EARLY POSTGLACIAL VEGETATION DEVELOPMENT IN THE GREATER YELLOWSTONE ECOSYSTEM

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree

of

Doctor of Philosophy

in

Ecology and Environmental Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

January 2015

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ACKNOWLEDGEMENTS

I would like to thank my advisor and committee chair, Dr. Cathy Whitlock, for her mentorship, dedication, and insight. I am grateful for all her instruction, advice, encouragement, and critiques. She was the first to introduce to me to the field of paleoecology, and for that, I am forever indebted. I would also like to thank my committee members, Drs. Kenneth Pierce, Bruce Maxwell, and Wyatt Cross, for their valuable insight and constructive suggestions. Thank you to our collaborators at the University of Nebraska-Lincoln, Drs. Sherilyn Fritz and Yanbin Lu, for their paleolimnological interpretations and thoughtful discussions. Thank you to everybody that helped me in the field, through snow and sun, and in the lab. I am sincerely grateful to my friends and colleagues in the MSU Paleoecology Lab for their support and encouragement. In particular, I would like to express my deepest appreciation to Virginia Iglesias, David Firmage, and James Benes. Not only did they help me realize my potential as a scientist, but they were also a continual source of clarity throughout this process. Thank you to my family for being an unlimited source of love and support.

The project was funded by National Science Foundation grants to Cathy Whitlock (EAR-0801467 and OISE-0966472). Thank you to LacCore and the Large Lakes Observatory at the University of Minnesota, and the Environmental Isotope Laboratory at the University of Arizona for providing analytical support. I would also like to acknowledge Christie Hendrix and Stacey Gunther with the National Park Service for facilitating fieldwork conducted in Yellowstone National Park.

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ABSTRACT

The last glacial-interglacial transition in the western US (20,000-8000 years ago) was a period of rapid environmental change. In the Greater Yellowstone Ecosystem (GYE), much research has focused on postglacial vegetation changes; however, questions still remain regarding the relative trade-off between climate and nonclimatic factors, such as edaphic conditions, disturbance, and biotic interactions, in driving early postglacial vegetation development at finer spatial and temporal scales in the region. This study reconstructed vegetation development in the GYE from the time of ice retreat to the early Holocene insolation maximum (17,000-8000 years ago) at sub-regional and regional scales using fossil pollen data from three sites in the northern GYE and across a regional network of 13 previously published records. Fossil pollen data from lake sediments were compared to independent measures of climate (paleoclimate model simulations, stable isotope data), edaphic conditions (lithologic and geochemical data), and fire activity (charcoal data) to better understand climatic and nonclimatic drivers of early postglacial vegetation development. Climate was the primary driver of early postglacial vegetation development in the GYE. Increasing summer insolation and its direct effects on summer temperature and effective moisture directed changes in vegetation from pioneering herb and shrub communities to spruce parkland during the late-glacial period to subalpine forest and eventually open Douglas-fir forest by the early Holocene summer insolation maximum. Nonetheless, fire activity, site-specific edaphic conditions, and biotic interactions mediated vegetation responses to climate change. Elevated regional fire activity between 12,500 and 10,000 cal yr BP, driven by increasing summer temperatures and fuel biomass, facilitated important ecosystem changes from an Engelmann spruce and subalpine fir dominated system to one dominated by whitebark and lodgepole pine. Site-specific edaphic conditions, namely erosional processes associated with newly deglaciated terrain, inhibited early conifer expansion, and important competitive interactions between lodgepole pine and whitebark pine after the early Holocene limited the range of whitebark pine at middle elevations in the GYE. This research provides new insight into how ecosystems and plant species have responded to past climate change and is critical for better understanding local responses to regional climate change predicted in the coming decades.

CHAPTER ONE

INTRODUCTION

The last glacial-interglacial transition (20,000-8000 years ago) was a period of dramatic global environmental change: continental glaciers retreated from full-glacial positions to their smallest extent by the early Holocene; sea-surface and air temperatures increased; and abrupt and widespread shifts in vegetation occurred. Much paleoecological research has focused on vegetation dynamics during this critical shift in climate and in the physical environment. This topic received much attention years ago when pollen analysis was first applied to the late-glacial and early-Holocene periods in eastern North America (e.g., Davis 1976, 1981, Wright 1980) and continues to be explored as chronologies improve and new paleoecological proxies of environmental change are developed (e.g., Hu et al. 2009, Gill et al. 2009, 2012, Anderson et al. 2011, Anderson-Carpenter et al. 2011). With greater temporal resolution and a larger array of analytical tools, paleoecologists can now ask and answer nuanced questions regarding biotic and physical environmental drivers of early postglacial vegetation change. Such questions are particularly pertinent in light of current anthropogenic climate change (IPCC 2014) and its effect on vegetation, inasmuch as the magnitude of current climate change mirrors that seen at the last glacial-interglacial transition.

The Greater Yellowstone Ecosystem

The present-day Greater Yellowstone Ecosystem (GYE) evolved from a sequence of ecological events put in motion by retreat of late-Pleistocene glaciers after ~17,000 cal yr BP. During the full-glacial period, the GYE supported the largest mountain glacier complex in the western US, and at its maximum, a large ice cap was centered over the Yellowstone Plateau, which served as a source for outlet glaciers to the north, west, and south (Licciardi and Pierce 2008). Freshly exposed landscapes created by ice recession during the late-glacial period provided new habitats for plants to colonize. By the early Holocene, most plant species present today had arrived to the GYE region, with their present-day distributions developing by the late Holocene.

The GYE is one of the largest and most pristine temperate ecosystems worldwide. The region is topographically complex and includes numerous valleys and mountain ranges from southwest Montana to northwest Wyoming, including the Bridger and Crazy Mountains in the north to the Teton and Wind River Ranges in the south. The central GYE is dominated by the Yellowstone Plateau, which was created by multiple Quaternary volcanic eruptions.

Present-day vegetation patterns in the GYE are largely influenced by local topography and its effect on temperature and effective moisture gradients (Despain 1990). Grassland and sagebrush steppe communities grow below lower treeline, ~1700 m elevation, and are dominated by big sagebrush (*Artemisia tridentata*), Idaho fescue (*Festuca idahoensis*), and rabbitbrush (*Ericameria nauseosa*). Great Basin wild rye (*Leymus cinereus*), shrubby cinquefoil (*Potentilla fruticosa*), and common juniper

(*Juniperus communis*) are also prevalent. Montane and subalpine forests grow between 1700 and 2900 m elevation and are replaced by alpine meadow and tundra at elevations above 2900 m. Within the forest zone, limber pine (*Pinus flexilis*) and Rocky Mountain juniper (*Juniperus scopulorum*) are most abundant between 1700 and 1900 m elevation, Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) are prevalent between 1900 and 2400 m elevation, and at high elevations above 2400 m, subalpine forests of Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and whitebark pine (*Pinus albicaulis*) grow. At upper treeline, whitebark pine is the dominant conifer species.

In addition to elevation, underlying substrate is an important driver of vegetation patterns in the GYE (Despain 1990). Calcareous fine-grained glacial till supports grassland and sagebrush-steppe due to the substrate's high water-holding capacity and is prevalent throughout the northern GYE. Rhyolite dominates on the Yellowstone Plateau, and the coarse nutrient-poor substrate supports lodgepole pine forests. Moderately-nutrient rich Tertiary outcrops of basalt and andesite are widespread in the eastern GYE and support mixed conifer forests of Engelmann spruce, subalpine fir, whitebark pine, and Douglas-fir.

At present, the GYE experiences both summer-dry and summer-wet precipitation regimes described by Whitlock and Bartlein (1993). The northern GYE is classified as summer-wet due to increased convective storms during the summer months produced by monsoonal circulation from the Gulf of Mexico and the subtropical Pacific Ocean (Mock 1996). In contrast, the central and southern GYE experiences a summer-dry regime,

inasmuch as the northeastern subtropical high pressure-system expands during the summer months, suppressing precipitation. Winter precipitation throughout the region is the result of westerly storm tracks from the Pacific Ocean and due to orographic effects, the Yellowstone Plateau and Beartooth Uplift receive large amounts of winter snowfall.

During the full-glacial period, climate in the GYE was influenced by cold and dry continental air masses due to low atmospheric greenhouse gas concentrations, low summer insolation, and glacial anticyclone circulation created by North American ice sheets (Bartlein et al. 1998). During the late-glacial/early Holocene transition, regional climate was driven by an amplification of the seasonal cycle of insolation, which produced progressively warmer summers and colder winters. By the early Holocene summer insolation maximum at ~10,000 cal yr BP, paleoclimate models suggest high summer insolation values (8% higher than present at 45°N; Berger and Loutre 1991) produced warm (~3°C above present, i.e., mean summer temperature over the 1998-2000 AD present) and effectively dry summer conditions (Alder and Hostetler 2014). In contrast, low winter insolation values (10% lower than present at 45°N; Berger and Loutre 1991) produced cold winters (2°C below present; Alder and Hostetler 2014), and winters were likely wetter due a northward shift in the jet stream following the retreat of North American ice sheets (Bartlein et al. 1998). Carbonate $\delta^{18}O$ data from Crevice Lake in the northern GYE provide evidence of wet winters during the early Holocene insolation maximum, with snowpack decreasing towards present day (Whitlock et al. 2012).

To date, our understanding of postglacial vegetation development in the GYE comes from fossil pollen records at a series of sites throughout the region that encompass its complex topography, geology, and climate (Waddington and Wright 1974, Baker 1976, 1983, Gennett and Baker 1986, Whitlock 1993, Whitlock and Bartlein 1993, Millspaugh et al. 2000, 2004, Huerta et al. 2009, Whitlock et al. 2012). Following deglaciation, vegetation development strongly tracked increasing summer insolation and was unidirectional through time. Following deglaciation, alpine tundra and meadow communities of *Artemisia*, Poaceae, Cyperaceae, and various herbs, including Asteraceae, western bistort (*Polygonum bistortoides*), and Ranunculaceae, grew throughout the GYE. Alpine vegetation transitioned to Engelmann spruce parkland after ~13,000 cal yr BP, followed by the development of closed subalpine forests of Engelmann spruce, subalpine fir, and whitebark pine after 12,000 cal yr BP. As summer temperatures peaked in the early Holocene, lodgepole pine and Douglas-fir forests developed after 11,000 cal yr BP; however, their development was delayed at summer-wet sites in the northern GYE until ~8000 cal yr BP due to increased summer convective storms from enhanced monsoonal circulation (Whitlock and Bartlein 1993) and/or due to the carryover of high winter snowpack into the summer growing season (Whitlock et al. 2012).

While millennial-scale climate change produced by increasing summer insolation was clearly the primary driver of postglacial vegetation change in the GYE, questions still remain regarding the relative trade-off between climate and nonclimatic factors in driving vegetation development at finer spatial and temporal scales in the region. For

example, what were the relative roles of soil conditions, biotic interactions, and disturbance in shaping early postglacial vegetation development in the GYE? Separating regional climate drivers from more local nonclimatic factors in the past is critical for inferring local responses to regional climate change predicted in the coming decades and centuries (Mote et al. 2008).

Objectives

This research reconstructs vegetation development in the GYE, from the time of ice retreat to the early Holocene insolation maximum (17,000 to 8000 years ago), and aims to disentangle the roles of regional climate change and nonclimatic factors in directing early postglacial vegetation development. This study focuses on vegetation change at high temporal (multidecadal) resolution, at both a sub-regional scale in the northern GYE and throughout the GYE region. Specifically, the objectives are to (1) reconstruct the sequence of early postglacial vegetation changes in the northern GYE and identify associations between vegetation, climate, fire, and physical landscape evolution; (2) assess the spatiotemporal patterns of early postglacial vegetation development in the northern GYE; and (3) reconstruct postglacial vegetation and fire history throughout the GYE region to better understand the role of millennial-scale climate change, fire, and species interactions in shaping early postglacial conifer dynamics.

To address objectives one and two, I collected new high-resolution paleoecological data from three small lakes in the northern GYE that fall along the path of ice recession of the late-Pleistocene northern Yellowstone outlet glacier. Fossil pollen,

charcoal, lithologic, geochemical, and stable isotope data from calibrated AMS radiocarbon-dated lake sediments provided a continuous record of environmental change during the late-glacial/early-Holocene transition. Local and regional vegetation changes were inferred from fossil pollen records; fluctuations in past fire activity were inferred from trends in charcoal data, and sediment core lithology and geochemical properties provided information on physical landscape evolution. Regional paleoclimate history was based on published paleoclimate model simulations (Bartlein et al. 1998, Alder and Hostetler 2014), and local past variations in seasonal climate were reconstructed from changes in carbonate $\delta^{18}O$ data.

To address objective three, General Additive Models (GAMs) (Wood 2011) were used to detect regional postglacial trends in vegetation history and fire activity. This analysis was based on 922 pollen samples and 1768 charcoal samples from calibrated radiocarbon-dated sites, three new northern GYE records (this dissertation) and thirteen previously published records. Vegetation GAMs were developed based on pollen percentage data, and the regional fire GAM was based on charcoal particle accumulation rates (CHAR).

Study Sites

Study sites in the northern GYE fall along the path of recession of the northern Yellowstone outlet glacier, which allowed me to track vegetation development as it related to the timing of ice retreat to the early Holocene insolation maximum. Northern GYE sites include (from oldest to youngest) (Fig. 1.1; Table 1.1):

(1) Dailey Lake (45.26° N, 110.82° W, 1598 m elev) occupies a shallow trench carved by the northern Yellowstone outlet glacier. Dailey Lake is a relatively low elevation site in the GYE below lower treeline. The site is located in the Yellowstone River Valley of southwestern Montana, ~23 km upvalley of the terminal moraine of the northern Yellowstone outlet glacier (dated to ~16,500 cal yr BP; Licciardi and Pierce, 2008) and thus provides one of the earliest paleorecords of postglacial environmental change in the region.

(2) Blacktail Pond (44.95° N, 110.60° W, 2012 m elev) is situated in a remnant late-Pleistocene meltwater channel in the Northern Range of Yellowstone National Park. Carbonate $\delta^{18}O$ data collected from this site provides a critical independent record of climate change for the region during the late-glacial/early-Holocene transition.

(3) Slough Creek Pond (44.92° N, 110.35° W, elev. 1884 m) is a kettle pond located in a pitted glacial outwash plain, also in the Northern Range of Yellowstone National Park. Slough Creek Pond is the youngest of the northern GYE sites and estimates of local glacial recession suggest the site was relatively ice-free after ~15,200 cal yr BP (Licciardi and Pierce 2008).

Blacktail and Slough Creek ponds have been studied previously. Gennett and Baker (1986) developed a postglacial pollen record from Blacktail Pond but the chronology was poorly constrained. Huerta et al. (2009) revisited the site and developed a postglacial vegetation and fire history from fossil pollen and charcoal data using a new AMS radiocarbon-dated sediment core. Whitlock and Bartlein (1993) and Millspaugh et al.

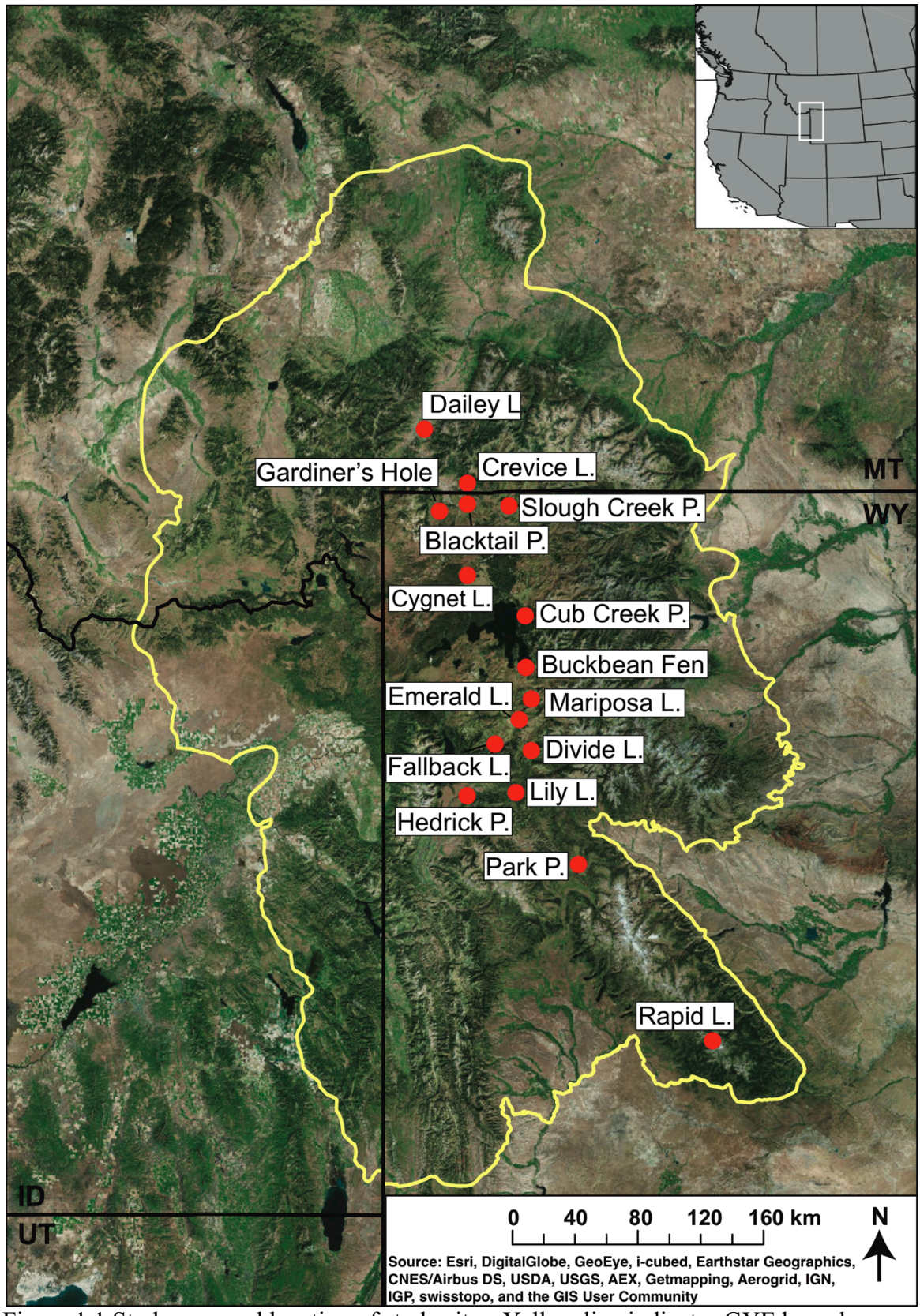


Figure 1.1 Study area and location of study sites. Yellow line indicates GYE boundary.

Table 1.1 GYE Study Sites

Site	Location	Elev. (m)	Modern vegetation
Blacktail Pond	44.96° N; 110.60° W	2012	Steppe-parkland
Buckbean Fen	44.45° N; 109.84° W	2362	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest
Crevice Lake	45.00° N; 110.78° W	1684	Steppe-parkland/*Pseudotsuga*
Cub Creek Pond	44.92° N; 110.73° W	2500	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest
Cygnet Lake Fen	44.65° N; 110.60° W	2530	*P. contorta* forest
Dailey Lake	45.27° N; 110.82° W	1598	Steppe-parkland
Divide Lake	43.93° N; 110.23° W	2628	*Picea*/*Abies*/*P. albicaulis* forest
Emerald Lake	44.07° N; 110.30° W	2634	*Picea*/*Abies*/*P. albicaulis* forest
Fallback Lake	43.97° N; 110.43° W	2597	*Picea*/*Abies*/*P. albicaulis* forest
Forest Pond Lake	43.37° N; 109.94° W	2797	*Picea*/*Abies*/*P. albicaulis* forest
Gardiner's Hole (Swan Lake)	44.92° N; 110.73° W	2215	Steppe-parkland
Hedrick Pond	43.75° N; 110.60° W	2073	Steppe-parkland
Lily Lake and Lily Lake Fen	43.77° N; 110.32° W	2469	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest
Mariposa Lake	44.15° N; 110.23° W	2730	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest
Park Pond	43.47° N; 109.96° W	2705	*Picea*/*Abies*/*P. albicaulis* forest
Rapid Lake	42.73° N; 109.19° W	3134	Alpine meadow and tundra
Slough Creek Pond	44.93° N; 110.35° W	1884	Steppe-parkland

(2004) reconstructed postglacial vegetation and fire histories at Slough Creek Pond. I build upon this work by focusing on the late-glacial/early-Holocene transition at a highertemporal (multi-decadal) resolution and incorporate multiple proxy datasets,

including stable isotope, geochemical, and lithologic data, to better understand the physical environment during this transition.

The GAMs analysis of regional vegetation and fire history comes from fossil pollen and charcoal data collected from sixteen small lakes throughout the GYE (Fig. 1.1; Table 1.1). The calibrated radiocarbon-dated sites span elevations between 1598 and 3134 m, and are located between 42.729 and 45.269 °N and 109.194 to 110.817 °W. All records are publicly available in the USGS North Central Paleoenvironmental Database (www.nccscpaleoenvironmentaldatabase.com).

Overview of Dissertation

My dissertation research uses fossil pollen data from lake sediments to reconstruct the sequence of vegetation changes occurring in the GYE during the late-glacial/early Holocene transition and compares it to independent proxies of climate, disturbance, and physical landscape evolution to determine the relative trade-off between climatic and nonclimatic drivers of early postglacial vegetation development in the GYE. Chapter 2 describes the sequence of landscape changes that occurred during the late-glacial/early-Holocene transition at Blacktail Pond using pollen, charcoal, lithologic, geochemical, and carbonate $\delta^{18}O$ isotope data. It also compares the paleoenvironmental reconstruction at Blacktail Pond with paleoclimate simulations and other paleoecological records from the GYE and the northern Rocky Mountains to assess regional patterns in vegetation change during the late-glacial/early-Holocene transition. Dr. Cathy Whitlock co-authored this chapter, and she helped define the experimental design, participated in fieldwork,

discussed the results and implications, and edited the manuscript. This chapter was published in *Quaternary Research* in May 2013 (Volume 79, 391-402).

Linkages between early postglacial terrestrial and limnologic development in the northern GYE are identified using pollen, charcoal, diatom, geochemical, and lithologic data from Dailey Lake in Chapter 3. This chapter describes the sequence of terrestrial and limnologic changes that occurred between the time of ice retreat to the early Holocene insolation maximum at Dailey Lake and identifies linkages between terrestrial and limnologic development to assess the relative trade-off between climate and nonclimatic drivers of early ecosystem development in the GYE. It also compares the Dailey Lake vegetation reconstruction with other paleocological records to better understand postglacial vegetation and climate dynamics in the northern GYE. Collaborators from University of Nebraska-Lincoln, Drs. Yanbin Lu and Sherilyn Fritz, co-authored the paper. Both helped with the experimental design, diatom interpretation, and commented on the manuscript, while Dr. Lu counted and analyzed the diatom samples from Dailey Lake. Dr. Cathy Whitlock and Dr. Kenneth Pierce were also co-authors on the chapter. Dr. Whitlock helped define the experimental design, participated in fieldwork, discussed the results and implications, and edited the manuscript. Dr. Pierce with the U.S. Geological Survey advised on the local glacial recessional history and geomorphic processes and commented on the manuscript. Chapter 3 was submitted to *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology* in March 2014.

In Chapter 4, fossil pollen data are used to examine the early postglacial population dynamics of five major conifer species in the GYE: Engelmann spruce,

subalpine fir, whitebark pine, lodgepole pine, and Douglas-fir. Spatiotemporal patterns of postglacial conifer expansion are first examined at a sub-regional scale by comparing fossil pollen data from Dailey Lake, Blacktail Pond, and Slough Creek Pond in the northern GYE. The pollen data are then compared to independent proxies of environmental change, including local climate (stable isotope data), geomorphic stability (magnetic susceptibility), and fire activity (macroscopic charcoal data) to infer the relative roles of climate change and nonclimatic factors in shaping early postglacial conifer dynamics. Vegetation and fire history is then reconstructed at a regional scale by modeling charcoal and pollen data from 16 sites across the GYE using General Additive Models to better understand the role of millennial-scale climate change, fire, and species interactions in shaping postglacial conifer history. Dr. Virginia Iglesias at the Université de Franche-Comté and Dr. Cathy Whitlock co-authored this chapter. Both helped define the experimental design, while Dr. Iglesias conducted the General Additive Models analysis and commented on the manuscript, and Dr. Whitlock discussed the results and implications and edited the manuscript. Chapter 4 has been prepared for submission to *Ecological Monographs*.

Finally, in Chapter 5, I summarize the major findings of the research conducted in each chapter and how it influences our understanding of early postglacial vegetation development in the GYE and its climatic and nonclimatic drivers. The results of my dissertation research emphasize the importance of considering nonclimatic factors, such as disturbance, edaphic conditions, and biotic interactions, in projections of species responses to current and future climate change.

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CHAPTER TWO

CLIMATE AND VEGETATION CHANGE DURING THE LATE-GLACIAL/EARLY-HOLOCENE TRANSITION INFERRED FROM MULTIPLE PROXY RECORDS FROM BLACKTAIL POND, YELLOWSTONE NATIONAL PARK, USA

Contribution of Authors and Co-Authors

Manuscript in Chapter 2

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Contributions: Defined the experimental design, described the lithology of sediment cores from Blacktail Pond, measured magnetic susceptibility, counted pollen samples, analyzed the data, and wrote the manuscript.

Co-Author: Cathy Whitlock

Contributions: Supported this research under National Science Foundation grant EAR-0801467, helped define the experimental design, participated in fieldwork, discussed the results and implications, and edited the manuscript.

Manuscript Information Page

Teresa R. Krause, Cathy Whitlock
Quaternary Research
Status of Manuscript:
____ Prepared for submission to a peer-reviewed journal
____ Officially submitted to a peer-review journal
____ Accepted by a peer-reviewed journal
_x__ Published in a peer-reviewed journal

Publisher: Elsevier
Issue 79 (2013), 391-402.

Abstract

A series of environmental changes from late-glacial ice recession through the early Holocene are revealed in a 7000-year-long record of pollen, charcoal, geochemistry, and stable isotopes from Blacktail Pond, a closed-basin lake in Yellowstone National Park. Prior to 11,500 cal yr BP, cool conditions dominated, fire activity was low, and alpine tundra and *Picea* parkland grew on the landscape. A step-like climate change to warm summer conditions occurred at 11,500 cal yr BP. In response, fire activity increased facilitating a transition from *Picea* parkland to closed *Pinus* forest. From 11,500 to 8280 cal yr BP, warm summers and abundant moisture mostly likely from high winter snowfall supported closed *Pinus contorta* forests. Cooler drier summer conditions prevailed beginning 8280 cal yr BP due to decreased summer insolation and winter snowpack, and lower parkland developed. The timing of vegetation change in the Blacktail Pond record is similar to other low- and middle-elevation sites in the northern Rocky Mountains during the late-glacial period, suggesting local plant communities responded to regional-scale climate change; however, the timing of vegetation changes was spatially variable during the early and middle Holocene due to the varying influences of strengthened summer monsoons and subtropical high on regional precipitation patterns.

Introduction

The late-glacial/early-Holocene transition, 20 to 8 ka, was a period of rapid environmental change around the world (Alley and Clark, 1999; Shakun and Carlson, 2010), and the magnitude of warming that occurred over thousands of years is similar to that projected under future climate scenarios in the coming century (IPCC, 2007; USCCSP, 2009). Superimposed on the late-glacial warming trend were a series of step-like changes and reversals in climate, most notably during the Younger Dryas Chronozone (12,900 to 11,500 cal yr BP; Alley et al., 2002). In the northern Rocky Mountains, valley glaciers and large ice fields extensively covered the landscape at the beginning of the late-glacial period (Pierce, 2004). Beginning ca. 17 ka, widespread rapid deglaciation occurred as a result of increasing summer insolation and greenhouse gases, and shifts in the positions of winter storms (Clark and Bartlein, 1995; Licciardi et al., 2004). Minor still stands or readvances of some northern Rocky Mountain glaciers occurred during the Younger Dryas Chronozone (Pierce et al., 2003), but then ice recession resumed as conditions warmed during the summer insolation maximum at ca. 9 ka (Bartlein et al., 1998). The range of climate variations in the northern Rocky Mountains makes the late-glacial/early Holocene transition an ideal case study for understanding ecological responses to past climate change. Most pollen records describe shifts in vegetation from barren deglaciated landscapes to closed forests from 20 to 8 ka. However, these records are primarily from high-elevation sites located in montane and subalpine forests (Whitlock and Brunelle, 2006), and little is known about how climate changes during this transition affected low- and middle-elevation landscapes at lower

treeline in the region. These areas were deglaciated prior to high-elevation sites and likely served as corridors for postglacial plant dispersal and colonization (e.g., Lyford et al., 2003).

This paper examines the late-glacial/early-Holocene transition in the northern Greater Yellowstone area based on pollen, charcoal, geochemical properties, and carbonate $\delta^{18}O$ isotopes data from Blacktail Pond (44.954°N, 110.604°W; 2012 m elev). This middle-elevation site has been studied previously. Gennett and Baker (1986) developed a postglacial pollen record; however, the sediment core was poorly dated as the chronology was based primarily on bulk sediment ^{14}C-dating that suffered errors related to the highly calcareous nature of the sediments. Huerta et al. (2009) developed a postglacial vegetation history and a high-resolution fire history from a new sediment core. The Huerta et al. (2009) chronology was based on tephrochronology and AMS ^{14}C-dated macrofossils and charcoal. We build upon this work by focusing on the late-glacial/early-Holocene transition at multidecadal temporal resolution and by using multiple proxy, particularly the inclusion of $\delta^{18}O$ analysis of authigenic carbonates and geochemical data, to better understand the physical environment during this transition. Our objectives in this study are to: (1) describe the sequence of landscape changes that occurred following the glacial retreat and leading up to the early-Holocene insolation maximum at Blacktail Pond; and (2) compare the Blacktail Pond results with paleoclimate simulations and other paleoecological records in Yellowstone and the northern Rocky Mountains to assess regional patterns of vegetation change during this critical period of ecological development.

Modern Setting

Blacktail Pond is situated in a remnant late-Pleistocene meltwater channel that formed when Blacktail Deer Creek abandoned its course during ice retreat and flowed north to the Yellowstone River, creating a marshy environment and a small closed-basin lake (Fig. 2.1; Pierce, 1979). Cosmogenic exposure dating of glacial boulders indicates an age of 14.3 ± 1.2 ^{10}Be ka for moraines up valley of the lake and 15.3 ± 1.4 ^{10}Be ka for moraines down valley (Licciardi and Pierce, 2008). These ages imply that ice recession at Blacktail Pond occurred between about 15,000 and 14,000 cal yr BP. Climate information is available from Mammoth, YNP, located 8 km west of Blacktail Pond. During the period from 1894 to 2011, the average January temperature at Mammoth

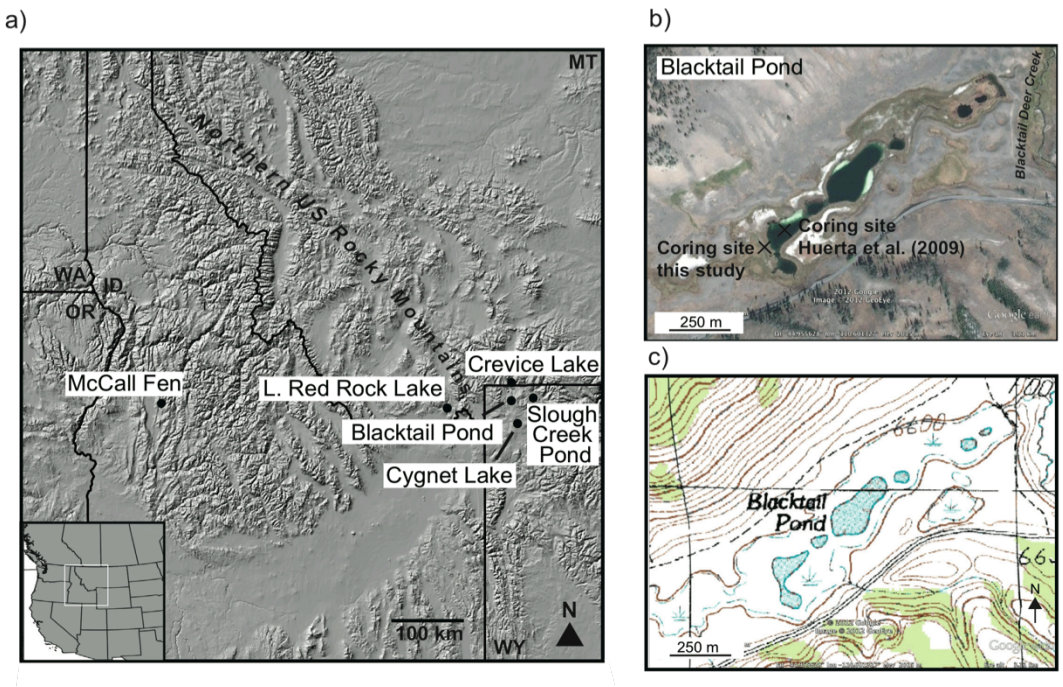


Figure 2.1 Location of Blacktail Pond. a) Location of sites discussed in the text. b) Aerial image of Blacktail Pond. c) Topographic map of Blacktail Pond. Contour interval 20 feet.

was -6.7° C, July temperatures averaged 17.4° C, and mean annual precipitation was 39 cm (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy9905). Blacktail Pond is located within the area of high July/January precipitation ratios classified as summer-wet, due to the penetration of summer convectional storms into northern Yellowstone (Whitlock and Bartlein, 1993).

Present-day vegetation patterns in northern Yellowstone are influenced by elevation, aspect, and geology (Despain, 1990). Grassland and steppe communities dominated by *Artemisia tridentata* (big sagebrush), *Festuca idahoensis* (Idaho fescue), and *Ericamaria nauseosa* (rabbitbrush) are present below 1700 m elevation. Montane and subalpine conifer forests grow between 1700 and 2900 m elevation and are replaced by alpine tundra at elevations above 2900 m. Within the forest zone, *Pinus flexilis* (limber pine) and *Juniperus scopulorum* (Rocky Mountain juniper) occur at lower elevations (1700 to 1900 m elevation), *Pseudotsuga menziesii* (Douglas-fir) (1900 to 2000 m elevation) and *Pinus contorta* (lodgepole pine) (2000 to 2400 m elevation) at middle to high elevations, and *Picea engelmannii* (Engelmann spruce), *Abies lasiocarpa* (subalpine fir), and *Pinus albicaulis* (whitebark pine) dominate at the highest elevations (2400 to 2900 m elevation). With regards to substrate, calcareous fine-grained glacial outwash and till support grassland and sagebrush steppe communities due to the substrate's high water-holding capacity, nutrient-poor rhyolite supports *Pinus contorta*, and Tertiary outcrops of andesite and basalt favor mixed conifer forests of *Picea engelmannii*, *Abies lasiocarpa*, *Pinus albicaulis,* and *Pseudotsuga menziesii*. Whitlock

(1993) showed that climate and edaphic controls influenced vegetation patterns in the past as well.

Blacktail Pond lies within calcareous glacial outwash and is surrounded by *Artemisia tridentata* steppe. *Pseudotsuga* forest grows on adjacent rocky slopes of basalt and andesite, while *Pinus contorta* forest grows on rhyolite areas, which dominate in the central part of Yellowstone National Park. Small populations of *Abies* and *Picea* are found in nearby cold air drainages, and stands of *Populus tremuloides* (quaking aspen) grow on the lower slopes in areas of seepage. *Salix* spp. (willow), *Scirpus americanus* (three-square bulrush), *Carex* spp., and *Typha latifolia* (broadleaf cattail) are present along the lake margin, and submerged aquatics include *Chara*, *Uticularia* (bladderwort), and *Myriophyllum* (water milfoil).

Methods

Field

A modified Livingstone square-rod sampler (Wright et al., 1983) was used to obtain a 2.85-m-long sediment core from 5.25 m to 8.10 m in depth below the fen surface at Blacktail Pond in October 2008. Core segments were extruded in the field and wrapped in plastic and aluminum foil and transported back to the MSU Paleoecology Lab where they were refrigerated.

Chronology and Correlation

Plant macrofossils, charcoal, and pollen concentrates were submitted for AMS radiocarbon dating. Pollen concentrates for dating consisted of 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). In addition, ash layers identified in the sediment core were utilized in the chronology. To include AMS ^{14}C age determinations from Huerta et al. (2009) in this study, the cores used in both studies were correlated based on lithogic and pollen stratigraphy.

Lithology and Geochemical Analysis

Initial core descriptions were performed at the LacCore facility, University of Minnesota-Twin Cities. Cores were split, imaged, and magnetic susceptibility was measured at contiguous 0.5-cm intervals using a Geotek XYZ MSCL logger to record changes in inorganic allochthonous sediment (Gedye et al., 2000). Measurements were reported in SI units. Geochemical elemental analysis of the cores was conducted at the Large Lakes Observatory, University of Minnesota-Duluth. Split cores were run through an ITRAX XRF scanner at contiguous 0.5-cm intervals, and the final analysis focused on the ratio of calcium (Ca) and titanium (Ti). The Ca:Ti record is interpreted as a measure of calcite production in the lake system through time. Ti is a detrital sediment indicator in our record because it is only produced allogenically through the physical erosion of Ti-bearing rocks (Cohen, 2003), and minerals containing Ti are not sensitive to dissolution (Demory et al., 2005). The Ca:Ti ratio corrects the influence of detrital Ca on the Ca geochemical record, which varies with detrital Ti in the lake sediments.

Calcite production is a proxy of lake productivity, inasmuch as calcite precipitation is triggered when algal photosynthesis during the summer months consumes

CO_2, increasing water pH, and CO_3^{2-} subsequently binds with available Ca^{2+} (Dean and Megard, 1993). Calcite production is thus related to more sunlight and higher summer temperatures (Meyers and Ishiwatari, 1993).

Oxygen Isotopes from Authigenic Carbonates

The $\delta^{18}O$ values on authigenic carbonates were measured from 5.26 to 7.21 m depth at 1.5-cm intervals at the Environmental Isotope Laboratory, University of Arizona, using an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). The carbonate content of sediment below 7.21 m depth was too low for accurate $\delta^{18}O$ measurements. Powdered samples were treated with dehydrated phosphoric acid under vacuum at 70°C. Measurements are reported as ppm relative to Vienna PeeDee *Belemnitella* (VPDB).

Many factors, including temperature, hydrology, and timing of carbonate precipitation, can influence the $\delta^{18}O$ values of authigenic carbonates (Shapley et al., 2008). Because Blacktail Pond is a closed system, with no surficial inflow or outflow, we infer that the $\delta^{18}O$ record from Blacktail Pond tracks changes in summer evaporation; but we cannot rule out the possible amplifying effects of groundwater on $\delta^{18}O$ values or changes in moisture source area through time. In our simple model, increases in (less negative) $\delta^{18}O$ correspond with increased evaporation of lake water and higher summer temperatures and vice versa (Benson, 2003). Alternatively, it is also possible that $\delta^{18}O$ values reflect changes in seasonal precipitation balance, with high $\delta^{18}O$ values reflecting some combination of increased rainfall and reduced snowfall (Anderson, 2011). In this case, lower (more negative) $\delta^{18}O$ values would be associated with periods of high snow

accumulation. However, the lack of significant inflowing streams and long lake-water residence time likely limited the influence of seasonal precipitation on the $\delta^{18}O$ record, and summer evaporative effects were more important. Therefore, we interpret the $\delta^{18}O$ record at Blacktail Pond as an evaporation proxy driven primarily by summer temperatures.

Pollen Analysis

Samples of 1 cm^3 were taken at 2 to 8 cm intervals from the core and prepared using pollen methods described by Bennett and Willis (2001), except a Schulze procedure was substituted for acetolysis to oxidize organics (Doher, 1980). A *Lycopodium* tracer was added to the samples to calculate pollen concentration (grains cm^{-3}) and pollen accumulation rates (PAR; grains cm^{-2} yr^{-1}). Pollen grains were identified at magnifications of 400x and 1000x, and 200 to 400 terrestrial pollen grains were counted per sample. Identifications were made to the lowest taxonomic level possible using reference collections and atlases (e.g., Kapp et al., 2000; Moore and Webb, 1978). *Pinus* grains were separated into haploxylon and diploxylon-types, and those missing a distal membrane were identified as "Undifferentiated *Pinus*". Based on modern phytogeography, haploxylon-type *Pinus* was attributed to *P. albicaulis* and diploxylon-type to *P. contorta*. A ratio of diploxylon-type *Pinus* to haploxylon-type *Pinus* (D_p/H_p) was calculated based on the relative proportion of grains with intact membranes.

Pollen percentages, ratios, and accumulation rates were used to reconstruct vegetation history. Reconstructions were aided by comparisons to modern pollen from surface samples in the Greater Yellowstone region (Baker, 1976; Whitlock, 1993; Fall,

1994). Percentages were calculated based on total pollen sum of terrestrial trees, shrubs, herbs, and pteridophytes. The pollen-percentage record was divided into zones using constrained cluster analysis (CONISS; Grimm, 1988) and visual inspection. Pollen accumulation rates (PARs) were determined by dividing pollen concentrations by deposition time (yr cm^{-1}).

Charcoal Analysis

Huerta et al. (2009) analyzed macroscopic charcoal particles (>125 μm) from Blacktail Pond to reconstruct high-severity fires occurring within a few kilometers of the site (Whitlock and Larsen, 2001; Higuera et al., 2010). Charcoal accumulation rates (CHAR; particles cm^{-2} yr^{-1}) were calculated using CharAnalysis (Higuera et al., 2008). Using this software, long-term trends in accumulation rates (background CHAR) were separated from positive deviations representing peak charcoal events. Charcoal concentrations and deposition times were interpolated into contiguous 25-year bins (the median resolution of the record) and CHAR was determined by dividing the time-interpolated concentrations (particles cm^{-3}) by new deposition times (yr cm^{-1}). Background CHAR was calculated by smoothing the CHAR time series (with a 500-year lowess smoother, robust to outliers) to infer levels of arboreal fuel biomass (Marlon et al., 2006). Charcoal peaks are the positive residuals remaining after background CHAR is removed from the CHAR time series and identified above a 95th percentile of the noise distribution (Whitlock et al., 2004; Higuera et al., 2010). A noise component of the charcoal peak values within 250 years of every sample was modeled using a Gaussian

mixture model. The time span between peaks is the fire-episode return interval, and fire-episode frequencies (number 1000 yr^{-1}) were determined by smoothing the time series using a 2000-year moving window (Huerta et al., 2009).

Results

Chronology

The Blacktail Pond chronology is based on four AMS ^{14}C dates, two known tephra ages, three AMS ^{14}C dates from the previously collected core (N76636, AA0024, AA70025; Huerta et al. 2009) (Table 2.1; Fig. 2.2). A 0.5-cm-thick ash layer from Mount Mazama was identified at 543.5 cm depth and assigned an age of 6730 ± 40 ^{14}C BP (Zdanowicz et al., 1999). Additionally, two 0.5-cm-thick ash layers presumably from Glacier Peak (B or G) were identified at 697.5 and 699.5 cm depth, and the former depth was assigned an age of 11,600 ± 50 ^{14}C yr BP (Kuehn et al., 2009). Two AMS ^{14}C age determinations at 604.75 and 721.25 cm depth were out of chronological order and left out of the age model.

The ^{14}C dates were converted to calendar ages using CALIB 6.0 (Stuiver et al., 2005; Reimer et al., 2009). The age-depth model was constructed using MCAgeDepth (Higuera et al., 2008). This modeling software employs a cubic smoothing spline and a Monte Carlo approach that allowed each date to influence the age model through the probability density function of the calibrated age (two sigma error; Stuiver et al., 2005; Higuera et al., 2008). The chronology suggests Blacktail Pond formed ca. 14,650 cal yr BP, an age that is consistent with recessional moraines (Licciardi and Pierce, 2008).

Table 2.1 Uncalibrated and calibrated ^{14}C ages for Blacktail Pond.

Depth (cm)[a]	Uncalibrated ^{14}C age (^{14}C yr BP)	Calibrated age (cal yr BP) with 2 sigma range[b]	Material dated	Lab number/ reference[c]
Core BTP08B				
543.75	6730 ± 40	7597 (7513-7667)	Mazama ash	Zdanowicz et al., 1999
564.50	8220 ± 340	9146 (8379-10128)	pollen	OS-84445
604.75	1160 ± 40	rejected	*Carex* leaf	OS-76344
644.50	9920 ± 460	11439 (10229-12654)	pollen	OS-84446
652.25	9180 ± 55	10348 (10235-10496)	*Carex* seed	OS-76229
697.75	11600 ± 50	13434 (13300-13616)	Glacier Peak ash	Kuehn et al., 2009
721.25	16450 ± 70	rejected	*Carex* leaf	OS-76184
786.25	12450 ± 50	14549 (14158-15000)	*Artemisia* wood	OS-86819
Core BTP06A[d]				
612.00	8485 ± 40	9501 (9450-9537)	charcoal	N76636
657.50	9444 ± 57	10683 (10515-11067)	charcoal	AA0024
689.00	10414 ± 71	12291 (12064-12546)	twig	AA70025

[a] Depth below mud surface
[b] Calibrated ages derived from CALIB 6.0. Two sigma range is given in parentheses.
[c] OS-National Ocean Sciences AMS Facility; N-Lawrence Livermore AMS Facility; AA-University of Arizona AMS Facility.
[d] Huerta et al., 2009

Lithology and Geochemical Data

Core BTP08B was divided into six lithologic units from 8.10 to 5.25 m depth (Fig. 2.3). From 8.10 to 7.57 m depth, Unit 1 consisted of interbedded silt and inorganic clay. This unit had the highest magnetic susceptibility values (124.6-463.7 SI units) and the lowest Ca:Ti ratios (average=4) of the record, implying considerable detrital mineral input and very little calcite production in the lake. Unit 2 (7.57-7.18 m depth) consisted of gray inorganic clay. Magnetic susceptibility remained high (12.3-293.6 SI units), but was slightly reduced from the previous unit. Ca:Ti ratios (average=29) increased slightly. Sediments from Unit 3 (7.18-6.89 m depth) were organic clay. Ca:Ti ratios

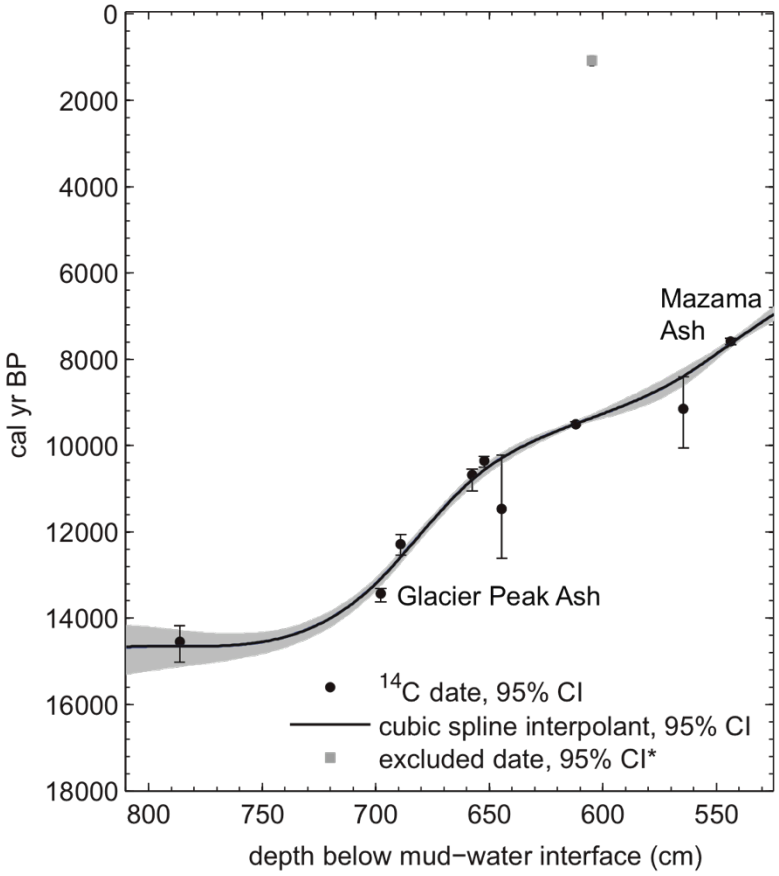


Figure 2.2 Age-depth model for Blacktail Pond based on radiocarbon determinations and tephrochronology. Gray shading represents range of dates and black line indicates the 50th (i.e., median age) percentile of all runs. The 50th (circle), 2.5th and 97.5th (bars) percentiles of the probability distribution function of calibrated dates are shown. See Table 2.1 for age determinations.

(average=195) continued to increase, while magnetic susceptibility was markedly lower (-0.1-16.5 SI units), with the exception of the Glacier Peak tephra couplet at 6.975 and 6.995 m depth (40.1 and 22.1 SI units, respectively), suggesting increased lake productivity and decreased mineral clastic input. Unit 4 (6.89-6.70 m depth) consisted of green fine-detritus gyttja. Magnetic susceptibility remained low (0-5.8 SI units), while Ca:Ti ratios (average=39) decreased. Unit 5 (6.70-6.45 m) was a transitional unit consisting of interbedded light-brown marl and green gyttja. Magnetic susceptibility was

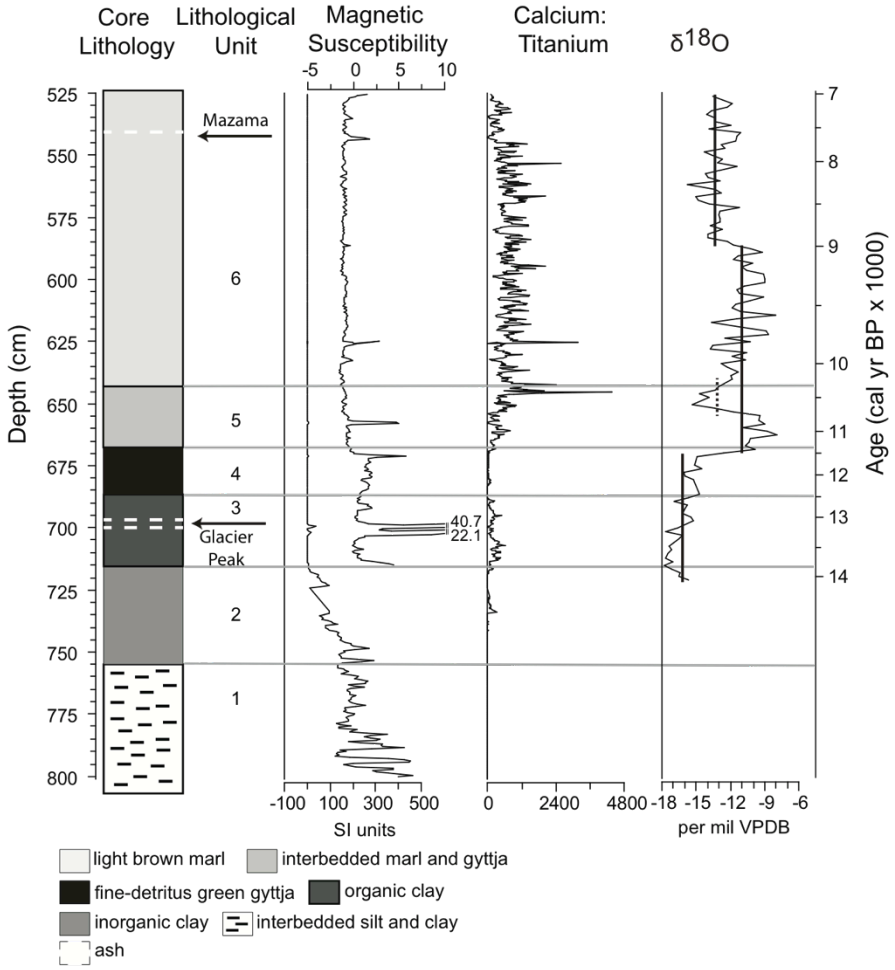


Figure 2.3 Lithologic, geochemical, and $\delta^{18}O$ isotope data for Blacktail Pond. Solid vertical lines on $\delta^{18}O$ isotope graph indicate mean values of phases; dotted vertical line indicated $\delta^{18}O$ excursion mean.

low (-1.3-5.0 SI units), and Ca:Ti ratios (average=429) increased. The topmost unit, 6.45 to 5.25 m, consisted of light-brown marl. Ca:Ti ratios (average=689) were at their highest for the entire record, while magnetic susceptibility values (-1.5-2.8 SI units) were at their lowest.

Oxygen Isotopes from Authigenic Carbonates

The carbonate $\delta^{18}O$ record for Blacktail Pond from 14,040 to ca. 7000 cal yr BP (7.21-5.26 m depth) ranged from -7.87 to -17.77 ppm (Fig. 2.3). $\delta^{18}O$ values were lowest from 14,040 to 11,500 cal yr BP, averaging -16.27 ppm. Values gradually increased during this period and then sharply increased at 11,500 cal yr BP. High values extended to 9000 cal yr BP, averaging -11.08 ppm. There is a brief excursion to low $\delta^{18}O$ values (averaging -13.25 ppm) between 10,600 and 10,100 cal yr BP. After 9000 cal yr BP, values decreased and averaged -13.10 ppm until 7000 cal yr BP.

Pollen Record

The pollen record from 14,500 to 7000 cal yr BP was divided into four zones (Fig. 2.4). Zone BP-1 (7.39-6.68 m depth; ca. 14,400-11,350 cal yr BP) featured high percentages of *Artemisia* (18-58%) and low to moderate percentages of *Pinus* (6-47%), *Abies* (<1%), and *Juniperus*-type (<3%) pollen. Percentages of *Salix* (1-6%), Rosaceae <10%), and *Shepherdia canadensis* (<2%) were their highest of the record, as were nonarboreal taxa, such as Poaceae (<3%) and Asteraceae Tubuliflorae (1-7%). Amaranthaceae (2-9%) and *Betula* (<3%) occurred at moderate levels. *Picea* pollen was low at the beginning of the period (<2%) and reached high levels (8%) by the end of the zone. PAR values were low (37-475 grains cm^{-2} yr^{-1}), however they may be inaccurate before 13,400 cal yr BP (Glacier Peak tephras) due to unreliable calculations of sedimentation rates. High percentages of indeterminate grains (2-24%) suggest subaerial exposure prior to deposition. High percentages of *Artemisia* and low values of arboreal taxa, in combination with *Salix*, *Betula*, and a diverse herb assemblage suggest a period

of alpine tundra similar to present-day alpine environments in the Rocky Mountains (Whitlock, 1993; Fall, 1994; Minckley et al., 2008). Increasing *Picea* pollen at the end of the zone marks a gradual transition to a parkland dominated by *Picea englemannii* species (Whitlock, 1993).

Zone BP-2a (6.68-6.30 m depth; 11,350-9900 cal yr BP) had dramatically increased levels of arboreal taxa (71-96%) and decreased levels of nonarboreal taxa (9-29%). *Pinus* (56-89%) and *Abies* (<5%) percentages increased, while those of *Picea* (2-5%) decreased slightly. Identifiable *Pinus* grains were attributed equally to *Pinus albicaulis*- and *Pinus contorta*-type ($P_D/P_H \sim 0.75$). *Artemisia* (3-16%) and Amaranthaceae (<4%) pollen decreased, as did most other nonarboreal taxa. Overall PAR values increased (60-317 grains cm^{-2} yr^{-1}). This zone resembles modern pollen rain studies from *Picea-Abies-Pinus* forests in the Yellowstone region (Baker, 1976; Whitlock, 1993). Due to edaphic controls on the vegetation, it is likely these forest grew on basaltic or andesitic slopes near the site, while *Artemisia* steppe or grassland grew on the calcareous glacial till of the valley. Although percentages of *Artemisia* and Poaceae were low during this period, it is likely that the dominance of *Pinus* in the pollen record diminished the relative contributions of *Artemisia* and Poaceae.

Zone BP-2b (6.30-5.60 m depth; 9900-8275 cal yr BP) is similar to zone BP-2a, but featured higher *Pinus* (44-95%) and *Pseudotsuga* (<4%) pollen percentages and increased overall PAR (97-1288 grains cm-2 yr-1). Consequently, *Picea* (<3%) and *Abie*s (<2%) pollen decreased. P_D/P_H ratios (~1.04) increased, suggesting increased

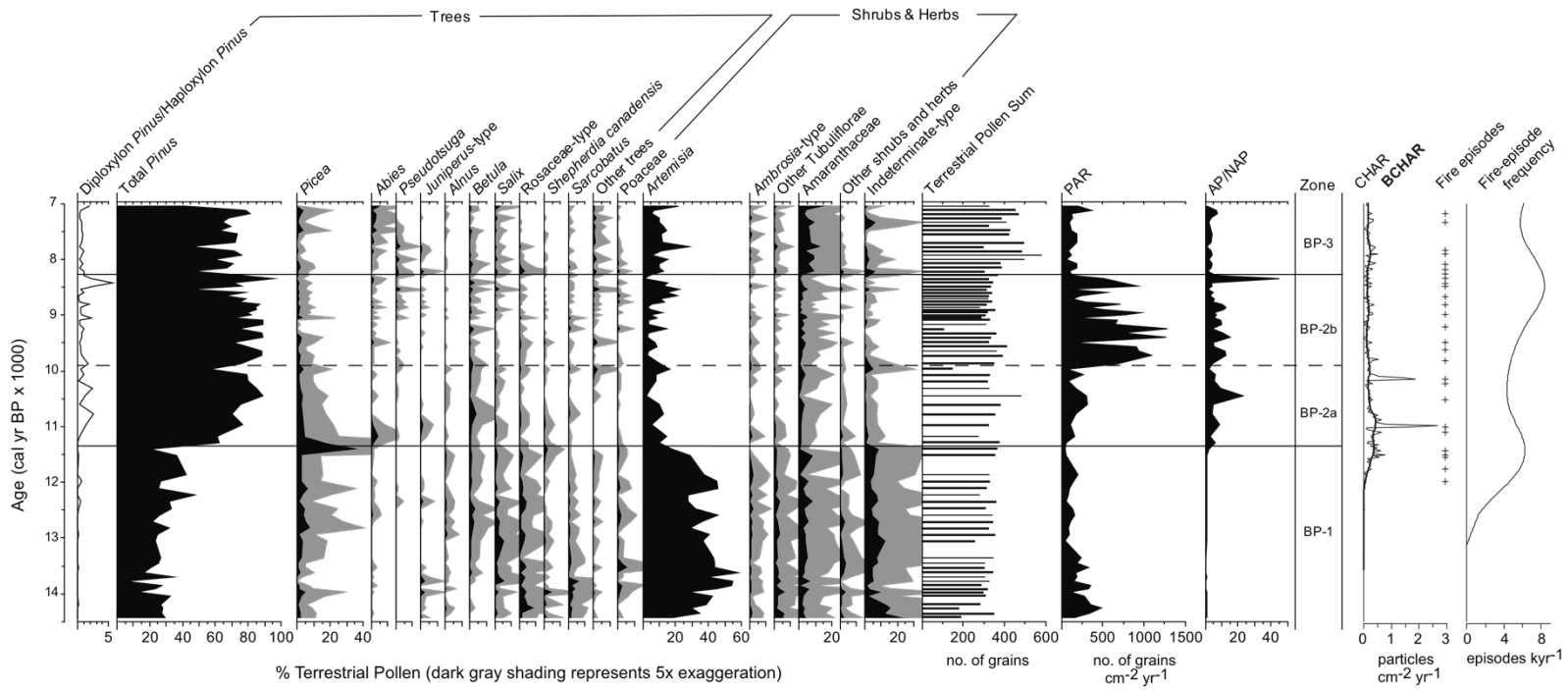


Figure 2.4 Charcoal and pollen data for selected taxa from Blacktail Pond.

presence of *Pinus contorta* on the landscape. The overall dominance of *Pinus* pollen in the record, particularly of *P. contorta*, in combination with low frequencies of shrub and herbaceous pollen, suggests a dense closed *Pinus contorta* forest growing on rhyolite outcrops near the site, and possibly on andesite and/or basalt areas. The high overall PAR values likely correspond with increased vegetation cover and/or more intense pollination season.

Zone BP-3 (5.60-5.25 m depth; 8275-7000 cal yr BP) was characterized by decreased levels of *Pinus* (42-81%) and increased *Artemisia* (5-28%), *Juniperus*-type (<3%), and Amaranthaceae (4-17%) frequencies. Levels of *Picea* (<4%), *Abies* (<6%), and *Pseudotsuga*-type (<3%) pollen remained relatively unchanged. Overall PAR decreased (56-367 grains cm^{-2} yr^{-1}), suggesting sparser vegetation cover compared with the previous period. Increased levels of *Artemisia* and Amaranthaceae, and moderate levels of conifer taxa suggest a mixture of *Artemisia* steppe and conifer forest. Again, edaphic controls likely created a mosaic of plant communities on the landscape, with *Artemisia* steppe near the lake, *Pseudotsuga* on adjacent slopes of basalt and/or andesite, and *Pinus contorta* populations on rhyolite outcrops.

Charcoal Record

Background CHAR values were initially low and increased to 0.04 particles cm^{-2} yr^{-1} at 12,000 cal yr BP (Fig. 2.4). Levels increased further at 11,000 cal yr BP to 0.43 particles cm^{-2} yr^{-1} and subsequently decreased and remained relatively constant for the rest of the record, averaging 0.18 cm^{-2} yr^{-1}. Charcoal peaks were not detected before 12,000 cal yr BP, implying few or very small fires. After that time, the fire frequency

fluctuated between 4 and 8 episodes 1000 yr^{-1}, and charcoal peaks ranged from 0.04 to 8.15 particles cm^{-2} yr^{-1} for the record, with the exception of large peaks at 10,975 and 10,125 cal yr BP. Between 12,000 and 10,500 cal yr BP, fire frequency was moderate (~ 6 episodes 1000 yr^{-1}), and the lowest fire activity occurred between 10,500 and 9,000 cal yr BP (~ 5 episodes 1000 yr^{-1}). Fire activity increased between 9000 and 7500 cal yr BP (~ 8 episodes 1000 yr^{-1}), and fire frequency was moderate (~ 6 episodes 1000 yr^{-1}) after 7500 cal yr BP.

Discussion

The Blacktail Pond data register changes in the local climate, watershed characteristics, and vegetation during the late-glacial and early Holocene (Fig. 2.5) and provide a point of comparison with other records from low- and middle-elevation forests in the northern Rocky Mountains (see Fig. 2.1). In addition, paleoclimate model simulations from 16, 11, and 6 ka provide a framework for understanding the regional climate history of western North America (Bartlein et al., 1998). In northern Yellowstone, comparison sites include Crevice Lake (45.000° N, 110.578° W, elev. 1684 m; 6 km E of Blacktail Pond; Whitlock et al., 2012), Slough Creek Pond (44.924° N, 110.353° W, elev. 1884 m; 20 km E; Whitlock and Bartlein, 1993; Millspaugh et al., 2004), and Cygnet Lake (44.660° N, 110.615° W, elev. 2350 m; 32 km S; Millspaugh et al., 2000). The Crevice Lake record began 9800 cal yr BP and thus provides only a Holocene comparison. The other comparison sites are Lower Red Rock Lakes in the Centennial Valley of southwest Montana (44.630° N, 111.837° W, elev 2015 m; 95 km

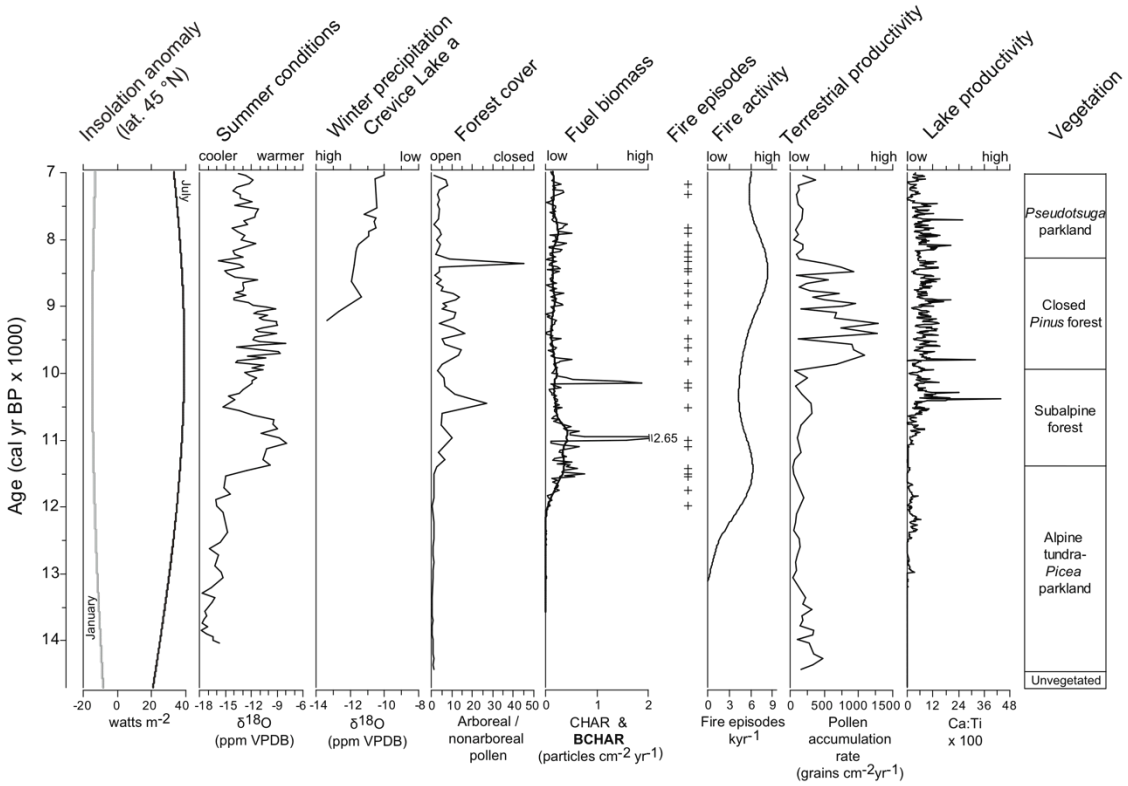


Figure 2.5 Summary of environmental proxy at Blacktail Pond during the late-glacial/early-Holocene transition plotted against January and July insolation anomalies. [a]Whitlock et al., 2012.

E; Mumma et al., 2012), and McCall Fen in the Long Valley of Central Idaho (44.933° N, 116.033° W, elev. 1615 m; 425 km E; Doerner and Carrara, 2001). All but Slough Creek Pond and Crevice Lake are located in summer-dry regions as described by Whitlock and Bartlein (1993) based on the fact that they receive the majority of precipitation during the winter months from westerly storm tracks (climate data: http://www.wrcc.dri.edu). Slough Creek Pond and Crevice Lake are located in summer-wet regions influenced by summer monsoonal circulation.

Environmental Reconstruction

Late-Glacial Period (>11,500 cal yr BP). Paleoclimate simulations for 16 and 11 ka show the direct and indirect effects of variations in the seasonal cycle of insolation on western North American climate (Bartlein et al., 1998). Direct effects include increasing temperatures and decreasing effective moisture relative to full-glacial conditions, while indirect effects include a strengthening of the northeast Pacific subtropical high-pressure system, resulting in warmer drier summers than before, and a northward shift of the jet stream. The northward shift of the jet stream in the late-glacial period was also aided by the retreat of North American ice sheets and likely resulted in increased winter precipitation in the region (Bartlein et al., 1998).

The environmental history of Blacktail Pond supports this climatic reconstruction. The period from 14,000 to 11,500 cal yr BP featured low carbonate $\delta^{18}O$ values, suggesting low evaporation, consistent with cool summer conditions and possibly higher-than-present snowfall. In addition, the $\delta^{18}O$ data show a slightly increasing trend over this period, suggesting increasing summer temperatures during the late-glacial period. Blacktail Pond initially occupied a sparsely vegetated landscape with little soil cover located just down valley of the wasting Yellowstone glacier complex (Pierce, 1979; Licciardi and Pierce, 2008). Lake sediments from this period are primarily inorganic silt and clay with high values of magnetic susceptibility and low Ca:Ti ratios, characteristic of poorly developed soils and unstable slopes.

Decreasing magnetic susceptibility and slightly increased Ca:Ti ratios after 14,600 cal yr BP are associated with low AP/NAP ratios and PARs that indicate sparse

open vegetation with low biological productivity. *Artemisia*, Rosaceae, *Salix*, and herbs as well as early successional species, such as *Shepherdia canadensis*, were present. Discontinuous fuels and cool conditions likely limited fire activity during this period.

After 12,900 cal yr BP, *Picea engelmannii* formed parkland vegetation at Blacktail Pond and nearby Slough Creek Pond, and after 12,500 cal yr BP, *Picea*, *Abies*, and *Pinus* were present in open forest communities at both sites Elsewhere in Yellowstone, the vegetation at Cygnet Lake shifted from alpine communities to closed *Pinus contorta* forest at 12,200 cal yr BP without an intervening mixed conifer parkland period (Whitlock, 1993). At Lower Red Rock Lakes, full-glacial tundra changed to *Picea-Pinus* parkland after 17,000 cal yr BP (Mumma et al., 2012), and the pollen record from McCall Fen indicates a transition from *Artemisia* steppe to closed *Picea-Pinus* forest at 14,300 cal yr BP (Doerner and Carrara, 2001). Thus, steadily increasing summer temperatures in the northern Rocky Mountains at the end of the late-glacial period supported the development of first alpine tundra, then spruce parkland and open mixed-conifer forest throughout the region.

Climate and vegetation proxies from Blacktail Pond do not show a climate reversal associated with the Younger Dryas Chronozone (12,900 to 11,500 cal yr BP; Alley et al., 2002). In the northern Rocky Mountains, Younger Dryas cooling is primarily inferred from minor glacial advances in the Wind River Range (Gosse et al., 1995a,b) and the Canadian Rockies (Reasoner et al., 1994). In contrast, most fossil pollen records in the region, including Blacktail Pond, do not register a cool event. The one exception may be McCall Fen (Doerner and Carrara, 2001) where decreases in *Pinus*/*Artemisia*

ratios and organic sedimentation from 12,700 to 12,200 cal yr BP imply a more open landscape than before or immediately after. The absence of a Younger Dryas signal in most paleoecologic records may be explained by: (1) the coarse sampling resolution of many late-glacial pollen records; (2) the presence of alpine and subalpine forest communities that were insensitive to an abrupt cold interval; and/or (3) the possibility that Younger Dryas cooling did not occur in this part of the northern Rocky Mountains. The climate and vegetation history and carbonate $\delta^{18}O$ data at Blacktail Pond indicate gradual warming and support the latter explanation.

Early Holocene (11,500-8275 cal yr BP). Greater summer insolation in the early Holocene directly increased summer temperatures and indirectly strengthened the subtropical high-pressure system and summer monsoonal circulation, creating drier summers than at present in some areas of the northern Rocky Mountains and wetter conditions in others (Bartlein et al., 1998; Whitlock and Bartlein, 1993). Beginning at 11,500 cal yr BP, Blacktail Pond carbonate $\delta^{18}O$ values sharply increased, indicating a dramatic rise in evaporation that was likely caused by increased summer temperatures. Fire activity also increased, as indicated by high CHAR values and increased fire frequency from 4 to 8 episodes kyr^{-1} (Fig. 2.5). It is likely that increased summer temperatures during the early Holocene dried fuels and promoted fire spread just as they have at present (Westerling et al., 2011).

Closed subalpine forest developed at Blacktail Pond after 11,350 cal yr BP, based on increasing AP/NAP pollen ratios dominated by *Pinus* (mostly *P. contorta*). This shift lagged the rise in summer temperature and fire activity, inferred from isotopic and

charcoal data, by approximately 150 years (Fig. 2.6). Mesophytic *Picea* populations were uncommon in the Blacktail Pond area by 9900 cal yr BP, and *Pinus* (presumably *P. contorta*) was the forest dominant. A similar lagged response in ecosystem changes is seen in other Yellowstone records where high-resolution charcoal and pollen data are available (Fig. 2.6). At Slough Creek Pond, fire activity (inferred from high CHAR) increased at ca. 12,250 cal yr BP, whereas forest closure (inferred from high AP/NAP) was delayed until 11,000 cal yr BP. The tradeoff between *Picea* and *Pinus* dominance occurred at 10,750 cal yr BP. Thus, the development of closed *Pinus* forest lagged the change in the fire regime by approximately 1500 years. At Cygnet Lake, fire activity increased at 13,000 cal yr BP, but did not substantially rise until 11,000 cal yr BP. Forests increased at 11,000 and the *Picea* to *Pinus* tradeoff occurred at 10,750 cal yr BP, such that closed *Pinus* forest lagged the change in fire activity by less than 250 years.

