Little Bitterroot Lake
Water Quality Monitoring Program
2024 Annual Report

Prepared For:
Little Bitterroot Lake Association
P.O. Box 1003
Marion, MT 59925
August 2025

Prepared By:
John Babcock
Montana Stormwater LLC
3110 Sheridan Ave.
Butte, MT 59701

TABLE OF CONTENTS

TABLES AND FIGURES

Glossary of Terms

Benthic	bottom region of a lake including the sediment surface
Bloom	significant increase in algae population triggered by favorable conditions for growth
Chlorophyll-*a*	green pigment found in photosynthetic plants and algae
Depth profile	chart showing a water chemistry parameter at various depths within a lake
Epilimnion	uppermost portion of a stratified lake
Eutrophic	having high biological productivity (meso-eutrophic is moderately high), high productivity is commonly an indicator of high nutrients and poor water quality
Hypolimnion	bottom layer of a stratified lake
Mesotrophic	having moderate biological productivity
Metalimnion	the middle (transitional) layer of a stratified lake
Oligotrophic	having low biological productivity (meso-oligotrophic is moderately low), low productivity is an indicator of low nutrient concentrations and good water quality
Trophic	relating to available nutrients (ex. trophic status)

List of Acronyms

AIS	aquatic invasive species
CFS	cubic feet per second
DEQ	Montana Department of Environmental Quality
DNRC	Montana Department of Natural Resources and Conservation
DO	dissolved oxygen
DOC	dissolved organic carbon
FLBS	Flathead Lake Biological Station
GPM	gallons per minute
LBLA	Little Bitterroot Lake Association
SAP	sampling and analysis plan
SC	specific conductance
TN	total nitrogen
TP	total phosphorus
TSI	trophic state index
TSS	total suspended sediment
USGS	United States Geological Survey
WLI	Whitefish Lake Institute

Executive Summary

Routine sampling was conducted on Little Bitterroot Lake twice in 2024, on August 8 and October 4 for field parameters (temperature, pH, dissolved oxygen, specific conductance) and nutrients (nitrogen and phosphorus) at 10 lake sites and 2 stream sites. Depth profiles were recorded at the lake center by Whitefish Lake Institute on July 10, 2024, for field parameters and chlorophyll-a. The addition of the October sampling event was one major change we made in 2024, but we otherwise maintained the same sampling locations and methods.

In 2024, total nitrogen concentrations were near average in Little Bitterroot Lake, but total phosphorus was very low and among our lowest years on record. One encouraging note is that average total nitrogen has been decreasing in the lake for 4 consecutive years. Lake temperatures in early August have also been decreasing recently, with August 2024 showing the coolest lake temperatures since 2019. One interesting result was that the lake was warmer at depth than usual in 2024, but cooler near the surface. Chlorophyll (algae) measurements in open water were also lower in 2024 after showing one of the highest years of measurements in 2023, but still near average in the water profile.

Herrig Creek routinely has higher concentrations of nutrients than the lake, especially phosphorus. One additional sample was collected upstream of the Herrig Creek mouth in October 2024, and nutrient results were slightly lower than those at the mouth. Herrig Creek will continue to be monitored in future years, and potential sources of nutrients such as septic systems or cattle impacts are being investigated along Herrig Creek.

In October 2024, nutrient concentrations were slightly higher than August, water temperatures were cooler, and there were no measurable algae in the water column. These results could be expected because algae consumes available nutrients during mid-summer when conditions are more favorable for algae growth. We propose to conduct additional sampling in spring and fall of 2025 to learn more about seasonal changes in water quality.

Isolated areas with significant algae growth have been observed in recent years, and several more were reported in 2024 and 2025. The cause of these localized algae outbreaks cannot be identified without an extensive study, but they are likely caused by nutrient loading from failing or over-loaded septic systems. LBLA is creating an algae work group in 2025 to monitor and address these large benthic algae plumes.

Little Bitterroot Lake continues to be phosphorus limited, meaning that sufficient nitrogen is available for algae growth, and any available phosphorus can contribute to algae growth. Little Bitterroot Lake has low primary productivity (oligotrophic) based on concentrations of chlorophyll-a and phosphorus, indicating the lake has very good water quality; however, total nitrogen concentrations indicate the lake has potential for high productivity (eutrophic). When compared to 11 regional large lakes, Little Bitterroot Lake typically ranks in the top four for both major nutrients.

To improve or maintain water quality in Little Bitterroot Lake, efforts should be made to reduce sources of nutrients by limiting application of fertilizer, maintaining septic systems, keeping a vegetated buffer area, and reducing shoreline erosion. Fertilizers with little or no phosphorus are recommended to help maintain good water quality, so select fertilizers with a zero as the middle value (i.e. 16-0-0). Maintaining and not overloading septic systems is also key for reducing nutrient inputs.

1.0 Introduction

Little Bitterroot Lake is the headwaters of the Little Bitterroot River located near the community of Marion at an approximate elevation of 3900 ft (1190 m) **(Figure 1)**. The lake has a maximum depth of 260 ft (80 m), a surface area of approximately 4.6 square miles (2,950 acres) and a drainage area of 34.4 square miles (22,000 acres). The area is in the Salish Mountains Ecoregion with a humid continental climate (Köppen classification Dfb) and an average annual precipitation of 21 inches. The geology of the watershed is primarily sedimentary rocks of the Belt series. The lake outlet is controlled by an earthen dam built in 1918 which is managed by the Flathead Irrigation Project for downstream irrigators. Herrig Creek is the only perennial stream flowing into the lake, although seven intermittent or ephemeral streams contribute seasonally. Groundwater contributes a substantial portion of water to the lake, especially from the Salish Mountains to the west and northeast. Local uses of the lake include water supply for domestic use, irrigation, fishing and recreation.

The Little Bitterroot Lake Association (LBLA) began in 1988 with the purpose of "preserving the high recreational value of Little Bitterroot Lake, maintaining its aesthetic integrity, and to educate the public and others as to the value of Little Bitterroot Lake as a recreational resource." Water quality monitoring has been conducted on the lake since 1999. The purpose of the monitoring program is to maintain a water quality and nutrient baseline for the inflow, outflow, and lake water during mid-summer, and to address emerging water quality issues as they arise. Information from this program may be used to make management decisions to help maintain the aesthetic and recreational conditions of the lake and surrounding drainages and to help prioritize future monitoring efforts. This report outlines the history of the monitoring program and presents water quality results from 2024 and past monitoring events. Long term trends in nutrient concentrations and trophic status are provided for consistent locations.

1.1 Monitoring Program History

Little Bitterroot Lake has been sampled 27 times since 1999. Data from 1999 to 2009 was collected sporadically from May to November; however, sampling from 2010 to 2024 has been consistently conducted in mid-summer to maintain continuity and evaluate long-term trends. Sampling is conducted during the first week of August in conjunction with the annual lake association meeting, although periodic spring and fall sampling has occurred to provide seasonal information. Data collected helps document existing water quality, track trends in nutrient concentrations, and characterize the lake's trophic status. Past monitoring events on Little Bitterroot Lake include:

November 30, 1999	May 24, 2000	September 27, 2004	September 1, 2005
September 25, 2006	October 8, 2007	October 13, 2008	October 5, 2009
June 3, 2010	August 23, 2010	September 20, 2011	September 10, 2012
May 20, 2013	August 29, 2013	August 11, 2014	August 11, 2015
August 3, 2016	August 2, 2017	June 13, 2018	July 31-August 1, 2018
August 7, 2019	August 5, 2020	August 4, 2021	August 3-4, 2022
August 3-4, 2023	August 8, 2024	October 4, 2024.	

Depth profile data is included which provides water quality information collected from depth at the lake center. This helps evaluate the stratification (layering) of the lake during mid-summer and identify where peak concentrations of algae may occur. These data were collected by Whitefish Lake Institute on July 10, 2024, as part of the Northwest Montana Lakes Volunteer Monitoring Network.

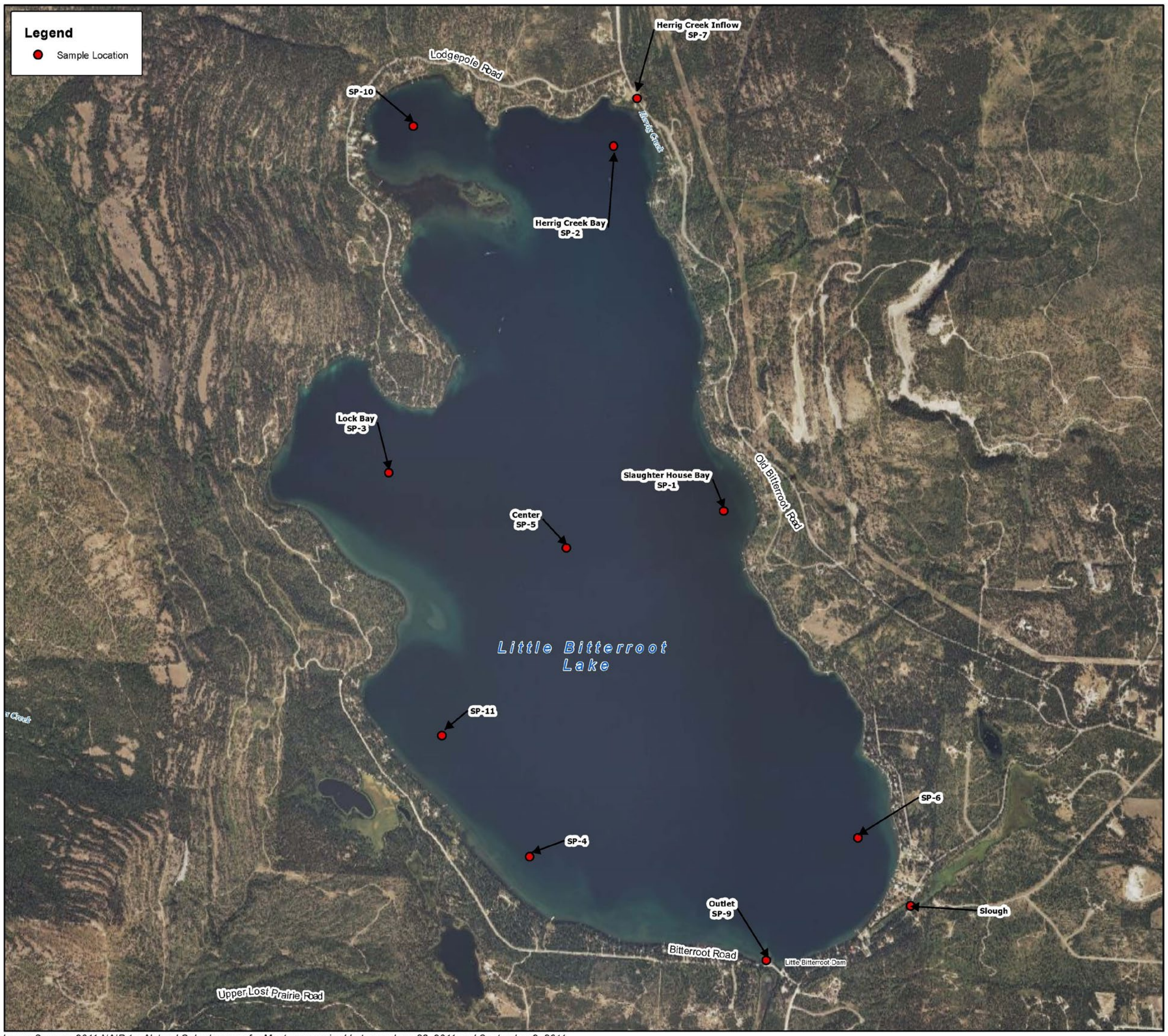


Image Source: 2011 NAIP 1m Natural Color Imagery for Montana acquired between June 23, 2011 and September 2, 2011

Figure 1. Little Bitterroot Lake Routine Sample Locations.

