Northwest Montana Lakes Volunteer Monitoring Network

2019 Summary Report

Volunteers Michelle Butz and Sue Corrigan monitoring Tetrault Lake.
Photo courtesy Whitefish Lake Institute

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June 2020

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Cite: Whitefish Lake Institute, Whitefish, MT. (2020). Northwest Montana Lakes Volunteer Monitoring Network 2019 Summary Report. Prepared for Montana Fish, Wildlife and Parks.

ACKNOWLEDGEMENTS

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Chuck Gailey: OTB Design Works
Shawn Devlin, PhD.: Flathead Lake Biological Station

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1.0 INTRODUCTION

The Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN) is a citizen science program that grew out of two lake monitoring programs previously underway at the Flathead Basin Commission (FBC) and the Whitefish Lake Institute (WLI). The Flathead Basin Commission, in cooperation with the University of Montana Flathead Lake Biological Station, coordinated the Volunteer Lakes Monitoring Program (VLMP) from 1992-2010. The VLMP trained, equipped and supported local volunteers who collected data and reported on over three dozen lakes in the Flathead Basin.

The Environmental Protection Agency (EPA) and FBC programs were the baseline models for the Whitefish to Eureka Volunteer Lake Monitoring Program which was initiated in 2007 by WLI in partnership with Montana Fish, Wildlife & Parks (MFWP). The program was established to provide local residents an opportunity to collect baseline data to help determine the trophic status of lakes and implement early Aquatic Invasive Species (AIS) detection and prevention in Northwest Montana. In 2010, the Whitefish to Eureka program combined with the FBC program to form the NWMTLVMN. The NWMTLVMN currently has more than fifty volunteers that monitor a total of fifty locations on forty lakes in Flathead, Lake, Lincoln and Missoula counties. The lakes in the program represent diversity in public use, accessibility, and morphology.

The goal of the NWMTLVMN is to provide training and equipment to volunteers to collect long-term trend information for program lakes. The program specifically aims to address the question of whether nutrients are on the rise due to anthropogenic activity around the lakes. To address this question and to develop trend information, total phosphorus, total persulfate nitrogen, and chlorophyll (*a*) are collected at the same time each year. Calcium is collected every five years, and alkalinity was collected once in 2012 to gain a better understanding of each lake's suitability for invasive zebra/quagga mussel habitation.

Among the most important parameters monitored by volunteers are Secchi disk depth and temperature; however, volunteers also serve as reporters for any major or sudden changes that are observed in or around their lake. The program relies on citizen involvement for success and provides training and instruction in accordance with WLI's Sampling and Analysis Plan (WLI, 2020). Another goal of the program is to address the growing concern and real threat to lakes from the colonization and infestation of aquatic invasive species (AIS). In response to this threat, NWMTLVMN is increasing its effort to provide training for volunteers in early detection monitoring, primarily focused on invasive mussels (zebra and quagga) and Eurasian watermilfoil (EWM). Prior to 2010, AIS monitoring was not included in the monitoring program.

This report details on-going results of data collected by the NWMTLVMN and provides interpretation and discussion for management purposes.

1.1 2019 Program Updates

As with any long term monitoring program, consistency and continuity are critical to ensure comparability of data through time. Often as methodology advances, monitoring programs must adapt and improve, while remaining consistent enough to ensure the integrity of the dataset. In 2019, the NWMTLVMN program underwent a major advancement in analysis, data communication, and data management. This involved conversion from an older software suite (NCSS) to an open source computer language R. This will enable easy preparation of figures and databases in the future and ensures quality control and assurance by moving away from user interfaces and towards scripted workflow. This year's report includes historical data from NCSS and new data from R. In 2020, WLI also uploaded all historic data from both original volunteer monitoring programs as well as the NWMTLVMN program into DEQ's EQuIS Water Quality Exchange Database, a publicly accessible database sponsored by the United States

Geological Survey, the Environmental Protection Agency and the National Water Quality Monitoring Council. A new program coordinator also took the helm of the NWMTLVMN in 2018.

Figure 1. Map of Program Lakes.

2.0 DATA COLLECTION METHODS

Current program methods are based on WLI's Sampling and Analysis Plan (SAP) which incorporated methods from Ellis and Craft (2008) and are summarized below. Historically, the FBC VLMP also followed these procedures. In order to maintain consistency with previous data collection, these methods will continue to be used by the NWMTLVMN whenever possible.

2.1 Volunteers

Volunteers are asked to monitor their sample site twice per month at roughly two week intervals or with at least three days in between sampling events. The ideal monitoring time is between 11:00 am and 3:00 pm, and volunteers are instructed to choose random times within that four-hour period rather than the same time for each sampling event. Volunteers are given GPS coordinates for their monitoring location; these coordinates are usually for the deepest location of the lake. If a volunteer does not have a GPS unit, they are asked to monitor at mid lake or are shown the monitoring location by the program coordinator.

