Palaeogeography, Palaeoclimatology, Palaeoecology 422 (2015) 46–56

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Patterns of terrestrial and limnologic development in the northern Greater Yellowstone Ecosystem (USA) during the late-glacial/early-Holocene transition

Teresa R. Krause [a,*], Yanbin Lu [b], Cathy Whitlock [a,c], Sherilyn C. Fritz [b], Kenneth L. Pierce [d]

[a] Department of Earth Sciences, Montana State University, Bozeman, MT 59717, USA
[b] Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, NE 68588, USA
[c] Montana Institute on Ecosystems, Montana State University, Bozeman, MT 59717, USA
[d] US Geological Survey, Northern Rocky Mountain Science Center, 2327 University Way, Box 2, Bozeman, MT 59715, USA

ARTICLE INFO

Article history:
Received 26 March 2014
Received in revised form 31 October 2014
Accepted 5 December 2014
Available online 22 January 2015

Keywords:
Late-glacial
Early Holocene
Pollen
Diatoms
Yellowstone

ABSTRACT

A high-resolution record of pollen, charcoal, diatom, and lithologic data from Dailey Lake in southwestern Montana describes postglacial terrestrial and limnologic development from ice retreat ca. 16,000 cal yr BP through the early Holocene. Following deglaciation, the landscape surrounding Dailey Lake was sparsely vegetated, and erosional input into the lake was high. As summer insolation increased and ice recessional processes subsided, *Picea* parkland developed and diatoms established in the lake at 13,300 cal yr BP. Closed subalpine forests of *Picea*, *Abies*, and *Pinus* established at 12,300 cal yr BP followed by the development of open *Pinus* and *Pseudotsuga* forests at 10,200 cal yr BP. Increased planktic diatom abundance indicates a step-like warming at 13,100 cal yr BP, and alternations between planktic and tychoplankic taxa suggest changes in lake thermal structure between 12,400 and 11,400 cal yr BP. An increasingly open forest, in combination with increased benthic diatoms, indicates warm dry summers during the early Holocene after 11,400 cal yr BP, in contrast to nearby records in northern Yellowstone that register prolonged summer-wet conditions until ca. 8000 cal yr BP. Because of its low elevation, Dailey Lake was apparently sensitive to the direct effects of increased summer insolation on temperature and effective moisture, registering dry summers. In contrast, higher elevations in northern Yellowstone responded to the indirect effects of an amplified seasonal insolation cycle on atmospheric circulation, including elevated winter snowpack and/or increased summer convective storms as a result of enhanced monsoonal circulation.

1. Introduction

The period from 20,000 to 8000 cal yr BP was a time of rapid environmental change in the western US as the region shifted from full-glacial conditions to the summer insolation maximum of the early Holocene. In the northern Rocky Mountains, glaciers receded from their maximum position by ca. 17,000 cal yr BP and were largely gone by 14,000 cal yr BP (Licciardi et al., 2004; Pierce, 2004; Licciardi and Pierce, 2008; Thackray, 2008). The freshly exposed landscapes created by ice recession afforded new habitats for plants and animals to colonize and set in motion a series of time-dependent changes in local-scale processes, including soil, vegetation, and limnologic development.

Although the record of postglacial colonization is clear from paleoecological data throughout the northern Rocky Mountains (e.g., Whitlock, 1993; Brunelle et al., 2005; Power et al., 2011), the relative trade-off between climate and local-scale controls in shaping the sequence of biotic development during the late-glacial/early-Holocene transition is poorly understood. Large-scale climatic variability is clearly the primary driver of postglacial ecosystem change at broad temporal and spatial scales; however, substrate, local topography, and species life-history traits become increasingly important at finer scales (e.g., Brubaker, 1975; Millspaugh et al., 2000; Oswald et al., 2003; Briles et al., 2011). Furthermore, modern studies have highlighted strong linkages between limnologic development and trajectories of soil and vegetation development in newly deglaciated catchments (Engstrom et al., 2000; Engstrom and Fritz, 2006), but few paleoecological sites compare terrestrial and aquatic responses in the past to understand how well these linkages were expressed in the early stages of postglacial landscape development (but see Birks et al., 2000).