2.0 Field and Analytical Methods

Water quality monitoring is routinely conducted at 7 lake and 2 stream sites, including the inlet (Herrig Creek) and the outlet (Little Bitterroot River) (**Figure 1**). Routine monitoring is typically conducted in early August; however, an additional sampling event was added in October 2024 to provide more information about nutrient concentrations in fall. In 2024, one additional sampling location was added in the north-center of the lake. This site was sampled from near the surface and at a depth of 60’. This site was requested by Montana DEQ to provide comparison with the traditional lake center site, which is located close to the deepest portion of the lake.

Monitoring includes on-site field measurements and samples collected for lab analysis. Field parameters include water temperature, dissolved oxygen, specific conductance, and pH. Lab samples include nutrient parameters (total nitrogen and total phosphorus). Calcium and alkalinity samples are collected at several locations to evaluate the potential for colonization of aquatic invasive species, especially invasive mussels and non-native vegetation. Samples are also analyzed for chlorophyll-a from open water at several lake locations, and benthic algae samples are collected from rock surfaces at one or two sites annually (Note: benthic samples were not collected in 2024). Chlorophyll-a samples provide a measure of algae growth in the water column. Depth profile monitoring is conducted annually at the lake center during mid-summer, which includes measurements of water temperature, specific conductance, dissolved oxygen, pH, and chlorophyll-a at depth. A summary of 2024 locations and parameters is provided below in **Table 1**.

Laboratory analyses in 2024 were provided by Energy Laboratories in Helena, MT, and funded by a grant from the Volunteer Monitoring Support Program administered by Montana Department of Environmental Quality (DEQ). Methods of each component of the monitoring program are summarized in the following sections. A complete description of field and analytical methods is available in the project Sampling and Analysis Plan (SAP) (Babcock, 2024), which is provided to Montana DEQ to procure funding from the volunteer monitoring grant program.

Table 1. 2024 Little Bitterroot Lake Sample Locations (August and October)

Site ID	Site Description	Parameters	Rationale
SP-7	Inlet - Herrig Cr.	N/F/DOC/A	Inlet Stream
SP-2	Herrig Cr. Bay	N/F	Bay near Inlet
SP-10	Northwest Bay	N/F	Shallow Isolated Bay
SP-1	Slaughterhouse Bay	N/F	Bay
SP-13	North Center – epi.	N/F/CW	Center (new site)
SP-13-60	North Center – meta	N/CW	Center, metalim. (new site)
SP-5	Lake Center – epi.	N/F/CW/DOC/A	Center, Deepest
SP-5-60	Lake Center – meta.	N/CW	Center, metalimnion
SP-3	Locke Bay	N/F/CW	Bay
SP-4	Southwest	N/F	Near Development
SP-6	Southeast	N/F	Near Development
SP-9	Outlet - Ltl. Bitterroot R.	N/F/DOC/A	Outlet Stream

N=nutrients, F=field parameters, CW=chlorophyll-a in water, DOC=dissolved organic carbon, A=alkalinity

2.1 Field Parameters

Field parameters are measured using a portable water quality meter (YSI brand) calibrated on the sample day. Measurements are taken in the upper 3' of the water column at lake locations, or within the flowing portion of stream locations. Parameters include water temperature, dissolved oxygen, specific conductance, and pH. Water clarity is measured at lake center using a Secchi disc. Stream flow is measured using a Marsh-McBirney electronic flow meter or visually estimated during low flow.

2.2 Laboratory Samples

Samples are collected for analysis in laboratory-provided bottles which are rinsed with sample water prior to collection. Bottles are filled from moving water at stream sites, and from just below the surface at lake sites. At the lake center, samples are collected from depth using a Van Dorn sampler. Samples are filtered or preserved as necessary and stored on ice or dry ice for delivery to the laboratory.

2.3 Algae Samples

Samples are collected from lake sites for chlorophyll-a, which provides a measure of algae growth in the water column. Chlorophyll-a samples are collected in amber glass bottles and are wrapped in aluminum foil to prevent exposure to sunlight, which can break down the chlorophyll and degrade sample integrity. Chlorophyll-a samples are collected from near-surface and from a depth of 60' using a Van-Dorn sampler. Samples are filtered in the field onto fiberglass filters which are stored on dry ice and then submitted to the laboratory for analysis.

2.4 Depth Profile Sampling

Depth profile sampling is conducted at the lake center to evaluate changes in field parameters at depth, which indicate the degree of lake stratification, or layering, at the time of sampling. Depth profile sampling is conducted by Whitefish Lake Institute using a portable Hydrolab water quality meter which measures depth, chlorophyll-a, water temperature, specific conductance, dissolved oxygen, and pH. In 2024 the Hydrolab had a maximum sampling depth of 215 ft, which is sufficient to see stratification in Little Bitterroot Lake but below the maximum depth of 260 ft.

4.0 2024 Monitoring Results

Routine sampling for field and nutrient parameters was conducted on August 4, 2024. Air temperature ranged from 17 to 23°C (63 to 73°F) with partly cloudy skies and a light breeze. An additional sampling event was conducted on October 4, which had temperatures from 6 to 12°C (43 to 53°F) and no wind. Depth profiles were collected on July 10, 2024, by Whitefish Lake Institute.

4.1 2024 Field Results

Field results from 2024 are provided in **Table 2** below. For a visual comparison over time and by location, statistical boxplots are also provided in **Appendix B** which show the range of field parameters from 2010 to 2024. The boxplots show the maximum, minimum, and interquartile values for each year. Long-term trends are also discussed in **Section 4.8** of this report.

During the August 2024 event, the lake had a surface temperature ranging from 20.4 to 21.3°C (68.7 to 70.3°F). Herrig Creek was contributing cool water around 13.4°C (56.1°F) at a flow of approximately 2.0 CFS (900 gallons per minute, GPM). The Little Bitterroot River at the outlet was similar to lake sites at 21.1°C (70.0°F) and had flow of 4.0 CFS (1800 GPM). Lake temperatures in October were considerably cooler, ranging from 13.9 to 14.5°C (57.0 to 58.1°F) in lake sites and outlet stream, while the inlet measured 4.6°C (40.3 °F).

The pH at lake sites varied between 7.37 and 7.49 in August 2024, while the inlet and outlet streams measured 7.24 and 7.46, respectively. The average lake pH (7.43) was below the average (7.93) of all years from 2010 to 2024. Results in October were similar, ranging from 7.29 to 7.74 with an average of 7.42. Biological activity by plants and algae raises pH during daytime hours when photosynthesis is occurring, so pH can be influenced by time of sampling during biologically productive years.

Dissolved oxygen (DO) varied from 8.4 to 10.3 mg/L in August 2024 at the lake sites and was at 10.9 mg/L in the inlet stream and 9.1 mg/L in the outlet stream. Average mid-summer DO in 2024 (8.9 mg/L) was above the long-term average (8.3 mg/L); however, DO can be quite variable depending on time of day. Dissolved oxygen is influenced by biological activity which raises concentrations during daytime hours, and cooler water can hold more dissolved oxygen, so the high DO measured in August 2024 was likely a result of cool temperatures. DO concentrations in October 2024 were relatively higher due to the cooler temperatures, ranging from 8.9 to 10.1 mg/L, with an average of 9.4 mg/L.

Specific conductance was low in the inlet stream in August 2024 (54 μS/cm) but uniformly around 115-117 μS/cm at the lake sites. The average SC in August 2024 (116 μS/cm) was near the average long-term value (113 μS/cm). SC values in October 2024 were similar ranging from 115-116 μS/cm. Specific conductance a measure of dissolved constituents in water, and values are generally lower in surface water sources than groundwater.

Table 2. 2024 Routine Monitoring Results.

Sample Info			Field Water Quality				Nutrients		Chlorophyll	Additional Samples		
Site	Date	Site Description	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (uS/cm)	pH	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Algae in Water (mg/L)	Calcium (mg/L)	Alkalinity (mg/L)	Dissolved Organic Carbon (mg/L)
			Analytical Detection Limits →				0.04	0.001	0.1	1.0	1.0	0.5
SP-2	8/8/24	Herrig Cr. Bay	20.4	8.7	115	7.40	**0.12**	0.001				
SP-10	8/8/24	Northwest Bay	21.1	10.3	117	7.48	**0.19**	**0.002**				
SP-13	8/8/24	North Center - epi.	20.7	8.9	116	7.43	**0.12**	0.001	0.1			
SP-13-60	8/8/24	North Center - hypo.					**0.13**	**0.003**	0.8			
SP-1	8/8/24	Slaughter House Bay	20.7	8.5	117	7.39	**0.14**	**0.002**				
SP-3	8/8/24	Locke Bay	21.3	8.5	116	7.49	**0.13**	**0.009**				
SP-5	8/8/24	Lake Center – epi.	20.7	8.4	116	7.50	**0.12**	**0.004**		**14**	**51**	2.9
SP-5-60	8/8/24	Lake Center – hypo.					**0.14**	**0.004**	0.9			
SP-4	8/8/24	Southwest	20.7	8.8	115	7.40	**0.13**	**0.002**				
SP-6	8/8/24	Southeast	20.4	9.1	116	7.37	**0.12**	0.001				
SP-7	8/8/24	Inlet - Herrig Cr.	13.4	10.9	54	7.24	**0.18**	**0.019**		**5**	**25**	**4.3**
SP-9	8/8/24	Outlet - Ltl. Bitterroot R.	21.1	9.1	119	7.46	**0.13**	**0.003**		**14**	**52**	**2.9**
SP-2	10/4/24	Herrig Cr. Bay	14.5	9.0	116	7.29	**0.15**	**0.003**				
SP-10	10/4/24	Northwest Bay	13.9	8.9	115	7.35	**0.17**	**0.002**				
SP-13	10/4/24	North Center - epi.	14.5	9.1	116	7.29	**0.14**	**0.002**	0.1			
SP-13-60	10/4/24	North Center - hypo.					**0.14**	**0.004**	0.1			
SP-1	10/4/24	Slaughter House Bay	14.3	9.8	116	7.29	**0.14**	**0.003**				
SP-5	10/4/24	Lake Center – epi.	14.4	9.3	115	7.31	**0.13**	**0.004**	0.1	**13**	**52**	**3.0**
SP-5-60	10/4/24	Lake Center – hypo.					**0.16**	**0.002**	0.1			
SP-3	10/4/24	Locke Bay	14.5	9.4	116	7.37	**0.14**	**0.003**				
SP-4	10/4/24	Southwest	14.3	9.7	115	7.71	**0.14**	**0.003**				
SP-6	10/4/24	Southeast	14.8	10.1	115	7.74	**0.14**	**0.003**				
HC-2	10/4/24	Herrig Creek - Middle	4.5	17.8	63	7.30	**0.11**	**0.005**				
SP-7	10/4/24	Inlet - Herrig Cr.	4.6	14.2	68	7.17	**0.14**	**0.008**		**5**	**31**	**4.0**
SP-9	10/4/24	Outlet - Ltl. Bitterroot R.	14.6	8.9	122	7.90	**0.13**	**0.002**		**14**	**56**	**3.0**

The analytical detection limit for water quality parameters are provided below the constituent name.
Values in **BOLD** are above the analytical detection limit.

4.2 2024 Nutrient Results

Nutrient results from 2023 are provided with field results above in **Table 2**. Data for total nitrogen (TN) and total phosphorus (TP) from August are also shown spatially below in **Figures 2-3**, organized left to right from the lake inlet (Herrig Creek) to the lake outlet (Little Bitterroot River).

