

LONG-TERM ENVIRONMENTAL HISTORY OF TWO LOW-ELEVATION MIXED-
CONIFER FORESTS, MISSION VALLEY, MONTANA

by

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TABLE OF CONTENTS

1. INTRODUCTION	1
Site Description.....	2
Present-day Climate	5
Present-day Vegetation	5
Modern Fire Regime	8
2. METHODS	9
Core Collection	9
Laboratory	9
Charcoal Analysis	10
Pollen Analysis	10
Biomarker Analysis	11
3. RESULTS	14
Lithology	14
Chronology	18
Wymore Lake Pollen and Charcoal	21
WY-Z1: 399-279 cm, 14,000-12,000 cal yr. BP.....	21
WY-Z2: 278-243 cm, 12,000-11,400 cal yr. BP	21
WY-Z3: 242-51 cm, 11,400-7,200 cal yr. BP.....	22
WY-Z4: 50-363 cm, 7,200-5,300 cal yr. BP	23
WY-Z5: 35-26 cm, 5,300-2,000 cal yr. BP	23
WY-Z6: 25-0 cm, 2,000 cal yr. BP-present	24
Rainbow Lake Pollen and Charcoal.....	26
RL-Z1: 724-374 cm, 9,800-5,300 cal yr. BP	26
RL-Z2: 373-125 cm, 5,300-1,200 cal yr. BP	27
RL-Z3: 124-44 cm, 1,200-500 cal yr. BP	27
RL-Z4: 43-0 cm, 500 cal yr. BP-present	28
Biomarker Time Series: Rainbow Lake.....	31
4. DISCUSSION.....	32
Late Glacial Period (>14,000-11,000 cal yr. BP)	32
Early Holocene (11,000-6,000 cal yr. BP).....	33
Late Holocene (6,000 cal yr. BP-Present).....	36
Regional Comparison.....	40
Fire Activity Across NRM Biophysical Gradients	40
NRM Fire Activity and Environmental Change	41

TABLE OF CONTENTS CONTINUED

Early-mid Holocene	41
Late Holocene	43
5. HUMAN INFLUENCE	46
6. CONCLUSIONS.....	48
REFERENCES CITED.....	51
APPENDICES	64
APPENDIX A: Supplementary Materials	65
APPENDIX B: Raw Pollen Data.....	71
APPENDIX C: Raw Charcoal Data.....	94

LIST OF FIGURES

Figure	Page
1a. Map of Wymore Lake	3
1b. Map of Rainbow Lake	4
1c. Regional Site Map.....	4
2. Vegetation across a generalized elevational gradient	7
3. Wymore Lithology	15
4a. Rainbow Lake Lithology (2015).....	16
4b. Rainbow Lake Lithology (2016).....	17
5. Wymore Age-depth Model	19
6. Rainbow Age-depth Model.....	20
7. Wymore Pollen Diagram	25
8. Rainbow Pollen Diagram.....	30
9. Rainbow Lake Coprostanol/(Coprostanol +5 α Cholestanol)	31
10. Charcoal Summary figure	38
11. Summary of Major taxa	39
12. Regional Pollen Ratios and Composite CHAR	45

ABSTRACT

Low elevation mixed-conifer forests are widespread throughout the Northern Rocky Mountains, yet there are few long-term environmental histories from these structurally and compositionally heterogeneous ecosystems. We reconstructed >10,000 years of vegetation change, fire activity, and human presence (e.g., pollen, charcoal, biomarkers) for two closed-basin lakes in mixed-conifer forests in the Mission Valley, western Montana. Environmental reconstructions highlight periods of pronounced changes in climate, vegetation, and fire activity. The late glacial period (>18,000-11,000 cal yr. BP) was characterized by post-glacial warming, generally wet conditions, establishment of mixed-conifer forests and infrequent fires. Following an abrupt, short-lived return to Juniper/Douglas fir parkland associated with the Younger Dryas (~12,900-11,500 cal yr. BP), warming temperatures during the early Holocene (11,000-6,000 cal yr. BP) promoted the expansion of open parkland/grasslands and frequent fire activity until cooler summers and warm, wet winters facilitated the development of modern-day closed mixed-conifer forests. Organic biomarker analyses indicate human presence within the Rainbow Lake watershed for millennia c. 7,000-3,000 cal yr. BP. Regional fire frequency increased during this period at Rainbow Lake, suggesting a possible increased role of human influence.

INTRODUCTION

Mixed-conifer forests in the Northern Rocky Mountains (NRM) are experiencing rapid climatic, environmental, and land-use change, yet there are few paleoenvironmental records documenting long-term response to changes in these controls. Over the last four decades, warming in the NRM has occurred at rates up to three times as fast as the global average (Pederson et al., 2010; Klos et al., 2014; McWethy et al., 2020). This accelerated rate of warming has resulted in reduced snowpack, earlier snowmelt and runoff, and increased vapor pressure deficit, which impacts fire activity by modifying fuel type, availability, and moisture in the NRM. (Higuera and Abatzoglou, 2020). These impacts are projected to continue to amplify over the coming decades as warming continues (Higuera and Abatzoglou, 2020), further promoting longer fire seasons and increased area burned (Abatzoglou and Williams, 2016; Higuera and Abatzoglou, 2020). Historically, low-elevation (<1200 masl) mixed-conifer forests experienced a range of low- to high-severity fires, as fire-adapted to fire-sensitive vegetation often co-occur within the same topographically varied landscape (Arno et al., 1997; Barrett and Arno, 1999; Power et al., 2011; McWethy et al., 2020). Low-severity fires within these landscapes, however, are thought to have declined as a result of over 100 years of fire suppression and subsequent forest infill (Dodge, 1972; Denison et al., 2014; McWethy et al., 2020). Here we examine multi-proxy millennial-scale paleoecological reconstructions for two lakes surrounded by structurally and compositionally heterogenous dry mixed-conifer forest. Our primary objectives are to:

- Develop a multi-proxy (e.g. pollen, charcoal, biomarker) reconstruction of vegetation, fire, and human history for two low-elevation mixed-conifer forest sites in the Mission Valley.
- Examine long-term climate-fire-vegetation interactions and feedbacks in these systems.
- Evaluate disturbance and environmental change in these dry mixed-conifer forest systems compared to regional paleoecological records spanning elevational and biophysical gradients.

Site Description

The underlying geology of the Mission Valley is predominantly composed of middle Proterozoic Belt Supergroup metasedimentary rocks, Pleistocene glacial deposits, fluvio-glacial deposits, flood deposits from Glacial Lake Missoula (GLM) outburst flooding, and Holocene Lake sediments (Harrison et al., 2000). Flathead Lake (495 km²) is the central feature of the valley (Power et al., 2006). Immediately to the east lies the Mission range, a north-south oriented range extending ~90 km in length with its highest peak reaching an elevation of 2,990 masl (Alt et al., 2018). Recent geology and geomorphology of the Mission Valley was strongly influenced by the Cordilleran ice sheet c. 21,000-14,000 cal yr. BP and advances/retreats of the Flathead Lobe into the valley where Flathead Lake exists today (Smith et al., 2020). These glacial advances dramatically shaped the landscape of the Mission Valley, carving out Flathead Lake, and creating numerous glacial formations including small kettle lakes, mountain valleys, drumlins, and moraines (Smith et al., 2020).

Wymore Lake is a small ~10-hectare lake located near the southwestern corner of Flathead Lake (47.786741°N, 114.171153°W, 884 masl) (Fig. 1a). It has a relatively uniform water depth of ~1-2 meters. During the Last Glacial Maximum, the site would have been covered by the Cordilleran ice sheet and likely formed as a kettle lake. Rainbow Lake is a small ~85-hectare lake located southwest of Wymore Lake near Plains, MT (47.525469°N, 114.761345°W, 1093 masl) (Fig. 1b) and is ~6 meters deep. It is also likely that Rainbow Lake was formed during the recession of the Cordilleran Ice Sheet.



Figure 1a: Map of Wymore Lake, MT, with coring location indicated as a white star (47.786741°N, 114.171153°W) (Image: Google Earth).



Figure 1b: Map of Rainbow Lake, MT, with coring location indicated as a white star ($47.525469^{\circ}\text{N}$, $114.761345^{\circ}\text{W}$) (Image: Google Earth).

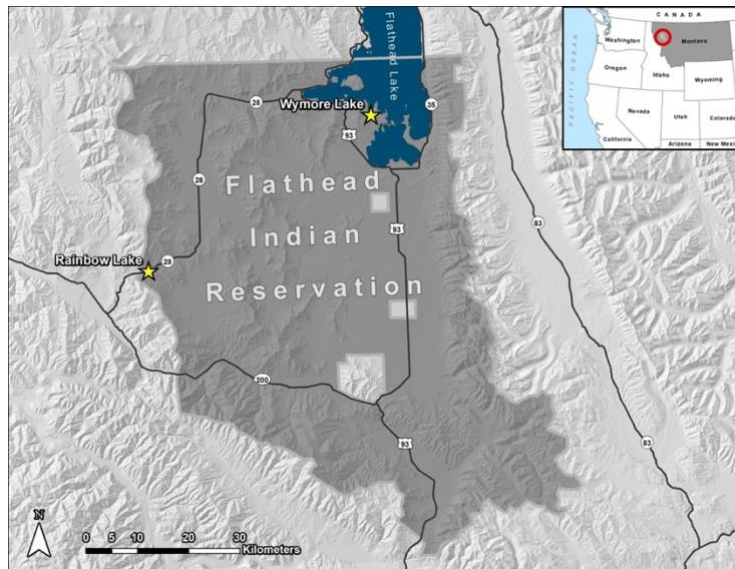


Figure 1c: Regional map with study sites Wymore Lake and Rainbow Lake indicated by yellow stars (Map: Nick Kichas).

Present-day Climate

Primary controls on climate in the Mission Valley today include storms entrained in the jet stream and air masses arriving from the Pacific Northwest, the southwestern US, and the arctic. Mean annual temperature at Wymore Lake (884 masl) is 7.4°C (PRISM Climate Group). Mean maximum summer temperature (JJA) is 26 °C and the mean minimum summer temperature is 9.6°C. Mean maximum winter temperature (DJF) is 1.2°C and mean minimum winter temperature is -6.5°C. Average annual precipitation at Wymore Lake is 40.6 mm, with 7.4 mm falling in the winter, 11.1 mm in the spring, 11.8 mm in the summer, and 10.4 mm in the fall (PRISM Climate Group) (Supplementary Materials Fig. 1-2). Mean annual temperature at Rainbow Lake (1093 masl) is 6.1 °C (PRISM Climate Group). Mean maximum summer temperature (JJA) is 24.43 °C and the mean minimum summer temperature is 8.77 °C. Mean maximum winter temperature (DJF) is -0.67 °C and mean minimum winter temperature is -7.03 °C. Average annual precipitation at Rainbow Lake is 591.56 mm, with seasonal averages of 56.69 mm, 46.34 mm 43.33 mm, and 50.82 (winter, spring, summer, fall respectively) (PRISM Climate Group). Annual precipitation is dominated by winter and early spring precipitation originating from North Pacific Aleutian low-pressure storm systems. Pacific high-pressure systems typically suppress precipitation during the late summer months. Localized convection cells and snowpack runoff provide some warm season precipitation.