Volunteers are provided with the necessary equipment for lake monitoring, including a four-quadrant Secchi disk, thermometer attached to a bobber and string, and a NWMTLVMN volunteer handbook which includes sampling methodology and data forms. Before beginning the Secchi disk measurement, the thermometer is placed in the lake, allowing it to remain submerged while the Secchi disk measurement is taken. The measurement end of the thermometer is 18 inches from a bobber, or lake surface. Once the monitoring site is reached, the boat is positioned so one side faces away from direct sunlight. Sunglasses are removed so that there is consistency across all program lakes. The Secchi disk is lowered on the shaded side of the boat until it disappears from view. The depth at which the Secchi disk disappears is recorded. The Secchi disk is lowered an additional five feet and slowly pulled toward the surface until the Secchi disk reappears. The depth at which the Secchi disk reappears is recorded, and the two depths are averaged and recorded as the final depth.

Qualitative atmospheric and water condition data are also recorded. Many of these observations are highly subjective. For water conditions, recorded observations are based on viewing the expanse of water in the vicinity of the monitoring site.

In 2011, the program launched an interactive website, www.nwmtlvmn.org that allows volunteers to view all program information, download field data forms, and submit data electronically. Volunteers record data on the Volunteer Standard Report Form (available on the website) which prompts them to fill out information for Secchi depth, temperature, atmospheric weather conditions, qualitative lake data, and AIS. Once a volunteer report is submitted through the website, the program coordinator reviews the information for quality control and then transfers information to the program database. (The Volunteer Standard Report Form can be found in Appendix D of this report). The website also provides information on the program for the public and prospective volunteers. Volunteers that choose not to use the website are mailed data collection forms and return envelopes.

Each field season, WLI offers an internship to an upper level university student to assist with field data collection. Each candidate intern must provide a letter of recommendation from a teacher or professor and submit a cover letter detailing their interest in the internship. The program has hosted interns from Middlebury College (2011), Westminster College (2012), Cornell University (2012), University of Wisconsin (2013), MSU, Bozeman (2014), Princeton University (2017), Brown University (2018) and Harvard University (2019) to assist with the collection of program data during the field season. Since 2011, volunteers have contributed more than 7,000 hours to the Program, which equates to more than 1,000 volunteer hours annually.

2.2 Hydrolab

2.2.1 Historic Methodology (Pre 2011)

A Hydrolab Series 3 H20 was used to collect depth, temperature, dissolved oxygen, and specific conductivity. The H20 model did not have a Surveyor (handheld computer), so all data collected were recorded manually.

2.2.2 Current Methodology

Once per summer (ideally between July 15th and August 15th), the program coordinator and a volunteer visit each lake with a Hydrolab MS5 and Surveyor to measure depth, temperature, dissolved oxygen (% saturation and mg/L), pH, specific conductivity, chlorophyll (*a*), total dissolved solids, salinity, oxidation reduction potential, and resistivity. Profiles are taken at the mid-lake deep site. The Hydrolab MS5 is lowered one meter at a time to 14 meters and the values for each parameter are recorded in the Surveyor 4a. Values are recorded every two meters from 14 meters to 30 meters, every three meters from 30 to 45 meters, and every five meters from 45 meters to the lake bottom. Following each sample event, data recorded on the Surveyor4a are downloaded into the program database.

2.3 Description of Hydrolab Parameters

Luminescent Dissolved Oxygen (LDO): Measuring the concentration of oxygen that is dissolved in a waterbody is a general indicator of the diversity of organisms that a lake can support and the overall health of a lake. Because of the biological need for oxygen, LDO may be the most important parameter monitored in lakes. Many organisms, including certain fish and invertebrates, require high concentrations of dissolved oxygen. Oxygen is dissolved into lakes through the atmosphere, and the amount of oxygen increases with wind generated waves. Tributaries are an additional contributor of oxygen to lakes. Water temperature, photosynthesis, respiration, decomposition, and lake depth are all determinate variables in the amount of dissolved oxygen that is available in lakes. LDO is measured in both mg/L and % saturation.

Chlorophyll (*a*): Chlorophyll (*a*) is a molecule that is present in all plant cells. The amount of phytoplankton (algae) can be quantified by analyzing the amount of chlorophyll (*a*) in a water sample. Although algae are a very important producer in the food web, elevated nutrient concentrations can cause excessive plant growth resulting in a decline in water quality. Lakes with high concentrations of chlorophyll (*a*) are less transparent and tend to have higher total nitrogen and total phosphorus loading. Chlorophyll (*a*) analysis is measured by fluorescence and is reported in μg/L.

pH: pH is a measure of the acidity and alkalinity of water and is measured by the concentration of hydrogen ions. The greater the concentration of hydrogen ions, the lower the pH, and vice versa. pH is measured on a scale from 0-14, with 0 being the most acidic and 14 being the most basic. A pH of 7 is typical of tap water, and considered neutral. The pH also determines the solubility of nutrients and metals in water and the availability of chemicals for aquatic life. A pH between 6.0 and 9.0 is generally suitable for most aquatic life. pH is measured in logarithmic units (a one-tenth difference represents ten times the actual value).