In August 2024, total nitrogen was relatively low and comparable on the lake, varying from 0.12 to 0.19 mg/L. Herrig Creek had similar results (0.18 mg/L), and the Little Bitterroot River (0.13 mg/L) was also within the range of lake sites. The average TN in August 2024 (0.13 mg/L) was below average for all lake samples collected from 2010-2023 (0.144 mg/L). In October 2024, TN concentrations ranged from 0.14 to 0.17 mg/L and were slightly higher than August results (0.15 mg/L average).

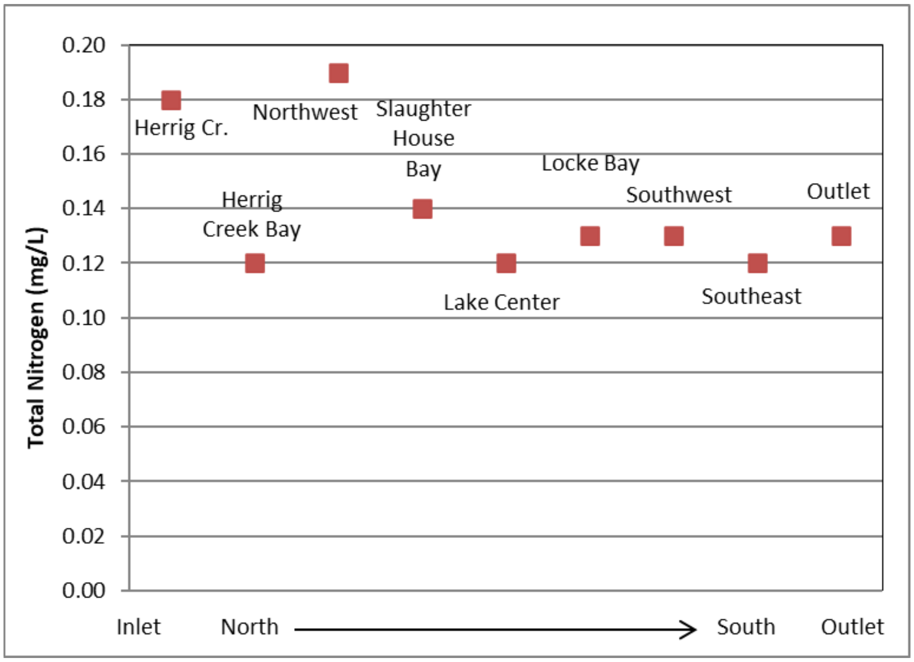


Figure 2. 2024 Mid-Summer Total Nitrogen Results.

Total phosphorus measurements in August 2024 ranged from 0.001-0.009 mg/L at lake sites. Herrig Creek measured 0.019 mg/L while the lake outlet was 0.003 mg/L. Results from October 2024 were similar, ranging from 0.002 to 0.004 mg/L. Little Bitterroot Lake has historically had low concentrations of total phosphorus and is phosphorus-limited, so inputs of phosphorus from the inlet stream or groundwater are likely consumed by algae and plants within the lake, resulting in lower measurements of TP in mid-summer. The average TP in August 2024 (0.004 mg/L) and October 2024 (0.003 mg/L) were among the lowest on record and below the long-term average (0.006 mg/L).

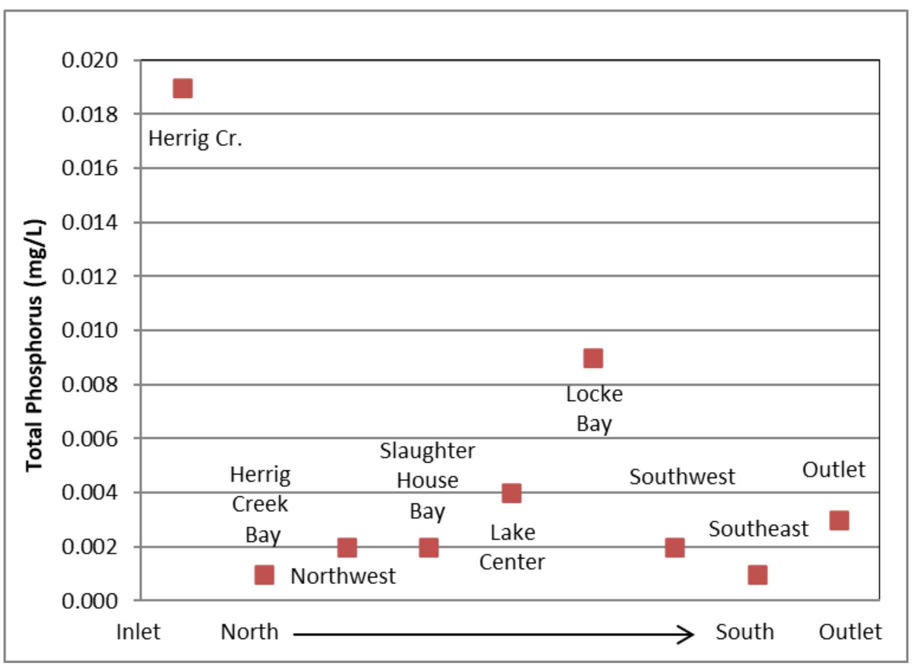


Figure 3. 2024 Mid-Summer Total Phosphorus Results.

4.3 2024 Chlorophyll-a Results

Results from chlorophyll-a sampling in 2024 are presented above in **Table 2**. Samples were collected from 4 locations in 2024, including the lake center near-surface and from 60' depth, and a new location at the north-center of the lake near-surface and from 60' depth. In August 2024, algae growth was above the analytical detection at all sample sites (<0.1 mg/L) which is uncommon for Little Bitterroot Lake, with a peak of 0.9 mg/L at a depth of 60'. Algae typically peaks near a depth of 60'; however, Hydrolab data collected from Whitefish Lake Institute shows that chlorophyll-a peaked at a depth of 90' in July 2024 (3.89 mg/L). Additional profile data are provided in **Section 4.6** for comparison. During October 2024, all samples were below the analytical detection limit of 0.1 mg/L, including those collected at depth.

Attached (benthic) algae was not sampled in 2024. This type of sampling provides algae concentrations on rocks; however, areas selected for sampling do not reflect worst-case conditions on Little Bitterroot Lake and the variability of results is not conducive to analyzing long-term trends. Prolific algae growth had been recorded at several locations around the lake, which is possibly due to non-functioning septic systems that are outdated or overused. Benthic algae sampling will likely be discontinued in future events; however, monitoring the prolific algae patches will continue in some capacity. LBLA plans to form an algae action committee in 2025 to evaluate and address the prolific algae blooms that are routinely observed by residents on the lake.

4.4 2024 AIS Related Parameters

AIS-related water quality parameters were added to the sampling program in 2018 to evaluate the potential for colonization from aquatic invasive species, especially mussels who rely on calcium for shell growth. Calcium and alkalinity were collected in 2024 at the lake center and the inlet and outlet streams (**Table 2**). Calcium concentrations were lowest in Herrig Creek (5 mg/L) and highest at the lake center and outlet (14 mg/L). Previous calcium concentrations from lake samples have ranged from 12.1 – 14.6 mg/l, which indicates that calcium concentrations are relatively stable in Little Bitterroot Lake and the surrounding watershed. Alkalinity concentrations in 2024 ranged from 25 mg/L in Herrig Creek to 56 mg/L in the Little Bitterroot River.

Risk categories have been published for determining the likelihood of invasive mussel establishment (Wells et al., 2011). Risk categories based on calcium are defined as very low (<12 mg/L), low (12-15 mg/L), medium (15-25 mg/L), and high (>25 mg/l). Calcium concentrations measured in Little Bitterroot Lake would put the lake at a low risk of mussel establishment, however, established mussel populations have been found in lakes with significantly lower calcium concentrations (<10 mg/L) than Little Bitterroot Lake. Furthermore, alkalinity and bicarbonate concentrations are within the range of concentrations to support mussel establishment. Compared to regional large lakes, Little Bitterroot Lake has the second lowest concentrations of calcium and alkalinity.

4.6 2024 Depth Profile Results

Depth profile sampling was conducted on July 10, 2024, to show changes in water chemistry at depth. Results from the depth profile sampling are shown in **Figure 4**, including charts for water temperature, dissolved oxygen, pH, and chlorophyll-a. Results from 2014 to present are shown for comparison, with 2024 data highlighted in red. Large scale charts are also provided in **Appendix C**.

In July 2024 the lake was thermally stratified with an epilimnion (upper layer) from 0 to 20 feet, a metalimnion (transitional layer) from 20 to 75 feet, and a hypolimnion (bottom layer) from 75 feet to the lake bottom. Near-surface temperatures were near the mid-range on record.

Depth profile measurements of pH in 2024 were among the lowest on record, similar to 2023. pH typically increases to more than 8.0 within the photic zone where algae are most prevalent; however, in 2024 pH remained near 8.0 in the photic zone. pH in the hypolimnion (deep portion of the lake) was also relatively low in 2024.

Dissolved oxygen (DO) measured 7.9 mg/L in the upper epilimnion in July 2024, with the peak occurring 69' below the lake surface (10.7 mg/L). DO measurements were relatively low throughout the water column in 2024. DO peaks just above the area with the highest algae growth because algae produce oxygen during photosynthesis and the oxygen rises in the water column. Dissolved oxygen concentrations are well above the threshold for aquatic life (5 mg/L) throughout the water column, which is typical of a lake with good water quality.

Concentrations of chlorophyll-a in July 2024 were slightly elevated above average in the photic zone with a peak concentration of 3.9 ug/L at 91' depth. This was a well below concentrations from 2023 which were among the highest on record. Chlorophyll-a is a measurement of algae production within the water column, and photosynthetic algae (phytoplankton) peak at the depth where availability of light, nutrients, and water density are optimal for algae growth.

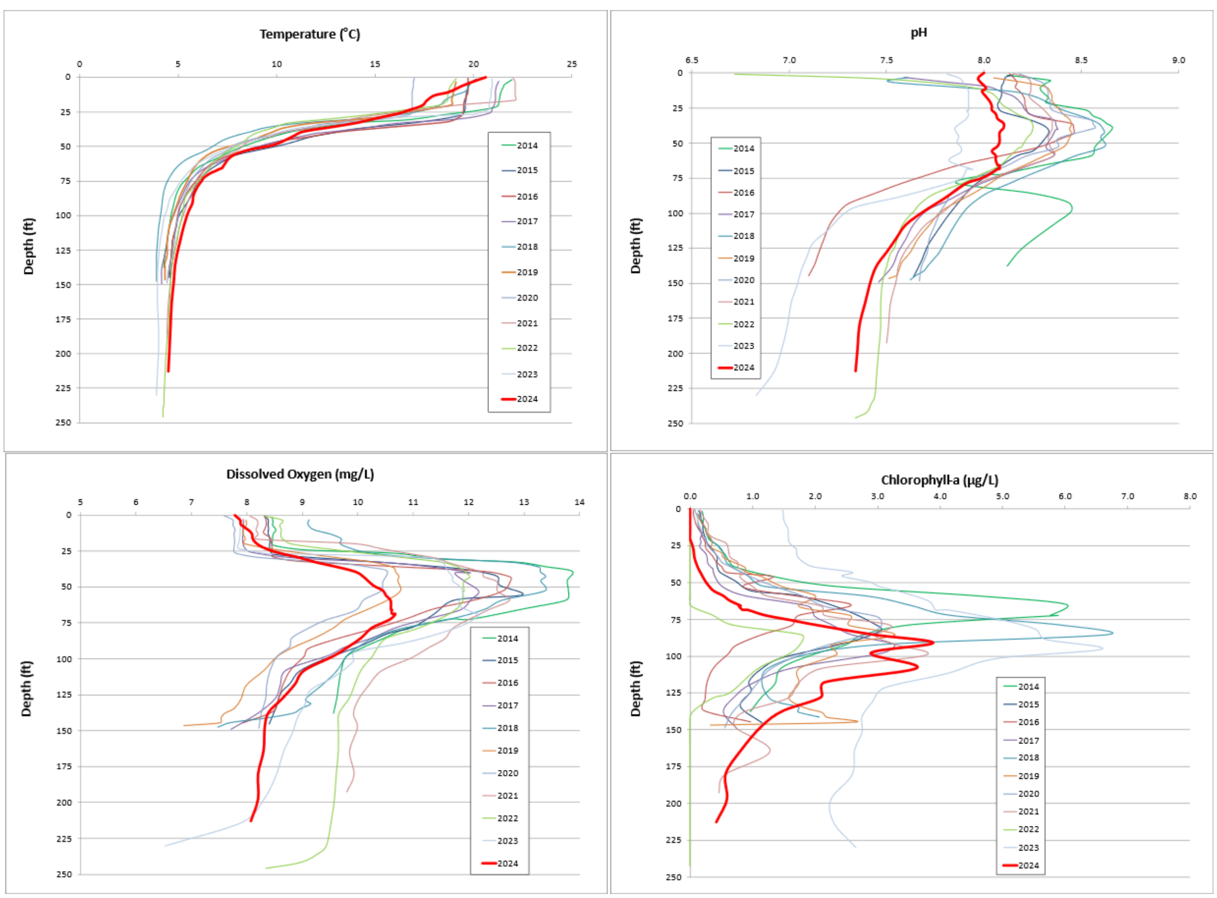


Figure 4. 2024 Depth Profile Results.

