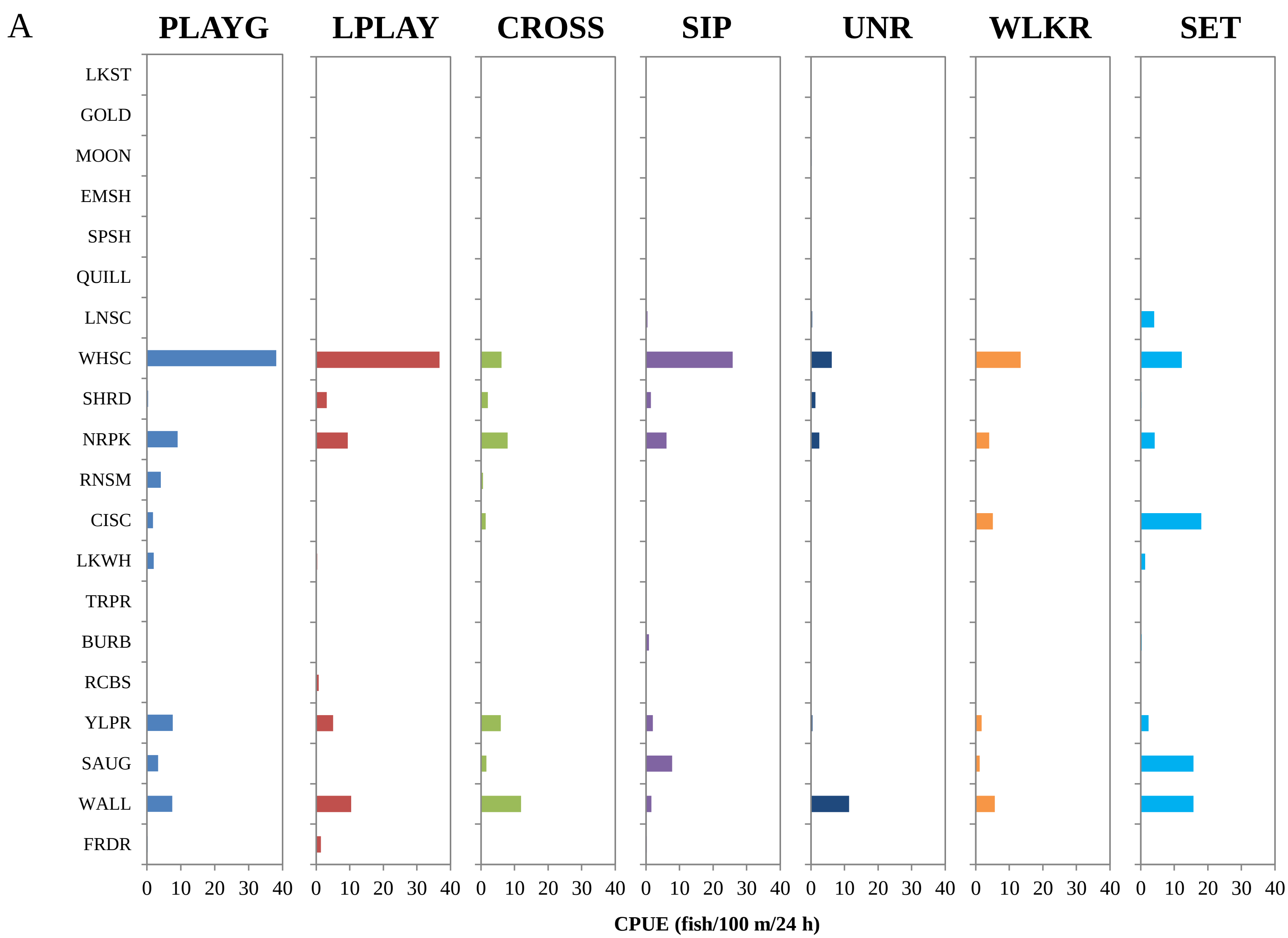


Figure 6-3. Mean catch-per-unit-effort in (A) standard gang (fish/100 m/24 h) and (B) small mesh (fish/30 m/24 h) index gill nets set in Upper Nelson River Region waterbodies, 2008-2013.

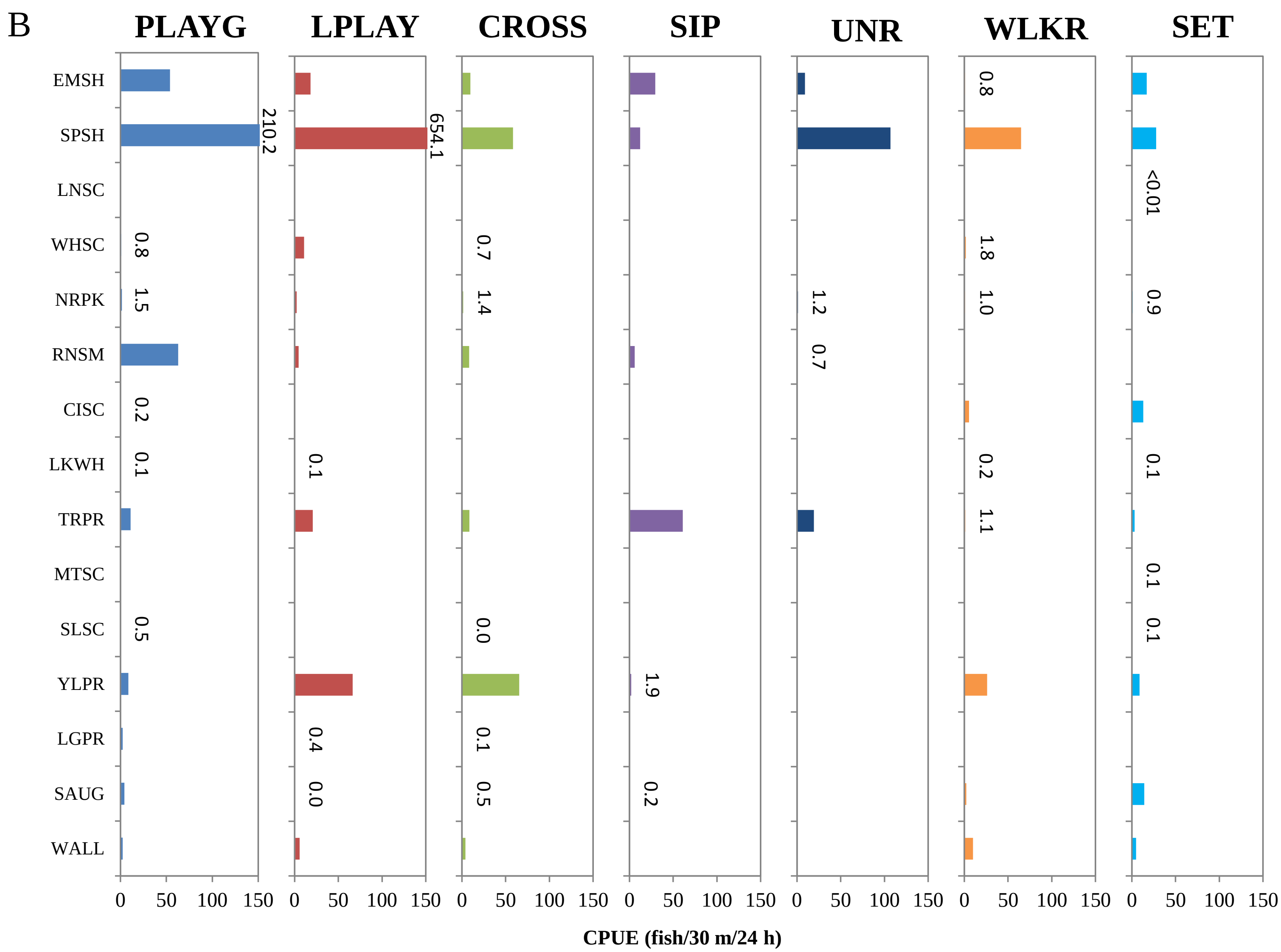


Figure 6-3. continued.

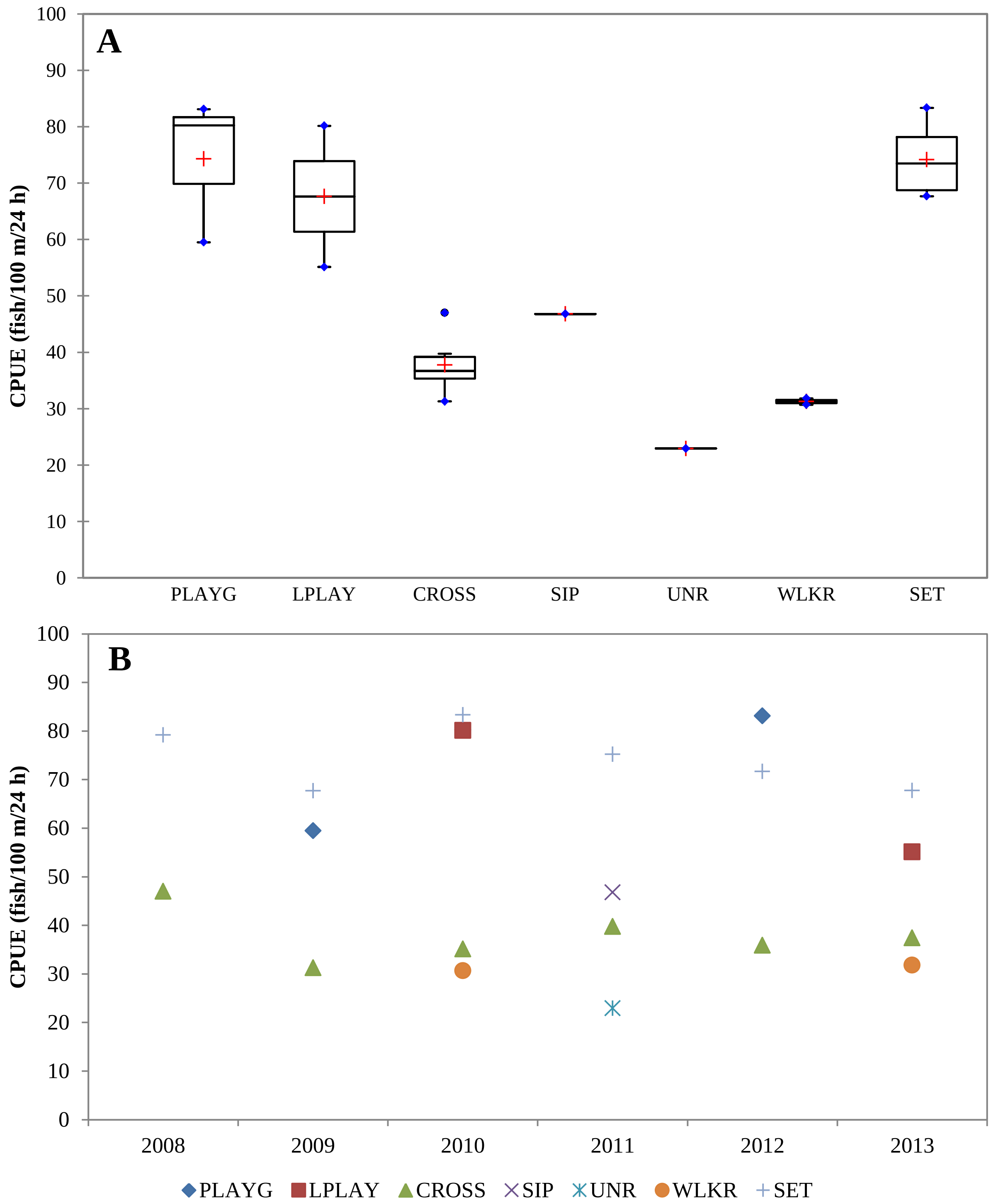


Figure 6-4. Annual mean catch-per-unit-effort (CPUE) calculated for the total catch in standard gang index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

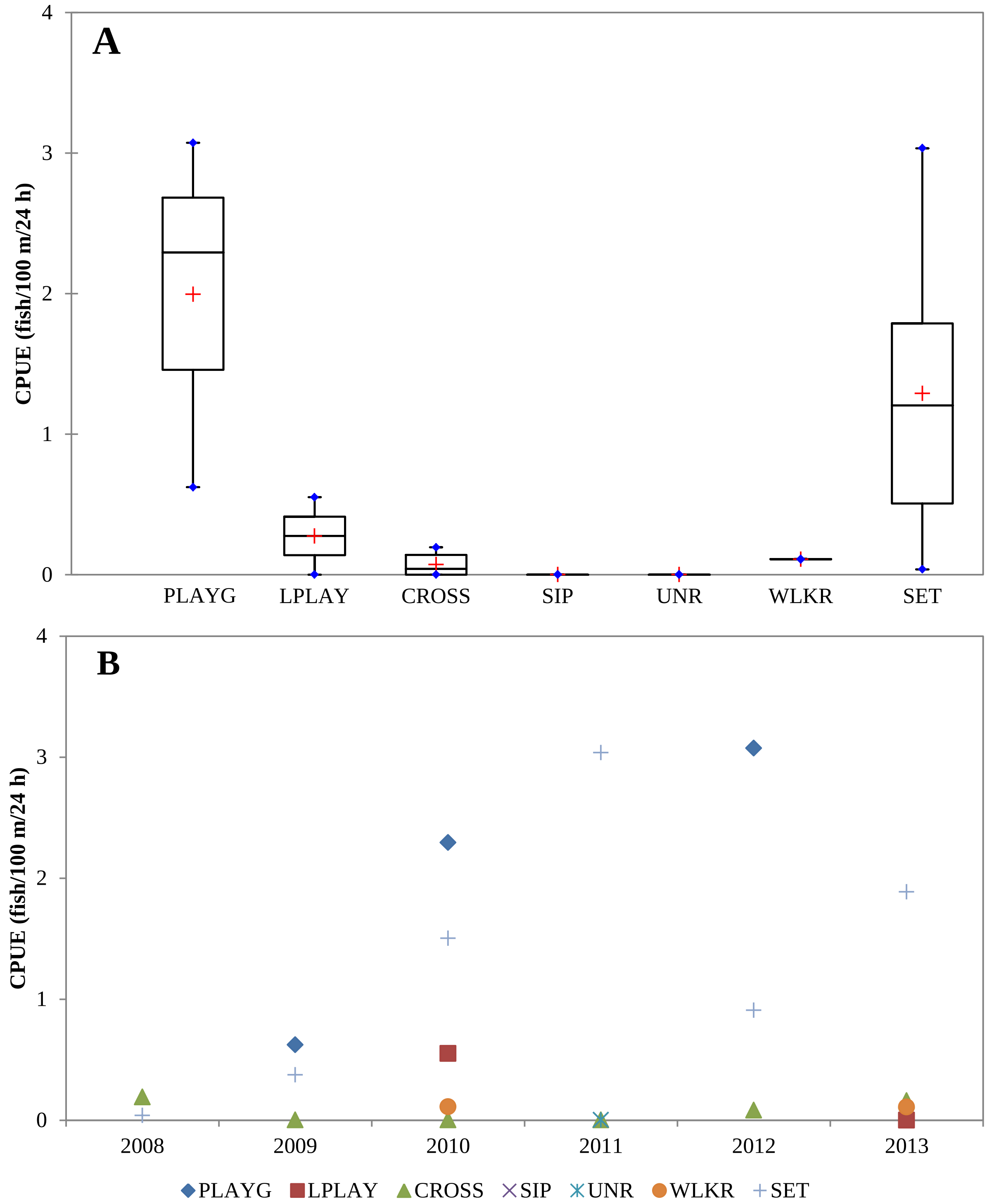


Figure 6-5. Annual mean catch-per-unit-effort (CPUE) calculated for Lake Whitefish captured in standard gang index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

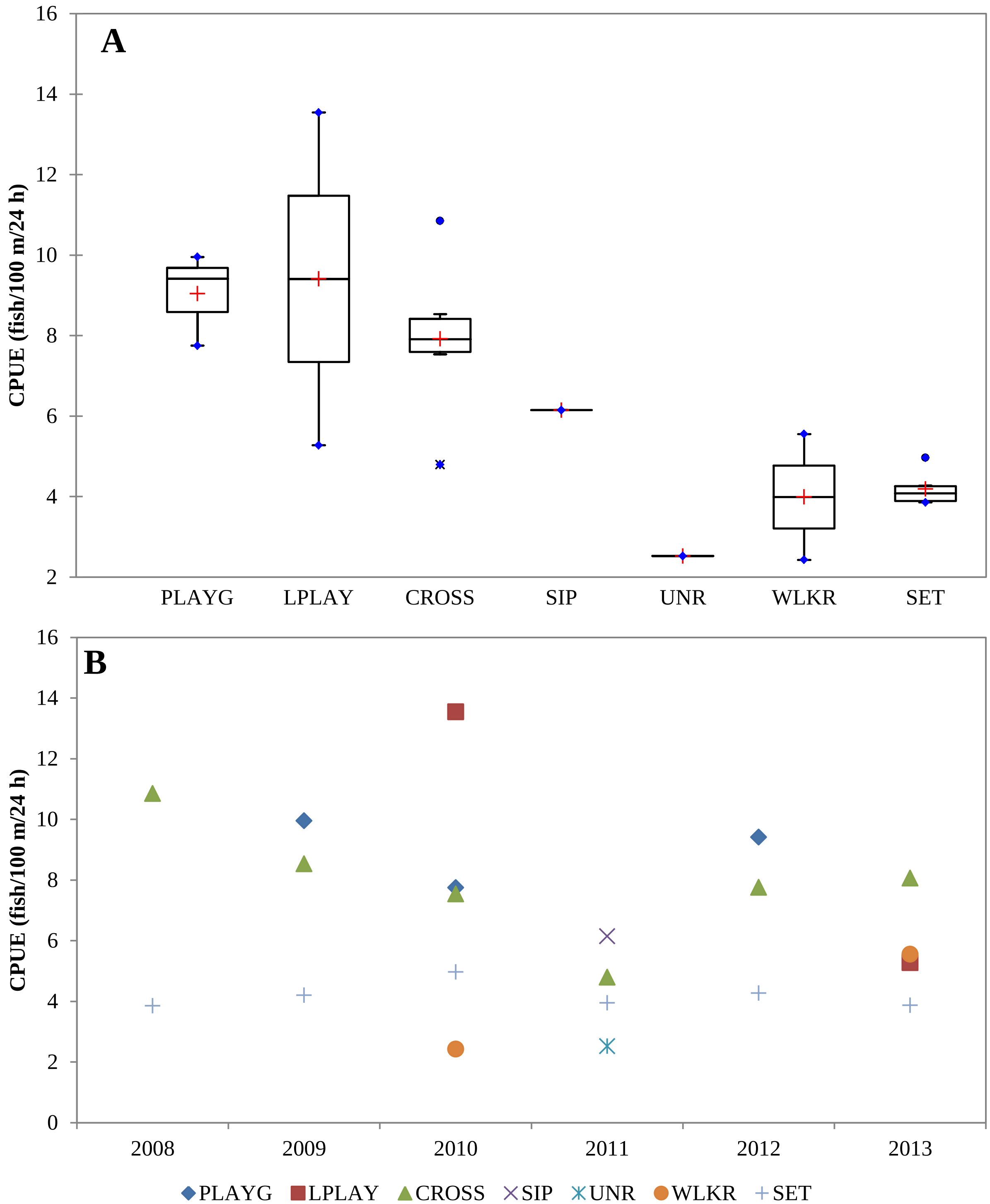


Figure 6-6. Annual mean catch-per-unit-effort (CPUE) calculated for Northern Pike captured in standard gang index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

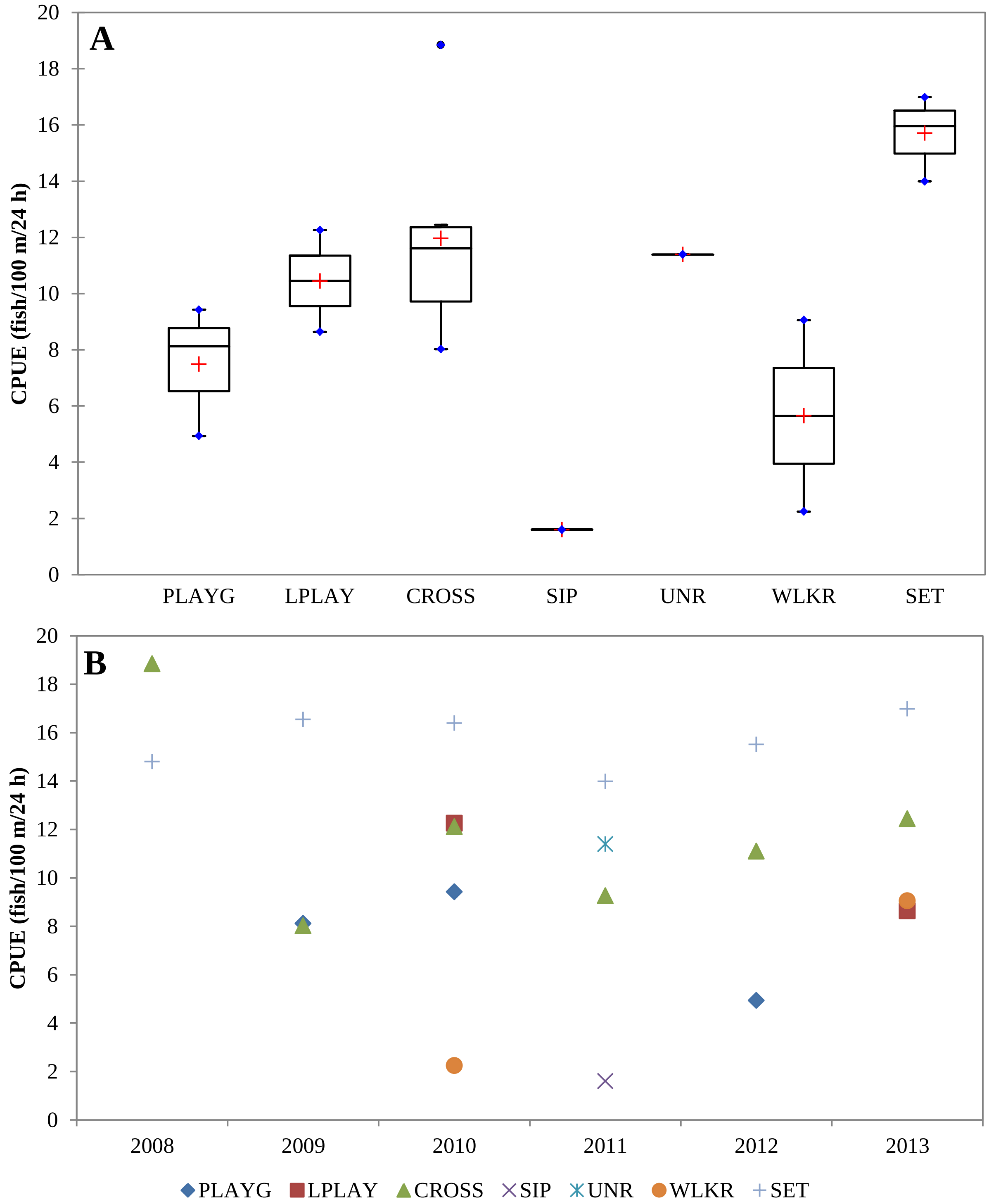


Figure 6-7. Annual mean catch-per-unit-effort (CPUE) calculated for Walleye captured in standard gang index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

