6.0 DISCUSSION

6.1 Study Results

Seasonal and annual variability are essential factors in determining trends and are the reason it is important for volunteers to provide information on atmospheric weather conditions and qualitative data. Some of the lakes in the program have more than twenty years of historical data while others only have a handful of years. Weather plays an important role in the variability of data collected. As mentioned before, 2011 - 2013 were colder and wetter than average. In 2014 - 2016, many program lakes were much warmer than they were historically. In 2017 and 2018 we had hot, dry summers with a lot of forest fires that could affect lake evaporative rates, temperature, clarity, and nutrient levels. It will be important to continue to maintain consistency in data collection in the future so that trends become apparent in lieu of annual variation.

Nutrient concentrations are generally variable based on lake size. Nutrient concentrations in lakes are influenced by the surrounding landscape; and lakes that drain agricultural areas may be likely to have higher nutrient concentrations than those that drain forested areas. Nutrient concentrations can also be driven by lake depth and morphology. Shallower lakes tend to have higher nutrient concentrations because they are more biologically productive. Because many of the smaller program lakes likely mix and stratify several times throughout the summer (polymictic), they can exhibit higher nutrient concentrations than larger lakes that mix and stratify twice per year (dimictic). Although trophic classification is determined by specific nutrient concentrations, lake size is an important factor in determining the speed at which eutrophication can occur.

Summer profiles have indicated Beaver, Bootjack, Foy, Murray, Lake Blaine, and Jette were found to be anoxic at some depth. Eutrophic lakes that are covered in ice and snow with large quantities of decaying organic matter can exhibit substantial dissolved oxygen losses in the winter. When the organic matter supply for decomposition is large relative to the mass of dissolved oxygen available, there may be fish and macroinvertebrate kills (Kalff, 2002). In the winter of 2011/2012, Jette Lake had a winter fish kill due to dissolved oxygen depletion.

Lakes with hypoxic hypnolimnia tend to be less than 10 m in depth, have high external phosphorus loading, and high algal biomass. Tally Lake is an exception and likely experiences hypoxia as a result of many complex processes including chemical oxidation of allocthonous humic matter in addition to the high wind energy required to mix this deep lake (Koopal, 2015 pers. comm.).

Program lakes are highly variable in terms of calcium concentration with a range from a low of 4 mg/L to 62 mg/L. Dreissenid mussels need calcium for shell development; however, calcium concentration is not the only relevant factor in determining whether a specific water body is suitable for mussel habitation. The calcium threshold is an indication for the potential of zebra or quagga mussel suitability among program lakes. Literature suggests the calcium threshold for Zebra mussel establishment can be <20 mg/L, however evidence suggests that long term survival, and establishment of zebra mussel colonies requires >28 mg/L, and 12-15 mg/L is the minimum concentration necessary for long term reproduction and growth (Cohen & Weinstein, 2008). This report classified waters with calcium < 20 mg/L as low risk for infestation, calcium 20 mg/L – 28 mg/L as moderate risk for infestation, and calcium >28 mg/L as high risk for zebra mussel infestation (Whittier *et al.,* 2008). Of the 53 monitoring sites that were sampled, 26 ranked as high risk, 20 ranked as moderate risk, and 7 ranked as low risk for calcium based risk assessment.

Alkalinity, pH, dissolved oxygen, and conductivity are other variables that determine suitability for long term survival of zebra/quagga mussels. Literature suggests that pH values below 7.3 are too acidic to support long term survival of zebra mussels, and levels between 7.4 and 9.4 are within the range for growth with 8.4 as ideal (Benson *et al*, 2017). Zebra mussels spawn between 12-18° C which is also the ideal temperature for larval development.

6.2 Study Limitations/Challenges

Through the years of the program, there have been challenges and unique situations that have occurred.

2011: The greatest challenge was the inability to begin the field season data collection on schedule because the Hydrolab MS5 that was expected to be used for the field season didn't arrive until October, and WLI's Hydrolab DS5 wasn't always available when needed. WLI's DS5 also needed to be shipped to Hach Environmental several times for repairs. However, Hydrolab profiles were taken on every lake at least once and were taken twice on 24 of the 42 lakes. The program now has the Hydrolab MS5 (and has back use of WLI's DS5).

2012: No summer Hydrolab profiles were taken on any of the Flathead Lake sites due to equipment maintenance issues.

2013: No fall Hydrolab profiles were collected on Flathead Lake, and water chemistry samples were not collected at three of the Flathead Lake sites. Fall Hydrolab profiles were collected at all eight Flathead Lake monitoring sites.

2014: Unseasonably cold weather caused many of the program lakes to freeze in early November. Because of this, fall Hydrolab profiles were not collected on some of the lakes.

2015: Hydrolab equipment repairs and fires prevented summer sampling on some of the program lakes.

2018: The transition from the NCSS software suite to using the open source computer language R has benefits in preparation of figures and databases and ensures quality control and assurance, but as with any conversion of database platforms, it created some graphic inconsistencies.

2019: During the sampling season, the Hydrolab MS5 began reading unusually high dissolved oxygen numbers, so it was sent in for evaluation. WLI's Hydrolab DS5 was used for the remainder of the season. We reconciled changes in the report's graphic output and style. We also created a mini-report template for existing Lake Association groups in order to distribute lake specific findings in a more manageable format.