4.7 Trophic Status

Trophic status is a lake's ability to produce and sustain populations of algae in response to available nutrients, also referred to as biological productivity. High biological productivity is an indicator of high nutrients and poor water quality, whereas low productivity is an indicator of low nutrient concentrations and good water quality. The trophic status of Little Bitterroot Lake was determined using the Carlson's Trophic State Index (TSI) for measurements of total nitrogen, total phosphorus, and chlorophyll-a (Carlson, 1977). The TSI for Little Bitterroot Lake is shown in **Figure 5** for data from 2010 to present.

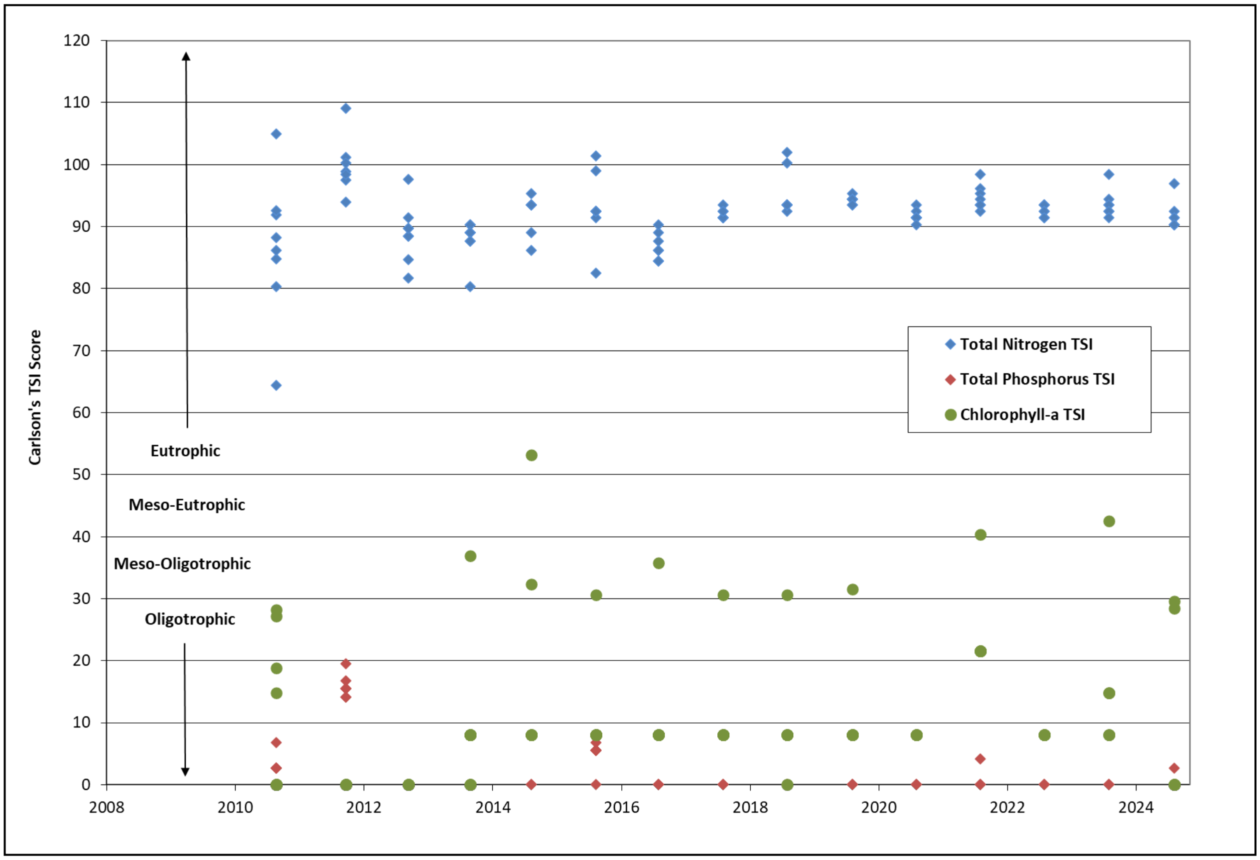


Figure 5. Carlson's Trophic State Index 2010-2024.

TSI data suggest that Little Bitterroot Lake is eutrophic based on concentrations of total nitrogen; however, measurements of total phosphorus and chlorophyll-a indicate that the lake is oligotrophic with low biological productivity. Despite having relatively high concentrations of total nitrogen, Little Bitterroot Lake typically does not experience large blooms of nuisance algae and has shown low concentrations of chlorophyll-a from 2010 to 2024. The low productivity is likely because the lake's morphology is favorable to oligotrophic conditions and limited by low phosphorus concentrations. Little Bitterroot Lake has steep sides, limited shallow shoreline habitat, and a low watershed/lake ratio of 4.8 (Ellis et al, 1998), all which help limit biological production. The lake is also phosphorus-limited, meaning that it has an adequate amount of nitrogen compared to the amount of phosphorus needed to support algae growth. Lakes that are phosphorus-limited often show increased algae growth when phosphorus concentrations increase, but not necessarily when nitrogen concentrations increase. Total phosphorus is commonly associated with sediment, so high concentrations often occur in years following land disturbance (such as road building or logging) or increased precipitation and runoff.

4.8 Long Term Trends

Little Bitterroot Lake has been sampled since 1999, although dates and locations have only been consistent since 2010 when mid-summer sampling became standard. As a result, data collected prior to 2010 is often outside the mid-summer window and may not be directly comparable for long-term trend analysis, but the data are still valuable for providing seasonal water quality information. Therefore, long-term trends are evaluated for lake sites only from the period of 2010 to present to ensure data are comparable based on location and time of year. Long-term trend results from 2010 to 2024 are shown below in **Figure 6** for total nitrogen and phosphorus, which shows concentrations for lake sites as well as the inlet and outlet streams for comparison, but trend lines are for lake data only. Long-term data are provided for individual sites in **Appendix D**.

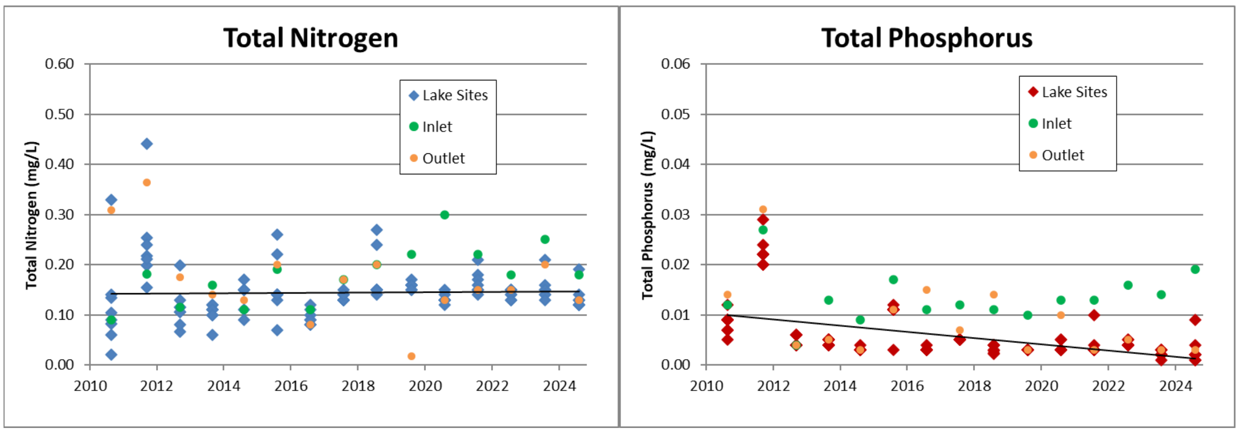


Figure 6. Long-term Trends 2010-2024.

Total nitrogen concentrations show a slightly increasing trend since 2010, however, the highest values were recorded in 2011 and the upward trend is more apparent past 2012. Total phosphorus shows a decreasing trend from 2010 to 2024, however, this trend is influenced by high values in 2011. Still, TP concentrations have been very low in recent sampling years, and TP typically shows its highest concentrations during high runoff years such as 2011 because it is commonly bound with sediment.

The decreasing trend in TP concentration is encouraging but data should be interpreted with caution because of the limited seasonal data available for Little Bitterroot Lake. Nutrient concentrations can vary between seasons or change rapidly due to episodic events such as runoff, blooms, or lake turnover, so sample events may not coincide with periods of peak nutrient concentrations. Data and trends become more robust as future measurements are added to the dataset, and continuity and consistency are maintained within the monitoring program.

The ratio between nitrogen and phosphorus is also analyzed for long term trends. Within a lake system, algae growth is optimized when the ratio between nitrogen and phosphorus is near 16:1. A ratio higher than 16:1 indicates that the system has sufficient nitrogen for algae growth, but phosphorus is limited. Conversely, a ratio lower than 16:1 indicates that the system has limited nitrogen for algae growth but has enough phosphorous. **Figure 7** displays the trend in N:P ratio from 2010 to present on Little Bitterroot Lake. The 16:1 ratio is indicated by the green line, and the trend line is shown as the dashed line. In 2024, the average N:P ratio was 76.9 (indicating that the lake is phosphorus limited), and the N:P ratio is increasing from 2010 to 2024. This is occurring because concentrations of total nitrogen are increasing from 2010 to present, while concentrations of total phosphorus have been decreasing.

This trend with increasing nitrogen is prevalent across the western United States and is expected with increased human occupation around lake communities. Nitrogen is a nutrient that is commonly associated with human sources such as septic systems or fertilizers and increasing trends in nitrogen concentrations are commonly seen around growing lake communities. Phosphorus is more commonly associated with natural sources such as surrounding geology or soils, and human sources can more easily be controlled with appropriate erosion or sediment control practices (although septic systems are also a primary source of phosphorus to lake systems). As a result, Little Bitterroot Lake has become increasingly phosphorus limited during this period of study, and land management around the lake should encourage practices that limited additional inputs of phosphorus by maintaining shoreline vegetation, limiting land clearing, and avoiding fertilizers that are high in phosphorus. Proper maintenance of septic systems will also help reduce nutrient inputs to Little Bitterroot Lake.

