Impacts of a Warming Arctic on Freshwater Ecosystem Productivity, Biogeochemical Processes, and Resources

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Overview

Lake Hazen, located on Ellesmere Island (82°N) is Canada's largest lake north of the Arctic Circle. Historically and culturally, this region served as a significant hunting and fishing ground for paleo-Inuit people approximately 4000 years ago. Lake Hazen watershed is currently experiencing various impacts of climate change (i.e., warmer temperatures, increased precipitation, decreasing ice cover, etc.). Consequently, this research focuses on how these changes are impacting freshwater processes, specifically primary productivity, which supports aquatic food webs (i.e. fish stocks) with energy necessary for survival. Metabolic process including net primary productivity (NPP) of surface waters, ecosystem respiration, and air-water carbon dioxide (CO_2) fluxes will be quantified during summer 2016 and spring 2017 to assess ice-on and ice-off ecosystem metabolism. A variety of techniques including the application of stable isotopes (δ^{18}O-DO), and the analysis of a complete suite of water chemistry parameters will aid in expanding our understanding of biogeochemical processes occurring within this aquatic system. Lake metabolism measurements will provide valuable data on the energetic processes that support aquatic life, allowing us to understand how climate change may impact the security of freshwater resources. This research program will inform and benefit a range of stakeholders, including public health officials and policy makers, as well as help secure the safety of food and water resources for Arctic indigenous communities.

Research Objectives

The objectives of this study are to determine how High-Arctic lakes are responding to climate change by calculating rates of total ecosystem productivity. To achieve these objectives, we aim to collectively quantify:
(1)Net Primary Productivity (NPP) in surface waters,
(2) Ecosystem Respiration,
(3) Air-water CO2 fluxes,
(4) and to characterize water chemistry.

Study Location

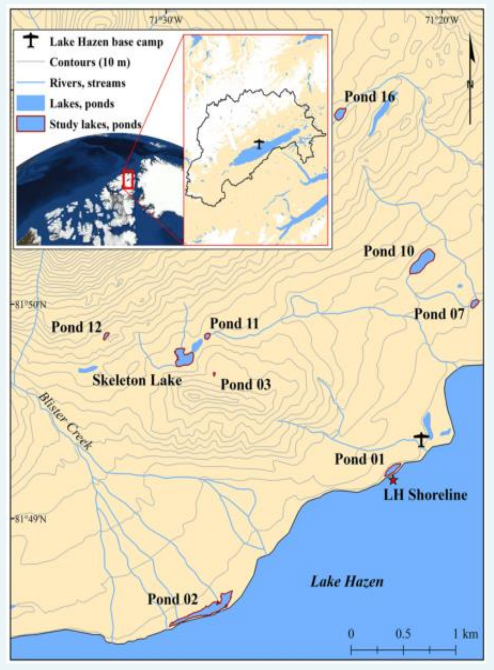


Figure 1 Study site map (Emmerton et al, 2016).

