Little Bitterroot Lake
Water Quality Monitoring Program
2019 Annual Report

LITTLE BITTERROOT LAKE ASSOCIATION

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Glossary of Terms

Benthic – the bottom region of a lake including the sediment surface

Bloom – a significant increase in algae population triggered by favorable conditions for growth

Chlorophyll-*a* – a green pigment found in photosynthetic plants and algae

Depth profile – a chart showing a water chemistry parameter at various depths within a lake

Epilimnion – the 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 – the 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)

Trophic status – a lake's ability to produce and sustain populations of algae in response to available nutrients, also referred to as lake productivity or biological productivity

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
WET – Water & Environmental Technologies
WLI – Whitefish Lake Institute

Executive Summary

Little Bitterroot Lake was sampled one time in 2019 during a mid-summer event on August 7, which was the 21st sampling event since 1999. Seven lake sites were sampled for field parameters, nutrients, and chlorophyll-a, and five stream sites were sampled for field parameters, nutrients, total suspended solids, and dissolved organic carbon. Four "near-shore" locations were added in 2019 to record nutrient impacts close to areas with high development, and two of the near-shore sites were sampled for attached algae. Depth profiles were recorded at the lake center by Whitefish Lake Institute on July 15.

Little Bitterroot Lake continued to show excellent water quality in 2019. Average total nitrogen in 2019 was slightly lower than 2018 and was near the average concentration for the entire monitoring period. Total nitrogen continues to show an upward trend since 2012, which is common for many lakes in developed areas. The average total phosphorus concentration in 2019 was the lowest on record with no samples measuring above the analytical detection limit. Nitrogen concentrations are higher in the inlet and outlet streams (0.23 mg/L average) when compared to lake sites (0.16 mg/L average). Total phosphorus is also higher in stream sites (0.012 mg/L average) when compared to lake sites (all below 0.003 mg/L). The four "near-shore" samples did not have sample results significantly different from the routine lake samples. Little Bitterroot Lake continues to be phosphorus limited, meaning that sufficient nitrogen is available for algae growth, and algae blooms are more likely to occur with inputs of phosphorus. The low concentrations of phosphorus are encouraging; however, during mid-summer much of the available nutrients are consumed by algae in the water column, and sample results may not represent worst-case conditions.

Near surface lake temperatures in August were around 21.0°C (70.0°F). The lake was thermally stratified with an epilimnion from 0 to 19 feet, a metalimnion from 19 to 60 feet, and a hypolimnion below 60 feet. The upper stratified layer (the epilimnion) was slightly shallower than most years and near-surface temperatures were slightly cooler than normal. Measurements of other field parameters in 2019 were consistent with previous years, including specific conductance, pH, and dissolved oxygen.

Algae in the water column (chlorophyll-a) was very low, with only one sample above the analytical detection limit (1.1 mg/L at the lake center, 60' below the lake surface. Algae concentrations in the water column did not reach nuisance levels and were comparable to data from previous sample years. Two attached (benthic) algae samples were collected in 2019 from northwest and southeast locations. Attached algae concentrations were relatively high compared to previous samples (8.6 and 4.8 mg/L), but did not reach nuisance levels. A significant sample of attached algae was collected in 2018 from the southeast location, however, algae conditions were much less in 2019, although sporadic patches of attached filamentous algae have been reported by landowners. Documenting observable patches of algae is important for document areas with potential nutrient impacts, such as locations of failing septic systems.

The trophic state index for Little Bitterroot Lake was oligotrophic based on concentrations of chlorophyll-a and phosphorus, meaning the lake has low primary productivity and good water quality. Total nitrogen concentrations indicate the lake has potential to be eutrophic, but the lake is phosphorus limited and the low concentrations of available phosphorus help prevent nuisance algae blooms. When compared to 10 regional large lakes, Little Bitterroot Lake ranks 5th lowest in nitrogen concentration, and 3rd lowest in phosphorus.

Additional samples have been collected from the Herrig Creek watershed from 2017-2019 to evaluate effects of logging and slash burning. The upper Herrig Creek sites have shown slightly higher nutrient

concentrations than the lake, which suggest that Herrig Creek may be a source of nutrient loading to Little Bitterroot Lake. Sediment concentrations coming from Herrig Creek are typically very low (below analytical detection). Dissolved organic carbon samples are also collected from Herrig Creek, and the highest concentrations are generally recorded at the upper Herrig Creek site.

In order to improve or maintain water quality in Little Bitterroot Lake, efforts should be made to reduce sources of nutrients, such as limiting application of fertilizer to lawns, maintaining septic systems, keeping a vegetated buffer area, and reducing shoreline erosion. Little Bitterroot Lake is phosphorus limited, meaning that additional inputs of phosphorus are more likely to cause undesirable algae blooms. Fertilizers with little or no phosphorus are recommended to help maintain good water quality. This can be accomplished by selecting fertilizers with a zero as the middle value (i.e. 16-0-0). Little Bitterroot Lake has routinely shown excellent water quality; however, nitrogen concentrations have been steadily increasing since 2012, which is a common trend for lakes in developed areas. Maintaining and not overloading septic systems is a key practice for reducing nutrient inputs into Little Bitterroot Lake.

1.0 Introduction

Little Bitterroot Lake is the headwaters for the Little Bitterroot River located southwest of Kalispell near the community of Marion at an elevation of approximately 3900 feet (**Attachment A**, **Figure 1**). The lake has a maximum depth of 260 feet, 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 exists within 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 and 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 establish a water quality and nutrient baseline for the inflow, outflow, and lake water in conjunction with prior water quality projects. Information from this monitoring 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 2019 and past monitoring events. Long term trends in nutrient concentrations and trophic status are provided for locations that have been sampled consistently since 1999.

2.0 Monitoring Program History

Water & Environmental Technologies (WET) have conducted 20 sampling events on Little Bitterroot Lake since 1999 with assistance from the Little Bitterroot Lake Association. Data collected during sampling helps document existing water quality, track changes in nutrient concentrations over time, and to characterize the lake’s productivity and trophic status. Additional data have been collected by the Flathead Lake Biological Station, Flathead Basin Commission, Flathead High School, Montana DEQ, University of Montana, and Whitefish Lake Institute.

Past monitoring events conducted by WET 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.			

Depth profiles included with this report were measured in Little Bitterroot Lake on July 15, 2019, by the Whitefish Lake Institute, which oversees the Northwest Montana Lakes Volunteer Monitoring Network. The following sections describe the locations, dates, and methods for field sampling conducted in 2019 on Little Bitterroot Lake and the surrounding watershed.

