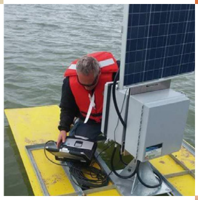
CAMP

Coordinated Aquatic Monitoring Program



Six Year Summary Report

Technical Document 9:
Lower Nelson River Region

2008-2013

Submitted to:
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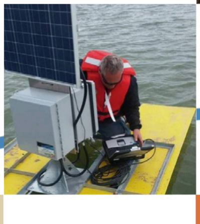

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TECHNICAL DOCUMENT 9:
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SIX YEAR SUMMARY REPORT (2008-2013)

Technical Document 9:

Lower Nelson River Region Results

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ABBREVIATIONS AND ACRONYNMS

ASL	Above sea level
ASSN	Assean Lake
BCMOE	British Columbia Ministry of Environment
BMI	Benthic macroinvertebrate(s)
BURNT	Burntwood River
CAMP	Coordinated Aquatic Monitoring Program
CCME	Canadian Council of Ministers of the Environment
CL	Confidence limit
CPUE	Catch-per-unit-effort
CRD	Churchill River Diversion
CS	Control Structure
DL	Detection limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
EPT:C	Ratio of the combined abundances of Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) to the abundance of Chironomidae (non-biting midges)
FL	Fork length
FL-at-age	Fork-length-at age
GS	Generating Station
HAYES	Hayes River
ISQG	Interim sediment quality guideline
K_F	Condition Factor
KHLP	Keeyask Hydropower Limited Partnership
LEL	Lowest effect level
LMFB	Limestone Forebay
LNR	Lower Nelson River downstream of the Limestone GS
LNRR	Lower Nelson River Region
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
n_F	Number of fish
n_Y	Number of years sampled
PAL	Protection of aquatic life
PEL	Probable effect level
ppm	Parts per million
Q (GN)	Average discharge (cms) during the gillnetting program
RCEA	Regional cumulative effects assessment
SAC	Sediment alert concentration
SE	Standard error of the mean
SEL	Severe effect level

SPLIT	Split Lake
SQG	Sediment quality guideline
STL-N	Stephens Lake - north
STL-S	Stephens Lake - south
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
WL (GN)	Average water level during the gillnetting program
WSL	Water surface level

1.0 INTRODUCTION

The following presents a description of results of monitoring conducted under the Coordinated Aquatic Monitoring Program (CAMP) for years 1 through 6 (i.e., 2008/2009 through 2013/2014) in the Lower Nelson River Region (LNRR). As described in Technical Document 1, Section 2.8.1, the LNRR is composed of the Nelson River extending from Split Lake to Gillam Island, and the Burntwood River downstream of First Rapids. Waterbodies and sites monitored in this region over this period included two off-system waterbodies (one lake and one river site) and six on-system waterbodies or river reaches as follows:

- the Burntwood River downstream of First Rapids;
- Split Lake;
- Stephens Lake – south;
- Stephens Lake – north;
- the Limestone Forebay;
- the lower Nelson River downstream of the Limestone Generating Station (GS);
- Assean Lake (off-system); and
- the Hayes River (off-system).

Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.8. 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 LNRR over this time period include hydrology, water quality, sediment quality, phytoplankton, benthic macroinvertebrates (BMI), fish community, and mercury in fish.

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

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

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

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

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

Table 1-1. Overview of CAMP sampling in the LNRR: 2008/2009-2013/2014.

						Sampling Years [1]					
Waterbody/Area	**Site Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**2008/09**	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**
Burntwood River - downstream of First Rapids	BURNT	**X**			**X** [2]		**X**			**X**	
Split Lake	SPLIT	**X**		**X**			**X**	**X**	**X**	**X**	**X**
Stephens Lake - South	STL-S	**X**			**X**		**X**			**X**	
Stephens Lake - North	STL-N	**X**			**X**		**X**			**X**	
Limestone Forebay	LMFB	**X**			**X**			**X**			**X**
Lower Nelson River - downstream of Limestone GS	LNR	**X**		**X**		**X**	**X**	**X**	**X**	**X**	**X**
Hayes River	HAYES		**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**
Assean Lake	ASSN		**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 annually beginning in 2009/2010; other components sampled on a rotational basis.

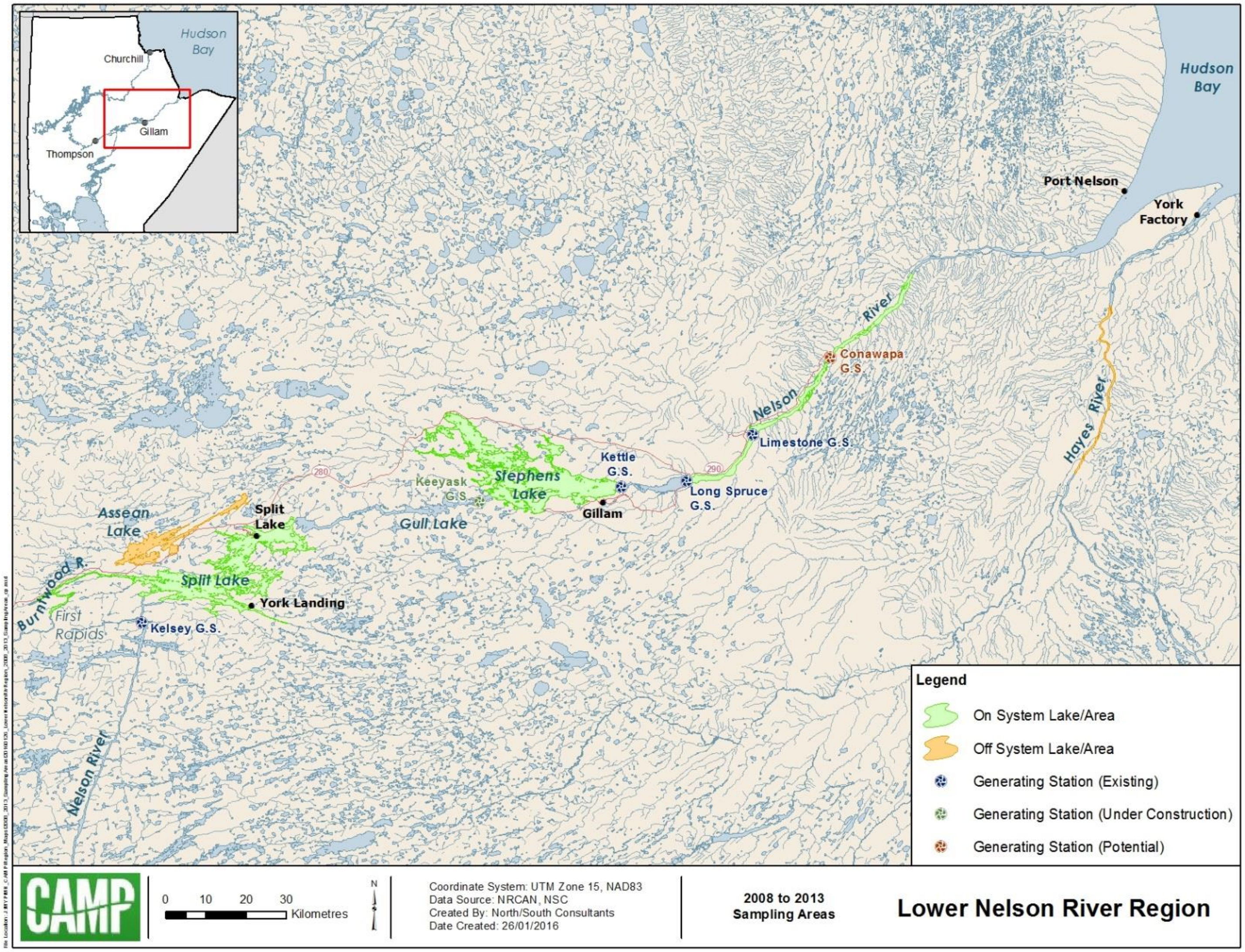


Figure 1-1. On-system and off-system waterbodies and river reaches sampled under CAMP in the Lower Nelson River Region: 2008/2009-2013/2014.

2.0 HYDROLOGY

The Nelson River drainage basin covers an area greater than one million square kilometers. Lower Nelson River flows are influenced by regulation of Lake Winnipeg outflows and the Churchill River Diversion (CRD), which diverts the majority of the Churchill River flow into the Nelson River through the Rat/Burntwood River system. CAMP monitoring in the region occurs on Split Lake, Stephens Lake, and in the Limestone GS forebay as well as the off-system Assean Lake and the Hayes River. Relative water levels for the lower Nelson River downstream of the Limestone GS can be inferred from lower Nelson River flows, which are reported at the Kettle GS. Lower Burntwood River flows are reported based on the gauge at Thompson.

From 2008 to 2013, lower Burntwood River flows were typically above average during the winter months due to flow releases at the Notigi Control Structure (CS) being at licensed maximum. Flows then typically peaked above the upper quartile with the spring freshet and were reduced to near or below the lower quartile during part of each summer as the Notigi CS releases were reduced to avoid aggravating high flow conditions on the Nelson River. The exception was 2012 when flows were reduced to near average in May and then remained above the upper quartile for the rest of the open-water period (Figure 2-1).

From 2008 to 2013, winter flow at the Kettle GS was generally above average each year and reached record highs in the winter of 2011. Flow were also mainly above average during the open-water seasons and peaked well above the upper quartile in each year except 2012. Record flows were also reached in late 2010 and parts of the 2011 open-water period. Record high flows were driven by generally above average precipitation in the Winnipeg, Saskatchewan, and Nelson River drainage basins. The only time when the Kettle GS flow dropped steadily below average was for a brief period in May to early June 2010 and 2012 (Figure 2-2).

Water levels on Split Lake generally followed a similar trend to lower Nelson River flows. Water levels were above average for the entire period from 2008 to 2013 except for May to early-June 2010 (Figure 2-3).

From 2008 to 2013, the water level on Stephens Lake generally varied above and below the lower and upper quartiles during the winter months as water was stored and released for power production. Each year during the open-water period the water level was held near the upper license limit for a varying amount of time. This was done to maximize power production when the spillway was being operated because flows exceeded the powerhouse capacity (Figure 2-4).

Water levels in the Limestone GS forebay typically fluctuate within a fairly narrow range of 84.5 m and 85.2 m and from 2008 to 2013 water levels were almost always within that range (Figure 2-5).

Water level monitoring on Assean Lake was initiated in August 2009 in support of CAMP. Water levels followed a similar pattern of slow decline throughout the winter each year with the first rise in mid-April to early-May as a result of the spring freshet. Water levels were more variable in the summer months depending on local precipitation in the basin. There appears to have been a large amount of precipitation in August-September 2010 which resulted in a rapid increase from the lowest to the highest open-water levels observed since 2009 (Figure 2-6).

From 2008 to 2013, the Hayes River flows were fairly similar in the winter and followed a typical pattern for an unregulated river with a slow decline throughout the winter. Flow started to increase in late-April to early-May each year with the spring freshet, except for 2012 when flows started to slowly increase in March. Flow tended to peak initially in May each year and then decline before peaking again later in the year in response to precipitation events within the drainage basin. Record high flows were reached in late August 2008, potentially in July 2009, in November-January 2010-2011, and in May 2011. Record low flows occurred from July to mid-August 2010 and February-March 2014 (Figure 2-7).

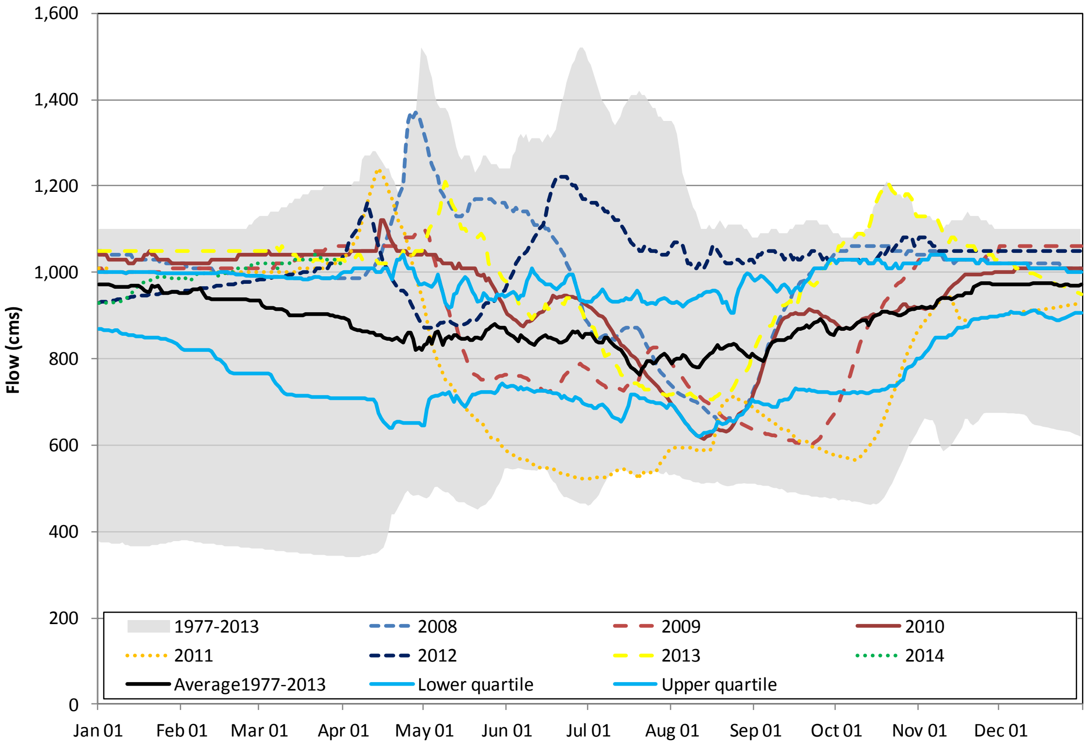


Figure 2-1. Lower Burntwood River (05TG001) flow: 2008-2013.

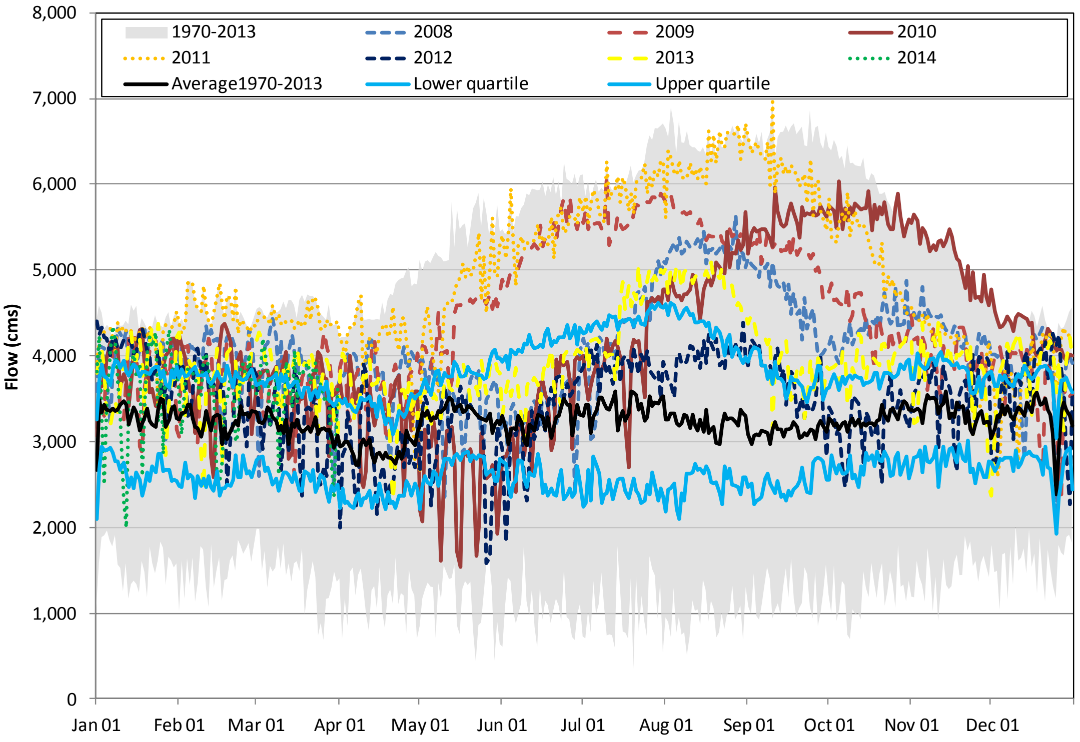


Figure 2-2. Kettle GS outflow: 2008-2013.

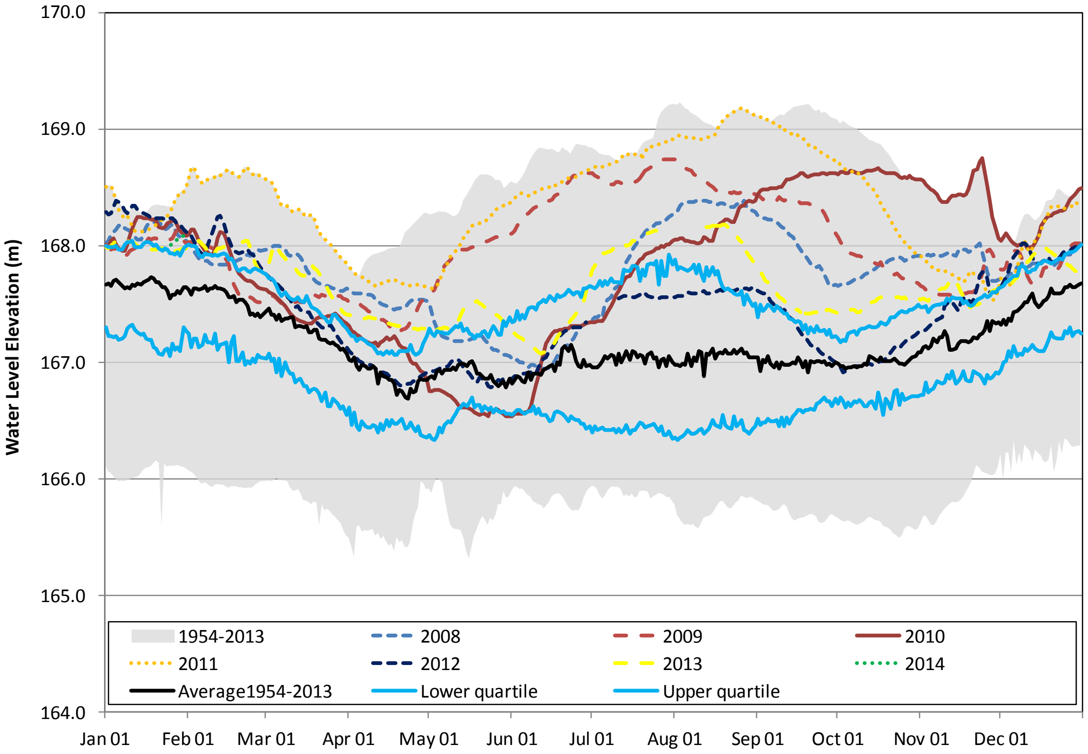


Figure 2-3. Split Lake (05UF003) water level elevation: 2008-2013.

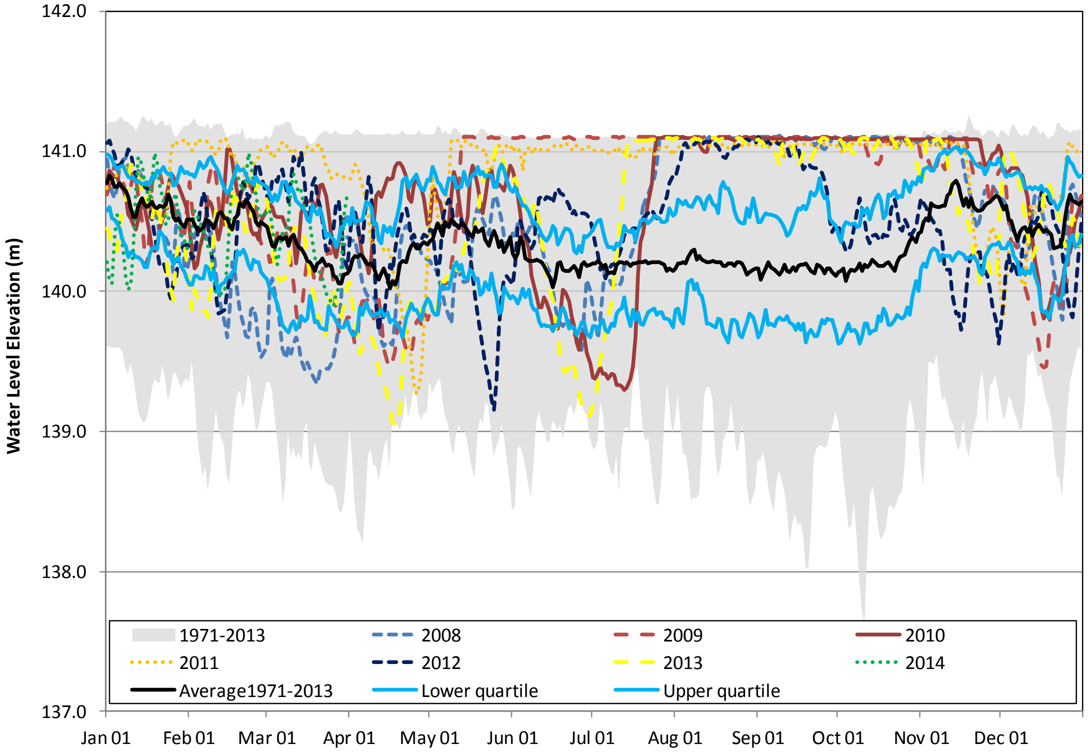


Figure 2-4. Kettle GS forebay (Stephens Lake) water level elevation: 2008-2013.

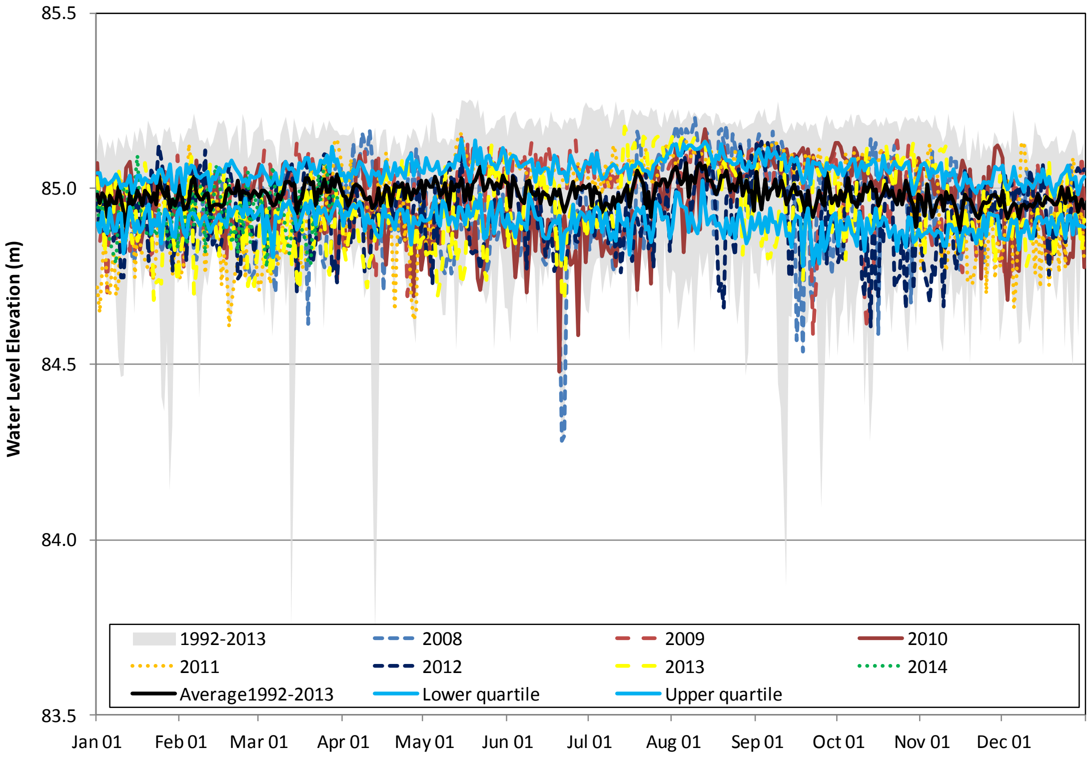


Figure 2-5. Limestone GS forebay water level elevation: 2008-2013.

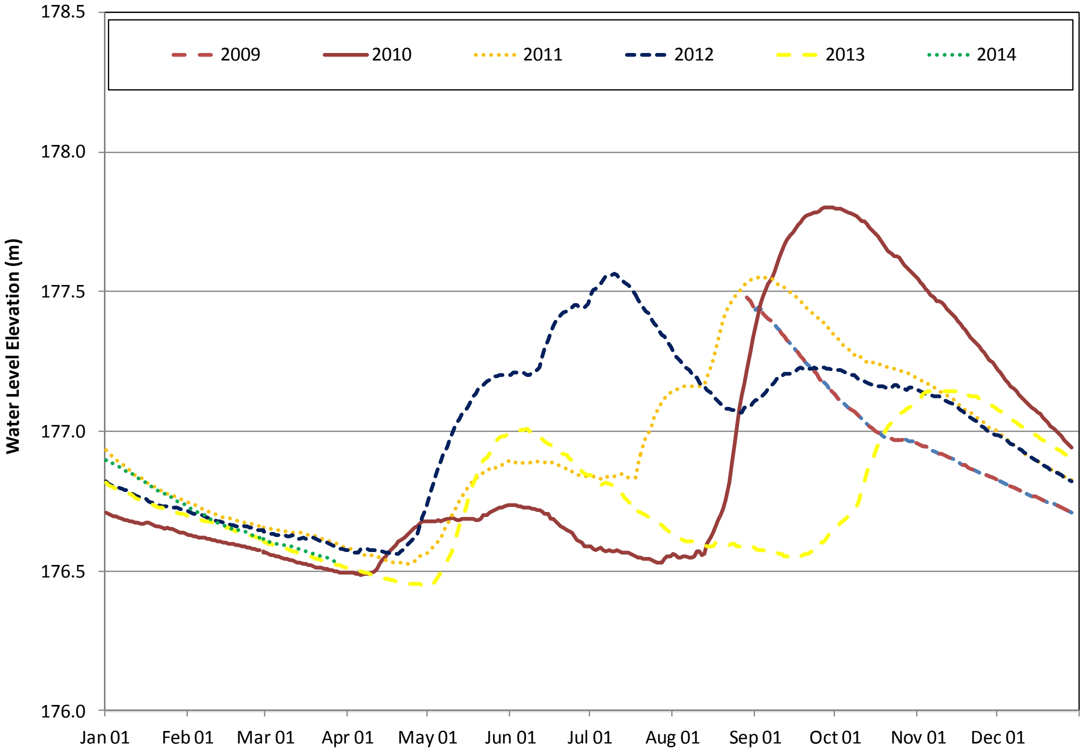


Figure 2-6. Assean Lake (05UF605) water level elevation: 2009-2013.

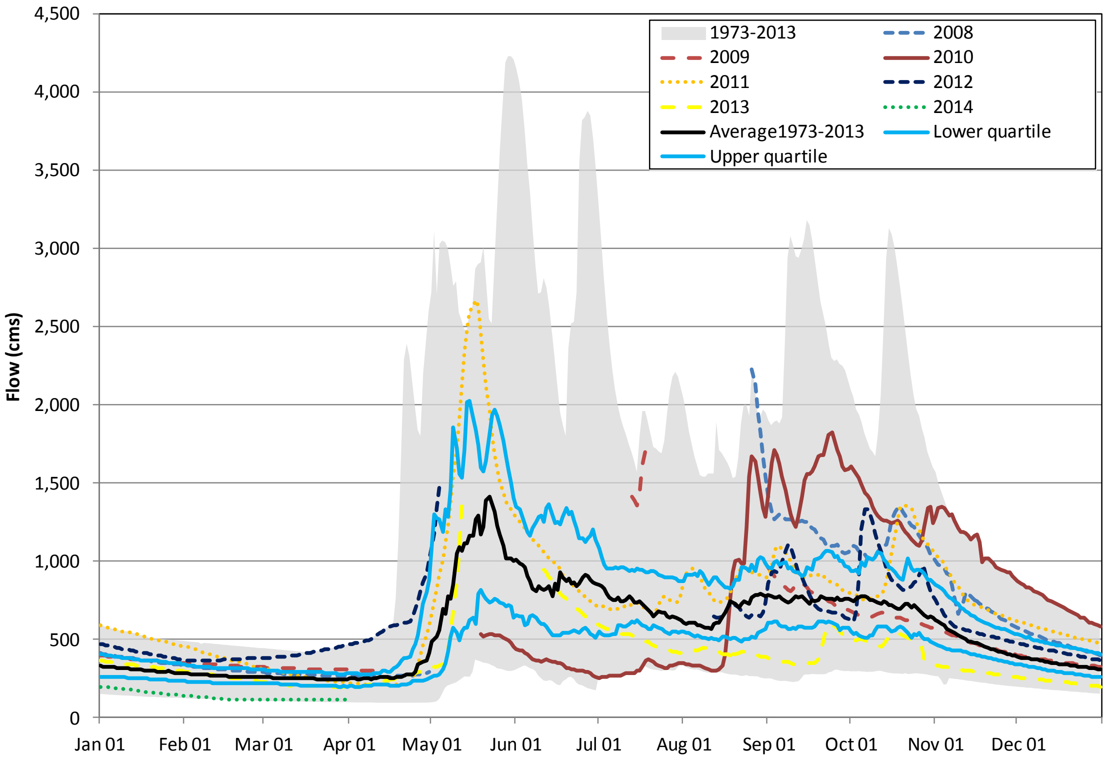


Figure 2-7. Hayes River (05AB001) flow: 2008-2013.

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 LNRR. Waterbodies/river reaches sampled annually for water quality included one on-system lake (Split Lake), two on-system riverine sites (the Burntwood River near the inflow to Split Lake and the lower Nelson River downstream of the Limestone GS), and two off-system sites (Assean Lake and the Hayes River; Table 3-1; Figure 3-1). Two additional on-system waterbodies (Stephens Lake and the Limestone GS forebay) were sampled on a rotational basis (Table 3-1; Figure 3-1). With one exception, sampling was completed at all locations and sampling periods as intended; sampling was not completed at the Hayes River site in the winter of 2008/2009 due to issues associated with site access.

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 annual sites; and (2) trends were examined visually through graphical plots for sites monitored annually. As noted in Technical Document 1, six years of data may be insufficient to detect trends over time, notably long-term trends, and the assessment was therefore restricted to qualitative assessment of the available data for sites monitored annually.

Additionally, any indications of potential trends over the six year period do not necessarily imply a long-term trend is occurring, as apparent trends over this interval may simply reflect the relatively limited time period assessed in conjunction with inter-annual variability in a metric. Consideration of a longer period of record is required to evaluate for long-term trends.

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

A detailed description of the approach and methods applied for analysis and reporting is provided in Technical Document 1, Section 4.3. Figures illustrating results for all sites sampled in the LNRR 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) indicated that, based on long-term records, water quality does not change notably along the length of the lower Nelson River and generally reflects the relative contribution of the two major inflows (the Burntwood and upper Nelson rivers) which have inherent differences in water quality conditions. However, analysis of the long-term data set from Split Lake suggested potential recent increases in some water quality metrics (i.e., alkalinity, hardness, specific conductance, and some major ions) in this region. It was suggested that these recent increases were likely a reflection of the increased influence of the upper Nelson River in recent years. 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 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 Lower Nelson River

None of the on-system waterbodies were thermally stratified during the period of study (Table 3-2; Figures 3-2 to 3-4), though depth profiles were not collected at all sampling times from the riverine sites due to high velocities.

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 3-11). The exception occurred in Split Lake in summer 2009, where a surface DO concentration of 4.1 mg/L was measured (a depth profile was not obtained for this sampling site at this time). This value is below the instantaneous minimum for the protection of cool-water aquatic life (5.0 mg/L) and near the objective for the protection of cold-water aquatic life (4.0 mg/L; MWS 2011). As described in CAMP (2014), this value is suspected to reflect a sampling error.

DO conditions were similar across the lower Nelson River sites located along the main flow path of the river and there is no indication of spatial trends over the first six years of CAMP (Figure 3-11). In the north arm of Stephens Lake, DO concentrations were lower near the bottom of the water column relative to near the surface at this site, and compared to sites located along the main flow of the lower Nelson River (Figure 3-8).

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

The off-system Assean Lake was thermally stratified during one winter (2011/2012) and one spring (2012; Figure 3-12). Both Assean Lake and the Hayes River were well-oxygenated during all sampling periods and all DO concentrations exceeded the Manitoba PAL objectives for cool-water and cold-water aquatic life during all sampling periods (Figures 3-13 and 3-14).

3.2.1.3 Temporal Comparisons and Trends

There were no statistically significant differences in dissolved oxygen concentrations (open-water season) between years at the annually monitored sites (i.e., Split Lake, the Burntwood River, or the lower Nelson River downstream of the Limestone GS). Some inter-annual differences in percent saturation were observed at the Burntwood and lower Nelson river sites (Figure 3-15), though saturation exceeded 90% on average in each open-water season indicating sites were generally well-oxygenated. There was no indication of an increasing or decreasing trend in oxygen conditions over the six year monitoring period at any of the annual monitoring sites.

3.2.2 Water Clarity

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

3.2.2.1 Lower Nelson River

TSS concentrations were moderate (overall means ranged from 10-26 mg/L) in this region and TSS was above the analytical detection limit of 2 mg/L in all samples collected at sites located along the mainstem of the Burntwood/Nelson rivers over the six years of monitoring. However, there were notable spatial differences in TSS and turbidity in this region. The Burntwood River contained higher concentrations of TSS (Figure 3-16) and turbidity levels (Figure 3-17) than lake and riverine sites along the mainstem of the Nelson River. In addition, Stephens Lake – north, which is more isolated from the main flow of the Nelson River, was clearer and was characterized by lower turbidity and TSS concentrations, and higher Secchi disk depths (Figure 3-18), than sites on the main flow of the river.

Available data suggest that TSS and turbidity decrease slightly, on average, from Split Lake to the Limestone Forebay (Figure 3-19). However, there was notable variability in TSS and turbidity within and between years, particularly in the Burntwood River.

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

TSS (Figure 3-16) and turbidity (Figure 3-17) were lower, and Secchi disk depth (Figure 3-18) was higher, in the off-system Assean Lake than lacustrine sites along the lower Nelson River. Conversely, the Hayes River had similar levels of TSS as the lower Nelson River sites, but lower levels of turbidity; this likely reflects differences in relationships between TSS and turbidity which are typically site-specific. 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 sites (the Burntwood River, Split Lake, and the lower Nelson River) indicate no significant differences; however, the lack of significant differences may reflect the relatively limited amount of data. Furthermore, qualitative examination of the data for the six-year period 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 waterbodies (i.e., Assean Lake and the Hayes River). The lack of significant relationships may reflect the relatively limited amount of data and/or that any correlations, should they exist, may relate to other hydrological metrics.

3.2.3 Nutrients, Chlorophyll *a*, and Trophic Status

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

3.2.3.1 Lower Nelson River

Lakes, forebays, and riverine sites near inflows to these waterbodies along the lower Nelson River were meso-eutrophic to eutrophic on the basis of mean open-water season TP concentrations (Figure 3-20). On-system lake/reservoir sites along the main flow of the Nelson River had a somewhat lower trophic status based on TN (oligotrophic to mesotrophic;

Figure 3-21) and chlorophyll *a* (oligotrophic to mesotrophic; Figure 3-22). Of the three metrics, chlorophyll *a* was the generally the most variable.

Neither TP nor TN was significantly correlated to chlorophyll *a* at any of the on-system sites sampled annually 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; however, lack of significant correlations may also be a reflection of the relatively limited amount of data. Most on-system waterbodies sampled annually under CAMP showed either the lack of a, or a weak, correlation between nutrients and chlorophyll *a* for the six year monitoring period; the exception was Lake Winnipeg (see Technical Document 4, Section 3.2.3.1).

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 in the Burntwood River, Split Lake, the Limestone Forebay, and Stephens Lake - south (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 (Environment Canada 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 and the upper Nelson River.

Conditions in the north arm of Stephens Lake (Stephens Lake – north) differed from the southern site in this lake (Stephens Lake – south) and other sites located along the main flow path of the lower Nelson River for several metrics, including TP. Other recent studies have shown that Stephens Lake – north, which is more isolated from the Nelson River flow, typically contains lower concentrations of TP than sites located along the mainstem of the lower Nelson River system (Keeyask Hydropower Limited Partnership [KHLP] 2012; Manitoba Hydro and the Province of Manitoba 2015). This difference was also observed under the CAMP monitoring conducted in 2009 and 2012, though concentrations were lowest on average in 2009 (Figure 3-24).

The ratio of chlorophyll *a* to total phosphorus - an indicator of the efficiency of assimilating phosphorus into algae - indicates lakes along the lower Nelson River produce a relatively low amount of chlorophyll *a* per unit phosphorus, with means ranging narrowly between 0.11 to 0.15. Though both TP and chlorophyll *a* were higher in on-system lakes relative to the off-system Assean Lake, the chlorophyll *a*:TP ratios were similar to the off-system Assean Lake (mean ratio of 0.13).

There is no clear spatial pattern evident along the main flow path of the lower Nelson River for TP, TN, or chlorophyll *a* for the six years of monitoring (Figure 3-25). Rather, nutrients and chlorophyll *a* were relatively similar across mainstem lower Nelson River sites which suggests that the major factor affecting these metrics in this region is the upstream inflow (i.e., upper Nelson and Burntwood rivers), rather than local influences. Similar observations were made in Manitoba Hydro and the Province of Manitoba's RCEA using long-term datasets (2015). In addition, chlorophyll *a* was lower in the Burntwood River than sites located along the lower Nelson River.

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

The off-system Assean Lake and Hayes River were less-phosphorus rich and contained lower concentrations of chlorophyll *a*, but similar concentrations of nitrogen, than sites located along the main flow of the lower Nelson River (Figure 3-25). However, trophic status of Assean Lake was similar to mainstem lake sites for TN (mesotrophic) and chlorophyll *a* (mesotrophic), but was lower based on phosphorus concentrations (meso-eutrophic). Trophic status of the Hayes River was also similar to the lower Nelson River site for TN (oligotrophic) and chlorophyll *a* (oligotrophic), but lower based on phosphorus concentrations (mesotrophic).

Like the on-system sites (i.e., Split Lake, the Burntwood River, and the lower Nelson River), TN and TP were not correlated to chlorophyll *a* in the off-system Assean Lake (Figure 3-26). As noted in Section 3.2.3.1, this may indicate factors other than nutrients are limiting to phytoplankton growth and/or that bioavailability of nutrients is limited, but may also reflect the relatively limited data acquired for examination of inter-relationships.

On average TP concentrations were below the Manitoba narrative nutrient guideline for TP for lakes (0.025 mg/L) and rivers (0.050 mg/L) in Assean Lake and the Hayes River, respectively (Table 3-3). However, occasional exceedances (four samples equivalent to 20% of measurements) were observed in Assean Lake.

3.2.3.3 Temporal Comparisons

There were no statistically significant inter-annual differences for major nutrients (TP and TN) at the annual on-system (the Burntwood River, Split Lake, and the lower Nelson River) or off-system (Assean Lake and the Hayes River) sites. Chlorophyll *a* was statistically lowest in 2010 at one on-system site (the lower Nelson River) and one off-system site (the Hayes River; Figure 3-27); however, these differences likely reflect, in whole or in part, that measurements were not collected for the summer period in 2010 at both sites, rather than an actual inter-annual difference.

Qualitative examination of the data for the six-year period does not suggest increasing or decreasing trends in these metrics over the six year monitoring period at on- or off-system sites. However, the lack of significant relationships may reflect the relatively limited amount of data and/or that any correlations, should they exist, may relate to other hydrological metrics.

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 in Split Lake. Specifically, several metrics displayed a similar pattern as observed upstream on the upper Nelson River at Cross Lake. This included notably higher levels of some metrics in 2013 as follows:

- total alkalinity (Figure 3-28);
- hardness (Figure 3-29);
- specific conductance (Figure 3-30);
- total dissolved solids (Figure 3-31);
- major cations (calcium, magnesium, potassium and sodium; Figures 3-32 to 3-35); and
- chloride and sulphate (Figures 3-36 and 3-37).

A similar pattern over the six year period was also observed downstream in the lower Nelson River (i.e., downstream of the Limestone GS), though the pattern was more attenuated. Although this may suggest a trend has recently begun to develop since the inception of CAMP (i.e., since 2008), additional data are required to truly determine if these observations reflect inter-annual, or short-term variability, relative to long-term trends.

The similarities between conditions observed upstream in the upper Nelson River (i.e., Cross Lake) with those observed in Split Lake reflect the large influence of the upper Nelson River on water quality in the LNRR. Flows in the lower Nelson River are dominated by the upper Nelson River which, on average, contributes approximately 75% of the flow to the lower Nelson River (Manitoba Hydro and the Province of Manitoba 2015).

Ammonia, nitrate/nitrite, and pH remained within PAL guidelines/objectives at all sites and times, both on- and off-system in the LNRR. Most metals were also consistently within Manitoba water quality PAL objectives and guidelines in the LNRR. Aluminum was above the PAL guideline (0.1 mg/L) in all samples, and iron was above the PAL guideline (0.3 mg/L) in 25-100% of samples from on-system sites in the LNRR (Table 3-4; Figure 3-38). Exceedances of both of these metals were also observed in the off-system Assean Lake (aluminum 85%; and iron: 35%) and the Hayes River (aluminum: 57%; and iron: 30%). In addition, copper marginally exceeded the PAL objective (site-specific based on hardness) and silver marginally exceeded the PAL guideline in single samples from the Burntwood River. Selenium was at the PAL guideline (0.001 mg/L) in a single sample from the lower Nelson River downstream of the Limestone GS. Exceedances of both of copper and silver were also observed in one or more of the off-system sites. 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; KHLP 2012; Manitoba Hydro and the Province of Manitoba 2015).

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

3.4 RELATIONSHIPS WITH HYDROLOGICAL METRICS

A number of water quality parameters fluctuate in Split Lake and the lower Nelson River as a function of the difference between conditions in, coupled with variations in the relative contribution of flows from, the upper Nelson and Burntwood rivers (Manitoba Hydro and the Province of Manitoba 2015). There are several fundamental differences in water quality between the Burntwood and upper Nelson rivers, which in turn, affect conditions in the lower Nelson River. Generally, when the relative contribution of the Burntwood River is higher, calcium, sodium, chloride, sulphate, alkalinity, hardness, and specific conductance are lower in Split Lake. In more recent years, these metrics were shown to have increased within the long-term record in the LNRR due to the greater contribution of flow from the upper Nelson River system (Manitoba Hydro and the Province of Manitoba 2015).

Although long-term patterns in some water quality metrics are known to occur in the LNRR in relation to variability in the major inflows, there were no significant correlations between hydrological metrics (i.e., Split Lake water level, upper Nelson River discharge, upper Nelson River + Burntwood River discharge, or the percent contribution of inflow from the upper Nelson River) and water quality metrics in Split Lake within the five year monitoring period (i.e., 2009-2013).

There were also no significant relationships observed for key water quality metrics monitored at the lower Nelson River site relative to several hydrological metrics (i.e., Kettle GS discharge, upper Nelson River discharge, percent of upper Nelson River discharge, or Stephens Lake water level). Significant, yet relatively weak, positive correlations were observed for dissolved organic carbon and hydrological metrics (Kettle GS discharge, upper Nelson River discharge, and Stephens Lake water level; Figure 3-39) and between manganese and discharge (Kettle GS and upper Nelson River; Figure 3-40). However, manganese was also significantly correlated to Julian date indicating that seasonality is also a potential factor affecting variability for this metric.

Few relationships between water quality and hydrological metrics were observed for the CAMP dataset, which may reflect the relatively limited quantity of data and/or that the range in hydrological conditions was relatively limited over the six year monitoring period. As such, these results should be considered as preliminary and exploratory in nature. Relationships between water quality and hydrology have been established using longer-term data sets for this region and further insight into these relationships may become apparent as additional data are acquired under CAMP.

3.5 SUMMARY

Overall, analysis of the six years of CAMP monitoring data collected in the LNRR 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.

The Burntwood River had higher levels, and the more isolated north arm of Stephens Lake had lower levels, of TSS and turbidity, than sites located along the main flow path of the Nelson River.

The lower Nelson River was, moderately to highly nutrient-rich and lakes were, on average, mesotrophic (based on nitrogen) to eutrophic (based on phosphorus). Chlorophyll *a* was also moderately high on average and indicative of mesotrophic conditions. Mean total phosphorus 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 lower Nelson River. This occurrence was also observed in other CAMP regions and is commonly observed in other more southern lakes and streams in Manitoba, including Lake Winnipeg. However, phosphorus concentrations were higher along the Nelson River (upper and lower) than most other river systems monitored under CAMP, which reflects the conditions upstream in Lake Winnipeg.

Water quality conditions along the lower Nelson River were relatively similar and available information indicates that conditions are largely defined by those of the major inflow (i.e., upper Nelson River), rather than local influences. The upper Nelson River contributes approximately

75% of the flow to the lower Nelson River on average and, therefore, is the dominating influence on water quality in this region.

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). Available information suggests that these recent increases, notably those observed in 2013, may reflect changes upstream (i.e., Lake Winnipeg drainage basin and the upper Nelson River) for at least some metrics. 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.

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

Waterbody/Area	**Site Abbreviation**	**Site ID**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
							2008/09	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**
Burntwood River - downstream of First Rapids	BURNT	TGS 015	**X**			**X**		**X**	**X**	**X**	**X**	**X**
Split Lake	SPLIT	UFS 011	**X**		**X**			**X**	**X**	**X**	**X**	**X**
Stephens Lake - South	STL-S	OFS 016	**X**			**X**		**X**			**X**	
Stephens Lake - North	STL-N	UFS 015	**X**			**X**		**X**			**X**	
Limestone Forebay	LMFB	UHS 004	**X**			**X**			**X**			**X**
Lower Nelson River-downstream of Limestone GS	LNR	UHS 002	**X**		**X**		**X**	**X**	**X**	**X**	**X**	**X**
Hayes River	HAYES	ABS 002		**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**
Assean Lake	ASSN	UFS 014		**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**

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

Metric		**Waterbody**							
		BURNT	**SPLIT**	**STL-S**	**STL-N**	**LMFB**	**LNR**	**HAYES**	**ASSN**
Years Sampled		2009/10-2013/14	2009/10-2013/14	2009/10, 2012/13	2009/10, 2012/13	2010/11, 2013/14	2008/09-2013/14	2008/09-2013/14	2009/10-2013/14
TP	(mg/L)	0.0354	0.0393	0.0428	0.0254	0.0378	0.0393	0.0163	0.0200
	Trophic Status	Eutrophic	Eutrophic	Eutrophic	Meso-eutrophic	Eutrophic	Eutrophic	Mesotrophic	Mesotrophic / Meso-eutrophic
TN	(mg/L)	0.40	0.45	0.47	0.42	0.41	0.51	0.44	0.43
	Trophic Status	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic
TKN	(mg/L)	0.38	0.41	0.43	0.39	0.37	0.46	0.41	0.41
Chlorophyll *a*	(µg/L)	2.08	4.30	3.70	2.22	2.90	3.57	2.07	2.13
	Trophic Status	Oligotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic
TN:TP	-	27	27	25	45	24	30	70	57
DOC	(mg/L)	8.4	8.4	8.2	8.7	8.5	8.2	9.6	10.0
Nitrate/nitrite	(mg N/L)	0.0278	0.0393	0.0422	0.0273	0.0432	0.0501	0.0244	0.0192
Ammonia	(mg N/L)	0.008	0.011	0.010	0.006	0.026	0.013	0.010	0.012
Dissolved Phosphorus	(mg/L)	0.012	0.020	0.024	0.010	0.020	0.020	0.006	0.008
DO Lower than MWQSOGs for PAL	(Y/N)	No	Yes (summer 2009)	No	No	No	No	No	No
DO - open-water season (surface)	(mg/L)	10.10	9.52	9.46	9.95	10.55	10.51	10.11	9.69
DO - open-water season (bottom)	(mg/L)	10.05	9.49	9.25	9.84	10.33	-	10.49	9.66
DO - ice-cover season (surface)	(mg/L)	16.38	15.82	15.74	16.14	15.89	-	13.02	15.86
DO - ice-cover season (bottom)	(mg/L)	16.58	15.68	15.72	14.05	15.85	-	12.80	13.96
Thermal Stratification	(Y/N)	-	No	No	No	No	-	-	Yes (winter 2011/2012, spring 2012)
Secchi Disk Depth	(m)	0.33	0.42	0.47	0.90	0.99	-	1.43	0.73
TSS	(mg/L)	26.3	12.6	11.1	4.9	10.2	14.3	12.9	8.3
Turbidity	(NTU)	30.9	19.7	21.6	9.67	15.8	21.0	7.06	8.9
True Colour	(TCU)	32.9	18.5	32.5	18.9	15.1	23.6	28.4	21.1
Specific Conductance	(µmhos/cm)	129	302	283	260	312	294	156	235
Total dissolved solids	(mg/L)	90.2	188	194	171	189	185	101	147
Hardness	(mg/L)	68.5	125	122	126	121	124	87.6	134
Hardness Category	-	Moderately Soft/Hard	Hard	Hard	Hard	Hard	Hard	Moderately Soft/Hard	Hard
pH	-	8.11	8.25	8.22	8.24	8.21	8.24	8.14	8.32
Total Alkalinity	(mg/L)	63.1	101	99.4	110	101	100	81.8	129

Table 3-2. - continued –

Metric		Waterbody							
		BURNT	**SPLIT**	**STL-S**	**STL-N**	**LMFB**	**LNR**	**HAYES**	**ASSN**
Metals > MWQSOGs for PAL	-	Al, Cu, Fe, Ag	Al, Fe	Al, Fe	Al, Fe	Al, Fe	Al, Fe, Se	Al, Cu, Fe, Ag	Al, Cu, Fe
Aluminum	(mg/L)	1.14	0.740	0.638	0.419	0.785	0.719	0.149	0.282
Iron	(mg/L)	1.01	0.598	0.525	0.294	0.612	0.599	0.248	0.238
Mercury (<26 ng/L DL only)	(ng/L)	11.4	1.2	<20	<20	1.9	<20	<20	<20
Mercury (≤1 ng/L DL only)	(ng/L)	3.2	1.2	1.2	1.0	1.9	<1.0	1.9	1.4
Calcium	(mg/L)	18.1	29.7	29.2	34.0	29.0	30.2	26.5	42.0
Magnesium	(mg/L)	5.62	12.2	11.9	9.87	11.9	11.8	5.18	7.10
Potassium	(mg/L)	1.48	2.89	2.80	1.99	2.89	2.82	0.602	0.83
Sodium	(mg/L)	3.64	17.3	17.8	11.5	16.7	16.2	1.90	2.38
Chloride	(mg/L)	1.72	17.6	18.8	13.0	18.9	18.4	1.11	1.07
Sulphate	(mg/L)	3.43	26.5	24.2	13.3	28.4	25.6	1.59	2.35

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

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

Indicator	**Metric**		**Units**	**Waterbody**							
				BURNT	**SPLIT**	**STL-S**	**STL-N**	**LMFB**	**LNR**	**HAYES**	**ASSN**
Nutrients	TP	Mean	(mg/L)	0.0360	0.0410	0.0436	0.0227	0.0371	0.0384	0.0184	0.0219
		Trophic Status	-	Eutrophic	Eutrophic	Eutrophic	Meso-eutrophic	Eutrophic	Eutrophic	Mesotrophic	Meso-eutrophic
	TN	Mean	(mg/L)	0.41	0.42	0.46	0.37	0.36	0.49	0.44	0.41
		Trophic Status	-	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic
	Chlorophyll *a*	Mean	(µg/L)	2.67	5.60	4.79	2.88	3.77	4.66	2.58	2.58
		Trophic Status	-	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Mesotrophic
	TN:TP	Mean	-	27	23	25	46	22	30	58	48
		Nutrient Limitation	-	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation	P-Limitation
	Chlorophyll *a*:TP	Mean	-	0.07	0.15	0.11	0.12	0.11	0.12	0.15	0.13
	Chlorophyll *a*:TN	Mean	-	0.007	0.015	0.010	0.007	0.014	0.009	0.006	0.007
	Algal Bloom Frequency (Chlorophyll *a* >10 µg/L)	-	(%)	0	0	0	0	0	0	0	0
Dissolved Oxygen	DO Lower than MWQSOGs for PAL	-	(Y/N)	N	Y	N	N	N	N	N	N
	DO	Surface	(mg/L)	10.10	9.52	9.46	9.95	10.55	10.51	10.11	9.69
		Bottom	(mg/L)	10.05	9.49	9.25	9.84	10.33	-	10.49	9.66
	Thermal Stratification	-	(Y/N)	-	No	No	No	No	-	-	Yes (spring 2012)
Water Clarity	Secchi Disk Depth	Mean	(m)	0.33	0.42	0.47	0.90	0.99	-	1.43	0.73
	TSS	Mean	(mg/L)	30.1	14.8	10.8	5.5	10.9	15.8	16.2	10.7
	Turbidity	Mean	(NTU)	33.94	22.35	22.88	9.12	16.35	22.43	8.72	11.42

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 Lower Nelson River Region: 2008-2013. Values in red indicate exceedances occurred at a given site.

Waterbody		**MWQSOGs PAL**																**CCME PAL**	**BCMOE PAL**
		Aluminum	**Arsenic**	**Chloride**	**Sulphate**	**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	120	0.0298 - 0.0843	0.0053 - 0.01515	0.3	0.00137 - 0.00655	0.000026	0.073	0.0298 - 0.0843	0.001	0.0001	0.0008	0.015	0.0684 - 0.194	120	218-309
Burntwood River	n	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	# Exceedances	**20**	0	0	0	0	**1**	**20**	0	0	0	0	0	**1**	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	**5**	**100**	0	0	0	0	0	**5**	0	0	0	0	0
Split Lake	n	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	# Exceedances	**20**	0	0	0	0	0	**17**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**85**	0	0	0	0	0	0	0	0	0	0	0
Stephens Lake-South	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	**5**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**63**	0	0	0	0	0	0	0	0	0	0	0
Stephens Lake-North	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	# Exceedances	**8**	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**25**	0	0	0	0	0	0	0	0	0	0	0
Limestone Forebay	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	**8**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**100**	0	0	0	0	0	0	0	0	0	0	0
Lower Nelson River – downstream of Limestone GS	n	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	# Exceedances	**24**	0	0	0	0	0	**20**	0	0	0	0	**1**	0	0	0	0	0	0
	% Exceedance	**100**	0	0	0	0	0	**83**	0	0	0	0	**4**	0	0	0	0	0	0
Hayes River	n	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
	# Exceedances	**13**	0	0	0	0	**1**	**7**	0	0	0	0	0	**1**	0	0	0	0	0
	% Exceedance	**57**	0	0	0	0	**4**	**30**	0	0	0	0	0	**4**	0	0	0	0	0
Assean Lake	n	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	# Exceedances	**17**	0	0	0	0	**1**	**7**	0	0	0	0	0	0	0	0	0	0	0
	% Exceedance	**85**	0	0	0	0	**5**	**35**	0	0	0	0	0	0	0	0	0	0	0

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

Table 3-5. Linear regressions between water quality of the lower Nelson River downstream of the Limestone GS and discharge at the Kettle GS and the Kelsey GS, and water level in Stephens Lake, for the open-water season. Values in red indicate significant correlations (p<0.05).

Metric	**Units**		**Water Quality vs. Kettle GS Discharge**			**Water Quality vs. Kelsey GS Discharge**			**Water Quality vs. Stephens Lake Water Level**		
			R^2	**p-value**	**Direction**	R^2	**p-value**	**Direction**	R^2	**p-value**	**Direction**
Dissolved Organic Carbon	(mg/L)	Log	**0.235**	**0.041**	**+**	**0.256**	**0.032**	**+**	**0.347**	**0.010**	**+**
Manganese	(mg/L)		**0.440**	**0.003**	**+**	**0.397**	**0.005**	**+**	0.289	0.021	

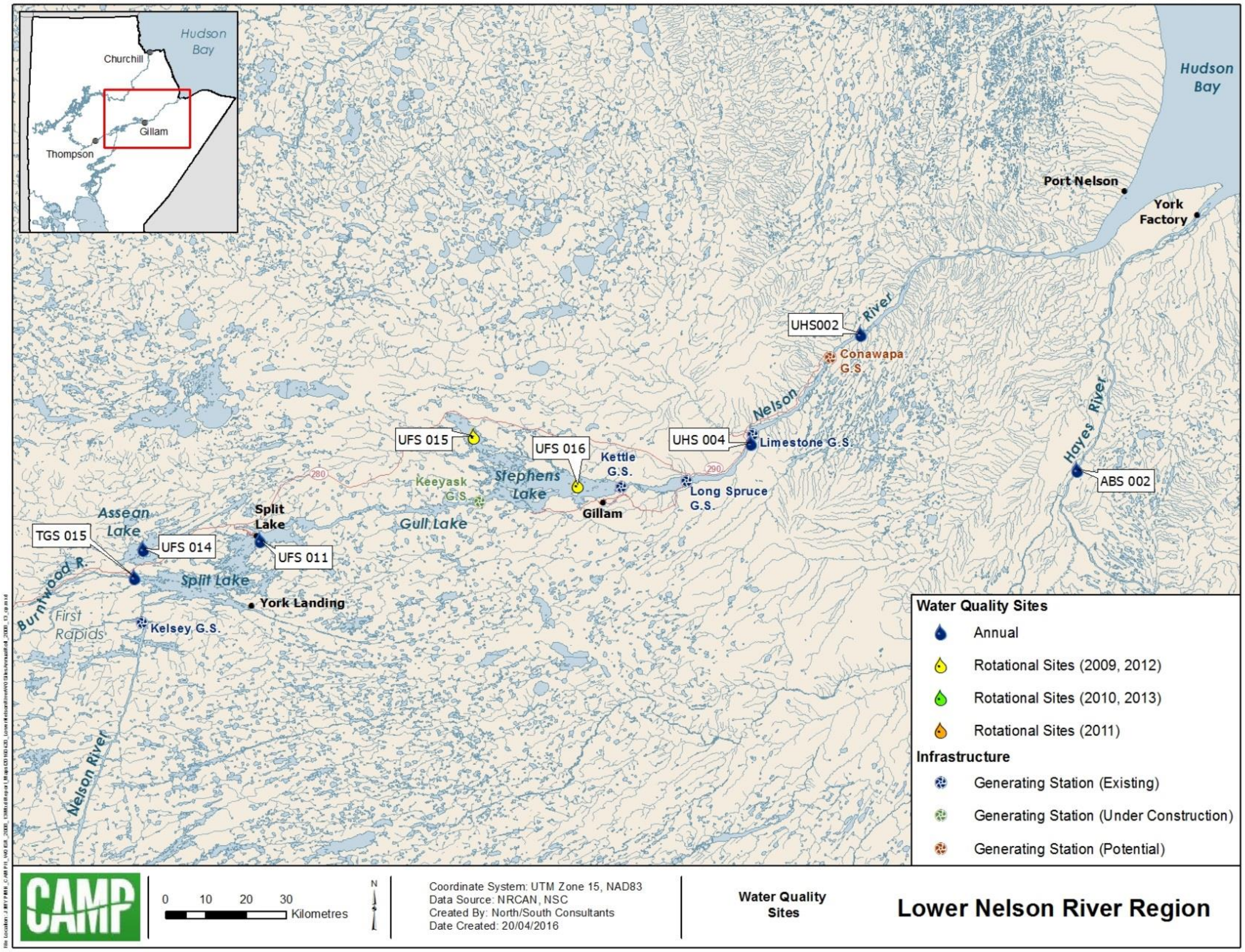


Figure 3-1. Water quality sampling sites in the Lower Nelson River Region: 2008/2009-2013/2014.

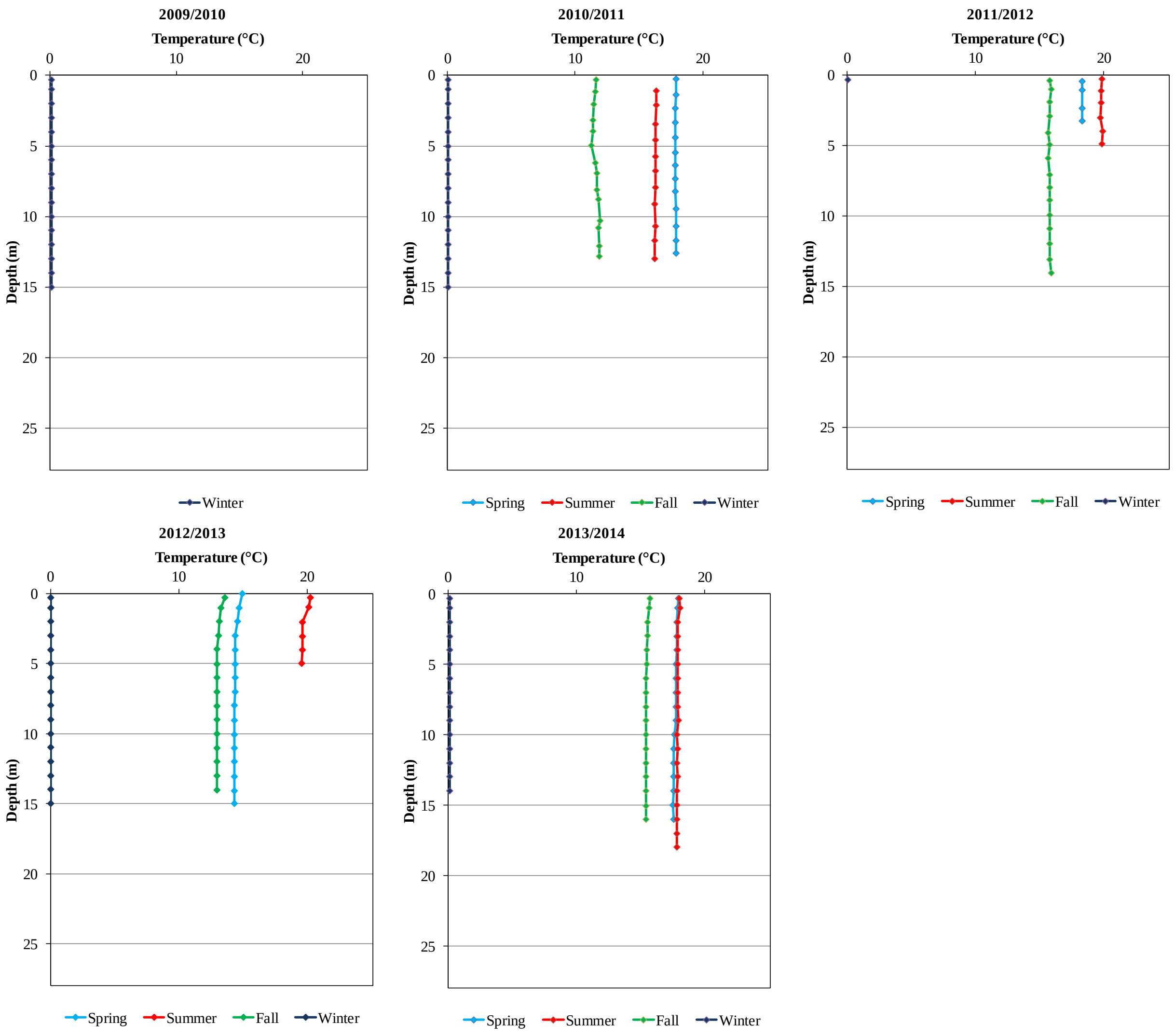


Figure 3-2. Temperature depth profiles in Split Lake: 2008/2009-2013/2014.

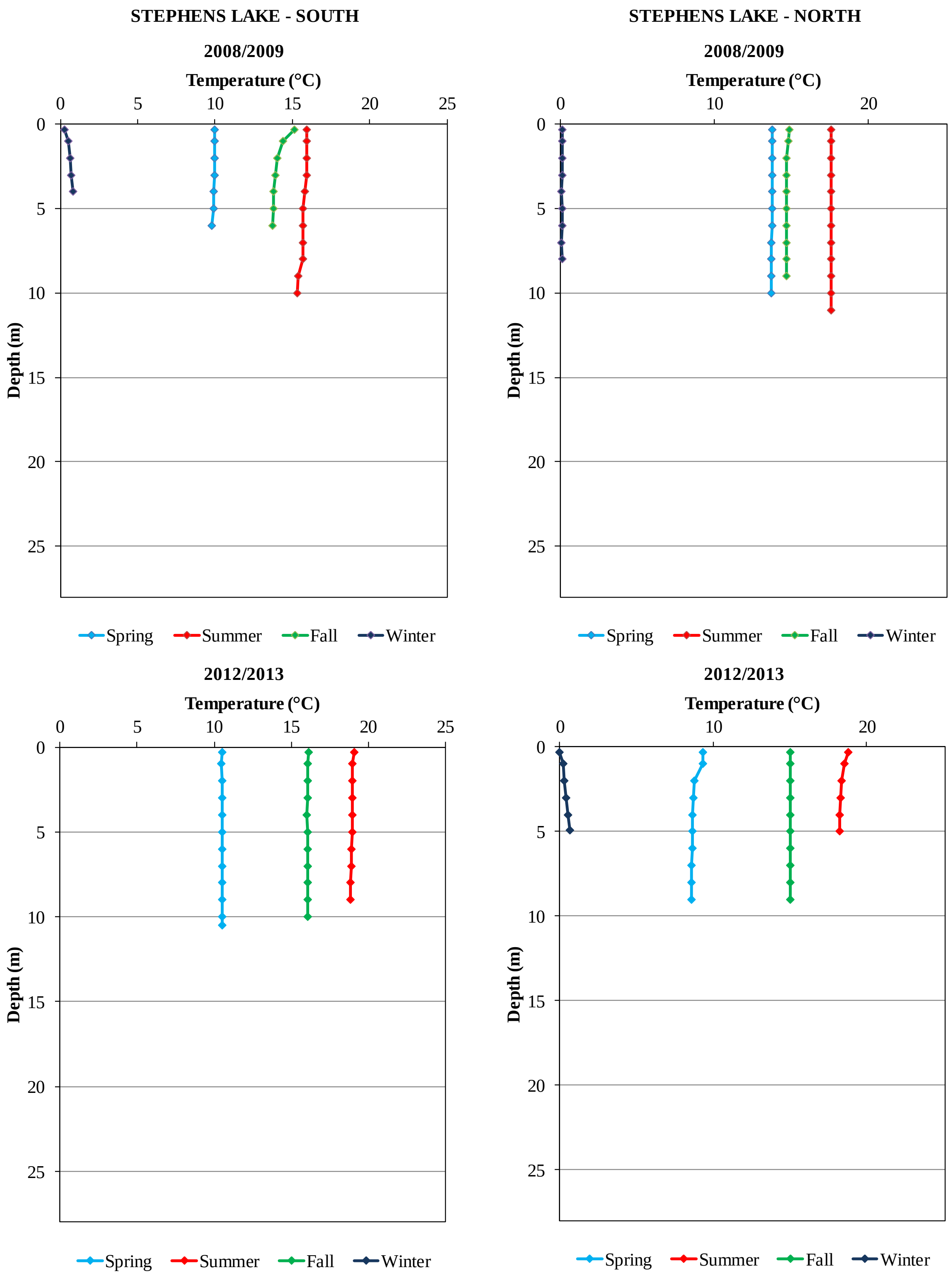


Figure 3-3. Temperature depth profiles in Stephens Lake: 2008/2009-2013/2014.