The data thus suggest that climate changes first drove a shift in fire activity, which in turn favored the expansion and dominance of *Pinus contorta* over *Picea engelmannii*. At present, *Picea engelmannii* is a "fire avoider", as it slowly reinvades burned areas and has essentially no adaptation to fire (Agee, 1993). Slow regeneration of *P. engelmannii* likely set the stage for *Pinus contorta,* a fire-adapted and early-seral species tolerant of warm summer conditions, to colonize burned areas. Although climate change was the primary control of postglacial vegetation change in Yellowstone, increased fire activity facilitated the transition from *Picea* parkland to eventually *Pinus contorta* forest during a sequence of events that took place over several centuries in the early-Holocene period.

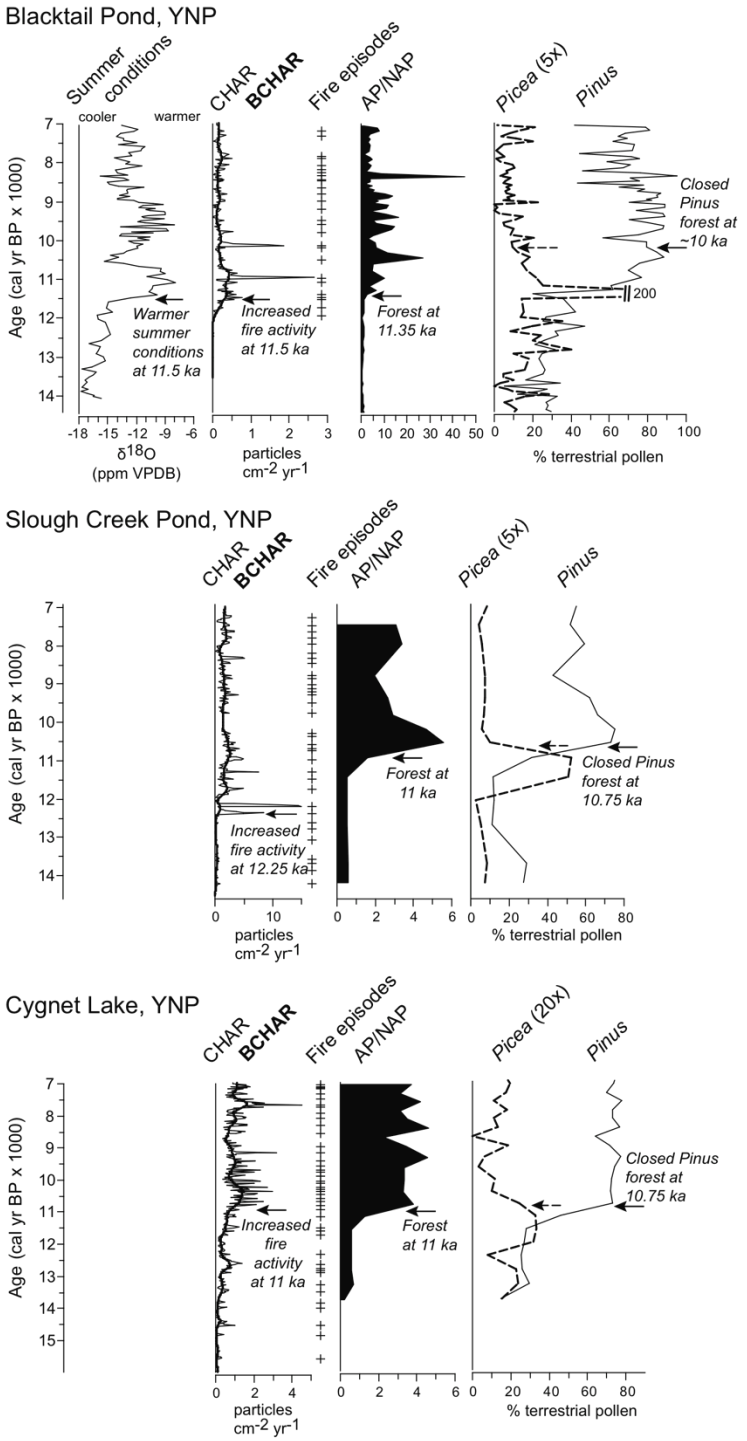


Figure 2.6 Comparison of fire and vegetation history at Blacktail Pond with other Yellowstone sites, Slough Creek Pond and Cygnet Lake. CHAR—charcoal accumulation rate; BCHAR—background charcoal accumulation rate; AP—arboreal pollen; NAP—nonarboreal pollen.

Carbonate $\delta^{18}O$ values in the early Holocene were the highest of the record, averaging -11.08 ppm from 11,500 to 9000 cal yr BP, suggesting high rates of evaporation in association with warm summer conditions. Within this period, an excursion to cool conditions is inferred from a decrease in $\delta^{18}O$ values between 10,600 and 10,100 cal yr BP. This event is not registered in the pollen, charcoal, nor the Ca:Ti data which shows a peak in values. Once again, the terrestrial records of the region seem rather insensitive to short cooling events than other paleoclimate proxy. Furthermore, it appears vegetation was the primary driver of lake productivity during this time versus climate. Like the Younger Dryas Chronozone, this isotopic event recorded at Blacktail Pond for the first time bears further study.

PARs at Blacktail Pond were high during the early Holocene and peaked at 9900 cal yr BP, suggesting elevated forest productivity and intense pollination season consistent with increased spring temperatures and longer as well as warmer summers than at present. *Pinus contorta* forest likely expanded on nearby rhyolite outcrops at this time, where edaphic factors favor their growth. *Picea* and *Abies* populations were greatly reduced at Blacktail Pond, suggesting that populations probably moved to higher elevations where temperatures and/or fire activity was lower or were confined to areas of cold-air drainage near the site. Calcareous substrates surrounding the lake likely supported *Artemisia* steppe or grassland, as they do today. *Pseudotsuga* became more abundant during this time, probably on rocky slopes of andesite and/or basalt. *Pseudotsuga* may have been present on these rocky slopes since 12,300 cal yr BP, given

the fact that trace amounts of *Pseudotsuga* pollen are found throughout the record, but it was not until conditions warmed sufficiently that these populations were able to expand.

At nearby Crevice Lake, a multi-proxy (carbonate, fossil pollen, diatoms, organic carbon, charcoal, and geochemical data) study of seasonal variability suggests that the early Holocene was characterized by cool winters, protracted springs, and warm but effectively wet summers that supported a closed forest. The Blacktail Pond data are consistent with this reconstruction. Increased PAR at Blacktail Pond between 9900 and 8280 cal yr BP are consistent with a long or more intense pollination season due to protracted springs and summers, while closed *Pinus contorta* forest during this time may reflect some combination of warm summer conditions and adequate soil moisture. Concurrently, *Pinus-Juniperus* forest at Slough Creek Pond suggest effectively wet summers, and all three sites in northern Yellowstone indicate low fire-episode frequency and high fuel biomass despite initial increases in fire activity at the beginning of the early Holocene. Large standing-replacing events occurred at widely spaced intervals at this time typical of *Pinus* and *Picea* forests in Yellowstone at present (Baker, 2009).

The Crevice Lake $\delta^{18}O$ record suggests that summer-wet conditions in the early Holocene arose from the carryover of moisture from high winter snowpack, rather than from increased summer precipitation (Whitlock et al., 2008, 2012). Low $\delta^{18}O$ values there are evidence of high winter snowpack between 9800 and 8200 cal yr BP (Fig. 2.5), given its groundwater connection with the Yellowstone River. High carbonate $\delta^{18}O$ values between 11,500 and 9000 cal yr BP at Blacktail Pond, in contrast, suggest warmer-than-present summers, because this closed lake is most sensitive to evaporation.

Although high carbonate $\delta^{18}O$ values can also occur due to more rainfall than snow due to increased spring, summer, or fall temperatures, or an enhanced monsoon (e.g. Anderson, 2011), the combination of $\delta^{18}O$ records from the two very different lake systems suggests that early-Holocene winters in northern Yellowstone were wetter than present while summer conditions were warmer and effectively wetter than today.

Other paleoecological records in the northern Rocky Mountains suggest warmer-than-present summer conditions during the early Holocene; however, many indicate that summer conditions were effectively drier than in northern Yellowstone. In central Yellowstone, *Pinus contorta* forest grew at Cygnet Lake and fire frequency was high, providing evidence of warm dry conditions. Lower Red Rock Lakes supported *Artemisia* steppe from 10,500 to 7100 cal yr BP (Mumma et al., 2012), and McCall Fen indicates open *Pinus* forest from 11,000 to 3500 cal yr BP (Doerner and Carrara, 2001), suggesting warmer drier conditions at each site during the early Holocene than at present At Jones Lake in the Ovando Valley of northwest Montana, maximum $\delta^{18}O$ values occurred between 10,000 and 8000 cal yr BP, indicating summer drought with little ground-water recharge (Shapley et al., 2009).

Thus, all paleoecological sites register higher-than-present summer temperatures in the early Holocene, but effective moisture varied. Sites in northern Yellowstone (Blacktail Pond, Crevice Lake, and Slough Creek Pond) were warmer and effectively wetter than at present, whereas those in central Yellowstone (Cygnet Lake) and further west (Lower Red Rock Lakes and McCall Fen) were warmer and effectively drier. The influence of possible strengthened monsoonal circulation, creating summer-wet

conditions in northern Yellowstone, and a stronger subtropical high, resulting in summer-dry responses further south and west in the northern Rocky Mountains may have created the spatial variability in moisture patterns (Whitlock and Bartlein, 1993; Bartlein et al., 1998). However, the carryover of winter moisture into the growing season, evident at Blacktail Pond and Crevice Lake, may also account for some of the summer-wet signal.

Middle Holocene (8280-7000 cal yr BP). The middle Holocene was characterized by declining summer insolation and rising winter insolation. Furthermore, paleoclimate model simulations for western North America at 6 ka suggest a weakening of the subtropical high-pressure system and summer monsoon, as well as slightly warmer winters (Bartlein et al., 1998). In northern Yellowstone, low carbonate $\delta^{18}O$ values from Blacktail Pond indicate reduced summer evaporation from 9000 to 7000 cal yr BP implying cooler summers than before. However, high carbonate $\delta^{18}O$ values from Crevice Lake suggest decreased winter precipitation after 8000 cal yr BP. Forests became sparser as indicated by decreasing AP/NAP pollen ratios and PARs after 8200 cal yr BP at Blacktail Pond and Crevice Lake, and after 7500 cal yr BP at Slough Creek Pond. Summers were effectively drier than before during the middle Holocene at these sites, based on high fire activity centered at 8000 cal yr BP at all three sites. At Cygnet Lake in central Yellowstone, fire frequency decreased at 8000 cal yr BP, and conditions were likely wetter there than in northern Yellowstone.

Other paleoecological records from the northern Rocky Mountains also indicate warm dry conditions in the middle Holocene. For example, at Lower Red Rock Lakes, *Artemisia* steppe was replaced at 7100 cal yr BP by closed mixed conifer forest (Mumma

et al., 2012), and at McCall Fen, open *Pinus* forest was followed by closed mixed conifer forest after 3500 cal yr BP (Doerner and Carrara, 2001). Both records suggest the establishment of cooler and/or wetter conditions in the early late Holocene. The late development at McCall Fen may be due to its lower elevation (100-600 m lower) than other sites or a combination of climatic and nonclimatic feedbacks.

Conclusions

The Blacktail Pond study contributes new information to our understanding of the ecological history of northern Yellowstone and middle-elevations in the northern Rocky Mountains during the late-glacial and early Holocene in several ways. First, the $\delta^{18}O$ record indicates gradual warming during the late-glacial period followed by a step-like transition to warmer summer temperatures at 11,500 cal yr BP, marking the beginning of the early Holocene at Blacktail Pond. There was no evidence of a climate reversal during the Younger Dryas Chronozone, in contrast with records from the Wind River Range, Canadian Rockies, and possibly central Idaho. Most late-glacial pollen records from the northern Rocky Mountains indicate unidirectional vegetation change, as the landscapes shifted from alpine tundra to parkland to forest, that implies progressive warming.

Second, increasing summer temperatures were the primary control of vegetation change in northern Yellowstone during the late-glacial and early Holocene; however, increased fire activity facilitated and preceded the development of closed *Pinus* forest in available paleoecological records from Yellowstone. In Yellowstone during the late-

glacial/early-Holocene transition, climate change served as a distal control of vegetation change, whereas fire was the likely the proximal control catalyzing that change.

Third, the Blacktail Pond record supports the findings at nearby Crevice Lake in that the carryover of winter moisture was as or more important as moisture contributions from enhanced summer monsoons at effectively wet sites during the early Holocene. Blacktail Pond data imply warmer-than-present summers, and the Crevice Lake $\delta^{18}O$ record indicates that moisture carryover from high winter snowpack supported closed forest. Our comparison with other paleoecological records in the region suggest the northern Rocky Mountains featured warm summer conditions in the early Holocene, while the patterns of precipitation were more variable due to the competing influences of strengthened summer monsoons and a stronger subtropical high.

Fourth, climatic conditions in northern Yellowstone became cooler and drier following the early Holocene period. *Artemisia* and Amaranthaceae became increasingly abundant, as did populations of *Pseudotsuga* after 8200 cal yr BP. Summers were cooler than before, as indicated by low $\delta^{18}O$ values at Blacktail Pond and drier due to decreased winter snowfall, as indicated by high $\delta^{18}O$ values at Crevice Lake. Other paleoecological records in the northern Rocky Mountains indicate prolonged warm dry conditions as late as 3500 cal yr BP, suggesting that the transition to middle Holocene conditions did not occur synchronously throughout the region due to climatic and nonclimatic feedbacks.

Finally, paleoecological records in Yellowstone provide evidence for past fire-facilitated vegetation change following warming conditions during the late-glacial/early-Holocene transition, and additional work examining the fire histories of low- and middle-

elevation areas of the northern Rocky Mountains is needed to adequately assess the sensitivity of the region's forests to future climate change. Nonetheless, the combination of proximal and distal drivers of vegetation change in the past suggests fire has the ability to amplify the effects of future warming on vegetation change in the northern Rocky Mountains.

Acknowledgements

This research was supported by National Science Foundation grant EAR-0801467. We thank C. Hendrix and S. Gunther (Yellowstone National Park) for logistical support; V. Nagashima, I. Jara, O. Pesce, and M. Valenzuela for field assistance; V. Nagashima, J. Giskaas, B. Ahearn, and A. Peery for lab assistance; and two anonymous reviewers for their thoughtful suggestions.

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CHAPTER THREE

PATTERNS OF TERRESTRIAL AND LIMNOLOGIC DEVELOPMENT IN THE NORTHERN GREATER YELLOWSTONE ECOSYSTEM (USA) DURING THE LATE-GLACIAL/EARLY-HOLOCENE TRANSITION

Contribution of Author and Co-Authors

Manuscript in Chapter 3

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Contributions: Defined the experimental design, participated in the fieldwork, described the lithology of sediment cores from Dailey Lake, measured magnetic susceptibility, counted charcoal and pollen samples, analyzed the data, and wrote the manuscript.

Co-Author: Yanbin Lu

Contributions: Helped define the experimental design, counted diatom samples from Dailey Lake, analyzed the diatom data, and commented on the manuscript.

Co-Author: Cathy Whitlock

Contributions: Supported this research under National Science Foundation grants EAR-0801467 and OISE 0966472, helped define the experimental design, participated in fieldwork, discussed the results and implications, and edited the manuscript.

Co-Author: Sherilyn C. Fritz

Contributions: Supported this research under National Science Foundation grant EAR-0801467, helped define the experimental design, assisted in diatom interpretation, and commented on the manuscript.

Co-Author: Kenneth L. Pierce

Contributions: Helped interpret local glacial recessional history and geomorphic processes and commented on the manuscript.

Manuscript Information Page

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Palaeogeography, Palaeoclimatology, Palaeoecology
Status of Manuscript:
____ Prepared for submission to a peer-reviewed journal
__x_ Officially submitted to a peer-review journal
____ Accepted by a peer-reviewed journal
____ Published in a peer-reviewed journal

Publisher: Elsevier
Date of Submission: March, 2014

Abstract

A high-resolution record of pollen, charcoal, diatom, geochemical, 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, slopes were unstable, and loess deposition occurred. 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.

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, geochemical, 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 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.

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. 3.1). Present-day vegetation patterns in northern

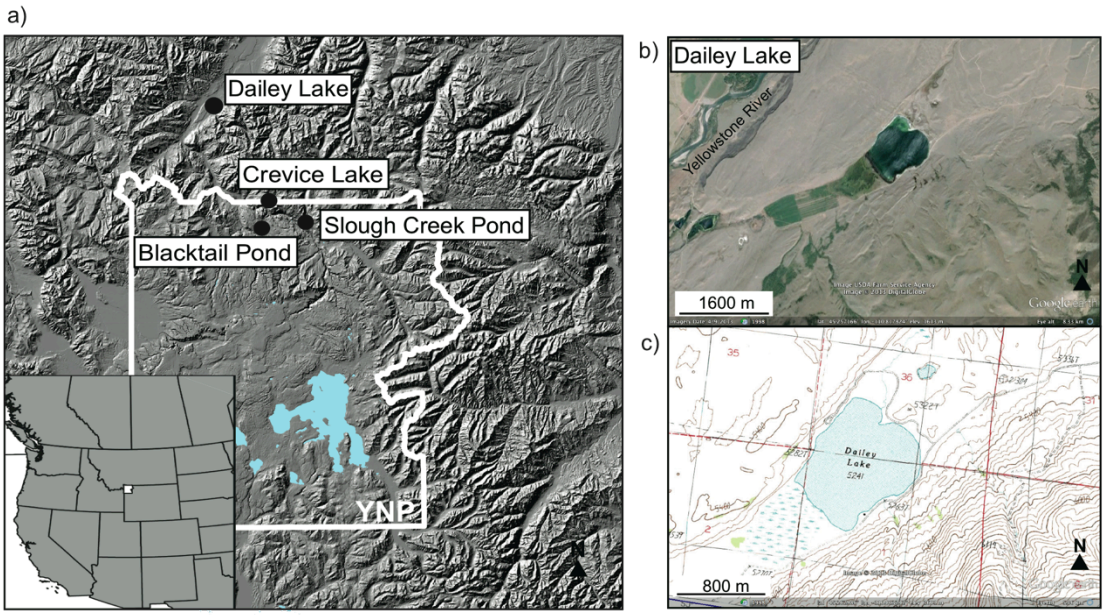


Figure 3.1 Location of Dailey Lake. a) Location of northern Yellowstone sites discussed in text. b) Aerial image of Dailey Lake. c) Topographic map of Dailey Lake. Contour interval 20 feet.

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).

Methods

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.

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.

The ^{14}C dates were converted to calendar ages using IntCal13 calibration curve (Reimer et al., 2013), and the age-depth model was constructed using Bayesian accumulation histories for deposits (Bacon) software for modeling in R (Blaauw and Christen, 2011). Bacon repeatedly samples from the probability density function of each calibrated age, fits many possible splines to the age-depth data, and rejects fitted splines

that result in age reversals. At each sediment core depth, a probability density function is generated from the population of retained splines. The software requires an *a priori* assignment of the mean accumulation rate throughout the sediment core, which we estimated as 10 years cm^{-1} based on core length and the age of local ice recession (~16,100 cal yr BP; Licciardi and Pierce, 2008). Splines were calculated piece-wise based on a user-defined section length of 10 cm. All dates were included in the model, including a suspected outlier at 1020.0 cm depth (Table 3.1), inasmuch as outlier dates only affect model uncertainty and do not affect the best age estimates.

Lithology and Geochemical Analysis

Initial core descriptions were performed at the LacCore facility, University of Minnesota-Twin Cities. Cores were split, imaged, and magnetic susceptibility was measured at contiguous 0.5-cm intervals using a Geotek XYZ MSCL logger to record changes in mineral clastic sedimentation (Gedye et al., 2000). Measurements were reported in SI units. Geochemical elemental analysis of the cores was conducted at the Large Lakes Observatory, University of Minnesota-Duluth. Split cores were run through an ITRAX XRF scanner at contiguous 0.5-cm intervals. Here, we focus on the calcium/titanium (Ca/Ti) and potassium/titanium (K/Ti) ratios derived from the XRF analysis.

The Ca/Ti record is interpreted as a measure of calcite production in the lake system through time. Fluctuations in calcite production are largely due to changes in summer temperatures and lake productivity due to algal photosynthesis during the

Table 3.1 Uncalibrated and calibrated ^{14}C ages for Dailey Lake.

Depth (cm)[a]	^{14}C age (^{14}C yr BP)	Calibrated age range[b] (cal yr BP)	Material dated	Lab number/reference[c]
100.00	1740 ± 25	1570-1709	pollen	OS-98610
200.00	3550 ± 25	3724-3906	pollen	OS-98617
300.00	5080 ± 35	5746-5909)	pollen	OS-98618
446.00	6730 ± 40	7514-7665	Mazama ash	Zdanowicz et al., 1999
509.25	8140 ± 35	9005-9242	pollen	OS-88594
585.00	9260 ± 40	10292-10559	pollen	OS-95045
604.50	9120 ± 50	10199-10412	pollen	Beta-330381
663.00	9130 ± 35	10226-10395	pollen	OS-88481
809.25	9630 ± 40	10786-11178	pollen	OS-88480
955.25	9660 ± 45	10791-11200	*Carex* leaf	OS-76183
972.50	10750 ± 50	12602-12743	pollen	OS-95044
988.50	11100 ± 45	12827-13074	pollen	OS-95077
1005.00	11250 ± 40	13050-13192	pollen	OS-90974
1020.00	15550 ± 75	18643-18951	pollen	OS-91010
1023.25	12000 ± 510	13001-15618	charcoal	OS-87766
1441.0	na	14440-17800	Chico Recessional Moraine	Licciardi and Pierce, 2008

[a] Depth below mud surface
[b] 95% calibrated age ranges determined using CLAM program and the IntCal13 curve calibration curve (Blaauw, 2010)
[c] OS-National Ocean Sciences AMS Facility; Beta-Beta Analytic

summer months (Dean and Megard, 1993); however, it can also be influenced by changes in pH and changes in ionic composition and concentration (Clark et al., 2002). Ti is a detrital sediment indicator in our record, because it is only produced allogenically through the physical erosion of Ti-bearing rocks (Cohen, 2003), and minerals containing Ti are not sensitive to dissolution (Demory et al., 2005). The Ca/Ti ratio corrects the influence of detrital Ca on the Ca geochemical record, which varies with detrital Ti in the lake sediments.

The K/Ti record provides information on the delivery of freshly eroded detrital material to the lake (Muhs et al., 2001), where low K/Ti ratios indicate input of highly altered material, and high K/Ti ratios indicate the accumulation of freshly eroded sediments (Mischke et al., 2010). Loss of soluble elements, in this case K, relative to an insoluble element, Ti, is typical of highly weathered sediments (Muhs et al., 2001), and low K/Ti ratios could suggest loess deposition into the lake. However, without K/Ti data from the local bedrock, we cannot rule out the possibility that the K/Ti ratio simply reflects eroded catchment material.

The magnetic susceptibility and K/Ti records serve as proxies of landscape stability. In this paper, landscape stability refers to the degree of erosion occurring in the Dailey Lake catchment as a result of ice-recessional processes, such as solifluction and surface run-off, poor soil development, and eolian activity. The combination of high magnetic susceptibility and low K/Ti ratios is hypothesized to reflect sediment input into the lake system both from increased slopewash and from wind-derived sources. Landscape stabilization occurs when erosional and eolian activity subsides and soils develop, as indicated by decreased magnetic susceptibility and increased K/Ti ratios.

Pollen Analysis

Samples of 1 cm^3 were taken at 2 to 8 cm intervals and prepared using pollen methods described by Bennett and Willis (2001), except a brief Schulze treatment was substituted for acetolysis to oxidize organics (Doher, 1980). A *Lycopodium* tracer was added to the samples to calculate pollen concentration (grains cm^{-3}) and pollen accumulation rates (PAR; grains cm^{-2} yr^{-1}). Pollen grains were identified at

magnifications of 400x and 1000x, and 200 to 400 terrestrial pollen grains were counted per sample. Identifications were made to the lowest taxonomic level possible using reference collections and atlases (e.g., Moore and Webb, 1978; Kapp et al., 2000). *Pinus* grains with intact distal membranes were distinguished between diploxylon-type and haploxylon-type. Based on phytogeography, diploxylon-type *Pinus* pollen is attributed to *P. contorta* and haploxylon-type *Pinus* pollen as either *P. albicaulis* or *P. flexilis*. *Pinus* grains missing a distal membrane were identified as "undifferentiated *Pinus*". Pollen grains that could not be identified using available reference material were classified as "unknown", while degraded or hidden pollen grains were classified as "indeterminate".

Pollen percentages, ratios, concentrations, and accumulation rates were used to reconstruct the vegetation history. Reconstructions were aided by comparisons to modern pollen assemblages from surface samples in the Greater Yellowstone region (Baker, 1976; Whitlock, 1993; Fall, 1994) and from surface samples collected from Dailey Lake (Table 3.2). Percentages were calculated based on the total pollen sum of terrestrial taxa, including pteridophytes, unknown, and indeterminate grains. The pollen-percentage record was divided into zones based on constrained cluster analysis (CONISS; Grimm, 1988) and visual inspection.

Dailey Lake's position below present-day lower treeline enabled us to examine lower treeline dynamics relative to present-day. Comparison of the modern pollen rain at Dailey Lake, specifically the arboreal to nonarboreal pollen ratios (AP/NAP), to its fossil assemblages was used to infer the relative position of lower treeline and/or changes in forest density. At present, the AP/NAP ratio is 2.23, which lies within the range of

Table 3.2 Modern pollen rain from Dailey Lake.

Pollen Taxa	**Relative Abundance**
Trees	
Total *Pinus*	59%
Pinus albicaulis/flexilis-type	5%
Pinus contorta-type	7%
Picea	3%
Abies	2%
Juniperus-type	4%
Pseudotsuga	1%
Shrubs and Herbs	
Alnus	2%
Salix	2%
Sarcobatus	1%
Betula	1%
Rosaceae-type	1%
Artemisia	12%
Poaceae	7%
Ambrosia-type	1%
Amaranthaceae	2%
Other Asteraceae	1%
AP/NAP	2.23

modern surface samples from below treeline at other sites in the region (1.23-2.79; Whitlock, 1993; Millspaugh et al., 2000; Mumma et al., 2012). In general, the lower forest/steppe boundary in the Rocky Mountains is controlled by effective moisture (precipitation – evaporation) (Thompson et al., 1999). Higher AP/NAP values compared to modern values are evidence of a downward shift in lower treeline and/or of increased forest density in its existing position. In either case, the data imply an increase in effective moisture. Lower AP/NAP values than at present suggest an upward expansion of steppe and grassland and/or an opening of the forest and thus effectively

drier conditions. Alternatively, variations in AP/NAP values could reflect changes in forest structure due to disturbance events such as fire (Baker, 2009), with increased fire activity associated with forest opening and decreased AP/NAP values.

Charcoal Analysis

Charcoal particles >125 μm were extracted at 2-cm intervals, 2 cm^3 volume samples at Dailey Lake using standard sieving methods (Whitlock and Larsen, 2001). Large charcoal particles >125 μm provide a record of high-severity fires within a few kilometers of the site (Higuera et al., 2010). Analysis focused on long-term trends in charcoal concentration (particles cm^{-3}) and accumulation rates (CHAR; particles cm^{-2} yr^{-1}) rather than the frequency of fire episodes, inasmuch the charcoal sampling interval was not contiguous and individual fire events may not have been detected. CHAR was calculated using CharAnalysis software (Higuera et al., 2008). Charcoal concentrations and deposition times were interpolated into contiguous bins based on the median resolution of the record (19 years), and CHAR was calculated by dividing resampled concentrations (particles cm^{-3}) by resampled deposition times (yr cm^{-1}). The long-term trends (background CHAR=BCHAR) were calculated by smoothing the CHAR time series with a 500-year lowess smoother, robust to outliers. BCHAR reflects levels of arboreal fuel biomass, which is related to the amount of forest cover as well as the size and severity of fires that produce charcoal (Marlon et al., 2006). BCHAR was compared to trends in charcoal concentration to identify depths where changes in sediment accumulation may have strongly affected charcoal accumulation rates.

Diatoms

Diatom samples were taken at 0.5 to 5 cm intervals and treated with cold hydrochloric acid and hydrogen peroxide to digest the carbonate and organic material, respectively. Samples were then rinsed four times and dried onto coverslips and mounted onto slides with a permanent mounting media (Battarbee, 1986). At least 300 diatom valves were counted on each slide, and diatom data are shown as relative abundance. Diatom zones were identified using constrained cluster analysis (CONISS; Grimm, 1988), using all species identified at any point in the record.

Results

Chronology

The Dailey Lake age model is based on fourteen AMS ^{14}C dates and the accepted age of the Mazama Ash (Table 3.1; Fig. 3.2). Due to the lack of dateable material near the base of the sediment core, the age of the Chico recessional moraines (16.1 ± 1.7 ^{10}Be ka, assumed 16,100 ± 1700 cal yr BP; Licciardi and Pierce, 2008) located 10 km down-valley from Dailey Lake was used as the core's basal maximum age. No substantial moraines or outwash are noted between Dailey Lake and the Chico moraines, implying rapid ice recession. Above 500 cm depth, the age model is primarily linear with moderate associated uncertainties. Accumulation rates decreased after 500 cm depth, and uncertainties increased rapidly after 1025 cm depth. The model yields a core basal date between 16,450 and 18,570 cal yr BP (2 sigma error).

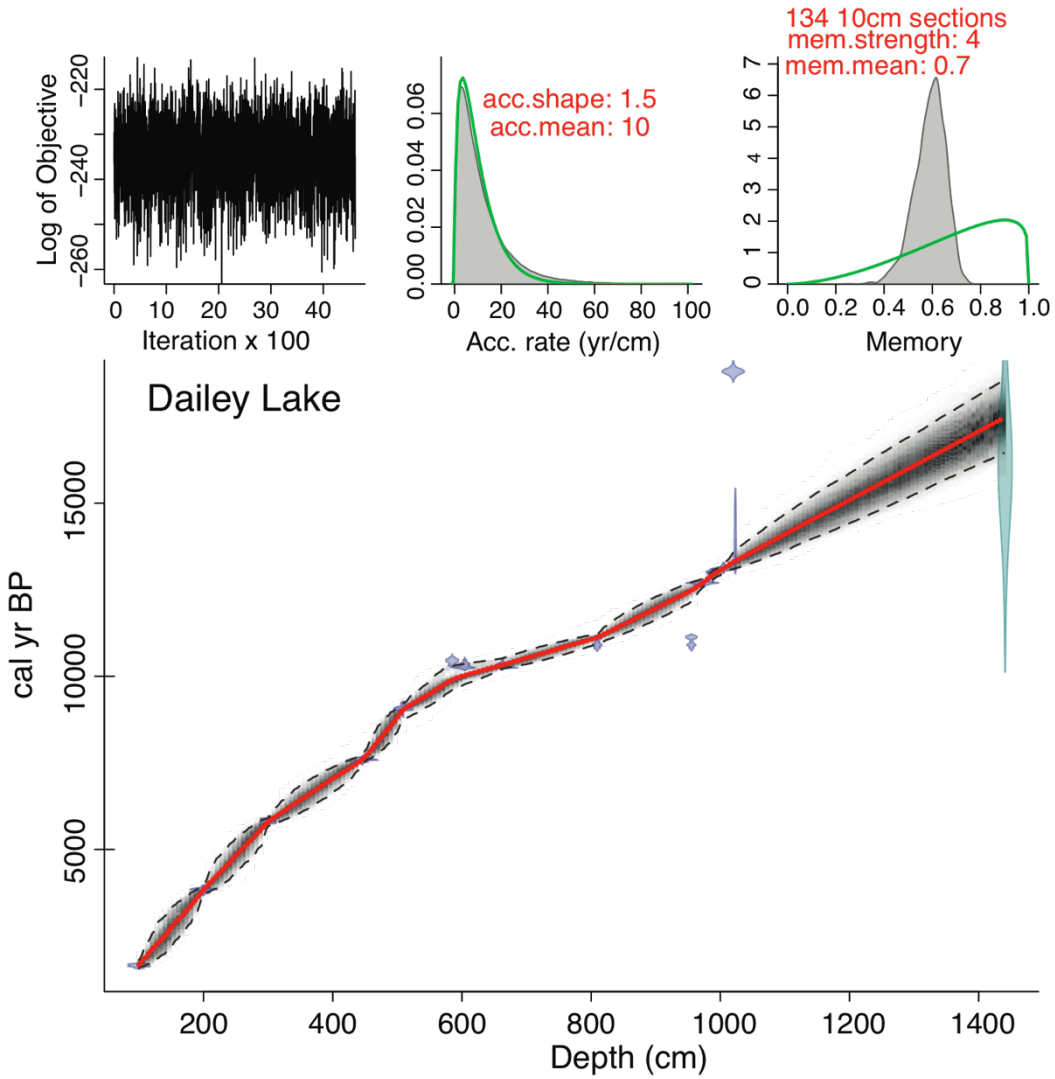


Figure 3.2 Age-depth model for Dailey Lake. Solid red line indicates weighted averages of all possible chronologies. Grayscale cloud represents age model probability and is bounded by dotted-line confidence interval (95%). Left inset shows the iteration history, the middle inset shows the prior (lines) and posterior densities (area fill) for the mean accumulation rate, and the right inset show the prior (line) and posterior (fill) of the memory (1-cm autocorrelation strength).

Lithology and Geochemical Analysis

The core lithology for the period of interest consisted of four units between 14.40 and 3.50 m depth (17,470-6430 cal yr BP; Fig. 3.3). Unit 1 (14.40-10.48 m depth;

17,730-13,580 cal yr BP) was glacial inorganic clay and featured the highest magnetic susceptibility (13.4-79.6 SI units; average = 57.0), indicating considerable mineral clastic input. Ca/Ti (1.14-3.46; average = 1.40) and K/Ti ratios (0.60-0.97; average = 0.84) were low in this unit, implying very little calcite production and deposition of highly altered sediments, possibly in the form of loess, and/or eroded catchment material. Unit 2 (10.48-10.18 m depth; 13,580-13,270 cal yr BP) was composed of organic clay with decreasing magnetic susceptibility (12.9-76.8 SI units; average = 37.2) and somewhat elevated Ca/Ti (0.99-8.05; average = 1.46) and K/Ti ratios (0.74-1.00; average = 0.79). Unit 3 (10.18-10.06 m depth; 13,370-13,130 cal yr BP) was a relatively thin layer of dark gray silt, and magnetic susceptibility continued to decrease through this unit (2.5-23.0 SI units; average = 7.2), while Ca/Ti (6.60-56.59; average = 40.50) and K/Ti ratios (0.90-1.45; average=1.18) increased. Unit 4 (10.06-3.50 m depth; 13,130-6430) was marl with fine-detritus gyttja and was divided into three subunits based on changes in magnetic susceptibility and Ca/Ti ratios. K/Ti ratios were relatively stable over this period (0.82-2.15; average =1.29). Unit 4a (10.06-7.00 m depth; 13,130-10,530 cal yr BP) had low magnetic susceptibility (-0.6-12.9 SI units; average = 0.8) and high Ca/Ti ratios (3.61-303.74; average = 121.90). Magnetic susceptibility increased (-0.1-12.7 SI units; average = 3.6) in Unit 4b (7.00-5.70 m depth; 10,530-9730 cal yr BP), while Ca/Ti ratios decreased (1.02-310.52; average = 39.0), which implies increased mineral clastic input and decreased calcite precipitation, respectively. Unit 4c (5.70-3.50 m depth; 9730-6430 cal yr BP) features a return to low magnetic susceptibility (-1.1-11.4 SI units; average = 1.5) and high Ca/Ti ratios (12.33-732.22; average =106.34).

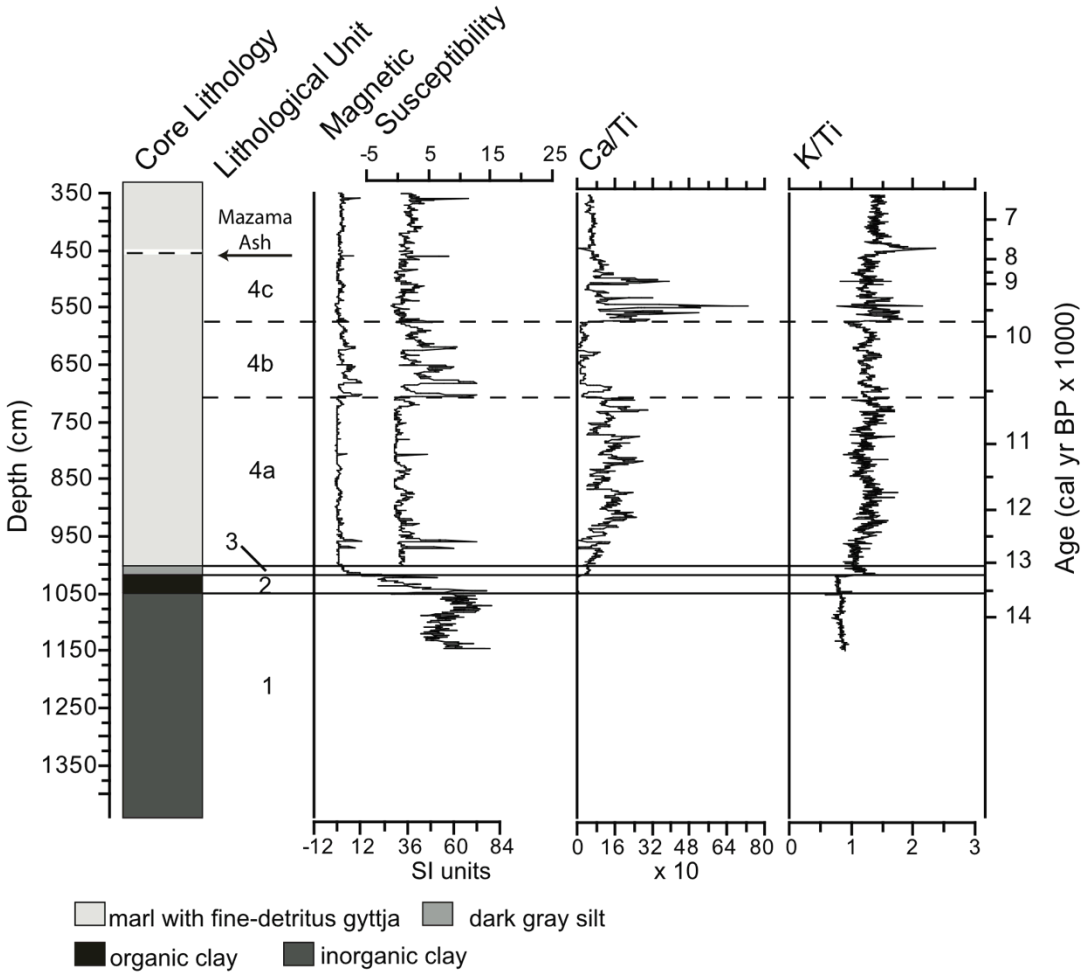


Figure 3.3 Lithologic and geochemical data from Dailey Lake.

Pollen and Charcoal Record

The pollen record at Dailey Lake was divided into four zones between 13,900 and 7500 cal yr BP (Fig. 3.4). Zone DLY-P1 (10.82-10.22 m depth; 13,900-13,300 cal yr BP) was characterized by very low pollen concentration (1000-16,200 grains cm^{-3}) and accumulation rates (PAR; 100-1600 grains cm^{-2} yr^{-1}), and high levels of indeterminate pollen grains (8-34%) suggest subaerial exposure prior to deposition. Taxa included early successional shrubs and forbs, including *Shepherdia canadensis* (<2%), *Juniperus*-type (<5%), Rosaceae-type (<6%), and Asteraceae (<10%). *Pinus* (12-77%) levels were

high but likely originated from distant source populations and were artificially elevated due to low pollen counts early in the record. Significant levels of *Abies* (<7%) were present at 13,600 cal yr BP. Charcoal concentration (average = 1.63 particles cm^{-3}) and background CHAR values (BCHAR; average = 0.02 particles cm^{-2} yr^{-1}) were extremely low.

Pollen zone DLY-P2 (10.22-9.40 m depth; 13,300-12,300 cal yr BP) featured high levels of *Artemisia* (14-37%) and *Picea* (3-9%). In addition, levels of *Betula* (<10%), *Juniperus*-type (1-8%), *Salix* (<4%), and Poaceae (1-17%) were high, while *Pinus* (17-51%), *Abies* (<3%), *Shepherdia canadensis* (<1%), and forbs such as Asteraceae (<8%) were moderate. Indeterminate-type grains (4-28%) decreased over DLY-P1, and average AP/NAP (0.81) was much lower than at present (2.23). Pollen concentrations (17,200-111,000 grains cm^{-3}) and PAR (1700-8500 grains cm^{-2} yr^{-1}) increased during this period, as did charcoal concentration (average =10.60 particles cm^{-3}) and BCHAR (average = 0.35 particles cm^{-2} yr^{-1}).

Pinus levels (41-85%) were at their highest of the record in pollen zone DLY-P3 (9.40-6.36 m depth; 12,300-10,200 cal yr BP). The majority of *Pinus* grains were attributed to *P. albicaulis*/*flexilis*-type (1-18%) versus *P. contorta*-type (<6%). *Abies* (<4%) increased while *Picea* (<1-8%) and *Juniperus*-type (<3%) levels decreased. The majority of shrub and herb taxa decreased, including *Artemisia* (2-19%), *Betula* (<4%), Asteraceae (<3%), and *Ambrosia*-type (<3%). *Alnus* (<1%), *Salix* (<4%), and Poaceae (1-20%) remained relatively unchanged, while Rosaceae-type (<6%) was elevated over the previous period, and *Sarcobatus* levels (<5%) increased towards the end of the zone.

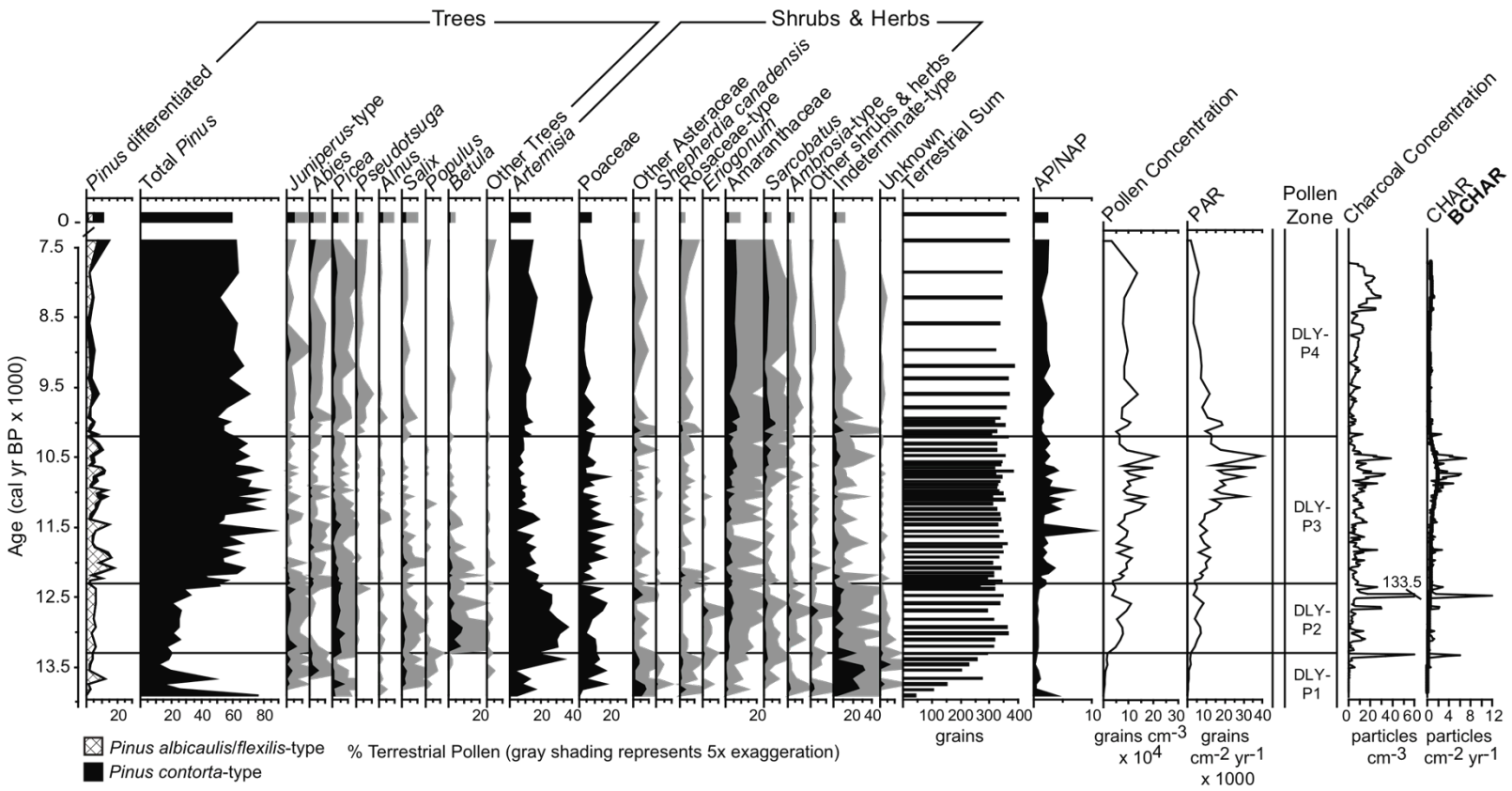


Figure 3.4 Charcoal and pollen data for selected taxa from Dailey Lake.

Average AP/NAP was slightly higher (2.74) than today (2.23). Indeterminate-type grains (1-8%) continued to decrease, and pollen concentrations (36,700-213,800 grains cm^{-3}) and PAR (4000-39,600 grains cm^{-2} yr^{-1}) were at their highest of the record, as was BCHAR (average = 1.09 particles cm^{-2} yr^{-1}). Charcoal concentrations were elevated (average = 9.12 particles cm^{-3}), but not as high as in the previous zone.

Pinus pollen (49-70%) slightly decreased in pollen zone DLY-P4 (6.36-4.40 m depth; 10,200-7500 cal yr BP), while *Pseudotsuga* levels (<2%) increased. Other conifers such as *Picea* (<4%), *Abies* (<3%), *Juniperus*-type (<3%), and *P. contorta*-type (<4%) were unchanged in the record, while *P. albicaulis*/*flexilis*-type decreased (1-5%). Riparian obligates like *Salix* (<2%), *Betula* (<1%), and *Alnus* (<1%) decreased, while levels of xerophytic shrub taxa, such as *Artemisia* (8-18%) and *Sarcobatus* (1-8%), were elevated. Average AP/NAP was lower (1.90) than at present (2.23). Pollen concentrations (50,600-138,200 grains cm^{-3}) and PAR (3200-218,700 grains cm^{-2} yr^{-1}) decreased during this period, as did BCHAR (average = 0.47 particles cm^{-2} yr^{-1}) and charcoal concentrations (average = 8.78 particles cm^{-3}).

Diatoms

The diatom record at Dailey Lake was divided into four zones between 13,270 and 10,470 cal yr BP (Fig. 3.5). Diatoms were absent in older and younger sediments. Diatom zone DLY-D1 (10.18-10.03 m depth; 13,270-13,090 cal yr BP) was characterized by the dominance of pioneering benthic taxa, including *Achnanthes rosenstockii* (1-5%),*Achnanthes ziegleri* (<5%), *Amphora pediculus* (6-22%), *Amphora thumensis* (5-12%), and *Navicula diluviana* (17-29%), as well as by relatively high percentages of the

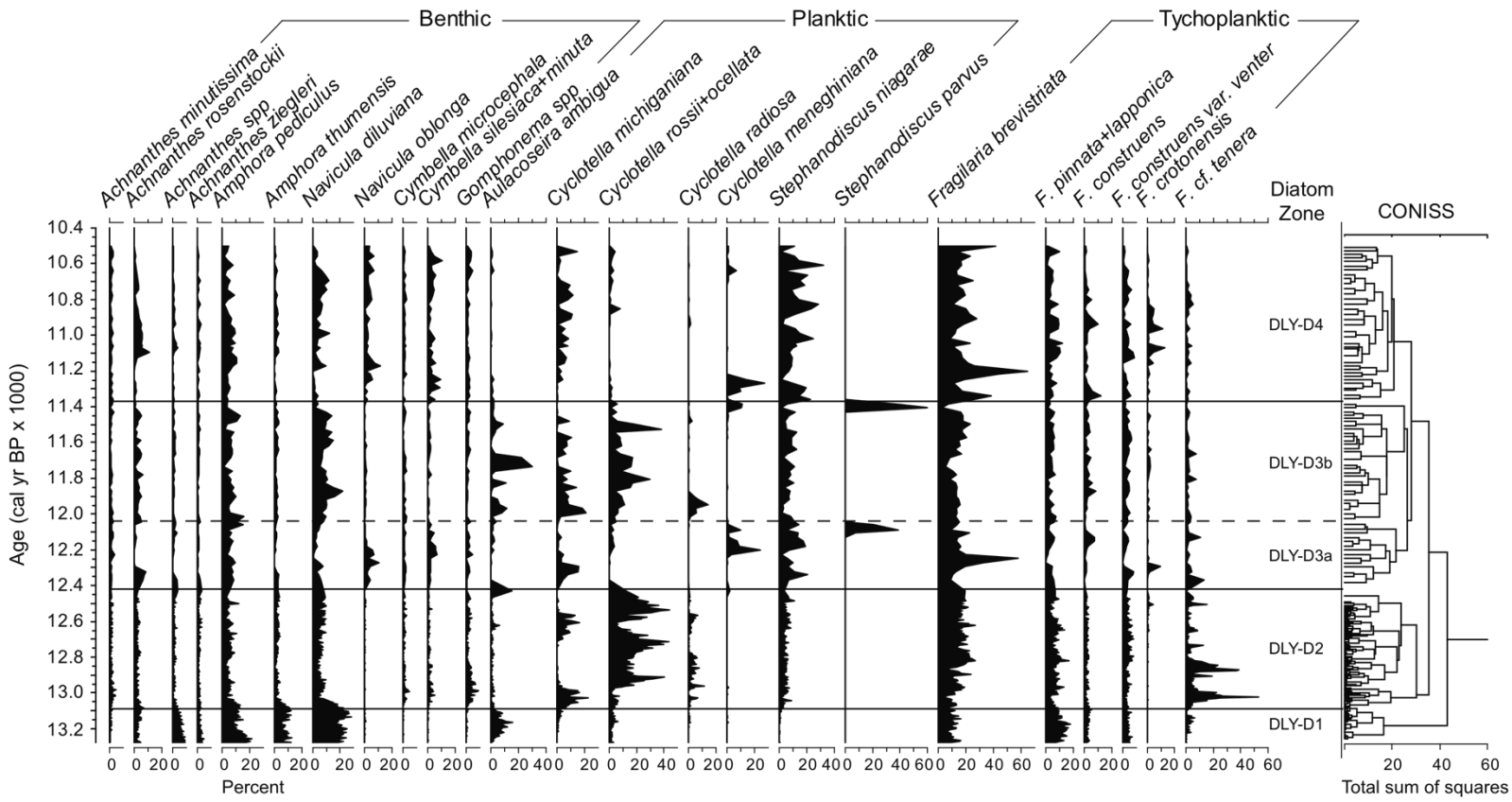


Figure 3.5 Percentages of selected diatom taxa from Dailey Lake.

planktic species *Aulacoseira ambigua* (<1-16%). Colonial *Fragilaria* species (*F. brevistriata*, *F. pinnata*, *F. construens* var. *venter*, and *F.* cf. *tenera*) were also present in relatively high abundance (20-40%) within the zone.

An increase in the abundance of planktic taxa, such as *Cyclotella michiganiana*, *C. rossii*, *C. ocellata*, *C. radiosa*, (combined abundance of 5-46%) and *Stephanodiscus niagarae* (1-11%), marked the transition to diatom zone DLY-D2 (10.03 m-9.48 m depth; 13,090-12,420 cal yr BP). This increase coincided with a decline in the abundances of pioneering benthic species, including *Achnanthes* (1-13%), *Amphora* (2-23%) and *Navicula* (4-25%).

Diatom zone DLY-D3 was divided into two subzones. Zone DLY-D3a (9.48-9.08 m depth; 12,420-12,040 cal yr BP) was marked by lower abundances of the common *Cyclotella* species found in the previous zone (1-16%) and increased percentages of colonial *Fragilaria* species (15-64%) in the lower part of the subzone and *Cyclotella meneghiniana* (1-24%) and *Stephanodiscus parvus* (7-40%) in the upper part of the subzone. The transition to zone DLY-D3b (9.08-8.36 m depth; 12,040-11,370 cal yr BP) was characterized by the return of the *Cyclotella* species common in zone DLY-D2 (*C. michiganiana, C. rossii, C. ocellata, C. radiosa*—combined abundance of 1-38%) and an increase in *Aulacoseira ambigua* (1-30%).

Diatom zone DLY-D4 (8.36-6.89 m depth; 11,370-10,470 cal yr BP) included the youngest samples analyzed in the diatom record and was marked by decreasing percentages of *Cyclotella* (<19%) and *Aulacoseira* (<2%) species and increased

abundance of all benthic species (17-55%) and *Stephanodiscus niagarae* (1-22%). Diatoms were not present above 6.89 m in the sediment core.

Discussion

Postglacial Terrestrial and Limnologic Development at Dailey Lake

The Dailey Lake datasets document postglacial terrestrial and limnologic development in the Greater Yellowstone region. During the late-glacial/early-Holocene transition, the record features significant changes in catchment processes, vegetation, fire activity, hydrology, and limnobiota (Fig. 3.6).

Late-Glacial Period (>12,300 cal yr BP). Paleoclimate model simulations for western North America during the late-glacial period highlight the direct and indirect effects of increasing summer insolation on regional climate (Bartlein et al., 1998). Direct effects included rising summer temperatures and decreasing effective moisture relative to full-glacial conditions, whereas the indirect effects were a strengthening of the northeast Pacific subtropical high-pressure system in summer and a northward shift of the jet stream from its full-glacial position. As a result, summers were warmer and drier than before, and winter precipitation increased (Bartlein et al., 1998).

Driven by increasing summer insolation and temperatures, the northern Yellowstone outlet glacier retreated from its maximum extent at ca. 16,500 cal yr BP (16.5 ± 1.4 ^{10}Be ka, 16.6 ± 1.3 ^{3}He ka; Licciardi and Pierce, 2008) in Paradise Valley,

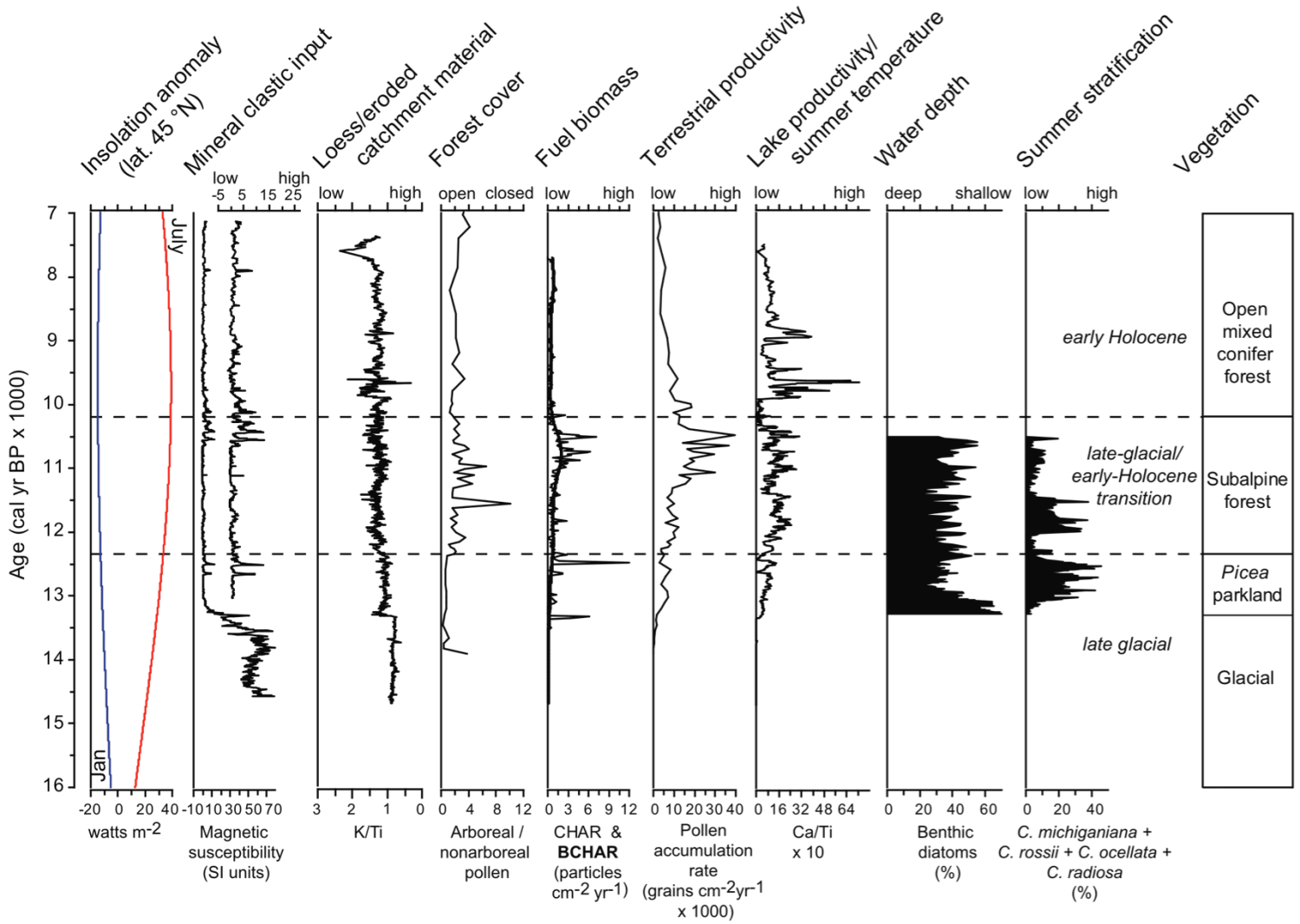


Figure 3.6 Summary of environmental proxy at Dailey Lake during the late-glacial/early-Holocene transition plotted against January and July insolation anomalies.

and for the next 3000 years, ice recessional processes shaped the Dailey Lake area. Prior to 13,300 cal yr BP, lake sediments were characterized by high magnetic susceptibility and low pollen concentration and accumulation rates (PAR), indicating a sparsely vegetated unstable landscape with considerable clastic mineral input into the lake, either as eroded sediment from the freshly deglaciated landscape, meltwater, or possibly wind-blown material (inferred from low K/Ti ratios). The pollen record implies discontinuous shrub-herb cover, and early-successional species, such as *Shepherdia canadensis*, *Salix*, *Alnus, Juniperus*, and Asteraceae species, likely established on stagnant outwash bars and rocky glacial till. Trees were rare; however, low persistent levels of *Abies* in the pollen record after 13,600 cal yr BP suggest local occurrence of *Abies lasiocarpa*. Low charcoal concentration and BCHAR values indicate limited fire activity, probably as a result of discontinuous fuels and cool conditions. Lake water temperatures and primary productivity were likely extremely low, as evidenced by low Ca/Ti ratios. Diatoms were absent from the lake during this time, likely as a result of high turbidity from the input of fine minerogenic sediment (Bradshaw et al., 2000).

Beginning at 13,300 cal yr BP, a number of environmental changes occurred in the vicinity of Dailey Lake. Magnetic susceptibility and K/Ti ratios reached their respective low and high values, indicating landscape stabilization as a result of decreased landscape erosion and the possible cessation of loess deposition. It is possible that early pioneering shrub species, such as *Shepherdia canadensis, Salix,* and *Alnus* present in the pollen record prior to 13,300 cal yr BP, helped stabilize the landscape. Overall pollen concentration and PAR subsequently increased, and an abrupt rise in *Picea* pollen

percentages marked the expansion of *P. engelmannii* populations. Increasing summer temperatures, in combination with more stable soils, likely favored its establishment. At present, *P. engelmannii* prefers moderately deep, well-drained soils compared to other subalpine tree species, such as *Abies lasiocarpa* which can establish on minerogenic substrates and rocky glacial till (Franklin and Mitchell, 1967; Alexander et al., 1984).

Within 100 years of landscape stabilization and *Picea* expansion, diatom populations developed in Dailey Lake beginning at 13,270 cal yr BP. As slopes became increasingly stabilized, clastic mineral input into the lake decreased and pioneering benthic diatoms, including *Navicula*, *Amphora*, and *Achnanthes* species, established in the lake. Shortly afterwards, populations of *Aulacoseira ambigua* expanded, reflecting increased nutrient availability for planktic diatom production and likely an unstratified water column because of cool temperatures. Ca/Ti ratios also increased at this time, indicating elevated calcite production as a result of increased lake productivity and/or rising summer temperatures. Euplanktic diatoms, particularly *Cyclotella* spp., colonized and expanded at 13,100 cal yr BP, and it is likely that the lake became thermally stratified during the summer months (Interlandi et al., 1999; Battarbee et al., 2002; Sorvari et al., 2002; Ruhland et al., 2003).

Late-Glacial to Early-Holocene Transition (12,300-10,200 cal yr BP). Summers became increasingly warmer and drier during the late-glacial/early-Holocene transition as summer insolation peaked in the region between 11,000 and 10,000 cal yr BP (Berger, 1978). Furthermore, increasing summer insolation indirectly strengthened the subtropical high-pressure system and summer monsoonal circulation, creating drier summers than at

present in some areas of western North America and wetter conditions in others (Whitlock and Bartlein, 1993; Bartlein et al., 1998). Winter precipitation was also likely higher in the early Holocene as a result of diverted storm tracks by the lingering ice sheet (Williams et al., 2010) and lower-than-present winter insolation at that time (Bartlein et al., 1998).

Warmer drier summers than before facilitated the expansion of *Abies lasiocarpa* and *Pinus* (likely *P. albicaulis*) into *Picea* parkland beginning at 12,300 cal yr BP at Dailey Lake. The *Picea*, *Abies*, and *P. albicaulis*/*flexilis*-type percentages during this period are consistent with those from modern *Picea*-*Abies*-*Pinus* forest in the Yellowstone region (Whitlock, 1993). Higher-than-present AP/NAP values suggest the upslope forest was either denser than it is presently, or forests grew at lower elevations where *Artemisia*-steppe and grassland grow today. Nonetheless, moderate levels of *Artemisia* and Poaceae pollen during this period indicate the presence of *Artemisia*-steppe/grassland but possibly only on the valley floor. Although conditions were likely warmer and drier than before, growing season moisture was apparently high enough to support a closed forest and/or forests at lower elevations than today.

At the end of the late-glacial period, the diatom record indicates a period of fluctuating conditions between 12,400 and 11,400 cal yr BP that is not evident in the pollen data. Starting approximately 12,400 cal yr BP, the dominant *Cyclotella* species decline in abundance and are replaced by a sequence of taxa, including tychoplanktic *Fragilaria* species, *Cyclotella meneghiniana*, and *Stephanodiscus parvus*. These taxa share a common life-history trait of blooming in unstratified waters, which suggests that

lakewater temperatures cooled or the lake became shallower or both. At least for the period between 12,400 and 12,000 cal yr BP, the dominance of *C. meneghiniana* suggests a moderately shallow unstratified lake during summer months, consistent with the inference of summer warming evident in the vegetation data. At 12,000 cal yr BP, the resurgence of *Cyclotella* species characteristic of stratified summer conditions (e.g., *C. rossii*, *C. ocellata*, *C. michiganiana, C. radiosa*) indicates that the lake became deeper and thermally stratified again, suggesting both warm summer conditions and increased water balance. A possible scenario for this interval is one of enhanced winter precipitation and snowpack coupled with early spring warming. The spring conditions, in particular, caused early ice off and longer periods of isothermal mixing. The moderate increase of *Aulacoseira ambigua*, a species characteristic of intervals of water-column mixing, is consistent with this hypothesis. Despite the high-frequency variation in the diatom assemblages, apparently the magnitude of the climate variability in this interval was not sufficient to alter the course of vegetation development.

Beginning 11,400 cal yr BP, lake level at Dailey Lake decreased, as indicated by increased percentages of benthic diatoms. Planktic taxa, such as *Cyclotella* and *Aulacoseira*, became less abundant, and percentages of benthic taxa, including *Achnanthes*, *Cymbella*, and *Navicula*, increased. In addition, colonial *Fragilaria* species (tychoplanktons) were also more abundant than in the previous period. Shallow lake conditions could explain the increased percentages of benthic and tychoplanktic species and the decrease in planktic taxa, and it is likely that Dailey Lake transitioned from an open/semi-closed lake system to a closed system at this time. Water levels likely

continued to decrease after 10,500 cal yr BP, reducing recharge to the lake and increasing water alkalinity; these conditions caused diatom dissolution and the end of the diatom record.

Fire activity also increased between 11,000 and 10,000 cal yr BP with rising summer temperatures, effectively drier summer conditions, and possibly more convective storms. High fuel availability is evidenced by high BCHAR, high terrestrial productivity (inferred from high PAR and pollen concentration), and forest cover (based on the high AP/NAP ratios). Increased magnetic susceptibility between 10,500 and 9700 cal yr BP may be a result of fire-related erosional events at this time, as BCHAR peaked just prior to elevated magnetic susceptibility.

Early Holocene (10,200-7500 cal yr BP). At 10,200 cal yr BP, warm dry summer conditions produced a more open landscape at Dailey Lake than immediately before or at present. *Artemisia*- steppe was more extensive based on higher pollen percentages of *Artemisia*, *Sarcobatus*, and Poaceae. *Pseudotsuga* and *P. contorta* expanded into the lower forests above the site based on increases in their pollen abundances, and AP/NAP decreased from the previous period, indicating an upward displacement and/or opening of the lower forest. It is also possible that increased fire activity between 11,000 and 10,000 cal yr BP created a more open landscape. *Abies* and *Picea* were still present at moderate levels and likely moved to cooler higher elevations. The development of a lower forest composed of *Pseudotsuga* and *P. contorta* and the upslope expansion of *Artemisia*-steppe suggests that the period from 10,200 to 7500 cal yr BP was the warmest and

effectively driest interval of the record. As the landscape became more open, fire activity decreased, indicated by low BCHAR after 10,000 cal yr BP, suggesting a shift to a fuel-limited system.

Linkages between Vegetation and Limnobiotic Development

Because high-resolution terrestrial and limnologic data are available from the same cores at Dailey Lake, it is possible to compare the timing of biotic development in the watershed with that of the lake as well as the sensitivity of the two systems to climate change. Early in landscape development at Dailey Lake, large-scale changes in catchment processes elicited synchronous responses in the vegetation and limnobiota. In the initial period of deglaciation, the geomorphic instability created by stagnant ice, wind, and meltwater inhibited vegetation and limnobiotic development. After 13,300 cal yr BP, dramatic changes in lithology (decreased MS) and sediment geochemistry (increased K/Ti) indicate stabilization of the terrestrial environment. This shift was accompanied by an expansion of *Picea* populations in the upland vegetation and the colonization of pioneering benthic diatoms in the lake. Not only did warmer summers in combination with stabilizing substrates allow for the germination and establishment of *Picea*, but also increasing slope stability decreased minerogenic input into the lake, that until this time had limited the growth of diatoms. It appears that erosional processes associated with ice recession mediated the effects of climate change on early biotic development at Dailey Lake.

Other studies show similar linkages between catchment processes and limnobiotic development in glaciated regions (Fritz and Anderson, 2013). At Krakenes Lake in western Norway, postglacial limnobiotic colonization was initiated once deglacial silt settled, and during the Younger Dryas Cold Interval, there was very little aquatic life due to high silt inwash into the lake (Birks et al., 2000). In northwestern Montana, Foy Lake shows a similar progression of postglacial vegetation and limnobiotic development as at Dailey Lake (Stone and Fritz, 2006; Power et al., 2011). At that site, *Picea* parkland establishment at 13,150 cal yr BP coincided with the colonization of *Navicula diluviana* within the lake system, and it is probable that landscape-scale processes of slope stabilization facilitated a synchronous shift in the terrestrial and aquatic system there as well. Like recently deglaciated lakes (Engstrom et al., 2000; Engstrom and Fritz, 2006), tight coupling between terrestrial succession and lake trophic change at Dailey Lake may have been facilitated by the establishment of nitrogen-fixing plants (e.g., *Shepherdia canadensis* and *Alnus*) that increased lake nitrogen loads and diatom productivity. However, synchrony between decreased minerogenic input and diatom establishment points to the importance of decreased landscape erosion in driving early limnobiotic development at Dailey Lake.

After 13,300 cal yr BP, vegetation and limnobiotic changes at Dailey Lake became asynchronous, reflecting different sensitivities to climate change. Vegetation development once initiated was unidirectional through time and tracked slowly increasing summer insolation and temperatures. The sparsely vegetated landscape became increasingly forested as *Picea* parkland developed, followed by the establishment of

closed subalpine forest, and eventually open mixed conifer forest in the early Holocene. In contrast, the abrupt shifts in diatom assemblages between planktic and tychoplanktic taxa between 12,400 and 11,400 cal yr BP suggest a response to climate-driven changes in spring and summer lake thermal structure and lake depth.

In general, the limnobiota at Dailey Lake were sensitive to short-term variations in climate during the late-glacial/early-Holocene transition, whereas the vegetation was more strongly directed by orbital-scale changes in the seasonal cycle of insolation and its effect on temperature and effective moisture. This difference in sensitivity is also evident at Crevice Lake in northern Yellowstone, where the diatom assemblages show dramatic excursions attributed to summer water-column mixing and spring duration that are not matched in the pollen data. The charcoal record, on the other hand, shows fluctuations in the fire activity that match some of the diatom events and suggest shared responses to summer conditions (Whitlock et al., 2012). At Foy Lake, diatom data indicate low water levels between 12,500 and 11,000 cal yr BP (Stone and Fritz, 2006) as a result of cool dry conditions (Shuman et al., 2009) at a time when the pollen data indicate little change in the prevailing mesophytic vegetation (Power et al., 2011). Similarly, at Krakenes Lake in Norway, changes in terrestrial and aquatic assemblages occurred asynchronously during the Holocene, highlighting their independent responses and sensitivity to environmental drivers (Birks et al., 2000).

Comparison with Other Northern Yellowstone Paleoecological Records

To gain better insight on local vegetation and climate dynamics during the late-glacial/early Holocene transition, the Dailey Lake record was compared with other sites in the northern Yellowstone region (Fig. 3.7; see Fig. 3.1 for site locations). These include: Blacktail Pond (44.95° N, 110.60° W, elev. 2012 m; Huerta et al., 2009; Krause and Whitlock, 2013; Chapter 2); Crevice Lake (45.00° N, 110.58° W, elev. 1684 m; Whitlock et al., 2012); and Slough Creek Pond (44.92° N, 110.35° W, elev. 1884 m; Whitlock and Bartlein, 1993; Millspaugh et al., 2004; Krause, unpublished data; Chapter 4). All sites are classified as summer-wet (*sensu* Whitlock and Bartlein, 1993), however, Blacktail Pond, Crevice Lake, and Slough Creek Pond are located 200 to 500 m in elevation above Dailey Lake and receive more winter snowfall. Blacktail and Slough Creek Ponds are situated on broad plateaus, and Crevice Lake lies in the Black Canyon of the Yellowstone River and has an analyzed record that begins 9800 cal yr BP. Dailey Lake's lower elevation in Paradise Valley and position in a precipitation shadow distinguish it from the other sites in northern Yellowstone; its climate is both warmer and drier.