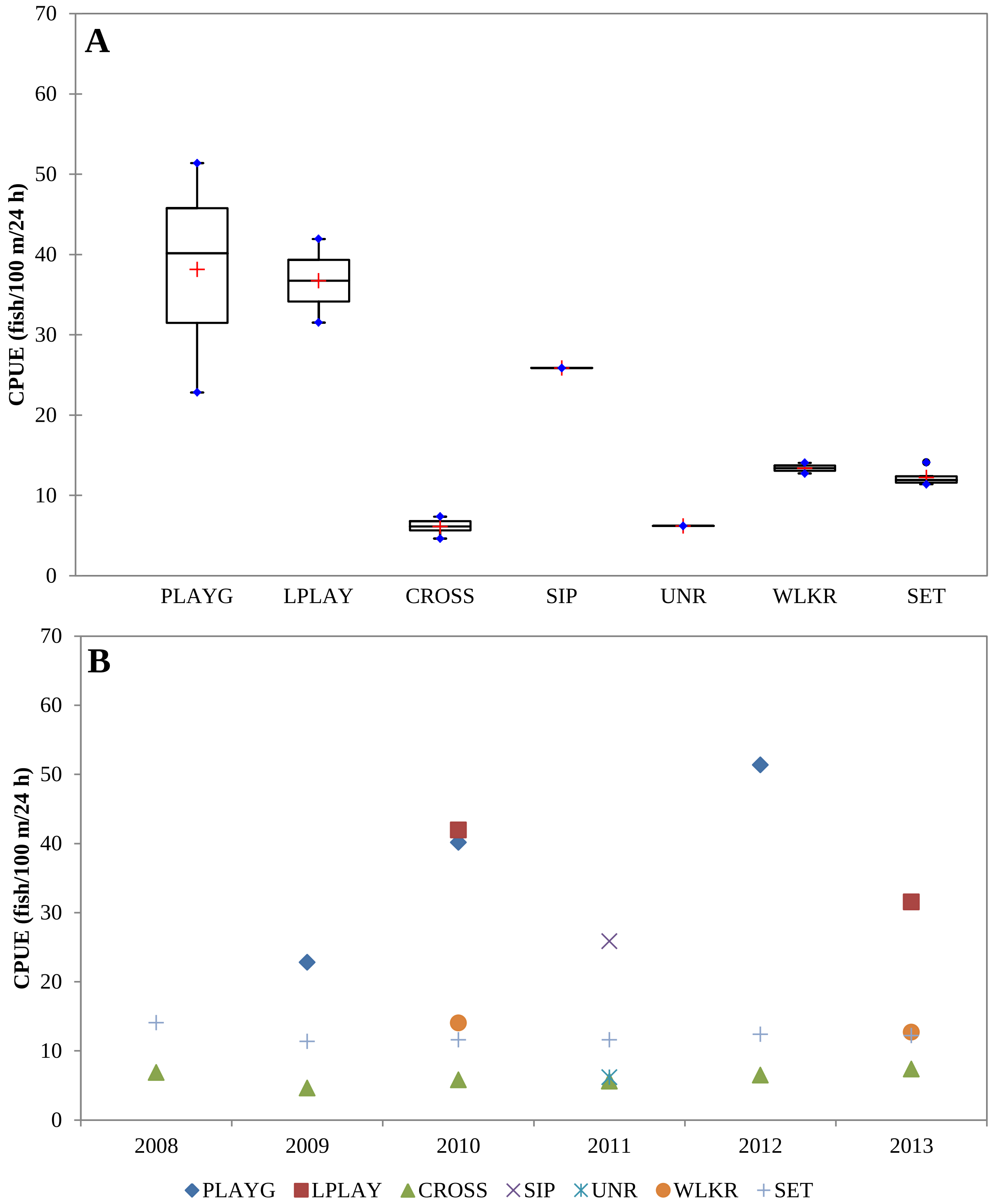
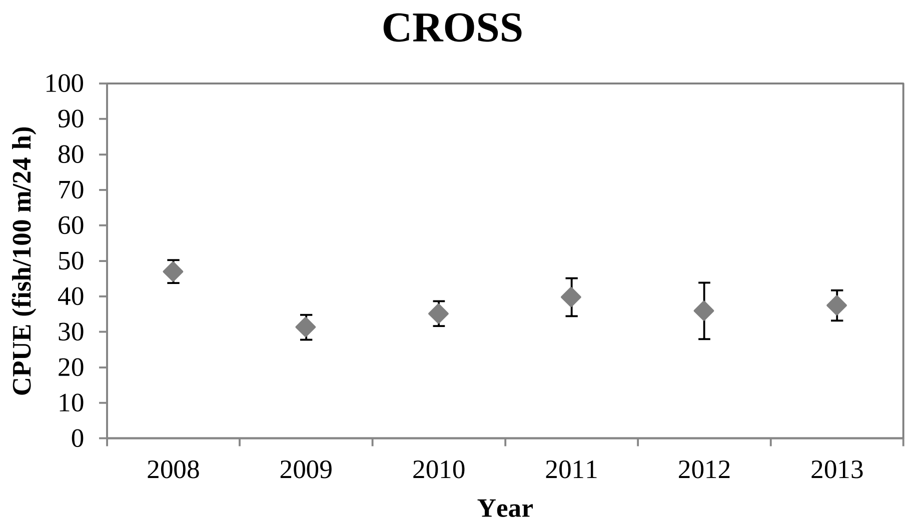


Figure 6-8. Annual mean catch-per-unit-effort (CPUE) calculated for White Sucker captured in standard gang index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



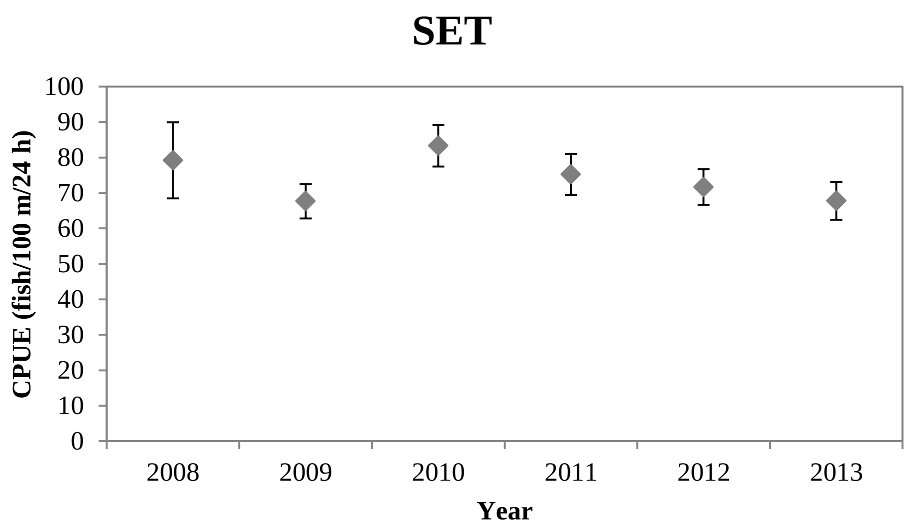


Figure 6-9. Total catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack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

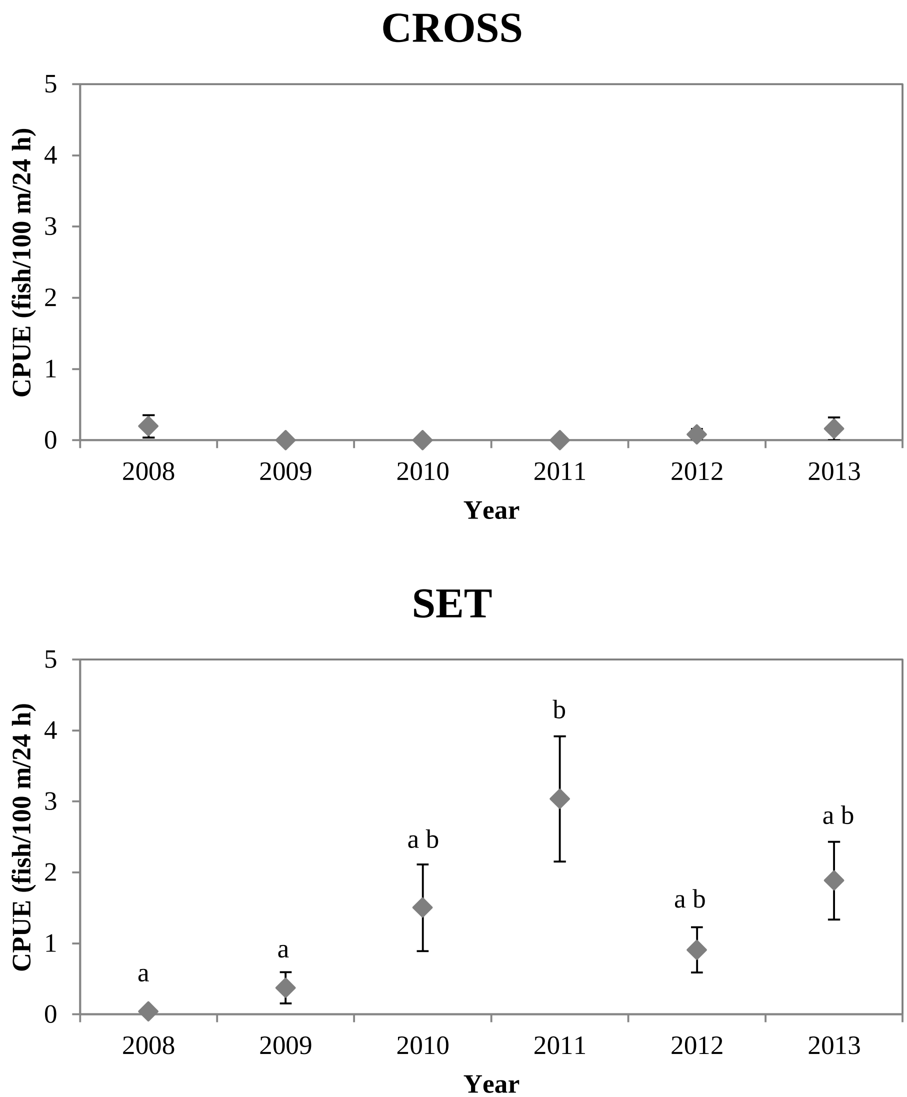


Figure 6-10. Lake Whitefish catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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

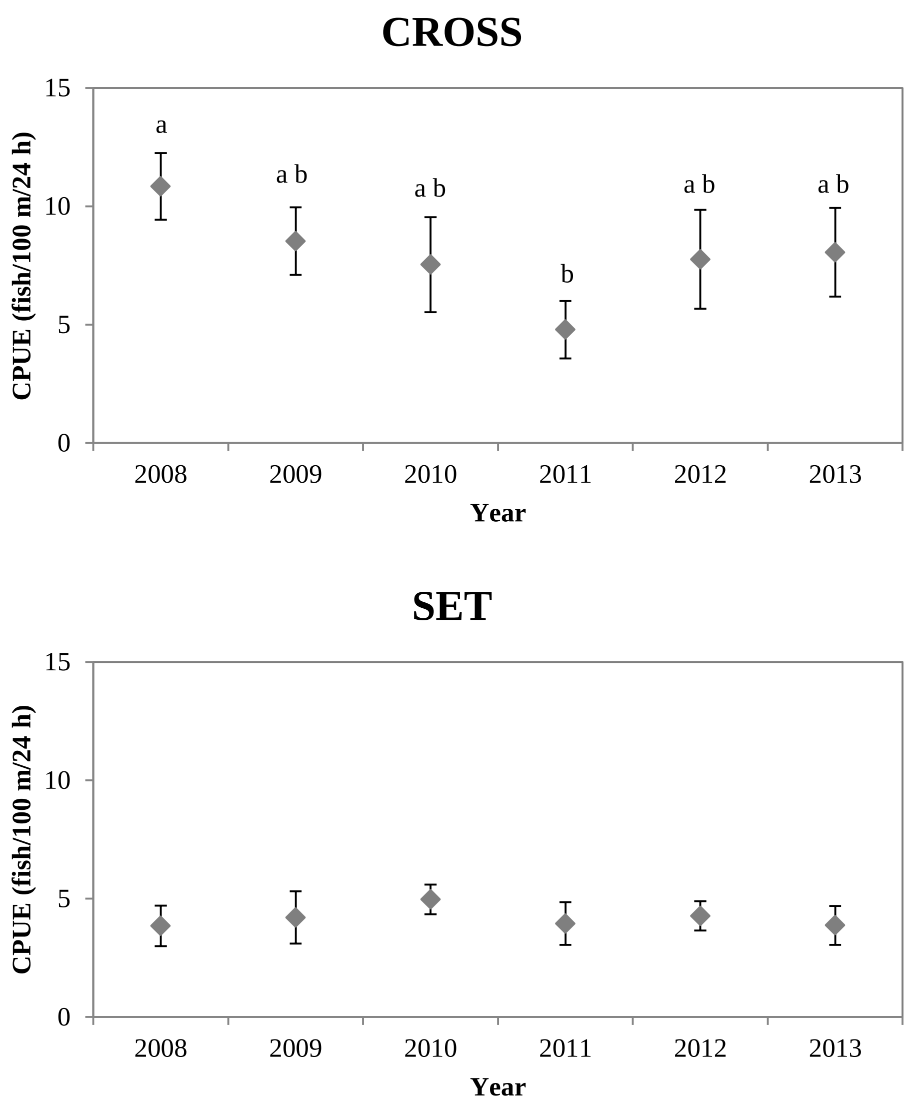


Figure 6-11. Northern Pike catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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

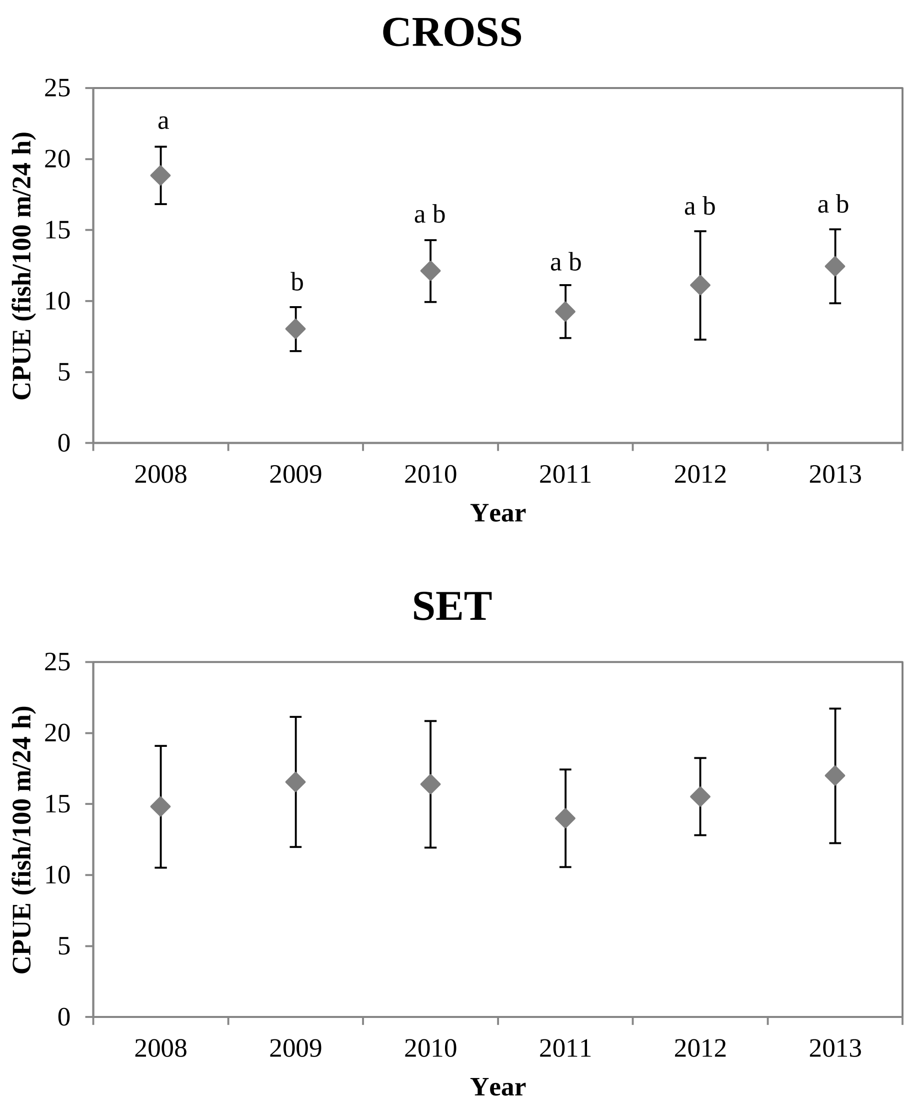
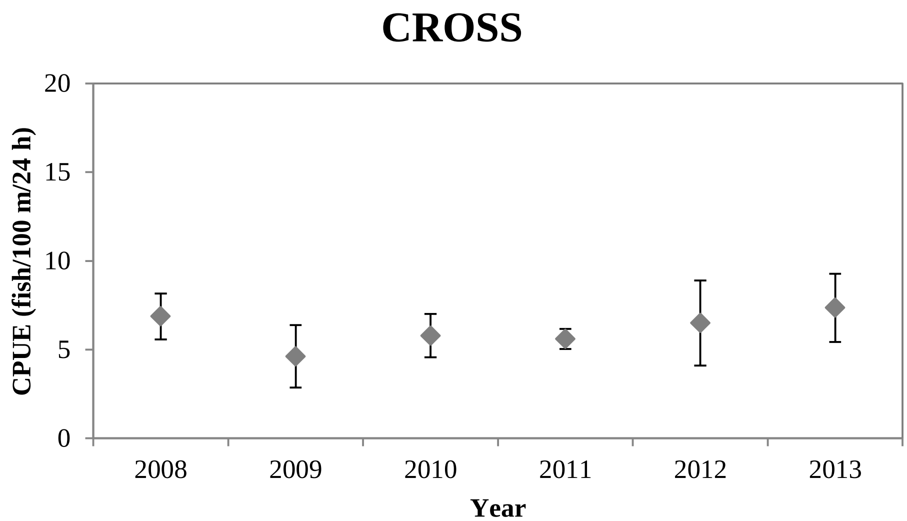


Figure 6-12. Walleye catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or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