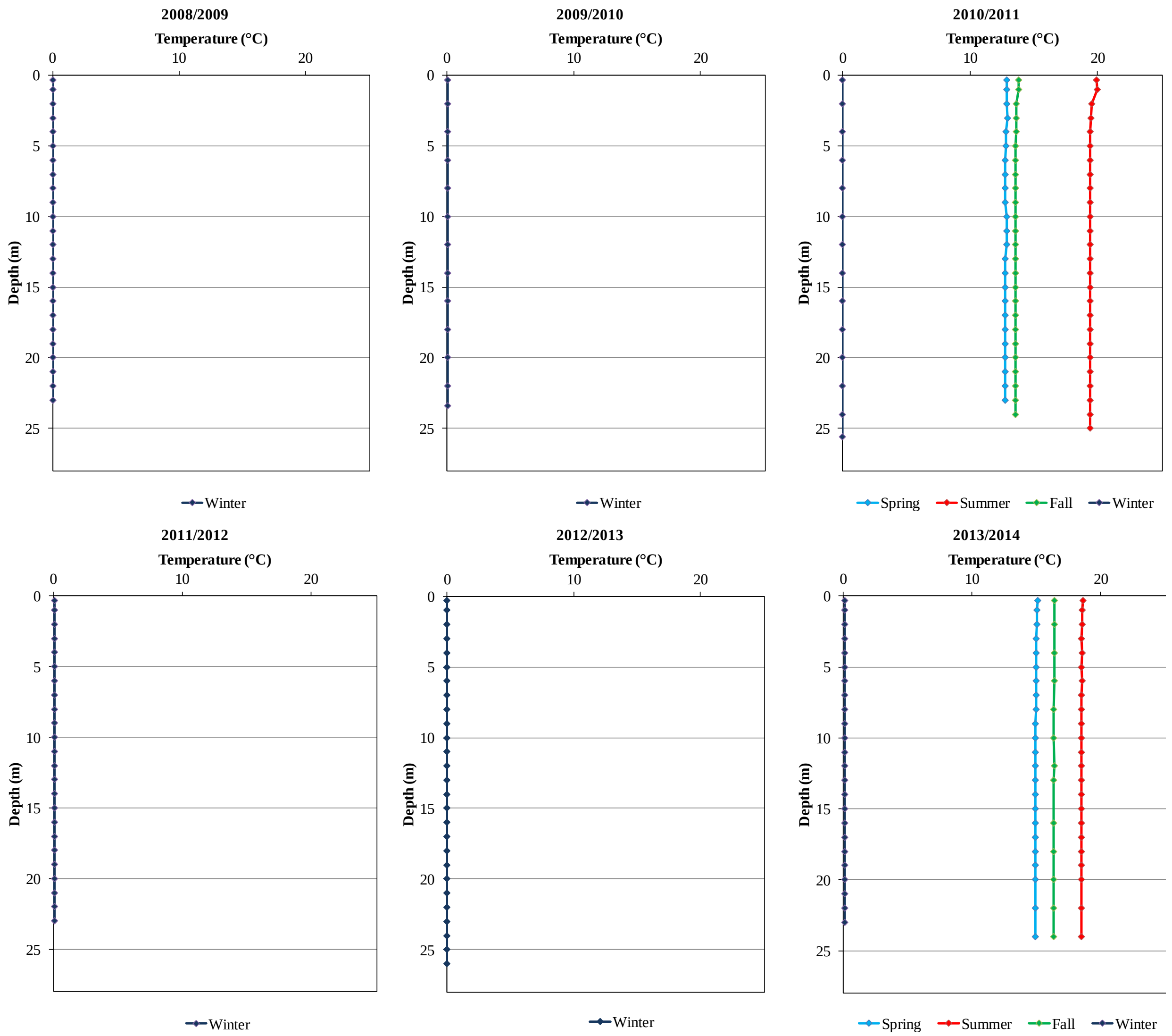
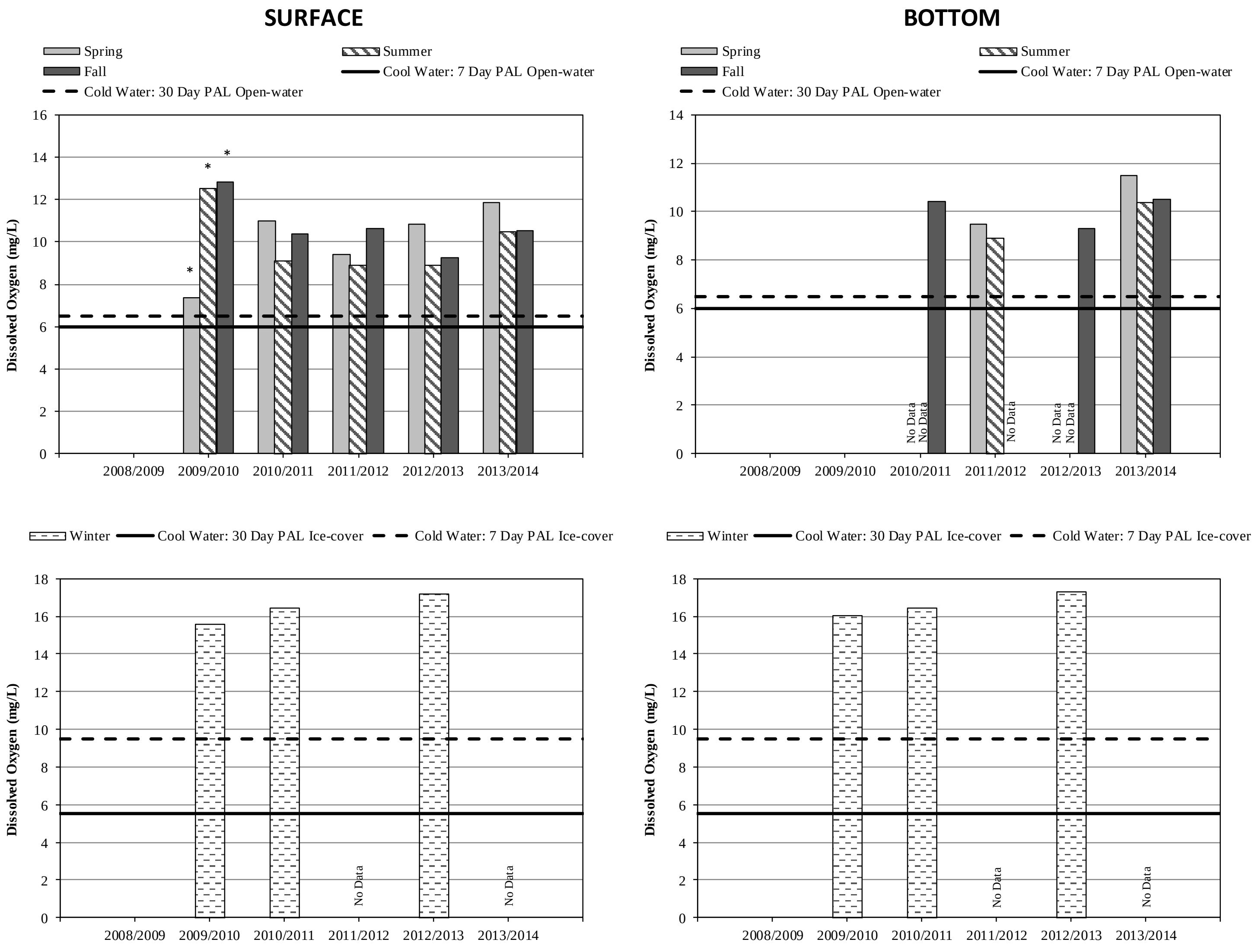
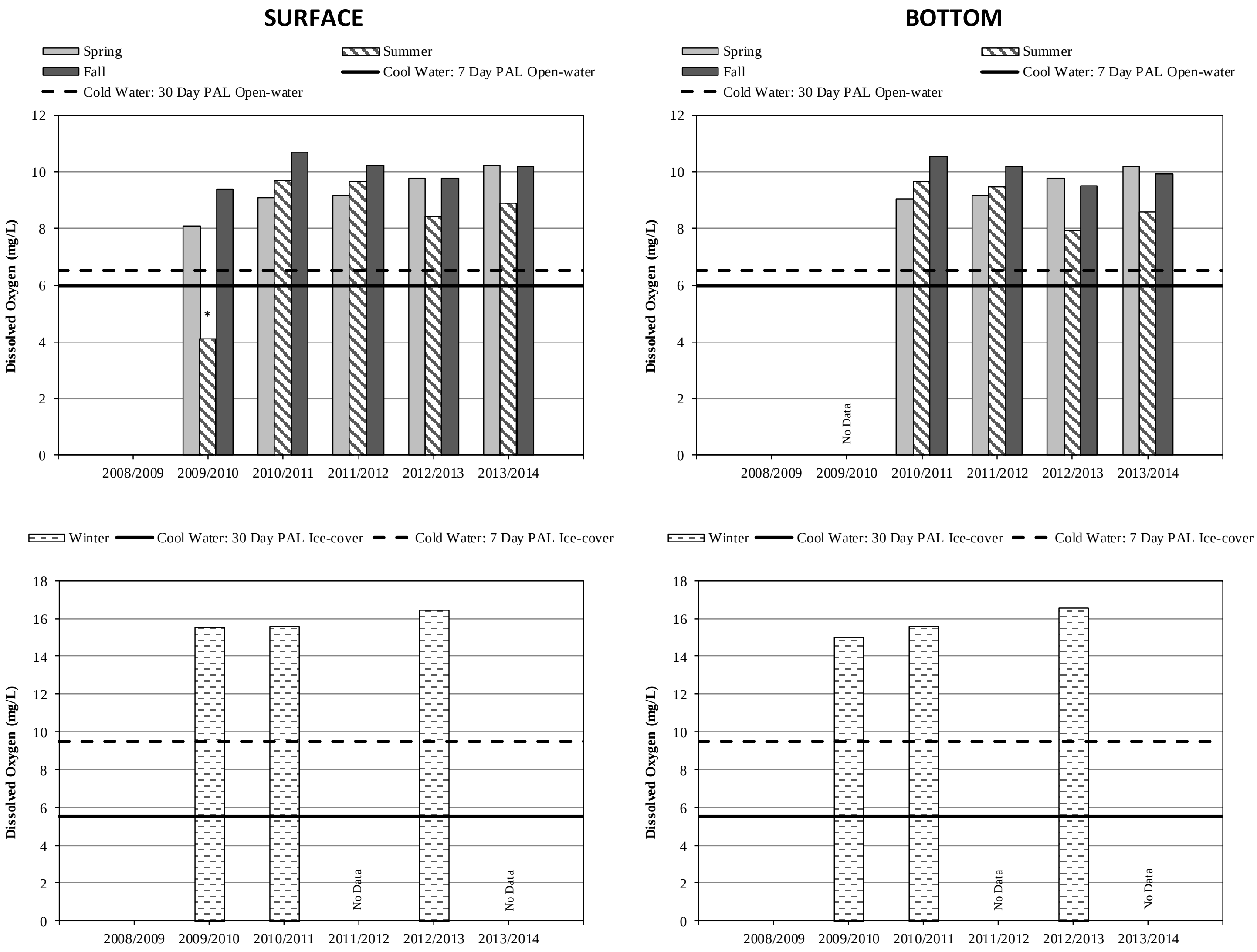


Figure 3-4. Temperature depth profiles in the Limestone Forebay: 2008/2009-2013/2014.



* Data are considered suspect.

Figure 3-5. Dissolved oxygen measured near the surface and bottom of the water column in the Burntwood River and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect.

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

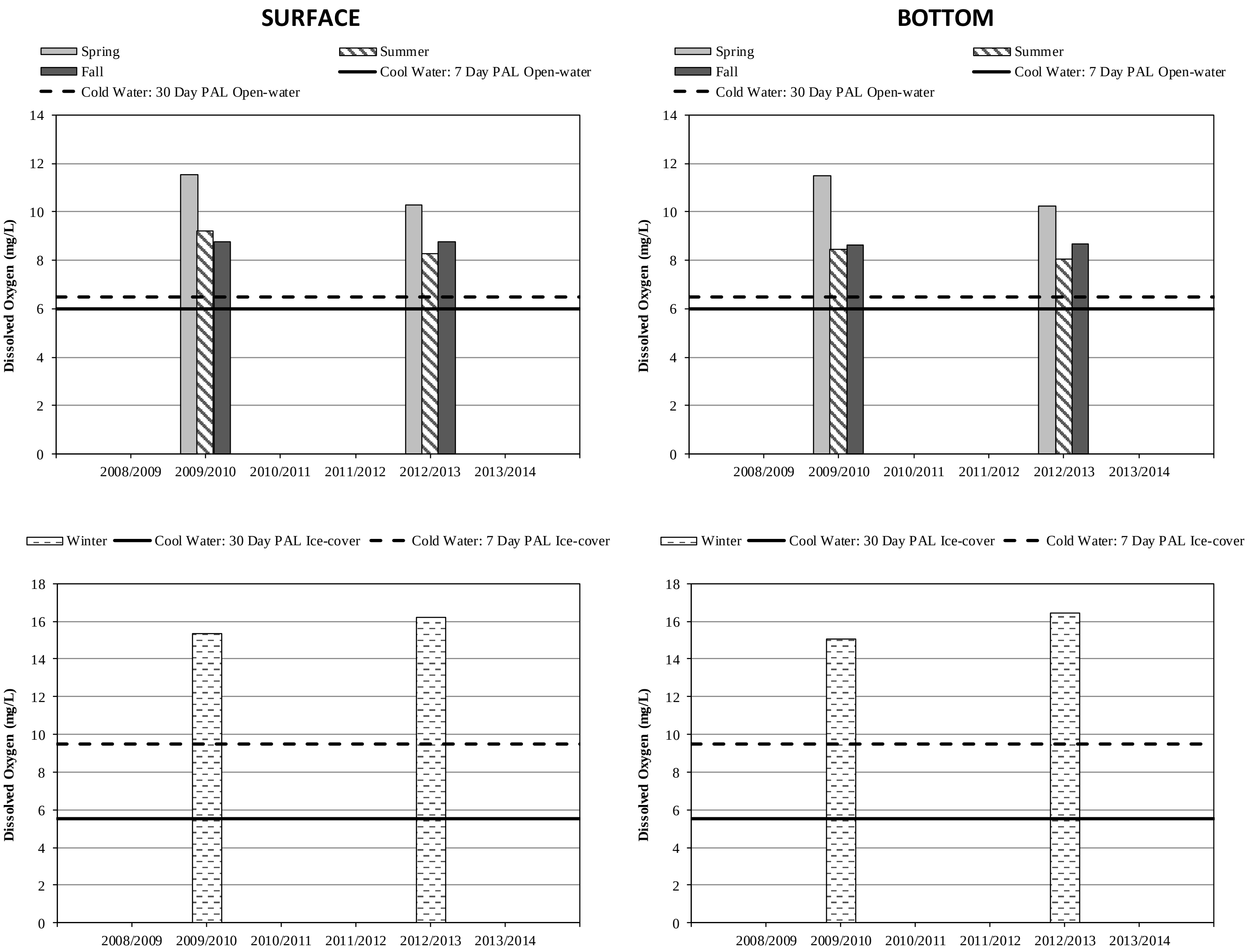


Figure 3-7. Dissolved oxygen measured near the surface and bottom of the water column in Stephens Lake - South and comparisons to MB PAL objectives: 2008/2009-2013/2014.

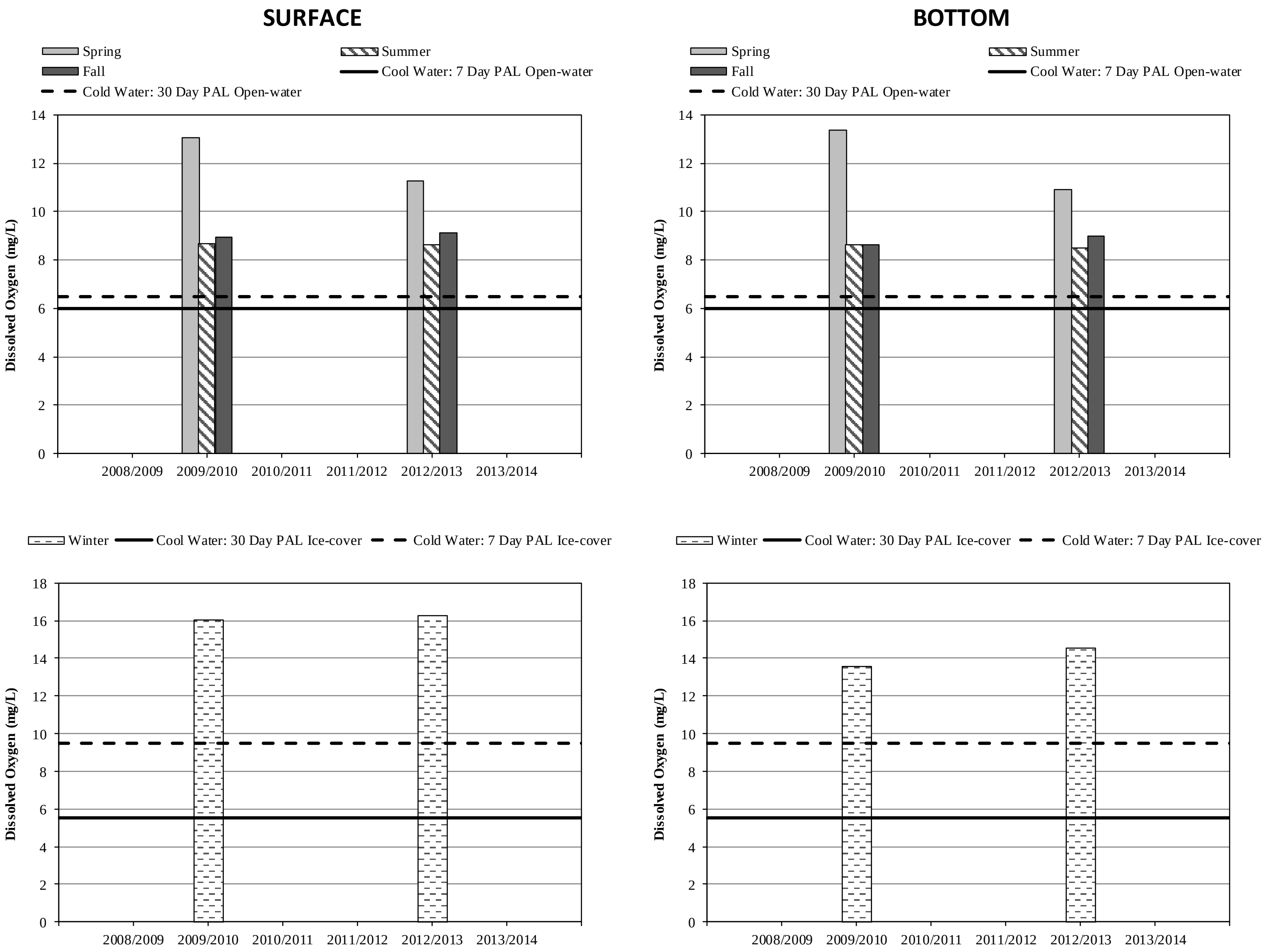


Figure 3-8. Dissolved oxygen measured near the surface and bottom of the water column in Stephens Lake - North and comparisons to MB PAL objectives: 2008/2009-2013/2014.

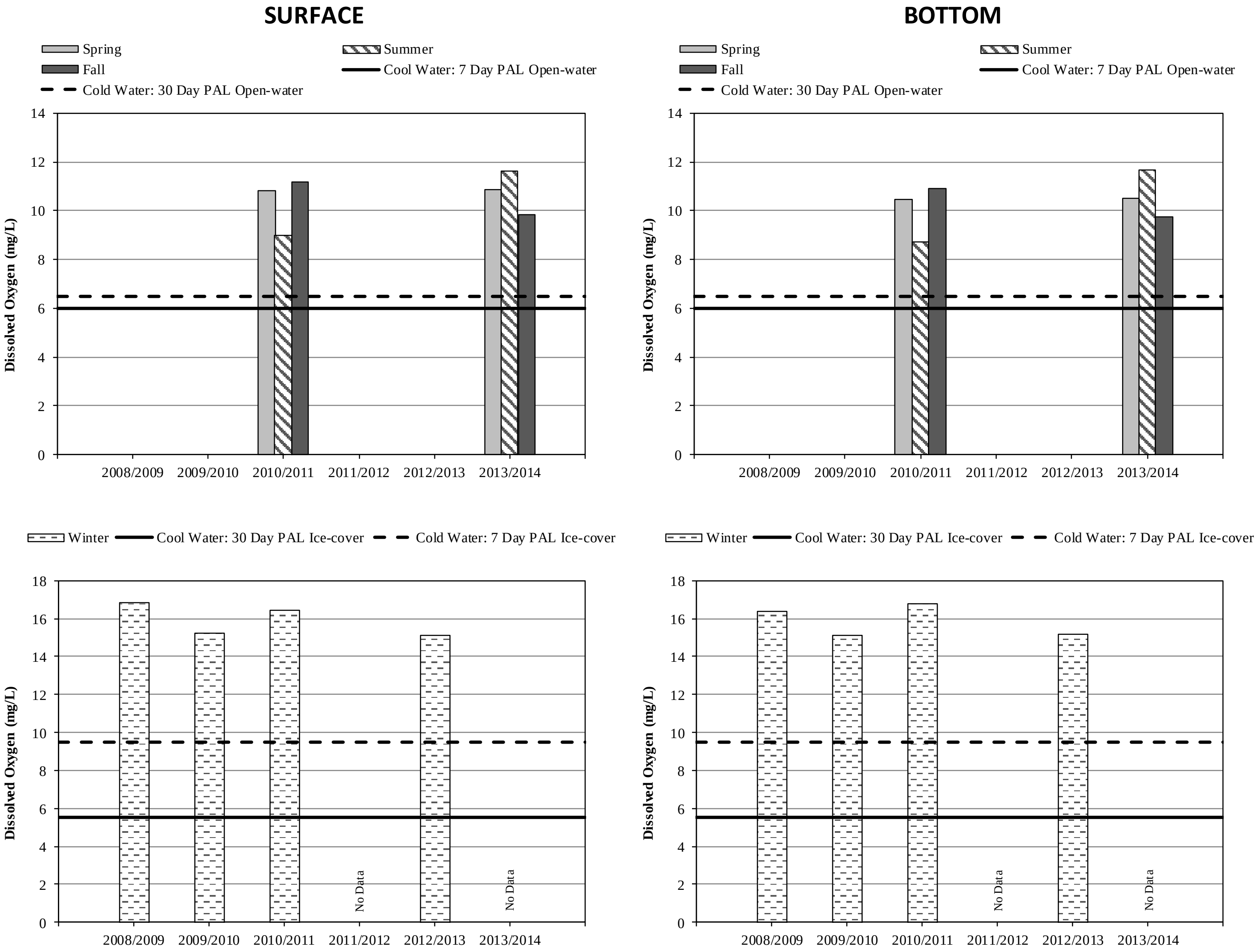
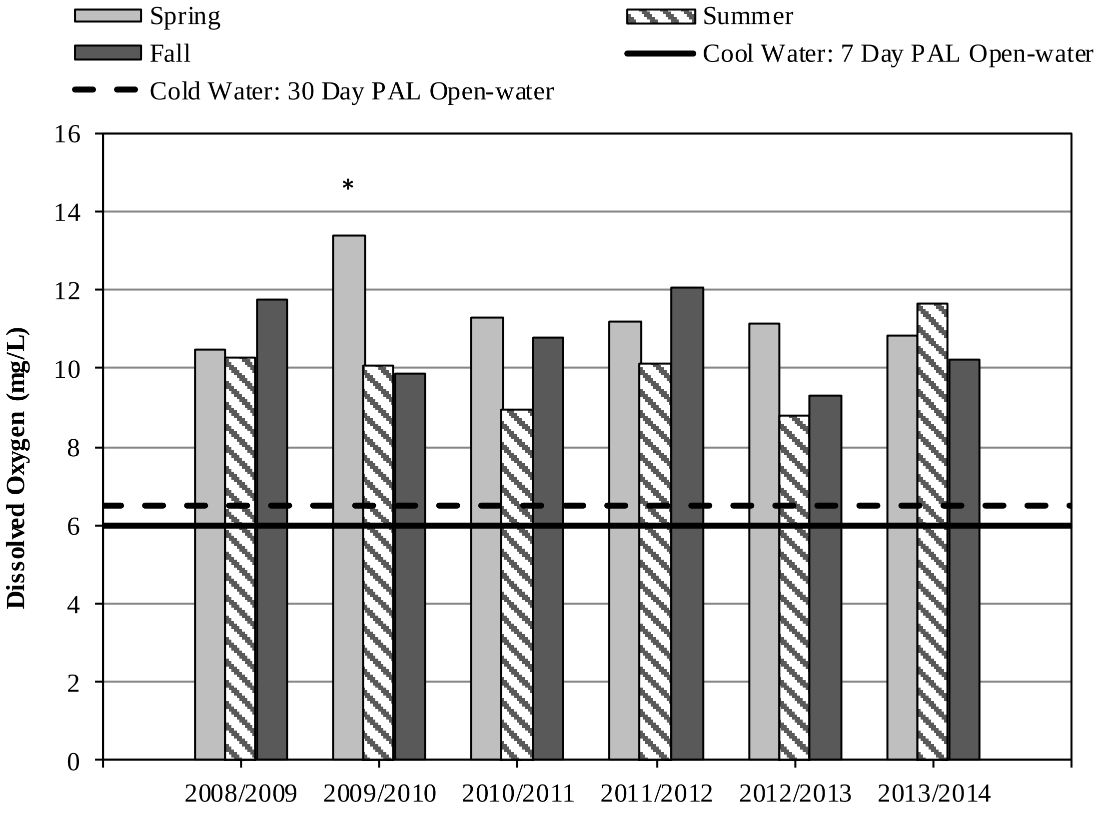


Figure 3-9. Dissolved oxygen measured near the surface and bottom of the water column in the Limestone Forebay and comparisons to MB PAL objectives: 2008/2009-2013/2014.



* Data are considered suspect

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

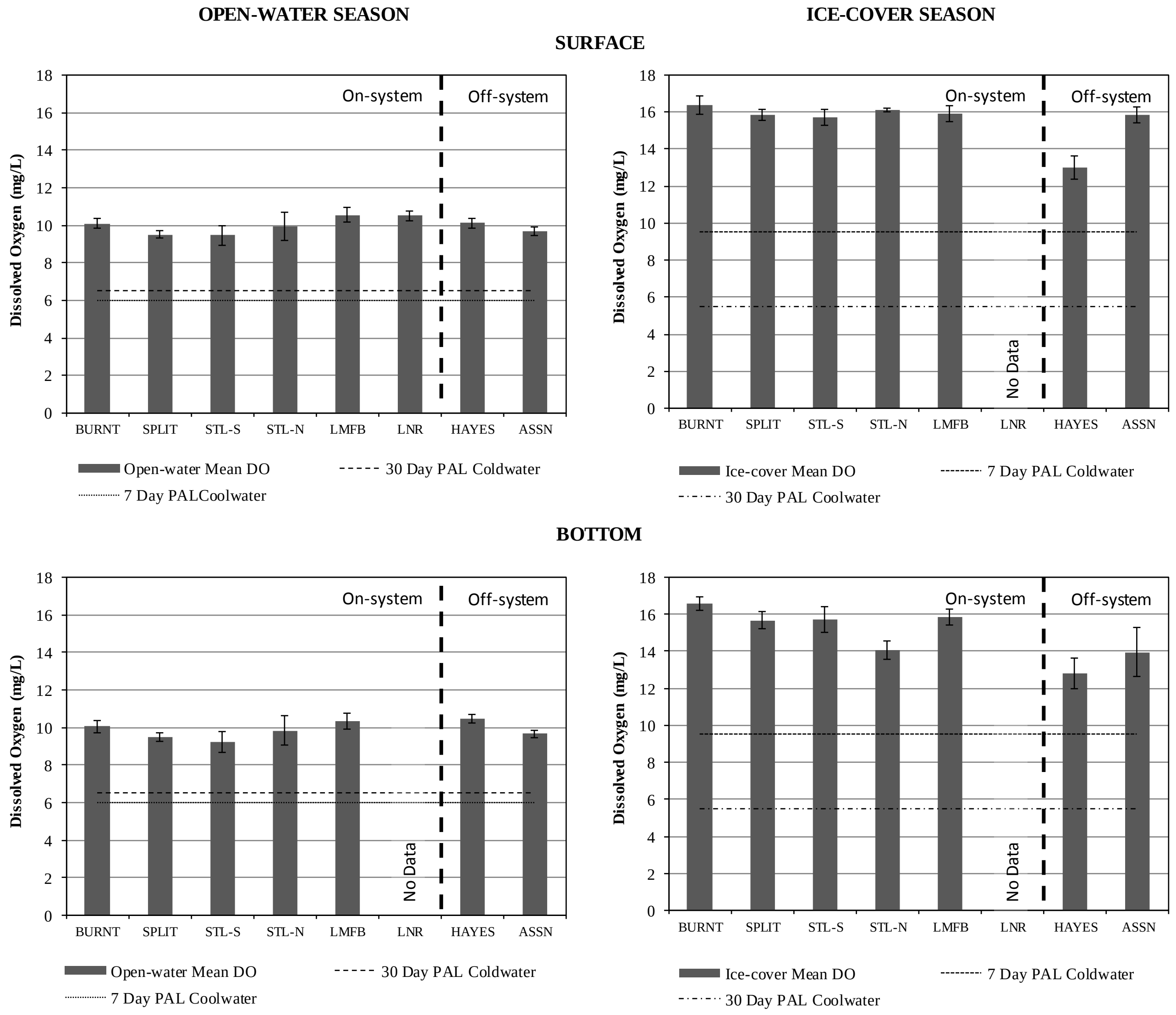


Figure 3-11. Dissolved oxygen (mean±SE) measured in the Lower Nelson River Region in the open-water and ice-cover seasons: 2008/2009-2013/2014.

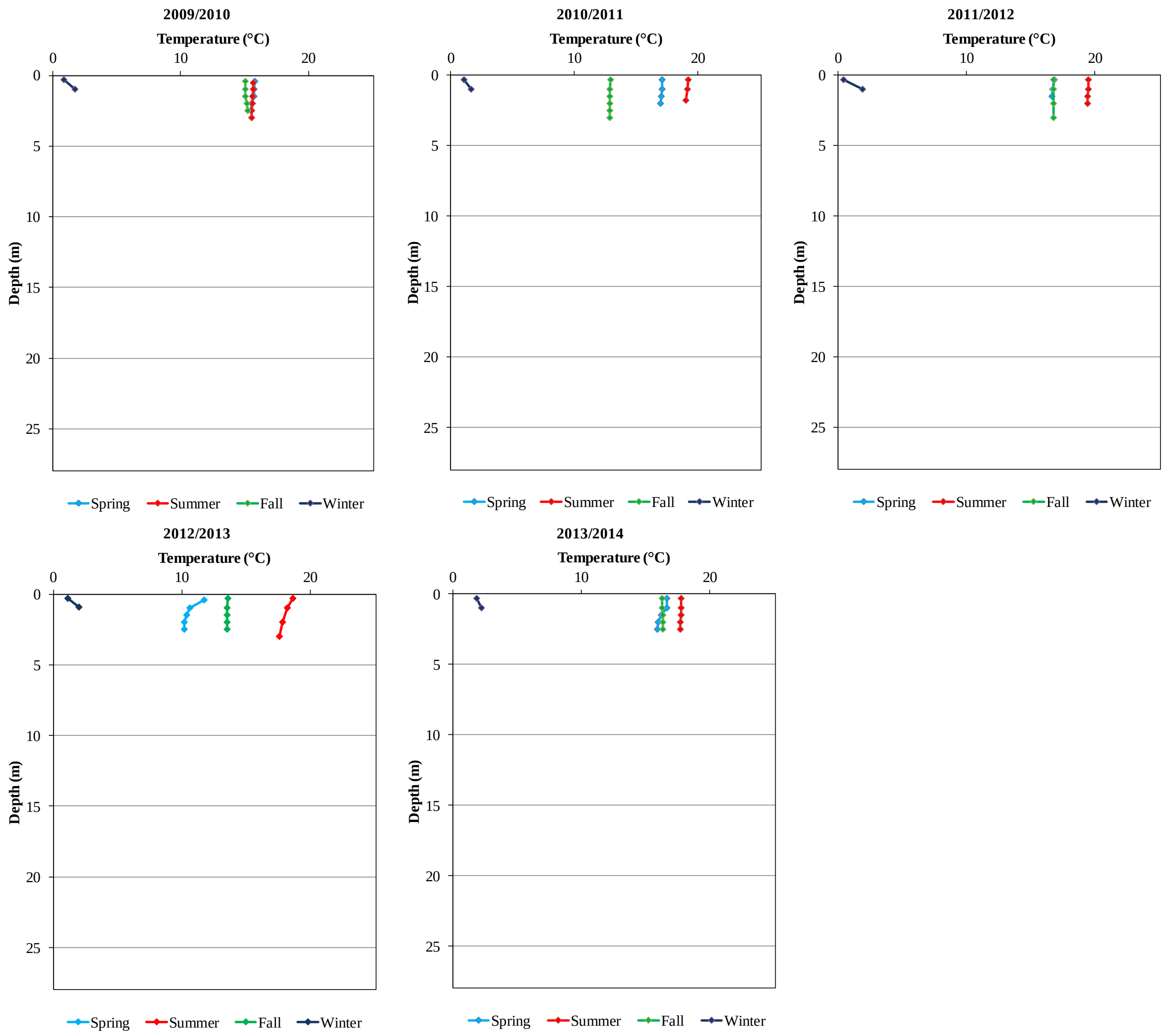
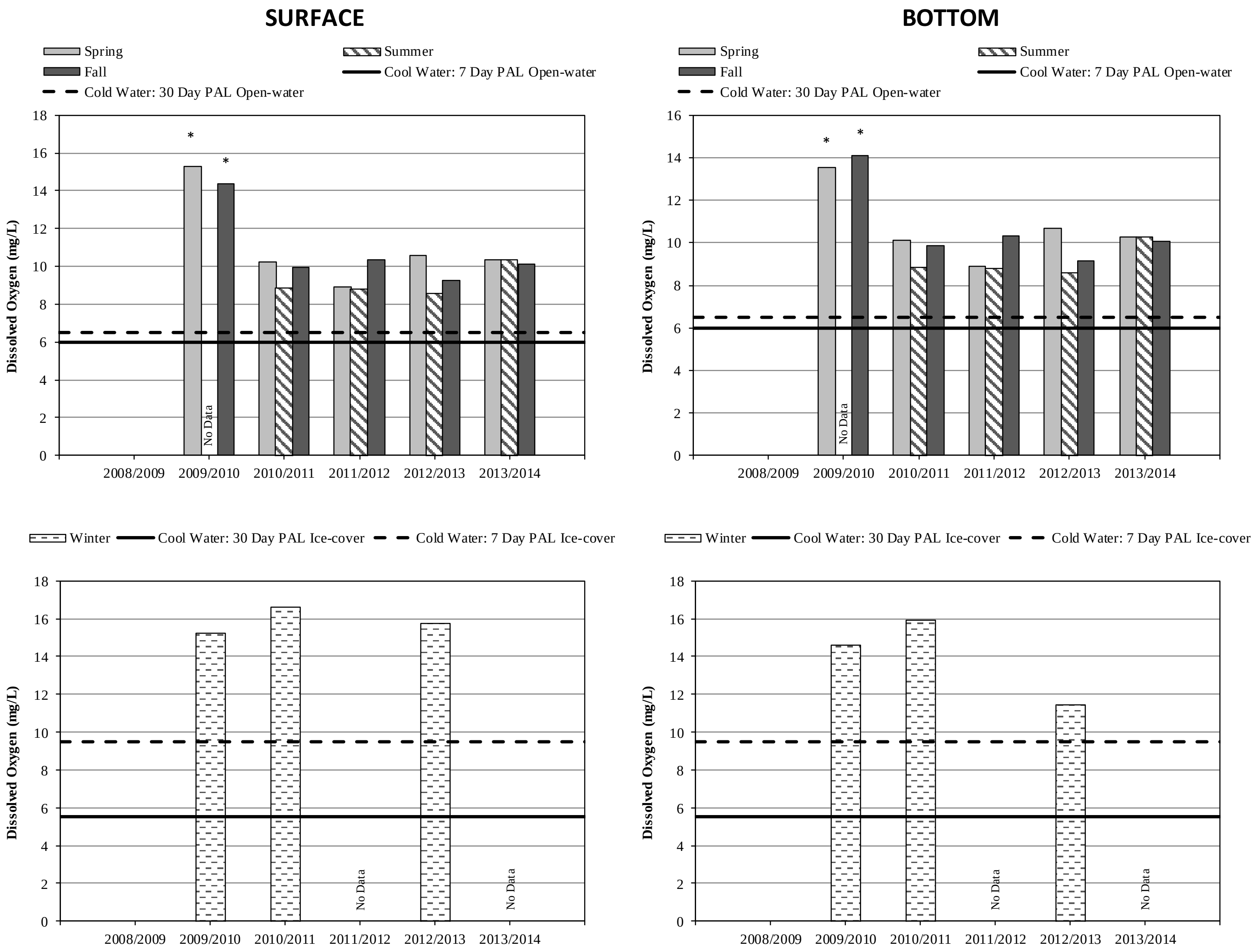
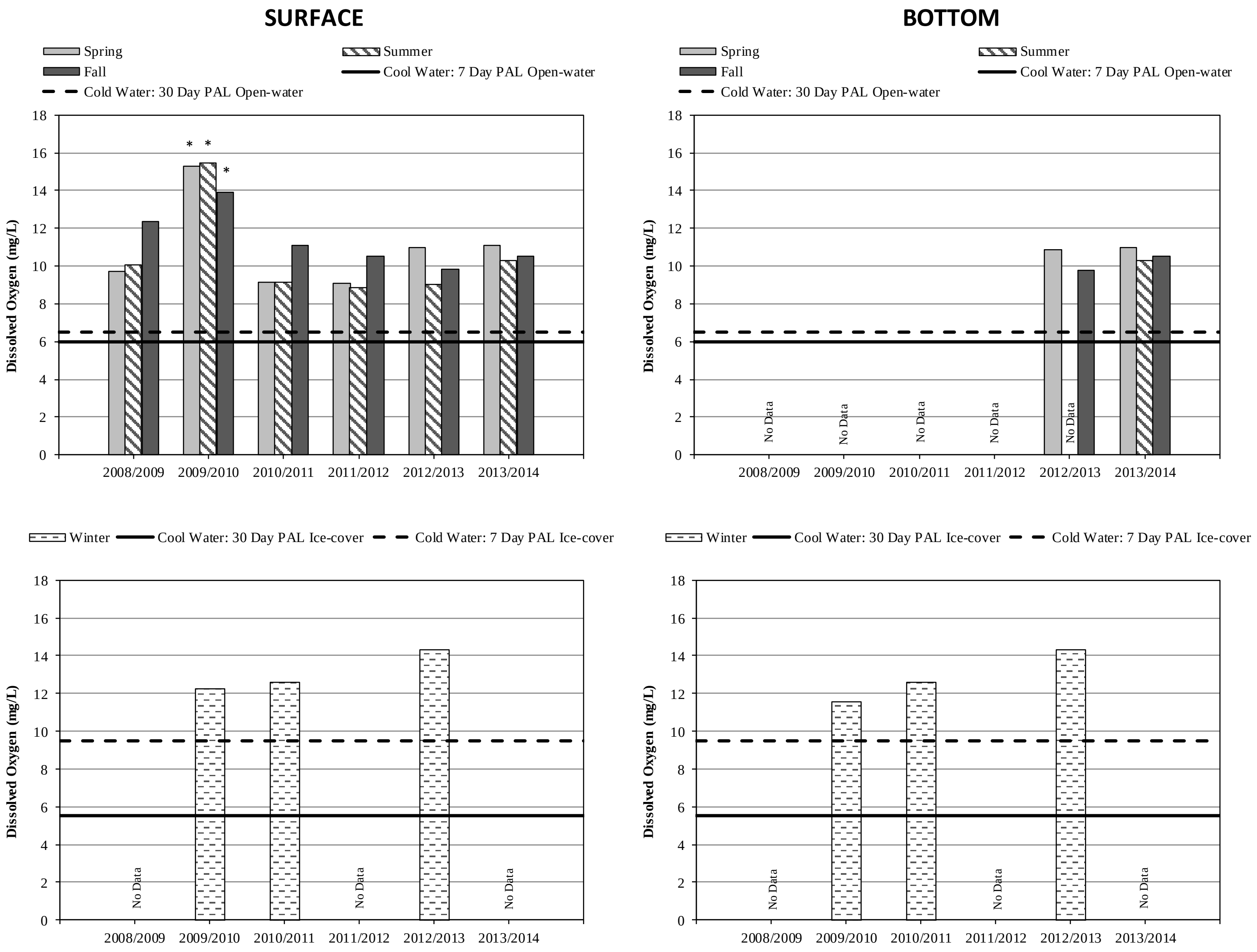


Figure 3-12. Temperature depth profiles in the off-system Assean Lake: 2008/2009-2013/2014.



* Data are considered suspect.

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



* Data are considered suspect. Concentrations likely overestimated.

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

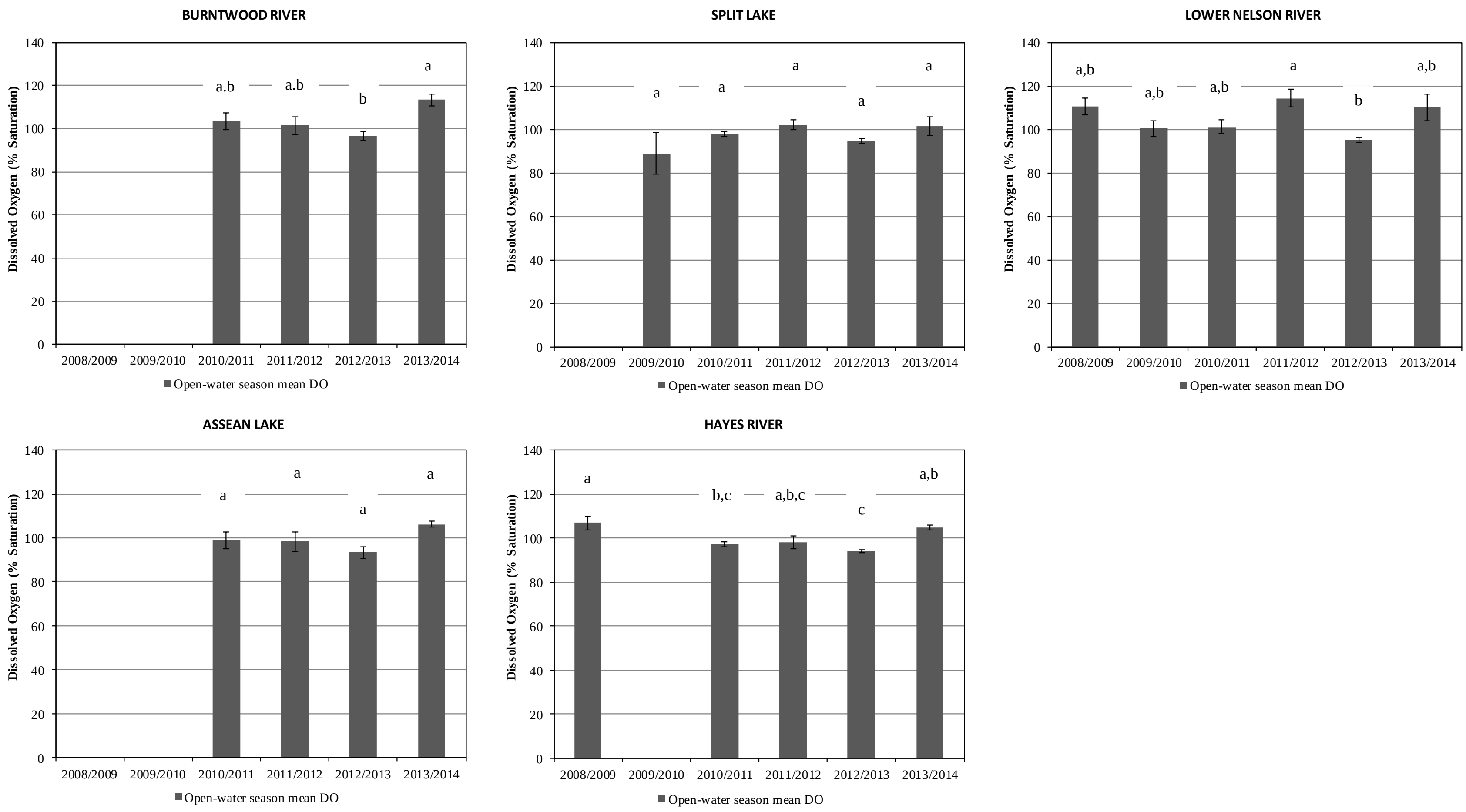


Figure 3-15. Open-water season dissolved oxygen percent saturation (mean±SE) at annual on-system and off-system sites. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

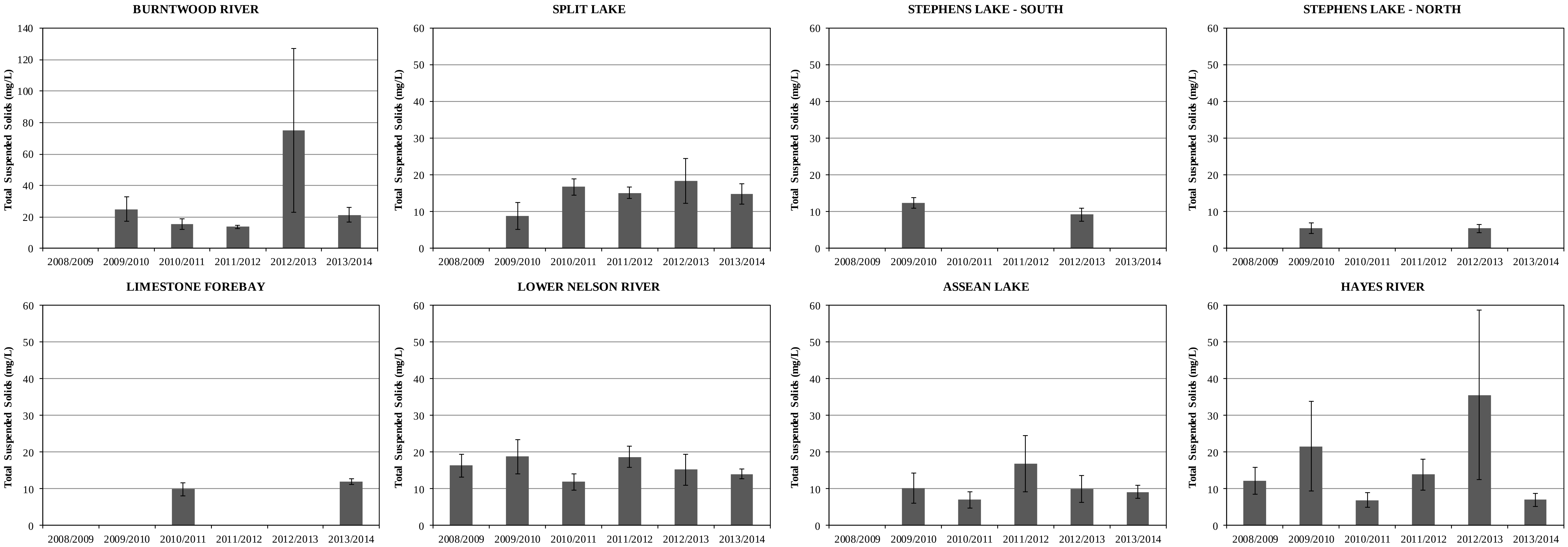
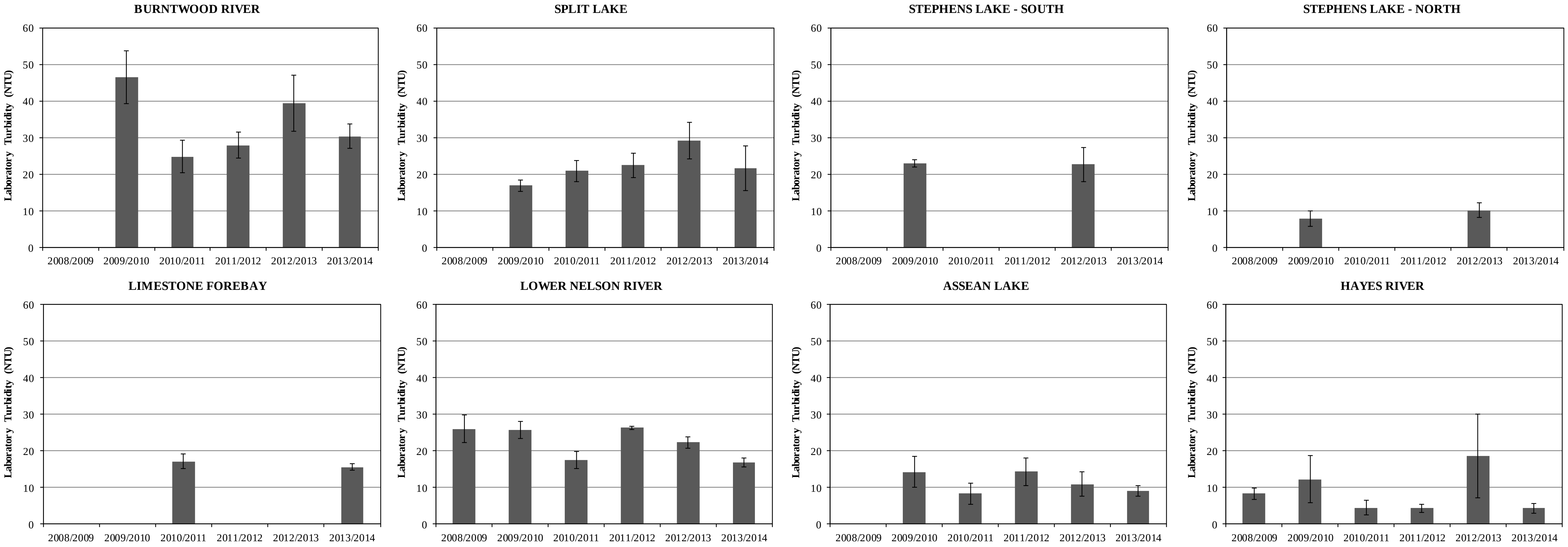


Figure 3-16. Total suspended solids (mean±SE) measured in the Lower Nelson River Region: 2008/2009-2013/2014. Note the difference in scale between the Hayes and Burntwood rivers and other sites.


BURNTWOOD RIVER

SPLIT LAKE

STEPHENS LAKE - SOUTH

STEPHENS LAKE - NORTH

LIMESTONE FOREBAY

LOWER NELSON RIVER

ASSEAN LAKE

HAYES RIVER

Figure 3-17. Laboratory turbidity (mean±SE) measured in the Lower Nelson River Region: 2008/2009-2013/2014.

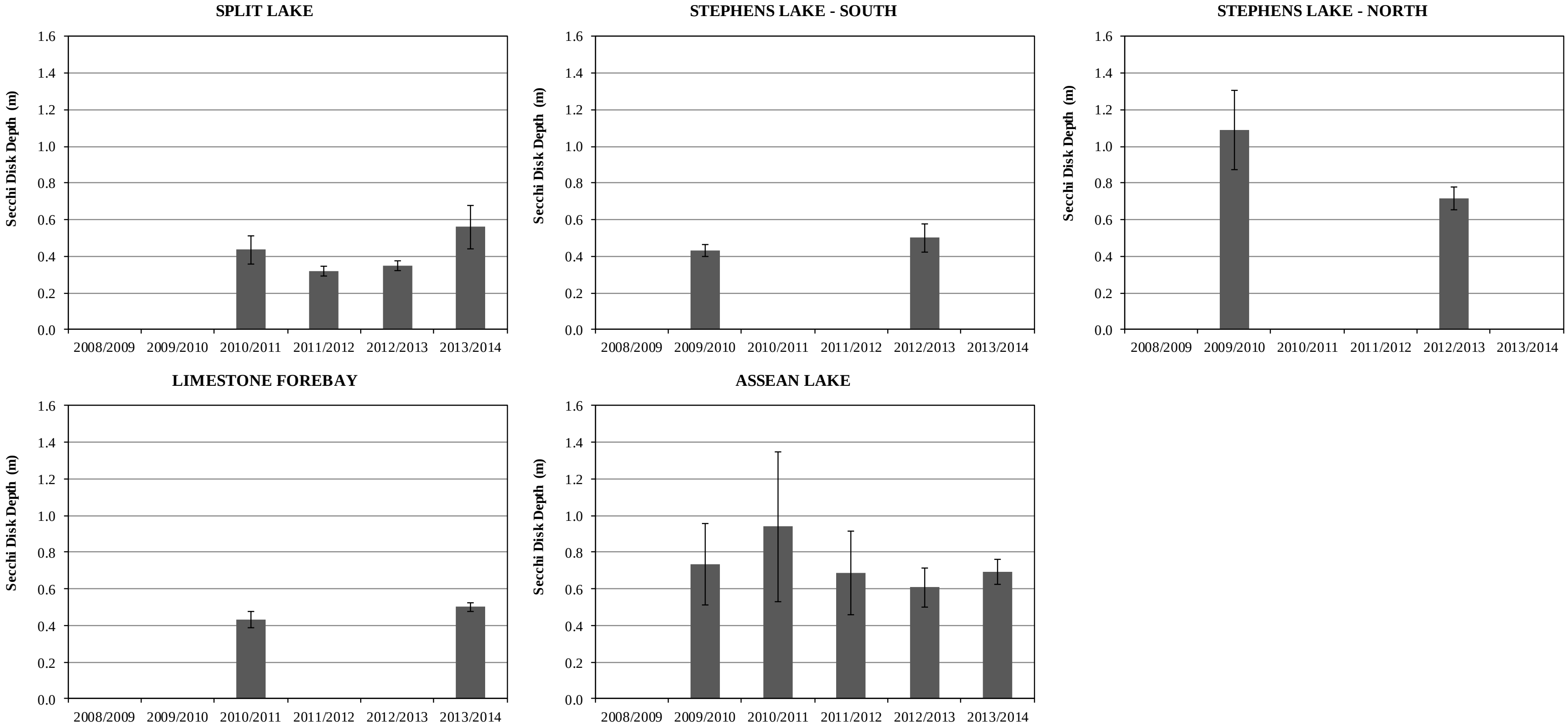


Figure 3-18. Secchi disk depths (mean±SE) measured in lacustrine areas in the Lower Nelson River Region: 2008/2009-2013/2014 (open-water season).

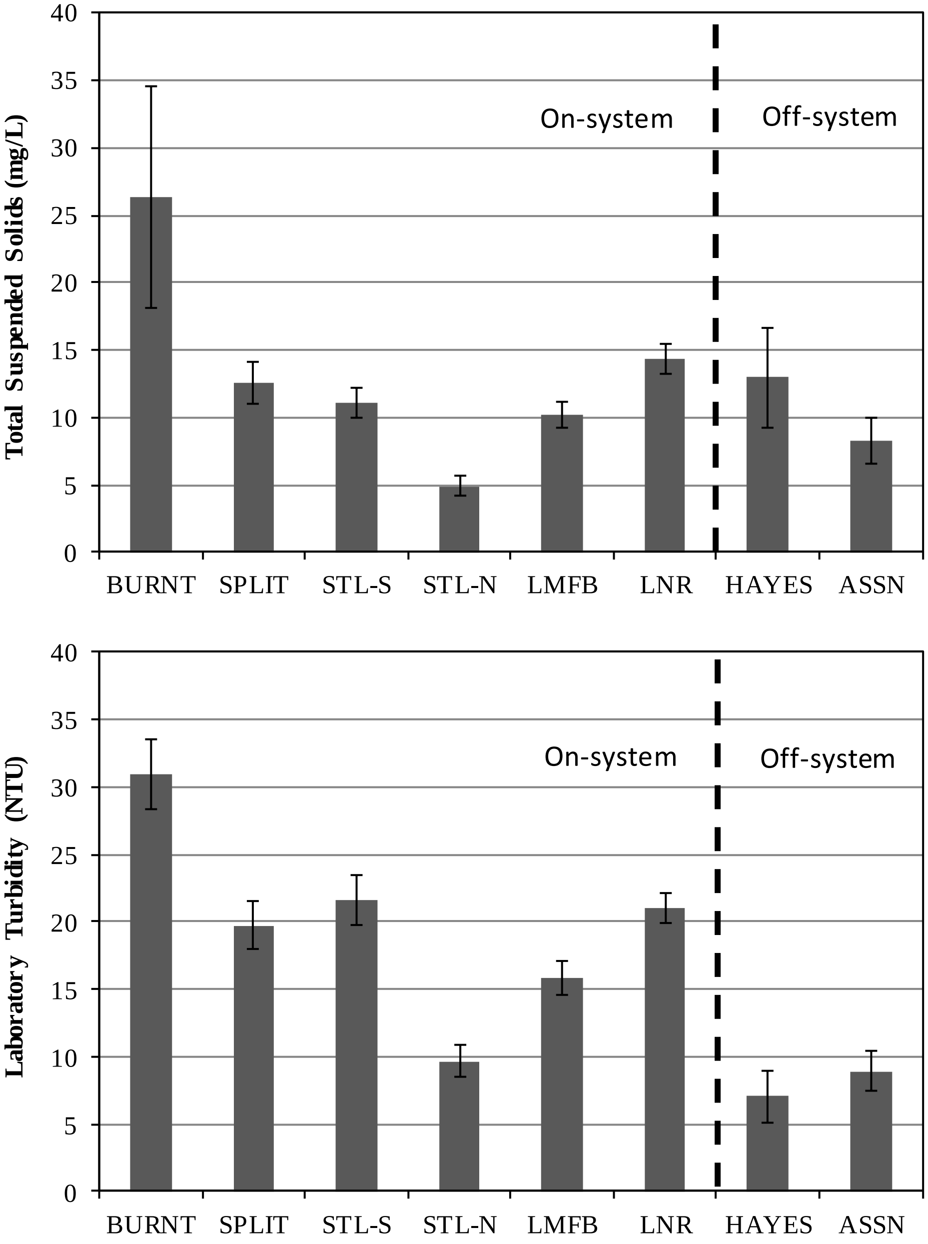


Figure 3-19. Total suspended solids and turbidity (mean±SE) measured in the Lower Nelson River Region: 2008/2009-2013/2014.

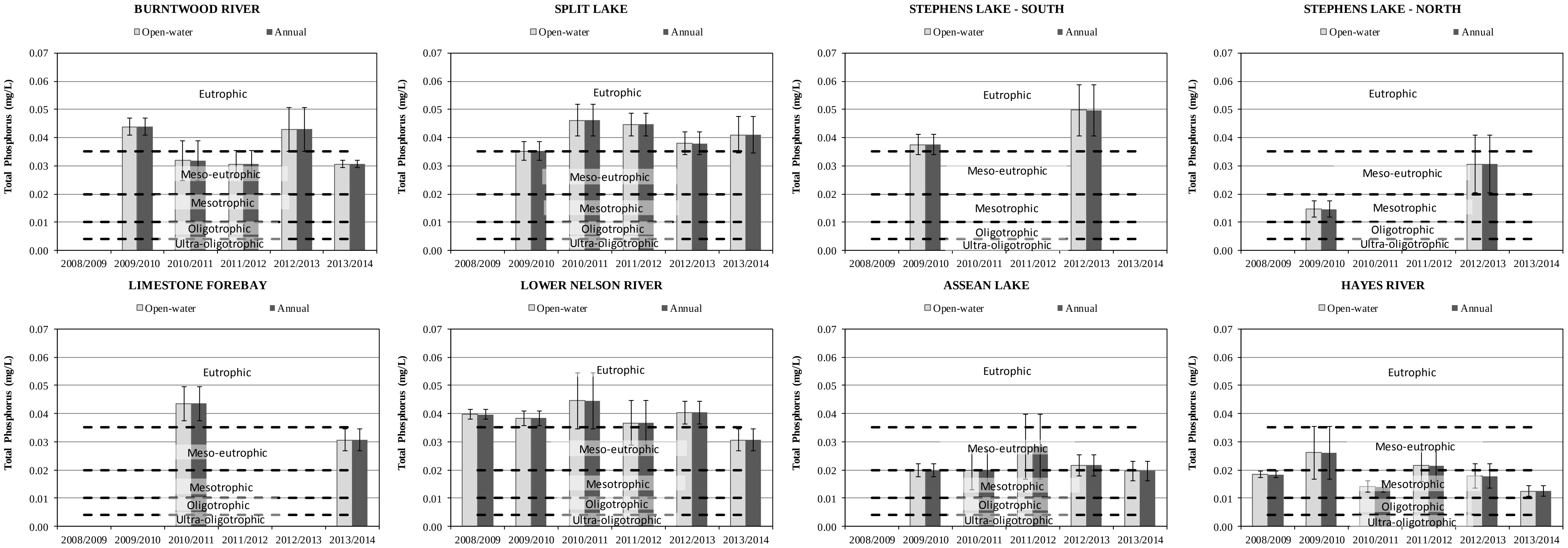


Figure 3-20. Total phosphorus (mean±SE) measured in the Lower Nelson River Region and comparison to trophic categories: 2008/2009-2013/2014.

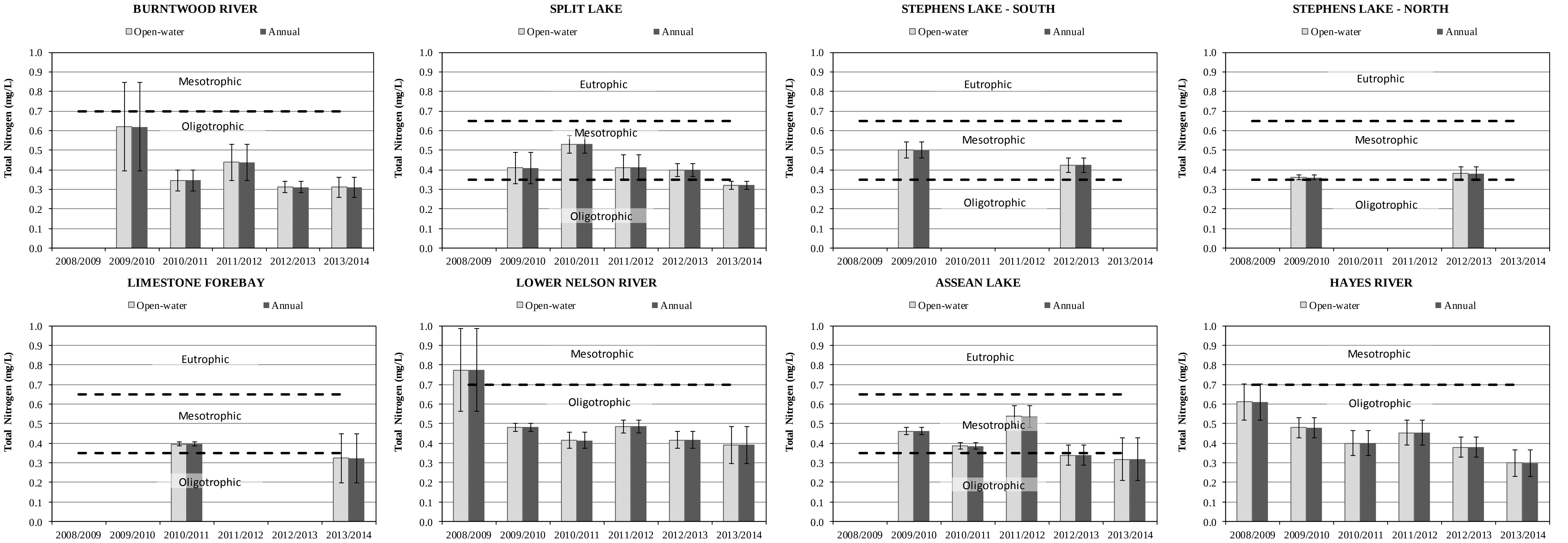
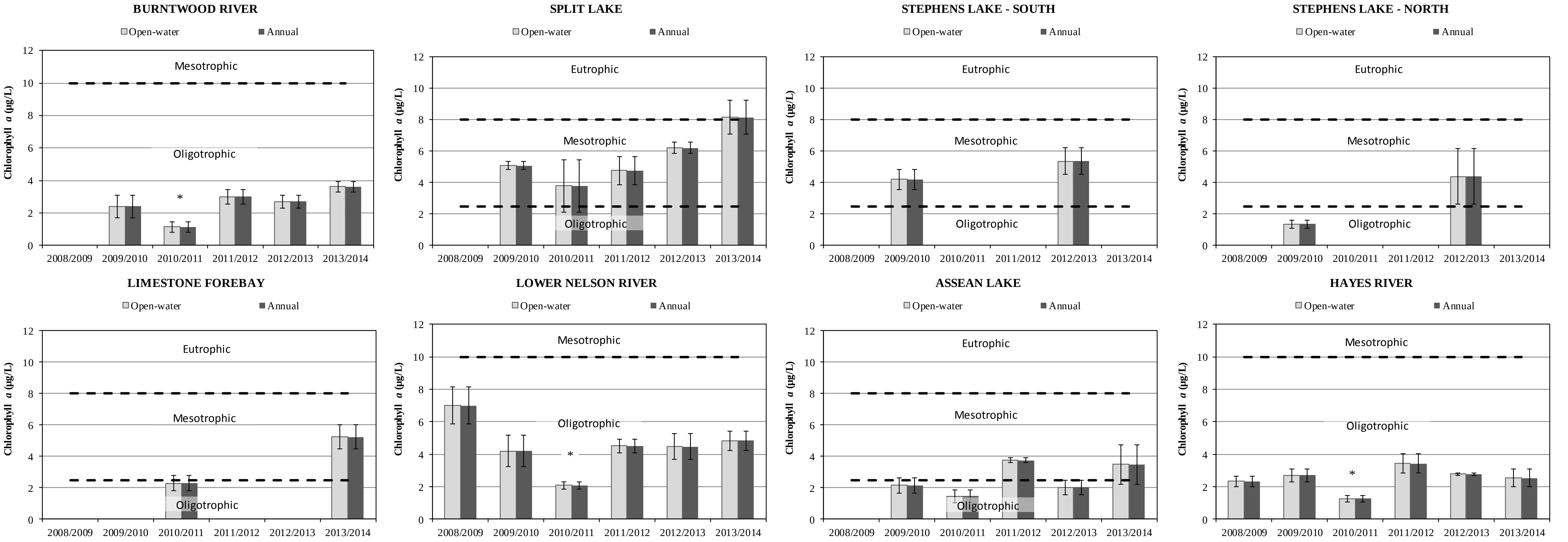


Figure 3-21. Total nitrogen (mean±SE) measured in the Lower Nelson River Region and comparison to trophic categories: 2008/2009-2013/2014. Note that trophic category boundaries differ between lake and river sites.



* No sample collected in summer period.

Figure 3-22. Chlorophyll *a* (mean±SE) measured in the Lower Nelson River Region and comparison to trophic categories: 2008/2009-2013/2014. Note that trophic category boundaries differ between lake and river sites.

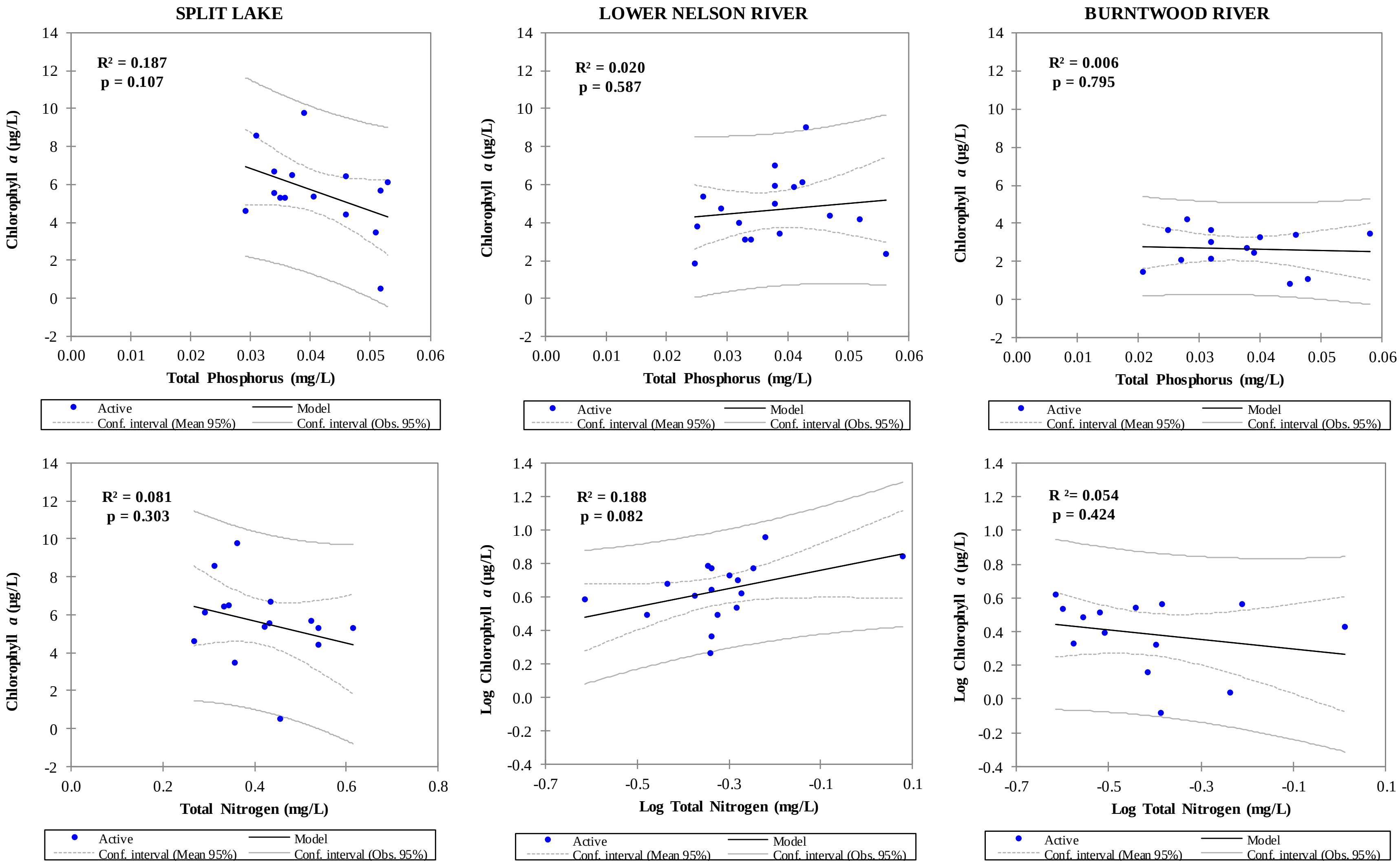


Figure 3-23. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* at on-system annual monitoring site in the LNRR: open-water seasons 2008-2013.

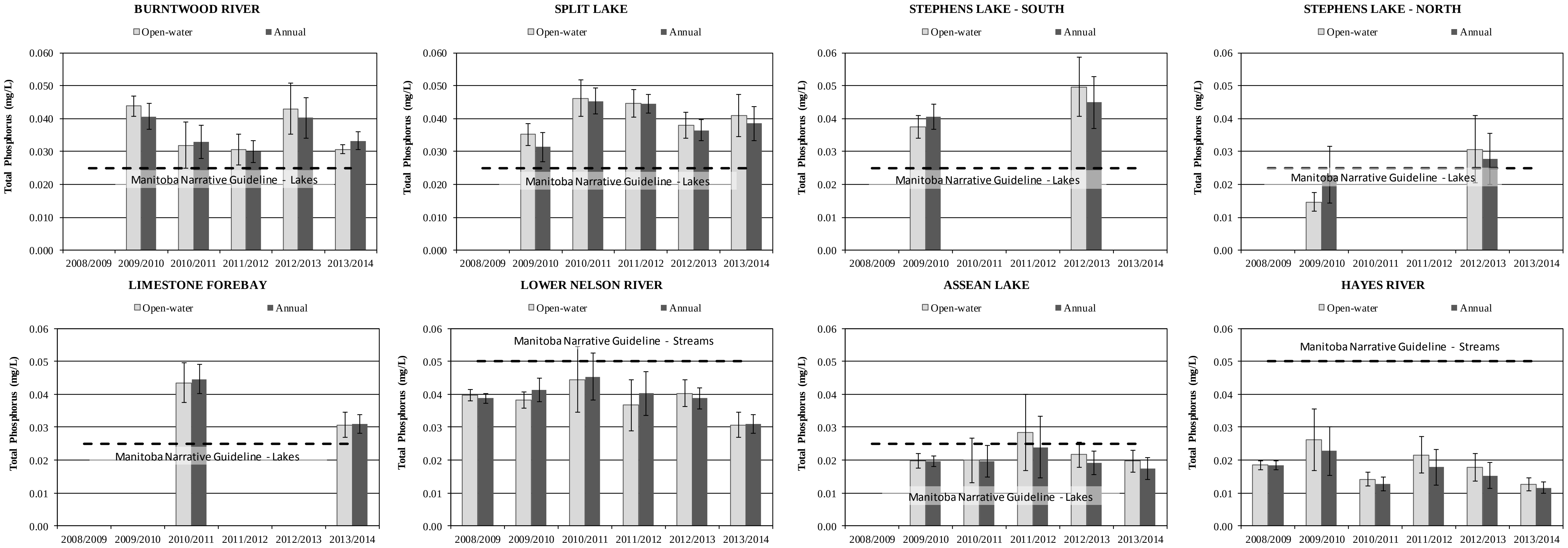


Figure 3-24. Total phosphorus (mean±SE) measured in the Lower Nelson River Region and comparison to the Manitoba narrative nutrient guidelines: 2008/2009-2013/2014. Note the different guidelines for river (excepting the Burntwood River site as it is near the point of entry to a lake) and lake sites.

