VARIABILITY AND DRIVERS OF PRIMARY PRODUCTIVITY BETWEEN EUTROPHIC AND OLIGOTROPHIC LAKES AT THE IISD EXPERIMENTAL LAKES AREA

University of Manitoba

Leah Dickenson[1], Mark Hanson[1], and Scott Higgins[2]

[1]Department of Environment and Geography, University of Manitoba

[2]International Institute for Sustainable Development Experimental Lakes Area

IISD Experimental Lakes Area

PURPOSE & OBJECTIVES

Primary productivity within a lake is a result of the photosynthetic activity of autotrophic organisms.[1] Total carbon fixation through photosynthesis is referred to as, gross primary production (GPP).[2] The remineralization of organic carbon to carbon dioxide represents respiration (R).[2] The difference is net ecosystem production (NEP = GPP - R).[2]

Long-term drivers of productivity can include, eutrophication, dissolved organic carbon, and climate change. Understanding more about these drivers can provide useful information about, lake ecosystem health and a lakes role in carbon cycling and how the role changes with a changing climate.[3,4,5,6]

The objectives of this thesis are:

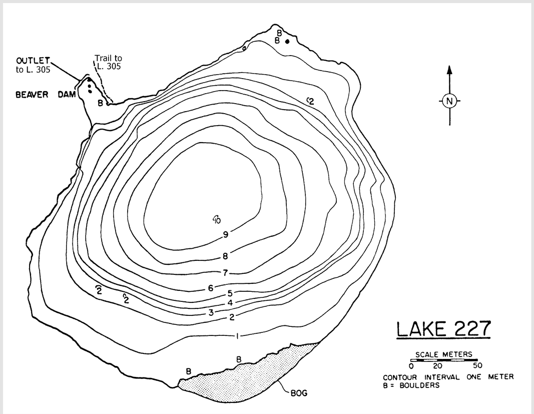
1. Determine the range and variation of NEP, GPP, and R that occurs in boreal lakes of different trophic status.
2. Determine the drivers of variation to NEP, GPP, and R.

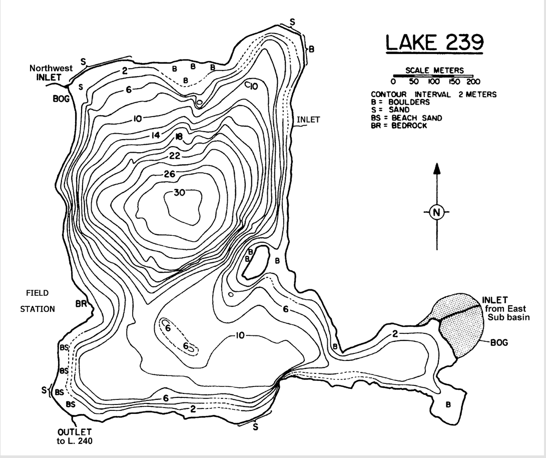
The hypotheses of this thesis are:

1. Eutrophic Lake 227 will have significantly higher values of GPP, R, and NEP than oligotrophic Lake 239.
2. In eutrophic Lake 227, the seasonal pattern of GPP, R, and NEP will track algal bloom development and decay.

METHODS

- **Study Site:** IISD Experimental Lakes Area, northwestern Ontario. Lake 227 (eutrophic) and Lake 239 (oligotrophic).
- NEP, GPP, and R of the 2020 open water season were calculated using the diel dissolved oxygen method within the 'Lakemetabolizer' function in R.[7]
- The variables (in 30-min intervals) required for the calculation were, dissolved oxygen (DO), air and water temperature, wind speed, relative humidity, and thermocline depth.
- Dissolved oxygen and water temperature were collected using a YSI EX02 sonde.
- Thermocline depth was calculated from bi-weekly to monthly temperature profiles and linearly interpolated between points.
- All meteorological variables were collected from the meteorological station located in the Lake 239 watershed.
- The calculation can produce negative GPP and positive R values, these unrealistic values were removed from the final metabolism results.





CHALLENGES & PROBLEMS

The initial challenges I had were:

- Re-learning the statistical software R.
- Organizing and interpolating the multiple different data files.
- Learning how to use the 'LakeMetabolizer' function.

