Climate change in Great Basin National Park: Lake sediment and sensor-based studies

By Scott A. Reinemann, Nathan A. Patrick, Gretchen M. Baker, David F. Porinchu, Bryan G. Mark, Jason E. Box

Researchers collect a sediment core at Stella Lake in August 2007.

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Abstract

Alpine and subalpine aquatic ecosystems are highly susceptible to direct and indirect effects of climate change, making them ideal study sites. We recovered a sediment core spanning the last 7,000 years from Stella Lake and a core of the last 100 years from Baker Lake in Great Basin National Park, Nevada, in 2005 and 2007. We examined the cores for subfossil chironomid (Insecta: Diptera: Chironomidae; i.e., midge) remains. The midge communities in the lakes underwent little compositional change through much of the 20th century; however, after 1980 a rapid lake-specific faunal turnover was observed. Because of limited dispersal ability and restricted habitats, some lake species will be extirpated by climate change. Fortunately, lake cores show that even during the most arid periods the lakes did not completely desiccate, but continued to support lake biological communities. To complement the limnological work, an air temperature and humidity micrologger network was deployed in 2005 and expanded in subsequent years, now numbering 36 instruments. The sensor network that spans the full park elevation range (1,639–3,892 m/5,377–13,063 ft) indicates coherent seasonal and elevational variations, which help to interpret the paleolimnology data. Climate models indicate increasing temperatures and uncertain change in precipitation for the Great Basin region. Although we may not be able to protect all ecosystems faced with climate change, our collaborative educational research project exemplifies how the National Park Service is equipped to document and interpret climate change.

Key words

aquatic ecosystems, climate change, paleolimnology, temperature network

WITH RECOGNITION THAT HIGH-ELEVATION ENVI-ronments are highly responsive to changes in temperature and precipitation, it is critical that we improve our understanding of how global climate change will affect freshwater resources and aquatic ecosystems in subalpine and alpine environments (Bradley et al. 2004; Parker et al. 2008). Further, the concern over changing water availability in the Intermountain West adds merit to alpine research. Improving our knowledge of the characteristics and behavior of aquatic ecosystems in alpine environments will strengthen our ability to develop meaningful adaptation strategies and scenarios describing the potential future response of these freshwater systems to projected climate change. Insight will also improve our ability to effectively manage these natural systems and the freshwater resources they contain (Adrian et al. 2009).

Lakes in Great Basin National Park are ideal for studying both past and future changes because of their protected status and relative lack of direct human influence. Paleolimnology is an excellent tool to study past changes by extracting information preserved in lake sediment records. In this way we can study the past distribution of aquatic fauna in high-elevation lakes and establish baseline conditions against which the effects of projected warming in these regions can be evaluated. In addition, paleolimnology can be used to assess how the biotic and abiotic components of aquatic ecosystems have responded to anthropogenic and natural stressors (Fenn et al. 2003; Parker et al. 2008).