Specific Conductivity (SpC): Conductivity is a measure of the ability of water to pass an electrical current, and it is therefore a good measure of dissolved solids and salinity. Conductivity values can differ seasonally with temperature and are most often impacted by the composition of tributaries which reflect the geology of their watershed. Common anthropogenic influences on conductivity are road salt, non-

point source pollution (agriculture and stormwater run-off), and industrial effluent. Specific conductivity is measured in mS/cm.

Total Dissolved Solids (TDS): Total dissolved solids concentration is the sum of positively charged and negatively charged ions in the water and is measured by the weight of all dissolved solids in the water. TDS can come from both organic and inorganic inputs, and there is a close relationship between TDS and SpC. Total dissolved solids are measured in g/L.

Oxidation-Reduction Potential (ORP): ORP is a composite measure of the overall intensity of the oxidizing and reducing conditions within a system and reflects the degree of balance between oxidizing and reducing processes. The seasonal and diurnal changes between photosynthesis and respiration determines the oxidation-reduction potential of lakes (Kalff 2002). Oxidation reduction potential is measured in mv.

Salinity: Salinity is a measurement of the concentration of salts that are dissolved in a waterbody and is closely related to specific conductivity except that it is reported in ppt as opposed to mS/cm. Salinity is measured in ppt.

Resistivity: Resistivity is the inverse measurement of specific conductivity and is a measurement of how strongly water opposes the flow of electric current. Resistivity is measured in kê-cm.

Table 1. Accuracy, Range and Resolution of Measurements Taken with Hydrolab MS5.

Parameter	Range	Accuracy	Resolution
Depth	0 to 100m	± 0.05 meters	0.01 meters
Temperature	-5 to 50° C	± 0.10° C	0.01° C
pH	0 to 14 units	± 0.2 units	0.01 units
LDO	0 to 20 mg/L	± 0.1 mg/L	0.01 mg/L
Conductivity	0 to 100 mS/cm	± 0.5% of reading	4 digits
Salinity	0 to 70 ppt	± 0.2 ppt	0.01 ppt
Chlorophyll (*a*)	0 to 500 µg/L	± 3% for level equivalents of 1 ppb	0.01 µg/L
ORP	–999 to 999 mV	± 20 mV	1 mV

2.4 Water Chemistry

2.4.1 Historic Methodology

Integrated water chemistry samples were collected using a 30-meter hose. Chlorophyll (*a*) samples were separated by filtering lake water through 45 µg filters. The vacuum on the filter was kept below 9.0 inches of Hg pressure to prevent cell rupture and loss of chlorophyll (*a*) into the filtrate (Wetzel and Likens, 1991). Because of the difficulty involved in cleaning the hose and the potential for spread of AIS, integrated samples are now collected using a horizontal Van Dorn Sampler that can be easily disinfected. Some of the dissolved oxygen and temperature profiles taken prior to 2010 displayed in the charts were collected by volunteers using handheld Yellow Springs Instruments (YSI) probes.

2.4.2 Current Methodology

Water chemistry samples are collected using a horizontal Van Dorn Sampler once annually, ideally between July 15 and August 15, and include total persulfate nitrogen (TPN), total phosphorus (TP), and

chlorophyll (*a*). Total calcium (Ca) is collected every five years (it was last collected in 2016). Alkalinity was collected in 2012. Each sample contains integrated water from the surface to the lake bottom. Therefore, the values for each parameter are representative of the lake vertical profile at the deep site.

The Van Dorn sampler is lowered into the water and 500 mL sample water is collected at each depth. An integrated sample is collected at discrete depths based on the maximum depth of the lake as shown in Table 2. If the lake depth is greater than 30 meters, an integrated sample is collected every five meters to a depth of 30 meters. All integrated samples include a surface sample, and benthos samples are collected approximately 1 meter above lake bottom if the lake has a depth of less than 30 meters. Sample water from each depth is composited in a carboy. The carboy is then shaken so that sample water can mix prior to dispensing.

Table 2. Integrated Sample Depth Intervals.

Lake Depth	Interval at Which Water is Collected for Integrated Sample
1-6 meters	1 meter
7-12 meters	2 meter
13-21 meters	3 meter
22-30 meters	5 meter

All sample bottles are high-density polyethylene (HDPE). HDPE bottles are filled with integrated water samples for TP, TPN, and Ca and immediately put on ice. All samples are collected and preserved according to the specifications outlined by the University of Montana Flathead Lake Biological Station (FLBS) Research Laboratory in Polson, Montana. Labels are printed and filled out in pencil prior to collection in the field, applied to the sample bottle in the field, and covered with tape to prevent water damage. All sampling equipment is rinsed with 10% hydrochloric acid prior to use in the field. All sample bottles are rinsed 3 times with native water before the sample is filled. Water samples are put on ice in coolers in the field and shipped via UPS ground service to the FLBS Research Laboratory. Each shipment contains a standard Chain of Custody (COC) form.