The problems I encountered were:

- An incorrect time zone error in the YSI data, which resulted in an initial incorrect output of the metabolism estimates.
- A bug in the 'LakeMetabolizer' function, which prevented the code from being ran any further.

PRELIMINARY RESULTS

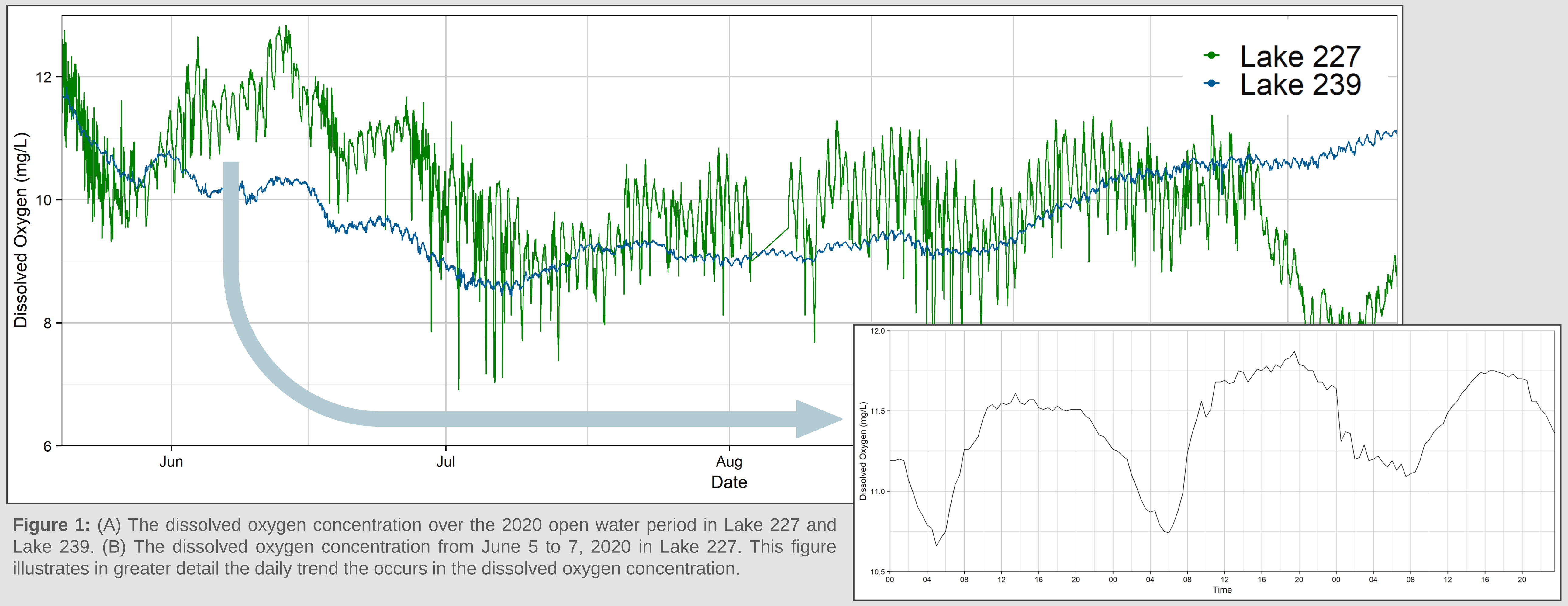


Figure 1: (A) The dissolved oxygen concentration over the 2020 open water period in Lake 227 and Lake 239. (B) The dissolved oxygen concentration from June 5 to 7, 2020 in Lake 227. This figure illustrates in greater detail the daily trend the occurs in the dissolved oxygen concentration.