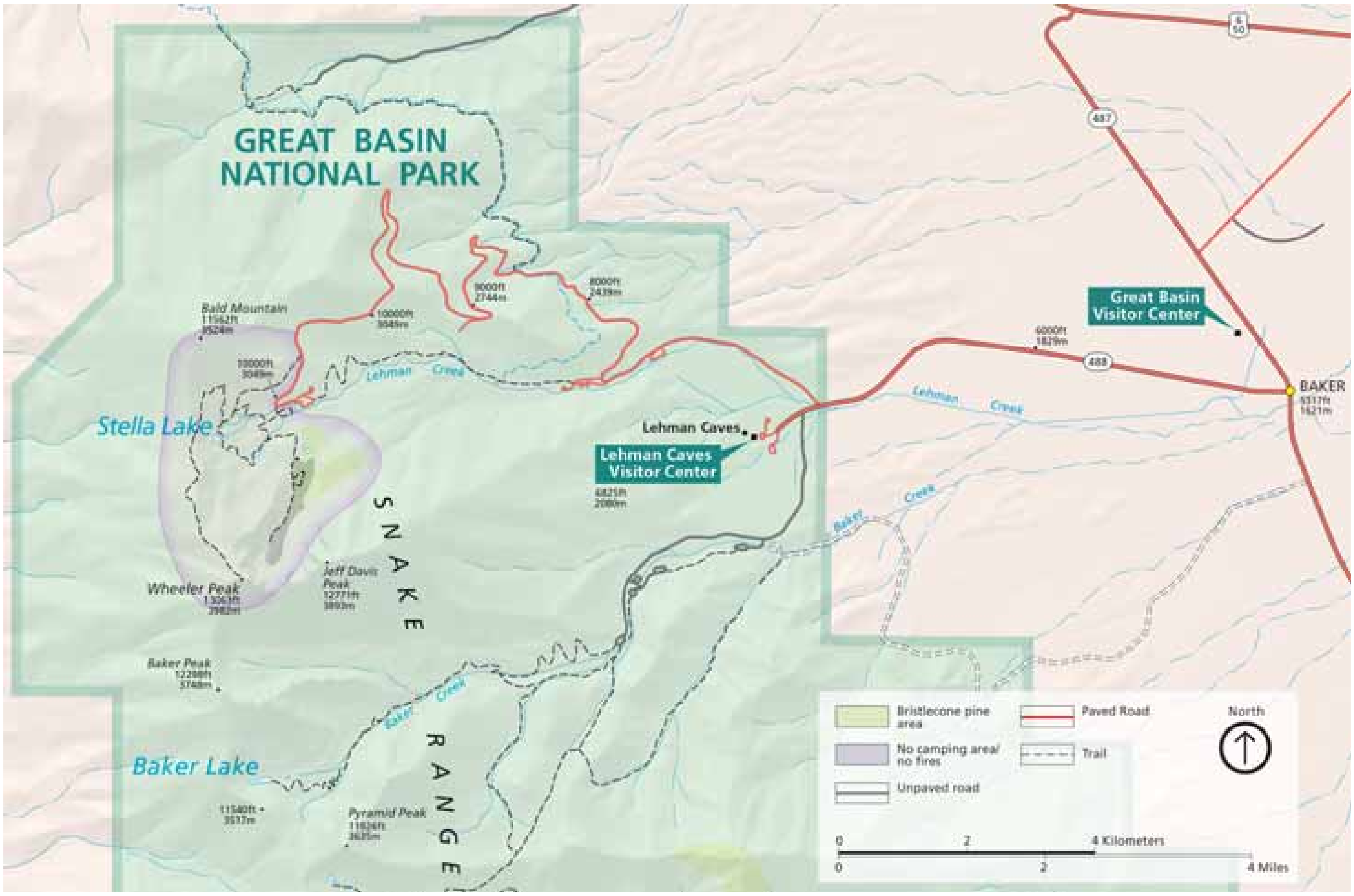

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Figure 1. Lake cores were taken from Baker and Stella lakes, located in and near glacial cirques in Great Basin National Park. The park is situated in east-central Nevada.

We have initiated a collaborative research project to assess climate change in Great Basin National Park, Nevada, using paleolimnology and direct climate observations. Using remains of lake midges (insects in the order Diptera, family Chironomidae) that are preserved in the lake sediments as a proxy for temperature, we have been able to describe variability in the park climate over almost 7,000 years. We also have deployed a network of climate microloggers to complement the limnological work and better characterize current lake-specific climate conditions for comparison with today's midge communities and the longer lake core records.

Study methods

Using a mini-Glew and modified Livingstone corer, we recovered sediment cores from Stella Lake in August 2005 and Stella and Baker lakes in August 2007 (fig. 1 and photo, previous page). We measured limnological variables, such as surface water temperature, Secchi depth (turbidity), maximum depth, dissolved oxygen, salinity, and specific conductivity at the time of sediment collection using a multimeter probe (Porinchu et al. 2010).

We dated sediments using lead-210 (^{210}Pb) and carbon-14 (^{14}C). We analyzed 12 stratigraphic samples from each lake for ^{210}Pb content. Six ^{14}C dates, obtained from wood fragments or conifer needles, indicated that the core spans approximately the last 7,000 years (Reinemann et al. 2009).

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Figure 2. Jason Box installs a Lascar air temperature sensor.

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We subsampled the sediment cores in the laboratory for midge analysis. Identifications were based on published keys and an extensive reference collection of midge remains housed at The Ohio State University. The midge-based inference model for average July air temperature was developed for the Intermountain West using a weighted averaging partial least squares approach (Porinchu et al. 2010). The model allows us to create a modern temperature relationship between climate and associated midge communities. Applying this model to past midge communities, we infer average air temperatures during the associated time interval at Stella and Baker lakes.

We installed a micrologger network to record hourly observations of surface air temperature and humidity (fig. 2). The Lascar USB EL-2 sensors situated 1.3–2.0 m (4.3–6.6 ft) aboveground have specified accuracies of ±0.5°C (±0.9°F) and ±3% relative humidity.