Following deglaciation, sparsely vegetated landscapes transitioned to *Picea* parkland at 13,300 cal yr BP near Dailey Lake, 12,900 cal yr BP near Blacktail Pond (Krause and Whitlock, 2013), and later at Slough Creek Pond beginning 12,500 cal yr BP (Millspaugh et al., 2004; Krause, unpublished data). As growing season temperatures increased, closed subalpine forests developed on the upper slopes near Dailey Lake at 12,300 cal yr BP and then later near Blacktail and Slough Creek ponds at 11,300 cal yr

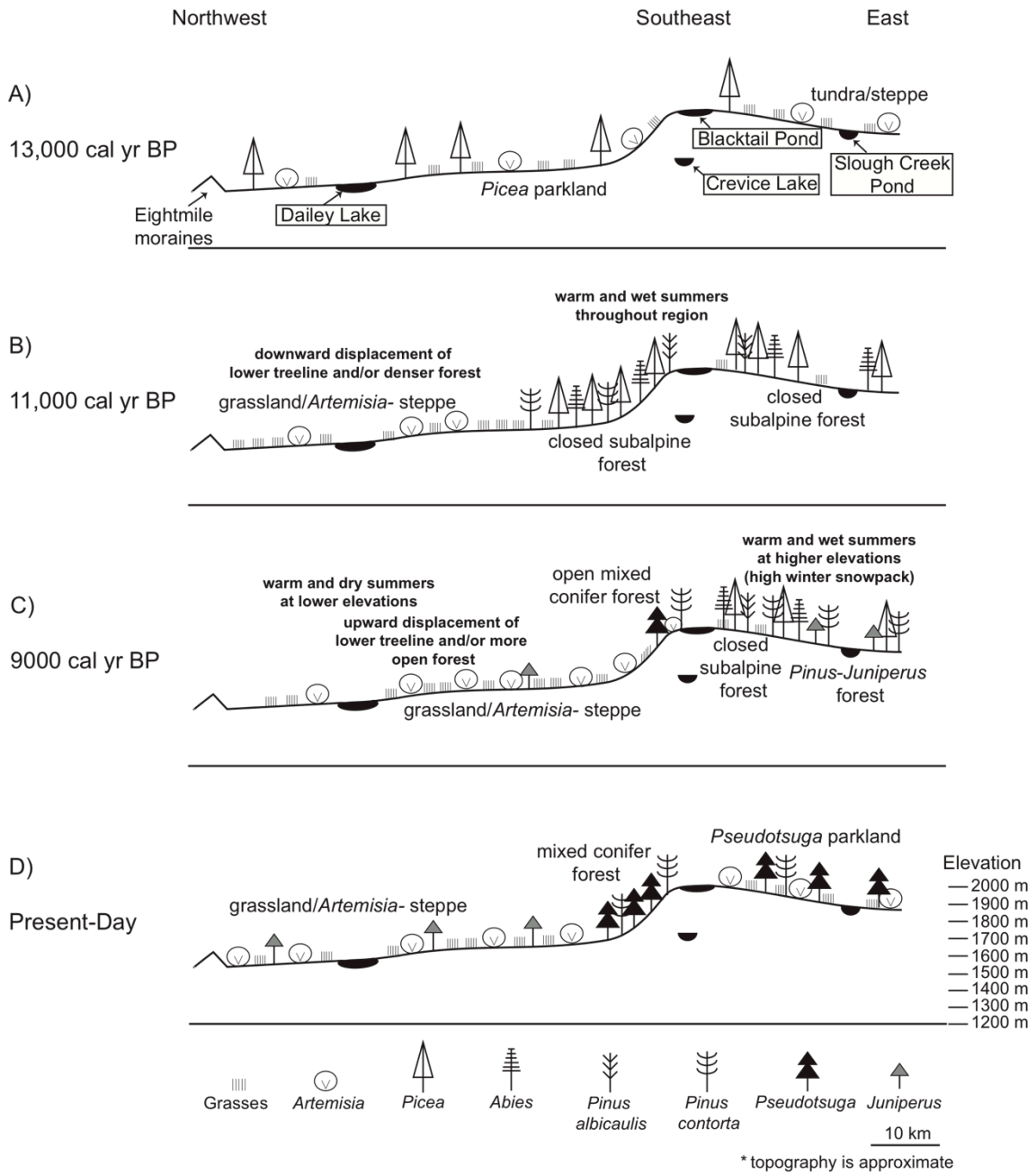


Figure 3.7 Schematic vegetation reconstruction of northern Yellowstone based on data presented in this paper and other published records.

BP. Although summers were gradually becoming warmer and drier than before, soil moisture was high enough to support closed forests at this time.

In the early Holocene, Crevice Lake, Blacktail Pond, and Slough Creek Pond, located above 1700 m in elevation, experienced relatively wet summer conditions. For example, mesophytic closed subalpine forests grew at Crevice Lake and Blacktail Pond until 8200 cal yr BP (Whitlock et al., 2012; Krause and Whitlock, 2013), and *Pinus-Juniperus* forest was present at Slough Creek Pond prior to 8000 cal yr BP (Millspaugh et al., 2004). In addition, charcoal data from the three sites indicate low fire-episode frequency during the early Holocene. Wet summers are attributed to a combination of high winter snowpack and/or summer precipitation from convectional storms. Low carbonate $\delta^{18}O$ values from Crevice Lake between 9800 and 8200 cal yr BP suggest that carryover of winter precipitation into the summer season was as important or more important than increased summer convectional storms in producing wet summers in northern Yellowstone (Whitlock et al., 2012).

In contrast, Dailey Lake received less winter precipitation in the early Holocene than the other sites in northern Yellowstone due to its lower elevation and orographic setting. As a result, the site was more influenced by the direct effects of the summer insolation maximum, namely changes in summer temperature and effective moisture. As a result, alkaline lake conditions led to the dissolution of the diatoms after 10,500 cal yr BP, closed subalpine forests were replaced by open mixed conifer forest as early as 10,200 cal yr BP, and fire activity, as indicated by BCHAR, peaked between 11,000 and 10,000 cal yr BP.

Conclusions

Our multi-proxy paleoecological reconstruction from Dailey Lake contributes new information on early postglacial development of the Greater Yellowstone Ecosystem. Following deglaciation, the Dailey Lake record describes an initial period of landscape instability driven by ice recessional processes from the northern Yellowstone outlet glacier. Once climate warmed and these processes attenuated, *Picea* population expansion occurred and *Picea* parkland grew on the slopes above the lake. As slopes stabilized and minerogenic input into the lake decreased, limnobiotic communities within the lake established. The nearly synchronous terrestrial and aquatic responses to landscape stabilization suggest erosional processes in the catchment inhibited early vegetation and limnobiotic development.

Once established, the plant and limnobiotic assemblages at Dailey Lake responded independently to climate change. Vegetation development following deglaciation to the early Holocene was largely a response to increasing summer insolation and temperatures and their influence on effective moisture. Concurrently, the diatom assemblage registered short-duration variations in climate seasonality. The differing response to past climatic variations may be explained by the fast generation times of the limnobiota as compared with the slow rate of population change among the dominant tree species.

The sequence of vegetation changes at Dailey Lake following ice retreat is comparable to other sites in northern Yellowstone during the late-glacial period: sparsely vegetated landscapes to *Picea* parkland to closed subalpine forest. However, as the

seasonal cycle of insolation amplified during the early Holocene, the high elevation sites were more strongly influenced by the indirect effects of insolation, namely changes in atmospheric circulation, whereas Dailey Lake at a low elevation was more strongly affected by the direct effects of greater-than-present summer insolation, higher summer temperature, and decreased effective moisture. As a result, Dailey Lake shows drier-than-present summers when higher elevation sites in northern Yellowstone register prolonged summer-wet conditions.

Although climate was the primary driver of postglacial ecosystem development in the greater Yellowstone region, this study shows that non-climatic factors, such as catchment stabilization, species life-history traits, and local topography, mediated the impacts of climate change. Once established, the terrestrial and limnologic systems responded independently to climate change, reflecting their unique sensitivities and response times. In spatially complex mountainous regions like Yellowstone, the combination of climate and non-climatic factors produced heterogeneous environmental histories at different elevations and among different proxy. These historical legacies need to be considered in interpreting the modern landscape and in projecting future trajectories of change.

Acknowledgments

This research was supported by National Science Foundation grants, including EAR-0801467 to Whitlock and Fritz and OISE-0966472 to Whitlock. Support in the field came from D. McWethy and V. Nagashima. We thank V. Nagashima, J. Giskaas,

M. Spendel, and A. Peery for lab assistance, and two anonymous reviewers for their helpful comments.

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CHAPTER FOUR

CLIMATIC AND NONCLIMATIC CONTROLS SHAPING EARLY POSTGLACIAL CONIFER HISTORY IN THE GREATER YELLOWSTONE ECOSYSTEM, USA

Contribution of Author and Co-Authors

Manuscript in Chapter 4

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Contributions: Defined the experimental design, participated in fieldwork, described the lithology of sediment cores, measured magnetic susceptibility, counted charcoal and pollen samples, analyzed the data, and wrote the manuscript.

Co-Author: Virginia Iglesias

Contributions: Helped define the experimental design, conducted the General Additive Models analysis, and commented on the manuscript.

Co-Author: Cathy Whitlock

Contributions: Supported this research under National Science Foundation grants EAR-0801467 and OISE 0966472, helped define the experimental design, participated in fieldwork, discussed the results and implications, and edited the manuscript.

Manuscript Information Page

Teresa R. Krause, Virginia Iglesias, Cathy Whitlock
Ecological Monographs
Status of Manuscript:
_x__ Prepared for submission to a peer-reviewed journal
____ Officially submitted to a peer-review journal
____ Accepted by a peer-reviewed journal
____ Published in a peer-reviewed journal

Publisher: Ecological Society of America

Abstract

The early postglacial conifer history of the Greater Yellowstone Ecosystem (GYE) was reconstructed at a sub-regional and regional scale using paleoecological data from a network of 16 sites. Fossil pollen data from lake sediments were compared to independent measures of climate, edaphic conditions, and fire activity to better understand the relative roles of climatic and nonclimatic factors in directing conifer population dynamics following late-Pleistocene glacial retreat in the GYE after ~16,000 cal yr BP. At a sub-regional scale focused on the northern GYE, Engelmann spruce populations were the first to expand at 13,300 cal yr BP in response to soil development, indicated by decreased sediment magnetic susceptibility, and warming summers due to increasing summer insolation. Subalpine fir populations expanded after 12,300 cal yr BP and likely lagged Engelmann spruce due to its poorer seed dispersing capacity. Lodgepole and whitebark pine expanded nearly synchronously in the northern GYE after 11,300 cal yr BP in response to increased summer temperatures, indicated by carbonate $\delta^{18}O$ data, and increased fire activity inferred from elevated charcoal accumulation rates between 11,900 and 9800 cal yr BP. Douglas-fir populations expanded last after 10,200 cal yr BP, likely from small localized populations, during the early-Holocene summer insolation maximum. At a regional scale, General Additive Models (GAMs) were fitted to pollen percentage and charcoal data to reconstruct regional trends in vegetation and fire history. With the initial rise in postglacial growing season temperatures due to increasing summer insolation, Engelmann spruce (13,000 cal yr BP), subalpine fir (12,500 yr BP), and whitebark pine (12,500 cal yr BP) established across most elevations

and became increasingly restricted to high elevations (above 2600 m) during the Holocene as summer insolation decreased and winter insolation increased. Modeled charcoal data suggest regional fire activity was high between 12,500 and 10,000 cal yr BP, and increased fire frequency likely favored fire-adapted whitebark pine during this period. Lodgepole pine steadily increased in abundance after 11,000 cal yr BP and likely outcompeted whitebark pine at middle elevations (2000-2500 m), becoming the dominant conifer species. Douglas-fir densities increased after 10,000 cal yr BP at middle and then low elevations (below 2000 m). The long-term paleoperspective of this study offers unique insights on conifer species responses to environmental conditions beyond those present today and stresses the importance of considering nonclimatic factors, such as edaphic conditions, dispersal capacity, and biotic interactions, in projecting species' responses to current climate change.

Introduction

Paleoecological data offer unique opportunities for understanding the response of plant species to a broad range of climatic and nonclimatic conditions occurring over different spatial and temporal scales (e.g., Brubaker 1975, Millspaugh et al. 2000, Oswald et al. 2003, Gavin and Hu 2006, Briles et al. 2011). Periods of past rapid change or dramatic warming are particularly insightful in light of current climate change, and past periods often encompass a broader spectrum of environmental conditions beyond those present today to better anticipate species responses to future climates (Dawson et al. 2011). In the Greater Yellowstone Ecosystem (GYE) and throughout the western US, the late-glacial/early-Holocene transition (20,000 to 8000 cal yr BP) was a period of rapid environmental change that featured rising summer insolation and increasing summer temperatures, receding glaciers, and new habitats for plants and animals to colonize. The GYE is particularly unique in that it supported a large glacial complex (Pierce 1979, Licciardi and Pierce 2008) and offers an exceptional opportunity to track biogeographic range shifts of plant species in response to climate change and nonclimatic factors, such as edaphic controls, biotic interactions, and disturbance, as they expanded their populations into previously glaciated regions.

In this study, we draw on fossil pollen data from lake sediments to better understand the postglacial population dynamics of five conifer trees species in the GYE: Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt. var. *lasiocarpa*), whitebark pine (*Pinus albicaluis* Engelm.), lodgepole pine (*Pinus contorta* Dougl. ex. Loud. var. *latifolia*), and Douglas-fir (*Pseudotsuga menziesii*

(Mirb.) Franco var. *glauca*). Our first objective is to compare spatiotemporal patterns of postglacial conifer population expansion at the sub-regional scale by comparing three fossil pollen records in the northern GYE. The pollen data at each site are compared with proxies of local climate (stable isotope data), geomorphic stability (magnetic susceptibility), and fire activity (macroscopic charcoal data) to infer the role of climate and nonclimatic factors in driving early postglacial vegetation change. Our second objective is to reconstruct vegetation and fire history at the regional scale, by comparing 16 paleorecords from across the GYE to better understand the role of millennial-scale climate change, fire, and species interactions in shaping postglacial conifer history.

Study Sites

Our sub-regional analysis focuses on previously published high-resolution multiple proxy paleorecords in the northern GYE from Dailey Lake (45.26° N, 110.82° W, 1598 m elev; Krause et al. in revision; Chapter 3) and Blacktail Pond (44.95° N, 110.60° W, 2012 m elev; Huerta et al. 2009, Krause and Whitlock 2013; Chapter 2), and new lithologic and pollen data from Slough Creek Pond (44.92° N, 110.35° W, elev. 1884 m; Whitlock and Bartlein 1993, Millspaugh et al. 2004). Whitlock and Bartlein (1993) and Millspaugh et al. (2004) developed postglacial vegetation and charcoal records for Slough Creek Pond but at a resolution that was too coarse (500-1000 years) to accurately pinpoint the timing of conifer population expansion. We build on their work by focusing on the vegetation record during the late-glacial/early-Holocene transition at multi-decadal resolution. Our regional analysis of postglacial conifer and fire history

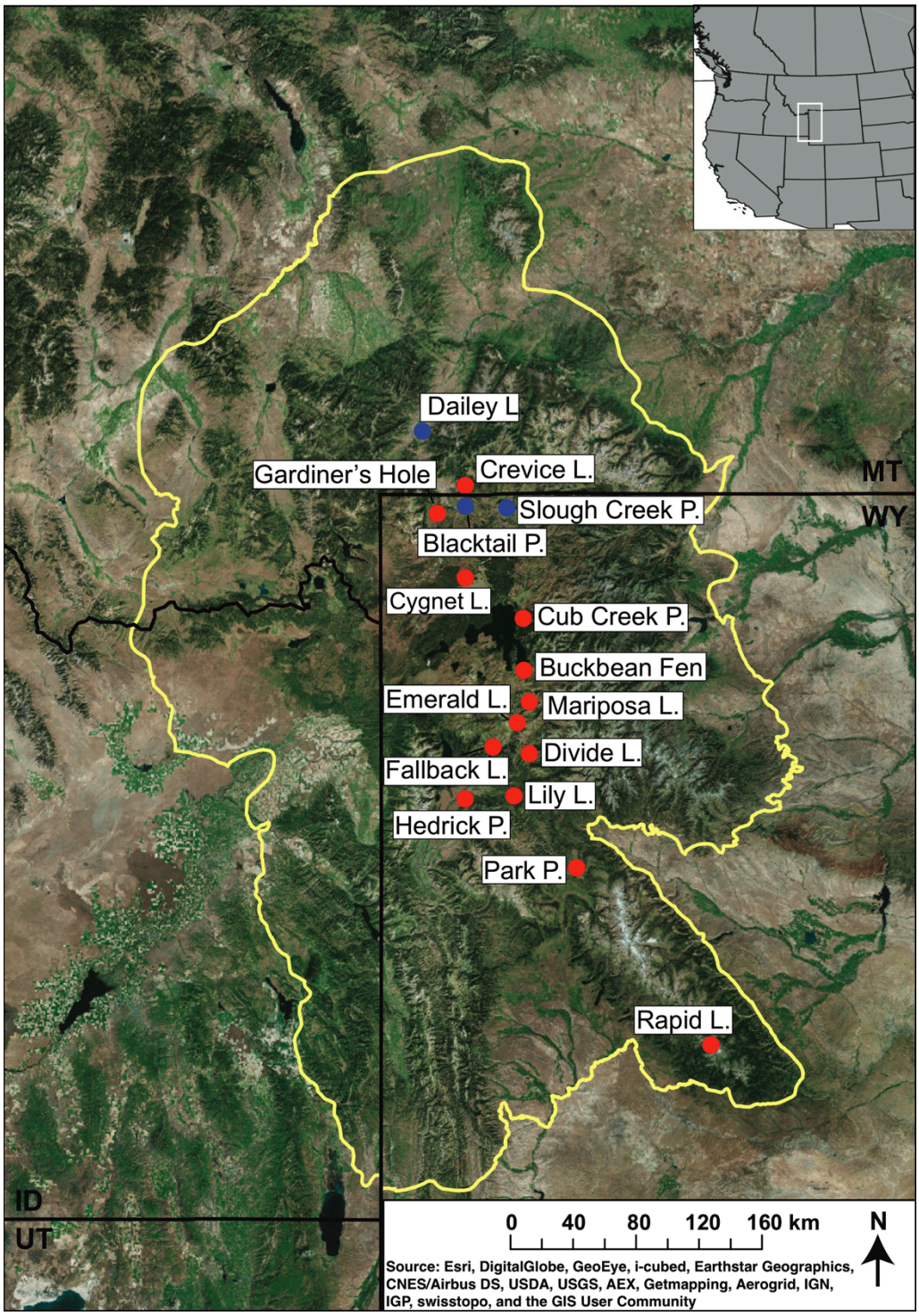


Figure 4.1 Location of lake sediment paleorecords in the Greater Yellowstone Ecosystem (GYE). Blue circles mark location of sites included in both the sub-regional (northern GYE) and regional analyses, and red circles mark location of sites included only in the regional analysis. Yellow line indicates GYE boundary. See Table 4.1 for site information.

utilizes fossil pollen and charcoal data from a network of 16 sites between 1598 and 3134 m elevation throughout the GYE (Fig. 4.1; Table 4.1).

Table 4.1 GYE study sites.

Site	Position	Elev. (m)	Modern vegetation	Data type
Blacktail Pond**	44.96° N; 110.60° W	2012	Steppe-parkland	Pollen & charcoal
Buckbean Fen	44.45° N; 109.84° W	2362	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest	Pollen
Crevice Lake	45.00° N; 110.78° W	1684	Steppe-parkland/*Pseudotsuga*	Pollen & charcoal
Cub Creek Pond	44.92° N; 110.73° W	2500	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest	Pollen
Cygnet Lake Fen	44.65° N; 110.60° W	2530	*P. contorta* forest	Pollen
Dailey Lake**	45.27° N; 110.82° W	1598	Steppe-parkland	Pollen & charcoal
Divide Lake	43.93° N; 110.23° W	2628	*Picea*/*Abies*/*P. albicaulis* forest	Pollen
Emerald Lake	44.07° N; 110.30° W	2634	*Picea*/*Abies*/*P. albicaulis* forest	Pollen
Fallback Lake	43.97° N; 110.43° W	2597	*Picea*/*Abies*/*P. albicaulis* forest	Pollen
Forest Pond Lake	43.37° N; 109.94° W	2797	*Picea*/*Abies*/*P. albicaulis* forest	Charcoal
Gardiner's Hole (Swan Lake)	44.92° N; 110.73° W	2215	Steppe-parkland	Pollen
Hedrick Pond	43.75° N; 110.60° W	2073	Steppe-parkland	Pollen
Lily Lake and Lily Lake Fen	43.77° N; 110.32° W	2469	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest	Pollen
Mariposa Lake	44.15° N; 110.23° W	2730	*P. contorta* - *Picea*/*Abies*/*P. albicaulis* forest	Pollen
Park Pond	43.47° N; 109.96° W	2705	*Picea*/*Abies*/*P. albicaulis* forest	Pollen & Charcoal
Rapid Lake	42.73° N; 109.19° W	3134	Alpine meadow and tundra	Pollen
Slough Creek Pond**	44.93° N; 110.35° W	1884	Steppe-parkland	Pollen & charcoal

**Northern GYE study sites examined in sub-regional analysis

GYE Glacial History

The GYE glacial history is well known from the studies of Kenneth Pierce and Joseph Licciardi (Pierce 1979, Licciardi et al. 2001, Licciardi and Pierce 2008). The region supported the largest mountain glacier complex in the western US during the Last Glacial Maximum (27,000-20,000 cal yr BP), and a large ice cap was centered over the Yellowstone Plateau that served as a source for outlet glaciers to the north, south, and west (Licciardi and Pierce 2008). In the southern GYE, the Teton and Wind River ranges supported local valley glaciers separate from the Yellowstone glacial complex. The glacial complex reached its northernmost extent in the Paradise Valley of southwestern Montana and retreated beginning 16.5 ± 1.4 ^{10}Be ka (Licciardi and Pierce 2008); its southernmost extent reached its maximum later near Jackson Hole, Wyoming and retreated beginning 14.6 ± 0.7 ^{10}Be ka (Licciardi and Pierce 2008). Valley glaciers on the eastern Front of the Teton Range reached a maximum 14.6 ± 0.7 ^{10}Be ka (Licciardi and Pierce 2008), while the late-Pleistocene glacial maximum in the Wind River Range occurred ~4000-6000 years earlier than the Yellowstone complex, between 24.7 and 18.0 ^{10}Be ka (23.9 ± 1.1 ^{10}Be ka mean exposure age, Gosse et al. 1995).

The northern GYE study sites that form the basis of our sub-regional analysis fall along the path of ice recession of the northern Yellowstone outlet glacier, and cosmogenic ^{10}Be surface exposure ages obtained from local recessional moraines constrain the timing of the outlet glacier's retreat (Fig. 4.2; Licciardi and Pierce 2008). These exposures ages provide maximum age estimates for when study sites were ice-free and plant colonization could occur. Dailey Lake is located closest to the northern

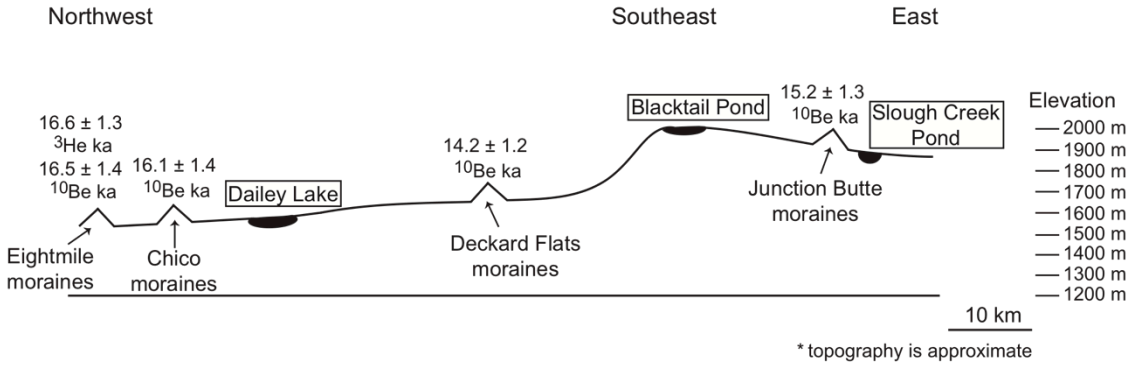


Figure 4.2 Schematic representation of recessional history of the northern Yellowstone outlet glacier based on cosmogenic ^{10}Be surface exposure ages (see Licciardi and Pierce 2008 for detailed discussion).

Yellowstone ice margin terminus (23 km up-valley) and is bracketed by the Chico and Deckard Flats moraines, suggesting glacial retreat occurred between 16.1 ± 1.7 and 14.2 ± 1.2 ^{10}Be ka, respectively. Blacktail Pond is bracketed by the Deckard Flats and Junction Butte moraines and suggests glacial retreat occurred between 14.2 ± 1.2 and 15.2 ± 1.3 ^{10}Be ka. Slough Creek Pond was the last deglaciated study site along the transect and is located 3 km up-valley of the Junction Butte moraines, indicating a deglacial age less than 15.2 ± 1.3 ^{10}Be ka.

Late-Glacial/Early-Holocene Climate

Climate in the western US during the late-glacial/early-Holocene transition was influenced by an amplification of the seasonal cycle of insolation. As a result, summer radiation values were 8% higher than present and winter values were 10% lower in the region by 10,000 cal yr BP (at 45°N; Berger and Loutre 1991). Paleoclimate models suggest rising summer insolation led to increased summer temperatures (~3°C above present, i.e., mean summer temperature over the 1998-2000 AD period) and lower-than-

present effective moisture (Alder and Hostetler 2014). In the GYE, carbonate $\delta^{18}O$ data from Blacktail Pond record cool but gradually increasing summer temperatures during the late-glacial period (14,000-11,500 cal yr BP), a step-like transition to warm summers at 11,500 cal yr BP, and after 9000 cal yr BP, cooler and effectively wetter conditions as summer insolation decreased (Krause and Whitlock 2013; Chapter 2). During the winter, decreased insolation resulted in colder winters (2°C below present; Alder and Hostetler 2014), and winters were likely wetter due to a northward shift in the jet stream following the retreat of North American ice sheets (Bartlein et al. 1998). Carbonate $\delta^{18}O$ data from Crevice Lake in the GYE provide evidence of wet winters during the early-Holocene summer insolation maximum, with winter snowpack decreasing towards present-day (Whitlock et al. 2012).

Modern Conifer Distribution

The present distribution of conifer populations in the GYE is strongly controlled by temperature and effective moisture gradients created by local topography, as well as by underlying substrates (Fig. 4.3) (Despain 1990). Lower treeline in the region generally occurs at 1700 m elevation, and lower forest conifers include limber pine (*Pinus flexilis*) and Rocky Mountain juniper (*Juniperus scopulorum*); however, they have limited distribution throughout the GYE and their postglacial expansions are not examined in this study. Douglas-fir and lodgepole pine grow between 1900 and 2400 m elevation and are replaced by Engelmann spruce, subalpine fir, and whitebark pine above 2400 m elevation. Upper treeline occurs at ~2900 m elevation, and conifers are replaced by alpine meadow and tundra.

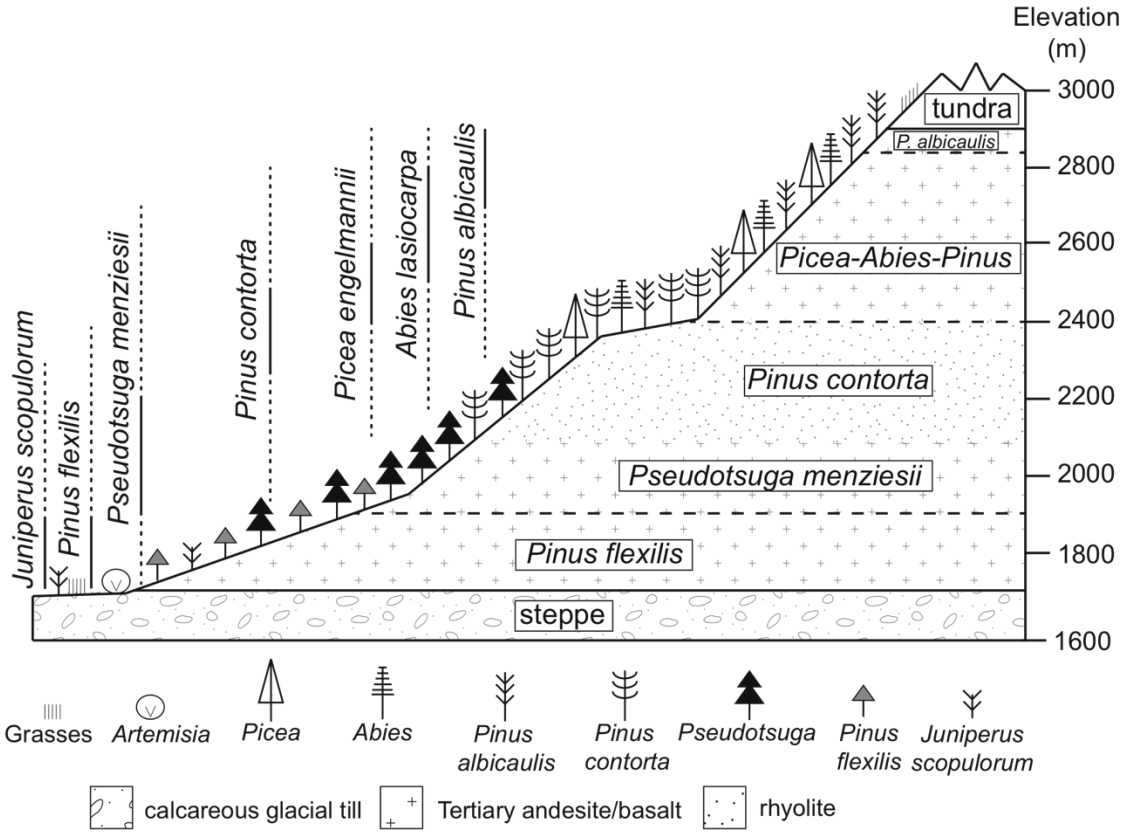


Figure 4.3 Vegetation zones of the Greater Yellowstone Ecosystem (GYE). Solid vertical lines show the elevational range where the species is important; dashed vertical lines indicated where the species is present (modified from Whitlock, 1993).

Elevations in the northern GYE range from 1500 to 3300 m elevation, and its patchwork of underlying substrates highlight the edaphic controls on regional vegetation distribution (Despain 1990). The northern GYE is primarily underlain by calcareous glacial till that supports sagebrush (*Artemisia tridentata*) steppe and grassland as a result of the substrate's fine texture and high water-holding capacity. Douglas-fir forests grow on adjacent rocky slopes of moderately nutrient-rich Tertiary andesite and basalt that transition to mixed conifer forests of Engelmann spruce, subalpine fir, and whitebark pine at higher elevations above 2400 m. Isolated pockets of lodgepole pine forests grow on

coarse nutrient-poor rhyolite areas, which dominate in the central part of Yellowstone, and small populations of subalpine fir and Engelmann spruce are found in local cold-air drainages below 2400 m elevation.

Methods

Sub-Regional Analysis: Northern GYE Conifer Expansion

Sediment cores from Dailey Lake, Blacktail Pond, and Slough Creek Pond were collected using a modified Livingstone square-rod piston sampler (Wright et al. 1983) and extruded in the field. At Slough Creek Pond, a 4.67-m long core was collected from a floating platform in September 2011 at a water depth of 8.95 m. All cores were transported to and stored at the MSU Paleoecology Lab.

Chronology and Lithology. Charcoal, macrofossil, and pollen samples were submitted for AMS radiocarbon dating. Pollen concentrates consisted of 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). The site chronologies were based on calibrated AMS ^{14}C dates and known tephra ages, and we used published chronologies for Dailey Lake and Blacktail Pond. The new Slough Creek Pond age model was constructed using Bacon software for Bayesian modeling in R (Blaauw and Christen 2011), and ^{14}C dates were converted to calendar ages using the IntCal13 calibration curve (Reimer et al. 2013). Bacon repeatedly samples from the probability density function of

each calibrated age and fits many possible splines to the age-depth data, rejecting any fitted splines that result in age reversals. The age model for Dailey Lake sediments was also constructed using Bacon, while the Blacktail Pond chronology was constructed using MCAgeDepth, which like Bacon, used the probability density function of each calibrated age to influence the overall chronology (Higuera et al. 2008).

In the laboratory, cores were split longitudinally, imaged, and described lithologically. Sediment magnetic susceptibility analysis was conducted to record changes in allogenic mineral clastic or erosional input (Gedye et al. 2000). Magnetic susceptibility of the Dailey Lake and Blacktail Pond sediments was measured at contiguous 0.5-cm intervals using a Geotek XYZ MCSL logger, and a Bartington MS2 logging sensor was used to measure the magnetic susceptibility of Slough Creek Pond sediments at contiguous 1.0-cm intervals.

Charcoal and Pollen Analysis. Fire history reconstructions in the northern GYE were based on macroscopic charcoal particle (>125 microns) analysis, which provides information on area burned within a 10-20 km radius of the study site (Whitlock and Larsen 2001, Higuera et al. 2011). Charcoal accumulation rates (CHAR; particles cm^{-2} yr^{-1}) and long-term trends in CHAR (background CHAR; BCHAR) were calculated using CharAnalysis (Higuera et al. 2008). Using this software, charcoal concentrations and deposition times were interpolated into contiguous bins based on the median resolution of the record, and CHAR was determined by dividing the time-interpolated concentrations (particles cm^{-3}) by new deposition times (yr cm^{-1}). BCHAR was calculated by smoothing the CHAR time series.

Pollen analysis was used to reconstruct vegetation history and constrain the timing of conifer population expansion in the northern GYE. Standard pollen processing procedures were followed (Bennett and Willis 2001), except a Schulze procedure was substituted for acetolysis to oxidize organics (Doher 1980) in sediments from Dailey Lake and Blacktail Pond. Pollen counts averaged between 300 and 400 grains. Genus identifications were based on pollen morphology, and species assignments were based on phytogeography. Haploxylon-type *Pinus* (*Pinus* subgenus *Strobus*) pollen grains were distinguished from diploxylon-type *Pinus* (*Pinus* subgenus *Pinus*). In the GYE, haploxylon-type pollen is attributed to whitebark pine (*P. albicaulis*) and limber pine (*P. flexilis)*. Limber pine is a relatively minor species in the GYE and is generally confined to low elevations, and we assumed that it was not a major contributor to the haploxylon pine of the late-glacial/early-Holocene periods. Support for this taxonomic assignment comes from the presence of fossil whitebark pine needles in late-glacial/early-Holocene sediments (Whitlock 1993). Diploxylon-type pollen grains were attributed to lodgepole pine (*P. contorta*), as ponderosa pine (*P. ponderosa*) is absent from the GYE and primarily grows at low elevations.

We used pollen percentage data to constrain the timing of conifer population expansion in the sub-regional study focused on the northern GYE. In general, pollen data are better suited for detecting population expansion rather than initial population establishment. Pollen reconstructions typically provide a distance-weighted integration of plant populations growing within 10-50 km of a site (Jackson and Overpeck 2000), and it is difficult to distinguish between pollen derived from local low-density

populations versus background pollen from larger regional populations. Given these constraints, our vegetation history is one of population expansion, not population arrival.

Pollen percentages were calculated based on the sum of terrestrial taxa pollen, including pteridophytes, unknown, and indeterminate grains. Timing of population expansion was determined qualitatively from the shape of the pollen percentage curve for each conifer species. Population expansion occurred when the rational limit (*sensu* Smith and Pilcher 1973) was reached, which is the point at which the pollen percentage curve initially rises to sustained high values. We also compared percentage values with pollen accumulation rates (calculated through use of *Lycopodium* tracer) to ensure that other taxa were not artificially influencing the relative abundance of the species of interest, nor that high percentage values were the result of low pollen counts.

We favored the rational limit method versus more quantitative methods, such as critical threshold values (e.g., Webb et al. 1983a, 1983b, Davis and Jacobson 1985), which are minimum pollen percentage values that indicate species presence and are determined based on comparisons between a species' present range and the pollen percentage recorded in nearby surface sediments. As Birks (1989) notes, vegetation composition relative to the interested taxa has changed through time, and therefore, critical threshold values based on modern pollen percentage values may not be accurate through space and time. This inaccuracy is particularly true for populations expanding into plant communities that differ from their current associates (e.g., spruce expanding into alpine tundra). Because rational limits are qualitative characteristics of the shape of

the pollen curve, they are largely indifferent to constraints imposed by pollen percentage values.

At the sub-regional scale, rates of population expansion were calculated for each conifer species. Given the glacial history, we assume population expansion followed the path of ice recession, and rates were calculated by measuring the geographic distance between adjacent sites (Dailey Lake to Blacktail Pond to Slough Creek Pond) and dividing by the difference in population expansion timing. Overall postglacial population expansion rates were determined by averaging the rates between adjacent sites. However, it is possible that population expansion did not follow the ice recession path, especially in the early Holocene when colonization could have occurred from any direction.

Regional Analysis: GYE Conifer History

At the regional scale, we used General Additive Models (GAMs) to estimate regional trends in postglacial conifer and fire history in the GYE. This analysis was based on 922 pollen samples and 1768 charcoal samples from 16 calibrated radiocarbon-dated sites spanning 1598 to 3134 m elevation and extending from 42.729 to 45.269 °N and 109.194 to 110.817 °W. Models were developed for each of the five conifer species under study based on pollen percentage data. The regional fire GAM was based on temporal trends in macroscopic charcoal particle accumulation (CHAR), and individual charcoal records were standardized to account for differences in particle size and laboratory techniques (Power et al. 2008). Models were compared based on Akaike's Information Criterion values (AIC; Akaike 1973), and models within two AIC units were

considered to have equal predictive ability (Burnham and Anderson 2002). Calculation and figures were made using R-programming version 3.0.2 with package mgcv version 1.7-29 (Wood 2011).

Reconstruction of regional conifer history in the GYE was aided by contour plots of elevation, time, and bipolar interpolation of pollen percentage data to better understand the temporal patterns of individual species expansion at different elevations. Pollen contour plots were based on the same pollen data used in the GAMs analysis (922 pollen samples from 16 sites between 1598 and 3134 m elevation). Contour plots were produced using R-programming version 3.0.2 with package akima version 0.5-11 (Akima 1978).

Results

Sub-Regional Analysis:
Northern GYE Conifer Expansion

Results from previously published records, Dailey Lake (Krause et al. in revision; Chapter 2), Blacktail Pond (Huerta et al. 2009, Krause and Whitlock 2013; Chapter 3) and Slough Creek Pond (charcoal record; Millspaugh et al. 2004) are only described briefly.

Chronology and Lithology. The Slough Creek Pond age model was constructed using five AMS ^{14}C dates and the known age of the Mazama ash (6730 ± 40 ^{14}C yr BP; Zdanowicz et al. 1999) (Table 4.2; Fig. 4.4). All dates were included in the model and the required a priori estimate of mean accumulation rate for Bacon modeling was set to

Table 4.2 Uncalibrated and calibrated ^{14}C ages for Slough Creek Pond.

Depth (cm)[a]	Uncalibrated ^{14}C age (^{14}C yr BP)	Calibrated age (2 sigma range)[b]	Material dated	Lab number/reference[c]
259.50	3170 ± 40	(3260-3475)	pollen	OS-104118
309.50	5410 ± 30	(6133-6288)	pollen	OS-104117
344.00	6730 ± 40	(7514-7665)	Mazama ash	Zdanowicz et al., 1999
359.50	7670 ± 50	(8387-8550)	pollen	OS-104116
409.50	9280 ± 40	(10298-10576)	pollen	OS-104115
459.50	10950 ± 45	(12711-12942)	pollen	OS-104119

[a] Depth below mud surface
[b] Calibrated ages derived from CLAM program in R (Blaauw 2010)
[c] OS-National Ocean Sciences AMS Facility

50 year/cm based on the length and maximum age of the sediment core established from the local glacial recession history (Licciardi and Pierce 2008). Overall, the model was primarily linear with low associated uncertainties. Uncertainties did increase below 460 m depth due to extrapolation; however, no significant changes in pollen stratigraphy occurred below this depth to affect our paleoecological interpretations. Large uncertainties in the Dailey Lake and Blacktail Pond chronologies occur below 1025 and 730 cm depth, respectively, due to large errors associated with near-basal ^{14}C and ^{10}Be dates (Fig. 4.4). However, like Slough Creek Pond, no significant changes in proxy stratigraphy occurred below these depths to affect our interpretations.

The lithology of sediment cores from the three sites was broadly similar during the late-glacial/early-Holocene transition (Fig. 4.5). The deepest sediments were glacially derived, including sands, gravels, silts, and clays (inorganic and organic) and featured high magnetic susceptibility values. Dailey Lake sediments had high magnetic susceptibility until 13,300 cal yr BP, Blacktail Pond until 13,900 cal yr BP, and until

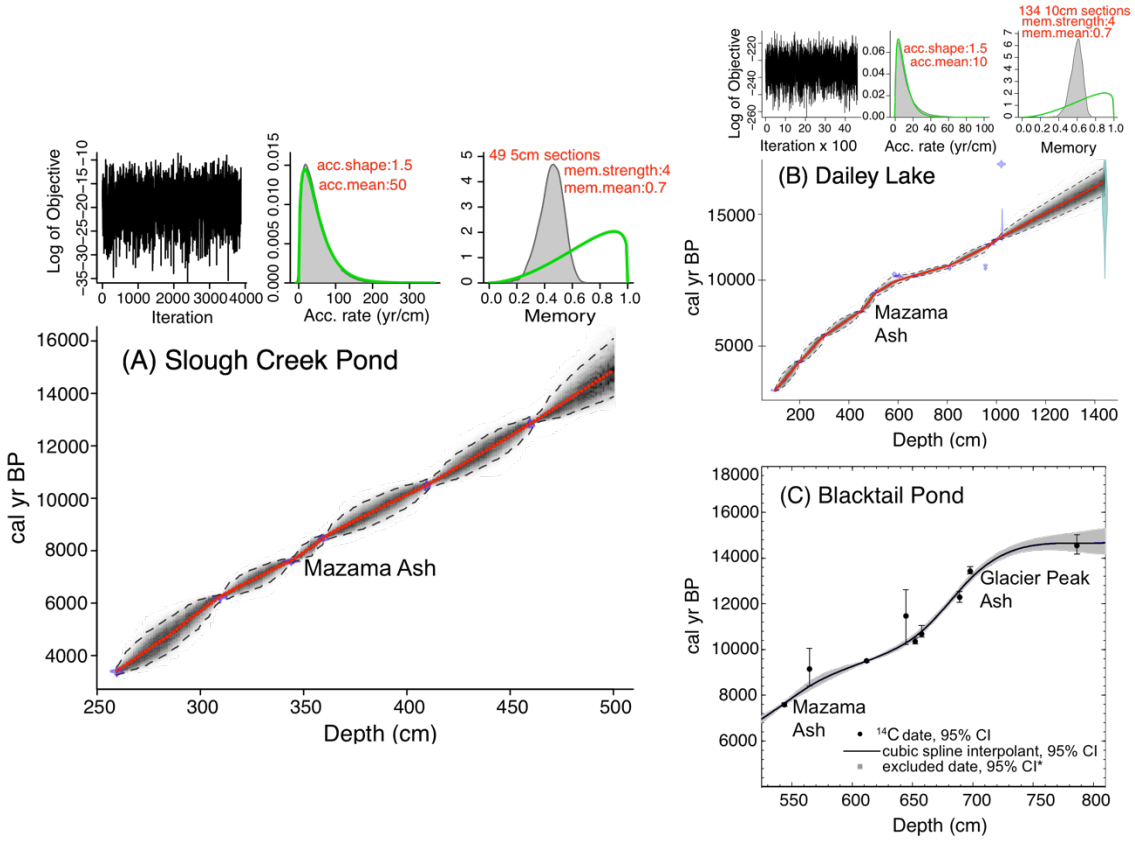


Figure 4.4 Age-depth models for (A) Slough Creek Pond, (B) Dailey Lake, and (C) Blacktail Pond. (A) and (B): solid red lines indicate weighted averages of all possible chronologies; grayscale cloud represents age model probability and is bounded by dotted-line confidence interval (95%); and top left inset shows the iteration history, the middle insets shows the prior (lines) and posterior densities (area fill) for the mean accumulation rate, and the right inset show the prior (line) and posterior (fill) of the memory (1-cm autocorrelation strength). (C): Gray shading represents range of dates and black line indicates the 50th (i.e. median age) of 1000 runs; and the 50th (circle), 2.5th and 97.5th (bars) percentiles of the probability distribution function of calibrated dates are shown. For age determinations at Dailey Lake and Blacktail Pond, see Krause et al., in revision (Chapter 3) and Krause and Whitlock (2013) (Chapter 2), and Table 4.2 for age determinations at Slough Creek Pond.

13,000 cal yr BP at Slough Creek Pond. Sediments became increasingly organic as fine detritus gyttja and then marl was deposited after 13,000 cal yr BP at Dailey Lake and ~11,500 cal yr BP at Blacktail and Slough Creek ponds.

Charcoal and Pollen Analysis. Immediately following deglaciation, charcoal accumulation was very low at the study sites (Fig. 4.5). Initial increases in BCHAR occurred at 13,300 cal yr BP at Dailey Lake, at 12,300 cal yr BP at Slough Creek Pond, and at 12,000 cal yr BP at Blacktail Pond. BCHAR levels were elevated between 11,300 and 10,300 cal yr BP at Dailey Lake and averaged 1.11 particles cm^{-2} yr^{-1}. BCHAR levels peaked earlier at Blacktail Pond and were elevated between 11,500 and 9800 cal yr BP, averaging 0.28 particles cm^{-2} yr^{-1}. At Slough Creek Pond, BCHAR reached high values between 11,900 and 10,500 cal yr BP and averaged 2.00 particles cm^{-2} yr^{-1}.Pollen data suggest conifer population expansion followed the path of ice recession of the northern Yellowstone outlet glacier, from Dailey Lake to Blacktail Pond to Slough Creek Pond, with some notable exceptions (Fig. 4.6; Table 4.3). Elevated *Picea* pollen percentages indicate that Engelmann spruce populations expanded near Dailey Lake at 13,300 cal yr BP, near Blacktail Pond at 12,900 cal yr BP, and lastly at Slough Creek Pond at 12,500 cal yr BP. *Abies* pollen percentages suggest subalpine fir population expansion near Dailey Lake at 12,300 cal yr BP, in the vicinity of Blacktail Pond at 11,300 cal yr BP, and near Slough Creek Pond at 10,500 cal yr BP.

Pinus albicaulis-type pollen trends suggest whitebark pine populations expanded near Dailey Lake at 12,100 cal yr BP and at 11,300 cal yr BP at both Blacktail and Slough Creek ponds. Lodgepole pine population expansion, as indicated by the initial rise of *Pinus contorta*-type pollen percentages, occurred at 11,300 cal yr BP at both Dailey Lake and Slough Creek Pond and later near Blacktail Pond at 11,100 cal yr BP.

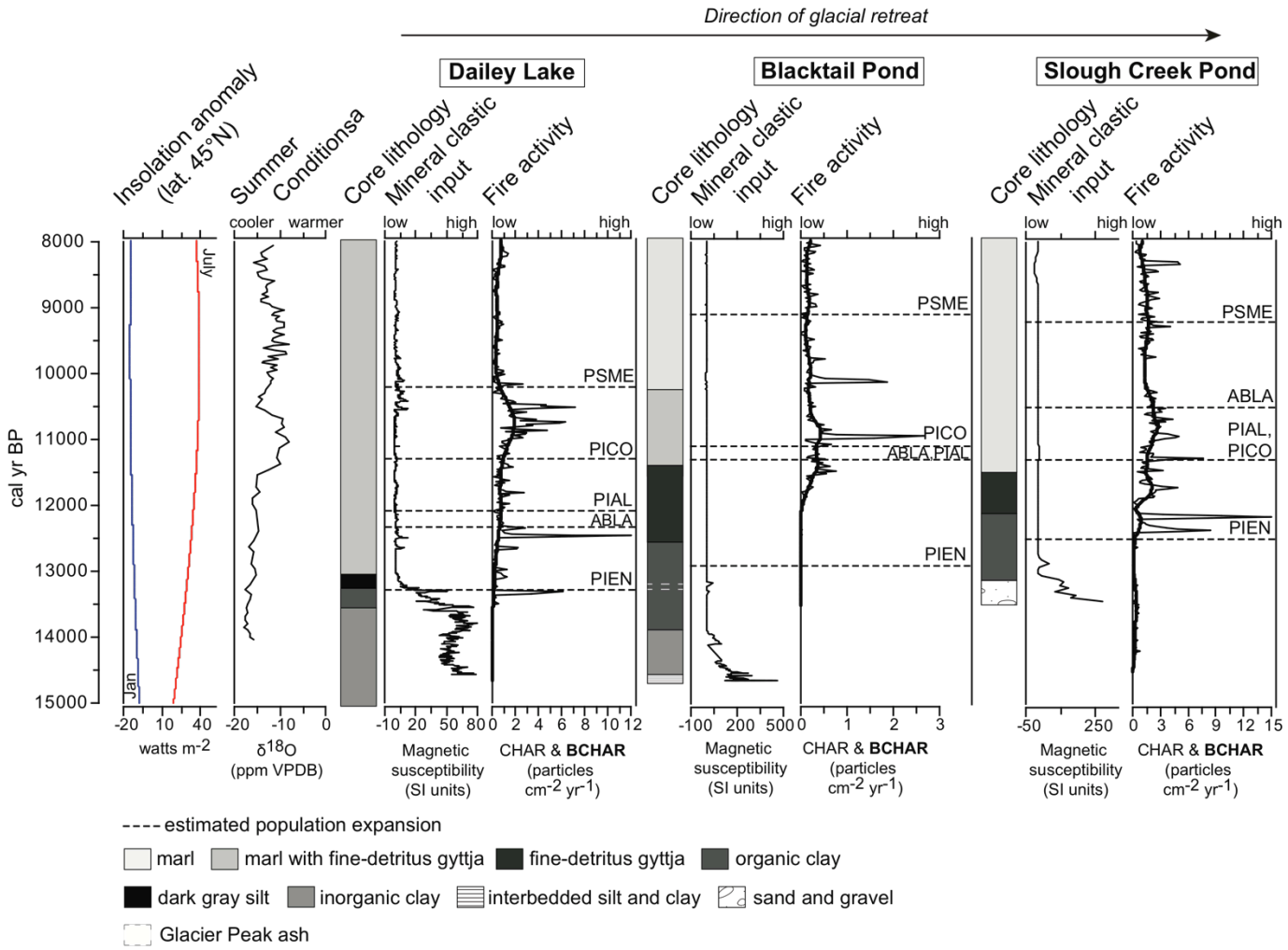


Figure 4.5 Summary of climatic, geomorphic stability, and fire activity proxies at Dailey Lake, Blacktail Pond, and Slough Creek Pond during the late-glacial/early-Holocene transition plotted against January and July insolation anomalies. PIEN = Engelmann spruce, ABLA = subalpine fir, PIAL = whitebark pine, PICO = lodgepole pine, PSME = Douglas-fir.

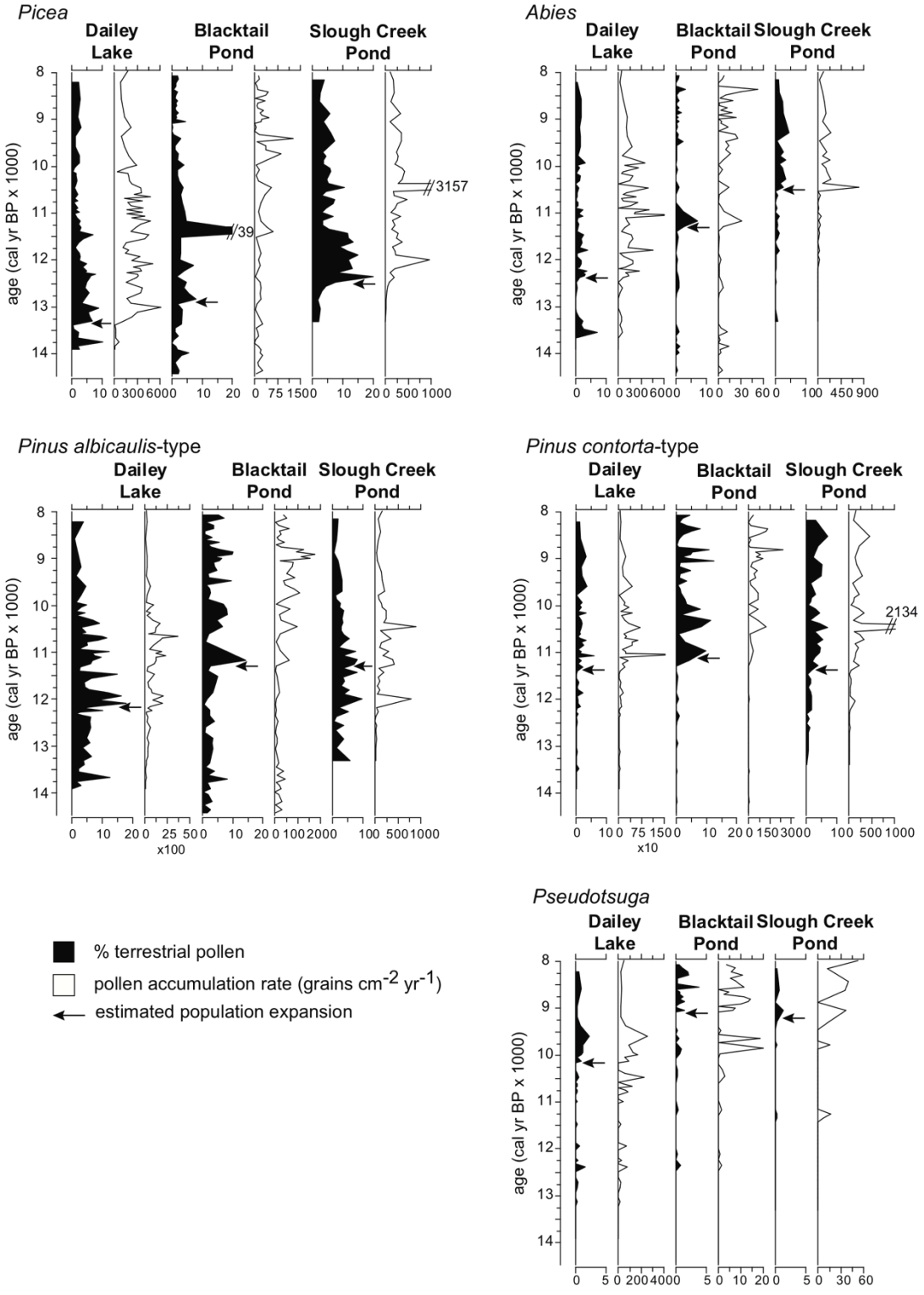


Figure 4.6 Pollen data for conifer taxa from Dailey Lake, Blacktail Pond, and Slough Creek Pond.

Table 4.3 Timing of conifer population expansion in the northern GYE and rates of population expansion inferred from pollen data.

Site	Engelmann spruce	Subalpine fir	Whitebark pine	Lodgepole pine	Douglas-fir
*Population Expansion (**cal yr BP**; 2σ error)*					
Dailey L.	**13,300**	**12,300**	**12,100**	**11,300**	**10,200**
	13,115-13,609	11,991-12,619	11,756-12,402	11,084-11,552	9994-10,446
Blacktail P.	**12,900**	**11,300**	**11,300**	**11,100**	**9100**
	12,776-13,029	11,200-11,416	11,200-11,416	10,944-11,316	8976-9248
Slough Creek P.	**12,500**	**10,500**	**11,300**	**11,300**	**9200**
	11,980-12,889	10,250-10,721	10,845-11,835	10,845-11,835	8772-9702
Rate of Population Expansion (m/yr)					
Dailey L. to Blacktail P.	95	38	48	190	35
Blacktail P. to Slough Creek P.	50	25	n/a	-100	-200
Average	73	32	n/a	145	118

Pseudotsuga pollen data suggest Douglas-fir populations expanded first near Dailey Lake at 10,200 cal yr BP, at 9100 cal yr BP near Blacktail Pond, and at 9200 cal yr BP near Slough Creek Pond.

Average postglacial population expansion rates varied between 145 m/yr for lodgepole pine and 32 m/yr for subalpine fir (Table 4.3). Engelmann spruce expanded at an average rate of 73 m/yr, 95 m/yr between Dailey Lake and Blacktail Pond and 50 m/yr between Blacktail and Slough Creek ponds. Subalpine fir expanded at a rate of 38 m/yr between Dailey Lake and Blacktail Pond, and 25 m/yr between Blacktail and Slough Creek ponds. The population expansion rate of whitebark pine was 48 m/yr between Dailey Lake and Blacktail Pond, while expansion was synchronous between Blacktail and Slough Creek ponds. Lodgepole pine populations expanded at a rate of 190 m/yr between Dailey Lake and Blacktail Pond, and 100 m/yr between Slough Creek and

Blacktail ponds. Douglas-fir population expansion averaged 117 m/yr, and populations expanded at 35 m/yr between Dailey Lake and Blacktail Pond and at 200 m/yr between Slough Creek and Blacktail ponds.

Regional Analysis: GYE Conifer History

Six GAMs were employed in the reconstruction of regional trends in vegetation and fire activity in the GYE (Table 4.4). Pollen and charcoal data were modeled as smoothing functions of the concatenated time data of all sites [$f(Time_i)=Time_{ij}$); with n=total number of covariates], the nominal variable $Site_i$, an intercept α, and the ith residual error ε_i. Resulting GAMs outperformed all other models: GAM of *Picea* pollen yielded ΔAIC = 26.7 and explained 61.1% of deviance; GAM of *Abies* pollen had ΔAIC = 5.9 and 45.5% deviance explained; *Pinus-albicaulis*-type pollen was modeled using a GAM with ΔAIC = 136.0 and 59.6% of deviance explained; GAM of *Pinus contorta*-type pollen yielded ΔAIC = 151.5 and explained 75.9 % of deviance; GAM of *Pseudotsuga* pollen had ΔAIC = 123.0 and 63.4% of deviance was explained; and macroscopic charcoal accumulation was modeled using a GAM with ΔAIC = 18.0 and 27.5% deviance explained.

Interpolated pollen contour plots revealed spatiotemporal trends in relative conifer pollen abundance throughout the GYE (Fig. 4.7). Postglacial *Picea* pollen percentages were highest (2.0-34%) across elevations between 13,000 and 11,000 cal yr BP, and afterwards remained high (2.0-20%) only at elevations above 2500 m. *Abies* pollen percentages were also high (1.0-11%) at most elevations between 13,000 and 11,000 cal

Table 4.4 Models employed in the reconstruction of regional trends in vegetation and fire in the GYE

Model	Family	ΔAIC	Deviance explained (%)
Pollen (%)			
$Picea_i = \alpha + f(Time_i)_{36} + Site_i + \varepsilon_i$	Negative binomial	26.7	61.1
$Abies_i = \alpha + f(Time_i)_{40} + Site_i + \varepsilon_i$	Negative binomial	5.9	45.5
$P.\ albicaulis_i = \alpha + f(Time_i)_{20} + Site_i + \varepsilon_i$	Negative binomial	136.0	59.6
$P.\ contorta_i = \alpha + f(Time_i)_{28} + Site_i + \varepsilon_i$	Gaussian	151.5	75.9
$Pseudotsuga_i = \alpha + f(Time_i)_{22} + Site_i + \varepsilon_i$	Negative binomial	123.0	63.4
Charcoal influx (particles $cm^{-2}\ yr^{-1}$)			
$Charcoal_i = \alpha + f(Time_i)_{80} + \varepsilon_i$	Gaussian	18.0	27.5

where pollen and charcoal data have been modeled as smoothing functions of the concatenated time data of all sites [$f(Time_i)=Time_{ij}$; with n=total number of covariates], the nominal variable $Site_i$, an intercept α and the ith residual error ε_i.

yr BP, and afterwards, high values (1.0-14%) were restricted to elevations above 2500 m. After 13,000 cal yr BP, *Pinus albicaulis*-type pollen was abundant (10-60%) at most elevations, but after 8000 cal yr BP, high values (10-50%) were mostly restricted to low elevations below 2000 m and at high elevations above 2600 m. *Pinus contorta*-type pollen percentages were high (20-80%) after 11,000 cal yr BP across all elevations, and *Pseudotsuga* pollen percentages were high (0.5-2.5%) at middle elevations between 2000 and 2500 m after 12,000 cal yr BP and subsequently increased (0.5-8.0%) at low elevations below 2000 m after 6000 cal yr BP.

Discussion

At millennial time and regional spatial scales, postglacial shifts in the geographic distribution of plant species have been shown to be strongly individualistic in response to climate change (Davis 1981, Webb 1987, Huntley 1991, Williams et al. 2001). According to ecological niche theory, each species possesses a unique fundamental niche

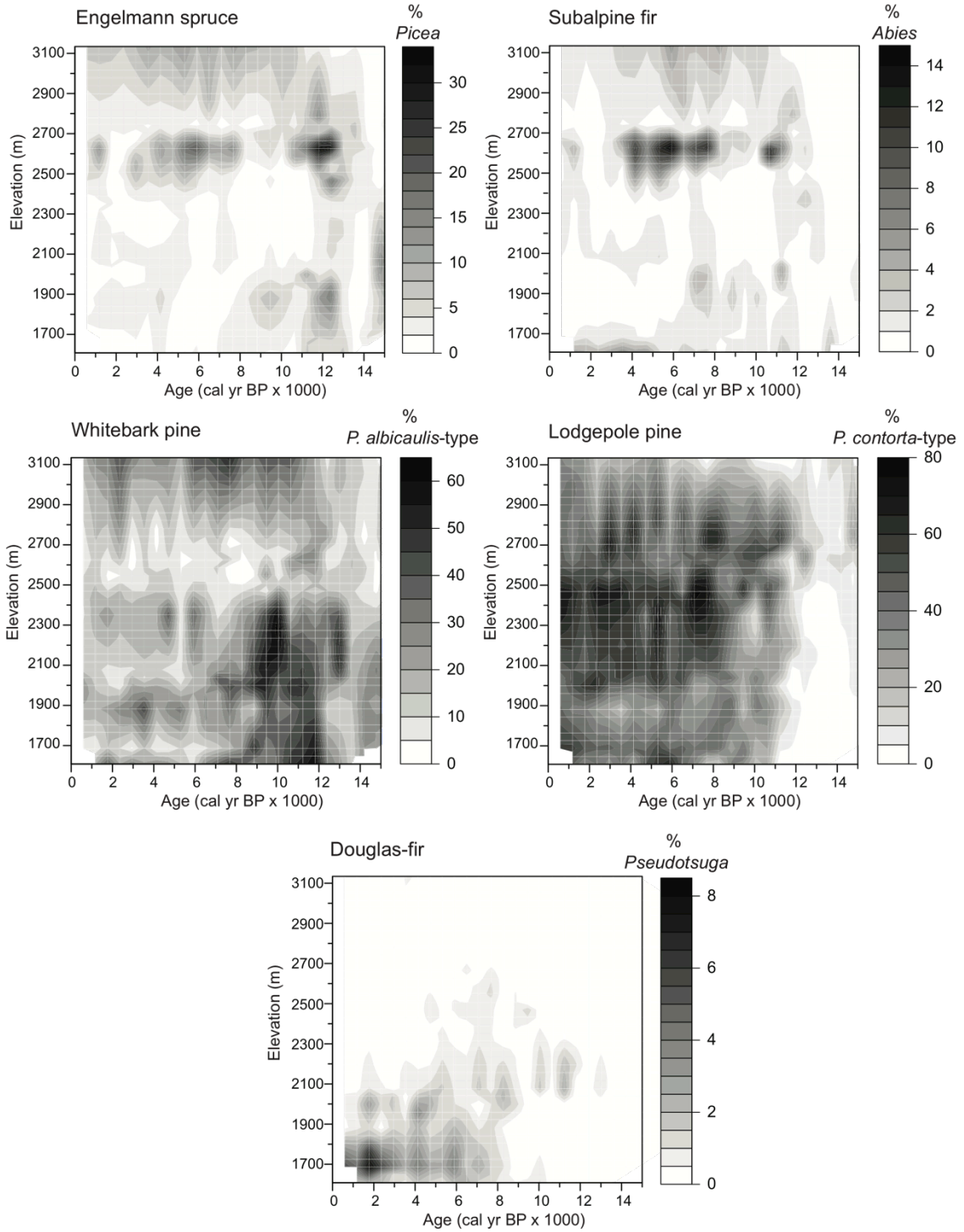


Figure 4.7 Spatio-temporal dynamics of conifers as inferred from bipolar interpolation of pollen percentage data of conifer taxa. Darker shades of gray show increasing pollen representation on a grid defined by elevation and time

that encompasses a combination of environmental variables that permit its survival and reproduction; however, the environmental factors under which the species actually occurs is the realized niche and that is largely governed by biotic interactions and the prevailing suite of environmental variables present at that time and place (environmental space) (Hutchinson 1957). As climate changes through time, the environmental space may move out of a species' fundamental niche, resulting in local extirpation via mortality or lack of recruitment.

But at the same time, the suite of environmental variables present at other sites may pass into the species' fundamental niche, resulting in colonization and eventual population expansion if propagules can reach the site, germinate, and survive to reproduction (Jackson and Overpeck 2000). These ecological processes of dispersal, establishment, reproduction, and population growth become increasingly important at the sub-regional scale and are driven by local biotic and abiotic factors, including intrinsic species characteristics, interspecific competition, disturbance, and edaphic conditions (e.g., Brubaker 1975, Millspaugh et al. 2000, Oswald et al. 2003, Gavin and Hu 2006, Briles et al. 2011). To better understand the spatiotemporal patterns of postglacial range expansion in the GYE, we examined the sub-regional scale ecological processes within the context of the large-scale controls of climate that governed regional vegetation change.

The ability of a plant population to disperse seed to unoccupied sites depends on inherent species characteristics, including seed morphology, dispersal adaptation, and growth rates (Matlack 1994, 2005, Honnay et al. 2002, Thomson et al. 2011), as well as

environmental characteristics such as habitat continuity, wind speeds, and dispersal barriers (Svenning and Sandel 2013). Climate can affect dispersal capacity by influencing seed source strength (e.g., population size, fecundity), wind direction and speed over prolonged time periods. Climate also controls habitat connectivity by affecting physical environmental variables such as soil moisture and temperature.

Successful dispersal does not guarantee successful establishment; biotic and abiotic conditions must be suitable for germination and competitive growth to reproductive status (Lake and Leishman 2004). For example, successful establishment may require openings in the existing vegetation, possibly produced by disturbance like fire (e.g., Johnstone and Chapin 2003). Disturbance not only provides access to the substrate for germination but also reduces competition with pre-existing species. The substrate itself, including soil texture and nutrient availability, must also be suitable for plant germination and establishment (e.g., Pennington 1986, Paus 1995, MacDonald et al. 2008, Henne et al. 2011). Once established, successful reproduction and population growth depends on climate and soil conditions, as well as on competitive interactions with other species (Fowells and Means 1990). Thus, we see population expansion as fundamentally driven by five drivers: inherent species characteristics, soil conditions, biotic interactions, disturbance, and climate.

To better understand postglacial conifer dynamics in the GYE, we first consider the ecological characteristics of the dominant conifer tree species. We focus specifically on their present-day climatic drivers, differences in seed dispersal capacities, and their responses to changes in fire activity (Table 4.5). Second, we discuss sub-regional

patterns of postglacial conifer expansion along the three-site transect in the northern GYE and compare them to proxies of local climate, geomorphic stability, and fire activity. Finally, we focus on the regional postglacial conifer and fire history of the GYE by comparing modeled pollen and charcoal data from sites across the region with independent measures of past climate change.

Table 4.5 Climatic and ecological tolerances of GYE conifers under study.

	Picea engelmannii	*Abies lasiocarpa*	*Pinus albicaulis*	*Pinus contorta*	*Pseudotsuga menziesii*
Temperature (°C)					
Mean January	-9.8	-11.6	-10.3	-11.4	-7.0
Mean July	13.5	13.4	12.4	13.9	15.2
Mean annual	2.1	0.8	1.1	1.2	4.1
Precipitation (mm)					
Mean January	79	61	101	64	87
Mean July	43	50	46	55	38
Mean annual	725	615	865	620	745
Ecological Characteristics					
Seed dispersal capacity	Moderate	Low	High	High	High
Fire tolerance	Low	Low	High	High	Moderate

Climatic data from Thompson et al., 1999

Modern Species Ecology

Engelmann Spruce (*Picea engelmannii*). Engelmann spruce grows throughout western North America, and its biogeographic range extends from British Columbia and Alberta, south to New Mexico and Arizona. Spruce is a highly frost-tolerant species presently found in areas of the western US with long cold winters and short cool

summers (Alexander and Shepperd 1990). The conifer is a moderate-to-good seed producer (Alexander and Noble 1976, Alexander 1986, Alexander et al. 1986), and small winged seeds are light and wind dispersed. Seed dispersal can occur up to 250 m from the parent tree (Klinka et al. 2000). In the Rocky Mountains, spruce is a late-successional species with subalpine fir (Alexander and Shepperd 1990), and at present, spruce has very few adaptations to fire (a fire avoider *sensu* Agee 1993) and is slow to reinvade burned areas.

Subalpine Fir (*Abies lasiocarpa*). Subalpine fir is widely distributed throughout western North America from the Yukon Territory, south to Arizona and New Mexico. In the western US, subalpine fir, like Engelmann spruce, grows in the coolest and wettest forests and is extremely frost tolerant; however, it can endure lower winter temperatures than spruce (Fowells 1965, Thompson et al. 1999). Subalpine fir has large winged seeds that are poorly dispersed by wind (Schopmeyer, 1974), and maximum dispersal occurs less than 100 m from the parent tree (Klinka et al. 2000). Establishment and seedling survival are favored by shade (Franklin and Dyrness 1973), and like spruce, fir is a fire avoider. The conifer suffers mortality even from low-intensity fires due to its thin bark, shallow root system, highly flammable foliage, and its dense forest habit (Uchytil 1991, Agee 1993).

Whitebark Pine (*Pinus albicaulis*). Whitebark pine grows in high-elevation forests and near timberline in western North America. The conifer grows at high elevations in the Sierra Nevada, Cascade Range, Pacific Coast Ranges, and the Rocky Mountains from

Wyoming to the Continental Ranges of Canada. At present, whitebark pine favors cold windy and snowy areas and is highly frost tolerant (Arno and Hoff 1990). It is dominant at upper treeline, ~2900 m elevation in the GYE, but also persists as an understory subdominant in subalpine forests at lower elevations. The low-elevation limit of whitebark pine is set by competition with subalpine fir, Engelmann spruce, and lodgepole pine for light, water, and nutrients (Weaver 2001). Long-distance dispersal of heavy wingless whitebark pine seeds is facilitated by Clark's nutcracker (*Nucifraga columbiana*), which caches seeds in the soil, often on burned and exposed sites (Tomback 1986, 1994). As such, it is common to find lone whitebark pine trees growing, often several kilometers from the nearest possible seed source (Arno and Hammerly 1984). Whitebark pine thrives in fire-prone ecosystems due to the survival of large refugial trees aided by its moderate bark thickness and the usual patchy fuel distribution in whitebark pine habitats, postfire seedling establishment facilitated by Clark's nutcracker (Fryer 2002), and seedling hardiness on burned exposed sites (Arno and Hoff 1990).

Lodgepole Pine (*Pinus contorta*). Lodgepole pine is one of the most widely distributed tree species in western North America, extending from interior Alaska and the Northwest Territories, east to Saskatchewan and the Black Hills of South Dakota, and south to Colorado, central Utah, and eastern Oregon. Lodgepole pine tolerates a wide range of climatic conditions: the species is highly frost tolerant (Klinka et al. 2000), but also experiences extremely high temperatures (grows to well over 38°C) and summer drought at low elevations in the interior western US (Lotan and Critchfield 1990). Lodgepole pine is a prolific seed producer, and begins producing viable seed at an early

age, commonly at 5-10 years old (Lotan and Critchfield 1990). Many lodgepole pine populations have serotinous cones, and once opened, seeds are dispersed less than 100 m (Klinka et al. 2000). Lodgepole pine dominance is maintained by high fire activity (Davis et al. 1980, Fischer and Clayton 1983, Smith and Fischer 1997) and has the competitive advantage over other conifer species due to its early and prolific seed production, high seed viability and seedling survival, rapid growth (Davis et al. 1980, Bradley et al. 1992, Smith and Fischer 1997), and serotiny, which is an adaptation to stand-replacing fires (Bradley et al. 1992, Arno et al. 1995).

Douglas-Fir (*Pseudotsuga menziesii*). Douglas-fir grows in the inland mountains of the Pacific Northwest and the Rocky Mountains from central British Columbia, south through eastern Washington and Oregon and central Idaho, and east to western Wyoming and western Montana. The species grows under a wide range of climatic conditions but is generally drought-resistant (Minore 1979) and favors long frost-free seasons (Hermann and Lavender 1990). Douglas-fir has high seed dispersal capacity. Winged seeds are dispersed by wind and gravity (Owston and Stein 1974) and most fall within 100 m of the parent tree (Hermann and Lavender 1990). Small amounts are dispersed by mammals, as well as by Clark's nutcracker, making long-distance seed dispersal possible (Hemstrom et al. 1987). Mature Douglas-fir trees have thick corky bark and can survive moderately severe surface fires (Fischer and Bradley 1987, Agee 1993).