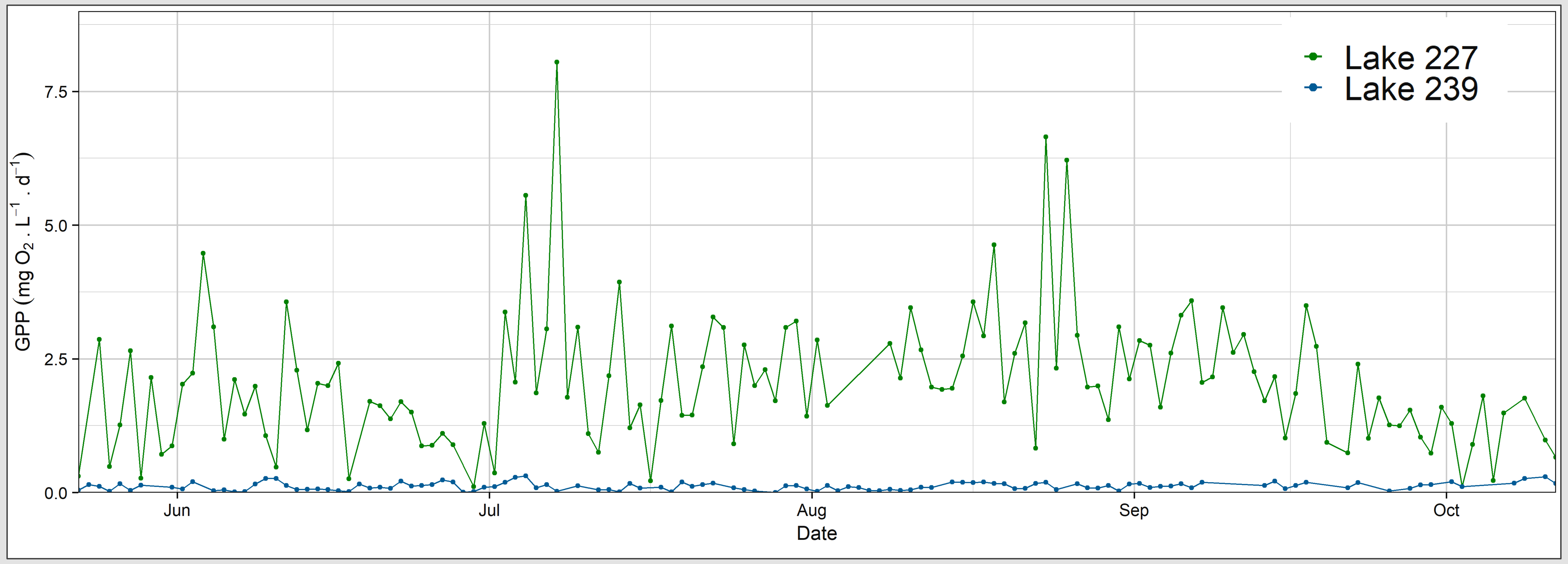


Figure 2: The calculated daily gross primary productivity over the 2020 open water period in Lake 227 and Lake 239, found using the diel dissolved oxygen method.