This paper examines early postglacial ecosystem development in the Greater Yellowstone region during the period from ca. 16,000 to ca. 7000 cal yr BP based on pollen, charcoal, diatom, and lithologic data from Dailey Lake, MT (45.262° N, 110.815° W; 1598 m elev, 82 ha). Dailey Lake is a low-elevation site located 23 km up-valley of the terminal moraine of the northern Yellowstone outlet glacier and thus

* Corresponding author.
E-mail address: teresa.krause@msu.montana.edu (T.R. Krause).

http://dx.doi.org/10.1016/j.palaeo.2014.12.018
0031-0182/

provides one of the earliest records of postglacial environmental change in the region. Our objectives in this paper are to: (1) describe the sequence of terrestrial and limnologic changes that occurred between the time of ice retreat to the early Holocene insolation maximum; (2) identify linkages between vegetation and limnobiotic development to assess the dominant climatic and nonclimatic drivers of ecosystem development; and (3) compare the Dailey Lake reconstruction with other paleoecological records to better understand postglacial vegetation and climate dynamics in the northern Yellowstone region.

1.1. Modern setting

Dailey Lake occupies a shallow trench on a low bench carved by the late-Pleistocene northern Yellowstone outlet glacier. The semi-closed basin lies on a bench 85 m above the Yellowstone River in the Paradise Valley of southwestern Montana, and the lake discharges periodically through a low gradient outlet (0.3 m/500 m) into a 500 m^2 wetland to the north (Fig. 1). Present-day vegetation patterns in northern Yellowstone are strongly influenced by elevation (Despain, 1990). Dailey Lake is located 100 m below lower treeline (1700 m elevation), and the surrounding vegetation is primarily grassland and steppe dominated by *Artemisia tridentata* (big sagebrush), *Ericameria nauseosa* (rabbitbrush), *Festuca idahoensis* (Idaho fescue), and *Leymus cinereus* (Great Basin wild rye), with isolated populations of *Juniperus scopulorum* (Rocky Mountain juniper). *Salix* (willow spp.), *Carex* (sedge), and *Typha latifolia* (cattail) are present along the lake margin and in the adjacent wetland. Montane and subalpine forests grow on nearby mountain slopes: *Pinus flexilis* (limber pine) is most abundant between 1700 and 1900 m elevation; *Pseudotsuga menziesii* (Douglas-fir) and *Pinus contorta* (lodgepole pine) grow between 1900 to 2400 m elevation and are replaced by *Picea engelmannii* (Engelmann spruce), *Abies lasiocarpa* (subalpine fir), and *Pinus albicaulis* (whitebark pine) above 2400 m elevation. Alpine tundra occurs above 2900 m elevation.

At present, northern Yellowstone receives the majority of its precipitation during the summer months from convective storms produced by monsoonal circulation from the Gulf of Mexico and the subtropical Pacific Ocean (Mock, 1996). Winter precipitation in the region is the result of westerly storm tracks from the Pacific Ocean. Available climate information for Dailey Lake comes from NOAA coop station Livingston 12S, located 31 km northeast of Dailey Lake in northern Paradise Valley. During the period from 1951 through 2012, January temperatures averaged -2.7 ° C, and July temperatures averaged 19.1 ° C. Mean annual precipitation was 41 cm, and May and June were the wettest months, 6.7 and 6.9 cm, respectively (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mt5080). The high summer/winter precipitation ratio (JJA/DJF = 3.29) classifies the lake as a summer-wet site (*sensu* Whitlock and Bartlein, 1993), as a result of low winter precipitation (January average = 1.6 cm) and frequent summer convectional storms (July average = 3.9 cm).

