Analysis of Northwestern Montana Lakes Based on Transparency and Temperature

Kari Minissale, Dan Stich, Cynthia Ingelfinger

Introduction

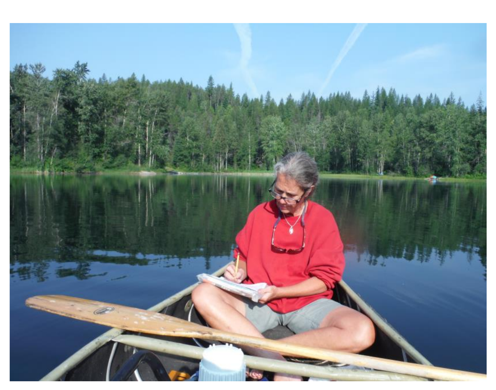
Lakes exhibit physical, chemical, and biological differences in their responses to climate change. Water transparency and temperature trends have been established as indicators of the quality of lakes. To better Understand lakes' responses to large-scale climatological changes, lakes Near Glacier National Park have been monitored by the Northwest Montana Lakes Network since 1992. Citizen science volunteers measured Secchi disk depths and temperature in 41 lakes in Montana, USA, to assess water quality between June and August from 2007 through 2020. We modeled seasonal and annual variability in measurements across years, and among months while accounting for lake-specific variation in seasonal and annual trends.

Flathead Lake in Montana

Methods

Data Collection:

Since 2011, there have been about 49 volunteers in the program. They were trained at Whitefish Lake Institute and take Secchi disk depth and temperature measurements at their assigned lake twice a month. Each volunteer submits their data through online data submission (WQI form).



Susie Bouton working on Bailey Lake

Joann monitoring Skyles Lake

Volunteers at Mary Ronan Lake

Statistical Analysis using Rstudio©:

- Year (continuous) and Month (categorical) as fixed effects explanatory variables and fixed effects
- Filtered month – June, July, August
- 5+ years of data
- Linear Mixed Models
- Random effect of lake
- Multi-phase model selection:
  - Step 1: Assess month and year
    - Null, additive, and interactive
  - Step 2: Assess previous best model with random effect
    - Random effect on intercept, on both intercept and slope
- Analysis of Variance (ANOVA) to determine statistical significance of fixed and random effects, as well as their interactions
- Plotted predictions of best model against observed data

Results

Fixed effects model selection based on AIC rankings supported the global interactive model of the effect of year and month on Secchi disk depth and temperature as the best model. This model allowed both variables to change differently across years within individual months and allowed mean Secchi or temp to vary by month.

Secchi depth:

- Generally increased, but this increase varied based on a lake's mean Secchi disk depth
  - Lakes with above average Secchi disk depth increased less over time
  - Flathead Lake is an exception; had the most data, weighed heavily on data set.
  - Four lakes showed statistically significant change in Secchi disk depth (Fig. 2).