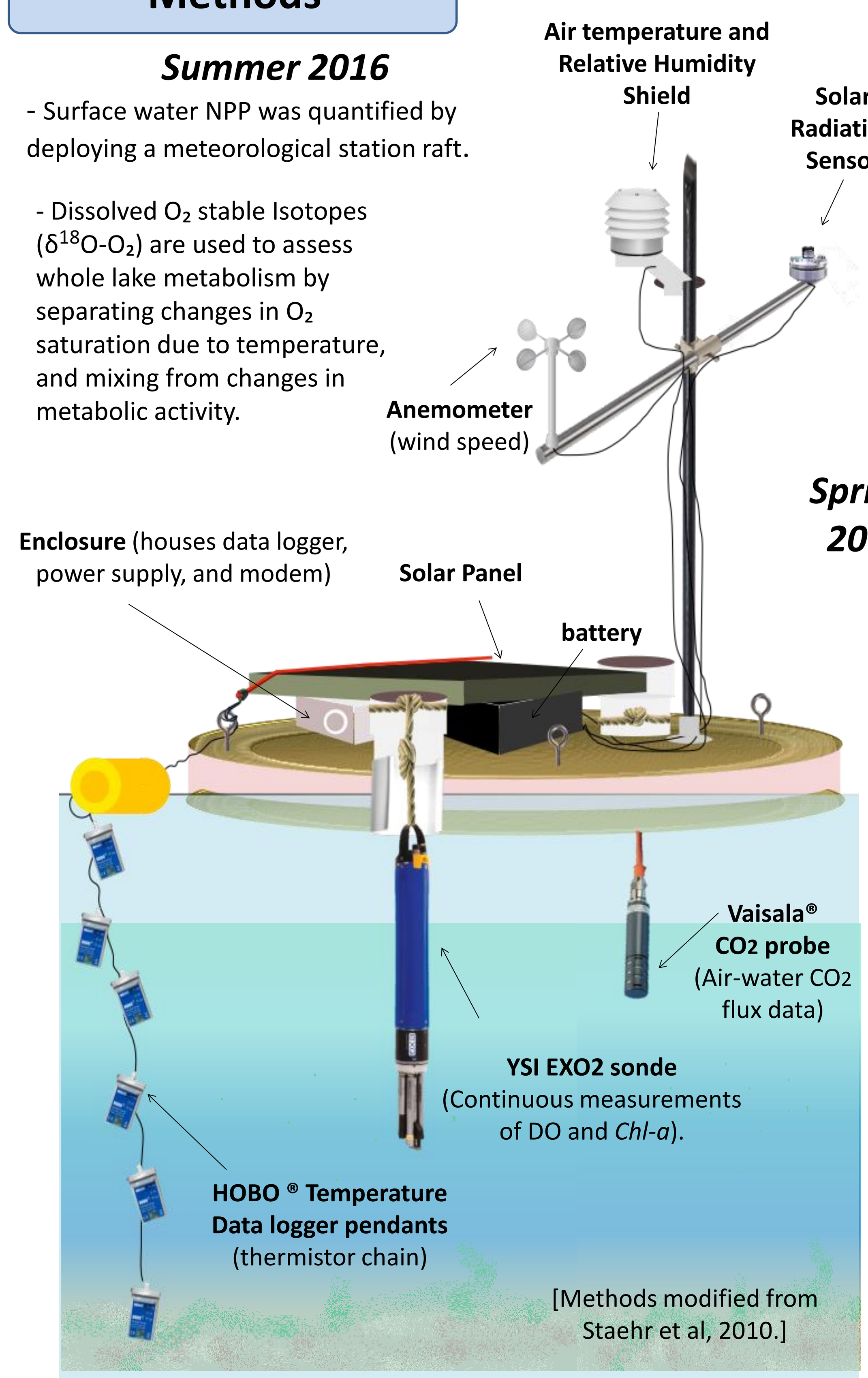
- Lake Hazen Watershed, Quttinirpaaq National Park (QNP), Ellesmere Island, Nunavut (82°N, 71°W).
- Historically and culturally significant hunting and fishing ground to paleo-Inuit peoples over 4000 years ago (Köck et al, 2012).
- **Skeleton Lake**, a smaller, but relatively more productive system than Lake Hazen.
- Stratified water body, approximately 4.5 m deep.
- "Meltwater system" (Emmerton et al, 2016).

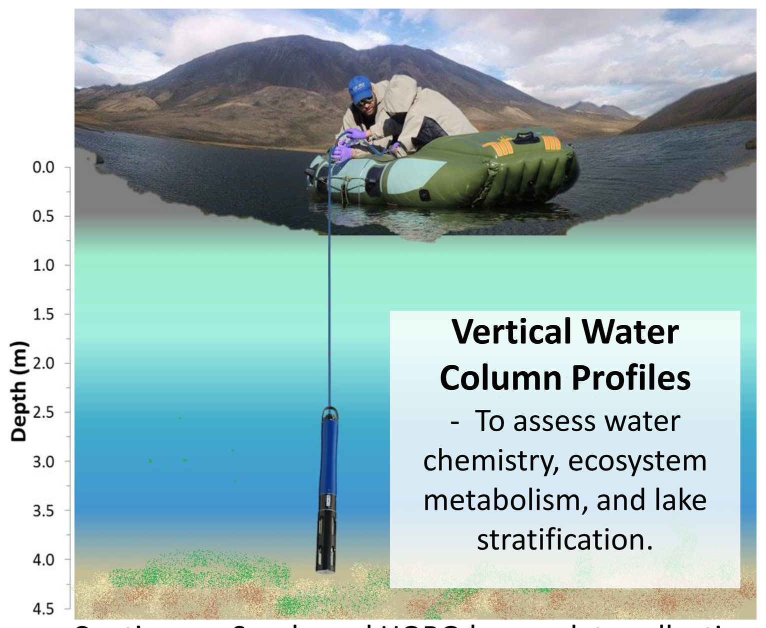
Methods

Summer 2016

- Surface water NPP was quantified by deploying a meteorological station raft.

