Evidence For A Shift To A Later Fall Overturn in a Large Dimictic Lake in Ontario Due to Climate Change

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Abstract

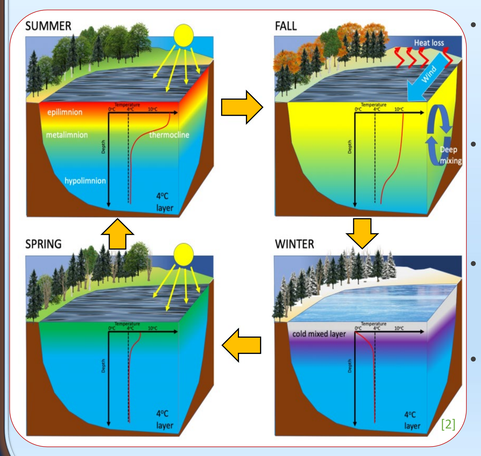
Aquatic ecosystems play a crucial role in maintaining the balance of our planet's biogeochemical cycles and supporting diverse ecosystems. However, these delicate systems are increasingly susceptible to the effects of climate change, which can lead to significant alterations in their physical and biological processes. In this study, we investigate the potential impacts of climate change on the Fall mixing dynamics of Opeongo Lake, a representative aquatic ecosystem.

Introduction

Hypothesis: In Opeongo, we will see a later Fall mixing date due to :

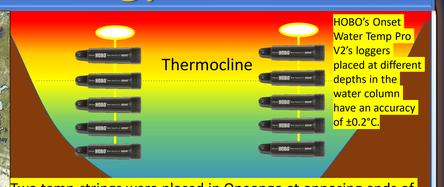
- Increased peak Summer water temperatures
- Warmer Fall air temperatures
- Decreased Fall wind speeds

Motivation From Prior Studies: In an analysis of *Lake Simcoe* from 1980-2008, *E.A Stainsby et Al*. found the Fall mixing date to change by a month[1]. A similar 30-year study by *Eric J. Anderson et Al*. of *Lake Michigan* found as the summer stratified period is extended, indicated by Fall warming trends at the surface, the Fall turnover date is delayed[3].



- **Summer:** Solar Radiation warms the surface layer of the lake, causing stratification with the warmer layer being separated from the cooler, lower layers by the thermocline.
- **Fall:** Cool air and winds mix the water column, redistributing oxygen and nutrients throughout the water column. Then, water cools to it's Temperature of Maximum Density of 4 °C.
- **Winter:** The lake freezes over, insulating the water below. Thus, the lake stratifies once again, with the denser 4 °C water at the bottom of the lake.
- **Spring:** With melting ice and a warming surface layer, water begins to mix redistributing oxygen and nutrients throughout the water column.

Methodology

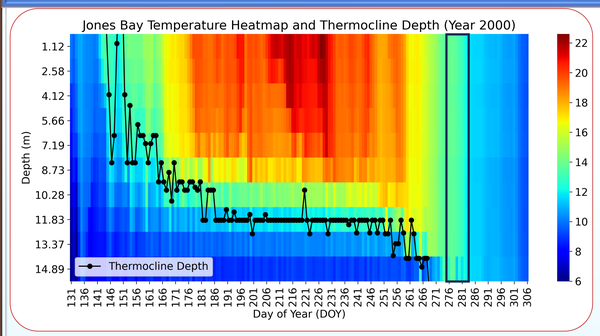


HOBO's Onset Water Temp Pro V2's loggers placed at different depths in the water column have an accuracy of ±0.2°C.

Two temp-strings were placed in Opeongo at opposing ends of the lake collecting temperature data from 1998-2022. The years of 1999, 2000, 2001, 2002, 2003 and, 2005 had sample intervals of 8 min, while the rest had a frequency of 15 min sample intervals.

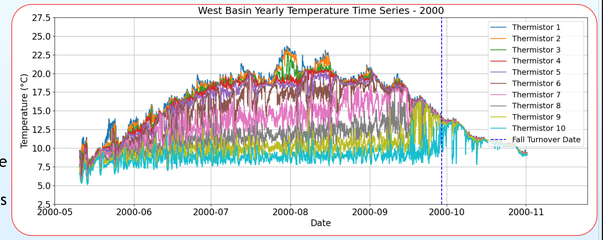
- Located closely West of Opeongo are 3 lakes, Smoke Canoe and Tea. These were also monitored in the same manner as Opeongo. But Canoe and Smoke have a larger mean depth, and Tea is shallower.

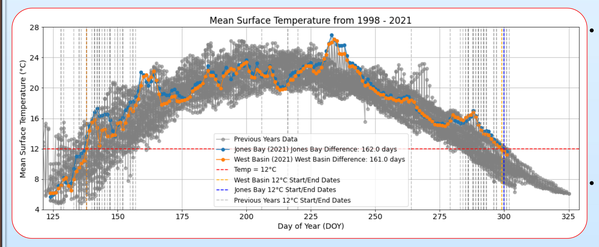
Results



- **Definition:** The Thermocline depth is the depth at which the water column is 12˚C.
- We observe that the water column temperature profile becomes isothermal in the plot when the entire vertical slice is the same colour.