Present-day Vegetation

Modern vegetation in the Mission Valley includes dry pasture and irrigated agricultural fields, wetlands, broad-leaved deciduous riparian woodlands, grasslands, mixed-conifer, and

subalpine forests. Low-elevation sites in the Mission Valley (<1200 masl) are dominated by pasture and agricultural lands, grasslands riparian and open coniferous woodlands of *Pinus Ponderosa*, *Pseudotsuga menziesii*, with scattered *Larix occidentalis*, and *Pinus contorta* (Fig. 2).

Wymore Lake is situated in a low elevation mixed-conifer forest in the Mission Valley. Dominant tree taxa include *Pinus ponderosa*, *Pseudotsuga menziesii*, with scattered *Larix occidentalis* and *Pinus contorta*. Understory growth is composed of Poaceae, Juncaceae, Bromus, *Prunus virginiana*, *Festuca scabrella*, and *Koeleria cristata* (Pfister et al., 1977). Open wetland and grassland vegetation dominates the lake margins. Rainbow Lake is located southwest of Wymore Lake and is ~300 masl higher in elevation. Upland vegetation surrounding the lake is dominated by *Pinus Ponderosa*, *Pseudotsuga menziesii*, *Larix occidentalis*, *Pinus contorta* and understory growth consists primarily of Poaceae, *Prunus virginiana*, *Festuca scabrella*, *Amelanchier alnifolia*, and *Rosa woodsia* (Pfister et al., 1977). *Populus*, Cyperaceae, *Salix*, and *Juncus* dominate the lake margins.