3.0 Field and Analytical Methods

The water quality monitoring program on Little Bitterroot Lake includes annual field measurements and sample collection for laboratory analysis. Monitoring is conducted during mid-summer, typically the first week of August, although additional monitoring events have been conducted in spring and fall to evaluate seasonal changes in water quality. Monitoring is routinely conducted at 7 lake sites and 2 stream sites, although additional parameters or sites are added as warranted. Routine measurements of field parameters include water temperature, dissolved oxygen, specific conductance, and pH. Routine samples collected for laboratory analysis include basic nutrient parameters, including nitrate+nitrite, ammonia, total nitrogen, and total phosphorus. Lake samples are also collected for chlorophyll-a, which is a measure of algae growth. Two sites have been sampled for chlorophyll-a on near-shore rocks since 2014 as a means of monitoring algae growth on natural substrate. Depth profile monitoring is conducted annually by Whitefish Lake Institute at the lake center during late July or early August, and includes measurements of water temperature, specific conductance, dissolved oxygen, and pH.

In 2019 sampling events were conducted by WET on August 7, and by Whitefish Lake Institute on July 15 with assistance from members of LBLA. Water quality sampling in 2019 was conducted at 11 lake locations and 4 stream locations, including 3 sites on the inlet stream (Herrig Creek) and one site on the outlet stream (Little Bitterroot River) (**Figure 1**).

Several additions were made to the routine water quality sampling program in 2019 in order to collect additional data and address emerging water quality issues around Little Bitterroot Lake. Calcium and alkalinity were added to three sites in 2019 in order to evaluate the potential for colonization of aquatic invasive species, especially invasive mussels and non-native vegetation. These parameters were collected at the lake center and at the inlet and outlet streams. Results from these parameters may be compared against published guidelines for potential colonization of aquatic invasive species. 2019 was the second year these parameters were sampled, although more sites were included in 2018.

Two sites were also included in the upper watershed of Herrig Creek in 2019 to help evaluate potential effects from recent logging and slash burning. These sites were sampled for field parameters, nutrients, total suspended solids, and dissolved organic carbon. 2019 represents the third year of sampling at these locations.

Additionally, four near-shore sites were added to the sampling program in 2019 to capture nutrients that may be entering the lake from residential septic systems. The near-shore locations were distributed around the lake near areas of development, and analytes included the same nutrient parameters as the routine lake sites.

Laboratory analyses in 2019 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 are provided in the project Sampling and Analysis Plan (SAP) (WET, 2019), which is provided to Montana DEQ to procure funding from the volunteer monitoring grant program.

3.1 Field Parameters

Field parameters are measured using a portable water quality meter (YSI Pro-Plus). Measurements are taken in the upper 3’ of the water column at lake locations, or within the flowing portion of the stream at surface water locations. Field parameters include water temperature, dissolved oxygen, specific conductance and pH. The water quality meter is calibrated during the day of sampling. Water clarity is measured at the lake center using a Secchi disc. Stream flow is measured at surface water locations using a Marsh-McBirney electronic flow meter.

3.2 Water Chemistry Samples

Samples are collected for laboratory analysis of nutrients at each lake and stream location. Bottles are filled from moving water at the inlet and outlet streams, and from just below the surface at lake sites. At the lake center, samples are collected at various depths using a Van Dorn type sampler. All sample bottles are triple-rinsed with sample water prior to collection. Samples are filtered or preserved if necessary, and stored in a cooler on ice for delivery to the laboratory. Nutrient parameters analyzed at the laboratory include various forms of nitrogen (nitrate+nitrite, ammonia, total Kjeldahl, organic, total) and phosphorous (dissolved and total). Samples for total suspended solids (TSS) and dissolved organic carbon (DOC) were also collected in 2019 from the lake center, the inlet and outlet streams, and from two additional sites on Herrig Creek. All laboratory analyses were performed by Energy Laboratories in Helena, MT, using standard analytical methods, which are described in detail in the project SAP.

3.3 Algae Samples

Samples are collected from lake sites to analyze the concentration of chlorophyll-a, which provides a measurement of algae growth in the water column. Chlorophyll-a samples from open water 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 the surface at 7 lake sites, and 2 samples are collected from various depths at the lake center using a Van-Dorn type sampler.

Samples were collected from two locations in 2019 to measure the algae growth on shoreline rocks, also called attached algae or benthic algae. For benthic algae collection, large rocks are selected from the wadeable portion of the lake that displays typical algae conditions for the area. A template is placed on the rock, and algae are removed from inside the template by scraping and brushing. The removed algae are filtered on a glass filter, placed in a centrifuge tube, wrapped in aluminum foil, and stored on dry ice for delivery to the Energy Laboratories in Helena, MT. Eleven template samples are collected at each location per the sampling protocol, which is described in the project SAP and based on standard collection methods approved by DEQ.

3.4 Depth Profile Sampling

Depth profile sampling is conducted at the lake center to evaluate changes in field parameters at depth, which indicates the degree of lake stratification at the time of sampling. Depth profile sampling was conducted by Whitefish Lake Institute on July 15, 2019, using a portable Hydrolab water quality meter which measures depth, chlorophyll-a concentration, water temperature, specific conductance, dissolved oxygen, and pH. The Hydrolab has a maximum sampling depth of 140 feet, which is sufficient to monitor for stratification in Little Bitterroot Lake.

4.0 2019 Monitoring Results

Results from 2019 are provided in **Attachments A** and summarized in the following sections below.

4.1 2019 Field Parameter Results

Field parameter results from 2019 are provided in **Table 1** in **Appendix A**.

During the August sampling event, weather was warm (75-85°F) with clear skies and very little wind. The lake had a surface temperature ranging from 20.1 to 21.1°C (68.2 to 70.0°F). Herrig Creek was contributing cooler water around 15.9°C (60.6°F) at a flow of approximately 1.8 CFS (800 gallons per minute, GPM). The Little Bitterroot River at the outlet was warmer than all lake sites at 22.1°C (71.8°F) and had flow of 5.5 CFS (2500 GPM). The pH at lake sites varied between 7.7 and 8.1, while the inlet and outlet streams measured 7.8 and 8.2, respectively. Biological activity by plants and algae raise pH during daytime hours when photosynthesis is occurring, which can attribute to the higher pH measurements at certain locations. Dissolved oxygen (DO) varied from 7.0 to 7.9 mg/L at the lake surface, while DO measured 8.1 mg/L in the inlet stream and 7.1 mg/L in the outlet stream. Specific conductance was quite low in the inlet stream (51 µS/cm) but uniformly around 116 µS/cm at the lake sites. Specific conductance at the outlet stream was similar to lake sites, measuring 117 µS/cm. These results are comparable to field parameters measured during previous sample years, and are indicative of good water quality and oligotrophic conditions.