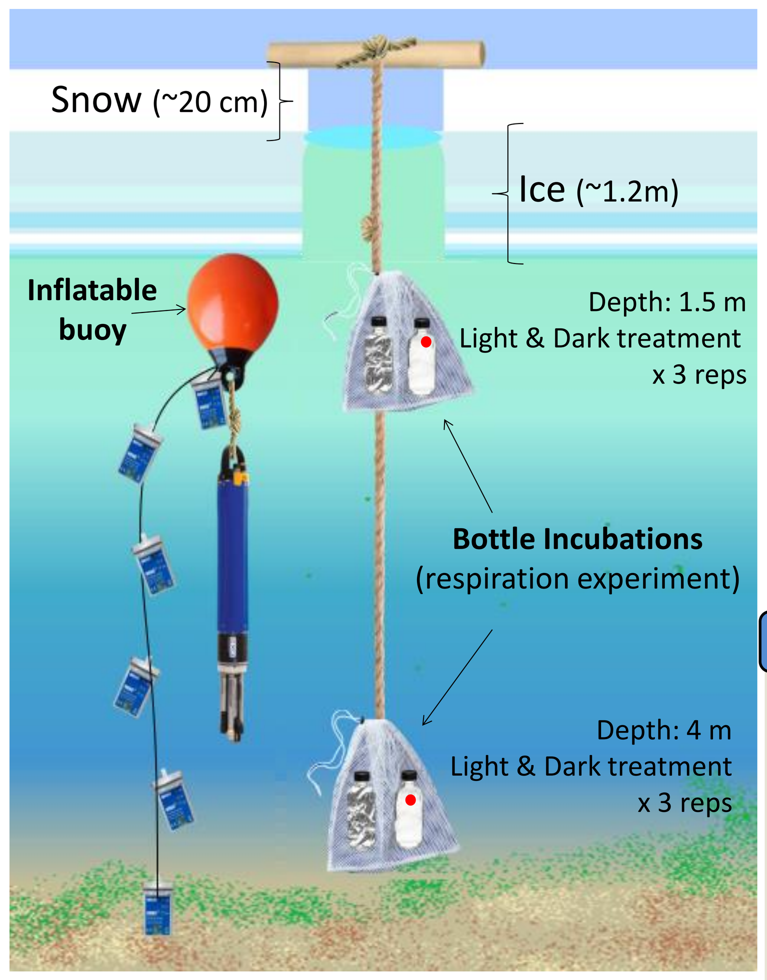
- Dissolved O_2 stable Isotopes ($\delta^{18}O$-O_2) are used to assess whole lake metabolism by separating changes in O_2 saturation due to temperature, and mixing from changes in metabolic activity.





Spring 2017

- Continuous Sonde and HOBO logger data collection
- Vertical Water Column Profiles
- Bottle incubation respiration experiment using Presens ® O_2 Sensor Spots