Results

The Lascar sensor network spans the full park elevation range (1,639–3,982 m or 5,377–13,063 ft) and includes sensors located at Baker (3,214 m/10,545 ft), Brown (2,976 m/9,764 ft), Stella (3,123 m/10,247 ft), and Teresa (3,132 m/10,276 ft) lakes. We analyzed data from autumn 2006 to autumn 2010. Data recovery has been limited at the uppermost elevation at Wheeler Peak (3,982 m/13,063 ft) because of vandalism to the sensor. Throughout the park, annual air temperature ranges are extreme, approaching 50°C (90°F). The temperature ranges at the lakes were 40°C (72°F) or more. We find that temperature and humidity decrease with increasing elevation (fig. 3, next page). The rate of temperature decrease with elevation is commonly taken to be 6.5°C/km (3.57°F/1,000 ft) (Barry and Chorley 1992). In the park, we observe the lapse rate to vary seasonally from 4.40°C/km (2.41°F/1,000 ft) in winter to 7.05°C/km (3.87°F/1,000 ft) in summer. The moisture regime became less linear and more complicated above 3,000 m (9,843 ft).

The midge communities in the lakes experienced compositional change through much of the 20th century; however, the post-1980 lake-specific midge community turnover is notable because of accelerated changes (Porinchu et al. 2010). The recently deposited sediment (last 10 years or so) in Baker Lake is characterized by decreases in relative abundance of three genera, the local extirpation of one genus, and an increase in the proportion of three taxa or organisms. The Stella Lake midge community shifted after 1990 from a community dominated by two genera to a single taxon. A similar degree of change in the Stella Lake midge community occurred approximately 1,000 years ago, during the Medieval Climatic Anomaly (MCA; AD 900–1300).

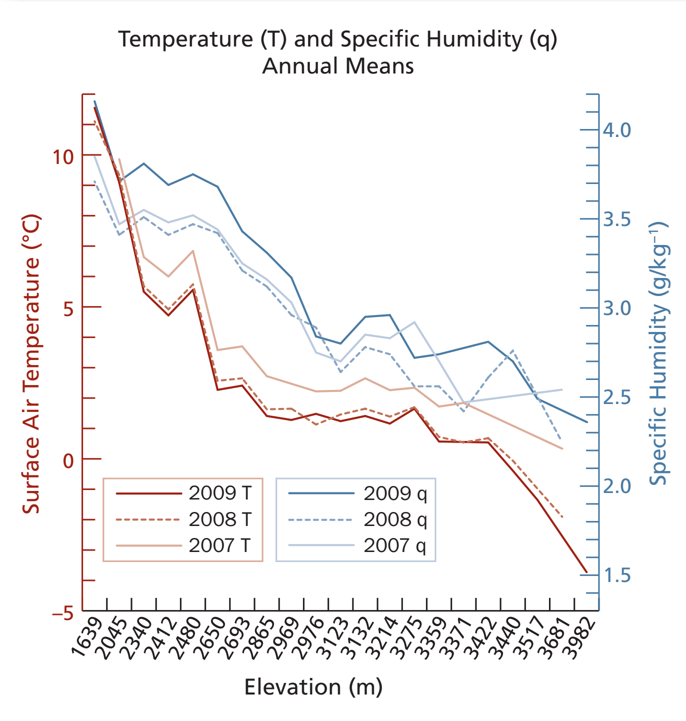

Figure 3 (above). Annual mean values of Lascar-recorded temperature and specific humidity from different elevations in the park in 2007–2009.