Integrated water samples for chlorophyll (*a*) analysis are collected at all monitoring locations at depth intervals based on maximum depth described above. A vertical opaque Van Dorn and a carboy covered with a sleeve are used to eliminate light penetration. The carboy is gently shaken prior to dispensing each sample to assure thorough mixing of the sample. In 2011, the program made a transition from field filtering chlorophyll (*a*) samples to having the FLBS's Research Laboratory filter the sample water for better quality control and sampling efficiency. Sample water for chlorophyll (*a*) is dispensed into a 1000 ml brown bottle to exclude light. Samples are immediately put on ice and shipped next day to the laboratory.

2.5 Description of Water Chemistry Parameters

Total Phosphorus (TP): Phosphorus is a nutrient that is used by aquatic organisms for growth. Phosphorus occurs naturally depending on the geologic inputs to a lake. Anthropogenic sources of phosphorus include but are not limited to fertilizer, wastewater, and detergents. Excessive phosphorous concentrations in a lake can cause eutrophication leading to rapid and excessive plant growth that may result in oxygen concentration depletion and fish and invertebrate kills. Lakes that are anoxic at or near the bottom may experience internal loading where phosphorus is released from sediments through a chemical process at the sediment/water interface.

Total Persulfate Nitrogen (TPN): Nitrogen is a nutrient that is used by aquatic organisms for growth. Nitrogen occurs naturally in soil, is produced by decaying plant matter and microorganisms and can enter lakes through the atmosphere. Common anthropogenic sources of nitrogen occur in wastewater, fertilizer, manure, agricultural runoff, and erosion. Excessive nitrogen concentrations in a lake can lead to eutrophication and can be harmful or fatal to fish and invertebrates.

Chlorophyll (*a*): Chlorophyll (*a*) samples measure the concentration of photosynthetic pigments to estimate phytoplankton biomass.

Total Calcium (Ca): Measuring calcium is one of the major components in determining the hardness of water; however, for the purposes of the program, total calcium was measured to understand which lakes may be suitable for invasive mussel colonization.

Alkalinity: Alkalinity is a measurement of water's capability of neutralizing an acid. Lakes with higher alkalinity are more suitable for invasive mussel colonization.

2.6 Analytical Methods and Reporting

Analytical methods are listed in Table 3 and represent standard accepted procedures. All analytical reporting from 2010-2014 was done by Energy Laboratories. Since 2015, analytical reporting has been completed by the FLBS Research Laboratory because of their ability to report at lower detection limits. For quality control, two duplicate water chemistry samples and three trip blanks were collected each field season. All of the sampling methods outlined in the 2011 SAP are used to collect trip blanks; however, each sample container is filled with deionized water instead of sample water. Field duplicate samples are collected at two sites using methods outlined in the SAP and sent to the laboratory with the site locations omitted from the chain of custody form. WLI maintains a copy of monitoring locations where trip blanks and field duplicates were collected.

Table 3. Laboratory Analytical Methods and Reporting Limits.

Analyte	Method	Analytical Reporting Limit (2010-2012)	Analytical Reporting Limit (2013-2014)	Analytical Reporting Limit (2015-2019)
Total Persulfate Nitrogen	A4500 N-C	0.05 mg/L	0.04 mg/L	.025 mg/L
Total Phosphorus as P	E365.1	0.005 mg/L	0.001 mg/L	0.0015 mg/L
Chlorophyll (*a*)	A 10200 H	0.1 mg/m³	0.1 mg/m³	0.1 mg/m³
Calcium	E200.7	1 mg/L	1 mg/L	1 mg/L

3.0 AIS MONITORING METHODS

3.1 Zebra and Quagga Mussels

Monitoring for the presence of zebra and quagga mussels is conducted on each lake between the middle of July and the middle of August. Veliger (mussel larvae) samples are collected using a vertical or horizontal haul method. If the depth of the monitoring location exceeds 7 meters, the vertical haul is used. For all locations less than 7 meters deep, the horizontal method is used. All samples are collected after surface water temperature exceeds 10° C. Sample locations are selected near inflows, outflows, boat launches, and areas that experience heavy boat traffic. Because veligers are passive swimmers, they generally end up on the windward side of lakes making these locations ideal for horizontal hauls. Both the vertical and horizontal haul samples are collected using a 30 cm X 120 cm X 64-micron plankton net. Once the haul is complete all samples are split and each is preserved in a 100 mL bottle with 95% ethanol.

Veliger samples contain a label on the outside of the sample bottle and a label written on "Rite in the Rain" waterproof paper on the inside of the sample bottle. All samples are sent via UPS to MFWP in Helena. Samples that are awaiting shipment are kept refrigerated. All samples are split by MFWP upon arrival, and a duplicate sample is kept in the event reanalysis is necessary. Microscopy is conducted by the lab that is under contract with MFWP with results reported in two weeks. A catalogue record is kept and maintained for veliger samples and includes the date, waterbody, location, GPS coordinates, tow data, sampler, and sample ID. Veliger samples are collected near public access sites. If the lake is entirely private samples are collected in the littoral zone near private docks.