Sub-Regional Analysis:
Northern GYE Conifer Expansion

Engelmann Spruce History. Pollen data suggest Engelmann spruce was the first conifer tree species to expand into the northern GYE following glacial retreat. Initial population expansion occurred at low elevations near Dailey Lake at 13,300 cal yr BP. Following deglaciation, high mineral clastic input at Dailey Lake (Fig. 4.5) indicates an initial period of geomorphic instability possibly due to the persistence of stagnant ice, glacial meltwater, erosion from the newly deglaciated landscape, and/or high catabatic winds originating from the Yellowstone Plateau. After 13,300 cal yr BP, decreased mineral clastic input was associated with a rise in *Picea* pollen that suggests an expansion of spruce in the drainage. At present, Engelmann spruce prefers moderately deep, well-developed soils (Alexander 1987), and geomorphic stabilization and subsequently more developed soils, likely favored spruce expansion.

Although increasing carbonate $\delta^{18}O$ data from Blacktail Pond suggest summer conditions were gradually warming (Fig. 4.5), the synchronous response of spruce populations to geomorphic stabilization in the Dailey Lake watershed suggests edaphic conditions, namely lack of soil cover, likely delayed initial conifer tree population expansion in the northern GYE. These findings are consistent with observations in other regions. In the British Isles, paleorecords indicate edaphic lags of 500-1000 years between initial postglacial warming and birch (*Betula pubescens*) forest development (Pennington 1986, Paus 1995), and postglacial delays in soil development in central and western Switzerland are considered critical in explaining 3000-6000 year delays in spruce

(*Picea abies*) establishment at high elevations (Henne et al. 2011). Furthermore, modern studies from Glacier Bay, Alaska indicate soil development during the first century of terrestrial succession (Crocker and Major 1955, Ugolini 1966, Bormann and Sidle 1990), with alder thickets establishing ~50 years after glacial retreat, followed by spruce establishment within ~100 years (Chapin et al. 1994). Like these other regional observations, late-glacial edaphic conditions near Dailey Lake likely produced a vegetation response that was not fully in equilbrium with the prevailing climatic conditions.

The watersheds of Blacktail and Slough Creek ponds were stabilized prior to Engelmann spruce expansion, and climate, rather than geomorphic instability and edaphic conditions, likely limited initial conifer expansion. Decreased mineral clastic input at Blacktail Pond suggests catchment stabilization at 13,900 cal yr BP, followed by spruce population expansion about 1000 years later at 12,900 cal yr BP (Fig. 4.5). Similarly, at Slough Creek Pond, mineral clastic input decreased at 13,000 cal yr BP, and spruce populations increased 500 years later at 12,500 cal yr BP. Over this time period, gradually increasing carbonate $\delta^{18}O$ data at Blacktail Pond suggest summer conditions were warming, and spruce likely tracked favorable climates to higher elevations in the northern GYE.

The comparison suggests that the proximity of Dailey Lake to the northern Yellowstone outlet glacier terminus and its exposure to enormous volumes of glacial meltwater and outwash influenced the initial development of vegetation. This outwash phase lasted a longer time period and was sourced from a larger ice volume than at later

deglaciated Blacktail and Slough Creek ponds. Prior to the Deckard Flats readjustment at ~14,200 cal yr BP (14.2 ± 1.2 ^{10}Be ka; Licciardi and Pierce 2008), the northern Yellowstone outlet glacier was fed by an ice complex emanating from the Yellowstone Plateau, and Dailey Lake was receiving outwash from this large source area. By the time of readjustment and ice retreat at Blacktail and Slough Creek ponds, the northern Yellowstone outlet glacier was decoupled from the Yellowstone Plateau ice complex, and the northern Yellowstone ice mass had diminished to 30-50% of its full-glacial volume (Pierce 1979). As such, Blacktail and Slough Creek ponds did not receive the large amounts of mineral clastic input recorded at Dailey Lake and watersheds were stabilized at the time of early conifer expansion.

Subalpine Fir History. Like Engelmann spruce, pollen data suggest the expansion of subalpine fir populations was time-transgressive in the northern GYE. Subalpine fir expansion near Dailey Lake at 12,300 cal yr BP and Blacktail Pond at 11,300 cal yr BP coincided with warmers summers than before as indicated by less negative carbonate $\delta^{18}O$ values from Blacktail Pond; however, expansion of subalpine fir near Slough Creek Pond occurred during a cool summer excursion as evidenced by decreased $\delta^{18}O$ values at Blacktail Pond between 10,600 and 10,100 cal yr BP (Fig. 4.5). This cooling may have delayed fir expansion at Slough Creek Pond, inasmuch as the rate of population spread between Blacktail and Slough Creek ponds was more than one-third less than the rate of expansion between Dailey Lake and Blacktail Pond (25 m/yr versus 38 m/yr; Table 4.3).

Sub-millenial climate variability was a likely factor in explaining subalpine fir history in the northern GYE. Despite similar climatic tolerances with Engelmann spruce,

subalpine fir populations expanded at a slower rate than Engelmann spruce (32 m/yr compared with 73 m/yr; Table 4.3), possibly due to its poorer seed dispersal capacity. By the time fir expanded near Blacktail Pond at 11,300 cal yr BP, increasing summer insolation and temperatures and decreasing effective moisture may have limited fir expansion, explaining the delayed rate of spread between Blacktail and Slough Creek ponds. Not only did more warm- and drought-tolerant conifer species expand before subalpine fir at Slough Creek Pond, including lodgepole pine (at 11,300 cal yr BP), but fir expansion near Slough Creek Pond occurred during an excursion to more favorable cooler summers. By controlling seed source strength (i.e. source population size and fecundity), fir expansion possibly occurred under favorable climatic conditions (cool summers) prior to 11,300 cal yr BP and after 10,500 cal yr BP, and in between, unfavorable climatic conditions (warm summers) suppressed population spread. Similar patterns of rapid postglacial tree expansion mixed with periods of quiescence or stillstands are evident in pollen and macrofossil records for Utah juniper in the western US (Lyford et al. 2003), and for white pine (Jacobson 1979), beech (Woods and Davis 1989), hemlock (Davis et al. 1994, Parshall 2002), and yellow birch (Jackson and Booth 2002) in the Great Lakes region.

Whitebark Pine and Lodgepole Pine History. Pollen data indicate near synchronous expansion of pine species across sites in the northern GYE. Whitebark pine expanded at low elevations near Dailey Lake at 12,100 cal yr BP. At 11,300 cal yr BP, it expanded at higher elevations in the northern GYE near Blacktail and Slough Creek ponds, and lodgepole pine expanded near Dailey Lake and Slough Creek Pond. Within

approximately 200 years, lodgepole pine populations were present near Blacktail Pond at 11,100 cal yr BP. Widespread expansion of pine populations occurred after a step-like increase in summer temperatures at 11,500 cal yr BP, which is indicated by less negative carbonate $\delta^{18}O$ data from Blacktail Pond (Fig. 4.5). Charcoal data from the northern GYE also indicate increased fire activity between 11,900 cal yr BP at Slough Creek Pond and 9800 cal yr BP near Blacktail Pond (Fig. 4.5).

More favorable summer temperatures likely promoted the expansion of whitebark and lodgepole pine, and elevated fire activity created sites suitable for pine recruitment and growth. Disturbance events, like fire, are essential in creating openings in the vegetation, and in this case, fire in spruce- and fir-dominated forests would have facilitated the expansion of whitebark and lodgepole pine, which thrive with frequent fires. Increased fire activity may have also been responsible for the stalled expansion of less fire-adapted subalpine fir populations near Slough Creek Pond at 11,300 cal yr BP. Fir abundance there did not increase until fire activity declined at 10,500 cal yr BP at the site (Fig. 4.5).

Disturbance-facilitated shifts in forest dominance have been observed in other paleorecords. In southern Scandinavia, local expansion of northward-migrating beech (*Fagus sylvatica*) populations was delayed for up to 1000 years after initial arrival and only expanded after disturbance (Björkman and Bradshaw 1996, Cowling et al. 2001, Bradshaw and Lindbladh 2005). Furthermore, modern studies highlight rapid lodgepole pine recruitment into burned spruce and fir forests in Yellowstone (Turner et al. 1999)

and also at its northern limit in Canada (Johnstone and Chapin 2003), similar to observations made from the northern GYE paleorecords.

Douglas-Fir History. Pollen data indicate Douglas-fir was the last conifer tree species to expand into the northern GYE. Douglas-fir populations expanded near Dailey Lake at 10,200 cal yr BP and synchronously near Blacktail and Slough Creek ponds at 9100 and 9200 cal yr BP, respectively. Summer insolation in the region reached its maximum between 9700 and 9800 cal yr BP (Berger and Loutre 1991), and carbonate $\delta^{18}O$ data from Blacktail Pond suggest continued warm summer conditions (Fig. 4.5). Because *Pseudotsuga* pollen tends to be under-represented in the pollen record due to the low pollen production and poor dispersal of Douglas-fir (Gugger and Sugita 2010), it is possible to estimate when small local populations established. Based on trace amounts of *Pseudotsuga* pollen present in the records, small local populations likely grew on the landscape as early as 12,800 cal yr BP at Dailey Lake, at 12,300 cal yr BP at Blacktail Pond, and at 11,300 cal yr BP at Slough Creek Pond. These populations, which may have been the result of animal-facilitated long-distance dispersal, initially established in localized suitable habitats at a time when the overall climate conditions were relatively unfavorable. As summer insolation increased to its maximum in the early Holocene, populations expanded from these small local populations first at lower elevations near Dailey Lake and then later throughout higher elevations near Blacktail and Slough Creek ponds.

Regional Analysis: GYE Conifer History

GAMs analysis of conifer pollen data in combination with interpolated contour plots captures spatiotemporal trends in conifer tree abundance in the GYE (Figs. 4.7 and 4.8). Modeled *Picea* and *Abies* pollen data suggest Engelmann spruce was abundant across elevations in the GYE between 13,000 and 11,000 cal yr BP, and subalpine fir became abundant in the region at most elevations after 12,500 cal yr BP. Although summer conditions were gradually warming, they were still likely cool and effectively wet. As an early colonizer of the deglaciated landscape, spruce likely increased fuel availability on the landscape, and in combination with increasing summer temperatures, created conditions favorable for fire. Modeled charcoal data from throughout the GYE indicate increased fire activity beginning 12,500 cal yr BP during the postglacial peak in spruce densities (Fig. 4.8). Trends in the pollen data suggest that fir abundance was relatively stable until 8000 cal yr BP, and increased fire activity between 12,500 and 10,000 cal yr BP may have stalled its expansion. As fire activity decreased after 10,000 cal yr BP, the pollen data indicate fir abundance peaked briefly at 7500 cal yr BP. Spruce decreased and stabilized to near-present densities by 8500 cal yr BP and fir decreased to near present levels by 6000 cal yr BP. As their abundance decreased throughout the region, contour plots suggest both species became restricted to higher elevations above 2500 m under low summer and elevated winter insolation.

Modeled and interpolated data of *Pinus albicaulis*-type pollen data suggest that whitebark pine abundance initially increased throughout the GYE at most elevations beginning 12,500 cal yr BP (Figs. 4.7 and 4.8). Highest postglacial whitebark pine

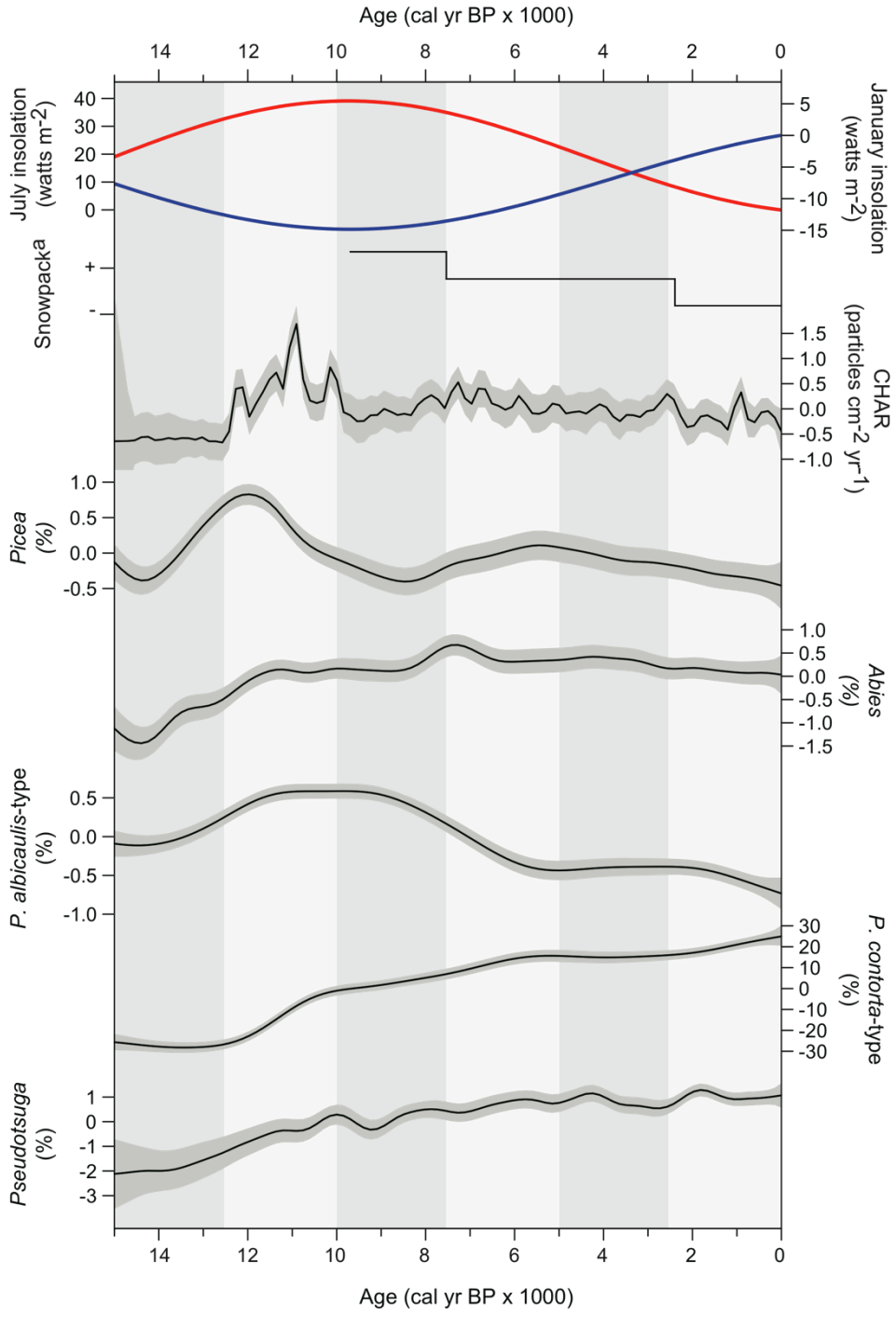


Figure 4.8 Environmental and conifer history in the Greater Yellowstone Ecosystem over the last 15,000 years, including trends in January and July insolation anomalies (Berger and Loutre, 1991), snowpack dynamics inferred from $\delta^{18}O$ variations at Crevice Lake ([a]Whitlock et al., 2012), fire activity (CHAR) and pollen abundance (%). Pollen and charcoal regional trends are estimated by GAMs applied to the charcoal accumulation and pollen percentage data. 95% confidence intervals are shown in gray.

densities correlated with the greatest seasonality over the last 15,000 years: summers were at their warmest and effectively driest; winters were at their coldest and effectively wettest. Furthermore, elevated regional fire activity between 12,500 and 10,000 cal yr BP may have facilitated whitebark pine expansion at the expense of less fire-adapted Engelmann spruce and subalpine fir. With decreasing summer and rising winter insolation during the middle and late Holocene, *P. albicaulis*-type pollen decreased with cooler summers and warmer winters. Furthermore, authigenic carbonate $\delta^{18}O$ data from Crevice Lake in the northern GYE suggest decreasing winter snowpack after 8200 cal yr BP (Whitlock et al., 2012), and dry and cold winters in the last 8000 cal yr BP likely limiting seedling establishment and survival of whitebark pine. By 7500 cal yr BP, the conifer was predominantly confined to high elevations above 2600 m. However, moderate levels of *Pinus albicaulis*-type pollen were still present at low and middle elevations in the region during the middle and late Holocene. This pollen could be attributed to the Holocene expansion of limber pine (*Pinus flexilis*) populations into the GYE. At present, limber pine is a minor component of low-elevation forests in the region.

Lodgepole pine and Douglas-fir abundances increased last in the GYE. Modeled pollen data show that *Pinus contorta*-type pollen steadily increased in the GYE after 11,000 cal yr BP followed by increased *Pseudotsuga* pollen levels after 10,000 cal yr BP (Fig. 4.8). Interpolated contour plots suggest postglacial lodgepole pine populations were likely always present across most elevations in the region, while initial Douglas-fir populations were abundant at middle elevations, 2000-2500 m, and became restricted to

low elevations below 2000 m after 6000 cal yr BP (Fig. 4.7). The initial rise in lodgepole pine and Douglas-fir densities occurred under high summer insolation, warm summers, and low effective moisture, while their increasing Holocene abundance occurred under opposite conditions: decreasing summer insolation, cool summers, and high effective moisture. Furthermore, carbonate $\delta^{18}O$ data from Crevice Lake suggest decreasing winter snowpack during the Holocene (Whitlock et al. 2012). In response, Douglas-fir populations shifted from middle elevations to warmer and effectively drier lower elevations in the region, while lodgepole pine continued to grow at all elevations, reflecting 1) its broad climatic tolerance, and 2) its competitive advantage over other conifer tree species in the GYE. This strong competitive advantage likely reduced whitebark pine to a subdominant role at middle elevations after 7500 cal yr BP.

Conclusions

In our sub-regional and regional analysis of early postglacial conifer dynamics in the GYE, we compared patterns of conifer expansion in the northern GYE to independent environmental proxies and resolved spatiotemporal trends in pollen and charcoal data available from throughout the GYE using GAMs and interpolated pollen contour plots. These approaches contribute new information to our understanding of postglacial conifer history in the GYE:

(1) Nonclimatic factors played important roles in directing early conifer population expansion in the northern GYE and in the regional conifer history. As witnessed at Dailey Lake, geomorphic instability and lack of soil cover inhibited early

conifer expansion, and a lag in soil development may have delayed the vegetation response to warming summer conditions indicated by independent climate proxy data. Intrinsic species characteristics, including superior seed dispersal capacity, favored early postglacial expansion of Engelmann spruce as compared with subalpine fir and highlight the importance of time-dependent processes of dispersal in directing early postglacial conifer dynamics. Lastly, postglacial trends in *Pinus albicaulis*- and *Pinus contorta*-type pollen draw attention to the competitive advantage of lodgepole pine over whitebark pine in middle elevation subalpine forests. As lodgepole pine densities increased in the Holocene, it replaced whitebark pine at middle elevations due to its rapid growth, and whitebark pine gained became restricted to higher elevations.

(2) Millenial-scale climate change associated with the seasonal cycle of insolation facilitated rapid conifer responses. Whitebark pine, lodgepole pine, and Douglas-fir populations each expanded nearly synchronously in the northern GYE during the late-glacial/early-Holocene transition under increasing summer insolation and temperatures and decreasing winter insolation and higher winter snowpack. Furthermore, warm summer conditions likely synchronized fire activity throughout the GYE, facilitating regional pine expansion at the expense of less fire-tolerant Engelmann spruce and subalpine fir. Despite unidirectional warming, sub-millenial scale climate variability was still important and warm summers ~11,300 cal yr BP likely stalled expansion of subalpine fir near Slough Creek Pond in the northern GYE.

(3) Many conifer species shifted their elevational ranges in response to Holocene climate change. Engelmann spruce and subalpine fir populations were

prevalent across most elevations in the GYE when they initially increased under late-glacial cool climatic conditions. Beginning in the early Holocene, they became restricted to higher elevations likely due to increasing summer insolation and temperatures, as well as increased fire activity. Douglas-fir populations initially increased at middle elevations during the early Holocene under warm and dry summer conditions, and shifted to lower elevations as summer insolation and temperatures decreased in the middle and late Holocene. In contrast, lodgepole pine has always been prevalent across elevations in the GYE since its initial increase during the early Holocene, and its strong competitive advantage over other conifers likely maintains its stronghold at middle elevations versus other subalpine conifers such as whitebark pine. It appears the elevation range of conifer species became more zonal through time, and the present-day zonation did not exist during late-glacial and early-Holocene periods.

Our study offers a unique paleoecological perspective of conifer biogeographic range shifts under climatic conditions and species associations beyond those present today. It stresses the importance of considering nonclimatic factors, such as edaphic conditions, dispersal capacity, and biotic interactions in projections of species' responses to current climate change. Furthermore, it highlights the ability of Yellowstone's conifers to adapt to past climate fluctuations and biotic interactions by shifting their elevational ranges. However, in the coming decades, climate projections indicate average temperature increases of up to 6 °C in the Northern Rocky Mountains (Mote et al. 2008), and the GYE will enter uncharted territory as both summer and winter

temperatures increase and interact with fire activity and unprecedented insect and pathogen outbreaks, producing a future of uncertainty for the region's conifers.

Acknowledgements

This research was supported by National Science Foundation grants, including EAR-0801467 and OISE-0966472 to Whitlock. We thank C. Hendrix and S. Gunther (Yellowstone National Park) for logistical field support; D. Firmage, C. Florentine, M. Spendel, L. Stahle, and A. White for help in the field; and C. Florentine and E. Merrell for lab assistance.

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CHAPTER FIVE

CONCLUSIONS

The Greater Yellowstone Ecosystem (GYE) is one of the largest and relatively intact temperate ecosystems worldwide, and its diversity in vegetation is largely due to the region's complex topography, which creates steep gradients in temperature and effective moisture, and the underlying mosaic of geologic substrates. This dissertation focuses on the initial stages of ecosystem development in the GYE following glacial retreat after ~17,000 cal yr BP. In particular, it uses fossil pollen records from lake sediments to trace early postglacial vegetation development in the GYE during the late-glacial/early-Holocene transition (17,000-8000 cal yr BP)

The work builds upon a legacy of paleoecological research in the GYE (e.g., Waddington and Wright 1974, Baker 1976, 1983, Gennett and Baker 1986, Whitlock 1993, Whitlock and Bartlein 1993, Elias 1997, Millspaugh et al. 2000, Huerta et al. 2009, Persico and Meyer 2009, Whitlock et al. 2012) and advances our understanding of postglacial vegetation dynamics in the western US by focusing on the late-glacial/early-Holocene transition at high temporal (multi-decadal) resolution. The study also incorporates independent information on summer and winter climatic conditions, landscape evolution, lake productivity, and fire to identify the early environmental conditions under which vegetation developed.

The specific objectives were to (1) reconstruct the sequence of early postglacial vegetation changes in the northern GYE and identify associations between vegetation,

climate, fire, and physical landscape evolution; (2) assess the spatiotemporal patterns of early postglacial vegetation development in the northern GYE; and (3) reconstruct postglacial vegetation and fire history throughout the GYE region to better understand the role of millennial-scale climate change, fire, and species interactions in shaping early postglacial conifer dynamics.

The project utilized two approaches:

(1) Examination of environmental changes at individual sites in the northern GYE, including Dailey Lake (Chapter 3), Blacktail Pond (Chapter 2), and Slough Creek Pond (Chapter 4). These AMS radiocarbon-dated sites lie along the path of ice recession of the northern Yellowstone outlet glacier. Carbonate $\delta^{18}O$ data from Blacktail Pond and nearby Crevice Lake (Whitlock et al., 2012) provided information of summer and winter climate, respectively; vegetation changes were inferred from fossil pollen records; lithologic and geochemical data provided information on landscape evolution; and changes in past fire activity were inferred from charcoal data. Temporal sequencing of events from each site revealed important local associations between different ecosystem components including vegetation, climate, fire, and physical landscape processes.

(2) Comparisons of early postglacial vegetation change in the northern GYE and throughout the region to determine spatiotemporal patterns of vegetation development and whether in-site associations among vegetation, climate, fire, and landscape evolution were consistent throughout the region. Chapter 4

focused specifically on conifer population expansion, including expansion of Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), whitebark pine (*Pinus albicaulis*), lodgepole pine (*Pinus contorta*), and Douglas-fir (*Pseudotsuga menziesii*), as it related to climate, fire, landscape evolution, and biotic interactions. General Additive Models (GAMs) of pollen and charcoal data were used to detect regional trends in vegetation and fire history throughout the GYE, and pollen data were interpolated across time and elevation to detect trends in the elevational distribution of conifer species.

The importance of the study lies in its findings on topics relevant to understanding present-day ecosystem dynamics:

Vegetation Response to Climate Change

Previous paleovegetation studies from the GYE region laid the foundation for this investigation (e.g., Baker 1976, 1983, Whitlock 1993, Huerta et al. 2009, Mumma et al. 2012, Whitlock et al. 2012). Based on fossil pollen evidence, these studies highlight regional climatic drivers of early postglacial vegetation development, namely increasing summer insolation and its direct effects on temperature (3 °C warmer than present; Alder and Hostetler 2014) and effective moisture. Furthermore, paleoclimate simulations and authigenic carbonate $\delta^{18}O$ data highlight colder (2 °C colder than present; Alder and Hostetler 2014) and wetter winters (Bartlein et al. 1998, Whitlock et al. 2012).

A closer focus on vegetation history in the northern GYE during the late-glacial/early Holocene transition reveals the following vegetation changes (Fig 5.1).

Fossil pollen data from Dailey Lake, Blacktail Pond, and Slough Creek Pond indicate that the newly deglaciated landscape was initially colonized by pioneering herb and shrub species, including Asteraceae species, willows *(Salix* spp.), and buffaloberry (*Shepherdia canadensis*). As growing season temperatures increased, populations of Engelmann spruce first expanded into the northern GYE after 13,300 cal yr BP. Other conifer populations, including subalpine fir (after 12,300 cal yr BP), whitebark pine (after 12,100

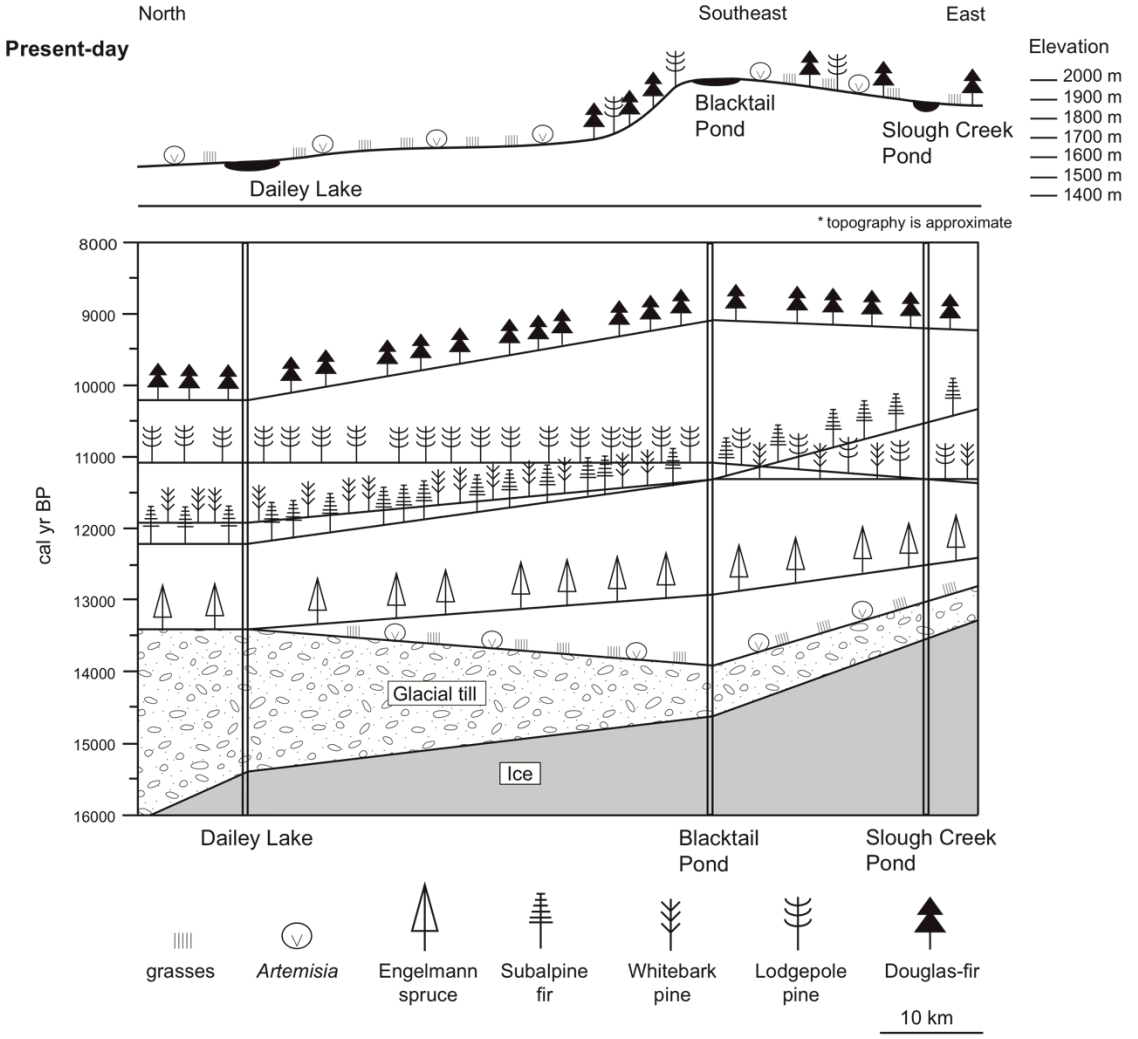


Figure 5.1 Schematic reconstruction of vegetation development in the northern GYE during the late-glacial/early-Holocene transition

cal yr BP), and lodgepole pine (after 11,300 cal yr BP), quickly followed, and closed subalpine forest replaced spruce parkland under warm but still effectively wet summer conditions. By the early Holocene summer insolation maximum at ~10,000 cal yr BP, pollen data suggest Douglas-fir populations expanded into the northern GYE under warm and dry summers and lower forests became less dense and more open. GAMs analysis of pollen data from throughout the GYE reveals similar temporal patterns of vegetation development in response to increasing summer insolation.

Interactions between local topography and regional climate change produced heterogeneous vegetation responses to regional climate change in the northern GYE. During the early Holocene, arboreal/nonarboreal pollen values from Dailey Lake suggest that forest cover decreased and/or lower treeline shifted to higher elevations while grassland and sagebrush-steppe expanded at lower elevations near Dailey Lake. On the otherhand, subalpine forest continued to grow at higher elevations near Blacktail and Slough Creek ponds until ~8000 cal yr BP. Dailey Lake, as a dry low-elevation site, was likely more sensitive to the direct effects of increasing summer insolation on summer temperatures and effective moisture as compared to higher elevation sites. Blacktail and Slough Creek ponds continued to support closed subalpine forest as a result of increased summer convective storms produced by enhanced monsoonal circulation (Whitlock and Bartlein 1993) and/or from the carryover of higher-than-present winter snowpack to the summer growing season (Whitlock et al. 2012).

Fossil pollen records from the GYE do not indicate reversals in vegetation development associated with the Younger Dryas Chronozone (12,900-11,500 cal yr BP;

Alley et al. 2002). Furthermore, carbonate $\delta^{18}O$ data from Blacktail Pond do not show evidence of a climate reversal during the Younger Dryas, but instead indicate unidirectional warming during the late-glacial period. To date, the Younger Dryas Chronozone is only recorded in the Northern Rocky Mountains as minor glacial advances in the Wind River Range (Gosse et al. 1995a, 1995b) and the Canadian Rocky Mountains (Reasoner et al. 1994). Younger Dryas associated vegetation reversals in the Rocky Mountains, typically recorded as a downward displacement of upper treeline, are limited to paleorecords obtained from the Southern Rocky Mountains, including Sky Pond and Black Mountain Lake (Reasoner and Jodry 2000) and Tiago Lake (Jiménez-Moreno et al. 2010).

Nonetheless, paleoenvironmental data from the northern GYE suggest significant climate variability superimposed on the long-term trends in warming during the late-glacial/early-Holocene transition. Associated diatom data from Dailey Lake indicate alternations between planktic and tychoplanktic taxa between 12,400 and 11,400 cal yr BP due to changes in lake thermal structure produced by variations in summer temperature and/or water depth. Carbonate $\delta^{18}O$ data from Blacktail Pond record an excursion to cooler summers between 10,600 and 10,100 cal yr BP. Despite these climate fluctuations, fossil pollen data suggest that the vegetation was not responsive to climate changes of this magnitude or duration. Rather, submillenial-scale climate variability may have altered the vegetation mosaic in ways that were undetected in the pollen data. Such climate changes also may explain differences in the rate of population expansion from one site to the next. For example, the rate of subalpine fir population

expansion between Blacktail and Slough Creek ponds in the northern GYE was more than one-third less than the rate of expansion between Dailey Lake and Blacktail Pond (25 m/yr versus 38 m/yr; Table 4.3). Adverse warm summer conditions between 11,300 and 10,500 cal yr BP likely stalled subalpine fir spread near Blacktail Pond, and populations did not expand to Slough Creek Pond until an excursion to cool summers at ~10,500 cal yr BP. Unidirectional vegetation change, and the absence of reversals in vegetation development in response to submillenial-scale climate variability, highlights the stability of established tree populations in the region during the late-glacial/early-Holocene transition.

Fire as a Catalyst of Vegetation Change

Increased fire activity during the late-glacial/early-Holocene transition was an important driver of vegetation change in the GYE. This information comes from charcoal and fossil pollen data from sites in the northern GYE and throughout the region. Fire activity was high in the northern GYE after 11,900 cal yr BP at Slough Creek Pond and until 9800 cal yr BP at Blacktail Pond. At a regional scale, modeled charcoal data using General Additive Models (GAMs) indicate a period of elevated fire activity between 12,500 and 10,000 cal yr BP. In combination with increasing summer temperatures due to elevated summer insolation, high fire activity likely resulted from rising fuel biomass levels on the landscape as conifer populations colonized the deglaciated terrain after 13,300 cal yr BP.

With increasing fire activity, a number of vegetation changes occurred at both sub-regional and regional scales in the GYE. At Blacktail Pond in the northern GYE, a sequence of environmental changes during the late-glacial/early-Holocene transition highlight interactions between climate, fire, and vegetation: elevated *Picea* pollen abundance at 12,900 cal yr BP indicates expansion of Engelmann spruce populations; less negative carbonate $\delta^{18}O$ data and increased charcoal accumulation rates after 11,500 cal yr BP implies warmer summers and high fire activity, respectively; and elevated *Pinus albicaulis*- and *Pinus contorta*-type pollen and decreased *Picea* pollen after 11,300 cal yr BP indicate the expansion of whitebark and lodgepole pine populations at the expense of Engelmann spruce.

At a regional scale based on modeled pollen data from sites throughout the GYE using GAMs, the peak in *Picea* pollen and Engelmann spruce abundance at 12,500 cal yr BP coincides with the initial increase in regional fire activity between 12,500 and 10,000 cal yr BP inferred from modeled charcoal data. Subsequently, regional trends in *Pinus albicaulis*- and *Pinus contorta*-type pollen suggest a rise in whitebark and lodgepole pine abundance after 12,000 and 11,000 cal yr BP, respectively. *Picea* pollen data indicate that spruce abundance decreased after 11,000 cal yr BP, and while modeled *Abies* pollen data suggest stable subalpine fir populations under high regional fire activity, populations increased at 7500 cal yr BP following decreased fire activity.

Warming summers, in conjunction with increasing fuel biomass, likely synchronized fire on the landscape during the late-glacial/early-Holocene transition, inasmuch as the timing of high fire activity was similar across most sites in the GYE.

Increased fire activity between 12,500 and 10,000 cal yr BP facilitated at shift in forest dominance from Engelmann spruce and subalpine fir to first whitebark pine and then lodgepole pine. Not only would increased fires have provided openings in the late-glacial spruce-fir forest for the germination and establishment of whitebark and lodgepole pine seedlings, but fire then maintained pine dominance as the climate became warmer in the early Holocene.

While climate was the distal control of early postglacial vegetation development in the GYE, fire activity was a proximal control. Vegetation development responded primarily to increasing summer growing season temperatures, but fire catalyzed vegetation changes by altering the structure of existing spruce-fir vegetation, increasing the probability of successful pine seedling germination and establishment. Even though warm early-Holocene summers favored whitebark and lodgepole pine, high fire activity favored these more fire-adapted pine species, as compared to spruce and fir.

Edaphic Controls of Vegetation Development

Time-dependent processes of landscape development put in motion by glacial retreat were another driver in the vegetation history of the northern GYE. The control of geology on present and past vegetation patterns in the GYE has been studied extensively (e.g., Despain 1990, Whitlock 1993, Millspaugh et al. 2000). This dissertation builds on this understanding by examining the influence of postglacial erosional processes on early postglacial vegetation development. At Dailey Lake, magnetic susceptibility data suggest considerable mineral clastic input into the lake following glacial retreat from erosion,

glacial meltwater, and/or wind-derived sources (inferred from K/Ti data). Despite warming summers, the Dailey Lake catchment featured unstable slopes and poor soil cover well into the late-glacial period, and the pollen record indicates a sparsely vegetated landscape dominated by pioneering herbs and shrubs such as willows (*Salix* spp.), buffaloberry (*Shepherdia canadensis*), and Asteraceae species. Once sediment magnetic susceptibility decreased and hence slopes stabilized after 13,300 cal yr BP and soil cover increased, elevated *Picea* pollen percentages indicate expansion of Engelmann spruce populations.

These edaphic controls on vegetation development were strongly expressed in the Dailey Lake catchment as a result of the large volumes of glacial outwash in the Yellowstone River valley. Similar edaphic influences were not observed at Blacktail Pond and Slough Creek ponds, where deglaciation occurred later and outwash deposition was less. Blacktail and Slough Creek ponds record periods of high erosional input inferred from elevated sediment magnetic susceptibility following deglaciation, but postglacial erosional processes subsided 500 to 1000 years before Engelmann spruce expansion in the local catchments.

Thus, despite rising temperatures, substrates in the Dailey Lake catchment were unsuitable for conifer colonization until 13,300 cal yr BP, almost 3000 years after ice retreat. Non-equilibrium vegetation responses to climate change due to edaphic conditions have been described in other paleoecological records (e.g., Pennington 1986, Paus 1995, MacDonald et al. 2008, Henne et al. 2011), and for the past 11,000 years in central Yellowstone, coarse nutrient-poor rhyolite substrates have inhibited the

establishment of conifer species other than lodgepole pine (Millspaugh et al., 2000), even if climate conditions were suitable for their survival, growth, and reproduction. Edaphic conditions have the potential to mute or impede vegetation responses to regional climate change.

Capturing the Fundamental Niche

Anticipating species responses to environmental change is rooted in ecological niche theory: each species possesses a fundamental niche that encompasses a unique combination of environmental conditions that permit its survival and reproduction (Hutchinson 1957). Where a species actually occurs, or its realized niche, is dependent on biotic interactions and the prevailing suite of environmental variables present at that time and place. Ecological niche modeling aims to predict species responses to future climate change based on current biogeographic ranges or realized niche spaces, which are often functions of the present-day or recent historical climate. By examining species responses over a broader range of environmental conditions beyond those present today, paleoecological research can better capture a species fundamental niche, and hence its potential response to future bioclimatic change.

This research reconstructed regional trends in vegetation and fire history using GAMs analysis of pollen percentage and charcoal accumulation data from sites throughout the GYE and compared the modeled data to millennial-scale climate change. In the case of one species, this analysis revealed that whitebark pine was most abundant in the GYE between 12,000 and 7500 cal yr BP, during the height of the early Holocene

summer insolation maximum, and tolerated summer conditions warmer than its current climate space at high elevations near upper treeline (Iglesias et al. in review). Cold winters and deep snowpack during the early Holocene are more consistent with its present high elevation range. Today, the low-elevation limit of whitebark pine is partially set by competition with Engelmann spruce, subalpine fir, and lodgepole pine for light, water, and nutrients (Weaver 2001), and under high fire activity, lodgepole pine quickly gains dominance over other conifers due to its prolific seed production, high seed viability and seedling survival, and rapid growth (Davis et al. 1980, Bradley et al. 1992, Smith and Fischer 1997). Lodgepole pine densities were still fairly low in the GYE during the peak in whitebark pine. As lodgepole pine densities increased in the early and middle Holocene after 11,000 cal yr BP, it likely outcompeted whitebark pine at middle elevations, constricting the realized niche of whitebark pine to its present-day climate space at high elevations.

While biotic interactions likely played an important role in limiting whitebark pine presence in middle-elevation forests, climate was still an important factor. Warmer winters during the middle and late Holocene likely limited whitebark pine establishment and survival. Furthermore, it is uncertain how mountain pine beetle (*Dendroctonus ponderosae*) infestations and white pine blister rust (*Cronartium ribicola)* affect its current distribution in the GYE as compared to the past. Blister rust is non-native pathogen recently introduced to the ecosystem, while records of past mountain pine beetle outbreaks are limited in the Rocky Mountains. Nonetheless, lake sediments dated to the middle and late Holocene suggest mountain pine beetle has been present on the

landscape for at least 8000 years (Brunelle et al. 2008). Nonetheless, by examining whitebark pine responses to a broad range of postglacial climate conditions in the absence of its biotic associates, lodgepole pine and pathogens, this paleoecological investigation offers valuable insight into the fundamental niche of whitebark pine.

Final Remarks

This study highlights important climatic and nonclimatic drivers of early postglacial vegetation change in the Greater Yellowstone Ecosystem (GYE). Climate was the primary driver of vegetation development during the late-glacial/early-Holocene transition, inasmuch as increasing summer insolation and its direct effects on summer temperature and effective moisture directed changes in vegetation from pioneering herb and shrub communities to spruce parkland during the late-glacial period to subalpine forest and eventually open Douglas-fir forest by the early Holocene summer insolation maximum. Nonetheless, fire activity, site-specific edaphic conditions, and biotic interactions mediated vegetation responses to climate change. Elevated regional fire activity during the late-glacial/early-Holocene transition, driven by increasing summer temperatures and fuel biomass, facilitated important ecosystem changes from an Engelmann spruce and subalpine fir dominated system to one dominated by whitebark and lodgepole pine. Site-specific edaphic conditions, namely erosional processes associated with newly deglaciated terrain, inhibited early conifer expansion, and important competitive interactions between lodgepole pine and whitebark pine after the early Holocene limited whitebark pine's range at middle elevations in the GYE.

Climate projections for the Northern Rocky Mountains in the coming decades indicate increased average temperatures of up to 6 °C (Mote et al. 2008). Climate change of this magnitude and rate will have varied consequence for the structure and function of the region's forested ecosystems and biodiversity. If the early Holocene is an analogue, paleoecological reconstructions suggest that forests could become less dense under near-future warm dry summer conditions, and warm and drought-tolerant conifer species, such as lodgepole pine and Douglas-fir, will become more prevalent throughout the region's forests. Furthermore, both upper and lower treeline would shift to higher elevations. Fire activity would also increase under warmer conditions, as it has in the past, likely favoring fire-adapted pine species; however, if the forest becomes less dense, then decreased fuel biomass could offset the effects of increased temperatures on fire activity. Edaphic constraints produced by rhyolitic substrates on the Yellowstone Plateau will continue to inhibit the establishment of all conifers except lodgepole pine, even if future climatic conditions become suitable. Lastly, this paleoecological study suggests that whitebark pine would likely tolerate the warm dry summers of the future, however, it is uncertain how warmer winters in combination with mountain pine beetle and white pine blister rust will affect its future distribution.

Nonetheless, this study highlights the ever-changing qualities of the Greater Yellowstone Ecosystem and its resiliency to past climate change. Not only did vegetation adapt to past climate fluctuations and biotic interactions by shifting elevational ranges, but in some instances, established tree populations persisted through short-duration climate fluctuations. Furthermore, this paleoecological study revealed a broader

range of climatic conditions under which whitebark pine survived, reproduced, and thrived. Paleoecological research expands our temporal understanding of an ecosystem and stresses the importance of considering a region's environmental history in interpreting the modern landscape and in projecting future trajectories of change.

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APPENDICES

APPENDIX A

BLACKTAIL POND CHRONOLOGY

Depth (cm)	Median Age (cal yr BP)	Minimum Age (95% CI) (cal yr BP)	Maximum Age (95% CI) (cal yr BP)
0	-58	-58	-58
1	-55	-60	-52
2	-53	-62	-45
3	-50	-64	-39
4	-48	-66	-32
5	-45	-68	-26
6	-43	-69	-19
7	-40	-71	-13
8	-38	-73	-6
9	-35	-75	0
10	-33	-77	6
11	-30	-79	13
12	-28	-81	19
13	-25	-83	26
14	-22	-85	32
15	-20	-87	39
16	-17	-88	45
17	-15	-90	52
18	-12	-92	58
19	-10	-94	64
20	-7	-96	71
21	-5	-98	77
22	-2	-100	84
23	1	-101	90
24	3	-103	97
25	6	-105	103
26	8	-107	110
27	11	-109	116
28	14	-110	123
29	16	-112	129
30	19	-114	136
31	22	-116	142
32	24	-118	149
33	27	-119	155
34	30	-121	162
35	32	-123	168
36	35	-124	175
37	38	-126	182
38	40	-128	188
39	43	-129	195
40	46	-131	201

41	48	-133	208
42	51	-134	214
43	54	-136	221
44	57	-138	227
45	59	-139	234
46	62	-141	241
47	65	-142	247
48	68	-144	254
49	71	-145	261
50	73	-147	267
51	76	-148	274
52	79	-150	280
53	82	-151	287
54	85	-153	294
55	88	-154	300
56	91	-156	307
57	93	-157	314
58	96	-158	320
59	99	-160	327
60	102	-161	334
61	105	-162	341
62	108	-164	347
63	111	-165	354
64	114	-166	361
65	117	-168	368
66	120	-169	374
67	123	-170	381
68	126	-171	388
69	129	-172	395
70	133	-173	402
71	136	-174	408
72	139	-176	415
73	142	-177	422
74	145	-178	429
75	148	-179	436
76	152	-180	443
77	155	-181	450
78	158	-182	457
79	161	-182	463
80	165	-183	470
81	168	-184	477
82	171	-185	484
83	174	-186	491
84	178	-187	498

85	181	-187	505
86	185	-188	512
87	188	-189	519
88	191	-189	526
89	195	-190	533
90	198	-191	540
91	202	-191	547
92	205	-192	555
93	209	-192	562
94	212	-193	569
95	216	-193	576
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257	1260	374	2036
258	1270	383	2047
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314	1954	1025	2762
315	1969	1040	2776
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317	1997	1068	2805
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795	14652	14254	15164
796	14652	14249	15171
797	14652	14243	15178
798	14653	14238	15185
799	14654	14234	15192
800	14655	14229	15200
801	14656	14224	15206
802	14657	14219	15213
803	14659	14215	15220
804	14661	14210	15227
805	14663	14205	15235
806	14665	14201	15242
807	14668	14196	15249
808	14671	14193	15258
809	14674	14190	15267
810	14678	14188	15277

APPENDIX B

POLLEN COUNTS FROM BLACKTAIL POND

Depth (cm)	Age (cal yr BP)	*Pinus contorta*-type	*Pinus albicaulis*-type	*Pinus* undiff.
527.25	7043	11	6	119
529.25	7114	21	37	295
531.25	7185	18	53	306
533.25	7257	12	36	214
535.25	7329	13	18	232
537.25	7402	15	22	185
539.25	7476	13	21	230
541.25	7550	15	18	276
545.25	7699	13	21	322
547.25	7774	14	40	78
549.25	7850	31	31	284
551.25	7925	41	62	335
553.25	7999	11	37	246
555.25	8073	17	20	231
557.25	8145	8	28	220
559.25	8216	3	3	134
561.25	8285	13	14	254
563.25	8353	26	12	270
565.25	8418	17	3	224
567.25	8480	8	3	241
569.25	8541	4	10	121
571.25	8599	3	3	256
573.25	8655	2	18	191
575.25	8709	1	6	244
577.25	8761	3	10	239
579.25	8811	34	18	218
581.25	8860	15	29	195
583.25	8908	17	35	247
585.25	8954	6	12	233
587.25	8999	13	20	218
589.25	9042	36	16	149
591.25	9085	4	12	273
595.25	9168	3	12	260
599.25	9248	5	5	67
603.25	9326	5	7	301
607.25	9404	4	7	286
611.25	9482	11	31	185
615.25	9562	2	5	323
619.25	9643	5	9	308
623.25	9728	6	10	325
629.25	9865	10	6	244
633.25	9964	5	10	68

637.25	10071	26	26	206
641.25	10187	5	26	222
645.25	10312	38	16	225
649.25	10450	40	32	354
653.25	10604	3	8	276
657.25	10778	10	4	232
661.25	10969	32	24	190
665.25	11177	12	41	116
667.75	11286	0	10	223
669.25	11397	0	7	65
671.25	11511	2	18	108
677.25	11865	0	11	127
679.25	11985	3	5	80
681.25	12106	0	2	77
683.25	12228	0	7	126
685.25	12349	4	9	100
687.25	12471	1	12	89
689.25	12591	0	4	86
691.25	12711	0	3	70
693.25	12828	0	11	92
695.25	12942	2	11	74
697.25	13053	0	9	50
703.25	13357	0	8	85
705.25	13450	0	3	75
707.25	13537	1	12	50
709.25	13621	0	6	50
711.25	13700	0	25	81
713.25	13775	0	5	13
715.25	13846	0	6	73
717.25	13913	0	9	64
719.25	13976	0	1	35
721.25	14035	0	6	94
727.25	14193	1	9	65
730.25	14261	0	1	48
735.25	14358	0	9	85
739.25	14423	0	3	52

Picea	*Abies*	*Pseudotsuga*	*Juniperus-type*	*Alnus*	*Betula*	*Salix*
1	19	0	0	1	3	13
19	8	0	0	0	5	3
13	17	0	0	2	0	1
6	12	0	1	1	2	9
3	12	1	0	0	1	3
7	4	3	0	0	0	2
17	21	4	0	2	7	6
4	8	3	0	1	4	4
1	16	5	0	0	3	2
2	5	9	3	0	2	4
5	9	0	6	0	3	4
1	13	3	4	0	6	4
3	6	12	2	1	2	11
7	4	2	0	1	9	2
8	3	4	0	1	5	4
4	0	6	8	0	3	6
5	0	8	2	0	2	5
2	10	1	0	0	0	0
6	4	1	0	0	12	1
4	1	1	0	0	1	3
3	2	12	2	1	8	11
6	4	0	0	0	3	1
4	1	2	1	0	1	4
5	1	2	0	0	4	1
4	4	4	2	0	4	1
4	1	2	0	0	0	1
6	6	4	3	0	2	2
5	0	2	0	1	3	7
5	3	0	0	0	6	1
3	0	1	2	0	1	3
13	3	4	0	1	3	2
0	1	0	0	0	0	1
1	2	0	0	0	0	0
0	0	0	0	0	3	0
2	3	0	2	0	4	1
10	2	0	0	0	0	1
7	8	1	0	0	4	2
4	2	0	1	1	2	2
4	1	2	0	0	2	0
8	2	0	0	0	2	2
6	1	3	0	0	7	1
6	0	1	0	1	2	2
6	2	0	0	0	4	1

6	0	0	0	0	4	4
8	0	1	0	2	3	3
18	5	1	0	2	3	2
11	1	0	1	2	8	2
12	0	0	0	0	16	0
14	8	0	5	0	5	5
14	20	1	2	1	2	4
68	10	0	0	0	4	1
142	1	0	0	1	4	5
10	3	0	0	4	6	8
10	0	0	0	1	4	3
9	2	0	1	0	5	4
22	1	1	1	1	3	6
11	1	0	0	2	1	0
6	3	3	6	4	4	12
15	3	0	0	3	10	5
14	4	0	0	1	5	5
19	1	0	1	4	11	12
26	0	0	0	2	7	10
7	0	0	0	6	6	9
9	0	0	0	0	3	15
11	0	0	0	1	4	9
3	2	0	0	0	2	4
3	4	0	2	1	2	6
7	0	0	0	2	5	7
2	1	0	3	1	2	11
0	0	0	10	1	2	21
4	4	0	0	0	0	1
6	1	0	0	4	0	2
17	4	0	9	0	0	8
10	0	0	2	0	0	3
3	0	0	1	1	1	3
3	0	0	1	2	1	2
8	2	0	0	2	0	7
4	0	0	2	0	0	2

Populus undiff.	*Quercus*	*Acer*	Rosaceae undiff.	*Prunus*	*Spiraea*
0	2	0	0	0	0
0	5	0	0	0	0
0	1	0	0	0	0
0	5	2	0	0	0
0	3	0	0	0	0
0	4	0	0	0	0
0	4	0	0	0	0
0	3	1	0	0	0
0	4	0	0	0	0
0	1	0	0	0	0
0	0	0	0	0	0
0	2	1	1	0	0
0	8	0	2	0	0
0	1	0	1	0	0
0	1	0	5	0	0
0	5	0	5	0	1
0	2	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	8	0	0	0	0
0	1	0	0	0	0
0	0	0	2	0	0
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0	1	0	1	0	0
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0	0	0	1	0	0
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0	0	0	1	0	0
0	1	0	3	0	0
0	0	0	1	0	0
0	0	0	1	0	0

0	1	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	4	0	0	0	0
0	0	0	1	0	0
0	0	0	1	0	0
0	0	0	1	0	0
0	0	0	0	0	0
0	0	0	3	0	0
0	0	0	3	0	0
0	3	1	4	0	1
0	0	0	1	0	0
0	2	0	4	0	1
0	0	0	6	0	0
0	0	0	3	0	2
0	0	0	2	0	4
1	0	0	6	0	2
0	0	0	5	0	0
0	4	0	0	0	2
0	0	0	5	0	0
0	0	0	8	0	1
1	0	0	5	0	0
0	0	0	0	0	0
0	0	0	5	0	1
1	0	0	8	0	1
0	0	0	3	0	0
0	0	0	7	0	1
0	0	0	0	0	0
0	0	0	5	0	0
0	0	0	7	0	1
0	3	0	4	0	1
0	0	0	8	0	0
0	0	0	10	0	1
0	0	0	15	0	1
1	0	0	8	0	0
0	0	0	3	0	1

Amelanchier	*Potentilla*	*Ceanothus*	*Shepherdia canadensis*	*Eleagnus argentea*-type
0	0	0	0	0
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0	0	0	0	0
0	0	0	1	0
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0	0	0	0	0
1	0	0	0	0
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2	0	3	2	0
0	0	2	2	0
3	0	1	0	0
3	0	1	1	0
7	0	2	1	0
3	1	2	1	0
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0	0	2	0	0
2	0	1	0	0
3	0	7	1	0
0	0	0	0	0
1	0	2	1	0
0	0	0	0	0
0	0	1	1	0
1	0	2	1	0
0	0	0	0	0
1	0	1	2	0
0	0	0	0	0
1	0	0	1	0
4	2	0	1	0
0	0	0	0	0
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2	0	6	4	1
0	0	0	1	0
2	0	0	1	0
0	0	0	1	0
1	0	0	0	0
1	0	3	1	0

3	0	1	1	0
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2	0	0	0	0
0	1	0	0	0
0	0	0	1	0
3	0	0	2	0
3	0	0	4	0
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2	0	0	2	0
3	6	0	18	0
2	0	1	0	0
2	1	0	6	0
1	0	0	0	0
0	0	0	2	0
0	0	1	4	0

Arceuthobium	*Ephedra*	*Sarcobatus*	Poaceae	Cyperaceae	*Artemisia*
2	0	2	1	0	70
0	0	1	0	0	31
0	0	0	0	0	25
2	0	1	1	0	38
0	0	2	0	0	42
1	0	0	0	0	40
0	0	3	0	0	61
0	0	1	0	0	47
0	0	0	2	0	58
0	0	0	1	0	83
0	0	3	3	0	55
0	0	0	1	0	31
1	0	0	2	0	75
0	0	3	4	0	37
0	0	4	0	0	38
0	0	0	5	1	39
0	0	4	0	0	16
0	0	0	0	0	3
0	0	2	4	0	53
0	0	2	0	0	43
0	1	2	1	1	69
0	0	0	1	0	48
0	1	2	5	0	69
0	1	1	1	0	34
1	0	2	6	1	45
0	0	0	2	1	18
0	0	0	0	0	8
0	2	1	0	0	17
0	0	1	2	0	37
2	0	0	0	1	15
0	0	6	0	0	24
0	0	2	0	0	11
0	0	1	0	0	11
0	0	2	2	2	15
0	0	0	0	0	13
0	0	0	0	0	9
0	0	2	0	0	24
0	0	2	0	0	35
0	0	1	0	0	13
0	0	0	1	0	12
0	0	1	2	0	37
2	0	2	0	0	24
1	0	0	1	0	26

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0	0	0	1	0	16
0	0	0	0	0	12
0	0	2	1	0	37
0	0	5	0	0	45
0	0	0	0	0	17
0	0	1	1	1	40
0	0	1	2	0	37
0	0	1	4	1	64
0	0	1	4	0	102
0	0	3	0	2	121
0	0	2	4	0	148
0	0	3	5	0	141
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1	0	4	2	0	99
0	0	2	4	3	98
0	0	5	8	0	157
0	0	1	5	1	123
0	0	4	2	0	94
0	0	4	0	1	142
0	0	2	2	1	92
0	0	7	2	0	151
0	0	6	10	0	134
0	1	3	18	2	133
0	0	2	2	10	200
0	0	2	2	1	121
0	0	23	0	0	177
0	0	7	9	1	154
0	0	15	7	0	141
0	0	8	5	0	82
0	0	10	4	2	131
0	0	4	0	6	107
0	0	4	0	1	52
0	0	7	1	1	121
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Ambrosia-type	Other Tubuliflorae	Liguliflorae	Amaranthaceae	*Salsola*-type
5	7	0	55	0
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8	2	0	22	0
1	3	0	43	0
0	3	0	20	0
2	5	0	31	0
8	1	0	29	0
1	4	1	38	0
0	7	0	42	2
6	4	0	25	0
5	3	0	54	0
8	3	0	47	0
1	1	0	24	0
2	6	2	33	0
2	5	0	31	0
2	3	0	9	0
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0	1	0	11	0
0	0	1	4	0
1	0	0	6	0
2	0	1	4	1
0	2	0	8	0
2	0	0	4	0
2	5	0	13	0
4	0	0	16	0
3	2	0	8	0
2	1	0	11	0
0	1	0	2	0
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1	0	0	8	0
1	2	0	10	0
4	1	0	5	0
2	2	0	4	1

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2	0	1	9	0
0	4	0	6	0
5	4	1	6	1
0	1	1	6	0
0	6	3	4	0
2	7	1	31	0
8	4	0	3	0
7	9	0	21	0
3	8	0	10	0
6	4	1	13	1
3	14	0	32	1
8	8	0	12	0
3	5	0	16	0
6	8	0	23	0
5	11	2	11	0
8	13	1	15	0
4	5	0	11	0
4	9	1	19	0
1	4	0	13	0
4	7	0	12	0
5	11	1	12	2
3	7	1	7	0
5	14	1	25	0
4	6	0	5	0
5	12	0	22	0
5	22	1	16	0
1	8	2	9	2
2	7	0	7	0
2	3	2	7	0
6	22	0	11	0
3	11	1	8	0

Ranunculaceae	Apiaceae	Brassicaceae	Caryophyllaceae	Polygonaceae
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0	2	0	0	0
0	1	0	0	0
0	1	0	0	0
0	0	0	0	0
0	0	0	3	0
0	0	0	3	0

Eriogonum	*Galium*	Fabaceae	*Dodecatheon*-type	*Urtica*-type	Other herbs
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0	3	0	0	0	0
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0	3	0	0	0	0
4	2	0	0	0	0
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4	1	0	0	0	0
0	0	0	0	0	0
1	0	0	0	0	0
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1	1	0	0	0	0
2	1	0	0	0	0
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0	2	0	0	0	0
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0	3	0	0	0	0
3	1	0	0	0	0
6	4	0	1	1	0
3	1	2	0	0	0
0	4	0	0	0	0
4	0	0	0	0	0
8	1	0	0	0	0
0	11	0	0	0	0
1	9	0	0	0	0
2	2	3	0	0	0
0	3	0	0	0	0
0	0	0	0	0	0
0	1	0	0	0	0
1	1	1	0	0	0
6	5	0	0	0	0
0	1	0	0	0	0
2	1	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
1	0	0	0	0	0

Indeterminate-type	Unknown	*Lycopodium* tracer mean = 13911	Terrestrial Sum
7	0	204	325
0	0	106	450
3	0	326	466
8	0	290	385
30	0	391	408
14	0	350	320
2	0	320	430
1	0	207	427
1	0	207	500
4	0	0	303
11	0	438	483
10	0	300	587
18	0	675	502
7	0	207	379
5	0	210	382
21	3	431	303
15	3	309	369
0	0	82	328
4	1	60	344
0	1	50	333
13	0	496	310
2	0	90	338
4	1	217	324
4	0	405	320
5	0	192	338
2	0	80	312
2	0	180	284
1	0	121	352
3	0	65	317
3	2	83	307
0	0	417	285
6	0	99	326
4	0	106	310
0	1	55	104
0	1	97	357
2	0	56	335
3	0	567	323
7	1	75	413
3	2	70	364
2	0	56	390
12	2	83	346
9	0	765	147

2	2	189	326
5	0	581	318
5	0	233	329
3	0	119	482
6	0	101	381
5	2	176	351
5	0	263	324
7	0	208	284
6	0	313	378
33	3	563	361
25	0	469	357
20	0	115	327
13	2	157	329
15	1	258	310
22	1	271	282
30	0	484	358
15	3	179	305
19	1	154	345
32	0	229	343
28	3	287	323
30	5	264	353
33	0	736	253
27	2	130	350
26	1	170	308
15	1	103	304
18	1	203	344
17	3	205	307
19	0	265	325
5	1	118	300
10	2	133	332
33	6	454	300
11	1	194	320
38	6	176	279
28	1	150	175
46	5	252	348
45	3	651	186

APPENDIX C

LITHOLOGIC, GEOCHEMICAL, AND STABLE ISOTOPE DATA FROM BLACKTAIL POND

Depth (cm)	Age (cal yr BP)	Magnetic Susceptibility (SI units)
525.5	6981	1.5
526.0	6999	0.5
526.5	7016	0.2
527.0	7034	-0.5
527.5	7052	-0.5
528.0	7069	-0.6
528.5	7087	-0.8
529.0	7105	-1
529.5	7123	-1.2
530.0	7140	-1.2
530.5	7158	-0.9
531.0	7176	-1
531.5	7194	-1.2
532.0	7212	-1
532.5	7230	-0.9
533.0	7248	-1
533.5	7266	-1
534.0	7284	-0.7
534.5	7302	-0.4
535.0	7320	-0.1
535.5	7339	-0.9
536.0	7357	-1
536.5	7375	-0.9
537.0	7393	-0.9
537.5	7412	-1.1
538.0	7430	-0.9
538.5	7448	-0.7
539.0	7467	-0.9
539.5	7485	-1.2
540.0	7503	-1.1
540.5	7522	-0.9
541.0	7541	-1
541.5	7559	-0.6
542.0	7578	-0.5
542.5	7596	-0.2
543.0	7615	1.3
543.5	7634	1.8
544.0	7652	-0.6
544.5	7671	-0.7
545.0	7690	-1
545.5	7709	-0.9

546.0	7727	-1.2
546.5	7746	-1.3
547.0	7765	-1.1
547.5	7784	-1
548.0	7803	-1
548.5	7822	-1.2
549.0	7840	-1.2
549.5	7859	-1.2
550.0	7878	-1.1
550.5	7897	-1.1
551.0	7915	-1
551.5	7934	-1.2
552.0	7953	-1
552.5	7971	-0.9
553.0	7990	-0.9
553.5	8008	-1
554.0	8027	-1.2
554.5	8045	-1.3
555.0	8064	-1.1
555.5	8082	-1.1
556.0	8100	-1
556.5	8118	-0.8
557.0	8136	-0.8
557.5	8154	-0.8
558.0	8172	-1.1
558.5	8190	-1.4
559.0	8207	-0.9
559.5	8225	-0.8
560.0	8242	-0.9
560.5	8260	-1.1
561.0	8277	-1.2
561.5	8294	-1.3
562.0	8311	-1.4
562.5	8328	-1.3
563.0	8344	-1.2
563.5	8361	-0.8
564.0	8377	-1.1
564.5	8394	-1
565.0	8410	-0.9
565.5	8426	-1
566.0	8441	-1.2
566.5	8457	-0.8
567.0	8473	-1
567.5	8488	-0.9

568.0	8503	-0.8
568.5	8518	-0.8
569.0	8533	-1
569.5	8548	-0.9
570.0	8563	-0.8
570.5	8577	-0.9
571.0	8591	-1.1
571.5	8606	-1
572.0	8620	-0.8
572.5	8634	-1
573.0	8648	-1
573.5	8661	-0.8
574.0	8675	-0.9
574.5	8689	-1.1
575.0	8702	-1.2
575.5	8715	-1.1
576.0	8728	-1.2
576.5	8742	-1.3
577.0	8754	-1.2
577.5	8767	-1.1
578.0	8780	-1.1
578.5	8793	-1.1
579.0	8805	-1
579.5	8818	-1.1
580.0	8830	-1
580.5	8842	-1.2
581.0	8854	-1
581.5	8866	-1
582.0	8878	-1.1
582.5	8890	-1.1
583.0	8902	-1.1
583.5	8913	-1.2
584.0	8925	-1.1
584.5	8937	-1.4
585.0	8948	-1.3
585.5	8959	-1.2
586.0	8971	-1
586.5	8982	-0.3
587.0	8993	-1.1
587.5	9004	-1
588.0	9015	-1
588.5	9026	-1
589.0	9037	-1.1
589.5	9048	-1.1

590.0	9058	-1
590.5	9069	-1.1
591.0	9080	-1.2
591.5	9090	-1.4
592.0	9101	-1.2
592.5	9111	-1.2
593.0	9121	-1
593.5	9132	-1.2
594.0	9142	-1.3
594.5	9152	-1.2
595.0	9163	-1.3
595.5	9173	-1.2
596.0	9183	-1.3
596.5	9193	-1.4
597.0	9203	-1.2
597.5	9213	-1.2
598.0	9223	-1.3
598.5	9233	-0.9
599.0	9243	-0.8
599.5	9253	-0.8
600.0	9263	-0.9
600.5	9273	-0.7
601.0	9282	-0.6
601.5	9292	
602.0	9302	-0.8
602.5	9312	-0.9
603.0	9322	-0.9
603.5	9331	-0.9
604.0	9341	-0.9
604.5	9351	-0.9
605.0	9360	-0.8
605.5	9370	-0.8
606.0	9380	-0.8
606.5	9390	-0.9
607.0	9399	-0.8
607.5	9409	-1
608.0	9419	-1
608.5	9429	-1
609.0	9438	-1
609.5	9448	-0.9
610.0	9458	-1
610.5	9468	-1.1
611.0	9477	-0.7
611.5	9487	-1

612.0	9497	-0.8
612.5	9507	-0.8
613.0	9517	-1
613.5	9527	-0.7
614.0	9537	-0.7
614.5	9547	-0.6
615.0	9557	-0.7
615.5	9567	-0.8
616.0	9577	-0.8
616.5	9587	-0.9
617.0	9597	-0.8
617.5	9607	-0.8
618.0	9617	-0.8
618.5	9628	-0.6
619.0	9638	-0.6
619.5	9648	-0.7
620.0	9659	-0.8
620.5	9669	-0.9
621.0	9680	-1
621.5	9691	-1
622.0	9701	-0.9
622.5	9712	-0.9
623.0	9723	-1
623.5	9734	-1.1
624.0	9745	-1.1
624.5	9756	-1.2
625.0	9767	-1.2
625.5	9778	-0.1
626.0	9790	0
625.0	9767	2.8
625.5	9778	1.8
626.0	9790	0.4
626.5	9801	-0.1
627.0	9812	-0.7
627.5	9824	-1
628.0	9836	-1
628.5	9847	-1.1
629.0	9859	-1.1
629.5	9871	-1.2
630.0	9883	-1.2
630.5	9895	-1
631.0	9908	-1.3
631.5	9920	-0.8
632.0	9933	-0.4

632.5	9945	-0.1
633.0	9958	-0.8
633.5	9971	-1
634.0	9984	-1.4
634.5	9997	-1.4
635.0	10010	-1.4
635.5	10023	-1.4
636.0	10037	-1.4
636.5	10050	-1.5
637.0	10064	-1.4
637.5	10078	-1.5
638.0	10092	-1.4
638.5	10106	-1.1
639.0	10120	-1.2
639.5	10135	-1.3
640.0	10149	-1.4
640.5	10164	-1.2
641.0	10179	-1
641.5	10194	-1
642.0	10209	-1.3
642.5	10225	-1.4
643.0	10240	-1.1
643.5	10256	-1.1
644.0	10272	-1.2
644.5	10288	-1
645.0	10304	-1
645.5	10320	-0.9
646.0	10337	-0.9
646.5	10354	-0.8
647.0	10371	-0.9
647.5	10388	-0.8
648.0	10405	-1
648.5	10423	-1.1
649.0	10441	-1.3
649.5	10459	-1.2
650.0	10477	-0.8
650.5	10496	-0.9
651.0	10515	-1.2
651.5	10534	-1.1
652.0	10554	-1
652.5	10574	-1.1
653.0	10594	-1.3
653.5	10614	-1
654.0	10635	-1

654.5	10656	-0.7
655.0	10678	-0.6
655.5	10699	-0.5
656.0	10721	-0.6
656.5	10744	-0.6
657.0	10766	-0.1
657.5	10789	4.7
658.0	10812	5
658.5	10836	-0.2
659.0	10860	-0.8
659.5	10883	-0.7
660.0	10908	-0.6
660.5	10932	-0.5
661.0	10957	-0.5
661.5	10982	-0.4
662.0	11007	-0.7
662.5	11033	-0.7
663.0	11058	-0.7
663.5	11084	-0.7
664.0	11111	-0.3
664.5	11137	-0.7
665.0	11163	-0.6
665.5	11190	-0.7
666.0	11217	-0.7
666.5	11244	-0.6
667.0	11272	-0.5
667.5	11299	-0.4
668.0	11327	-0.2
668.5	11355	-0.3
669.0	11383	-0.3
669.5	11411	0
670.0	11440	0
670.5	11468	2
671.0	11497	5.8
671.5	11525	2.5
672.0	11554	1.7
672.5	11583	1.6
673.0	11613	1.7
673.5	11642	1.9
674.0	11671	1.6
674.5	11701	1.4
675.0	11730	1.4
675.5	11760	1.2
676.0	11790	1.5

676.5	11820	1.6
677.0	11850	1.3
677.5	11880	1.9
678.0	11910	2.1
678.5	11940	1.8
679.0	11970	1.8
679.5	12000	2.1
680.0	12030	1.9
680.5	12061	1
681.0	12091	0.9
681.5	12121	1.3
682.0	12152	1.5
682.5	12182	1.7
683.0	12213	1.8
683.5	12243	1.7
684.0	12273	1.7
684.5	12304	1.4
685.0	12334	1
685.5	12365	0.8
686.0	12395	0.7
686.5	12425	0.7
687.0	12455	0.9
687.5	12486	0.7
688.0	12516	0.5
688.5	12546	0.7
689.0	12576	0.4
689.5	12606	0.4
690.0	12636	0.6
690.5	12666	1.7
691.0	12696	1.5
691.5	12725	1.9
692.0	12755	2
692.5	12784	1.4
693.0	12813	0.5
693.5	12842	0.4
694.0	12871	0.4
694.5	12900	0.4
695.0	12928	0.4
695.5	12957	0.2
696.0	12985	0.2
696.5	13012	0.4
697.0	13040	0.3
697.5	13067	0.6
698.0	13094	1.3

698.5	13120	1.6
699.0	13146	5.5
699.5	13172	40.7
700.0	13198	22.1
700.5	13223	3.2
701.0	13248	2.8
701.5	13273	4.2
702.0	13298	16.5
702.5	13322	8.6
703.0	13346	1.3
703.5	13369	1.2
704.0	13393	0.6
704.5	13416	0.5
705.0	13438	0.2
705.5	13461	0
706.0	13483	0.2
706.5	13505	0.1
707.0	13527	-0.1
707.5	13548	0.2
708.0	13569	0.4
708.5	13590	1.1
709.0	13610	0.2
709.5	13631	-0.1
710.0	13651	0.1
710.5	13671	0.7
711.0	13690	0.4
711.5	13709	0.5
712.0	13728	0.5
712.5	13747	0.8
713.0	13766	0.8
713.5	13784	2
714.0	13802	2.9
714.5	13819	3.9
715.0	13837	4.4
715.5	13854	5
716.0	13871	4.7
716.5	13888	5.8
717.0	13904	8.9
717.5	13921	13.6
718.0	13937	19.1
718.5	13953	31.1
719.0	13968	46.2
719.5	13984	49.4
720.0	13999	45.4