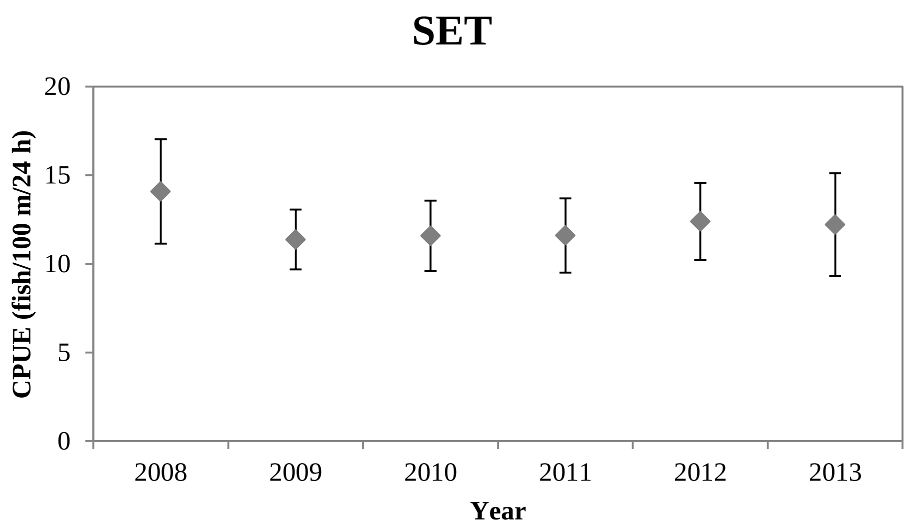
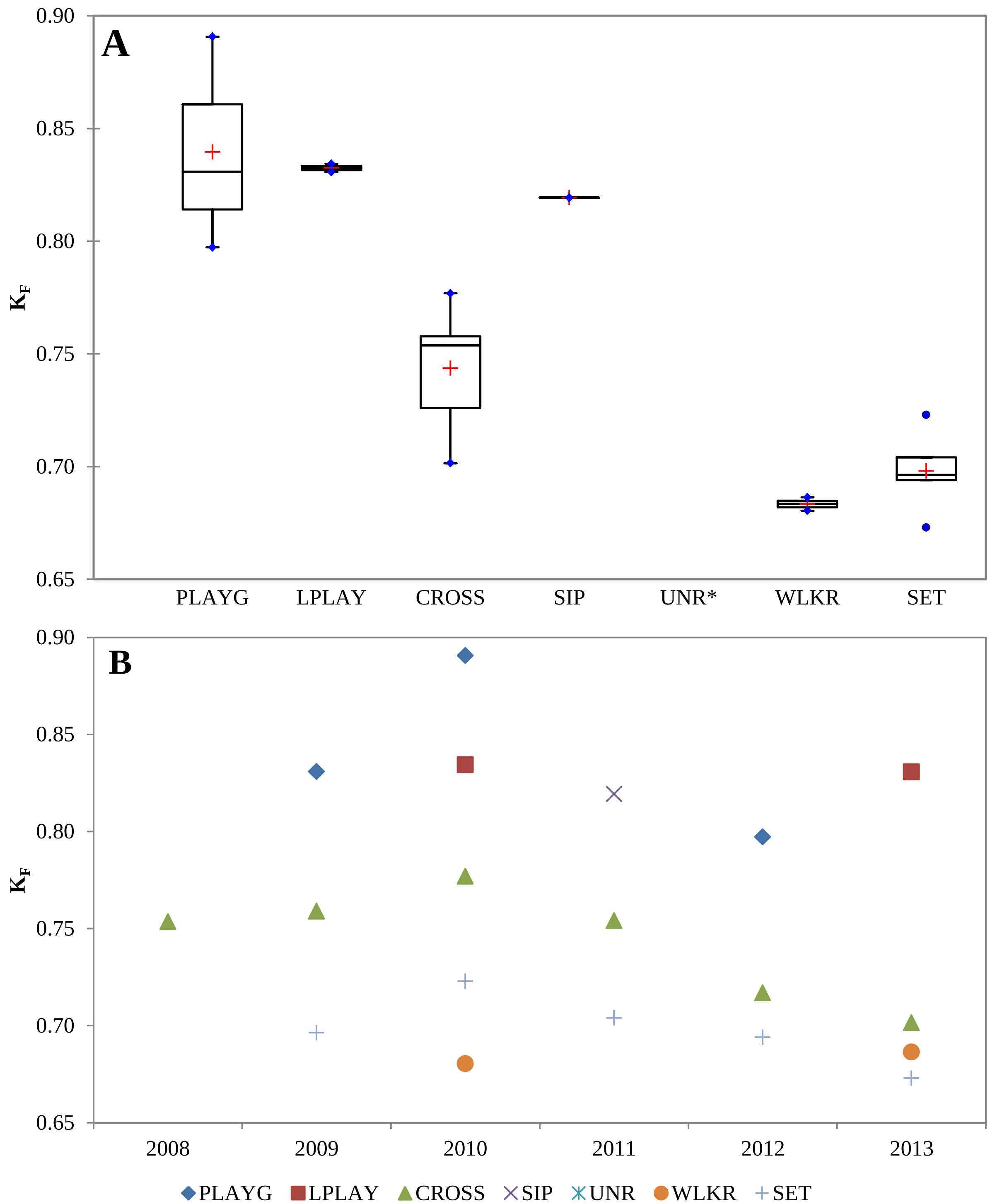
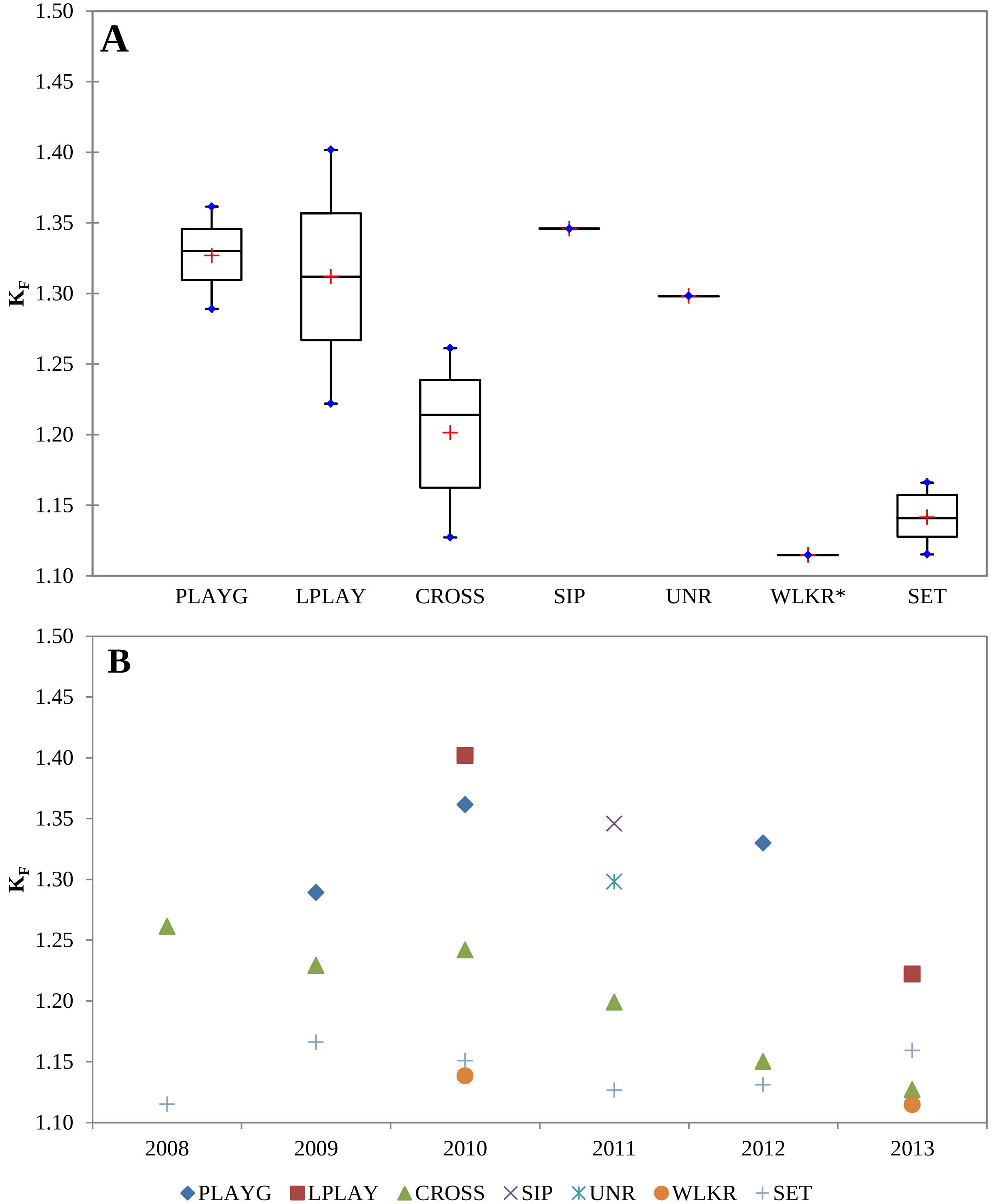


Figure 6-13. White Sucker catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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



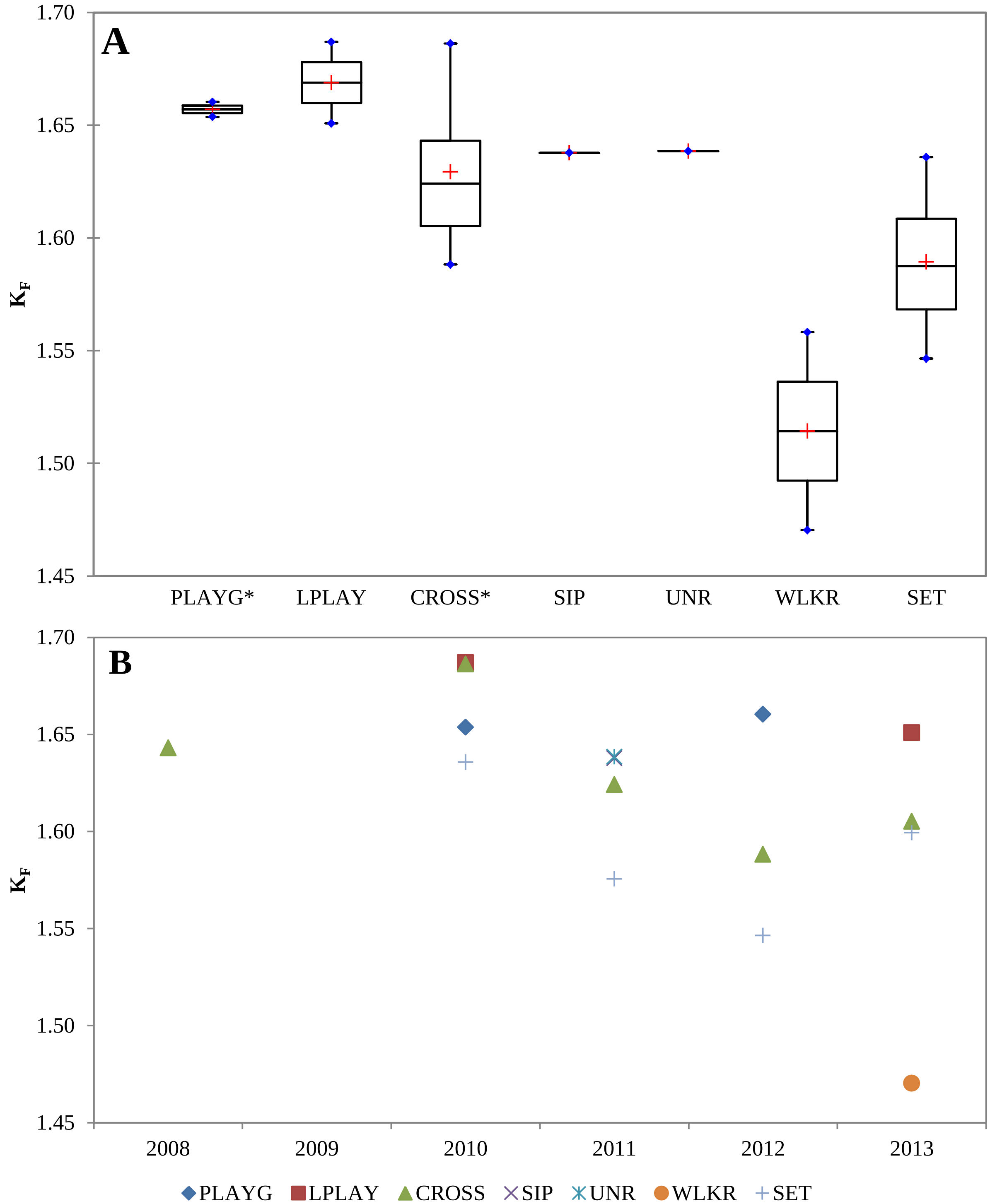
*Too few fish were captured in UNR.

Figure 6-14. Annual mean Fulton's condition factor (K_F) calculated for Northern Pike between 400 and 699 mm in fork length captured in gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



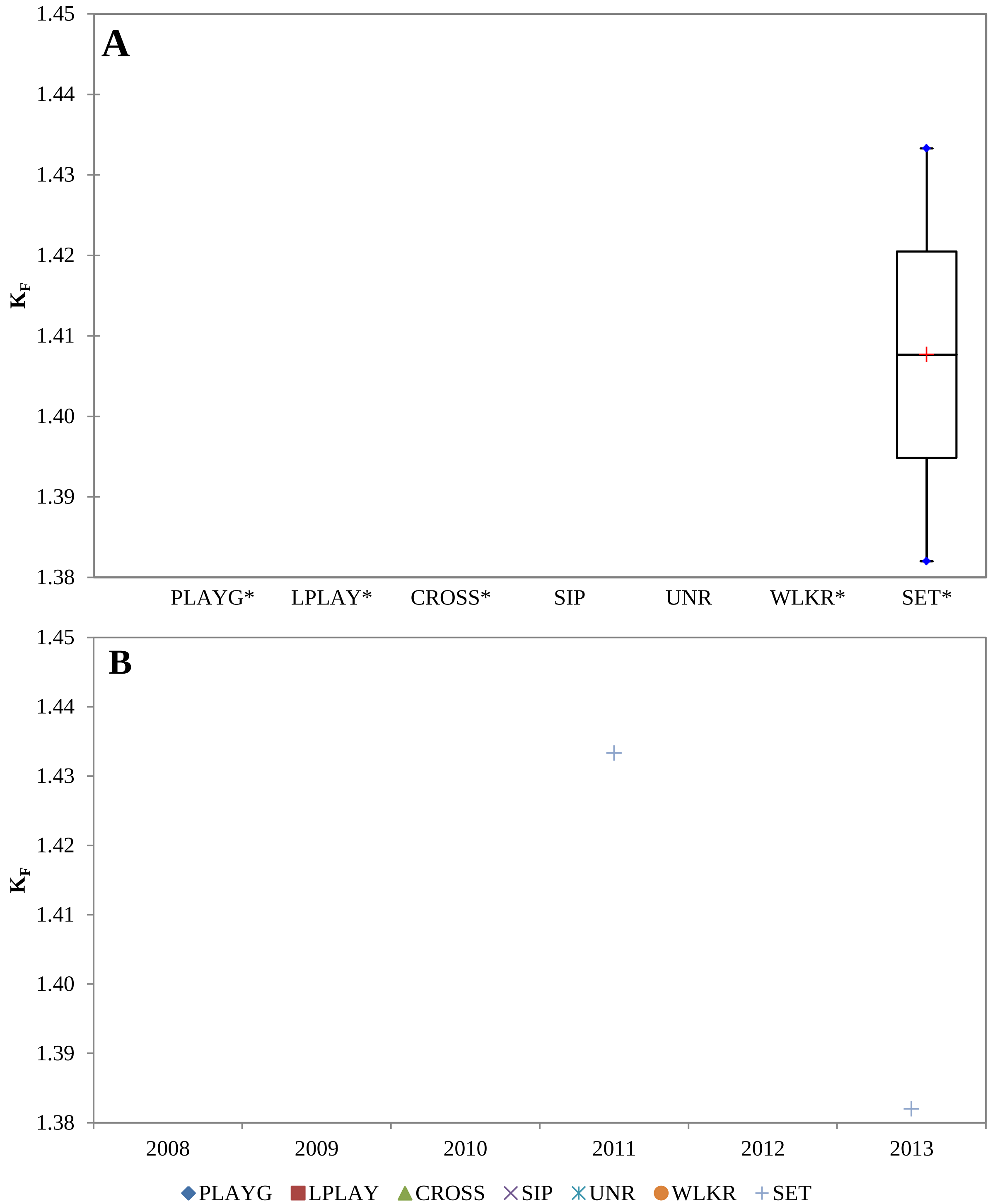
*Too few fish were captured in WLKR in 2010.

Figure 6-15. 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 Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



*Species was not measured for fork length at PLAYG and CROSS in 2009.

Figure 6-16. 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 Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



*Too few fish were captured in some years.

Figure 6-17. 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 Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

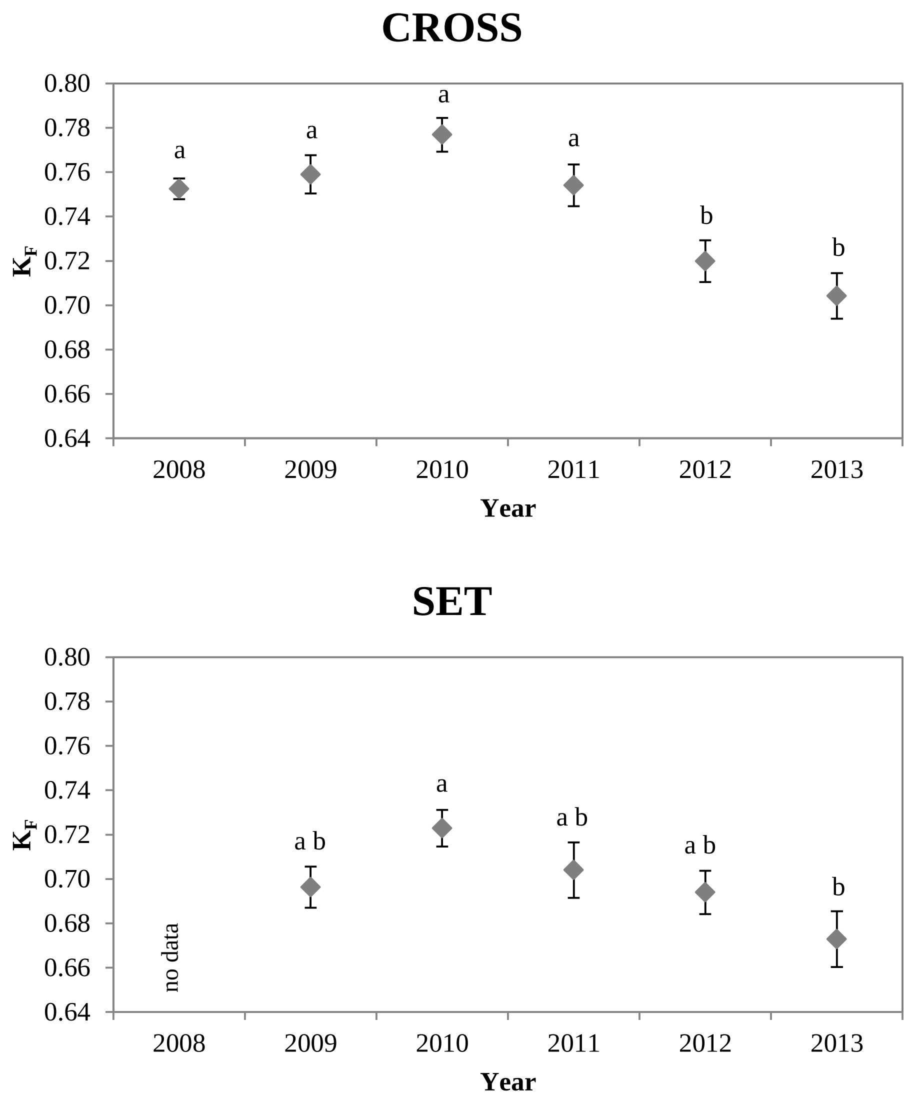


Figure 6-18. Fulton's condition factor (K_F; mean ± SE) of Northern Pike between 400 and 699 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

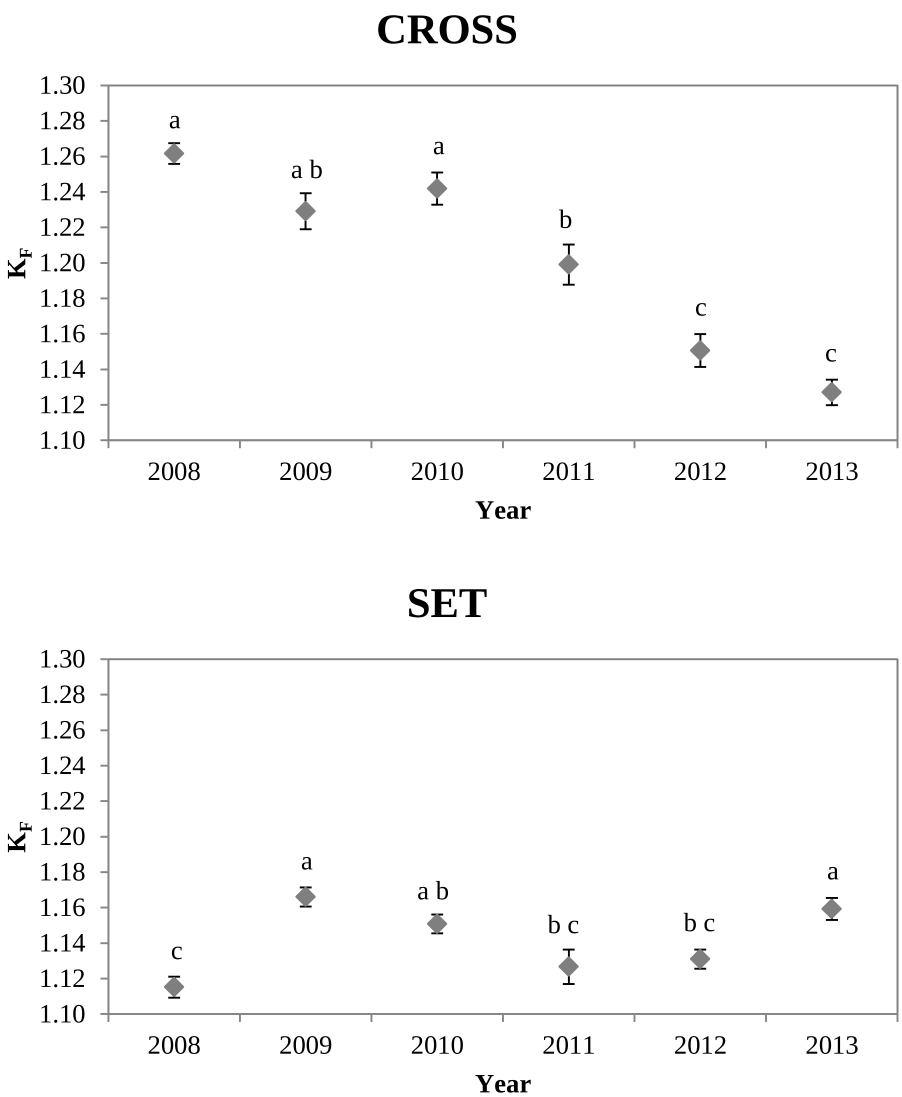
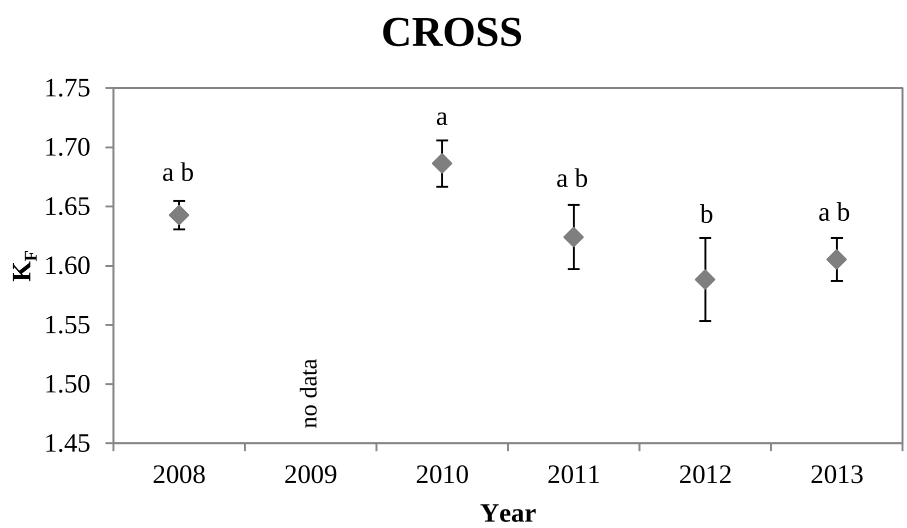