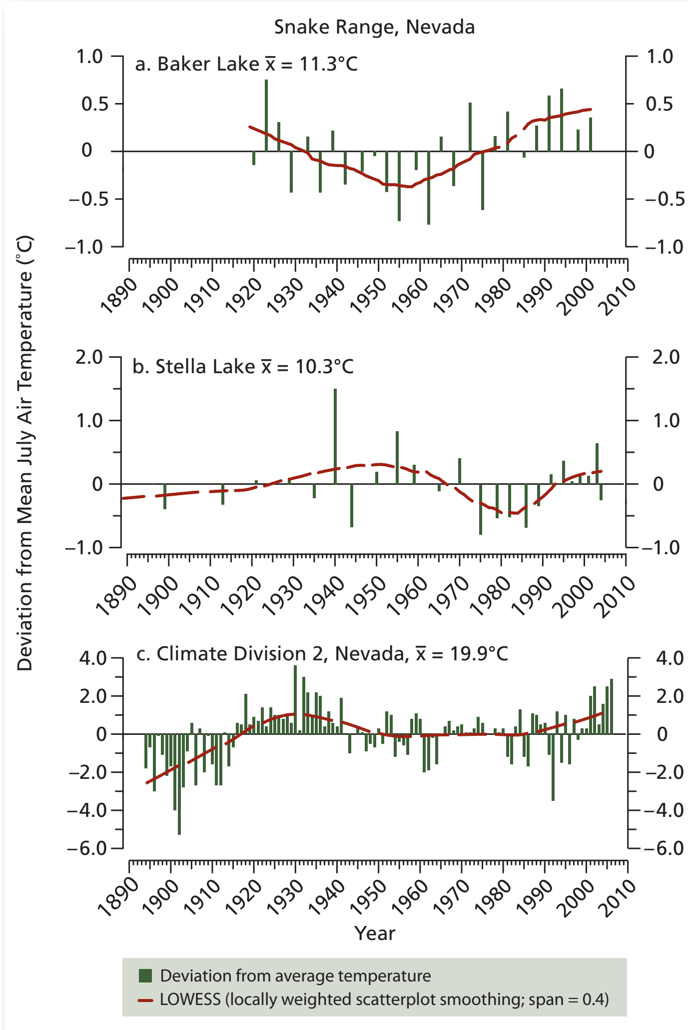

Figure 4 (right). Midge-based mean July air temperature (MJAT) anomalies in the 20th century for (a) Baker Lake, (b) Stella Lake, and (c) Climate Division 2, Nevada, encompassing averages from several stations in northwestern Nevada (Porinchu et al. 2010).

We reconstructed the 20th-century climate regime for the region using our midge-based inference model (fig. 4). We also used a longer sediment record (with each sample representing about 100 years) to reconstruct the midge-based July temperature record for approximately the last 7,000 years (see Reinemann et al. 2009 and the online version of this article for the full record). Results indicate that the central Great Basin experienced significant temperature shifts over the Holocene Epoch, with peak temperature occurring approximately 5,300 years ago.

Discussion and conclusions

The recent air temperature and humidity variations at the lakes, as recorded from the Lascar data, suggest that the elevations near and above 3,000 m (9,843 ft) may be particularly susceptible to climate changes, complementing other work (Bradley et al. 2004). Baker, Brown, Stella, and Teresa lakes exist at or above 3,000 m (9,843 ft). Therefore the Lascar sensors data provide a valuable baseline with which future and past climate conditions at the lake locations may be compared. The July air temperatures we are observing at Stella and Baker lakes are as high as the lake cores have shown over the last 1,000 years and possibly over the last 7,000 years, indicating that climate has recently altered around the lakes of Great Basin National Park.

The findings from the Stella and Baker lake core analysis suggest that the lakes have experienced increasing mean July temperature since 1980 (fig. 3). On longer time scales of climate change ranging from a century to millennia, Stella Lake has experienced large changes in mean July air temperature, corresponding to changes detected in paleoclimate records from around the region. This regional comparison suggests that during times of aridity in the Great Basin, as indicated from pollen and oxygen-18 isotopes from Pyramid Lake, Nevada (Benson et al. 2002; Mensing et al. 2004), Stella Lake experienced elevated air temperatures. Overall, *The knowledge that subalpine lakes and their biota have persisted through other warm and dry periods gives staff at Great Basin National Park a positive message to share with visitors.*

Stella Lake and the park were characterized by a warm and arid middle Holocene followed by a cool and moist neoglacial interval and a return to warmer conditions during the late Holocene. Fortunately, the Stella Lake sediment record reveals that the lake did not completely dry out during past intervals of severe regional aridity (mid-20th century, MCA) and continuously supported a diverse aquatic ecosystem for at least the last 7,000 years (Reinemann et al. 2009; also see the online version of this article at www.nature.nps.gov/ParkScience). These records broaden our knowledge of the temperature conditions that existed during the 20th century and Holocene Epoch in the park by providing an independent quantitative reconstruction of July air temperatures.

The knowledge that subalpine lakes and their biota have persisted through other warm and dry periods gives staff at Great Basin National Park a positive message to share with visitors. As the midge record shows, community structure has changed substantially through time, because of some midge species having relatively narrow temperature ranges. These shifts in the aquatic ecosystem are part of what makes lakes so sensitive and thus so useful as sentinels of climate change (Parker et al. 2008). Park researchers and staff are conducting additional studies and modeling how park resources might respond to climate change. This scientific knowledge will inform managers, which is an important emphasis of the NPS Climate Change Response Strategy. Although we may not be able to protect all ecosystems faced with climate change, this collaborative educational research project exemplifies how the National Park Service is equipped to document and interpret ecosystem change.

Acknowledgments

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