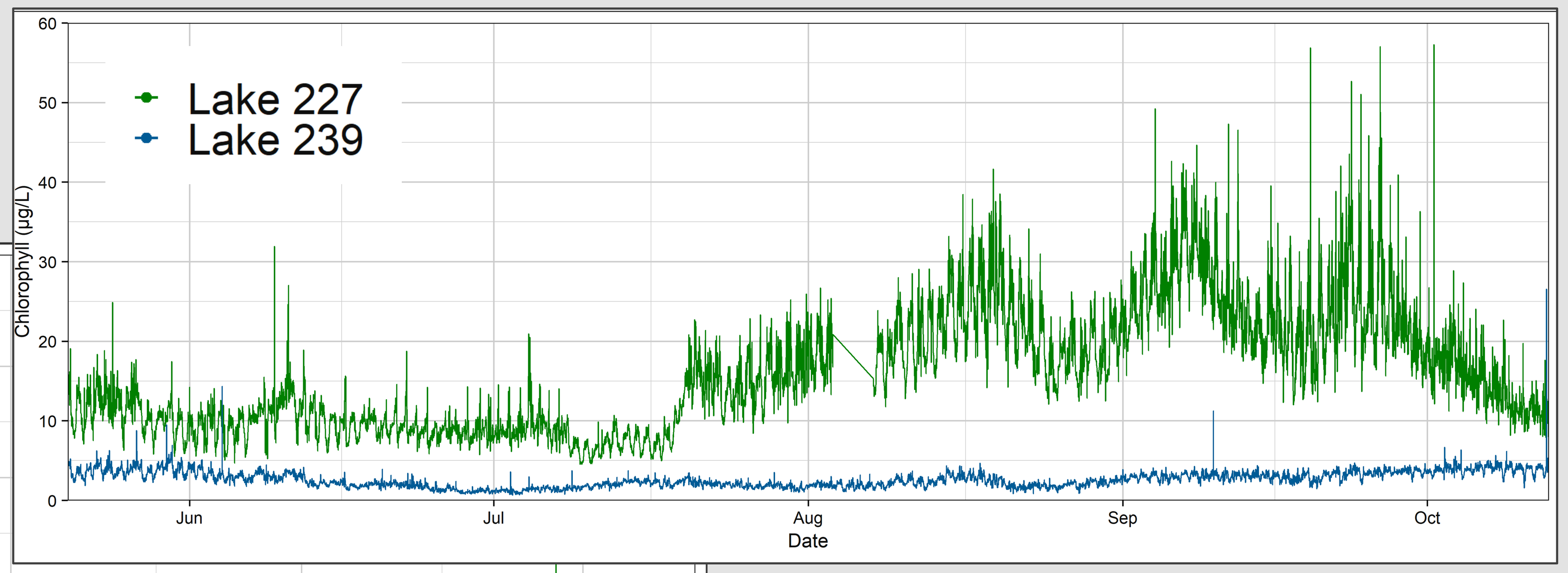


Figure 3: The chlorophyll *a* concentration over the 2020 open water period in Lake 227 and Lake 239.