Figure 6-19. Fulton's condition factor (K_F; mean ± SE) of Walleye between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical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



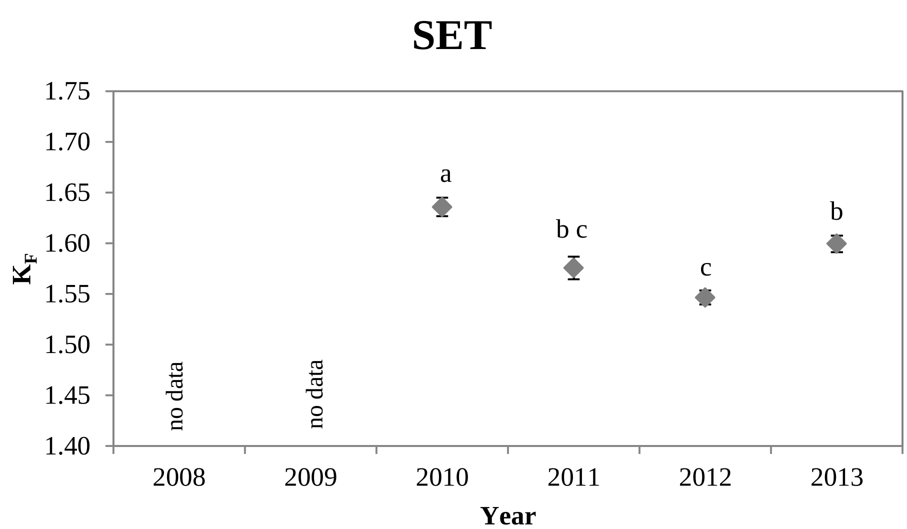
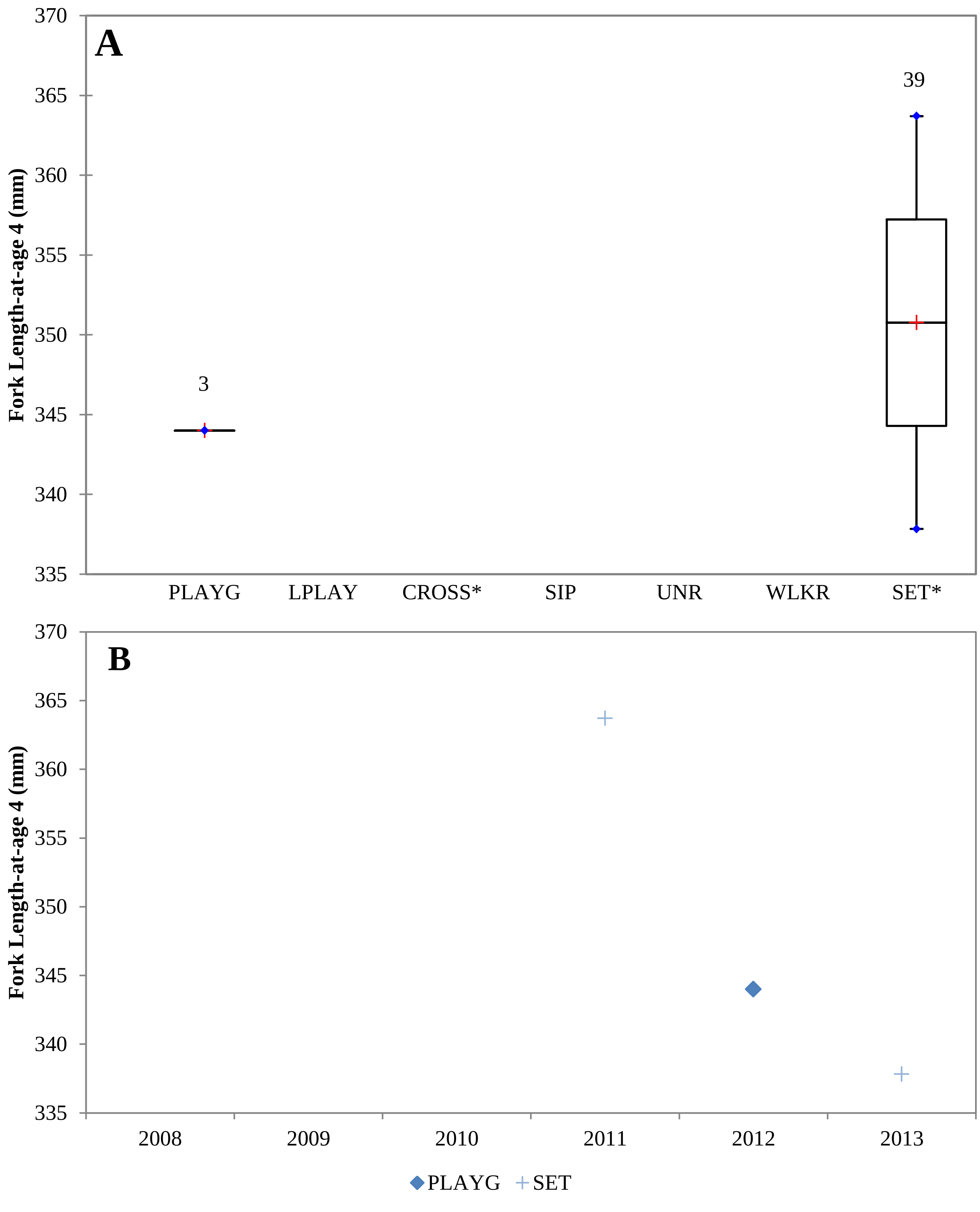
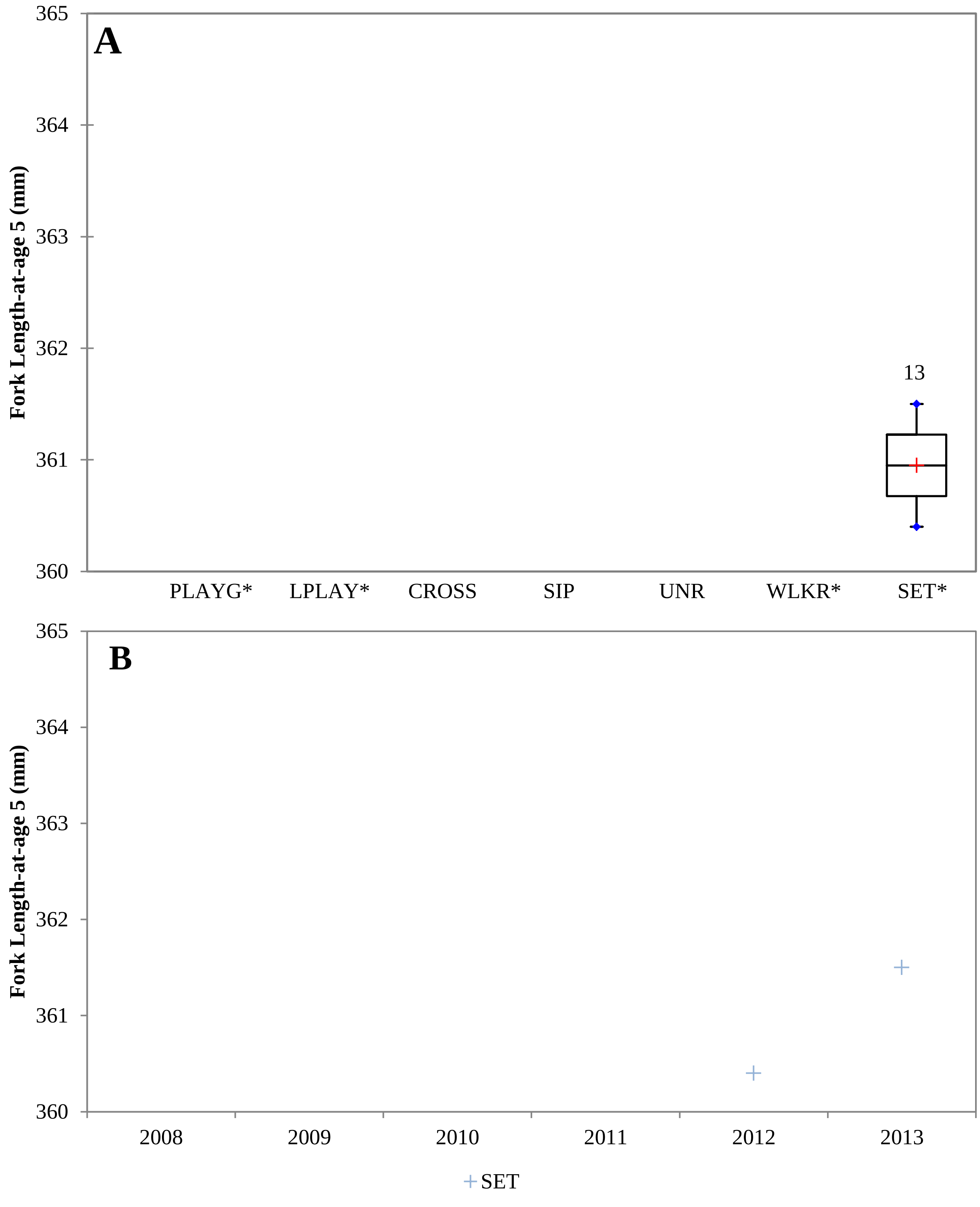


Figure 6-20. Fulton's condition factor (K_F; mean ± SE) of White Sucker between 300 and 499 mm in fork length captured at annual on-system (top) and off-system (bottom) locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical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



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

Figure 6-21. Annual mean length-at-age 4 of Lake Whitefish captured in standard gang and small mesh index gill nets set in Upper Nelson 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 age.



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

Figure 6-22. Annual mean length-at-age 5 of Lake Whitefish captured in standard gang and small mesh index gill nets set in Upper Nelson 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 age.

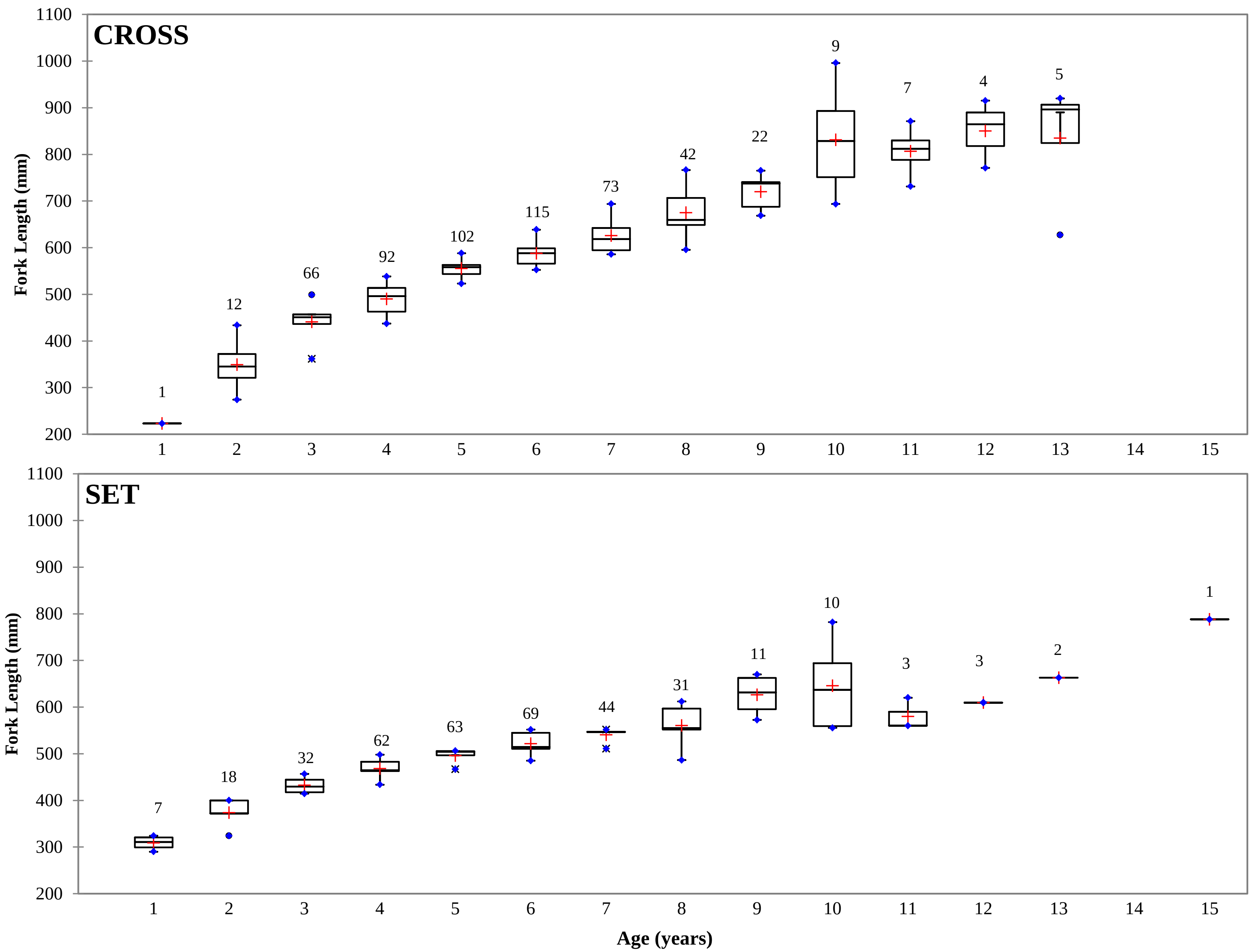


Figure 6-23. Annual mean length-at-age of Northern Pike captured in standard gang and small mesh index gill nets set at annual sampling locations in the Upper Nelson River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.

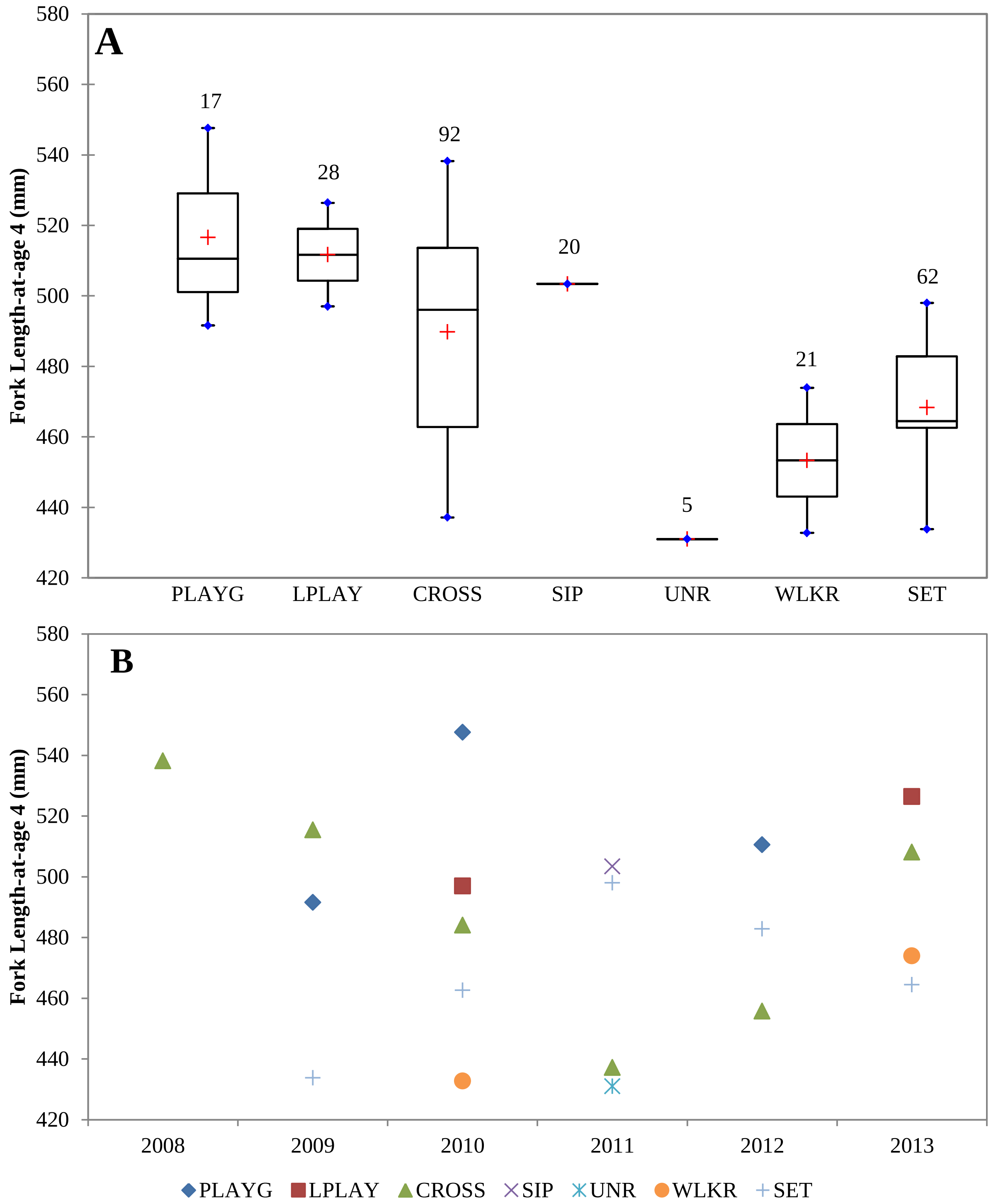


Figure 6-24. Annual mean length-at-age 4 of Northern Pike captured in standard gang and small mesh index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 4-year-old fish captured over the 6-year sampling period is shown above the box for each age.