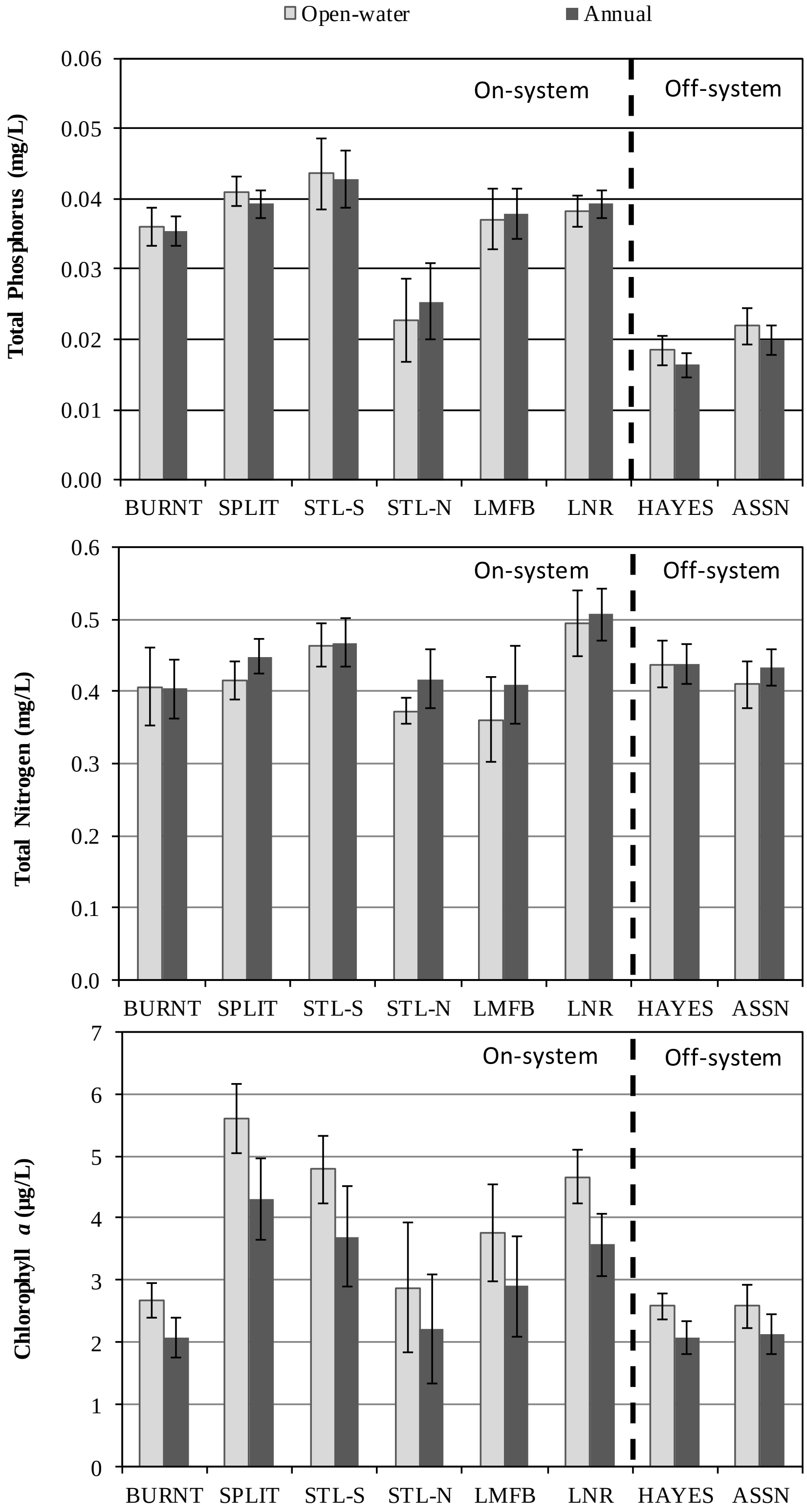


Figure 3-25. Total phosphorus, total nitrogen, and chlorophyll *a* (mean±SE) measured in the Lower Nelson River Region: 2008/2009-2013/2014.

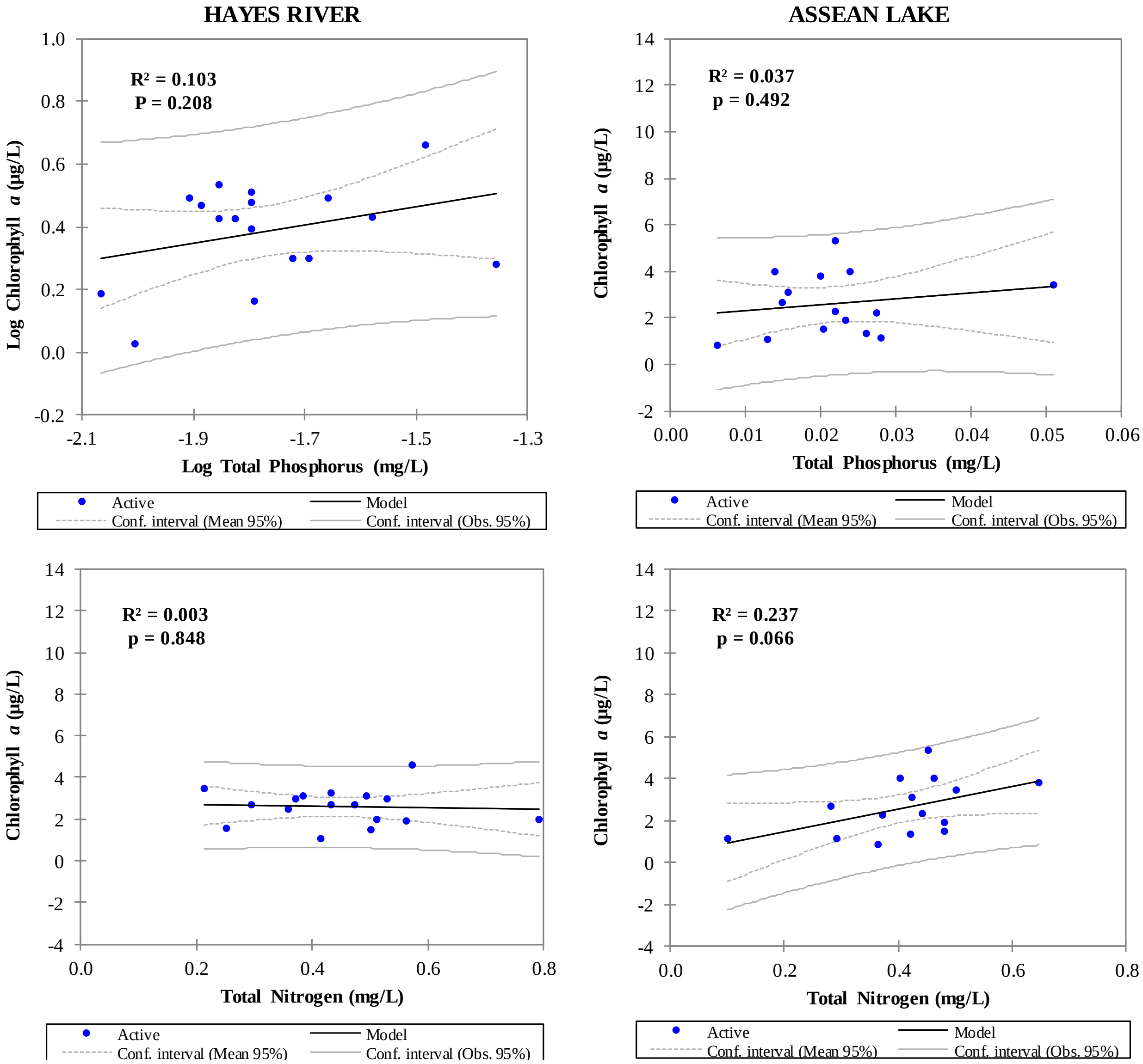
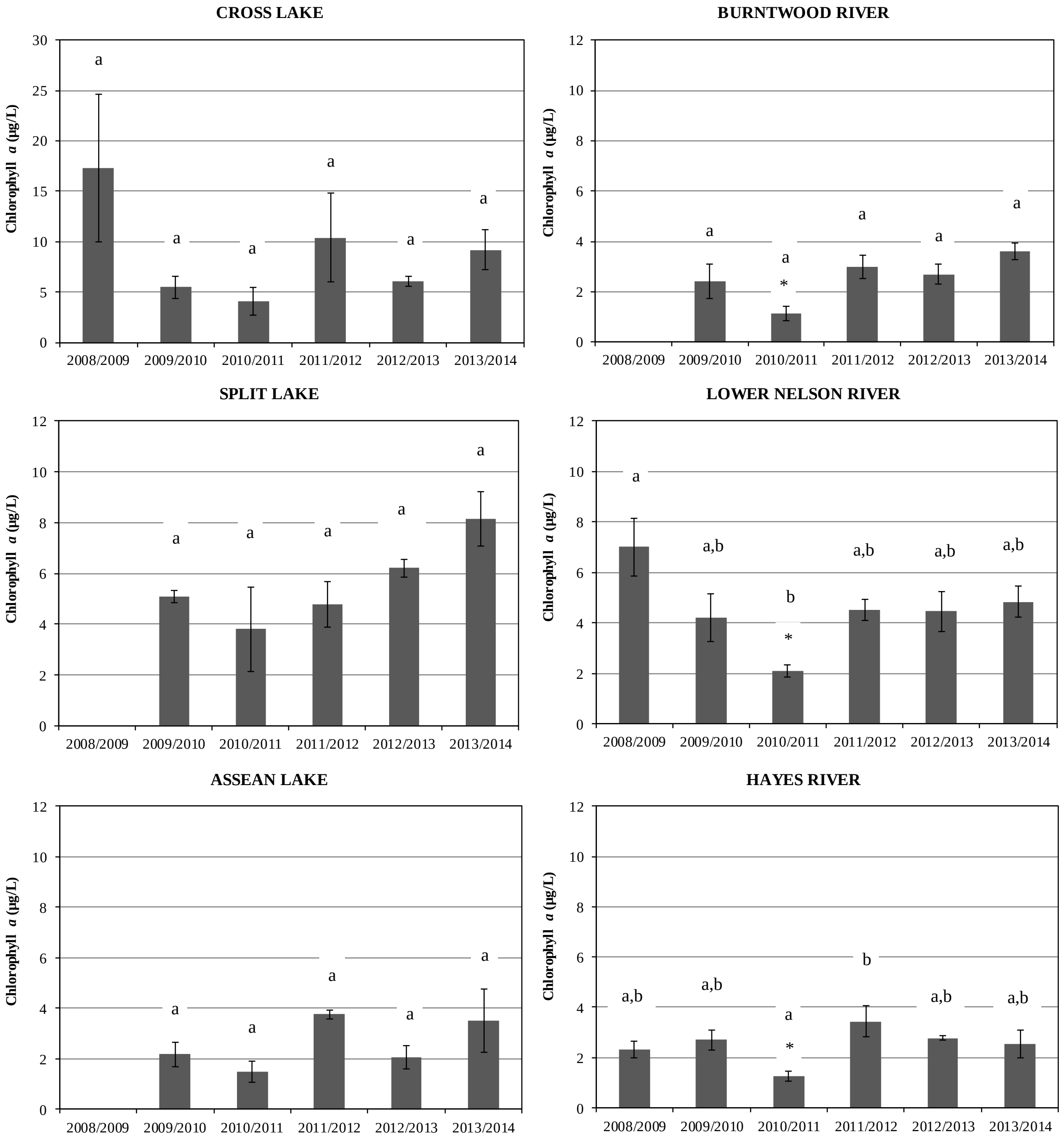


Figure 3-26. Linear regression between total phosphorus and total nitrogen and chlorophyll *a* at off-system annual monitoring site in the LNRR: open-water seasons 2008-2013.



* No sample collected in summer period.

Figure 3-27. Open-water season chlorophyll *a* (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

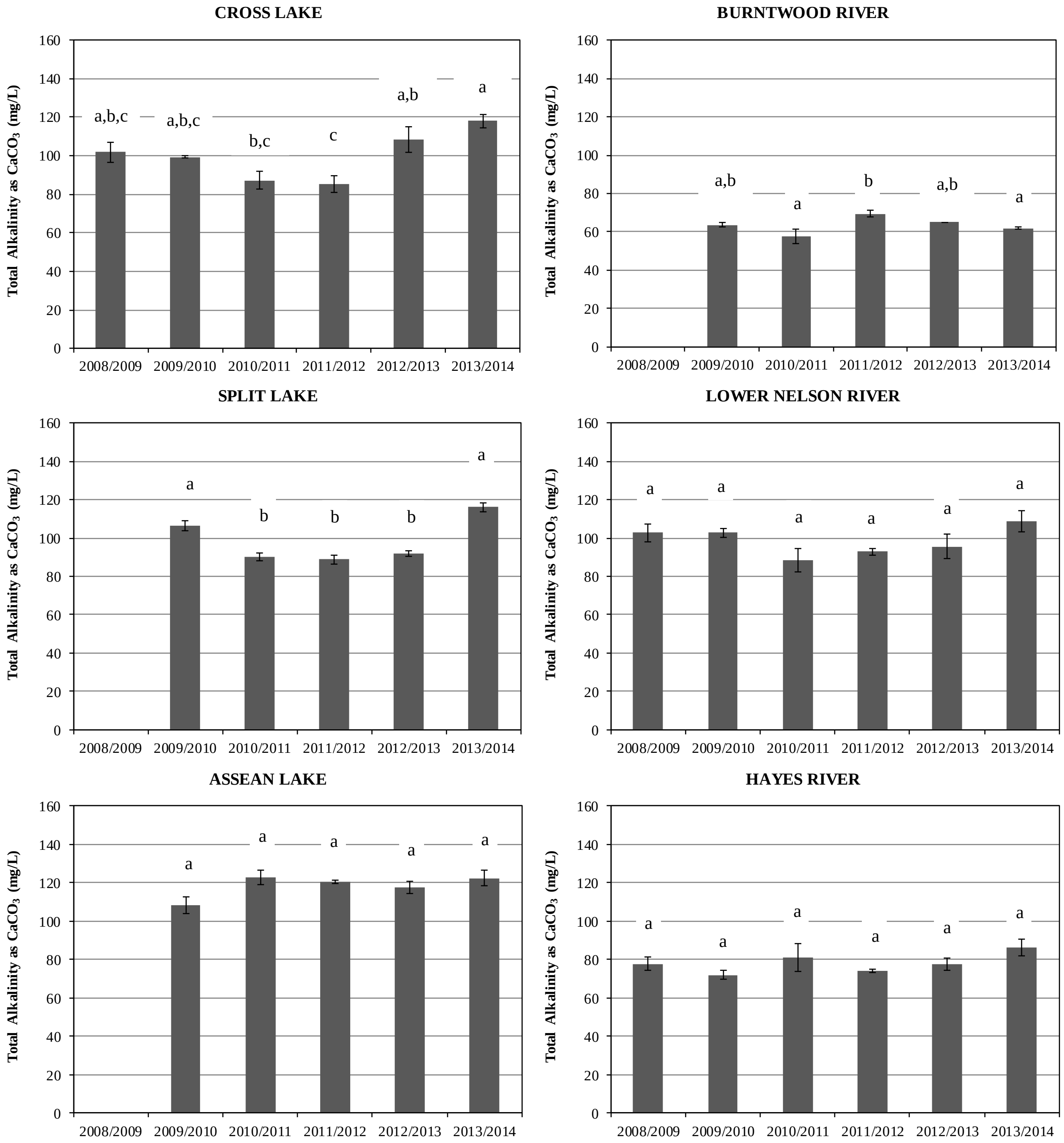


Figure 3-28. Open-water season total alkalinity (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

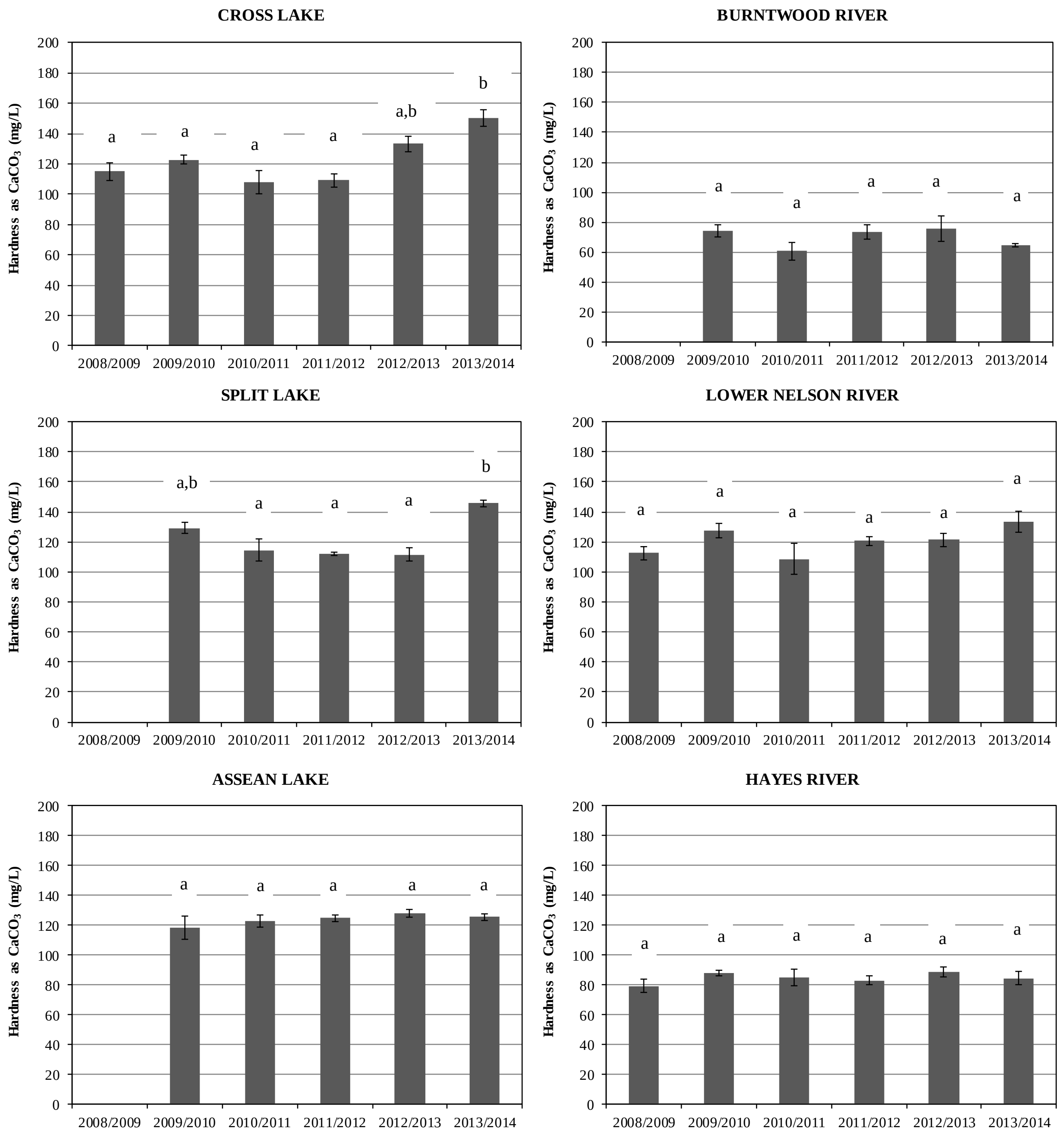


Figure 3-29. Open-water season water hardness (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

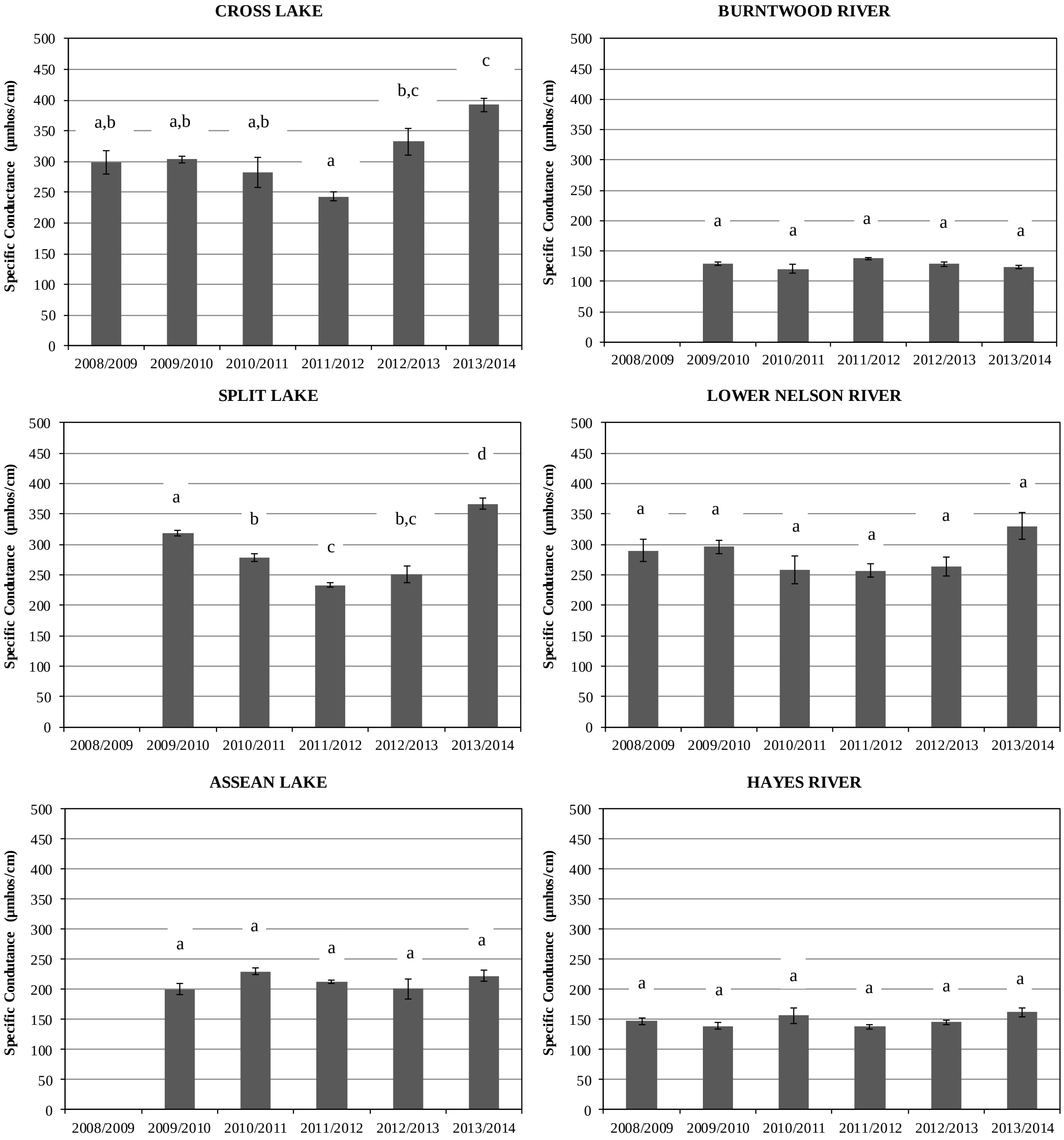


Figure 3-30. Open-water season specific conductance (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

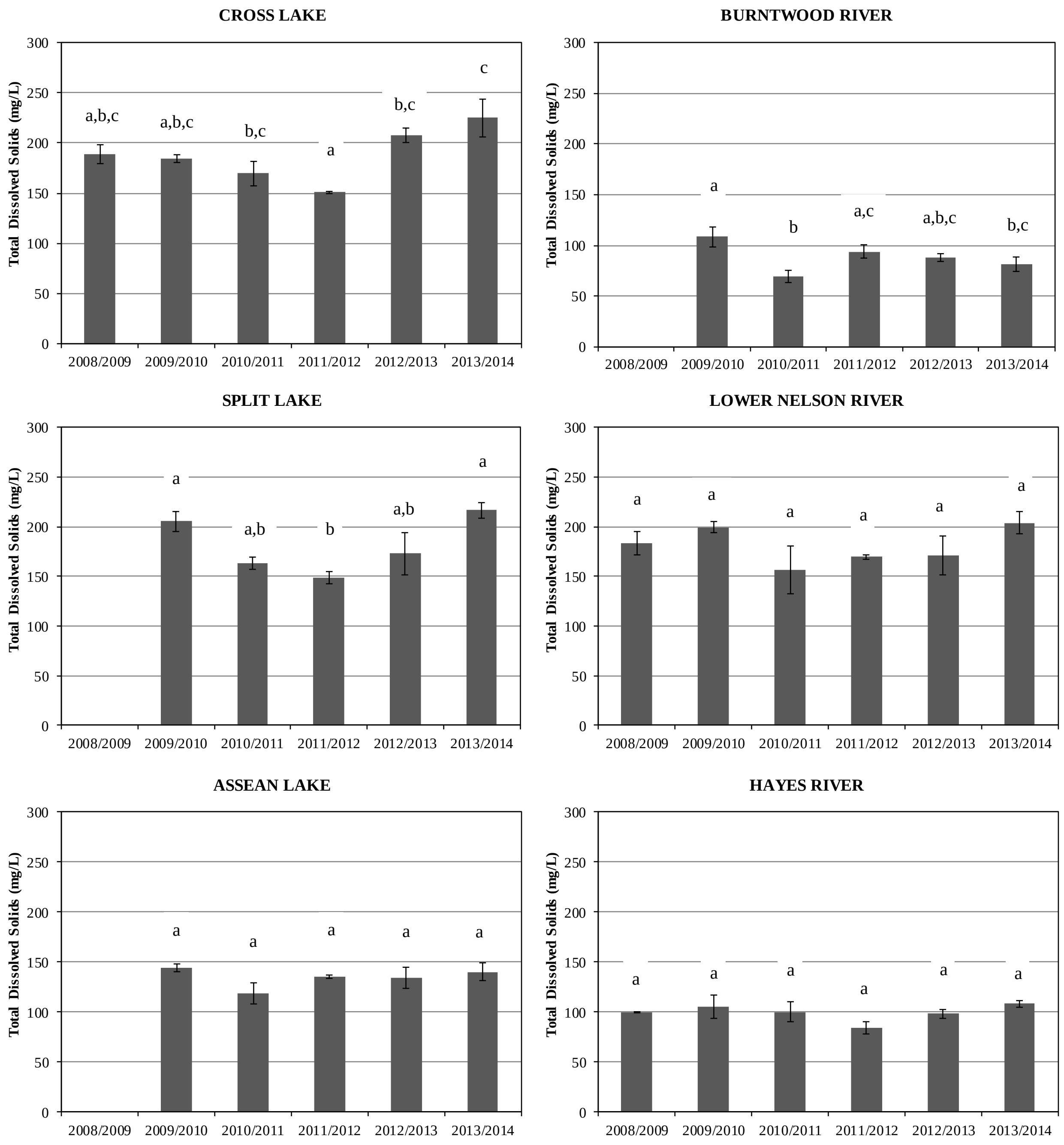


Figure 3-31. Open-water season total dissolved solids (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

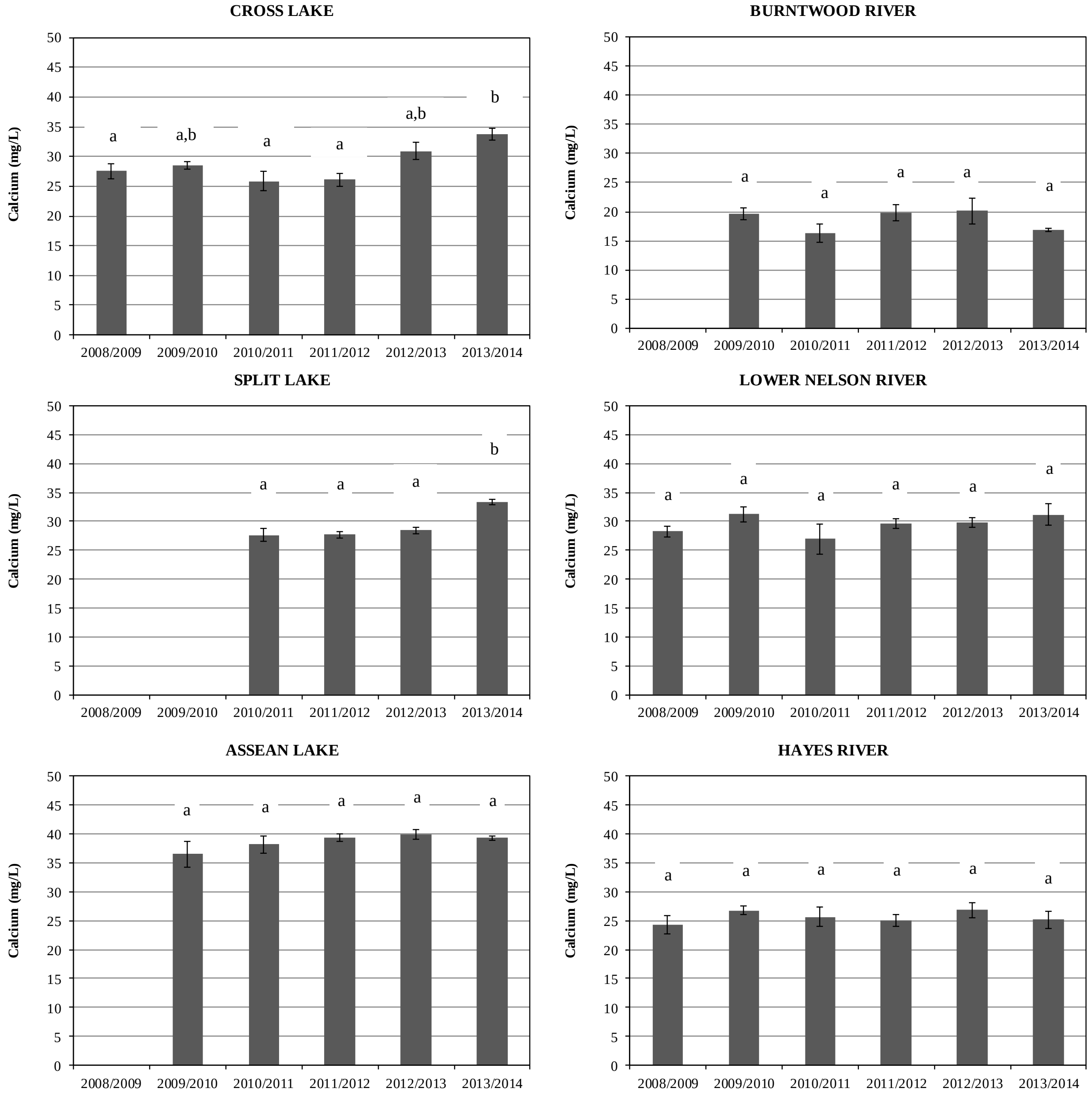


Figure 3-32. Open-water season calcium concentrations (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

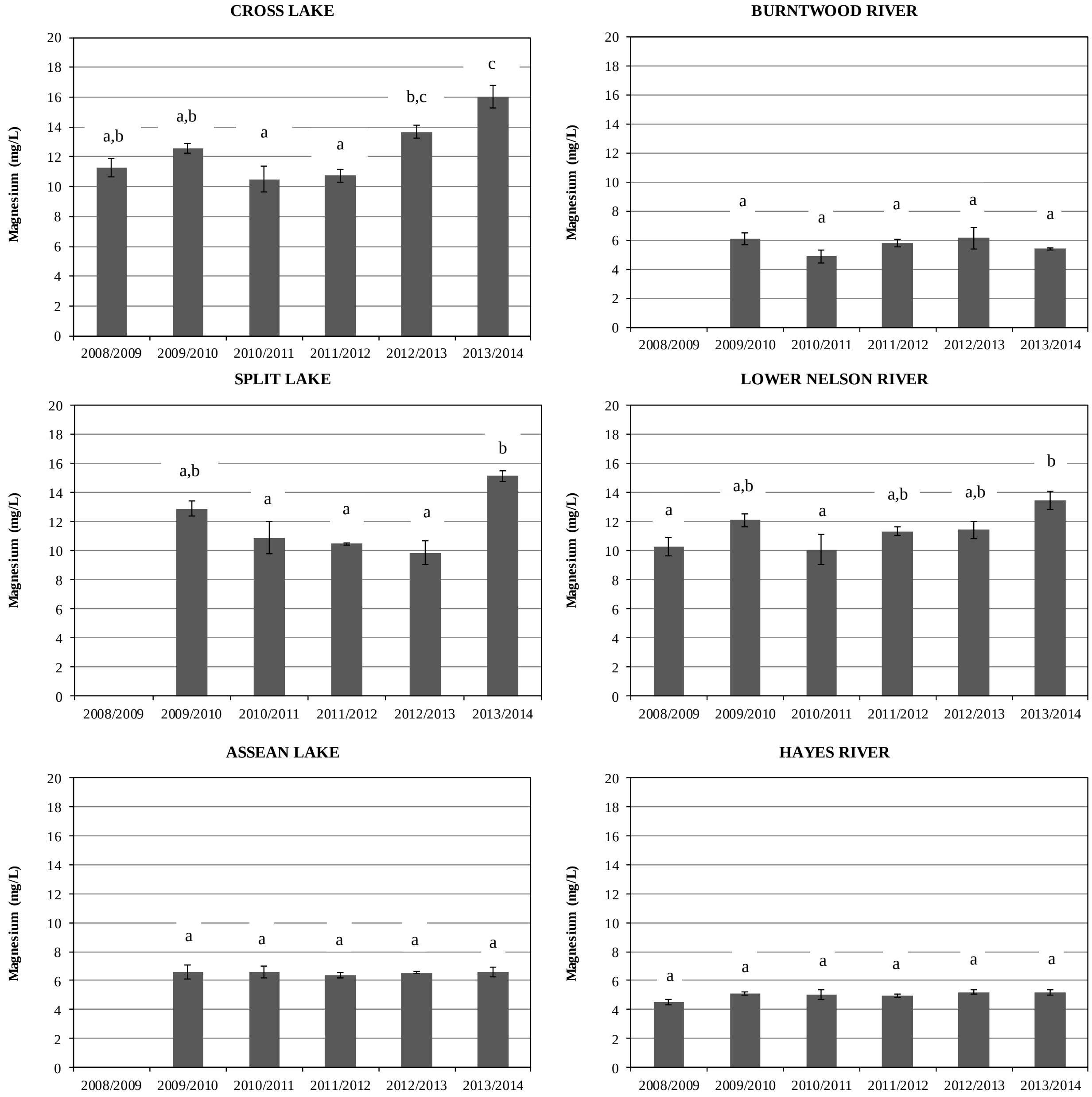


Figure 3-33. Open-water season magnesium concentrations (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

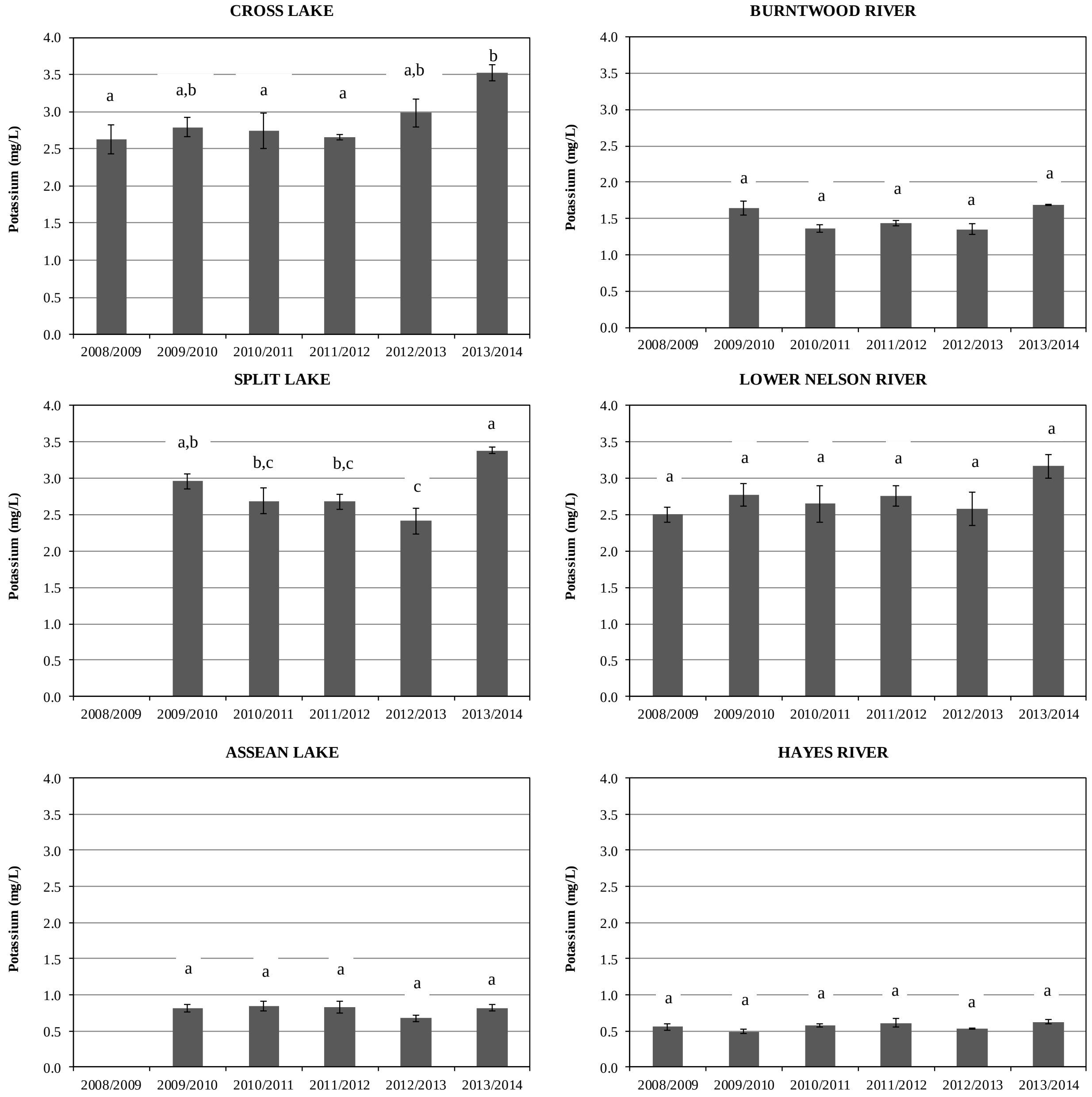


Figure 3-34. Open-water season potassium concentrations (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

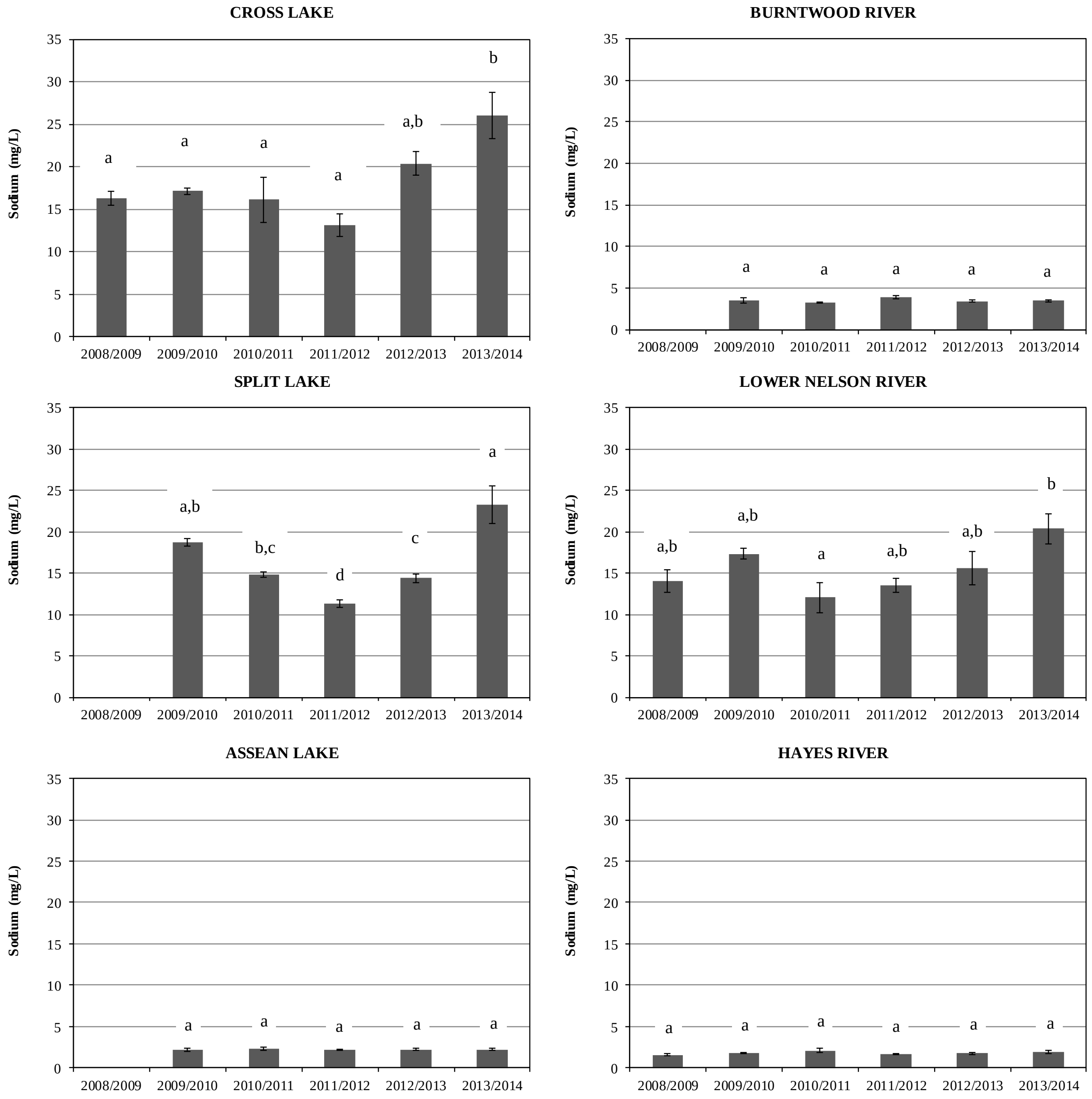
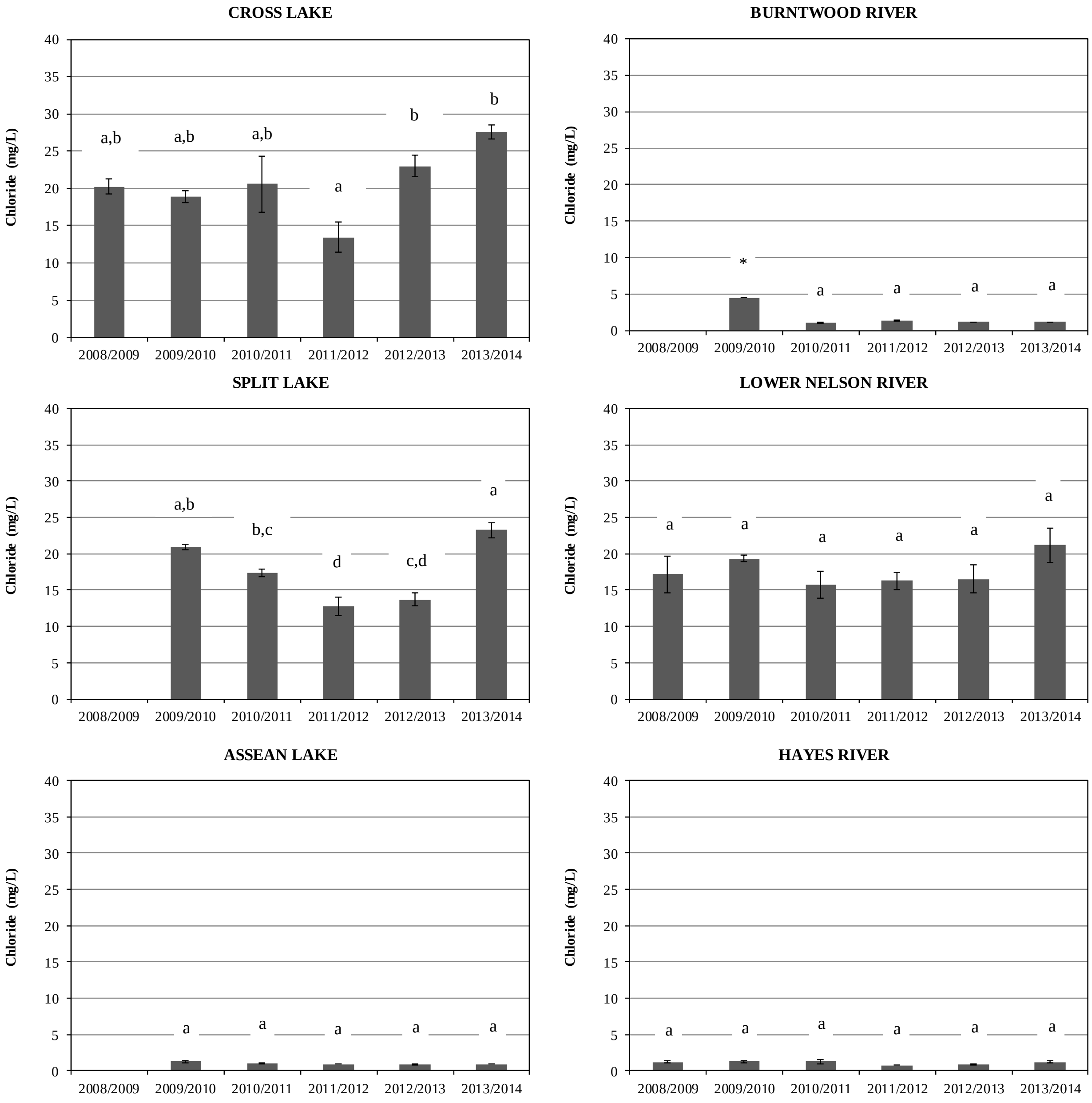
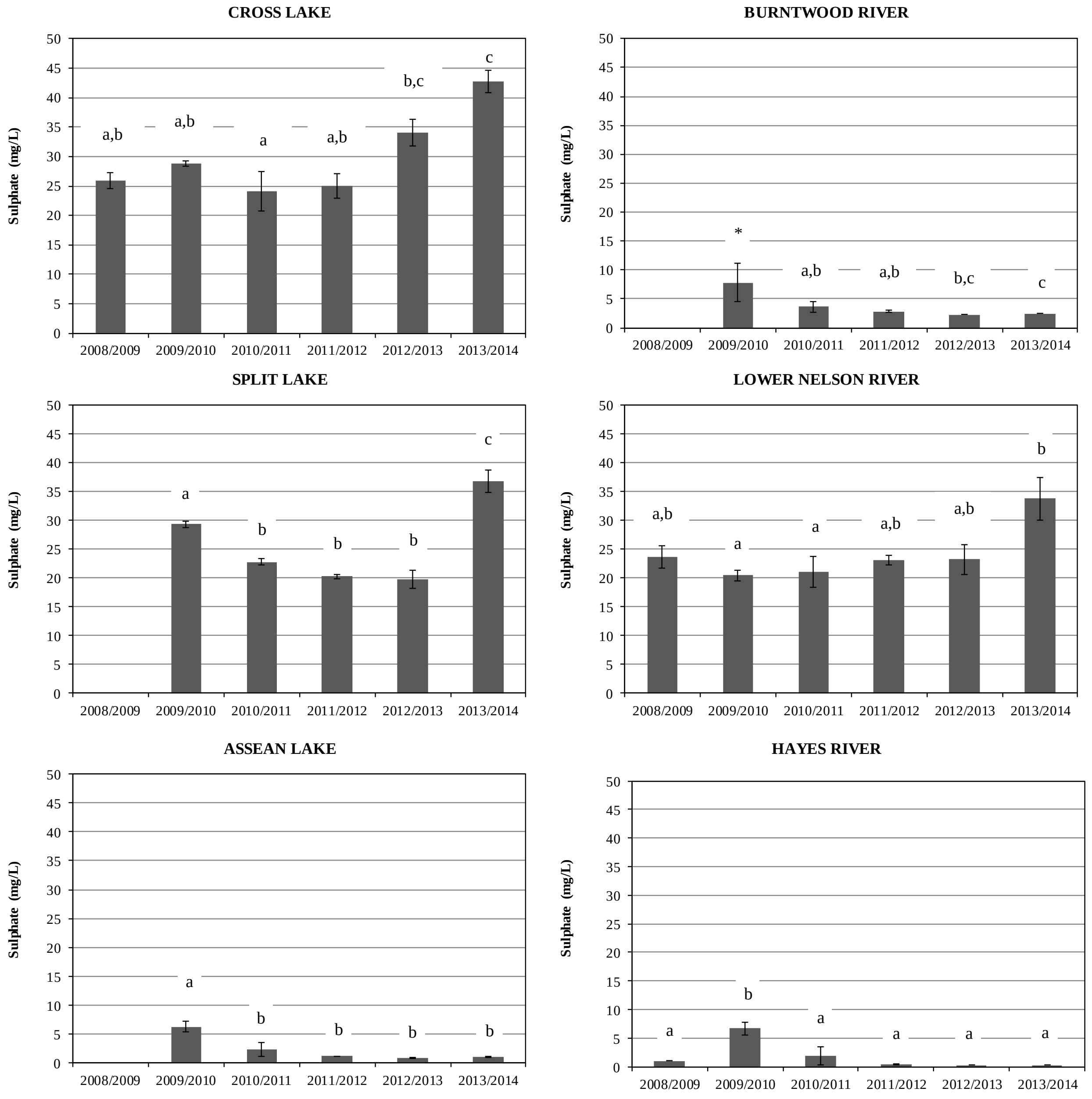


Figure 3-35. Open-water season sodium concentrations (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



* No comparison made due to higher analytical detection limits for these samples.

Figure 3-36. Open-water season chloride concentrations (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.



* No comparison made due to higher analytical detection limits for these samples.

Figure 3-37. Open-water season sulphate concentrations (mean±SE) at the annual on-system and off-system sites in the LNRR. Data from the closest annual upstream site (Cross Lake) on the upper Nelson River are included for comparison. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

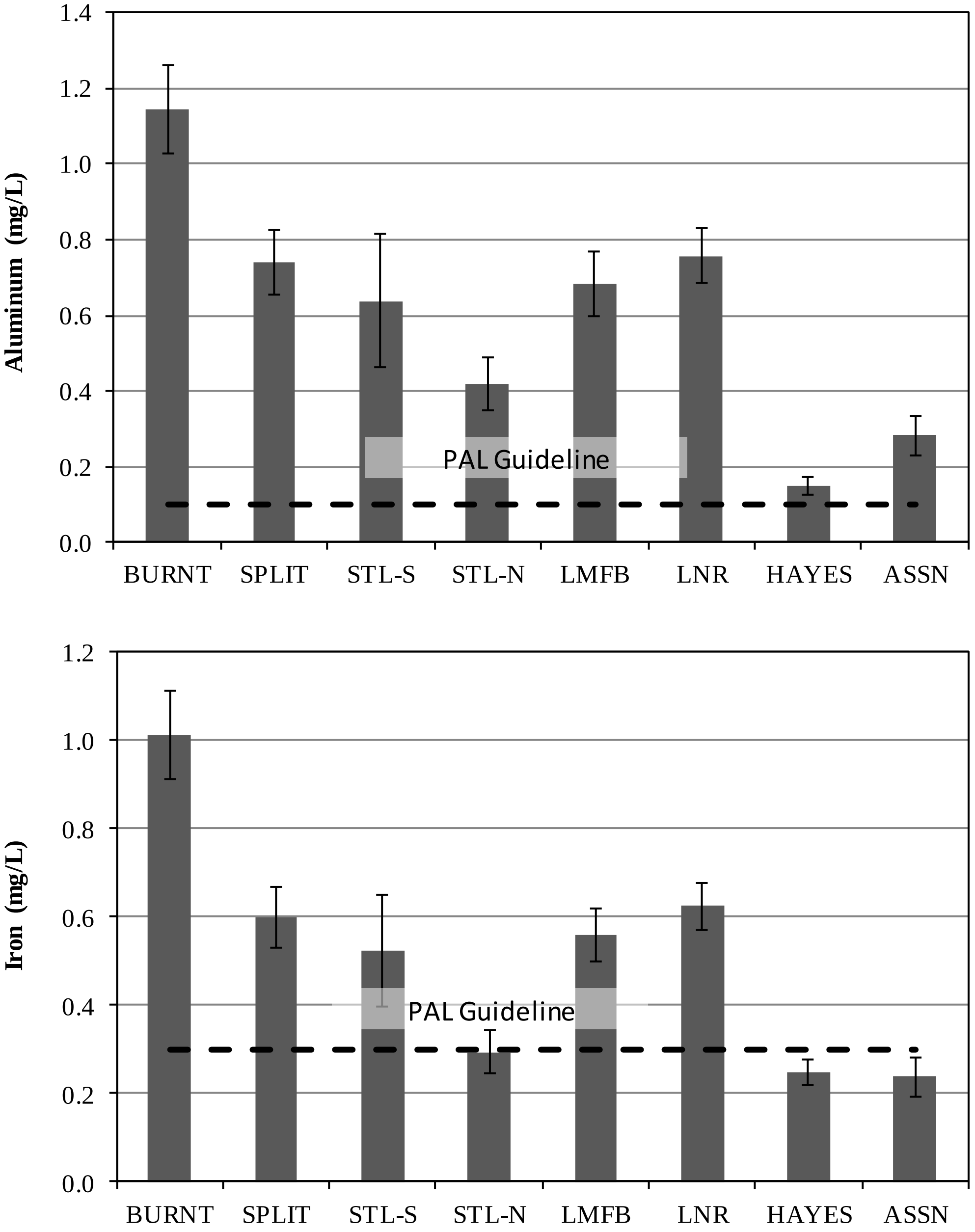


Figure 3-38. Aluminum and iron (mean±SE) measured in the Lower Nelson River Region: 2008/2009-2013/2014.

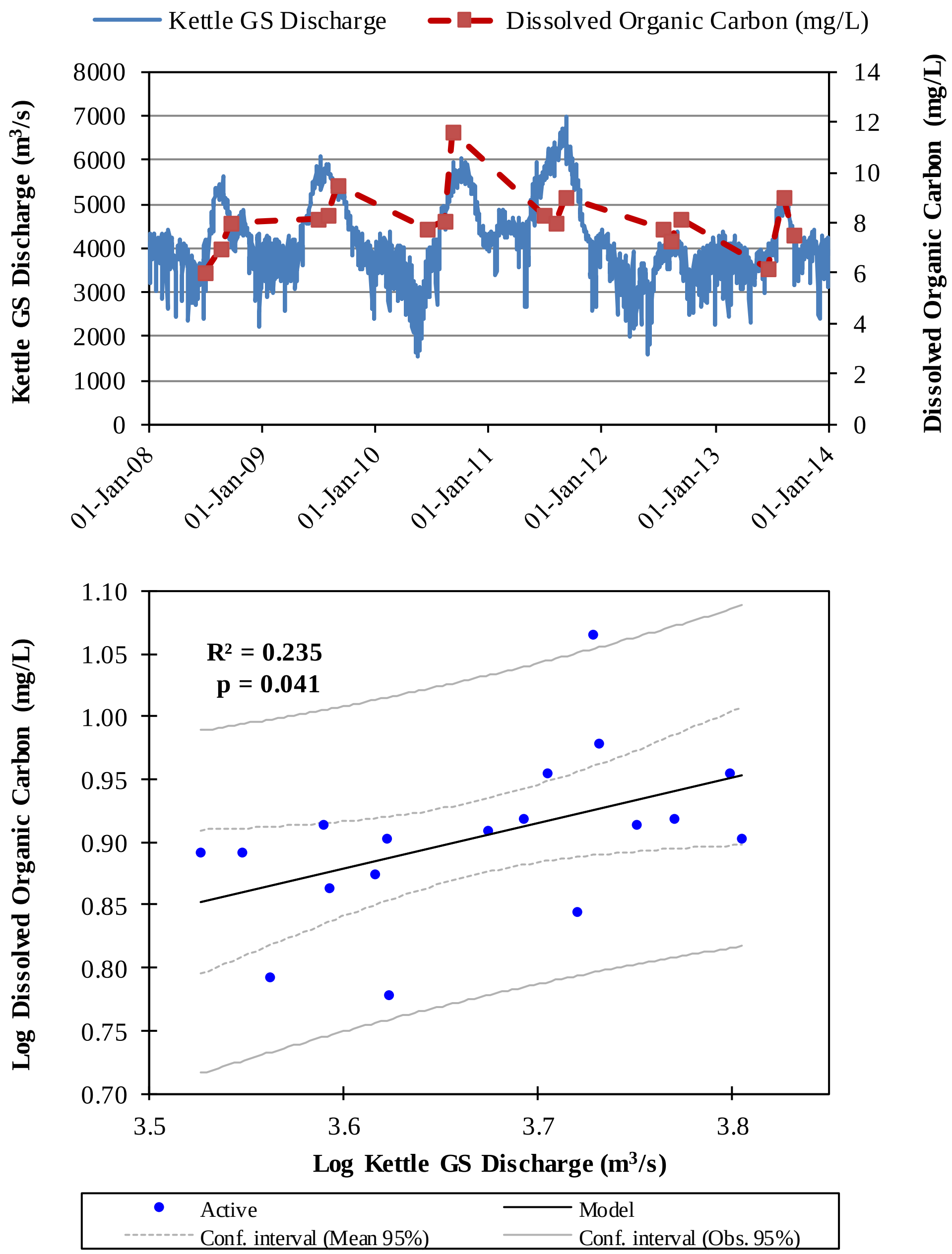


Figure 3-39. Open-water season dissolved organic carbon in the lower Nelson River versus Kettle GS discharge in the Lower Nelson River Region.

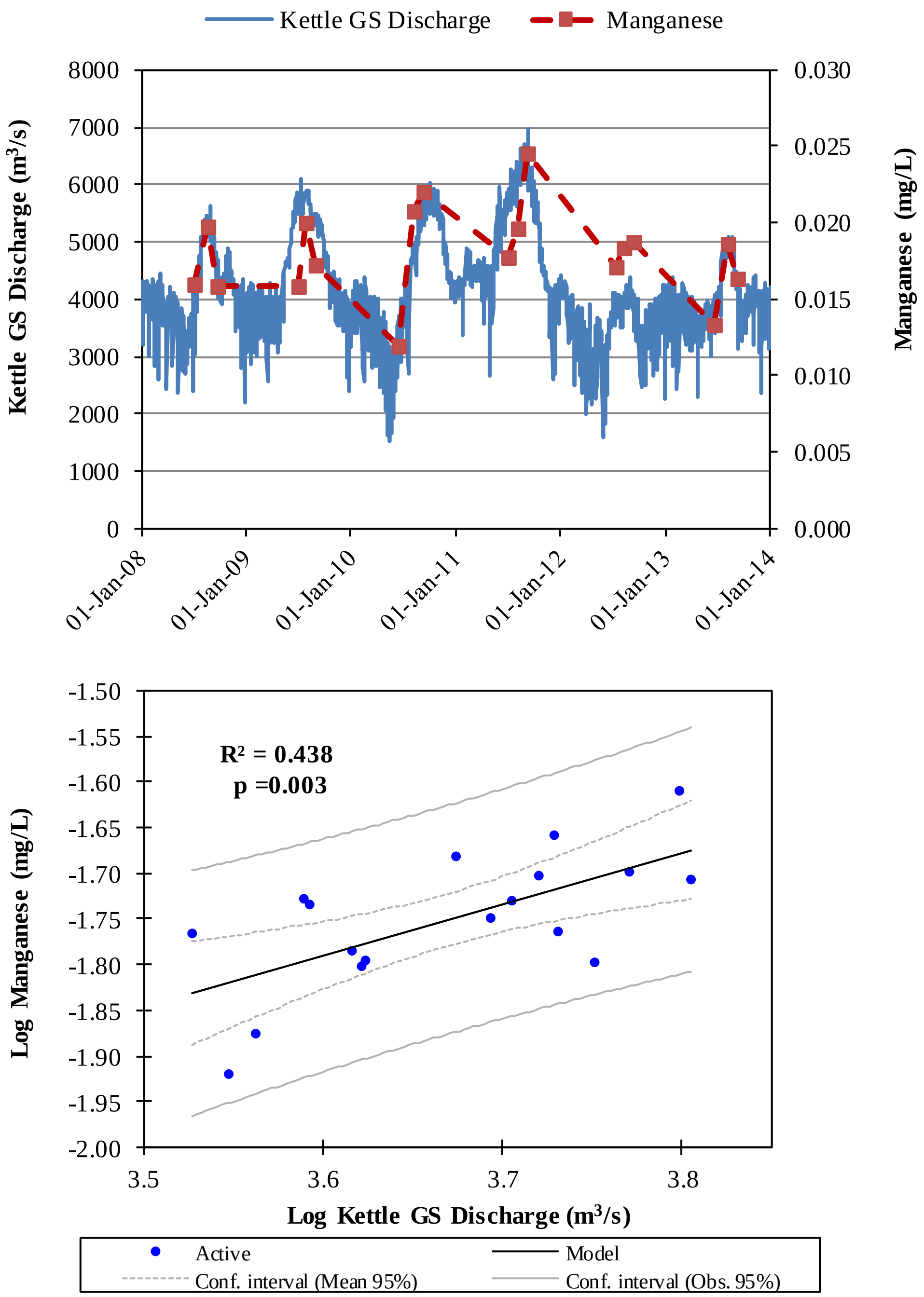


Figure 3-40. Open-water season manganese concentrations in the lower Nelson River versus Kettle GS discharge in the Lower Nelson River Region.

4.0 SEDIMENT QUALITY

4.1 INTRODUCTION

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

Sediment quality was measured in 2011 in the Burntwood River (at the inlet to Split Lake) and Split and Assean lakes (Figure 4-1). Samples could not be retrieved from the lower Nelson River downstream of the Limestone Forebay or from the off-system Hayes River due to rocky substrates.

4.1.1 Objectives and Approach

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

4.1.2 Indicators

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

4.2 LOWER NELSON RIVER

Surficial sediment samples from the Burntwood River and Split Lake were dominated by silt/clay (94 and 97%, respectively; Table 4-1 and Figure 4-2) and had moderate levels of total organic carbon (TOC; Figure 4-3). The particle size and TOC content were similar to that observed in the off-system Assean Lake, though both on-system sites contained more sand and slightly lower TOC than Assean Lake (see Section 4.3).

While similar between the Burntwood River and Split Lake, mean concentrations of organic carbon and nutrients (TP and total Kjeldahl nitrogen [TKN]) were near sediment quality benchmarks and differed in terms of exceedances of these benchmarks. TOC exceeded the Ontario LEL in Split Lake but not the Burntwood River (Figure 4-3), TP exceeded the Ontario LEL in the Burntwood River (Figure 4-4), and TKN exceeded the Ontario LEL at both sites (Figure 4-5).

All metals (including arsenic, cadmium, chromium, copper, lead, mercury, and zinc) in the Burntwood River, and all but one (chromium) in Split Lake, were on average within the Manitoba SQGs (Figures 4-6 to 4-12). Chromium exceeded the Manitoba SQG in Split Lake but was marginally below the guideline in the Burntwood River (Figure 4-8).

Iron (Figure 4-13), manganese (Figure 4-14), and nickel (Figure 4-15) exceeded the Ontario LEL, but not the SEL, in Split Lake. Results were similar in the Burntwood River, except that iron concentrations were marginally below the LEL. Exceedances of these benchmarks were also observed in the off-system Assean Lake.

Selenium was not detected in surficial sediments from either on-system site (Figure 4-16) and the analytical detection limit (1.1 µg/g) was below the BC SAC and the AB ISQG (2.0 µg/g). Results for additional metrics are presented in Table 4-2.

4.3 OFF-SYSTEM WATERBODY: ASSEAN LAKE

Particle size and nutrient and metal concentrations in surficial sediments from Assean Lake were generally similar to those collected in the Burntwood River and Split Lake (Figures 4-2 to 4-16), and exceedances of sediment quality benchmarks were similar to those observed in the neighbouring on-system Split Lake. TOC and TKN exceeded the Ontario LEL but not the SEL, while TP was within the benchmark. As observed in Split Lake, all metals excepting chromium (which exceeded the SQG) were within the Manitoba SQGs, and iron, manganese, and nickel exceeded the Ontario LEL but not the SEL. Selenium was below the analytical detection limit and therefore well below the BC SAC and the AB ISQG.

4.4 SUMMARY

Half of sediment quality metrics were within sediment quality benchmarks at on-system sites in the LNRR, though more exceedances were observed in Split Lake than the Burntwood River. However, concentrations of nutrients and metals, and exceedances of benchmarks, were similar between Split Lake and the off-system Assean Lake. Metrics that exceeded sediment quality benchmarks were also above these benchmarks, and concentrations were similar to those observed, in other lakes and rivers monitored under CAMP.

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

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

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

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

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

Table 4-2. continued.

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

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

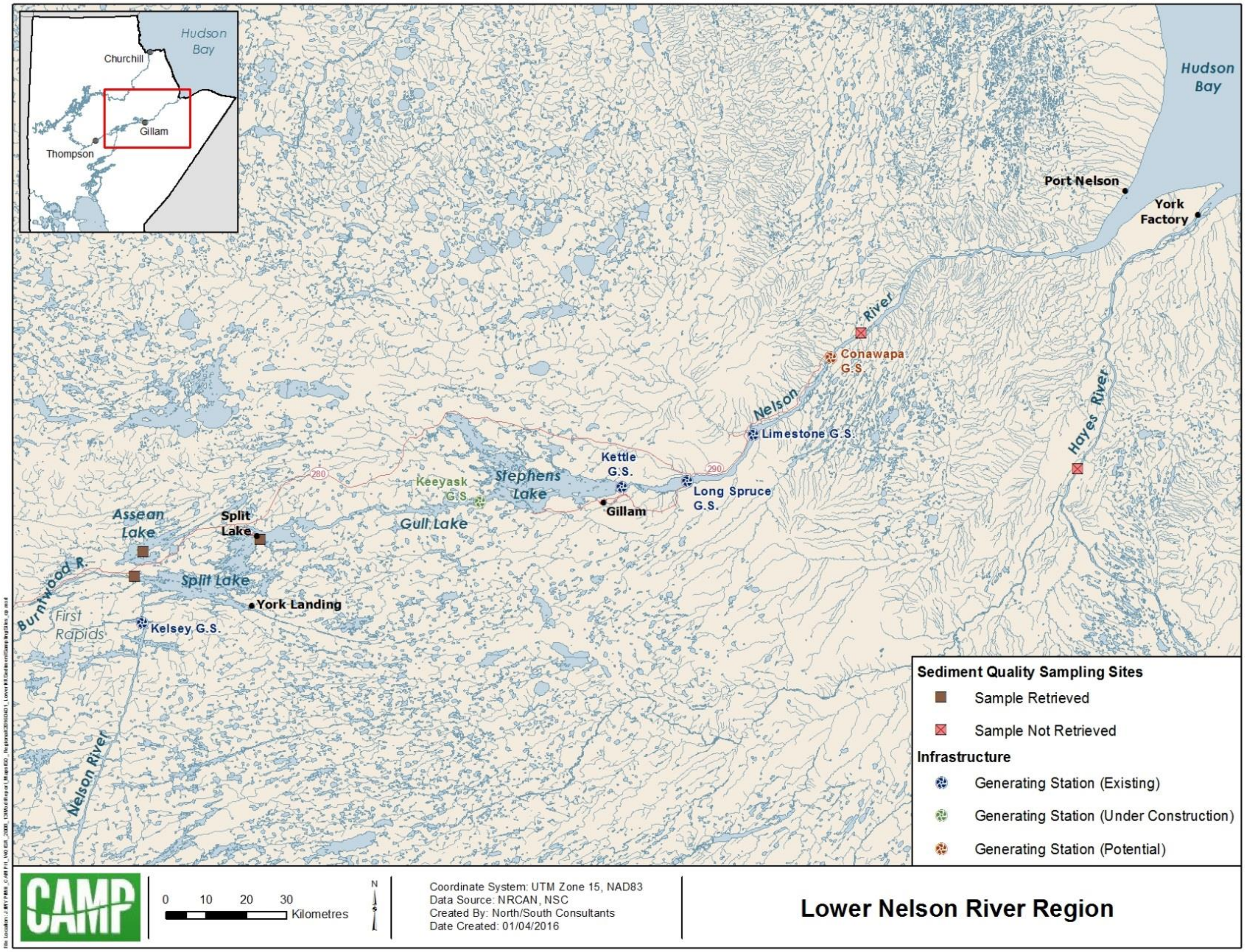


Figure 4-1. Sediment quality sampling sites in the Lower Nelson River Region: 2008-2013.

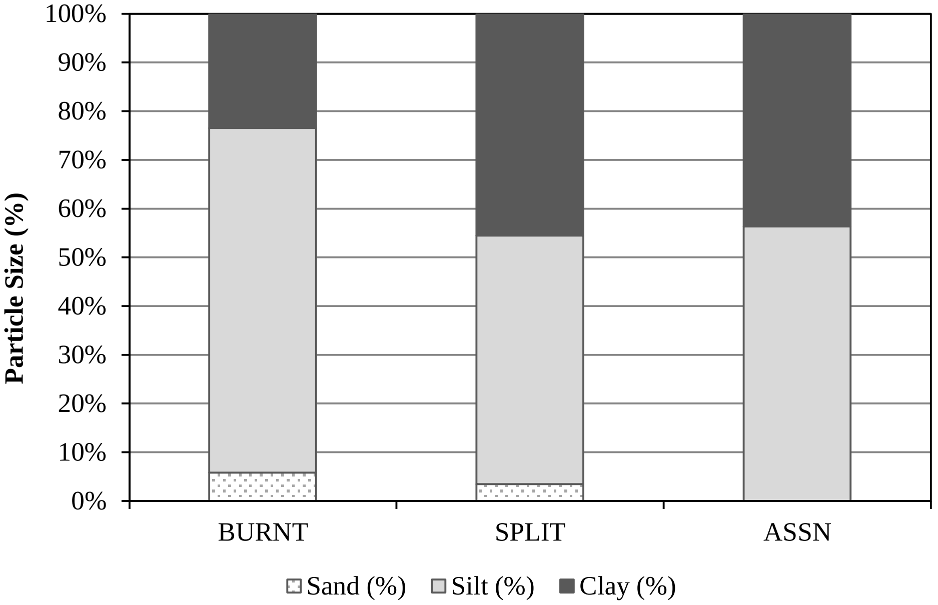


Figure 4-2. Particle size of surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN).

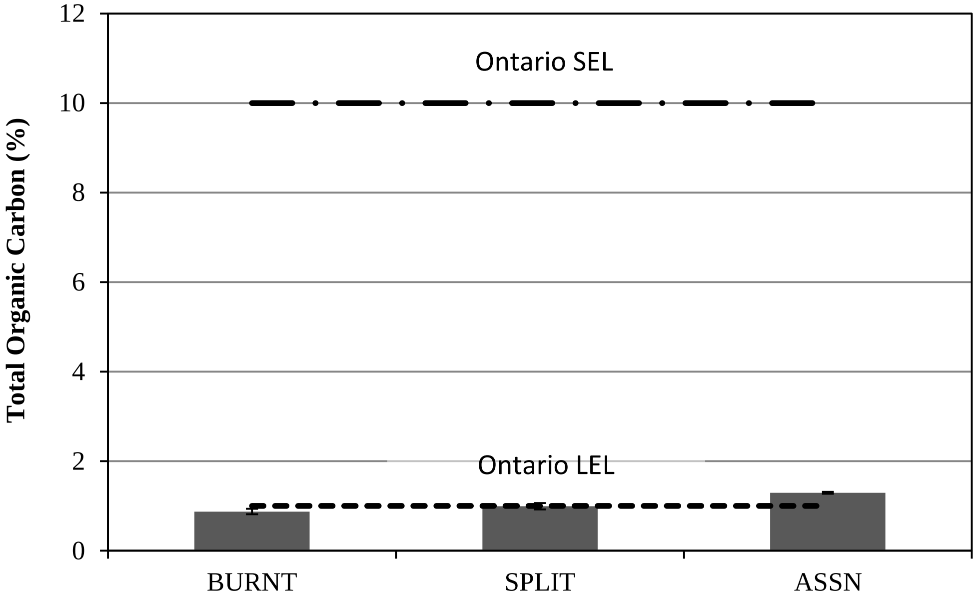


Figure 4-3. Percentage of total organic carbon (mean±SE) in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Ontario sediment quality guidelines.

