Biol812: Project Proposal

Broadening the spectra: looking beyond VRS-inferred chlorophyll a (650-700nm) to identify changes in whole-lake primary production.

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1 Team name: The Biomath 5

2 Introduction

Water quality information is critical in assessing lake health, but little long-term monitoring data are available to determine whether modern conditions are within a range of pre-impact (e.g. prior to eutrophication) variability. Typically, impacted lake systems are monitored after the impact has occurred, resulting in possibly optimistic, but arguably unrealistic, management strategies. In Canada, regular lake monitoring typically only covers the past few decades (if present at all) and is often initiated in response to detection of an environmental problem, and as a result aims to answer how have humans altered conditions in a system after a specific event (e.g. a cyanobacterial bloom). Given the paucity of monitoring data, understanding how, where and when anthropogenic activities have changed aquatic environments beyond their natural range of variability is difficult, as many impacts are regionally or locally specific Michelutti et al. (2009).

3 Data Collection and Description

Paleolimnological approaches use a variety of biological, physical and chemical indicators preserved in lake sediments to reconstruct past environmental conditions (Smol, 2008). Visible range spectroscopy (VRS) can track past changes in whole lake primary production by tracking sedimentary chlorophyll a and its degradation products, providing information on shifts in lake trophic status (Michelluti et al., 2010). Most cores were collected and had the sediment-water interface stabilized with Zorbitol© before refrigerated shipment to Université Laval, Laval, QC. Cores were then split and stored in a cold room (<4°C) prior to shipment to PEARL, Queen's University, Kingston, ON. Individual intervals of freeze-dried sediment have been dated via gamma spectroscopy at Queen's University using unsupported 210Pb activities in a constant rate of supply (CRS) model (Appleby and Oldfield, 1978; Binford 1990). Freeze-dried sediments have been sieved (120µm mesh) and sub-sampled such that a 50mL glass scintillation vial has at least 1mm of sediment. The sediments have been scanned through the base of the glass vials using a Rapid Content Analyzer (FOSS NIRSystems Inc.) operating over a range of 400-2,500 nm.

The data is comprised of a series of absorbance values from 400-2,500nm through time, which broadly represents the proportion of organic matter in the sediment. The absorbance values demonstrate the type of algae present in the lake depending on where absorbance peaks through the spectra (e.g. chlorophyll a is expected to occur between 650-700nm, representing whole-lake primary production). Each sediment interval has 2100 values and each lake core can have over 30 intervals of sediment stored in 2D datasets. Our largest data set, Muskrat Lake, has 71 intervals of sediment with 2100 values per interval for a total of ~72 000 data points.

The simulated data will be generated according to a variation on Agent-based modelling (ABM) that is commonly used in ecology, referred to as invidivual-based modelling (IBM) . In particular, we shall use the parameter of absorbance to simulate the evolution of an algae population in a lake according to individual behavior. The data obtained will be used to make predictions about how the enviroment will change according to varying levels of absorbance.

4 Sites

Stoco Lake was classified as eutrophic (spring TP ranged from $30 - 50\ \mu g \cdot L^{-1}$) until sewage management upgrades were installed in the late 1980's. Currently, the lake is mesotrophic (spring TP $\sim 15\ \mu g \cdot L^{-1}$, maximum depth $12m$), though cyanobacterial blooms and excessive summer algal growth still occur frequently, likely due to the internal loading of phosphorus from the sediments.

Lac Duhamel (maximum depth $26m$; oligotrophic, summer TP $< 4\ \mu g \cdot L^{-1}$) is located upstream of Mont Tremblant, Quebec, has records of high human impact, including forestry and highway road salt application. It is extremely sensitive to cultural eutrophication, primarily due to the channelization of its tributaries, Shield bedrock, and long water residence time of 2 years (Biofilia, 2004).

Lac-des-Îles (maximum depth $37m$) is located on the Canadian Shield near Mont-Laurier, Quebec, and is classified as oligo-mesotrophic (summer TP $\sim 10.5\ \mu g \cdot L^{-1}$; Enviro'Eau, 2009). The lake supports a variety of sports fish, including lake trout, and is generally considered environmentally sensitive to eutrophication due to its relatively low nutrient levels.