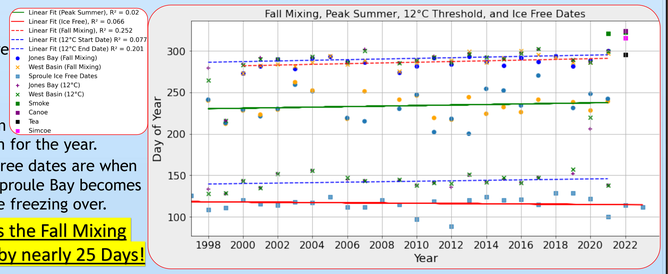
- **Definition**: The date of Fall turnover is when the difference between thermistors 1 and 9 was < 1˚C.
- I have Indicated the date of the Fall Turnover on the plot. We can see it is where the thermistor lines overlap.

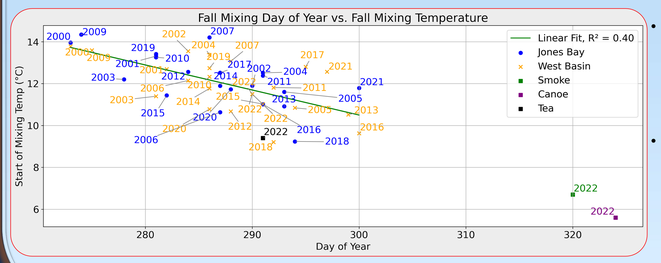




- **Definition**: The 12˚C Start/End dates are when the daily mean averaged temperature of the shallowest thermistor rises above 12˚C and then falls below 12˚C.
- We can also notice data from previous years which form a trend.

- **Definition**: Peak Summer dates are when the daily averaged temperature of the water column is at its maximum for the year.
- **Definition**: Ice Free dates are when a neighbouring Sproule Bay becomes ice free after the freezing over.
- The Plot shows the Fall Mixing Date delaying by nearly 25 Days!





- The temperature at which Fall Mixing occurs is correlated to the date it occurs.
- Data from Smoke, Canoe, and Tea Lakes also follow the trend line.

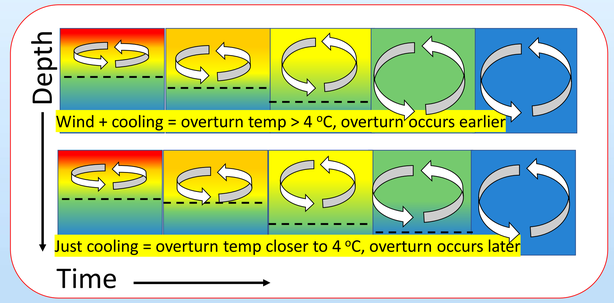
Discussion

It is significant that we can see such a large delay in Fall Mixing due to what it means for the ecosystem. Opeongo breathes during Fall turnover. Since Fall turnover leads to a mixing of the water layers, the timing of the distribution of oxygen and nutrients in the water column changes. A Later Fall turnover affects the Habitat and Food availability for fish!

- **Habitat Changes:** from Temperature variations in the water column and lack of vegetation.
- **Oxygen Levels:** A delayed turnover results in oxygen depletion in deeper waters.
- **Availability:** A later turnover disrupts the timing of nutrient cycling and production in the water, affecting the abundance and availability of plankton, invertebrates, and other prey organisms.

Conclusion

- **Peak Summer Dates:** There is high variability indicated by a low R^2 value, allowing us to turn away from suspecting increased peak summer water temperatures.
- **12°C Start/End Dates:** The start and end dates are both trending towards being 10 days later. However, the duration of 12°C dates remains similar throughout the years. We do not suspect it to cause a delayed Fall mixing. The 12°C dates are significant for the fish population as it is period that most fish will be able to access the entire water column.
- **Fall Mixing Date Temperature:** Fall air temperature plays a large part in Fall Mixing. As warmer temperatures correlate to an earlier mixing date. However, to account for the large difference in date between Smoke, Canoe, Tea, and Opeongo we must look at wind data as we could presume the air temperature to be same across the lakes, while wind is variable.



- **Lake Size Dependance:** Another Parameter is lake size. A larger surface area of the lake exposes the lake to wind more. A deeper lake will also affect Fall mixing, as the deeper layers require more energy to upwell.
- **Future Sustainability:** What recommendations can be made to help maintain healthy fish populations and ecosystem functioning considering a changing Fall turnover schedule?

References/Acknowledgements

Special Thanks to *Trevor Middel, Mark Ridgeway* and the rest of the crew from *Harkness Laboratory of Fisheries Research* for their help collecting the data used in this research

[1] : E.A. Stainsby, J.G. Winter, H. Jarjanazi, A.M. Paterson, D.O. Evans, J.D. Young, Changes in the thermal stability of Lake Simcoe from 1980 to 2008, Journal of Great Lakes Research, Volume 37, Supplement 3, 2011

[2] : Wells, M. G., & Troy, C. D. (2022). Surface Mixed Layers in Lakes. In Encyclopedia of Inland Waters (pp. 546–561). Elsevier

[3] : Anderson, Eric & Stow, Craig & Gronewold, Andrew & Mason, Lacey & McCormick, Michael & Qian, Song & Ruberg, Steven & Beadle, Kyle & Constant, Stephen & Hawley, Nathan. (2021). Seasonal overturn and stratification changes drive deep-water warming in one of Earth's largest lakes. Nature Communications. 12. 10.1038/s41467-021-21971-1.