Characterizing and Monitoring the Water Properties and Dynamics of Lhù'ààn Mā̄n (Kluane Lake), Yukon, in the Face of Climate Change

by Ellorie McKnight

INTRODUCTION

CLIMATE CHANGE AMPLIFICATION in the Arctic is increasing the impacts on both terrestrial and aquatic systems in northern regions (Serreze and Barry, 2011; Vincent et al., 2011). The impacts on large lakes are of particular interest: these waterbodies hold a significant portion of the North's freshwater, provide habitat and travel corridors for many species, regulate hydrological processes and local climate, and have significant cultural value (Evans, 2000; Rouse et al., 2005; Vincent et al., 2011; Cott et al., 2016; Reist et al., 2016). Studies have shown that these large lakes are sensitive to incremental and cumulative climatic changes and that small shifts in physical, chemical, and biological water properties may have significant consequences for surrounding ecosystems and communities (Magnuson et al., 2000; Smol et al., 2005; Rosenzweig et al., 2007; Adrian et al., 2009; Heino et al., 2009; Mueller et al., 2009; Schindler, 2009). For example, increasing air temperatures may cause longer open-water seasons and increased water temperatures, which affect oxygen availability, productivity, and habitat for aquatic species (Vincent, 2009; Prowse et al., 2011). Glacier-influenced systems are also susceptible following changes in the contribution of glacial meltwater to headwater lakes (Shugar et al., 2017).

Despite rapid change in the North, as well as the general importance of these large lake systems to ecosystems, climate, and communities, scientific knowledge of the dynamics and water properties of these systems is still limited (Evans, 2000; Cott et al., 2016; Reist et al., 2016). Baseline studies, a better understanding of general lake dynamics, and consistent monitoring are needed in order to investigate how climate change may be affecting large northern lakes.

Yukon is home to many large lakes, the largest being Lhù'ààn Mā̄n (Kluane Lake), located in the southwest of the territory at the foot of the St Elias Mountains (Fig. 1). Lhù'ààn Mā̄n lies within the traditional territories of the Kluane First Nation and White River First Nation and borders those of the Champagne and Aishihik First Nations. The lake is important to local communities for fishing, cultural activities, and travel. Lhù'ààn Mā̄n also provides an excellent case study for assessing the potential impacts of climate change on the properties of large northern lake systems. The southwest Yukon has experienced significant warming over the past few decades, which has resulted in changes to the surrounding vegetation (Danby et al., 2011; Myers-Smith and Hik, 2017) and cryosphere (including snowcover, permafrost degradation and glacier recession

FIG. 1. Location of Lhù'ààn Mā̄n (Kluane Lake), Yukon Territory, Canada.

(Bonnaventure and Lewkowicz, 2011; Flowers et al., 2014; Bokhorst et al., 2016) with inevitable consequences for the hydrosphere (Streicker, 2016). As is true for many other large northern lakes, historical scientific data for Lhù'ààn Mā̄n is limited: some temperature profiles were collected in the 1980s by Dr. Eddy Carmack (pers. comm. 2014), and limited point sampling has been completed by the Fish and Wildlife Branch, Government of Yukon, during routine fish surveys (Barker et al., 2014), as well as by university-based researchers (Crookshanks and Gilbert, 2008). Over the course of 2013–14, Dr. David Hik and I met several times with representatives of the Kluane First Nation (KFN), the Dän Keyi Renewable Resources Council (DKRRC), and local community members to identify common research interests. One of these was to investigate how climate change may be affecting the water properties of Lhù'ààn Mā̄n.

Given the current and historical lack of scientific water property data, our first objective was to conduct a