Field parameters were also recorded at the additional sites on Herrig Creek during August 2019 (HC-1 and HC-2). Water temperature at Herrig Creek sites increased from 13.1°C (55.6°F) at the upper site to 13.6°C (56.5°F) at the middle site, and 15.9°C (60.6°F) at the mouth. Dissolved oxygen was highest at the middle Herrig Creek site (HC-2) with a concentration of 9.1 mg/L, although all sites had relatively high concentrations of dissolved oxygen sufficient to support aquatic life. Specific conductance measured 97 µS/cm at the upper site, and 53 and 51 µS/cm at the middle and lower sites, respectively. Readings of pH were lowest at the upper Herrig Creek site (7.35) and measured 8.06 and 7.82 at the middle and lower sites, respectively. Stream flow measured 0.5 CFS (225 GPM) at the upper Herrig Creek site, while the middle and lower Herrig Creek sites were flowing at approximately 2.0 CFS (900 GPM) and 1.8 CFS (800 GPM), respectively. These field parameter results are typical for a healthy mountain stream and consistent with previous sample results.

4.2 2019 Nutrient Results

Nutrient results from 2019 are provided in **Table 1**, and data for total nitrogen (TN) and total phosphorus (TP) are shown spatially in **Figure 3**, organized left to right from the lake inlet (Herrig Creek) to the lake outlet (Little Bitterroot River).

In 2019, total nitrogen concentrations were relatively low and very comparable throughout the lake, varying from 0.15 to 0.18 mg/L. The highest values (0.18 mg/L) were recorded at the near shore locations in the Northeast and Northwest bays and at the lake center at a depth of 60'. The lowest total nitrogen values were measured at lake center and the Southeast sample location. Samples collected from Herrig Creek were higher than values measured in the lake, ranging from 0.21 mg/L at the middle location to 0.33 mg/L at the upper Herrig Creek site. The outlet at the Little Bitterroot River was comparable to lake sites (0.17 mg/L).

Total phosphorus measurements were below detection (<0.003 mg/L) at all lake sites and the lake outlet in August 2019. Samples collected from Herrig Creek ranged from 0.01 mg/L at the middle and lower sites to 0.026 at the upper Herrig Creek site, which suggests that Herrig Creek is a source of phosphorus to the lake during mid-summer months. Little Bitterroot Lake has historically shown low concentrations of total phosphorus and is described as "phosphorus-limited". Inputs of phosphorus from the inlet stream are likely consumed by algae and aquatic plants within the lake, resulting in lower measurements of total phosphorus in the lake samples.

4.3 2019 Chlorophyll-a Results

Samples for chlorophyll-a were collected from 11 locations in August 2019, including 9 samples from the water column of the lake, and 2 samples from natural substrate. The water column samples were collected from 7 locations near the lake surface, and 2 samples were collected from depth at the lake center.

In August 2019, algae growth in the water column was very low, with most samples being below the analytical detection limit. The only sample above detection was collected from the lake center at a depth of 60 feet below the lake surface (1.1 mg/L). The highest concentration of dissolved oxygen occurred approximately 53' below the lake surface, which is expected because algae produce oxygen during daytime hours which increases oxygen within the lake profile. Depth profile measurements collected by WLI measured a peak algae concentration of 3.3 mg/L at a depth of 85'.

Attached algae, also called benthic algae, were sampled at two shoreline locations in August 2019, including the northwest bay near the public boat launch and the southeast corner. Benthic algae concentrations measured 8.6 mg/m^2 at the northwest location and 4.8 mg/m^2 at the southeast location. The southeast location had previously displayed visible algae on rocks and vegetation which measured 26.0 mg/m^2 during summer 2018; however, algae growth was not as prolific in 2019. Results from 2019 were higher than previous benthic algae concentrations (apart from the southeast corner in 2018), which have ranged from 0.1 to 3.6 mg/m^2 since sampling began in 2014.

Prolific algae growth can be a problem because it consumes oxygen from the water column during the night, which can cause low oxygen levels for fish and other aquatic organisms. Algae can also be a physical nuisance to homeowners and recreationists due to prolific growth.

4.4 2019 Depth Profile Results

Depth profile sampling was conducted on July 15, 2019, 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 2019 are shown for comparison. Overall, depth profile measurements from July 2019 were comparable to previous years, showing similar trends at depth.

In July 2019 the lake was thermally stratified with an epilimnion (upper layer) from 0 to 25 feet, a metalimnion (transitional layer) from 25 to 60 feet, and a hypolimnion (bottom layer) from approximately 60 feet to the lake bottom, which is typical for Little Bitterroot Lake in mid-summer. Near-surface temperatures on July 15, 2019, were the lowest on record; however, previous depth profile measurements have been recorded as late as mid-August. Temperatures in the metalimnion and epilimnion were within the range of previous measurements.

Dissolved oxygen (DO) measured 8.0 mg/L in the upper epilimnion in July 2019, with the peak occurring 53' below the lake surface (10.8 mg/L). DO measurements in 2019 were typically lower than previous readings in all lake layers; however, concentrations can vary throughout the day, and the depth profile from July 2019 was recorded in early morning before biological production was active. DO typically peaks just above the area with the highest algae growth because algae produce oxygen during photosynthesis. Dissolved oxygen concentrations are well above the threshold for aquatic life (5 mg/L) throughout the water column, which is typical of an oligotrophic lake with good water.

Depth profile measurements of pH in July 2019 were comparable to previous years, ranging from 8.05 near the lake surface to 8.45 in the metalimnion. pH typically ranges from 7.5 to 8.2 in the upper epilimnion and increases to more than 8.6 within the photic zone of the metalimnion where phytoplankton are most prevalent. These results are expected because photosynthetic activity from algae raises the pH during daytime hours.

The depth profile for chlorophyll-a in July 2019 was also comparable to previous years, with peak concentrations occurring between 60 and 90 feet. Chlorophyll-a serves as a measurement of algae production within the water column, and photosynthetic algae (phytoplankton) commonly peak at depth where availability of light, nutrients, and water density are optimal for algae growth.

4.5 Long Term Trends

Results from 2004 to 2019 are shown for all sample locations in **Figure 5**. **Figure 6** shows minimum, maximum, and average nutrient concentrations from 2004-2019 for mid-summer concentrations at lake sites only. Nutrient concentrations have generally shown a decreasing trend since consistent yearly monitoring began in 2004, although total nitrogen concentrations have been increasing steadily since 2012. In August 2019, total nitrogen and total phosphorus concentrations in Little Bitterroot Lake were comparable to samples collected since 2012. Higher concentrations of nutrients were recorded during the high water year of 2011. All lake samples were below the analytical detection limit (<0.003 mg/L) for total phosphorus during August 2019.