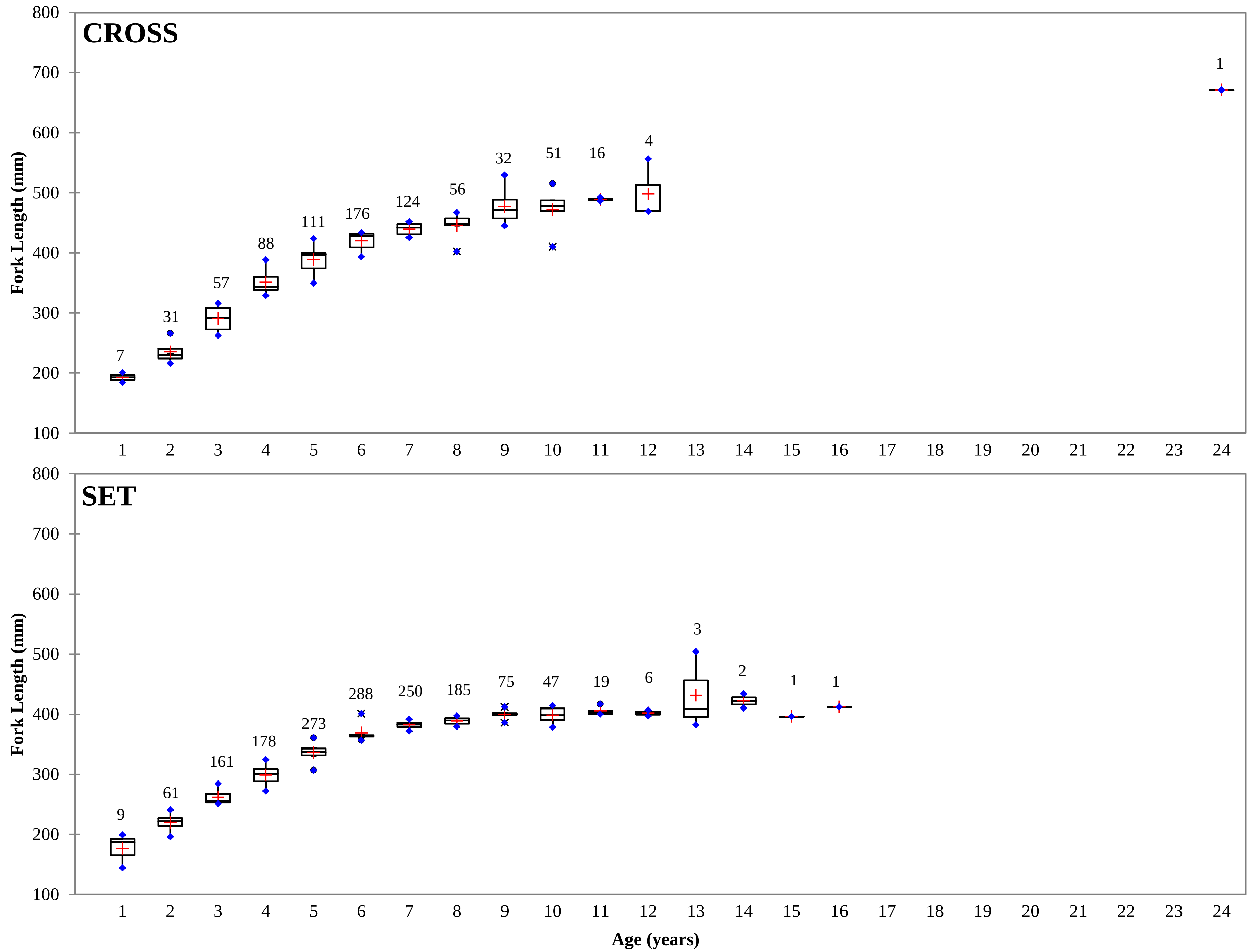
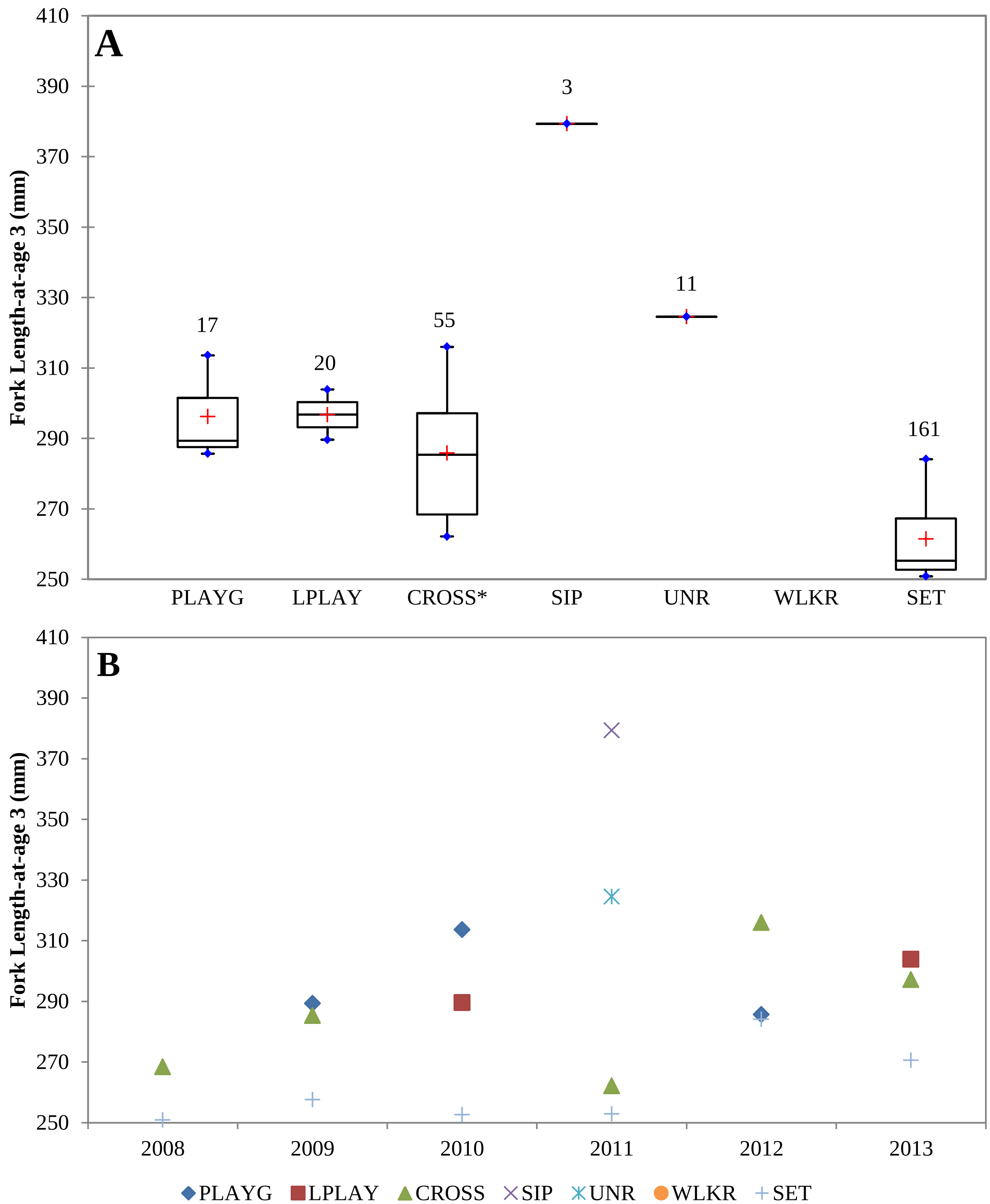
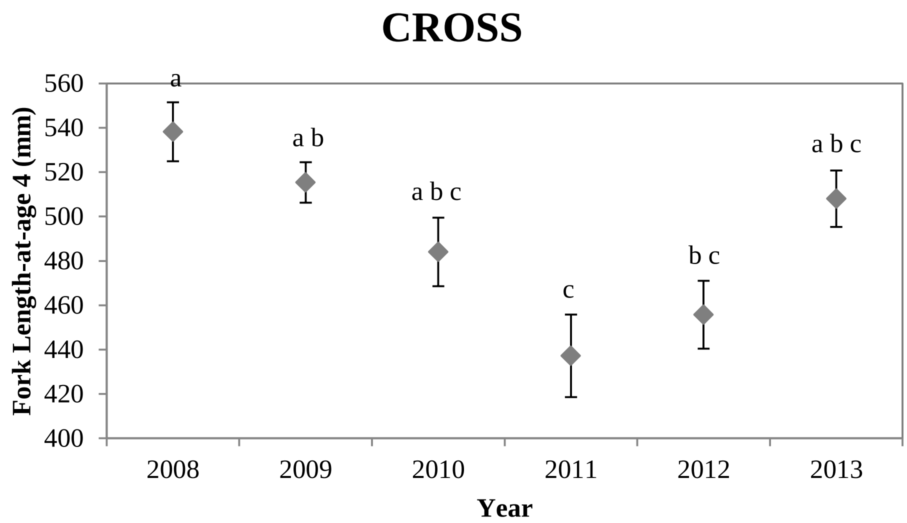


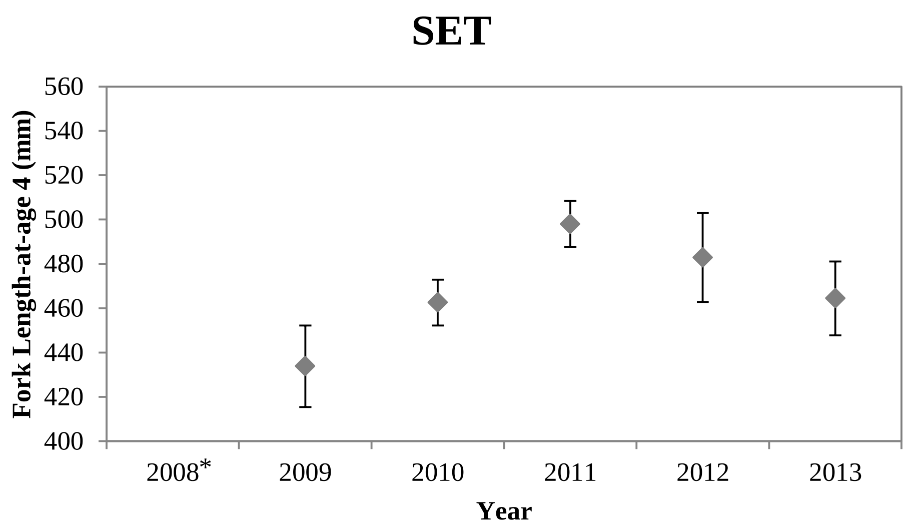
Figure 6-25. Annual mean length-at-age of Walleye captured in standard gang and small mesh index gill nets set at annual sampling locations in the Upper Nelson River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.



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

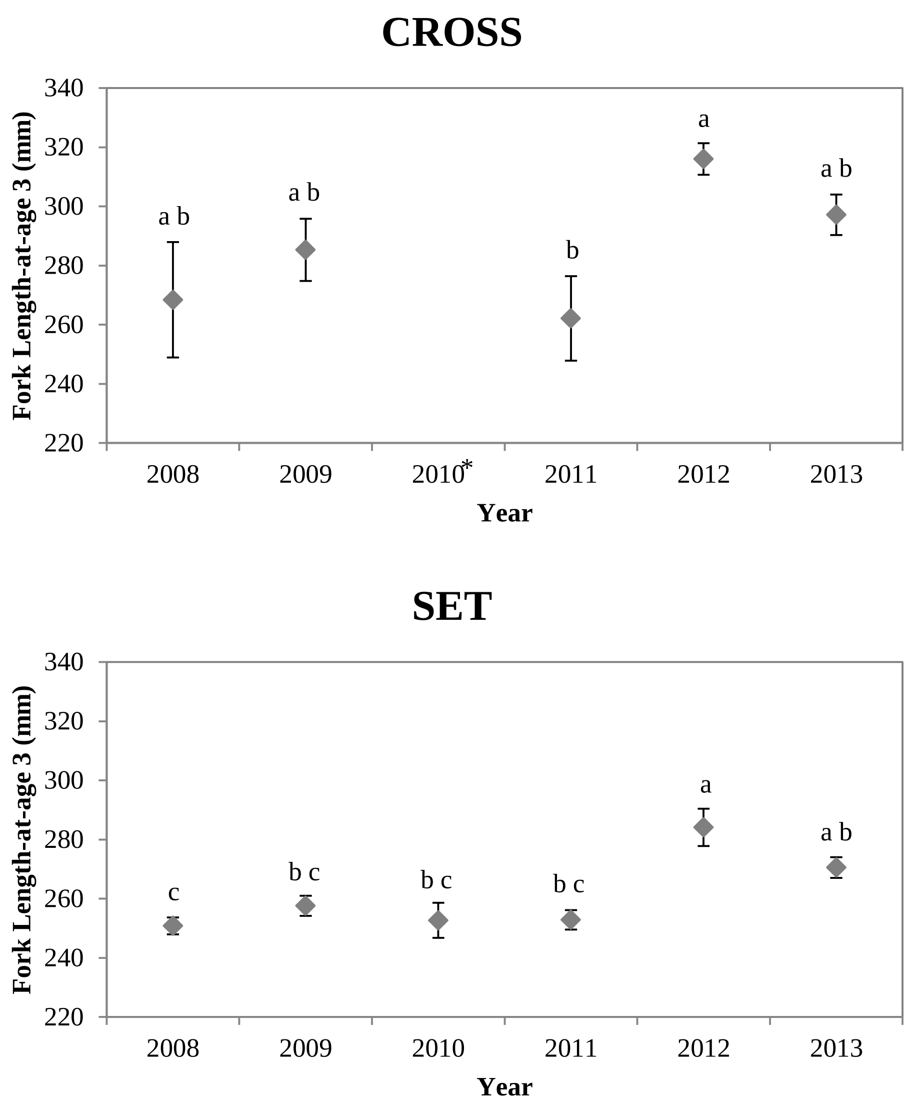
Figure 6-26. Annual mean length-at-age 3 of Walleye captured in standard gang and small mesh index gill nets set in Upper Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 3-year-old fish captured over the 6-year sampling period is shown above the box for each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





*Too few fish were captured in 2008 in SET to include in the analysis

Figure 6-27. 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.



*Too few fish were captured in 2010 in CROSS to include in the analysis

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

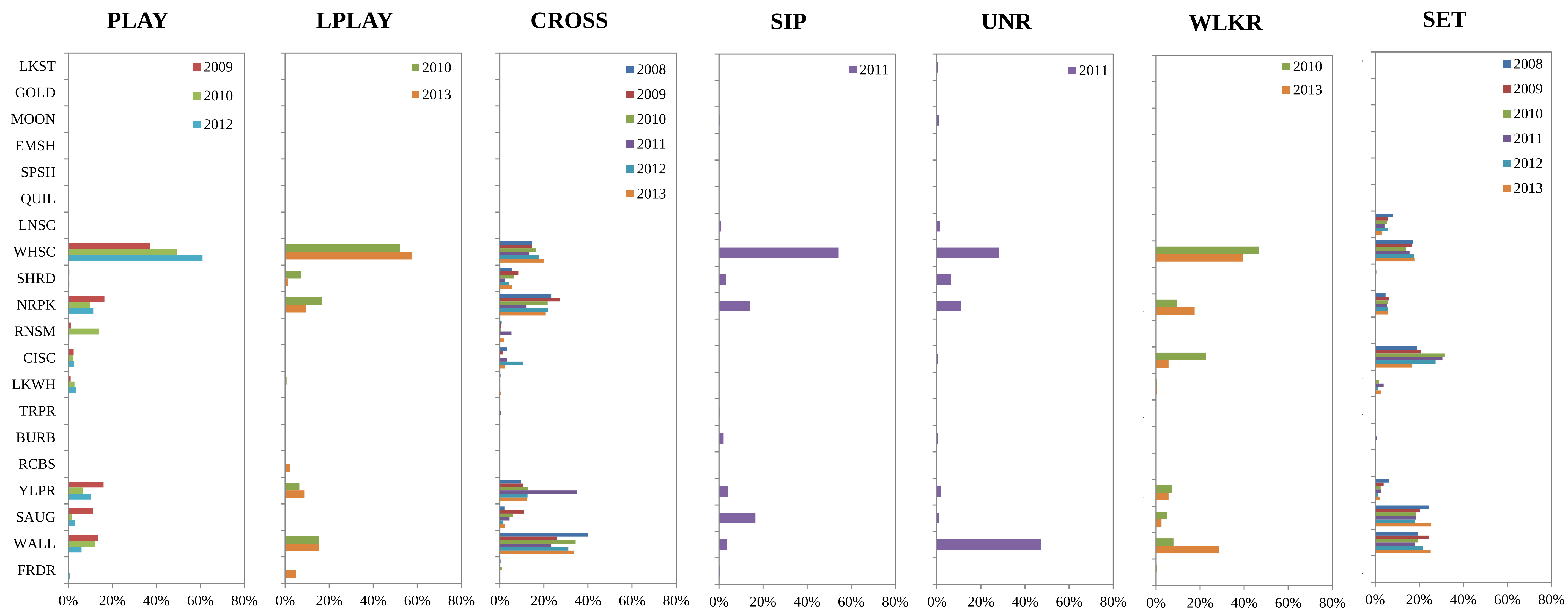


Figure 6-29. Relative abundance of fish species captured in standard gang index gill nets in Upper Nelson River Region waterbodies, 2008-2013.

7.0 FISH MERCURY

7.1 INTRODUCTION

The following provides an overview of the results of fish mercury monitoring conducted in the UNRR under CAMP in the first six years of the program; fish mercury sampling was conducted on a three-year rotation (2010 and 2013 at most waterbodies; 2011 for Sipiwesk Lake) in this region. Waterbodies sampled included Little Playgreen Lake, Playgreen Lake, Cross Lake, Sipiwesk Lake, and the off-system Setting Lake.

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

7.1.1 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 (Manitoba Water Stewardship [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 Upper Nelson River

Mean length-standardized concentrations of mercury measured in Northern Pike, Walleye, and Lake Whitefish from waterbodies on the upper Nelson River were consistently 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; Table 7-1). Length-standardized concentrations could not be derived for Lake Whitefish in Little Playgreen or Cross lakes due to limited sample sizes (Table 7-1).

Based on mercury concentrations in individual fish from both sampling years, a few pike and Walleye exceeded the 0.5 ppm standard in all four lakes (Figures 7-1 to 7-3). The percentage of fish exceeding the standard out of the total number of fish analyzed in both monitoring years ranged from 3% for pike from Playgreen Lake, and Walleye from Little Playgreen and Cross lakes to 14% for pike from Sipiwesk Lake. Maximum observed concentrations were 0.82 ppm for a pike from Sipiwesk Lake and 0.75 ppm for a Walleye from Cross Lake. None of the whitefish or perch exceeded a mercury concentration of 0.5 ppm, reaching maxima of 0.11, 0.13, and 0.10 ppm, respectively (Figures 7-1 to 7-4).

Standard mean concentrations of mercury in pike from little Playgreen, Playgreen, Cross, and Sipiwesk lakes were similar throughout the monitoring period. Concentrations were similar in Walleye from Little Playgreen and Sipiwesk lakes (i.e., approximately 0.24 ppm), but significantly higher than those measured in Walleye from Playgreen and Cross lakes (0.14-0.18 ppm; Table 7-1). Due to the limited sample sizes obtained for Lake Whitefish, spatial comparisons were not possible for this species.

7.2.2 Off-system Waterbody: Setting Lake

Mean length-standardized mercury concentrations of Northern Pike, Walleye, and Lake Whitefish were all well 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). Length-standardized concentrations could not be derived for Lake Whitefish for 2010 due to limited sample size.

Based on mercury concentrations in individual fish, 3% of the Walleye and 19% of the pike, but none of the whitefish from Setting Lake exceeded the 0.5 ppm Health Canada standard in both sampling years (Figure 7-2).

7.2.3 Temporal Comparisons

Length-standardized concentrations of mercury were similar for the large-bodied fish species between the two sampling years within each on-system waterbody. Conversely, concentrations in Walleye were significantly lower in 2013 than 2010 in the off-system Setting Lake (Figure 7-5).

Arithmetic means for perch collected from Little Playgreen and Cross lakes were significantly higher in 2010 compared to 2013. The observed difference for perch from Little Playgreen Lake may be an artifact of the substantially larger size of the fish sampled in 2010 (Figure 7-8). However, the inter-annual difference observed for perch from Cross Lake cannot be attributed to a similar length (and age) bias, as in fact the fish sampled in 2010 were smaller than those analyzed in 2013 (Table 7-2).

7.3 SUMMARY

Mean length-standardized concentrations of mercury were below the 0.5 ppm Health Canada standard for commercial marketing of fish (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011) in all on-system and off-system waterbodies. Only a few pike and Walleye out of the more than 850 fish analyzed for the region had a mercury concentration above the 0.5 ppm standard. The highest percentage exceedance was 3% in Walleye, recorded for several lakes, and 19% in pike from Setting Lake.

Mercury concentrations (length-standardized) were similar for pike across waterbodies but Walleye had higher concentrations in Playgreen and Sipiwesk lakes than Cross and Playgreen lakes within the same sampling year. There is insufficient data for spatial comparisons of mercury concentrations in whitefish and perch.

Comparisons between 2010 and 2013 indicated that of all species and for all lakes, only Walleye from Setting Lake and 1 to 2-year-old perch from Cross Lake had mean mercury concentrations that differed significantly between the two years. In both instances concentrations were lower in 2013.

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

Waterbody	Year	Species	n	Mercury Concentration (ppm)			
				Arithmetic Mean	SE	Standard Mean	95% CL
Little Playgreen Lake	2010	Pike	35	0.227	0.013	0.214	0.196 - 0.235
		Walleye	36	0.265	0.020	0.231	0.199 - 0.269
		Whitefish	5	0.058	0.015	-*	0.017 - 0.099
		Perch	10	0.052	0.010	-	-
	2013	Pike	34	0.183	0.013	0.195	0.177 - 0.213
		Walleye	36	0.198	0.019	0.237	0.213 - 0.264
		Perch	17	0.012	0.001	-	-
Playgreen Lake	2010	Pike	36	0.242	0.011	0.215	0.197 - 0.234
		Walleye	36	0.181	0.017	0.156	0.137 - 0.178
		Whitefish	27	0.018	0.003	0.024	0.019 - 0.030
	2012	Pike	37	0.281	0.019	0.186	0.157 - 0.222
		Walleye	37	0.147	0.015	0.135	0.117 - 0.155
		Whitefish	36	0.026	0.004	0.021	0.018 - 0.024
Cross Lake	2010	Pike	36	0.233	0.026	0.187	0.159 - 0.219
		Walleye	36	0.202	0.021	0.149	0.130 - 0.170
		Perch	25	0.075	0.003	-	-
	2013	Pike	36	0.300	0.023	0.237	0.200 - 0.280
		Walleye	36	0.188	0.018	0.183	0.163 - 0.205
		Whitefish	2	0.042	0.013	-*	0.000 - 0.201
		Perch	20	0.049	0.003	-	-
Sipiwesk Lake	2011	Pike	36	0.285	0.031	0.237	0.211 - 0.267
		Walleye	23	0.254	0.028	-*	0.196 - 0.312
Setting Lake	2010	Pike	36	0.391	0.048	0.392	0.332 - 0.463
		Walleye	35	0.269	0.021	0.277	0.243 - 0.315
		Whitefish	24	0.025	0.001	-*	0.021 - 0.029
		Perch	13	0.054	0.005	-	-
	2013	Pike	36	0.272	0.033	0.314	0.269 - 0.367
		Walleye	36	0.173	0.011	0.206	0.184 - 0.229
		Whitefish	28	0.025	0.002	0.025	0.021 - 0.030
		Perch	15	0.008	0.000	-	-

* The relationship between mercury concentration and fish length was not significant, the 95% CL is for the arithmetic mean.