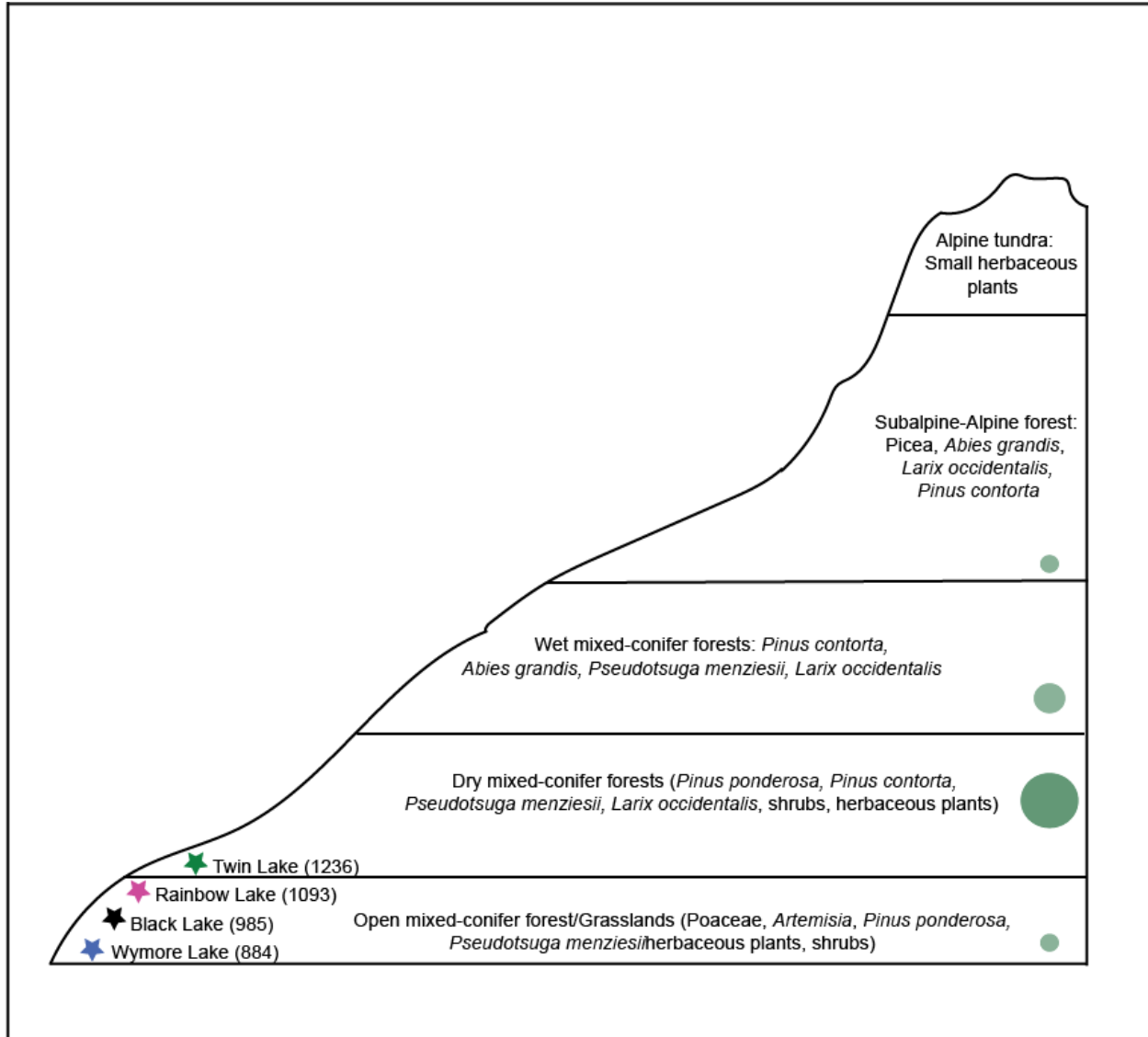


Figure 2: Vegetation across a generalized elevational gradient in the Mission Range (adapted from Pfister, 1977; Arno et al., 1979; Alt et al., 2018). Stars indicate the four primary sites discussed in this study. Total number of sites studied in the region are indicated by green circles in three zones: Open forest/grassland (3 sites) (McWethy et al., 2020), dry mixed-conifer forest (9 sites) (Mack et al., 1978a; Mack et al., 1978b; Mack et al., 1978c; Mack et al., 1979; Mack et al., 1983; Whitlock et al., 1992; Power et al., 2011; Alt et al., 2018), wet mixed-conifer forest (4 sites) (Mehring et al., 1985; Brunelle et al., 2005; Whitlock et al., 2011), subalpine-alpine forest (3 sites) (Mehring et al., 1977a; Brunelle et al., 2005).

Modern Fire Regime

Mixed-conifer forests support highly variable fire regimes in the Mission Valley, from low- to high-severity fires occurring as frequent as every few years, up to 200+ years between fires. Dendroecological studies indicate frequent surface fires occur in grasslands and in open forests in the Mission Valley every 15-25 years, while crown fires and/or stand-replacing fires in wetter mid- and high-elevation forests are infrequent and occur once every 100-300 years (Arno et al., 1997; Swaney, 2005; Alt et al., 2018).

Widespread fire suppression and land management efforts over the last 100 years have altered forest structure and fuel conditions in the Mission Valley (Dodge, 1972; Dennison et al., 2014). The legacy of fire suppression has resulted in forest infill, an increase in the abundance of woody shrubs and saplings, and an increase in ladder fuels, which can promote crown fires. This is especially common in dry mixed-conifer forests along the ecotonal boundary between valley grassland and wetter subalpine forests, where a combination of open grassland and mixed-conifer forests with diverse herbaceous and woody understory vegetation results in mixed-severity fire regimes, such as Wymore Lake and Rainbow Lake. Mixed stands of thick-barked *Pinus ponderosa*, *Larix occidentalis*, and *Pseudotsuga menziesii* forests where the understory vegetation is dominated by herbaceous taxa support frequent, low-severity fires. Wetter *Pinus contorta*, *Abies* and *Picea* forest stands support less frequent high-severity fires (Pfister et al., 1977).

METHODS

Core Collection

At Wymore and Rainbow Lakes, sediment cores were collected using a raft platform and a modified Livingston square-rod piston coring device (Wright et al., 1983). At Wymore Lake five ~37-100 cm long 50 mm diameter cores were collected (1.1 m depth) in August 2020. Core 1A measured 37 cm in length, and cores 1B, 1C, and 1D, and 2B each measured 100 cm in length. Cores 1A-1D were all retrieved consecutively from the initial drive hole, while core 2B was retrieved from a second drive hole. At Rainbow Lake six cores were collected (6 m depth) in September 2015 using the same modified Livingston square-rod piston coring device and a polycarbonate corer. Seven additional cores were collected the following year (October 2016). All cores were extruded from the coring device, wrapped in plastic wrap and tin foil to avoid contamination and oxidation, and stored in PVC pipes. The cores were transported to Montana State University, where they were refrigerated in the cold storage room until analysis.

Laboratory

Cores were split longitudinally in the Paleoecology Laboratory at Montana State University and core lithology was detailed. Cores were examined for presence of macrofossils, photographed, and then subsampled and analyzed for charcoal and pollen concentrations. All cores for Wymore and Rainbow Lakes were subsampled at 1.0 cm contiguous intervals for macroscopic charcoal ($> 125 \mu\text{m}$) except for the top 50 cm at Rainbow Lake which was subsampled at a higher resolution (0.5 cm intervals) and processed following procedures

described by Whitlock and Larsen (2001). Core sections were correlated based on lithology and macroscopic charcoal records to create a continuous sediment record.

Charcoal Analysis

To reconstruct the fire history at both sites, statistical analysis of charcoal counts was performed using CharAnalysis (<https://sites.google.com/site/charanalysis/>) following methods outlined by Higuera et al. (2009). Raw charcoal counts were converted to charcoal accumulation rates (CHAR: particles $\text{cm}^{-2} \text{yr}^{-1}$). A 500-yr Loess smoother robust to outliers was used to distinguish background trends in charcoal deposition (BCHAR). Positive departures from BCHAR were attributed to fire peaks or noise. Fire peaks were separated from noise using a locally defined threshold. Fire peaks were calculated using residuals ($C_{\text{peak}} = C_{\text{interpolated}} - C_{\text{background}}$). Threshold values for peak identification were based on a percentile cut-off of a noise distribution (determined by a Gaussian mixture model), modeled with a 0- or 1-mean Gaussian (for cPeak method = 1 or 2, respectively), then smoothed with a 1000-yr window to produce the fire frequency record (fires 1000 yrs^{-1}).