The downward trends in nutrient concentrations are encouraging from the standpoint of improving water quality, but should be interpreted with caution because of the limited temporal data available for Little Bitterroot Lake. Nutrient concentrations can vary between seasons or change rapidly due to episodic events such as runoff 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 around 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 sufficient quantities of phosphorous. **Figure 7** displays the trend in N:P ratio from 2004 to 2019 on Little Bitterroot Lake. The 16:1 ratio is indicated by the green line on the graph, and the trend line is shown as the dashed line. In 2019, the N:P ratio was 54 (indicating that the lake is phosphorus limited), and the N:P ratio appears to be increasing from 2004 to 2019 even though concentrations of both nutrients are declining over this period. This result is occurring because concentrations of nitrogen are not declining as rapidly as phosphorus, and total nitrogen even shows an increasing trend from 2012 to present. Conversations with limnologists from FLBS reveal that this trend is prevalent across the western United States, and is primarily a result from 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.

4.6 Trophic Status

Trophic status refers to 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 biological productivity is an indicator of low nutrient concentrations and good water quality. The trophic status of Little Bitterroot Lake was determined by calculating the Carlson's Trophic State Index (TSI) from measurements of total nitrogen, total phosphorus and chlorophyll-a (Carlson, 1977). The TSI for Little Bitterroot Lake is shown in **Figure 8** for data from 2004 to 2019.

TSI data suggest that Little Bitterroot Lake is classified as 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. Total phosphorus concentrations in 2019 were below detection at all sites, indicating oligotrophic conditions.

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 during sample events conducted from 2010 to 2019. The low biological 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 littoral (shallow shoreline) habitat, and a low watershed/lake ratio of 4.8 (Ellis et al, 1998). 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.

4.7 Additional Sample Results from Herrig Creek

Additional samples were collected from two sites on Herrig Creek in August 2019 in response to recent logging and slash burning in the watershed. Baseline samples for nutrient parameters were collected, along with dissolved organic carbon and total suspended sediment, which can increase due to land disturbance such as logging, burning, or road building. Dissolved organic carbon (DOC) is an important food source for algae, and total suspended sediment (TSS) is a measure of the amount of sediment that is carried in the stream. For comparison, samples of DOC and TSS were also collected at the lake center and in the outlet stream. This is the third year of sampling the additional sites on Herrig Creek.

In 2019, concentrations of DOC ranged 2.5 to 3.7 mg/L, which were comparable to previous results which have ranged from 2.0 to 6.9 mg/L. Concentrations of TSS were below the analytical detection limit at all sites in 2019 (<4.0 mg/L). These concentrations are considered typical for undisturbed watersheds, and serve as a baseline that can be evaluated against future results.

4.8 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 August 2019 at the lake center and the inlet and outlet streams. Calcium concentrations were lowest in Herrig Creek (4 mg/L) and highest in Little Bitterroot River and at the lake center (13 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 2019 ranged from 21 mg/L at lake center to 52 mg/L in the Little Bitterroot River.

Risk categories have been published for determining the likelihood of dreissenid mussel establishment based on multiple field and laboratory studies (Wells et al., 2011). Risk categories based on calcium concentration 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 dreissenid 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 dreissenid mussel establishment.

6.0 Discussion and Conclusions

Water quality in Little Bitterroot Lake was again very good in 2019, with low concentrations of nutrients and chlorophyll-a. Total nutrient concentrations (nitrogen and phosphorus) have generally been decreasing since the inception of the monitoring program in 1999. Elevated concentrations of both nutrients were exhibited in 2011, which was a high precipitation year during which excess nutrients may have been flushed into Little Bitterroot Lake from the surrounding watershed, although this result has not been exhibited in other high water years such as 2018. Past sampling events indicate that lake water quality is strongly influenced by ground water with less input from Herrig Creek and other intermittent streams.

The trophic state index for Little Bitterroot Lake suggests eutrophic conditions exist due to elevated concentrations of total nitrogen, but measurements of total phosphorus and chlorophyll-a indicate oligotrophic conditions with low biological productivity and very good water quality. Little Bitterroot Lake has typically been phosphorus-limited, meaning it has an inadequate amount of phosphorus compared to the amount of nitrogen needed to support algae growth. Based on this observation, Little Bitterroot Lake is more likely to experience algae blooms with the addition of phosphorus since concentrations of nitrogen are already relatively elevated. However, nutrient concentrations can vary significantly, and efforts to reduce inputs of both phosphorus and nitrogen should be encouraged to help maintain the water quality of Little Bitterroot Lake and limit algae growth. Water quality parameters (calcium and alkalinity) indicate that Little Bitterroot Lake has low potential for colonization by invasive mussels based on water chemistry; however, invasive mussels have been detected in lakes with lower concentrations of calcium and alkalinity than those measured in Little Bitterroot Lake.

Overall, Little Bitterroot Lake has shown excellent water quality throughout its monitoring history. Nutrient and chlorophyll-a concentrations are low, algae blooms are rare, and field data indicate suitable ranges of temperature, dissolved oxygen, and pH to support a viable fishery. Little Bitterroot Lake also displays excellent water quality when compared to other regional lakes. 41 lakes are presently monitored annually through the Northwest Montana Lakes Network (NMLN), including 10 lakes classified as large lakes with surface areas greater than 500 acres (WLI, 2019). Among the large lakes monitored through NMLN, Little Bitterroot Lakes is the 5th lowest in nitrogen concentration, and 3rd lowest in phosphorus concentration. These results are consistent with our monitoring program, which indicate that Little Bitterroot Lake is phosphorus limited and has a trophic status of oligotrophic.