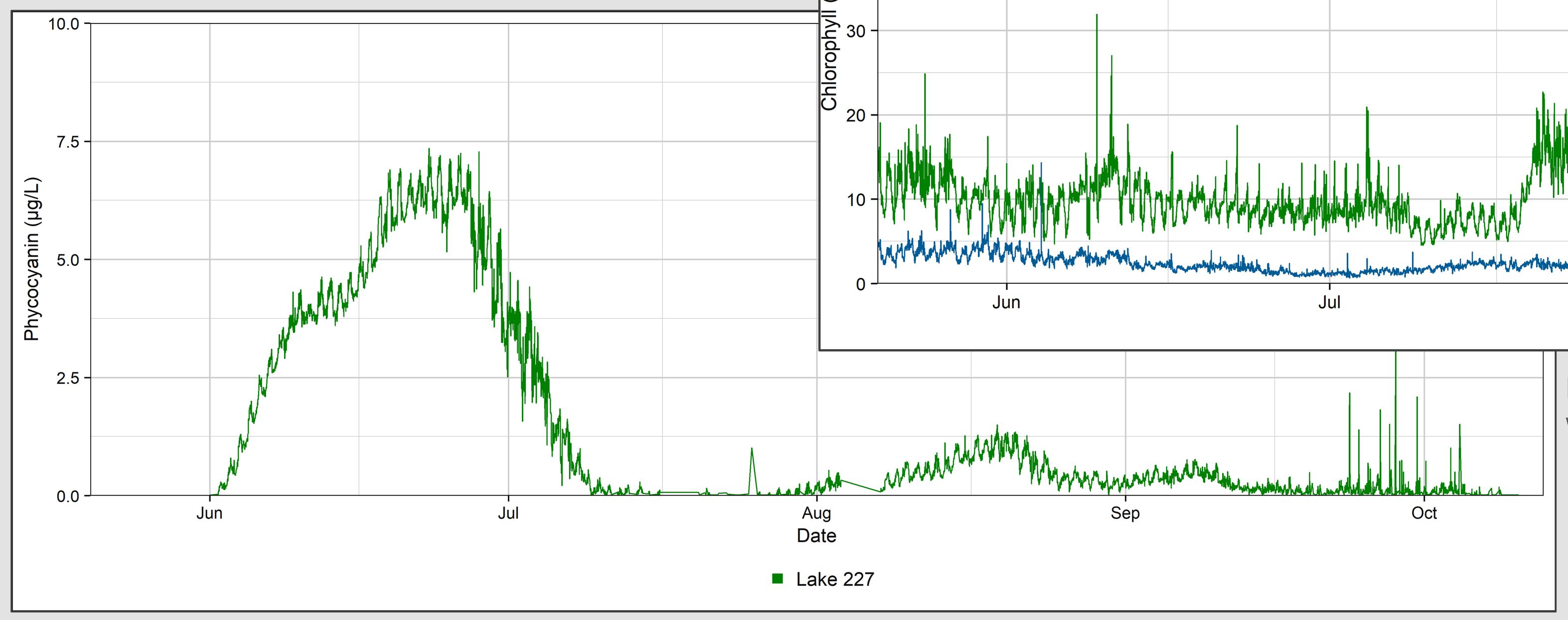


Figure 4: The phycocyanin concentration over the 2020 open water period in Lake 227.

DISCUSSION

Several observations can be made regarding the productivity results and the potential drivers. These observations are only preliminary and must be analyzed statistically to determine significance.

1. **The DO data can validate the GPP estimates.** The extreme daily fluctuation of the DO concentration seen in Lake 227 indicates that daily a high concentration of DO was produced via photosynthetic processes (Fig. 1).[8] When compared to Lake 239, there was very little fluctuation that occurred, which indicates that there was minimal activity in this lake.
2. **There appears to be a relationship between GPP and trophic status**, when comparing GPP in Lake 227 to Lake 239 (Fig. 2). Since trophic status is directly related to the nutrient concentration of a lake, it can be assumed that the productivity was driven by nutrients, like phosphorus.[2] This relationship has been found in previous studies, such as one on 19 meso-eutrophic Danish lakes.[9]
3. **There is evidence of a relationship between GPP and both chlorophyll and phycocyanin concentration**. An increase in either of these measures should reflect an increase in GPP.[10] Lake 227 had a consistently higher chlorophyll concentration compared to Lake 239, and as a result there was more GPP (Fig. 3). In Lake 227, there were two peaks of high GPP (Fig. 2). This is likely explained by the occurrence of two different algal blooms within this lake.[11] The first would have been primarily dominant in cyanobacteria species (Fig. 4).
4. **Both lakes were net heterotrophic, meaning they were net sources of carbon dioxide to the atmosphere.**[4,6] However, Lake 227 was expected to be autotrophic due to its eutrophic status.[12] The result could have been be due to high background respiration.[13] This can occur if the lake had allochthonous sources of organic carbon, which can drive microbial activity and contribute to heterotrophic respiration.[4,14] This is highly plausible as these boreal lakes tend to be high in dissolved organic carbon.

OUTLOOK FOR SUCCESSFUL COMPLETION

A few final steps are required to ensure a complete and thorough analysis of the data is conducted:

- The productivity results need to be statically compared. This comparison will help to analyze and demonstrate the significant differences in productivity between lakes of different nutrient status.
- The metabolism data of each lake will be compared to other lake parameters such as phosphorus, chlorophyll, and DOC.
- I will begin to question and discuss the implications that future climatic changes may have on annual productivity.

REFERENCES

[1]Wetzel, 2001. *Limnology: lake a river ecosystems*. San Diego Academic Press.
[2]Odum, 1956. *Limnology and Oceanography*. 1:102-17.
[3]Solomon et al., 2013. *Limnology and Oceanography*. 58:849-66.
[4]Hoellein et al., 2013. *Limnology and Oceanography*. 58:2089-100.
[5]Castro et al., 2021. *Water Resources Research*. 57:1-24.
[6]Cole et al., 2007. *Ecosystems*. 10:172-85.
[7]Winslow et al., 2016. *Inland Waters*. 6:622-36.
[8]Staehr et al., 2010. *Limnology and Oceanography*. 55:817-30.
[9]Sand-Jensen and Staehr, 2009. *Ecosystems.* 12:336-48.
[10]Phillips, 2020. *Limnology and Oceanography*. 65:652-66.
[11]Schindler et al., 2008. *Proceedings of the National Academy of Sciences*. 105:11254-8.
[12]Cole et al., 2000. *Limnology and Oceanography*. 45:1718-30.
[13]Cremona et al., 2014. *Ecological Modelling*. 294:27-35.
[14]Hanson et al., 2003. *Limnology and Oceanography*. 48:1112-9.