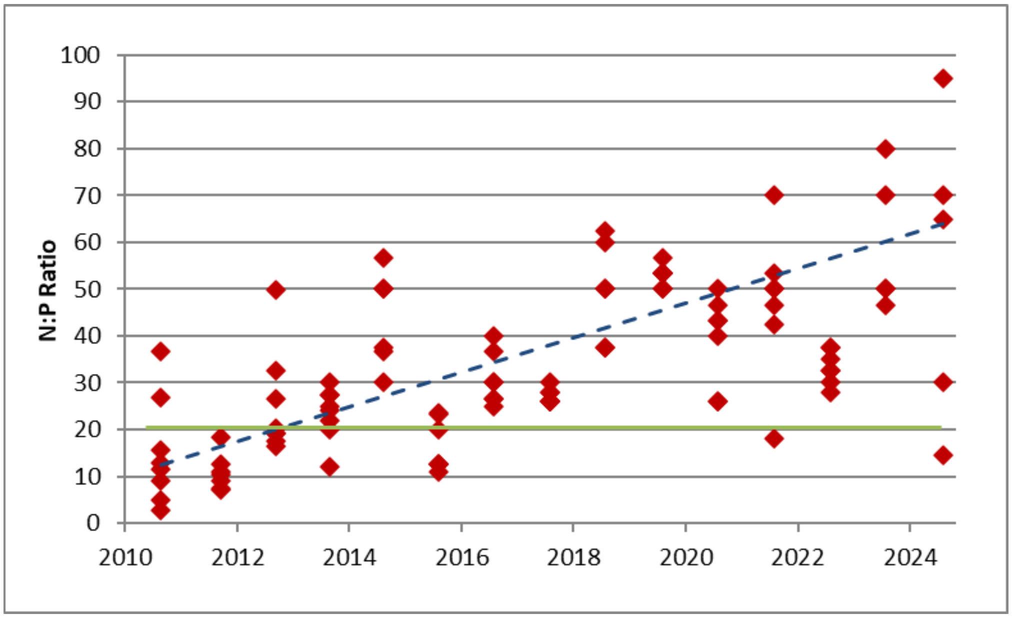


Figure 7. Nitrogen:Phosphorus Ratio 2010-2024.

4.9 Spatial Trends

Nutrient data are collected routinely at 7 locations on Little Bitterroot Lake which helps evaluate spatial trends such as influences from Herrig Creek, isolated bays, or areas with increased development. Spatial data are shown in **Figure 8** from 2010-2024 for all lake sites and the inlet and outlet streams. Data are organized from left to right in the direction of flow through the lake. Since 2010, the highest average concentration of total nitrogen is from Herrig Creek, which influences concentrations in Herrig Creek Bay to have the second highest average concentration. The lowest average concentration of TN is at Slaughterhouse Bay. Total phosphorus shows similar trends with the highest concentrations coming from Herrig Creek, although the lowest average concentration of TP is measured at the lake center. In general, the lake shows little spatial variability, but by maintaining consistency with locations and sample timing these trends will become more robust over time and may reveal spatial differences in nutrient concentrations. Spatial data are also provided as statistical boxplots in **Appendix B**, which show the minimum, maximum, and interquartile range for each site.

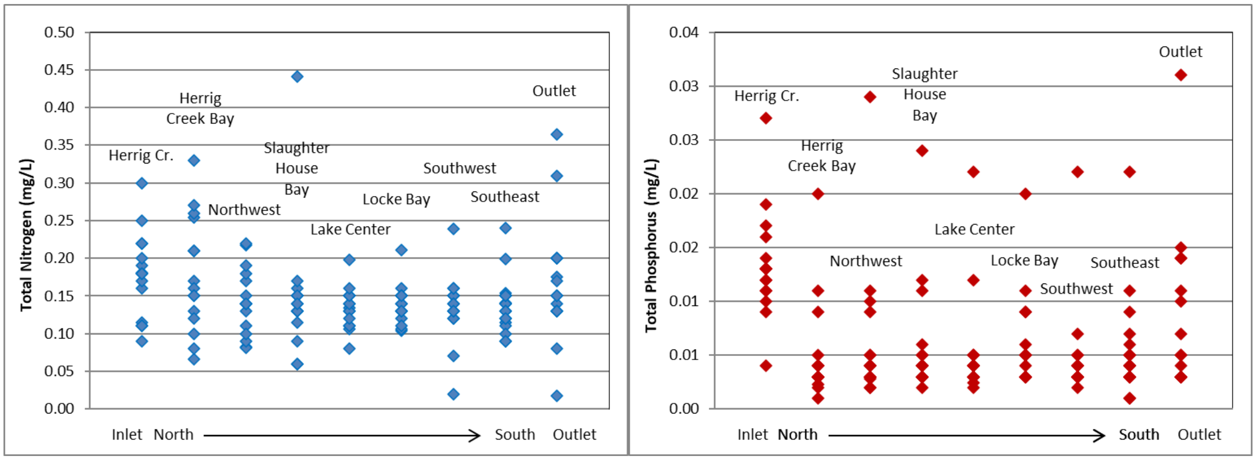


Figure 8. Spatial Trends 2010-2024.

5.0 References

Babcock JN. 202d4. Little Bitterroot Lake Eutrophication Study 2024 Sampling and Analysis Plan. Prepared for Montana DEQ on behalf of Little Bitterroot Lake Association.

Carlson RE. 1977. A trophic state index for lakes. Limnology and Oceanography. Vol 22, Pgs 361-9.

Cole GA. 1983. Textbook of Limnology, 3rd Edition. Waveland Press.

Ellis B K and Craft JA. 2008. Trophic status and trends in water quality for Volunteer Monitoring Program lakes in northwestern Montana, 1993–2007. Flathead Lake Biological Station Report 200-08. Prepared for Flathead Basin Commission.

Ellis BK, Craft JA, Stanford JA. 1998. Baseline Water Quality Study of Little Bitterroot, Mary, Ronan, Ashley and Lindbergh Lakes, Montana. Flathead Lake Biological Station Report 148-98.

Little Bitterroot Lake Zoning District. 1996. Little Bitterroot Lake Neighborhood Plan and Development Code: An Amendment to the Flathead County Master Plan. Adopted February 27, 1996.

Montana DEQ Water Quality Planning Bureau. 2012. Circular DEQ-7 – Montana Numeric Water Quality Standards. Helena, MT.

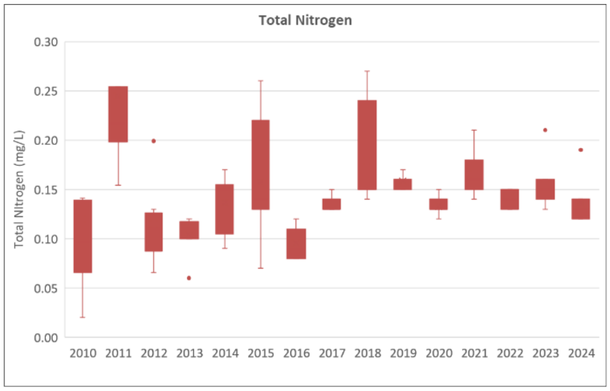
Wells SW, Counihan TD, Puls A, Sytsma M, Adair B. 2011. Prioritizing Zebra and Quagga Mussel Monitoring in the Columbia River Basin. Center for Lakes and Reservoirs Publications and Presentations, Paper 10.

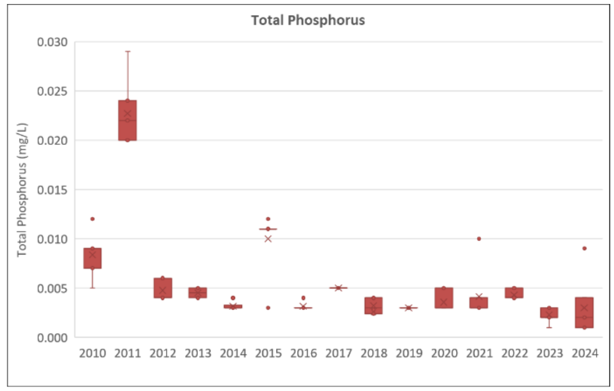
Whitefish Lake Institute (WLI). 2013. Montana Lake Book – Second Edition. Whitefish, MT. Available online at: http://www.nwmtlvmn.org/docs/Montana%20Lake%20Book%202nd.pdf.

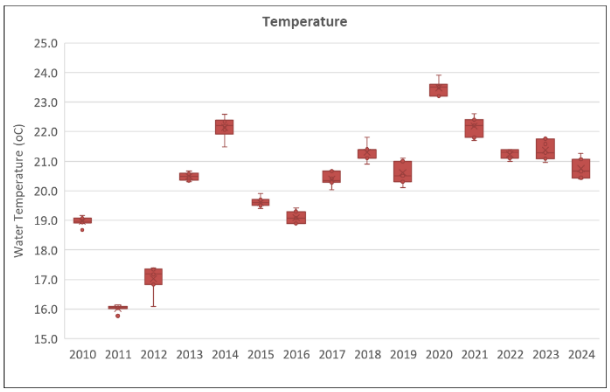
Whitefish Lake Institute (WLI). 2025. Northwest Montana Lakes Network 2024 Summary Report. Prepared for Montana Fish, Wildlife & Parks.

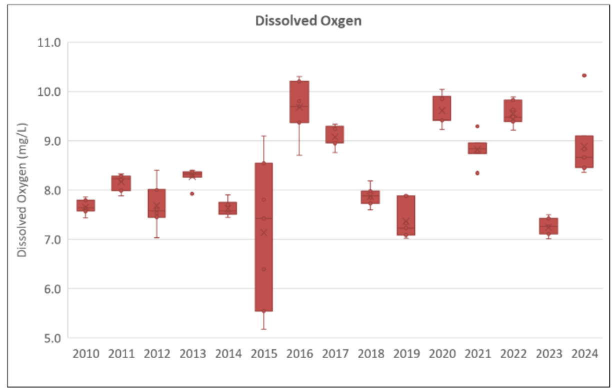
Appendix A – 2024 Statistical Boxplots

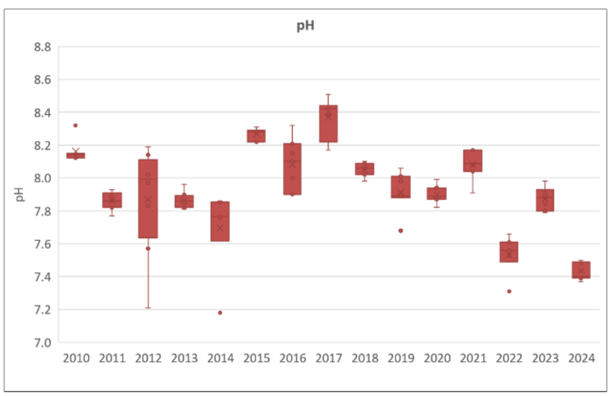
Boxplots – Nutrient and Field Parameters 2010 – 2024 by Year