720.5	14014	56.3
721.0	14028	60.4
721.5	14043	67.2
722.0	14057	80.6
722.5	14071	83.7
723.0	14085	97.2
723.5	14098	61.8
724.0	14111	12.3
733.5	14326	97.1
734.0	14335	98.5
734.5	14345	97.6
735.0	14354	75.9
735.5	14363	56.5
736.0	14371	62.5
736.5	14380	69.2
737.0	14388	67
737.5	14396	90.1
738.0	14404	105.2
738.5	14412	115
739.0	14420	132.6
739.5	14427	78.5
740.0	14435	80.7
740.5	14442	91.5
741.0	14449	94.7
741.5	14456	130.3
742.0	14462	139.9
742.5	14469	135.2
743.0	14475	131.7
743.5	14482	140.4
744.0	14488	151.3
744.5	14494	152
745.0	14499	145.7
745.5	14505	153.2
746.0	14511	167.5
746.5	14516	193.8
747.0	14521	191.7
747.5	14526	200
748.0	14531	241.9
748.5	14536	272.1
749.0	14541	208
749.5	14546	162.2
750.0	14550	163.9
750.5	14554	150
751.0	14559	137.8

751.5	14563	146.3
752.0	14567	151.2
752.5	14571	148.2
753.0	14574	217.4
753.5	14578	293.6
754.0	14582	239.6
754.5	14585	153.4
755.0	14588	139.6
755.5	14592	135.6
756.0	14595	132.8
756.5	14598	133.7
757.0	14601	157.9
757.5	14603	166.5
758.0	14606	182.3
758.5	14609	152.1
759.0	14611	190
759.5	14613	224.2
760.0	14616	220.6
760.5	14618	206.6
761.0	14620	241.4
761.5	14622	267.6
762.0	14624	254.2
762.5	14626	257.5
763.0	14628	179.6
763.5	14630	200.8
764.0	14631	252.6
764.5	14633	192.2
765.0	14634	173.6
765.5	14636	175.6
766.0	14637	188
766.5	14638	188.9
767.0	14639	187.8
767.5	14641	213
768.0	14642	195.5
768.5	14643	191
769.0	14644	190.5
769.5	14645	179.4
770.0	14645	185.2
770.5	14646	197.8
771.0	14647	216.9
771.5	14648	256.9
772.0	14648	211.2
772.5	14649	165.2
773.0	14649	163.4

773.5	14650	172.5
774.0	14650	158.6
774.5	14651	176.9
775.0	14651	209.1
775.5	14651	205.2
776.0	14651	182.3
776.5	14652	171.9
777.0	14652	182.3
777.5	14652	183.6
778.0	14652	161.8
778.5	14652	127.2
779.0	14652	145.3
779.5	14653	190.8
780.0	14653	136.8
780.5	14653	140.2
781.0	14653	217.4
781.5	14653	196.5
782.0	14653	184.9
782.5	14652	259.3
783.0	14652	353.7
783.5	14652	275.2
784.0	14652	247.9
784.5	14652	277.4
785.0	14652	321.2
785.5	14652	304.2
786.0	14652	183.7
786.5	14652	236.1
787.0	14652	329.9
787.5	14652	322.6
788.0	14651	328.7
788.5	14651	425.2
789.0	14651	280.5
789.5	14651	144.3
790.0	14651	168.9
790.5	14651	133.1
791.0	14651	127.1
791.5	14651	139.3
792.0	14651	124.6
792.5	14651	184.9
793.0	14651	357.9
793.5	14651	427
794.0	14651	453
794.5	14651	444.3
795.0	14652	202.6

795.5	14652	159.7
796.0	14652	214.1
796.5	14652	378
797.0	14652	379.2
797.5	14653	288.9
798.0	14653	302.3
798.5	14653	356.6
799.0	14654	410.8
799.5	14654	463.7
800.0	14655	396.6

Depth (cm)	Age (cal yr BP)	Ca (counts)	Ti (counts)
525.60	6890	81808	642
525.85	6897	113057	720
526.10	6904	127803	778
526.35	6912	132119	840
526.60	6919	142327	741
526.85	6926	140835	732
527.10	6934	117623	635
527.35	6941	121619	737
527.60	6948	121364	997
527.85	6955	121899	932
528.10	6963	133851	845
528.35	6970	168870	542
528.60	6977	174249	397
528.85	6985	171388	379
529.10	6992	143884	354
529.35	6999	153323	274
529.60	7007	160298	405
529.85	7014	151167	399
530.10	7021	124268	430
530.35	7028	132706	432
530.60	7036	179007	344
530.85	7043	167648	238
531.10	7050	186684	245
531.35	7058	198032	251
531.60	7065	163276	355
531.85	7072	145023	565
532.10	7080	189245	532
532.35	7087	199216	417
532.60	7094	214851	451
532.85	7101	220084	255
533.10	7109	201435	454
533.35	7116	212623	490
533.60	7123	206114	412
533.85	7131	138414	756
534.10	7138	70147	1378
534.35	7145	53603	1946
534.60	7153	69937	1835
534.85	7160	100229	1537
535.10	7167	125211	1345
535.35	7174	166193	876
535.60	7182	214815	507
535.85	7189	196913	533

536.10	7196	177158	526
536.35	7204	148321	520
536.60	7211	122628	711
536.85	7218	155941	583
537.10	7226	210784	501
537.35	7233	115067	975
537.60	7240	120561	1008
537.85	7247	130248	1168
538.10	7255	134525	984
538.35	7262	160769	883
538.60	7269	170807	660
538.85	7277	167258	492
539.10	7284	168462	407
539.35	7291	205771	402
539.60	7299	199557	516
539.85	7306	224158	385
540.10	7313	229342	426
540.35	7320	194537	509
540.60	7328	152395	731
540.85	7335	167655	882
541.10	7342	168336	965
541.35	7350	187607	759
541.60	7357	175977	932
541.85	7364	187846	835
542.10	7372	121038	1386
542.35	7379	57241	2150
542.60	7386	47969	2750
542.85	7393	41924	3344
543.10	7401	62867	2250
543.35	7408	115119	1084
543.60	7415	138964	734
543.85	7423	150251	467
544.10	7430	156836	495
544.35	7437	166046	554
544.60	7445	171707	657
544.85	7452	186792	520
545.10	7459	263368	298
545.35	7466	275933	197
545.60	7474	227724	335
545.85	7481	216509	232
546.10	7488	201576	256
546.35	7496	215154	280
546.60	7503	219159	196
546.85	7510	167738	522

547.10	7518	159747	618
547.35	7525	173606	662
547.60	7532	176402	513
547.85	7539	194022	401
548.10	7547	204887	454
548.35	7554	200848	387
548.60	7561	228876	228
548.85	7569	198689	208
549.10	7576	181024	459
549.35	7583	185992	427
549.60	7591	202251	514
549.85	7598	241128	405
550.10	7605	249840	315
550.35	7612	253533	206
550.60	7620	229852	474
550.85	7627	208649	258
551.10	7634	167664	471
551.35	7642	200676	404
551.60	7649	181270	379
551.85	7656	164675	508
552.10	7664	179226	666
552.35	7671	189200	573
552.60	7678	214181	435
552.85	7685	216397	353
553.10	7693	265627	370
553.35	7700	287175	110
553.60	7707	277687	241
553.85	7715	220529	307
554.10	7722	203617	190
554.35	7729	176139	277
554.60	7737	192222	393
554.85	7744	211074	393
555.10	7751	216202	318
555.35	7758	176840	487
555.60	7766	171945	440
555.85	7773	174481	543
556.10	7780	203685	349
556.35	7788	234252	243
556.60	7795	195661	540
556.85	7802	181130	290
557.10	7810	181886	375
557.35	7817	191540	498
557.60	7824	257041	228
557.85	7831	229364	184

558.10	7839	223835	246
558.35	7846	244727	297
558.60	7853	251545	247
558.85	7861	206104	239
559.10	7868	155098	254
559.35	7875	145207	396
559.60	7883	145933	408
559.85	7890	180909	288
560.10	7897	215167	309
560.35	7904	190795	309
560.60	7912	218368	198
560.85	7919	208809	290
561.10	7926	225431	187
561.35	7934	215092	141
561.60	7941	175489	328
561.85	7948	203154	175
562.10	7956	214623	153
562.35	7963	192549	232
562.60	7970	178590	438
562.85	7977	194923	455
563.10	7985	221311	389
563.35	7992	232604	268
563.60	7999	194312	219
563.85	8007	177537	258
564.10	8014	186318	253
564.35	8021	207797	208
564.60	8029	205428	333
564.85	8036	210000	315
565.10	8043	215718	244
565.35	8050	188867	335
565.60	8058	186709	294
565.85	8065	202645	318
566.10	8072	211842	384
566.35	8080	240482	304
566.60	8087	266754	130
566.85	8094	281039	190
567.10	8102	256541	280
567.35	8109	270735	235
567.60	8116	287439	205
567.85	8123	254292	228
568.10	8131	290973	217
568.35	8138	251820	232
568.60	8145	249592	188
568.85	8153	224822	181

569.10	8160	202511	208
569.35	8167	170462	295
569.60	8175	180924	458
569.85	8182	186617	341
570.10	8189	179090	298
570.35	8196	171649	357
570.60	8204	170337	287
570.85	8211	176168	354
571.10	8218	186623	347
571.35	8226	182769	359
571.60	8233	170578	354
571.85	8240	172195	356
572.10	8248	186295	337
572.35	8255	188428	326
572.60	8262	186758	290
572.85	8269	183664	281
573.10	8277	175564	350
573.35	8284	169099	326
573.60	8291	194148	388
573.85	8299	168757	327
574.10	8306	163551	322
574.35	8313	170487	301
574.60	8320	181829	216
574.85	8328	176107	207
575.10	8335	203132	149
575.35	8342	188423	247
575.60	8350	191509	314
575.85	8357	190449	203
576.10	8364	201079	166
576.35	8372	175344	219
576.60	8379	177497	286
576.85	8386	181747	304
577.10	8393	201252	238
577.35	8401	219078	241
577.60	8408	234807	272
577.85	8415	232787	162
578.10	8423	227559	160
578.35	8430	236084	163
578.60	8437	207849	276
578.85	8445	164527	358
579.10	8452	173596	332
579.35	8459	135351	355
579.60	8466	122338	360
579.85	8474	93860	486

580.10	8481	108004	362
580.35	8488	124772	401
580.60	8496	140620	383
580.85	8503	132218	474
581.10	8510	153874	498
581.35	8518	178105	370
581.60	8525	205999	378
581.85	8532	241189	235
582.10	8539	247211	227
582.35	8547	248363	202
582.60	8554	208683	264
582.85	8561	191008	234
583.10	8569	191149	305
583.35	8576	219622	304
583.60	8583	243694	224
583.85	8591	247933	163
584.10	8598	250665	201
584.35	8605	241693	230
584.60	8612	224363	260
584.85	8620	220278	220
585.10	8627	230397	172
585.35	8634	240218	390
585.60	8642	217600	330
585.85	8649	215518	196
586.10	8656	205872	319
586.35	8664	215439	257
586.60	8671	221376	256
586.85	8678	220519	372
587.10	8685	227048	344
587.35	8693	200651	277
587.60	8700	183209	158
587.85	8707	187943	258
588.10	8715	209123	257
588.35	8722	187242	173
588.60	8729	174525	291
588.85	8737	171840	257
589.10	8744	172247	251
589.35	8751	168982	350
589.60	8758	176484	495
589.85	8766	190362	370
590.10	8773	192141	410
590.35	8780	193676	220
590.60	8788	199786	288
590.85	8795	178777	209

591.10	8802	203917	216
591.35	8810	201389	397
591.60	8817	202864	389
591.85	8824	194826	353
592.10	8831	215164	293
592.35	8839	231351	245
592.60	8846	189497	349
592.85	8853	167251	323
593.10	8861	161870	344
593.35	8868	164218	227
593.60	8875	171923	287
593.85	8883	206561	242
594.10	8890	211918	182
594.35	8897	225034	155
594.60	8904	207162	101
594.85	8912	198650	238
595.10	8919	198805	179
595.35	8926	217631	222
595.60	8934	226888	134
595.85	8941	222732	200
596.10	8948	207116	203
596.35	8956	219151	196
596.60	8963	213798	307
596.85	8970	212353	322
597.10	8977	215039	376
597.35	8985	221133	363
597.60	8992	246571	198
597.85	8999	232803	332
598.10	9007	228348	370
598.35	9014	178671	449
598.60	9021	146624	703
598.85	9029	160689	737
599.10	9036	160913	571
599.35	9043	186249	450
599.60	9050	221675	387
599.85	9058	223575	339
600.10	9065	225148	252
600.35	9072	232739	232
600.60	9080	231564	252
600.85	9087	253341	266
601.10	9094	222222	410
601.35	9102	211900	375
601.60	9109	190383	287
601.85	9116	184568	347

602.10	9123	209517	274
602.35	9131	218483	219
602.60	9138	219168	354
602.85	9145	233549	211
603.10	9153	234315	215
603.35	9160	204683	450
603.60	9167	189793	271
603.85	9175	176216	362
604.10	9182	227599	251
604.35	9189	210996	155
604.60	9196	235448	221
604.85	9204	237674	199
605.10	9211	208401	225
605.35	9218	229856	294
605.60	9226	231721	317
605.85	9233	248574	243
606.10	9240	251602	180
606.35	9248	259844	173
606.60	9255	254949	176
606.85	9262	238049	204
607.10	9269	233331	292
607.35	9277	189676	406
607.60	9284	165988	392
607.85	9291	189992	521
608.10	9299	212521	516
608.35	9306	218612	361
608.60	9313	228393	199
608.85	9321	229949	260
609.10	9328	224470	197
609.35	9335	227072	195
609.60	9342	213125	153
609.85	9350	197732	157
610.10	9357	219271	160
610.35	9364	192754	219
610.60	9372	184702	318
610.85	9379	209076	210
611.10	9386	211157	288
611.35	9394	200129	445
611.60	9401	210396	338
611.85	9408	226558	325
612.10	9415	231729	298
612.35	9423	219174	190
612.60	9430	197232	137
612.85	9437	168668	200

613.10	9445	174077	236
613.35	9452	199372	249
613.60	9459	229541	264
613.85	9467	230396	340
614.10	9474	205727	444
614.35	9481	169596	426
614.60	9488	167975	537
614.85	9496	172446	494
615.10	9503	168147	382
615.35	9510	212093	303
615.60	9518	197811	231
615.85	9525	188438	137
616.10	9532	169012	227
616.35	9540	204835	203
616.60	9547	188480	236
616.85	9554	174726	242
617.10	9561	165375	278
617.35	9569	170268	274
617.60	9576	244761	217
617.85	9583	250068	185
618.10	9591	233624	151
618.35	9598	208185	230
618.60	9605	181611	313
618.85	9613	179892	424
619.10	9620	231485	314
619.35	9627	245919	399
619.60	9634	208951	342
619.85	9642	167648	381
620.10	9649	153693	421
620.35	9656	145095	417
620.60	9664	135954	418
620.85	9671	172573	186
621.10	9678	188568	150
621.35	9686	180261	176
621.60	9693	194977	257
621.85	9700	206859	223
622.10	9707	198925	216
622.35	9715	199290	303
622.60	9722	161370	268
622.85	9729	159519	227
623.10	9737	198207	263
623.35	9744	200736	283
623.60	9751	219183	318
623.85	9759	227030	250

624.10	9766	223819	280
624.35	9773	214043	200
624.60	9780	213057	242
624.85	9788	235090	267
625.10	9795	57544	18
625.35	9802	56	0
625.60	9810	51	28
625.40	9804	92961	260
625.65	9811	184554	308
625.90	9818	198876	307
626.15	9826	174586	327
626.40	9833	167543	359
626.65	9840	159249	302
626.90	9848	149516	409
627.15	9855	154660	579
627.40	9862	155277	598
627.65	9869	167484	462
627.90	9877	160707	491
628.15	9884	153858	612
628.40	9891	169970	537
628.65	9899	189517	494
628.90	9906	212360	358
629.15	9913	220350	396
629.40	9921	223601	335
629.65	9928	220619	279
629.90	9935	194896	304
630.15	9942	166012	210
630.40	9950	177584	144
630.65	9957	188017	293
630.90	9964	197038	313
631.15	9972	186258	269
631.40	9979	187820	334
631.65	9986	180191	402
631.90	9994	168975	653
632.15	10001	130526	1576
632.40	10008	159278	926
632.65	10015	156995	589
632.90	10023	177061	394
633.15	10030	171450	333
633.40	10037	169416	329
633.65	10045	137194	247
633.90	10052	132183	206
634.15	10059	159625	320
634.40	10067	169398	266

634.65	10074	156915	322
634.90	10081	181388	208
635.15	10088	196849	186
635.40	10096	181677	201
635.65	10103	133539	305
635.90	10110	145480	259
636.15	10118	142898	228
636.40	10125	151178	146
636.65	10132	143711	98
636.90	10140	126163	147
637.15	10147	113052	151
637.40	10154	127244	270
637.65	10161	127315	338
637.90	10169	153253	290
638.15	10176	156445	350
638.40	10183	144173	451
638.65	10191	145408	353
638.90	10198	155373	339
639.15	10205	169167	357
639.40	10213	177053	315
639.65	10220	168841	197
639.90	10227	168818	336
640.15	10234	169388	235
640.40	10242	170259	230
640.65	10249	170181	307
640.90	10256	175311	335
641.15	10264	185718	212
641.40	10271	196209	234
641.65	10278	176254	208
641.90	10286	207969	182
642.15	10293	200214	82
642.40	10300	211628	163
642.65	10307	209641	157
642.90	10315	185372	228
643.15	10322	194858	200
643.40	10329	201274	168
643.65	10337	193837	190
643.90	10344	167723	213
644.15	10351	180569	127
644.40	10359	167901	133
644.65	10366	224457	112
644.90	10373	173970	295
645.15	10380	215735	186
645.40	10388	245104	56

645.65	10395	216059	113
645.90	10402	219159	123
646.15	10410	185814	202
646.40	10417	150609	196
646.65	10424	141150	367
646.90	10432	159023	341
647.15	10439	182612	277
647.40	10446	163861	359
647.65	10453	124031	385
647.90	10461	117636	335
648.15	10468	154771	343
648.40	10475	158229	365
648.65	10483	151664	324
648.90	10490	144219	337
649.15	10497	133042	333
649.40	10505	164682	280
649.65	10512	181096	225
649.90	10519	168785	698
650.15	10526	181336	539
650.40	10534	240198	238
650.65	10541	252064	366
650.90	10548	214468	223
651.15	10556	192219	216
651.40	10563	179786	313
651.65	10570	158625	298
651.90	10578	158434	274
652.15	10585	187880	272
652.40	10592	164917	373
652.65	10599	158088	312
652.90	10607	176204	257
653.15	10614	146876	406
653.40	10621	159486	411
653.65	10629	116032	513
653.90	10636	25761	873
654.15	10643	31715	1033
654.40	10651	89423	803
654.65	10658	134363	434
654.90	10665	151079	354
655.15	10672	123254	530
655.40	10680	101286	702
655.65	10687	113793	799
655.90	10694	149239	798
656.15	10702	149165	757
656.40	10709	142486	531

656.65	10716	168325	439
656.90	10724	180814	432
657.15	10731	182900	805
657.40	10738	58179	4130
657.65	10745	107700	2896
657.90	10753	60548	3961
658.15	10760	121332	1954
658.40	10767	183687	902
658.65	10775	175410	647
658.90	10782	175210	348
659.15	10789	173263	370
659.40	10796	166834	549
659.65	10804	169195	503
659.90	10811	155733	430
660.15	10818	159024	473
660.40	10826	206951	388
660.65	10833	263414	325
660.90	10840	277919	348
661.15	10848	237772	414
661.40	10855	106601	714
661.65	10862	89216	579
661.90	10869	127885	549
662.15	10877	165113	433
662.40	10884	195812	324
662.65	10891	196250	504
662.90	10899	204202	495
663.15	10906	194722	495
663.40	10913	181905	412
663.65	10921	179046	478
663.90	10928	198737	478
664.15	10935	156490	580
664.40	10942	153840	509
664.65	10950	146801	644
664.90	10957	107800	786
665.15	10964	96918	743
665.40	10972	95991	687
665.65	10979	89234	738
665.90	10986	120436	770
666.15	10994	139498	790
666.40	11001	137071	877
666.65	11008	134760	526
666.90	11015	132982	624
667.15	11023	134814	677
667.40	11030	164213	753

667.65	11037	151154	807
667.90	11045	135194	860
668.15	11052	143415	865
668.40	11059	210435	719
668.65	11067	166806	892
668.90	11074	88921	1406
669.15	11081	72615	1698
669.40	11088	83348	1343
669.65	11096	96504	1094
669.90	11103	64171	1405
670.15	11110	48848	1312
670.40	11118	66157	1277
670.65	11125	102550	1855
670.90	11132	88074	2215
671.15	11140	80186	2164
671.40	11147	79070	2053
671.65	11154	71486	2077
671.90	11161	86926	2035
672.15	11169	75082	2214
672.40	11176	81595	2209
672.65	11183	92173	1828
672.90	11191	102924	2024
673.15	11198	97814	1877
673.40	11205	82019	1904
673.65	11213	48909	2098
673.90	11220	79519	1923
674.15	11227	82271	1820
674.40	11234	74752	1963
674.65	11242	73274	2064
674.90	11249	84008	1917
675.15	11256	75116	2035
675.40	11264	72551	2029
675.65	11271	84212	1935
675.90	11278	72801	1911
676.15	11286	66893	2210
676.40	11293	48690	2381
676.65	11300	28642	2428
676.90	11307	66764	2083
677.15	11315	89849	1982
677.40	11322	39366	2309
677.65	11329	24961	2742
677.90	11337	58498	2533
678.15	11344	77506	2278
678.40	11351	75664	2258

678.65	11359	71312	2301
678.90	11366	82352	2192
679.15	11373	108031	1824
679.40	11380	97716	1941
679.65	11388	101473	2038
679.90	11395	108183	1901
680.15	11402	125417	2216
680.40	11410	139150	1894
680.65	11417	156771	1165
680.90	11424	120287	1470
681.15	11432	141274	1371
681.40	11439	137597	1617
681.65	11446	167521	1507
681.90	11453	133151	1623
682.15	11461	128526	1603
682.40	11468	98158	1951
682.65	11475	78700	2012
682.90	11483	59019	2491
683.15	11490	30786	2510
683.40	11497	8951	2623
683.65	11505	7530	2408
683.90	11512	7355	2618
684.15	11519	7725	2696
684.40	11526	7857	2599
684.65	11534	7589	2527
684.90	11541	7400	2739
685.15	11548	7413	2936
685.40	11556	7014	2504
685.65	11563	7582	2611
685.90	11570	7817	2621
686.15	11578	7597	2602
686.40	11585	7643	2558
686.65	11592	8885	2467
686.90	11599	21966	2322
687.15	11607	24958	2195
687.40	11614	28912	2486
687.65	11621	26934	1956
687.90	11629	31952	2029
688.15	11636	52136	1831
688.40	11643	97630	1705
688.65	11651	138408	1518
688.90	11658	226754	983
689.15	11665	213861	887
689.40	11672	177684	922

689.65	11680	108046	1261
689.90	11687	103875	1101
690.15	11694	117358	1543
690.40	11702	109552	1901
690.65	11709	92000	1954
690.90	11716	100853	1624
691.15	11724	135408	1835
691.40	11731	143381	1766
691.65	11738	144659	1658
691.90	11745	148232	1460
692.15	11753	158913	1419
692.40	11760	142429	1183
692.65	11767	148847	1107
692.90	11775	167084	888
693.15	11782	188511	851
693.40	11789	191349	934
693.65	11797	187997	834
693.90	11804	184623	879
694.15	11811	166463	792
694.40	11818	190649	814
694.65	11826	210583	855
694.90	11833	209205	787
695.15	11840	251215	499
695.40	11848	201975	616
695.65	11855	170743	861
695.90	11862	155800	955
696.15	11870	167862	784
696.40	11877	179481	667
696.65	11884	160946	716
696.90	11891	117468	844
697.15	11899	115010	908
697.40	11906	114001	752
697.65	11913	105228	938
697.90	11921	121888	1146
698.15	11928	140445	712
698.40	11935	138319	805
698.65	11943	121090	880
698.90	11950	130264	941
699.15	11957	98306	1417
699.40	11964	61982	2360
699.65	11972	26252	2467
699.90	11979	101702	1874
700.15	11986	188409	1042
700.40	11994	213622	1015

700.65	12001	175427	1604
700.90	12008	171992	1738
701.15	12016	221030	1085
701.40	12023	193807	1025
701.65	12030	180444	1249
701.90	12037	169935	1570
702.15	12045	105520	1857
702.40	12052	137462	1784
702.65	12059	159314	1709
702.90	12067	184276	1471
703.15	12074	218450	1499
703.40	12081	203598	1619
703.65	12089	168540	1461
703.90	12096	186444	1480
704.15	12103	220179	1300
704.40	12110	247949	1173
704.65	12118	243683	1100
704.90	12125	241903	1022
705.15	12132	262694	1041
705.40	12140	273343	788
705.65	12147	281094	675
705.90	12154	291857	676
706.15	12162	289441	797
706.40	12169	281534	823
706.65	12176	279344	631
706.90	12183	291954	452
707.15	12191	273905	552
707.40	12198	241350	816
707.65	12205	257629	717
707.90	12213	258884	695
708.15	12220	239886	1120
708.40	12227	178514	1381
708.65	12235	195937	1640
708.90	12242	234604	1386
709.15	12249	261637	931
709.40	12256	258906	870
709.65	12264	286570	606
709.90	12271	270994	597
710.15	12278	256437	744
710.40	12286	225436	867
710.65	12293	200025	1313
710.90	12300	236605	903
711.15	12307	211979	896
711.40	12315	229055	993

711.65	12322	258146	976
711.90	12329	275861	790
712.15	12337	313531	661
712.40	12344	299989	735
712.65	12351	273637	870
712.90	12359	293170	808
713.15	12366	268743	688
713.40	12373	185740	1615
713.65	12380	162953	2199
713.90	12388	174356	2174
714.15	12395	173675	2154
714.40	12402	187926	2119
714.65	12410	192161	2180
714.90	12417	212205	1781
715.15	12424	209132	2141
715.40	12432	181422	2173
715.65	12439	188160	1783
715.90	12446	211020	1854
716.15	12453	236370	1515
716.40	12461	247575	1252
716.65	12468	229552	1518
716.90	12475	187148	2021
717.15	12483	141695	2336
717.40	12490	113920	2771
717.65	12497	94405	3118
717.90	12505	110425	2973
718.15	12512	82485	3485
718.40	12519	83713	3596
718.65	12526	79225	3843
718.90	12534	57877	4316
719.15	12541	50244	4582
719.40	12548	47220	4938
719.65	12556	44684	4988
719.90	12563	51890	4835
720.15	12570	49448	4730
720.40	12578	46613	4749
720.65	12585	44316	4841
720.90	12592	41764	4963
721.15	12599	43413	4878
721.40	12607	41737	5092
721.65	12614	41435	4907
721.90	12621	41174	4800
722.15	12629	37279	4732
722.40	12636	41747	4988

722.65	12643	47088	4766
722.90	12651	53406	4702
723.15	12658	50601	4615
723.40	12665	47352	4603
723.65	12672	64823	4434
723.90	12680	52160	4580
724.15	12687	24386	2209
724.40	12694	285	33
727.60	12788	166443	1802
727.85	12795	161097	1887
728.10	12802	135738	2207
728.35	12810	138101	2140
728.60	12817	121971	2808
728.85	12824	104904	3511
729.10	12832	95948	3651
729.35	12839	94784	3540
729.60	12846	100454	3267
729.85	12854	115424	2492
730.10	12861	121804	2211
730.35	12868	126021	1974
730.60	12875	137011	1485
730.85	12883	146754	1529
731.10	12890	157088	1096
731.35	12897	158357	1095
731.60	12905	135924	1194
731.85	12912	121504	1080
732.10	12919	113925	1337
732.35	12926	133449	1383
732.60	12934	144156	1294
732.85	12941	153895	1015
733.10	12948	154435	875
733.35	12956	159808	652
733.60	12963	158920	618
733.85	12970	190445	555
734.10	12978	189869	528
734.35	12985	71575	4085
734.60	12992	48154	5113
734.85	12999	46867	5337
735.10	13007	66325	4432
735.35	13014	69769	4317
735.60	13021	66600	4449
735.85	13029	56977	4748
736.10	13036	52770	4580
736.35	13043	59076	4530

736.60	13051	67359	3989
736.85	13058	77969	3774
737.10	13065	57018	4020
737.35	13072	72435	3773
737.60	13080	100220	3518
737.85	13087	63482	4433
738.10	13094	51974	4479
738.35	13102	68328	3822
738.60	13109	110537	2935
738.85	13116	63072	4295
739.10	13124	50470	4841
739.35	13131	44819	5112
739.60	13138	43097	5023
739.85	13145	45110	5255
740.10	13153	47739	4971
740.35	13160	57086	4454
740.60	13167	64046	4004
740.85	13175	69209	4004
741.10	13182	74255	3696
741.35	13189	89516	3485
741.60	13197	72299	4041
741.85	13204	51187	4226
742.10	13211	50244	4401
742.35	13218	46378	4023
742.60	13226	38272	4596
742.85	13233	30716	4909
743.10	13240	18695	5238
743.35	13248	16860	5759
743.60	13255	13016	5435
743.85	13262	12652	5477
744.10	13270	13946	5355
744.35	13277	13519	5409
744.60	13284	16699	5493
744.85	13291	16110	5471
745.10	13299	13494	5351
745.35	13306	13336	5558
745.60	13313	13415	5620
745.85	13321	13465	5698
746.10	13328	13532	5722
746.35	13335	13761	5572
746.60	13343	14279	5516
746.85	13350	14541	5825
747.10	13357	14743	5790
747.35	13364	14564	5779

747.60	13372	14093	5973
747.85	13379	14057	6239
748.10	13386	15022	6244
748.35	13394	15144	6320
748.60	13401	14801	6380
748.85	13408	14905	6219
749.10	13416	15784	6587
749.35	13423	16322	6666
749.60	13430	16597	6910
749.85	13437	18007	6828
750.10	13445	20139	6746
750.35	13452	21893	6724
750.60	13459	22642	5467
750.85	13467	15122	5902
751.10	13474	14937	6130
751.35	13481	15888	6292
751.60	13489	15637	5799
751.85	13496	14530	5940
752.10	13503	13313	5484
752.35	13510	12993	5658
752.60	13518	13125	5875
752.85	13525	13360	5677
753.10	13532	14017	6061
753.35	13540	13971	5862
753.60	13547	14166	6074
753.85	13554	15050	6155
754.10	13562	15152	6082
754.35	13569	16122	6586
754.60	13576	16344	6772
754.85	13583	17918	6864
755.10	13591	18680	7020
755.35	13598	18521	6799
755.60	13605	17394	5974
755.85	13613	14267	5671
756.10	13620	13598	5242
756.35	13627	14671	5490
756.60	13635	15606	5039
756.85	13642	16089	5134
757.10	13649	21505	4848
757.35	13656	28098	4354
757.60	13664	26297	4608
757.85	13671	23988	4829
758.10	13678	19850	4999
758.35	13686	24576	5021

758.60	13693	29149	5084
758.85	13700	26889	5021
759.10	13708	25814	4824
759.35	13715	32266	4793
759.60	13722	37874	4351
759.85	13729	32069	4624
760.10	13737	30905	4555
760.35	13744	39161	4537
760.60	13751	35614	5113
760.85	13759	33903	5286
761.10	13766	35987	5251
761.35	13773	30557	4888
761.60	13781	21775	3793
761.85	13788	22787	4349
762.10	13795	23291	4346
762.35	13802	23539	4077
762.60	13810	25632	4279
762.85	13817	24600	4337
763.10	13824	23350	4284
763.35	13832	24524	4097
763.60	13839	24390	4137
763.85	13846	26214	4299
764.10	13854	27743	4012
764.35	13861	27994	4838
764.60	13868	33946	5102
764.85	13875	30446	5013
765.10	13883	27385	5039
765.35	13890	23736	5508
765.60	13897	20748	5563
765.85	13905	19895	5562
766.10	13912	19935	5469
766.35	13919	19478	5451
766.60	13927	17456	5619
766.85	13934	15898	5441
767.10	13941	16918	5749
767.35	13948	15151	5501
767.60	13956	15760	5914
767.85	13963	16286	5308
768.10	13970	18871	5340
768.35	13978	15817	5586
768.60	13985	15582	5756
768.85	13992	15585	5535
769.10	14000	14990	5786
769.35	14007	15194	5615

769.60	14014	15557	5840
769.85	14021	15305	6163
770.10	14029	15155	6034
770.35	14036	15291	5786
770.60	14043	15408	5868
770.85	14051	15455	5944
771.10	14058	16043	6117
771.35	14065	16045	5997
771.60	14073	15633	6163
771.85	14080	16145	5907
772.10	14087	16304	5711
772.35	14094	16275	5984
772.60	14102	16081	6280
772.85	14109	16292	5886
773.10	14116	17705	6307
773.35	14124	22664	5781
773.60	14131	19635	5837
773.85	14138	20341	6377
774.10	14146	23284	5789
774.35	14153	24991	5294
774.60	14160	25024	5046
774.85	14167	26009	4835
775.10	14175	28179	5312
775.35	14182	27671	6341
775.60	14189	22468	6016
775.85	14197	21881	5999
776.10	14204	19674	6220
776.35	14211	17181	5959
776.60	14219	16575	5876
776.85	14226	16103	6007
777.10	14233	15544	5824
777.35	14240	15497	5978
777.60	14248	14466	5894
777.85	14255	15144	6238
778.10	14262	14488	6217
778.35	14270	14819	6283
778.60	14277	14865	6132
778.85	14284	14759	6122
779.10	14292	15997	6096
779.35	14299	15944	5962
779.60	14306	15940	6048
779.85	14313	16129	6116
780.10	14321	16729	5963
780.35	14328	17151	6588

780.60	14335	17967	5572
780.85	14343	15677	4171
781.10	14350	16868	3770
781.35	14357	21588	8309
781.60	14365	18314	4876
781.85	14372	15117	3442
782.10	14379	15764	3565
782.35	14386	23834	3876
782.60	14394	19164	4403
782.85	14401	14762	3869
783.10	14408	17407	2886
783.35	14416	25797	5136
783.60	14423	26899	5435
783.85	14430	26079	4861
784.10	14438	27028	5532
784.35	14445	27220	5686
784.60	14452	24001	5828
784.85	14459	23888	7131
785.10	14467	23192	6505
785.35	14474	23955	6024
785.60	14481	23400	5532
785.85	14489	24014	4977
786.10	14496	23849	4681
786.35	14503	21154	4106
786.60	14510	23421	4993
786.85	14518	23250	4801
787.10	14525	21016	4736
787.35	14532	25268	4914
787.60	14540	28066	6683
787.85	14547	25265	4395
788.10	14554	29098	4920
788.35	14562	23769	3993
788.60	14569	20367	3423
788.85	14576	25495	4211
789.10	14583	31948	5270
789.35	14591	28767	4844
789.60	14598	38787	5465
789.85	14605	26550	4491
790.10	14613	21870	3834
790.35	14620	20610	4045
790.60	14627	23154	4680
790.85	14635	26786	4997
791.10	14642	29664	5331
791.35	14649	29799	6226

791.60	14656	29258	5221
791.85	14664	26636	4724
792.10	14671	23342	4031
792.35	14678	25975	4573
792.60	14686	28381	5279
792.85	14693	29392	5174
793.10	14700	28960	5652
793.35	14708	27602	5493
793.60	14715	28103	5406
793.85	14722	30504	5971
794.10	14729	30795	6089
794.35	14737	27035	4986
794.60	14744	24475	4355
794.85	14751	26039	5211
795.10	14759	23832	5886
795.35	14766	24823	5406
795.60	14773	26182	5742
795.85	14781	25515	5837
796.10	14788	27994	5916
796.35	14795	24032	5967
796.60	14802	24277	6545
796.85	14810	29488	7343
797.10	14817	28942	6368
797.35	14824	31441	6381
797.60	14832	32107	6256
797.85	14839	30046	5693
798.10	14846	22197	4676
798.35	14854	18907	3984
798.60	14861	28881	5670
798.85	14868	30786	5454
799.10	14875	27535	4873
799.35	14883	26354	5508
799.60	14890	28416	6893
799.85	14897	28443	6295
800.10	14905	28980	6194
800.35	14912	29681	5320
800.60	14919	22975	4339
800.85	14927	179	44
801.10	14934	133	27

Depth (cm)	Age (cal yr BP)	$\delta^{18}O$ (per VPDB)
526.25	7007	-13.49
527.75	7043	-12.64
529.25	7114	-11.81
530.75	7167	-12.23
532.25	7221	-13.66
533.75	7275	-14.07
535.25	7329	-13.30
536.75	7384	-13.31
538.25	7439	-11.91
539.75	7494	-13.90
541.25	7550	-11.11
542.75	7606	-11.46
544.25	7662	-11.55
545.75	7718	-12.81
547.25	7774	-12.43
548.75	7831	-14.25
550.25	7887	-13.57
551.75	7943	-12.69
553.25	7999	-13.15
554.75	8054	-11.43
557.75	8163	-14.15
559.25	8216	-13.92
560.75	8268	-12.92
562.25	8319	-15.77
563.75	8369	-13.33
565.25	8418	-12.79
566.75	8465	-15.01
568.25	8511	-14.77
569.75	8555	-13.91
571.25	8599	-11.21
572.75	8641	-12.91
574.25	8682	-12.99
575.75	8722	-12.87
577.25	8761	-12.91
578.75	8799	-13.76
580.25	8836	-12.64
581.75	8872	-14.01
583.25	8908	-14.00
584.75	8942	-12.28
586.25	8976	-11.78
587.75	9010	-10.25

589.25	9042	-9.14
590.75	9074	-11.30
592.25	9106	-11.72
593.75	9137	-10.09
595.25	9168	-11.03
596.75	9198	-10.62
598.25	9228	-9.06
599.75	9258	-9.01
601.25	9287	-8.98
602.75	9317	-10.74
604.25	9346	-11.46
605.75	9375	-11.18
607.25	9404	-9.10
608.75	9433	-10.24
610.25	9463	-11.55
611.75	9492	-11.80
613.25	9522	-11.09
614.75	9552	-8.03
616.25	9582	-11.44
617.75	9612	-13.70
619.25	9643	-10.99
620.75	9675	-8.87
622.25	9707	-8.66
623.75	9739	-12.45
625.25	9773	-10.28
626.75	9807	-13.59
628.25	9842	-13.74
629.75	9877	-10.54
631.25	9914	-11.87
632.75	9952	-10.65
634.25	9990	-12.77
635.75	10030	-12.25
637.25	10071	-11.35
638.75	10113	-11.92
640.25	10157	-11.89
643.25	10248	-13.00
644.75	10296	-13.34
646.25	10345	-14.66
647.75	10397	-13.89
650.75	10506	-15.30
652.25	10564	-13.37
653.75	10625	-11.76
655.25	10689	-9.36
656.75	10755	-9.52

658.25	10824	-9.00
659.75	10896	-10.88
661.25	10969	-8.77
662.75	11046	-7.87
664.25	11124	-10.22
665.75	11204	-10.39
667.25	11286	-10.63
668.75	11369	-9.80
670.25	11454	-12.53
671.75	11540	-14.93
674.75	11716	-15.14
676.25	11805	-14.45
677.75	11895	-16.06
679.25	11985	-16.03
680.75	12076	-15.26
686.75	12380	-14.70
688.25	12531	-15.61
689.75	12621	-16.89
691.25	12711	-15.78
692.75	12799	-15.98
694.25	12886	-16.18
695.75	12971	-15.48
697.25	13053	-15.25
700.25	13211	-16.63
701.75	13285	-17.64
703.25	13357	-16.17
704.75	13427	-16.53
706.25	13494	-16.95
707.75	13559	-17.34
709.25	13621	-17.18
710.75	13680	-17.52
712.25	13738	-17.69
713.75	13793	-17.05
715.25	13846	-17.77
716.75	13896	-17.12
718.25	13945	-16.42
719.75	13991	-16.47
721.25	14035	-15.69

APPENDIX D

DAILEY LAKE CHRONOLOGY

Depth (cm)	Weighted Mean Age (cal yr BP)	Minimum Age (95% CI) (cal yr BP)	Maximum Age (95% CI) (cal yr BP)
0	-59	-62	-56
1	-41	-59	-2
2	-24	-59	54
3	-6	-58	110
4	12	-58	167
5	31	-57	223
6	49	-57	280
7	67	-56	336
8	85	-55	393
9	103	-54	450
10	121	-54	506
11	136	-43	518
12	153	-34	531
13	169	-27	546
14	186	-21	562
15	203	-15	581
16	220	-9	600
17	236	-4	613
18	253	0	629
19	269	4	648
20	286	8	671
21	304	30	684
22	321	45	697
23	339	58	712
24	356	69	730
25	374	80	749
26	392	90	770
27	410	99	796
28	427	107	829
29	445	115	859
30	462	121	891
31	477	140	904
32	493	156	916
33	508	169	929
34	524	179	940
35	539	190	950
36	554	200	960
37	570	207	975
38	586	216	990
39	601	225	1009
40	617	233	1030

41	633	257	1041
42	649	276	1053
43	666	298	1067
44	682	314	1082
45	699	330	1096
46	715	342	1116
47	731	352	1135
48	748	360	1152
49	764	371	1173
50	780	379	1193
51	798	405	1203
52	816	432	1213
53	834	451	1224
54	852	469	1238
55	870	483	1251
56	889	497	1268
57	907	508	1288
58	925	519	1310
59	943	528	1334
60	962	538	1364
61	979	562	1373
62	997	585	1382
63	1015	610	1393
64	1032	632	1406
65	1050	652	1418
66	1068	670	1431
67	1086	684	1449
68	1103	699	1464
69	1121	710	1480
70	1139	721	1500
71	1159	761	1506
72	1179	797	1513
73	1199	828	1518
74	1219	851	1528
75	1239	874	1538
76	1259	893	1550
77	1280	913	1562
78	1300	927	1576
79	1321	939	1594
80	1341	951	1616
81	1355	986	1621
82	1370	1018	1627
83	1385	1044	1631
84	1399	1071	1637

85	1414	1089	1644
86	1429	1103	1650
87	1444	1116	1658
88	1458	1132	1666
89	1473	1142	1678
90	1488	1152	1693
91	1505	1201	1696
92	1521	1250	1701
93	1538	1298	1704
94	1555	1345	1710
95	1572	1390	1718
96	1589	1434	1728
97	1606	1477	1741
98	1623	1515	1753
99	1640	1544	1768
100	1673	1569	1811
101	1694	1586	1829
102	1714	1598	1857
103	1735	1610	1889
104	1755	1619	1933
105	1776	1624	1979
106	1795	1629	2028
107	1815	1634	2082
108	1835	1638	2136
109	1855	1640	2193
110	1875	1643	2251
111	1898	1666	2269
112	1921	1679	2288
113	1944	1689	2309
114	1967	1698	2335
115	1990	1706	2361
116	2013	1713	2388
117	2036	1720	2426
118	2059	1726	2463
119	2081	1731	2506
120	2104	1736	2554
121	2124	1754	2576
122	2144	1772	2598
123	2164	1788	2628
124	2184	1802	2661
125	2205	1816	2697
126	2224	1828	2736
127	2244	1838	2782
128	2264	1848	2826

129	2283	1854	2870
130	2303	1861	2920
131	2321	1882	2931
132	2340	1901	2946
133	2358	1916	2959
134	2377	1932	2970
135	2395	1944	2986
136	2414	1955	3002
137	2432	1963	3019
138	2450	1970	3040
139	2468	1977	3057
140	2486	1983	3076
141	2513	2020	3089
142	2538	2047	3102
143	2565	2071	3120
144	2591	2092	3142
145	2617	2109	3167
146	2644	2127	3190
147	2670	2140	3216
148	2696	2154	3250
149	2722	2167	3285
150	2748	2179	3330
151	2768	2214	3343
152	2789	2242	3351
153	2810	2277	3362
154	2831	2309	3377
155	2852	2338	3389
156	2873	2360	3399
157	2894	2379	3413
158	2915	2395	3428
159	2936	2408	3452
160	2958	2418	3475
161	2976	2447	3486
162	2994	2470	3494
163	3012	2492	3503
164	3030	2513	3515
165	3049	2532	3528
166	3067	2550	3543
167	3086	2565	3558
168	3104	2580	3572
169	3122	2597	3592
170	3140	2610	3612
171	3163	2649	3619
172	3186	2684	3627

173	3209	2721	3636
174	3232	2751	3646
175	3255	2781	3657
176	3278	2801	3671
177	3301	2821	3685
178	3324	2837	3700
179	3347	2853	3723
180	3369	2866	3751
181	3393	2910	3758
182	3416	2954	3763
183	3440	2993	3770
184	3464	3026	3779
185	3488	3060	3788
186	3511	3086	3799
187	3535	3108	3810
188	3559	3130	3825
189	3583	3151	3842
190	3607	3165	3864
191	3629	3230	3869
192	3652	3293	3872
193	3674	3356	3878
194	3696	3418	3883
195	3719	3479	3889
196	3741	3539	3897
197	3763	3592	3907
198	3786	3638	3920
199	3808	3678	3938
200	3831	3707	3956
201	3852	3726	3980
202	3873	3736	4008
203	3893	3744	4052
204	3914	3750	4096
205	3934	3757	4145
206	3955	3762	4192
207	3975	3766	4244
208	3995	3772	4295
209	4016	3775	4352
210	4036	3778	4408
211	4055	3796	4435
212	4074	3810	4459
213	4094	3824	4490
214	4113	3834	4518
215	4131	3843	4547
216	4150	3850	4582

217	4169	3857	4617
218	4187	3862	4659
219	4206	3870	4699
220	4225	3876	4738
221	4244	3895	4749
222	4263	3912	4763
223	4281	3924	4780
224	4300	3937	4795
225	4319	3946	4812
226	4338	3955	4832
227	4356	3960	4852
228	4375	3967	4874
229	4393	3973	4901
230	4412	3979	4932
231	4432	3999	4947
232	4452	4021	4962
233	4472	4039	4978
234	4492	4057	4995
235	4512	4070	5014
236	4532	4081	5033
237	4553	4094	5054
238	4573	4104	5086
239	4593	4116	5115
240	4613	4125	5144
241	4635	4154	5159
242	4657	4178	5172
243	4679	4203	5185
244	4701	4227	5200
245	4723	4247	5216
246	4745	4264	5231
247	4767	4284	5249
248	4789	4298	5273
249	4810	4313	5300
250	4832	4324	5328
251	4850	4348	5336
252	4868	4373	5345
253	4887	4393	5361
254	4905	4413	5374
255	4923	4430	5392
256	4941	4448	5407
257	4960	4470	5424
258	4978	4483	5441
259	4996	4499	5460
260	5014	4511	5480

261	5034	4539	5487
262	5054	4560	5496
263	5073	4587	5505
264	5093	4604	5517
265	5113	4618	5529
266	5132	4634	5542
267	5152	4642	5557
268	5172	4651	5575
269	5192	4660	5596
270	5211	4669	5623
271	5230	4696	5628
272	5248	4724	5635
273	5267	4751	5645
274	5285	4782	5653
275	5304	4805	5665
276	5322	4823	5677
277	5341	4839	5691
278	5359	4854	5706
279	5378	4868	5722
280	5397	4881	5742
281	5416	4913	5747
282	5436	4951	5754
283	5457	4985	5763
284	5477	5011	5768
285	5497	5032	5779
286	5516	5046	5787
287	5537	5063	5800
288	5557	5077	5814
289	5577	5092	5832
290	5597	5107	5853
291	5618	5178	5856
292	5638	5248	5859
293	5659	5319	5863
294	5679	5386	5868
295	5700	5450	5872
296	5721	5510	5877
297	5741	5567	5882
298	5763	5612	5889
299	5784	5645	5899
300	5805	5665	5914
301	5818	5676	5926
302	5830	5686	5945
303	5843	5693	5968
304	5855	5701	5997

305	5868	5706	6025
306	5880	5712	6055
307	5892	5718	6087
308	5904	5723	6120
309	5916	5728	6156
310	5928	5733	6192
311	5941	5748	6201
312	5954	5762	6212
313	5966	5772	6226
314	5979	5781	6242
315	5991	5787	6262
316	6004	5794	6282
317	6016	5797	6306
318	6027	5801	6329
319	6040	5807	6360
320	6052	5809	6391
321	6064	5822	6399
322	6077	5833	6410
323	6089	5843	6421
324	6102	5851	6433
325	6115	5859	6449
326	6127	5866	6465
327	6140	5873	6483
328	6152	5878	6503
329	6165	5884	6526
330	6178	5888	6549
331	6191	5902	6560
332	6204	5912	6569
333	6217	5920	6584
334	6231	5930	6597
335	6244	5936	6609
336	6257	5943	6626
337	6270	5951	6646
338	6284	5958	6668
339	6297	5962	6696
340	6310	5965	6723
341	6322	5978	6732
342	6334	5992	6743
343	6346	6003	6754
344	6357	6014	6765
345	6370	6020	6774
346	6382	6029	6789
347	6394	6038	6806
348	6406	6044	6820

349	6417	6050	6836
350	6429	6057	6857
351	6441	6069	6866
352	6452	6084	6872
353	6463	6095	6881
354	6475	6106	6891
355	6486	6116	6904
356	6497	6127	6915
357	6509	6135	6929
358	6520	6140	6943
359	6531	6148	6960
360	6542	6155	6972
361	6555	6168	6981
362	6567	6182	6988
363	6580	6193	7000
364	6593	6205	7010
365	6605	6217	7021
366	6618	6229	7032
367	6631	6237	7044
368	6644	6248	7057
369	6656	6255	7068
370	6669	6263	7082
371	6682	6282	7090
372	6695	6299	7097
373	6709	6314	7106
374	6722	6329	7114
375	6736	6341	7124
376	6749	6353	7134
377	6762	6363	7146
378	6775	6373	7160
379	6788	6384	7175
380	6801	6394	7189
381	6813	6406	7197
382	6825	6418	7205
383	6837	6432	7213
384	6848	6441	7219
385	6860	6450	7226
386	6872	6460	7234
387	6883	6470	7245
388	6895	6478	7258
389	6907	6487	7273
390	6918	6493	7291
391	6931	6515	7297
392	6944	6538	7301

393	6957	6556	7308
394	6971	6575	7315
395	6984	6591	7324
396	6997	6605	7330
397	7010	6617	7339
398	7023	6628	7350
399	7037	6639	7362
400	7050	6647	7376
401	7061	6666	7383
402	7073	6679	7390
403	7084	6691	7395
404	7096	6704	7405
405	7107	6718	7413
406	7119	6725	7420
407	7130	6738	7430
408	7141	6749	7442
409	7153	6757	7454
410	7164	6768	7468
411	7175	6789	7473
412	7186	6806	7479
413	7198	6821	7485
414	7209	6834	7491
415	7221	6846	7498
416	7232	6860	7506
417	7244	6873	7514
418	7255	6883	7522
419	7267	6895	7532
420	7278	6904	7544
421	7290	6928	7548
422	7301	6949	7552
423	7312	6967	7557
424	7323	6987	7561
425	7335	7004	7568
426	7347	7020	7575
427	7358	7036	7583
428	7370	7051	7594
429	7382	7062	7607
430	7394	7072	7620
431	7406	7104	7623
432	7418	7133	7629
433	7430	7160	7633
434	7442	7185	7638
435	7454	7209	7646
436	7466	7230	7653

437	7478	7246	7661
438	7491	7264	7671
439	7503	7276	7684
440	7515	7287	7697
441	7530	7331	7704
442	7546	7373	7714
443	7561	7412	7721
444	7576	7445	7734
445	7592	7474	7745
446	7608	7497	7759
447	7624	7513	7772
448	7640	7520	7791
449	7656	7529	7819
450	7672	7535	7853
451	7693	7557	7871
452	7715	7573	7896
453	7737	7585	7930
454	7759	7597	7967
455	7781	7604	8013
456	7803	7612	8058
457	7825	7618	8109
458	7847	7624	8164
459	7869	7629	8226
460	7890	7634	8279
461	7913	7656	8300
462	7937	7674	8317
463	7960	7691	8333
464	7983	7703	8354
465	8007	7714	8383
466	8030	7727	8409
467	8052	7738	8442
468	8075	7745	8477
469	8098	7752	8515
470	8121	7761	8560
471	8142	7785	8577
472	8165	7810	8593
473	8187	7829	8609
474	8209	7847	8630
475	8231	7862	8651
476	8253	7875	8677
477	8276	7886	8702
478	8298	7899	8730
479	8320	7907	8765
480	8342	7915	8799

481	8365	7947	8808
482	8388	7974	8818
483	8411	7997	8828
484	8435	8016	8842
485	8458	8034	8856
486	8481	8048	8871
487	8505	8061	8889
488	8528	8074	8912
489	8551	8085	8936
490	8574	8099	8966
491	8598	8145	8971
492	8622	8185	8979
493	8646	8228	8986
494	8671	8263	8995
495	8694	8290	9006
496	8718	8313	9018
497	8742	8331	9034
498	8766	8350	9048
499	8790	8366	9066
500	8814	8384	9090
501	8838	8436	9096
502	8861	8487	9102
503	8885	8539	9111
504	8909	8586	9121
505	8933	8623	9130
506	8957	8652	9146
507	8981	8679	9161
508	9005	8701	9179
509	9029	8724	9203
510	9053	8738	9226
511	9065	8755	9237
512	9076	8765	9248
513	9087	8781	9261
514	9098	8793	9279
515	9110	8803	9298
516	9121	8814	9321
517	9132	8821	9344
518	9143	8830	9371
519	9154	8839	9397
520	9165	8845	9424
521	9176	8860	9432
522	9187	8870	9445
523	9198	8882	9456
524	9209	8894	9471

525	9219	8900	9484
526	9230	8908	9500
527	9241	8915	9516
528	9252	8925	9531
529	9263	8935	9551
530	9274	8939	9572
531	9284	8956	9582
532	9296	8974	9591
533	9307	8990	9602
534	9318	9004	9614
535	9329	9018	9630
536	9340	9030	9646
537	9351	9039	9658
538	9363	9050	9677
539	9374	9059	9695
540	9385	9064	9715
541	9395	9076	9723
542	9406	9084	9735
543	9416	9091	9747
544	9426	9103	9758
545	9437	9111	9774
546	9447	9120	9788
547	9457	9128	9803
548	9467	9136	9820
549	9478	9145	9839
550	9488	9151	9857
551	9501	9166	9869
552	9514	9180	9881
553	9527	9191	9895
554	9539	9201	9910
555	9552	9216	9924
556	9565	9225	9945
557	9578	9236	9973
558	9591	9246	10005
559	9603	9258	10031
560	9616	9266	10060
561	9628	9285	10071
562	9639	9302	10079
563	9651	9318	10089
564	9663	9333	10102
565	9675	9347	10113
566	9686	9356	10124
567	9698	9365	10139
568	9710	9374	10155

569	9721	9381	10175
570	9732	9389	10194
571	9744	9412	10201
572	9755	9432	10206
573	9767	9452	10211
574	9779	9468	10218
575	9791	9484	10226
576	9803	9499	10233
577	9815	9510	10243
578	9827	9522	10251
579	9839	9530	10265
580	9851	9537	10278
581	9859	9553	10282
582	9867	9568	10286
583	9876	9582	10290
584	9884	9595	10294
585	9893	9608	10297
586	9901	9619	10302
587	9910	9629	10307
588	9918	9638	10312
589	9927	9647	10316
590	9935	9652	10324
591	9942	9664	10326
592	9949	9676	10327
593	9956	9685	10332
594	9963	9693	10333
595	9969	9699	10336
596	9976	9706	10338
597	9983	9711	10341
598	9990	9718	10343
599	9997	9725	10346
600	10003	9729	10348
601	10009	9739	10351
602	10015	9749	10353
603	10020	9757	10357
604	10026	9768	10359
605	10032	9775	10362
606	10038	9783	10365
607	10044	9790	10369
608	10049	9796	10372
609	10055	9802	10374
610	10061	9808	10376
611	10066	9815	10379
612	10071	9822	10381

613	10076	9828	10384
614	10081	9834	10388
615	10086	9839	10390
616	10092	9845	10393
617	10097	9850	10395
618	10102	9855	10398
619	10107	9861	10401
620	10112	9865	10405
621	10117	9877	10407
622	10122	9886	10410
623	10128	9896	10412
624	10133	9905	10414
625	10138	9913	10417
626	10143	9920	10419
627	10148	9927	10421
628	10154	9932	10423
629	10159	9937	10425
630	10164	9944	10429
631	10169	9954	10431
632	10174	9963	10434
633	10179	9972	10437
634	10184	9980	10441
635	10189	9988	10443
636	10194	9994	10446
637	10200	10001	10449
638	10205	10007	10453
639	10210	10011	10456
640	10215	10016	10461
641	10220	10026	10462
642	10225	10037	10465
643	10230	10048	10466
644	10235	10056	10468
645	10240	10063	10470
646	10245	10070	10472
647	10250	10078	10475
648	10255	10083	10478
649	10260	10088	10481
650	10265	10093	10485
651	10270	10105	10486
652	10274	10117	10489
653	10280	10129	10492
654	10284	10140	10493
655	10290	10150	10496
656	10295	10159	10498

657	10300	10169	10500
658	10305	10176	10504
659	10310	10183	10507
660	10315	10189	10511
661	10320	10201	10515
662	10325	10211	10519
663	10331	10219	10524
664	10336	10225	10528
665	10341	10230	10534
666	10347	10234	10540
667	10352	10236	10546
668	10357	10238	10551
669	10363	10241	10557
670	10368	10243	10564
671	10373	10249	10568
672	10379	10253	10574
673	10384	10256	10580
674	10389	10260	10585
675	10394	10262	10592
676	10400	10266	10599
677	10405	10268	10606
678	10411	10270	10613
679	10416	10272	10621
680	10421	10274	10627
681	10426	10280	10632
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1326	16342	15485	17290
1327	16351	15495	17302
1328	16361	15506	17317
1329	16371	15514	17326
1330	16381	15520	17338
1331	16391	15532	17351
1332	16401	15542	17358
1333	16411	15550	17364
1334	16421	15560	17381
1335	16431	15568	17395
1336	16441	15580	17404
1337	16452	15591	17420
1338	16462	15602	17430
1339	16472	15610	17444
1340	16482	15620	17460
1341	16492	15629	17466
1342	16501	15634	17478
1343	16511	15643	17494
1344	16521	15651	17505
1345	16531	15661	17512
1346	16541	15671	17521
1347	16551	15678	17534
1348	16561	15688	17545
1349	16571	15692	17557
1350	16580	15698	17566
1351	16591	15709	17574
1352	16600	15717	17584
1353	16611	15726	17592
1354	16621	15734	17598
1355	16630	15742	17609
1356	16641	15750	17624
1357	16651	15758	17634
1358	16661	15766	17645
1359	16671	15771	17656
1360	16681	15775	17674

1361	16691	15786	17685
1362	16700	15794	17693
1363	16710	15806	17703
1364	16719	15818	17713
1365	16729	15827	17727
1366	16739	15836	17745
1367	16748	15842	17750
1368	16758	15850	17766
1369	16768	15859	17779
1370	16778	15865	17791
1371	16788	15873	17796
1372	16797	15879	17808
1373	16807	15889	17822
1374	16817	15900	17830
1375	16826	15910	17844
1376	16836	15922	17856
1377	16846	15928	17867
1378	16856	15934	17875
1379	16865	15942	17891
1380	16875	15948	17903
1381	16885	15959	17914
1382	16895	15970	17923
1383	16905	15976	17936
1384	16915	15986	17946
1385	16925	15993	17948
1386	16935	15997	17957
1387	16945	16006	17968
1388	16954	16014	17984
1389	16965	16023	17999
1390	16975	16029	18011
1391	16985	16039	18021
1392	16994	16051	18029
1393	17004	16062	18041
1394	17015	16072	18048
1395	17025	16082	18062
1396	17036	16090	18075
1397	17046	16101	18087
1398	17056	16109	18097
1399	17066	16119	18108
1400	17076	16127	18121
1401	17086	16135	18137
1402	17096	16143	18148
1403	17106	16152	18157
1404	17116	16159	18169

1405	17126	16166	18177
1406	17136	16176	18186
1407	17146	16181	18198
1408	17156	16193	18210
1409	17166	16198	18222
1410	17176	16201	18232
1411	17185	16211	18241
1412	17195	16224	18252
1413	17204	16231	18263
1414	17214	16240	18278
1415	17224	16242	18286
1416	17234	16247	18288
1417	17244	16257	18306
1418	17253	16265	18325
1419	17263	16272	18335
1420	17273	16279	18339
1421	17284	16288	18348
1422	17293	16302	18363
1423	17303	16311	18370
1424	17313	16322	18388
1425	17323	16333	18400
1426	17334	16341	18412
1427	17344	16351	18418
1428	17355	16365	18431
1429	17365	16373	18443
1430	17376	16380	18453
1431	17386	16387	18464
1432	17396	16394	18483
1433	17406	16403	18495
1434	17416	16410	18505
1435	17427	16421	18514
1436	17437	16429	18532
1437	17447	16435	18545
1438	17457	16443	18556
1439	17467	16451	18567

APPENDIX E

POLLEN AND CHARCOAL COUNTS FROM DAILEY LAKE

Depth (cm)	Age (cal yr BP)	*Pinus contorta*-type	*Pinus albicaulis*-type	*Pinus* undiff.
398.50	7030	26	16	167
414.50	7215	18	19	182
430.50	7400	27	27	174
458.25	7852	1	7	207
474.25	8215	4	13	159
490.25	8580	4	3	202
506.25	8963	10	7	175
522.25	9190	6	11	241
538.25	9365	7	5	195
558.25	9594	13	16	230
574.25	9782	0	10	189
590.25	9937	6	4	156
598.25	9991	3	15	166
606.25	10039	6	10	175
622.25	10124	2	4	168
630.25	10165	10	13	152
638.25	10206	2	5	214
658.25	10306	5	22	197
674.25	10390	6	29	168
690.25	10476	6	10	231
706.25	10563	4	15	190
714.75	10608	4	8	196
722.25	10649	2	31	196
730.75	10695	4	43	251
738.25	10735	10	27	182
746.25	10778	5	16	182
758.25	10843	8	17	215
766.75	10890	4	10	216
774.25	10931	2	8	212
782.75	10976	5	40	228
790.25	11017	4	23	228
798.25	11059	18	23	139
806.25	11103	1	33	241
814.25	11163	5	20	178
822.25	11237	2	20	234
830.25	11312	7	9	167
838.25	11386	1	8	174
846.25	11460	0	48	114
856.25	11552	0	22	271
864.25	11627	3	13	168
872.25	11732	1	15	222
880.25	11779	2	19	148

888.25	11853	7	41	171
896.25	11928	1	53	122
904.25	12004	2	26	138
912.25	12079	2	60	167
920.25	12151	4	23	170
924.25	12189	1	11	117
928.25	12228	0	29	100
932.25	12265	0	9	182
936.25	12302	2	4	155
940.25	12339	1	9	125
944.25	12376	0	19	69
954.25	12474	1	20	90
964.25	12587	0	20	48
972.25	12691	0	16	60
980.25	12812	0	15	64
988.25	12927	0	21	69
996.25	13016	0	12	65
1004.25	13105	1	15	65
1012.25	13202	0	20	34
1020.25	13301	0	11	47
1028.25	13383	0	10	37
1036.25	13462	2	5	19
1044.25	13542	0	4	36
1056.25	13661	0	34	96
1064.25	13741	0	2	18
1072.25	13822	0	3	24
1080.25	13903	0	0	33

Picea	*Abies*	*Pseudotsuga*	*Juniperus*-type	*Alnus*	*Betula*
4	16	6	5	0	1
9	6	4	4	1	0
3	16	5	4	0	0
13	4	4	0	1	0
7	2	2	3	0	0
9	7	3	0	0	2
6	6	1	10	0	0
11	6	1	2	0	0
4	6	3	3	0	3
4	6	8	4	1	1
8	3	4	3	0	1
8	11	4	3	3	0
5	2	3	0	1	0
3	5	1	2	0	0
1	2	3	1	0	0
4	1	0	3	0	1
5	6	0	1	0	2
5	4	0	3	1	0
4	0	1	1	0	1
3	4	2	2	0	0
5	2	0	0	1	0
6	2	1	2	1	1
4	2	1	4	0	1
3	1	0	0	2	0
6	1	1	4	2	1
2	3	1	1	1	2
4	3	0	2	1	1
6	0	0	0	0	2
3	8	0	2	0	0
8	5	1	0	0	0
3	4	0	2	2	2
4	7	0	5	0	3
6	3	0	4	1	2
8	2	0	1	0	1
7	3	0	0	0	0
10	3	0	7	4	3
8	2	0	6	5	5
22	9	1	1	0	6
13	7	0	1	0	0
7	7	0	1	0	1
4	5	0	2	1	3
5	13	0	0	1	7
8	2	0	0	2	2

9	2	2	0	0	4
7	6	0	7	0	9
16	6	0	0	0	11
11	5	0	6	1	5
12	1	0	6	1	12
14	11	1	8	1	3
14	8	0	7	0	5
24	10	0	10	0	7
16	8	2	3	0	5
18	4	5	23	1	6
16	1	0	7	2	3
14	2	0	12	0	17
16	1	1	10	0	6
13	0	1	7	3	8
11	0	0	6	1	36
32	0	0	6	0	31
17	1	1	9	2	16
18	4	0	26	1	29
19	7	0	3	0	0
1	5	0	9	1	1
1	6	0	3	0	1
4	15	0	10	0	0
5	0	0	3	1	0
15	0	0	4	0	0
2	0	0	0	1	0
1	0	0	0	0	0

Salix	*Populus* undiff.	*Quercus*	*Acer*	*Arceuthobium*	Rosaceae undiff.
1	0	2	0	0	4
0	0	1	0	1	6
1	2	3	0	1	9
2	0	0	0	0	3
2	0	1	0	0	1
0	0	0	0	0	2
3	0	0	0	0	3
1	0	2	0	0	3
1	0	1	0	0	3
1	0	0	0	0	2
3	0	0	0	0	6
6	0	1	0	0	4
2	0	0	0	0	0
1	0	0	0	0	5
2	0	0	0	0	6
3	0	0	0	1	1
3	0	0	0	1	4
0	0	0	0	0	4
0	1	0	0	0	5
0	0	0	0	0	1
1	0	0	0	0	1
1	0	0	0	0	0
2	1	1	0	0	2
1	0	0	0	0	2
0	1	0	0	0	2
2	0	1	0	0	2
0	0	0	0	0	4
0	0	0	0	1	2
2	0	0	0	0	3
1	0	0	0	0	2
0	0	0	0	0	2
4	0	0	0	0	1
1	0	0	0	0	1
1	4	0	0	0	0
0	0	0	0	0	3
3	0	1	0	0	1
1	0	1	0	0	5
2	2	0	0	0	1
0	0	1	0	0	1
5	0	0	0	0	2
2	0	0	0	0	3
4	2	0	0	0	0

4	0	0	0	1	1
5	0	1	0	0	2
13	0	3	0	0	0
3	0	0	0	0	0
1	0	0	0	0	6
4	0	0	0	0	12
2	0	0	0	0	4
2	0	0	0	0	5
1	0	2	0	0	2
3	0	0	0	0	6
1	0	1	0	1	2
2	0	0	0	0	1
6	3	0	0	0	0
4	0	0	0	0	1
8	1	1	1	0	1
15	0	0	0	0	0
7	0	1	0	0	0
7	2	1	0	0	2
5	1	0	0	0	3
2	7	2	0	0	2
6	3	0	0	0	6
3	3	0	0	0	3
8	3	2	0	0	3
7	0	0	0	0	3
5	1	0	0	0	0
0	0	0	0	0	5
0	0	0	0	0	0

Prunus	*Spiraea*	*Amelanchier*	*Potentilla*	*Ceanothus*	*Shepherdia canadensis*
0	0	0	0	0	0
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0	0	0	0	0	0
0	0	1	0	1	0
0	0	1	0	0	0
0	0	1	0	0	0
0	0	0	0	1	0
0	0	0	0	0	0
0	0	3	0	0	0
0	0	0	0	3	0
0	0	0	0	0	0
0	0	0	0	1	0
0	0	0	0	1	0
0	0	2	0	0	0
0	0	3	0	0	0
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0	0	0	0	3	0
0	0	1	0	0	0
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1	0	0	1	0	0
0	0	0	0	0	0
0	0	1	0	0	0
0	0	2	0	1	1
0	0	0	0	0	0
0	0	1	0	1	0
0	0	0	0	0	0
0	0	0	0	1	2
0	0	1	1	1	1
0	0	0	0	0	0
0	0	0	1	0	0
0	0	1	0	0	0
0	0	0	0	0	0
0	1	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	1	0	1	0	0
0	0	0	0	0	0

0	1	0	0	1	1
0	0	0	0	0	0
0	1	1	0	0	0
0	0	0	0	1	0
0	1	3	0	0	1
0	2	4	0	0	0
0	0	0	0	0	0
0	0	4	0	0	1
0	0	2	0	1	1
0	1	1	0	0	0
0	0	1	0	0	0
0	1	1	2	0	1
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0	0	0	0	0	0
0	0	0	0	0	0
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0	0	0	0	0	0
0	1	0	0	0	1
0	2	1	0	0	2
0	0	0	0	0	1
0	0	3	0	0	0
0	0	0	0	0	3
0	0	1	0	0	0
0	0	0	0	0	0

Eleagnus argentea-type	*Ephedra*	*Sarcobatus*	Poaceae	*Artemisia*	*Ambrosia*-type
0	0	3	1	47	0
0	1	0	2	24	2
0	0	4	3	53	1
0	0	8	12	38	2
0	0	13	27	60	4
0	0	10	13	48	2
0	0	9	9	36	3
0	0	3	16	36	3
0	0	10	25	49	6
0	0	9	10	36	4
0	0	14	34	36	7
0	0	16	13	38	3
0	1	24	25	45	3
0	0	28	33	30	2
0	0	4	8	31	3
0	0	25	28	39	1
0	1	19	30	28	2
0	0	4	21	28	3
0	0	16	20	27	0
0	0	9	17	21	0
0	0	11	35	28	3
0	0	12	29	21	2
0	0	6	11	14	2
0	0	4	15	23	1
0	0	6	12	28	4
0	0	9	63	21	6
0	0	6	17	21	2
0	0	4	28	21	1
0	0	2	10	33	4
1	0	3	7	21	1
0	0	2	7	31	0
0	0	1	32	29	2
0	0	1	15	22	1
0	0	3	40	30	2
0	0	1	20	10	1
0	0	1	42	49	4
0	0	0	20	64	2
0	0	3	66	37	4
0	0	0	7	8	1
0	0	4	51	49	1
0	0	2	20	34	1

0	0	1	52	54	2
0	0	3	27	42	3
0	0	2	56	43	3
0	0	1	14	49	1
2	0	2	25	29	1
0	0	3	4	48	2
0	0	4	18	57	2
0	0	4	27	51	2
0	0	6	9	55	4
0	1	2	2	60	1
0	0	1	2	54	3
0	0	2	44	56	1
0	1	2	19	93	7
0	0	10	58	90	3
0	3	5	42	71	11
0	0	3	25	93	3
0	0	4	22	134	4
0	0	7	15	117	4
0	0	5	31	96	7
0	0	6	33	97	1
0	0	8	31	42	0
0	0	8	32	87	1
0	0	3	20	44	1
0	0	1	33	5	1
0	0	5	10	35	3
0	0	1	25	11	4
0	0	0	2	17	3
0	0	0	0	2	0

Other Tubuliflorae	Liguliflorae	Amaranthaceae	*Salsola*-type	*Thalictrum*
2	0	16	0	0
3	2	16	0	1
1	4	26	0	0
2	0	27	0	0
4	2	26	0	0
2	0	22	0	0
6	0	25	0	0
3	1	30	1	0
2	0	23	0	0
0	0	12	0	0
2	0	29	0	0
5	1	34	0	0
0	1	16	0	0
4	1	28	0	0
6	13	25	0	0
4	1	11	0	0
2	0	22	0	0
3	0	10	0	0
8	2	17	0	0
1	0	18	0	0
2	0	24	0	0
2	0	27	0	0
4	1	26	0	0
0	0	19	0	0
2	1	20	0	0
4	0	11	0	0
1	0	15	0	0
1	1	15	0	0
1	0	26	0	0
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3	1	25	0	0
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4	0	11	0	0
2	1	15	1	0
4	0	2	0	0
0	2	3	0	0
1	0	3	0	0
0	1	17	0	0
3	0	14	0	0