7.0 References

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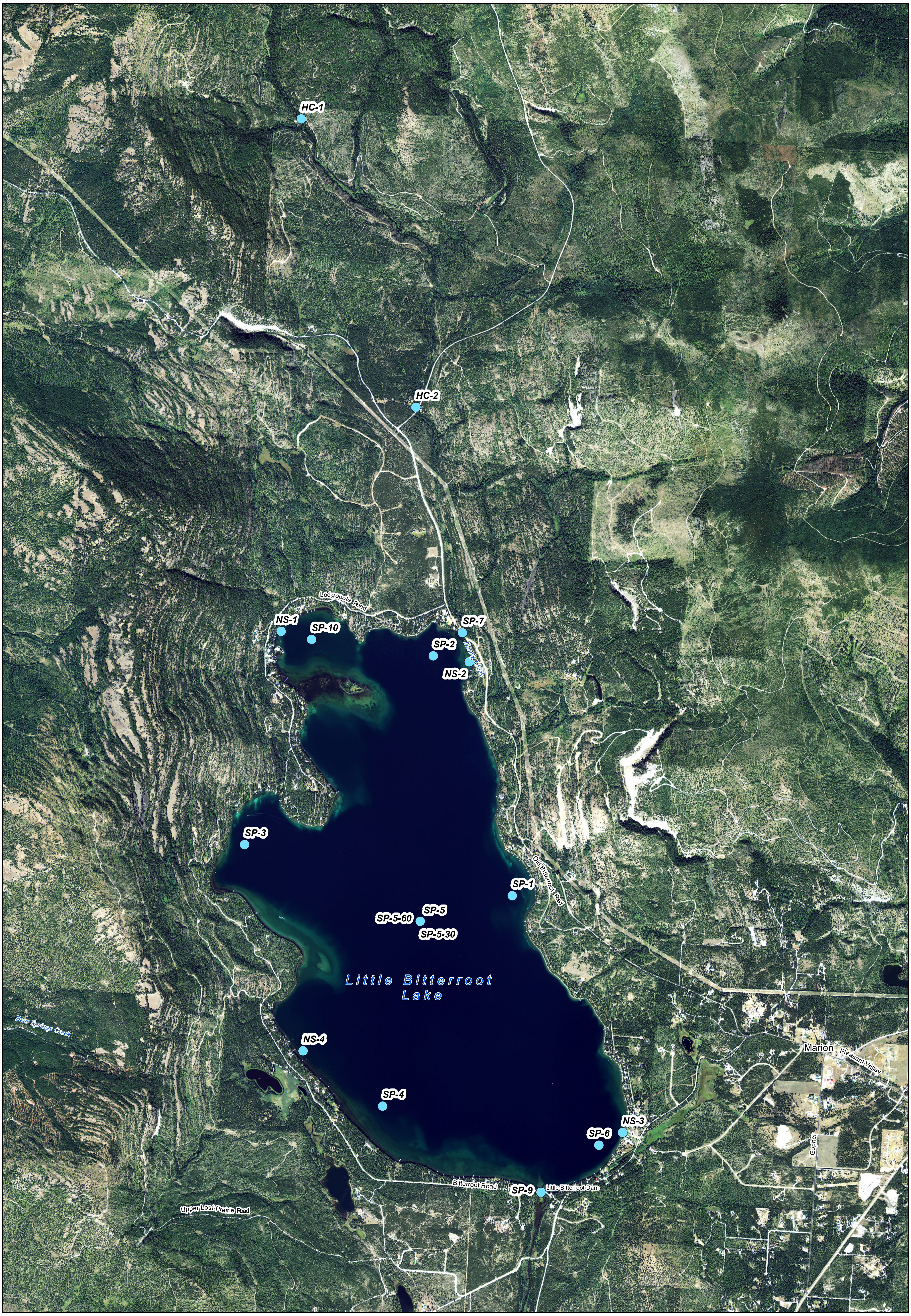
Attachment A – Tables and Figures

Table 1. 2019 Water Quality Data.

Sample Info			Field Water Quality				Nutrients				Chlorophyll-a		Additional Samples			
Site	Date	Site Description	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (uS/cm)	pH	Nitrate + Nitrite Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Algae in Water (mg/L)	Benthic Algae (mg/m^2)	Calcium (mg/L)	Alkalinity (mg/L)	Total Suspended Solids (mg/L)	Dissolved Organic Carbon (mg/L)
							0.01	**0.05**	**0.04**	**0.003**	**0.1**	**0.1**	**1.0**	**1.0**	**4.0**	**0.5**
SP-2	8/7/19	North - Herrig Cr. Bay	20.10	7.3	115	7.68	0.010	0.050	**0.16**	0.003	0.1					
NS-2	8/7/19	Northeast - Near Shore					0.010	0.050	**0.18**	0.003						
SP-10	8/7/19	Northwest - Northwest Bay	20.30	7.0	116	7.89	0.010	0.050	**0.17**	0.003	0.1					
NS-1	8/7/19	Northwest - Near Shore					0.010	0.050	**0.18**	0.003		**8.6**				
SP-1	8/7/19	East - Slaughter House Bay	21.00	7.9	115	7.88	0.010	0.050	**0.16**	0.003	0.1					
SP-3	8/7/19	West - Locke Bay	20.30	7.2	115	7.98	0.010	0.050	**0.16**	0.003	0.1					
SP-5	8/7/19	Lake Center - surface	20.50	7.9	115	7.89	0.010	0.050	**0.15**	0.003	0.1		**13**	**21**	0.8	**2.7**
SP-5-30	8/7/19	Lake Center - 30' depth	14.72	9.6	104	8.41	0.010	0.050	**0.16**	0.003	0.1					
SP-5-60	8/7/19	Lake Center - 60' depth	6.22	10.5	103	8.31	0.010	0.050	**0.18**	0.003	**1.1**					
SP-4	8/7/19	Southwest	21.00	7.1	116	8.06	0.010	0.050	**0.16**	0.003	0.1					
NS-4	8/7/19	Southwest - Near Shore					0.010	0.050	**0.16**	0.003						
SP-6	8/7/19	Southeast	21.10	7.1	116	8.01	0.010	0.050	**0.15**	0.003	0.1					
NS-3	8/7/19	Southeast - Near Shore					0.010	0.050	**0.17**	0.003		**4.8**				
HC-1	8/7/19	Herrig Creek - upper site	13.10	6.4	97	7.35	**0.120**	0.050	**0.33**	**0.026**					3.2	**3.7**
HC-2	8/7/19	Herrig Creek - middle site	13.90	9.1	53	8.06	**0.050**	0.050	**0.21**	**0.010**					1.2	**2.6**
SP-7	8/7/19	Herrig Creek - at mouth	15.90	8.1	51	7.82	**0.020**	0.050	**0.22**	**0.010**			**4**	**24**	2.0	**3.2**
SP-9	8/7/19	Ltl. Bitterroot River - at outlet	22.10	7.1	117	8.18	0.010	0.050	**0.17**	**0.003**			**13**	**52**	0.0	**2.5**

The analytical detection limit for water quality parameters are provided below the constituent name.
Values in **BOLD** are above the analytical detection limit.
ND indicates "no detection", value is below the analytical detection limit.