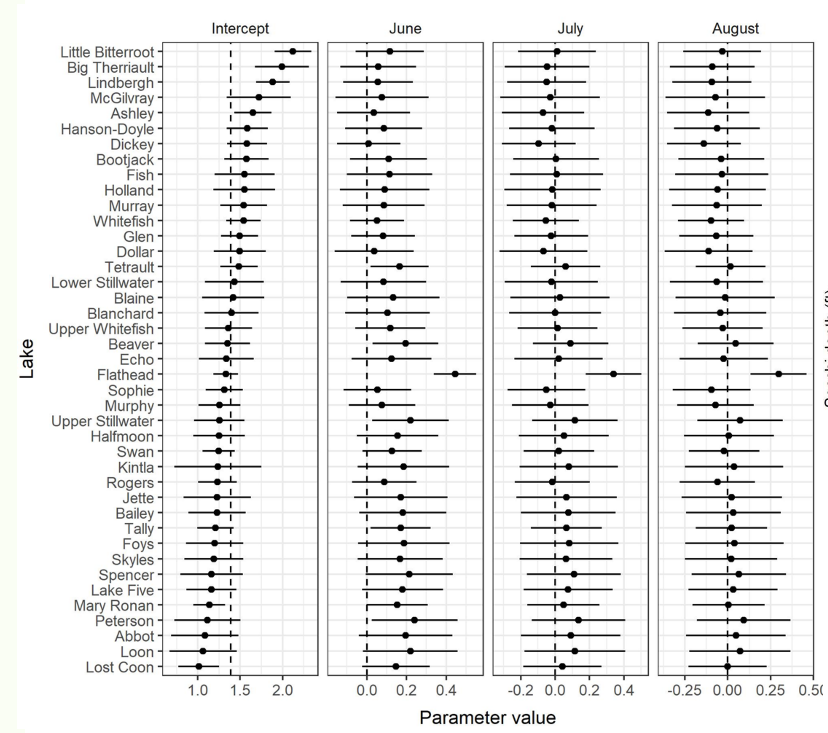


Figure 1. Secchi disk depth random effects coefficients

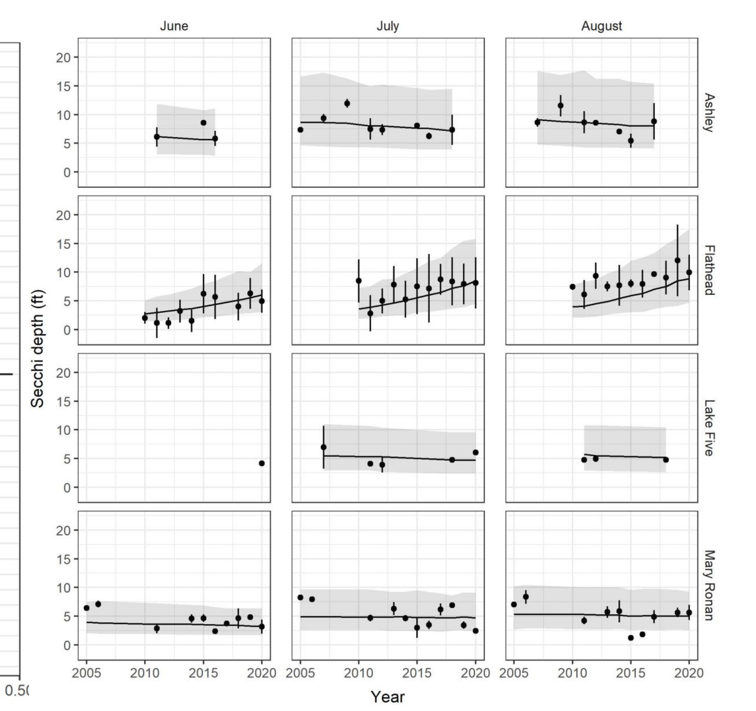


Figure 2. Secchi disk depth predictions of significant lakes

Temperature:

- Generally increased, but this increase also varied based on a lake's mean temperature.
  - Ten lakes showed statistically significant change in temperature (Fig. 4).