Vertical Haul: Nets are slowly lowered to 7 meters. Then the net is slowly pulled up using a hand-over-hand motion. The net is lifted so the cod end is completely out of the water allowing the water to drain. Water is then sprayed on the net so that the sample can collect in the cod end. Once the water has been drained from the net, it is rinsed by dipping the net into the water and lifting it up and down, allowing any remaining microorganisms on the net to be rinsed into the cod end. It is important not to lower the mouth of the net below the water's surface as this will allow microorganisms to escape. A spray bottle is used to clear the net of microorganisms that still remain after rinsing. After sample collection, the cod end is removed and contents are poured into the sample bottle. 95% ethanol and 5 ml of 5% baking soda solution are added to the sample bottle to preserve the sample.

Horizontal Haul: Nets are tossed with a rope to about 10 feet behind the boat and are sunk to .5 - 1 meter below the surface. The net is towed behind the boat at a slow speed for approximately 60 meters. Once the boat is stopped, the net is quickly removed from the water allowing the water to drain and for the sample to collect in the cod end. Once the water has been drained from the net, it is rinsed by dipping the net into the water and lifting it up and down steadily, allowing any remaining microorganisms on the net to be rinsed into the cod end. It is important not to lower the mouth of the net below the water's surface as this will allow microorganisms to escape. A spray bottle is used to clear the net of microorganisms that still remain after rinsing. After sample collection, the cod end is removed and contents are poured into the sample bottle. Ninety-five percent ethanol and 5 ml of 5% baking soda solution are added to the sample bottle to preserve the sample.

3.2 Environmental DNA (eDNA)

Environmental DNA (eDNA) early detection sample collection is a partnership between WLI and the City of Whitefish outside the NWMTLVMN core mission, but since it overlaps with some of the program lakes, data can be collected during summer field visits by the program coordinator. Plankton samples are

collected for eDNA analysis using FLBS collection protocols. The FLBS lab performs the analysis by looking for DNA sequences of EWM, northern milfoil (native) and dreissenid mussels. There were no positive detections for EWM or dreissenid mussels from 2013-2018. EWM was detected in Beaver Lake in 2019. Detailed information for 2019 can be found in Appendix C.

Table 4. Environmental DNA early detection sampling collection.

Year	# of Lakes Sampled
2013	25
2014	24
2015	21
2016	8
2017	5
2018	7
2019	4

3.3 Macrophyte Surveys

Another partnership between WLI and the City of Whitefish included aquatic macrophyte surveys and early AIS detection for six lakes in 2014, one in 2015, and three in 2016, five in 2017, seven in 2018, and 4 in 2019. Lakes were chosen based on proximity to Whitefish Lake and included; Blanchard, Dollar, Lost Coon, Murray, Skyles, Smith, Spencer, Tally, Upper Stillwater Lower, Lower Stillwater, Whitefish, and Upper Whitefish Lake depending on the year. Lakes were sampled between August 15th and September 14th. The survey consisted of determining the composition and relative abundance of plant species at each lake along with characterizing the lake substrate to determine areas suitable for plant colonization. Sites were randomly chosen to represent full coverage of the lake. Both ocular surveys and rake throws were used to determine plant dominance. The maximum depth of the rake was 6.1 m. Where lake depth exceeded 7.6 m, the rake was not thrown and a data point was not recorded. All plants observed at each site were recorded, and rated on a scale of 1-5 for density. If any substrate was visible, it was recorded in order of dominance.

Each surveyed point is included on a Google Earth map and color coded to match the color in a pie chart for dominant plant distribution. These maps and charts are included in the lakes' results section beginning on page 15. Only the most dominant or highest density plant at each survey point was used to construct the graphics and tables, except in cases where there were two or more plants observed with equally high density. For example; if observed plants at survey point 1 were: Yellow water lily (density 5), northern watermilfoil (density 3), Mare's tail (density 3), and bladderwort (density 1), only yellow water lily is depicted as dominant. There were several plants observed at many of the surveys sites, and the maps and charts do not represent overall distribution.

4.0 EQUIPMENT MAINTENANCE, CALIBRATION & DECONTAMINATION

The Hydrolab MS5 is sent annually prior to the field season to Hydrotech ZS Consulting for performance testing and evaluation. The Hydrolab is calibrated for dissolved oxygen prior to sampling each day it is used. Depth is calibrated in the field at each monitoring site prior to sampling. When the Hydrolab MS5 is not in use, it is stored with its sensors in its calibration cup with a pH buffer solution. If the Hydrolab MS5 is reporting values outside a specific parameters range, it is sent to for a diagnostic and repaired if necessary.

All sample containers and Van Dorn samplers are rinsed with 10% hydrochloric acid prior to sampling each waterbody. Plankton nets are soaked in vinegar for at least 4 hours and are then sprayed with a 10%

bleach solution after use and rinsed thoroughly with fresh water. All plankton sampling nets are inspected by WLI staff for rips or tears. The boat used by WLI staff in sample collection is decontaminated following every sampling event or prior to sampling in another water body. Additionally, volunteers are trained in decontamination protocols and are instructed to clean all equipment that has come in contact with the water.