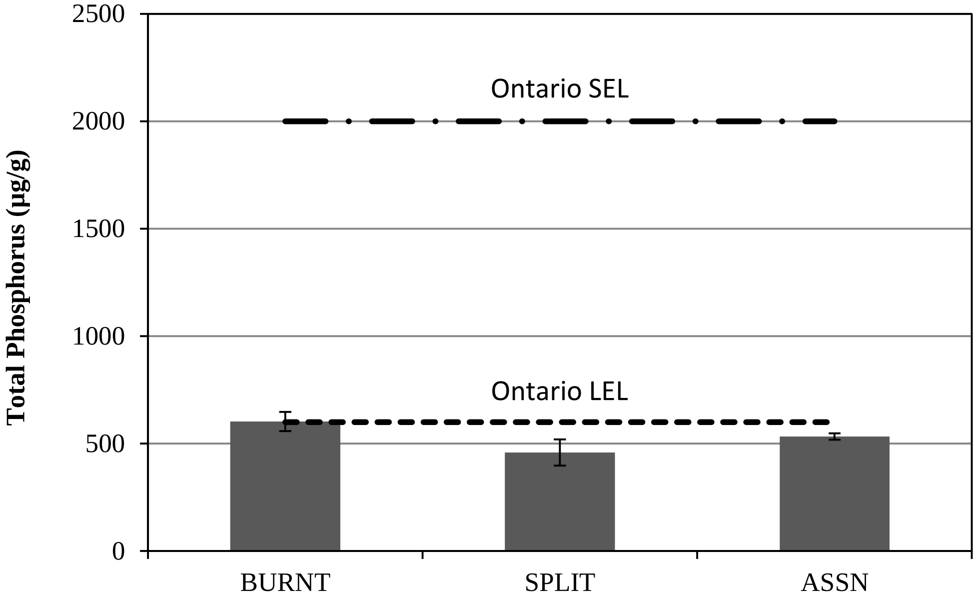


Figure 4-4. Mean (±SE) concentrations of total phosphorus in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Ontario sediment quality guidelines.

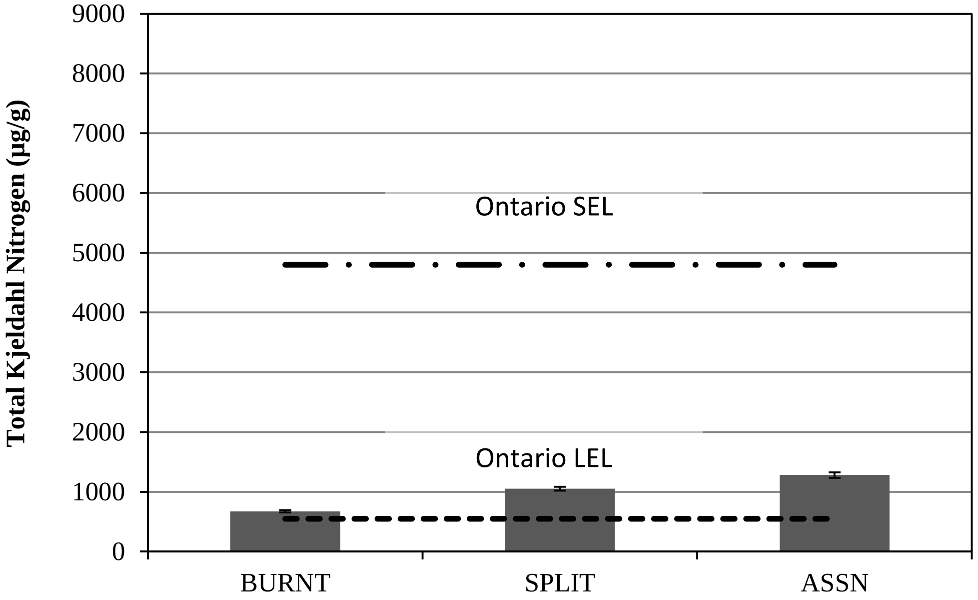


Figure 4-5. Mean (±SE) concentrations of total Kjeldahl nitrogen in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Ontario sediment quality guidelines.

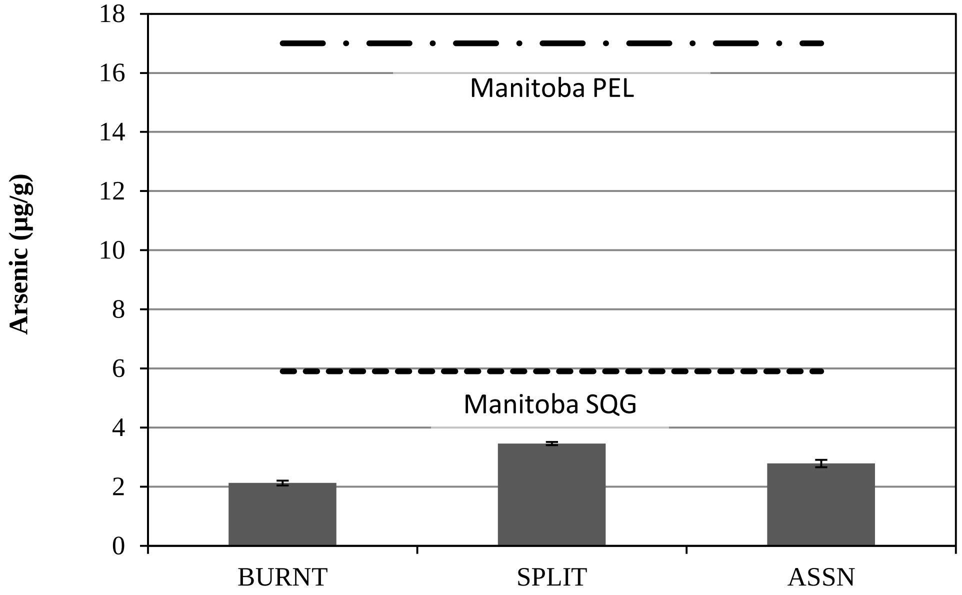


Figure 4-6. Mean (±SE) concentrations of arsenic in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines.

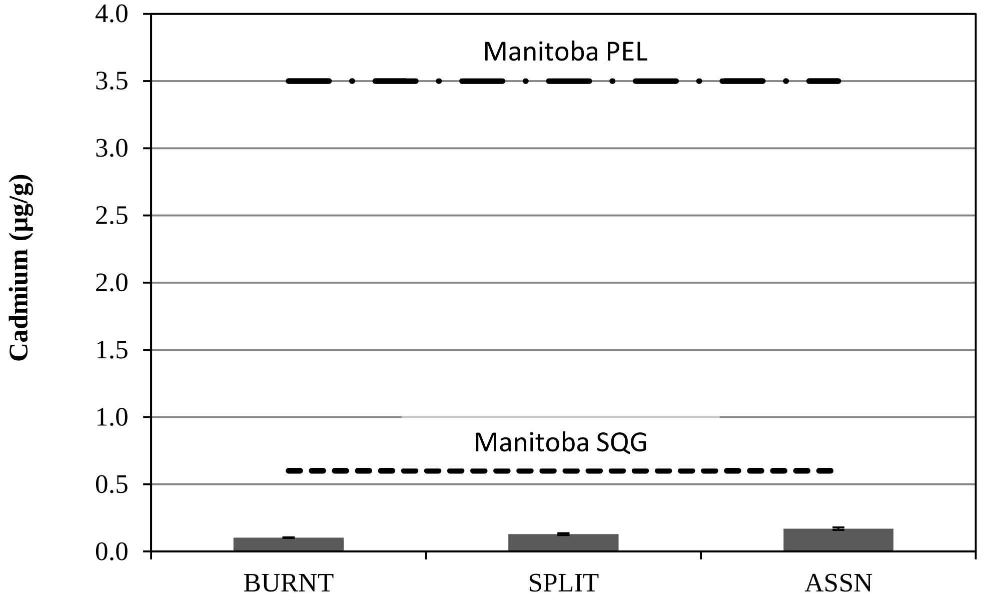


Figure 4-7. Mean (±SE) concentrations of cadmium in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines.

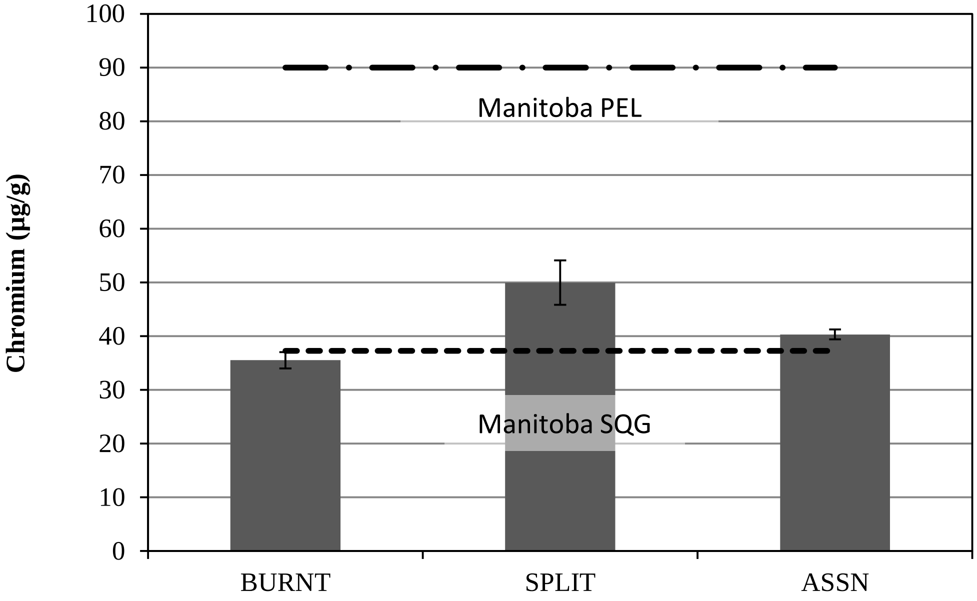


Figure 4-8. Mean (±SE) concentrations of chromium in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines.

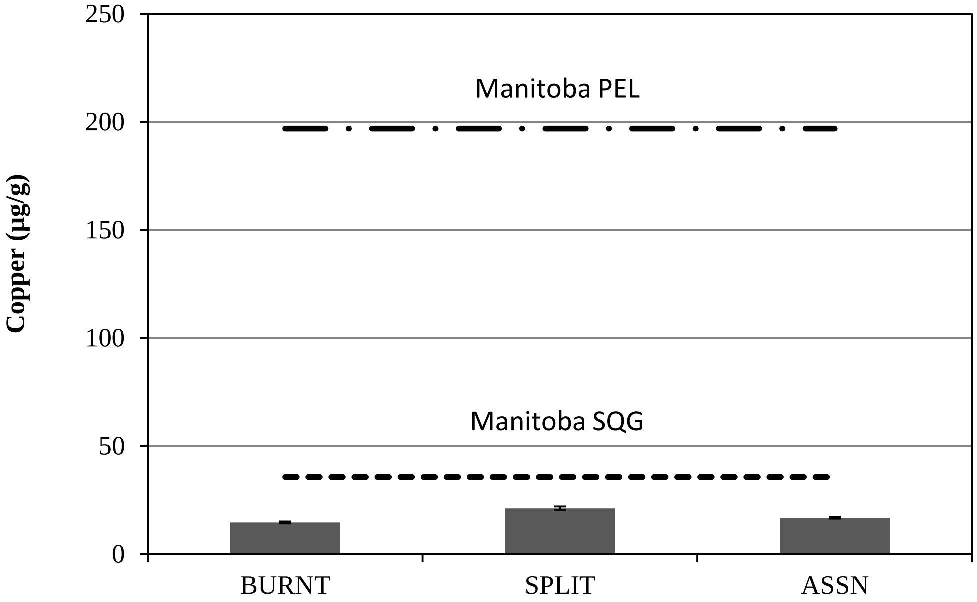


Figure 4-9. Mean (±SE) concentrations of copper in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines.

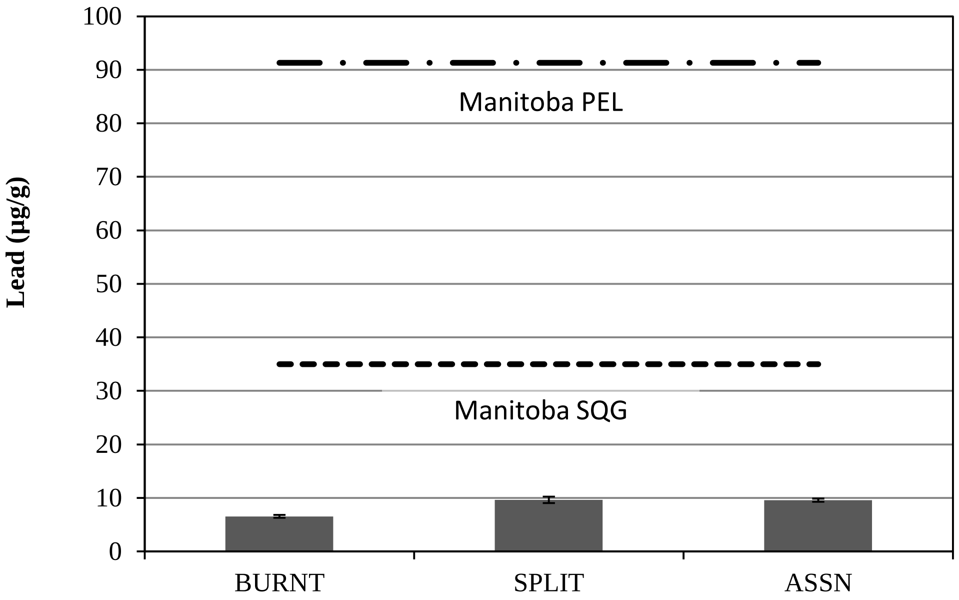


Figure 4-10. Mean (±SE) concentrations of lead in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines.

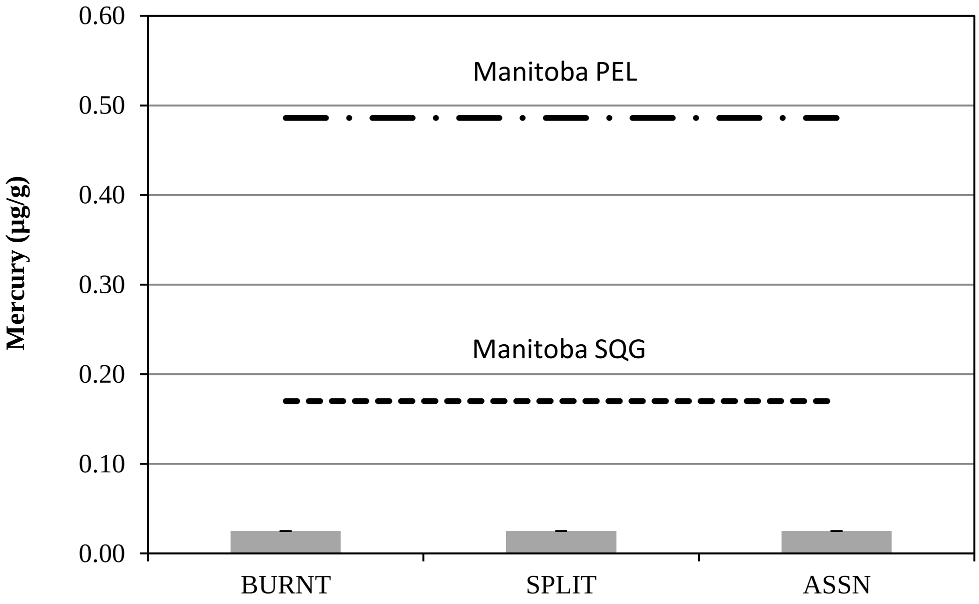


Figure 4-11. Mean (±SE) concentrations of mercury in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines. All measurements were below the analytical detection limit (0.05 µg/g).

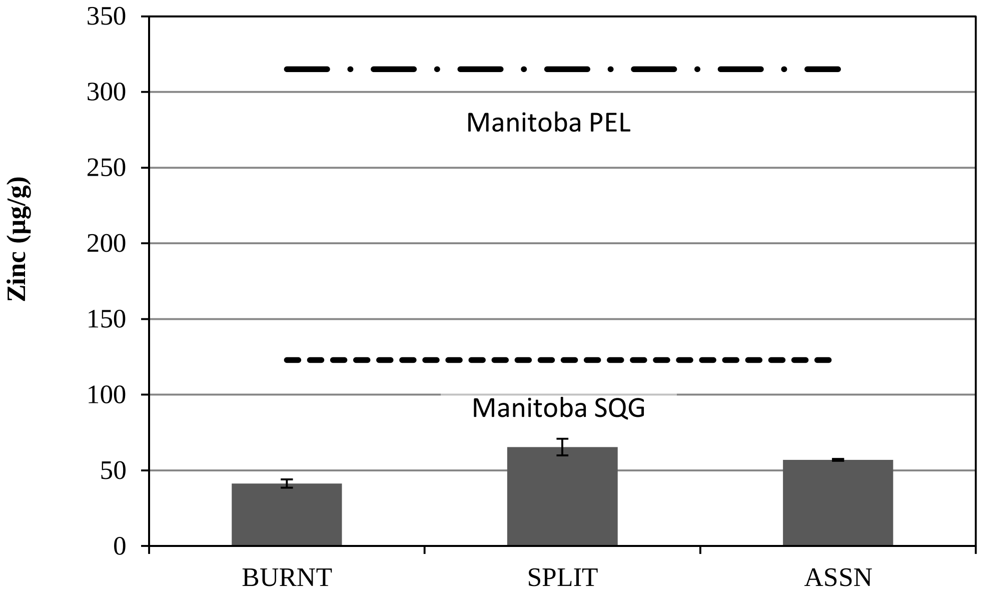


Figure 4-12. Mean (±SE) concentrations of zinc in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Manitoba sediment quality guidelines.

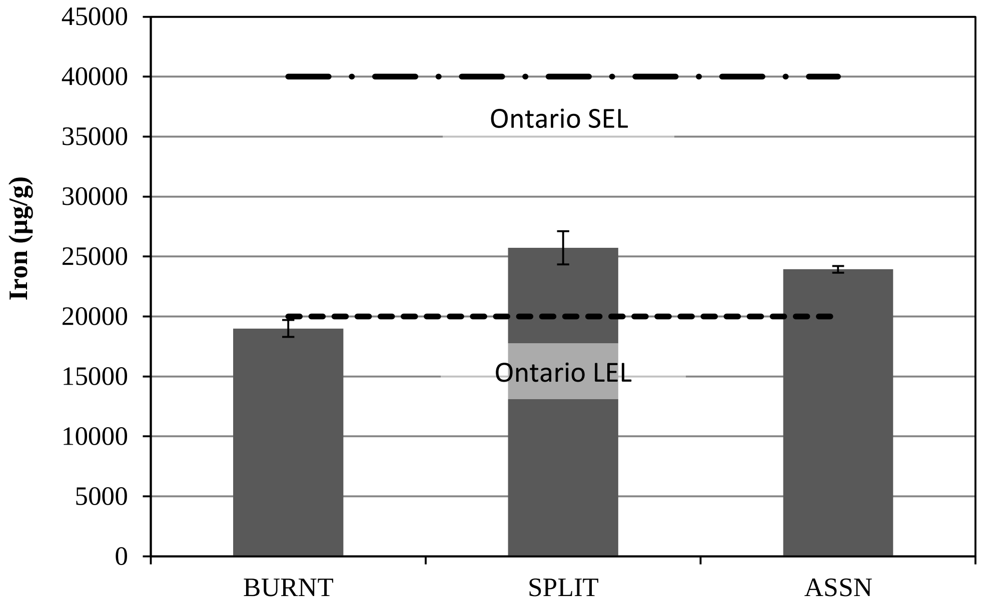


Figure 4-13. Mean (±SE) concentrations of iron in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Ontario sediment quality guidelines.

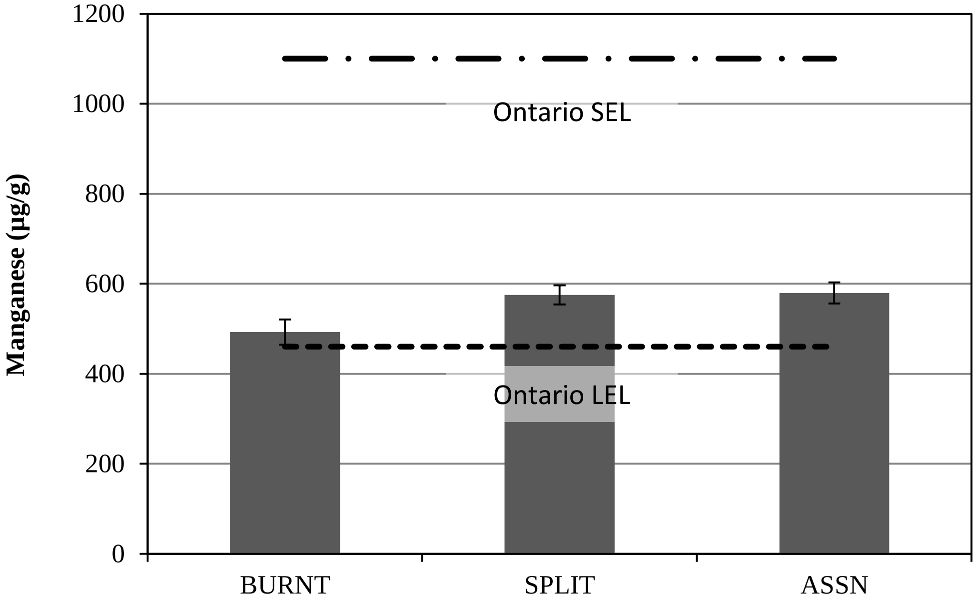


Figure 4-14. Mean (±SE) concentrations of manganese in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Ontario sediment quality guidelines.

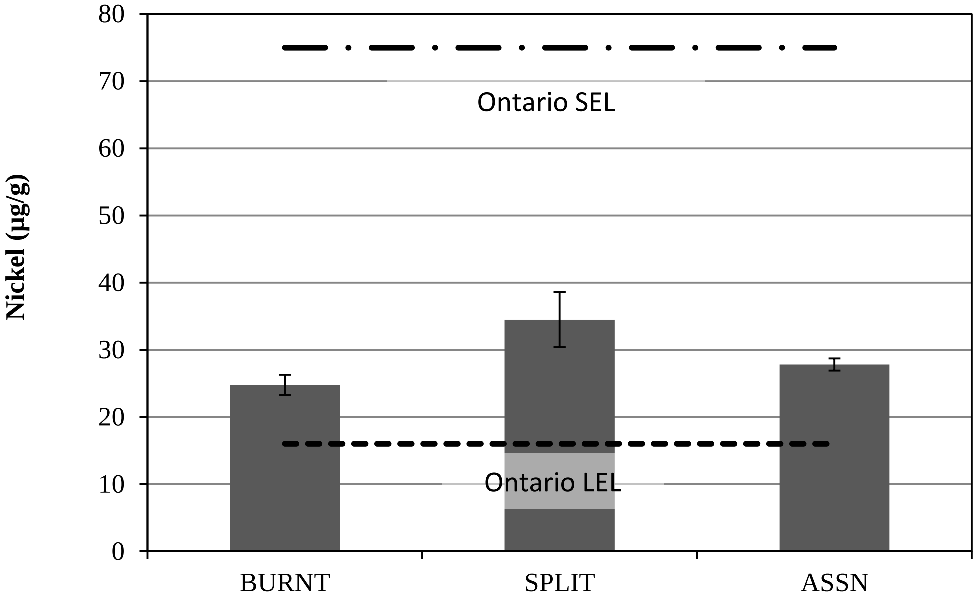


Figure 4-15. Mean (±SE) concentrations of nickel in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to Ontario sediment quality guidelines.

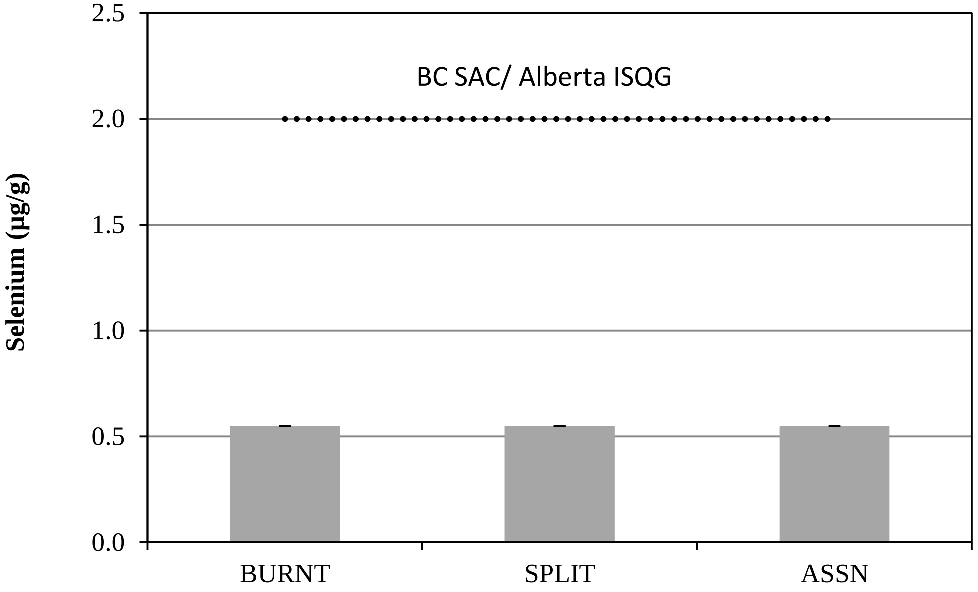


Figure 4-16. Mean (±SE) concentrations of selenium in surficial sediment from the Burntwood River (BURNT), Split Lake (SPLIT), and Assean Lake (ASSN), and comparison to the BC sediment alert concentration and the Alberta ISQG. Means indicated in light grey were below the analytical detection limit.

5.0 BENTHIC MACROINVERTEBRATES

5.1 INTRODUCTION

The following provides an overview of the BMI community for key metrics measured over 2010-2013 under CAMP in the LNRR. 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 two on-system sites (Split Lake and the lower Nelson River downstream of the Limestone GS) and two off-system sites (Assean Lake and the Hayes River). Four additional on-system waterbodies or areas were sampled on a rotational basis for BMIs, including the Burntwood River (2011), Stephens Lake - South (2012), Stephens Lake - North (2012), and the Limestone Forebay (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 is comprised of sample collection at nearshore (water depth ≤ 1 m, sampled with travelling kick/sweep net) and offshore (water depth 5-10 m, sampled with Ekman/petite Ponar dredge) habitat sites in the late summer/fall within each monitoring waterbody (annual and rotational). Depending on the water level at time of sampling, sample collection in the nearshore habitat could include sites that are periodically dewatered, the frequency and duration of dewatering depending on the elevation along the shoreline where samples were collected in relation to the hydrograph. Offshore habitats were always permanently wetted.

Offshore habitat at the lower Nelson River site cannot be sampled every year due to high water velocity and hard substrate, but sample collection is attempted annually because, at times, flow conditions permit successful sample collection. During the current reporting period, offshore habitat was only sampled in 2010. Offshore habitat in the Hayes River is not included in the sampling program due to high velocity and hard substrate.

5.1.1 Objectives and Approach

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

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

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

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

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

5.1.2 Indicators

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

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

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

5.2 SUPPORTING HABITAT VARIABLES

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

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

5.2.1 Lower Nelson River

Substrate in the nearshore zone of Split Lake, as well as other on-system waterbodies including Stephens Lake-North and Stephens Lake-South and the lower Nelson River, was typically greater than 50% sand; substrate composition was generally similar among sampling years where one location was sampled on several occasions (Figure 5-2). At some locations, large substrates such as cobbles were also present (Table 5-1). The Burntwood River was an exception, in that the nearshore habitat consisted mainly of silt and clay (99%; Figure 5-2). With the exception of the Burntwood River in 2011 and Split Lake in 2012, the TOC content of all sediments sampled was low (less than 2%; Figure 5-3).

The offshore habitats in all on-system waterbodies with the exception of the lower Nelson River were comprised of fine substrates, primarily silt and clay (Figure 5-4). In contrast to upstream on-system waterbodies, the offshore habitat of the lower Nelson River consisted mainly of sand (93%; Figure 5-4). The TOC content of all sediments sampled was low (approximately 2% or less; Figure 5-5).

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

The nearshore habitat of Assean Lake typically consisted of large, hard substrate (mainly cobble/boulder); as such sediment samples were only successfully collected for laboratory analysis in 2010 and 2013; those samples consisted predominantly of sand (greater than 85%; Table 5-1 and Figure 5-2). Hayes River sediments largely consisted of sand (greater than 80%), with the exception of 2013 when no sediment samples were collected for analysis due to the predominance of gravel substrate (Table 5-1 and Figure 5-2). The TOC content of Assean Lake (approximately 1%) and Hayes River (less than 0.5%) sediments was low (Figure 5-3).

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 Lower Nelson River

The mean total abundance of BMIs in nearshore habitat varied over eight-fold among locations and among years at annual locations (e.g., Split Lake, the lower Nelson River; Figure 5-6).

Total abundance of BMIs in the nearshore habitat of Split Lake was lowest in 2010 and highest in 2012, with 2011 and 2013 intermediate (Figure 5-6). However, abundance was only statistically significantly higher in 2012 than in 2010. The BMI community was quite variable during this period, and changes in abundance did not reflect changes in community composition. In most years, non-insects comprised over 50% of the fauna (in 2012 they only comprised 44% of the total). Amphipoda were consistently the most abundant group, although in several years Ephemeroptera were also abundant. Oligochaeta and Chironomidae were the other common groups. In 2011, when sampling occurred high on the shoreline, Amphipoda comprised 75% of the fauna, Chironomidae and Corixidae dominated the insects, and Ephemeroptera were almost absent. In 2012, when sampling was lowest on the shoreline, Ephemeroptera were more abundant than Chironomidae, and small numbers of Bivalvia, specifically Pisidiidae, were present. Ephemeroptera were represented by one species of the free swimming Caenidae and two species of burrowing Ephemeridae. These groups are typical of a sandy substrate with varying amounts of finer material.

Results for the lower Nelson River were as variable as Split Lake, with 2010 again being the year of lowest abundance and 2012 being the highest (Figure 5-6). In the lower Nelson River, 2011 was intermediate and 2013 was also very low, with statistically significant differences between 2012 and each of 2010 and 2013. Due to large differences in flows, sampling in 2011 was much higher on the shoreline, while 2012 was the lowest and 2010 and 2013 were intermediate (Table 5-1). Although substrates were generally sandy loam, the sampling location in 2011 also included cobble (Table 5-1). Overall, insects were relatively more abundant than non-insects (except in 2011 when they were present in approximately equal numbers). Unlike upstream locations, Oligochaeta were generally the most abundant non-insect and Amphipods were uncommon. Chironomidae and Corixidae were generally the most common insects and Ephemeroptera were relatively uncommon.

The Burntwood River nearshore was only sampled in 2011, at which time abundance in the nearshore was somewhat higher than in both Split Lake and the Nelson River (Figure 5-6). Roughly two-thirds of the invertebrates in samples were non-insects. Amphipods were abundant (53% of all invertebrates). The most abundant insects were Corixidae and Chironomidae, and Oligochaeta were also relatively common. Because habitat conditions such as substrate (silt/clay vs sandy loam) were very different from the Nelson River, it is not possible to determine whether the difference in the BMI between these two riverine sites was due to substrate as opposed to the water regime.

Abundance in the nearshore was low in the two on-system rotational lacustrine waterbodies. Abundances in Stephens Lake in both the north and south (river channel) locations were much lower than in Split Lake when all sites were sampled in 2012 (Figure 5-6). Substrate at both Stephens Lake sites was sand/gravel (Table 5-1) but the BMI composition differed markedly, with the southern site dominated by Oligochaeta (45%) with smaller numbers of Chironomidae and Ephemeroptera (primarily Heptageniidae). In the northern part of the lake, Chironomidae made up more than three-quarters of the sample (77%), and Oligochaeta were the most common non-insect (comprising 14% of the sample).

Abundance in the Limestone Forebay was lower than Split Lake but comparable to the lower Nelson River when the same years were compared (Figure 5-6). Chironomidae and Corixidae comprised the majority of the BMI in both years of sampling.

The mean density of BMIs in offshore habitat in Split Lake varied among years, but was highest in 2013 (Figure 5-7). BMI density in Split Lake was notably higher than all of the on-system waterbodies except Stephens Lake South (sampled in 2012). Non-insects generally were somewhat more abundant than insects. Amphipoda, Bivalvia, and Ephemeroptera each comprised more than 10% of the fauna in each year, while the densities of Gastropoda and Chironomidae were much more variable (e.g., Gastropoda comprised 3% of the catch in 2012 and 43% in 2013). The higher abundance of BMI in Split Lake and Stephens Lake South than other lake sites (including off-system Assean Lake) was not due to differences in substrate particle composition or TOC content (which were similar); however, chlorophyll concentrations were notably higher (Section 3), suggesting that overall productivity may be greater.

Offshore habitat in the lower Nelson River was only sampled in 2010; in that year abundance was less than half of Split Lake and comprised primarily of Oligochaeta, Chironomidae, and Trichoptera. Density at the other river site, the Burntwood, was much lower and Chironomidae and Trichoptera dominated the catch. Abundance in the Limestone Forebay was lower than Split Lake but comparable to the lower Nelson River when the same years were compared. Chironomidae, Ephemeroptera and Trichoptera comprised much of the catch in both 2010 and 2013, while Bivalvia were abundant in 2010 and Oligochaeta in 2013. The composition of the catch in the southern and northern basins of Stephens Lake was notably different: Amphipoda comprised half the catch in the south, with Chironomidae and Ephemeroptera comprising most of the remainder, while in the north Ephemeroptera comprised half the catch with Chironomidae and, to a lesser extent, Oligochaeta comprising most of the remainder. In all waterbodies, the Ephemeroptera in the offshore were primarily the burrowing Ephemeridae, which are typical of a fine-textured substrate.

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

The mean abundance of BMIs in the nearshore habitat of Assean Lake was within the range of abundances observed in Split lake but the temporal pattern was different: the peak abundance observed in 2010 was significantly higher than the lowest abundance observed in 2011, and 2012 and 2013 were intermediate (Figure 5-6). The nearshore habitat of Assean Lake consisted of cobble/boulder in comparison to the sandy substrate of the on-system lakes (Table 5-1). The relative abundance of insects and non-insects varied, with insects dominating in 2010 and 2011, and non-insets dominating in 2012 and 2013. The composition was extremely variable, with Amphipoda being the only group that was consistently abundant (comprising at least 15% of the fauna each year). Oligochaeta, Chironomidae, Ephemeroptera, and Corixidae all comprised > 10% of the catch in some years (e.g., Ephemeroptera relative abundance varied from 2-42% among years).

For the Hayes River, mean total abundance followed a pattern dissimilar to the lower Nelson River; mean abundance in the Hayes River was higher in 2010 and 2013 and lower in 2011 and 2012 (Figure 5-6). The proportion of insects was consistently much higher than the proportion of non-insects. Corixidae comprised the majority of the catch in 2010, while in the other years Corixidae, together with Chironomidae and Ephemeroptera were the dominant groups, although Oligochaeta and Bivalvia made up greater than 10% of the fauna in some years.

The mean density of BMIs in the offshore habitat of Assean Lake was substantially lower than Split Lake and Stephens Lake-South (2012), but comparable to other on system waterbodies (Figure 5-7). Ephemeroptera and Bivalvia were consistently present in substantial numbers, comprising 37-66% and 21-36% of the total catch, respectively. Chironomidae comprised a substantial portion of the catch in all years except 2012.

5.3.1.3 Temporal Comparisons and Trends

Benthic invertebrates in the nearshore were more abundant in on-system waterbodies (Split Lake and Nelson River) in 2012 than in other years. In off-system waterbodies, abundance was lowest in Assean Lake in 2011 and highest in 2010. No marked difference was apparent in the Hayes River (Figure 5-6).

In the offshore environment, abundance was significantly greater in Split Lake in 2013. Although the magnitude of the difference was small, abundance was also significantly higher in Assean Lake in 2013.

There were no indications of increasing or decreasing trends over the four year sampling period at sites sampled annually.

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

5.3.2 Ratio of EPT to Chironomidae

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

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

5.3.2.1 Lower Nelson River

The mean ratio of EPT to Chironomidae in nearshore habitat of Split Lake was greater than one (1.0-2.5) in all years except for 2011, when it was less than one (Figure 5-8). The ratio was less than one in all other on-system water bodies with the exception of Stephens Lake–South (ratio of one), indicating that Chironomidae were relatively more abundant than EPT. Typically, Chironomidae 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, being capable of colonizing bare substrates within a month (Fisher and Lavoy 1972; Scheifhacken et al. 2007).

In the offshore environment, EPT were relatively more abundant than Chironomidae in Stephens Lake-North, the Limestone Forebay (2013) and most notably, Split Lake (in particular in 2011) (Figure 5-9).

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

With the exception of 2011 (ratio of 0.6), the mean EPT:C in the nearshore habitat of Assean Lake was greater than 1 (ratio of 1.3-15.7) and notably higher than all on-system waterbodies in 2010 (Figure 5-8). The nearshore of Assean Lake consisted mainly of boulder with cobble which is suitable for several families of Ephemeroptera. For the Hayes River, mean EPT:C ratio was typically greater than 1 (with the exception of 2013).

Similar to the majority of on-system waterbodies, EPT:C in the offshore habitat of Assean Lake was greater than 1 (Figure 5-9).

5.3.2.3 Temporal Comparisons and Trends

No consistent inter-annual differences in EPT:C were apparent. The EPT:C ratio in the nearshore of Split Lake was lower in 2011 and higher in 2013 (Figure 5-8). In the offshore the opposite was apparent, with EPT:C being highest in 2011 compared to other years (Figure 5-9).

In Assean Lake, the ratio in the nearshore was notably higher in 2010 than the other years, although only the difference to 2010 and 2013 was statistically significant. In the offshore, 2012 had a notably higher ratio than other years. In the lower Nelson River nearshore EPT:C also varied but the magnitude of the difference was small.

However, no long term temporal trend was apparent. The potential relation to water levels is discussed in Section 5.5.

5.3.3 Total Richness

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

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

5.3.3.1 Lower Nelson River

Mean total richness (family-level) in nearshore habitat in on-system waterbodies generally ranged between approximately 10-15 families (Figure 5-10). Richness in the nearshore was marginally higher in Split Lake in 2012 and in the lower Nelson River in 2011, compared to other years in the same waterbody. Richness in the offshore was generally lower, with fewer than ten families typically represented (Figure 5-11). No inter-annual differences were noted.

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

The mean total richness of BMIs in the nearshore of Assean Lake was higher than the on-system waterbodies (Figure 5-10). In the offshore of Assean Lake, richness was lower than in nearshore habitat, and was marginally lower than in Split Lake (Figure 5-11).

Richness in the Hayes River nearshore was notably higher than in the Nelson River in 2011 and 2012, but numbers in 2010 and 2013 were comparable (Figure 5-10).

5.3.3.3 Temporal Comparisons and Trends

Total taxonomic richness exhibited notable inter-annual variability, including statistically significant differences (Figures 5-10 and 5-11). However, there were no indications of increasing or decreasing trends over the four-year sampling period at sites sampled annually. The potential relation to hydrology is discussed in Section 5.5.

5.3.4 Ephemeroptera, Plecoptera, and Trichoptera Richness

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

5.3.4.1 Lower Nelson River

EPT richness tended to follow the same pattern as richness but given the small number of species present, differences among sites or sampling times are of small magnitude (Figures 5-10 and 5-11).

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

The mean EPT richness in the nearshore habitat of Assean Lake was very similar among years and was higher than the number of taxa observed in on-system lakes (Figure 5-10). For the Hayes River, EPT richness varied among years but was also higher in comparison to nearshore on-system river sites.

5.3.4.3 Temporal Comparisons and Trends

EPT richness exhibited similar between-site and year differences as observed for total richness, although there were fewer significant differences as overall variability was lower.

5.3.5 Simpson's Diversity Index

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

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

5.3.5.1 Lower Nelson River

Simpson’s Diversity Index for the nearshore BMI community ranged from approximately 0.5 to 0.8 among on-system sites for all sampling periods (Figure 5-12). Although the difference was not statistically significant, diversity in 2011 at Split Lake was noticeably lower than in other years. Relatively low diversity was also noted for Stephens Lake North (2012) and the Limestone Forebay (2010 only).

Diversity in offshore habitat also ranged from approximately 0.5 to 0.8 among on-system sites for all sampling periods (Figure 5-13).

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

Simpson’s Diversity Index for the nearshore community in Assean Lake ranged from 0.7-0.8, which was higher than Split Lake in some years (e.g., 2011; Figure 5-12). Diversity was marginally lower in the offshore when compared with nearshore, and, in 2012, was significantly lower than most of other survey years (Figure 5-13).

Diversity in the Hayes River was more variable than other locations, and 2010 was notably lower than other years, although only the difference between 2010 and 2012 was statistically significant (Figure 5-12).

5.3.5.3 Temporal Comparisons and Trends

There were few notable or significant differences among years and no indication of temporal trends. The potential relation to hydrology is discussed in Section 5.5.

5.4 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

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

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

5.4.1 Ephemeroptera Richness

5.4.1.1 Lower Nelson River

Mean Ephemeroptera richness (genus-level) in nearshore habitat ranged from 1-5 genera and thus the magnitude of differences among sites and years was small (Figure 5-14). This was even more pronounced in the offshore, where most sites averaged only one species (Figure 5-15).

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

The mean Ephemeroptera richness in the nearshore habitat of Assean Lake was marginally higher (3-6 genera) than lakes along the lower Nelson River (Figure 5-14), while it was comparable in the offshore environment (Figure 5-15). Mean nearshore richness of Ephemeroptera was greater in the Hayes River than in all other waterbodies.

5.4.1.3 Temporal Comparisons and Trends

Due to the small number of genera, the magnitude of differences among sites and years is small, so trends could not be identified.

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 LNRR Waterbodies, 2010-2013

Water levels on Split Lake were above average for all sampling years 2010 to 2013 except for May to early-June in 2010 and 2012, when water levels dropped to average or slightly below. Water levels began rising in June, and in all years except 2012, BMI collection occurred when water levels were still rising, and well above upper quartile levels (record levels occurred in 2011). In contrast, 2012 levels at the time of sample collection were at upper quartile levels and had been relatively constant from late June to the time of sampling in late August. The greatest range in lake level during one growing season occurred during 2010, when water level rose ~2 m from the low in May to the time of sampling in late August. Therefore, nearshore BMI samples were collected once under high water levels (2011), once under relatively constant levels (2012), and twice during periods of increasing water level through the open water season (2010 and 2013). In all cases the nearshore zone would have been dewatered during the winter months.

In contrast to Split Lake, water levels on Stephens Lake are regulated by the Kettle GS. BMI collection occurred in late August 2012. During 2012, water levels in Stephens Lake reached a minimum of ~139 m ASL in late May, before increasing and varying between 140-141 m ASL until late July when levels remained at the full supply level ~141 m ASL through August.

Water levels in the Limestone Forebay are also regulated but tend to vary more frequently, over a smaller range (0.7 m), than Stephens Lake. In 2010 and 2013, when BMI sampling occurred, water level in the reservoir generally ranged 0.5 m throughout the open water season.

The water regime in the Nelson River downstream of the Limestone GS is complex due to the combined effects of natural inflows, seasonal flow regulation, and weekly and daily cycling at the Limestone GS. From 2010 to 2013, flow at the Kettle GS, which is a reasonably proxy for flow at the Limestone GS, was mainly above average during the open-water seasons and peaked well above the upper quartile in each year except 2012. Record flows were also reached in late 2010 and parts of the 2011 open-water period. The only time when the Kettle GS flows were steadily below average was for a brief period in May to early June 2010 and 2012.

Although water level measurements are not available for the BMI sampling site in the lower Nelson River, water level measurements in a borehole at the Conawapa site provide a relative indication. Water levels were high and relatively constant during the 2011 open water season. In 2010, 2012, and 2013, water levels were low in May and began to rise in June. The increase continued to the end of August sampling period in 2010 and 2013 but levelled off in 2012 so that at the time of sampling, the nearshore had been wetted for most of the growing season. The BMI site would also be affected by daily water level cycling but direct information is not available. However, water level variation on the Limestone Forebay suggests that during the open water season little cycling occurred in 2011, and that cycling did occur during 2010, 2012 and for June and July in 2013.

BMI were also sampled upstream of Split Lake in the Burntwood River in 2011. Flows were high in the river over winter but discharge at the Notigi CS was cut back during the open water season due to high flows on the Nelson River. Flows were constant through the open water season, suggesting that the nearshore BMI site was wetted throughout the growing season as well as the previous winter.

The water regime at the off-system lakes varied, due to both high and low water conditions. In Assean Lake, water levels declined over winter and reached minimum levels in April/May and then rose with the spring freshet. Lake levels during the open water season were quite variable, likely as a result of local precipitation. Sampling in 2012 and 2013 was conducted in areas that were wetted the entire growing season. In 2010, a small portion of the sampled area was dewatered, while in 2011 much of the nearshore zone would have been dewatered earlier in the growing season. The sample in 2013 would have been at the winter low water level, so invertebrates would not have been dewatered during the winter months.

From 2008 to 2013, the Hayes River flows were fairly similar in the winter and followed a typical pattern for an unregulated river with a slow decline throughout the winter. Flow started to increase in late winter/early spring each year and reached an initial peak in May. Flow for the remainder of the growing season varied among years (no water level data are available). Record low flows occurred until mid-August 2010 before increasing sharply; therefore it is possible that the BMI site was wetted only in late summer. In 2011 and 2012, flows varied during the summer months but the nearshore was likely wetted for much of the time. In 2013 sampling occurred during the lowest flow period, after a flood in spring so the site would have been wetted all year.

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

The period 2010-2013 was characterized by generally above average flow in on-system waterbodies, including record levels in 2010 and 2011. The increases in summer water levels that occurred on Split Lake during 2010-2012 affected the proportion and duration of wetting in the nearshore zone sampled during the BMI program. In 2010, the area sampled only became wetted in late June, in 2011 the area became wetted in May, in 2012 a portion was wetted for the entre open water season and all of it was wetted after late June, and in 2013, as in 2012, the whole area was wetted after late June (see Split Lake water levels Figure 2-3, Section 2.0). However, the elevation at which samples were collected was higher in 2013 than in 2012 (Table 5-1). The nearshore invertebrate community, therefore, is affected on an annual basis by the timing and duration of seasonal wetting. The highest abundance and richness were found in samples collected in 2012, when the area sampled had been wetted the entire growing season and was relatively low on the shoreline. Much of the habitat sampled in 2011 was also wetted for much of the growing season, but lake levels were at record levels and total abundance and diversity were lower, and the EPT:C ratio was very low, indicating that a few groups such as Chironomidae could colonize the infrequently wetted habitat. It is noteworthy that abundance in 2011 was comparable to or greater than 2010 and 2013, when samples were collected within the more typical lake range but the nearshore habitat had been wetted for a shorter period.

Both 2010 and 2013 were sampled at a similar elevation but a drought in spring 2010 temporarily dewatered the area later sampled; the overall abundance in 2010 was much lower than in 2013, but diversity, richness and EPT:C were similar, indicating that all invertebrate groups were able to colonize and/or survive temporary dewatering although productivity was decreased.

The benthic community of the offshore environment did not exhibit a direct relationship to inter-annual variations in water level. Inter-annual variation may be linked to other environmental factors. For example, abundance in 2013 was significantly higher than the other years, which was concurrent with higher concentrations of chlorophyll measured during the water quality program, potentially indicative of greater productivity in that year (Section 3).

The nearshore environment of the lower Nelson River was also sampled annually. Inter-annual differences in abundance followed a generally similar pattern to that observed in Split Lake, reflecting the importance of seasonal discharge. Abundance was highest in 2012, when sampling occurred at a lower elevation in an area that was likely wetted through the growing season (based on borehole data discussed in Section 5.5.1 and elevations in Table 5-1). Sampling at a very high elevation in an area that was wetted for much of the growing season in 2011 yielded abundance less than 2012 but greater than 2010 and 2013. Abundance in 2013 was as low as in 2010, although on average the area sampled would have been wetted for more of the growing season. The difference may be related to the frequency of cycling: although no direct information on the frequency of dewatering as a result of cycling is available, water levels on the Limestone Forebay (Figure 2-5, Section 2.0) suggested cycling during a portion of the growing season in 2013, which may have resulted in the periodic exposure of habitat that would have been wetted at average water levels. Despite variations in the frequency of wetting, there was little variation in richness and diversity, indicating that most taxa were adapted to this variable environment.

Variation in BMI abundance and diversity in the off-system waterbodies also showed the effects of annual variation in water level and flow. However, due to differences in local versus regional hydrology, the timing of high versus low years is markedly different from the on-system waterbodies. In 2011, sampling in Assean Lake occurred as water levels increased, and abundance was much lower than in years when the majority of the sampled area would have been wetted throughout the growing season, although only the difference between 2010 and 2011 was statistically significant (Figure 5-16). In the Hayes River, sampling in 2013 occurred at the lowest elevations in areas that were commonly wetted, yielding the greatest abundance, although the difference was not statistically significant from other sampling years.

Insufficient sampling has occurred on the rotational waterbodies to determine a relationship to hydrology. However invertebrate abundance in Stephens Lake North and South in 2012 was much lower than in Split Lake; examination of the hydrograph indicates that these areas were wetted less than 50% of the growing season. Abundance in the Limestone Forebay was similar between years (2010 and 2013) and comparable to the lower Nelson River; however, as with the lower Nelson River the degree of dewatering is site-specific and difficult to estimate. Only a single year of data is available for the Burntwood River and as noted previously, the habitat is quite different so direct comparisons cannot be made. However, abundance in the nearshore was high, potentially related in part to the continuous wetting experienced through the open water season.

As noted previously, four years of data are insufficient to support a statistical analysis to determine whether average water levels or discharge during the growing season are related to key benthic invertebrate indicators. As discussed above, the duration of wetting/exposure during the growing season immediately preceding sample collection appears to be important in determining invertebrate abundance in nearshore samples as well as affecting species composition. Inspection of key indicators in relation to the average water level and discharge during the growing season during a given year in the two annual lakes does not indicate any obvious relationships (Table 5-2). However, as more data are collected over a greater range of hydrological conditions, a relationship with average conditions may become apparent.

BMI abundance and species composition in the offshore environment is not directly affected by episodic wetting and drying and may, therefore, be more responsive to average conditions during the growing season. Inspection of graphs indicting results for invertebrate abundance, richness, and diversity for Split (Figure 5-16) and Assean (Figure 5-17) lakes does not indicate a relationship, at least within the range of conditions sampled during 2010-2013.

5.6 SUMMARY

In the nearshore of Split Lake, Amphipoda were consistently abundant, along with Oligochaeta, Chironomidae, Ephemeroptera and Corixidae, although the relative abundance of these groups varied among years. The elevation at which sampling was conducted, as well as the duration of watering of the sampling location, appeared to affect both abundance and species composition. Abundance was higher for longer times of watering. Ephemeroptera were relatively less abundant at high elevations and/or shorter periods of watering. When sampling was conducted where habitat was seldom dewatered, groups such as Bivalvia were also present. It should be noted that in years of high water level, BMI abundance at lower elevations may be comparable to that at higher elevations; therefore high water levels may be associated with a net gain in productivity.

Downstream of Split Lake in the nearshore of Stephens Lake, the Limestone Forebay and the lower Nelson River, Amphipoda were relatively uncommon, and Chironomidae, Oligochaeta, and, at some times and locations, Corixidae and Ephemeroptera, were relatively abundant. As with Split Lake, the duration of exposure and elevation affected abundance in BMI samples.

The BMIs in the nearshore of the off-system waterbodies were more diverse, possibly due to the presence of cobble, rather than sand/silt substrates. As with the on-system waterbodies, abundance was affected by the duration of wetting in the nearshore habitat.

Abundance in the offshore environment in Split Lake and Stephens Lake-South was much greater than in other on-system as well as off-system waterbodies. This difference may in part be attributed to generally greater productivity, as chlorophyll concentrations were also greater in these two waterbodies. Richness and diversity were generally lower in the offshore than in the nearshore environment in all waterbodies where sampling occurred in both habitats, suggesting that greater habitat diversity in the nearshore offset potentially negative effects of periodic dewatering.

Overall, analysis of the four years of CAMP BMI monitoring data collected in the LNRR indicated that none of the key metrics, including the additional metric Ephemeroptera richness, have undergone a consistent increasing or decreasing trend over this time period; however, some statistically significant inter-annual variability was observed (e.g., total invertebrate abundance in the nearshore and offshore habitat of Split Lake, EPT:C ratio in Assean Lake). These differences may be related in part to the water regime, in particular the degree of exposure in the nearshore habitat. Significant differences in offshore habitat may be related to other factors (e.g., productivity as indicated by chlorophyll in Split Lake).

Table 5-1. Supporting variables measured in the nearshore and offshore habitats of the Lower 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)
SPLIT	22-Aug-10	0.9	standing	sand, organic matter (clay)	sand (loam, silt)	7.4	standing	clay, shells	silt clay loam	1.27	0.90	168.21	--
LMFB	25-Aug-10	0.9	standing	sand (woody debris, organic matter, boulder)	loam, sand	6.6	standing	clay (sand, silt)	silt loam	2.10	1.74	85.07	--
LNR	28-Aug-10	1.0	standing	sand (organic matter)	sandy loam	4.2	standing	sand, gravel (silt)	sand (loamy sand)	1.59	1.27	--	5038.03
HAYES	27-Aug-10	1.0	low	sand, gravel, cobble	sand (loamy)	--	--	hard substrate; no benthic grabs	--	0.82	0.19	22.12	1640.00
ASSN	21-Aug-10	1.0	standing	boulder, cobble (clay)	sand (loam)	5.6	standing	clay, shells (cobble, woody debris)	loam (silt loam, sandy loam)	1.15	0.43	176.70	--
BURNT	19-Aug-11	1.0	standing	organic matter, clay	silty clay loam	9.0	medium	clay, silt	silty clay loam	1.52	n.r.	--	677.00
SPLIT	16-Aug-11	1.0	standing	sand, organic matter	sandy clay loam	8.4	low	silt (clay)	silty clay loam (silt loam)	0.44	n.r.	168.96	--
LNR	16-Aug-11	1.0	standing	sand, cobble (organic matter, silt)	sand (loam)	--	--	hard substrate; no benthic grabs	--	0.94	0.39	--	6001.38
HAYES	17-Aug-11	1.0	standing	sand, cobble	loamy sand	--	--	hard substrate; no benthic grabs	--	1.57	0.21	20.87	772.00
ASSN	17-Aug-11	1.0	standing	cobble, boulder (bedrock)	--	6.2	standing	clay, silt	clay loam (sandy loam)	0.72	n.r.	177.23	--
SPLIT	21-Aug-12	0.9	standing	organic matter, sand (gravel)	silt, clay, loam	6.2	standing	silt, clay	silt loam	1.67	n.r.	167.62	--
STL-S	23-Aug-12	1.0	standing	sand, gravel	sand	8.7	standing	silt, clay	silt loam	1.66	n.r.	141.03	--
STL-N	26-Aug-12	1.0	standing	sand, gravel	sandy loam (loamy sand)	9.0	standing	silt, clay	silty clay	1.58	n.r.	141.09	--
LNR	21-Aug-12	1.0	standing	silt, sand	loamy sand (sand)	--	--	hard substrate; no benthic grabs	--	3.04	1.77	--	3887.35
HAYES	19-Aug-12	1.0	standing	gravel, cobble (silt)	loamy sand (sand)	--	standing	hard substrate; no benthic grabs	--	2.07	0.94	20.80	733.00
ASSN	22-Aug-12	1.0	standing	boulder, cobble	--	6.1	standing	clay, silt	silt loam (sandy loam)	0.86	n.r.	177.09	--
SPLIT	22-Aug-13	0.9	standing	sand	sand (clay, loam)	7.4	standing	clay	silt loam (silt clay loam)	1.16	0.95	168.15	--
LMFB	24-Aug-13	0.7	standing	cobble, gravel (sand)	loam (silt, sand)	6.7	standing	clay	silt loam	1.91	1.67	85.04	--
LNR	25-Aug-13	0.7	standing	sand (silt)	sandy loam (sand, loam	--	--	hard substrate; no benthic grabs	--	1.60	0.95	--	4857.21
HAYES	26-Aug-13	0.4	standing	gravel	--	--	--	hard substrate; no benthic grabs	--	2.11	1.48	20.10	410.00
ASSN	21-Aug-13	0.7	standing	cobble	sand	5.4	standing	clay (organic matter)	sandy loam (silty clay loam)	1.42	0.87	176.60	--

[1] substrate type and texture: parentheses indicate present to a lesser extent.

[2] -- indicates habitat type not sampled (due to high water velocity) or no sediment sample collected (due to predominantly hard substrate).

[3] Relative water level is the distance up the shore to the benchmark installed for the BMI program.

n.r means data was not recorded.

Table 5-2. Average abundance, total richness, Simpson's Diversity, and hydrological metrics (average water level and discharge for the "growing season") for Split and Assean lakes, 2010 to 2013.

Split Lake

Year	Abundance (Number/Kicknet Or Number/m^2)	Richness	Diversity	Water Level (m ASL)	Discharge (m^3/s)
Nearshore					
2010	286	12.80	0.81	167.6	3938.7
2011	942	13.60	0.49	168.7	5673.2
2012	2145	18.20	0.76	167.2	3500.0
2013	813	14.20	0.66	167.6	4121.7
Offshore					
2010	4917	9.40	0.75	167.6	3922.3
2011	5038	9.40	0.73	168.7	5673.2
2012	2981	7.60	0.74	167.2	3500.0
2013	7978	8.60	0.64	167.6	4121.7

Assean Lake

Year	Abundance	Richness	Diversity	Water Level	Discharge
Nearshore					
2010	2125	18.60	0.71	176.6	no data
2011	459	20.80	0.79	176.9	no data
2012	1410	23.60	0.76	177.3	no data
2013	1733	20.60	0.75	176.8	no data
Offshore					
2010	1094	5.60	0.67	176.6	no data
2011	638	7.00	0.71	176.9	no data
2012	1258	5.80	0.51	177.3	no data
2013	1913	9.60	0.70	176.8	no data

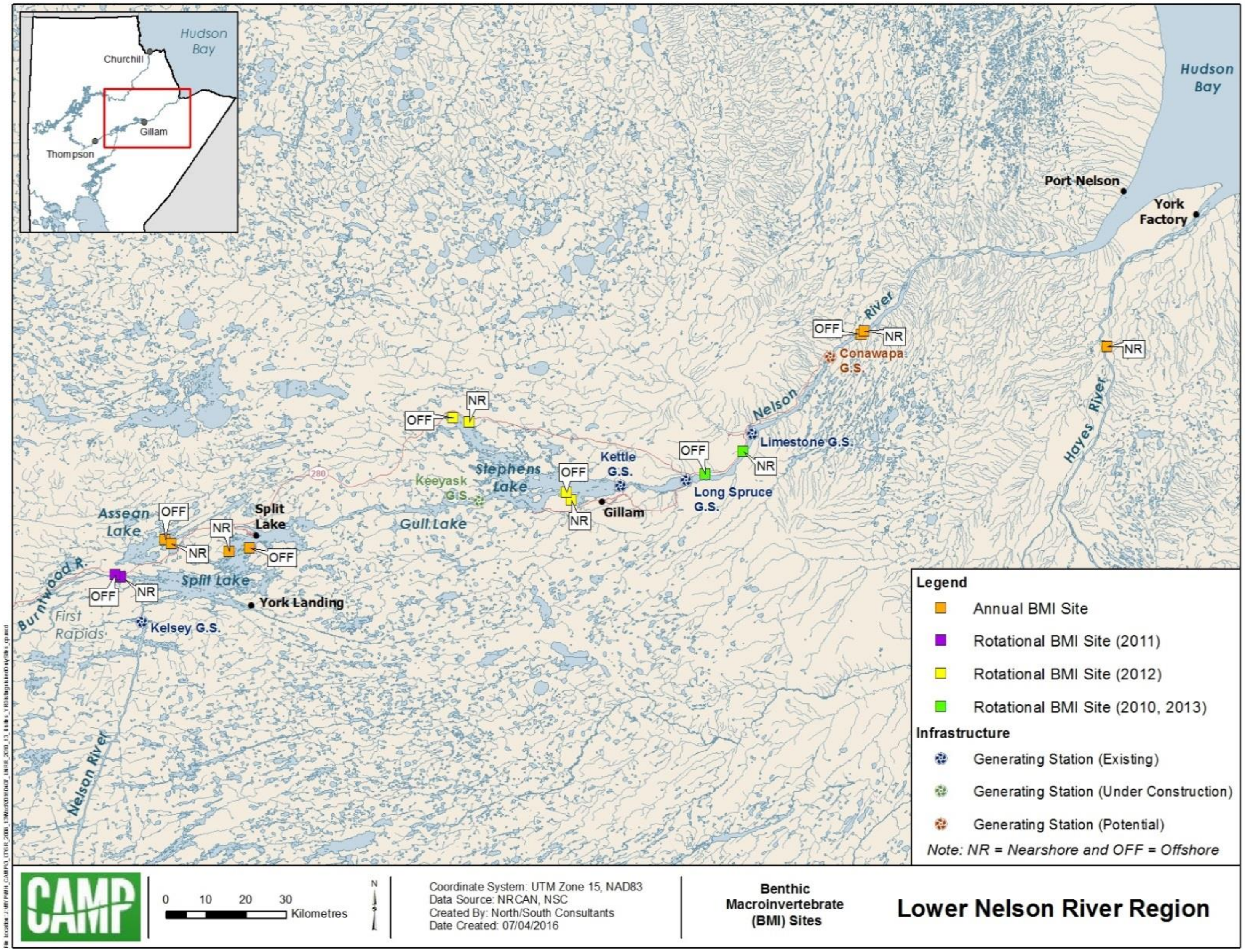
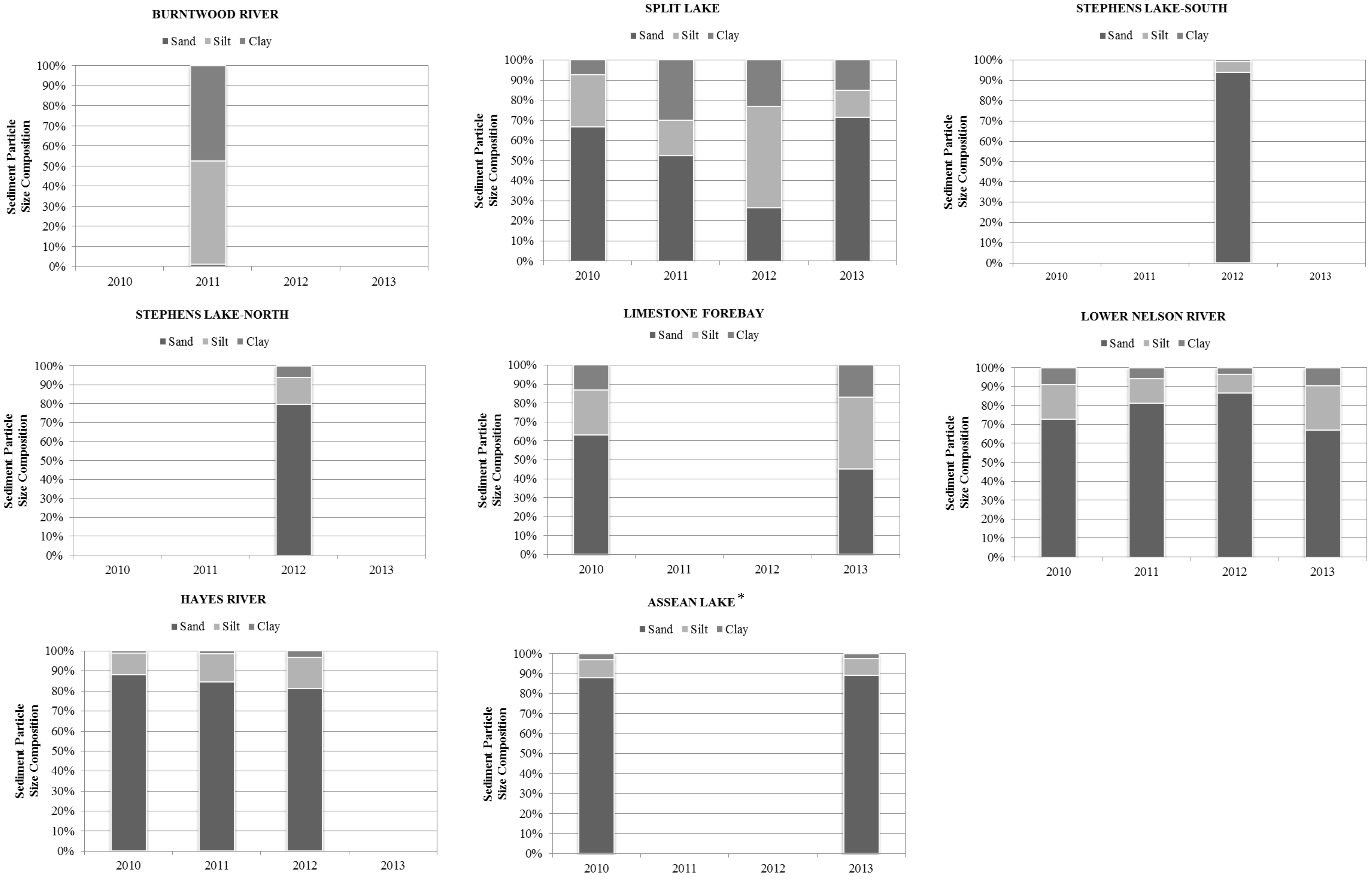
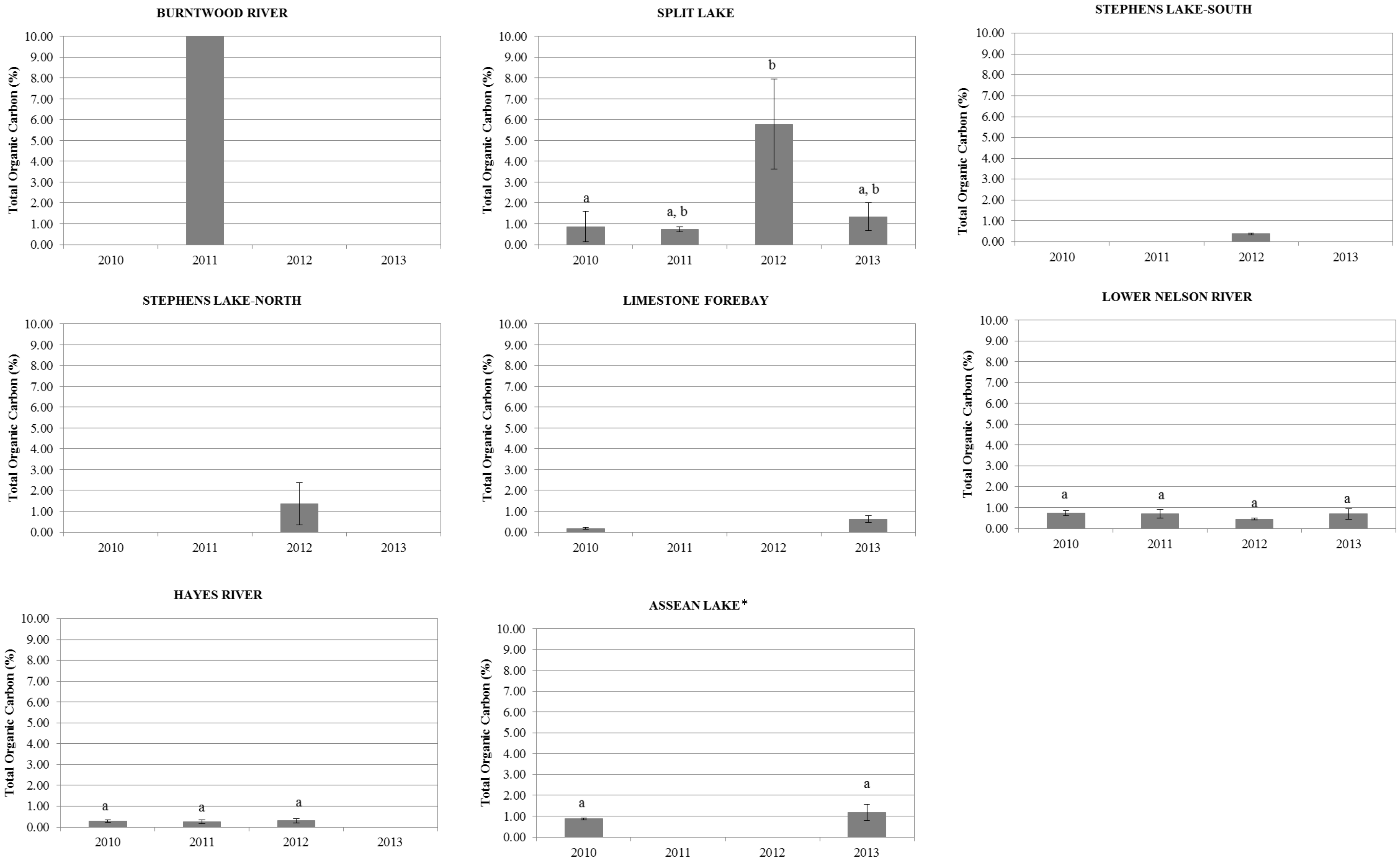


Figure 5-1. Benthic macroinvertebrate sampling sites in the Lower Nelson River Region: 2010 – 2013.