6	1	9	0	0
2	1	13	0	0
2	1	17	0	0
0	0	3	0	0
2	0	9	0	0
3	2	15	0	0
1	0	12	0	0
2	1	19	0	0
4	1	14	0	0
1	0	12	0	0
8	3	7	1	0
7	19	15	2	0
0	1	19	0	0
1	0	11	0	0
4	2	16	0	0
2	1	11	0	0
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7	1	6	1	0
9	3	7	0	0
9	1	2	0	0
3	1	3	0	0
4	1	6	0	0
8	4	1	0	0
8	2	3	0	0
1	2	0	0	0

Apiaceae	Brassicaceae	Caryophyllaceae	Other Polygonaceae	*Eriogonum*
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0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
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0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	3
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0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	5
0	0	0	0	0
0	0	0	0	0
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0	0	0	0	0
0	0	0	0	0
1	0	0	0	0
0	0	0	0	1
1	0	0	0	0
0	0	0	0	1
0	0	0	0	13
0	0	0	0	2
1	0	0	0	4
0	0	0	0	4
0	0	0	0	2
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0	1	0	0	2
0	0	0	0	0
0	0	0	0	0
0	0	1	0	2
0	0	0	0	0
0	0	0	0	0

Galium	Fabaceae	Other herbs	Cyperaceae	Indeterminate-type	Unknown
0	0	0	9	4	0
0	0	0	3	1	0
0	0	0	3	3	0
0	0	0	1	8	0
1	0	0	5	7	3
1	0	1	1	2	1
2	0	0	6	7	0
0	0	0	6	7	1
1	0	0	7	13	1
0	0	0	2	6	2
1	0	0	2	6	1
0	0	0	5	19	0
0	0	0	3	3	1
0	0	0	0	17	0
2	0	0	0	40	0
0	0	0	0	7	0
0	0	0	2	12	1
0	0	0	1	13	1
1	1	0	1	14	0
0	0	0	2	29	0
0	0	0	2	18	0
2	0	0	6	13	1
0	0	0	0	5	0
0	0	0	3	9	0
1	0	0	3	8	2
0	0	0	8	9	0
0	0	0	7	13	1
1	0	0	5	15	0
0	0	0	3	6	1
1	0	0	3	2	0
0	0	0	7	3	1
0	0	0	13	19	1
1	0	0	4	6	0
0	0	0	14	5	1
3	0	0	5	4	0
0	0	0	7	8	1
2	0	0	9	15	0
0	0	0	25	4	1
0	0	0	1	9	0
0	0	0	12	11	3
2	0	0	8	24	0
0	0	0	3	13	0

3	0	0	16	7	1
0	0	0	13	6	2
0	0	0	15	11	0
0	1	0	20	4	1
2	0	0	13	6	0
2	0	0	19	26	1
0	0	0	11	18	3
1	0	0	2	8	1
1	0	0	7	10	0
0	0	0	2	10	1
1	0	0	6	39	1
0	0	0	20	28	2
0	0	0	8	27	3
0	1	0	12	15	2
0	0	0	14	37	4
0	0	0	7	13	3
0	1	0	17	41	3
0	0	0	8	19	6
0	0	0	18	21	1
0	0	0	13	80	8
0	0	0	16	21	2
0	0	0	12	70	21
0	0	0	35	68	0
0	0	0	7	59	0
0	1	0	19	38	6
0	4	0	4	30	0
0	0	0	0	4	0

Lycopodium tracer mean = 13911	Terrestrial Sum
147	321
104	304
161	368
35	341
57	342
60	335
46	319
65	385
61	364
37	368
65	357
65	336
41	317
50	353
89	324
67	305
79	363
69	325
48	323
23	354
38	341
61	338
22	317
60	380
43	321
30	343
48	335
42	328
48	325
58	332
51	346
26	309
51	353
26	310
31	325
55	336
57	340
76	328
50	346
51	331
94	361
43	340

85	345
40	329
47	309
50	339
66	313
54	313
60	293
130	343
120	318
80	265
92	315
137	344
42	335
44	290
80	312
66	359
65	363
66	317
92	314
235	290
275	254
193	225
372	201
674	275
425	150
758	105
585	43

Top Depth (cm)	Bottom Depth (cm)	Top Age (cal yr BP)	Bottom Age (cal yr BP)	Sediment Volume (cm^3)	Charcoal Count
451	453	7693	7737	2	19
453	455	7737	7781	2	18
455	457	7781	7825	2	28
457	459	7825	7869	2	28
459	461	7869	7913	2	30
461	463	7913	7960	2	48
463	465	7960	8007	2	43
465	467	8007	8052	2	32
467	469	8052	8098	2	36
469	471	8098	8142	2	41
471	473	8142	8187	2	44
473	475	8187	8231	2	59
475	477	8231	8276	2	33
477	479	8276	8320	2	33
479	481	8320	8365	2	19
481	483	8365	8411	2	49
483	485	8411	8458	2	6
485	487	8458	8505	2	15
487	489	8505	8551	2	9
489	491	8551	8598	2	7
491	493	8598	8646	2	25
493	495	8646	8694	2	27
495	497	8694	8742	2	25
497	499	8742	8790	2	5
499	501	8790	8838	2	19
501	503	8838	8885	no data	no data
503	505	8885	8933	no data	no data
505	507	8933	8981	2	16
507	509	8981	9029	2	13
509	511	9029	9065	2	11
511	513	9065	9087	2	15
513	515	9087	9110	2	13
515	517	9110	9132	2	15
517	519	9132	9154	2	2
519	521	9154	9176	2	5
521	523	9176	9198	2	6
523	525	9198	9219	2	13
525	527	9219	9241	2	18
527	529	9241	9263	2	12
529	531	9263	9284	2	24
531	533	9284	9307	2	12

533	535	9307	9329	2	14
535	537	9329	9351	2	11
537	539	9351	9374	2	10
539	541	9374	9395	2	8
541	543	9395	9416	2	5
543	545	9416	9437	2	8
545	547	9437	9457	2	6
547	549	9457	9478	2	1
549	551	9478	9501	no data	no data
551	553	9501	9527	2	21
553	555	9527	9552	2	10
555	557	9552	9578	2	8
557	559	9578	9603	2	5
559	561	9603	9628	2	3
561	563	9628	9651	2	3
563	565	9651	9675	2	13
565	567	9675	9698	2	5
567	569	9698	9721	2	16
569	571	9721	9744	2	6
571	573	9744	9767	2	9
573	575	9767	9791	2	6
575	577	9791	9815	2	4
577	579	9815	9839	2	2
579	581	9839	9859	2	1
581	583	9859	9876	2	2
583	585	9876	9893	2	4
585	587	9893	9910	2	6
587	589	9910	9927	2	10
589	591	9927	9942	2	1
591	593	9942	9956	2	3
593	595	9956	9969	2	13
595	597	9969	9983	2	12
597	599	9983	9997	2	15
599	601	9997	10009	2	3
601	603	10009	10020	2	4
603	605	10020	10032	2	12
605	607	10032	10044	2	15
607	609	10044	10055	2	3
609	611	10055	10066	2	1
611	613	10066	10076	2	0
613	615	10076	10086	2	2
615	617	10086	10097	2	2
617	619	10097	10107	2	1
619	621	10107	10117	no data	no data

621	623	10117	10128	2	2
623	625	10128	10138	2	1
625	627	10138	10148	2	1
627	629	10148	10159	2	4
629	631	10159	10169	2	2
631	633	10169	10179	2	12
633	635	10179	10189	2	39
635	637	10189	10200	2	14
637	639	10200	10210	2	8
639	641	10210	10220	2	6
641	643	10220	10230	2	7
643	645	10230	10240	2	0
645	647	10240	10250	2	5
647	649	10250	10260	2	3
649	651	10260	10270	no data	no data
651	653	10270	10280	2	8
653	655	10280	10290	2	3
655	657	10290	10300	no data	no data
657	659	10300	10310	no data	no data
659	661	10310	10320	2	1
661	663	10320	10331	2	1
663	665	10331	10341	2	16
665	667	10341	10352	2	11
667	669	10352	10363	2	11
669	671	10363	10373	2	12
671	673	10373	10384	2	7
673	675	10384	10394	2	10
675	677	10394	10405	2	8
677	679	10405	10416	2	8
679	681	10416	10426	2	9
681	683	10426	10437	2	29
683	685	10437	10448	2	33
685	687	10448	10459	2	3
687	689	10459	10470	2	10
689	691	10470	10480	2	19
691	693	10480	10491	2	69
693	695	10491	10502	2	48
695	697	10502	10513	2	45
697	699	10513	10524	2	102
699	701	10524	10535	2	44
701	703	10535	10545	2	47
703	705	10545	10556	2	7
705	707	10556	10567	2	19
707	709	10567	10577	2	20

709	711	10577	10588	2	9
711	713	10588	10599	2	28
713	715	10599	10609	2	37
715	717	10609	10620	2	24
717	719	10620	10631	2	12
719	721	10631	10642	2	18
721	723	10642	10653	2	22
723	725	10653	10664	2	11
725	727	10664	10675	2	18
727	729	10675	10685	2	20
729	731	10685	10696	2	15
731	733	10696	10707	2	53
733	735	10707	10718	2	39
735	737	10718	10729	2	23
737	739	10729	10739	2	26
739	741	10739	10750	2	68
741	743	10750	10761	2	66
743	745	10761	10772	2	82
745	747	10772	10783	2	28
747	749	10783	10793	2	34
749	751	10793	10804	2	28
751	753	10804	10815	2	44
753	755	10815	10826	2	29
755	757	10826	10836	2	18
757	759	10836	10847	2	6
759	761	10847	10858	2	9
761	763	10858	10869	2	27
763	765	10869	10880	2	24
765	767	10880	10891	2	74
767	769	10891	10902	2	12
769	771	10902	10913	2	13
771	773	10913	10924	2	37
773	775	10924	10935	2	29
775	777	10935	10946	2	36
777	779	10946	10956	2	16
779	781	10956	10967	2	20
781	783	10967	10978	2	26
783	785	10978	10988	2	26
785	787	10988	10999	2	38
787	789	10999	11010	2	14
789	791	11010	11021	2	13
791	793	11021	11031	2	22
793	795	11031	11042	2	12
795	797	11042	11053	2	8

797	799	11053	11063	2	9
799	801	11063	11074	2	8
801	803	11074	11085	no data	no data
803	805	11085	11096	no data	no data
805	807	11096	11107	2	14
807	809	11107	11119	2	20
809	811	11119	11134	2	7
811	813	11134	11152	2	17
813	815	11152	11170	2	27
815	817	11170	11189	2	16
817	819	11189	11207	2	22
819	821	11207	11225	2	25
821	823	11225	11244	2	30
823	825	11244	11263	2	6
825	827	11263	11282	2	12
827	829	11282	11300	2	10
829	831	11300	11319	2	6
831	833	11319	11337	2	22
833	835	11337	11356	2	9
835	837	11356	11374	2	15
837	839	11374	11393	2	23
839	841	11393	11412	2	28
841	843	11412	11430	2	23
843	845	11430	11449	2	38
845	847	11449	11468	2	9
847	849	11468	11486	2	6
849	851	11486	11504	2	15
851	853	11504	11522	2	5
853	855	11522	11541	2	15
855	857	11541	11559	2	7
857	859	11559	11577	2	11
859	861	11577	11596	2	2
861	863	11596	11615	2	13
863	865	11615	11634	2	17
865	867	11634	11654	2	29
867	869	11654	11673	2	3
869	871	11673	11692	2	22
871	873	11692	11711	2	7
873	875	11711	11730	2	3
875	877	11730	11749	2	15
877	879	11749	11768	2	13
879	881	11768	11786	2	10
881	883	11786	11804	2	17
883	885	11804	11823	2	20

885	887	11823	11841	2	53
887	889	11841	11860	2	8
889	891	11860	11879	2	28
891	893	11879	11897	2	12
893	895	11897	11916	2	10
895	897	11916	11935	2	13
897	899	11935	11954	2	15
899	901	11954	11973	2	4
901	903	11973	11992	2	30
903	905	11992	12011	2	14
905	907	12011	12030	2	14
907	909	12030	12049	2	20
909	911	12049	12067	2	19
911	913	12067	12085	2	8
913	915	12085	12104	2	2
915	917	12104	12121	2	2
917	919	12121	12139	2	10
919	921	12139	12158	2	17
921	923	12158	12177	2	9
923	925	12177	12197	2	7
925	927	12197	12216	2	12
927	929	12216	12235	2	6
929	931	12235	12254	2	10
931	933	12254	12272	2	15
933	935	12272	12291	2	18
935	937	12291	12309	2	18
937	939	12309	12328	2	11
939	941	12328	12346	2	14
941	943	12346	12365	2	53
943	945	12365	12383	2	51
945	947	12383	12402	2	15
947	949	12402	12420	no data	no data
949	951	12420	12440	no data	no data
951	953	12440	12461	2	22
953	955	12461	12482	2	50
955	957	12482	12503	2	343
957	959	12503	12524	2	15
959	961	12524	12547	2	11
961	963	12547	12571	2	9
963	965	12571	12596	2	10
965	967	12596	12621	2	6
967	969	12621	12646	2	13
969	971	12646	12673	2	78
971	973	12673	12703	2	7

973	975	12703	12732	2	4
975	977	12732	12763	2	12
977	979	12763	12794	2	5
979	981	12794	12823	2	7
981	983	12823	12851	2	4
983	985	12851	12880	2	9
985	987	12880	12909	2	2
987	989	12909	12937	2	3
989	991	12937	12962	2	3
991	993	12962	12983	2	12
993	995	12983	13003	2	27
995	997	13003	13024	2	3
997	999	13024	13044	2	7
999	1001	13044	13066	2	18
1001	1003	13066	13090	2	20
1003	1005	13090	13114	2	30
1005	1007	13114	13138	2	22
1007	1009	13138	13161	2	4
1009	1011	13161	13186	2	0
1011	1013	13186	13211	2	4
1013	1015	13211	13237	2	1
1015	1017	13237	13262	2	14
1017	1019	13262	13287	2	0
1019	1021	13287	13309	2	0
1021	1023	13309	13329	2	4
1023	1025	13329	13350	2	171
1025	1027	13350	13370	2	14
1027	1029	13370	13390	2	0
1029	1031	13390	13410	2	9
1031	1033	13410	13430	2	3
1033	1035	13430	13450	2	0
1035	1037	13450	13470	no data	no data
1037	1039	13470	13490	2	2
1039	1041	13490	13509	2	15
1041	1043	13509	13529	2	0
1043	1045	13529	13549	2	1
1045	1047	13549	13569	2	2
1047	1049	13569	13589	2	1
1049	1051	13589	13609	2	0
1051	1053	13609	13629	2	1
1053	1055	13629	13649	2	0
1055	1057	13649	13668	2	1
1057	1059	13668	13688	2	0
1059	1061	13688	13708	2	0

1061	1063	13708	13729	2	0
1063	1065	13729	13749	2	0
1065	1067	13749	13769	2	0
1067	1069	13769	13790	2	0
1069	1071	13790	13810	2	0
1071	1073	13810	13830	2	0
1073	1075	13830	13850	2	0
1075	1077	13850	13870	2	0
1077	1079	13870	13891	2	0
1079	1081	13891	13911	2	0
1081	1083	13911	13931	2	0
1083	1085	13931	13951	2	0
1085	1087	13951	13970	2	0
1087	1089	13970	13990	2	0
1089	1091	13990	14010	2	0
1091	1093	14010	14030	2	0
1093	1095	14030	14051	2	0
1095	1097	14051	14072	2	0
1097	1099	14072	14092	2	0
1099	1101	14092	14112	2	0
1101	1103	14112	14131	no data	no data
1103	1105	14131	14150	no data	no data
1105	1107	14150	14170	2	0
1107	1109	14170	14190	2	0
1109	1111	14190	14210	2	0
1111	1113	14210	14231	2	0
1113	1115	14231	14251	2	0
1115	1117	14251	14272	2	0
1117	1119	14272	14293	2	0
1119	1121	14293	14313	2	0
1121	1123	14313	14333	2	0
1123	1125	14333	14354	2	0
1125	1127	14354	14374	2	0
1127	1129	14374	14394	2	0
1129	1131	14394	14414	2	0
1131	1133	14414	14434	2	0
1133	1135	14434	14454	2	0
1135	1137	14454	14474	2	0
1137	1139	14474	14494	2	0
1139	1141	14494	14514	2	0
1141	1143	14514	14534	2	0
1143	1145	14534	14554	2	0

APPENDIX F

DIATOM COUNTS FROM DAILEY LAKE

Depth (cm)	Age (cal yr BP)	*Achnanthes clevei*	*Achnanthes conspicua*	*Achnanthes exigua*
695.25	10504	0	0	0
700.25	10531	0	0	0
705.25	10557	0	0	0
710.25	10584	1	0	0
715.25	10610	1	0	0
720.25	10638	0	0	0
725.25	10665	0	0	0
730.25	10692	1	0	0
735.25	10719	0	2	0
740.25	10746	0	0	0
745.25	10773	0	1	0
750.25	10800	1	0	0
755.25	10827	0	0	0
760.25	10854	0	0	0
765.25	10882	0	0	0
770.25	10909	0	0	0
775.25	10936	0	2	0
780.25	10963	0	0	0
785.25	10990	0	0	0
790.25	11017	0	1	0
795.25	11044	0	0	0
798.25	11059	0	0	0
800.25	11070	0	3	0
805.25	11098	0	0	0
810.25	11127	0	0	0
813.25	11154	0	0	0
815.25	11173	0	0	0
818.25	11200	0	0	0
820.25	11218	0	0	0
823.25	11247	0	0	0
825.25	11265	0	0	0
828.25	11293	1	0	0
830.25	11312	0	0	0
833.25	11340	0	0	0
835.25	11358	0	0	0
838.25	11386	0	0	0
840.25	11404	0	0	0
843.25	11433	0	0	0
845.25	11451	0	0	0
848.25	11479	0	0	0
850.25	11497	0	0	0
853.25	11525	0	0	0

855.25	11543	0	0	0
858.25	11570	0	0	0
860.25	11588	0	0	0
863.25	11617	0	0	0
865.25	11637	0	0	0
868.25	11666	2	0	0
870.25	11685	0	0	0
875.25	11732	0	0	0
878.25	11760	0	0	0
880.25	11779	0	0	0
883.25	11807	0	0	0
885.25	11825	0	0	0
888.25	11853	0	0	0
890.25	11871	0	0	0
893.25	11900	0	0	0
895.25	11918	0	0	0
898.25	11947	0	0	0
900.25	11966	0	0	0
903.25	11994	0	0	0
905.25	12013	0	0	0
908.25	12042	0	0	0
910.25	12061	1	1	0
913.25	12088	0	0	0
915.25	12106	0	3	0
918.25	12133	0	0	0
920.25	12151	0	0	0
923.25	12180	0	0	0
925.25	12199	0	0	0
928.25	12228	0	0	0
930.25	12247	0	0	0
933.25	12275	0	0	0
935.25	12293	0	0	0
938.25	12321	0	0	0
940.25	12339	0	2	0
943.25	12367	0	0	0
950.25	12432	0	0	0
953.25	12463	0	0	0
954.25	12474	0	0	0
955.25	12484	0	0	0
955.75	12489	0	0	0
956.25	12495	0	0	0
956.75	12500	0	0	0
957.25	12505	0	0	0
957.75	12511	0	0	0

958.25	12516	0	0	0
958.75	12521	0	0	0
959.25	12527	0	0	0
959.75	12532	0	0	0
960.25	12538	0	0	0
960.75	12544	0	0	0
961.25	12550	0	0	0
961.75	12556	0	0	0
962.25	12562	0	0	0
962.75	12568	0	0	0
963.25	12574	0	0	0
963.75	12581	0	0	0
964.25	12587	0	0	0
964.75	12593	0	0	0
965.25	12599	0	0	0
965.75	12606	0	0	0
966.25	12612	0	0	0
966.75	12618	0	0	0
967.25	12624	0	0	0
967.75	12631	0	0	0
968.25	12637	0	0	0
968.75	12643	0	0	0
969.25	12649	0	0	0
969.75	12655	0	0	0
970.25	12662	0	0	0
970.75	12669	0	0	0
971.25	12677	0	0	0
971.75	12684	0	0	0
972.25	12691	0	0	0
972.75	12699	0	0	0
973.25	12706	0	0	0
973.75	12714	0	0	0
974.25	12721	0	2	0
974.75	12729	0	0	0
975.25	12736	0	0	0
975.75	12744	0	0	0
976.25	12751	0	0	0
976.75	12759	0	0	0
977.25	12767	0	0	0
977.75	12774	0	0	0
978.25	12782	0	0	0
978.75	12790	0	0	0
979.25	12797	0	2	0
979.75	12805	0	0	0

980.25	12812	0	0	0
980.75	12819	0	0	0
981.25	12826	0	0	0
981.75	12833	0	0	0
982.25	12840	0	0	0
982.75	12847	0	0	0
983.25	12855	0	0	0
983.75	12862	0	0	0
984.25	12869	0	0	0
984.75	12876	0	0	0
985.25	12883	0	0	0
985.75	12891	0	0	0
986.25	12898	0	0	0
986.75	12905	0	0	0
987.25	12912	0	0	0
987.75	12920	0	0	0
988.25	12927	0	0	0
988.75	12934	0	0	0
989.25	12941	0	0	0
989.75	12948	0	0	0
990.25	12954	0	0	0
990.75	12959	0	0	0
991.25	12965	0	0	0
991.75	12970	0	0	0
992.25	12975	0	0	0
992.75	12980	0	0	0
993.25	12985	0	1	0
993.75	12990	0	0	0
994.25	12995	0	0	0
994.75	13001	0	0	0
995.25	13006	0	0	0
995.75	13011	0	0	0
996.25	13016	0	0	0
996.75	13021	0	0	0
997.25	13026	0	0	0
997.75	13031	0	0	0
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1000.25	13057	0	0	0
1000.75	13063	0	0	0
1001.25	13069	0	0	0
1001.75	13075	0	0	0

1002.25	13081	0	0	0
1002.75	13087	0	0	0
1003.25	13093	0	1	0
1003.75	13099	0	0	0
1004.25	13105	0	0	0
1004.75	13111	0	0	0
1005.25	13117	0	0	0
1005.75	13123	0	0	0
1006.25	13129	0	0	0
1006.75	13135	0	0	0
1007.25	13141	0	0	0
1007.75	13147	0	0	0
1008.25	13152	0	5	0
1008.75	13158	0	0	0
1009.25	13164	0	0	0
1009.75	13170	0	0	0
1010.25	13176	0	0	0
1010.75	13183	0	0	0
1011.25	13189	0	0	0
1011.75	13195	0	0	0
1012.25	13202	0	0	0
1012.75	13208	0	0	0
1013.25	13215	0	0	0
1013.75	13221	0	0	0
1014.25	13227	0	0	0
1014.75	13234	0	0	0
1015.25	13240	0	0	0
1015.75	13246	0	0	0
1016.25	13252	0	0	0
1016.75	13259	0	0	0
1017.25	13265	0	0	0
1017.75	13271	0	0	0
1018.25	13277	0	0	1

Achnanthes kuelbsii	*Achnanthes minutissima*	*Achnanthes rosenstockii*	*Achnanthes* sp.	*Achnanthes ziegleri*
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0	4	1	1	2
0	4	4	0	2
0	9	6	1	2
0	6	8	0	0
0	4	10	0	7
2	6	12	0	1
1	4	11	2	3
1	8	1	0	0
0	5	4	3	1
0	2	5	2	7
0	3	10	6	1
0	3	11	3	0
0	7	12	4	1
0	4	17	5	8
0	5	16	0	6
0	9	19	1	1
0	3	20	3	1
0	5	18	8	7
0	10	20	9	5
10	7	17	0	7
3	3	41	0	6
0	6	9	0	4
0	6	3	1	0
0	3	1	0	2
0	1	0	0	6
0	7	0	1	0
0	3	0	2	4
1	8	5	0	2
0	5	5	3	1
0	8	5	1	3
0	4	3	2	7
0	9	2	4	2
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3	3	2	0	3
0	12	13	6	1
1	6	19	0	5
0	5	10	5	4
4	6	9	0	2
0	2	3	0	9

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2	5	17	3	4
0	2	5	6	3
3	1	13	3	5
0	4	20	6	6
0	3	16	1	4
3	3	1	0	3
0	5	8	5	4
2	8	21	0	4
0	7	8	5	2
2	5	10	0	0
0	1	15	4	5
4	5	11	0	0
0	5	21	4	2
1	5	14	0	1
0	4	9	1	1
2	6	10	0	3
0	10	8	2	1
4	5	14	0	4
0	10	20	8	8
3	6	1	3	2
0	7	3	4	2
3	9	2	4	1
0	10	5	3	3
1	5	3	3	4
0	4	2	1	3
2	5	0	1	3
0	14	0	1	0
0	8	0	0	2
0	2	1	0	2
0	6	1	0	2
0	4	34	0	1
1	6	32	2	4
0	7	24	12	8
3	4	10	10	11
0	6	5	7	3
0	4	11	4	10
2	0	5	3	6
0	3	14	2	8
0	4	3	9	3
0	10	6	4	8
0	4	5	2	2
0	10	4	0	3

0	3	8	7	4
0	5	7	8	4
0	1	1	3	1
0	5	7	3	3
3	3	10	1	5
0	4	7	3	2
0	7	9	3	3
0	5	8	2	5
0	6	10	1	4
0	5	9	4	6
0	5	10	6	5
0	6	11	5	1
0	9	11	5	15
0	4	10	4	8
1	4	14	3	6
0	8	16	5	12
0	6	8	3	8
0	8	14	6	4
0	2	6	6	2
0	2	11	7	13
0	8	6	13	5
0	4	6	2	3
0	7	8	5	4
0	6	12	5	2
3	9	12	2	9
0	6	10	5	3
0	4	9	5	4
0	8	9	5	9
0	5	8	8	8
0	1	11	9	6
0	5	6	4	5
0	4	8	8	5
5	7	10	1	7
0	2	4	6	4
0	1	11	3	3
0	9	11	8	5
0	6	10	5	7
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0	6	16	4	10
0	3	22	5	5
0	5	13	5	6
0	2	18	4	5
7	1	10	0	6
0	6	11	9	3

0	7	10	10	4
0	3	6	1	5
0	6	10	9	5
0	5	6	1	1
0	8	7	6	4
0	9	8	3	4
0	7	9	2	3
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0	5	14	1	4
0	6	10	7	4
0	5	8	6	3
0	2	4	7	5
2	5	7	2	5
0	8	15	5	2
0	11	7	10	5
0	14	9	6	10
0	7	9	3	4
0	4	12	6	2
0	5	6	9	4
0	9	8	5	4
0	8	6	4	4
0	11	11	4	10
3	19	12	0	4
0	13	9	8	6
0	9	15	2	6
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0	9	13	3	7
0	16	10	3	7
0	18	9	3	9
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0	6	19	6	8
0	10	21	9	11
0	6	12	11	6
0	2	13	7	8
0	6	17	4	9
0	6	18	17	6

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0	2	30	15	11
10	7	20	4	6
0	6	17	17	7
0	4	21	10	2
0	0	20	26	4
0	4	18	17	2
0	5	13	19	10
0	3	12	28	2
0	3	18	17	6
0	6	23	24	5
0	1	13	22	5
14	2	19	7	10
0	7	11	18	4
0	1	9	34	9
0	6	10	16	5
0	2	13	34	3
0	6	9	20	10
0	3	12	24	8
0	3	11	24	6
0	2	9	26	7
0	6	10	23	10
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0	2	14	42	10
0	2	9	33	7
0	3	6	32	20
0	3	10	39	13
0	2	16	32	12
19	3	20	18	16

Amphora libyca	*Amphora pediculus*	*Amphora* sp.	*Amphora thumensis*	*Anomoeoneis sphaerophora*
7	18	1	2	0
6	12	0	1	0
4	5	0	4	5
1	14	0	0	0
7	28	0	2	0
12	11	2	7	0
1	8	0	3	0
0	22	0	2	0
3	15	0	1	0
3	14	0	1	0
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1	14	0	3	0
2	5	0	3	0
0	12	0	7	0
0	16	0	9	0
0	24	0	6	0
0	19	0	8	0
1	30	0	3	0
0	31	0	10	0
1	22	0	5	0
0	31	0	4	0
0	14	0	4	0
2	27	0	9	0
0	23	0	11	0
2	43	0	3	0
1	37	0	1	0
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3	15	0	3	0
0	33	0	10	0
1	47	0	5	0
0	44	0	12	0
0	13	0	12	0
0	11	0	1	0

0	30	0	3	0
0	22	0	9	0
2	26	0	7	0
2	24	0	9	0
0	26	0	11	0
0	27	1	7	0
0	22	0	4	0
0	3	0	3	0
0	25	0	3	0
0	13	0	1	0
0	25	0	6	0
0	20	0	5	0
0	33	0	8	0
0	23	0	6	0
0	40	0	10	0
0	30	0	6	0
1	19	0	6	0
0	19	0	9	0
0	21	0	5	0
1	56	1	10	0
0	39	0	6	0
1	51	0	3	0
5	16	0	3	0
3	24	0	6	0
1	18	0	5	0
2	28	0	3	0
2	20	0	1	0
4	19	2	3	0
1	14	0	0	0
1	31	0	0	0
1	40	1	0	0
0	24	0	0	0
0	32	0	7	0
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0	20	0	9	0
0	11	0	13	0
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0	17	0	13	0
0	23	0	5	0
0	32	0	7	0
0	43	0	7	0
0	19	1	10	0
0	8	0	5	0

0	24	0	15	0
0	20	0	6	0
0	16	0	4	0
0	15	0	7	0
0	16	0	6	0
0	15	0	3	0
0	18	0	5	0
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2	19	0	10	0
1	44	0	13	0
0	35	0	11	0
0	26	0	5	0
0	29	0	8	0
0	26	0	7	0

0	19	0	4	0
0	16	0	6	0
0	15	0	7	0
1	14	0	5	0
1	12	0	5	0
0	10	0	2	0
0	20	0	2	0
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1	36	0	15	0
0	28	1	13	0
0	46	0	23	0
0	38	0	24	0
2	50	0	34	0
0	57	0	33	0
3	45	0	34	0

0	58	1	47	0
0	55	0	48	0
0	40	0	38	0
1	49	0	54	0
0	55	1	47	0
0	51	0	35	0
1	35	0	26	0
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0	42	0	27	0
0	58	1	41	0
0	25	0	21	0
1	42	0	27	0
2	34	0	22	0
1	42	0	24	0
2	45	0	33	0
0	30	0	30	0
1	48	0	28	0
0	30	0	24	0
0	43	0	22	0
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0	48	0	28	0
0	65	0	47	0
0	75	0	36	0
2	83	1	43	0
2	73	0	33	0
0	69	0	56	0
0	89	0	37	0
0	70	0	24	0
0	88	0	25	0
0	76	1	53	0

Anomoeoneis sphaerophora	*Aulacoseira ambigua*	*Brachysira vitrea*	*Caloneis silicula*	*Cocconeis placentula* var. *englypta*
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0	0	1	0	4
0	2	0	0	11
0	7	0	0	1
0	0	0	0	5
0	0	1	0	3
0	0	2	0	2
0	0	3	0	3
0	0	1	0	7
0	0	1	0	6
0	2	0	0	2
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0	0	4	0	4
0	0	3	0	1
0	2	3	0	7
0	1	0	0	2
0	0	0	0	5
0	2	3	0	3
0	0	0	0	2
0	0	1	0	2
0	0	2	0	5
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0	0	3	0	11
0	0	3	0	1
0	0	0	0	7
1	7	1	0	9
0	2	1	0	12
0	4	0	0	6
0	6	0	0	2
0	3	0	0	1
0	7	0	0	2
0	9	0	0	1
0	9	0	0	0
0	5	2	0	1
0	5	0	0	4
0	16	1	0	1
0	32	0	0	1

0	18	0	0	2
0	11	0	0	1
0	4	2	0	0
0	1	2	0	3
0	0	0	0	1
0	4	0	0	3
0	12	1	0	10
0	76	0	0	1
0	104	2	0	1
0	11	0	0	2
0	1	1	0	0
0	4	0	0	0
0	39	0	0	1
0	6	2	0	1
0	1	0	0	0
0	0	1	0	1
0	17	4	0	0
0	23	0	0	0
0	45	0	0	1
0	28	1	0	3
0	4	1	0	2
0	15	0	0	2
0	5	4	0	4
0	6	1	0	0
0	1	1	0	1
0	8	0	0	5
0	9	0	0	7
0	0	0	0	7
0	7	0	0	3
0	0	0	0	13
0	0	0	0	6
0	2	0	0	5
0	0	3	0	8
0	0	3	0	0
0	0	1	0	4
0	0	0	0	4
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0	6	1	0	0
0	1	0	0	0
0	2	1	0	0
0	0	2	0	2
0	4	2	0	2
0	0	1	0	0
0	4	0	0	1

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0	2	0	0	1
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0	2	1	0	1
0	1	0	0	2
0	1	1	0	3
0	2	0	0	2
0	3	1	0	1
0	2	1	0	2
0	7	0	0	0
0	7	0	0	1
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0	4	1	0	2
0	2	0	0	1
0	4	0	0	3
0	6	2	0	1
0	4	2	0	0
0	10	1	0	2
0	10	0	0	2
0	23	2	0	0
0	9	1	0	2
0	7	0	0	0
0	11	0	0	1
0	3	1	0	6
0	3	2	0	2
0	1	3	0	5
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0	1	0	0	1
0	1	1	0	3
0	2	0	0	2
0	5	2	0	3
0	8	1	0	0
0	3	0	0	2
0	8	0	0	1
0	9	0	0	2
0	1	1	0	2

0	8	0	0	1
0	3	2	0	5
0	0	0	0	4
0	5	0	0	1
0	1	3	0	1
0	2	2	0	2
0	7	0	0	4
0	4	1	0	1
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0	3	0	0	0
0	2	1	0	2
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0	0	0	0	1
0	5	0	0	1
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0	8	0	0	4
0	3	0	0	6
0	8	0	0	2
0	8	0	0	2
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0	4	0	0	2
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0	9	0	0	1
0	6	0	0	2

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0	9	1	0	2
0	8	0	0	3
0	11	0	0	0
0	13	0	0	0
0	22	0	0	2
0	32	0	0	1
0	33	0	0	1
0	18	0	0	1
0	33	0	0	3
0	18	0	0	3
0	25	0	0	2
0	17	0	0	2
0	30	0	0	2
0	47	1	0	0
0	81	0	0	2
0	45	0	0	0
0	27	0	0	2
0	34	0	0	2
0	49	0	0	1
0	36	0	0	0
0	33	0	0	2
0	27	0	0	4
0	34	0	0	1
0	38	0	0	2
0	32	0	0	2
0	21	0	0	2
0	29	0	0	2
0	18	0	0	0
0	14	0	0	4
0	6	0	0	3
0	8	0	0	2
0	7	0	0	0
0	2	0	0	1

Cocconeis sp.	*Craticula ambigua* (Ehrenb.)	*Craticula cuspidata*	*Craticula halophila*	*Cyclotella bodanica* var. aff. *Lemanica*
0	0	0	0	0
0	0	0	0	1
0	0	1	0	0
0	0	0	0	0
0	0	2	0	1
0	0	0	0	0
0	0	0	0	0
0	0	0	0	7
0	0	2	0	15
0	0	0	0	8
0	0	1	0	2
0	0	0	0	1
0	0	0	0	1
0	0	0	3	2
0	0	0	0	11
0	0	0	0	4
0	0	0	0	4
0	0	0	0	7
0	0	0	0	0
0	0	2	0	0
0	0	0	0	0
0	0	2	0	1
2	0	1	0	2
1	0	0	0	5
2	0	0	0	0
0	0	1	0	0
4	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	2
0	0	0	0	0
0	0	0	0	0
5	0	0	0	0
0	0	0	0	0
1	0	0	0	1
0	0	0	0	1
0	2	0	0	1
0	0	0	0	1
1	0	0	0	2

0	0	0	0	5
0	0	0	0	2
0	0	1	0	4
0	0	0	0	0
0	0	0	0	4
0	1	0	0	3
0	0	0	0	2
0	0	0	0	2
0	0	0	0	8
0	0	0	0	5
0	0	0	0	8
0	0	0	0	2
0	0	0	0	1
0	0	0	0	2
0	0	0	0	3
0	0	0	0	1
0	0	0	0	2
0	0	0	0	0
0	0	0	0	0
0	0	0	0	2
0	0	2	0	0
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	1	0	1
0	0	0	0	2
1	0	0	0	1
0	0	0	0	3
0	0	1	0	1
0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	1	0	4
0	0	0	0	4
0	1	0	0	5
0	0	0	0	2
0	0	0	0	1
0	0	0	0	0
0	0	1	0	0
0	0	0	0	1
0	0	0	0	4
0	0	0	0	1
0	0	0	0	5

0	0	0	0	3
0	0	0	0	2
0	0	0	0	5
0	0	0	0	7
0	0	0	0	6
0	0	1	0	2
0	0	0	0	6
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0	0	0	0	5
0	0	0	0	2
0	0	0	0	5
0	0	0	0	8
0	0	0	0	0
0	0	0	0	2
0	0	0	0	1
0	0	0	0	2
0	0	0	0	0
0	0	0	0	0
0	0	0	0	5
0	0	0	0	2
0	0	0	0	0
0	0	0	0	1
0	0	0	0	3
0	0	0	0	2
0	0	0	0	3
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	2
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
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0	0	0	0	0
0	0	1	0	1
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

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0	0	0	0	0
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	0	0	3
0	0	0	0	0
0	0	0	0	0
0	0	0	0	1
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	3
0	0	0	0	3
0	0	0	0	2
0	0	0	0	1
0	0	0	0	1
0	0	1	0	1
0	0	0	0	4
0	0	0	0	1
0	0	0	0	0
0	0	0	0	4
0	0	0	0	5
0	0	0	0	2
0	0	0	0	4
0	0	0	0	2
0	0	0	0	3
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0	0	0	0	1
0	0	0	0	4
0	0	0	0	5
0	0	0	0	3
0	0	0	0	0
0	0	0	0	1
0	0	0	0	3
0	0	0	0	2
0	0	0	0	2
0	0	0	0	2
0	0	0	0	1
0	0	0	0	3

0	0	0	0	6
0	0	0	0	2
0	0	0	0	1
0	0	0	0	1
0	0	0	0	4
0	0	0	0	2
0	0	0	0	1
0	0	0	0	2
0	0	0	0	1
0	0	1	0	3
0	0	0	0	2
0	0	0	0	2
0	0	0	0	2
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	2
0	0	0	0	1
0	0	0	0	4
0	0	0	0	2
0	0	0	0	1
0	0	1	0	2
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Cyclotella distinguenda	*Cyclotella meneghiniana*	*Cyclotella michiganiana*	*Cyclotella ocellata*	*Cyclotella radiosa*
0	3	1	0	0
0	4	52	0	0
0	0	3	0	0
0	3	10	0	0
0	3	5	0	1
0	23	3	0	0
0	3	0	0	0
0	3	9	0	0
0	0	36	0	0
0	0	26	0	0
0	0	41	0	0
0	0	25	3	1
0	0	3	2	0
0	0	7	28	0
0	0	36	1	0
0	0	34	1	3
6	0	2	1	6
0	0	20	0	0
0	0	8	0	0
0	0	28	0	0
0	0	11	0	0
0	0	27	0	0
0	1	2	0	0
0	0	13	0	0
0	0	28	0	0
0	0	19	0	0
0	0	0	0	0
0	0	11	0	0
0	0	6	0	0
0	52	15	0	0
0	105	0	0	0
0	35	3	0	0
0	36	0	3	0
0	1	3	0	0
0	3	1	2	0
0	46	0	0	2
0	40	0	2	0
0	2	2	0	1
0	3	0	3	2
0	2	36	0	11
0	0	2	64	0
0	3	0	0	0

0	0	0	10	0
0	1	39	0	1
0	0	26	10	0
0	0	28	0	0
0	0	13	5	1
0	0	23	0	0
0	0	0	24	0
0	0	4	9	0
0	0	34	0	1
0	0	10	16	0
0	0	29	0	0
0	0	10	17	0
0	2	56	0	1
0	0	16	1	0
0	0	33	0	16
0	0	27	5	25
0	0	31	0	52
0	0	71	2	20
0	0	77	0	22
0	0	10	0	6
0	2	5	0	0
0	3	1	0	1
0	41	1	0	0
0	4	2	0	0
0	6	11	0	0
0	26	3	0	0
0	33	4	0	0
0	88	1	0	0
0	11	17	0	0
0	1	12	0	0
0	2	13	0	0
0	0	60	0	0
0	1	61	0	0
0	1	34	0	0
0	0	16	0	0
0	7	0	0	1
0	0	0	0	4
0	0	1	0	0
0	0	3	0	5
0	0	4	0	2
0	0	0	0	2
0	0	0	0	1
0	1	1	0	1
0	0	0	0	2

0	0	1	0	1
0	0	2	0	0
0	0	2	0	0
0	0	1	0	0
0	0	7	0	2
0	0	1	0	2
0	0	6	0	2
0	0	17	0	3
0	0	34	0	17
0	0	61	0	30
0	0	42	0	11
0	0	19	0	22
0	0	13	0	14
0	0	24	0	14
0	0	41	0	15
0	0	66	0	11
0	0	45	0	6
0	0	34	0	6
0	0	24	0	3
0	0	26	0	9
0	0	20	0	9
0	0	20	0	5
0	0	22	0	1
0	0	32	0	6
0	0	46	0	11
0	0	29	0	4
0	0	14	0	0
0	0	13	0	1
0	0	17	0	3
0	0	18	0	2
0	0	9	0	3
0	0	0	0	1
0	0	1	0	2
0	1	0	0	0
0	0	4	0	2
0	0	0	0	2
0	0	0	0	0
0	0	1	0	2
0	0	0	0	1
0	0	0	0	6
0	0	1	0	10
0	0	0	0	15
0	1	1	0	21
0	0	0	0	28

0	1	0	0	14
0	0	0	0	13
0	0	1	0	17
0	0	0	0	21
0	0	1	0	23
0	1	1	0	7
0	0	2	0	9
0	1	3	0	33
0	0	2	0	12
0	0	1	0	16
0	1	1	0	20
0	0	0	0	23
0	0	2	0	7
0	0	2	0	9
0	1	2	0	6
0	0	2	0	15
0	0	3	0	7
0	0	4	0	5
0	0	8	0	5
0	0	3	0	9
0	0	2	0	10
0	0	7	0	27
0	0	15	0	50
0	4	12	0	8
0	4	11	0	18
0	0	32	0	8
0	0	34	0	4
0	1	67	0	1
0	0	33	0	1
0	0	66	0	0
0	3	49	0	0
0	0	34	0	2
0	0	38	0	4
0	0	43	0	10
0	0	96	0	29
0	0	58	0	21
0	1	50	0	7
0	0	45	0	1
0	0	61	0	8
0	0	71	0	2
0	0	43	0	2
0	0	37	0	5
0	0	36	0	2
0	0	28	0	6

0	0	32	0	1
0	0	17	0	1
0	0	10	0	1
0	0	8	0	1
0	0	18	0	0
0	0	4	0	1
0	1	10	0	3
0	0	9	0	0
0	3	13	0	5
0	0	4	0	2
0	2	9	0	5
0	0	2	0	2
0	0	5	0	4
0	0	4	0	1
0	5	5	0	7
0	0	3	0	1
0	1	3	0	1
0	0	4	0	0
0	1	3	0	3
0	0	5	0	0
0	0	1	0	0
0	0	2	0	0
0	1	4	0	0
0	0	1	0	0
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0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Cyclotella rossii	*Cyclotella* sp.	*Cymbella affinis*	*Cymbella cesatii*	*Cymbella* cf. *cistula*
1	0	0	0	4
15	0	0	0	3
9	0	0	0	7
5	0	0	0	4
4	0	0	0	1
11	0	0	0	4
1	0	0	0	4
9	0	0	0	1
6	0	0	0	1
3	0	0	0	1
0	0	0	0	4
0	1	4	0	5
0	0	0	0	3
1	0	0	0	2
0	1	0	0	3
0	2	0	0	1
0	2	0	0	0
0	1	0	0	1
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0
0	0	0	0	4
0	1	0	0	0
0	0	0	0	1
0	0	0	0	5
1	0	0	0	0
1	1	0	0	3
0	0	0	0	2
0	0	0	0	6
4	0	0	0	2
0	3	0	0	0
8	0	0	0	1
0	4	0	0	1
6	0	0	0	0
0	1	0	0	1
24	0	0	0	1
2	1	0	0	0
19	0	0	0	1
0	0	0	0	3
25	0	0	0	3
0	0	0	0	0
184	0	0	0	1

4	2	0	0	4
29	0	0	0	2
20	2	0	0	1
35	0	0	0	4
7	4	0	0	2
29	0	0	0	2
34	0	0	0	0
47	0	0	0	0
29	0	0	0	1
44	0	0	0	1
115	0	0	0	1
43	0	0	0	1
59	0	0	0	0
13	3	0	0	2
35	0	0	0	2
30	2	0	0	0
42	0	0	0	4
23	0	0	0	0
23	0	0	0	1
14	2	0	2	1
19	0	0	0	0
3	0	0	0	0
12	1	0	0	0
4	0	0	0	0
10	0	0	0	0
10	0	0	0	0
13	0	0	0	0
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0	0	0	0	3
2	0	0	0	5
0	0	0	0	3
0	0	0	0	2
1	0	0	0	0
0	0	0	0	4
46	0	0	0	3
77	0	0	0	1
68	0	0	0	0
95	1	0	0	0
112	0	0	0	1
100	0	0	0	2
72	0	0	0	1
112	0	0	0	1
143	0	0	0	1

132	1	0	0	2
118	0	0	0	8
124	0	0	0	3
153	0	0	0	3
199	0	0	0	3
158	0	0	0	4
112	1	0	0	6
92	0	0	0	2
34	0	0	0	3
49	0	0	0	1
109	0	0	0	0
100	0	0	0	5
104	0	0	0	2
56	0	0	0	3
43	0	0	0	3
15	0	0	0	1
23	1	0	0	1
25	0	0	0	2
16	0	0	0	1
27	0	0	0	3
32	1	0	0	0
31	0	0	0	2
64	1	0	0	0
32	0	0	0	6
79	0	0	0	0
50	0	0	0	1
117	0	0	0	3
89	1	0	0	2
84	0	0	0	0
89	0	0	0	6
122	0	0	0	0
198	0	0	0	1
132	0	0	0	1
166	0	0	0	0
114	0	0	0	1
109	0	0	0	2
133	0	0	0	3
86	0	0	0	3
109	0	0	0	5
90	0	0	0	1
80	0	0	0	3
77	0	0	0	3
74	0	0	0	1
74	0	0	0	3

51	0	0	0	1
49	0	0	0	0
62	0	0	0	0
67	0	0	0	2
76	1	0	0	0
41	0	0	0	0
57	0	0	0	4
74	0	0	0	3
35	0	0	0	0
55	0	0	0	0
65	0	0	0	2
77	0	0	0	1
54	1	0	0	2
91	0	0	0	1
171	0	0	0	1
136	0	0	0	1
98	0	0	0	0
119	0	0	0	4
64	0	0	0	6
54	0	0	0	2
60	0	0	0	3
74	0	0	0	2
51	0	0	0	1
38	0	0	0	1
14	0	0	0	2
19	0	0	0	5
14	0	0	0	0
5	0	0	0	5
10	0	0	0	0
4	0	0	0	0
10	0	0	0	15
9	1	0	0	2
31	0	0	0	5
9	0	0	0	1
7	0	0	0	0
17	0	0	0	2
21	0	0	0	1
26	0	0	0	2
29	0	0	0	2
26	0	0	0	0
21	0	0	0	3
24	0	0	0	1
17	0	0	0	1
15	0	0	0	2

20	0	0	0	1
6	0	0	0	1
10	0	0	0	0
6	0	0	0	1
7	0	0	0	0
12	0	0	0	0
12	0	0	0	0
6	0	0	0	1
19	0	0	0	1
11	0	0	0	0
15	0	0	0	0
17	0	0	0	0
9	0	0	0	0
28	0	0	0	0
19	0	0	0	0
9	0	0	0	0
14	0	0	0	0
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11	0	0	0	0
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4	0	0	0	0
4	0	0	0	0
8	0	0	0	0
6	0	0	0	0
10	0	0	0	0
11	0	0	0	0
9	0	0	0	0
5	0	0	0	0
6	0	0	0	0
6	0	0	0	0
4	0	0	0	1
14	0	0	0	0

Cymbella cymbiformis var. *nonpunctata*	*Cymbella leptoceros*	*Cymbella microcephala*	*Cymbella minuta*	*Cymbella muelleri* fo. *Ventricosa*
9	5	1	0	15
6	0	5	0	3
13	14	3	0	3
22	41	3	0	5
4	2	1	0	0
9	2	2	0	5
13	1	7	0	2
10	0	1	0	0
4	0	6	0	0
2	5	3	0	1
7	1	8	0	5
4	4	8	0	2
4	0	1	1	3
0	2	3	0	2
2	1	5	0	1
0	0	4	0	0
2	2	5	0	0
1	3	3	0	0
5	2	3	0	0
6	1	5	0	3
2	2	4	0	1
3	5	8	0	1
0	2	4	0	1
4	0	5	0	1
3	9	7	0	2
2	0	3	0	1
5	1	4	0	3
4	0	3	0	0
14	2	9	0	3
7	2	0	0	5
5	1	2	0	3
4	4	1	0	6
3	5	0	0	1
1	1	1	0	1
4	6	6	0	2
1	0	1	0	1
1	0	4	0	1
3	0	7	0	1
3	4	5	0	3
2	3	5	0	2

1	0	2	0	0
2	0	0	0	2
3	1	1	0	6
4	3	0	0	0
1	0	2	0	5
1	8	2	0	8
2	8	1	0	2
3	2	4	0	2
0	6	7	0	2
2	2	5	0	1
3	0	9	0	3
3	6	2	0	1
2	2	3	0	1
1	5	4	0	2
4	2	4	0	0
2	4	4	0	0
3	3	3	0	0
3	2	7	0	1
0	8	1	0	1
1	4	6	0	1
3	0	3	0	1
3	2	9	0	1
4	1	8	0	0
0	1	1	0	2
0	0	4	0	0
3	6	8	0	3
7	0	4	0	3
6	0	4	0	2
4	1	4	0	5
4	3	4	0	3
18	4	5	0	2
3	5	3	0	0
6	1	6	0	1
4	2	7	0	2
4	2	8	0	1
8	2	7	0	3
2	3	6	0	4
0	0	1	0	6
1	1	5	0	0
1	2	0	0	2
0	1	0	0	0
3	5	3	0	0
0	5	5	0	1
2	0	5	0	0

4	1	5	0	0
0	1	5	0	0
2	3	1	0	3
7	1	5	0	0
3	6	3	0	2
0	3	11	0	0
1	4	2	0	2
0	0	1	0	0
2	2	2	0	2
4	3	5	0	1
2	3	5	0	4
4	3	12	0	0
0	3	6	0	1
6	4	3	0	0
1	3	3	0	2
2	1	2	0	1
1	2	1	0	2
2	0	4	0	1
2	2	1	0	2
2	1	5	0	1
1	2	2	0	0
3	5	5	0	1
1	0	4	0	0
4	7	4	0	0
2	4	5	0	0
2	0	6	0	0
3	3	9	0	0
1	4	2	0	0
1	8	7	0	1
0	1	5	0	1
1	3	2	0	1
2	4	1	0	2
6	4	1	0	2
0	3	3	0	1
0	2	7	0	1
2	4	5	0	0
5	0	2	0	1
7	2	4	0	1
2	2	6	0	0
7	1	2	0	0
3	1	1	0	1
7	0	2	0	5
3	1	3	0	2
1	4	1	0	2

0	1	3	0	0
2	4	0	0	0
4	3	2	0	0
1	0	1	0	0
5	0	5	0	0
4	3	0	0	1
1	3	5	0	0
4	5	7	0	0
7	2	7	0	3
2	6	6	0	2
0	5	4	0	0
7	0	8	0	0
11	4	5	0	2
3	16	4	0	0
5	10	3	0	1
2	0	7	0	1
1	4	6	0	1
5	8	1	0	1
2	10	8	0	0
4	14	5	0	2
7	7	3	0	0
5	17	6	0	0
3	2	4	0	3
2	8	4	0	2
6	4	5	0	0
5	4	6	0	0
10	6	6	0	0
8	11	10	0	1
1	9	16	0	0
8	3	14	0	1
14	5	20	0	0
0	1	6	0	0
0	2	2	0	5
4	4	5	0	0
1	2	2	0	2
4	2	5	0	0
1	6	9	0	0
0	6	10	0	0
1	0	8	0	2
1	2	2	0	1
0	2	6	0	2
1	0	5	0	0
3	3	3	0	0
0	3	2	0	1

4	1	3	0	0
2	0	0	0	1
1	2	1	0	0
0	0	1	0	1
1	1	2	0	0
0	1	1	0	0
0	0	2	0	0
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1	0	2	0	0
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0	0	0	0	0
0	0	0	0	1
0	0	1	0	0
0	0	0	0	0
0	0	1	0	0
0	0	1	0	0
0	0	0	0	0

Cymbella naviculiformis	*Cymbella proxima*	*Cymbella pusilla*	*Cymbella silesiaca*	*Cymbopleuro* sp.
0	0	0	4	0
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0	1	0	17	0
0	1	0	37	0
0	0	0	10	6
0	0	0	11	0
1	2	0	20	0
0	0	0	13	0
0	0	0	13	0
0	0	0	16	0
0	0	0	13	0
0	1	1	9	0
1	1	0	0	0
0	0	0	9	0
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0	2	0	7	0
0	0	0	3	0
0	0	0	2	0
0	0	0	8	0
1	1	0	18	0
0	3	0	8	0
0	0	0	10	0
0	0	0	2	0
0	0	0	14	0
0	0	0	9	0
0	1	0	21	0
0	0	0	5	0
0	0	0	12	0
0	0	0	10	0
0	3	0	35	0
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0	0	0	35	0
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0	1	1	0	2
0	0	0	5	0
1	0	0	5	0
6	0	0	2	0
0	0	0	3	0
0	0	0	5	0

0	0	0	5	0
0	0	0	7	0
0	0	0	4	0
4	0	0	8	0
0	2	0	7	0
0	0	0	5	0
0	0	0	4	0
0	0	0	0	0
1	0	0	3	0
0	3	0	9	0
0	1	0	0	0
0	1	0	1	0
0	0	0	1	0
0	0	0	0	0
0	0	0	0	0
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0	0	0	9	0
0	0	0	2	0
0	0	0	17	0
1	0	0	10	2
0	0	0	6	0
0	0	0	20	0
0	0	0	22	0
0	1	0	25	0
0	0	0	8	0
0	1	0	9	0
0	2	0	8	0
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0	0	0	2	0
0	0	0	3	0
0	0	0	3	0
0	0	0	1	0
1	0	0	1	0
0	0	0	4	0

0	0	0	0	0
0	1	0	4	0
0	0	0	3	0
0	1	0	13	0
0	0	0	2	0
0	0	0	3	0
0	2	0	3	0
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0	0	0	4	0
0	1	0	7	0
0	0	0	4	0
0	0	0	4	0
0	0	0	3	0
0	0	0	5	0

0	0	0	0	0
3	0	0	1	0
0	0	0	3	0
0	0	0	2	0
0	0	0	4	0
0	0	0	16	0
0	0	0	12	0
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0	0	0	9	0
0	2	0	14	0
0	0	0	16	0
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0	0	0	10	0
2	0	0	20	0
0	0	0	11	0
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0	0	0	5	0
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0	0	0	13	0
0	0	0	1	0
0	0	0	2	1
0	0	0	5	3
1	0	0	5	0
0	0	0	2	0

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0	0	0	2	0
0	0	0	0	0
0	0	0	0	0
0	0	0	2	0
0	0	0	2	0
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2	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	0	0	1	0

Cymbella sp.	*Denticula kuetzingii*	*Diatoma tenue* var. *elongatum*	*Epithemia adnata*	*Epithemia smithii*
9	1	1	0	3
10	0	1	0	2
6	3	0	2	5
12	13	0	0	1
0	2	1	2	6
9	3	0	0	5
5	6	0	1	1
1	3	0	0	0
1	4	0	1	2
4	1	0.5	0	3
3	1	1	0	3
5	4	0	1	0
5	6	1	0	0
2	1	1	0	0
3	5	0	0	0
0	9	1	0	0
3	4	1	0	0
3	4	2	0	0
4	5	0	0	0
2	7	0	1	0
1	1	1	0	0
2	3	0	0	0
1	2	1	0	0
3	2	0	1	0
8	4	0	0	0
6	4	0	0	1
6	4	0	1	0
2	2	0	0	0
4	4	0	0	0
3	4	1	3	23
5	0	0	1	0
2	2	0	0	4
3	0	0	0	0
2	1	0	0	0
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0	0	0	0	0
6	2	2	0	0
6	1	1	0	0
7	0	0	0	0
1	0	0	2	0
0	2	0	0	0

3	1	0	1	0
3	0	1	0	0
0	1	0	0	0
5	2	0	1	2
1	1	0	0	0
4	6	0	0	0
2	1	1	0	0
2	0	1	2	3
1	2	0	0	0
2	1	0	0	0
1	3	0	0	0
0	2	0	1	4
2	0	0	0	0
2	2	0	0	1
3	1	0	0	0
8	3	0	0	0
0	1	0	0	0
3	0	0	0	0
4	1	0	0	0
1	3	1	0	0
6	1	0	0	0
3	0	0	0	1
2	1	0	0	0
5	0	1	0	0
0	0	0	0	0
3	0	1	1	0
4	2	0	0	0
6	1	0	0	17
6	6	0	0	0
4	7	0	0	0
1	4	0	0	0
1	1	2	0	1
1	2	0	0	0
7	5	0	0	5
4	4	0	0	0
5	0	1	1	3
2	0	0	0	0
2	1	0	0	1
2	0	1	0	0
5	0	0	0	0
4	4	0	0	0
1	1	0	0	0
5	1	1	0	0
3	3	0	0	0

5	8	0	0	0
4	1	0	0	0
4	2	0	0	0
3	0	0	0	0
3	2	0	0	0
5	3	0	0	0
1	1	0	0	0
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4	1	0	0	0
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3	1	0	0	0
8	4	0	0	0
0	1	0	0	0
9	1	0	0	0
2	0	0	1	0
2	0	0	0	0

1	2	0	0	0
3	1	0	0	0
4	1	0	0	0
8	5	0	0	0
0	2	0	0	0
7	8	0	0	0
4	1	0	0	0
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1	2	0	0	0
3	3	0	0	0
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0	2	0	0	0
3	1	1	0	0
0	2	0	0	0
0	3	0	0	0
6	1	0	0	0
0	0	0	0	0

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2	3	1	0	0
1	1	0	0	0
2	0	0	0	0
1	1	0	0	0
0	1	0	0	0
0	0	0	0	0
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0	0	0	0	0
2	0	0	0	0
0	0	0	0	0
0	0	0	0	0
1	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	1	0	0	0

Epithemia sorex	*Epithemia* sp.	*Epithemia turgida* var. *granulata*	*Fragilaria biceps*	*Fragilaria brevistriata*
0	6	3	0	150
0	4	0	0	47
3	8	5	0	85
0	0	3	0	57
1	5	8	0	62
1	2	2	0	44
2	2	0	0	46
2	0	0	0	93
1	0	0	0	47
1	0	2	0	64
0	0	0	0	68
3	2	1	0	48
3	0	0	2	35
1	0	0	3	70
3	0	0	3	76
0	0	0	0	96
0	0	0	0	62
0	0	1	0	45
5	0	1	0	39
4	1	0	0	29
0	0	0	0	77
4	2	0	0	42
4	0	0	0	39
0	1	1	0	60
0	1	0	0	71
0	1	2	0	77
9	0	1	0	99
0	0	0	0	242
5	1	0	0	152
0	6	0	0	71
9	5	0	0	42
0	3	0	0	56
1	0	1	0	63
3	0	0	0	159
0	1	0	0	90
1	2	0	0	32
7	1	0	0	10
0	1	0	0	61
1	0	0	0	65
0	3	0	0	73
1	2	0	0	84

0	2	0	0	85
0	2	1	0	63
0	0	1	0	76
1	0	0	0	55
0	0	0	0	57
0	1	0	0	42
0	0	1	0	62
0	0	0	0	30
1	0	0	0	19
0	0	0	0	36
0	0	0	0	46
0	0	0	0	31
1	0	0	0	44
0	0	0	0	52
1	0	0	0	46
1	0	1	0	51
0	0	0	0	54
0	0	0	0	56
0	0	1	0	52
0	0	0	0	51
0	0	0	0	45
0	2	2	0	59
1	0	0	0	47
4	1	0	0	35
3	0	1	0	77
0	2	0	0	52
7	0	1	0	48
5	10	1	0	58
2	1	0	0	48
9	4	0	0	71
0	2	1	0	236
0	14	0	0	136
0	0	0	0	73
0	0	0	0	52
1	0	1	0	47
0	1	0	0	35
0	0	0	0	70
2	1	0	0	68
0	0	0	0	69
0	0	0	0	75
0	0	0	0	59
0	2	0	0	59
0	0	0	0	67
0	2	1	0	40

0	3	0	0	67
0	0	0	0	83
0	0	0	0	94
0	2	0	0	79
0	1	0	0	64
0	0	0	0	61
0	6	0	0	75
0	2	0	0	52
0	2	0	0	73
0	5	0	0	68
0	0	0	0	77
0	0	0	0	63
0	1	0	0	54
0	0	0	0	53
0	0	0	0	71
0	0	1	0	55
0	0	0	0	51
0	0	0	0	83
0	1	0	0	81
0	0	0	0	99
0	0	0	0	65
0	2	1	0	71
0	0	0	0	53
0	1	0	0	53
0	6	0	0	68
0	0	1	0	75
0	0	0	0	71
0	1	0	0	80
0	2	0	0	91
0	1	0	0	78
0	3	0	0	71
0	1	0	0	85
0	0	0	0	67
1	0	0	0	60
0	2	0	0	87
0	0	0	0	60
0	1	0	0	58
0	4	0	0	60
0	5	0	0	79
0	4	0	0	103
0	5	0	0	87
0	1	0	0	92
0	1	0	0	98
1	2	0	0	94

0	1	0	0	100
0	0	0	0	96
0	0	0	0	111
0	0	0	0	86
0	5	0	0	88
0	3	0	0	78
0	4	0	0	84
0	3	0	0	53
0	2	0	0	35
1	0	0	0	24
0	1	0	0	53
0	1	0	0	67
0	4	0	0	74
0	2	0	0	95
0	2	0	0	42
0	0	0	0	44
0	2	0	0	45
0	0	0	0	50
0	1	0	0	66
0	1	0	0	47
0	2	0	0	66
0	1	0	0	60
0	4	0	0	68
0	3	0	0	58
0	1	0	0	77
0	5	0	0	81
0	2	0	0	61
1	0	0	0	69
0	4	0	0	56
0	1	0	0	39
0	1	0	0	48
0	3	0	0	52
0	3	0	0	30
0	4	0	0	24
0	1	0	0	20
0	2	0	0	23
0	1	0	0	35
0	1	0	0	37
0	1	0	0	32
0	0	0	0	41
0	5	0	0	40
0	1	0	0	53
0	3	0	0	56
0	2	0	0	59

0	1	0	0	49
0	3	0	0	39
0	1	0	0	36
1	1	0	0	30
0	0	0	0	54
0	1	0	0	43
0	0	0	0	33
0	2	0	0	35
0	0	0	0	42
0	1	0	0	65
0	0	0	0	38
0	0	0	0	38
0	1	0	0	68
0	0	0	0	27
0	0	0	0	47
0	0	0	0	41
0	0	0	0	58
0	0	0	0	56
0	1	0	0	36
0	1	0	0	44
0	0	0	0	59
0	1	0	0	51
0	1	0	0	33
0	0	0	0	27
0	0	0	0	30
0	1	0	0	40
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0	0	0	0	42
0	0	0	0	51
0	1	0	0	44
0	2	0	0	34
0	0	0	0	71
0	2	0	0	64
0	1	0	0	36

Fragilaria capucina	*Fragilaria* cf. *tenera* (W. Sm.) Lange-Bertalot	*Fragilaria construens*	*Fragilaria construens* var. *venter*	*Fragilaria crotonensis* Kitt.
1	1	3	3	0
8	5	6	5	0
4	1	1	3	1
1	0	1	1	4
0	2	2	3	0
8	1	2	14	1
10	2	3	12	1
5	2	6	9	0
8	8	5	11	3
6	3	11	22	0
7	13	4	11	0
6	10	17	13	3
9	18	6	8	4
1	0	2	2	18
7	0	9	6	14
3	0	20	2	12
5	1	33	20	15
5	9	12	8	38
5	0	7	11	2
7	4	7	14	3
2	4	7	14	1
6	15	1	13	22
5	3	2	11	43
5	8	5	27	15
1	4	9	34	3
7	14	3	0	16
4	4	9	0	1
4	2	6	2	4
5	6	0	7	6
6	1	5	9	0
4	2	8	14	2
5	3	17	8	0
9	10	22	13	6
4	4	50	24	0
5	6	15	5	1
7	3	8	8	1
1	2	4	6	0
5	10	9	17	0
9	8	12	9	7
6	2	7	20	3
2	1	12	12	0

0	2	17	17	0
3	3	15	20	4
4	7	2	23	1
4	8	5	24	2
4	4	7	15	0
2	5	10	17	10
4	27	2	15	0
0	5	16	11	5
0	7	6	5	8
7	9	9	18	5
2	3	13	13	3
2	29	8	10	3
1	1	20	14	0
1	7	8	19	0
7	2	29	16	2
4	9	10	12	0
6	3	7	6	4
4	6	5	8	0
3	4	8	13	6
3	10	1	19	0
7	13	4	12	3
4	12	2	14	1
6	3	2	9	0
6	6	4	1	0
3	7	10	5	0
10	40	28	13	1
4	7	26	16	2
4	3	10	10	0
4	1	6	7	0
28	9	4	3	0
5	6	2	3	5
11	2	7	0	0
1	12	5	4	37
4	17	6	32	6
7	4	4	32	2
2	51	0	15	0
1	0	4	11	0
3	20	8	8	3
1	20	6	19	4
0	9	6	12	1
2	14	6	14	5
2	15	2	8	3
1	31	4	9	10
0	60	6	15	17

2	20	3	11	10
3	10	7	21	6
0	7	13	18	0
2	5	10	15	4
5	7	8	18	3
2	3	6	17	2
3	5	4	12	2
1	7	8	14	2
2	16	4	20	1
2	8	13	7	4
2	4	1	12	2
0	7	3	13	1
2	14	8	17	0
2	9	13	10	2
3	6	11	25	1
0	5	5	17	0
0	7	11	12	1
0	4	4	18	0
3	8	9	13	3
2	7	8	26	1
3	11	8	22	2
2	23	13	13	3
6	10	0	13	2
0	32	10	9	5
1	33	8	12	4
3	4	9	30	1
0	7	7	20	0
1	2	10	21	0
2	8	11	31	0
1	6	7	20	0
2	6	9	32	0
1	3	14	24	0
0	6	9	20	0
7	4	4	10	0
2	7	9	16	3
1	51	6	14	0
4	23	8	27	2
2	12	7	18	0
5	13	11	28	0
5	12	11	22	0
3	19	10	19	0
2	5	9	20	1
1	3	15	15	0
0	4	12	32	0

0	9	13	26	0
2	17	13	25	0
4	27	4	29	0
2	49	9	18	2
4	68	10	19	0
2	70	5	10	0
3	115	8	18	0
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2	75	7	10	0
6	131	5	4	0
4	169	9	11	0
1	45	15	19	0
3	15	12	13	0
2	23	8	19	0
4	85	1	21	0
2	10	5	11	0
2	26	5	12	0
0	5	10	11	0
0	25	4	13	0
1	12	14	14	0
6	20	4	19	0
1	9	2	24	0
0	19	10	12	0
2	26	7	10	2
2	22	13	20	0
2	21	8	17	0
1	40	17	22	0
1	35	7	8	0
2	29	4	17	0
3	46	4	18	0
0	91	5	10	0
1	79	7	12	0
3	99	4	11	0
4	112	1	12	0
3	233	4	3	0
6	108	6	5	0
3	75	9	10	0
4	33	11	10	3
1	64	5	10	0
0	41	8	12	0
2	16	7	15	0
0	19	13	10	0
2	12	6	14	0
0	22	10	11	0

1	8	15	17	0
0	17	16	20	0
0	9	12	12	0
1	7	20	11	0
0	3	16	12	0
0	2	13	9	0
0	3	19	27	0
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0	1	14	20	0
0	11	6	11	0
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1	3	5	14	0
0	1	9	32	0
1	0	11	22	0
0	2	11	21	0
0	0	16	21	0
0	0	13	11	0
0	2	9	23	0

Fragilaria dilatata	*Fragilaria famelica*	*Fragilaria lapponica*	*Fragilaria leptostauron*	*Fragilaria paracitica*
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0	0	1	2	0
1	0	2	0	0
1	0	8	0	0
2	5	4	0	0
1	7	2	0	0
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0	0	0	0	0
0	0	1	0	0
0	0	2	0	0
0	0	1	0	0
0	0	2	0	0
0	0	0	0	0

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0	0	2	0	0
0	0	1	0	0
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0	0	0	0	0
0	0	0	0	0

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0	0	0	0	0
1	0	2	2	0
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0	0	0	0	0
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0	0	0	0	0
0	0	0	0	0
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1	0	1	0	0
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0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
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0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	3	6	0

Fragilaria pinnata	*Fragilaria ulna* aff *Synedra ulna* var. *claviceps*	*Fragilaria ulna* var. *acus*	*Gomphonema angustum*	*Gomphonema gracile*
5	2	5	2	0
33	1	4	2	7
9	3	1	4	5
5	3	7	6	0
2	1	2	2	0
16	1	2	15	0
16	2	10	7	0
20	1	1	3	0
13	0	1	3	0
11	1	1	5	0
12	1	2	0	0
4	1	0	3	0
22	0	0	7	0
8	0	0	0	0
7	0	0	4	0
30	2	0	3	0
32	1	0	4	0
29	2	0	4	0
8	3	0	4	0
8	2	0	1	0
38	3	0	3	0
19	2	2	1	0
34	1	1	3	0
38	1	2	5	0
31	2	1	2	0
5	4	2	3	0
15	3	2	3	0
7	0	1	4	0
16	0	2	3	0
12	0	3	1	0
26	0	0	6	0
11	1	2	5	2
15	1	4	3	0
21	0	1	6	0
7	1	3	3	0
14	0	1	4	0
7	0	0	1	0
22	0	0	12	0
18	0	1	6	0
8	0	2	9	0
19	1	0	1	0

22	1	1	0	0
19	0	2	4	0
24	0	1	5	0
19	0	0	6	0
21	0	0	7	0
20	0	1	11	0
8	0	2	5	0
13	1	0	4	0
10	1	1	0	0
14	1	0	4	0
13	1	1	4	0
5	0	0	3	0
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24	0	1	8	0
9	0	1	1	0
7	0	0	0	0
13	2	4	4	0
23	1	1	6	0
20	0	1	5	0
12	1	0	4	0
8	0	2	3	0
5	3	5	3	0
2	1	2	1	0
1	0	4	0	0
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34	0	0	5	0
17	0	2	3	0
17	1	1	4	0
20	0	0	0	0
10	0	0	0	0
9	1	0	3	0

16	0	0	2	0
13	1	3	4	0
20	1	1	2	0
22	1	1	6	0
19	0	2	7	0
10	0	3	4	0
12	1	2	11	0
11	1	2	5	0
19	1	1	16	0
14	0	1	9	0
20	1	1	7	0
20	0	2	5	0
22	2	1	17	0
39	0	1	11	0
24	0	3	7	0
30	0	3	8	0
31	0	2	9	0
27	0	1	3	0
30	1	1	8	0
40	1	2	5	0
31	1	1	9	0
47	0	2	6	0
16	0	1	11	0
54	1	0	6	0
28	1	0	9	0
33	0	0	1	0
34	0	0	3	0
28	0	0	3	0
16	1	1	3	0
29	1	0	4	0
28	0	0	5	0
40	0	0	0	0
27	0	0	1	0
20	0	1	6	0
20	1	1	2	0
27	1	1	4	0
18	0	1	5	0
21	1	1	5	0
36	1	1	5	0
32	0	0	6	0
46	0	1	5	0
27	0	2	3	0
38	0	1	5	0
41	1	1	2	0