5.0 RESULTS

Results are organized into the following sub-sections; volunteers, water chemistries, Hydrolab profiles, and AIS. Lakes have been organized into small, medium, and large for interpretation and comparability. Each lake description includes a lake map or satellite photo, a chart showing historic summer oxygen profiles, a chart showing historic summer temperature profiles, and a Trophic State Index (TSI) chart. The temperature charts Fall temperature and oxygen profiles were collected from 2008-2014. Appendix A compares water chemistry concentrations for each lake size class. Appendix B shows additional summer and fall (through 2014) Hydrolab parameter data for each lake, which are updated biennially. Fish distribution records, lake size, and lake elevation data were taken from MFWP's *Montana Fisheries Information System* (MFISH). Most geologic information was taken from *Trophic Status and Trends in Water Quality for Volunteer Monitoring Program Lakes in Northwestern Montana (Ellis and Craft, 2008).*

5.1 Volunteers

Secchi Disc
All of the volunteer data collected has been compiled and stored in the program database and can be queried for specific data requests. The most important data collected by volunteers is Secchi depth. Secchi depth is averaged and shown in the TSI chart for each monitoring location. Secchi data from volunteers and the annual program coordinator's visit is also submitted to NALMS's annual Secchi Dip-In project.

Observations
In 2013, many volunteers began reporting increased wake erosion and more recreational use from wake-board style boats, many of which contain ballast tanks. Volunteers are instructed to take photos to document shoreline erosion. One of the most common observations from volunteers in 2011-2013 was that lake elevations were above average for most lakes throughout the monitoring season. Spring 2011 (April 1 - June 20) ranked 11th highest in recorded history for total precipitation in Kalispell with 6.64 inches. The highest recorded spring precipitation was in 1998 with 8.28 inches. Additionally, Kalispell had the second lowest spring temperatures in 2011 averaging 47.0 °F, only one-tenth of a degree warmer than the historical low average of 46.9 °F. Many volunteers reported less emergent aquatic vegetation than historically observed, likely a result of the colder temperatures and limited sunlight during the spring months. In 2014 and 2015, volunteers observed warmer than normal summer water temperatures with reports of more algae than usual. The summer of 2017 & 2018 included regional forest fires and a flash drought in northwest Montana. 2019 brought lower than average lake levels for a majority of lakes sampled.

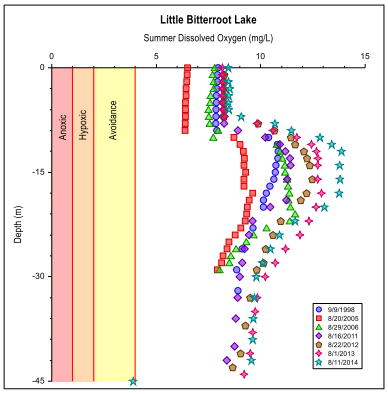
5.2 Hydrolab

Sections 5.7-5.9 display temperature and dissolved oxygen vertical profiles for program lakes. Mixing or stratification is caused by changes in water temperature resulting in a change in density. Additionally, wind is necessary for most lakes to become mixed. An unstratified or mixed lake becomes stratified when wind caused currents are unable to mix the solar energy received at the lake surface throughout the entire epilimnion of a lake, inhibiting the lake from sustaining a uniform water temperature (Kalff, 2003).

When a lake is stratified, an epilimnion, metalimnion and hypolimnion are established. Lakes typically stratify during the summer months, some mixing and stratifying several times throughout the summer (polymictic), and even display diurnal patterns. The amount of mixing is variable from lake to lake based on morphology, depth and exposure to wind. When completely mixed, wind exposed lakes will typically exhibit a near constant concentration of oxygen throughout the entire water column. Most of the Hydrolab profiles that were taken in the fall/early winter show mixed lakes with constant oxygen concentrations at depth. The determination for oxygen thresholds have been made by comparing generalized life history requirements for salmonids.

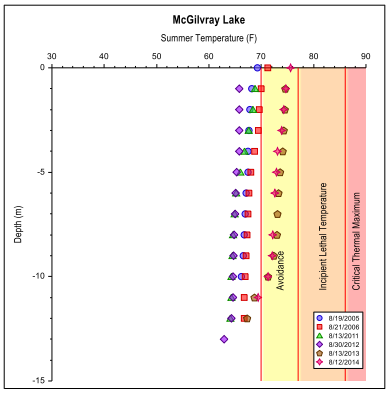
5.2.1 Interpreting Hydrolab Depth Profiles for Temperature and Dissolved Oxygen

Figure 4. Positive Heterograde Example.