Pollen Analysis

For all sediment cores, 1 cm^3 subsamples were processed for pollen analysis following procedures described by Bennet and Willis (2001). Samples were taken at 5-10 cm resolutions at both sites to provide a detailed record of vegetation change. To calculate pollen concentration per sample (grains cm^{-3}) and pollen accumulation rate (PAR; grains $\text{cm}^{-3} \text{yr}^{-1}$), Lycopodium tablets of known concentration were added to each sample. Slides were prepared by mounting pollen residue in silicon oil. Each pollen grain was identified to the lowest taxonomic level with

the aid of the Montana State University reference slide collection and pollen identification books (McAndrews et al., 1973; Faegri and Iversen, 1989; Kapp et al., 2000). Pollen grains were counted at a magnification of 400x to 1000x. Pollen counts were converted to percentages based on the terrestrial pollen sum.

Pollen types were grouped into 4 categories: “Trees”, “Shrubs and Herbs”, “Aquatic”, and “Indeterminate”. *Pinus* pollen grains were separated into three taxa categories based on morphology: *Pinus* subgenus *strobus* (Haploxylon-type; verrucae present on their distal membrane), *Pinus* subgenus *pinus* (Diploxylon-type; verrucae absent on their distal membrane), and undifferentiated (half-grains and grains missing identifying morphological features). “Trees” included *Pinus* undifferentiated, *P. subg. strobus*, *P. subg. pinus*, *Pseudotsuga/Larix*, Cupressaceae (attributed to *Juniperous communis*), *Abies*, *Picea*, and *Quercus* grains. “Shrubs and Herbs” included *Alnus*, Amaranthaceae, *Sarcobatus vermiculatus*, Roseaceae, *Ambrosia*, Apiaceae, Betulaceae, Asteroidaea, Fabaceae, Ranunculaceae, Caryophyllaceae, *Polygonum* undifferentiated, *Polygonum bistorta*, Cichoroideae, *Salix*, Malvaceae, Myriophyllum, *Rhamus*, *Epilobium*, and *Rhus* grains. “Aquatic” consisted of Cyperaceae and Typha grains. “Indeterminate” consisted of damaged and hidden grains. Pollen percentage data from both Wymore Lake and Rainbow Lake were divided into zones based on visual inspection and CONISS cluster analysis (Grimm, 1987).

Biomarker Analysis

We analyzed organic biomarkers in 28 samples from 2015 Rainbow Lake cores from 10-725 cm depth with a 15 cm resolution in the first section (10-225 cm) and 25 cm resolution in the second (225-725 cm), following methods outlined in McWethy et al. 2020. Samples were

analyzed for a suite of sterols and stanols (afterwards broadly indicated as fecal sterols), including: Coprostanol, *epi*-Coprostanol, Cholesterol, and 5α -Cholestanol. Fecal sterols are transported via runoff and deposited into lake sediments (Meyers, 1997), and therefore represent inputs from the surrounding watershed. Coprostanol has been used as a biomarker of human presence as it is up to 10 times more abundant in human feces than in other omnivorous species (Leeming et al., 1996). *epi*-Coprostanol forms when coprostanol is degraded by soil microbes (Bull et al., 2003; Keenan et al., 2021), and 5α Cholestanol is formed by the reduction of cholesterol in sediments (Battistel et al., 2016; Argiriadis et al., 2018).

We use the ratio $\text{Coprostanol}/(\text{Coprostanol} + \textit{epi}\text{-Coprostanol} + 5\alpha \text{ Cholestanol})$ as the primary indicator of human presence in our analyses. The use of ratios is considered more reliable than concentrations or fluxes, as they can account for diagenetic biases, degradation processes, and/or transportation dynamics. For example, Grimalt et al. (1990) proposed $\text{Coprostanol}/(\text{Coprostanol} + 5\alpha \text{ Cholestanol})$ as well as $\text{Coprostanol}/(\text{Coprostanol} + \textit{epi}\text{-Coprostanol} + 5\alpha \text{ Cholestanol})$, to account for these different processes, where values above 0.7 indicate intensive human inputs to the watershed. However, in this context, a local increase in coprostanol values likely indicates an increase in human population size and/or intensity of use of the watershed.

Samples were freeze dried (Modulo Freeze Dryer, Edwards, UK) and then homogenized by hand milling in a ceramic mortar. Samples were sealed in vials and stored at room temperature until extraction analysis, performed using an ASE 350 (Accelerated Solvent Extraction, Dionex Thermo Fischer Scientific). Samples were combined with diatomaceous earth

and spiked with a known amount of internal standard solution to quantify fecal sterol levels. Two extractions per sample were performed at 150° C and 1500 psi with dichloromethane (DCM).