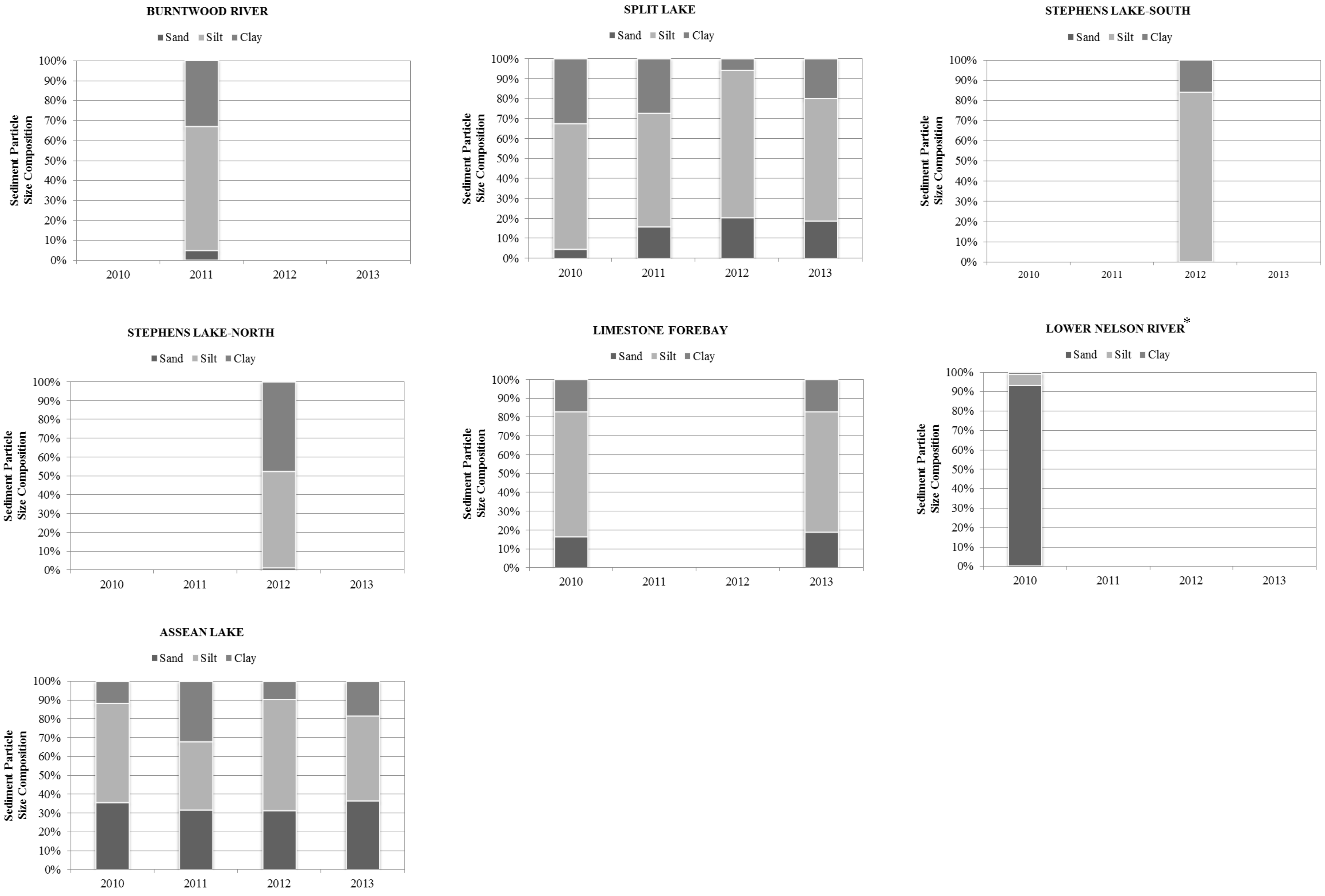
* No sediment samples collected at Assean Lake (2011, 2012) due to predominantly hard substrate.

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



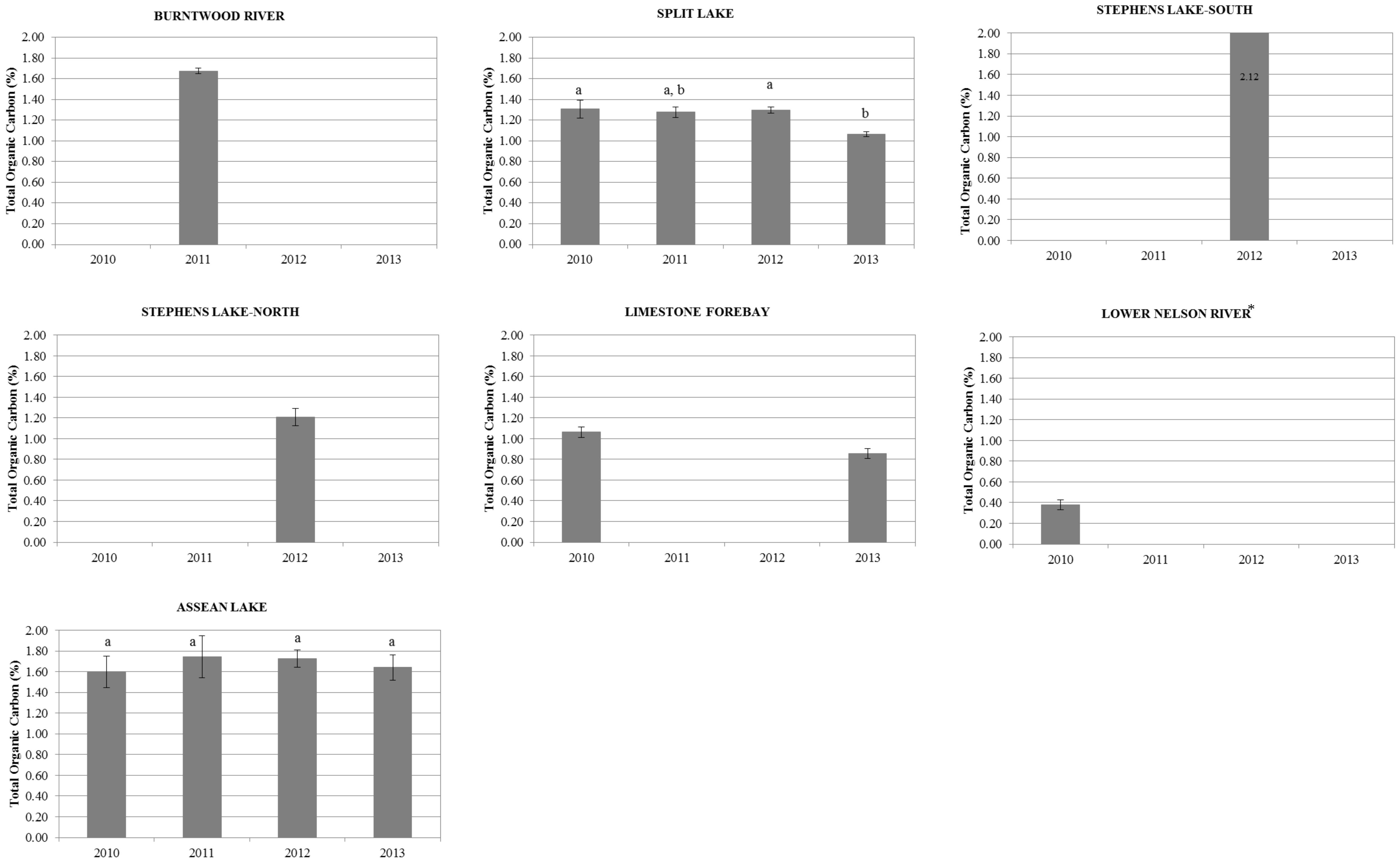
* No sediment samples collected at Assean Lake (2011, 2012) due to predominantly hard substrate.

Figure 5-3. Total organic carbon (mean % ± SE) in the nearshore habitat of the Lower 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.



* No sediment samples collected at the lower Nelson River (2011 to 2013) due to predominantly hard substrate.

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



* No sediment samples collected at the lower Nelson River (2011 to 2013) due to predominantly hard substrate.

Figure 5-5. Total organic carbon (mean % ± SE) in the offshore habitat of the Lower 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.

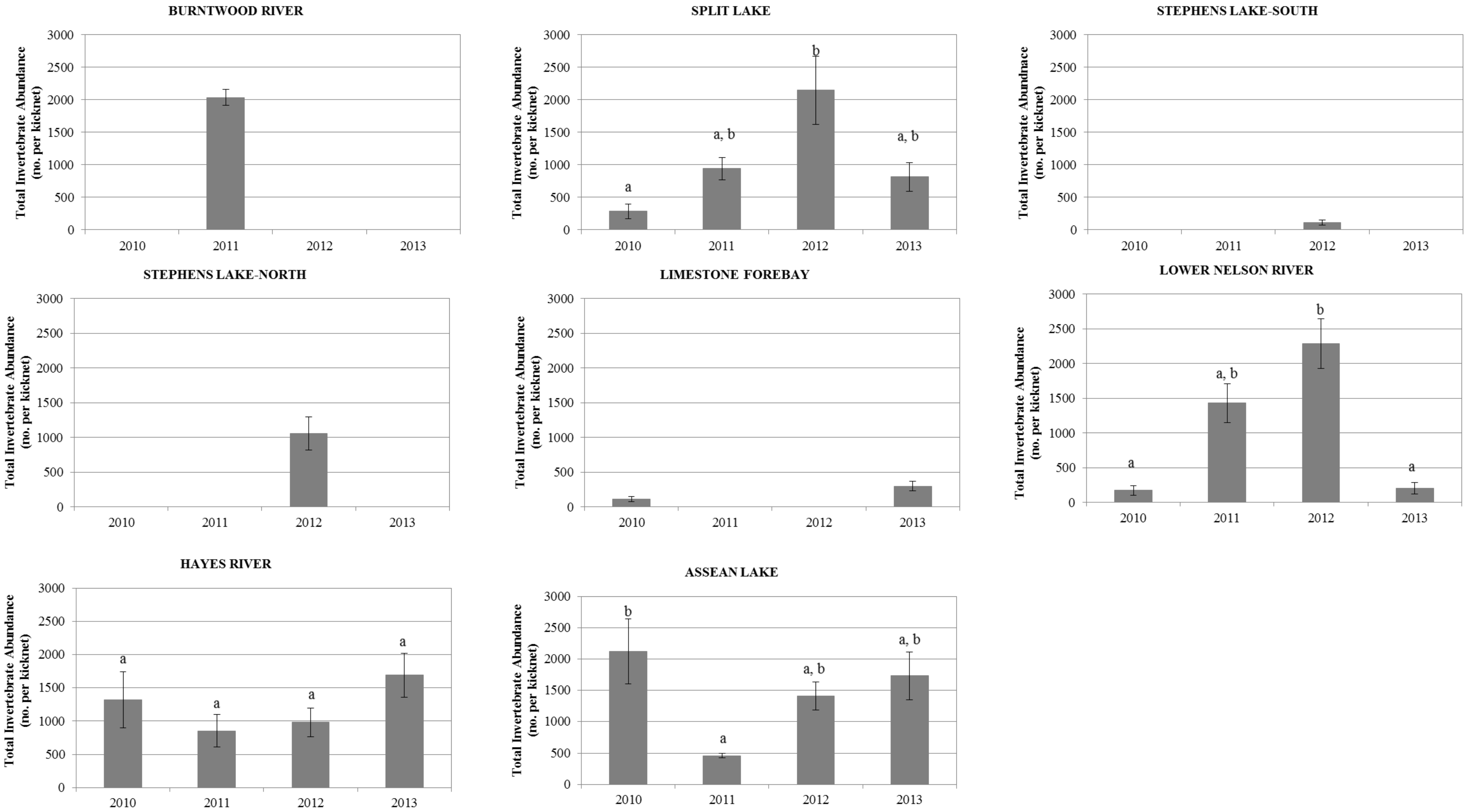


Figure 5-6. Total invertebrate abundance (mean ± SE) in the nearshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

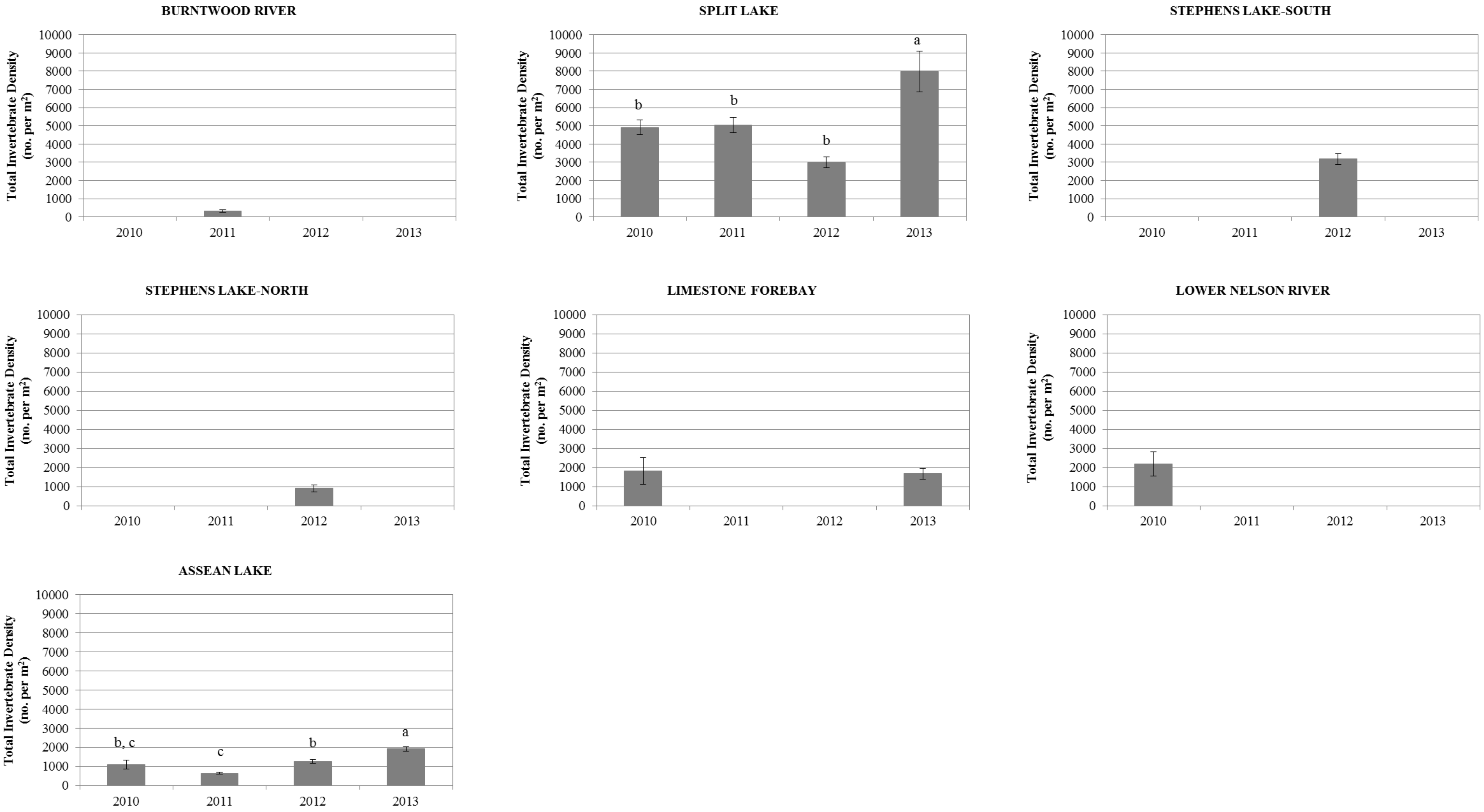


Figure 5-7. Total invertebrate density (mean ± SE) in the offshore of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

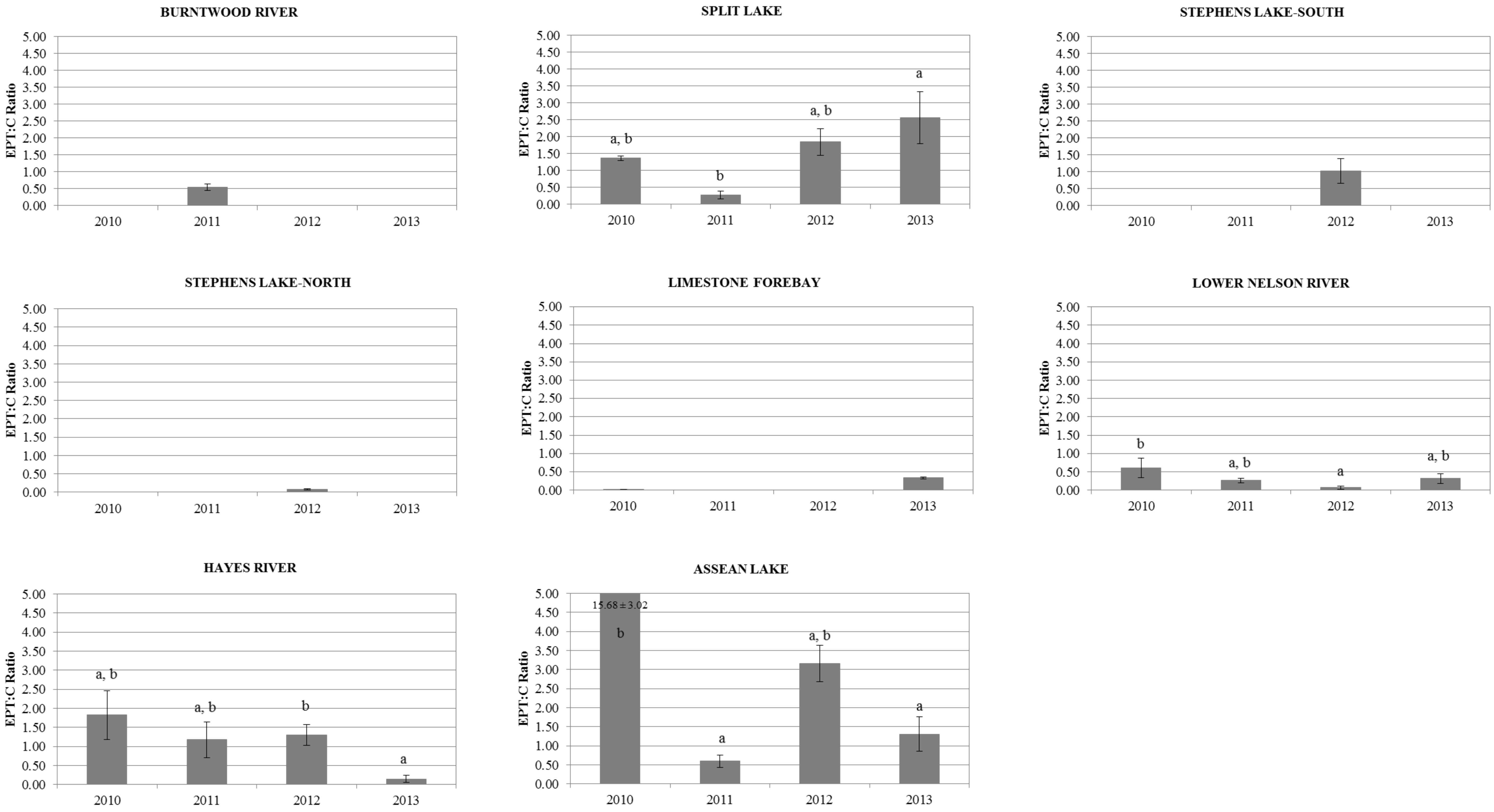


Figure 5-8. EPT:C ratio (mean ± SE) in the nearshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

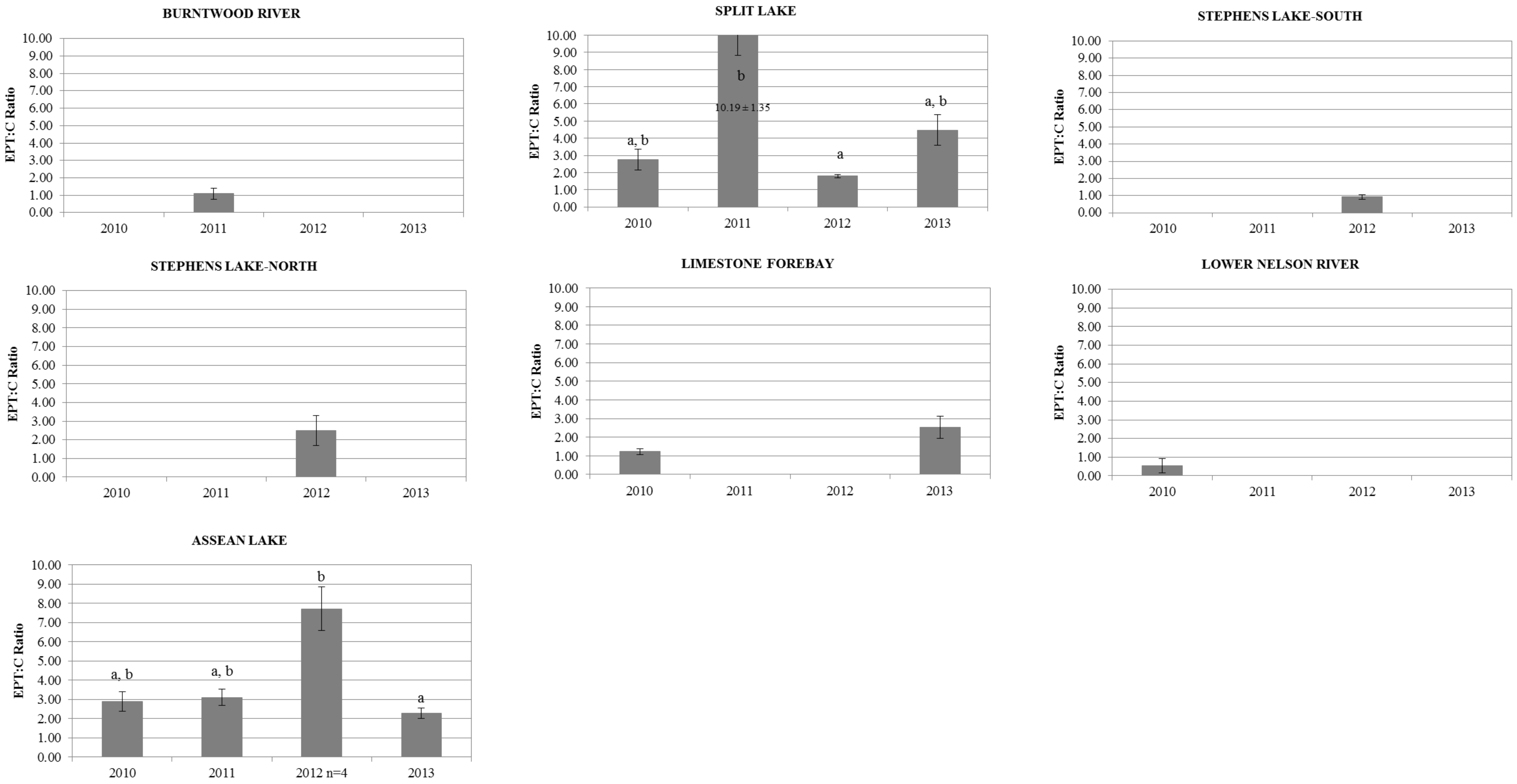


Figure 5-9. EPT:C ratio (mean ± SE) in the offshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant difference.

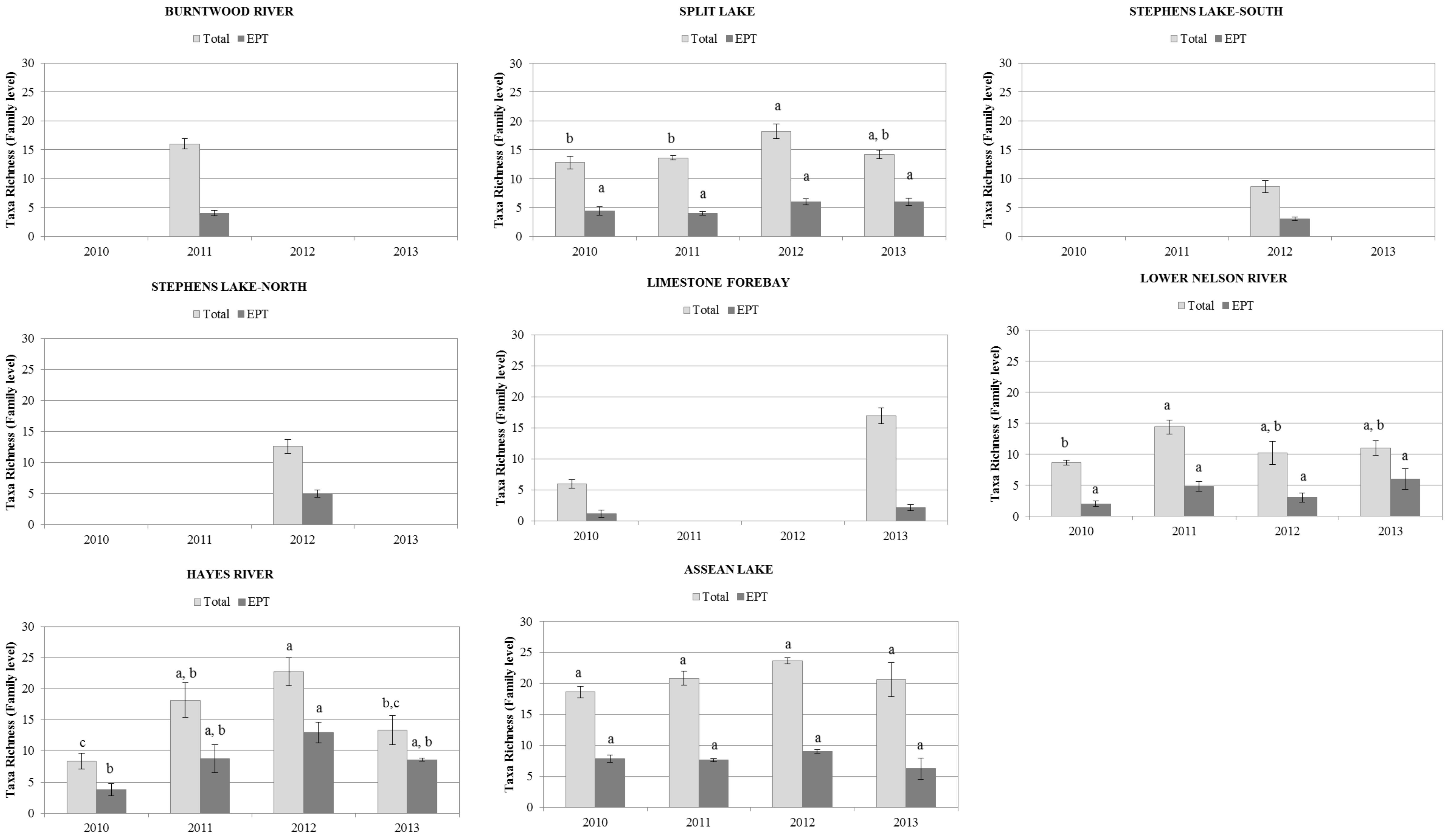


Figure 5-10. Taxonomic richness (total and EPT to family level; mean ± SE) in the nearshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote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

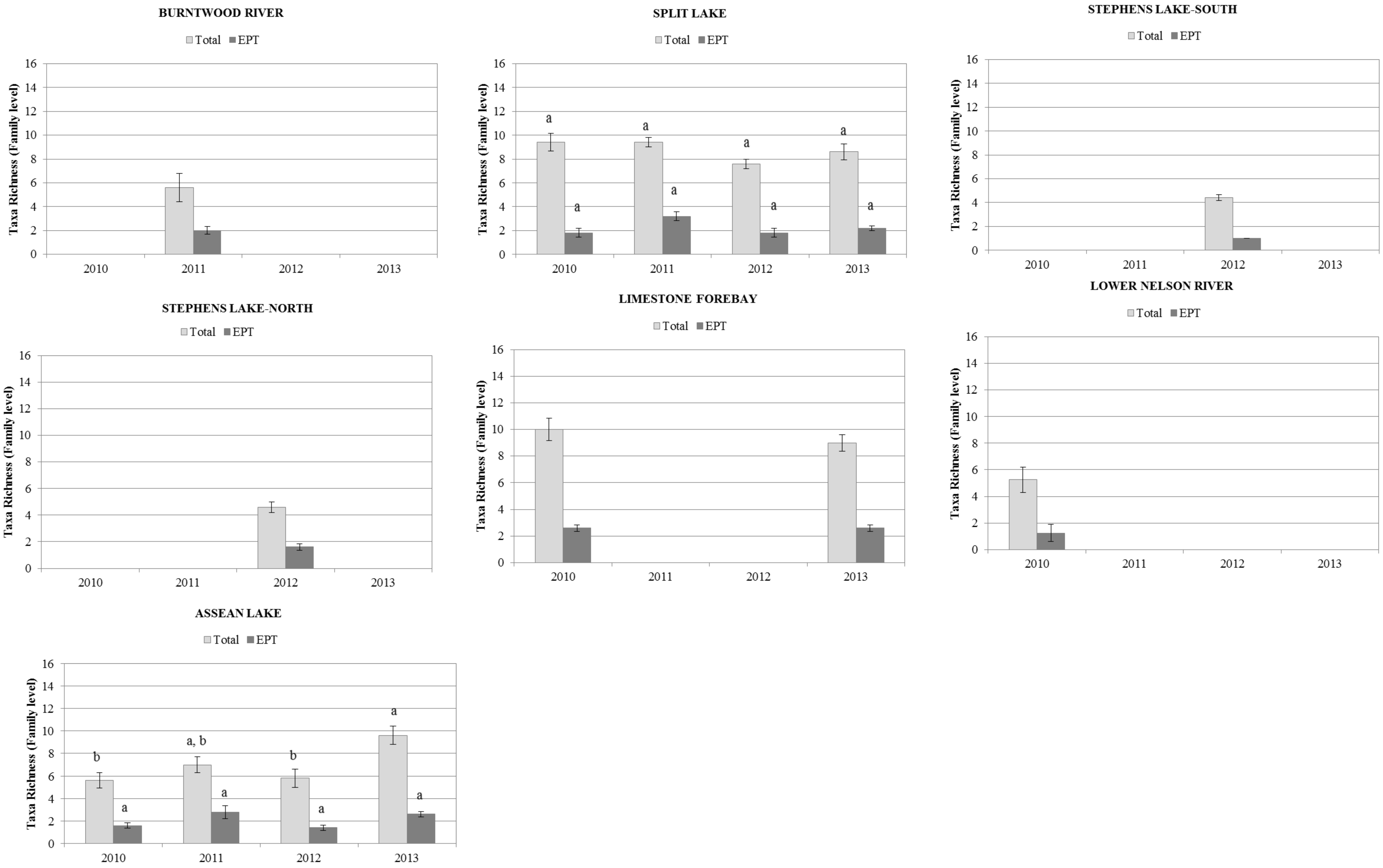


Figure 5-11. Taxonomic richness (total and EPT to family level; mean ± SE) in the offshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote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

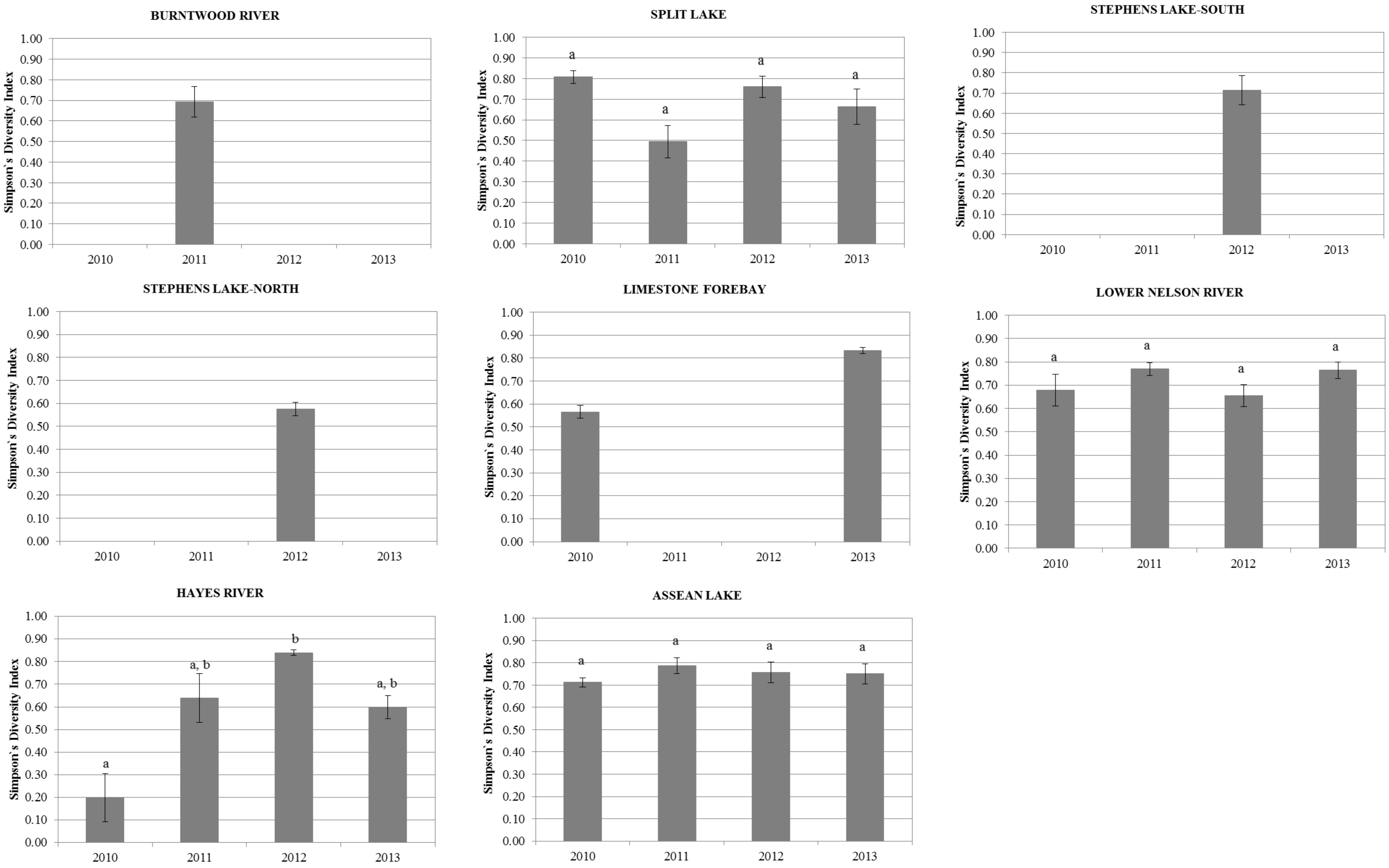


Figure 5-12. Simpson’s Diversity Index (mean ± SE) in the nearshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

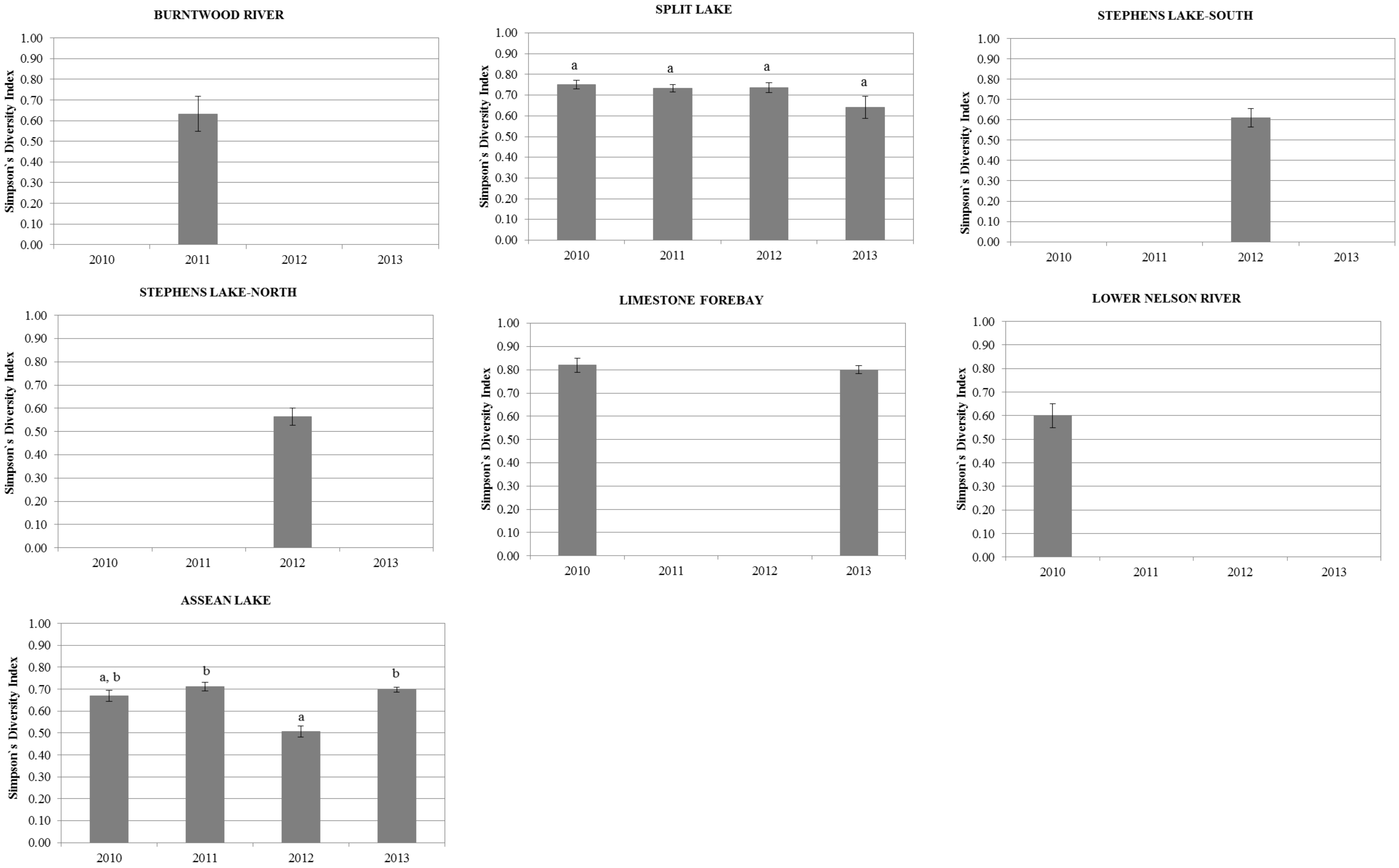


Figure 5-13. Simpson’s Diversity Index (mean ± SE) in the offshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically significant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

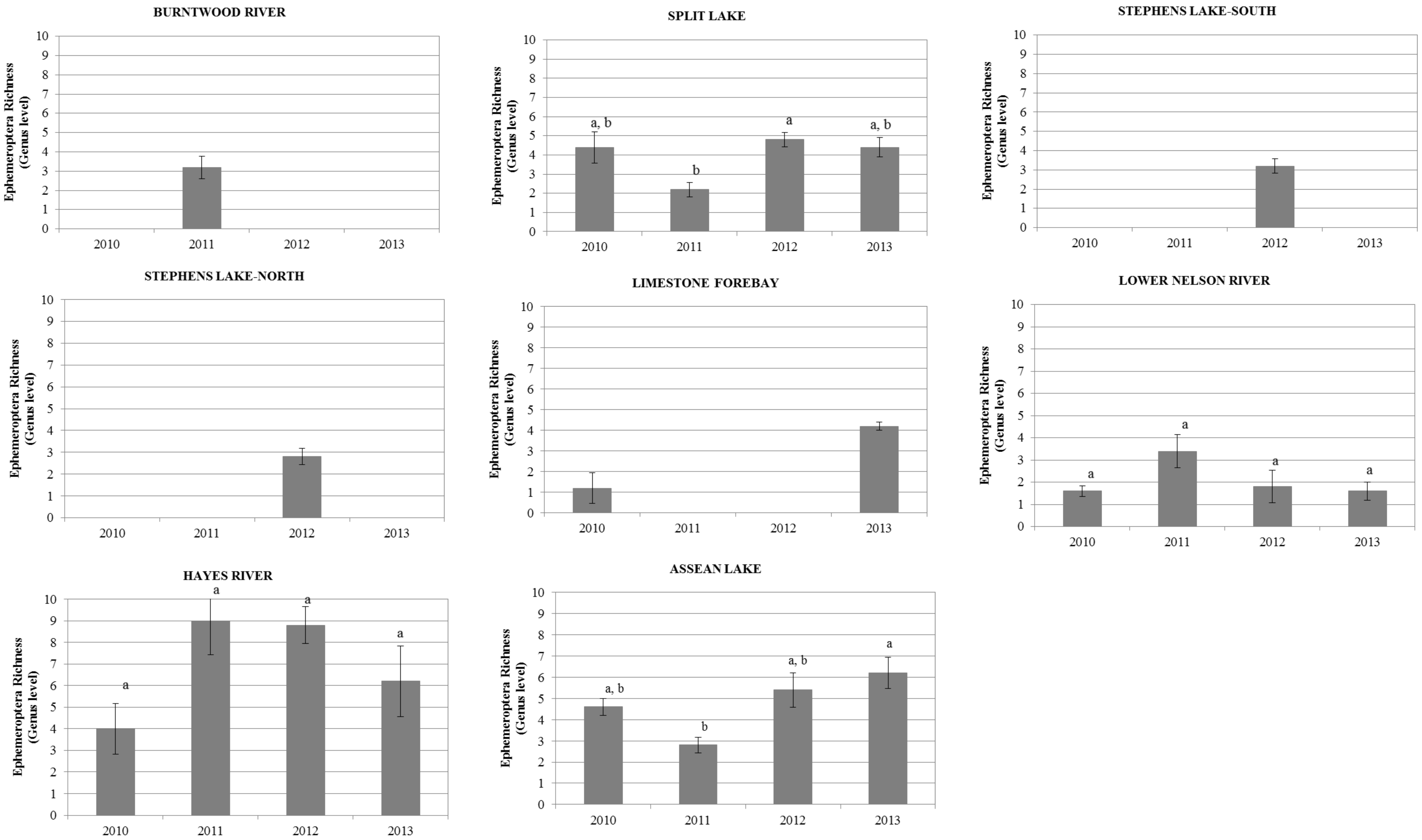


Figure 5-14. Ephemeroptera richness (genus level; mean ± SE) in the nearshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

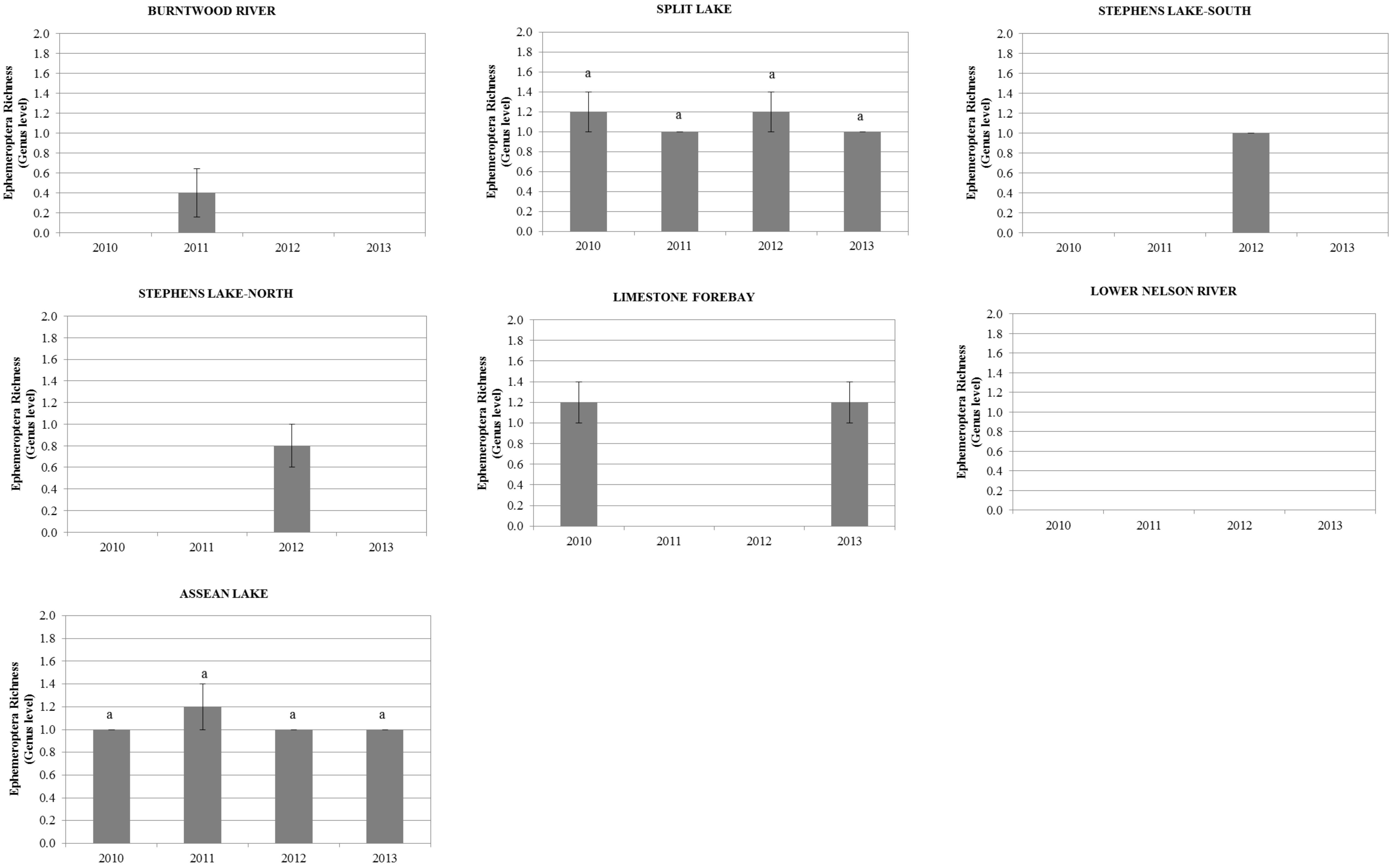


Figure 5-15. Ephemeroptera richness (genus level; mean ± SE) in the offshore habitat of the Lower Nelson River Region, by year: 2010 – 2013. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts denote no statistically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

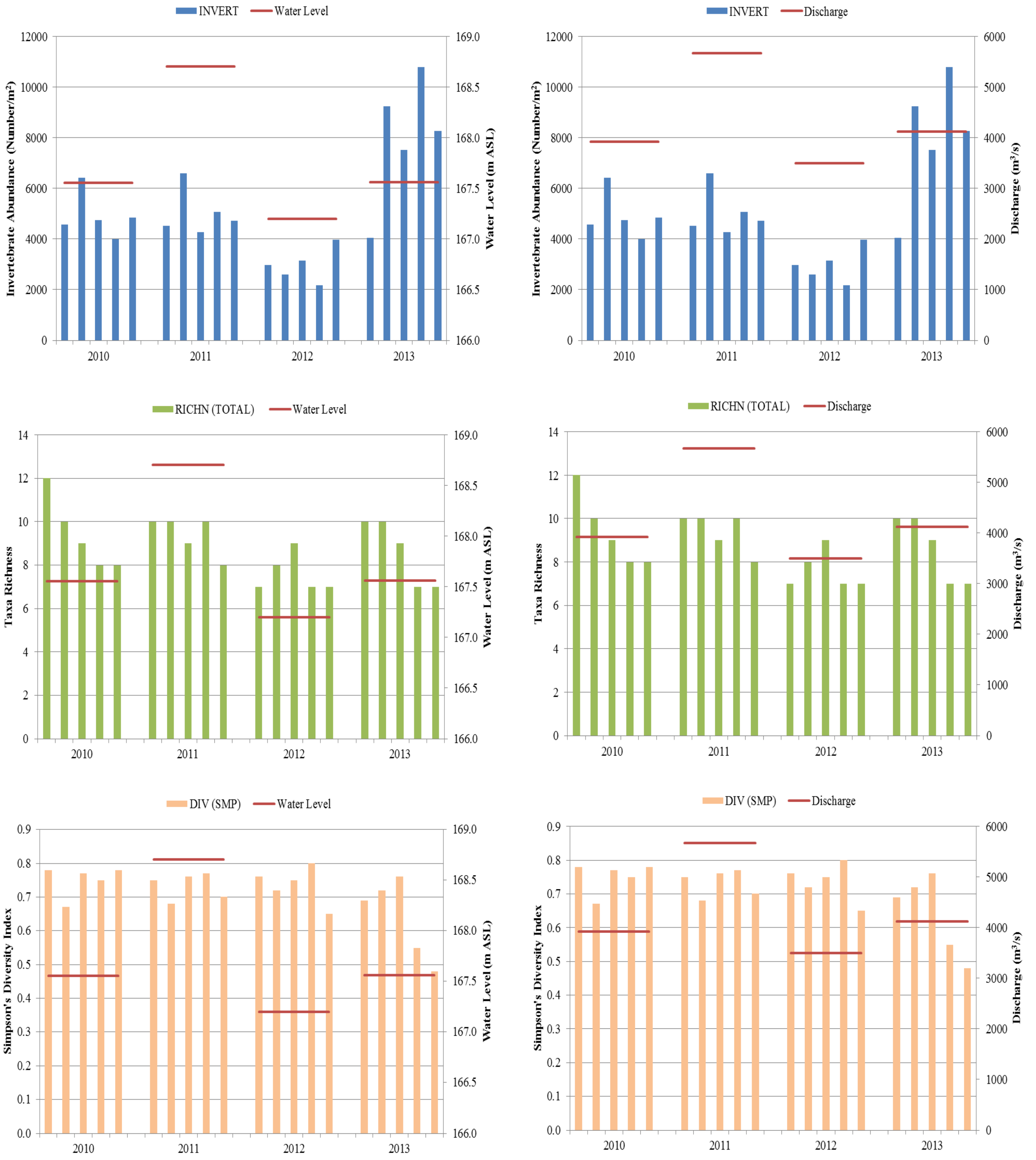


Figure 5-16. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Split Lake site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

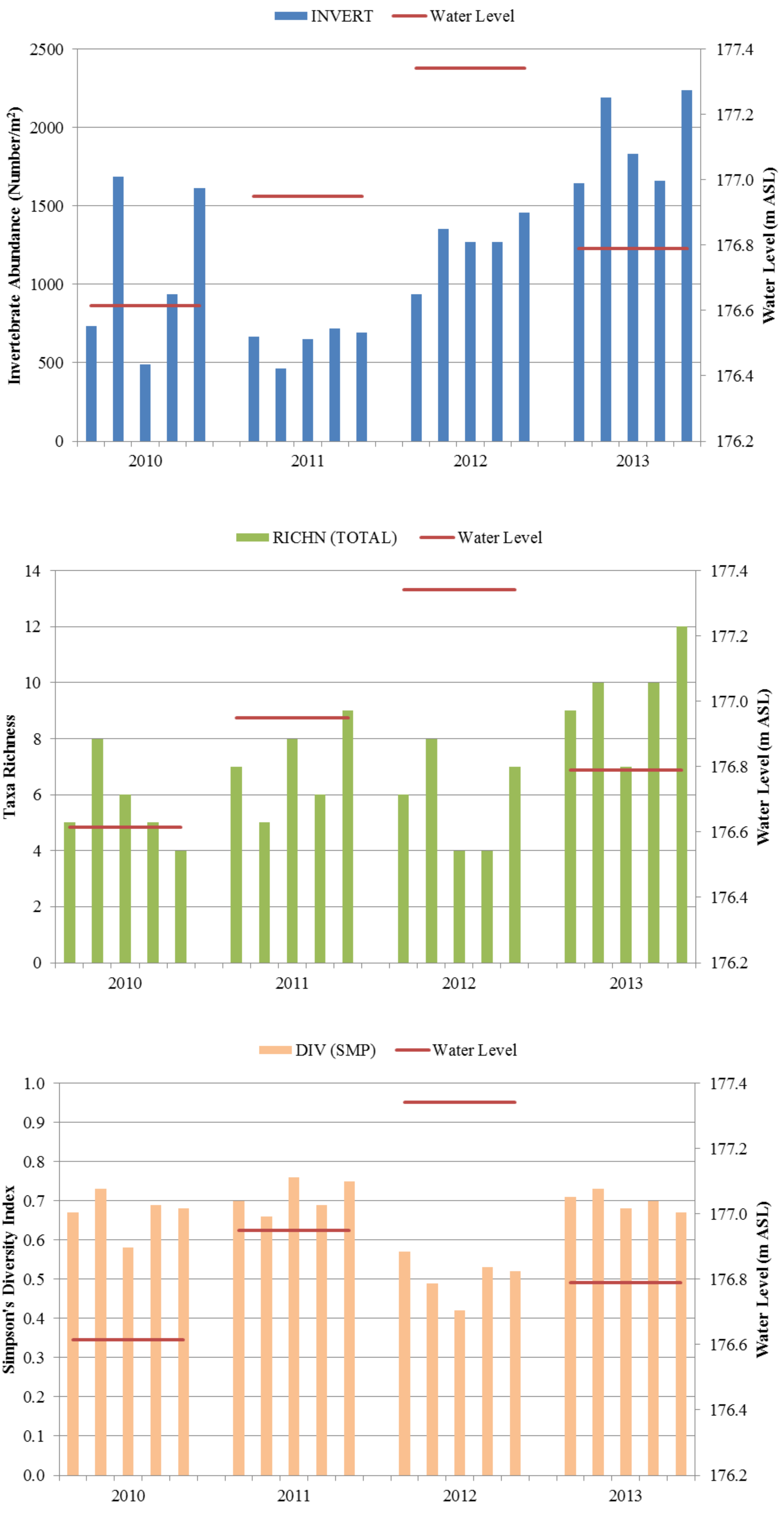


Figure 5-17. Invertebrate abundance, total richness, and Simpson's diversity index for replicate samples collected at the offshore Assean Lake site: 2010 to 2013. The average water level and discharge during the "growing season" are shown.

6.0 FISH COMMUNITY

6.1 INTRODUCTION

The following provides an overview of the fish community component of CAMP using key metrics measured over years 1-6 in the LNRR. As noted in Section 1.0, waterbodies/river reaches sampled annually included two on-system sites (Split Lake and the lower Nelson River – downstream of the Limestone GS) and two off-system sites (Hayes River and Assean Lake). Four additional on-system waterbodies or areas were sampled on a rotational basis: Burntwood River – downstream of First Rapids; Stephens Lake – South; Stephens Lake – North; and the Limestone Forebay (Table 6-1; Figure 6-1). Descriptions of the region and waterbodies monitored under CAMP are provided in Technical Document 1, Section 2.8 and the abbreviations for the sampling locations used in the tables and figures are provided in Table 6-1.

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 LNRR 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 (KF); and length-at-age. A description of and the rationale for the selection of the metrics and indicators is provided in Section 5.6.1 of Technical Document 1.

Manitoba Hydro and the Province of Manitoba's (2015) RCEA identified several effects of hydroelectric development on fish communities along the lower Nelson River and its associated lakes. The Nelson River between the Kelsey and Kettle GSs experienced increased flows in winter and changes in seasonal flow patterns as a result of CRD/Lake Winnipeg Regulation along with an increase in erosion and sediment deposition. Habitat changes, predominantly in the reach impounded by the Kettle GS that became Stephens Lake, also occurred. Since the 1980s, total CPUE has decreased in both Split and Stephens lakes, and species composition changed with an increase in Walleye (Sander vitreus) CPUE and a decrease in Lake Whitefish (Coregonus clupeaformis) CPUE in both lakes. While the RCEA could not conclusively determine reasons for the changes in CPUE, they were considered likely to be related to a variety of factors including changes in flow and climate.

The Nelson River experienced changes in water levels and flows downstream of Kettle, Long Spruce, and Limestone GSs as a result of GS construction and operation. There was increased erosion and sediment deposition in each of the reservoirs along with habitat change in the reaches impounded by each of the GSs and changes to fish movements both upstream and downstream past the GSs. Impoundment by the GSs resulted in shifts in species composition and abundance in the mainstem, but effects were difficult to quantify due to difficulty in sampling the reservoirs and river in a comparable manner. Key CAMP indicators were largely unaffected by hydroelectric developments. Therefore, the results for parameters in addition to the key metrics were also reviewed and summarized in Section 6.3, where of particular note (e.g., where there was evidence of temporal trends).

6.2 KEY INDICATORS

6.2.1 Diversity (Hill's Index)

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

6.2.1.1 Lower Nelson River Region

The mean Hill's number ranged from a high of 8.3 in Split Lake to a low of 5.4 in the Limestone Forebay (Table 6-3). The Hill's number was highest for the two most upstream sites in the region: Split Lake and the Burntwood River – downstream of First Rapids (Figure 6-2). Stephens Lake – South had a higher Hill's number than Stephens Lake – North because the species present there were more evenly represented (Figure 6-2). The Limestone Forebay had the lowest Hill's number due to it having the lowest total number of species and the catches were often dominated by only one or two species, most notably Longnose Sucker (*Catostomus catostomus*) in standard gangs and Trout-perch (*Percopsis omiscomaycus*) in the small mesh gangs. At the riverine locations, the Hill's number was higher upstream in the Burntwood River – downstream of First Rapids, with an average of 7.9, compared to the lower Nelson River – downstream of the Limestone GS where the average value was 6.3.

6.2.1.2 Off-system Waterbodies: Assean Lake and Hayes River

The mean Hill's number was similar between the off-system riverine (6.2 for the Hayes River) and lacustrine (Hill's number = 6.3 for Assean Lake) locations. The Hill's numbers for both off-system waterbodies were within the range of values observed in the lower Nelson River – downstream of the Limestone GS, and between those in Stephens Lake – South (7.0) and Stephens Lake – North (5.8).

6.2.1.3 Temporal Comparisons and Trends

The Hill's numbers for waterbodies sampled annually showed little variability among sampling years and there was no indication of trends at any of the locations (Figure 6-2). The values for the lower Nelson River – downstream of the Limestone GS were consistent initially around 7.0 from 2008 to 2011 and then decreased to 4.8 in 2012 and then increased slightly in 2013 to 5.9. For the Hayes River, the values ranged from 5.4 in 2010 to 7.4 in 2011. At the lacustrine locations, the Hill's values were fairly consistent over time, ranging from 7.4 in 2013 to 9.2 in 2012 for Split Lake and from 5.3 in 2009 to 7.2 in 2011 for Assean Lake.

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 Lower Nelson River Region

Fish Community

In standard gangs, the mean CPUE ranged from a high of 36 fish/100 m/24 h in Split Lake to a low of 12 fish/100 m/24 h in the Burntwood River – downstream of First Rapids and the Limestone Forebay (Table 6-3). The most abundant large-bodied species captured in LNRR waterbodies were typically Walleye, Northern Pike (*Esox lucius*), Longnose Sucker and White Sucker (*Catostomus commersonii*; Figure 6-3). Lake Sturgeon (*Acipenser fulvescens*) was abundant in the lower Nelson River - downstream of the Limestone GS. Although there was some annual variability within waterbodies, the abundance of large-bodied fish appeared to decrease in the on-system lakes in a downstream direction, with a higher mean total CPUE in standard gangs set in Split Lake (36 fish/100 m/24 h) compared to the Limestone Forebay (12 fish/100 m/24 h; Figure 6-4). There was no overlap in interquartile ranges among the four lacustrine sites indicating differences in mean total CPUE.

Like standard gangs, the highest CPUE for small mesh gangs occurred in Split Lake (mean of 102 fish/30 m/24 h) and the lowest in the Burntwood River – downstream of First Rapids (mean of 7 fish/30 m/24 h; Table 6-3). Small mesh gillnet catches were more variable than standard gang catches, but the more common small-bodied species included

Spottail Shiner (*Notropis hudsonius*), Trout-perch, Rainbow Smelt (*Osmerus mordax*) and Emerald Shiner (*Notropis atherinoides*; Figure 6-3).

Species composition in the standard gangs was generally similar among the LNRR waterbodies, however, some notable differences were apparent. Walleye was the most abundant species in the Burntwood River – downstream of First Rapids, Split Lake and both Stephens Lake – North and Stephens Lake – South, while in the Limestone Forebay and, to a lesser extent, the lower Nelson River – downstream of the Limestone GS it accounted for a much smaller proportion of the catch. Longnose Sucker and Northern Pike were the most abundant species in the Limestone Forebay and in the lower Nelson River – downstream of the Limestone GS (Figure 6-3). White Sucker were only abundant in Split Lake and Sauger (*Sander canadensis*) were only present in large numbers in Split Lake and Stephens Lake – North. The differences in the abundance of species among the waterbodies of the LNRR likely reflect differences in habitat. Species like Walleye were more abundant in the more lacustrine upstream waterbodies while Longnose Sucker were more abundant in the downstream and predominantly riverine waterbodies.

The species composition in the small mesh nets was similar among Split Lake and both areas of Stephens Lake with a high prevalence of Spottail Shiner, Rainbow Smelt and Trout-perch (Figure 6-3). Within the Limestone Forebay the composition was dominated by Trout-perch with very few other species present, including an absence of Rainbow Smelt from all but a few catches (Figure 6-3). The lower Nelson River - downstream of the Limestone GS had small mesh catches that were not dominated by any one species; instead similar proportions of Rainbow Smelt, Trout-perch, and Emerald Shiner were captured (Figure 6-3).

Lake Whitefish

Lake Whitefish catches were low throughout the on-system waterbodies (Figure 6-5). Lake Whitefish mean CPUE ranged from a high of 2 fish/100 m/24 h in Split Lake and the lower Nelson River – downstream of the Limestone GS to a low of <1 fish/100 m/24 h in the Limestone Forebay and the species was completely absent from catches in the Burntwood River – downstream of First Rapids (Table 6-3). The CPUE of Lake Whitefish in Split Lake and the lower Nelson River – downstream of the Limestone GS was higher than the other on-system waterbodies as indicated by the lack of overlap of the interquartile ranges of the box plots (Figure 6-5).

Northern Pike

Northern Pike mean CPUE ranged from a high of 8 fish/100 m/24 h in the lower Nelson River – downstream of the Limestone GS to a low of 1 fish/100 m/24 h in the Burntwood River – downstream of First Rapids (Table 6-3). Upstream of the Kettle GS, catches of Northern Pike were similar in both areas of Stephens Lake and slightly lower in Split Lake (Figure 6-6). Northern Pike were uncommon in the Burntwood River – downstream of First Rapids, while downstream of the Kettle GS catches were considerably higher in the lower Nelson River – downstream of the Limestone GS compared to the Limestone Forebay.

Walleye

Walleye mean CPUE ranged from a high of 12 fish/100 m/24 h in Stephens Lake – South to a low of 1 fish/100 m/24 h in the Limestone Forebay (Table 6-3). In general, Walleye were more frequently captured in waterbodies upstream of the Kettle GS compared to those farther downstream (Figure 6-7). CPUEs in Split Lake and Stephens Lake – South were similar, while the CPUE in the lower Nelson River – downstream of the Limestone GS was slightly higher than in the Limestone Forebay.

White Sucker

White Sucker mean CPUE in standard gangs ranged from a high of 11 fish/100 m/24 h in Split Lake to a low of <1 fish/100 m/24 h in both the Burntwood River – downstream of First Rapids and Stephens Lake – North (Table 6-3). White Sucker abundance was low (≤2 fish/100 m/24 h) throughout the region with the exception of Split Lake (Figure 6-8).

6.2.2.2 Off-system Waterbodies: Assean Lake and Hayes River

Fish Community

In standard gangs, the mean CPUE was 50 fish/100 m/24 h in Assean Lake and 10 fish/100 m/24 h in the Hayes River (Table 6-3). The large-bodied fish community in Assean Lake was dominated by Walleye, White Sucker, and Northern Pike, while the most abundant species in the Hayes River were Walleye and Lake Sturgeon (Figure 6-3).

In small mesh gangs, the mean CPUE was also higher in Assean Lake (150 fish/30 m/24 h) than the Hayes River (5 fish/30 m/24 h; Table 6-3). The small-bodied fish community of Assean Lake was dominated by Spottail Shiner and Yellow Perch (*Perca flavescens*), with smaller numbers of Emerald Shiner, Trout-perch and both juvenile and adult Walleye (Figure 6-3). Very few fish were captured in small mesh nets set in the Hayes River.

Fish abundance in the off-system Assean Lake was higher than those of any of the on-system lakes as indicated by a lack of overlap of the interquartile ranges between Assean Lake and any of the other waterbodies (Figure 6-4). Total CPUE in Assean Lake was influenced largely by a particularly high abundance of Walleye (Figure 6-4).

Fish abundance in the Hayes River (10 fish/100 m/24 h) was similar to that in the Burntwood River – downstream of First Rapids but was lower than in the lower Nelson River – downstream of the Limestone GS (Figure 6-4). Though the fish communities of the Hayes River and the lower Nelson River – downstream of the Limestone GS differed, the abundance of some species (e.g., Walleye and Lake Sturgeon) were nearly identical between the two (Figure 6-3).

Lake Whitefish

Lake Whitefish had a mean CPUE in standard gangs of 5 fish/100 m/24 h in Assean Lake and <1 fish/100 m/24 h in the Hayes River (Table 6-3). The mean CPUE of Lake Whitefish in Assean Lake was considerably higher than those observed for the on-system lacustrine waterbodies as indicated by the lack of overlap between the interquartile ranges (Figure 6-5). However, the lowest annual value observed in Assean Lake was within the range observed in Split Lake. Catch rates of Lake Whitefish in the Hayes River were lower than in the lower Nelson River – downstream of the Limestone GS but higher than in the Burntwood River – downstream of First Rapids (Figure 6-5).

Northern Pike

Northern Pike had a mean CPUE in standard gangs of 7 fish/100 m/24 h in Assean Lake and <1 fish/100 m/24 h in the Hayes River (Table 6-3). Northern Pike CPUE in the off-system Assean Lake was slightly higher than that observed for the on-system lakes (Figure 6-6). At the riverine locations, Northern Pike catch rates in the Hayes River were similar to that in the Burntwood River – downstream of First Rapids but considerably lower than that in the lower Nelson River – downstream of the Limestone GS (Figure 6-6).

Walleye

Walleye had a mean CPUE in standard gangs of 25 fish/100 m/24 h in Assean Lake and 3 fish/100 m/24 h in the Hayes River (Table 6-3). Walleye CPUE in Assean Lake was considerably higher than in any of the on-system lakes, as shown by the lack of overlap of the interquartile ranges (Figure 6-7). The CPUE of Walleye in the Hayes River was similar to both the lower Nelson River – downstream of the Limestone GS and the Burntwood River – downstream of First Rapids.

White Sucker

White Sucker had a mean CPUE in standard gangs of 8 fish/100 m/24 h in Assean Lake and 1 fish/100 m/24 h in the Hayes River (Table 6-3). The CPUE of White Sucker in Assean Lake was slightly lower than that in Split Lake but was considerably higher than in the other on-system lakes (Figure 6-8). Catch rates in the off-system Hayes River were within the range observed in the two on-system riverine locations.

6.2.2.3 Temporal Comparisons and Trends

Fish Community

Sites sampled annually (Split Lake, lower Nelson River – downstream of the Limestone GS, Assean Lake, and the Hayes River) were examined for temporal trends. In Split Lake, the annual total CPUE values showed little variability (ranging from 32 to 38 fish/100 m/24 h) among sampling years with no statistical difference between years and no indication of a trend (Figures 6-4 and 6-9). Statistically significant inter-annual differences were observed for the lower Nelson River – downstream of the Limestone GS, but like Split Lake there was no indication of a trend. CPUE was highest in 2011 (36 fish/100 m/24 h) and lowest in 2013 (19 fish/100 m/24 h) at this location (Figure 6-9).

The mean CPUE in Assean Lake ranged from 34 fish/100 m/24 h in 2013 to 63 fish/100 m/24 h in 2010 (Figure 6-4). Overall CPUE rose from 2009 to 2010, followed by a decline from 2010 to 2013 in Assean Lake (Figure 6-4). The mean in 2013 was statistically lower than all years except 2009 (Figure 6-9) and was influenced by a sharp decline in Lake Whitefish CPUE.

The annual CPUE values in the Hayes River ranged from 6 fish/100 m/24 h in 2009 to 15 fish in 2010 and tended to fluctuate between high and low values in consecutive years over the 6-year period (Figure 6-4). However, due to large variability each year, only 2010, the year with the highest mean CPUE, and 2009, the year with the lowest, were significantly different from one another (Figure 6-9).

Lake Whitefish

Lake Whitefish CPUE in on-system waterbodies sampled annually showed little variability among sampling years. The mean CPUE ranged from 1 fish/100 m/24 h in 2009 to just over 2 fish/100 m/24 h in 2011 in Split Lake and from 1 fish/100 m/24 h in 2008 to 3 fish in 2011 in the lower Nelson River – downstream of the Limestone GS (Figure 6-5). Statistical comparisons of CPUE at annual on-system locations indicated that there were no statistical differences among sampling years in Split Lake while Lake Whitefish CPUE from the lower Nelson River –

downstream of the Limestone GS in 2011 was found to be statistically higher than all years except 2010 (Figure 6-10). The CPUE of Lake Whitefish showed a similar temporal pattern in Split Lake and the lower Nelson River – downstream of the Limestone GS, peaking in 2011.

Lake Whitefish catch rates for Assean Lake varied the most of any waterbody in the region, as indicated by the large interquartile range, with annual values ranging from 1 fish/100 m/24 h in 2013 to 8 fish/100 m/24 h in 2011 (Figure 6-5). Lake Whitefish CPUE for 2013 was found to be significantly lower than in 2011 and 2012 and showed a similar temporal pattern to the on-system waterbodies (Figure 6-10). The mean CPUE at the Hayes River ranged from no catch in 2013 to just over 1 fish/100 m/24 h in 2008. No statistical differences were found between mean annual CPUE values for Lake Whitefish from the Hayes River and no trend was apparent (Figure 6-10).

Northern Pike

The CPUE of Northern Pike in Split Lake was relatively consistent over the sampling period, ranging from 4 fish/100 m/24 h from 2009 to 2011 to 5 fish in 2012 and 2013 (Figure 6-6). Annual CPUE in the lower Nelson River – downstream of the Limestone GS increased gradually from 4 fish/100 m/24 h in 2008 to 10 fish/100 m/24 h in 2012, followed by a decrease to about 8 fish/100 m/24 h in 2013 (Figure 6-6). Statistical comparisons of CPUE at annual on-system locations indicated no significant differences, although visual examination of the data for the lower Nelson River – downstream of the Limestone GS suggests an increasing trend in this metric (Figure 6-11).

Catch rates in Assean Lake over the sampling period showed a similar pattern as observed in the lower Nelson River – downstream of the Limestone GS. The annual CPUE in Assean Lake increased from 6 fish/100 m/24 h in 2009 to 10 fish/100 m/24 h in 2012 and then decreased to 7 fish/100 m/24 h in 2013. Catch-per-unit-effort values of Northern Pike in the Hayes River were the lowest of all LNRR waterbodies ranging from <1 fish/100 m/24 h in 2009 to 1 fish/100 m/24 h in 2010 with no apparent trend in abundance (Figure 6-6). Neither off-system waterbody was found to have statistically significant differences among years for Northern Pike CPUE (Figure 6-11).

Walleye

The CPUE of Walleye at both on-system waterbodies sampled annually varied little over the sampling years. The mean CPUE in Split Lake was lowest in 2012 at 5 fish/100 m/24 h and ranged from 12 to 13 fish/100 m/24 h in the other years (Figure 6-7). In the lower Nelson River – downstream of the Limestone GS the CPUE ranged from 2 fish/100 m/24 h in 2008 and 2012 to

5 fish/100 m/24 h in 2009. No statistically significant inter-annual differences in CPUE were found (Figure 6-12). This metric did not show a consistent increasing or decreasing trend over the sampling period for either on-system waterbody.