Legend

Water Quality Sampling Location

Water & Environmental TECHNOLOGIES

Little Bitterroot Lake
2019 Sample Locations

Flathead County, Montana

Job#: LBHAM01

Date: 7/25/2019

FIGURE 1

Path: M:\LBHAM01\Fig1_SamplingLocations2019.mxd, Author: brutherford

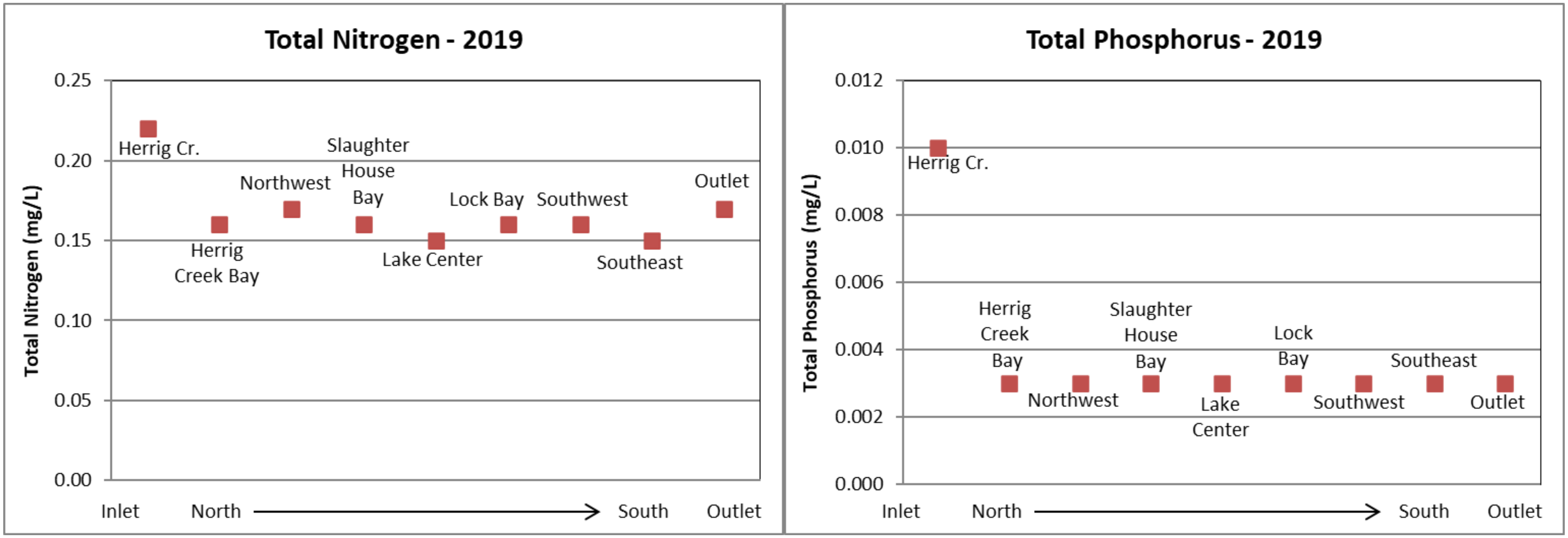


Figure 2. Total Nitrogen and Total Phosphorus Results for 2019.

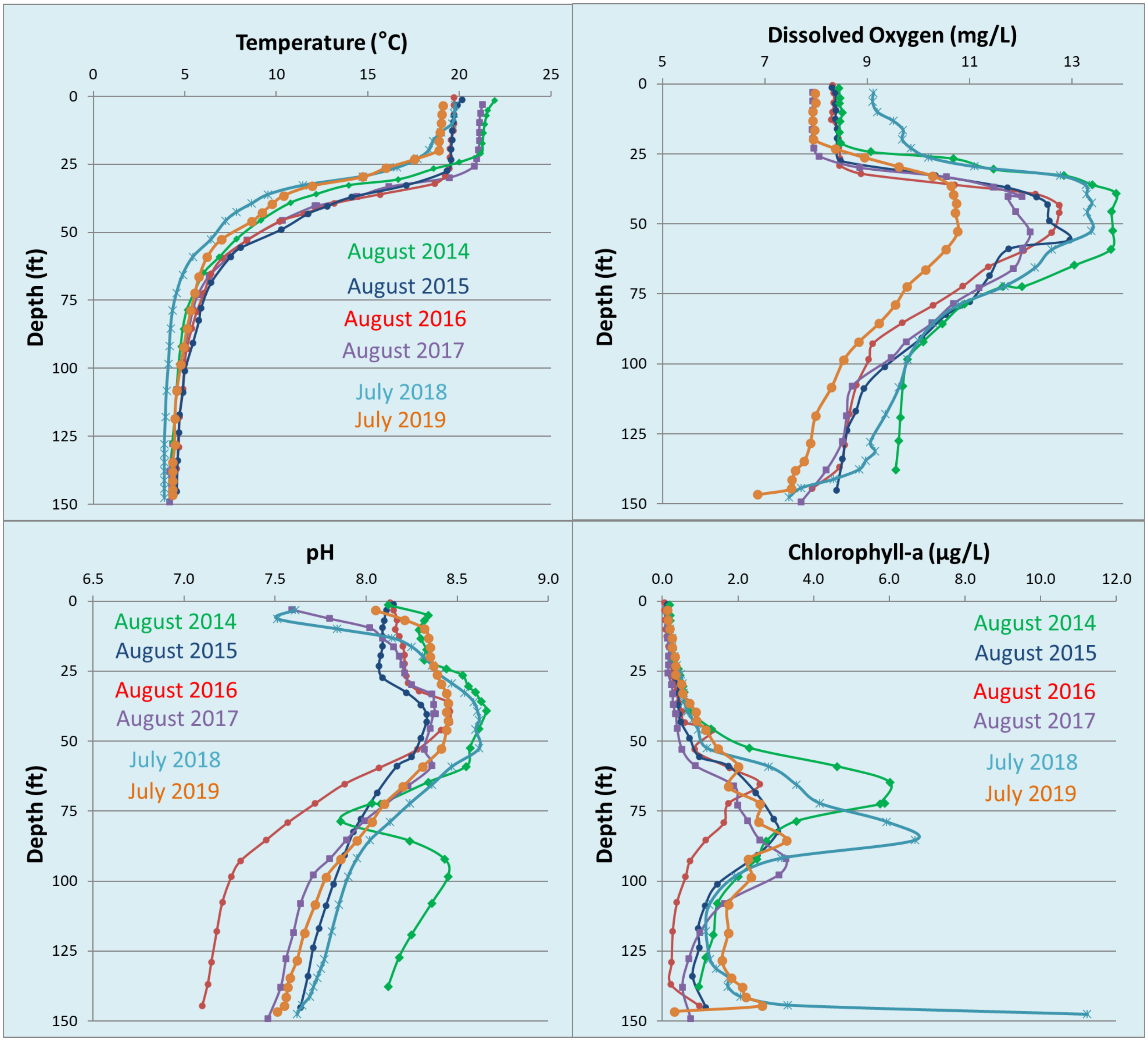


Figure 3. Depth Profile Results for 2019.

