Year-Round Hydrologic Monitoring of Subalpine Lakes in Great Basin National Park

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Introduction

Lakes have many characteristics that make them excellent ecosystems for monitoring long-term changes, such as climate change (Adrian et al. 2009). They integrate landscape and atmospheric changes, and are responsive to environmental changes (Williamson et al. 2008). In the case of high-elevation lakes in protected areas, few confounding factors are present, due to limited anthropogenic stressors (Figure 1). Lakes are also excellent at storing information about past climate conditions. Lake sediment studies show that sub-alpine lakes in the western U.S. have had numerous temperature fluctuations over the past 7000 years (Reinemann et al. 2009; Porinchu et al. 2010).

The National Park Service (NPS) Inventory and Monitoring (I&M) program is charged with developing a long-term monitoring program for elements of national parks that are considered vital. The Mojave Desert Network I&M program includes Great Basin National Park. One of the goals of the Streams and Lakes protocol is to monitor lake levels, water temperatures, and the length of the ice-covered period, and determine trends for these parameters.

Six sub-alpine lakes, at elevations ranging from 2915 m to 3292 m, are located within Great Basin National Park (Figure 2). All are relatively small, with volumes ranging from 600 m^3 to 15,000 m^3, and with maximum depth running up to 4.9 m. Four of these lakes nearly freeze solid during the winter (Metcalf et al. 1989).

Methods

In order to record lake temperature and pressure, HOBO U-20 data loggers were installed in four

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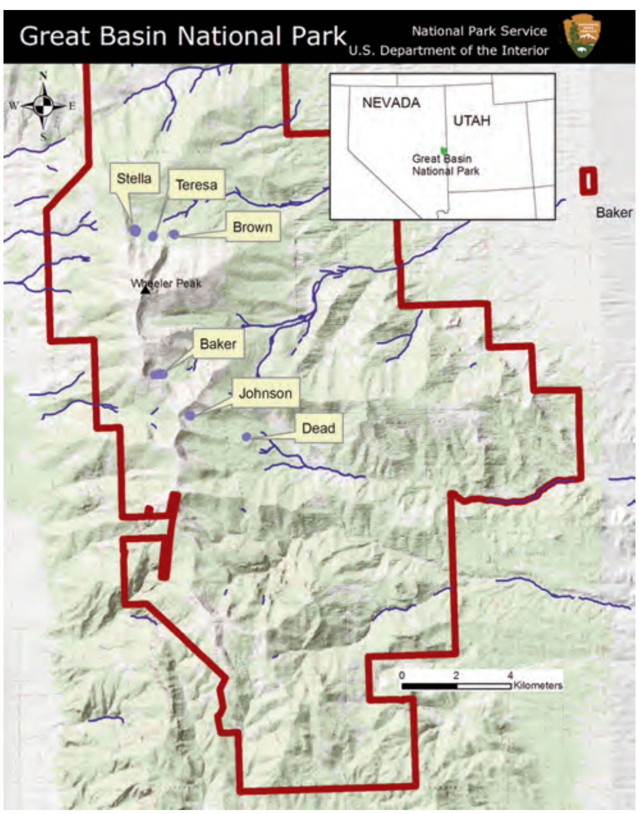


Figure 1 (above). Stella Lake, Great Basin National Park. This sub-alpine lake is protected from many anthropogenic effects, thus making it an ideal study location for climate change. NPS Photo.

Figure 2 (left). Location of six sub-alpine lakes in Great Basin National Park.

lakes in 2009, Baker, Johnson, Stella, and Teresa. The pressure of the water above the data logger was comparable to the depth of water above the logger. Data loggers in Baker and Johnson lakes were programmed to record data twice daily, at midnight and noon. Data loggers in Stella and Teresa lakes were programmed to record at 15-minute intervals.

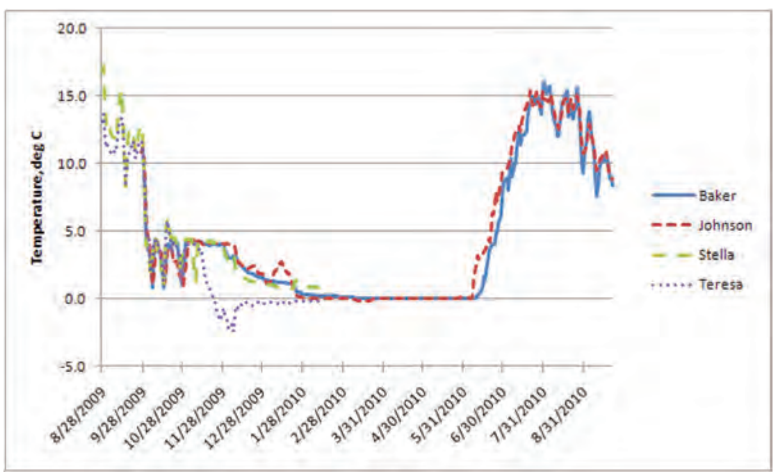
Data loggers were placed in PVC stilling wells attached to steel fence posts, and secured to the lake bottom in water approximately one meter deep, which approximated the deepest a crewmember could install a data logger without submerging him- or herself. Additional data loggers were placed in trees near the lake shore as controls, to account for barometric pressure changes, as recommended by the manufacturer. The location of the data logger was determined using GPS and surveyed using the line level method (Hoffman et al. 2005). The area was sketched, and water quality was measured.