49	0	0	3	0
36	0	1	3	0
68	1	2	3	0
40	0	0	6	0
39	1	1	9	0
31	0	2	5	0
37	0	1	12	0
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22	0	1	15	0
16	0	1	7	0
29	0	1	5	0
24	0	1	13	0
42	1	1	18	0
36	1	1	14	0
33	0	2	15	0
16	0	1	10	0
43	1	1	15	0
26	0	1	8	0
40	1	1	13	0
32	1	1	19	0
33	1	2	30	0
29	2	1	27	0
30	0	1	10	0
33	3	1	10	0
54	0	1	16	0
48	1	1	13	0
46	0	2	21	0
17	1	2	20	0
20	0	1	39	0
35	1	1	34	0
32	0	3	11	0
38	0	1	17	0
8	1	4	18	0
16	3	1	10	0
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15	0	1	15	0
23	0	1	16	0
26	0	1	10	0
20	0	1	7	0
14	0	1	4	0
31	0	0	5	0

27	0	0	4	0
29	1	0	3	0
40	0	1	0	0
24	0	0	5	0
41	0	0	0	0
44	0	0	5	0
34	0	1	2	0
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39	0	0	2	0
17	0	0	0	0
50	0	0	3	0
77	0	0	0	0
64	0	0	0	0
78	0	1	0	0
53	0	0	0	0
56	0	1	1	0
73	0	0	5	0
47	0	0	1	0
61	0	0	2	0
62	0	0	3	0
49	0	1	0	0
49	0	0	1	0
58	0	0	0	0
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46	0	0	1	0
48	0	0	0	0
35	0	0	0	0
57	0	0	0	0
42	0	0	0	0
29	0	1	0	0

Gomphonema sp.	*Gomphonema subtile*	*Gomphonema truncatum*	*Hantzschia spectabilis* (Ehrenb.) Hust.	Indeterminate
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3	0	2	0	3
4	0	1	0	2
3	0	0	0	3
0	0	0	0	0
1	0	2	0	3
0	0	0	0	2
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	3
0	1	0	0	0
3	1	0	0	5
2	0	0	0	1
0	1	0	0	0
0	0	0	0	1
0	1	0	0	0
0	1	0	0	1
0	1	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	2	0	2
0	0	0	0	3
8	0	0	0	0
2	0	0	0	3
2	0	0	0	0
0	0	0	0	1
2	0	1	1	0
8	0	0	0	3
3	0	0	0	0
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1	0	0	0	0
1	0	0	0	1
1	0	0	0	0
0	0	0	0	0
1	0	0	0	0
0	0	0	0	1

1	0	0	0	2
2	0	0	0	0
3	0	0	0	1
0	0	0	0	0
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
2	0	0	0	0
0	0	0	0	0
0	0	0	0	0
4	0	0	0	3
0	0	0	0	1
4	0	0	0	0
0	0	0	0	0
3	0	0	0	0
1	0	0	0	0
2	0	0	0	4
0	0	0	0	0
0	0	0	0	3
2	0	0	0	0
2	0	0	0	0
0	0	0	0	0
5	0	0	0	2
0	0	0	0	0
2	0	0	0	4
1	0	0	0	1
3	0	0	0	2
1	0	0	0	1
5	0	0	0	4
0	0	0	0	2
13	0	0	0	0
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5	0	0	0	2
0	0	0	0	0
10	0	0	0	2
0	0	2	0	0
2	0	0	0	0
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7	0	0	0	2
0	0	0	0	2
2	0	0	0	4
4	0	0	0	4
1	0	0	1	4

0	0	0	0	1
1	0	0	0	0
1	0	0	0	1
2	0	0	0	2
3	0	0	0	2
3	0	0	0	0
1	0	1	0	0
0	0	0	0	2
1	0	0	0	1
0	0	0	0	0
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1	0	0	0	1
0	0	0	0	0
1	0	0	0	1
3	0	0	0	4
0	0	0	0	0
0	0	0	0	2
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1	0	0	11	3
2	0	0	0	9
1	0	0	1	1
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1	0	0	0	0
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0	0	0	0	1
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3	0	0	0	2
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0	0	0	0	0
1	0	0	0	0
0	0	0	0	0

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1	0	0	1	0
2	0	0	1	0
0	0	0	0	0
1	0	0	0	0
4	0	0	0	0
2	0	0	0	0
2	0	0	0	0
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0	0	0	0	0
1	0	0	0	0
4	0	0	0	0
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1	0	0	0	0
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2	0	0	0	1
0	0	0	0	0
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1	0	0	0	0
8	0	0	0	0
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5	0	0	0	0
2	0	0	0	0
1	0	0	0	1
2	0	0	0	1
0	0	0	0	0
1	1	0	0	1
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1	0	0	0	0
1	0	0	0	0
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7	0	0	0	0
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4	0	0	0	1
2	0	0	0	0
2	0	0	0	0
1	0	0	0	0
1	0	0	0	0

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0	0	0	0	0
0	0	0	0	1
0	0	0	0	3
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0	0	0	0	1
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0	0	0	0	0
0	0	0	0	1
2	0	0	0	1
0	0	0	0	1
0	0	0	0	0
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0	0	0	0	0
1	0	0	0	2
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
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0	0	0	0	2
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
1	0	0	0	0

Mastogloia grevillei	*Mastogloia smithii*	*Navicula cari*	*Navicula* cf. *trivialis*	*Navicula cincta*
0	2	0	1	0
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0	1	0	0	0
0	2	1	0	0
0	6	3	0	0
0	6	0	0	0
1	3	0	3	0
1	5	0	1	0
4	5	4	2	0
0	0	1	2	0
0	3	0	1	0
1	2	1	2	0
1	7	0	2	0
0	4	0	0	0
0	7	0	0	0
0	4	0	0	1
0	4	0	1	0
2	7	1	0	0
0	2	0	0	0
0	3	1	0	0
0	6	1	0	0
2	2	0	2	0
0	1	0	1	0
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0	2	0	0	0
0	4	0	0	0
2	3	1	3	0
0	1	0	6	0
0	3	0	0	0
0	2	0	0	0

0	10	0	0	0
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1	4	1	0	0
0	8	1	2	0
0	1	0	1	0
0	0	0	2	0
1	1	0	1	1
0	2	0	3	0
0	3	0	3	0
1	2	0	1	0
0	3	0	1	0
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0	3	0	2	0
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0	2	0	1	0
0	5	0	0	0
0	1	0	0	0
0	2	0	1	0
0	1	0	1	0
0	2	0	0	0

0	5	0	0	0
0	6	0	0	0
0	10	0	0	0
0	5	0	0	0
0	3	0	3	0
0	4	0	2	0
0	1	0	1	0
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0	0	0	0	0
0	1	0	0	0
0	3	0	2	0
0	8	0	0	0
0	4	0	0	0
0	4	0	0	0

0	2	0	1	0
0	4	0	0	0
0	1	0	0	0
0	2	0	0	0
0	2	0	0	0
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0	1	0	0	0
0	4	0	0	0
0	3	0	0	0
0	2	0	1	0
0	3	0	0	0
0	3	0	0	0

0	2	0	0	0
0	0	0	0	0
0	3	1	0	0
0	4	0	0	0
0	1	0	0	0
0	3	0	0	0
0	0	0	0	0
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0	3	0	0	0
0	0	0	0	0
0	3	0	0	0
0	0	0	0	0
0	1	0	0	0
0	0	2	0	0

Navicula cryptotenella Lange-Bertalot	*Navicula diluviana*	*Navicula halophila*	*Navicula mutica*	*Navicula oblonga*
0	1	0	0	13
4	11	0	0	11
1	11	0	0	25
0	3	0	0	8
0	8	1	0	16
1	22	0	0	23
3	31	1	0	9
2	43	0	0	9
3	30	1	0	12
2	36	1	0	15
1	23	0	0	16
1	15	0	0	17
0	22	0	0	10
0	22	0	0	2
1	17	0	0	3
2	8	0	0	12
1	18	2	0	6
3	11	0	0	7
2	40	1	0	8
2	13	1	0	9
5	10	0	0	6
2	10	0	0	9
3	18	0	0	7
4	5	0	0	5
3	14	0	0	17
1	22	2	0	26
3	37	0	0	44
3	0	0	0	4
1	0	4	0	15
1	4	0	0	22
0	4	1	0	6
1	7	0	0	1
2	3	0	0	8
1	16	0	0	1
0	8	0	0	7
2	15	1	0	2
1	6	0	0	0
8	35	1	0	0
1	50	0	0	1
1	40	1	0	0
1	35	0	0	0

3	42	0	0	1
0	51	0	0	2
1	39	1	0	2
1	56	0	0	0
0	46	0	0	6
7	26	0	0	2
1	26	2	0	1
0	25	0	0	1
1	18	0	0	3
2	34	0	0	5
2	32	0	0	4
0	41	0	0	2
1	30	0	0	3
1	58	1	0	3
0	77	0	0	4
0	63	0	0	2
3	35	0	0	3
0	38	0	0	3
1	37	0	0	3
1	24	0	0	1
2	35	0	0	1
1	29	0	0	0
1	18	0	0	2
1	17	1	0	3
0	9	2	0	1
3	9	0	0	2
0	6	0	0	5
0	11	0	0	6
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1	29	1	0	15
6	10	0	0	9
4	19	0	0	10
5	22	0	0	17
1	31	0	0	0
1	32	1	0	0
0	32	0	0	1
4	27	0	3	3
2	25	1	0	0
1	19	0	0	3
5	31	0	0	1
3	23	0	0	2

0	39	0	0	0
1	43	0	0	5
1	32	0	0	2
1	25	0	0	0
2	10	0	0	0
0	20	0	0	1
1	38	0	0	1
1	29	0	0	0
2	39	1	0	0
1	29	2	0	1
1	40	0	0	0
1	16	0	0	0
1	29	1	0	0
0	44	0	0	1
1	25	0	0	2
1	34	2	0	2
2	30	0	0	1
1	33	0	0	0
1	37	0	0	3
1	19	0	0	1
3	22	0	0	1
2	20	1	0	0
2	14	0	20	3
1	17	0	0	0
3	25	0	0	1
2	46	1	0	0
1	25	0	0	0
0	27	0	0	1
1	21	0	0	1
1	25	0	0	0
0	15	0	0	0
1	14	0	0	2
0	22	0	0	0
0	31	0	0	1
0	10	0	0	0
3	24	0	0	1
2	33	1	0	2
1	18	1	0	0
1	33	1	0	2
2	23	0	0	0
1	30	0	0	2
0	24	0	0	0
1	31	0	0	1
2	16	0	0	0

1	27	0	0	0
2	14	0	0	1
1	13	0	0	0
0	19	0	0	0
1	11	0	0	2
2	12	0	0	0
2	25	0	0	1
4	14	0	0	0
4	19	0	0	1
3	5	0	0	1
0	16	0	0	2
3	22	0	0	0
2	27	0	0	1
1	22	0	0	0
0	21	0	0	0
0	25	1	0	1
1	16	0	0	0
0	36	0	0	1
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2	32	1	0	0
1	33	0	0	1
2	36	0	0	0
1	27	1	0	1
0	37	1	0	0
3	36	0	0	2
4	18	0	0	2
2	34	0	0	1
1	34	1	0	0
3	20	0	0	0
3	21	0	0	0
7	23	0	0	1
5	17	0	0	0
3	18	1	0	0
2	16	1	0	0
2	33	0	0	0
5	38	0	0	0
4	47	0	0	1
2	56	0	0	0
1	70	0	0	0
1	64	0	0	1
1	78	0	0	1
1	56	0	0	0

0	81	0	0	0
4	71	0	0	1
0	100	1	0	0
0	82	0	0	1
2	99	0	0	0
0	120	0	0	0
0	108	0	0	0
2	108	0	0	2
0	100	0	0	1
1	81	0	0	1
1	130	0	0	0
2	94	0	0	3
1	97	0	0	0
0	71	0	0	1
2	82	0	0	4
0	90	0	0	0
0	67	0	0	1
1	84	0	0	0
1	89	0	0	0
0	79	0	0	0
0	101	0	0	0
0	103	0	0	3
1	95	0	0	1
0	84	0	0	1
0	99	0	0	1
0	89	0	0	0
0	104	0	0	2
0	91	0	0	0
0	90	0	0	0
0	110	0	0	0
0	85	0	0	0
0	77	0	0	0
0	95	0	0	0
0	82	0	0	0

Navicula pseudotuscula	*Navicula pupula*	*Navicula pusilla*	*Navicula radiosa*	*Navicula* sp.
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0	0	0	0	3
0	0	0	1	3
0	0	0	0	1
0	0	0	1	1
0	1	0	0	2
0	0	0	0	1
0	0	0	0	1
0	0	0	1	4
0	4	1	0	1
0	0	0	0	1
0	0	0	0	1
0	1	0	0	1
0	0	0	2	2
0	0	0	0	0
0	0	0	1	0
2	0	0	1	2
0	0	0	0	2
0	0	0	0	1
0	0	0	1	0
0	0	0	0	0
0	0	0	0	1
0	1	0	0	2
2	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	3
0	0	0	0	0
0	1	0	0	3
0	0	0	0	4
0	0	0	0	1
0	0	0	0	0
0	0	0	0	2
0	0	0	0	0
0	0	0	0	6
0	0	0	0	1
0	0	0	0	4
0	0	0	0	2
0	1	0	0	3

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0	0	0	0	0
0	0	0	0	2
0	1	0	0	0
1	0	0	0	2
0	0	0	0	4
0	0	0	0	1
0	0	0	1	1
0	2	0	0	2
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	1	2
0	1	0	0	1
0	0	0	0	2
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0	1	0	0	1
0	0	0	1	1
0	0	0	0	1
0	0	0	0	2
0	2	0	0	0
0	1	0	2	2
0	0	0	1	3
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0	0	0	0	2
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0	1	0	0	4
0	1	0	0	4
0	0	0	0	2
0	0	0	0	2

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0	0	0	0	1
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0	0	1	1	2
0	0	0	1	0
0	0	0	0	1
0	2	0	0	4
0	0	0	0	1
0	0	0	0	1
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0	1	0	0	2
0	0	0	0	3
0	0	0	0	6
0	0	0	0	4
0	0	0	0	4
0	0	0	0	0
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0	0	0	0	0
0	0	0	0	1
0	1	0	1	1
0	0	0	0	0
0	3	0	0	1
0	1	0	0	2
0	1	0	0	2
0	0	0	0	1
0	0	0	0	2
0	0	0	0	0
0	0	0	0	1
0	0	0	0	2
0	0	0	0	2
0	0	0	0	4
0	0	0	0	2
0	1	0	1	5
0	0	0	0	0

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0	2	0	0	2
0	1	0	0	0
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0	0	0	0	3
0	2	0	0	1
0	0	0	0	3
0	0	0	0	2
0	0	0	0	1
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0	0	0	0	1
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0	0	0	0	4
0	1	0	0	2
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0	0	0	0	6
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0	1	0	0	1
0	1	0	0	2
0	1	0	0	3
0	0	0	0	5
0	0	0	0	1
0	2	0	0	0
0	0	0	0	1
0	0	0	0	1
0	0	0	0	3
0	1	0	0	3
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0	0	0	0	2
0	0	0	0	2
0	0	0	0	2
0	0	0	0	0
0	0	0	0	1
0	0	0	0	3
0	0	0	0	8
0	0	0	0	3
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	2

Navicula veneta	*Navicula vitabunda*	*Neidium ampliatum*	*Nitzschia amphibia*	*Nitzschia angustiforaminata*
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0	0	0	2	0
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0	1	0	2	0
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0	1	1	2	2
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0	0	0	0	0
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0	0	0	0	0
0	1	0	0	0
0	3	0	0	1
0	2	0	0	0

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0	0	0	1	0
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0	1	0	0	0
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0	2	0	0	0
0	0	0	1	0
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0	1	0	0	0
0	1	0	2	0

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0	1	0	0	0
0	2	0	1	0
0	0	1	0	0
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0	4	0	1	0
0	1	0	0	0
0	3	0	1	0
0	3	1	2	0
1	4	1	0	0
0	0	0	1	0

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0	1	0	0	0
0	2	0	2	0
0	1	0	2	0
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0	1	0	0	0
0	3	0	0	0
0	4	0	0	0
0	1	0	1	0
0	5	0	0	0
0	9	0	0	0

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0	4	0	0	0
0	7	0	0	0
0	10	0	0	0
0	7	0	0	0
0	5	0	0	0
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0	3	0	0	0
0	11	0	0	0
0	6	0	0	0
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0	13	0	0	0
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0	4	0	0	0
0	5	0	0	0
0	6	0	0	0
0	6	0	0	0
0	5	0	0	0
0	6	0	0	0

Nitzschia cf. *bacillum*	*Nitzschia* cf. *fonticula*	*Nitzschia commutata*	*Nitzschia* sp.	*Pinnularia gibba*
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0	0	0	2	0
0	0	0	2	0
0	0	0	2	0
0	0	0	0	1
0	0	0	0	0
0	1	0	1	1
0	0	0	2	0
0	0	0	1	0
0	0	0	0	0
0	0	0	4	0
0	0	0	3	0
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0	0	0	3	1
0	0	0	1	0
0	0	0	3	2
0	0	0	1	3
2	0	0	0	0
0	0	0	1	0
2	0	0	3	0
0	0	0	0	0
1	0	0	1	0
0	0	0	6	0
0	0	0	0	0
0	0	0	1	0
0	0	0	0	0
0	0	0	0	0
1	0	0	0	0
0	0	0	2	0

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0	0	0	0	0
0	0	0	1	0
0	0	0	3	2
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0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	2	2
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0	0	0	1	0
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0	0	0	1	0
0	0	0	0	0

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0	0	0	0	0
0	0	0	2	0
0	0	0	2	0
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0	0	0	1	0
0	0	0	1	0
0	0	0	1	2
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0	0	0	4	0
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0	0	0	2	0
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0	0	0	2	0
0	0	0	2	0

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0	0	0	1	0
0	0	0	2	0
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0	0	0	2	0
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0	0	0	7	0
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0	0	0	2	0
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0	0	0	6	1
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0	0	0	1	0
0	0	0	5	0
0	0	0	6	1
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0	0	0	4	0
0	0	0	2	0
0	0	0	4	1
0	0	0	4	1
0	0	0	7	0
0	0	0	9	0
0	0	0	2	0
0	0	0	4	0
0	0	0	4	0
0	0	0	8	0
0	0	0	5	0
0	0	0	3	0
0	0	0	3	0

Pinnularia sp.	*Pinnularia microstauron*	*Rhopalodia gibba*	*Stephanodiscus niagarae*	Total Sum
0	1	1	41	363
0	0	1	3	348
0	1	3	40	369
0	4	2	51	353
0	2	2	116	364
0	3	4	9	334
0	0	0	69	340
0	0	0	54	373
0	0	3	68	371
0	0	3	32	356
0	0	0	40	357
0	0	1	46	325
0	4	0	93	327
0	0	2	82	353
0	4	0	39	333
0	1	0	13	345
0	0	1	9	332
0	0	1	40	341
0	2	2	47	323
0	5	0	83	338
0	3	1	37	335
0	2	1	43	347
0	4	0	34	335
0	2	2	27	363
0	0	3	38	405
0	7	1	32	360
0	7	1	33	374
0	0	1	26	375
0	3	0	17	346
1	4	1	6	380
0	5	2	37	382
0	3	0	75	381
0	3	1	65	368
0	0	0	60	415
0	0	0	80	351
0	0	0	24	425
0	0	0	6	381
0	0	0	43	372
0	0	1	24	362
0	1	1	17	411
0	0	1	17	361
0	1	1	26	483

0	0	0	46	362
0	0	0	34	375
0	1	1	32	367
0	0	1	35	383
0	0	1	44	343
0	0	0	21	367
0	0	2	11	346
0	1	2	38	346
1	2	0	26	348
0	0	1	29	344
1	0	1	22	388
0	0	1	37	350
0	0	0	15	387
0	0	0	28	347
0	0	0	26	391
0	0	0	27	366
0	0	1	10	372
0	0	0	13	391
0	0	0	8	366
0	0	2	29	354
0	3	1	42	382
0	0	0	48	338
0	0	1	20	400
0	0	1	47	344
0	1	0	48	371
0	2	2	59	360
0	1	0	69	361
0	5	2	23	365
0	1	1	5	356
0	1	0	23	409
0	5	5	42	414
0	1	0	21	378
0	4	0	44	405
0	3	0	91	445
0	3	2	27	384
0	0	2	14	377
0	0	0	24	360
0	0	0	25	367
0	0	0	41	376
3	0	0	23	392
5	0	0	10	361
2	0	0	10	360
1	0	0	18	396
1	1	0	16	396

0	0	1	12	452
0	0	0	22	435
0	0	0	17	399
0	0	0	14	411
0	0	1	25	453
0	0	0	19	426
0	0	1	20	364
0	0	1	30	434
0	0	0	30	386
0	0	0	34	455
0	0	0	19	391
0	0	0	19	414
0	0	0	34	449
0	0	0	26	387
0	0	0	27	387
1	0	1	33	400
0	0	0	19	378
0	0	1	24	406
0	0	0	19	368
1	0	0	27	392
9	0	1	35	409
32	0	0	15	353
8	0	0	16	409
2	0	0	17	391
0	0	0	15	479
0	0	0	13	382
0	0	0	16	418
0	0	0	22	421
0	0	0	16	398
0	0	0	14	414
0	0	1	17	427
0	0	0	17	453
0	0	1	28	404
0	0	0	12	415
0	0	0	15	400
0	0	1	20	435
0	0	0	23	418
0	0	0	17	432
0	0	0	16	450
0	0	1	18	481
0	0	0	22	416
0	0	0	28	444
0	0	0	8	412
0	0	2	13	440

0	0	1	25	388
0	0	1	23	410
0	0	0	17	411
0	0	0	26	443
0	0	1	17	416
0	0	0	27	491
0	0	0	19	402
0	0	0	22	417
0	0	0	18	340
0	0	0	18	457
0	0	0	24	453
0	0	0	14	439
2	1	0	15	399
0	0	0	19	439
0	0	0	26	423
0	0	0	20	426
0	0	0	24	382
0	0	0	17	462
0	0	0	25	429
0	0	0	25	479
0	1	0	23	391
0	0	0	13	410
0	0	0	13	430
0	0	0	18	412
0	0	0	31	434
0	0	0	24	496
0	0	1	18	408
0	0	1	28	443
0	0	1	27	446
0	0	1	23	411
0	0	0	18	431
0	0	1	5	400
1	0	1	14	414
0	0	1	4	440
0	0	1	7	421
0	0	1	13	407
0	0	1	21	402
0	0	0	38	415
0	0	0	10	444
0	0	0	8	460
0	0	0	18	420
0	0	0	11	424
0	2	0	14	440
0	0	0	12	439

0	0	0	14	462
0	0	0	4	442
0	1	0	5	377
0	1	1	5	439
0	0	0	7	456
0	0	0	2	444
0	0	0	3	404
0	0	0	2	420
0	0	0	3	434
0	1	0	0	454
0	1	1	4	455
0	1	0	3	421
0	0	0	1	377
0	0	0	2	435
0	1	0	2	514
0	0	0	2	406
0	0	0	1	442
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0	1	0	0	452
0	0	0	1	406
0	2	0	0	400
0	1	0	2	445
0	0	0	0	403
0	1	0	2	443
0	0	0	1	463
0	0	0	0	465
0	0	0	1	459
0	0	0	0	449
0	0	0	0	409
0	0	0	1	433
0	0	0	0	424
0	0	0	2	434

APPENDIX G

LITHOLOGIC AND GEOCHEMICAL DATA FROM DAILEY LAKE

Depth (cm)	Age (cal yr BP)	Magnetic Susceptibility (SI units)
350.0	6429	2
350.5	6435	0.5
351.0	6441	2.3
351.5	6446	2.7
352.0	6452	3
352.5	6457	2.5
353.0	6463	2.6
353.5	6469	2.1
354.0	6475	1.9
354.5	6480	2.5
355.0	6486	2.2
355.5	6492	2.1
356.0	6497	2
356.5	6503	2.6
357.0	6509	3.4
357.5	6514	2.7
358.0	6520	2.1
358.5	6525	2.2
359.0	6531	2.3
359.5	6536	3.2
360.0	6542	11.4
360.5	6549	2.9
361.0	6555	3.4
361.5	6561	6
362.0	6567	1.9
362.5	6574	1.8
363.0	6580	2.1
363.5	6587	2.2
364.0	6593	2.3
364.5	6599	2.9
365.0	6605	3.6
365.5	6612	3.7
366.0	6618	3.5
366.5	6624	4
367.0	6631	4.4
367.5	6637	3.5
368.0	6644	2.7
368.5	6650	2.4
369.0	6656	1.8
369.5	6663	1.9
370.0	6669	1.6

370.5	6675	1.2
371.0	6682	1.4
371.5	6689	1.6
372.0	6695	1.8
372.5	6702	1.9
373.0	6709	2.2
373.5	6715	2
374.0	6722	1.8
374.5	6729	1.9
375.0	6736	1.7
375.5	6742	1.9
376.0	6749	2
376.5	6755	2.2
377.0	6762	2.6
377.5	6769	2.6
378.0	6775	2.3
378.5	6782	2.9
379.0	6788	3.3
379.5	6795	2.8
380.0	6801	2.1
380.5	6807	1.9
381.0	6813	2.2
381.5	6819	1.4
382.0	6825	1.2
382.5	6831	1.3
383.0	6837	1.2
383.5	6842	1.3
384.0	6848	1.5
384.5	6854	1.7
385.0	6860	2
385.5	6866	2.2
386.0	6872	2.2
386.5	6877	2.3
387.0	6883	2.3
387.5	6889	2.5
388.0	6895	1.8
388.5	6901	1.5
389.0	6907	2
389.5	6912	2.1
390.0	6918	1.8
390.5	6925	2.1
391.0	6931	2.3
391.5	6938	2.3
392.0	6944	2.4

392.5	6951	2.3
393.0	6957	2.6
393.5	6964	3.1
394.0	6971	2.5
394.5	6977	2.6
395.0	6984	2.4
395.5	6990	2.2
396.0	6997	2.7
396.5	7004	3.2
397.0	7010	3
397.5	7017	2.4
398.0	7023	2.3
398.5	7030	2.6
399.0	7037	2.5
399.5	7043	2.4
400.0	7050	2.3
400.5	7056	2.7
401.0	7061	2.2
401.5	7067	2.1
402.0	7073	2.1
402.5	7078	2.1
403.0	7084	1.9
403.5	7090	1.7
404.0	7096	1.7
404.5	7101	1.7
405.0	7107	1.7
405.5	7113	2.1
406.0	7119	1.9
406.5	7124	2.1
407.0	7130	3.9
407.5	7136	2.5
408.0	7141	2.1
408.5	7147	2.2
409.0	7153	2.4
409.5	7158	3.7
410.0	7164	2.8
410.5	7169	2.9
411.0	7175	2.9
411.5	7180	2.9
412.0	7186	2.8
412.5	7192	2.8
413.0	7198	2.8
413.5	7203	3
414.0	7209	3

414.5	7215	3
415.0	7221	3.1
415.5	7226	2.9
416.0	7232	2.7
416.5	7238	1.9
417.0	7244	1.7
417.5	7250	1.9
418.0	7255	2
418.5	7261	1.7
419.0	7267	1
419.5	7272	0.4
420.0	7278	0.6
420.5	7284	0.7
421.0	7290	0.6
421.5	7295	0.5
422.0	7301	0.3
422.5	7307	0.2
423.0	7312	0.4
423.5	7318	0.6
424.0	7323	1.2
424.5	7329	1.2
425.0	7335	1.3
425.5	7341	0.9
426.0	7347	1.6
426.5	7352	1.5
427.0	7358	1.6
427.5	7364	1.8
428.0	7370	1.3
428.5	7376	1.1
429.0	7382	1.1
429.5	7388	1.1
430.0	7394	1.2
430.5	7400	1.3
431.0	7406	1.5
431.5	7412	1.4
432.0	7418	1.2
432.5	7424	1.1
433.0	7430	1.6
433.5	7436	1.1
434.0	7442	1.2
434.5	7448	1.5
435.0	7454	2
435.5	7460	2.8
436.0	7466	1.5

436.5	7472	1.5
437.0	7478	1.2
437.5	7485	1
438.0	7491	1.2
438.5	7497	0.6
439.0	7503	0.5
439.5	7509	0.4
440.0	7515	0.5
440.5	7523	1.1
441.0	7530	0.7
441.5	7538	0.7
442.0	7546	0.8
442.5	7553	0.9
443.0	7561	0.7
443.5	7568	1
444.0	7576	1.3
444.5	7584	1.4
445.0	7592	1.8
450.5	7682	0.9
451.0	7693	0.4
451.5	7704	2.5
452.0	7715	2.3
452.5	7726	2.3
453.0	7737	2.4
453.5	7748	2.1
454.0	7759	2.2
454.5	7770	2.5
455.0	7781	2.3
455.5	7792	0.7
456.0	7803	0.7
456.5	7814	0.9
457.0	7825	1.2
457.5	7836	1.1
458.0	7847	1.3
458.5	7858	1.3
459.0	7869	1.7
459.5	7879	1.8
460.0	7890	6.7
460.5	7902	8.3
461.0	7913	2.3
461.5	7925	1.8
462.0	7937	1.7
462.5	7948	1.7
463.0	7960	2

463.5	7972	2.5
464.0	7983	3.4
464.5	7995	1.9
465.0	8007	1.3
465.5	8018	0.4
466.0	8030	0.4
466.5	8041	1
467.0	8052	1.1
467.5	8064	1.4
468.0	8075	1.3
468.5	8087	0.7
469.0	8098	0.9
469.5	8109	1.2
470.0	8121	1.3
470.5	8132	1.2
471.0	8142	1.7
471.5	8154	1.1
472.0	8165	0.5
472.5	8176	0.3
473.0	8187	0.3
473.5	8198	0.2
474.0	8209	0.6
474.5	8220	1.4
475.0	8231	1
475.5	8242	0.8
476.0	8253	1.2
476.5	8265	1.3
477.0	8276	0.6
477.5	8287	0.2
478.0	8298	0.3
478.5	8309	0.3
479.0	8320	0.7
479.5	8331	0.5
480.0	8342	0.2
480.5	8353	0.3
481.0	8365	0.5
481.5	8376	0.9
482.0	8388	1
482.5	8399	1.1
483.0	8411	1.1
483.5	8423	1
484.0	8435	3.1
484.5	8446	1.4
485.0	8458	0.6

485.5	8470	0.5
486.0	8481	0.5
486.5	8493	-0.2
487.0	8505	-0.4
487.5	8516	-0.2
488.0	8528	-0.2
488.5	8540	0
489.0	8551	0.1
489.5	8563	0.1
490.0	8574	0
490.5	8586	0.1
491.0	8598	0.5
491.5	8610	0.7
492.0	8622	1
492.5	8634	1.1
493.0	8646	1
493.5	8658	0.9
494.0	8671	0.8
494.5	8682	1.1
495.0	8694	0.6
495.5	8706	0.2
496.0	8718	0.1
496.5	8730	0.6
497.0	8742	0.1
497.5	8754	0
498.0	8766	-0.5
498.5	8778	-0.4
499.0	8790	0
499.5	8802	0.4
500.0	8814	0
500.5	8826	0.2
501.0	8838	-0.3
501.5	8849	-0.3
502.0	8861	-0.3
502.5	8873	-0.3
503.0	8885	-0.2
503.5	8897	0.3
504.0	8909	1.4
504.5	8921	1.5
505.0	8933	1.7
505.5	8945	1.7
506.0	8957	1.5
506.5	8969	2.3
507.0	8981	0.7

507.5	8993	0.7
508.0	9005	1.2
508.5	9017	1.5
509.0	9029	1.7
509.5	9041	2.2
510.0	9053	3.3
510.5	9059	2.6
511.0	9065	2.6
511.5	9070	3.1
512.0	9076	2.9
512.5	9082	4.3
513.0	9087	3
513.5	9093	2.5
514.0	9098	3.5
514.5	9104	2.6
515.0	9110	2.9
515.5	9115	2.4
516.0	9121	2.6
516.5	9126	2.2
517.0	9132	1.8
517.5	9137	1.2
518.0	9143	0.5
518.5	9149	1.1
519.0	9154	2.1
519.5	9160	2.2
520.0	9165	2.8
520.5	9170	2.3
521.0	9176	0.7
521.5	9182	1.4
522.0	9187	0.7
522.5	9193	0.4
523.0	9198	1.3
523.5	9203	3.1
524.0	9209	1.4
524.5	9214	1.1
525.0	9219	0.8
525.5	9225	0.9
526.0	9230	1
526.5	9236	0.8
527.0	9241	1
527.5	9246	1.1
528.0	9252	1.1
528.5	9257	0.8
529.0	9263	0.9

529.5	9268	0.8
530.0	9274	0.6
530.5	9279	-0.1
531.0	9284	-0.1
531.5	9290	0.2
532.0	9296	0.3
532.5	9301	0.6
533.0	9307	0.9
533.5	9312	0.8
534.0	9318	0.5
534.5	9324	1.1
535.0	9329	1.1
535.5	9335	1.4
536.0	9340	2.4
536.5	9346	3.6
537.0	9351	1.4
537.5	9357	0.7
538.0	9363	1.1
538.5	9368	1.1
539.0	9374	1
539.5	9379	0.5
540.0	9385	0.8
540.5	9390	1.1
541.0	9395	0.6
541.5	9400	0.5
542.0	9406	0.8
542.5	9411	0.2
543.0	9416	0.2
543.5	9421	-0.2
544.0	9426	-0.7
544.5	9431	-0.6
545.0	9437	-0.6
545.5	9442	-0.8
546.0	9447	-0.7
546.5	9452	-0.9
547.0	9457	-1.1
547.5	9462	-0.9
548.0	9467	-0.4
548.5	9473	-0.4
549.0	9478	-0.2
549.5	9483	-0.3
550.0	9488	-0.2
550.5	9495	1
551.0	9501	2

551.5	9507	1.5
552.0	9514	1.3
552.5	9520	0.8
553.0	9527	0.2
553.5	9533	-0.6
554.0	9539	-0.4
554.5	9546	0
555.0	9552	0.4
555.5	9559	0.2
556.0	9565	-0.3
556.5	9571	-0.6
557.0	9578	-0.5
557.5	9584	0.1
558.0	9591	0.4
558.5	9597	1
559.0	9603	0.2
559.5	9610	1.4
560.0	9616	0
560.5	9622	-0.2
561.0	9628	-0.2
561.5	9633	-0.1
562.0	9639	0.4
562.5	9645	0.8
563.0	9651	0.9
563.5	9657	1
564.0	9663	1.3
564.5	9669	1.2
565.0	9675	1
565.5	9680	0.6
566.0	9686	0.8
566.5	9692	0.6
567.0	9698	0.6
567.5	9704	0.6
568.0	9710	0.8
568.5	9715	0.6
569.0	9721	0.5
569.5	9727	0.4
570.0	9732	1.7
570.5	9738	3.4
571.0	9744	0.2
571.5	9750	0.3
572.0	9755	2
572.5	9761	3.3
573.0	9767	4

573.5	9773	5.5
574.0	9779	1.9
574.5	9785	-0.1
575.0	9791	0.1
575.5	9797	0.2
576.0	9803	0.7
576.5	9809	0.6
577.0	9815	0.7
577.5	9821	0.9
578.0	9827	0.8
578.5	9833	0.8
579.0	9839	1
579.5	9845	1.4
580.0	9851	1.5
580.5	9855	1.5
581.0	9859	1.8
581.5	9863	1.9
582.0	9867	2
582.5	9872	2.1
583.0	9876	2.7
583.5	9880	2.6
584.0	9884	2.8
584.5	9888	2.6
585.0	9893	3.1
585.5	9897	3.1
586.0	9901	3.4
586.5	9906	3.4
587.0	9910	3.7
587.5	9914	3.9
588.0	9918	3.9
588.5	9923	3.2
589.0	9927	3.4
589.5	9931	5.4
590.0	9935	4.4
590.5	9939	4.4
591.0	9942	4.6
591.5	9946	4.5
592.0	9949	3.7
592.5	9953	3.5
593.0	9956	2.9
593.5	9959	2.3
594.0	9963	2.3
594.5	9966	3.1
595.0	9969	3.3

595.5	9973	3.2
596.0	9976	2.8
596.5	9980	1.8
597.0	9983	1.4
597.5	9986	1.9
598.0	9990	2.5
598.5	9993	1.9
599.0	9997	1.5
599.5	10000	2.3
600.0	10003	3
600.5	10006	3.3
601.0	10009	2.9
601.5	10012	2
602.0	10015	2.1
602.5	10018	2.5
603.0	10020	2.3
603.5	10024	1.5
604.0	10026	1.5
604.5	10029	2
605.0	10032	2.7
605.5	10035	2.9
606.0	10038	3.4
606.5	10041	3.8
607.0	10044	3.7
607.5	10047	3.6
608.0	10049	3.7
608.5	10052	3.3
609.0	10055	3.4
609.5	10058	3.9
610.0	10061	4
610.5	10064	3.9
611.0	10066	4.6
611.5	10069	5.8
612.0	10071	4.2
612.5	10074	3.9
613.0	10076	4
613.5	10079	3.6
614.0	10081	4.9
614.5	10084	5.2
615.0	10086	3.6
615.5	10089	3.2
616.0	10092	3.2
616.5	10094	3.6
617.0	10097	3.9

617.5	10099	5.3
618.0	10102	6
618.5	10104	7.7
619.0	10107	9.5
619.5	10109	9.1
620.0	10112	8.3
620.5	10114	9.3
621.0	10117	8.4
621.5	10120	7.6
622.0	10122	8.2
622.5	10125	7.9
623.0	10128	3.9
623.5	10130	2.6
624.0	10133	1.7
624.5	10135	0.9
625.0	10138	0.8
625.5	10141	1
626.0	10143	1.1
626.5	10146	0.7
627.0	10148	0.7
627.5	10151	0.9
628.0	10154	1
628.5	10156	1.1
629.0	10159	0.7
629.5	10162	0.6
630.0	10164	0.6
630.5	10167	0.7
631.0	10169	1.2
631.5	10172	2.1
632.0	10174	2.7
632.5	10177	3.4
633.0	10179	1.8
633.5	10182	1.8
634.0	10184	1.5
634.5	10187	0.9
635.0	10189	1.3
635.5	10192	0.9
636.0	10194	0.7
636.5	10197	0.9
637.0	10200	1.2
637.5	10202	1.3
638.0	10205	1.2
638.5	10207	1.2
639.5	10212	1.6

640.0	10215	1.9
640.5	10217	2.1
641.0	10220	2.2
641.5	10222	2.3
642.0	10225	2.7
642.5	10227	2.9
643.0	10230	3.2
643.5	10232	3.7
644.0	10235	3.6
644.5	10237	3.1
645.0	10240	2.9
645.5	10242	2.5
646.0	10245	2.3
646.5	10247	2.3
647.0	10250	2.4
647.5	10252	2.6
648.0	10255	2.8
648.5	10257	2.8
649.0	10260	1.2
649.5	10262	0.3
650.0	10265	3.3
650.5	10267	0.9
651.0	10270	7.7
651.5	10272	7.9
652.0	10274	6.2
652.5	10277	5.1
653.0	10280	7.7
653.5	10282	7.7
654.0	10284	9
654.5	10287	8.6
655.0	10290	6.3
655.5	10292	6.1
656.0	10295	5.6
656.5	10297	5.5
657.0	10300	4.9
657.5	10302	5.2
658.0	10305	6.9
658.5	10307	7.2
659.0	10310	5.9
659.5	10312	5.8
660.0	10315	6.1
660.5	10317	6.6
661.0	10320	5.8
661.5	10323	5.4

662.0	10325	5.1
662.5	10328	4.2
663.0	10331	3.3
663.5	10333	3.1
664.0	10336	3.7
664.5	10339	3.1
665.0	10341	2.8
665.5	10344	3
666.0	10347	3.3
666.5	10350	3.3
667.0	10352	3.4
667.5	10355	3.5
668.0	10357	3.6
668.5	10360	4.2
669.0	10363	4.9
669.5	10365	5.3
670.0	10368	4.4
670.5	10371	4.4
671.0	10373	4.1
671.5	10376	3.5
672.0	10379	3.7
672.5	10381	3.7
673.0	10384	4
673.5	10386	4.4
674.0	10389	5.2
674.5	10392	5.8
675.0	10394	6.3
675.5	10397	7.4
676.0	10400	8.9
676.5	10402	9.2
677.0	10405	9.8
677.5	10408	9.9
678.0	10411	10
678.5	10413	9.9
679.0	10416	10.6
679.5	10418	11.7
680.0	10421	12.2
680.5	10424	12.7
681.0	10426	11.8
681.5	10429	9
682.0	10432	7.4
682.5	10435	5.2
683.0	10437	3.7
683.5	10440	3.2

684.0	10443	2.7
684.5	10445	1.8
685.0	10448	1.7
685.5	10451	1
686.0	10453	0.9
686.5	10456	1.1
687.0	10459	0.9
687.5	10461	0.7
688.0	10464	1.1
688.5	10467	1.1
689.0	10470	1.3
689.5	10472	1.4
690.0	10475	1
690.5	10478	1.2
691.0	10480	1.2
691.5	10483	1.6
692.0	10486	1.7
692.5	10489	1.7
693.0	10491	1.6
693.5	10494	1.5
694.0	10497	2
694.5	10499	1.9
695.0	10502	2.1
695.5	10505	2.5
696.0	10508	2.8
696.5	10510	2.8
697.0	10513	2.7
697.5	10516	2.9
698.0	10519	3.2
698.5	10521	3.8
699.0	10524	5
699.5	10527	6.4
700.0	10530	6.6
700.5	10532	7.7
701.0	10535	9.1
701.5	10538	9.1
702.0	10540	10.1
702.5	10543	11.1
703.0	10545	12.9
703.5	10548	11.3
704.0	10551	10.3
704.5	10553	7
705.0	10556	4.1
705.5	10559	3

706.0	10561	0.5
706.5	10564	-0.1
707.0	10567	0.1
707.5	10569	-0.1
708.0	10572	0.1
708.5	10574	0.1
709.0	10577	-0.3
709.5	10580	-0.4
710.0	10582	-0.4
710.5	10585	0.3
711.0	10588	0.3
711.5	10590	1.1
712.0	10593	1
712.5	10596	1.4
713.0	10599	1.9
713.5	10601	1.7
714.0	10604	1.5
714.5	10607	1.8
715.0	10609	2.8
715.5	10612	2.3
716.0	10615	2.6
716.5	10617	2.5
717.0	10620	2.2
717.5	10623	1.9
718.0	10625	2.2
718.5	10628	2.2
719.0	10631	2.8
720.0	10636	3.4
720.5	10639	2.7
721.0	10642	1.6
721.5	10644	0.6
722.0	10647	0.4
722.5	10650	0.3
723.0	10653	0.3
723.5	10655	0.5
724.0	10658	0.6
724.5	10661	0.4
725.0	10664	0
725.5	10666	0.2
726.0	10669	0.1
726.5	10672	-0.1
727.0	10675	-0.1
728.0	10680	-0.3
728.5	10683	-0.3

729.0	10685	-0.5
729.5	10688	-0.3
730.0	10691	0
730.5	10694	0.2
731.0	10696	0.1
731.5	10699	0.1
732.5	10705	0
733.0	10707	-0.1
733.5	10710	0
734.0	10713	-0.3
734.5	10715	-0.4
735.0	10718	-0.3
735.5	10721	-0.5
736.0	10723	-0.5
736.5	10726	-0.4
737.0	10729	0.5
737.5	10732	-0.3
738.0	10734	-0.2
738.5	10737	-0.4
739.0	10739	-0.3
739.5	10742	-0.1
740.0	10745	-0.1
740.5	10747	-0.2
741.0	10750	0.2
741.5	10753	-0.5
742.0	10755	-0.4
742.5	10758	-0.2
743.0	10761	0
743.5	10763	-0.2
744.0	10766	-0.3
744.5	10769	-0.2
745.0	10772	-0.4
745.5	10774	-0.1
746.0	10777	0.6
746.5	10780	0.3
747.0	10783	0.3
747.5	10785	0
748.0	10788	0.1
748.5	10791	0
749.0	10793	0.1
749.5	10796	0.2
750.0	10799	0
750.5	10801	0.2
751.0	10804	0

751.5	10807	0
752.0	10809	1.4
752.5	10812	0.4
753.0	10815	0
753.5	10817	-0.2
754.0	10820	-0.1
754.5	10823	-0.1
755.0	10826	-0.1
755.5	10828	0
756.5	10834	-0.1
757.0	10836	0
757.5	10839	-0.1
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758.5	10845	-0.2
759.0	10847	-0.1
759.5	10850	-0.2
760.0	10853	-0.3
760.5	10855	-0.3
761.0	10858	-0.1
761.5	10861	0.2
762.0	10864	0.4
762.5	10867	0.3
763.0	10869	-0.3
763.5	10872	-0.1
764.0	10875	-0.1
764.5	10877	-0.2
765.0	10880	-0.1
765.5	10883	-0.1
766.0	10886	0.1
766.5	10889	0.2
767.0	10891	0.1
767.5	10894	0
768.0	10897	0.3
768.5	10900	0.6
769.0	10902	0.8
769.5	10905	0.6
770.0	10908	0.5
770.5	10910	0
771.0	10913	-0.1
771.5	10916	0
772.0	10919	0
772.5	10921	-0.1
773.0	10924	-0.1
773.5	10927	-0.1

774.0	10929	-0.2
774.5	10932	-0.2
775.0	10935	-0.1
775.5	10937	-0.3
776.0	10940	-0.1
776.5	10943	-0.1
777.0	10946	-0.1
777.5	10948	-0.2
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778.5	10954	0.1
779.0	10956	1.9
779.5	10959	0
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780.5	10964	-0.2
781.0	10967	-0.2
781.5	10970	-0.1
782.0	10972	-0.1
782.5	10975	0
783.0	10978	0
783.5	10981	0.1
784.0	10983	-0.3
784.5	10986	-0.3
785.5	10991	-0.3
786.0	10994	-0.2
786.5	10997	-0.2
787.0	10999	-0.3
787.5	11002	-0.3
788.0	11005	-0.3
788.5	11007	-0.4
789.0	11010	-0.5
789.5	11013	-0.5
790.0	11016	-0.6
790.5	11018	-0.5
791.0	11021	-0.2
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792.5	11029	-0.4
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793.5	11034	-0.4
794.0	11037	-0.3
794.5	11040	-0.4
795.0	11042	-0.5
795.5	11045	-0.5
796.0	11048	-0.5

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797.0	11053	-0.4
797.5	11055	-0.4
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798.5	11061	-0.5
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799.5	11066	-0.5
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800.5	11071	-0.4
801.0	11074	-0.6
801.5	11077	-0.4
802.0	11080	-0.4
802.5	11082	-0.3
803.0	11085	-0.5
803.5	11088	-0.3
804.0	11091	-0.2
804.5	11094	-0.2
805.0	11096	-0.3
805.5	11099	-0.3
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806.5	11105	-0.1
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807.5	11110	-0.3
808.0	11113	-0.3
808.5	11116	-0.3
809.0	11119	-0.4
809.5	11122	-0.3
810.0	11124	-0.4
810.5	11129	-0.4
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811.5	11138	-0.3
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812.5	11147	-0.2
813.0	11152	-0.4
813.5	11157	-0.2
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814.5	11166	-0.3
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817.0	11189	-0.3
817.5	11193	-0.3
818.0	11198	-0.4

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820.5	11221	0.2
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822.0	11235	0.2
822.5	11239	0
823.0	11244	0
823.5	11249	0.2
824.0	11254	0.2
824.5	11258	0.5
825.0	11263	0.7
825.5	11268	1
826.0	11272	1
826.5	11277	1
827.0	11282	1.1
827.5	11286	1.3
828.0	11291	1.3
828.5	11296	1.2
829.0	11300	1.4
829.5	11305	1.2
830.0	11310	1.4
830.5	11314	1.5
831.0	11319	1.4
831.5	11323	1.3
832.0	11328	1.4
832.5	11333	2
833.0	11337	2.3
833.5	11342	1.9
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835.0	11356	0.4
835.5	11360	0.3
836.0	11365	0.5
836.5	11370	0.4
837.0	11374	0.7
837.5	11379	0.8
838.0	11384	0.8
838.5	11388	1
839.0	11393	1.7
839.5	11397	2
840.0	11402	1.6

840.5	11407	1.6
841.0	11412	1.5
841.5	11416	1.2
842.0	11421	1.1
842.5	11426	1.1
843.0	11430	0.8
843.5	11435	0.8
844.0	11440	0.7
844.5	11444	0.8
845.0	11449	1
845.5	11453	0.9
846.0	11458	0.3
846.5	11463	0.1
847.0	11468	0.1
847.5	11472	0.1
848.0	11477	-0.2
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849.0	11486	-0.6
849.5	11490	0.8
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850.5	11499	-0.2
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851.5	11508	-0.3
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852.5	11518	-0.4
853.0	11522	-0.6
853.5	11527	-0.6
854.0	11531	-0.6
854.5	11536	-0.5
855.0	11541	-0.6
855.5	11545	-0.4
856.0	11550	-0.4
856.5	11554	-0.6
857.0	11559	-0.4
857.5	11564	
858.0	11568	-0.4
858.5	11573	-0.5
859.0	11577	-0.4
859.5	11582	-0.5
860.0	11586	-0.6
860.5	11591	-0.4
861.0	11596	-0.3
861.5	11601	-0.5
862.0	11605	-0.4

862.5	11610	-0.3
863.0	11615	-0.2
863.5	11620	0
864.0	11624	0
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865.5	11639	0.2
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866.5	11649	0.1
867.0	11654	0.4
867.5	11658	0.8
868.0	11663	1.1
868.5	11668	1.5
869.0	11673	1.4
869.5	11678	1.5
870.0	11683	1.3
870.5	11687	1.4
871.0	11692	1.6
871.5	11697	1.5
872.0	11702	1.9
872.5	11706	2.5
873.0	11711	1.7
873.5	11716	1.8
874.0	11720	1.8
874.5	11725	1.8
875.0	11730	2.7
875.5	11735	1.9
876.0	11739	0.7
876.5	11744	0.5
877.0	11749	0.5
877.5	11753	1
878.0	11758	1.3
878.5	11763	1.3
879.0	11768	1.5
879.5	11772	1.7
880.0	11777	1.9
880.5	11781	2.2
881.0	11786	2.4
881.5	11791	2
882.0	11795	1.5
882.5	11800	0.9
883.0	11804	1
883.5	11809	0.8
884.0	11813	1

884.5	11818	1.8
885.0	11823	1.5
885.5	11828	1.3
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886.5	11837	0.3
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887.5	11846	0.2
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889.0	11860	0
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891.0	11879	0.5
891.5	11883	0.6
892.0	11888	0.8
892.5	11893	0.7
893.0	11897	0.9
893.5	11902	0.9
894.0	11907	0.7
894.5	11911	-0.2
895.0	11916	-0.4
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896.0	11926	-0.3
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899.5	11959	-0.4
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913.0	12085	-0.4
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914.5	12099	-0.2
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917.0	12121	0.2
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919.0	12139	1
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923.0	12177	1.3
923.5	12182	1.2
924.0	12187	1.2
924.5	12192	1.4
925.0	12197	0.9
925.5	12201	0.7
926.0	12206	0.6
926.5	12211	1.3
927.0	12216	1.3
927.5	12221	2.8
928.0	12225	3.4

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930.5	12249	1.4
931.0	12254	0.7
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941.5	12351	0.9
942.0	12356	1.4
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943.0	12365	2.4
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947.5	12406	0.2
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950.5	12434	2.4

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953.0	12461	3
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954.5	12476	3.7
955.0	12482	4.6
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956.0	12492	6.6
956.5	12497	7.7
957.0	12503	12.7
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959.0	12524	0.8
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962.0	12559	0.2
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963.5	12578	0.7
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965.5	12603	0.7
966.0	12609	0.7
966.5	12615	1.4
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967.5	12627	1.3
968.0	12634	1.8
968.5	12640	5.8
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970.5	12666	1.3
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972.0	12688	0.8
972.5	12695	0.9

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975.0	12732	0.5
975.5	12740	0.3
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986.0	12894	1
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987.0	12909	0.9
987.5	12916	0.9
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989.0	12937	0.8
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993.5	12988	0.7
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996.5	13019	0.6
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1007.0	13138	3.2
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1011.0	13186	6.2
1011.5	13192	6
1012.0	13199	5.4
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1014.5	13230	11.9
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1015.5	13243	6.2
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1016.5	13255	8.5

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1021.5	13314	49.7
1022.0	13319	33.8
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1024.5	13345	22.7
1025.0	13350	22.8
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1029.0	13390	31.4
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1051.0	13609	39.9
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1052.0	13619	59.4
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1053.5	13634	61.2
1054.0	13639	65.7
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1055.0	13649	62
1055.5	13653	63.9
1056.0	13659	62.2
1056.5	13663	66.9
1057.0	13668	54
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1059.0	13688	67.6
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1066.5	13764	63.4
1067.0	13769	62.2
1067.5	13775	58.4
1068.0	13780	66.7
1068.5	13785	67.3
1069.0	13790	69.5
1069.5	13795	67.3
1070.0	13800	70.4
1070.5	13805	79.6
1071.0	13810	70.2
1071.5	13815	74.7
1072.0	13820	71.2
1072.5	13825	69.3
1073.0	13830	62.8
1073.5	13835	72.2
1074.0	13840	60.1
1074.5	13845	71.8
1075.0	13850	69.8
1075.5	13855	74
1076.0	13860	73.3
1076.5	13865	70.7
1077.0	13870	67.8
1077.5	13875	59.9
1078.0	13880	66.2
1078.5	13886	58.1
1079.0	13891	61.9
1079.5	13896	64.9
1080.0	13900	72.6
1080.5	13906	71.9
1081.0	13911	71.3
1081.5	13916	65.3
1082.0	13921	62.1
1082.5	13926	56.9
1083.0	13931	55.8
1083.5	13936	54
1084.0	13941	57.3
1084.5	13946	60.3

1085.0	13951	53.2
1085.5	13956	51
1086.0	13961	52.6
1086.5	13966	50.8
1087.0	13970	46.3
1087.5	13975	43.5
1088.0	13980	49.9
1088.5	13985	53.7
1089.0	13990	48.8
1089.5	13994	62.6
1090.0	14000	54
1090.5	14004	53.4
1091.0	14010	65.7
1091.5	14015	50.6
1092.0	14020	52.2
1092.5	14025	59.4
1093.0	14030	51.9
1093.5	14035	54.5
1094.0	14041	60.9
1094.5	14046	57.5
1095.0	14051	56.3
1095.5	14056	55.6
1096.0	14061	56.6
1096.5	14066	51.9
1097.0	14072	58.6
1097.5	14077	55
1098.0	14082	48.6
1098.5	14087	48.4
1099.0	14092	48.2
1099.5	14097	48.4
1100.0	14102	46.7
1100.5	14107	46.2
1101.0	14112	52.6
1101.5	14117	53
1102.0	14121	60.6
1102.5	14126	60.2
1103.0	14131	60.7
1103.5	14136	55
1104.0	14141	55.3
1104.5	14146	59.3
1105.0	14150	54.4
1105.5	14155	50.6
1106.0	14161	52.1
1106.5	14165	53.5

1107.0	14170	51.7
1107.5	14175	54
1108.0	14180	51.1
1108.5	14185	48.2
1109.0	14190	44.9
1109.5	14195	51.6
1110.0	14200	51.8
1110.5	14205	53.8
1111.0	14210	50.7
1111.5	14215	57.4
1112.0	14221	55.7
1112.5	14226	55.9
1113.0	14231	52.9
1113.5	14236	50.9
1114.0	14241	49.9
1114.5	14246	61.7
1115.0	14251	48.5
1115.5	14256	49.7
1116.0	14262	46.8
1116.5	14267	52.9
1117.0	14272	44.9
1117.5	14277	47
1118.0	14283	50.7
1118.5	14287	55.3
1119.0	14293	54.9
1119.5	14298	45.8
1120.0	14303	43
1120.5	14308	43.1
1121.0	14313	48.3
1121.5	14318	50.3
1122.0	14323	53.9
1122.5	14328	57.4
1123.0	14333	50.3
1123.5	14339	54.8
1124.0	14344	52.1
1124.5	14348	49.9
1125.0	14354	46.6
1125.5	14359	44.5
1126.0	14364	46.2
1126.5	14369	48.6
1127.0	14374	56.5
1127.5	14379	45.9
1128.0	14384	50.4
1128.5	14389	52.2

1129.0	14394	51.6
1129.5	14399	46.9
1130.0	14404	46.5
1130.5	14409	46
1131.0	14414	50.1
1131.5	14420	48.6
1132.0	14424	49.8
1132.5	14429	50.5
1133.0	14434	56.2
1133.5	14439	58.6
1134.0	14444	62.7
1134.5	14449	60.4
1135.0	14454	61.3
1135.5	14459	61.7
1136.0	14464	62.7
1136.5	14469	70.4
1137.0	14474	62.6
1137.5	14479	62.9
1138.0	14484	64.1
1138.5	14489	54.7
1139.0	14494	57.1
1139.5	14499	59.6
1140.0	14504	62.6
1140.5	14509	56.9
1141.0	14514	59.1
1141.5	14520	58.4
1142.0	14524	56
1142.5	14529	64.4
1143.0	14534	61.8
1143.5	14539	61
1144.0	14544	60.9
1144.5	14549	61.2
1145.0	14554	62.3
1145.5	14559	76.5
1146.0	14564	63.3
1146.5	14569	79.2
1147.0	14574	55.2
1147.5	14579	13.4

Depth (cm)	Age (cal yr BP)	Ca (counts)	K (counts)	Ti (counts)
352.0	6452	78264	2065	1497
352.5	6457	132899	3498	2415
353.0	6463	135321	3392	2559
353.5	6469	130141	3398	2513
354.0	6475	130306	3094	2376
354.5	6480	133100	3484	2267
355.0	6486	132475	3176	2370
355.5	6492	132775	2957	2227
356.0	6497	144554	3338	2459
356.5	6503	144651	3515	2291
357.0	6509	151662	3467	2416
357.5	6514	151943	3559	2396
358.0	6520	149424	3613	2431
358.5	6525	148258	3590	2511
359.0	6531	146781	3556	2570
359.5	6536	142823	3352	2295
360.0	6542	145060	3357	2325
360.5	6549	142049	3306	2355
361.0	6555	145975	3363	2488
361.5	6561	145377	3572	2567
362.0	6567	146763	3569	2476
362.5	6574	149626	3288	2322
363.0	6580	154119	3322	2195
363.5	6587	152045	3082	2313
364.0	6593	150400	2882	2078
364.5	6599	153744	3471	2386
365.0	6605	144090	4000	2555
365.5	6612	150658	3905	2690
366.0	6618	151025	4243	2945
366.5	6624	143848	4571	3198
367.0	6631	145216	5122	3365
367.5	6637	143296	5053	3486
368.0	6644	148573	5439	3536
368.5	6650	138952	5357	3677
369.0	6656	117921	3581	2700
369.5	6663	129894	4686	3326
370.0	6669	127426	4378	3044
370.5	6675	121702	3540	2536
371.0	6682	121477	3315	2454
371.5	6689	126945	3091	2326
372.0	6695	130927	3174	2321
372.5	6702	142524	2884	2125

373.0	6709	139469	2773	1980
373.5	6715	145872	2938	2143
374.0	6722	138744	3108	2262
374.5	6729	118202	2893	2087
375.0	6736	137540	3420	2324
375.5	6742	136653	3407	2542
376.0	6749	139379	3472	2482
376.5	6755	140533	3545	2499
377.0	6762	143843	3598	2470
377.5	6769	144722	3877	2766
378.0	6775	143403	3634	2605
378.5	6782	142043	3763	2588
379.0	6788	144004	3799	2698
379.5	6795	131272	3862	2692
380.0	6801	132546	4227	2984
380.5	6807	125356	4185	3020
381.0	6813	118358	4121	2981
381.5	6819	112544	3924	2909
382.0	6825	109523	3708	2873
382.5	6831	115002	3862	2756
383.0	6837	124123	3603	2403
383.5	6842	133882	3175	2294
384.0	6848	150148	3119	2087
384.5	6854	155648	3150	2113
385.0	6860	160034	3179	1992
385.5	6866	163499	3241	2135
386.0	6872	169550	3398	2205
386.5	6877	158833	3285	2335
387.0	6883	149667	3140	2093
387.5	6889	133446	3014	2077
388.0	6895	148850	3312	2364
388.5	6901	146258	3451	2377
389.0	6907	147336	3315	2376
389.5	6912	145451	2814	2088
390.0	6918	147587	3057	2269
390.5	6925	139254	2721	2146
391.0	6931	148763	3265	2346
391.5	6938	143072	2923	1976
392.0	6944	144592	2884	2059
392.5	6951	129164	2610	1988
393.0	6957	148269	2822	2075
393.5	6964	170424	3183	2215
394.0	6971	170187	3371	2387
394.5	6977	153402	3034	2217

395.0	6984	150292	3055	2258
395.5	6990	147627	2717	1860
396.0	6997	150752	2953	2229
396.5	7004	161975	3449	2428
397.0	7010	162313	3304	2377
397.5	7017	155400	2877	2045
398.0	7023	160943	3276	2278
398.5	7030	157423	3295	2575
399.0	7037	162407	3381	2225
399.5	7043	164227	3461	2176
400.0	7050	164230	3132	2208
400.5	7056	161161	3104	2127
401.0	7061	157548	3082	2109
401.5	7067	163028	3097	2175
402.0	7073	150527	2776	2144
402.5	7078	163660	3086	2000
403.0	7084	158394	3051	2250
403.5	7090	161856	3114	2099
404.0	7096	160702	3180	2272
404.5	7101	143095	3177	2380
405.0	7107	142883	2851	2227
405.5	7113	151919	3131	2444
406.0	7119	150298	2954	2325
406.5	7124	172484	3108	2163
407.0	7130	144144	2768	2045
407.5	7136	112227	2187	1679
408.0	7141	73603	1429	1006
408.5	7147	78462	1549	1278
409.0	7153	104536	1980	1557
409.5	7158	144207	3136	2246
410.0	7164	148752	3330	2547
410.5	7169	139592	3374	2381
411.0	7175	135208	2987	2379
411.5	7180	148810	3486	2495
412.0	7186	142370	3680	2546
412.5	7192	150738	3823	2772
413.0	7198	155330	3757	2586
413.5	7203	147654	3645	2789
414.0	7209	156899	3391	2406
414.5	7215	130913	3630	2617
415.0	7221	160561	3463	2466
415.5	7226	160121	3209	2500
416.0	7232	155921	3378	2397
416.5	7238	130853	3804	2690

417.0	7244	141631	3818	2700
417.5	7250	145500	3398	2366
418.0	7255	135584	2791	2111
418.5	7261	139411	2747	1770
419.0	7267	137362	2696	2015
419.5	7272	134038	3033	2051
420.0	7278	123010	2760	1876
420.5	7284	117659	2626	1940
421.0	7290	109164	2565	1656
421.5	7295	122190	2963	1871
422.0	7301	121523	2791	2016
422.5	7307	122170	2767	1742
423.0	7312	121988	2656	1964
423.5	7318	117486	2409	1709
424.0	7323	115864	2459	1742
424.5	7329	109575	2654	1890
425.0	7335	119580	3007	2116
425.5	7341	133747	3388	2277
426.0	7347	146867	3464	2116
426.5	7352	144942	2974	2046
427.0	7358	140025	3690	2538
427.5	7364	143723	3550	2344
428.0	7370	146897	3476	2464
428.5	7376	146193	3564	2444
429.0	7382	139737	3397	2375
429.5	7388	138687	3243	2347
430.0	7394	136704	2981	2145
430.5	7400	136747	2908	2023
431.0	7406	137678	2928	2183
431.5	7412	141807	3138	2322
432.0	7418	144839	3192	2273
432.5	7424	136551	2796	2067
433.0	7430	132101	2860	1910
433.5	7436	133667	2475	1831
434.0	7442	142213	2627	1985
434.5	7448	128696	2348	1761
435.0	7454	118005	2271	1851
435.5	7460	124642	2520	1909
436.0	7466	136395	2981	2097
436.5	7472	137338	2804	2086
437.0	7478	127167	2996	2111
437.5	7485	125622	3091	1875
438.0	7491	123405	2464	1675
438.5	7497	126116	2647	1647

439.0	7503	121527	3100	1950
439.5	7509	108133	3160	1805
440.0	7515	110263	3412	1942
440.5	7523	103583	3451	1927
441.0	7530	102309	3504	2137
441.5	7538	97518	3886	2128
442.0	7546	103347	3887	2024
442.5	7553	108318	3586	2037
443.0	7561	113230	3619	2086
443.5	7568	106813	3386	2088
444.0	7576	108040	3689	1979
444.5	7584	88657	4289	2335
445.0	7592	81508	5367	2724
445.5	7600	47045	8053	3817
446.0	7608	5840	3220	1367
451.0	7693	76235	1664	1091
451.5	7704	136237	3423	2019
452.0	7715	143931	3288	2360
452.5	7726	139826	3100	2033
453.0	7737	143417	3568	2270
453.5	7748	142161	3251	2325
454.0	7759	147284	3336	2383
454.5	7770	148639	3424	2390
455.0	7781	150548	3264	2320
455.5	7792	162519	3334	2330
456.0	7803	154673	3286	2372
456.5	7814	148284	2584	1905
457.0	7825	144832	2090	1693
457.5	7836	143289	2141	1534
458.0	7847	148716	2466	1817
458.5	7858	157290	2422	1829
459.0	7869	148986	2226	1691
459.5	7879	146995	2314	1686
460.0	7890	155656	2317	1797
460.5	7902	155111	2253	1887
461.0	7913	148952	2502	2098
461.5	7925	153260	2917	2592
462.0	7937	143093	2789	2380
462.5	7948	146678	2418	1955
463.0	7960	147764	2424	2109
463.5	7972	153567	2486	2052
464.0	7983	152345	2355	1825
464.5	7995	160221	2626	2029
465.0	8007	156444	2588	2013

465.5	8018	148432	2608	2190
466.0	8030	152720	2459	1849
466.5	8041	153256	2004	1562
467.0	8052	156135	1636	1322
467.5	8064	162275	1872	1421
468.0	8075	154002	2094	1580
468.5	8087	160122	2200	1623
469.0	8098	160993	2483	1688
469.5	8109	153213	2106	1733
470.0	8121	150248	2030	1487
470.5	8132	152636	2080	1464
471.0	8142	154624	2140	1680
471.5	8154	144064	2084	1564
472.0	8165	152361	2159	1696
472.5	8176	153326	2100	1702
473.0	8187	139535	1708	1457
473.5	8198	137518	1477	1062
474.0	8209	145406	1510	1119
474.5	8220	139502	1507	1131
475.0	8231	148873	1776	1463
475.5	8242	154439	1942	1589
476.0	8253	151434	1920	1423
476.5	8265	157833	1849	1415
477.0	8276	164624	2030	1525
477.5	8287	160550	2183	1520
478.0	8298	146731	1795	1423
478.5	8309	141407	1852	1358
479.0	8320	141007	1747	1362
479.5	8331	139884	1808	1307
480.0	8342	147919	1982	1517
480.5	8353	152750	1925	1532
481.0	8365	151850	1846	1359
481.5	8376	144605	1592	1329
482.0	8388	146987	1592	1443
482.5	8399	144035	1815	1577
483.0	8411	136203	2095	1624
483.5	8423	127367	1939	1613
484.0	8435	130660	2031	1711
484.5	8446	127450	2260	1657
485.0	8458	129405	2334	1803
485.5	8470	119679	1931	1528
486.0	8481	124674	1843	1601
486.5	8493	128405	1654	1474
487.0	8505	121691	1236	1078

487.5	8516	108635	891	874
488.0	8528	114748	960	859
488.5	8540	111119	870	837
489.0	8551	112511	854	713
489.5	8563	108715	993	810
490.0	8574	116167	1121	1047
490.5	8586	103465	951	829
491.0	8598	131522	992	871
491.5	8610	137727	1004	899
492.0	8622	143366	1361	1140
492.5	8634	140693	1414	1306
493.0	8646	139357	1871	1469
493.5	8658	136579	1990	1709
494.0	8671	139595	2075	1710
494.5	8682	140028	2194	1765
495.0	8694	151170	2087	1493
495.5	8706	123593	2207	1695
496.0	8718	112809	1748	1468
496.5	8730	121822	1435	1051
497.0	8742	132794	1297	967
497.5	8754	146282	1181	861
498.0	8766	174134	1034	762
498.5	8778	196737	956	805
499.0	8790	182909	935	711
499.5	8802	207888	770	669
500.0	8814	229240	940	667
500.5	8826	193789	1524	1016
501.0	8838	196768	1188	863
501.5	8849	184351	987	866
502.0	8861	172996	635	766
502.5	8873	195243	822	600
503.0	8885	213782	990	606
503.5	8897	221548	747	567
504.0	8909	244878	859	659
504.5	8921	231958	1146	864
505.0	8933	153282	2743	2150
505.5	8945	134308	3326	2436
506.0	8957	141310	3210	2436
506.5	8969	126907	2316	2011
507.0	8981	151107	1845	1425
507.5	8993	174090	1442	1193
508.0	9005	199052	1366	901
508.5	9017	199442	1655	1205
509.0	9029	191393	1831	1235

509.5	9041	151010	2527	1775
510.0	9053	121974	2949	2424
510.5	9059	114648	3370	2700
511.0	9065	111300	3362	2840
511.5	9070	127527	3566	2845
512.0	9076	120089	3119	2594
512.5	9082	120144	3109	2529
513.0	9087	116309	2966	2512
513.5	9093	120128	2994	2778
514.0	9098	117386	3495	2855
514.5	9104	121228	3020	2394
515.0	9110	122331	2926	2518
515.5	9115	116531	2926	2477
516.0	9121	119410	3029	2601
516.5	9126	113410	3230	2811
517.0	9132	101688	3330	3004
517.5	9137	98753	3258	2731
518.0	9143	92542	3025	2635
518.5	9149	100269	2343	2005
519.0	9154	129356	1880	1605
519.5	9160	133847	2248	1902
520.0	9165	130457	2427	1850
520.5	9170	123760	2141	1709
521.0	9176	134302	1708	1468
521.5	9182	154872	1681	1410
522.0	9187	156837	1617	1181
522.5	9193	155739	1437	1161
523.0	9198	148679	1516	1091
523.5	9203	154831	1919	1356
524.0	9209	149411	2354	1757
524.5	9214	153743	2436	1748
525.0	9219	147480	2324	1699
525.5	9225	143606	2043	1595
526.0	9230	149977	1855	1528
526.5	9236	151766	1812	1581
527.0	9241	148338	1834	1551
527.5	9246	144978	1856	1411
528.0	9252	136286	1821	1487
528.5	9257	124740	1973	1474
529.0	9263	129086	1874	1741
529.5	9268	140563	2182	1749
530.0	9274	135304	1808	1398
530.5	9279	132744	1398	1115
531.0	9284	125334	1080	836

531.5	9290	159268	700	495
532.0	9296	188253	797	691
532.5	9301	188469	1081	872
533.0	9307	188723	1413	848
533.5	9312	173422	1942	1265
534.0	9318	177599	2098	1367
534.5	9324	150221	2280	1532
535.0	9329	166275	2036	1261
535.5	9335	168511	1920	1272
536.0	9340	174603	1771	1405
536.5	9346	173991	2351	1441
537.0	9351	146218	2279	1758
537.5	9357	141473	2031	1624
538.0	9363	150355	2169	1706
538.5	9368	150419	2155	1598
539.0	9374	152707	2387	1743
539.5	9379	152559	2338	1701
540.0	9385	151140	2120	1626
540.5	9390	148735	2019	1646
541.0	9395	153732	2093	1636
541.5	9400	167588	2097	1713
542.0	9406	164600	1622	1260
542.5	9411	168898	1664	1297
543.0	9416	158139	1580	1303
543.5	9421	116849	1054	857
544.0	9426	122358	770	766
544.5	9431	159504	562	458
545.0	9437	203622	660	307
545.5	9442	234649	803	502
546.0	9447	199644	595	413
546.5	9452	223150	523	405
547.0	9457	280440	548	383
547.5	9462	194727	347	444
548.0	9467	200211	441	379
548.5	9473	200366	945	696
549.0	9478	191807	971	696
549.5	9483	178817	827	693
550.0	9488	15950	23	72
550.5	9495	14	8	0
551.5	9507	110877	1381	859
552.0	9514	160857	2004	1371
552.5	9520	162009	2256	1570
553.0	9527	147923	2166	1603
553.5	9533	154587	2018	1546