The CPUE of Walleye in the off-system Assean Lake increased from 23 fish/100 m/24 h in 2009 to 28 fish/100 m/24 h in 2010 and 2011, after which it decreased to 19 fish/100 m/24 h in 2013 (Figure 6-7). However, the differences among years were not statistically significant and no real trend in abundance is apparent based on the available data (Figure 6-12). Walleye abundance in the off-system Hayes River has been consistently low, fluctuating between 2 fish/100 m/24 h from 2009 to 2011 and 4 fish/100 m/24 h in the other years. No significant statistical differences were found for annual Walleye CPUE values from the Hayes River and no increasing or decreasing trends in Walleye abundance were apparent (Figure 6-12).

White Sucker

Annual White Sucker CPUE values over the sampling period in the on- and off-system waterbodies were relatively consistent from year to year with the exception of Split Lake (Figure 6-8). A general increasing trend was observed in Split Lake over the monitoring period (from 7 to 9 fish/100 m/24 h in 2009-2011 to 13 and 15 fish/100 m/24 h in 2012 and 2013, respectively. Catches in the lower Nelson River – downstream of the Limestone GS were much lower, ranging between 1 and 4 fish/100 m/24 h (Figure 6-8). There were significant inter-annual differences in CPUE at both waterbodies (Figure 6-13). At Split Lake, CPUE was highest in 2012, while in the lower Nelson River – downstream of the Limestone GS CPUE was significantly highest in 2011 (Figure 6-13).

The CPUE observed in Assean Lake was consistent across years ranging from 7 fish/100 m/24 h in 2009 to 9 fish/100 m/24 h in 2011 and no trends were evident (Figure 6-13). Catches in the Hayes River were much lower ranging from <1 to 3 fish/100 m/24 h (Figure 6-8), but a statistically lower catch was observed at this location in 2008 (Figure 6-13). Like Assean Lake there was no indication of a trend in White Sucker abundance in the Hayes River.

6.2.3 Condition (Fulton’s Condition Factor)

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

6.2.3.1 Lower Nelson River Region

Lake Whitefish

Mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length from on-system waterbodies ranged from a high of 1.67 in Split Lake to a low of 1.50 in the lower Nelson River – downstream of the Limestone GS (Figure 6-14). Lake Whitefish were absent from catches in the Burntwood River – downstream of First Rapids and were captured in insufficient numbers in both areas of Stephens Lake and the Limestone Forebay for detailed analysis.

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length was similar among the on-system waterbodies, ranging from a high of 0.75 in the Limestone Forebay and 0.74 in Stephens Lake – South to a low of 0.71 in Stephens Lake – North and the lower Nelson River – downstream of the Limestone GS (Figure 6-15).

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm in fork length from on-system waterbodies ranged from a high of 1.34 in Stephens Lake – South to a low of 1.25 in the lower Nelson River – downstream of the Limestone GS (Figure 6-16). The condition of Walleye varied slightly among on-system waterbodies, with both areas of Stephens Lake having the highest values (1.32-1.34), while the remaining waterbodies ranged from 1.25 (lower Nelson River – downstream of the Limestone GS) to 1.28 (Burntwood River – downstream of First Rapids; Figure 6-16). Split Lake had the greatest variability in Walleye condition as indicated by the length of the interquartile range of annual K_F values. There was little separation of the interquartile ranges among the on-system waterbodies, suggesting that there was little difference in condition among the populations.

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm in fork length from on-system waterbodies ranged from a high of 1.71 in Stephens Lake – South to a low of 1.50 in the lower Nelson River – downstream of the Limestone GS (Figure 6-17). With the exception of Split Lake, White Sucker were not a common species in the region, therefore there were an insufficient number of fish captured for biometric analysis in most years in most waterbodies.

6.2.3.2 Off-system Waterbodies: Assean Lake and Hayes River

Lake Whitefish

Mean Fulton's condition factor for Lake Whitefish between 300 and 499 mm in fork length from Assean Lake was 1.58 (Figure 6-14). Lake Whitefish in Assean Lake were within the range observed in Split Lake and the lower Nelson River – downstream of the Limestone GS (Figure 6-14). There were an insufficient number of individuals that met the fork length criteria from the Hayes River for inclusion in the analysis.

Northern Pike

Mean Fulton's condition factor for Northern Pike between 400 and 699 mm in fork length from Assean Lake (0.67; Figure 6-15) was lower than those in the on-system lakes (0.71-0.75; Figure 6-15). Condition was notably lower at this location in 2009 and 2010 than in the on-system waterbodies. There were an insufficient number of individuals that met the fork length criteria from the Hayes River for inclusion in the analysis.

Walleye

Mean Fulton's condition factor for Walleye between 300 and 499 mm was similar between the two off-system locations (mean of 1.11 in Assean Lake and 1.10 in the Hayes River) but lower than those measured in on-system waterbodies (Figure 6-16).

White Sucker

Mean Fulton's condition factor for White Sucker between 300 and 499 mm from Assean Lake was 1.60 (Figure 6-17). There was no difference in White Sucker condition between Assean Lake and the on-system Split Lake as the interquartile ranges overlapped (Figure 6-17). There were an insufficient number of White Sucker from the Hayes River that met the fork length criteria for analysis.

6.2.3.3 Temporal Comparisons and Trends

Lake Whitefish

Among the sites that were sampled annually, the condition of Lake Whitefish was similar among sampling years in Split Lake but more variable in the lower Nelson River – downstream of the Limestone GS and in Assean Lake (Figure 6-14). In Split Lake, the mean K_F ranged from 1.62 to 1.71 for the years with sufficient data for analysis (2010-2012). Mean condition of Lake Whitefish in the lower Nelson River – downstream of the Limestone GS, which ranged from 1.40 in 2010 to 1.57 in 2009, was statistically lowest in 2010 (Figure 6-14). Data were insufficient from the on-system sites to assess potential trends.

Although fish from Assean Lake had a fairly narrow range of annual K_F values (1.49 to 1.62; Figure 6-14), the condition of Lake Whitefish was significantly lowest in 2011 (Figure 6-18). No increasing or decreasing trends in Lake Whitefish condition in Assean Lake over the period of 2009-2012 were apparent.

Northern Pike

The annual mean condition of Northern Pike between 400 and 699 mm varied notably between years in both on-system sites and in the off-system lake (Assean Lake; Figure 6-19). Condition was highest in Split Lake (0.74-0.77) and the lower Nelson River – downstream of the Limestone GS (0.73-0.77) over the period of 2009-2011 (peaking in 2011), and notably lower in both locations in 2012 and 2013. The reverse temporal pattern was observed at Assean Lake where condition was lower and similar in 2009 and 2010 (0.63) and higher for the period of 2012-2013 (0.69). The one commonality observed at all three sites was the peak in condition in 2011. A possible explanation for the decline in Northern Pike condition after 2011 is discussed in Section 6.3. Insufficient data were available for the Hayes River to conduct statistical analyses or assess potential temporal trends (Figure 6-19).

Walleye

The condition of Walleye in Split Lake declined over the sampling period, with mean condition decreasing fairly consistently from 1.32 to 1.15 from 2009 to 2013 (Figure 6-16). Values from the first three years (2009-2011) were significantly higher than those from the last two years (2012 and 2013; Figure 6-20). The decrease in condition of Walleye in Split Lake has continued to at least 2015 (CAMP unpublished data). A possible explanation for the decline in condition is discussed in Section 6.3.

Trends could not be assessed for the lower Nelson River – downstream of the Limestone GS as there were insufficient data for 2012 and 2013 for analysis. However, condition was significantly lower in 2008 (1.13) than in 2009-2011 (1.26-1.31; Figure 6-20).

There were significant inter-annual differences in the condition of Walleye from the off-system Assean Lake and although the trend observed in Split Lake was not observed in this lake, like Split Lake, condition was lowest in 2013 (Figure 6-20). Insufficient data were available for the Hayes River to conduct statistical analyses or assess potential temporal trends (Figure 6-20).

White Sucker

The annual mean condition of White Sucker in Split Lake fluctuated between 1.60 and 1.71 for the four years for which sufficient data were available (Figure 6-17), and values were significantly lower in 2010 and 2011 than the latter two years (2012 and 2013; Figure 6-21). Although data were insufficient to assess trends, available data suggest a similar pattern may have occurred as observed for Walleye (i.e., lower condition in 2012 and 2013. There were insufficient data for the lower Nelson River – downstream of the Limestone GS to conduct statistical analyses or assess potential temporal trends.

Over the period of 2010-2013 (period with sufficient data for analysis), the condition of White Sucker from the off-system Assean Lake was significantly higher in 2010 (1.68) than later years (Figure 6-21). Data are insufficient for assessing trends at this site. In the Hayes River, there were insufficient numbers of White Sucker to assess inter-annual differences or temporal trends in condition.

6.2.4 Growth (Length-at-age)

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

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

6.2.4.1 Lower Nelson River Region

Lake Whitefish

Lake Whitefish captured in the annually sampled on-system waterbodies ranged from 2 to 25 years of age (Figure 6-22). The majority of fish captured in Split Lake and the lower Nelson River – downstream of the Limestone GS were from 5 to 12 years of age. Only two individual fish under the age of 5 were collected in the lower Nelson River – downstream of the Limestone GS, making it difficult to compare the growth patterns of young fish between the two on-system waterbodies. However, Lake Whitefish from both waterbodies reached similar maximum sizes (475 mm in Split Lake and 450 mm in the lower Nelson River – downstream of the Limestone GS; Figure 6-22).

There were insufficient numbers of 4- and 5-year-old Lake Whitefish captured in the on-system locations for detailed analysis (Table 6-3; Figures 6-23 and 6-24).

Northern Pike

Northern Pike captured in the annually sampled on-system waterbodies ranged from 1 to 18 years of age, with most of the fish captured over the 6-year sampling period aged between 3 and 9 years for Split Lake and 4 and 10 years for the lower Nelson River – downstream of the Limestone GS (Figure 6-25). Growth patterns and the maximum size attained by Northern Pike from both sites were similar, increasing gradually to a maximum size of approximately 850 mm (Figure 6-25).

The mean fork length for 4-year-old Northern Pike was fairly similar between the two on-system lakes. Mean fork lengths for Northern Pike in Split Lake ranged between 420 and 460 mm while those for Stephens Lake – North and Stephens Lake – South ranged from 460-472 mm (Figure 6-26). Northern Pike in the Limestone Forebay had a length-at-age 4 of 548 mm based on six individuals captured in 2013 (Figure 6-26). For riverine sites the mean length-at-age 4 ranged from a low of 390 mm at the Burntwood River – downstream of First Rapids to a high of 502 mm in the lower Nelson River – downstream of the Limestone GS (Figure 6-26).

Walleye

Walleye captured in the annually sampled on-system waterbodies ranged from 1 to 22 years (Figure 6-27). Most of the catch in Split Lake was between 2 and 10 years of age while the majority of Walleye from the lower Nelson River – downstream of the Limestone GS ranged in age from 3 to 9 years. Both locations displayed similar growth patterns and a maximum size of approximately 500 mm. Mean fork length for 3-year-old Walleye for the two sites sampled annually were 272 mm in Split Lake and 256 mm in the lower Nelson River – downstream of the Limestone GS (Figure 6-28).

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

Lake Whitefish

Similar to Split Lake, Lake Whitefish captured from Assean Lake ranged from 1 to 20 years of age (Figure 6-22). Likewise, the pattern of growth and maximum fork length attained was similar to Split Lake (Figure 6-22). Very few Lake Whitefish were captured from the Hayes River (n = 29); those that were ranged from 4-11 years (Figure 6-22).

Fork length-at-age 4 and 5 for Lake Whitefish captured in Assean Lake ranged considerably between years, averaging 317 mm and 350 mm, respectively (Figures 6-23 and 6-24). There were insufficient numbers of 4- and 5-year-old Lake Whitefish captured in the Hayes River for analysis (Table 6-3).

Northern Pike

Northern Pike from Assean Lake ranged from 1 to 18 years with the majority ranging from 3 to 8 years of age (Figure 6-25). The annual mean length-at-age of Northern Pike was similar in both Split Lake and the lower Nelson River – downstream of the Limestone GS in terms of initial growth pattern and maximum fork length (Figure 6-25). In the Hayes River there were insufficient length at age data for interpretation; however, those that were captured ranged from 3 to 12 years of age (Figure 6-25).

Four-year-old Northern Pike from Assean Lake, which averaged 441 mm in length, were of a similar size as observed in Split Lake (Figure 6-26).

Walleye

The age range of Walleye captured in Assean Lake (1 to 20 years) was similar to the on-system waterbodies (Figure 6-27). Most of the catch was between 5 and 12 years of age. Compared to Split Lake, Assean Lake Walleye appeared to be slower growing and achieved a slightly lower maximum overall mean fork length (approximately 400 mm; Figure 6-27). Walleye from the Hayes River ranged from 1 to 28 years of age with the majority of fish aged between 3 and 13 years (Figure 6-27).

The length of 3-year-old Walleye from the Hayes River (mean = 288 mm) was limited to data from 2012 with values similar to those from Split Lake in 2010 and 2011. They appeared to have a slow growth pattern after age 3 and the maximum mean fork length obtained was slightly higher than measured in both Split Lake and the lower Nelson River – downstream of the Limestone GS (Figure 6-28).

The mean length-at-age 3 of Walleye from Assean Lake (230 mm) was lower than the range observed at all on-system waterbodies, except Stephens Lake – South, for which the sample size was limited to five fish (Figure 6-28).

6.2.4.3 Temporal Comparisons and Trends

Lake Whitefish

There were insufficient numbers of 4- and 5-year-old Lake Whitefish captured in the region to facilitate analysis of inter-annual differences or trends.

Northern Pike

There was little variation in the annual mean length-at-age 4 of Northern Pike in Split Lake (range of 420 to 460 mm), the on-system lake that was monitored annually (Figure 6-26). There were no statistical differences in the length of 4-year-old Northern Pike among years (Figure 6-29) or an increasing or decreasing trend for this waterbody.

Although fork lengths of 4-year-old Northern Pike ranged more widely in the lower Nelson River – downstream of the Limestone GS (476-550 mm; Figure 6-26), no statistically significant differences were found between years and no trends were apparent (Figure 6-29).

The mean fork length-at-age 4 of Northern Pike in the off-system Assean Lake ranged from an average of 397 mm in 2009 to 482 mm in 2013 (Figure 6-29). No statistically significant differences were found between years for Northern Pike mean fork length-at-age 4 (Figure 6-29); however, available data suggest an increasing trend over the five year monitoring period (2009-2013). Insufficient numbers of 4-year-old Northern Pike were captured in the Hayes River in any given year to facilitate analysis.

Walleye

The mean length-at-age 3 of Walleye in Split Lake ranged between 236 and 297 mm (Figure 6-28). Lengths were similar over the period of 2010 to 2013 but were significantly lower in 2009 (Figure 6-30). There were insufficient years with enough fish to conduct a statistical analysis for Walleye captured in the lower Nelson River – downstream of the Limestone GS.

The length of 3-year-old Walleye in the off-system Assean Lake was relatively similar across years (range of 214 to 242 mm), but notably lower than fish from Split Lake (Figures 6-28 and 6-30).

6.3 ADDITIONAL METRICS AND OBSERVATIONS OF NOTE

Two additional fish community metrics measured under CAMP were evaluated for the LNRR: relative abundance; and the CPUE of Rainbow Smelt. The relative abundance of fish species captured in standard gang index gill nets was assessed to provide information on the overall composition of the fish community (Figure 6-31). The abundance of Rainbow Smelt was evaluated as this species was reported to be the primary food source for Walleye and Northern Pike in the lower Nelson River during the early 2000s (KHLP 2012; Johnson and MacDonell 2004; Johnson et al. 2004) and trends in the condition of these species were observed in this region in the studies conducted under CAMP.

The relative abundance of fish species captured in standard gang index gill nets set at CAMP waterbodies over the period of 2008-2013 is shown in Figure 6-31. Walleye and Northern Pike were the dominant species within the waterbodies upstream of the Kettle GS; whereas farther downstream, in the Limestone Forebay and the lower Nelson River – downstream of the Limestone GS, Longnose Sucker and Northern Pike dominated the catch (Figure 6-31). Some notable differences among the on-system waterbodies were that Sauger and White Sucker were a large component of the catches in Split Lake and Stephens Lake - South, and Lake Whitefish were relatively more abundant in the lower Nelson River – downstream of the Limestone GS compared to the Limestone Forebay. The two on-system riverine sites differed in their predominant species with the Burntwood River – downstream of First Rapids being dominated by Walleye and Sauger and the lower Nelson River – downstream of the Limestone GS being dominated by Northern Pike and Longnose Sucker (Figure 6-31). Lake Sturgeon were only abundant in the lower Nelson River – downstream of the Limestone GS.

Catches in the off-system lacustrine site, Assean Lake, were dominated by Walleye, Northern Pike, and White Sucker, which was similar to the on-system lakes, but generally contained fewer species and the abundance of Cisco (*Coregonus artedi*) and Lake Whitefish was higher (Figure 6-31). The fish community at the Hayes River, the off-system riverine location, differed from the on-system Burntwood River – downstream of First Rapids location in that species such as Brook Trout (*Salvelinus fontinalis*), Lake Whitefish and Silver Lamprey (*Ichthyomyzon unicuspis*) were captured. The Hayes River and the lower Nelson River – downstream of the Limestone GS had similar species compositions with Lake Sturgeon accounting for a large proportion of the catch for both. However, Walleye were more abundant in the Hayes River while Northern Pike dominated the catches from the lower Nelson River – downstream of the Limestone GS (Figure 6-31).

Rainbow Smelt were first reported in Split and Stephens lakes and the Limestone Forebay in 1996 (Remnant et al. 1997), and quickly became established as an important component of the small-bodied fish community of the region. CAMP monitoring data indicate a decrease in the abundance of smelt captured in small-mesh gill nets set in Split Lake and the lower Nelson River – downstream of the Limestone GS (Figure 6-32). From 2009-2011, the forage fish community in Split Lake was relatively equally represented by Trout-perch, Spottail Shiner, and

Rainbow Smelt. In 2012 there was a large decline in the abundance of smelt. A large decrease in Rainbow Smelt abundance was observed concurrently in the lower Nelson River – downstream of the Limestone GS (Figure 6-32).

These changes in the Rainbow Smelt population may have contributed to the reduction in the condition of Walleye and Northern Pike that were first observed in 2012. Data collected in 2014 and 2015 indicate that numbers of smelt have remained low at both sites and trends in condition of Walleye and Northern Pike have persisted (CAMP unpublished data). Reasons for the decline in Rainbow Smelt abundance are not known. However, a decline in smelt was also observed in the north basin of Lake Winnipeg beginning in 2011 and this coincided with reductions in Walleye condition and growth (see Technical Document 4, Section 6.3).

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 data provided by Manitoba Hydro from water level gauges in Split Lake, the Limestone Forebay, and the Hayes River and discharge data from the Burntwood River and Kelsey GS outflows, Kettle GS outflows, and the Hayes River and fish community metrics) indicated very few statistically significant relationships (Table 6-4). The only statistically significant relationship that was found for an on-system waterbody was a positive relationship between White Sucker CPUE and lower Nelson River discharge during the sampling period. However, more typically the relationship between CPUE and water level/discharge is negative and statistically significant negative relationships between Northern Pike and total CPUE and discharge and water level during the sampling period were found for the Hayes River (Table 6-4; Figure 6-33).

6.6 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 the on-system waterbodies of the LNRR were typically Walleye and Northern Pike, although there were differences in species composition among waterbodies.
- Longnose Sucker were also abundant within the Limestone Forebay and the lower Nelson River – downstream of the Limestone GS.
- The diversity of the fish community of the lacustrine waterbodies within the LNRR, as measured by the Hill’s index, generally decreased in a downstream direction. At the riverine locations, the Hill’s number was higher in the Burntwood River – downstream of First Rapids compared to the lower Nelson River – downstream of the Limestone GS.
- The mean total CPUE among the on-system lacustrine waterbodies within the LNRR appeared to decrease in a downstream direction, although there was some annual variability within waterbodies. The CPUE in the lower Nelson River – downstream of the Limestone GS had a mean total CPUE similar to that of Stephens Lake – South and much higher than that of the Burntwood River – downstream of First Rapids, although the latter was based on only one year of data. Assean Lake had the highest CPUE of all waterbodies in the region.
- There were some differences from the general patterns for total catch within each species:
  - Lake Whitefish were generally not abundant within the on-system waterbodies; however, they were fairly abundant in Assean Lake;
  - Northern Pike abundance was generally higher in the lower Nelson River – downstream of the Limestone GS than other on-system sites;
  - Walleye were abundant in most on-system waterbodies upstream of the Kettle GS, but accounted for a smaller proportion of catches downstream of the GS. This species was most abundant in off-system Assean Lake; and
  - White Sucker were most abundant in Split and Assean lakes and not very abundant in any other LNRR waterbodies.
- The condition of Lake Whitefish was higher in Split Lake than in the lower Nelson River – downstream of the Limestone GS and Assean Lake. The condition of Northern Pike and Walleye was generally similar among the on-system waterbodies and somewhat lower in Assean Lake.

- Four-year old Northern Pike were generally longer in the lower Nelson River – downstream of the Limestone GS compared to Split Lake, while the reverse was observed for three-year old Walleye.

The condition of Walleye in Split Lake (data were insufficient to assess trends in the lower Nelson River – downstream of the Limestone GS for Walleye) and Northern Pike in Split Lake and the lower Nelson River – downstream of the Limestone GS was notably lower in 2012 and 2013 than prior years. Though data are too limited to determine if this represents a long-term trend versus short-term inter-annual variability, these relatively abrupt changes coincided with a reduction in the abundance of the principal prey item (Rainbow Smelt). These co-occurring trends were also observed for Walleye condition and length-at-age 3 in the north basin of Lake Winnipeg, suggesting some fundamental changes in populations of key target fish species such as Walleye may be linked to a general collapse of the relatively newly introduced prey item. The reasons for the decline in Rainbow Smelt are unknown.

A quantitative consideration of hydrological conditions and fish community metrics for annual sites (Split Lake, the lower Nelson River – downstream of the Limestone GS, and the Hayes River) found very few statistically significant relationships. White Sucker CPUE and lower Nelson River discharge during the sampling period showed a statistically significant positive relationship, and statistically significant negative relationships between Northern Pike and total CPUE and discharge and water level during the sampling period were found for the Hayes River.

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

Location	**Site Abbreviation**	**On-system**	**Off-system**	**Annual**	**Rotational**	**Sampling Years**					
						2008	**2009**	**2010**	**2011**	**2012**	**2013**
Burntwood River	BURNT	X			X				X		
Split Lake	SPLIT	X		X			X	X	X	X	X
Stephens Lake - South	STL-S	X			X		X			X	
Stephens Lake - North	STL-N	X			X		X			X	
Limestone Forebay	LMFB	X		X		X	X	X	X	X	X
Lower Nelson River - downstream of Limestone GS	LNR	X			X			X			X
Hayes River	HAYES		X	X		X	X	X	X	X	X
Assean Lake	ASSN		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 Lower Nelson River Region waterbodies: 2008-2013.

Species	**Abbreviation**	**BURNT** $n_Y=1$	**SPLIT** $n_Y=5$	**STL-N & S** $n_Y=2$	**LMFB** $n_Y=2$	**LNR** $n_Y=6$	**HAYES** $n_Y=6$	**ASSN** $n_Y=5$
Silver Lamprey	SLLM					X*	X*	
Lake Sturgeon	LKST	X	X*	X*		X	X	
Mooneye	MOON	X	X	X	X*	X		
Lake Chub	LKCH		X			X*	X*	X*
Carp	CARP		X*	X*			X*	X
Emerald Shiner	EMSH	X	X	X*	X*	X		
Spottail Shiner	SPSH	X	X	X	X	X*	X*	X
Longnose Dace	LNDC	X					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	
Northern Pike	NRPK	X	X	X	X	X	X	X
Rainbow Smelt	RNSM	X	X	X	X*	X		
Cisco	CISC		X	X		X*	X*	
Lake Whitefish	LKWH		X	X	X	X	X	X
Brook Trout	BRTR					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*					
Spoonhead Sculpin	SPSC	X						
Johnny Darter	JHDR						X*	
Yellow Perch	YLPR		X	X		X*		X
Logperch	LGPR			X*				
Sauger	SAUG	X	X	X	X	X*		X*
Walleye	WALL	X	X	X	X	X	X	X
Freshwater Drum	FRDR		X	X*	X*	X*		

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

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

Component	**Waterbody**	**Hills Index**			**CPUE**[1]			**K_F**[2]			**FL_{at-age}**[3]		
		n_Y	**Mean**	**SE**	**n_F**	**Mean**	**SE**	**n_F**	**Mean**	**SE**	**n_F**	**Mean**	**SE**
Diversity	BURNT	1	7.9	-	-	-	-	-	-	-	-	-	-
	SPLIT	5	8.3	0.3	-	-	-	-	-	-	-	-	-
	STL-S	2	7.0	0.6	-	-	-	-	-	-	-	-	-
	STL-N	2	5.8	0.1	-	-	-	-	-	-	-	-	-
	LMFB	2	5.4	0.2	-	-	-	-	-	-	-	-	-
	LNR	6	6.3	0.4	-	-	-	-	-	-	-	-	-
	HAYES	6	6.2	0.3	-	-	-	-	-	-	-	-	-
	ASSN	5	6.3	0.3	-	-	-	-	-	-	-	-	-
Standard gang	BURNT	-	-	-	122	11.8	1.7	-	-	-	-	-	-
	SPLIT	-	-	-	2563	35.5	1.5	-	-	-	-	-	-
	STL-S	-	-	-	551	24.7	6.9	-	-	-	-	-	-
	STL-N	-	-	-	378	17.4	1.8	-	-	-	-	-	-
	LMFB	-	-	-	207	12.3	1.8	-	-	-	-	-	-
	LNR	-	-	-	1750	25.8	2.9	-	-	-	-	-	-
	HAYES	-	-	-	307	10.4	1.5	-	-	-	-	-	-
	ASSN	-	-	-	2636	49.7	5.0	-	-	-	-	-	-
Small mesh	BURNT	-	-	-	23	7.3	2.3	-	-	-	-	-	-
	SPLIT	-	-	-	2162	102.0	30.8	-	-	-	-	-	-
	STL-S	-	-	-	339	52.1	8.5	-	-	-	-	-	-
	STL-N	-	-	-	328	47.1	19.6	-	-	-	-	-	-
	LMFB	-	-	-	106	54.5	11.5	-	-	-	-	-	-
	LNR	-	-	-	433	22.0	4.9	-	-	-	-	-	-
	HAYES	-	-	-	67	4.8	0.9	-	-	-	-	-	-
	ASSN	-	-	-	2308	149.9	22.6	-	-	-	-	-	-

Table 6-3. continued.

Component	Waterbody	Hills Index			CPUE[1]			K_F[2]			Fl_{at-age}[3]		
		n_Y	Mean	SE	n_F	Mean	SE	n_F	Mean	SE	n_F	Mean	SE
Lake	BURNT	-	-	-	0	-	-	-	-	-	-	-	-
Whitefish	SPLIT	-	-	-	121	1.7	0.3	94	1.70	0.06	4	305	4.8
											11	355	24.7
	STL-S	-	-	-	11	0.5	0.1	5	1.85	0.16	-	-	-
											1	360	-
	STL-N	-	-	-	17	0.8	0.2	10	1.73	0.23	-	-	-
											1	305	-
	LMFB	-	-	-	3	0.2	0.1	1	1.49	-	-	-	-
	LNR	-	-	-	120	1.8	0.3	114	1.49	0.03	1	303	-
											4	365	11.6
	HAYES	-	-	-	29	0.6	0.2	27	1.42	0.04	2	256	54.0
											3	329	32.8
	ASSN	-	-	-	289	5.4	1.4	226	1.52	0.06	47	317	18.0
											73	360	13.3
Northern	BURNT	-	-	-	12	1.2	0.7	8	0.70	-	3	390	-
Pike	SPLIT	-	-	-	327	4.3	0.3	251	0.73	0.02	56	447	7.5
	STL-S	-	-	-	136	5.8	1.3	104	0.74	0.02	16	461	0.8
	STL-N	-	-	-	130	6.0	1.3	114	0.72	0.02	22	472	0.2
	LMFB	-	-	-	54	2.6	1.5	45	0.73	0.02	8	538	18.3
	LNR	-	-	-	524	7.7	0.8	347	0.71	0.02	47	506	13.1
	HAYES	-	-	-	32	0.6	0.1	17	0.70	0.02	1	405	-
	ASSN	-	-	-	379	7.2	0.6	323	0.67	0.02	39	450	13.6
Walleye	BURNT	-	-	-	59	5.7	1.3	48	1.28	-	4	282	-
	SPLIT	-	-	-	779	10.8	1.4	592	1.26	0.04	85	279	10.2
	STL-S	-	-	-	255	11.7	5.3	165	1.34	0.06	5	230	-
	STL-N	-	-	-	202	9.3	0.3	152	1.32	0.07	3	282	26.0
	LMFB	-	-	-	15	0.8	0.3	8	1.30	0.14	-	-	-
	LNR	-	-	-	219	3.2	0.5	152	1.23	0.03	23	247	26.0
	HAYES	-	-	-	179	3.2	0.5	108	1.09	0.02	14	287	13.2
	ASSN	-	-	-	1305	25.0	1.8	1147	1.11	0.02	60	232	6.1

Table 6-3. continued.

Component	Waterbody	Hills 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	BURNT	-	-	-	9	0.8	0.2	8	1.56	-	-	-	-
	SPLIT	-	-	-	744	10.5	1.5	546	1.61	0.04	-	-	-
	STL-S	-	-	-	49	2.1	0.6	26	1.68	0.03	-	-	-
	STL-N	-	-	-	14	0.6	0.1	9	1.68	-	-	-	-
	LMFB	-	-	-	41	2.0	0.9	31	1.65	0.04	-	-	-
	LNR	-	-	-	136	2.0	0.5	65	1.45	0.04	-	-	-
	HAYES	-	-	-	67	1.2	0.3	52	1.43	0.03	-	-	-
	ASSN	-	-	-	407	7.6	0.5	279	1.61	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 Lower 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
CPUE	NRPK	HAYES	Q (GN)	2	48.11	0.02	0.96	-
		HAYES	WL (GN)	2	35.88	0.03	0.95	-
	WHSC	LNR	Q (GN)	4	8.47	0.04	0.68	+
	Total	HAYES	Q (GN)	2	200.16	0.00	0.99	-
		HAYES	WL (GN)	2	201.81	0.00	0.99	-

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

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

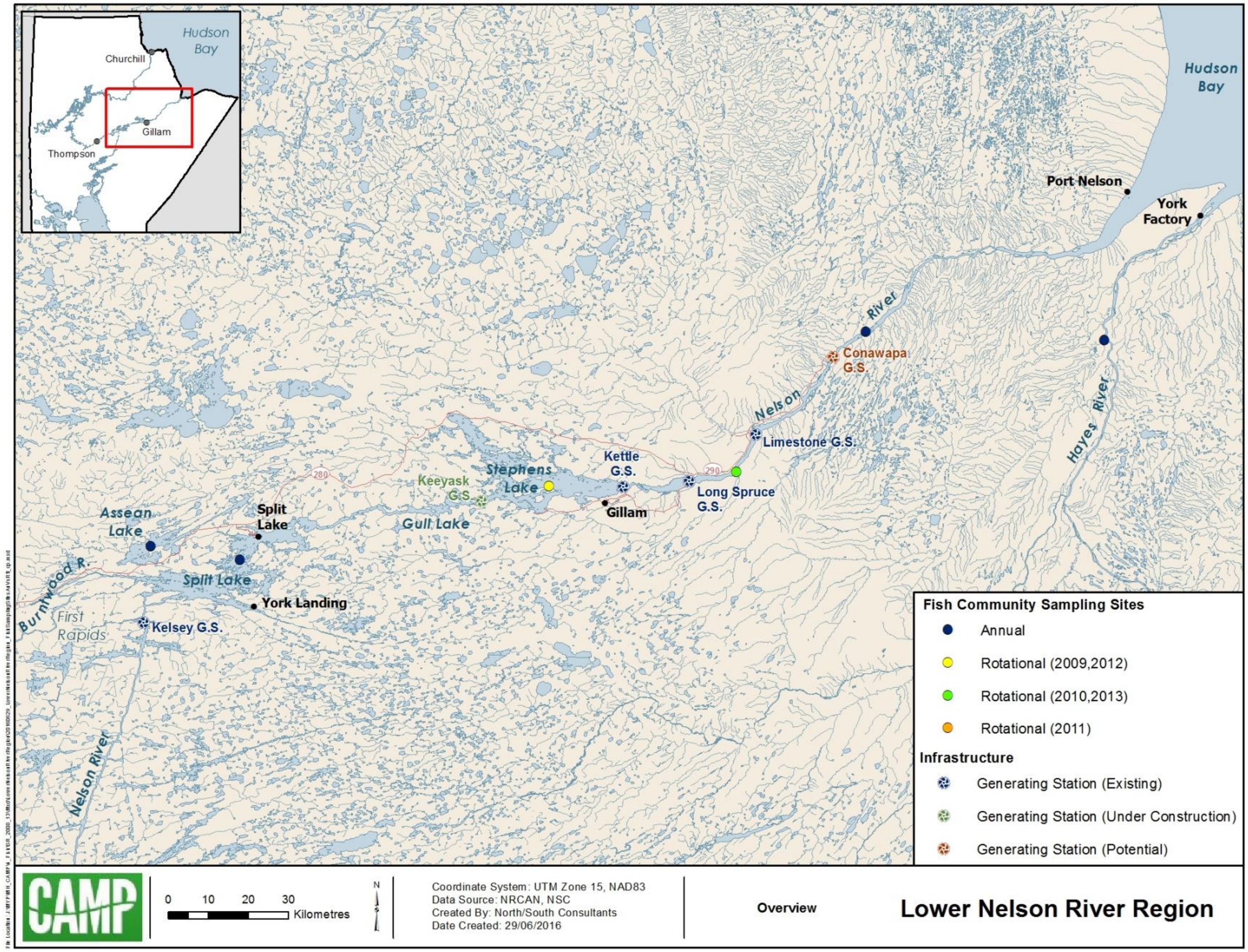


Figure 6-1. Waterbodies sampled in the Lower Nelson River Region: 2008-2013.

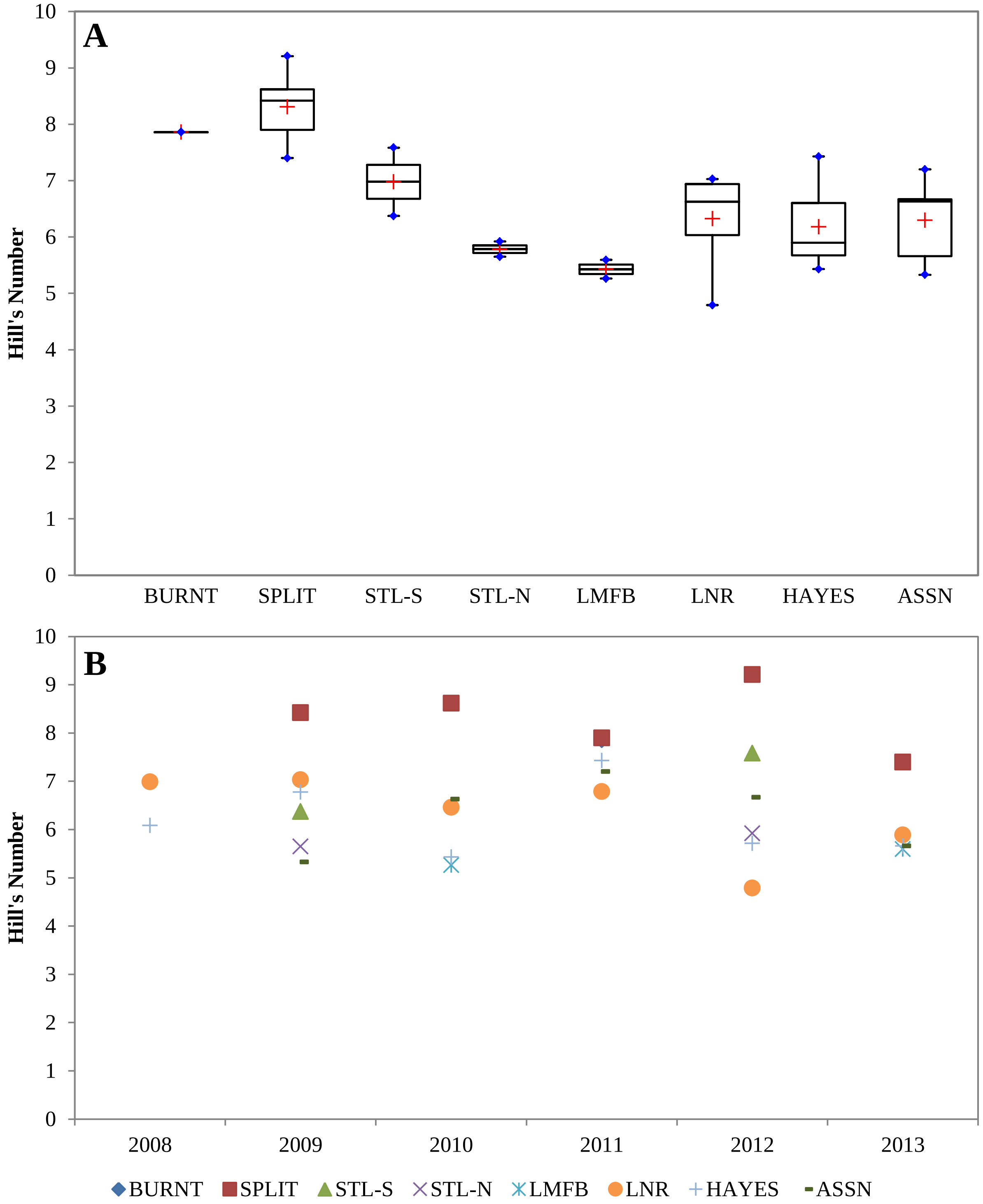


Figure 6-2. Annual mean Hill's effective species richness index (Hill's Number) for standard gang and small mesh index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

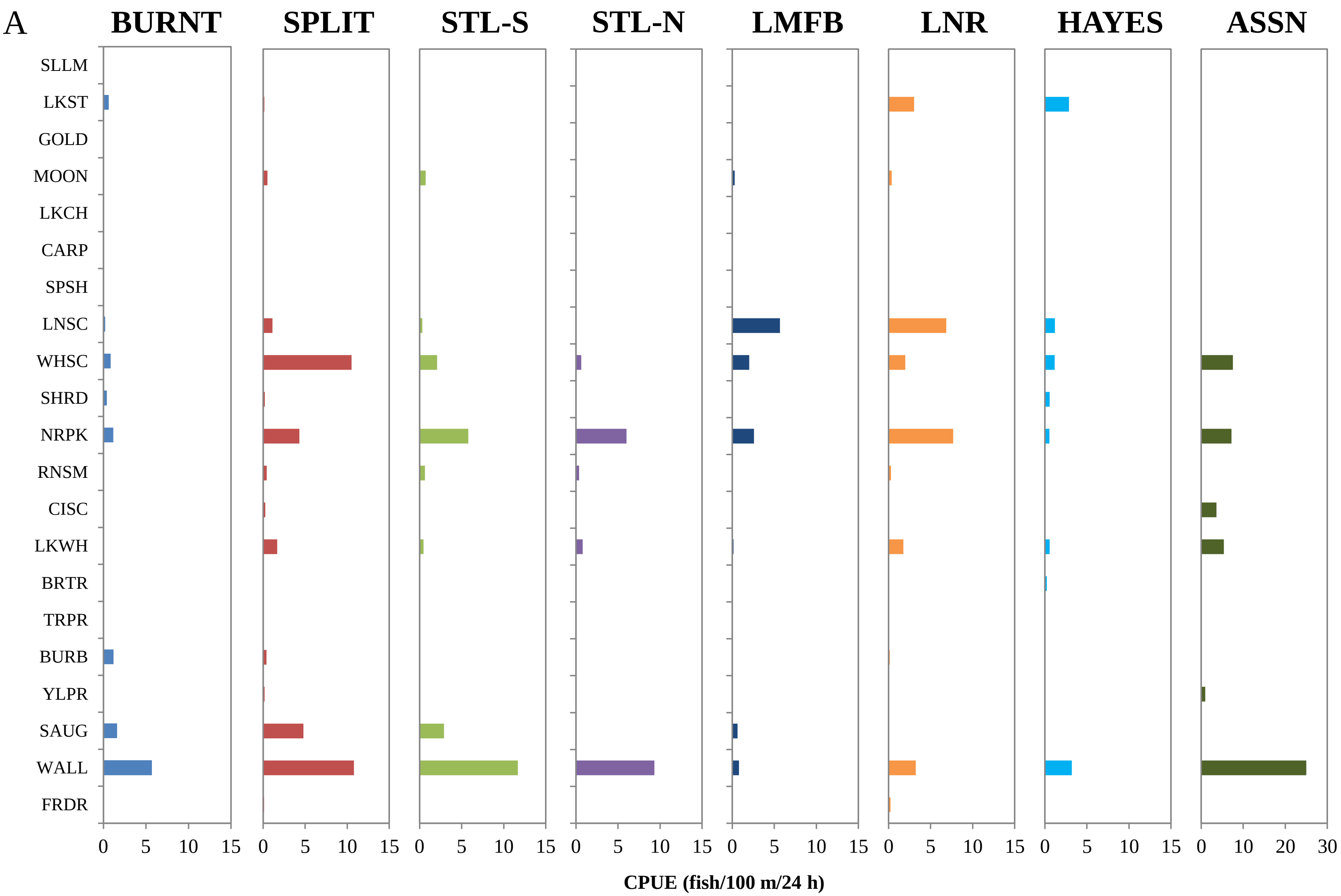


Figure 6-3. Mean catch-per-unit-effort in (A) standard gang (fish/100 m/24 h) and (B) small mesh (fish/30 m/24 h) index gill nets set in Lower Nelson River Region waterbodies:2008-2013. Note: Assean Lake x axis varies from all other waterbodies.

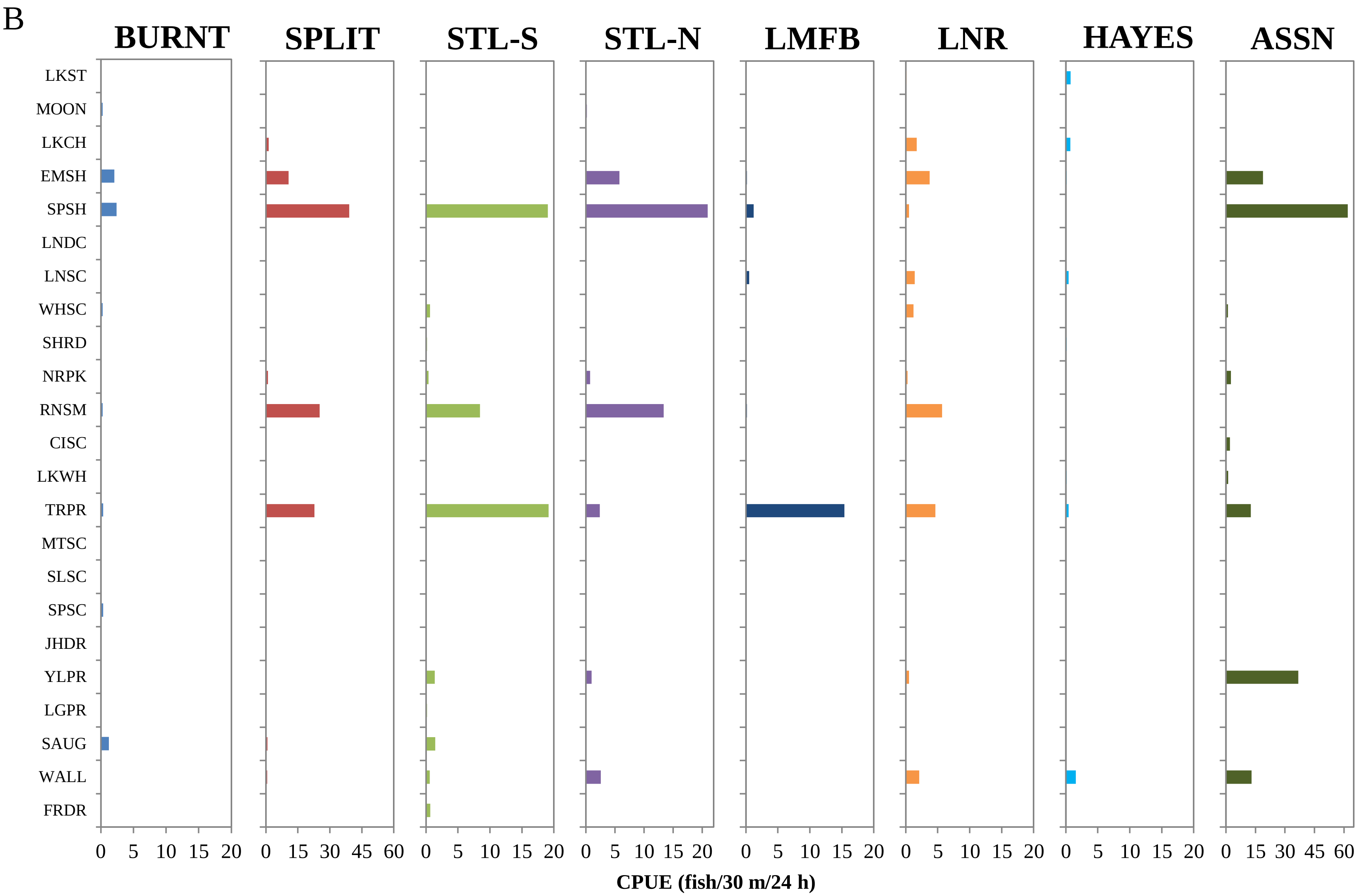


Figure 6-3. continued.

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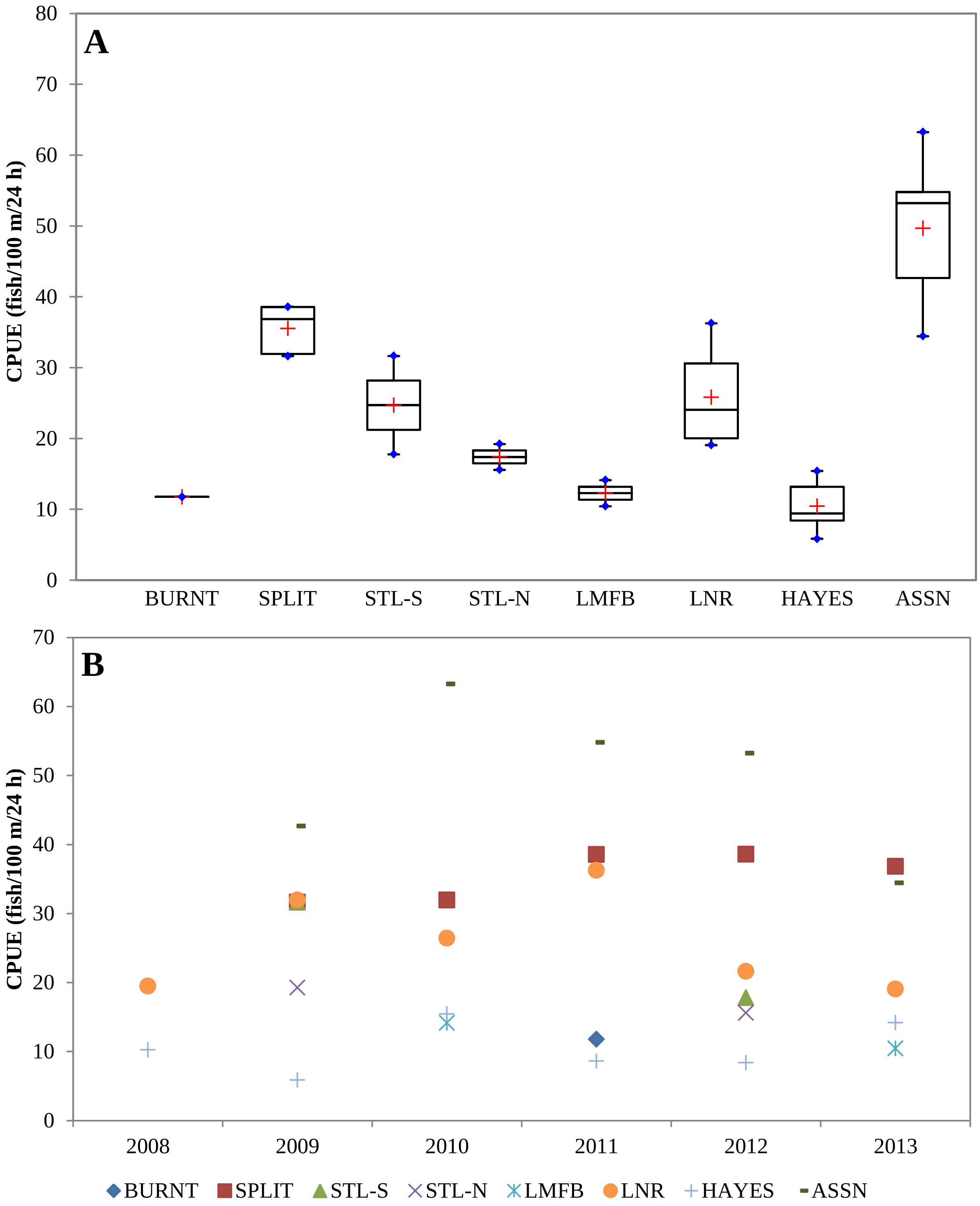


Figure 6-4. Annual mean catch-per-unit-effort (CPUE) calculated for the total catch in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

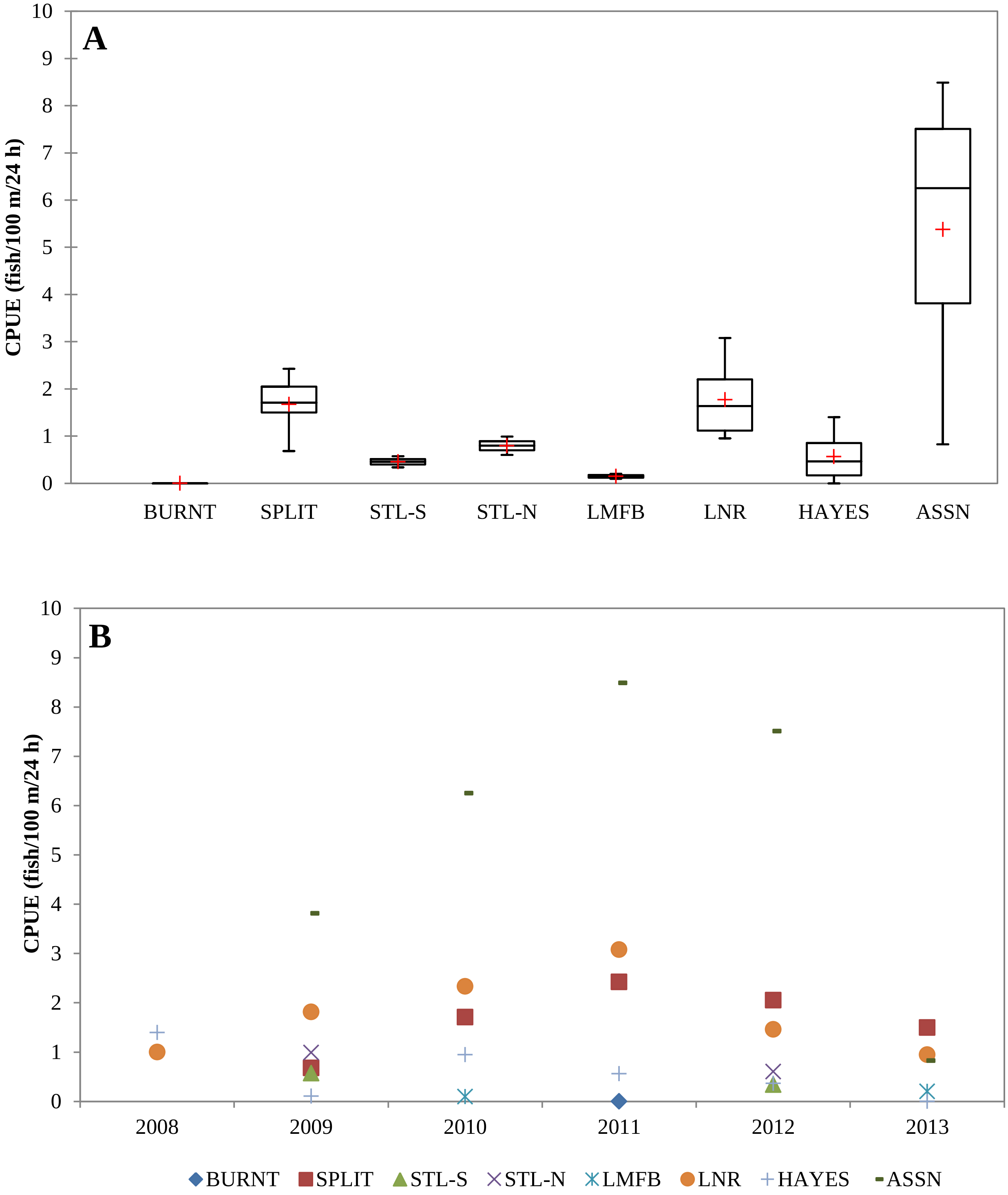


Figure 6-5. Annual mean catch-per-unit-effort (CPUE) calculated for Lake Whitefish captured in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

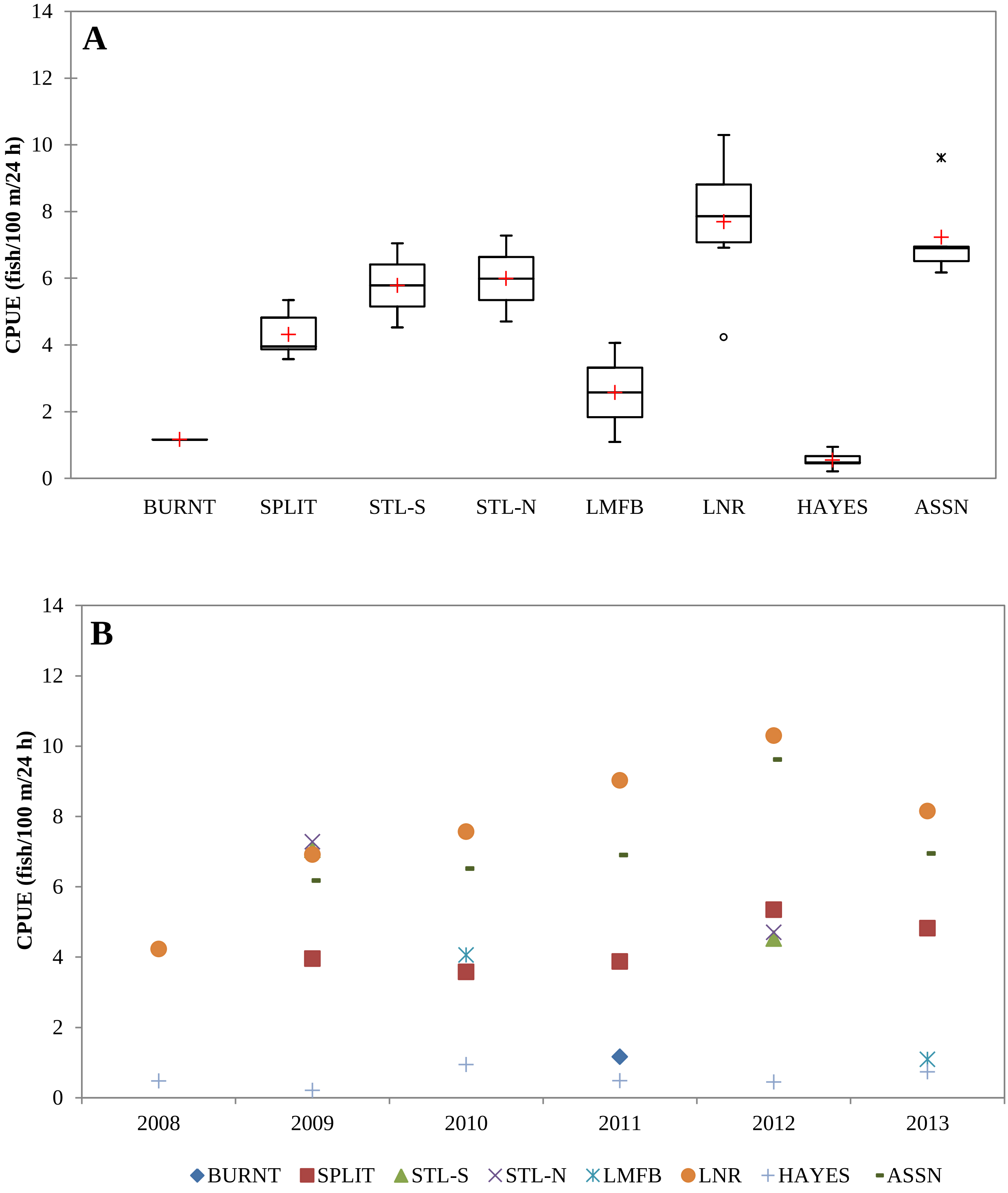


Figure 6-6. Annual mean catch-per-unit-effort (CPUE) calculated for Northern Pike captured in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

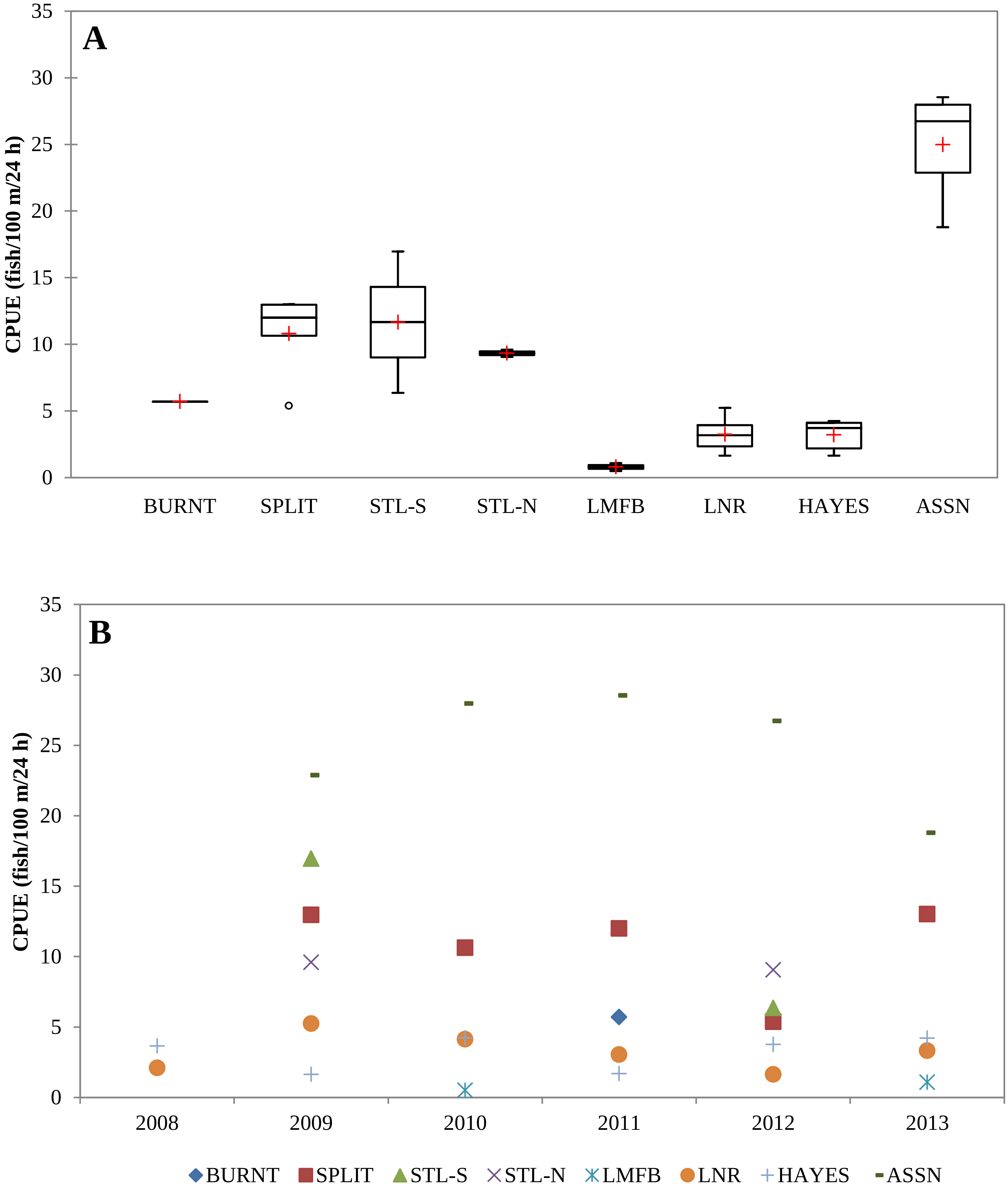


Figure 6-7. Annual mean catch-per-unit-effort (CPUE) calculated for Walleye captured in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).

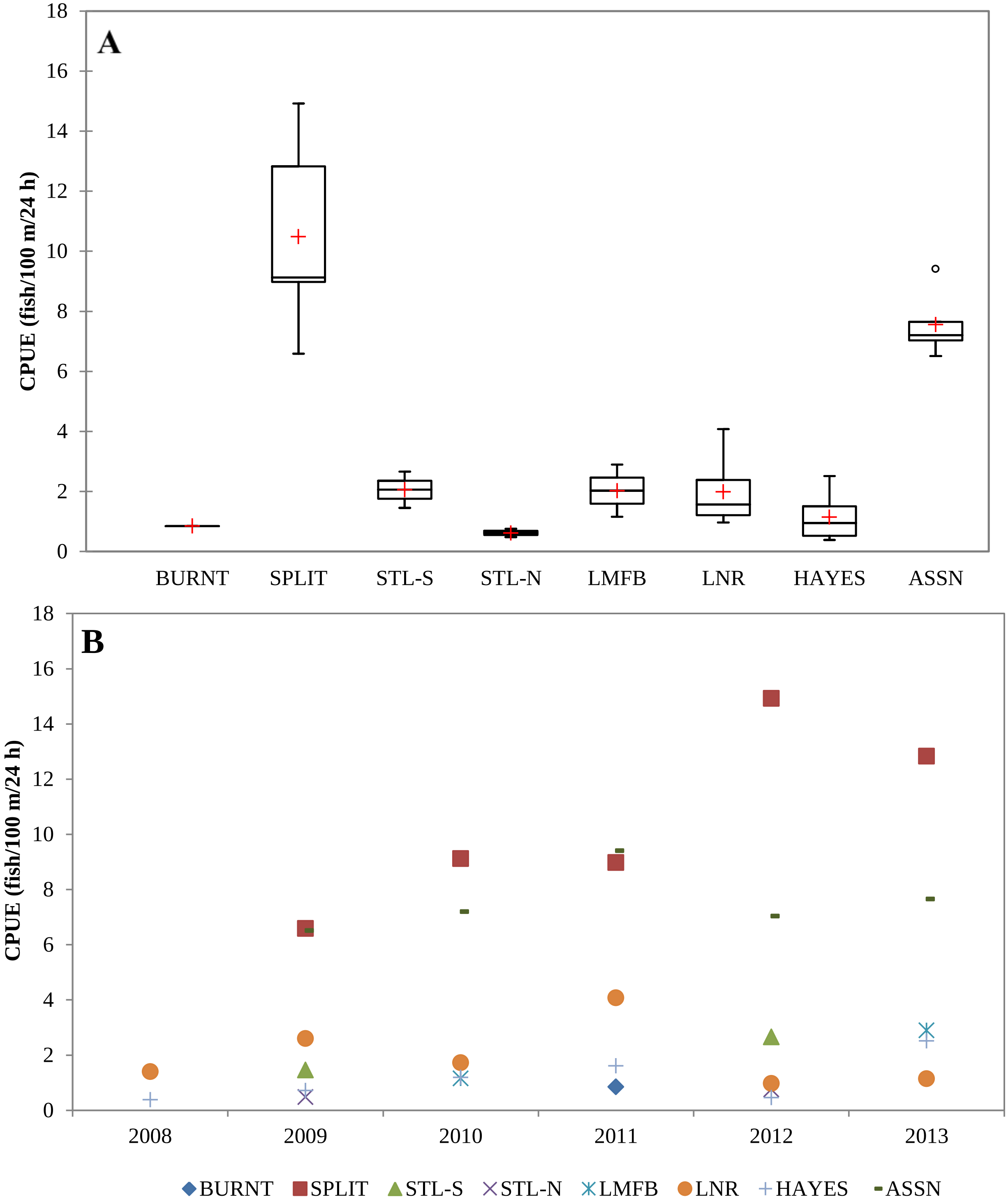
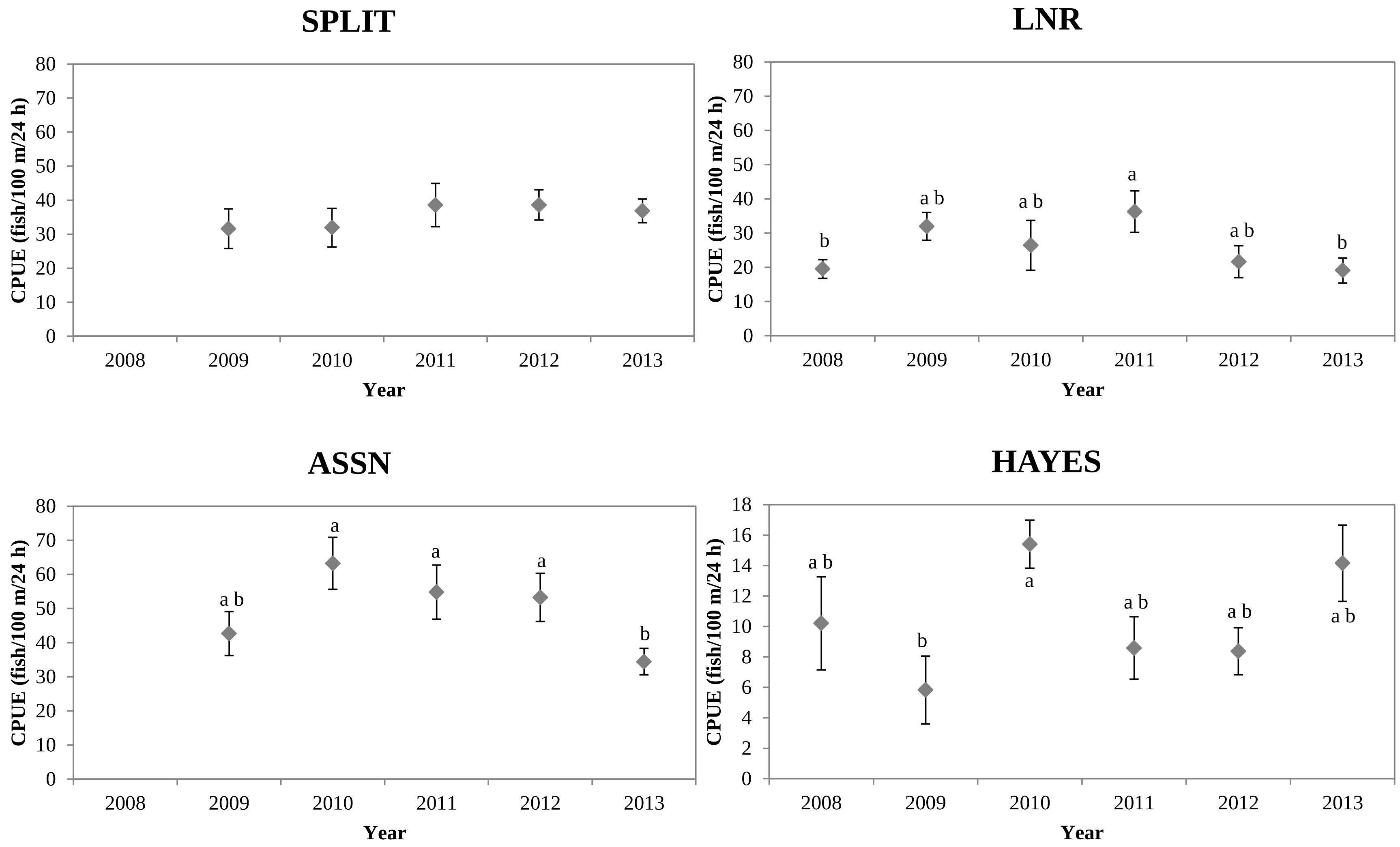


Figure 6-8. Annual mean catch-per-unit-effort (CPUE) calculated for White Sucker captured in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B).