Muskrat Lake (maximum depth $60m$) is valued for its recreational use and as a drinking water source for the town of Cobden, Ontario, located at the south end of the lake. High total phosphorus ($> 40\ \mu g/L$), low water clarity, and algal blooms have raised water quality concerns, largely attributed to eutrophication from heavy agricultural watershed development.

5 Research Questions

We aim to determine whether (1) chlorophyll a changes over time in each lake, and (2) we can "fingerprint" deep vs shallow eutrophic lakes, and, if so, whether the differences correlate to the wavelengths of known specific pigments.

6 Significance

This study aims to explore the environmental histories of previously unmonitored lakes to inform local lake management decisions regarding water quality. Further, absorbance has been previously used to quantitatively reconstruct chlorophyll a, but other spectra have not been fully explored despite the potential use for reconstructing soft-bodied algal communities (i.e. cyanobacteria using genus-specific pigments such as echinenone). This information can be further used to determine if a lake system has reached an ecological tipping point and fundamentally changed from pre-eutrophication conditions.

7 Pipeline

Our analysis will plot and determine differences in absorbance values through time. Each member of our team will be responsible for a different module (Figure 1). Bash script will be used to access and organize all files, as well as generate README files and text descriptions of the data sets. R and/or Python will be used for the remainder of the processing. GitHub will be used to pull raw data, store text-based files (for example, the text for the poster), and for general communication or troubleshooting of code. See appendix for visual representation.

Brigitte will be responsible for the module relating to reconstructing chlorophyll a, plotting and processing the raw absorbance data, and determining the VRS regions with the greatest variance through time. This will involve the creation of functions for use in loops to generate the inferred chlorophyll a data, creation of a function or other program to determine the regions with the most variance and plotting of data.

Collin will be responsible for accessing climate data using Python or R and plotting the georeferenced coring locations using spatial ecology approaches. He is also responsible for plotting climate data, determining its change over time and accessing it appropriately using Python or R.

Stefanie will be responsible for creating a mathematical model and programming a simulation in python based on that model. She will run the simulation mutliple times while varying the parameters of the model and plot one key finding. She will also work with R-markdown and LaTeX to create a poster for everyone's work to be included.

Leif will be creating and applying machine learning techniques to identify and contrast VRS spectra for each lake, with the goal of investigating whether the depth or trophic status can be identified from only the absorbance values.

Nazila will observe each component of the project to ensure analysis and visualizations are informative and void of extraneous 'ink'. She will also assist Stefanie with her python code and will make comparisons with R script.

8 Predicted or hypothesized results

9 References

Appleby, P.G., and Oldfield, F. 1978. The calculation of lead-210 dates assuming a constant rate of supply of unsupported 210Pb to the sediment. Catena, 5:1-8.

Binford, M. 1990. Calculation and uncertainty analysis of 210Pb dates for PIRLA project lake sediment cores. Journal of Paleolimnology, 3(3): 253-267.

Biofilia (Consultants en Environnement). 2004. Diagnose de basin versant: Lac Duhamel, Ville de Mont-Tremblant. Rapport final (only available in French), URL: http://lacduhamel.ca/wp-content/uploads/2015/09/diagnose-bassin-versant.pdf, accessed 15 Nov 2017.

Enviro'Eau (Services-Conseils). 2009. Diagnose du Lac- des- Îles: Municipalité de Sain-Aimé-du-Lac-des- Îles et Ville de Mont-Laurier, Québec. Rapport final (only available in French), URL: www.villemontlaurier.qc.ca/DATA/DOCUMENT/Rapport et annexes-diagnose lac des Îles-2009.pdf, accessed 9 Nov 2017.

Michelutti, Neal, Jules M. Blais, Brian F. Cumming, Andrew M. Paterson, Kathleen Rühland, Alexander P. Wolfe, and John P. Smol. 2009. "Do Spectrally Inferred Determinations of Chlorophyll a Reflect Trends in Lake Trophic Status?" *Journal of Paleolimnology* 43 (2). Springer Nature: 205–17. doi:10.1007/s10933-009-9325-8.