Preliminary Results: Summer 2016

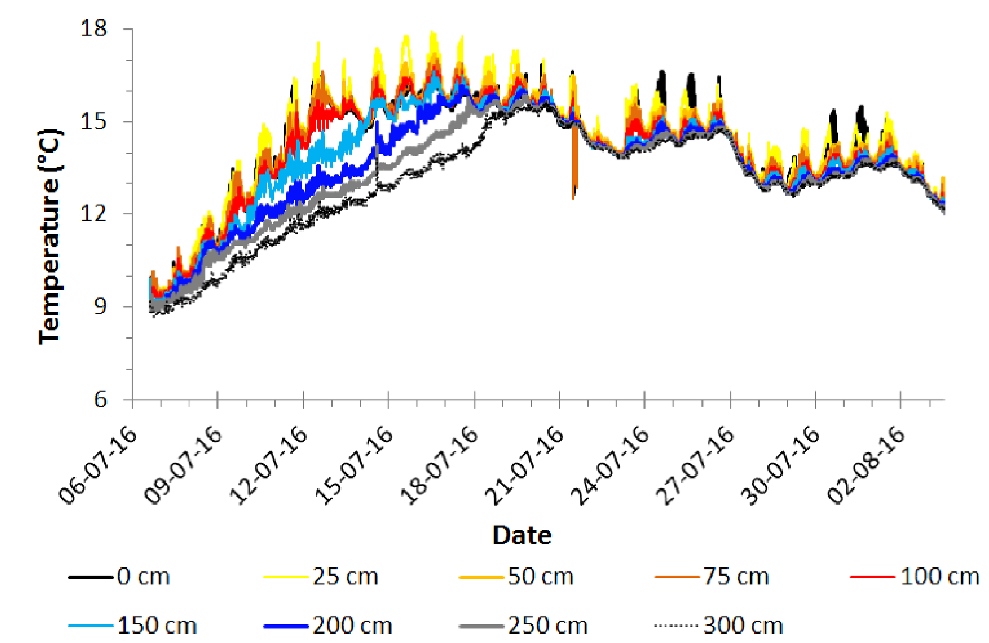


Figure 2: Summer 2016 continuous water column temperature data using HOBO® data loggers.