554.0	9539	165018	1483	1161
554.5	9546	183191	649	504
555.0	9552	192179	864	536
555.5	9559	189299	871	578
556.0	9565	209478	1327	745
556.5	9571	203214	1327	866
557.0	9578	194641	1396	942
557.5	9584	192518	1179	801
558.0	9591	220149	731	559
558.5	9597	249969	850	481
559.0	9603	230331	1225	744
559.5	9610	223674	1210	862
560.0	9616	145018	1439	1173
560.5	9622	135712	1304	981
561.0	9628	133767	1321	1015
561.5	9633	155427	1210	1101
562.0	9639	185840	1278	924
562.5	9645	202617	1427	885
563.0	9651	216019	1316	844
563.5	9657	206391	1443	828
564.0	9663	216997	1747	1146
564.5	9669	216543	2022	1200
565.0	9675	213203	2028	1342
565.5	9680	201695	2280	1308
566.0	9686	201874	2452	1444
566.5	9692	211241	1711	1049
567.0	9698	217485	1734	1077
567.5	9704	228307	1653	980
568.0	9710	232633	1887	1025
568.5	9715	235035	1782	1001
569.0	9721	243299	1695	1072
569.5	9727	253936	1598	869
570.0	9732	257733	1353	830
570.5	9738	262671	1447	890
571.0	9744	258309	1412	898
571.5	9750	212353	1258	865
572.0	9755	152221	1269	972
572.5	9761	169844	1307	933
573.0	9767	129367	1405	1142
573.5	9773	57479	1607	1534
574.0	9779	44895	1844	1969
574.5	9785	37263	1784	1826
575.0	9791	29065	1592	1684
575.5	9797	27840	1381	1552

576.0	9803	30072	1555	1641
576.5	9809	34870	1699	1781
577.0	9815	48815	1804	1881
577.5	9821	55826	1828	1689
578.0	9827	54329	1843	1642
578.5	9833	58916	1858	1806
579.0	9839	70494	2087	1780
579.5	9845	73713	2446	2133
580.0	9851	64214	2672	2577
580.5	9855	47882	2969	3008
581.0	9859	42353	3255	2980
581.5	9863	49765	3460	3158
582.0	9867	56772	3741	3496
582.5	9872	62207	3986	3667
583.0	9876	64928	4237	3753
583.5	9880	67633	4453	3876
584.0	9884	70200	4845	4093
584.5	9888	73396	5276	4285
585.0	9893	75796	5050	4231
585.5	9897	81089	5771	4694
586.0	9901	79960	5487	4389
586.5	9906	82478	5540	4642
587.0	9910	85951	5793	4494
587.5	9914	90630	6140	4720
588.0	9918	89252	6437	5197
588.5	9923	85640	6446	5161
589.0	9927	75115	6108	4999
589.5	9931	70821	5967	4994
590.0	9935	76236	6228	4988
590.5	9939	81838	6379	5297
591.0	9942	85006	6496	5028
591.5	9946	94726	6376	4711
592.0	9949	101390	5974	4914
592.5	9953	99320	5467	4383
593.0	9956	103709	5236	4078
593.5	9959	112293	5306	3778
594.0	9963	104292	4808	3725
594.5	9966	107206	4451	3333
595.0	9969	108462	4320	3171
595.5	9973	108616	4746	3600
596.0	9976	108631	4806	3622
596.5	9980	115410	5066	3933
597.0	9983	114040	4533	3347
597.5	9986	119815	4213	3131

598.0	9990	128156	3984	2864
598.5	9993	134031	3771	2701
599.0	9997	123462	3896	2993
599.5	10000	116551	4089	2959
600.0	10003	120843	4219	3222
600.5	10006	101599	4955	3939
601.0	10009	100120	5174	3869
601.5	10012	87699	5509	4468
602.0	10015	82401	5860	4561
602.5	10018	86509	5720	4495
603.0	10020	91823	5197	4019
603.5	10024	99067	5266	4006
604.0	10026	105354	4867	3679
604.5	10029	116841	4257	2908
605.0	10032	124915	4132	3238
605.5	10035	119188	4264	3124
606.0	10038	110458	4532	3485
606.5	10041	116771	5018	3803
607.0	10044	112514	5435	4032
607.5	10047	103350	5789	4654
608.0	10049	90462	5941	4745
608.5	10052	88440	6090	4550
609.0	10055	85944	5978	4740
609.5	10058	91064	5879	4655
610.0	10061	86692	5864	4640
610.5	10064	76061	5934	4892
611.0	10066	68976	6149	5455
611.5	10069	67441	6664	5557
612.0	10071	62183	6778	5757
612.5	10074	57574	7263	6088
613.0	10076	62960	7076	5939
613.5	10079	71098	6835	5521
614.0	10081	72686	6144	5211
614.5	10084	80730	5369	4651
615.0	10086	86338	5444	4120
615.5	10089	84878	5128	4424
616.0	10092	81238	5253	4449
616.5	10094	77132	5483	4605
617.0	10097	64103	4589	4161
617.5	10099	61963	5274	4356
618.0	10102	60055	6101	5382
618.5	10104	41053	7206	7049
619.0	10107	26112	8453	8100
619.5	10109	18337	9507	8830

620.0	10112	19107	9339	8989
620.5	10114	20419	9517	8453
621.0	10117	24365	9388	8445
621.5	10120	18843	9795	8934
622.0	10122	11531	10273	9264
622.5	10125	9865	10722	9641
623.0	10128	13615	9849	8955
623.5	10130	22109	9205	7765
624.0	10133	56945	6611	5558
624.5	10135	77647	5742	4514
625.0	10138	95488	4042	3258
625.5	10141	110797	2946	2362
626.0	10143	128444	3099	2382
626.5	10146	132194	2908	2309
627.0	10148	145516	2700	1990
627.5	10151	162034	2212	1639
628.0	10154	166673	2292	1764
628.5	10156	155169	2557	1804
629.0	10159	162939	2900	2293
629.5	10162	160469	3249	2309
630.0	10164	157077	3006	2059
630.5	10167	151738	2624	1973
631.0	10169	141163	2618	1846
631.5	10172	150376	3177	2140
632.0	10174	138519	3799	2578
632.5	10177	91332	5355	4337
633.0	10179	73019	6716	5592
633.5	10182	81375	6869	5527
634.0	10184	78725	6186	5123
634.5	10187	80623	5731	4675
635.0	10189	104867	4588	3667
635.5	10192	119108	4240	3164
636.0	10194	121162	4229	2852
636.5	10197	123332	3722	2727
637.0	10200	131877	3642	2640
637.5	10202	128445	3919	2768
638.0	10205	123592	4361	3440
638.5	10207	109854	4564	3558
639.0	10210	111855	4454	3372
639.5	10212	103510	4282	3480
640.0	10215	104124	4446	3756
640.5	10217	110332	4825	3905
641.0	10220	106165	5237	3970
641.5	10222	105558	5794	4365

642.0	10225	93080	6272	5004
642.5	10227	77207	6185	5483
643.0	10230	75586	6624	5528
643.5	10232	69846	6983	5794
644.0	10235	65134	7196	6029
644.5	10237	64482	7674	6467
645.0	10240	53516	7665	6905
645.5	10242	57264	7517	6534
646.0	10245	67170	7170	6338
646.5	10247	70997	7318	6163
647.0	10250	79464	7298	6148
647.5	10252	84104	7240	6039
648.0	10255	88050	7191	5810
648.5	10257	94163	7570	5848
649.0	10260	93542	6820	5436
649.5	10262	25117	1566	1356
650.0	10265	21	0	0
650.5	10267	13	0	0
651.0	10270	76261	5345	4289
651.5	10272	97029	6701	5337
652.0	10274	116826	5824	4663
652.5	10277	116735	4529	3455
653.0	10280	115034	5373	4001
653.5	10282	109004	5804	4615
654.0	10284	97465	6510	5260
654.5	10287	94351	6742	5413
655.0	10290	91768	6977	5410
655.5	10292	84502	7304	5852
656.0	10295	78679	7240	6199
656.5	10297	71251	6953	5799
657.0	10300	79554	7204	5904
657.5	10302	89100	6816	5775
658.0	10305	88496	6572	5383
658.5	10307	89363	6494	5255
659.0	10310	81230	7155	5801
659.5	10312	82000	7038	5785
660.0	10315	86738	6664	5619
660.5	10317	83338	6586	5367
661.0	10320	81967	6525	5247
661.5	10323	77753	6213	5184
662.0	10325	77949	6342	5273
662.5	10328	77401	6208	5364
663.0	10331	76573	5998	5146
663.5	10333	78568	5438	4817

664.0	10336	84259	5178	4312
664.5	10339	99680	4559	3771
665.0	10341	107730	4387	3574
665.5	10344	112927	4466	3483
666.0	10347	115584	4359	3354
666.5	10350	119754	4561	3334
667.0	10352	121948	4564	3428
667.5	10355	118672	4611	3386
668.0	10357	120946	4904	3624
668.5	10360	117078	4923	3684
669.0	10363	119825	5049	3899
669.5	10365	118702	5538	4047
670.0	10368	114483	5440	4112
670.5	10371	114209	5548	4269
671.0	10373	112002	5455	4390
671.5	10376	110170	5083	4083
672.0	10379	108139	4684	3617
672.5	10381	116003	4498	3510
673.0	10384	121047	4759	3733
673.5	10386	122111	4963	3736
674.0	10389	126638	4924	3813
674.5	10392	125024	5307	4119
675.0	10394	121592	5310	4006
675.5	10397	116461	5472	4502
676.0	10400	107395	5574	4677
676.5	10402	105150	6212	5099
677.0	10405	93452	6489	5490
677.5	10408	82135	6541	5756
678.0	10411	74015	6768	6036
678.5	10413	67438	6633	5933
679.0	10416	71021	6896	5956
679.5	10418	73097	7095	5962
680.0	10421	69078	7007	6178
680.5	10424	74543	6836	6096
681.0	10426	78897	6741	5929
681.5	10429	85116	6677	5639
682.0	10432	96110	5894	5277
682.5	10435	108747	5034	4093
683.0	10437	124666	4771	3794
683.5	10440	135215	3514	2988
684.0	10443	143686	3462	2681
684.5	10445	145874	3557	2667
685.0	10448	159545	2833	2178
685.5	10451	158752	2484	1931

686.0	10453	165479	2086	1691
686.5	10456	170457	1854	1413
687.0	10459	169013	1948	1449
687.5	10461	176507	1917	1317
688.0	10464	175939	1752	1433
688.5	10467	191522	2013	1416
689.0	10470	195033	1803	1325
689.5	10472	203198	2141	1447
690.0	10475	216100	2081	1504
690.5	10478	211619	2307	1610
691.0	10480	207225	2262	1590
691.5	10483	203675	2415	1508
692.0	10486	197707	2156	1499
692.5	10489	197381	2144	1500
693.0	10491	204915	2361	1611
693.5	10494	194943	2006	1401
694.0	10497	201260	2222	1665
694.5	10499	206047	2679	1860
695.0	10502	195547	2632	1774
695.5	10505	169917	2405	1924
696.0	10508	149141	2744	2140
696.5	10510	128141	2995	2590
697.0	10513	118899	3079	2589
697.5	10516	119152	3050	2589
698.0	10519	120769	3202	2671
698.5	10521	110620	3302	2758
699.0	10524	105311	3568	3064
699.5	10527	100518	3853	3265
700.0	10530	111310	4549	3775
700.5	10532	111636	4900	4095
701.0	10535	113633	5319	4281
701.5	10538	113050	5601	4453
702.0	10540	111786	5513	4661
702.5	10543	114688	5916	4742
703.0	10545	109233	5804	4828
703.5	10548	105091	6179	4848
704.0	10551	109950	5904	4932
704.5	10553	112828	5689	4517
705.0	10556	129784	4069	3180
705.5	10559	138673	3236	2475
706.0	10561	143026	2454	1916
706.5	10564	150333	1836	1371
707.0	10567	169354	1235	849
707.5	10569	167222	1445	1130

708.0	10572	166068	1087	690
708.5	10574	160294	1407	886
709.0	10577	141500	1264	968
709.5	10580	140225	1164	904
710.0	10582	158679	910	641
710.5	10585	166940	865	690
711.0	10588	176511	1129	897
711.5	10590	158600	1256	1192
712.0	10593	151809	1305	1302
712.5	10596	156136	1556	1221
713.0	10599	162709	1813	1378
713.5	10601	171300	2095	1672
714.0	10604	169772	1825	1366
714.5	10607	178399	1802	1403
715.0	10609	181922	1985	1517
715.5	10612	181641	2149	1581
716.0	10615	180929	2324	1617
716.5	10617	167616	2065	1616
717.0	10620	178249	2145	1610
717.5	10623	177968	2210	1783
718.0	10625	194062	2388	1634
718.5	10628	183406	2228	1748
719.0	10631	191900	2499	1778
719.5	10634	196852	2620	1869
720.0	10636	206162	2698	1960
720.5	10639	205815	2621	1859
721.0	10642	199039	1990	1399
721.5	10644	202660	1770	1296
722.0	10647	215959	1620	1016
722.5	10650	214505	1614	968
723.0	10653	218684	1634	1014
723.5	10655	220524	1709	1072
724.0	10658	232366	1814	1123
724.5	10661	236799	1837	1149
725.0	10664	229438	1863	1138
725.5	10666	203554	1445	973
726.0	10669	204000	1702	1146
726.5	10672	193786	1560	1059
727.0	10675	199054	1564	1036
727.5	10677	203707	1629	990
728.0	10680	198380	1334	947
728.5	10683	212925	1195	701
729.0	10685	208524	1102	780
729.5	10688	183391	1187	702

730.0	10691	152328	1305	941
730.5	10694	147338	1612	1195
731.0	10696	148998	1751	1261
731.5	10699	133888	1675	1324
732.0	10702	118208	1651	1441
732.5	10705	138405	1868	1429
733.0	10707	152436	1716	1229
733.5	10710	138341	1366	1054
734.0	10713	148555	1632	1207
734.5	10715	140079	1490	1032
735.0	10718	131740	1319	1105
735.5	10721	137943	1407	1078
736.0	10723	134727	1303	1008
736.5	10726	135158	1279	1090
737.0	10729	154879	1639	1133
737.5	10732	155757	1800	1222
738.0	10734	165414	1778	1159
738.5	10737	147752	1396	1024
739.0	10739	150250	1540	1012
739.5	10742	163916	1560	1127
740.0	10745	174364	1513	1117
740.5	10747	178299	1627	1137
741.0	10750	175877	1532	1157
741.5	10753	173818	1449	1073
742.0	10755	152926	1478	1050
742.5	10758	151829	1471	1207
743.0	10761	155418	1599	1197
743.5	10763	143909	1502	1164
744.0	10766	156060	1627	1102
744.5	10769	158571	1705	1155
745.0	10772	158205	1591	1120
745.5	10774	152121	1517	1030
746.0	10777	146519	1468	1119
746.5	10780	155406	1607	1056
747.0	10783	161227	1582	1189
747.5	10785	147368	1603	1160
748.0	10788	139444	1370	1140
748.5	10791	144759	1599	1144
749.0	10793	142857	1527	1138
749.5	10796	152345	1779	1246
750.0	10799	170363	1721	1339
750.5	10801	165421	1788	1293
751.0	10804	87972	1398	895
751.5	10807	0	0	16

752.0	10809	76752	2010	1660
752.5	10812	139779	2786	2200
753.0	10815	177311	2056	1530
753.5	10817	160357	1675	1239
754.0	10820	158843	1582	1119
754.5	10823	153194	1556	1175
755.0	10826	152934	1439	1125
755.5	10828	162940	1501	1238
756.0	10831	158640	1487	1141
756.5	10834	147086	1475	1231
757.0	10836	131964	1677	1352
757.5	10839	128802	1692	1398
758.0	10842	109387	1584	1493
758.5	10845	103337	1569	1535
759.0	10847	111009	1723	1398
759.5	10850	123880	1758	1453
760.0	10853	127957	1747	1347
760.5	10855	121018	1780	1520
761.0	10858	115907	2126	1736
761.5	10861	109542	2442	2066
762.0	10864	112880	2506	2136
762.5	10867	111072	2266	2083
763.0	10869	113795	1716	1298
763.5	10872	68513	857	794
764.0	10875	94107	1279	1110
764.5	10877	97950	1397	1386
765.0	10880	112332	1616	1403
765.5	10883	119701	1757	1580
766.0	10886	126856	1787	1664
766.5	10889	126180	1753	1442
767.0	10891	137294	2059	1523
767.5	10894	143095	1929	1659
768.0	10897	142414	1981	1636
768.5	10900	143510	2715	1982
769.0	10902	124211	3181	2629
769.5	10905	104979	3231	2581
770.0	10908	117771	2862	2223
770.5	10910	151542	2170	1598
771.0	10913	173631	1552	1583
771.5	10916	175175	1509	1307
772.0	10919	182247	1470	1151
772.5	10921	184485	1507	1218
773.0	10924	185972	1450	1267
773.5	10927	191897	1357	999

774.0	10929	198004	1444	974
774.5	10932	201739	1156	960
775.0	10935	214540	1353	802
775.5	10937	221589	1366	1032
776.0	10940	217819	1325	995
776.5	10943	211096	1297	969
777.0	10946	200485	1344	1076
777.5	10948	208366	1338	1085
778.0	10951	201000	1410	1004
778.5	10954	177645	1214	1034
779.0	10956	185965	1236	982
779.5	10959	175918	1302	1072
780.0	10962	168730	1220	1051
780.5	10964	172354	1413	1170
781.0	10967	168231	1466	1244
781.5	10970	163773	1568	1261
782.0	10972	159995	1651	1357
782.5	10975	166197	1641	1392
783.0	10978	169459	1674	1356
783.5	10981	163861	1695	1398
784.0	10983	161688	1800	1379
784.5	10986	160809	1463	1276
785.0	10988	170626	1191	939
785.5	10991	180203	1241	989
786.0	10994	186600	1127	841
786.5	10997	188581	1081	1063
787.0	10999	172926	1350	1027
787.5	11002	166785	1199	1032
788.0	11005	162052	1287	993
788.5	11007	158147	1289	1045
789.0	11010	180716	1292	1050
789.5	11013	198538	1251	1088
790.0	11016	170656	1145	899
790.5	11018	139966	942	820
791.0	11021	148597	1187	1065
791.5	11024	143520	1250	899
792.0	11026	133748	1223	997
792.5	11029	158030	1283	1093
793.0	11031	158465	1300	1059
793.5	11034	160161	1192	886
794.0	11037	149131	1168	995
794.5	11040	161310	1174	924
795.0	11042	151326	1285	1033
795.5	11045	144492	1271	1043

796.0	11048	141766	1323	1126
796.5	11050	139451	1158	932
797.0	11053	131301	1110	817
797.5	11055	144559	1100	1024
798.0	11058	135815	1053	892
798.5	11061	136956	985	944
799.0	11063	134721	1202	1122
799.5	11066	129214	1092	991
800.0	11069	136748	1119	1007
800.5	11071	140824	1217	1021
801.0	11074	121212	1182	1088
801.5	11077	122775	1301	1254
802.0	11080	113838	1112	1176
802.5	11082	108147	1055	1016
803.0	11085	115694	1051	1060
803.5	11088	108465	1038	938
804.0	11091	116725	1287	1136
804.5	11094	116277	1163	1318
805.0	11096	128614	1202	1293
805.5	11099	133245	1342	1104
806.0	11102	137113	1195	1094
806.5	11105	148278	1193	995
807.0	11107	160308	1208	1025
807.5	11110	147097	1105	933
808.0	11113	144390	974	873
808.5	11116	139855	957	931
809.0	11119	142273	917	842
809.5	11122	147560	1058	969
810.0	11124	157060	1064	860
810.5	11129	169578	867	888
811.0	11134	171915	886	683
811.5	11138	180111	979	745
812.0	11143	163843	1049	990
812.5	11147	147915	1065	1090
813.0	11152	147976	1047	857
813.5	11157	167029	1066	955
814.0	11161	177725	1140	720
814.5	11166	179155	951	792
815.0	11170	174872	1041	861
815.5	11175	179752	1153	935
816.0	11179	179347	958	886
816.5	11184	182841	1113	922
817.0	11189	185633	999	848
817.5	11193	188140	876	726

818.0	11198	194795	931	695
818.5	11202	190596	926	800
819.0	11207	161792	1020	881
819.5	11211	137192	1006	832
820.0	11216	136065	1159	1037
820.5	11221	129427	1271	972
821.0	11225	132770	1193	1187
821.5	11230	160323	1254	1028
822.0	11235	194480	1237	880
822.5	11239	198968	1154	984
823.0	11244	196781	1165	977
823.5	11249	210467	1353	1086
824.0	11254	204895	1503	1152
824.5	11258	204855	1769	1515
825.0	11263	197179	1844	1596
825.5	11268	200322	1837	1511
826.0	11272	193560	2050	1660
826.5	11277	198114	1932	1396
827.0	11282	198500	1832	1494
827.5	11286	199085	1859	1464
828.0	11291	196985	1887	1552
828.5	11296	197436	1868	1694
829.0	11300	188838	1873	1565
829.5	11305	187875	1769	1368
830.0	11310	170631	1833	1518
830.5	11314	165860	1967	1631
831.0	11319	167011	2007	1725
831.5	11323	171582	2131	1849
832.0	11328	160337	2276	1904
832.5	11333	143466	2791	2467
833.0	11337	168460	2290	2007
833.5	11342	175989	1827	1448
834.0	11346	187590	1590	1183
834.5	11351	180376	1291	1133
835.0	11356	188479	1249	1209
835.5	11360	183067	1399	1322
836.0	11365	185531	1711	1443
836.5	11370	183027	1649	1386
837.0	11374	175144	1686	1498
837.5	11379	157882	1758	1648
838.0	11384	156632	1781	1644
838.5	11388	155683	2377	1909
839.0	11393	141973	2619	2373
839.5	11397	128549	2396	2160

840.0	11402	123904	2250	2147
840.5	11407	126115	2171	1970
841.0	11412	121249	2250	1989
841.5	11416	120436	2006	2038
842.0	11421	117232	2171	1990
842.5	11426	123699	2177	1841
843.0	11430	138706	2159	2086
843.5	11435	141477	2080	1727
844.0	11440	178446	2131	1625
844.5	11444	191039	2048	1593
845.0	11449	188129	2138	1753
845.5	11453	180796	1927	1518
846.0	11458	176695	1561	1280
846.5	11463	155082	1571	1195
847.0	11468	152241	1573	1338
847.5	11472	150089	1520	1346
848.0	11477	149366	1521	1284
848.5	11481	154649	1539	1128
849.0	11486	161377	2687	2046
849.5	11490	157921	1635	1180
850.0	11495	148620	1617	1328
850.5	11499	149353	1440	1194
851.0	11504	154628	1652	1253
851.5	11508	164094	1582	1237
852.0	11513	165989	1649	1373
852.5	11518	166232	1716	1279
853.0	11522	147520	1687	1402
853.5	11527	141787	1697	1371
854.0	11531	146559	2082	1566
854.5	11536	133669	2146	1812
855.0	11541	115383	2054	1726
855.5	11545	117527	1701	1401
856.0	11550	121173	1770	1398
856.5	11554	123834	1891	1306
857.0	11559	124562	1944	1473
857.5	11564	121843	2296	1658
858.0	11568	112649	2653	2129
858.5	11573	112678	2905	2310
859.0	11577	102045	3382	2629
859.5	11582	116414	2756	2195
860.0	11586	129774	1972	1419
860.5	11591	116603	1676	1369
861.0	11596	114053	1804	1399
861.5	11601	122398	1941	1521

862.0	11605	131076	2013	1652
862.5	11610	132339	2054	1659
863.0	11615	141440	2281	1650
863.5	11620	146955	2333	1814
864.0	11624	151563	2398	1698
864.5	11629	144067	2399	1675
865.0	11634	139187	2832	1943
865.5	11639	128444	3267	2338
866.0	11644	113583	3521	2580
866.5	11649	123609	3063	2215
867.0	11654	154486	2643	1846
867.5	11658	177835	1834	1205
868.0	11663	181519	1667	1247
868.5	11668	185076	1662	1268
869.0	11673	191794	1717	1253
869.5	11678	191507	1617	1082
870.0	11683	194858	1532	1287
870.5	11687	205322	1491	1119
871.0	11692	209508	1377	1041
871.5	11697	217658	1605	910
872.0	11702	209612	1226	962
872.5	11706	224620	1374	967
873.0	11711	230961	1432	990
873.5	11716	197281	1360	994
874.0	11720	187652	1331	902
874.5	11725	184869	1237	1034
875.0	11730	186519	1405	980
875.5	11735	190803	1548	1063
876.0	11739	190821	1461	1158
876.5	11744	180238	1585	1117
877.0	11749	174983	1479	1140
877.5	11753	166357	1576	1216
878.0	11758	162386	1558	1282
878.5	11763	145564	1593	1201
879.0	11768	134152	1392	1094
879.5	11772	147487	1539	1255
880.0	11777	152111	1741	1302
880.5	11781	159459	1969	1150
881.0	11786	159768	1596	1325
881.5	11791	173076	1611	1086
882.0	11795	184147	1460	1044
882.5	11800	194326	1371	1051
883.0	11804	193366	1296	1062
883.5	11809	188908	1378	1131

884.0	11813	184186	1509	1237
884.5	11818	175572	1482	1135
885.0	11823	165399	1491	1113
885.5	11828	174506	1419	1074
886.0	11832	180631	1257	936
886.5	11837	184575	1283	990
887.0	11841	164174	1372	986
887.5	11846	154269	1395	939
888.0	11851	151206	1379	1100
888.5	11855	140853	1372	1093
889.0	11860	146432	1302	1021
889.5	11864	159623	1371	980
890.0	11869	171489	1315	1002
890.5	11874	159339	1283	939
891.0	11879	159818	1201	883
891.5	11883	154279	1454	1022
892.0	11888	145546	1338	1140
892.5	11893	144519	1401	1066
893.0	11897	138802	1350	1087
893.5	11902	136303	1199	891
894.0	11907	138494	1148	897
894.5	11911	145469	1295	1069
895.0	11916	135651	1064	887
895.5	11921	138658	1179	827
896.0	11926	131466	1321	1095
896.5	11930	136347	1275	961
897.0	11935	150636	1252	1039
897.5	11940	135075	1387	1125
898.0	11945	130629	1444	1178
898.5	11950	122774	1345	1182
899.0	11954	111987	1238	1048
899.5	11959	116179	1102	895
900.0	11963	114033	1162	906
900.5	11968	116894	1335	1159
901.0	11973	124181	1380	1200
901.5	11978	118884	1265	1096
902.0	11982	133094	1275	1130
902.5	11987	133213	1311	1014
903.0	11992	144191	1268	1060
903.5	11997	159684	1239	911
904.0	12001	153181	1226	962
904.5	12006	141680	955	792
905.0	12011	140901	1036	783
905.5	12016	138668	982	811

906.0	12020	145854	1021	887
906.5	12025	160203	1096	964
907.0	12030	173552	1111	771
907.5	12035	182701	950	767
908.0	12039	191509	1047	965
908.5	12044	182855	1072	863
909.0	12049	158623	1219	1072
909.5	12054	148348	1341	978
910.0	12059	165260	1338	1041
910.5	12063	180367	1292	959
911.0	12067	190291	1181	872
911.5	12072	186261	1063	802
912.0	12076	183526	1187	905
912.5	12081	189794	1325	935
913.0	12085	191451	1285	878
913.5	12090	191335	1216	827
914.0	12094	190998	1116	787
914.5	12099	197276	1169	967
915.0	12104	206362	1117	826
915.5	12108	194359	1178	915
916.0	12113	154128	976	829
916.5	12117	141542	1018	915
917.0	12121	133033	1155	1109
917.5	12126	134875	1341	1050
918.0	12130	157858	1458	1196
918.5	12135	184955	1379	1016
919.0	12139	206145	1301	1053
919.5	12144	205920	1351	994
920.0	12149	206067	1441	1049
920.5	12153	217983	1755	1110
921.0	12158	222214	1865	1399
921.5	12163	209474	1994	1286
922.0	12168	206133	2043	1349
922.5	12172	198100	2234	1561
923.0	12177	194752	2341	1776
923.5	12182	199512	2271	1566
924.0	12187	198155	2056	1468
924.5	12192	201679	1972	1555
925.0	12197	196906	2174	1390
925.5	12201	185035	2014	1546
926.0	12206	197721	2016	1665
926.5	12211	192803	2139	1439
927.0	12216	183408	2203	1763
927.5	12221	168703	2211	1893

928.0	12225	172338	2289	1701
928.5	12230	172763	2294	1829
929.0	12235	155909	2806	2343
929.5	12240	152689	2835	2292
930.0	12245	182844	2797	2036
930.5	12249	193157	2126	1478
931.0	12254	196853	1390	1154
931.5	12258	194919	1286	1147
932.0	12263	199755	1423	1134
932.5	12268	204676	1582	1319
933.0	12272	201476	1839	1485
933.5	12277	183075	1932	1421
934.0	12282	183072	2147	1682
934.5	12286	173705	2080	1824
935.0	12291	174823	1998	1824
935.5	12295	149314	2495	2072
936.0	12300	141780	2972	2804
936.5	12305	143080	3007	2393
937.0	12309	137829	2736	2480
937.5	12314	138035	2886	2341
938.0	12319	141990	2515	2427
938.5	12323	130544	2500	2319
939.0	12328	129913	2540	2416
939.5	12332	140336	2621	2243
940.0	12337	149715	2583	2151
940.5	12342	143881	2274	2025
941.0	12346	190901	2533	1703
941.5	12351	195971	2457	1703
942.0	12356	191221	2360	1677
942.5	12360	177619	2172	1537
943.0	12365	173505	1844	1401
943.5	12369	170747	1792	1406
944.0	12374	160331	1749	1453
944.5	12379	149519	1708	1305
945.0	12383	160261	1689	1362
945.5	12388	116821	1242	962
946.0	12392	90339	1123	792
946.5	12397	37636	699	5584
947.0	12402	1816	899	26491
950.0	12429	117948	3472	2867
950.5	12434	127513	3086	2617
951.0	12440	131709	3268	2589
951.5	12445	142770	2485	2294
952.0	12450	127990	2926	2441

952.5	12455	94702	3336	3177
953.0	12461	92335	3705	3297
953.5	12466	91644	4208	3646
954.0	12471	83827	3945	3499
954.5	12476	75471	3652	3436
955.0	12482	62357	4325	4069
955.5	12487	38667	5909	5977
956.0	12492	40538	4926	5108
956.5	12497	41612	5220	5324
957.0	12503	28257	6888	6566
957.5	12508	106955	2950	2434
958.0	12513	135297	1734	1440
958.5	12519	148763	1668	1397
959.0	12524	141636	1630	1502
959.5	12529	154961	1373	1281
960.0	12535	147696	1136	1065
960.5	12541	132761	1333	1011
961.0	12547	124614	1098	1097
961.5	12553	145471	1094	1186
962.0	12559	161617	1147	1229
962.5	12565	134071	1421	1629
963.0	12571	118818	1569	1509
963.5	12578	115250	1520	1355
964.0	12584	113858	1592	1556
964.5	12590	121434	1629	1608
965.0	12596	105686	1509	1566
965.5	12603	103874	1574	1635
966.0	12609	101384	1860	1711
966.5	12615	110482	1917	1689
967.0	12621	107359	1914	1956
967.5	12627	111136	2437	2208
968.0	12634	84686	2937	2607
968.5	12640	36547	6138	5829
969.0	12646	27557	7312	6678
969.5	12652	24374	7447	6759
970.0	12658	68072	4906	4198
970.5	12666	120510	1931	1736
971.0	12673	130618	1704	1297
971.5	12680	135213	1432	1428
972.0	12688	130146	1500	1347
972.5	12695	128041	1895	1663
973.0	12703	127747	1683	1648
973.5	12710	132582	1405	1448
974.0	12717	131542	1313	1246

974.5	12725	135669	1316	1290
975.0	12732	144552	1310	1334
975.5	12740	143015	1439	1272
976.0	12748	120447	1530	1403
976.5	12755	117374	1667	1442
977.0	12763	129080	1717	1472
977.5	12771	131393	1509	1508
978.0	12778	122986	1712	1628
978.5	12786	125317	1845	1753
979.0	12794	126737	1749	1705
979.5	12801	120640	1648	1488
980.0	12809	118528	1590	1513
980.5	12816	115480	1433	1465
981.0	12823	128703	1471	1322
981.5	12830	126185	1394	1375
982.0	12837	129369	1395	1275
982.5	12844	135945	1182	1254
983.0	12851	128552	1599	1499
983.5	12858	108460	1841	1657
984.0	12865	110970	1325	1394
984.5	12872	130311	1528	1428
985.0	12880	142764	1701	1468
985.5	12887	140049	1788	1483
986.0	12894	145108	1911	1707
986.5	12901	140704	1943	1763
987.0	12909	109119	2149	2059
987.5	12916	113189	2098	1935
988.0	12923	123619	2076	1952
988.5	12930	127511	1941	1835
989.0	12937	120436	1968	1786
989.5	12945	108320	2064	2003
990.0	12952	105559	2119	2015
990.5	12957	101630	2063	1927
991.0	12962	102798	1862	1769
991.5	12967	109647	1857	1801
992.0	12972	120188	2206	2042
992.5	12978	114447	2102	1920
993.0	12983	100034	1788	1754
993.5	12988	84634	1791	1737
994.0	12993	71406	1696	1908
994.5	12998	75766	1645	1617
995.0	13003	82913	1647	1597
995.5	13008	93386	1629	1561
996.0	13014	98913	1772	1653

996.5	13019	114072	1646	1473
997.0	13024	78608	1302	1447
997.5	13029	98134	2142	2044
998.0	13034	67935	2116	2110
998.5	13039	64620	2506	2406
999.0	13044	95068	2549	2507
999.5	13049	98337	2544	2431
1000.0	13054	90841	2542	2341
1000.5	13060	107670	2776	2661
1001.0	13066	114033	2658	2389
1001.5	13072	107602	2501	2398
1002.0	13078	107017	2732	2327
1002.5	13084	105385	2863	2452
1003.0	13090	108552	2653	2294
1003.5	13096	113623	2798	2863
1004.0	13102	116602	2778	2500
1004.5	13108	117449	2873	2465
1005.0	13114	116174	2747	2549
1005.5	13120	112643	2649	2173
1006.0	13126	115517	2469	2703
1006.5	13132	120675	2821	2310
1007.0	13138	118722	2490	2098
1007.5	13144	122839	2553	2481
1008.0	13150	113536	2522	2207
1008.5	13155	127880	3064	2484
1009.0	13161	128567	2852	2309
1009.5	13167	130288	2822	2639
1010.0	13173	129048	3093	2739
1010.5	13180	131251	3294	2866
1011.0	13186	133306	3362	2921
1011.5	13192	131271	3765	3106
1012.0	13199	137657	3789	3117
1012.5	13205	131374	3871	3254
1013.0	13211	135677	4049	2905
1013.5	13218	123922	3806	3127
1014.0	13224	129222	4151	3135
1014.5	13230	122514	4399	3557
1015.0	13237	122276	4501	3778
1015.5	13243	122678	4219	4135
1016.0	13249	117025	4764	3293
1016.5	13255	111796	4836	4043
1017.0	13262	98667	4258	3514
1017.5	13268	77786	4530	4217
1018.0	13274	40850	5583	6198

1018.5	13280	16203	6342	8120
1019.0	13287	12647	6588	8845
1019.5	13293	12867	6641	8579
1020.0	13299	17302	6589	8278
1020.5	13304	17410	6161	7984
1021.0	13309	11918	6691	8599
1021.5	13314	13336	6729	8693
1022.0	13319	13233	6647	8319
1022.5	13324	16596	6139	8079
1023.0	13329	14629	6532	8398
1023.5	13335	12834	6568	8428
1024.0	13340	12446	6390	8170
1024.5	13345	12264	6659	8506
1025.0	13350	13170	6299	7637
1025.5	13355	11449	6058	7770
1026.0	13360	9461	6354	8194
1026.5	13365	10045	7157	9073
1027.0	13370	10075	7063	8985
1027.5	13375	10385	6552	8513
1028.0	13380	11803	6381	8501
1028.5	13385	10275	7004	8607
1029.0	13390	10108	6293	8278
1029.5	13395	10457	6575	8483
1030.0	13400	11524	7063	8584
1030.5	13405	10134	6720	8672
1031.0	13410	10903	6738	8672
1031.5	13415	11238	7095	9014
1032.0	13420	10969	6978	8806
1032.5	13425	10316	7040	8819
1033.0	13430	10848	7557	9370
1033.5	13435	10252	7396	9242
1034.0	13440	10976	7259	8985
1034.5	13445	9877	7038	9034
1035.0	13450	10459	6874	9218
1035.5	13455	11411	7208	9306
1036.0	13460	9522	7071	9051
1036.5	13465	9063	7217	9119
1037.0	13470	9600	7549	9735
1037.5	13475	11561	7359	9680
1038.0	13480	10639	7098	9177
1038.5	13485	12008	6902	8764
1039.0	13490	10835	7093	8729
1039.5	13495	9837	6509	8195
1040.0	13500	10544	6739	8444

1040.5	13505	10890	6926	8562
1041.0	13509	10790	6782	8512
1041.5	13514	10666	6982	9088
1042.0	13519	10866	7210	8860
1042.5	13524	10542	6935	8619
1043.0	13529	10400	6901	8908
1043.5	13534	10606	6952	9141
1044.0	13539	11528	7309	9171
1044.5	13544	11190	7039	9124
1045.0	13549	12026	7178	9092
1045.5	13554	12898	7192	8624
1046.0	13559	16107	7142	9067
1046.5	13564	38339	4758	4762
1047.0	13569	313	53	0
1050.0	13599	23698	6675	11180
1050.5	13604	17769	7692	9426
1051.0	13609	19698	7348	8707
1051.5	13614	20039	7807	9179
1052.0	13619	20026	8299	9706
1052.5	13623	13697	8229	9743
1053.0	13629	16427	8477	10210
1053.5	13634	14727	8569	9978
1054.0	13639	14000	8414	10051
1054.5	13643	13727	8224	10014
1055.0	13649	13170	8326	9599
1055.5	13653	13251	8940	9962
1056.0	13659	14190	9023	10389
1056.5	13663	13228	8984	10469
1057.0	13668	13128	8735	10489
1057.5	13673	12896	8159	9694
1058.0	13678	13477	8534	9851
1058.5	13683	13088	8447	9838
1059.0	13688	12771	8737	10019
1059.5	13693	12998	8502	9893
1060.0	13698	15218	9233	10705
1060.5	13703	13555	8790	10172
1061.0	13708	13800	8606	10355
1061.5	13713	12290	7861	9167
1062.0	13719	13273	8629	9662
1062.5	13724	13494	9208	10103
1063.0	13729	14155	9162	10391
1063.5	13733	12483	8380	10044
1064.0	13739	12920	8308	9568
1064.5	13744	13165	8478	9820

1065.0	13749	12663	8220	9936
1065.5	13754	12708	8195	9860
1066.0	13759	14152	8860	10106
1066.5	13764	11705	8110	9898
1067.0	13769	14327	9164	10887
1067.5	13775	13809	8825	10338
1068.0	13780	13251	8569	10039
1068.5	13785	12788	8505	9907
1069.0	13790	12528	7979	9612
1069.5	13795	12651	8218	9851
1070.0	13800	13177	8773	10249
1070.5	13805	12929	8156	10000
1071.0	13810	12815	8004	9814
1071.5	13815	12805	8848	10530
1072.0	13820	14550	9231	10610
1072.5	13825	13959	8391	9832
1073.0	13830	13111	8138	9991
1073.5	13835	13056	8151	10008
1074.0	13840	14530	8614	10275
1074.5	13845	13859	7930	9988
1075.0	13850	14519	8791	10877
1075.5	13855	13174	8085	9785
1076.0	13860	13116	8420	10259
1076.5	13865	13232	8196	10041
1077.0	13870	13504	8673	10397
1077.5	13875	12901	8472	10019
1078.0	13880	11937	8622	10464
1078.5	13886	13495	8665	10003
1079.0	13891	12332	7763	9215
1079.5	13896	13215	8169	9179
1080.0	13900	11164	7250	9361
1080.5	13906	12406	7868	9330
1081.0	13911	13152	8469	9872
1081.5	13916	14383	8746	10098
1082.0	13921	13595	9513	10759
1082.5	13926	14198	8944	10125
1083.0	13931	13350	8143	10038
1083.5	13936	12399	8041	9860
1084.0	13941	12183	7754	9472
1084.5	13946	11409	7096	9096
1085.0	13951	10736	6788	8831
1085.5	13956	11318	7132	9348
1086.0	13961	12970	7838	9907
1086.5	13966	11183	6725	9286

1087.0	13970	11415	6895	8764
1087.5	13975	11320	7196	9228
1088.0	13980	11539	7236	9233
1088.5	13985	11593	7127	9195
1089.0	13990	11570	6692	9007
1089.5	13994	11810	7495	9523
1090.0	14000	11800	7512	9720
1090.5	14004	10964	6996	9464
1091.0	14010	13931	8344	10442
1091.5	14015	13197	7205	9233
1092.0	14020	11845	6266	9236
1092.5	14025	15404	7283	9295
1093.0	14030	11794	7528	9073
1093.5	14035	11449	7671	9332
1094.0	14041	12999	8484	9946
1094.5	14046	11815	7658	8912
1095.0	14051	11423	7542	9351
1095.5	14056	12715	8486	9955
1096.0	14061	12093	7982	9589
1096.5	14066	11869	7746	9463
1097.0	14072	11308	8451	9842
1097.5	14077	11893	8176	9659
1098.0	14082	10803	7706	9283
1098.5	14087	13187	8549	10107
1099.0	14092	13742	8868	10429
1099.5	14097	11656	7430	9536
1100.0	14102	11904	8079	9750
1100.5	14107	11815	7934	9360
1101.0	14112	11483	7535	9555
1101.5	14117	10651	7190	8765
1102.0	14121	10850	7151	8843
1102.5	14126	11543	7753	9464
1103.0	14131	11257	7582	9523
1103.5	14136	12826	8594	10090
1104.0	14141	12194	8351	10141
1104.5	14146	12850	8576	9932
1105.0	14150	12390	8106	9604
1105.5	14155	12399	7847	9256
1106.0	14161	13734	8126	9582
1106.5	14165	12506	8158	9653
1107.0	14170	12613	7634	9443
1107.5	14175	14215	8150	9960
1108.0	14180	15164	8001	9569
1108.5	14185	13220	8080	9350

1109.0	14190	13104	8368	9827
1109.5	14195	13786	7782	9233
1110.0	14200	12832	7575	9097
1110.5	14205	12160	7590	9240
1111.0	14210	14031	8400	10048
1111.5	14215	16302	8454	9803
1112.0	14221	14050	8370	9892
1112.5	14226	13228	7934	9685
1113.0	14231	13751	8662	9805
1113.5	14236	13421	8501	10170
1114.0	14241	13866	9226	10755
1114.5	14246	13019	8562	10071
1115.0	14251	12701	8365	9533
1115.5	14256	14384	9013	10227
1116.0	14262	12306	7704	8970
1116.5	14267	12197	7842	9236
1117.0	14272	13273	8105	9720
1117.5	14277	13573	8596	10237
1118.0	14283	13828	8545	9968
1118.5	14287	12252	8218	9621
1119.0	14293	12068	7974	9913
1119.5	14298	13263	8575	10230
1120.0	14303	15619	8652	10349
1120.5	14308	16158	8850	9880
1121.0	14313	13918	8275	9426
1121.5	14318	12909	7987	9414
1122.0	14323	14081	7988	9572
1122.5	14328	12397	8206	9627
1123.0	14333	12708	8684	9911
1123.5	14339	13204	8424	9991
1124.0	14344	12898	8129	9913
1124.5	14348	12282	8249	9890
1125.0	14354	15644	8935	10574
1125.5	14359	13969	8352	9964
1126.0	14364	14922	8913	10369
1126.5	14369	18723	7992	9368
1127.0	14374	12694	7797	9260
1127.5	14379	12565	8118	9498
1128.0	14384	14376	8502	10011
1128.5	14389	13804	8480	9980
1129.0	14394	11747	7687	9189
1129.5	14399	14283	8649	9737
1130.0	14404	14035	8059	9461
1130.5	14409	17898	8846	10055

1131.0	14414	14205	8256	9776
1131.5	14420	11862	6944	9398
1132.0	14424	13963	7289	9688
1132.5	14429	17595	8362	9629
1133.0	14434	13934	8100	9399
1133.5	14439	12700	8309	9488
1134.0	14444	13501	9620	10441
1134.5	14449	14070	9010	10400
1135.0	14454	14018	8528	9668
1135.5	14459	17450	8971	9999
1136.0	14464	14528	9255	10362
1136.5	14469	15058	9522	9841
1137.0	14474	15860	8447	9550
1137.5	14479	16805	9043	10103
1138.0	14484	17640	9174	10535
1138.5	14489	18001	8801	9807
1139.0	14494	18025	8765	9776
1139.5	14499	16806	8729	10168
1140.0	14504	14257	8282	9854
1140.5	14509	16185	8834	9851
1141.0	14514	14776	8832	10259
1141.5	14520	14101	8715	9532
1142.0	14524	13754	8865	10148
1142.5	14529	12830	8730	9935
1143.0	14534	12353	8102	9717
1143.5	14539	15075	8612	9797
1144.0	14544	19783	9567	10689
1144.5	14549	16004	9648	11008
1145.0	14554	14781	9870	11165
1145.5	14559	15910	9046	10370
1146.0	14564	13125	8838	9859
1146.5	14569	13361	9214	10706
1147.0	14574	20140	9252	10380
1147.5	14579	29717	7698	8591
1148.0	14584	20481	890	51718

APPENDIX H

SLOUGH CREEK POND CHRONOLOGY

Depth (cm)	Weighted Mean Age (cal yr BP)	Minimum Age (95% CI) (cal yr BP)	Maximum Age (95% CI) (cal yr BP)
0	-61	-64	-58
1	-43	-62	-1
2	-24	-61	59
3	-5	-60	119
4	14	-59	178
5	33	-58	238
6	51	-49	258
7	70	-43	290
8	88	-39	324
9	106	-36	356
10	123	-35	394
11	142	-19	415
12	162	-8	443
13	182	1	473
14	202	8	507
15	221	13	549
16	240	27	568
17	259	39	595
18	278	47	621
19	297	55	652
20	315	63	691
21	335	81	707
22	354	94	729
23	373	106	756
24	392	116	784
25	411	122	816
26	431	139	837
27	451	153	865
28	470	165	890
29	490	176	922
30	509	186	958
31	527	203	968
32	546	218	992
33	564	230	1017
34	582	240	1038
35	600	247	1070
36	619	267	1084
37	637	284	1101
38	656	300	1127
39	675	312	1150
40	693	320	1180

41	712	338	1197
42	731	352	1218
43	750	364	1238
44	769	376	1262
45	787	387	1293
46	807	406	1315
47	826	422	1334
48	845	433	1354
49	864	443	1379
50	883	452	1405
51	902	471	1420
52	920	488	1440
53	938	498	1463
54	956	512	1488
55	974	524	1512
56	993	542	1533
57	1012	555	1554
58	1031	569	1573
59	1050	581	1595
60	1069	591	1620
61	1087	607	1639
62	1105	622	1655
63	1123	636	1676
64	1141	647	1703
65	1159	657	1730
66	1179	680	1741
67	1198	696	1761
68	1216	714	1777
69	1235	726	1801
70	1254	739	1825
71	1273	763	1843
72	1292	777	1861
73	1312	788	1878
74	1331	801	1896
75	1350	815	1920
76	1368	832	1936
77	1386	846	1953
78	1403	862	1978
79	1421	872	1997
80	1438	884	2024
81	1457	903	2037
82	1475	917	2053
83	1494	936	2070
84	1512	948	2090

85	1531	958	2116
86	1550	975	2132
87	1569	993	2156
88	1588	1007	2174
89	1606	1026	2201
90	1626	1040	2230
91	1645	1058	2249
92	1664	1069	2268
93	1684	1086	2288
94	1703	1101	2310
95	1723	1115	2336
96	1741	1133	2356
97	1759	1150	2380
98	1778	1166	2407
99	1797	1181	2433
100	1816	1195	2461
101	1835	1214	2481
102	1854	1229	2496
103	1873	1241	2515
104	1892	1252	2536
105	1912	1268	2559
106	1930	1286	2574
107	1948	1305	2591
108	1967	1321	2606
109	1985	1340	2628
110	2003	1352	2652
111	2022	1370	2670
112	2041	1383	2691
113	2060	1393	2716
114	2079	1409	2739
115	2097	1423	2761
116	2116	1435	2781
117	2135	1449	2800
118	2154	1465	2820
119	2173	1481	2846
120	2192	1498	2871
121	2210	1514	2886
122	2229	1529	2900
123	2248	1546	2922
124	2267	1567	2942
125	2285	1580	2964
126	2303	1597	2983
127	2322	1615	3007
128	2340	1632	3030

129	2358	1644	3055
130	2377	1658	3085
131	2395	1674	3100
132	2415	1690	3113
133	2433	1702	3136
134	2452	1717	3157
135	2470	1728	3178
136	2489	1741	3195
137	2508	1758	3216
138	2527	1776	3236
139	2546	1789	3253
140	2565	1803	3268
141	2584	1821	3287
142	2603	1837	3309
143	2621	1851	3330
144	2641	1864	3350
145	2660	1881	3368
146	2678	1892	3387
147	2697	1914	3405
148	2716	1928	3422
149	2734	1943	3444
150	2752	1956	3463
151	2772	1977	3483
152	2791	1999	3503
153	2810	2021	3523
154	2830	2040	3546
155	2849	2057	3568
156	2867	2074	3585
157	2886	2086	3600
158	2905	2098	3620
159	2923	2108	3640
160	2942	2120	3661
161	2960	2137	3678
162	2979	2163	3696
163	2998	2181	3715
164	3017	2199	3737
165	3035	2215	3758
166	3054	2228	3783
167	3073	2245	3803
168	3092	2258	3824
169	3111	2268	3843
170	3130	2278	3867
171	3149	2300	3884
172	3169	2312	3906

173	3189	2328	3923
174	3207	2340	3943
175	3226	2354	3962
176	3246	2369	3983
177	3266	2382	3996
178	3287	2400	4013
179	3307	2414	4036
180	3326	2431	4060
181	3345	2451	4074
182	3363	2466	4086
183	3382	2479	4109
184	3401	2494	4128
185	3419	2509	4152
186	3437	2526	4169
187	3455	2536	4184
188	3474	2545	4205
189	3491	2556	4223
190	3511	2567	4249
191	3530	2584	4262
192	3549	2598	4278
193	3567	2613	4296
194	3586	2627	4317
195	3605	2639	4341
196	3624	2655	4357
197	3642	2664	4373
198	3661	2674	4389
199	3679	2684	4409
200	3698	2699	4426
201	3717	2712	4437
202	3735	2724	4456
203	3754	2739	4476
204	3774	2754	4498
205	3793	2766	4520
206	3812	2781	4534
207	3831	2794	4560
208	3849	2815	4578
209	3868	2828	4595
210	3887	2850	4621
211	3906	2853	4639
212	3926	2865	4653
213	3945	2879	4676
214	3965	2892	4705
215	3984	2900	4724
216	4002	2915	4741

217	4021	2926	4759
218	4039	2945	4777
219	4057	2958	4796
220	4076	2974	4815
221	4094	2993	4828
222	4113	3001	4842
223	4132	3017	4858
224	4151	3027	4875
225	4170	3043	4899
226	4189	3058	4914
227	4207	3067	4928
228	4225	3077	4946
229	4243	3087	4958
230	4262	3103	4979
231	4281	3114	4994
232	4300	3123	5006
233	4318	3135	5024
234	4338	3145	5045
235	4356	3154	5063
236	4375	3172	5082
237	4393	3185	5093
238	4412	3200	5112
239	4430	3216	5131
240	4449	3228	5149
241	4467	3236	5166
242	4486	3247	5182
243	4503	3255	5199
244	4521	3267	5222
245	4539	3270	5241
246	4558	3284	5254
247	4577	3299	5272
248	4596	3315	5292
249	4614	3330	5306
250	4633	3346	5325
251	4652	3358	5339
252	4671	3369	5358
253	4690	3385	5375
254	4709	3400	5393
255	4728	3406	5414
256	4748	3428	5428
257	4768	3443	5445
258	4788	3460	5458
259	4808	3473	5475
260	4827	3482	5494

261	4849	3512	5509
262	4873	3539	5524
263	4895	3560	5542
264	4918	3591	5561
265	4941	3618	5584
266	4970	3686	5599
267	4999	3766	5617
268	5029	3842	5635
269	5058	3894	5658
270	5087	3964	5683
271	5115	4015	5699
272	5143	4070	5716
273	5170	4125	5733
274	5199	4173	5750
275	5226	4221	5771
276	5255	4272	5786
277	5284	4318	5804
278	5313	4363	5825
279	5342	4399	5845
280	5371	4419	5873
281	5398	4465	5888
282	5426	4508	5904
283	5453	4545	5923
284	5481	4592	5949
285	5508	4632	5977
286	5534	4679	5991
287	5561	4731	6004
288	5588	4773	6021
289	5614	4826	6043
290	5640	4858	6065
291	5669	4905	6077
292	5697	4969	6088
293	5727	5049	6105
294	5757	5124	6121
295	5787	5179	6143
296	5814	5234	6155
297	5841	5281	6165
298	5868	5334	6177
299	5895	5387	6194
300	5922	5434	6221
301	5951	5486	6227
302	5980	5536	6238
303	6009	5591	6249
304	6038	5632	6265

305	6068	5664	6288
306	6095	5744	6291
307	6122	5817	6298
308	6149	5880	6303
309	6177	5928	6315
310	6264	6074	6347
311	6307	6112	6436
312	6351	6139	6545
313	6393	6162	6660
314	6436	6179	6783
315	6479	6226	6814
316	6522	6263	6856
317	6566	6291	6904
318	6608	6311	6971
319	6651	6328	7056
320	6689	6367	7082
321	6728	6396	7113
322	6766	6418	7144
323	6804	6436	7194
324	6842	6450	7253
325	6880	6496	7275
326	6918	6529	7301
327	6956	6560	7331
328	6994	6587	7369
329	7031	6605	7417
330	7072	6668	7437
331	7115	6714	7458
332	7157	6748	7481
333	7198	6779	7513
334	7240	6809	7559
335	7280	6887	7571
336	7318	6946	7585
337	7357	7000	7603
338	7397	7039	7628
339	7437	7074	7664
340	7473	7171	7672
341	7510	7271	7681
342	7547	7365	7698
343	7585	7438	7717
344	7623	7481	7746
345	7675	7564	7778
346	7727	7602	7849
347	7779	7624	7953
348	7831	7644	8074

349	7882	7656	8199
350	7936	7709	8233
351	7990	7740	8275
352	8044	7766	8324
353	8098	7786	8397
354	8151	7800	8485
355	8211	7922	8498
356	8272	8022	8518
357	8333	8103	8540
358	8395	8162	8570
359	8455	8209	8623
360	8506	8329	8645
361	8558	8409	8684
362	8609	8449	8783
363	8660	8472	8925
364	8711	8490	9080
365	8751	8521	9110
366	8792	8543	9154
367	8831	8557	9211
368	8870	8571	9288
369	8909	8581	9372
370	8950	8615	9408
371	8991	8643	9443
372	9032	8664	9496
373	9072	8684	9559
374	9112	8700	9641
375	9153	8743	9671
376	9193	8772	9701
377	9233	8796	9740
378	9273	8812	9799
379	9314	8831	9857
380	9351	8878	9884
381	9388	8911	9913
382	9426	8943	9945
383	9464	8965	9985
384	9502	8990	10036
385	9542	9037	10062
386	9583	9075	10090
387	9623	9100	10123
388	9664	9128	10158
389	9704	9153	10203
390	9743	9208	10228
391	9782	9262	10252
392	9820	9304	10278

393	9858	9335	10314
394	9897	9368	10356
395	9937	9438	10374
396	9976	9489	10393
397	10016	9527	10420
398	10056	9564	10449
399	10096	9596	10488
400	10134	9662	10500
401	10173	9727	10513
402	10212	9782	10535
403	10251	9821	10558
404	10290	9851	10596
405	10329	9946	10612
406	10367	10029	10627
407	10405	10110	10644
408	10444	10161	10672
409	10484	10199	10711
410	10525	10297	10733
411	10566	10373	10756
412	10609	10422	10790
413	10651	10447	10850
414	10694	10470	10936
415	10740	10512	10986
416	10786	10542	11056
417	10831	10563	11145
418	10876	10583	11251
419	10922	10599	11367
420	10971	10640	11409
421	11021	10671	11463
422	11070	10695	11534
423	11118	10713	11619
424	11165	10727	11711
425	11212	10777	11742
426	11259	10815	11787
427	11305	10846	11837
428	11352	10868	11894
429	11399	10889	11964
430	11445	10940	11996
431	11492	10980	12032
432	11538	11018	12076
433	11584	11049	12135
434	11631	11073	12215
435	11676	11127	12236
436	11720	11175	12273

437	11766	11214	12311
438	11811	11243	12362
439	11856	11276	12425
440	11903	11346	12448
441	11950	11393	12476
442	11996	11428	12514
443	12043	11461	12558
444	12090	11485	12629
445	12138	11557	12650
446	12186	11624	12677
447	12234	11671	12713
448	12282	11714	12756
449	12330	11745	12809
450	12378	11837	12826
451	12426	11899	12847
452	12475	11953	12870
453	12525	12006	12906
454	12574	12047	12952
455	12623	12148	12971
456	12672	12246	12993
457	12720	12333	13016
458	12770	12388	13049
459	12820	12434	13097
460	12866	12571	13111
461	12914	12702	13133
462	12961	12818	13158
463	13009	12883	13201
464	13057	12906	13279
465	13108	12939	13349
466	13158	12957	13463
467	13208	12969	13591
468	13257	12978	13731
469	13305	12985	13881
470	13356	13018	13939
471	13407	13040	14009
472	13458	13058	14082
473	13508	13069	14166
474	13558	13078	14290
475	13609	13121	14337
476	13662	13150	14394
477	13714	13176	14461
478	13765	13197	14555
479	13817	13221	14653
480	13868	13264	14711

481	13919	13294	14766
482	13969	13322	14852
483	14019	13339	14941
484	14068	13361	15027
485	14120	13409	15075
486	14170	13443	15123
487	14220	13475	15190
488	14271	13495	15265
489	14320	13521	15343
490	14371	13558	15403
491	14422	13599	15473
492	14473	13625	15536
493	14523	13650	15604
494	14574	13669	15687
495	14625	13711	15730
496	14675	13742	15804
497	14727	13774	15863
498	14778	13798	15941
499	14830	13835	16031
500	14883	13879	16087

APPENDIX I

POLLEN COUNTS FROM SLOUGH CREEK POND

Depth (cm)	Age (cal yr BP)	*Pinus contorta*-type	*Pinus albicaulis*-type	*Pinus* undiff.
350.5	7963	9	9	248
354.5	8181	9	6	168
360.5	8532	25	6	176
364.5	8731	11	4	174
370.5	8970	7	2	184
374.5	9132	16	6	171
380.5	9369	18	10	221
384.5	9522	4	10	176
390.5	9762	10	11	191
392.5	9839	6	4	213
394.5	9917	4	4	220
396.5	9996	2	9	217
398.5	10077	11	9	231
400.5	10154	14	12	222
404.5	10309	4	12	240
406.5	10386	18	15	260
408.5	10464	25	11	211
410.5	10546	11	12	265
412.5	10630	15	15	240
414.5	10717	20	21	244
416.5	10808	12	14	230
418.5	10899	20	9	248
420.5	10996	14	26	178
422.5	11094	10	13	165
424.5	11188	7	29	171
426.5	11282	13	25	186
428.5	11376	5	11	124
430.5	11469	1	27	109
432.5	11561	5	13	164
434.5	11653	4	13	117
436.5	11743	2	9	97
438.5	11834	4	18	145
440.5	11927	5	13	133
442.5	12020	5	32	171
446.5	12210	5	7	102
448.5	12306	0	19	61
450.5	12402	3	5	43
452.5	12500	0	2	39
454.5	12598	4	13	44
456.5	12696	2	4	32

460.5	12890	2	12	34
464.5	13082	2	5	38
470.5	13382	0	17	41

Picea	*Abies*	*Pseudotsuga*	*Juniperus*-type	*Alnus*	*Betula*
5	7	3	9	0	13
13	3	1	4	2	15
10	5	2	14	1	34
7	7	2	9	0	23
19	9	0	6	0	19
12	11	4	12	1	11
24	18	1	12	1	14
23	2	0	6	1	13
12	9	0	12	0	12
17	6	1	7	1	25
12	11	0	7	0	6
13	5	0	5	3	10
21	9	0	8	0	6
20	9	0	3	0	4
18	13	0	4	2	11
22	7	0	1	0	13
39	10	0	2	0	12
18	0	0	3	1	25
13	3	0	7	1	23
28	1	0	4	0	10
26	1	0	6	0	13
20	2	0	5	0	26
11	0	0	8	1	15
25	5	0	17	1	15
12	2	0	13	1	24
12	3	1	7	0	17
18	2	1	16	0	28
39	4	0	10	0	5
46	3	0	11	0	13
44	0	0	6	1	10
28	2	0	8	1	14
38	5	0	2	1	12
51	1	0	6	0	8
39	1	0	7	0	13
44	1	0	8	0	11
29	0	0	3	5	21
73	0	0	8	3	31
26	1	0	1	0	55
15	0	0	3	1	52
12	0	0	4	3	72

6	0	0	7	0	37
9	0	0	2	1	46
6	3	0	7	3	25

Salix	*Populus* undiff.	*Quercus*	*Acer*	Rosaceae undiff.	*Spiraea*
0	0	1	0	1	1
3	0	0	0	0	1
0	0	0	0	1	1
1	0	1	0	0	0
5	0	0	0	0	0
0	0	1	0	0	0
2	0	0	0	1	1
2	0	2	0	1	0
2	0	1	0	0	0
3	0	0	0	1	0
0	0	0	0	0	0
2	0	1	0	1	0
3	0	0	0	0	0
2	0	1	0	0	0
3	0	1	0	1	0
4	0	1	0	0	0
1	0	0	1	1	0
2	0	1	0	0	0
2	0	3	0	0	0
0	0	0	0	0	0
3	0	0	0	0	0
3	0	1	0	1	1
2	0	0	0	0	1
3	0	0	0	0	0
4	0	0	0	2	0
5	0	0	0	0	1
8	0	0	0	2	0
2	0	0	0	5	0
1	0	0	0	0	1
6	0	0	0	0	0
3	0	1	0	0	2
2	0	4	0	0	0
3	0	1	0	0	1
8	0	0	0	0	0
9	0	1	0	2	0
5	0	0	0	0	0
1	0	0	0	1	2
9	0	0	0	3	0
3	1	0	0	3	1
5	2	0	0	4	1

2	0	0	0	2	0
3	0	0	0	2	2
3	0	0	0	4	0

Amelanchier	*Potentilla*	*Ceanothus*	*Shepherdia canadensis*	*Ephedra*	*Sarcobatus*
1	0	0	0	0	2
1	0	0	0	0	0
1	0	1	0	2	3
0	0	0	1	0	5
1	1	0	0	0	1
0	0	0	1	0	3
0	0	0	0	1	0
0	0	0	1	0	0
1	0	1	0	0	3
0	0	0	2	0	5
0	0	0	0	0	3
0	0	1	0	0	1
1	0	0	0	0	0
0	0	0	0	0	3
1	0	0	0	0	4
1	0	0	0	0	3
0	0	0	0	0	1
0	0	0	0	0	6
2	0	1	0	0	2
0	0	0	0	0	2
0	0	0	0	1	5
0	0	0	1	0	3
2	0	0	0	0	3
0	0	0	0	0	2
1	0	1	1	0	4
0	0	0	0	0	3
1	0	0	1	1	1
1	0	0	1	0	5
2	0	0	0	0	10
1	0	0	2	0	3
1	0	0	1	0	8
1	0	0	1	1	8
0	0	0	0	0	1
1	0	0	0	0	1
1	0	0	2	0	5
0	0	0	0	0	3
3	2	1	0	0	5
0	1	0	1	0	6
0	1	1	0	0	5
0	1	0	3	0	3

4	0	0	0	0	5
1	1	0	1	0	9
0	2	0	0	0	3

Poaceae	Cyperaceae	*Artemisia*	*Ambrosia*-type	Other Tubuliflorae	Liguliflorae
5	4	36	3	2	0
7	5	63	5	2	0
5	10	64	2	1	0
5	2	36	2	1	0
4	4	46	9	3	0
4	2	46	0	2	0
10	9	38	2	1	0
11	1	37	2	1	0
9	5	46	3	3	0
7	6	50	7	0	0
8	1	27	1	0	0
4	1	61	6	3	0
3	5	44	6	3	0
3	4	30	3	3	1
7	4	37	4	0	0
16	3	48	1	1	0
12	7	31	4	0	0
6	4	37	3	1	0
7	4	51	1	1	0
8	9	28	1	2	1
9	0	38	3	1	0
13	1	68	6	4	0
12	1	43	4	1	0
9	7	73	4	1	1
10	13	57	1	2	1
12	13	51	2	4	0
16	14	66	4	4	1
12	3	67	2	2	2
10	4	74	8	1	0
7	9	89	3	2	0
8	17	103	2	4	0
11	14	54	4	2	0
9	3	84	1	4	3
13	5	28	2	1	0
21	14	86	2	7	1
18	3	156	3	11	1
13	0	112	0	6	0
11	5	150	3	5	1
13	5	139	4	7	1
8	2	178	3	5	2

4	1	148	3	9	0
6	1	179	5	7	0
12	2	118	1	10	1

Amaranthaceae	Apiaceae	Brassicaceae	Caryophyllaceae	Polygonaceae
7	0	0	0	0
19	0	0	0	0
5	0	1	1	0
12	0	0	0	0
7	0	0	1	0
12	0	0	0	0
11	0	0	0	0
14	0	0	1	0
17	1	0	1	0
18	0	0	0	0
8	0	1	0	1
14	0	0	0	0
15	0	0	0	0
7	0	0	0	0
14	0	0	1	0
12	0	0	0	0
6	0	0	0	0
17	0	0	0	0
11	0	0	1	0
9	0	1	2	0
14	0	0	0	0
10	0	2	0	0
6	0	0	0	0
12	1	1	0	0
11	0	0	0	0
8	1	0	0	0
12	0	0	2	0
19	0	0	1	2
22	0	0	2	1
12	1	1	0	2
13	0	2	0	0
7	0	0	1	0
10	1	0	0	0
6	0	0	0	0
9	0	0	0	0
8	0	0	0	1
4	0	0	1	1
5	0	1	1	0
7	0	0	0	1
13	0	0	1	0

12	0	0	0	0
21	0	0	3	0
7	0	2	1	3

Eriogonum	*Galium*	Scrophulariaceae-type	Fabaceae	*Botrychium*-type	*Selaginella densa*-type
0	0	0	0	0	0
0	1	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
2	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	1	0	0	0
0	0	0	0	0	0
1	0	0	0	0	0
0	0	1	0	0	0
0	0	0	0	0	0
0	1	0	0	0	0
0	0	0	0	0	0
0	0	1	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	2	0	0
1	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	1	1
1	1	0	0	0	1
1	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
0	1	0	0	0	0
1	0	0	0	0	0

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Indeterminate-type	Unknown	*Lycopodium* tracer mean = 13911	Terrestrial Sum
4	0	16	366
1	1	24	325
2	0	16	363
3	0	18	304
3	0	19	327
2	1	36	318
3	1	23	390
3	0	22	310
6	1	17	352
3	0	21	377
2	0	15	315
2	0	21	360
1	0	19	371
1	0	16	338
2	1	16	380
4	1	25	428
3	1	4	371
1	0	33	409
3	0	21	403
3	1	19	386
6	1	32	384
6	1	29	451
8	0	27	335
6	3	23	368
4	1	23	359
4	2	18	358
3	0	39	328
15	3	41	334
2	1	57	390
3	2	36	329
5	1	51	317
4	0	52	326
6	1	67	343
3	0	12	333
7	2	63	336
5	3	88	353
27	1	113	347
13	2	89	336
25	0	88	345
23	0	121	382

39	0	85	326
7	2	130	352
19	5	375	293

APPENDIX J

LITHOLOGIC DATA FROM SLOUGH CREEK POND

Depth (cm)	Age (cal yr BP)	Magnetic Susceptibility (SI Units)
260	3445	-1.3
261	3497	-1.5
262	3547	-1.4
263	3598	-1.3
264	3648	-1.1
265	3701	-0.9
266	3754	-1
267	3807	-0.8
268	3860	-0.5
269	3913	-0.5
270	3970	-0.4
271	4029	-0.3
272	4086	-0.3
273	4142	-0.2
274	4200	0.4
275	4254	0
276	4308	0
277	4363	-0.1
278	4418	0.1
279	4472	-0.1
280	4523	0.1
281	4574	0.2
282	4626	0.2
283	4676	0.7
284	4726	0.6
285	4786	0.3
286	4845	0.4
287	4905	0.3
288	4965	0.6
289	5025	1
290	5089	0.9
291	5154	0.4
292	5219	0.6
293	5285	0.6
294	5350	0.6
295	5408	0.6
296	5467	0.4
297	5525	0.7
298	5584	0.7
299	5642	0.8
300	5703	0.6

301	5764	0.3
302	5825	0.1
303	5886	0.1
304	5946	0.1
305	6001	0.4
306	6055	0.4
307	6110	0.1
308	6164	0.2
309	6220	0
310	6264	0
311	6307	0
312	6351	0.1
313	6393	0.1
314	6436	0
315	6479	-0.1
316	6522	-0.1
317	6566	-0.1
318	6608	-0.1
319	6651	-0.2
320	6689	-0.2
321	6728	-0.3
322	6766	-0.1
323	6804	-0.2
324	6842	-0.2
325	6880	-0.2
326	6918	-0.2
327	6956	-0.3
328	6994	-0.3
329	7031	-0.4
335	7280	0.7
336	7318	1.6
337	7357	1.8
338	7397	1.6
339	7437	1.3
340	7473	0.7
341	7510	0.2
342	7547	0
343	7585	0
344	7623	0.5
345	7675	2.6
346	7727	2.8
347	7779	2
348	7831	1.4
349	7882	1.6

350	7936	1.4
351	7990	1.7
352	8044	1.2
353	8098	1.2
354	8151	1.2
355	8211	-2.3
356	8272	-5.3
357	8333	-8.2
358	8395	-11.1
359	8455	-15.6
360	8506	-14.4
361	8558	-10.6
362	8609	-6.6
363	8660	-4.2
364	8711	-1.1
365	8751	1.7
366	8792	1.7
367	8831	1.6
368	8870	1.3
369	8909	0.8
370	8950	1.2
371	8991	1.4
372	9032	1.4
373	9072	1.4
374	9112	1.5
375	9153	1.9
376	9193	1.4
377	9233	1.9
378	9273	1.3
379	9314	1.8
380	9351	2.3
381	9388	2.1
382	9426	1.7
383	9464	1.7
384	9502	1.7
385	9542	1.8
386	9583	1.7
387	9623	1.7
388	9664	1.5
389	9704	1.3
390	9743	1.6
391	9782	1.4
392	9820	2
393	9858	2.9

394	9897	1.6
395	9937	1.4
396	9976	1.8
397	10016	1.5
398	10056	1.8
399	10096	1.6
400	10134	1.7
401	10173	1.4
402	10212	1.7
403	10251	0.9
404	10290	0.8
405	10329	1.6
406	10367	1.6
407	10405	1.3
408	10444	1.4
409	10484	1.6
410	10525	1.2
411	10566	1.5
412	10609	1.6
413	10651	1.6
414	10694	1.5
415	10740	1.9
416	10786	1.6
417	10831	2
418	10876	1.8
419	10922	1.4
420	10971	2.1
421	11021	2.3
422	11070	2
423	11118	5.6
424	11165	6.7
425	11212	6.9
426	11259	7.2
427	11305	6.4
428	11352	2.8
429	11399	2.5
430	11445	2.3
431	11492	1.5
432	11538	2.3
433	11584	1.3
434	11631	0.9
435	11676	1.6
436	11720	1.5
437	11766	1.9

438	11811	2.3
439	11856	2.1
440	11903	1.6
441	11950	1.4
442	11996	1.9
443	12043	1.5
444	12090	5
445	12138	1.8
446	12186	2.7
447	12234	3.4
448	12282	2.8
449	12330	3.6
450	12378	2.7
451	12426	4.2
452	12475	3.2
453	12525	3.7
454	12574	4.6
455	12623	3.3
456	12672	3.7
457	12720	3.4
458	12770	3.8
459	12820	6.4
460	12866	17.2
461	12914	48.6
462	12961	6.5
463	13009	4.8
464	13057	4.9
465	13108	15.8
466	13158	91.7
467	13208	112.2
468	13257	94.8
469	13305	131.7
470	13356	78.1
471	13407	167.4
472	13458	143.8
473	13508	283