Extracts were concentrated using a gentle stream of nitrogen (Turbovap, Caliper Life Sciences) up to ~0.5 mL and purified onto glass columns packed with 1 g neutral activated silica, previously conditioned with *n*-hexane: DCM (1:1, v/v), with 3 mL of *n*-hexane (non-polar fraction) followed by 10 mL of DCM (polar fraction). The two fractions were collected separately. The non-polar fraction was stored for further analysis of aliphatic and aromatic hydrocarbons. The more polar fraction was evaporated until dry and redissolved in 100 µL of DCM, then 100 µL of BSTFA + 1% TMCS (N,O-Bis(trimethylsilyl)trifluoroacetamide + 1% trimethylchlorosilane) were added to the samples to allow derivatization at 70° C for 1 hour. The subsequent analyses were carried out by GC-MS following the method described in Battistel et al. (2015). Analytes were quantified based on an internal standard, using ¹³C₆-Cholesterol (200 absolute ng) that was spiked within the sample matrix before the extraction step. Several procedural blanks were also analyzed to quantify possible contamination from the laboratory equipment. Coprostanol, *epi*-Coprostanol and 5 α -Cholestanol were not detected in blanks and therefore no correction was applied. However, Cholesterol amounts in blanks ranged from 13-54 ng, and final concentration values were corrected by the blank. The average accuracy and precision were 90-110% and 10-15%, respectively, for all the fecal sterols analyzed. The concentrations of each fecal sterol analyzed are reported in Table S3 (Appendix A: Supplementary Materials).

RESULTS

Lithology

Sediment cores taken from Wymore Lake were primarily composed of gyttja and clay (Fig. 3). Core 1A was composed of grey clay from 0-39 cm and light grey clay from 39-53 cm. Core 1B was composed entirely of brown gyttja with a layer of tephra from 55-63 cm attributed to the eruption of Mt. Mazama 7,682-7,584 cal yr. BP (Egan et al., 2015). Core 1C was composed of banded brown gyttja from 153-183 cm, grey silty clay 183- 243 cm, and light brown silty clay 243-253 cm. Core 1D was composed of light brown silty clay from 253-263 cm and black and grey banded clay from 263-353 cm. Core 2B was composed of black and grey banded clay from 353-413 cm and pink silty clay from 413-450 cm, with a ~3 cm layer of tephra from 382-384 cm attributed to an eruption of Glacier Peak c. 13,710-13,410 cal yr. BP (Kuehn et al., 2009). Magnetic susceptibility values remain relatively stable throughout the entirety of the cores, with two peaks of 11.5 SI and 217.5 SI, which are attributed to the Mt. Mazama and Glacier Peak tephras, respectively, based on previously dated tephras from multiple sites (Kuehn et al., 2009; Egan et al., 2015), although tephras were not geochemically analyzed to confirm their origins in this study. All sediment cores taken from Rainbow Lake were composed of Grey/brown gyttja (Fig. 4a) except for core 2016E, which featured a tephra layer from 522-532 cm. We interpret this tephra to represent one of the primary eruptions of Mt. Mazama 7,682-7,584 cal yr. BP (Egan et al., 2015) (Fig. 4b).