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

Waterbody	Year	Species	n	Length (mm)	Weight (g)	K_F	Age (years)
Little Playgreen Lake	2010	Pike	35	560.9 ± 17.9	1646.9 ± 137.9	0.86 ± 0.01	5.8 ± 0.4
		Walleye	36 [2]	409.6 ± 12.9	1077.2 ± 80.5	1.41 ± 0.02	6.9 ± 0.5
		Whitefish	5	472.0 ± 16.4	1912.0 ± 229.0	1.79 ± 0.02	9.6 ± 2.5
		Perch	10	166.0 ± 2.3	83.0 ± 5.6	1.80 ± 0.07	-
	2013	Pike	34	521.4 ± 13.8	1261.2 ± 105.7	0.83 ± 0.01	4.6 ± 0.3
		Walleye	36	344.9 ± 15.2	608.3 ± 87.6	1.19 ± 0.02	4.4 ± 0.5
		Perch	17 [1]	86.5 ± 1.5	9.7 ± 0.5	1.48 ± 0.04	1 - 2
Playgreen Lake	2010	Pike	36 [3]	614.1 ± 18.5	2239.4 ± 212.6	0.89 ± 0.01	6.4 ± 0.5
		Walleye	36 [4]	412.1 ± 19.1	1171.8 ± 112.2	1.35 ± 0.02	6.1 ± 0.3
		Whitefish	27 [5]	260.1 ± 22.1	461.1 ± 126.9	1.44 ± 0.04	3.5 ± 1.1
	2012	Pike	37	671.6 ± 19.2	2633.5 ± 230.0	0.80 ± 0.01	8.2 ± 0.5
		Walleye	37	399.9 ± 18.3	1006.6 ± 102.4	1.26 ± 0.02	5.2 ± 0.4
		Whitefish	36	339.7 ± 20.8	868.9 ± 128.6	1.54 ± 0.03	8.1 ± 1.5
Cross Lake	2010	Pike	36 [3]	588.9 ± 23.2	1835.0 ± 226.3	0.77 ± 0.01	5.5 ± 0.4
		Walleye	36	427.5 ± 11.5	1093.1 ± 113.1	1.28 ± 0.02	7.3 ± 0.6 [a]
		Perch	25	84.0 ± 1.0	6.7 ± 0.2	1.13 ± 0.02	1.2 ± 0.1
	2013	Pike	36	642.9 ± 23.3	2192.2 ± 273.4	0.71 ± 0.02	6.9 ± 0.4
		Walleye	36 [7]	385.9 ± 13.9	755.8 ± 87.1	1.10 ± 0.02	5.5 ± 0.5
		Whitefish	2	347.5 ± 85.5	790.0 ± 580.0	1.43 ± 0.26	5.5 ± 1.5
		Perch	20	93.1 ± 1.3	9.7 ± 0.5	1.18 ± 0.02	1.9 ± 0.1
Sipiwesk Lake	2011	Pike	36	566.8 ± 18.3	1613.1 ± 164.3	0.80 ± 0.01	6.0 ± 0.4
		Walleye	23 [8]	414.3 ± 14.3	1023.5 ± 101.2	1.33 ± 0.02	4.5 ± 0.3
Setting Lake	2010	Pike	36	514.3 ± 17.1	1123.6 ± 141.4	0.73 ± 0.02	5.9 ± 0.4
		Walleye	36	376.4 ± 11.4	677.8 ± 49.6	1.16 ± 0.01	5.9 ± 0.4
		Whitefish	24	286.6 ± 9.4	354.2 ± 34.4	1.41 ± 0.02	2.8 ± 0.1
		Perch	13	64.3 ± 1.0	3.1 ± 0.2	1.15 ± 0.04	-
	2013	Pike	36	494.3 ± 16.8	933.9 ± 106.1	0.69 ± 0.01	5.2 ± 0.4
		Walleye	36 [9]	350.6 ± 12.6	562.6 ± 49.0	1.12 ± 0.01	5.3 ± 0.4
		Whitefish	28 [10]	340.5 ± 5.3	544.8 ± 26.4	1.38 ± 0.02	4.2 ± 0.2
		Perch	15 [11]	70.4 ± 3.2	5.3 ± 0.8	1.42 ± 0.04	1 - 2

[1] n=8 for age; [2] n=33 for age; [3] n=34 for age; [4] n=32 for age; [5] n=26 for age; [6] n=9 for weight and K_F; [7] n=35 for age; [8] n=21 for age; [9] n=35 for weight and K_F; [10] n=27 for weight and K_F; [11] n=7 for age

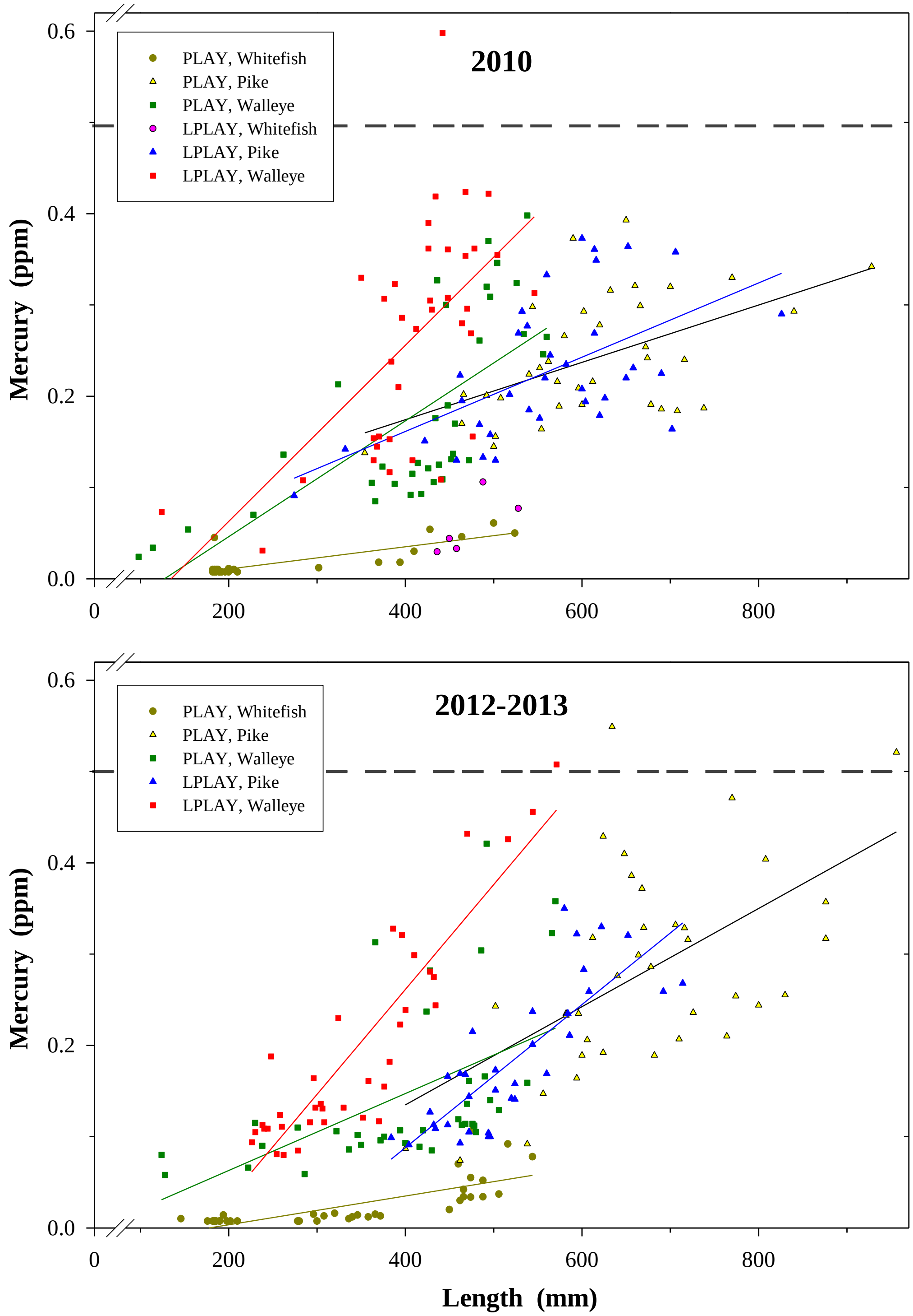


Figure 7-1. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from Playgreen and Little Playgreen lakes in 2010, 2012 (Playgreen Lake only), and 2013. Significant linear regression lines are shown. Dashed lines represent the Health Canada standard for retail fish.

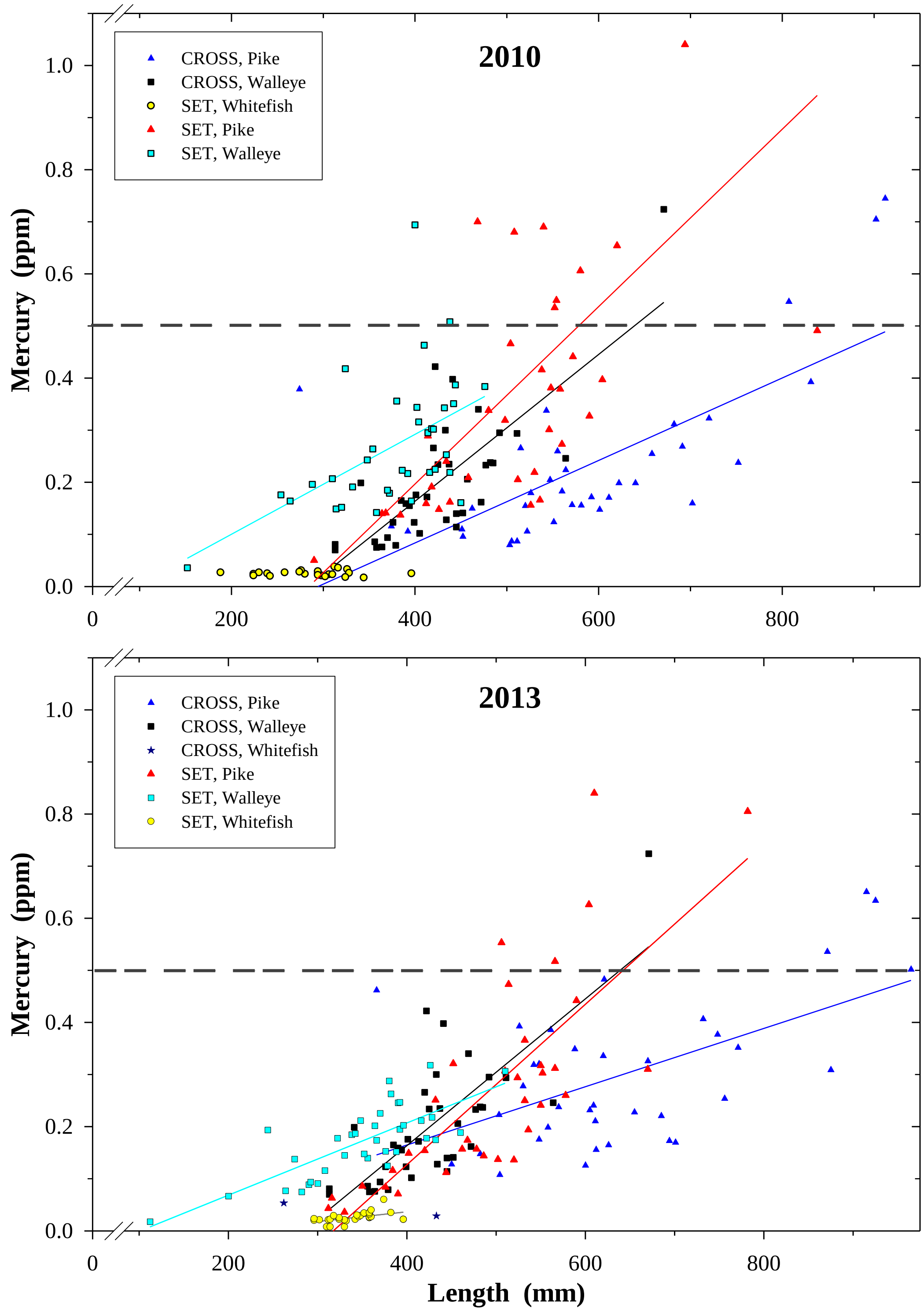


Figure 7-2. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from Cross and Setting lakes in 2010 and 2013. Significant linear regression lines are shown. Dashed lines represent the Health Canada standard for retail fish.

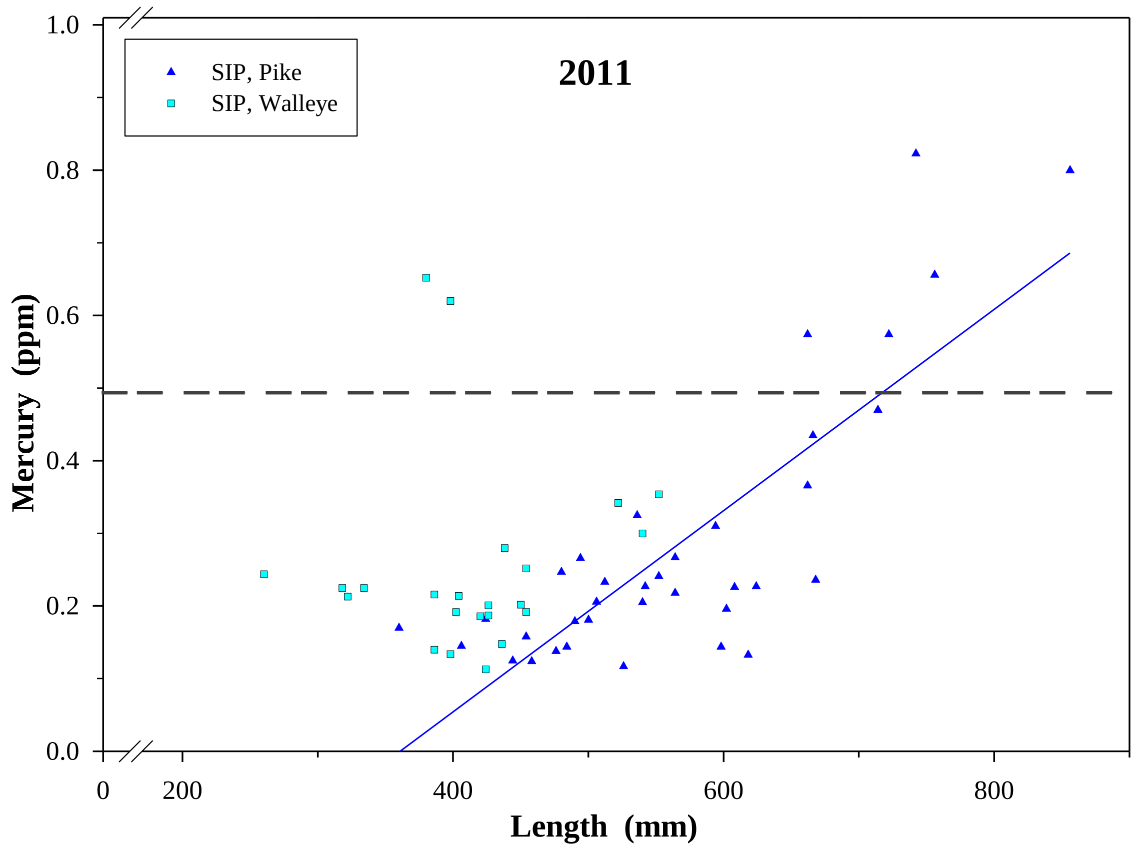


Figure 7-3. Relationship between mercury concentration and fork length for Northern Pike and Walleye from Sipiwesk Lake in 2011. Significant linear regression lines are shown. The dashed line represents the Health Canada standard for retail fish.

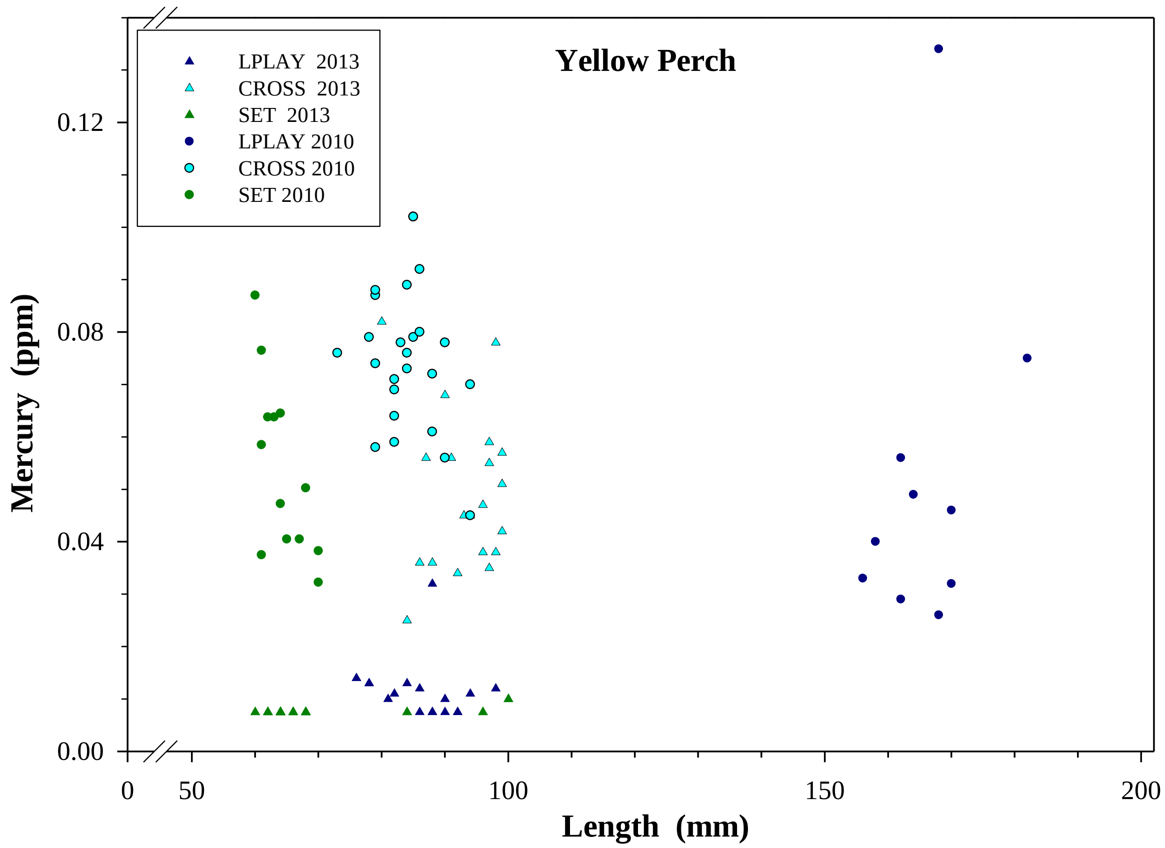
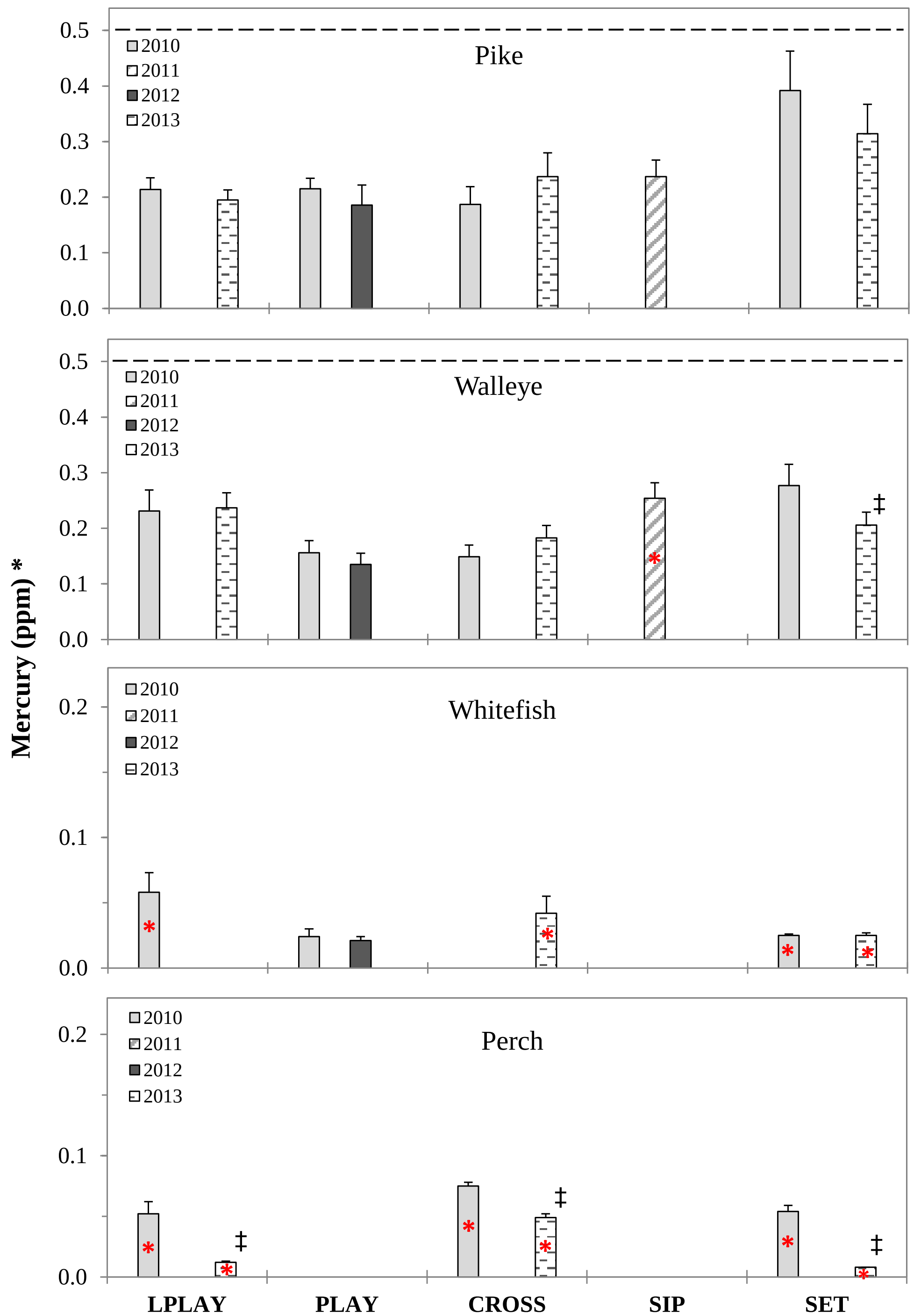


Figure 7-4. Mercury concentration versus fork length for Yellow Perch from the Upper Nelson River Region (2010 and 2013).



* Note differences in mercury scale among species.

Figure 7-5. Standard or arithmetic (asterisk) mean (upper 95% CL) mercury concentrations of Northern Pike, Walleye, Lake Whitefish, and Yellow Perch from the UNRR for 2010-2013. Different letters indicate a significant difference between years for the same waterbody (for perch the comparison is for arithmetic means). Dotted lines represent the 0.5 ppm standard for retail fish.

8.0 AQUATIC HABITAT INVENTORY

8.1 INTRODUCTION

The primary objective of the CAMP aquatic habitat inventories is to create depth and substrate distribution maps, which are two common habitat variables used in aquatic habitat assessments. A detailed description of the program design and sampling methods is provided in Technical Document 1, Section 3.2. In brief, the CAMP aquatic habitat inventory program consists of hydroacoustic bottom surveys and collection of physical samples to validate the hydroacoustic data. Surveys were conducted in the west basin of Cross Lake (2011) and Playgreen Lake (2012).