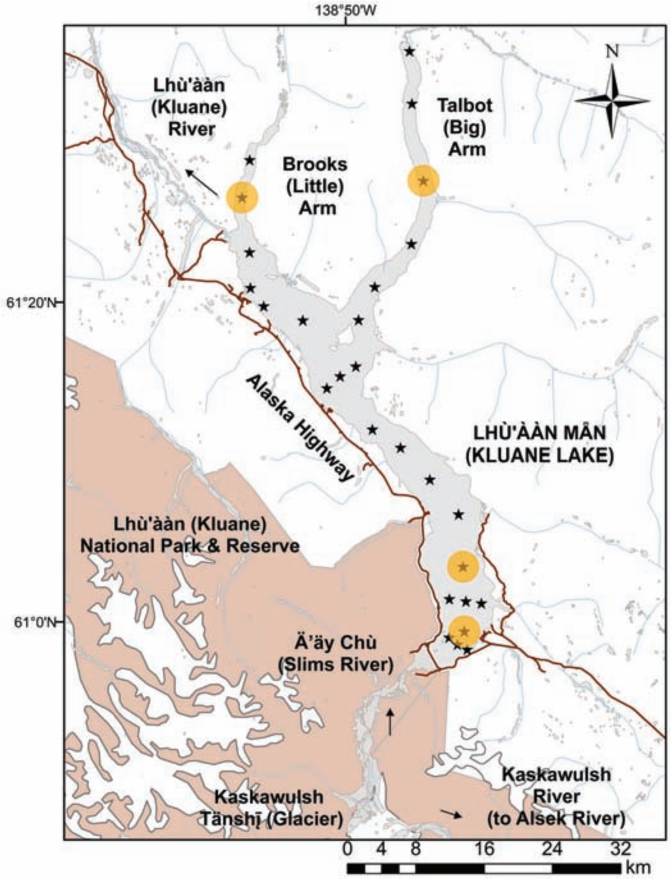

FIG. 2. Sampling locations for 2015 baseline data collection (indicated by stars) and long-term mooring locations (indicated by circles and deployed in April 2017) at Lhù'ààn Mā̀n.

comprehensive baseline study to characterize the physical, chemical, and biological water properties of Lhù'ààn Mā̀n. This study was conducted throughout 2015 and was accomplished by collecting data and water samples from various sampling sites across the lake. Data from the baseline study were subsequently used to identify longer-term monitoring sites that were representative of distinctive ecozones within the lake. In 2016, this project received funding from the DKRRC and support from KFN to construct and deploy four moorings in Lhù'ààn Mā̀n, one in each of the identified ecozones of the lake. Each mooring was equipped with continuously recording temperature and conductivity loggers.

This research also coincided with a drastic reduction in flow of the Ä'äy Chù (Slims River; Lhu'aan Mā̀n's primary inflow) in May 2016 (Shugar et al. 2017). The Kaskawulsh Glacier meltwater had fed both the Ä'äy Chù and the Kaskawulsh River until recession and terminus changes resulting from climate change reached a critical point in 2016, causing the glacier's meltwater to flow entirely into the Kaskwulsh River. The Ä'äy Chù now comprises only tributary waters. The significant decrease of water flowing into Lhù'ààn Mā̀n from the Ä'äy Chù valley in turn produced the lowest lake water levels recorded since

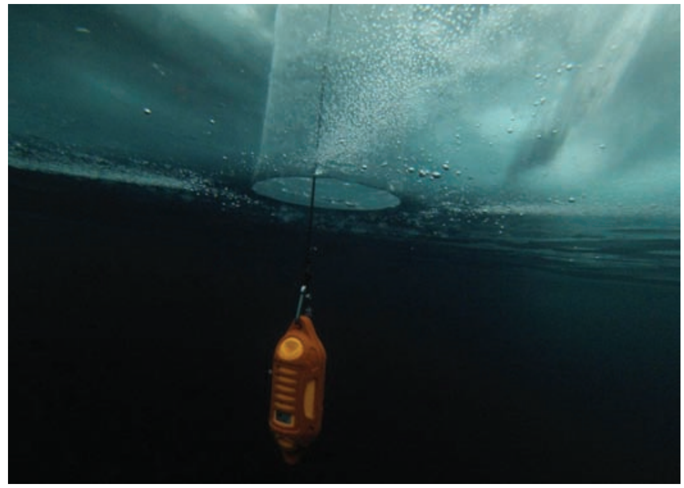

FIG. 3. Castaway CTD instrument being deployed through the ice at Lhù'ààn Mā̀n.

1952, when regular record-keeping began (historical lake level data available from Environment and Climate Change Canada at https://wateroffice.ec.gc.ca). The full impact on the lake's water properties of this significant reduction of cold, silty water inflowing to Lhù'ààn Mā̀n is unknown. However, the 2015 baseline study provides a unique record of the lake's water properties before the change in flow, and the moorings have been providing post-change thermal and conductivity data for the lake since their deployment in spring 2017. If Ä'äy Chù flow remains low, and once lake water properties stabilize, it may be possible to use the 2015 baseline study and the mooring data to investigate how this change has affected the thermal and conductivity dynamics of the lake.