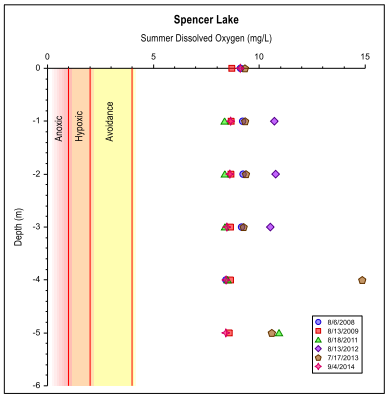
The Hydrolab depth profile for Little Bitterroot Lake represents a common stratification regime for many of the program lakes in the summer. The epilimnion extends to roughly 8 m; the metalimnion from 8 m to 18 m; and the hypolimnion 18 m to benthos. The oxygen profile illustrates a positive heterograde profile where the maximum DO concentration is in the metalimnion and is a result of elevated algal production just below that point.

Figure 5. Mixed Lake Example.



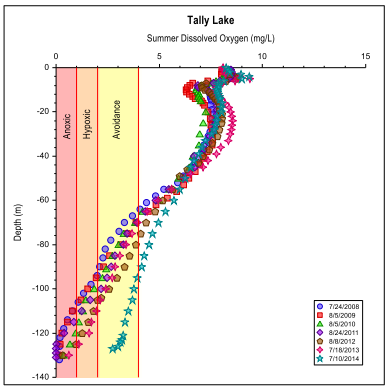
The depth profile of McGilvray Lake shows a mixed profile for program lakes resulting in a uniform temperature throughout the water column. As the temperature declines, water density becomes more uniform increasing the propensity of water to mix. Mixing is typically aided by wind energy.

Figure 6. Spike in Dissolved Oxygen Near Benthos Example.



Spencer Lake shows an increase in dissolved oxygen near the lake bottom which was a phenomenon recorded in a handful of program lakes. Spencer Lake may be influenced by diurnal changes in oxygen consumption and production. In oligotrophic lakes, low algal biomass allows deeper light penetration and less decomposition. Algae are able to grow relatively deeper in the water column and less oxygen is consumed by decomposition. The dissolved oxygen (DO) concentrations may therefore increase with depth below the thermocline where colder water is carrying higher DO leftover from a mixing event.

Figure 7. Negative Heterograde Example.



Tally Lake illustrates a unique negative heterograde profile where there is a decrease in DO concentration in the metalimnion, a result of respiration from high numbers of macrozooplankton or heterotrophic bacteria oxidizing organic matter from the overlying water (Kalff 2002).

5.3 Winter Hydrolab Profiles

Winter Hydrolab profiles have been collected on select lakes that are anoxic near the lake bottom to describe the potential for winter fish kills. In 2014, winter profiles were collected at Jette Lake, Lake Mary Ronan, and Foys Lake. All lakes had sufficient dissolved oxygen for salmonid habitation within the upper most four meters. No winter Hydrolab profiles have been collected since 2014.

5.4 Trophic Classification

All of the lakes in the program are classified as oligotrophic, oligo-mesotrohic, meso-oligotrophic or mesotrophic with the exception of Jette Lake, which is classified as eutrophic with historical data suggesting it is borderline hypereutrophic.

Nutrient richness is the basis for the trophic classification of lakes. Oligotrophic lakes tend to be very clear, nutrient poor and typically cold. There is less zooplankton, phytoplankton, algae, and macrophytes, and fish tend to be smaller because of limited food availability. Because there are fewer plants and algae, dissolved oxygen concentrations tend to be higher throughout the water column. Oligotrophic substrate composition usually consists of rocks and gravel and lacks significant accumulation of sediment.

Eutrophic lakes are the contrast to oligotrophic lakes. They are rich in plant nutrients resulting in high productivity. Large amounts of phytoplankton suspended in the water column give the water a cloudy appearance, and Secchi disk depths tend to be much shallower. Eutrophic lakes also tend to have prolific macrophytes growing in the littoral zone. Eutrophic lakes have a thick sediment layer at the bottom which is nutrient rich and provides food for invertebrates contributing to a high production of fish generally with fast growth rates. Mesotrophic lakes fall between oligotrophic and eutrophic and should be monitored closely to determine if they are trending toward eutrophic.

Table 5: General Trophic Classification of Lakes (Wetzel 2001).

Trophic classification	TP mean (range)	TN mean (range)	Secchi mean (range)
Oligotrophic	.008 (.003-.0177)	.661 (.307-1.630)	9.9 (5.4-28.3)
Mesotrophic	.0267 (.0109-.0956)	.753 (.361-1.387)	4.2 (1.5-8.1)
Eutrophic	.0844 (.016-.386)	1.875 (.393-6.100)	2.45 (0.8-7.0)
Hypereutrophic	(.750-1.200)		(0.4-0.5)

5.5 Carlson's Trophic State Index (TSI)

The Carlson's Trophic State Index (TSI) is used in the report to classify the trophic status of each lake. Carlson's TSI uses chlorophyll (*a*), total phosphorus and Secchi depth to determine trophic state. A formula for total nitrogen was later developed and is also used in this report. The TSI is calculated by the formula below. Refer to Table 5 for information on how "No Detect" samples were calculated. For actual chemistry concentrations comparisons (2011-2015) refer to Appendix A. Contact WLI to request historical chemistry concentrations prior to 2011.