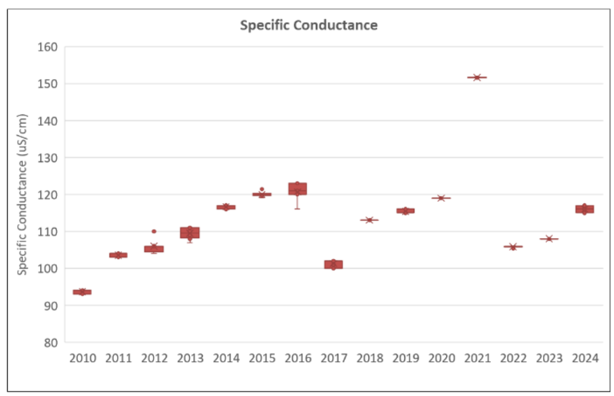


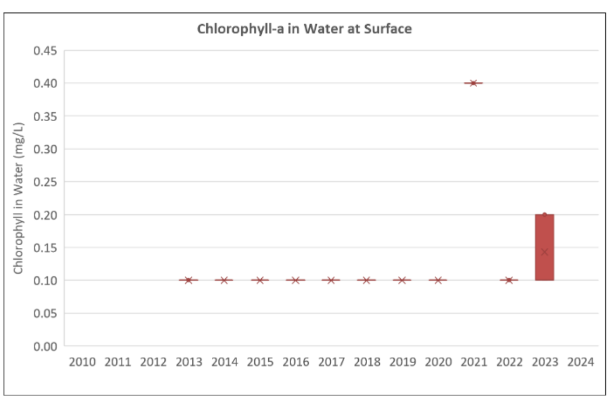


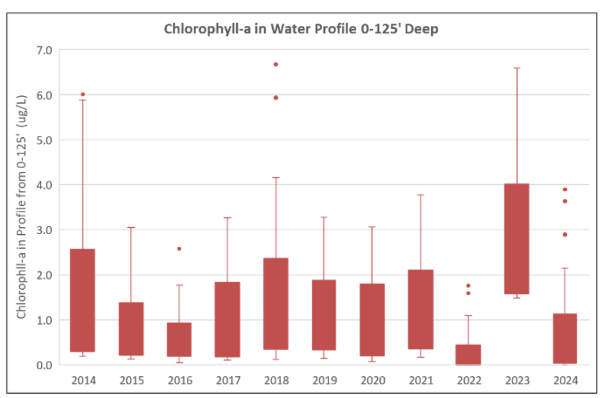




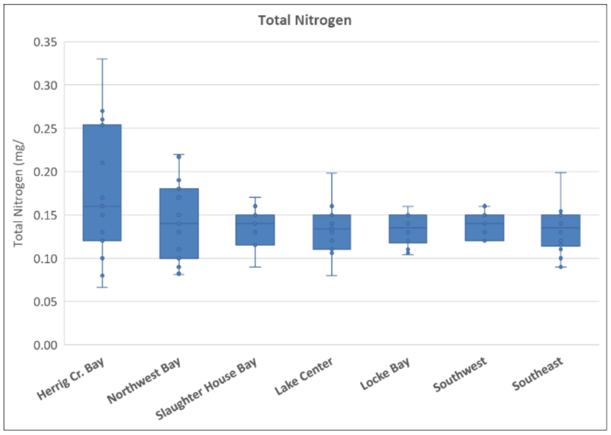


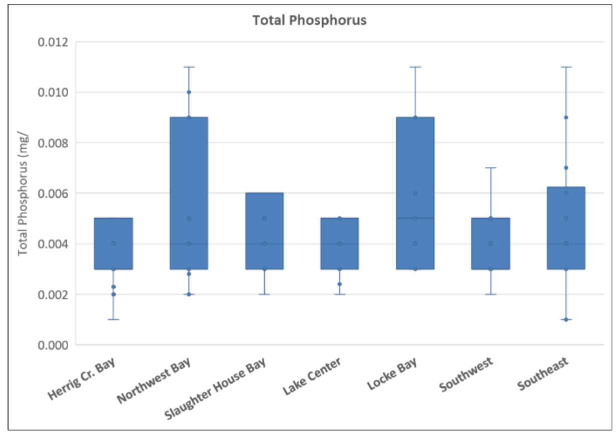


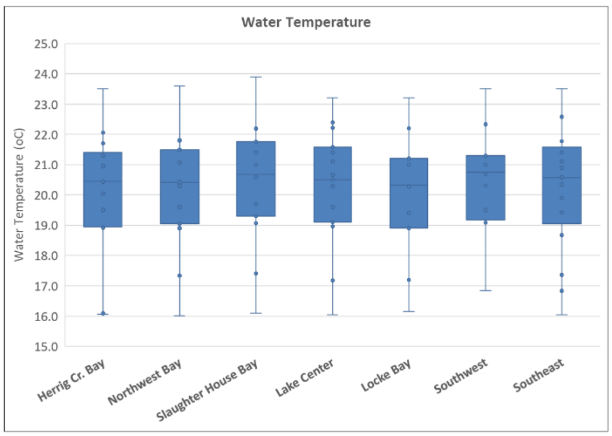


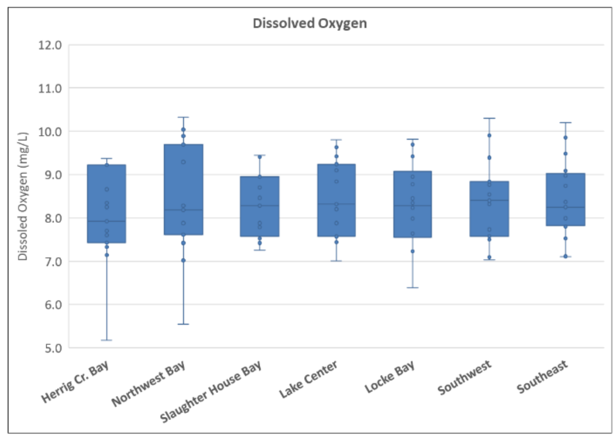


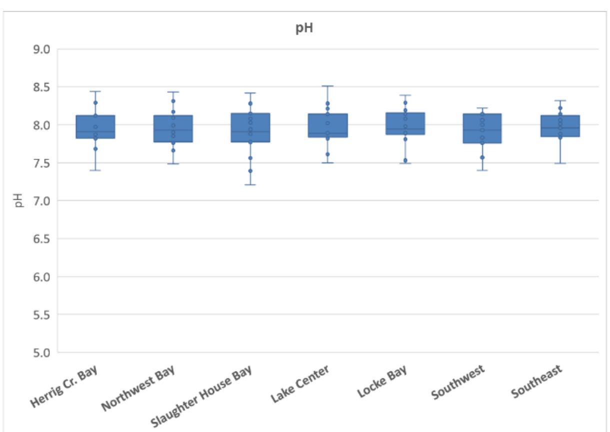
Boxplots – Nutrient and Field Parameters 2010 – 2024 by Location