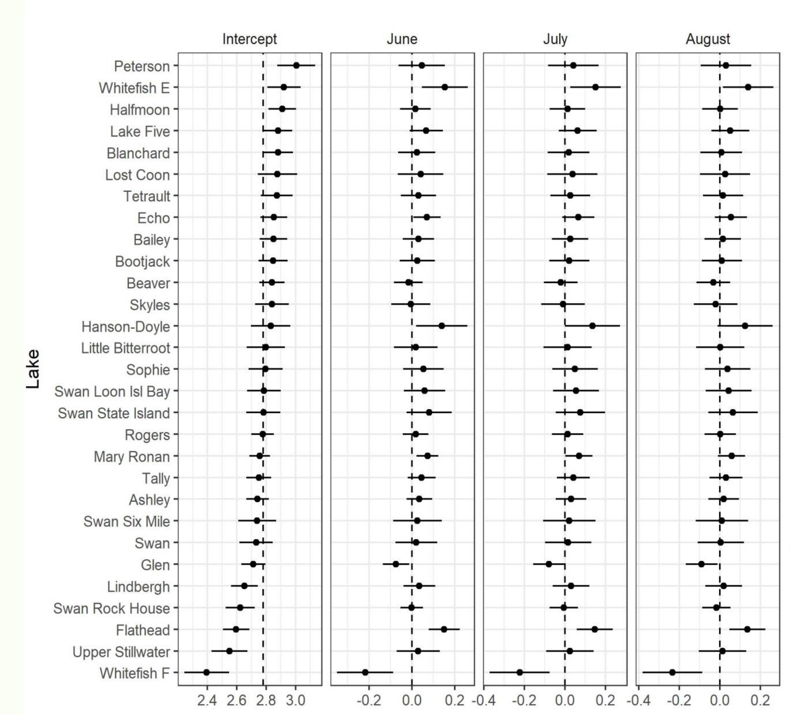


Figure 3. Temperature random effects coefficients

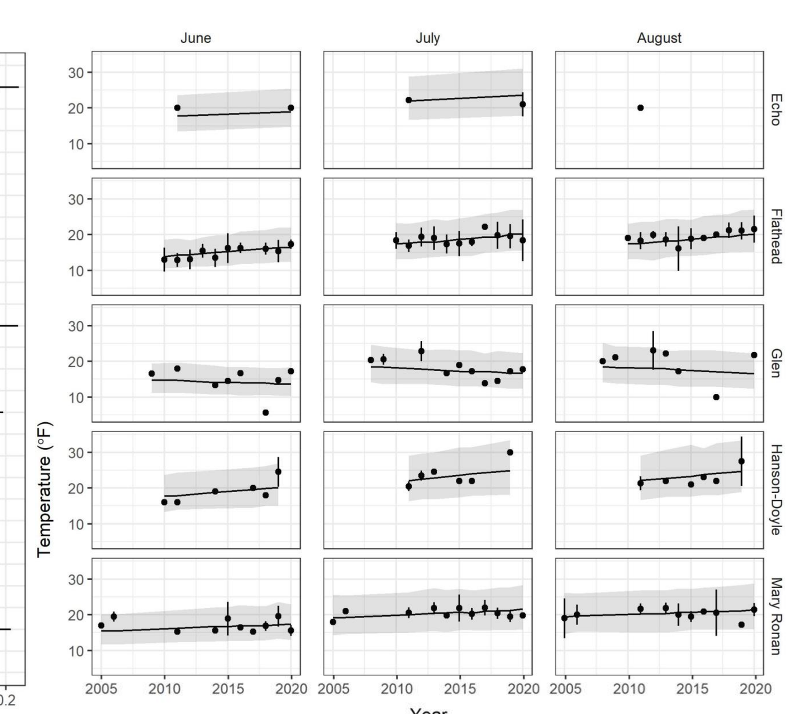


Figure 4. Temperature predictions of significant lakes

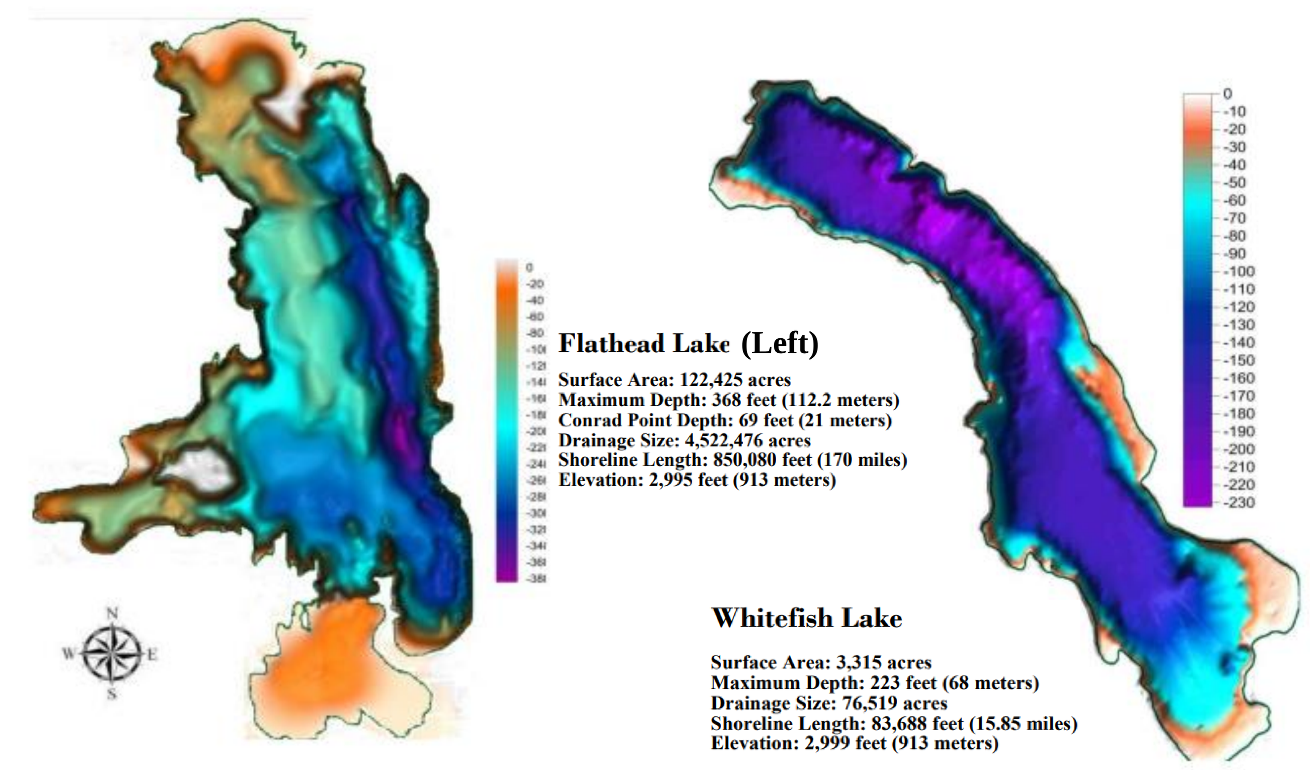
Both Secchi disk depth and temperature varied seasonally (significant effect of month and months across years) and regionally (significant effect of lake) , and there are noticeable differences in these changes between each lake.

Where do we go from here?

We received a much more substantial data set with data from 1992 until 2020. We also received nutrient data from each lake including total phosphorus, total nitrogen, and chlorophyl *a*. This data will be analyzed to see whether there have been any changes or trends in the nutrient composition of these lakes and will then be compared with temperature and Secchi data.

For example, chlorophyll *a* is an indicator of algae. If the chlorophyll *a* concentration decreases over time, we can expect Secchi depth to increase as the algae disappears and lakes become clearer. Many species of algae and phytoplankton are sensitive to temperature, so if temperature is increasing, we can expect chlorophyl *a* and Secchi disk depth to decrease.

By eventually combining this data together, we can form a big picture as to how these variables are connected. We're hoping to perform a comprehensive analysis on the spatiotemporal effects of climate change on lakes using Trophic Status Indicators (TSI's).



Acknowledgements

Cynthia Ingelfinger, Whitefish Lake Institute
Dr. Stich, SUNY Oneonta