SPLIT

LNR

ASSN

HAYES

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

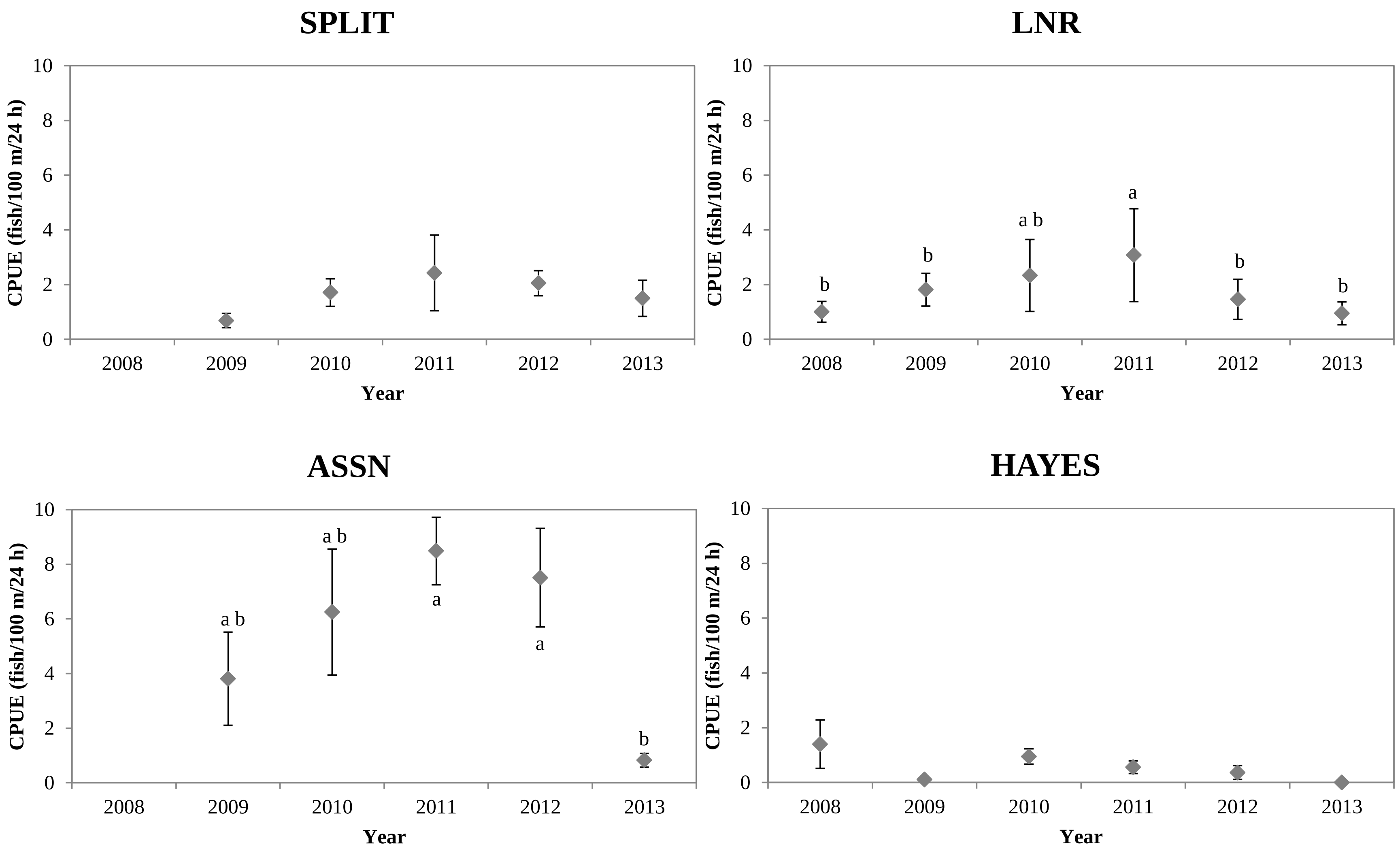


Figure 6-10. Lake Whitefish catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts,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

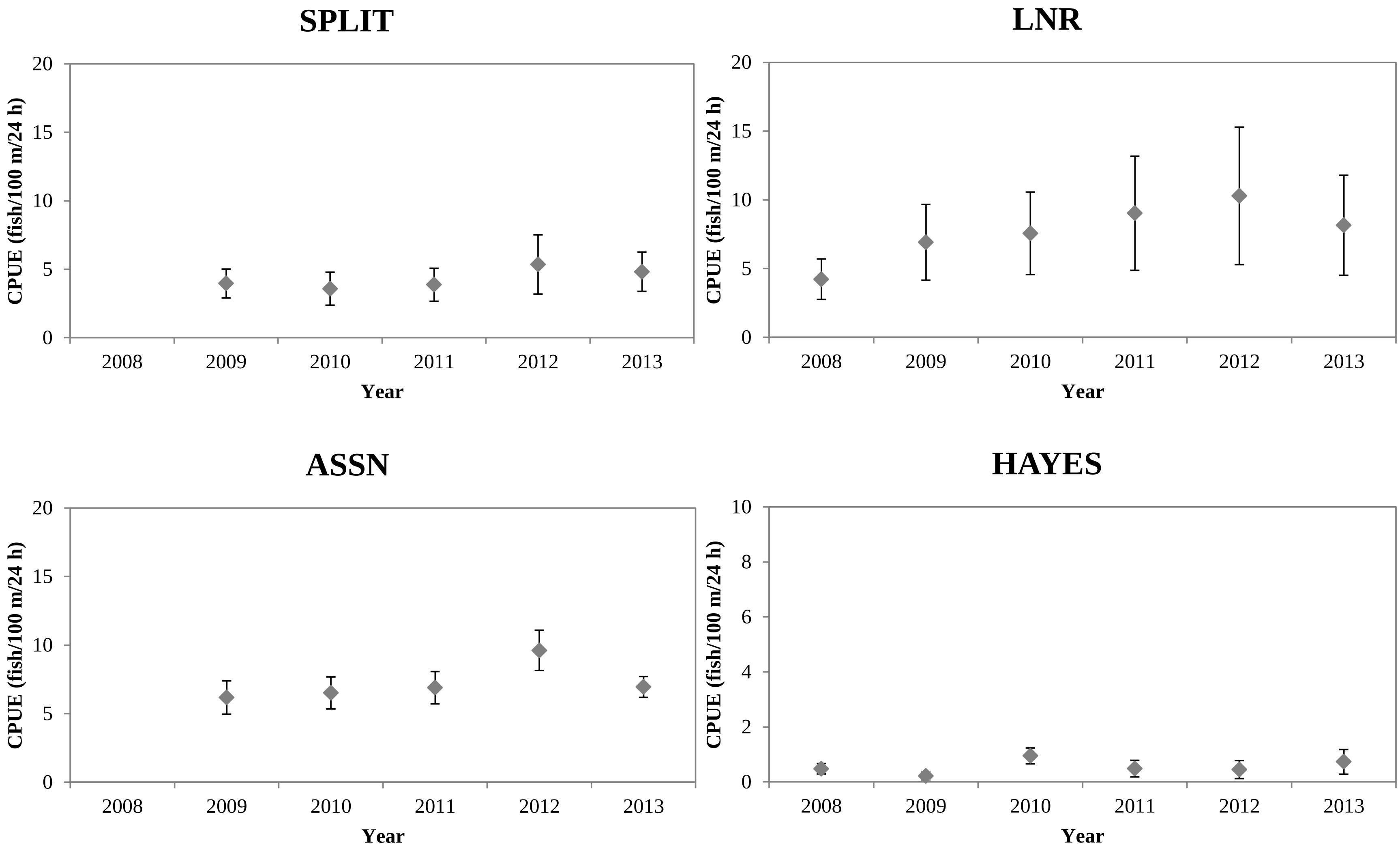


Figure 6-11. Northern Pike catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on-and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts,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

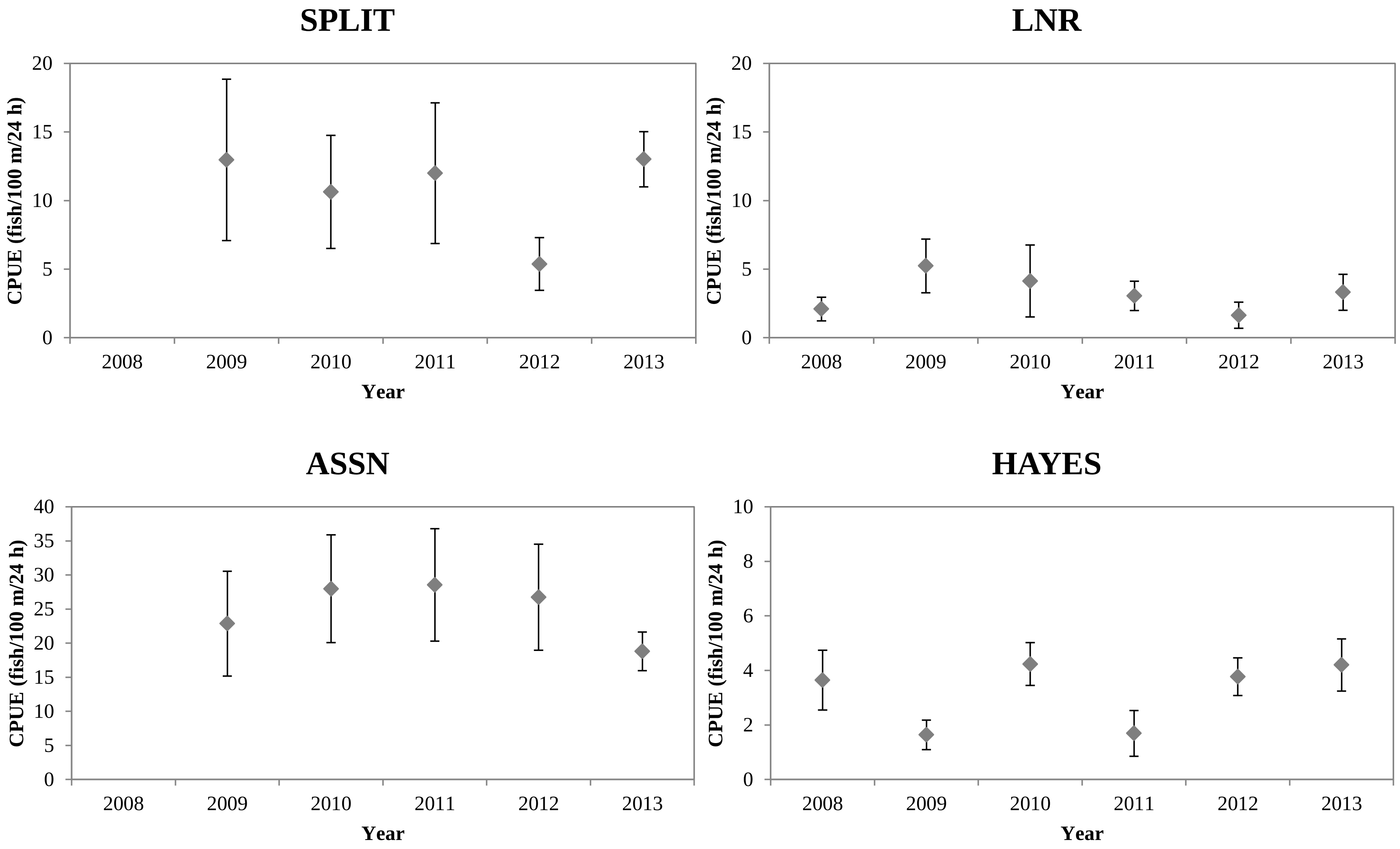


Figure 6-12. Walleye catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts,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

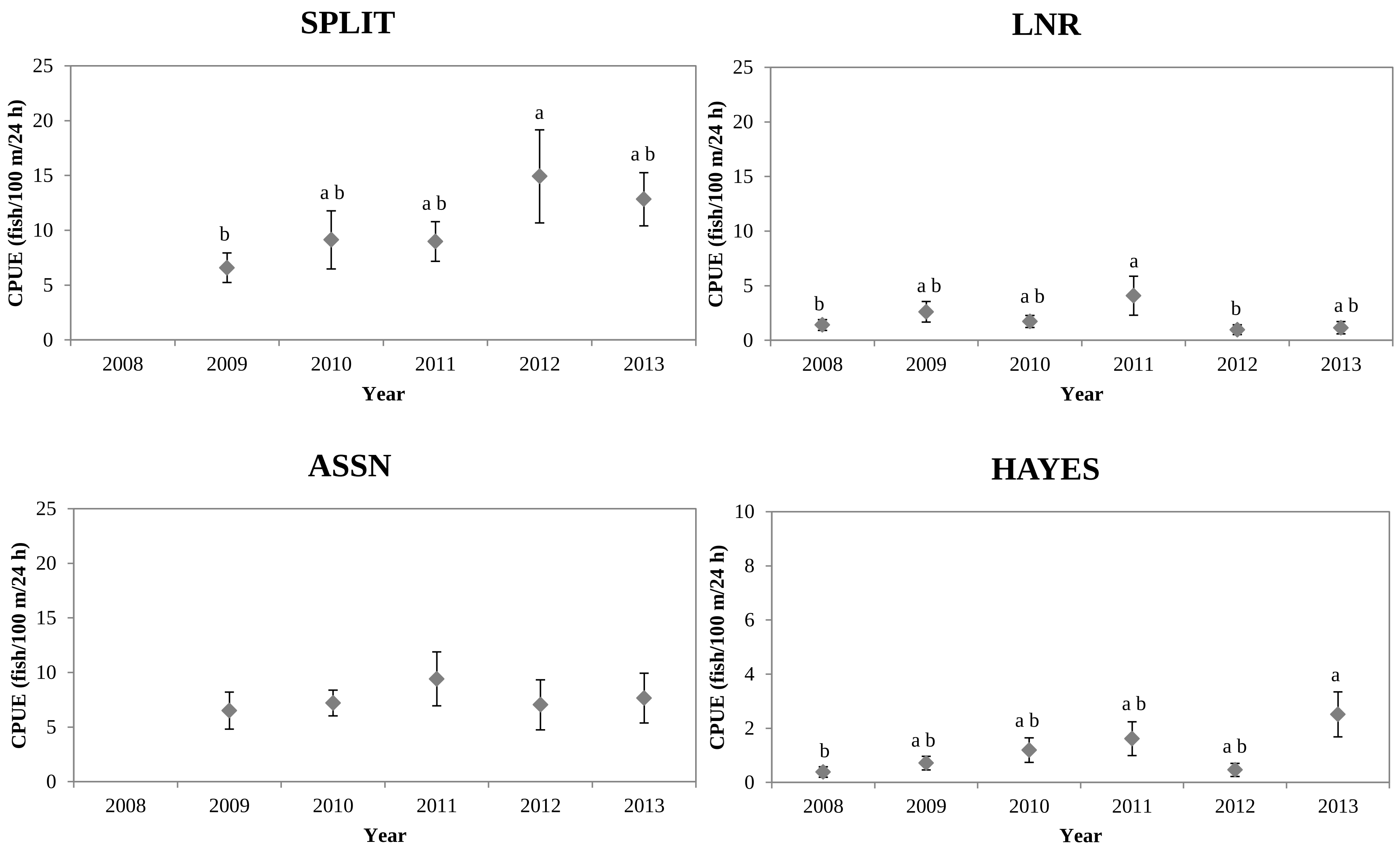
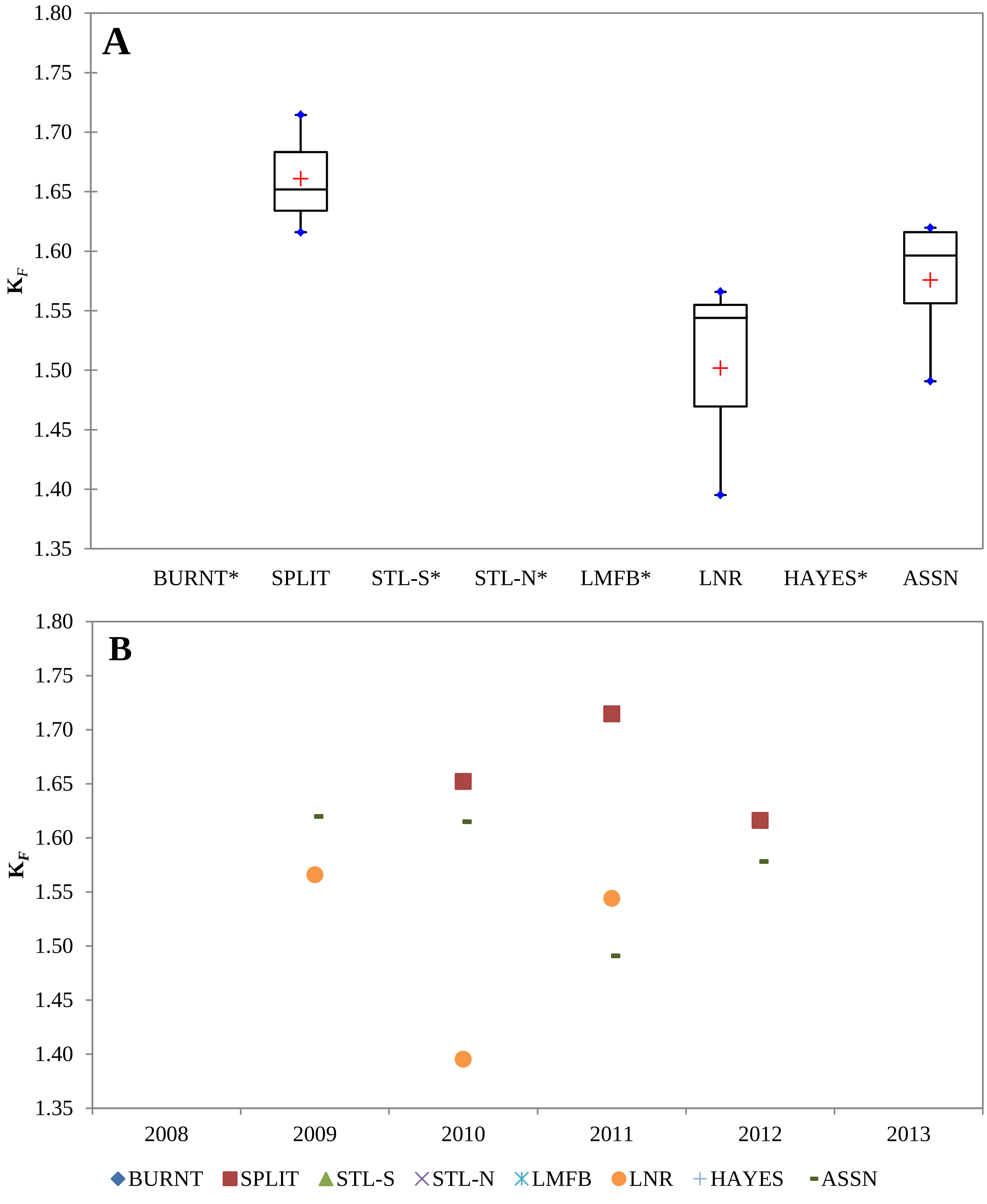
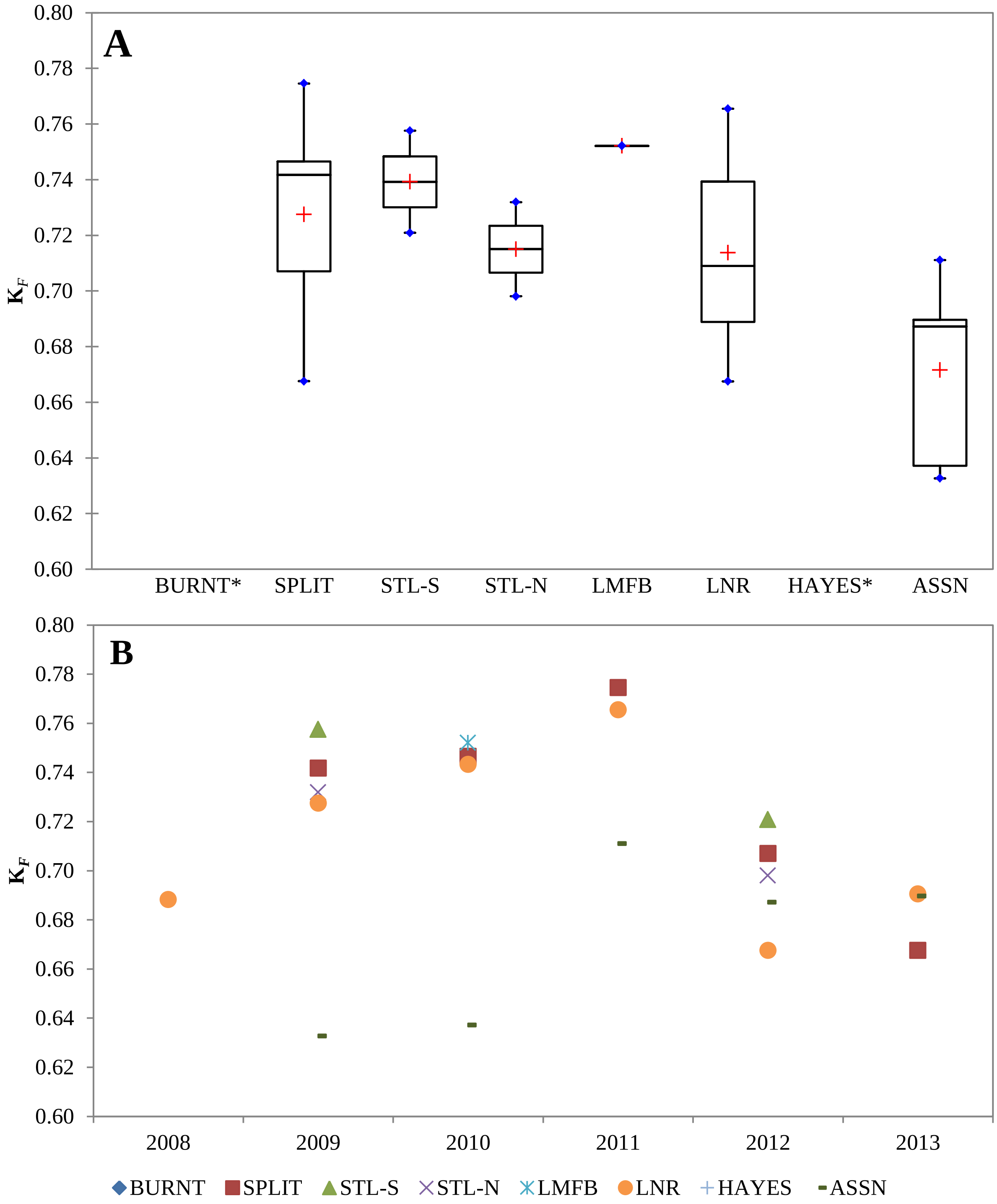


Figure 6-13. White Sucker catch-per-unit-effort (CPUE; mean ± SE) in standard gang index gill nets set at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts,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



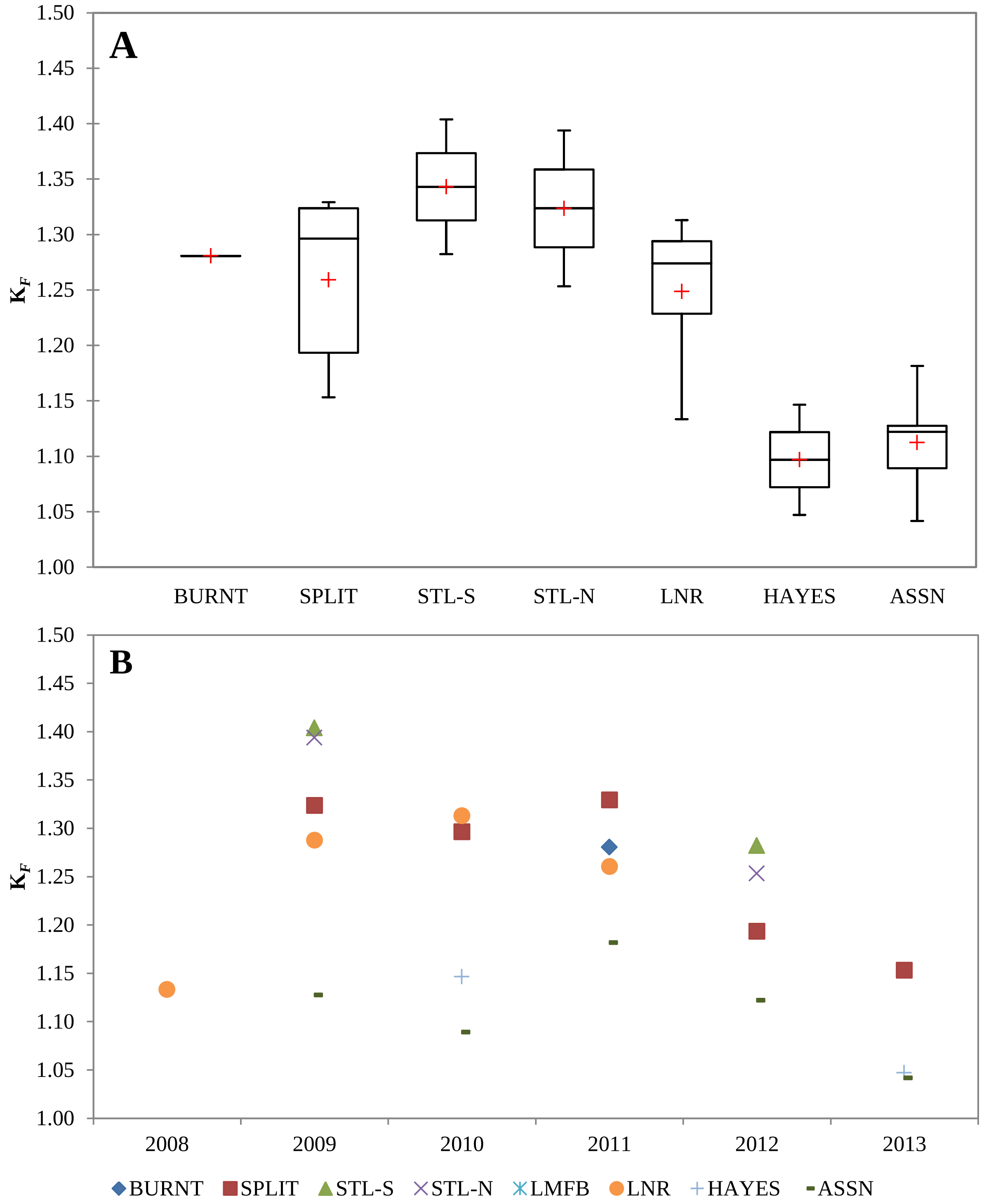
*Too few fish were captured in BURNT, STL-S, STL-N, LMFB and HAYES.

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



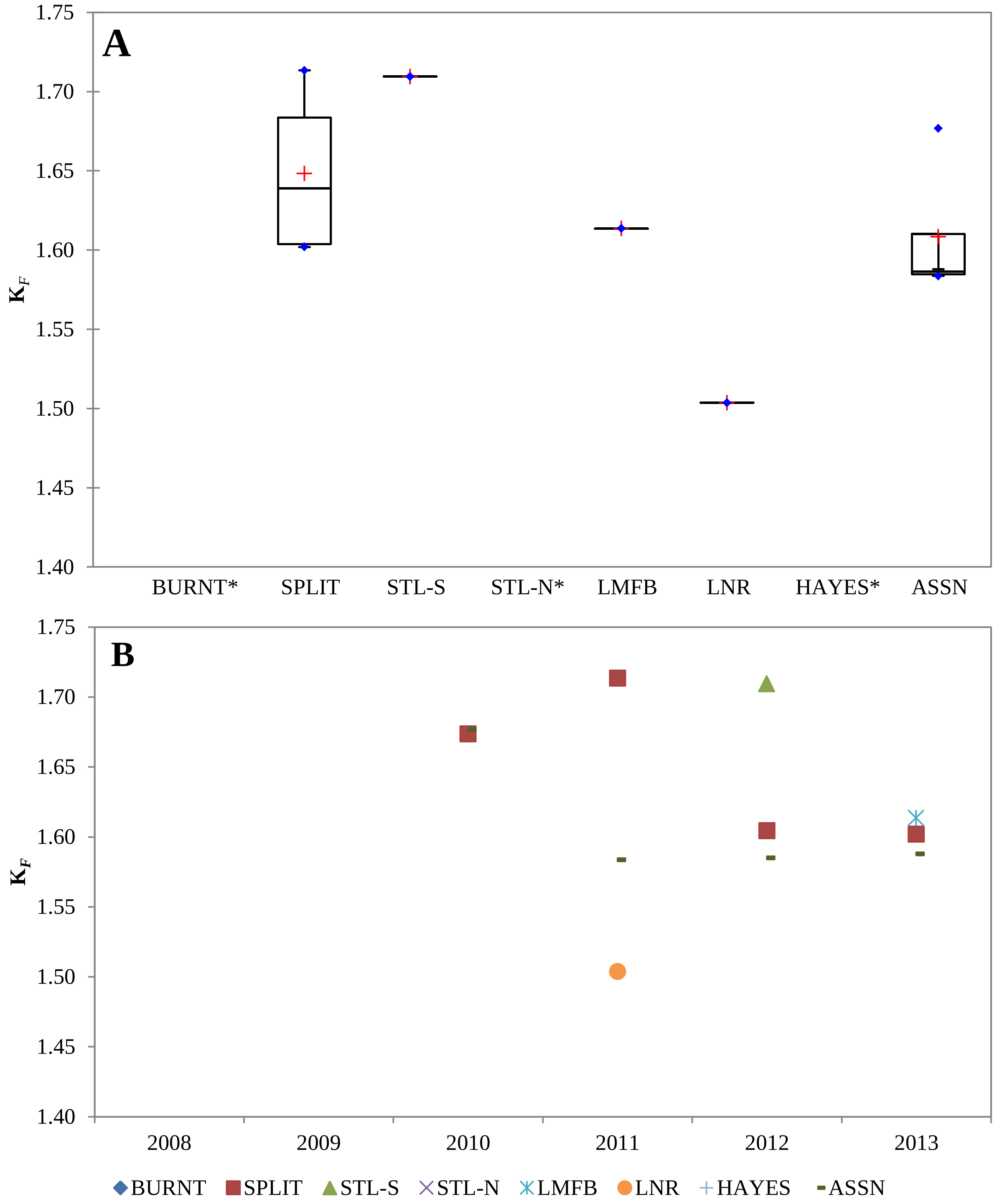
*Too few fish were captured in BURNT and HAYES.

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



*Too few fish were captured in LNR in 2012 and 2013

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



*Too few fish were captured in BURNT, STL-N and HAYES.

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

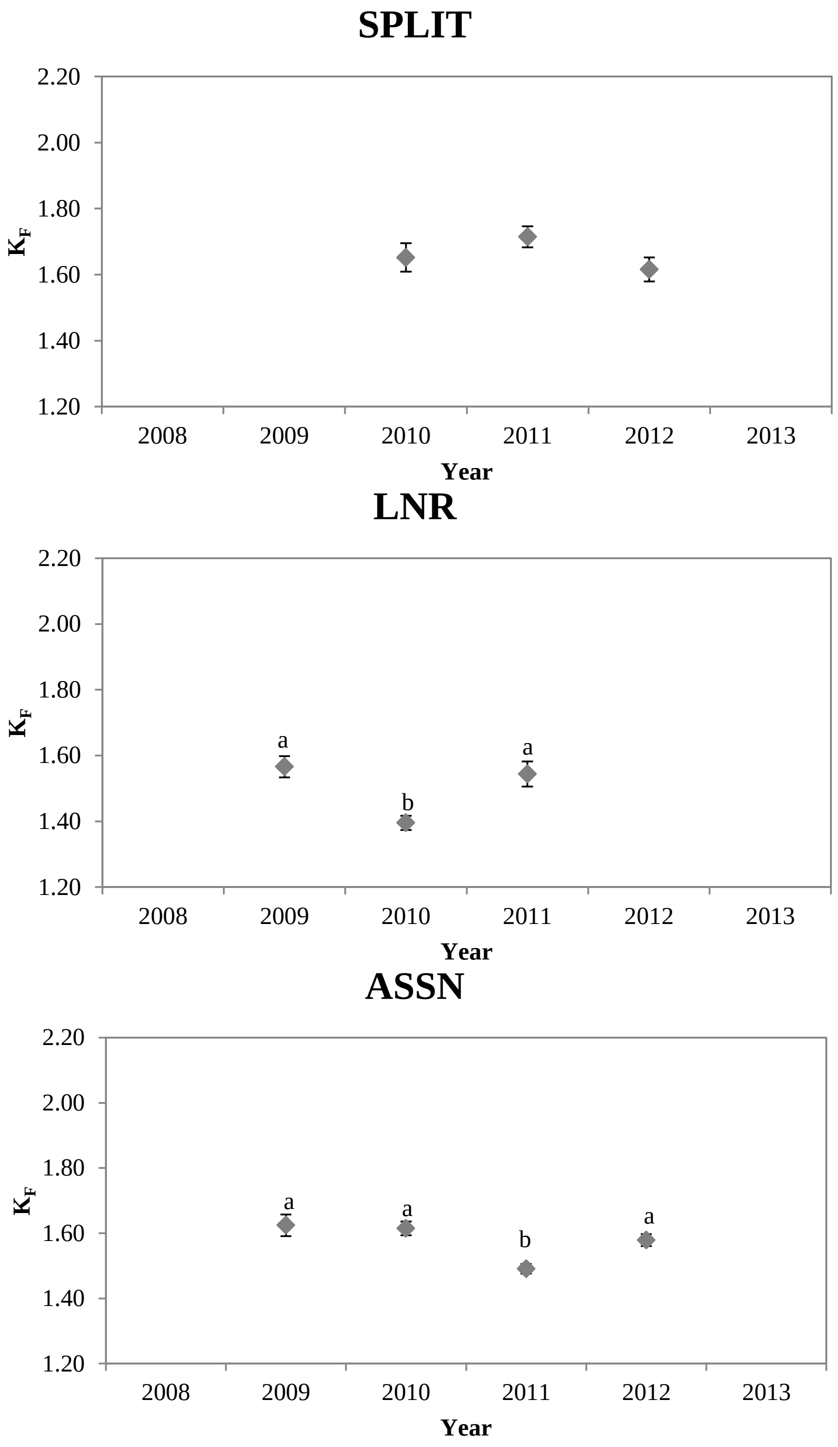


Figure 6-18. Fulton's condition factor (K_F; mean ± SE) of Lake Whitefish between 300 and 499 mm in fork length captured at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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

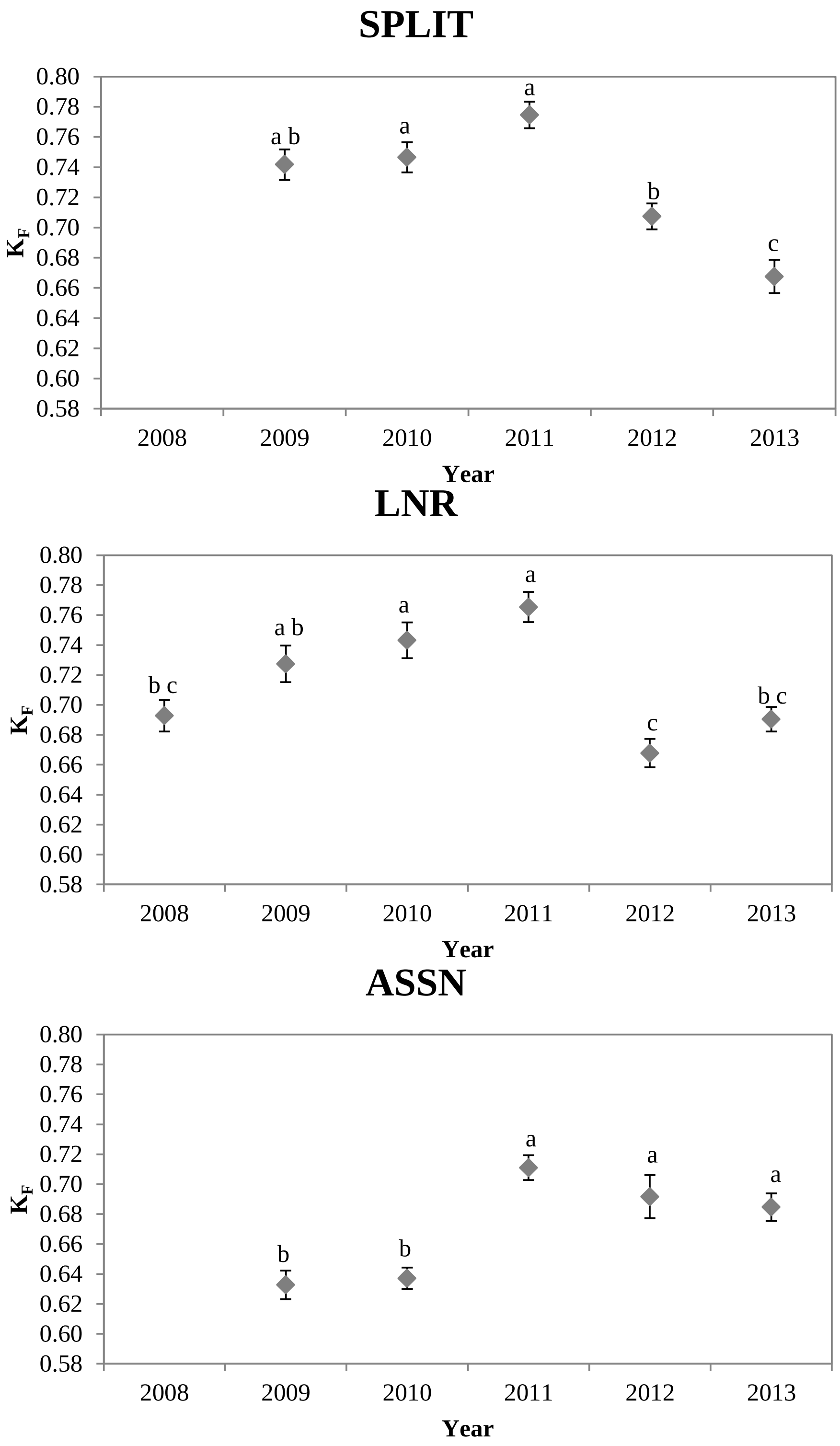


Figure 6-19. Fulton's condition factor (K_F; mean ± SE) of Northern Pike between 400 and 699 mm in fork length captured at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts,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

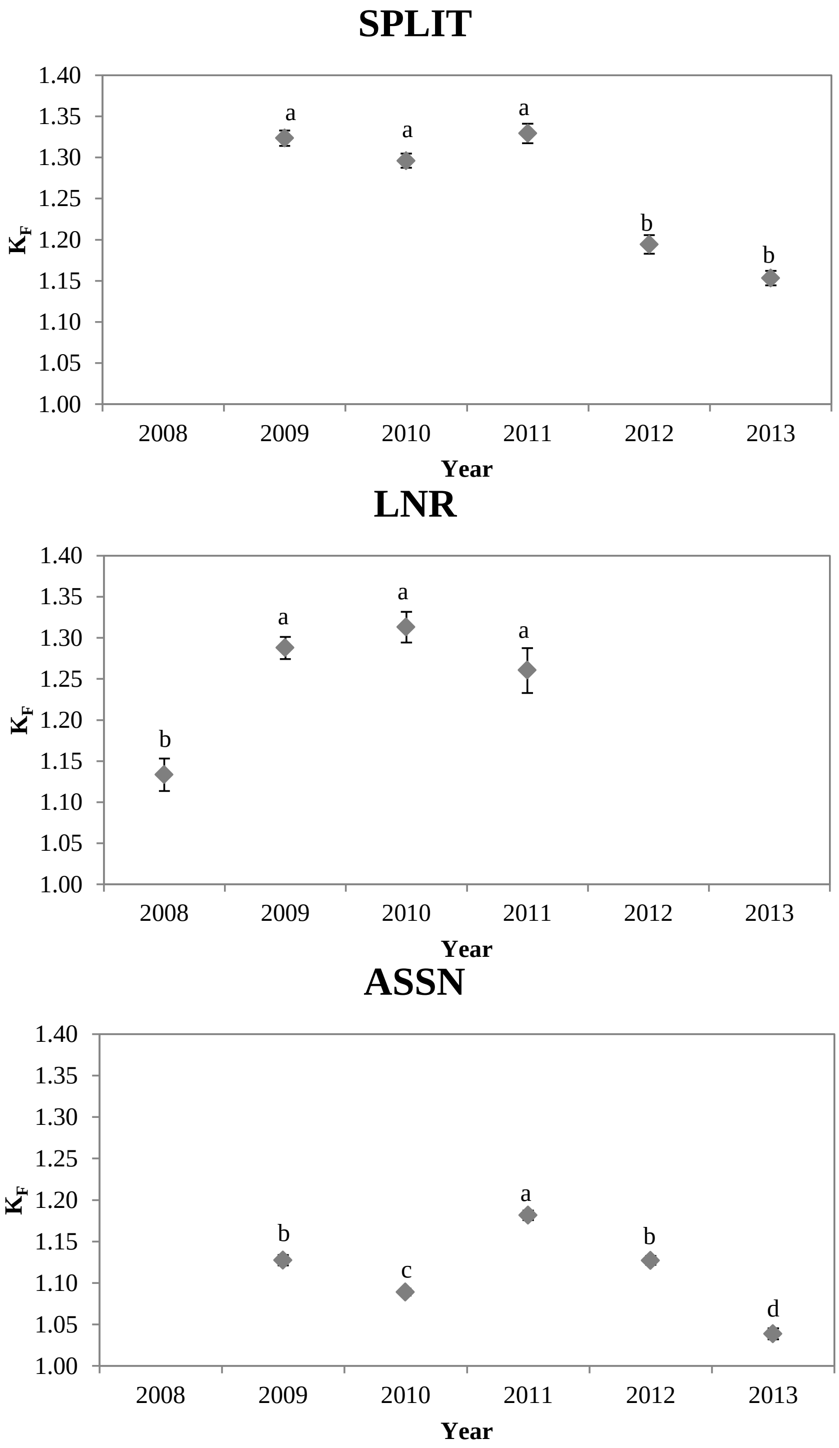


Figure 6-20. Fulton’s condition factor (K_F; mean ± SE) of Walleye between 300 and 499 mm in fork length captured at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack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

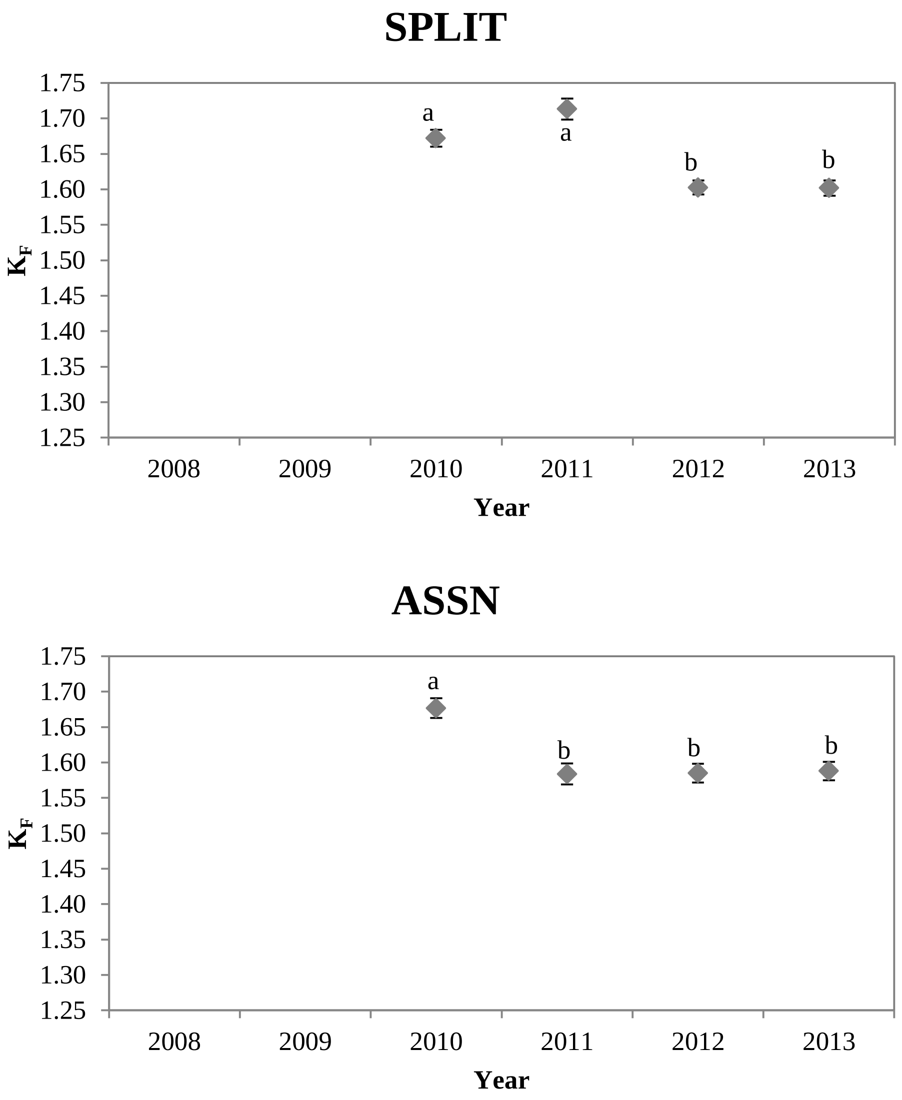


Figure 6-21. Fulton’s condition factor (K_F; mean ± SE) of White Sucker between 300 and 499 mm in fork length captured at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or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

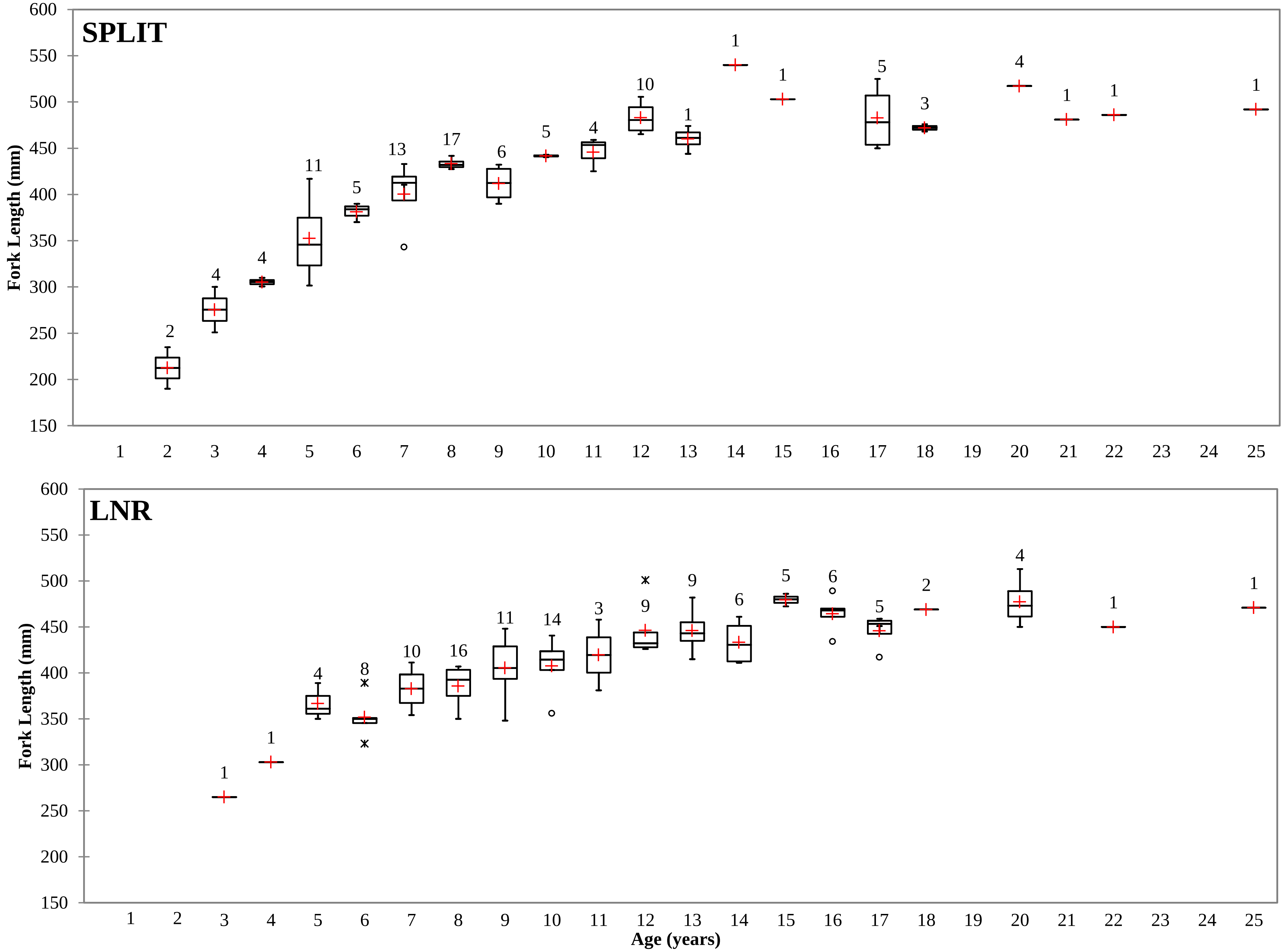


Figure 6-22. Annual mean length-at-age of Lake Whitefish captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Nelson River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.

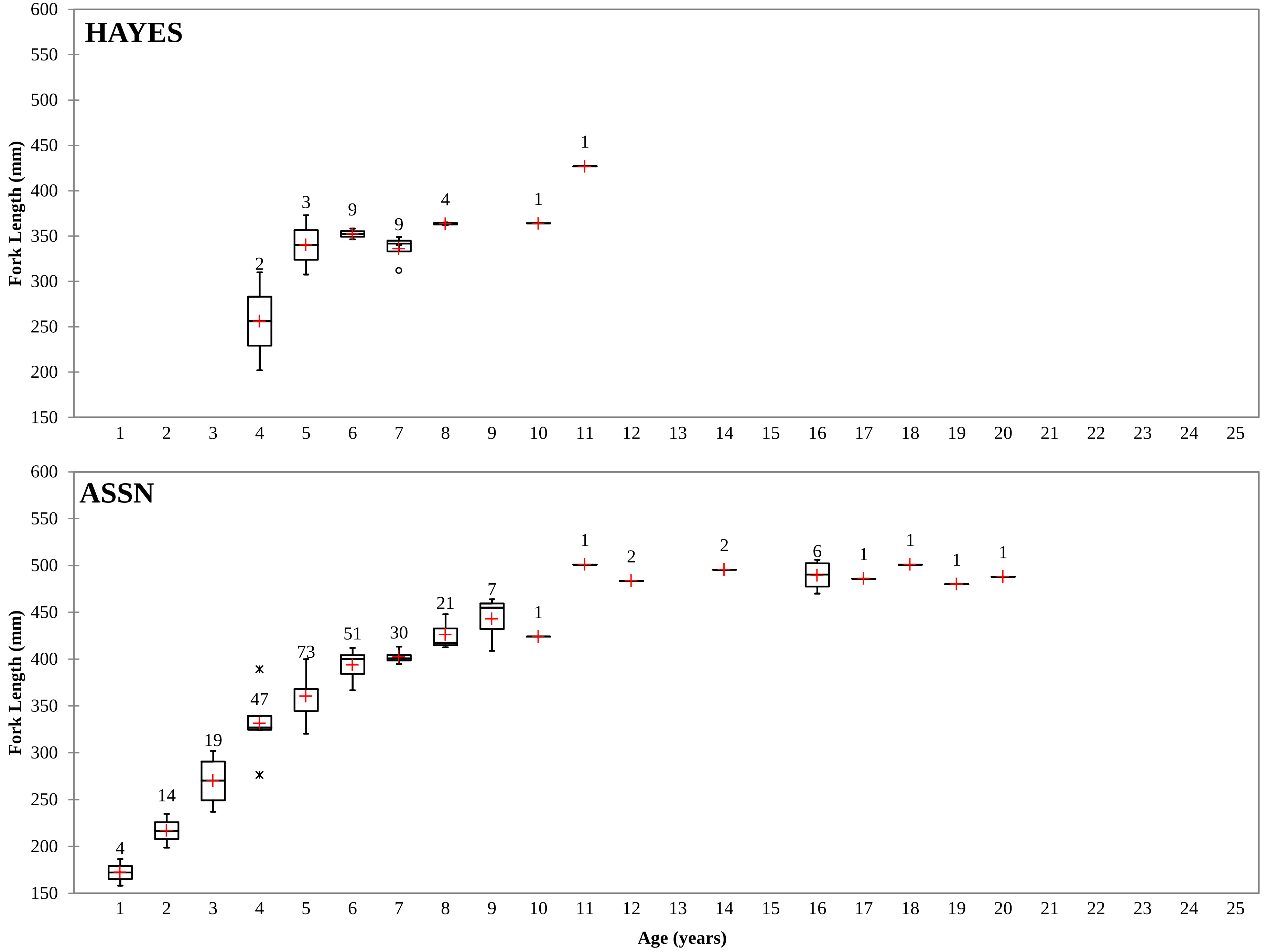
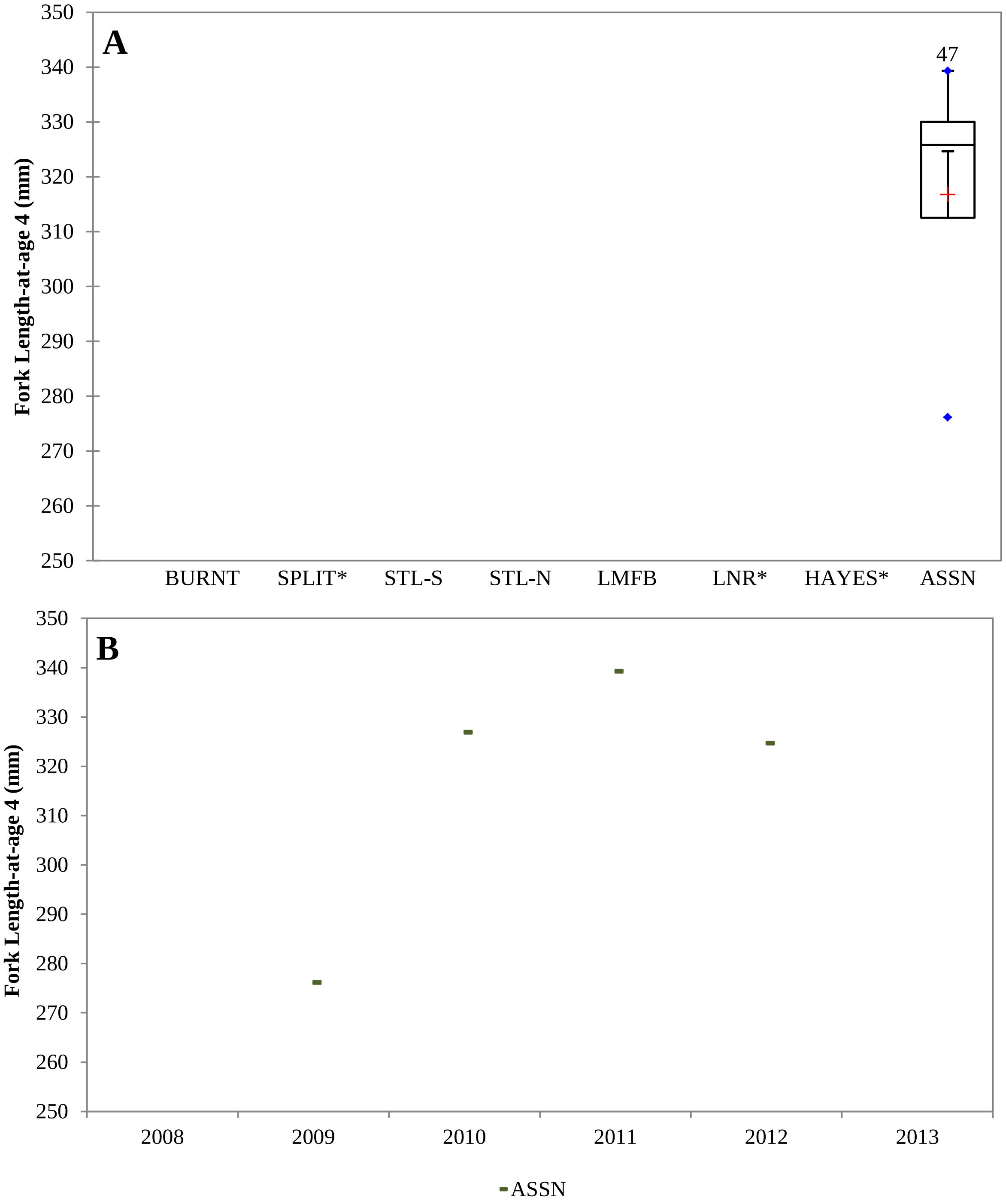
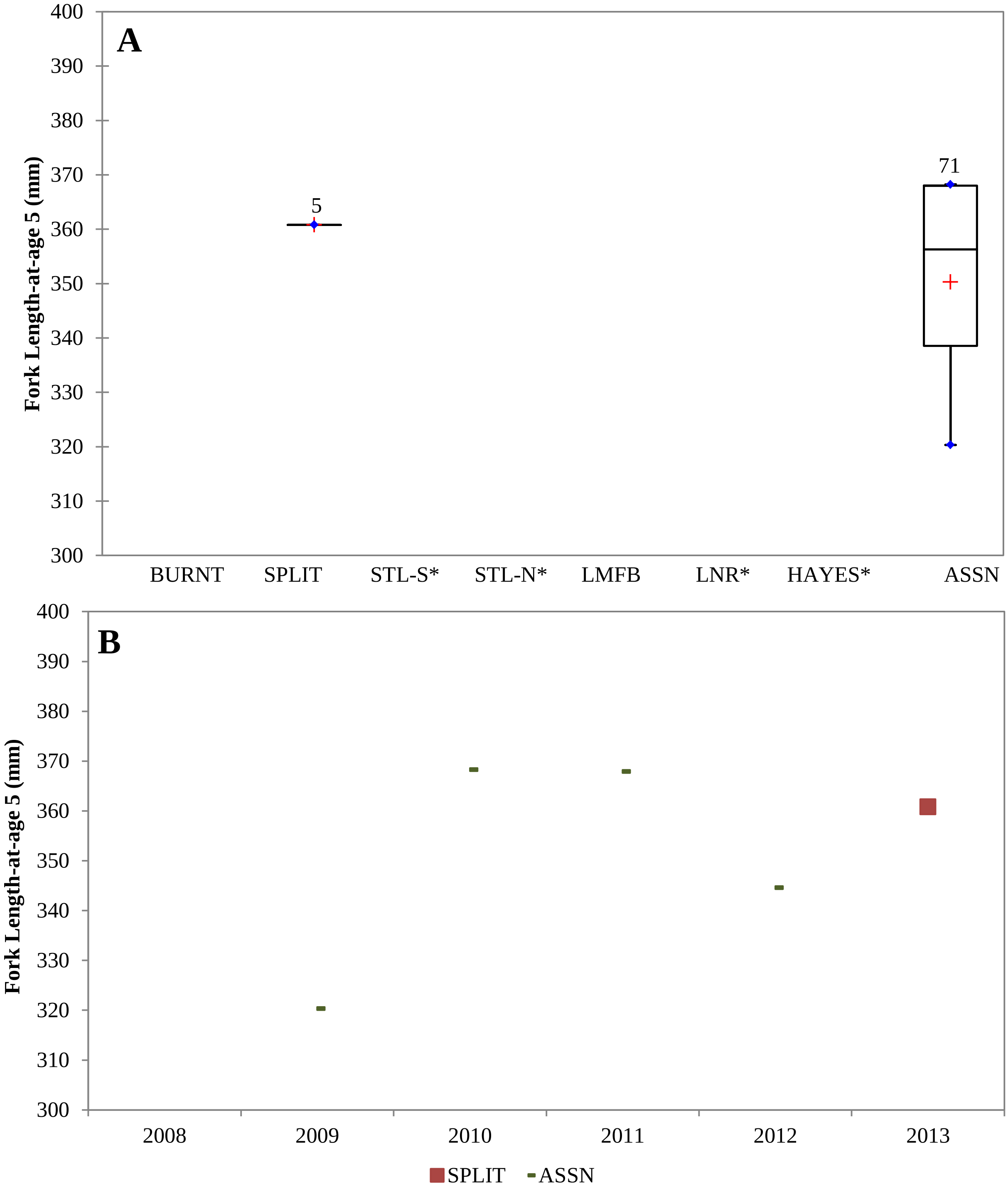


Figure 6-22. continued.



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

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



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

Figure 6-24. Annual mean length-at-age 5 of Lake Whitefish captured in standard gang and small mesh index gill nets set in Lower 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 waterbody.

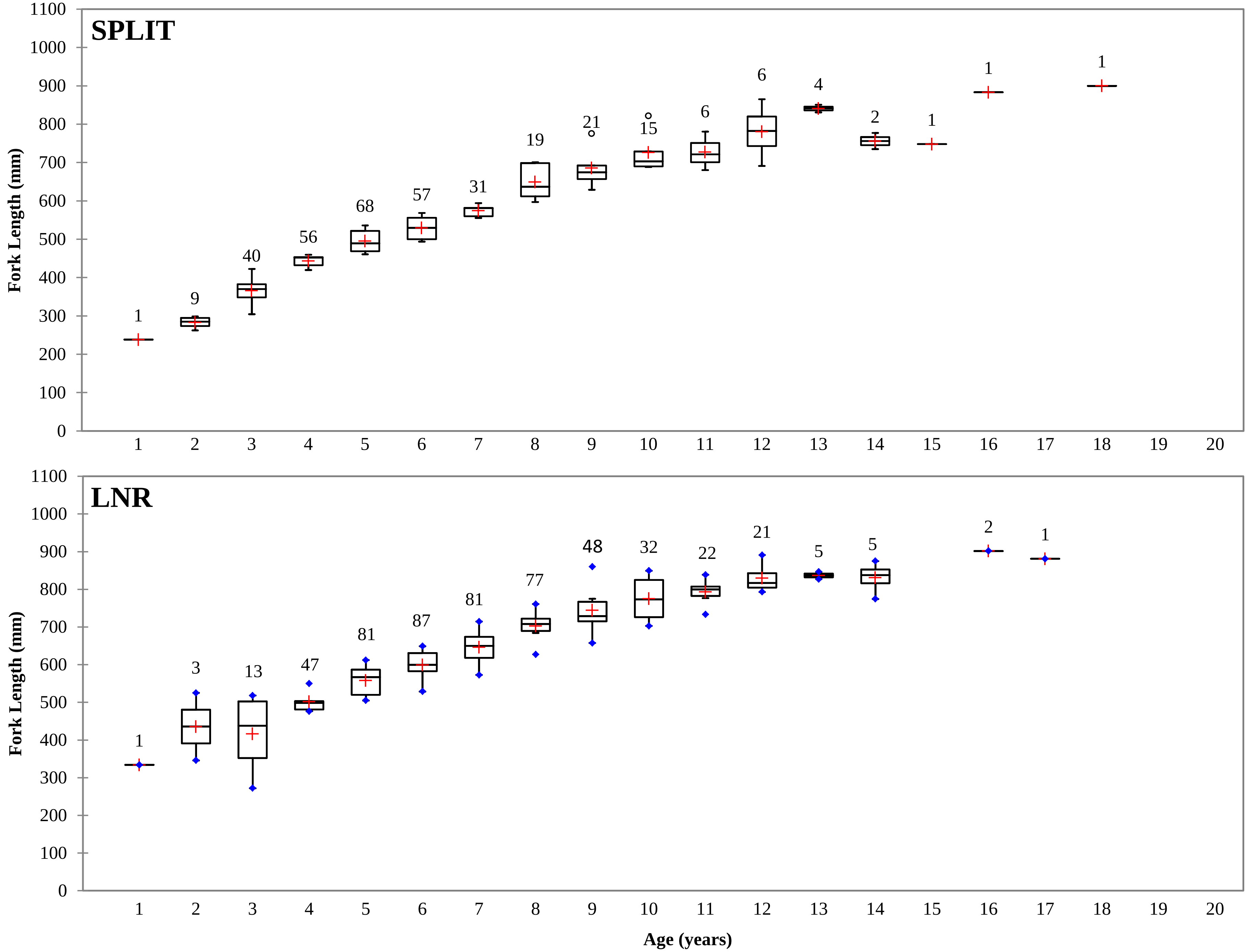


Figure 6-25. Annual mean length-at-age of Northern Pike captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Nelson River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.

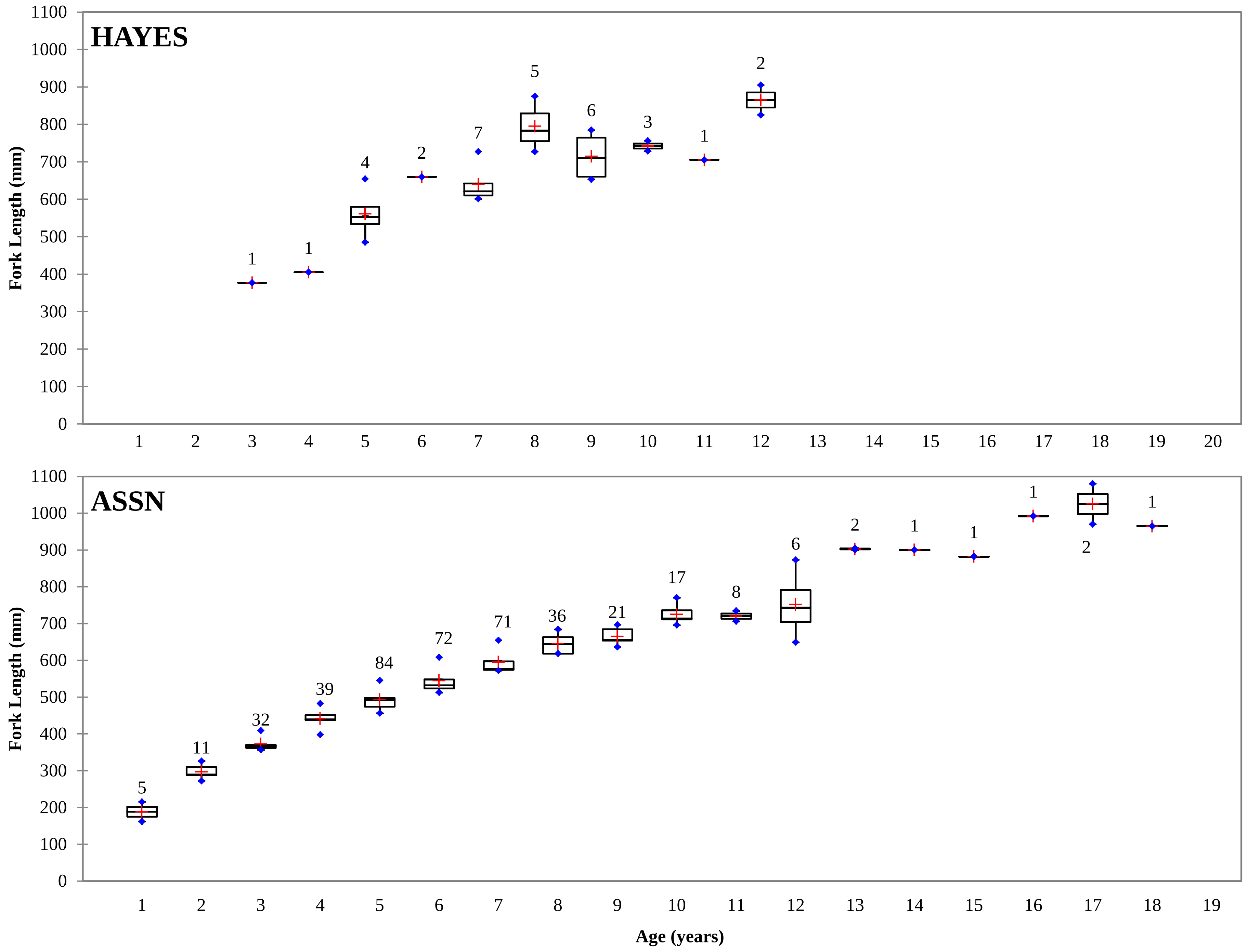


Figure 6-25. continued.

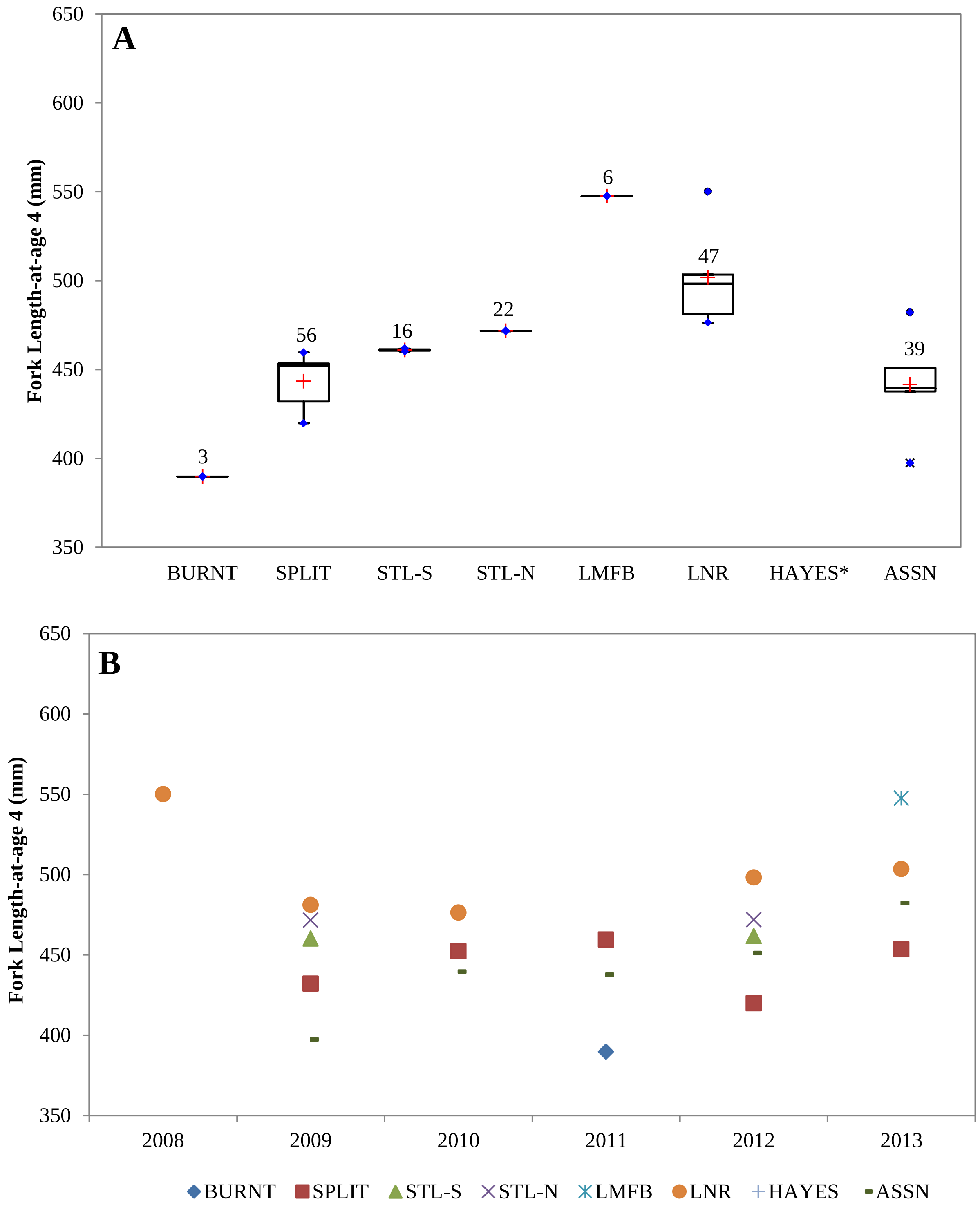


Figure 6-26. Annual mean fork length-at-age 4 calculated for Northern Pike captured in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 4-year-old fish captured over the 6-year sampling period is shown above the box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

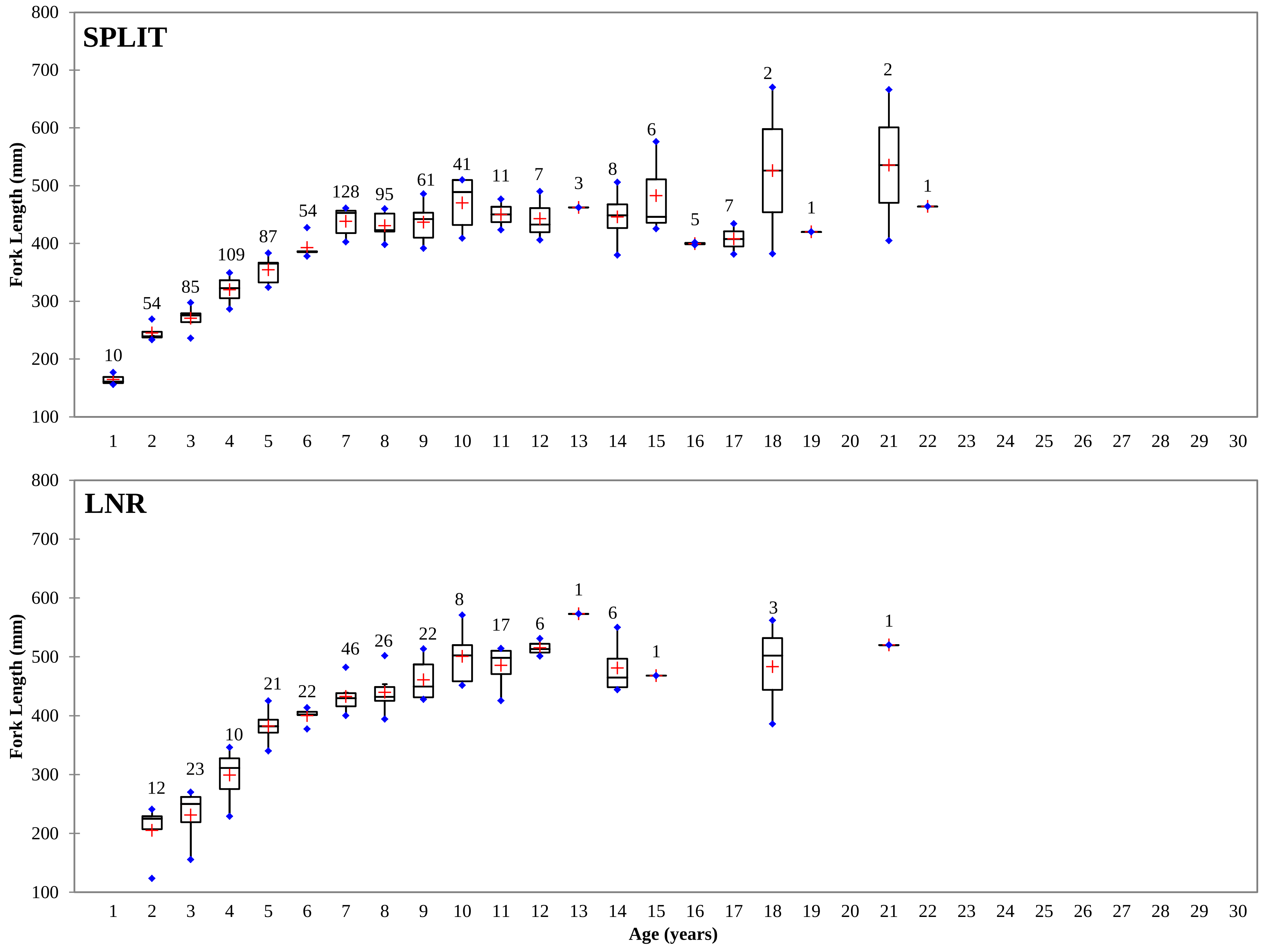


Figure 6-27. Annual mean length-at-age of Walleye captured in standard gang and small mesh index gill nets set at annual sampling locations in the Lower Nelson River Region, 2008-2013. The number of fish captured over the 6-year sampling period is shown above the box for each age.