8.2 PLAYGREEN LAKE

Aquatic habitat inventory surveys were conducted in the UNRR on the north and south basins of Playgreen Lake in May and June of 2012 (Figure 8-1). Large portions of the lake were not surveyed due to shallow waters with numerous navigational hazards. The data collected during the surveys were used to produce depth and substrate distribution habitat maps, which were used to describe the depth, substrate, and overall aquatic habitat characteristics of Playgreen Lake.

8.2.1 Bathymetry

A total of 48,465 ha, or approximately 70%, of Playgreen Lake was mapped for depth in May and June 2012, relative to a mean survey water surface elevations of 217.56 m (GS of CVGD28, local adj. 1969) in the south basin and 217.47 (GS of CVGD28, local adj. 1969) in the north basin (Figure 8-2; Table 8-1). Playgreen Lake is generally a shallow lake, with over 50% of the mapped area of the lake less than 3 m in depth (Figure 8-3). Many of the deeper areas occur along the central channel running through the centre portion of the lake. The maximum and average depths varied throughout the various reaches that were mapped (Table 8-1). The north basin of Playgreen Lake was mapped on the west side of the basin. The eastern half of the large northern basin is very shallow and contains many rocky reefs. These areas were not surveyed due to navigational concerns. The western half of the north basin had an average depth of 2.97 m and a maximum depth of 19.85 m found in the deep channel at Whiskey Jack Narrows. The west channel of the Nelson River entering the north basin of Playgreen Lake has a distinct deep channel that becomes shallow and wide as the flow dissipates into the wide basin north of Lulu Island. The channel is re-established approximately 10 km upstream of Whiskey Jack Narrows. Overall the north basin is shallow and flat with a mean slope of 0.5%.

A large area of the west channel of the Nelson River was also not surveyed due to navigational concerns. This area of the waterbody is narrow relative to the north and south basins of the lake but still averages approximately 2 km wide from bank to bank. The ~500 m wide deep channel runs parallel to the banks almost directly through the centre. It is expected that this deep channel is maintained throughout the areas that were not surveyed. The mean depth in this surveyed reach was 2.02 m with a maximum depth of 22.85 m. The maximum bed slope is 18.30% with an average of 1.51%.

The southern basin of Playgreen Lake had a mean depth of 2.56 m with a maximum depth of 19.72 m found near the inlet to the west channel of the Nelson River. The basin is shallow and flat with a mean slope of 0.4%. A large wide channel meanders down the east central portion of the lake parallel to the shoreline. A large area in the southeastern portion of the lake was not surveyed due to navigational concerns. This area of the lake is spotted with hundreds of small islands, shoals, and reefs. A few shallow bays and backwater inlets were also not surveyed in the southern basin due to shallow water conditions.

The two constructed channels have the highest mean depths and slopes of all the surveyed reaches. Eight-Mile Channel had a maximum depth of 15.16 m and a mean depth of 5.47 m. Two-Mile Channel had a maximum depth of 12.04 m and a mean depth of 6.88 m. The calculated total volume of Playgreen Lake (including the excavated channels) based on the extent of bathymetric data collected in 2012 is 1,467,906,000m^3.

8.2.2 Substrate

A total of 47,916 ha of Playgreen Lake was classified and mapped for dominant bottom types in 2012 (Table 8-2; Figures 8-4). Silt/Clay (39%) and Clay (24%) based substrates dominate the substrate composition of the classified areas of the waterbody. Sand (26%) is found throughout the waterbody beginning at the inlet near Warren Landing. This channelized area of the waterbody contains cobble, gravel, and sand materials. Cobble, gravel, and sand based substrates comprise 3% of the total substrate composition in the waterbody. The shoreline and nearshore areas of the eastern shore in the southern basin are dominated by bedrock and rock shoals. Similarly in the north basin the shorelines are dominated by bedrock. Shallow bedrock outcrops and shorelines or shoals comprise 5% of the total mapped substrate distribution. The western shoreline of the south basin, unlike the eastern shore, is dominated by low lying glaciolacustrine fine tills and organic peatland soils. Organic substrates account for 3% of the total substrate composition, which is evident of the benthic area proximate to Peat Point.

8.2.3 Aquatic Habitat Summary

Playgreen Lake is a 95 km-long, shallow on-system waterbody that has distinct areas of lentic and lotic habitat. It has a distinct deep central channel running almost the entire length from the Warren Landing inlet to the Whiskey Jack Narrows outlet on the north basin. It has been hypothesized that Playgreen Lake began as a river channel and broadened into a riverine lake (MacLaren Plansearch 1985). The inlets to Playgreen Lake including Two-Mile Channel and the Nelson River at Warren Landing move large quantities of water out of Lake Winnipeg. The flows continue through the central portions of the lake and outlet at Eight-Mile Channel, the east channel of the Nelson River, and the west channel of the Nelson River at Whiskey Jack Narrows.

Playgreen Lake is found at the divide of the Boreal Plains and Boreal Shield ecozones. The landscape along the west bank is dominated by fine glacial tills overlain by areas of thick peat accumulation, while the eastern shore's landscape is generally bedrock outcrops.

Silty-clay and clay substrates dominate the majority of the lake but sands and silty sands also constitute large areas of the lake. Coarser materials are generally restricted to the eastern Precambrian shield shoreline in the south basin or in the deeper channel running the length of the lake. The wide, western channel of the Nelson River connecting the north and south basins is spotted with frequent rocky shoals and bedrock outcrops as is the eastern half of the north basin. Macrophytes were not identified during surveys as the survey period was selected to avoid periods of heavy macrophyte growth for navigational purposes. However, the survey identified large shallow areas of lentic habitat with fine substrates that would potentially be suitable for macrophyte growth.

8.3 CROSS LAKE – WEST BASIN

Aquatic habitat inventory surveys were conducted in the UNRR on the west basin of Cross Lake in June and July of 2011 under CAMP (Figure 8-5). For ease of reading, 2011 habitat survey results in the following sections pertaining to the west basin of Cross Lake will be referred to as Cross Lake. The data collected during the surveys were used to produce depth and substrate distribution habitat maps, which were used to describe the depth, substrate, and overall aquatic habitat characteristics of Cross Lake. Additional survey data collected in 2014 as part of the Lake Sturgeon Stewardship Enhancement Program (LSSEP; Henderson et al. 2015) were integrated with data collected under CAMP to maximize spatial coverage of the lake.

8.3.1 Bathymetry

A total combined area of 16,886 ha of Cross Lake was mapped for depth in June and July 2011 through CAMP habitat inventory studies and in 2014 as a part of LSSEP studies (Henderson et al. 2015; Figure 8-6). Depth is relative to a water surface elevation of 209.19 m (G.S. of C, MB Hydro and Provincial Water Resources Extension), which was the mean survey elevation in 2011.Cross Lake is generally shallow with approximately 30% of the lake less than 3 m in depth and 80% of the lake less than 5 m (Figure 8-7). Mean water depth was 3.96 m, the average bed slope was 3%, and the volume was 668,700,000 m^3 (Table 8-3).

The deepest recorded depth in Cross Lake at the time of surveys was 36.6 m in a small hole in the central channelized area of the waterbody. The deepest areas of the lake occur where there are distinct channels; there are no deep extensive basins within the studied portion of the waterbody. With the exception of these deep, highly sloped channelized areas, much of the lake bed has flat undulating hummocky topography. This is evident in the northeast area of the lake where flat terrain containing islands and bedrock shoals dominates the benthic landscape. To the northwest of the Jenpeg GS, a relatively shallow (~ 6 m) and broad (~ 400 m) channel sinuously flows through a broad flat basin (Jenpeg Basin). Where the basin narrows 5 km downstream of the Jenpeg GS at a central island there is a large deep (~18 m) hole before the channel broadens, disappears and becomes part of the broad shallow basin. A series of channels reappear approximately 9 km downstream of the hole where the basin begins to again narrow. These channels seemingly join together with one of the central deep narrow channels that originate to the northeast of the spillway. This deep (~ 20 m) channel heads north towards the Nelson River outlet at Eves and Ebb and Flow Rapids. The other two channels to the east dissipate into Sagatawak Basin, which is shallow (~ 4.5 m) and flat but dominated by hummocky terrain due to islands and shoals.

8.3.2 Substrate

Substrate was mapped for a total area of 17,901 ha (Figure 8-8; Table 8-4). Cross Lake is dominated by clay and silt/clay substrates, which account for approximately 88% of the total area that was mapped. Off-current lacustrine areas primarily consist of soft silt/clay materials. Mud-based Ponar grabs were generally light grey to light brown in colour and often contained varying proportions of clam shells, small gravels and sand. Sand accounted for the next highest class composition (4%). Sand substrates were mapped primarily in the deeper channel sections of the large shallow flat basins and in the central channelized areas of the waterbody. Dominant rocky substrates including cobble and gravel materials were mapped below Jenpeg GS and in the bottoms of channelized areas in the basin known as Jenpeg Basin and the central channelized area of the waterbody. Rock including bedrock and cobble and gravel sized materials were found along the shoreline throughout most of the lake. A number of extensive bedrock and cobble and boulder shoals occur intermittently throughout the waterbody, creating extensive areas of bottom structure, however rock substrates account for less than 2% of the total substrate composition of the waterbody.

8.3.3 Aquatic Habitat Summary

Cross Lake has a number of unique habitats due to its combination of channels and basins. The basins tend to be homogeneously shallow and mud-bottomed whereas the central channels tend to be deep, highly-sloped and consisting of a varying range of soft and hard substrates. At the time of survey in 2011 Cross Lake was experiencing record or near record high water levels, and shorelines and shoreline vegetation were generally flooded. Although water movement was not measured for this report, it is expected that there are distinct areas of lentic and lotic habitat throughout the waterbody. The presence of aquatic vegetation (emergent and submerged species) was observed in various locations throughout the nearshore area of the lake. In general, the habitats of Cross Lake can be considered moderately heterogeneous ranging from lentic to lotic, deep to shallow, and having hard and soft substrates.

Table 8-1. Summary of depth, slope, and volume statistics for areas of Playgreen Lake resulting from aquatic habitat surveys and mapping conducted in May and June 2012.

Mapped Area	Area (ha)	Maximum Depth (m)	Mean Depth (m)	Maximum Slope (%)	Mean Slope (%)	Volume (m^3)
Playgreen Lake (North Basin)	12732	19.95	2.97	15	0.5	387,482,000
Playgreen Lake (South Basin)	30013	19.72	2.56	17	0.4	896,694,000
Warren's Landing Inlet	3072	19.38	2.80	13	1	86,445,000
West Nelson River Channel	2187	22.85	2.02	18	1.5	70,436,000
Eight Mile Channel	401	15.16	5.47	10	5	22,693,000
Two Mile Channel	60	12.04	6.88	12	3.5	4,155,000
Total	48465	-	-	-	-	1,467,906,000

Table 8-2. Summary of substrate distribution for Playgreen Lake resulting from aquatic habitat surveys and mapping conducted in May and June 2012.

Substrate	**Area (ha)**	**Total Area (%)**
Bedrock	2,564	4
Cobble/Gravel/Sand	1,391	2
Sand	12,436	18
Silt/Clay	18,747	27
Clay	11,543	16
Organics	1,235	2
Unclassified	22,635	32
Total	70,551	100

Table 8-3. Summary of depth, slope, and volume statistics of Cross Lake resulting from CAMP aquatic habitat surveys and mapping conducted in June and July 2011 and under CAMP and additional surveys conducted in 2014 as reported in Henderson et al. (2014).

Water Body Name	**Area (ha)**	**Maximum Depth (m)**	**Mean Depth (m)**	**Maximum Slope (%)**	**Mean Slope (%)**	**Volume (m^3)**
Cross Lake – West Basin	17678	29.0	3.96	75	2.82	668,700,148

Table 8-4. Summary of substrate distribution for Cross Lake resulting from aquatic habitat surveys and mapping conducted in June and July 2011 under CAMP and additional surveys conducted in 2014 as reported in Henderson et al. (2014).

Substrate	**Area (ha)**	**Total Area (%)**
Bedrock	9	< 1
Gravel/Cobble	290	2
Gravel/Sand	78	< 1
Sand	654	4
Silty Sand	516	3
Silt/Clay	5383	30
Clay	10344	58
No Data	627	3
Total	17901	100

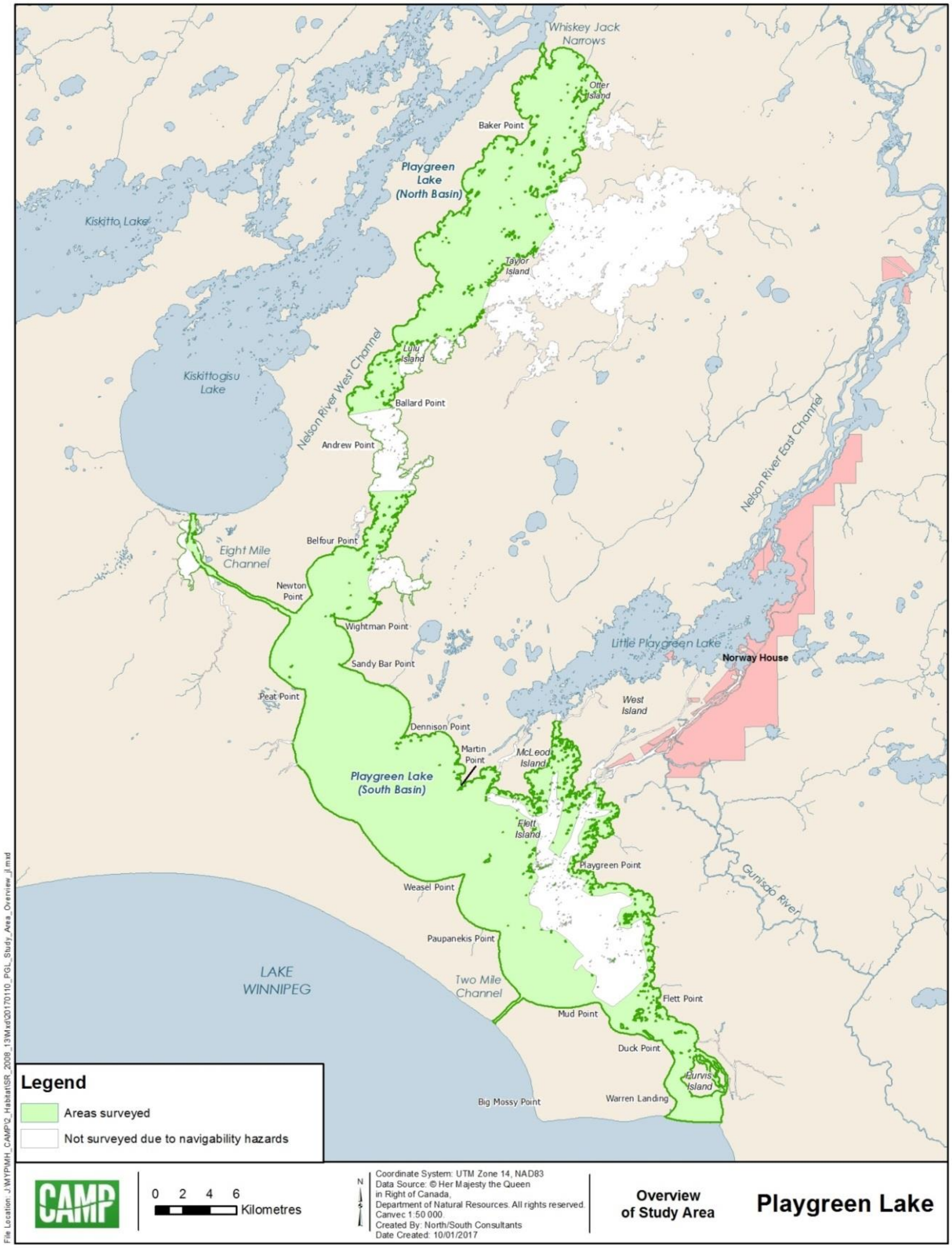


Figure 8-1. Area of habitat surveys conducted on Playgreen Lake.

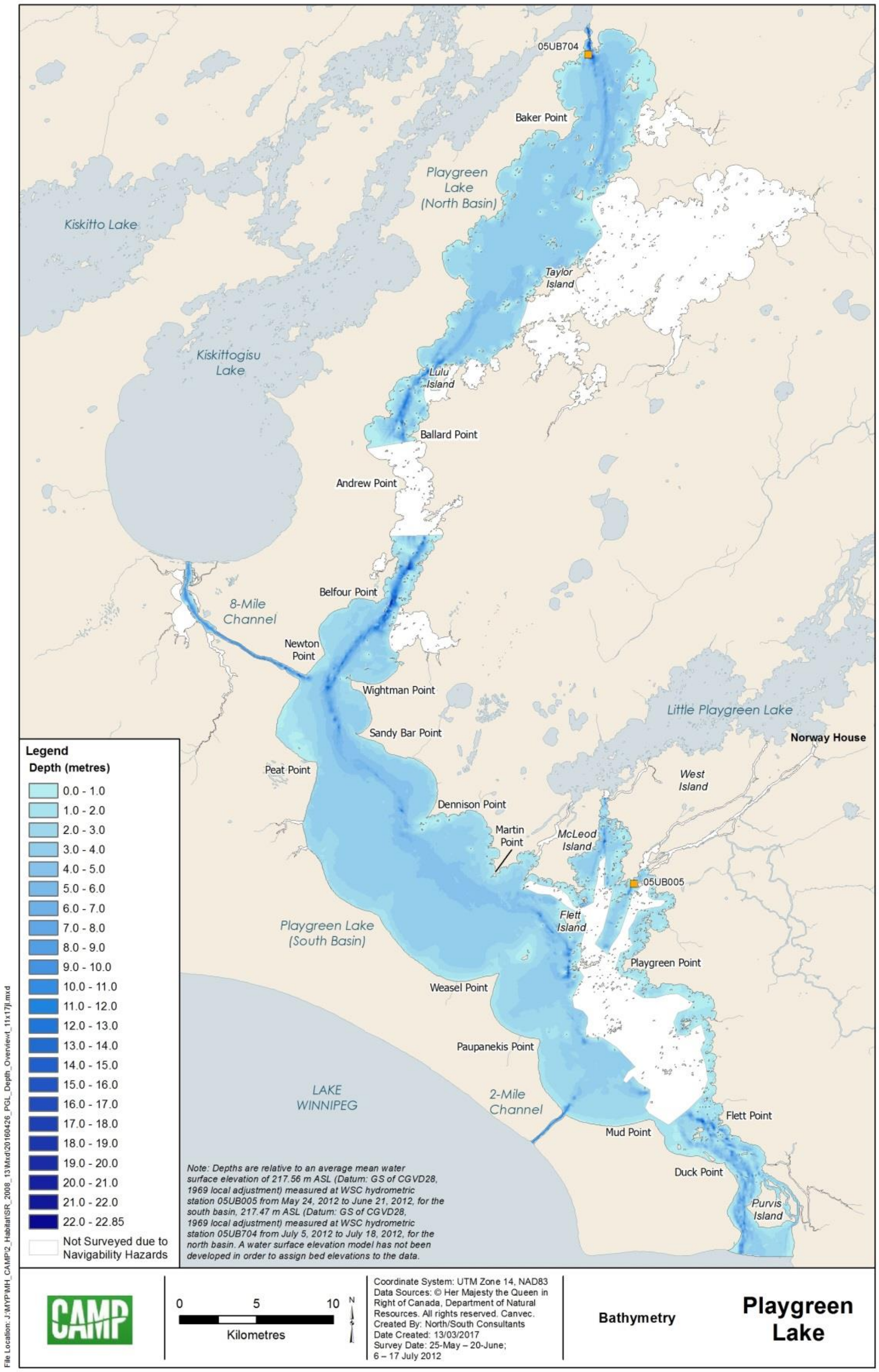


Figure 8-2. Overview bathymetric map of Playgreen Lake produced from the May and June 2012 habitat inventory surveys.