TSI Calculations:
TSI(SD) = 60 - 14.41 ln(SD)
TSI(CHL) = 9.81 ln(CHL) + 30.6
TSI(TP) = 14.42 ln(TP) + 4.15
TSI(TN) = 54.45 + 14.43 ln(TN)

Table 6: Chemistry Concentration Values for "No Detect" Samples Used in TSI Calculation

Year	Total Phosphorus (mg/L)	Total Persulfate Nitrogen (mg/L)	Chlorophyll (*a*) (mg/m3)
2011	0.001	0.025	0.05
2012	0.001	0.025	0.05
2013	0	0	0.05
2014	0	0	0.05

5.6 Aquatic Invasive Species

5.6.1 Zebra and Quagga Mussels

Veliger samples and duplicates from plankton tows were collected at program lakes 2011-2019 and sent to MFWP for microscopy analysis. Select lakes from non-program partnerships also had eDNA samples taken and sent to the University of Montana laboratory. The majority of program lakes fall within the tolerance threshold for invasive mussel habitation if calcium is analyzed independently. All but six lakes had calcium concentrations that exceeded 20 mg/L. Although there is much variability in calcium concentrations between program lakes, it is evident that the overall risk based habitat suitability is high. Determining lakes that are most suitable for zebra/quagga mussels will be especially important in making management decisions unique to each lake, especially if an infestation occurs. Alkalinity concentrations for all program lakes meet the minimum requirement of 18 mg/L for zebra/quagga mussel habitation.

5.6.2 Eurasian Watermilfoil

Eurasian watermilfoil (EWM) is a non-native perennial plant that roots to the bottom of water bodies and can grow in water up to 7.5 meters deep in favorable conditions. It forms dense mats at the water's surface shading out native plants and can clog boat motor propellers, decreasing recreational quality. EWM has the ability to spread rapidly because it reproduces through stem fragmentation. Pieces the size of postage stamps that have broken off the main stem can reproduce. EWM is most commonly spread overland by boats that have not been cleaned after use in an infested water body and are then transported to non-infested waters.

Montana first discovered EWM in Noxon reservoir in 2007. In 2010, EWM was discovered at Tosten Reservoir, Fort Peck Reservoir, the Jefferson River, and the upper and lower Missouri Rivers. EWM was discovered at Beaver Lake in October of 2011. The isolated patch was estimated to be about 50 square feet in size. A thorough survey of Beaver Lake's littoral zone was conducted in late October of 2011, and no other isolated patches were found. The Flathead County Weed District hired a diver to evaluate the extent of the infestation. After discovering that the patch was too large to remove by hand pulling, several bottom barriers were placed over the infestation to prevent it from receiving sunlight and to help minimize the spread through fragmentation. In 2012, a suction dredge was used to eradicate the majority of the EWM infestation. Additional dredging and surveying in 2013 revealed isolated patches of EWM. A total of 6 lbs. of EWM were removed by Hanson Environmental in 2013. Management of EWM at Beaver Lake became an important component of the Whitefish Lake AIS Management Program – a partnership between WLI and the City of Whitefish. In the summers of 2014 and 2015, Hanson Environmental removed roughly 1 lb. of EWM; in 2017, two plants were removed, and no plants were found in 2018. New EWM plants were discovered in 2019 and were promptly removed. Bottom barriers were again placed over the suction dredged areas to block out sunlight for any remaining plants. A follow up survey was conducted by the partners in August. Because of the real threat to Whitefish Lake and the watershed, suction dredging will continue indefinitely until there is confidence that EWM has been eradicated.

After EWM was discovered in Beaver Lake, a joint effort between the Flathead County Weed District, MT Department of Agriculture, WLI, the Flathead Basin Commission and Hanson Environmental was made to survey boat ramps at lakes in close proximity to Beaver Lake. No other infestations were identified. However, these surveys were conducted late in the season, after plants had already started to desiccate. In 2012 and 2013, twenty-four lakes were surveyed for EWM. No infestations were found. In 2013, plankton samples were collected on 25 lakes for eDNA analysis. In 2014, 35 plankton samples from 24 lakes were collected for eDNA analysis. In 2015, 30 plankton samples were collected from 21 lakes for eDNA analysis. In 2016, 13 plankton samples were collected from 8 lakes. In 2017, 28 plankton samples were collected from 6 lakes. In 2018, 25 samples were taken from 7 lakes. In 2019, 34 samples were taken from 5 lakes. Tally, Whitefish, and Blanchard did not test positive for EWM, but one sample collected from Beaver Lake in 2019 did detect Eurasian watermilfoil. This sampling site is near the known infestation of Eurasian milfoil where there has recently been plant removal efforts, so our results are not unexpected. Detailed information for 2019 can be found in Appendix C.