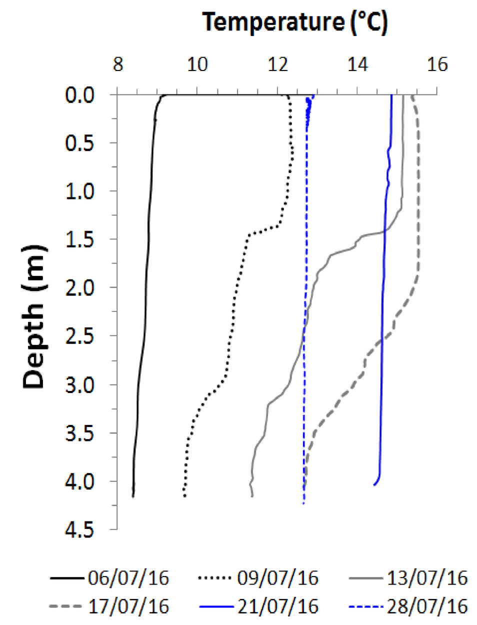


Figure 3: Summer 2016 temperature water column profiles

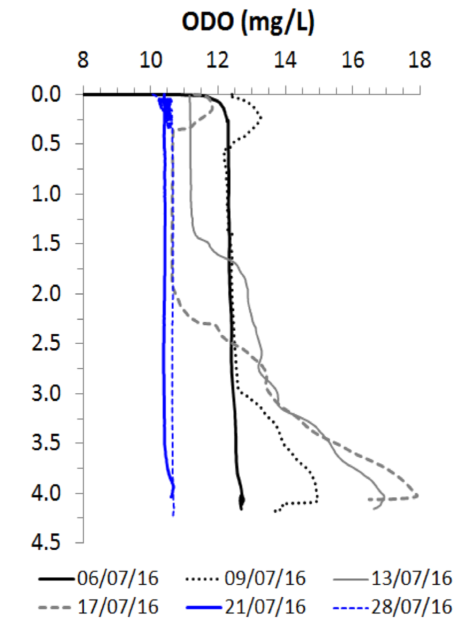


Figure 4: Dissolved oxygen water column profiles

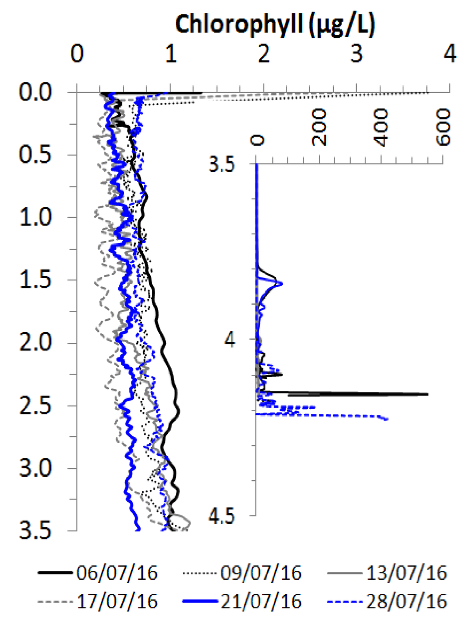


Figure 5: Chlorophyll-a water column profiles

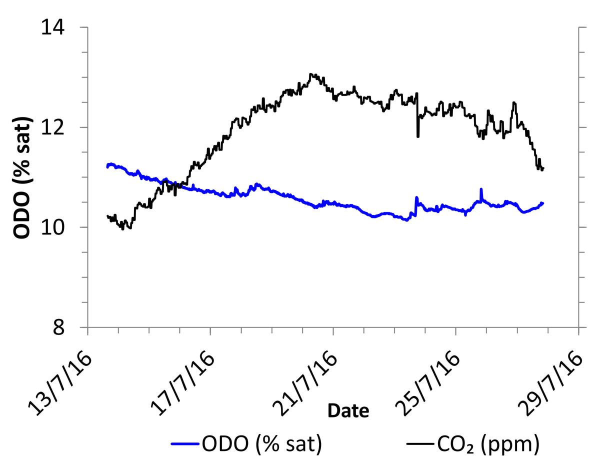


Figure 6: Continuous ODO (% sat) and CO_2 (ppm) concentration of surface waters.

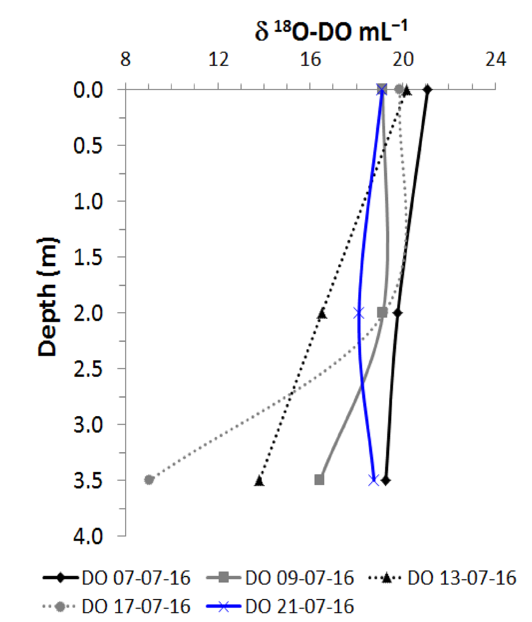


Figure 7: δ^{18}O-DO isotopic ratio over depth and time.

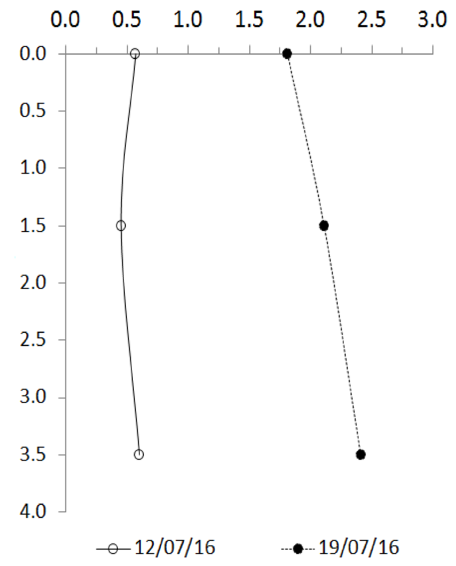


Figure 8: δ^{13}C-DIC isotopic ratio over depth and time.