Dailey Lake is presently warmer and effectively drier than other parts of the northern Yellowstone region because of its low elevation and location in precipitation shadows of the Gallatin Range and Yellowstone Plateau. This orographic effect particularly impacts westerly storm tracks during the winter months, and Dailey Lake receives approximately 165 cm of winter snowfall (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mt5080) compared with similar lower forest settings at higher elevations in northern Yellowstone that receive between 190-250 cm (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy9905; http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy9025).

2. Methods

2.1. Field

A 14.40-m long sediment core was collected from the ice surface at Dailey Lake in February 2009 using a Livingstone square-rod piston sampler (Wright et al., 1983). Core segments were extruded in the field and wrapped in plastic and aluminum foil and transported back to the Montana State University Paleoecology Lab and refrigerated.

2.2. Chronology

Plant macrofossils, charcoal, and pollen concentrates were submitted for AMS radiocarbon dating. Pollen concentrates for dating were obtained from the pollen residue remaining after standard pollen preparation procedures (Bennett and Willis, 2001), except no alcohols were used in processing and a Schulze procedure was substituted for acetolysis to oxidize organics (Doher, 1980). When possible, dates were obtained from organic material near critical lithologic transitions to accurately estimate changes in sedimentation rates.

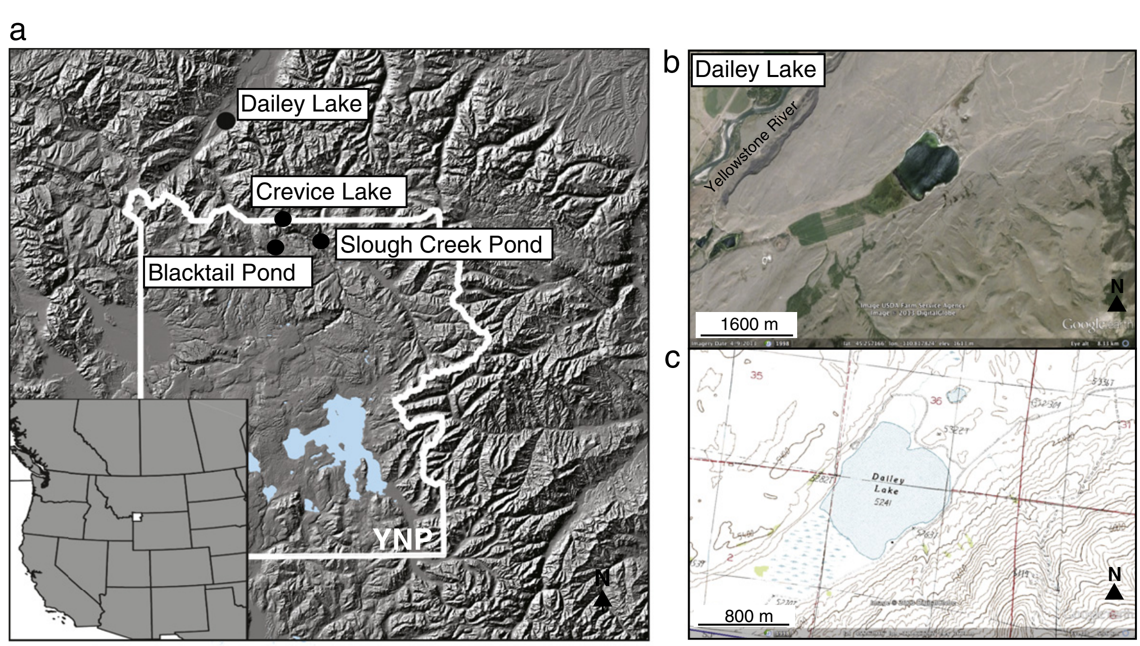

Fig. 1. Location of Dailey Lake. a) Location of northern Yellowstone sites discussed in text. b) Aerial image of Dailey Lake. c) Topographic map of Dailey Lake. Contour interval 20 feet.