Data loggers were retrieved in September 2010, when water levels were near minimum, but access to the lakes did not require any special equipment. The data was downloaded using Hoboware software, and then exported to Excel for analysis.

Results

Water temperature and water levels. Data loggers at Baker and Johnson lakes recorded data for almost an entire year, while the data loggers at Stella and Teresa lakes stopped recording February 13, 2010, due to a full memory. The data show that water temperatures varied significantly over the course of the year (Figure 3).

Figure 3. Water temperatures in four sub-alpine lakes.



Daily average water levels were similar for both Johnson and Baker Lakes. Maximum water levels occurred in early June for both, with minimums in November and December. Water temperatures were similar for all three lakes (Table 1). The daily maximum temperature occurred in late July and August for Baker and Johnson lakes. Minimum daily temperatures for the year, based on the available data, occurred from December (Teresa Lake) to April (Baker Lake). Seasonality influenced the diurnal temperature ranges. During the winter, when the sensor was likely frozen, the temperature ranges varied the least.

Table 1. Water temperature and water level averages and ranges for four sub-alpine lakes. Note that the data for Baker and Johnson lakes span nearly one year; for Stella and Teresa lakes it spans 5.5 months.

Lake	Dates of Record	Average Temp (°F)	Temp Range (°F)	Average Water Level (ft)	Water-Level Range (ft)	Ice-covered Days
Baker	9/26/09–9/23/10	39.3	27.9	3	3.8	201
Johnson	9/26/09–9/22/10	39.8	28.9	3.3	4.8	199
Stella	8/27/09–2/13/09	40.0	29.7	1.9	1.5	na
Teresa	8/27/09–2/13/09	37.4	28.9	4.6	14.3	na

Ice-out and ice-over. Ice-out (absence of ice on the lake) was determined for both Baker and Johnson lakes by looking at water levels, which rapidly changed from near-constant levels to increasing values in early summer. Ice-out was on or about 5/31/2010 on Johnson Lake, and 6/2/2010 on Baker Lake. Water temperatures lagged 5–7 days to show an increase from near-freezing to above-freezing.

Ice-over (presence of ice over the entire lake) when the entire lake is was more difficult to determine. Large temperature drops occurred at the end of September and the end of October, likely causing periodic freezing on the lakes. Subsequent water and air temperatures were above freezing. Complete ice-over for the year was determined by noting a decrease in daily temperature variation. This occurred on all four lakes on or about November 13, 2009.

Discussion

Over the past 150 years, ice-over dates in Northern Hemisphere lakes and rivers have averaged 5.8 days per 100 years later, and ice-out dates have averaged 6.5 days per 100 years earlier (Magnuson et al. 2000). Although the period of ice-cover on Great Basin National Park lakes currently exceeds six months, it is likely to change. An increase in the ice-free period on the lakes may alter aquatic food webs by changing seasonal timing of predator-prey relationships (Winder and Schindler 2004) and increasing primary production (Regier et al. 1990) due to accelerated warming of the open water in comparison to snow and ice (Williamson et al. 2008).

Ice-out and ice-over dates have been found to be closely correlated with air temperatures one to two months beforehand (Livingstone 1997). Further studies will examine temperatures and LANDSAT imagery to compare how park lakes compare. Additional methods may be employed to better detect ice-over and ice-out, including strings of data loggers suspended in the lakes and remote cameras.

Although the data loggers in Stella and Teresa lakes did not provide a full year's data, the 15-minute-interval data they recorded was analyzed to determine the optimum sampling frequency. We recommend a minimum sampling frequency of two hours, because longer sampling intervals resulted in changes to estimated daily mean temperature.

Current predictions of climate change are for warmer temperatures, which will result in earlier snow pack disappearance, greatly affecting the hydrology of these lakes. Long-term, year-round monitoring will help detect these changes, and determine how they affect water chemistry and biological communities.

Acknowledgements

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