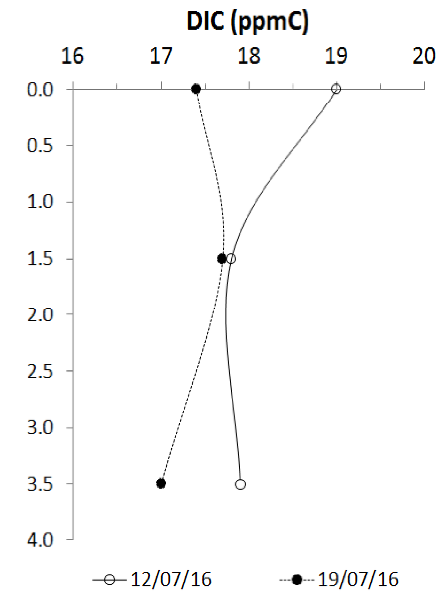


Figure 9: DIC (ppmC) concentration over depth and time

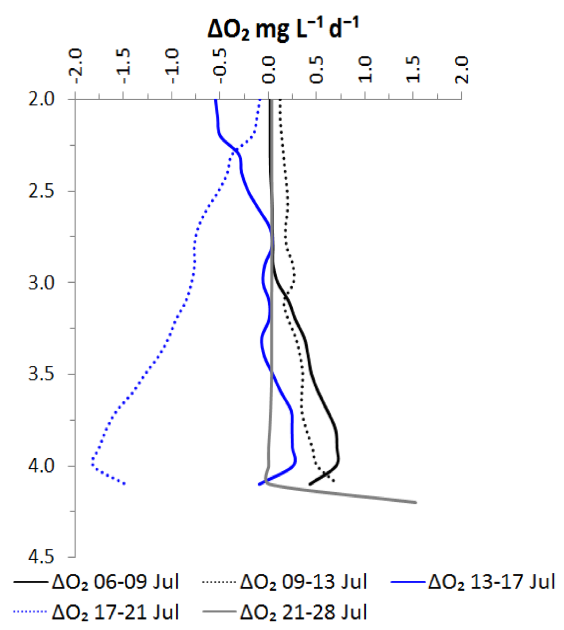


Figure 10: ΔO_2 (mg L^{-1} d^{-1}) between water column profiles within the hypolimnion.

Preliminary Results: Spring 2017

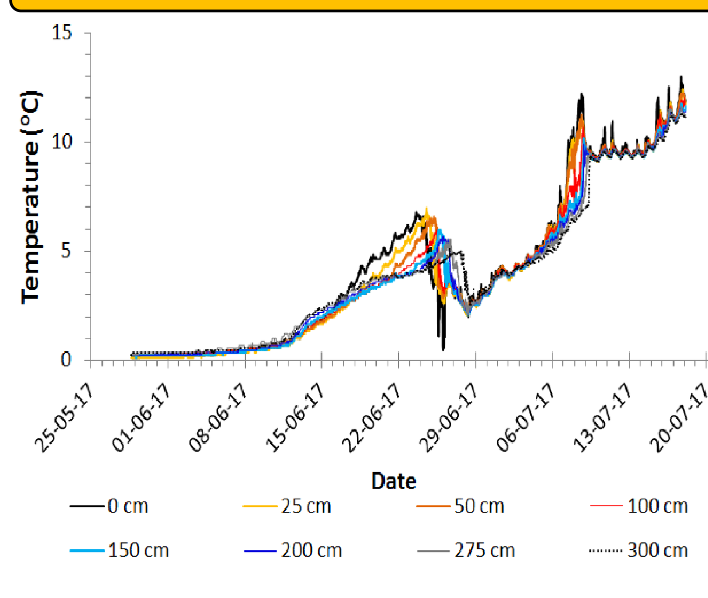


Figure 11: Spring 2017 continuous water column temperature data using HOBO® data loggers. Ice breakup occurs from 18-24 June, and total ice-off occurs on 29-June.

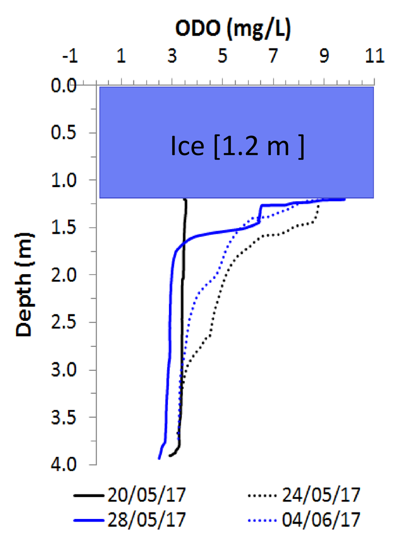


Figure 12: Dissolved oxygen water column profiles beneath the ice.

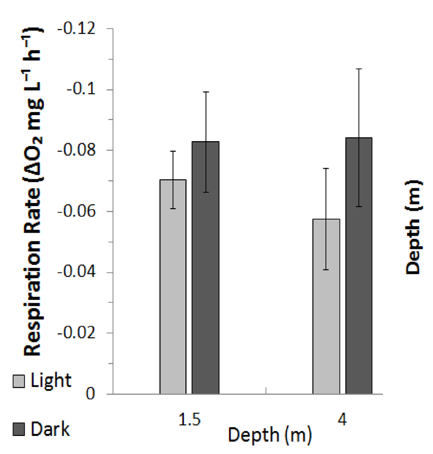


Figure 13: Water column respiration incubation using light and dark treatments for determination of photosynthesis and respiration beneath the ice.