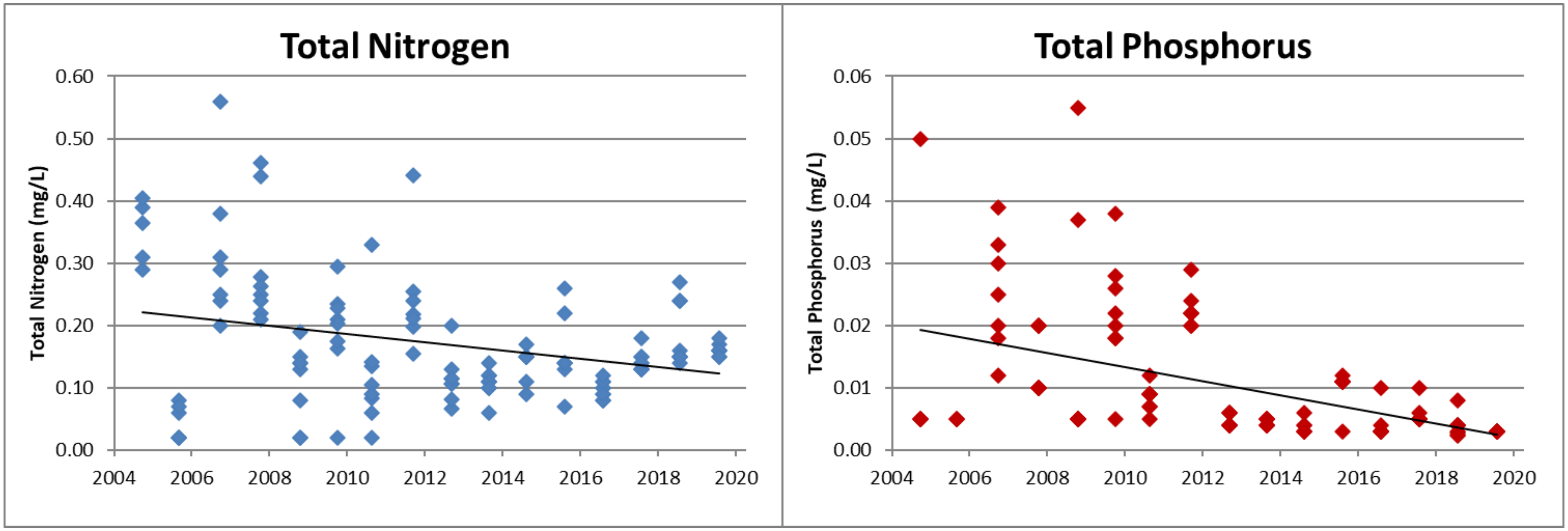


Figure 4. Total Nitrogen and Total Phosphorus Results for 2004-2019.

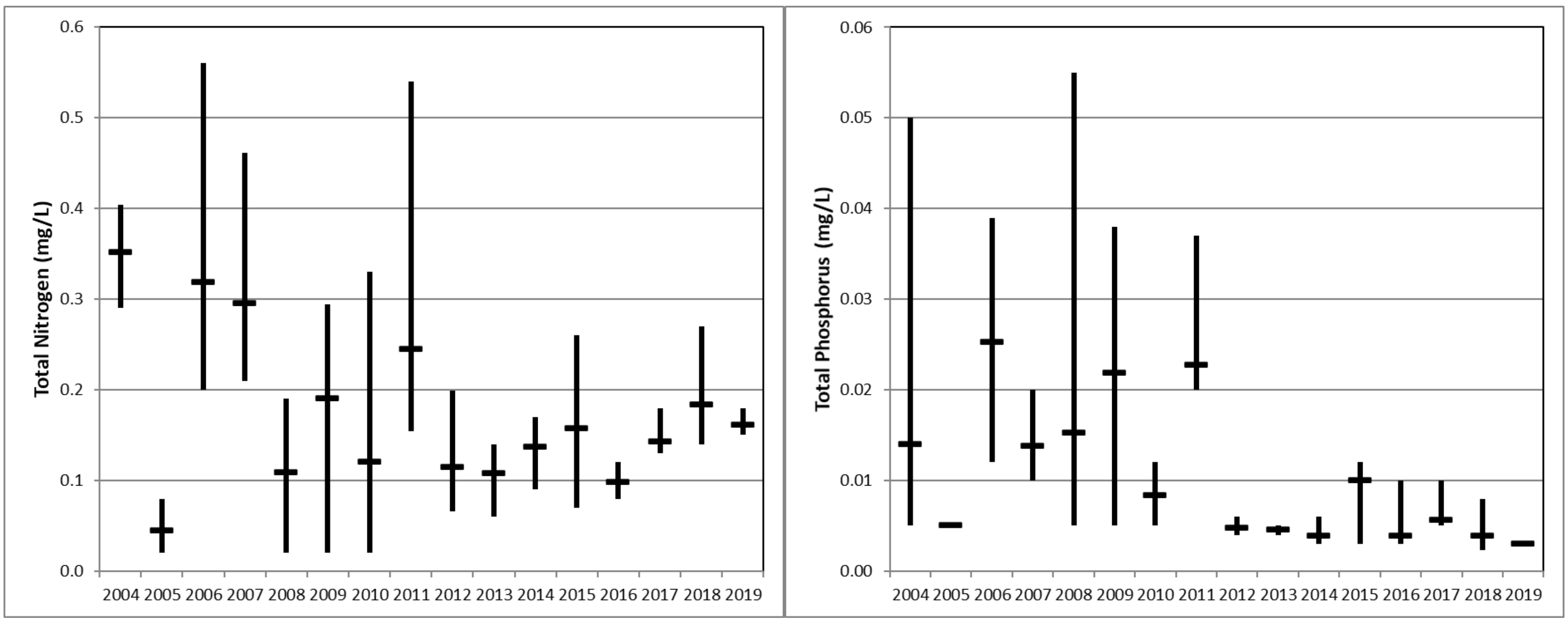


Figure 5. Yearly Nutrient Statistics (Minimum, Maximum, Average) from 2004-2019.