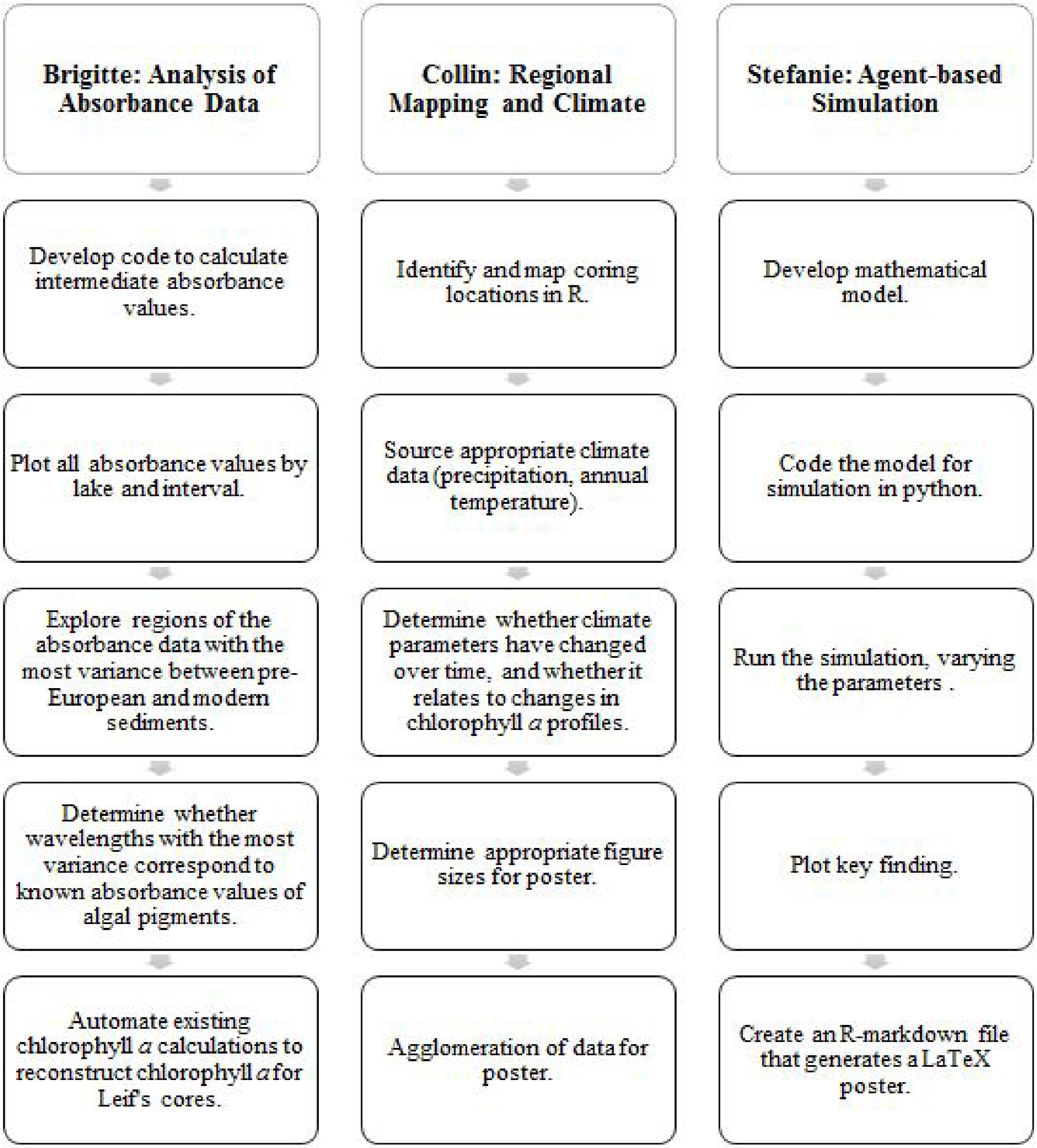

Figure 1: General workflow and areas of responsibility for data processing.