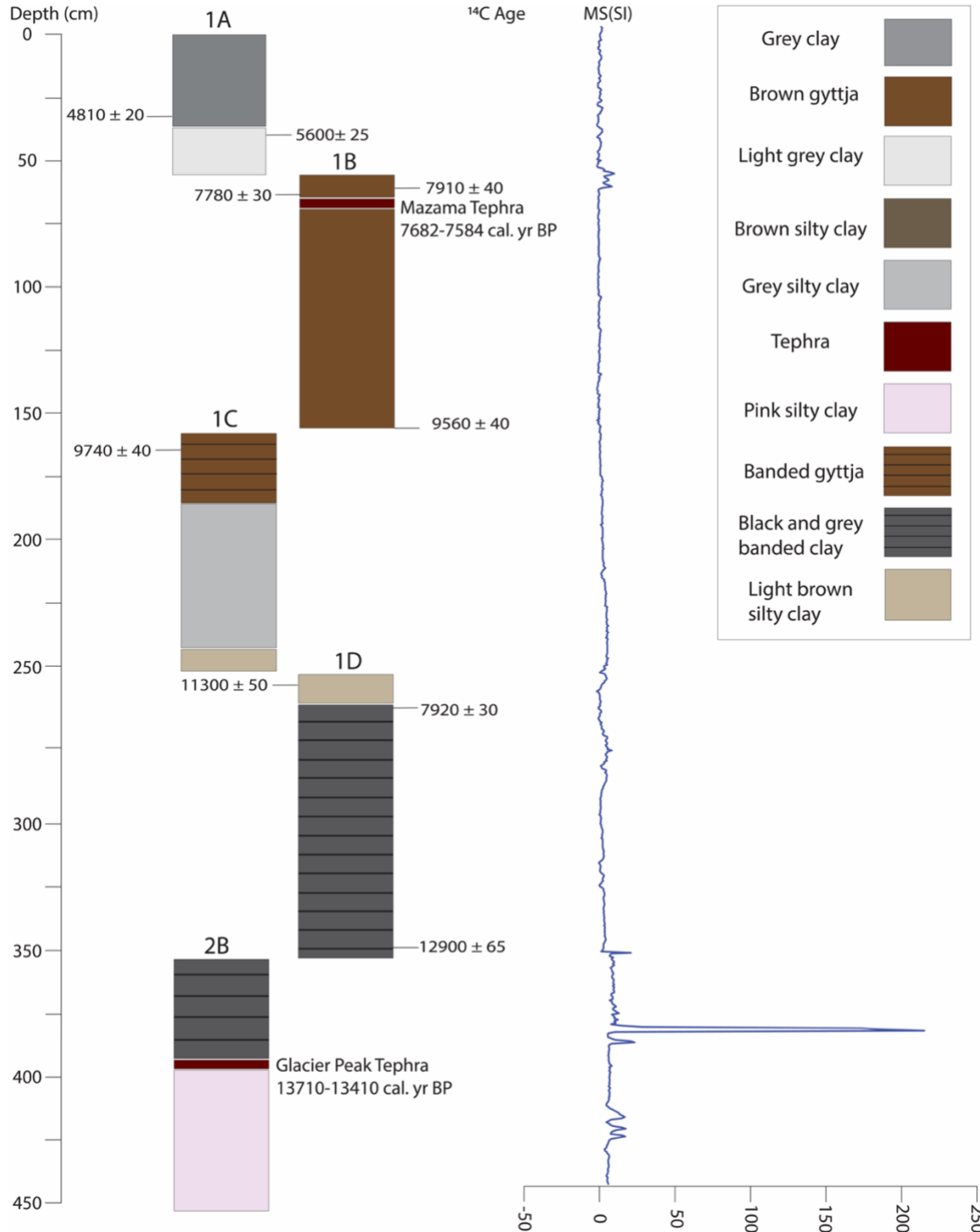


Figure 3: Lithology diagram of the 5 cores from Wymore Lake, MT, location of uncalibrated radiocarbon dates taken from the 5 cores, and magnetic susceptibility values taken at contiguous 0.5cm intervals. Tephra layers are inferred to be from the eruption of Mt. Mazama 7,682-7,584 cal yr. BP (Egan et al., 2015) and an eruption of Glacier Peak c. 13,710-13,410 cal yr. BP (Kuehn et al., 2009).

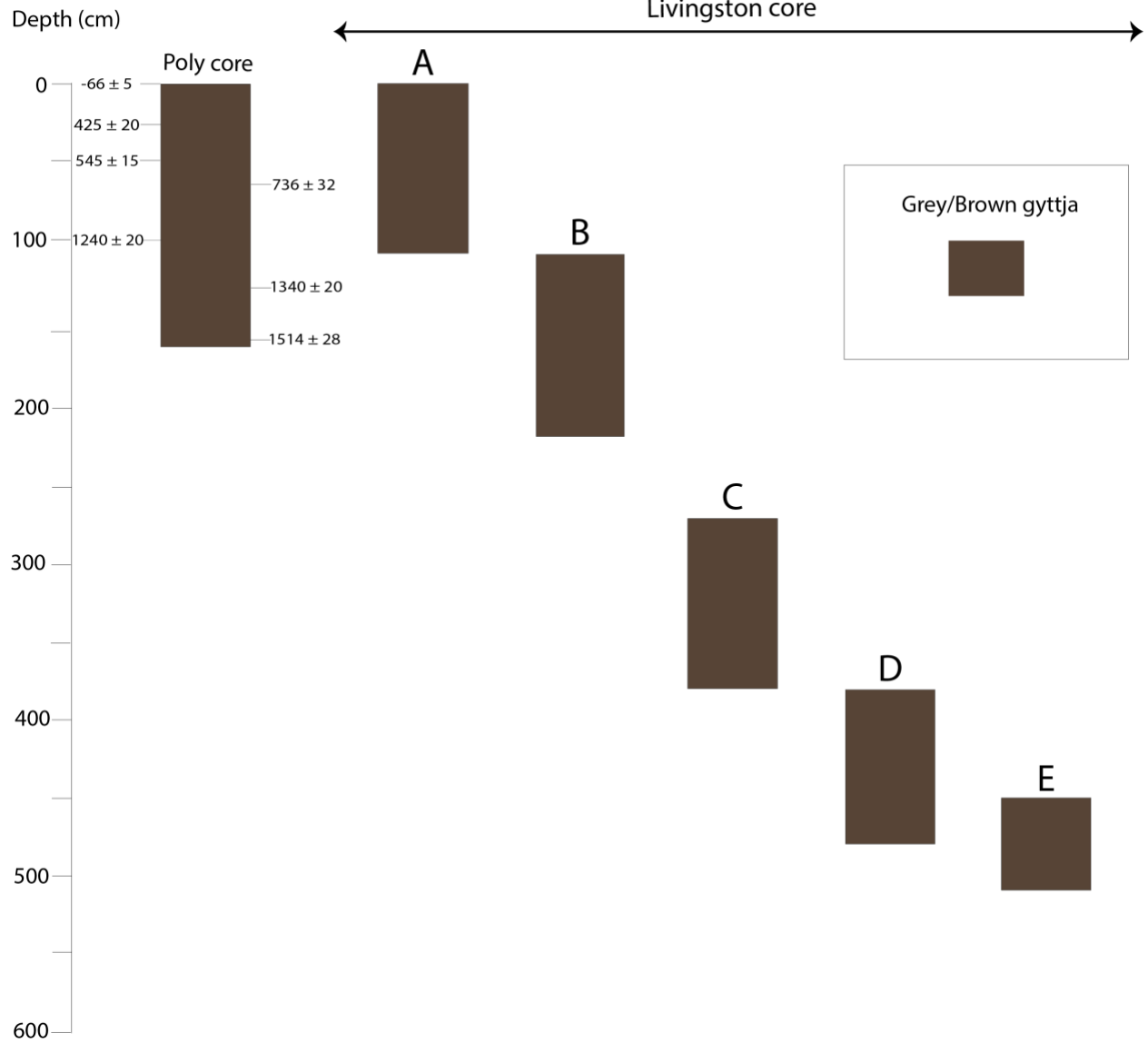


Figure 4a: Lithology diagram of the 6 cores taken from Rainbow Lake, MT (2015) and location of uncalibrated radiocarbon ages obtained.