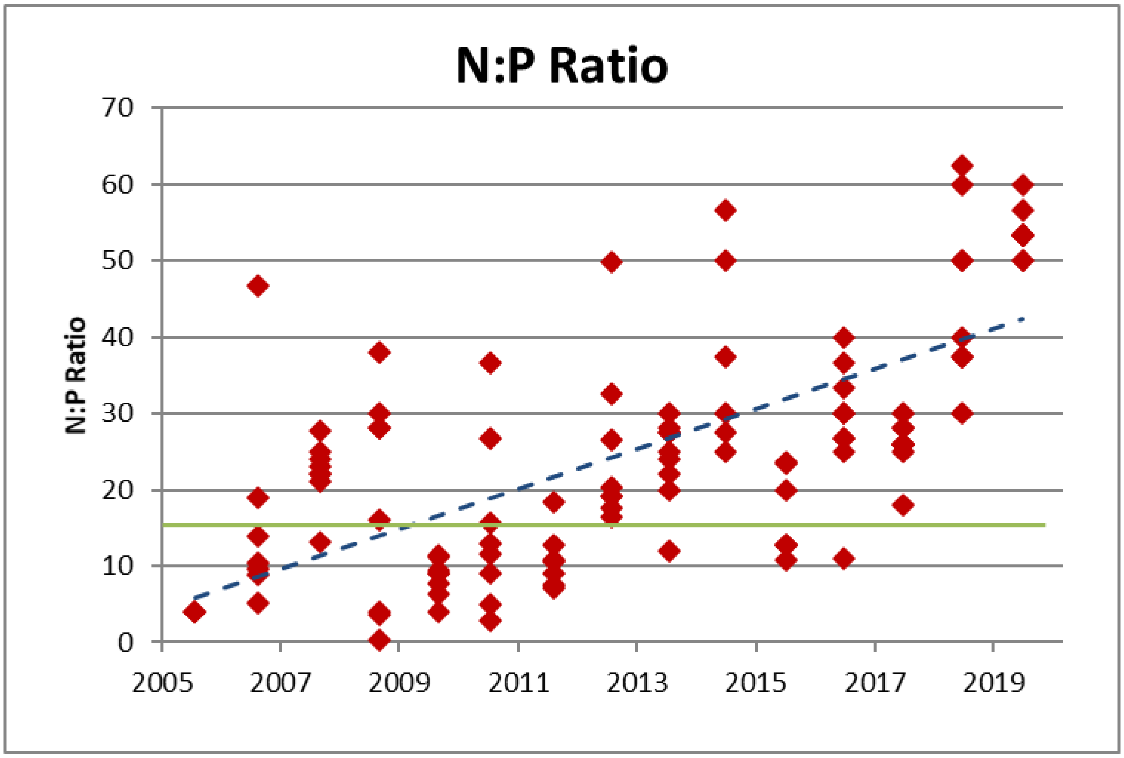


Figure 6. Nitrogen:Phosphorus Ratio from 2004-2019.

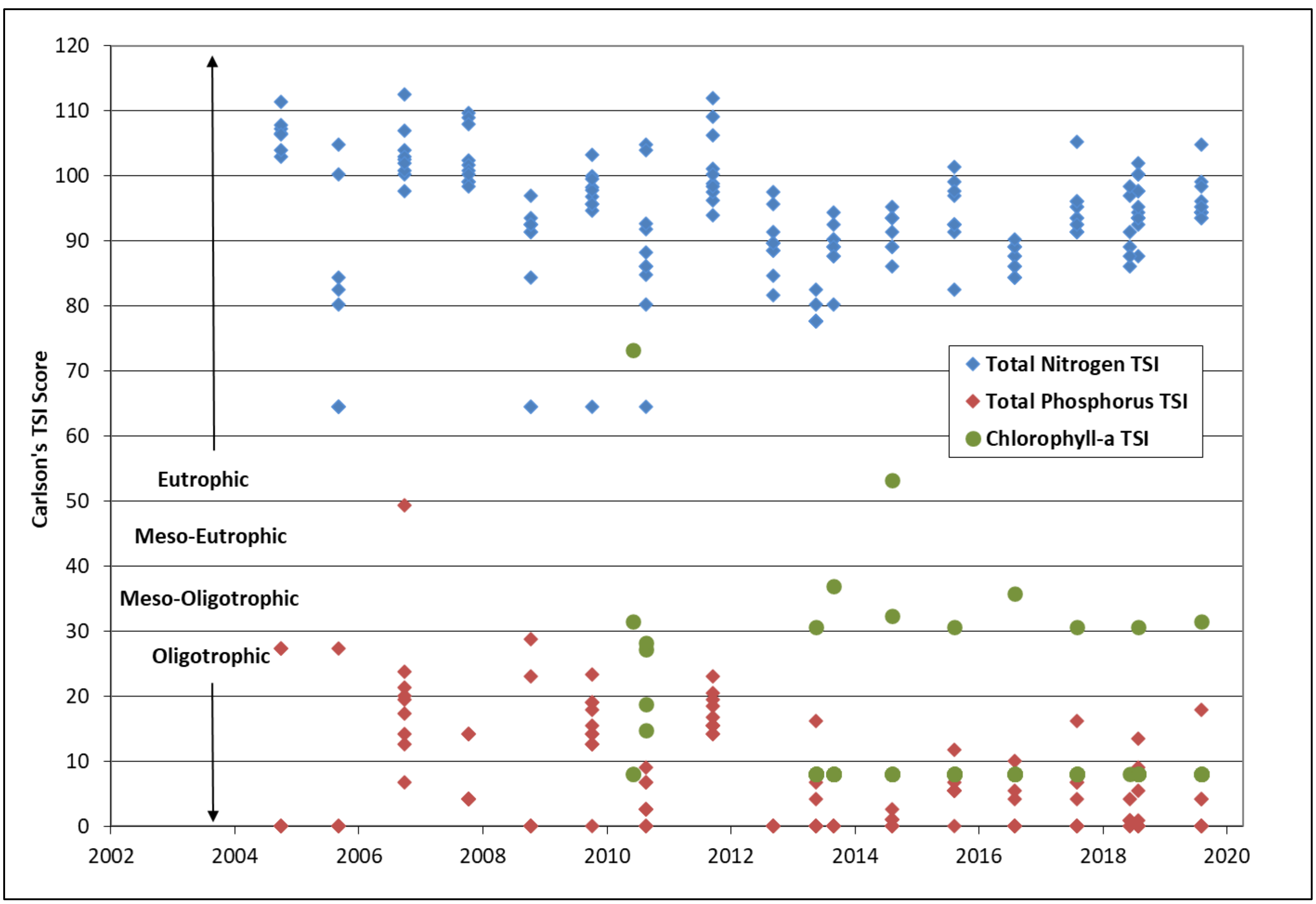


Figure 7. Trophic Status of Little Bitterroot Lake from 2004-2019.