RESEARCH METHODS

2015 Comprehensive Baseline

During the meetings and conversations held with the KFN and the DKRRC, we identified 28 sampling sites throughout Lhù'ààn Mā̀n in the fall of 2014 (Fig. 2). These sites were visited at least once per season during 2015 (depending on weather), starting in February. A combination of sondes was deployed, and water samples were collected at each site both through the ice and multiple times during the open-water season. Data on physical (water temperatures, turbidity, isotopes), chemical (oxygen, pH, conductivity, total nitrogen and phosphorous, dissolved organic carbon), and biological (total photosynthetic pigments including chlorophyll a) water properties were collected using a Castaway conductivity, temperature and depth (CTD) instrument (Fig. 3), an RBR multi-channel sonde, a Hydrolab DS5 sonde, and water samples (analyzed by the University of Alberta Biogeochemical Analytical Services Laboratory). Photosynthetic pigments were determined using high-performance-liquid

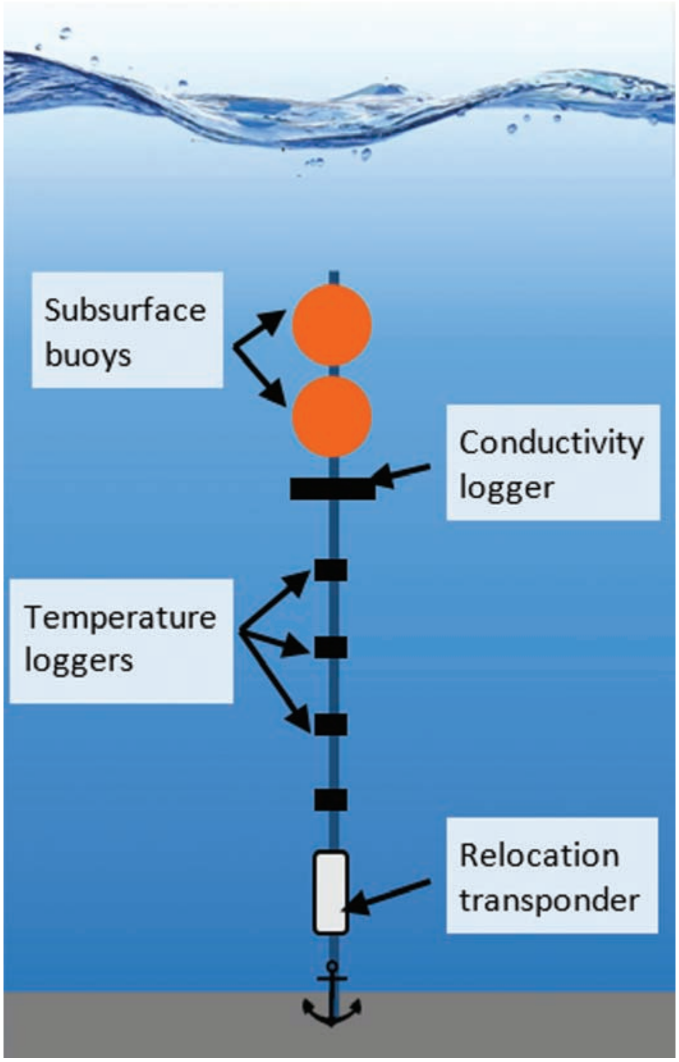

FIG. 4. The moorings in Lhù'ààn Mān̄ are equipped with subsurface buoys, a near-surface HOBO U24 conductivity logger, HOBO Tidbit temperature loggers (every 2–5 m throughout the water column), and a SubSea Sonic Accoustic Release unit used as a relocating transponder.

chromatography. Isotopes were processed at the BIOTRON Institute for Experimental Climate Change Research (Western University).

Long-term Moorings

Four moorings (Brooks Arm [8 m], Talbot Arm [35 m], Deep [72 m], and Slims [40 m]) (for locations see Fig. 2) were designed and constructed with the support of the Dän Keyi Renewable Resources Council Accumulated Surplus Fund and the Department of Fisheries and Oceans (Mike Dempsey and Eddy Carmack). The moorings are equipped with HOBO Tidbit Temperature loggers (located every 2–5 m throughout the water column, logging every hour), and a HOBO U24 Conductivity logger (located near the surface, logging every 2 hours) (Figs. 4–6). The tops of the moorings are located approximately 2 m below the

FIG. 5. HOBO Tidbit temperature dataloggers ready to be mounted on the mooring line.

FIG. 6. Checking the moorings and downloading data during the open-water season. Photo credit: Lance Goodwin.

surface of the water so as to eliminate disturbance by ice and minimize drag or pull from wind and waves during the open-water season. We find the moorings again by GPS locations and using SubSea Sonic Accoustic Releases as transponders. The moorings were built and the loggers programmed to collect data for up to five years.