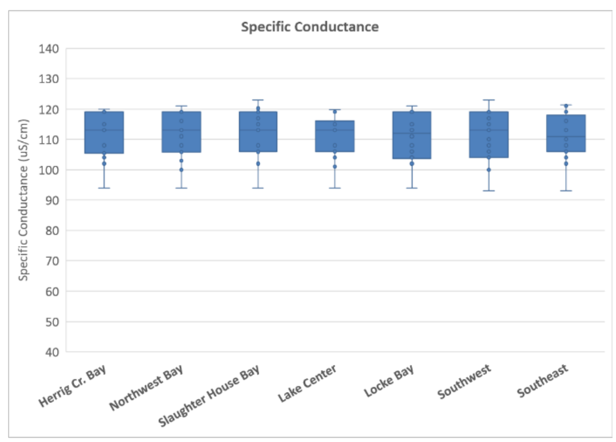






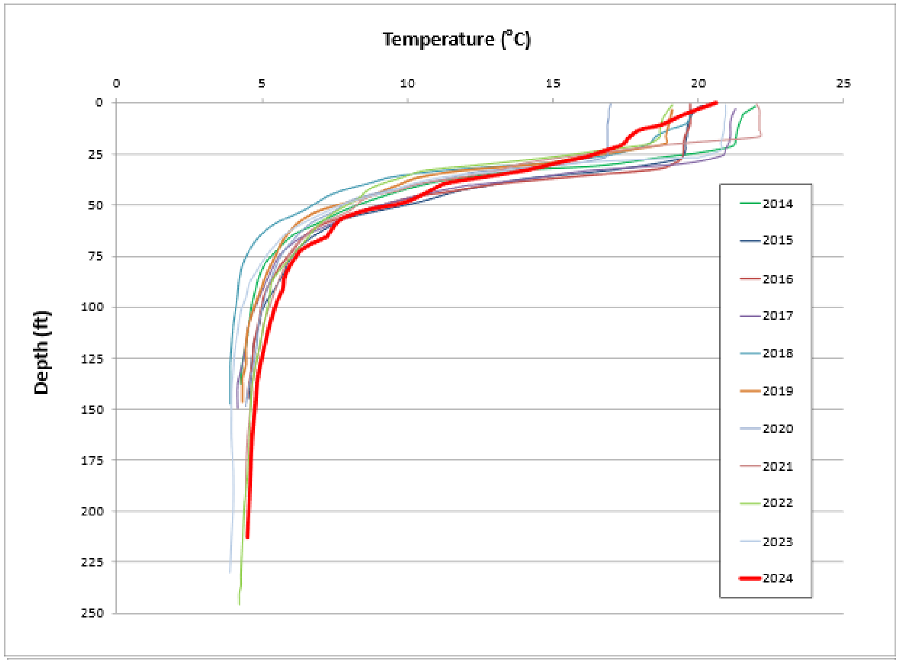


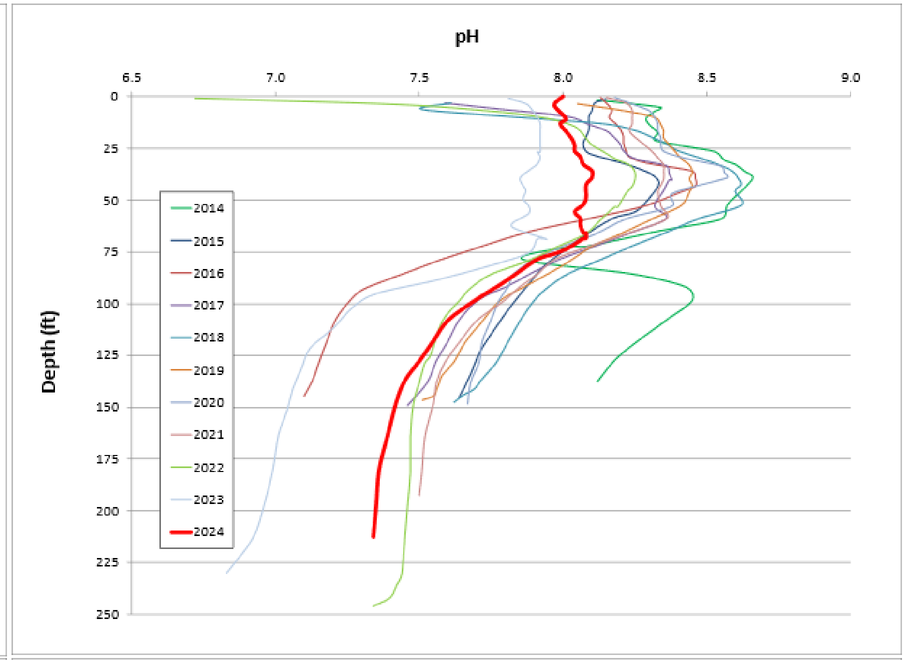


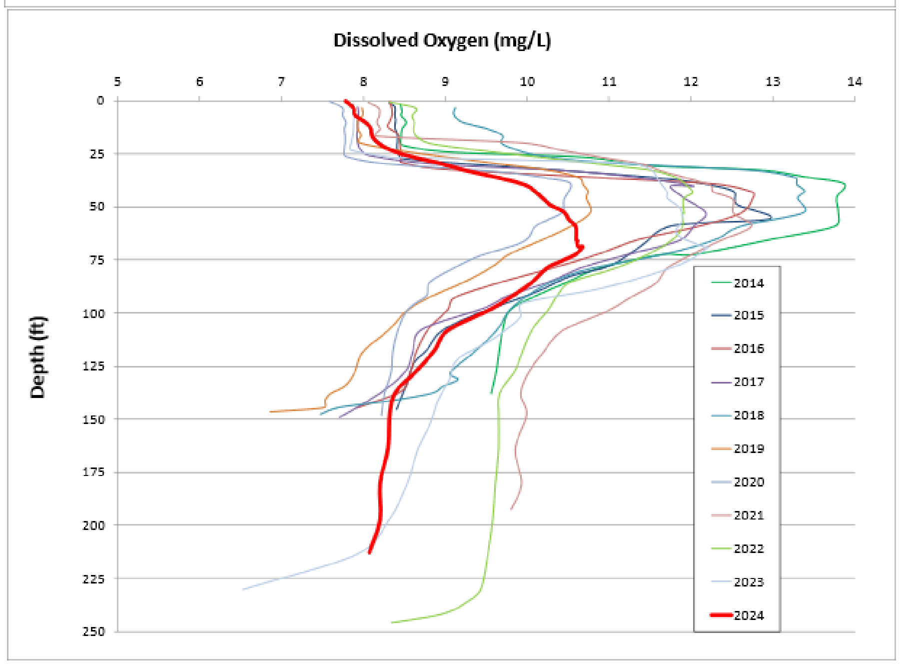


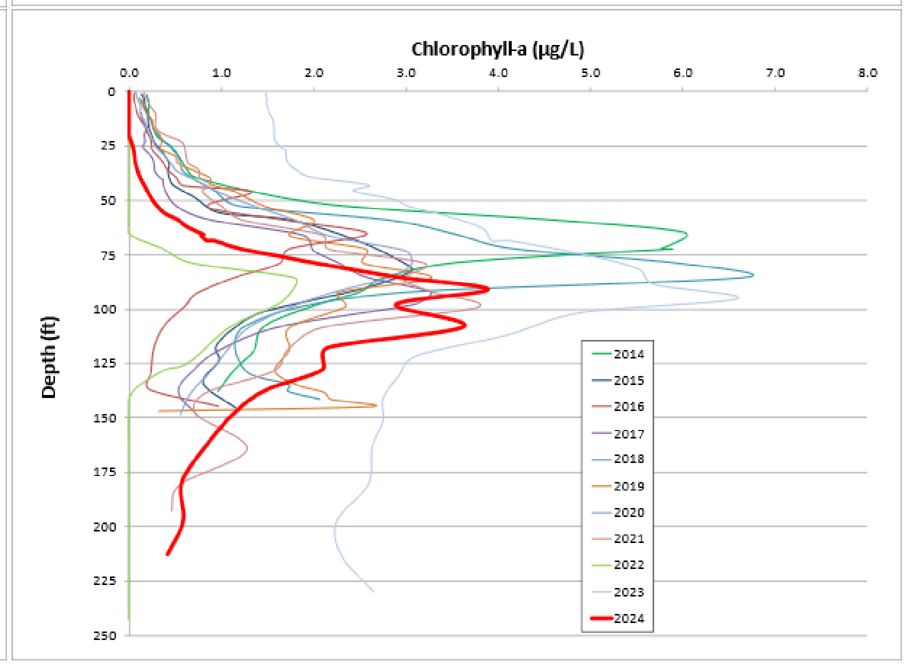
Appendix B – Depth Profiles for Individual Parameters

Depth Profiles (data collected 7/10/2024 by Whitefish Lake Institute)



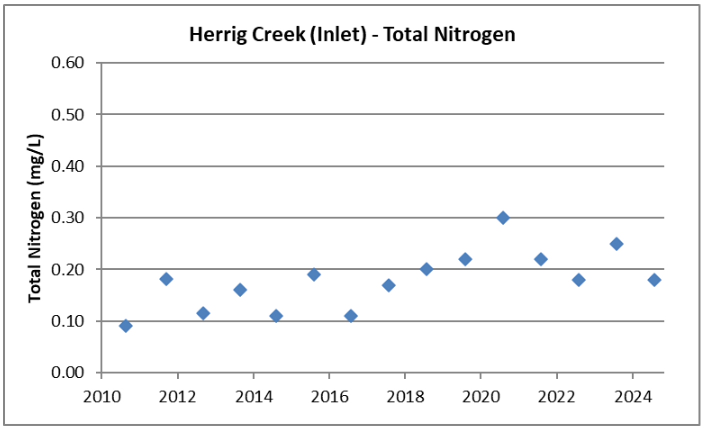


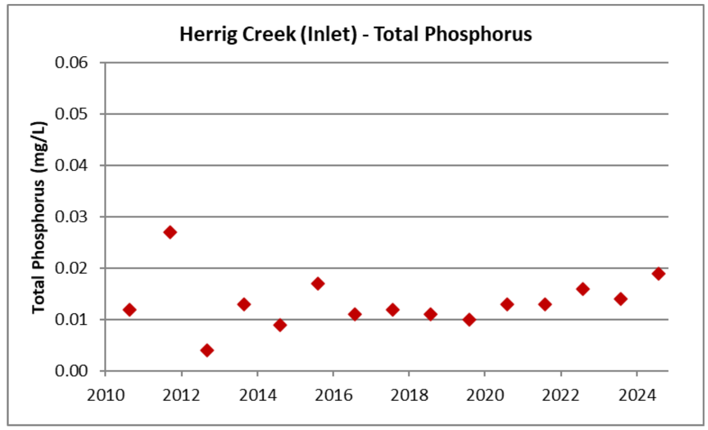


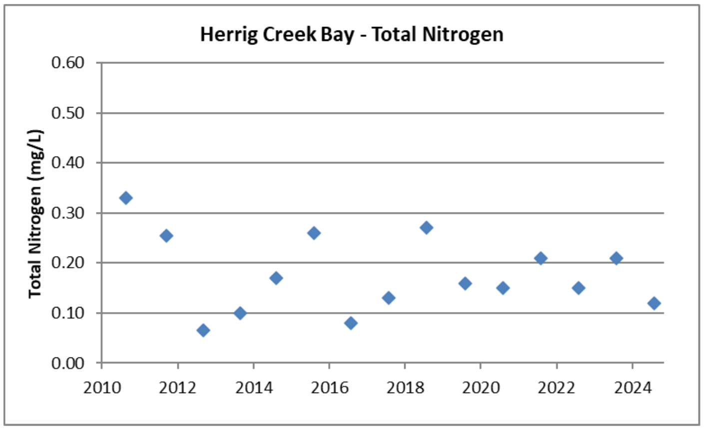


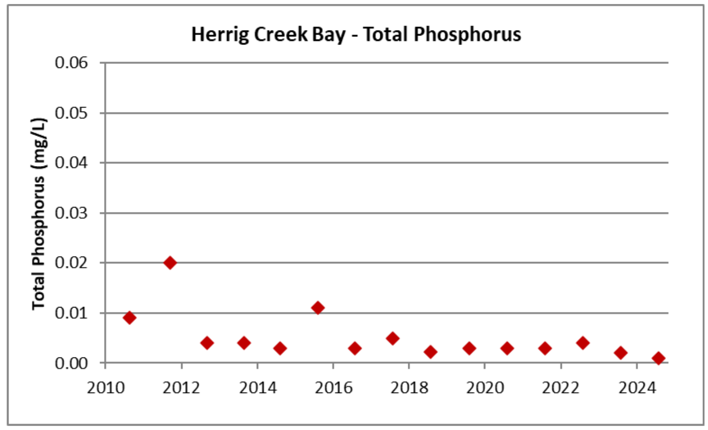
Appendix C – Nutrients at Individual Sites 2010-2024

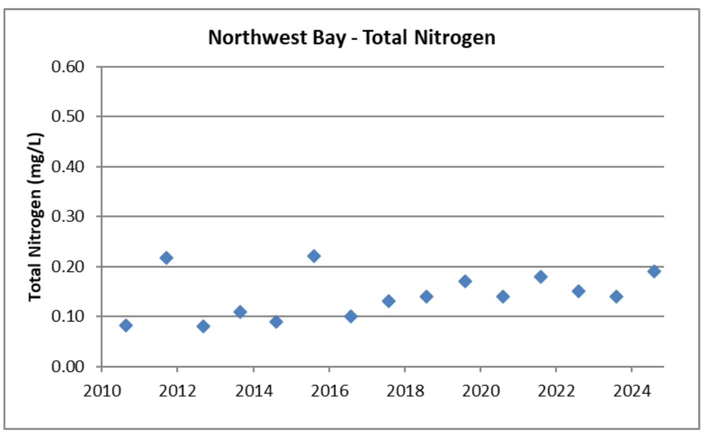
Nutrients at Individual Sites 2010 - 2024