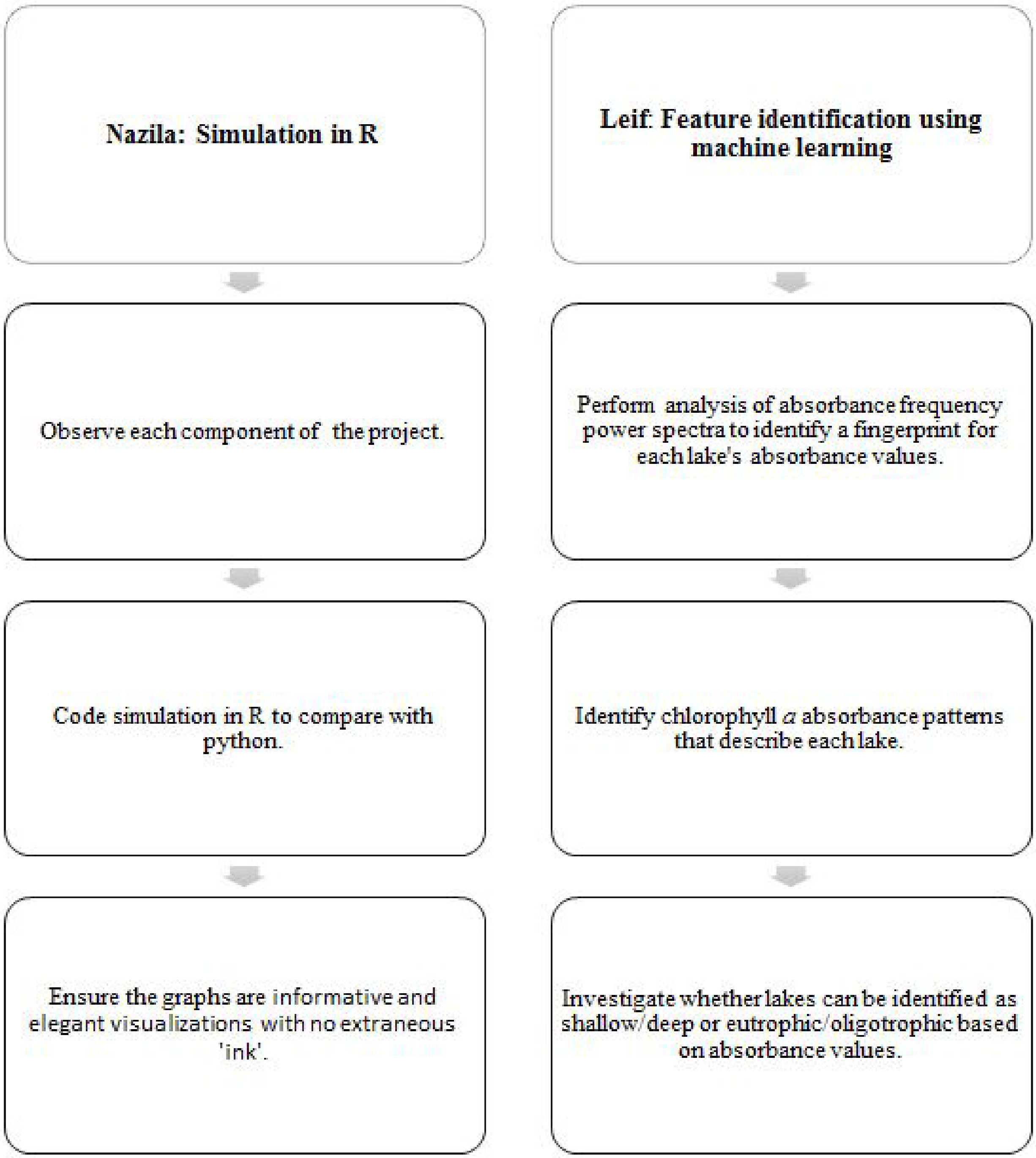

Figure 2: General workflow and areas of responsibility for data processing.