General limitations: Water chemistry samples are only collected once each year at one site and Hydrolab profiles are only collected once each year at each lake limiting the spatial and temporal data. In addition, each lake is affected by seasonal variability. Data are intended to provide an inter-annual snapshot of summer conditions, hence the importance for consistency in sampling between mid-July and mid-August. The Carlson TSI also only includes one data point for each year except for Secchi depth, wherein all depths collected for the year are averaged then calculated in the TSI equation.

7.0 RECOMMENDATIONS

We recommend more intensive sampling on lakes with unique biological and chemical characteristics, those with native focal fish species, or lakes that have direct surface connection to those waters. Examples include Upper and Lower Stillwater, Upper Whitefish, Smith, Tally, Beaver, Swan, Lindbergh, Holland, Foys Lake, and Flathead.

Given the increasing pressures on Montana's lakes from AIS, climate change, and increased human development, the need to gather consistent, accurate information on conditions from Montana's lakes has never been greater. Lake volunteer water quality and AIS monitoring programs such as this one are important models for other regions and lake associations. With this in mind, WLI initiated a program with funds from the Bureau of Reclamation and distributed through the Upper Columbia Conservation Commission (UC3) that identifies gaps in geographical coverage of lakes in the Upper Columbia River region and engages additional volunteer groups and citizens in long-term stewardship of basin lakes and reservoirs. This program trains Upper Columbia stakeholders in plankton tow net sampling techniques, visual identification of aquatic invasive plant species, and collecting water quality measurements. It also provides those stakeholders with the necessary monitoring and decontamination equipment as well as an outreach messaging consistent with FWP's Clean, Drain, Dry campaign. A large part of this project is to enhance coordination and support among existing monitoring partners within the Upper Columbia Basin as well as supporting and outfitting new monitoring efforts. Incorporating additional partner groups adds to the volunteer base in the region and allows more lakes to be monitored that are a high priority but are not currently sampled. WLI created a new website highlighting all participating partner groups, sampling and decontamination protocols, and background resources for volunteers (ucln.net).

This program relies on volunteers and project partners for long term success. Continued support is essential for the monitoring efforts to provide scientific data, education and outreach, and AIS early detection monitoring for the currently monitored forty-one lakes in northwest Montana. This information will help citizens and resource managers navigate the complex resource management decision making process.

Lastly, in 2020, WLI uploaded data from the two original monitoring programs as well as all of the NWMTLVMN data into DEQ's MT-eWQX EQUIS database. All data from program lakes is now available to more users in order to better our overall understanding of lake resources.

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9.0 MAP SOURCES CITED

Abbot: *Google Maps*
Ashley: *MFWP*
Bailey: *Google Maps*
Beaver: *MFWP*
Big Therriault: *MFWP*
Blaine: *MFWP*
Blanchard: *MFWP*
Bootjack: *MFWP*
Dickey: *Mark Reller; Constellation Services*
Dollar: *MFWP*
Echo: *Mark Reller; Constellation Services*
Fish: *Google Maps*
Five: *MFWP*
Flathead: *Mark Reller; Constellation Services*
Foys: *MFWP*
Glen: *MFWP*
Halfmoon: *MFWP*
Hanson-Doyle: *Google Maps*
Holland: *Mark Reller; Constellation Services*
Jette: *Google Maps*
Lake of the Woods: *MFWP*
Lindbergh: *Mark Reller; Constellation Services*
Little Bitterroot: *Mark Reller; Constellation Services*
Loon: *MFWP*
Lost Coon: *Google Maps*
Lower Stillwater: *Mark Reller; Constellation Services*
Mary Ronan: *Mark Reller; Constellation Services*
McGilvray: *Google Maps*
Murphy: *Mark Reller; Constellation Services*
Murray: *MFWP*
Peterson: *Google Maps*
Rogers: *MFWP*
Skyles: *MFWP*
Sophie: *Mark Reller; Constellation Services*
Spencer: *MFWP*
Swan: *Mark Reller; Constellation Services*
Tally: *Mark Reller; Constellation Services*
Tetrault: *Google Maps*
Upper Stillwater: *Mark Reller; Constellation Services*
Upper Whitefish: *MFWP*
Whitefish: *Mark Reller; Constellation Services*

10.0 LIST OF ACRONYMS

AIS:	Aquatic Invasive Species
Chl (a):	Chlorophyll (*a*)
COC:	Chain of Custody
DEQ:	Department of Environmental Quality
DS5:	Data Sonde 5
eDNA:	Environmental Deoxyribonucleic Acid
EPA:	Environmental Protection Agency
EWM:	Eurasian Watermilfoil
FBC:	Flathead Basin Commission
FLBS:	Flathead Lake Biological Station
GPS:	Global Positioning System
HDPE:	High Density Polyethylene
LDO:	Luminescent Dissolved Oxygen
MDA:	Montana Department of Agriculture
MFWP:	Montana Fish, Wildlife and Parks
MS5:	Mini Sonde 5
NWMTLVMN:	Northwest Montana Lakes Network
ORP:	Oxidation Reduction Potential
pH:	Parts Hydrogen
SAP:	Sampling and Analysis Plan
SpC:	Specific Conductivity
TDS:	Total Dissolved Solids
TP:	Total Phosphorus
TPN:	Total Persulfate Nitrogen
TSI:	Trophic State Index
VLMP:	Volunteer Lakes Monitoring Program
WLI:	Whitefish Lake Institute