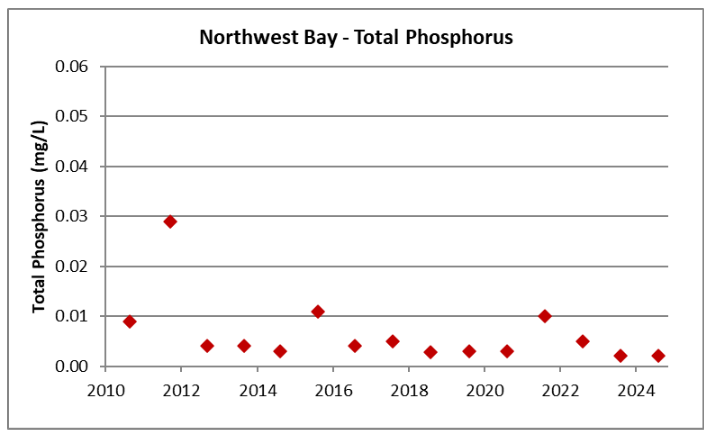


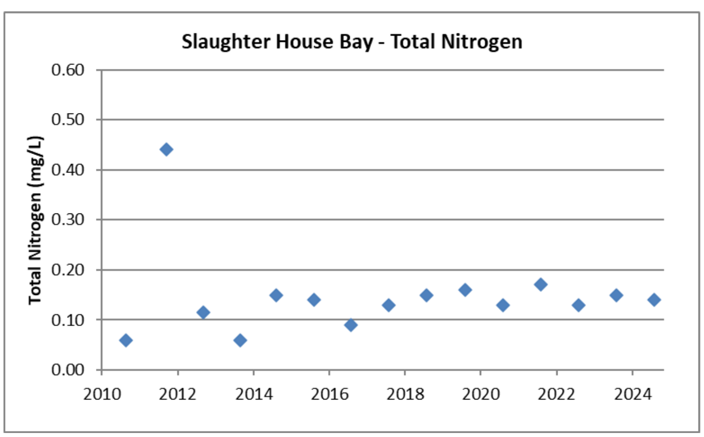


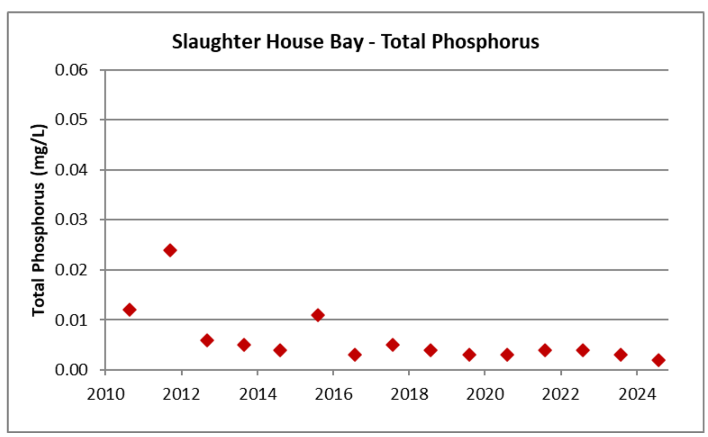


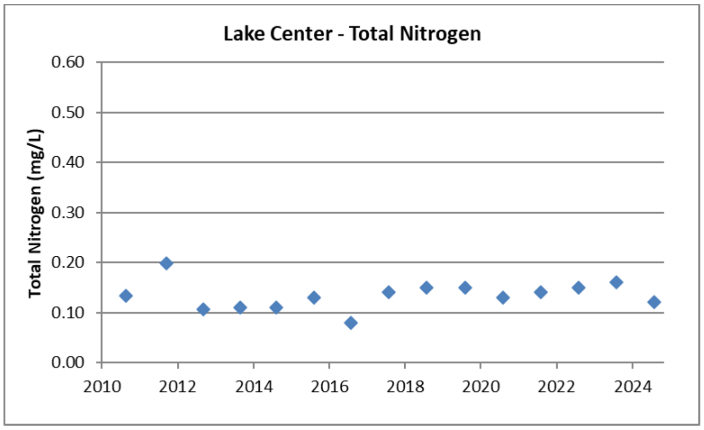


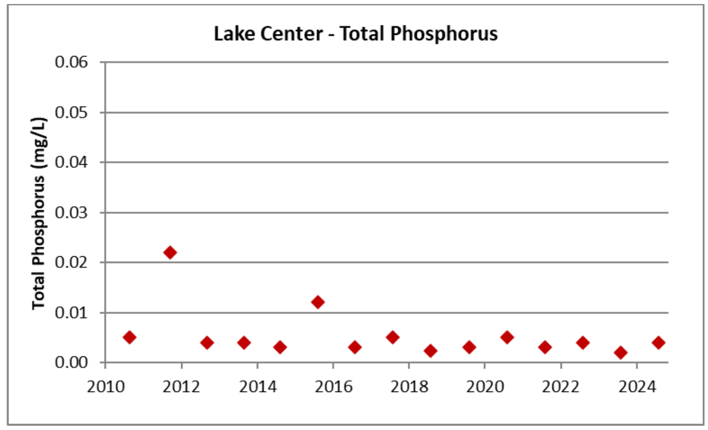


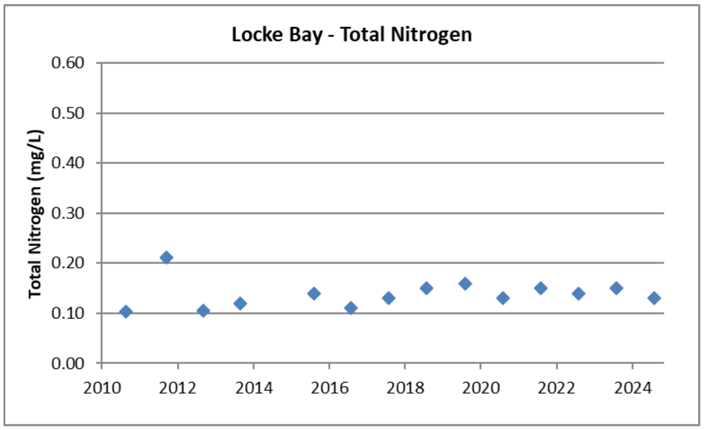


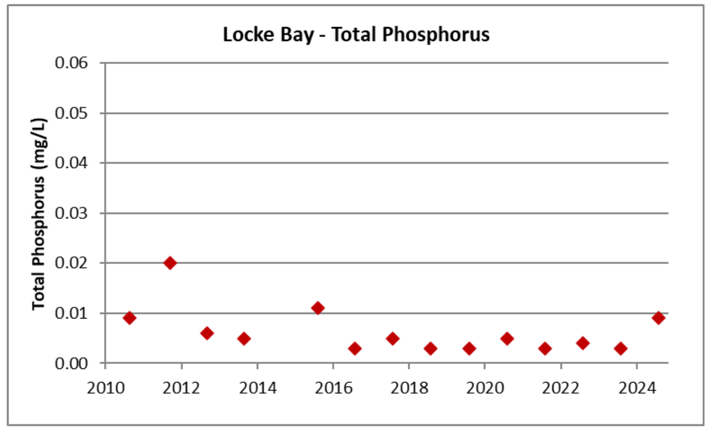


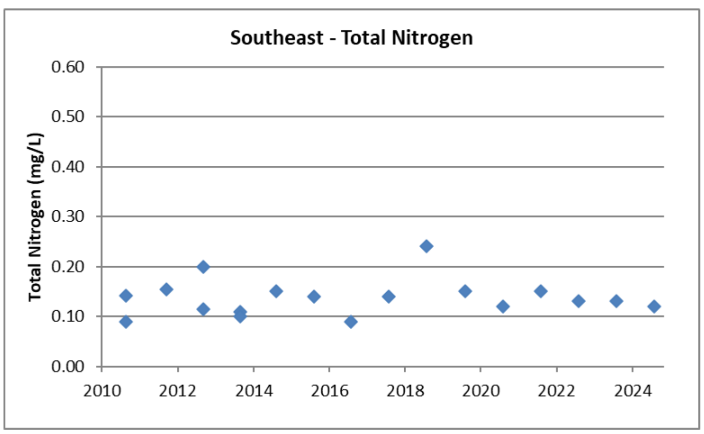


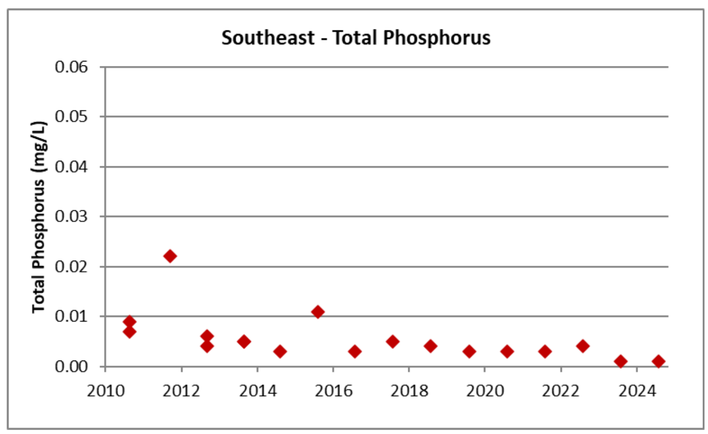

Lake Center - Total Nitrogen
Total Nitrogen (mg/L)
0.00 0.10 0.20 0.30 0.40 0.50 0.60
2010 2012 2014 2016 2018 2020 2022 2024

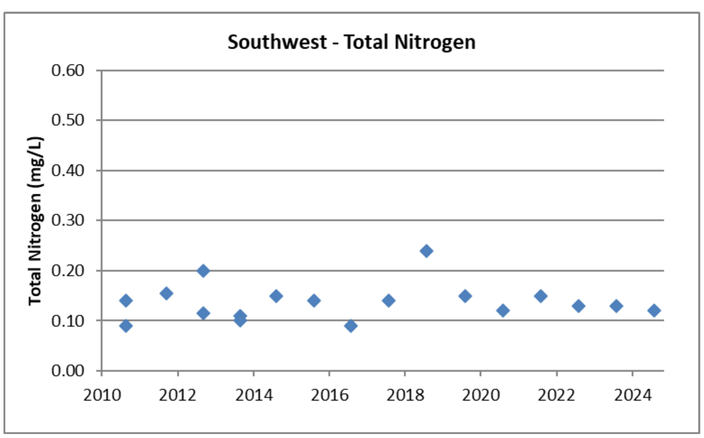

Lake Center - Total Phosphorus
Total Phosphorus (mg/L)
0.00 0.01 0.02 0.03 0.04 0.05 0.06
2010 2012 2014 2016 2018 2020 2022 2024

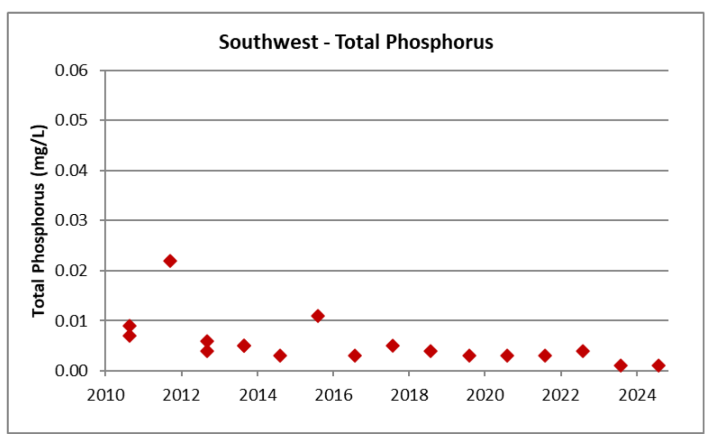

Locke Bay - Total Nitrogen
Total Nitrogen (mg/L)
0.00 0.10 0.20 0.30 0.40 0.50 0.60
2010 2012 2014 2016 2018 2020 2022 2024

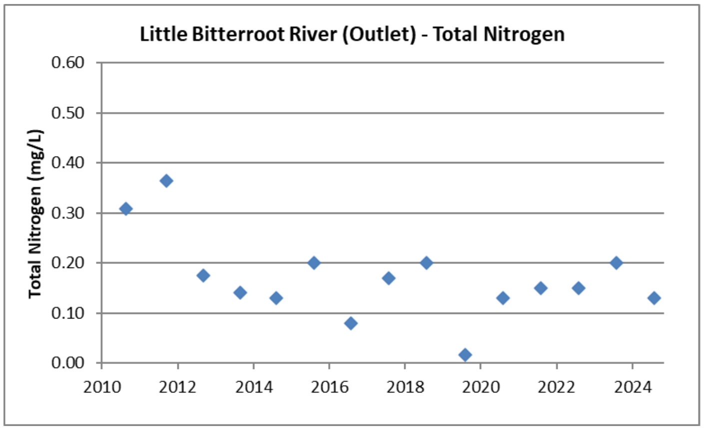

Locke Bay - Total Phosphorus
Total Phosphorus (mg/L)
0.00 0.01 0.02 0.03 0.04 0.05 0.06
2010 2012 2014 2016 2018 2020 2022 2024

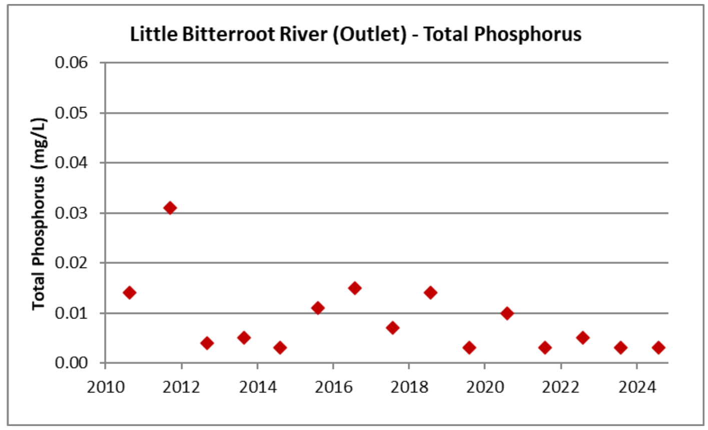

Southeast - Total Nitrogen
Total Nitrogen (mg/L)
0.00 0.10 0.20 0.30 0.40 0.50 0.60
2010 2012 2014 2016 2018 2020 2022 2024


Southeast - Total Phosphorus
Total Phosphorus (mg/L)
0.00 0.01 0.02 0.03 0.04 0.05 0.06
2010 2012 2014 2016 2018 2020 2022 2024


Southwest - Total Nitrogen
Total Nitrogen (mg/L)
0.00 0.10 0.20 0.30 0.40 0.50 0.60
2010 2012 2014 2016 2018 2020 2022 2024


Southwest - Total Phosphorus
Total Phosphorus (mg/L)
0.00 0.01 0.02 0.03 0.04 0.05 0.06
2010 2012 2014 2016 2018 2020 2022 2024





Nutrients at All Sites 2010 - 2024 (trendline shown for lake sites)