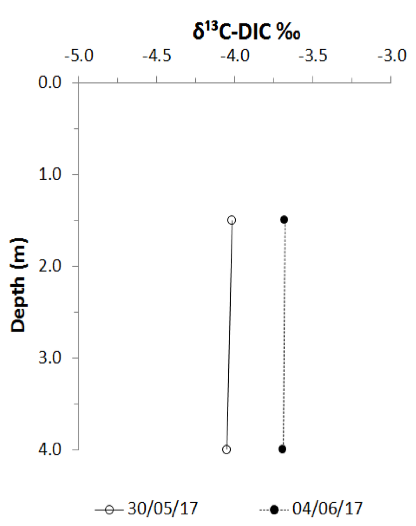


Figure 14: δ^{13}C-DIC isotopic ratio over depth and time.

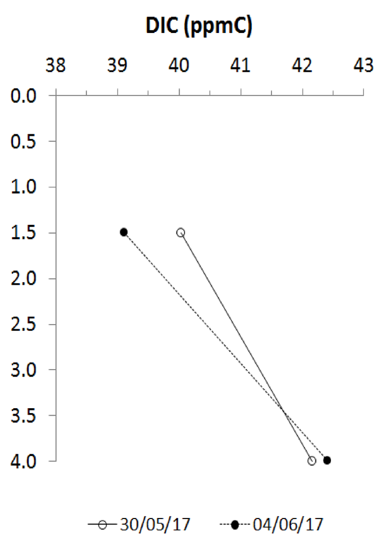


Figure 15: DIC (ppmC) concentration over depth and time.

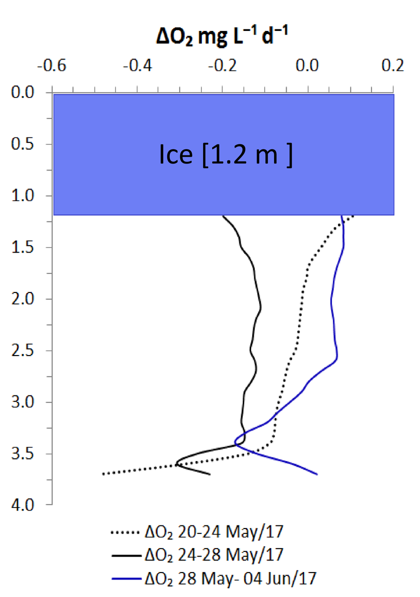


Figure 16: ΔO_2 (mg L^{-1} d^{-1}) between water column profiles beneath the ice.

Discussion and Observations

- During **Summer 2016**, Skeleton Lake is well mixed on 6-July, as indicated by the black solid line in **Figure 3.** Stratification of the lake occurs between 6-17 July, as shown by the continuous temperature data and water column profiles (**Figures 2** and **3**).
- During this stratification period, there is a large increase in dissolved oxygen (DO) below the mixed layer due to NPP (**Figure 4**), with a net metabolic rate of 3.3 mg O_2 L^{-1} d^{-1}.
- The isotopic values δ^{18}O-DO becomes more depleted with depth (**Figure 7)**, indicating high rates of NPP.
- Most of the NPP occurs at the bottom of the lake. Benthic mosses play a large role in this process. **Figure 5** displays how chlorophyll-a significantly increases around 4 m depth until the bottom of the lake.
- Net oxygen metabolism within Skeleton Lake's total hypolimnion volume during the stratified period resulted in the production of 1,196,305.9 mg O_2.
- During the **Spring 2017** season, ice breakup is observed between 18-24 June in **Figure 11.** The open water season commences on 29-June.
- Prior to ice break up in Spring 2017, Skeleton Lake's total water column volume beneath the ice consumed 466,112.0 mg O_2 between 20-May and 4-June.
- This translates to a below ice respiration rate of 1.22 mg O_2 L^{-1} d^{-1} during that same period.
- DIC (ppmC) concentrations are higher under the ice (**Figure 15**), while DO concentrations are depleted **(Figure 12).** Compared with the summer values (**Figure 8** and **9**), there is a lower δ^{13}C-DIC value due to organic matter respiration.

Acknowledgements

ArcticNet ᐊᒃᑎᒃᓀᑦ

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References

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