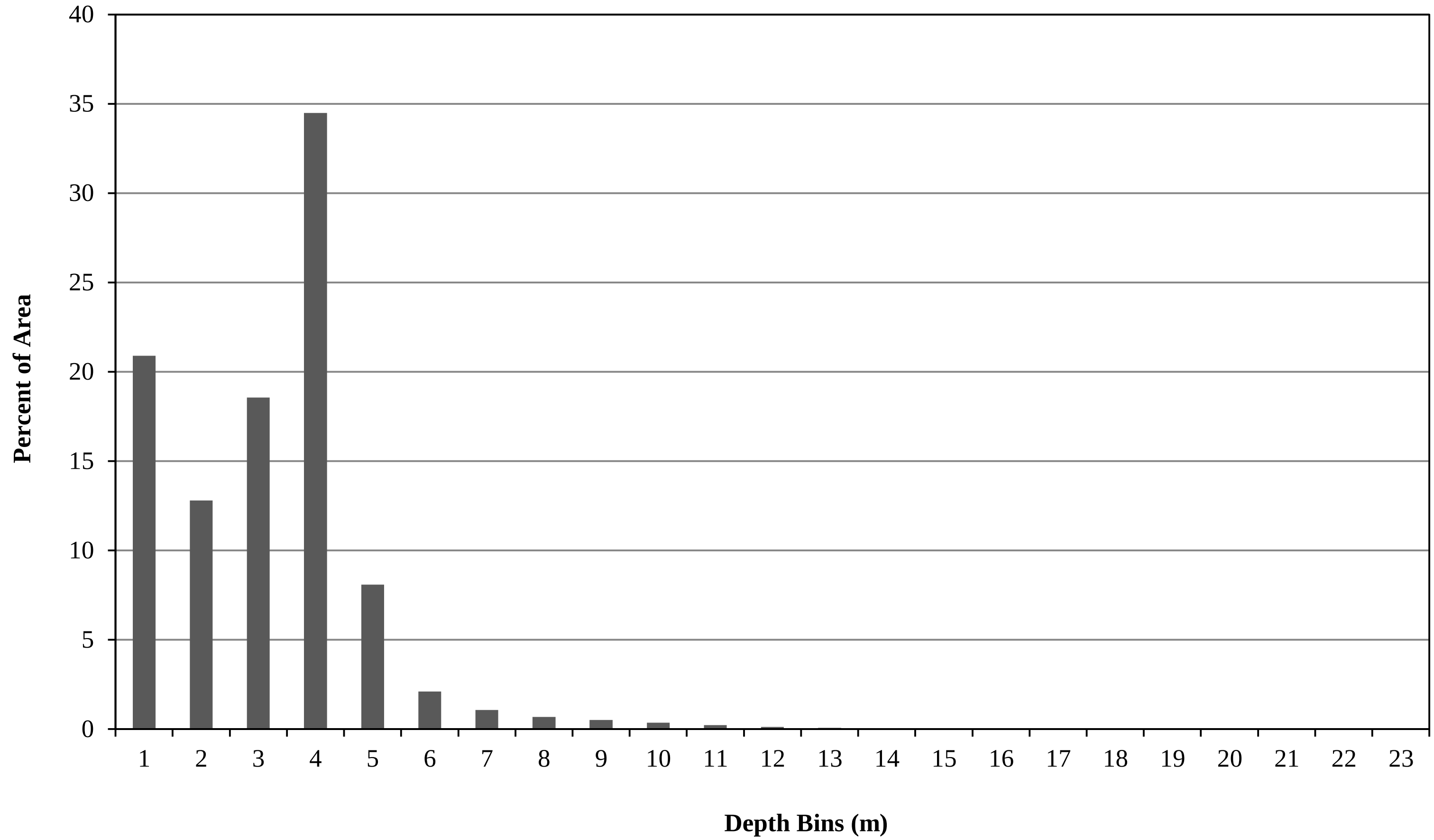


Figure 8-3. Depth distribution histogram depicting 1 m depth intervals by percentage of area covered by the Playgreen Lake surveys relative to mean survey water surface elevations of 217.56 m (GS of CVGD28, local adj. 1969) in the south basin and 217.47 (GS of CVGD28, local adj. 1969) in the north basin.

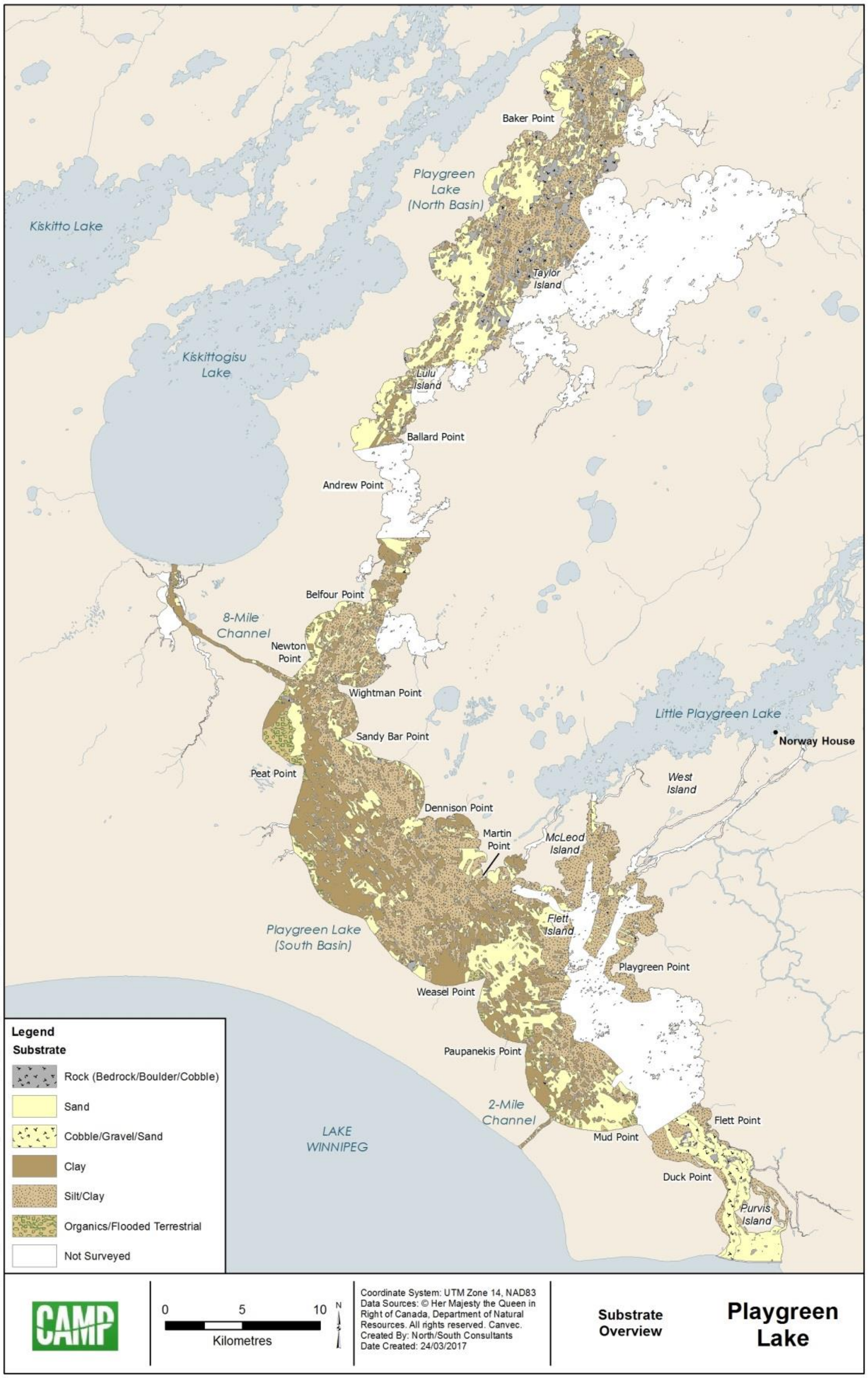


Figure 8-4. Overview substrate map of Playgreen Lake produced from the May and June 2012 habitat inventory survey.

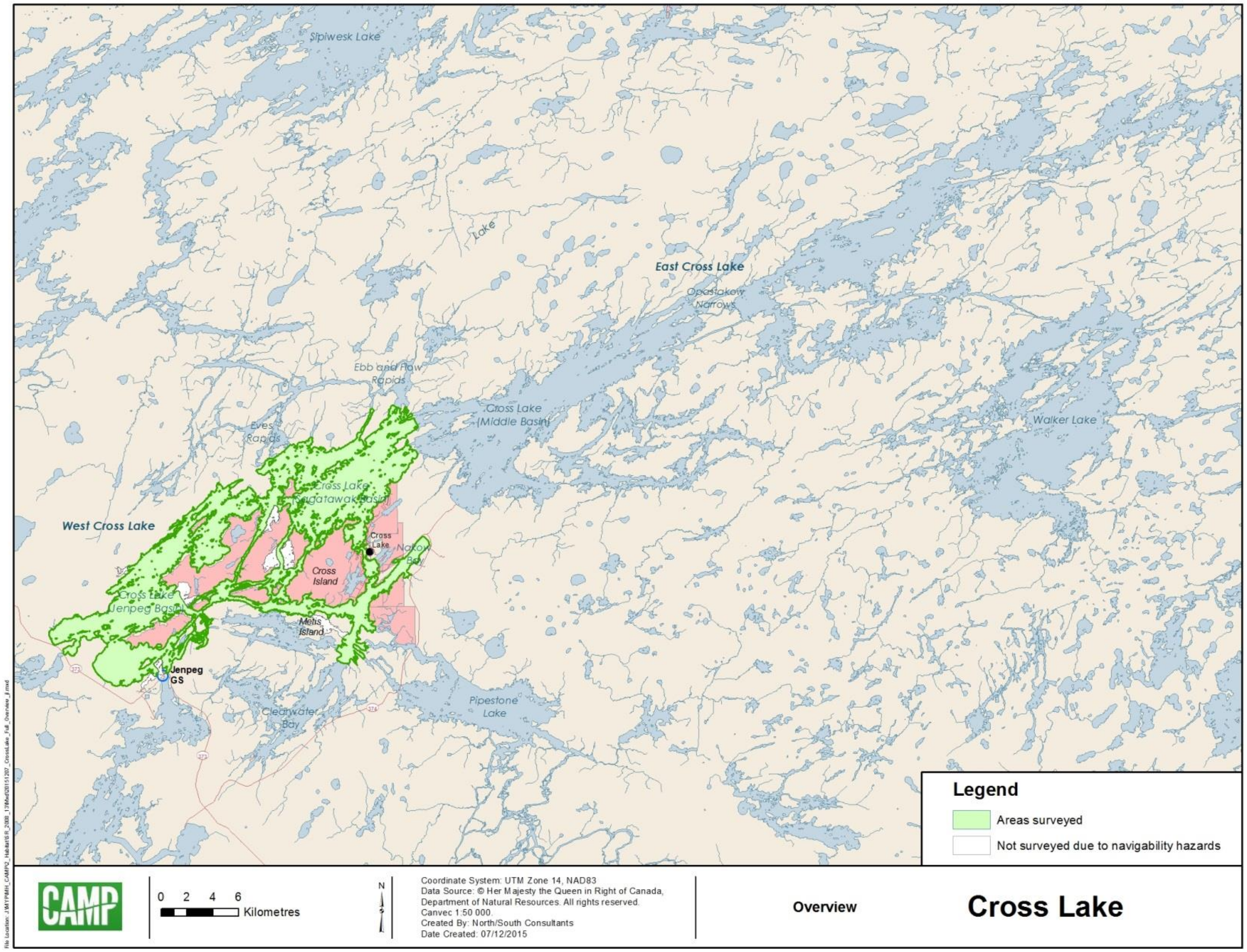


Figure 8-5. Area of habitat surveys in Cross Lake.

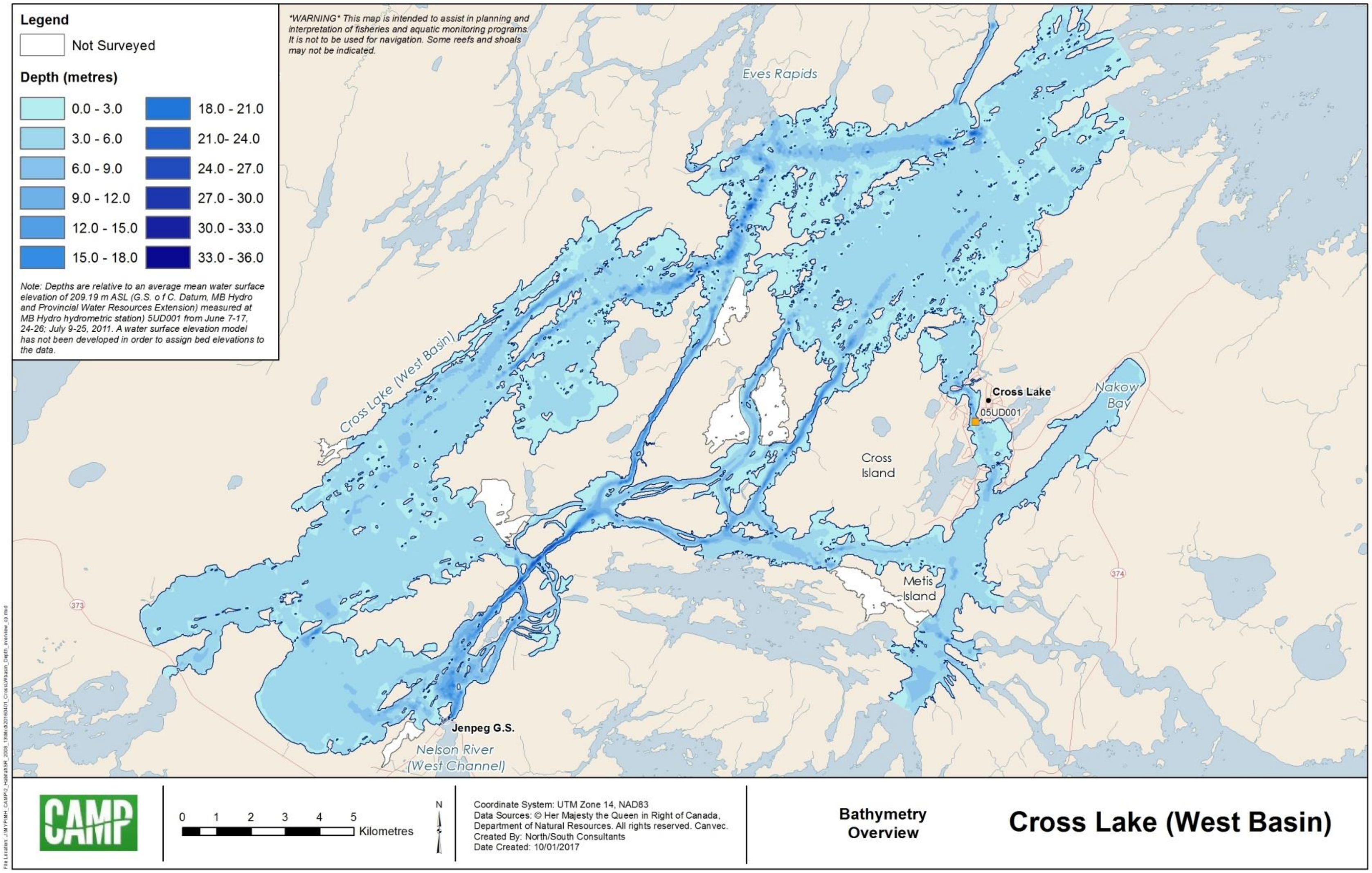


Figure 8-6. Overview bathymetric map of Cross Lake produced from the June and July 2011 CAMP habitat inventory surveys and the Henderson et al. (2014) surveys.

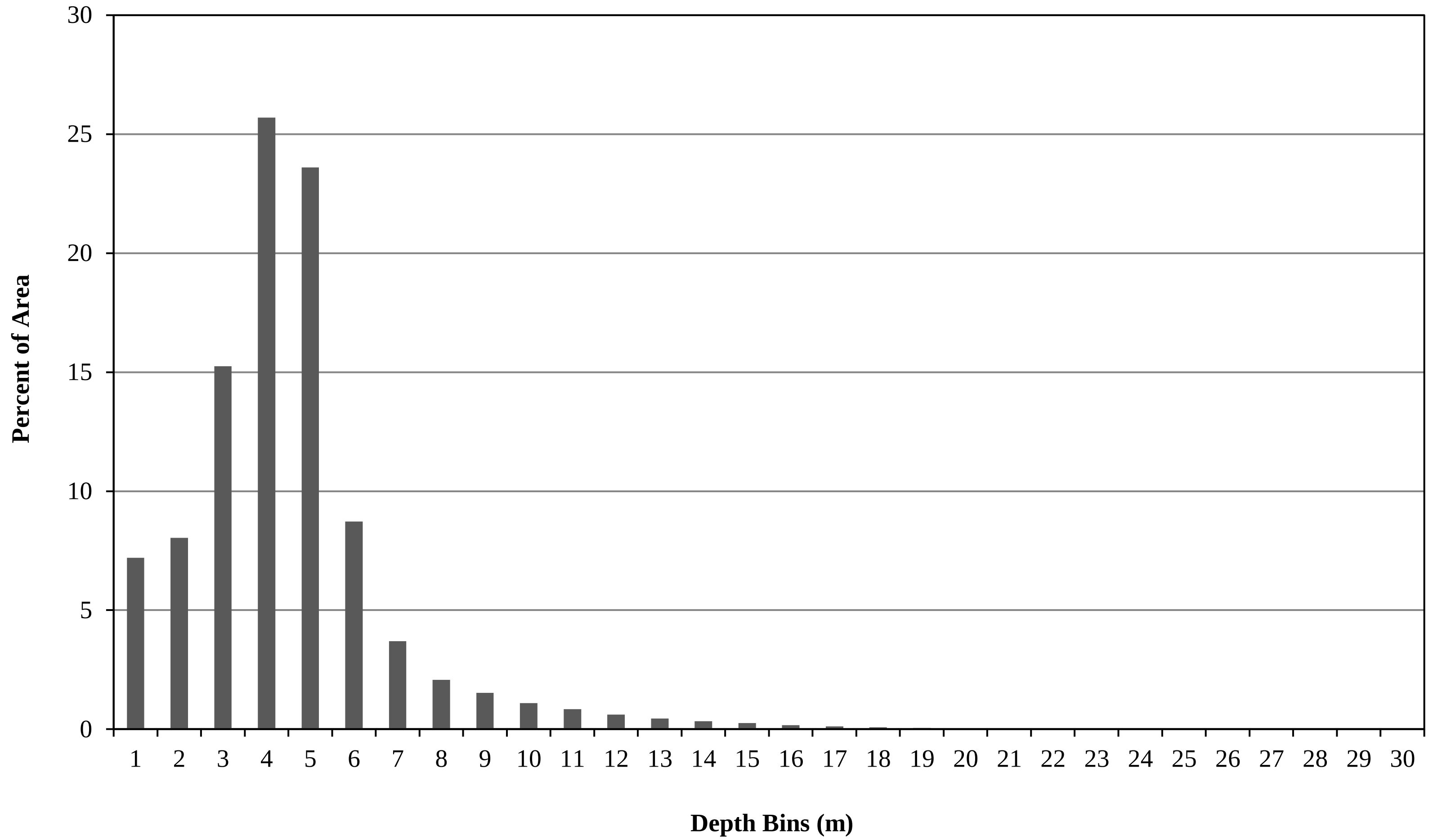


Figure 8-7. Depth distribution histogram depicting 1 m depth intervals by percentage of area covered in Cross Lake relative to a water surface elevation of 209.19 m (G.S. of C, Manitoba Hydro and Provincial Water Resources Extension).

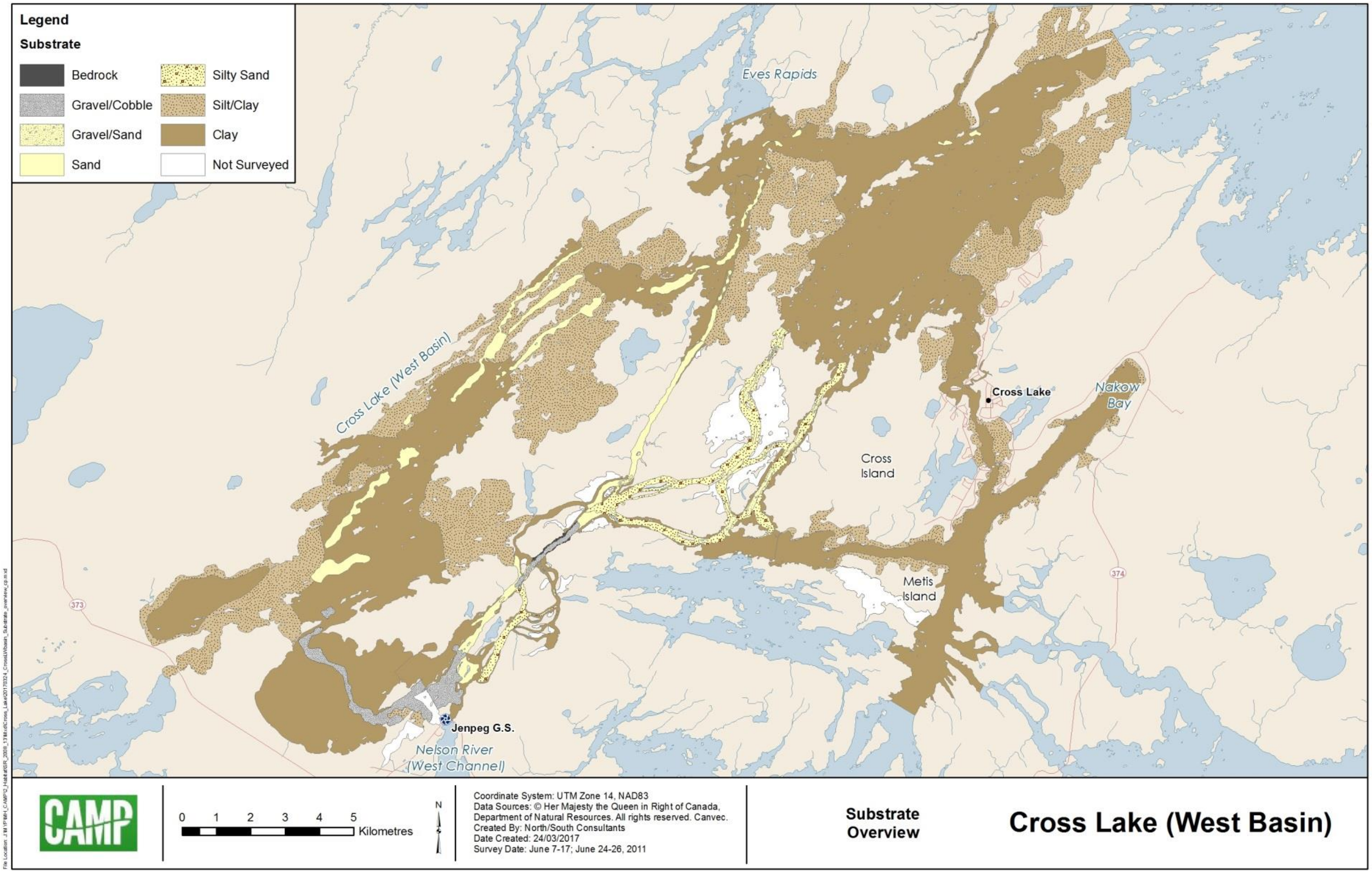


Figure 8-8. Overview substrate map of Cross Lake produced from the 2011 CAMP habitat inventory surveys and Henderson et al. (2014) surveys.

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