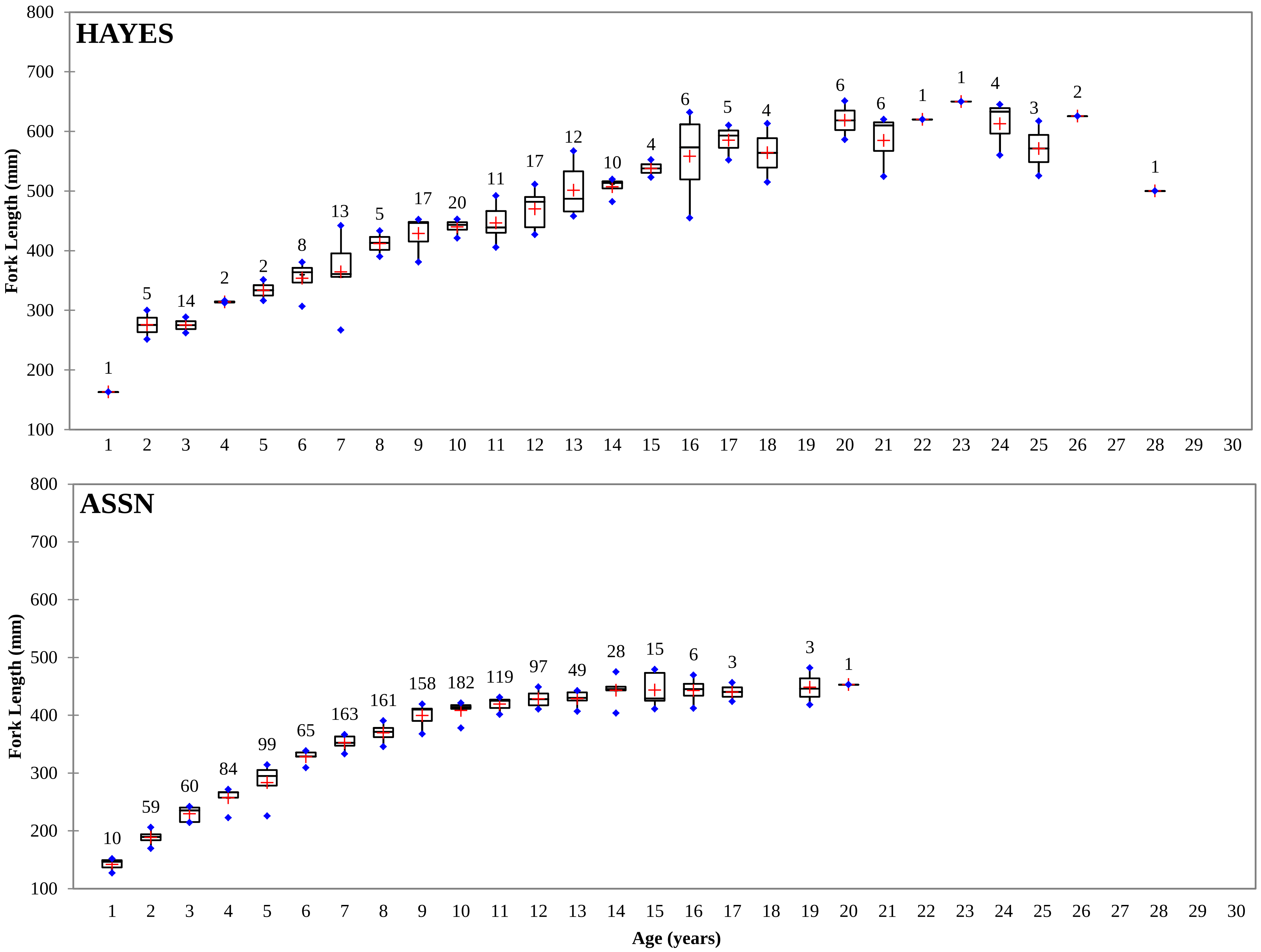


Figure 6-27. continued.

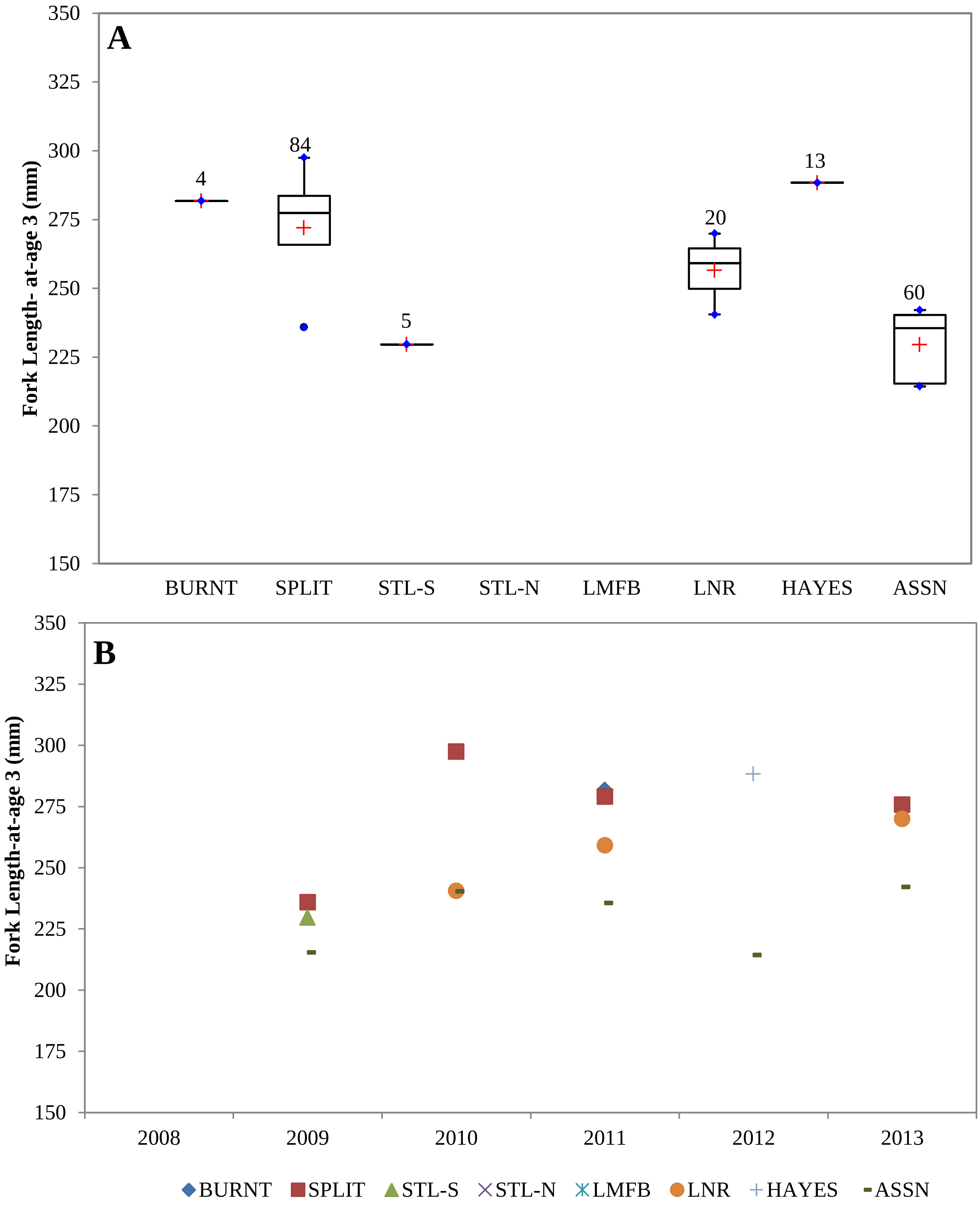
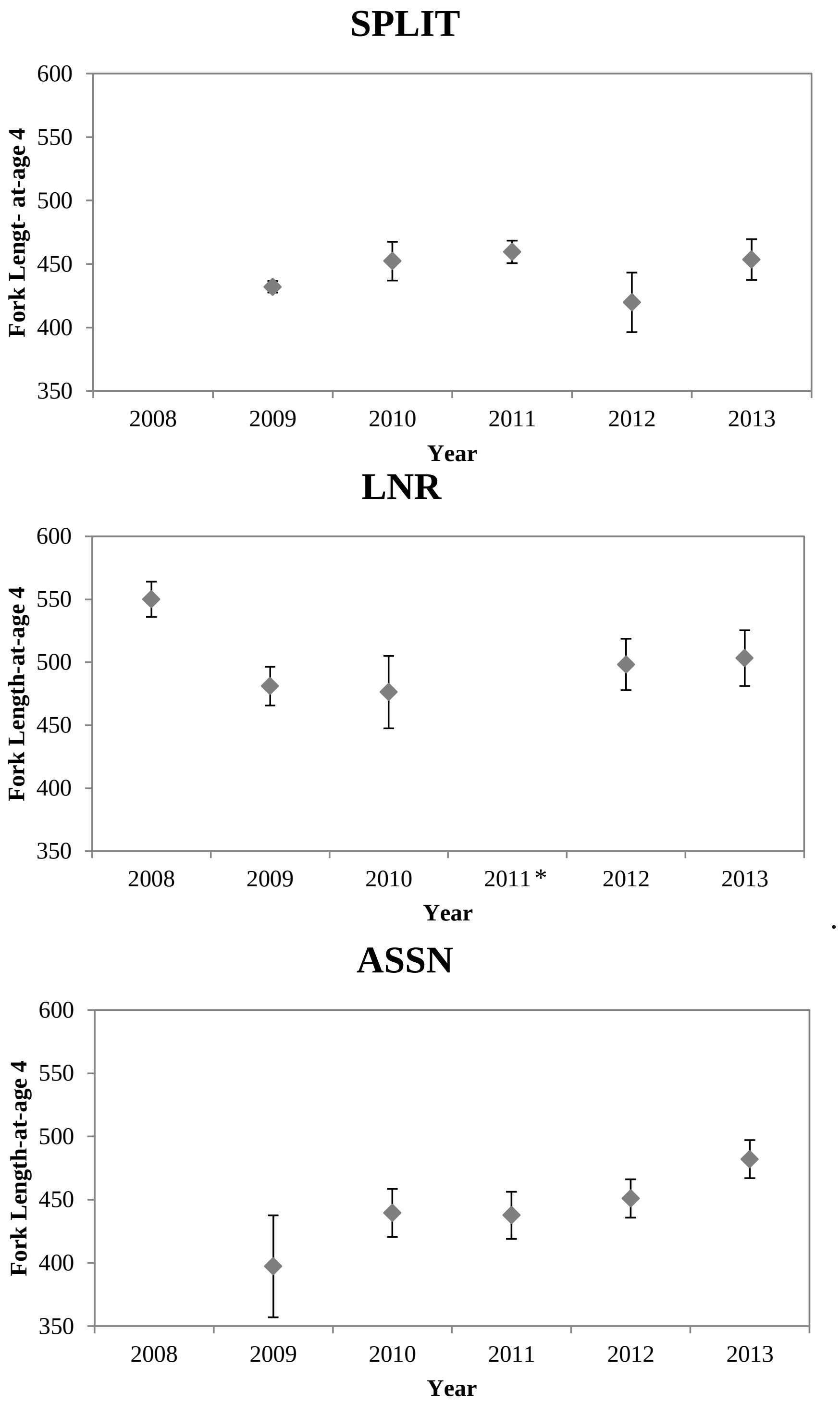
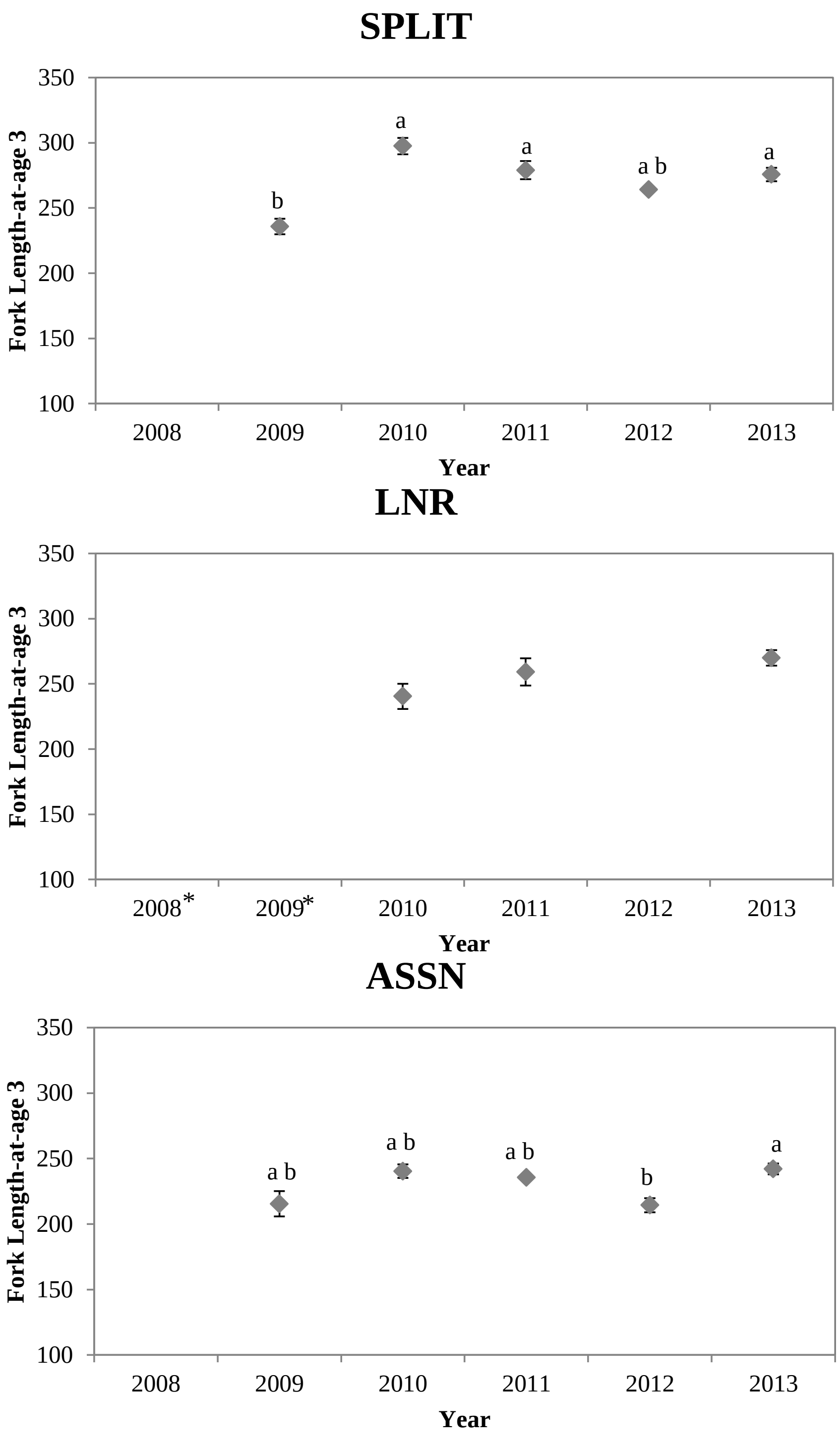


Figure 6-28. Annual mean fork length-at-age 3 calculated for Walleye captured in standard gang index gill nets set in Lower Nelson River Region waterbodies, 2008-2013 by waterbody (A) and by year (B). The number of 3-year-old fish captured over the 6-year sampling period is shown above the box for each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



*No age 4 Northern Pike were captured in 2011 in LNR

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



*No age 3 Walleye were captured in 2009 and 2012 in LNR.

Figure 6-30. Fork length-at-age 3 (mean ± SE) calculated for Walleye captured at annual on- and off-system locations. Different superscripts denote statistically significant differences between groups not sharing the same superscript. Identical superscripts, or lack of superscripts, denote no statistically significant difference.

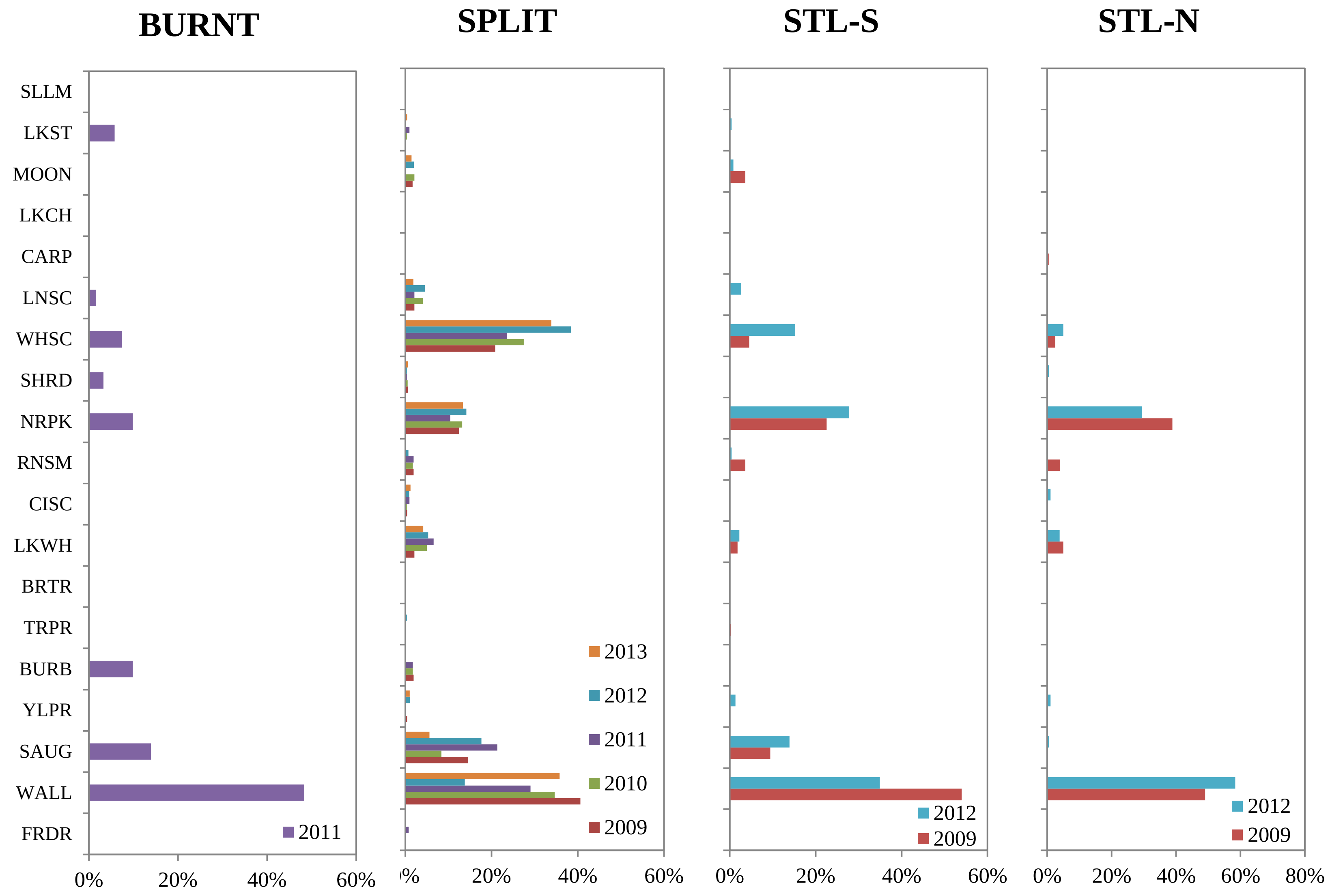


Figure 6-31. Relative abundance of fish species captured in standard gang index gill nets in on-system Lower Nelson River Region waterbodies and off-system waterbodies: 2008-2013.

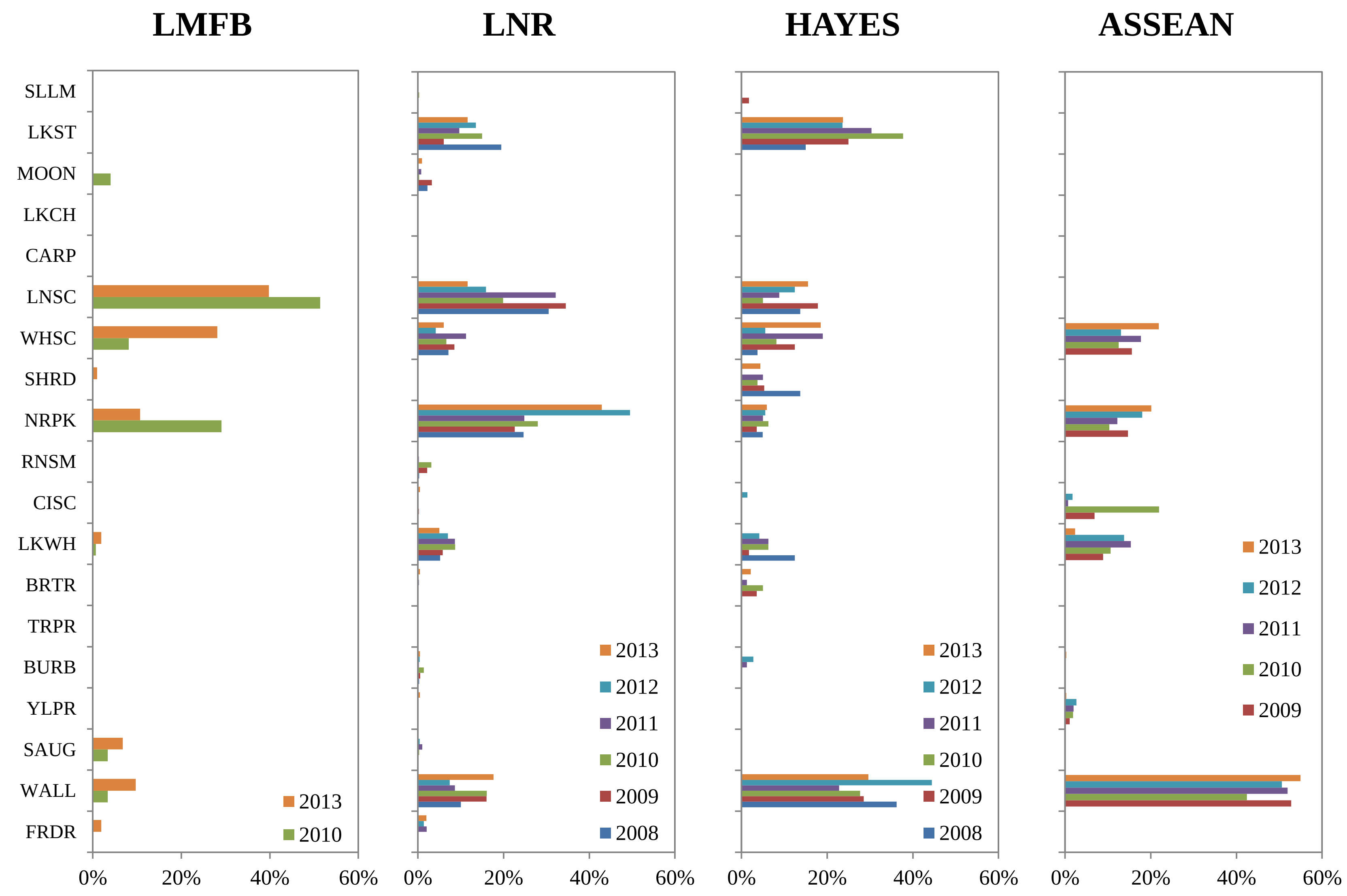


Figure 6-31. continued.

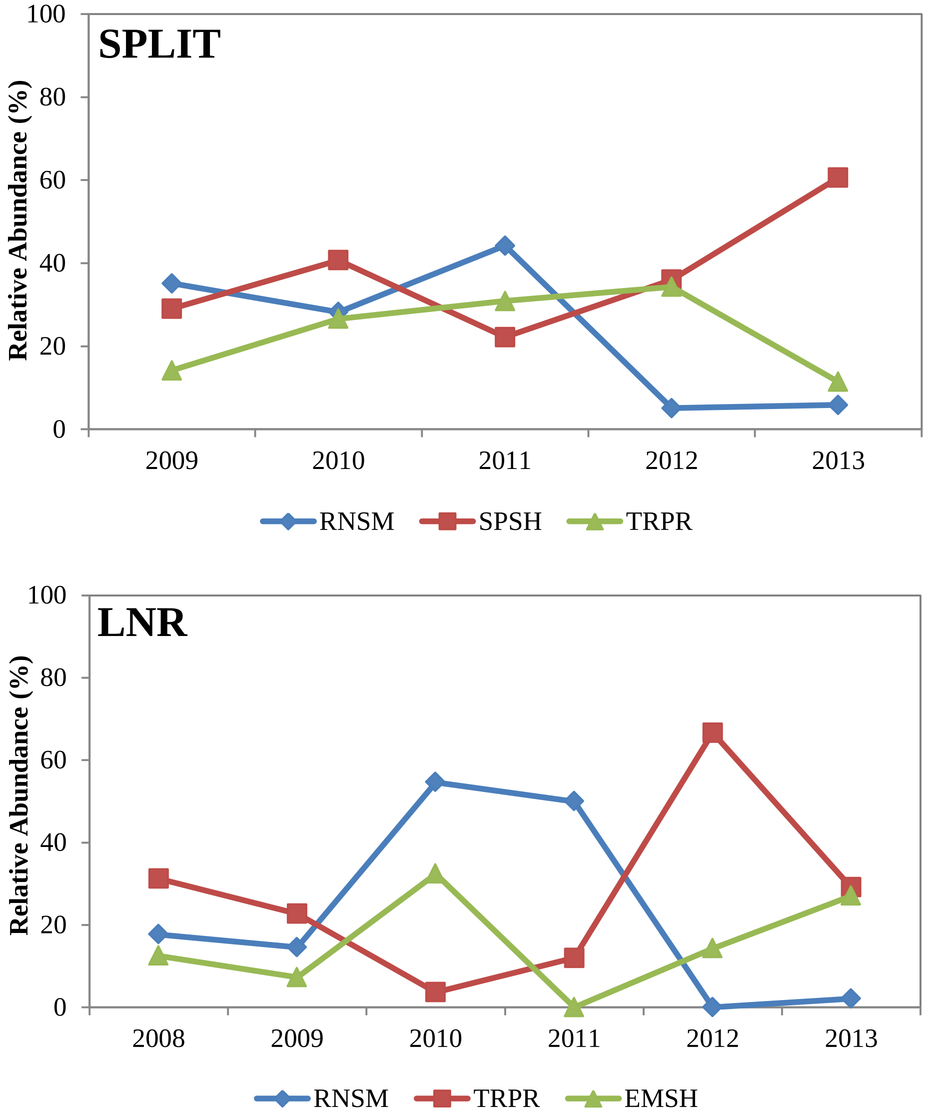


Figure 6-32. Relative abundance of Rainbow Smelt captured in small mesh index gill nets set in Split Lake and the lower Nelson River, 2008-2015.

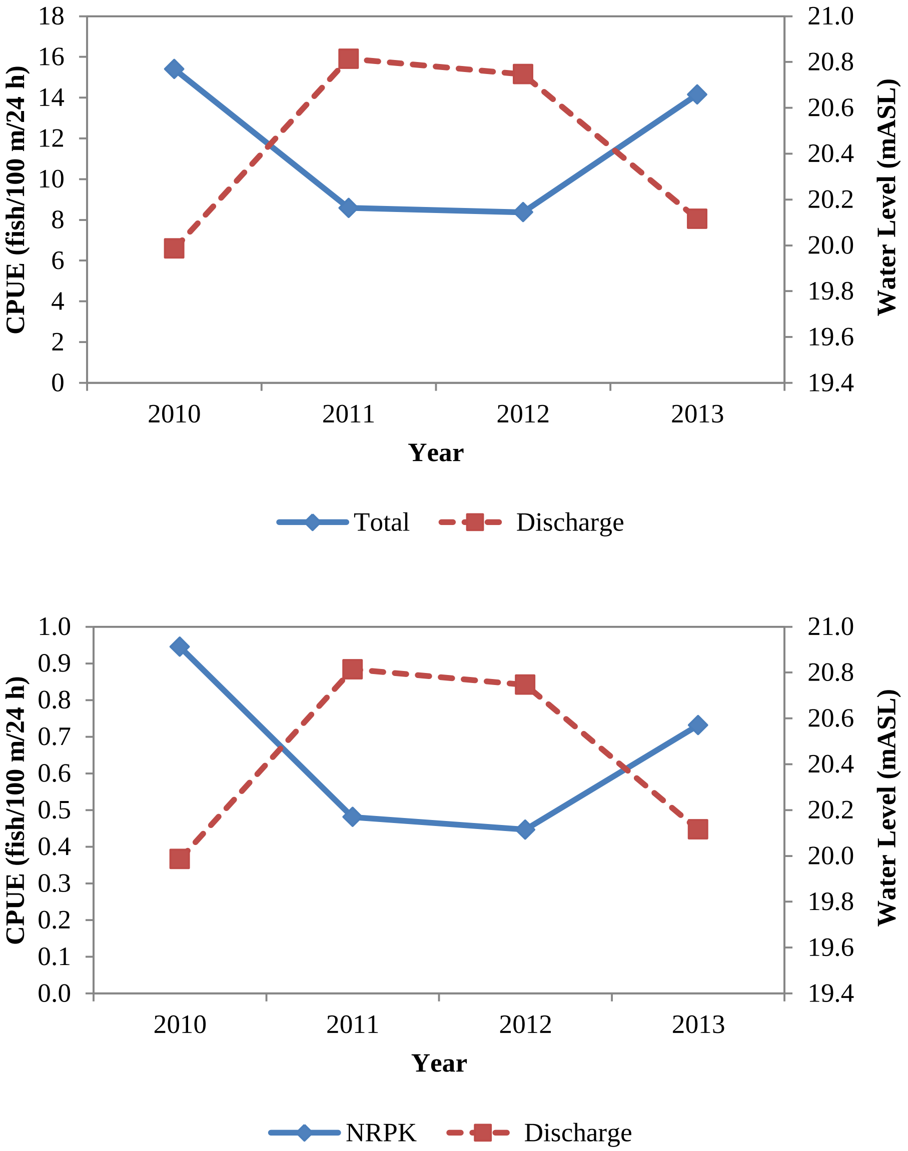


Figure 6-33. Abundance of total (top) and Northern Pike (bottom) in gillnet catches in the Hayes River as measured by CPUE in relation to the average water level at the same location during the gillnetting period: 2008-2013.

7.0 FISH MERCURY

7.1 INTRODUCTION

The following provides an overview of the results of fish mercury monitoring conducted in the LNRR under CAMP in the first six years of the program. Fish mercury sampling was conducted on a three-year rotation in Split Lake, Stephens Lake, the Limestone Forebay, the lower Nelson River downstream of the Limestone GS, and the off-system Assean Lake and the Hayes River. Sampling was completed in 2010 and 2013 at each site, excepting Stephens Lake which was sampled in 2009 and 2012. Additional sampling was conducted in 2011 for waterbodies where sample sizes obtained in 2010 were substantially below target numbers (i.e., Yellow Perch from Assean Lake and Lake Whitefish from the Hayes River). Mercury concentrations in Lake Sturgeon were measured in incidental mortalities from the lower Nelson and the Hayes rivers for years from 2008-2013.

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

7.1.1 Objectives and Approach

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

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

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

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

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

7.1.2 Indicators

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

7.2 KEY INDICATOR: MERCURY CONCENTRATIONS IN FISH

7.2.1 Lower Nelson River

A total of 707 fish were analyzed for mercury from Split Lake, Stephens Lake - South, the Limestone Forebay, and the lower Nelson River downstream of the Limestone GS (Table 7-1). Sample sizes for Northern Pike and Walleye generally met or approached the target sample size in all waterbodies except the Limestone Forebay, where only a small number of Walleye were collected (Table 7-1). In contrast, sample size targets were not met for Lake Whitefish and Yellow Perch from any of the waterbodies (Table 7-1). Mercury was also analysed in a small number of incidental Lake Sturgeon mortalities (Table 7-1) from Stephens Lake (n = 1), the lower Nelson River (n = 10), and the Hayes River (n = 3).

In cases where relationships between fish mercury and fork length were significant, the mean length-standardized mercury concentration was below the 0.5 parts per million (ppm) Health Canada standard for commercial marketing of fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011) for all species and waterbodies sampled during the monitoring program (Table 7-1). Length-standardized mercury concentrations could not be derived for whitefish from the Limestone Forebay (2010 and 2013) or for sturgeon in most years due to small sample sizes.

Arithmetic mean mercury concentrations for Lake Whitefish were consistently below 0.3 ppm and mean arithmetic concentrations for Yellow Perch and Lake Sturgeon were consistently below 0.5 ppm for all on-system sites in all years (Table 7-1).

Based on mercury concentrations in individual fish from all sampling years, 23% of the pike and 21% of the Walleye sampled from all on-system waterbodies exceeded the 0.5 ppm standard, reaching maximum concentrations of 0.95 ppm in pike and 1.33 ppm in Walleye (Table 7-1; Figures 7-1 and 7-2). Except for a single large Lake Whitefish captured in 2010 in the lower Nelson River that had a mercury concentration of 0.51 ppm, mercury was below 0.5 ppm in all whitefish, Yellow Perch, and Lake Sturgeon (Figures 7-1 to 7-4).

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

A total of 333 fish were analyzed for mercury from Assean Lake and the Hayes River (Table 7-1). Sample sizes for all target species except Yellow Perch were achieved in all years at Assean Lake (Table 7-1). In contrast, only Walleye were captured in sufficient numbers to reach target sample sizes for the Hayes River. A small number of incidental Lake Sturgeon mortalities (n = 3) was also sampled from the Hayes River (Table 7-1).

Where it could be reliably calculated, the mean length-standardized mercury concentration was below the 0.5 ppm Health Canada standard for commercial marketing of fish in Canada (Health Canada 2007a,b) and the Manitoba aquatic life tissue residue guideline for human consumers (MWS 2011) for all species and both off-system waterbodies sampled during the monitoring program (Table 7-1).

Arithmetic mean mercury concentrations remained below the 0.5 ppm standard for all species and all years, except for Walleye sampled from the Hayes River in 2010 (Table 7-1). The latter is largely due to the inclusion of an abundance of larger Walleye in the dataset for 2010 (Table 7-2).

Based on mercury concentrations in individual fish, 44% of the Walleye and 10% of the pike from the Hayes River exceeded the 0.5 ppm Health Canada standard in all sampling years (Figure 7-3). A lower number of fish (1% of Walleye and 7% of Northern Pike) sampled from Assean Lake exceeded 0.5 ppm mercury (Figure 7-3). Higher concentrations in Walleye from the Hayes River may reflect the greater proportion of larger, older fish in the Hayes River samples (Table 7-2). None of the whitefish (Figure 7-3), perch (Figure 7-2), or sturgeon (Figure 7-3) exceeded the 0.5 ppm standard at either site.

7.2.3 Temporal Comparisons

Few significant inter-annual differences in fish mercury concentrations were noted within the LNRR (Figure 7-5 and Figure 7-6). Exceptions include Walleye from Split Lake, which had significantly higher mercury concentrations in 2013 than 2011 (Figure 7-5). While the same difference was also observed in Assean Lake, the opposite was observed for the Hayes River (i.e., mercury was lower in 2013 than 2010). The latter may reflect the greater proportion of larger and older Walleye in 2010.

Like Walleye, Lake Whitefish from Split Lake contained lower length-standardized mercury concentrations in 2013 than 2010. However, unlike Walleye, no significant inter-annual differences were observed for any other site, including off-system sites. Insufficient numbers of whitefish were captured from most years at other sites to facilitate calculation of length-standardized concentrations.

Length-standardized mercury concentrations in pike were relatively consistent between years and sites. Catches of perch were too low to facilitate a temporal comparison.

7.3 SUMMARY

Mean length-standardized mercury concentrations in Northern Pike, Walleye, and Lake Whitefish 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) from all waterbodies in the LNRR.

Based on mercury concentrations in individual fish from all sampling years, 23% of the pike and 15% of the Walleye sampled from on-system waterbodies exceeded the 0.5 ppm standard. Exceedances of the standard were also observed at the off-system sites. Forty-four percent of Walleye and 10% of pike from the Hayes River exceeded the 0.5 ppm Health Canada standard in all sampling years. A lower number of fish (1% of Walleye and 7% of Northern Pike) sampled from Assean Lake exceeded 0.5 ppm mercury. Higher concentrations in Walleye from the Hayes River may have been affected by the greater proportion of larger, older fish in the Hayes River samples. Except for a single large Lake Whitefish captured in 2010 in the lower Nelson River that had a mercury concentration of 0.51 ppm, no whitefish, Yellow Perch or Lake Sturgeon had a mercury concentration exceeding 0.5 ppm.

Few temporal differences in mercury concentrations were observed in the LNRR. Exceptions include Walleye and Lake Whitefish sampled from Split Lake where an increase in mercury concentration was observed between 2010 and 2013. A similar temporal difference was observed for Walleye in Assean Lake but the opposite was observed for the Hayes River. The higher concentrations observed in the Hayes River in 2010 may be related to the high representation of larger, older fish in that sample.

Table 7-1. Arithmetic mean (±SE) and length-standardized (95% confidence limits, CL) mercury concentrations (ppm) for Lake Whitefish, Northern Pike, Walleye, Yellow Perch and Lake Sturgeon captured in the Lower Nelson River Region: 2008-2013.

				Mercury Concentration (ppm)			
Waterbody	**Year**	**Species**	**n**	**Arithmetic Mean**	**SE**	**Standard Mean**	**95% CL**
Split Lake	2010	Pike	24	0.363	0.043	0.289	0.249 - 0.335
		Walleye	33	0.197	0.023	0.196	0.173 - 0.222
		Whitefish	16	0.092	0.013	0.062	0.049 - 0.078
	2013	Pike	37	0.353	0.032	0.374	0.332 - 0.422
		Walleye	37	0.368	0.043	0.413	0.355 - 0.482
		Whitefish	20	0.150	0.013	0.102	0.082 - 0.127
		Perch	5	0.074	0.016	-	-
Stephens Lake - South	2009	Pike	36	0.293	0.042	0.260	0.229 - 0.296
		Walleye	36	0.315	0.030	0.262	0.236 - 0.291
		Whitefish	7	0.159	0.029	0.046	0.026 - 0.084
	2012	Pike	42	0.267	0.022	0.276	0.249 - 0.305
		Walleye	41	0.431	0.046	0.283	0.248 - 0.322
		Whitefish	5	0.168	0.020	0.053	0.024 - 0.117
		Sturgeon	1	0.174	-	-	-
		Perch	1	0.031	-	-	-
Limestone Forebay	2010	Pike	36	0.399	0.027	0.292	0.264 - 0.324
		Walleye	5	0.526	0.074	0.250	0.179 - 0.347
		Whitefish	1	0.304	-	-	-
	2013	Pike	11	0.261	0.035	0.241	0.215 - 0.270
		Walleye	10	0.526	0.091	0.393	0.280 - 0.551
		Whitefish	2	0.242	0.012	-	-
		Perch	4	0.011	0.002	-	-
Lower Nelson River	2010	Pike	36	0.368	0.032	0.242	0.206 - 0.285
		Walleye	36	0.322	0.025	0.277	0.255 - 0.302
		Whitefish	21	0.178	0.029	0.070	0.056 - 0.088
		Sturgeon	6	0.313	0.033	0.200	0.126 - 0.317
	2011	Sturgeon	3	0.166	0.021	NS	-
	2013	Pike	36	0.457	0.043	0.297	0.268 - 0.328
		Walleye	36	0.295	0.038	0.280	0.239 - 0.328
		Whitefish	10	0.191	0.021	0.114 [1]	0.066 - 0.198
		Sturgeon	1	0.035	-	-	-

Table 7-1. continued.

Waterbody	Year	Species	n	Mercury Concentration (ppm)			
				Arithmetic Mean	SE	Standard Mean	95% CL
Hayes River	2009	Sturgeon	2	0.098	0.033	-	-
	2010	Pike	10	0.259	0.029	0.202	0.179 - 0.228
		Walleye	36	0.722	0.060	0.463	0.403 - 0.532
		Whitefish	9	0.063	0.006	0.070	0.064 - 0.077
		Sturgeon	1	0.194	-	-	-
	2011	Pike	3	0.295	0.014	NS	-
		Whitefish	5	0.066	0.003	NS	
		Sturgeon	1	0.213	-	-	-
	2013	Pike	8	0.390	0.080	0.171	0.098 - 0.298
		Walleye	36	0.364	0.050	0.290	0.248 - 0.339
		Sturgeon	1	0.176	-	-	-
Assean Lake	2010	Pike	36	0.251	0.028	0.248	0.220 - 0.280
		Walleye	36	0.195	0.012	0.235	0.215 - 0.257
		Whitefish	36	0.039	0.005	0.039	0.035 - 0.043
	2011	Perch	15	0.008	0.0004	-	-
	2013	Pike	37	0.250	0.022	0.233	0.202 - 0.269
		Walleye	37	0.251	0.021	0.317	0.275 - 0.365
		Whitefish	9	0.060	0.008	NS	-
		Perch	15	0.020	0.002	-	-

[1] The relationship between mercury concentration and fish length close to being significant (p=0.070);

NS = Not significant

Table 7-2. Mean (±SE) fork length, round weight, condition (K_F), and age of Lake Whitefish, Northern Pike, Walleye, Yellow Perch and Lake Sturgeon captured in the Lower Nelson River Region: 2008-2013.

Waterbody	Year	Species	n	Length (mm)	Weight (g)	K_F	Age (years)
Split Lake	2010	Pike	24	583.8 ± 33.0	1936.1 ± 320.0	0.78 ± 0.01	6.0 ± 0.6
		Walleye	33	376.4 ± 19.3	853.9 ± 121.9	1.22 ± 0.02	5.2 ± 0.5
		Whitefish	16[1]	411.8 ± 19.3	1323.6 ± 159.1	1.69 ± 0.06	7.5 ± 0.9
	2013	Pike	37	505.7 ± 21.9	1070.3 ± 148.3	0.68 ± 0.01	5.3 ± 0.3
		Walleye	37	345.3 ± 20.8	688.6 ± 134.0	1.13 ± 0.03	6.4 ± 0.8
		Whitefish	20	413.4 ± 10.9	1177.1 ± 112.2	1.58 ± 0.04	8.5 ± 0.7
		Perch	5	136.6 ± 1.9	37.4 ± 2.2	1.46 ± 0.06	3.0 ± 0.0
Stephens Lake - South	2009	Pike	36[2]	526.4 ± 32.5	1500.9 ± 227.0	0.75 ± 0.02	6.8 ± 0.7
		Walleye	36[3]	419.2 ± 18.5	1241.5 ± 142.7	1.37 ± 0.02	11.5 ± 1.2
		Whitefish	7[4]	483.0 ± 28.3	2410.0 ± 428.4	1.99 ± 0.08	12.7 ± 2.1
	2012	Pike	42	510.6 ± 22.1	1205.6 ± 144.8	0.72 ± 0.01	6.0 ± 0.5
		Walleye	41	462.3 ± 15.2	1425.2 ± 121.2	1.29 ± 0.03	9.2 ± 0.9
		Whitefish	5	525.6 ± 22.3	2718.0 ± 343.1	1.82 ± 0.04	16.0 ± 2.6
		Sturgeon	1	802	4380	0.85	11
		Perch	1	94	11	1.32	-
Limestone Forebay	2010	Pike	36	611.8 ± 14.1	1815.6 ± 118.3	0.76 ± 0.01	6.7 ± 0.3
		Walleye	5[5]	497.6 ± 24.5	1660.0 ± 189.1	1.33 ± 0.06	12.0 ± 2.1
		Whitefish	1	512	2320	1.73	14
	2013	Pike	11	559.0 ± 34.2	1368.6 ± 207.4	0.71 ± 0.01	4.7 ± 0.4
		Walleye	10	445.1 ± 30.5	1182.0 ± 237.6	1.16 ± 0.05	10.6 ± 2.0
		Whitefish	2	476.5 ± 75.5	1892.5 ± 932.5	1.58 ± 0.10	13.5 ± 4.5
		Perch	4[6]	78.8 ± 3.2	6.8 ± 0.8	1.37 ± 0.02	1.7 ± 0.3
Lower Nelson River	2008	Sturgeon	7[7]	672.3 ± 40.2	2136.4 ± 456.5	0.64 ± 0.03	11.2 ± 1.2
	2010	Pike	36[8]	624.6 ± 22.9	2151.9 ± 252.2	0.76 ± 0.01	6.9 ± 0.4
		Walleye	36[9]	410.2 ± 14.1	979.4 ± 83.1	1.27 ± 0.02	7.2 ± 0.5
		Whitefish	21[10]	400.2 ± 12.0	959.0 ± 94.2	1.40 ± 0.02	11.7 ± 1.1
		Sturgeon	6	1086.7 ± 98.3	10637.0 ± 2324.4	0.75 ± 0.03	38.5 ± 4.5
	2011	Sturgeon	3	693.7 ± 19.9	2100.0 ± 110.2	0.63 ± 0.02	15.0 ± 4.0
	2013	Pike	36	621.6 ± 27.0	2091.4 ± 261.1	0.72 ± 0.01	6.3 ± 0.4
		Walleye	36	375.9 ± 20.3	815.2 ± 114.9	1.15 ± 0.02	6.2 ± 0.7
		Whitefish	10	428.8 ± 12.3	1225.0 ± 127.9	1.51 ± 0.05	9.1 ± 1.1
		Sturgeon	1	425	525	0.68	5

Table 7-2. continued.

Waterbody	Year	Species	n	Length (mm)	Weight (g)	K_F	Age (years)
Hayes River	2009	Sturgeon	2	550.5 ± 7.5	1090.0 ± 0.0	0.68 ± 0.03	8.0 ± 0.0
	2010	Pike	10	619.8 ± 43.6	1916.0 ± 320.4	0.71 ± 0.02	6.5 ± 0.7
		Walleye	36	470.7 ± 16.6	1350.3 ± 140.5	1.15 ± 0.02	12.9 ± 0.9
		Whitefish	9 [11]	318.1 ± 21.4	517.3 ± 72.8	1.45 ± 0.04	5.8 ± 0.4
		Sturgeon	1	664	1998	0.68	13
	2011	Pike	3	728.0 ± 66.4	2903.3 ± 656.7	0.73 ± 0.02	9.3 ± 1.5
		Whitefish	5	289.8 ± 22.3	334.6 ± 62.0	1.28 ± 0.03	6.4 ± 0.6
		Sturgeon	1	720	2160	0.58	-
	2013	Pike	8	707.1 ± 42.2	2967.5 ± 556.8	0.78 ± 0.03	9.4 ± 0.6
		Walleye	38	407.4 ± 21.6	920.0 ± 122.2	1.04 ± 0.01	8.7 ± 1.0
		Sturgeon	1	664	1998	0.68	13
Assean Lake	2010	Pike	36	509.9 ± 29.0	1131.0 ± 156.7	0.65 ± 0.01	5.7 ± 0.5
		Walleye	36 [12]	348.4 ± 13.3	531.0 ± 54.4	1.07 ± 0.01	7.7 ± 0.5
		Whitefish	36 [12]	332.6 ± 17.4	784.9 ± 112.1	1.56 ± 0.03	5.4 ± 0.7
	2011	Perch	15	89.5 ± 0.9	9.0 ± 0.2	1.37 ± 0.04	-
	2013	Pike	37	539.0 ± 26.3	1416.3 ± 198.5	0.69 ± 0.01	5.5 ± 0.4
		Walleye	37	327.6 ± 16.7	476.1 ± 57.7	1.02 ± 0.02	7.7 ± 0.7
		Whitefish	9	408.9 ± 7.4	926.7 ± 52.5	1.35 ± 0.06	6.6 ± 0.6
		Perch	15	113.9 ± 10.1	27.0 ± 5.1	1.25 ± 0.02	2.2 ± 0.2

[1] n=15 for age; [2] n=28 for age; [3] n=33 for age; [4] n=6 for age; [5] n=4 for age; [6] n=3 for age; [7] n=5 for age; [8] n=35 for age; [9] n=35 for weight and K_F; [10] n=19 for age; [11] n=8 for age; [12] n=32 for age.

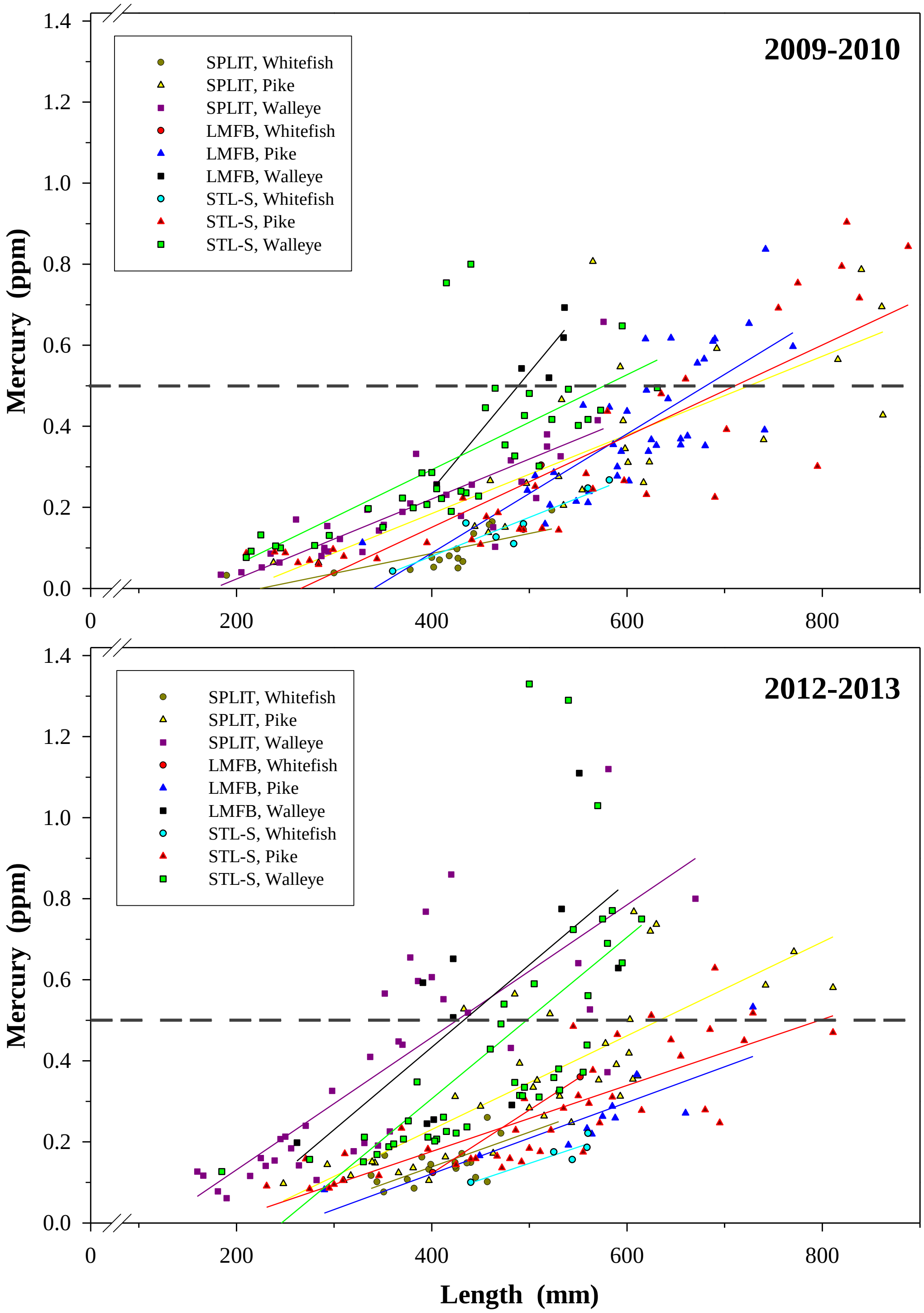


Figure 7-1. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from Split Lake, the Limestone Forebay, and Stephens Lake from 2009 to 2013. Significant linear regression lines are shown. Dashed lines represent the Health Canada standard for retail fish.

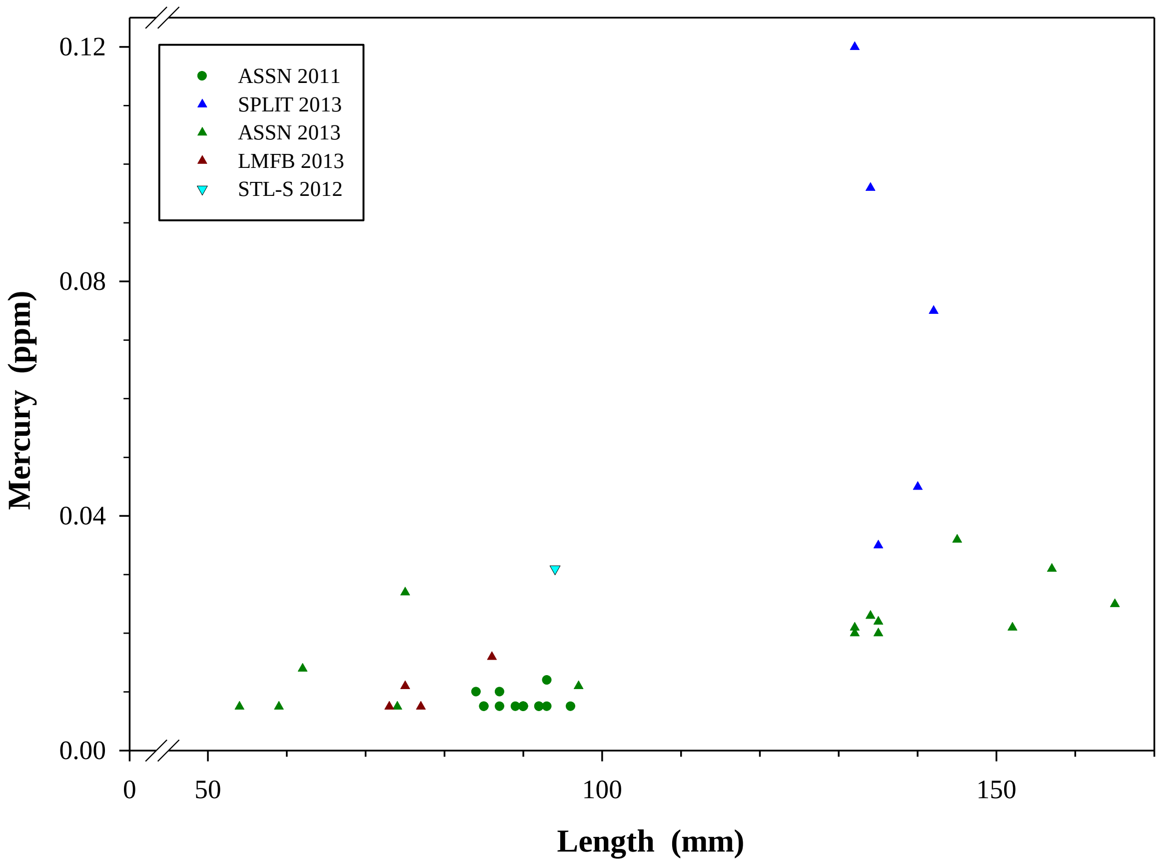


Figure 7-2. Relationship between mercury concentration and fork length for Yellow Perch from the Lower Nelson River Region: 2011-2013.

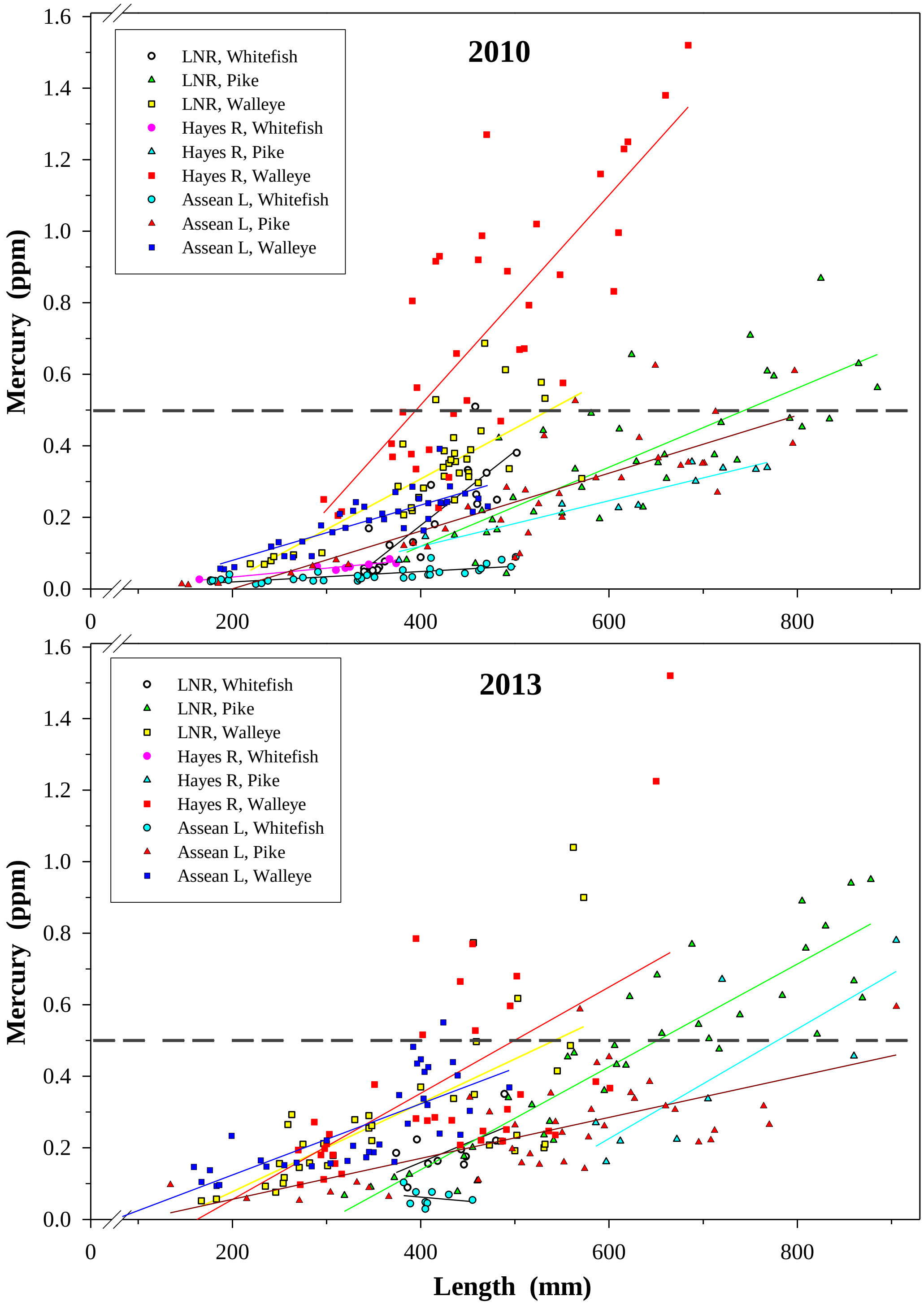


Figure 7-3. Relationship between mercury concentration and fork length for Lake Whitefish, Northern Pike, and Walleye from the lower Nelson River, the Hayes River, and Assean Lake in 2010 and 2013. Significant linear regression lines are shown. Dashed lines represent the Health Canada standard for retail fish.

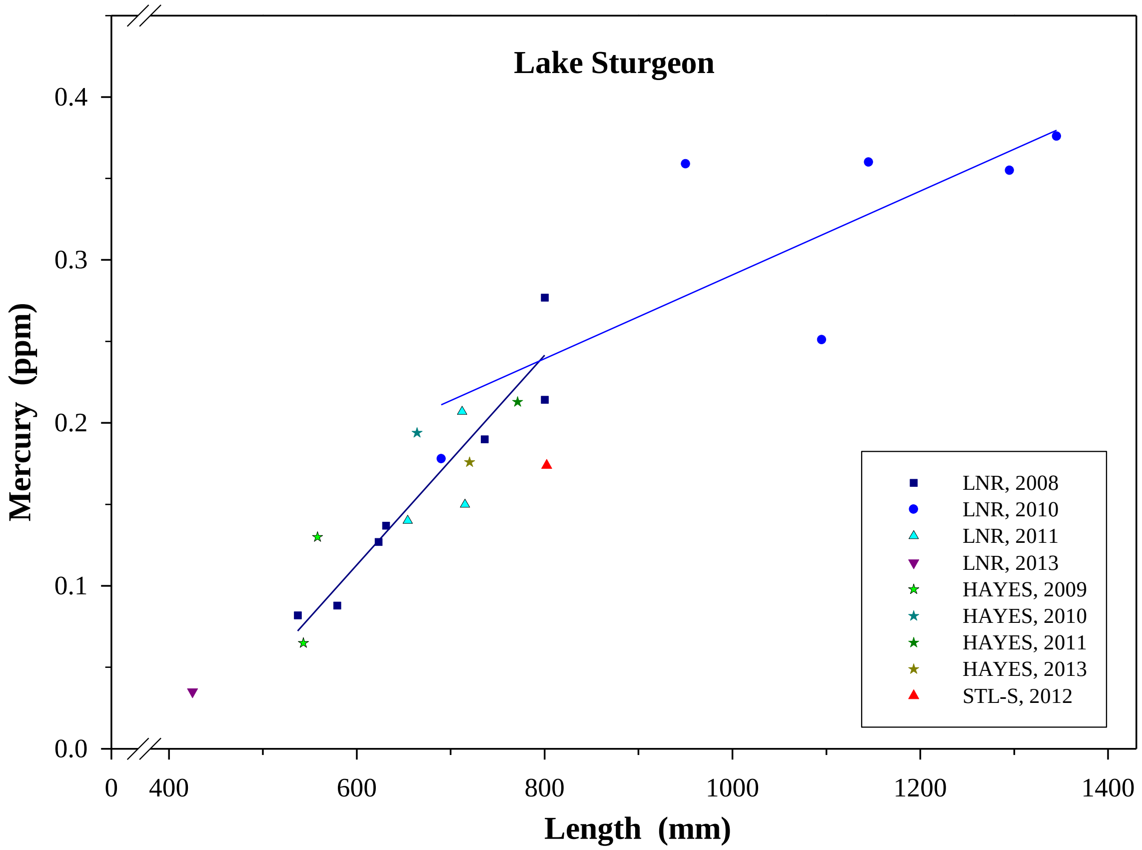
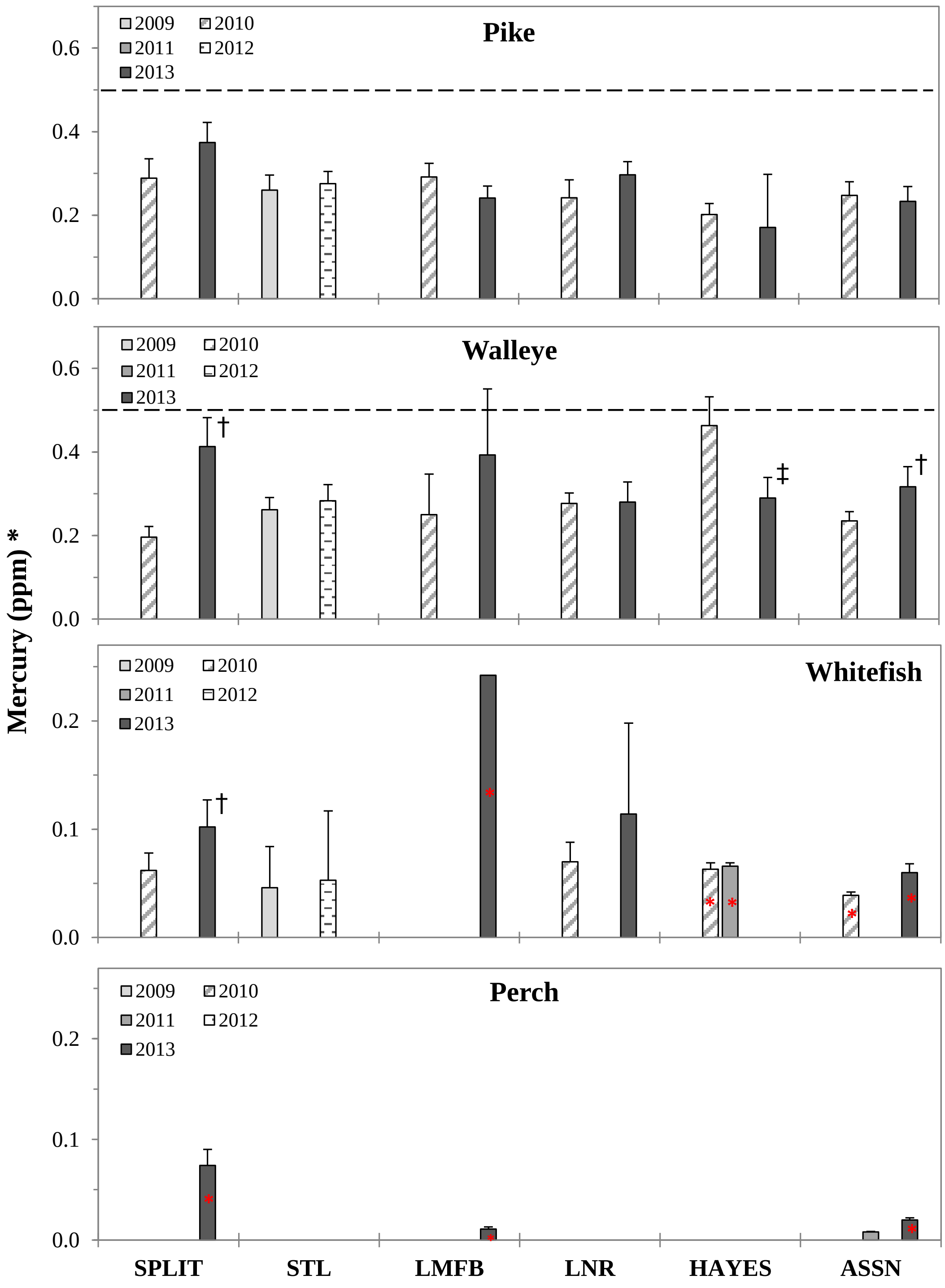


Figure 7-4. Relationship between mercury concentration and fork length for Lake Sturgeon from the Lower Nelson River Region from 2008-2013. Significant linear regression lines are shown.



* 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 Lower Nelson River Region: 2009-2013. Significant differences between years are indicated by † (higher than 2010) or ‡ (lower than 2010). Dashed lines represent the 0.5 ppm standard for retail fish.

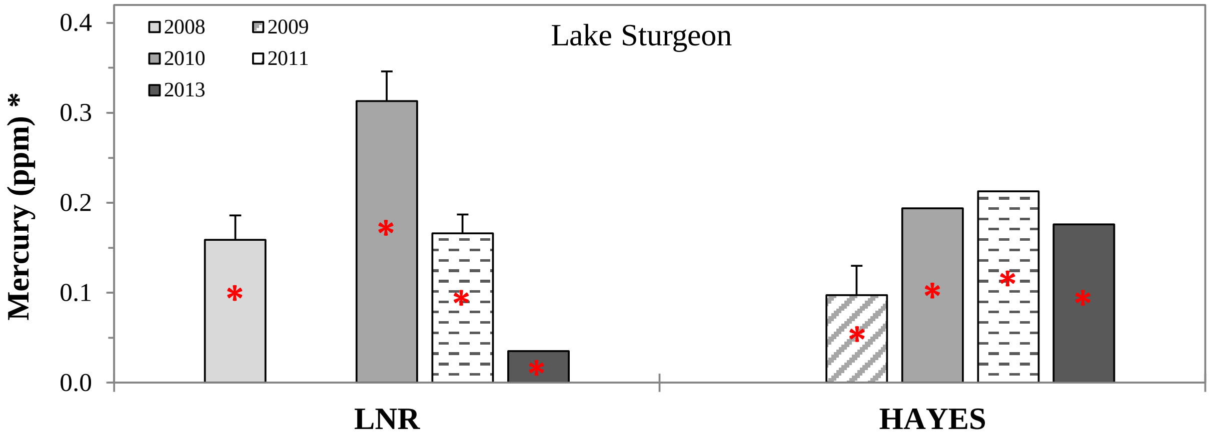


Figure 7-6. Standard or arithmetic (asterisk) mean (error bars indicate upper 95% CL) mercury concentrations of Lake Sturgeon from the Lower Nelson River Region: 2008-2013. Data for the Hayes River represent results for individual fish or for two fish (2009).

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