RESULTS

2015 Comprehensive Baseline

The 2015 data were used to characterize the physical, chemical, and biological water properties and dynamics of Lhù'ààn Mān̄ prior to the change in flow of the Ä'äy Chù. Lhù'ààn Mān̄ was a unique and diverse large northern lake system with a cold, deep southern basin and two warmer, shallower northern arms. During the open-water season, the southern basin was heavily influenced by the extremely turbid and cold waters of the Ä'äy Chù: surface water temperatures in the southern part of the lake did not exceed 12˚C, with minimal stratification occurring throughout the water column even during the warmest months. Surface temperatures in the Brooks Arm reached up to 17˚C in late summer 2015, and no stratification was observed because of the arm's shallowness. A gradient of surface temperatures between these two maximum values was observed from the southern to the northern end of the lake, with distinct stratification occurring throughout the water column closer to the center of the lake, as well as in Talbot Arm. In winter and under ice, without the inflow of turbid glacial meltwater, turbidity levels were low throughout the lake, and temperatures were consistent between 0˚C and −1˚C near the surface (just under the ice), while approaching 4˚C at lake bottom in most locations. In winter, specific conductivity values ranged from ~260 to 320 μS cm depending on location (values were highest in the Brooks Arm and lowest in Talbot Arm), whereas summer conductivity values ranged from ~230 to 260 μS/cm, with highest values found in the main body of the lake and Talbot Arm and lowest values in the Brooks Arm. Lhù'ààn Mān̄ was well-oxygenated (≥ 95% dissolved oxygen) throughout the water column and at all times of the year in 2015, with slightly lower values (92% dissolved oxygen) in the Brooks Arm during midsummer. Total photosynthetic pigment values were low and ranged between 0.1 μg/L in the south end to 1.75 μg/L in the Brooks Arm. Total nitrogen and phosphorous values were also highest in the Brooks Arm (~200 μg/L and ~8 μg/L respectively, midsummer values) (E. McKnight and D. Hik, unpubl. data).

Long-term Moorings

The four long-term moorings were deployed through the ice in April. We visited each mooring, downloaded data from the loggers, and redeployed the moorings in both June and October 2017. This first dataset from the moorings will provide detailed information on the annual thermal dynamics of Lhù'ààn Mān̄, including data collected during spring breakup, when temperatures are notoriously difficult to measure. Over the longer term, these data will be used to determine whether and how the thermal properties and dynamics of Lhù'ààn Mān̄ may be changing in relation to warming air temperatures, longer open-water seasons, and the shift in the Ä'äy Chù.

SIGNIFICANCE

Warming air temperatures due to climate change are having impacts on both terrestrial and aquatic systems in the North. Glaciers are receding, permafrost is degrading, and changes in both vegetation and animal ecology are increasingly evident. The impacts of warming on freshwater systems in the North are difficult to quantify, in part because we lack historical and baseline data, but also because these systems are often complex and logistically difficult to study. However, the potential impacts of warming on freshwater systems, and particularly large lakes in the North, may have far-reaching consequences. Water temperature plays a fundamental role in the ecology and dynamics of lake systems. With longer open-water seasons and warmer air temperatures, warmer lake surface waters and deeper thermoclines could reduce habitat for certain species, but provide more suitable habitat for other species. Shifts in thermal dynamics could also influence nutrient and oxygen availability and affect the productivity of these systems. Establishing reliable baselines and continued long-term monitoring of basic water properties in large northern lake systems are critical steps towards understanding how these lakes may be changing, as well as shaping adaptation strategies and policies to ensure their sustainability.

Lhù'ààn Mān̄ is a unique and interesting system in and of itself, and the 2015 baseline data collection has allowed for an analysis of the basic water properties of the lake and a better understanding of the lake's physical, chemical, and biological dynamics, contributing to our general knowledge of large northern lake systems. The impacts of climate change (from both incremental change and more dramatic events, such as the change in flow of the Ä'äy Chù) make Lhù'ààn Mān̄ a particularly interesting case study. By combining data from the 2015 baseline study, mooring data, and future research, it will be possible to investigate how flow reduction from the Ä'äy Chù and lowered lake levels will affect the water properties (particularly thermal dynamics) of Lhù'ààn Mān̄.

Many environmental, logistical, and historical/cultural challenges are present when conducting research in remote northern areas, including large northern lake systems. Collaborating with local communities, First Nations, local governments, and other community groups, councils, and citizens builds relationships and trust between researchers and communities, creates space and opportunity for valuable dialogue and information exchange, and is critical to successful data collection, analysis, understanding, and use in decision-making. The collaborations with the Kluane First Nation, the Dän Keyi Renewable Resources Council, and various community members and entities have been paramount to every step of this research.

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Ellorie McKnight is the recipient of the 2017 Lorraine Allison Scholarship. She is currently a doctoral student in Biological Sciences at the University of Alberta.
E-mail: ellorie@ualberta.ca