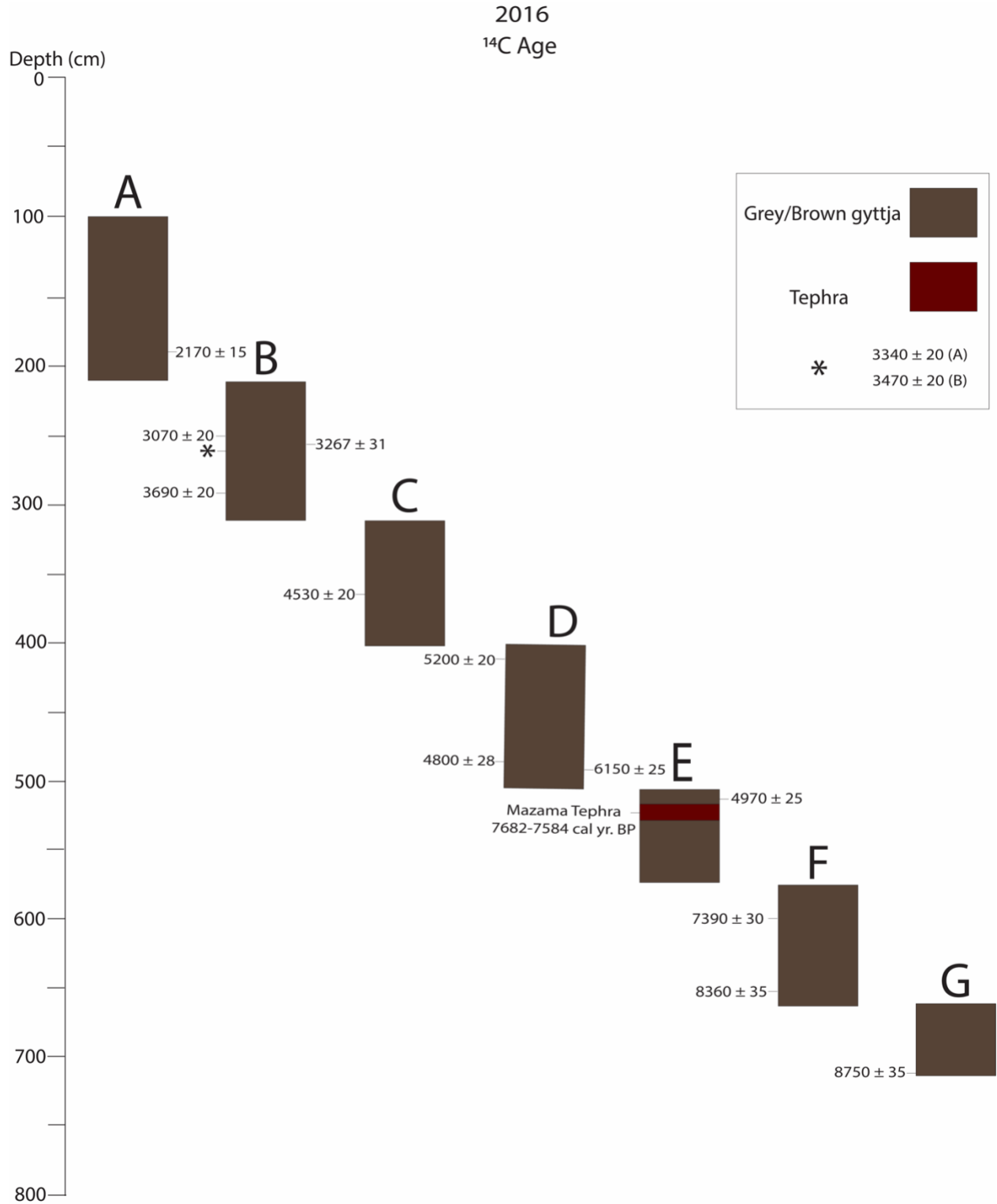


Figure 4b: Lithology diagram of the 6 cores taken from Rainbow Lake, MT (2016) and location of uncalibrated radiocarbon ages obtained. Tephra layer is inferred to be from the eruption of Mt. Mazama 7,682-7,584 cal yr. BP (Egan et al., 2015).

Chronology

Age-depth chronologies for both sites were developed using accelerator mass spectrometry (AMS) ^{14}C dates and applying known ages to tephra layers inferred to be deposited by eruptions from Mt. Mazama (Egan et al., 2015) and Glacier Peak (Kuehn et al., 2009). All ^{14}C dates were converted to calibrated ages using the IntCal20 calibration curve (Reimer et al., 2020), and the final age-depth models were constructed using Bayesian accumulation histories for deposits (Bacon) software for modeling in R (Blaauw and Christen, 2011; R Core Team, 2015) (Fig. 5-6; Tables S1-S2). Twenty-one (AMS) ^{14}C dates and one tephra attributed to Mazama (Egan et al., 2015) were used to derive an age-depth chronology at Rainbow Lake (Fig. 6). Ten (AMS) ^{14}C dates and Mazama and Glacier Peak tephtras (Egan et al., 2015) were used to derive the age-depth chronology for Wymore Lake (Fig. 5). Wymore Lake and its surrounding area lies on the Helena Formation; composed of a suite of carbonate rock variations dating to the Middle Proterozoic (c. 1-1.5 gya) (Harrison et al., 1986). As it erodes into the reservoir, it could contribute an “old carbon” signal in our sediments (Walker, 2005). To account for this contribution, we included a reservoir adjustment to calibrated ^{14}C dates.

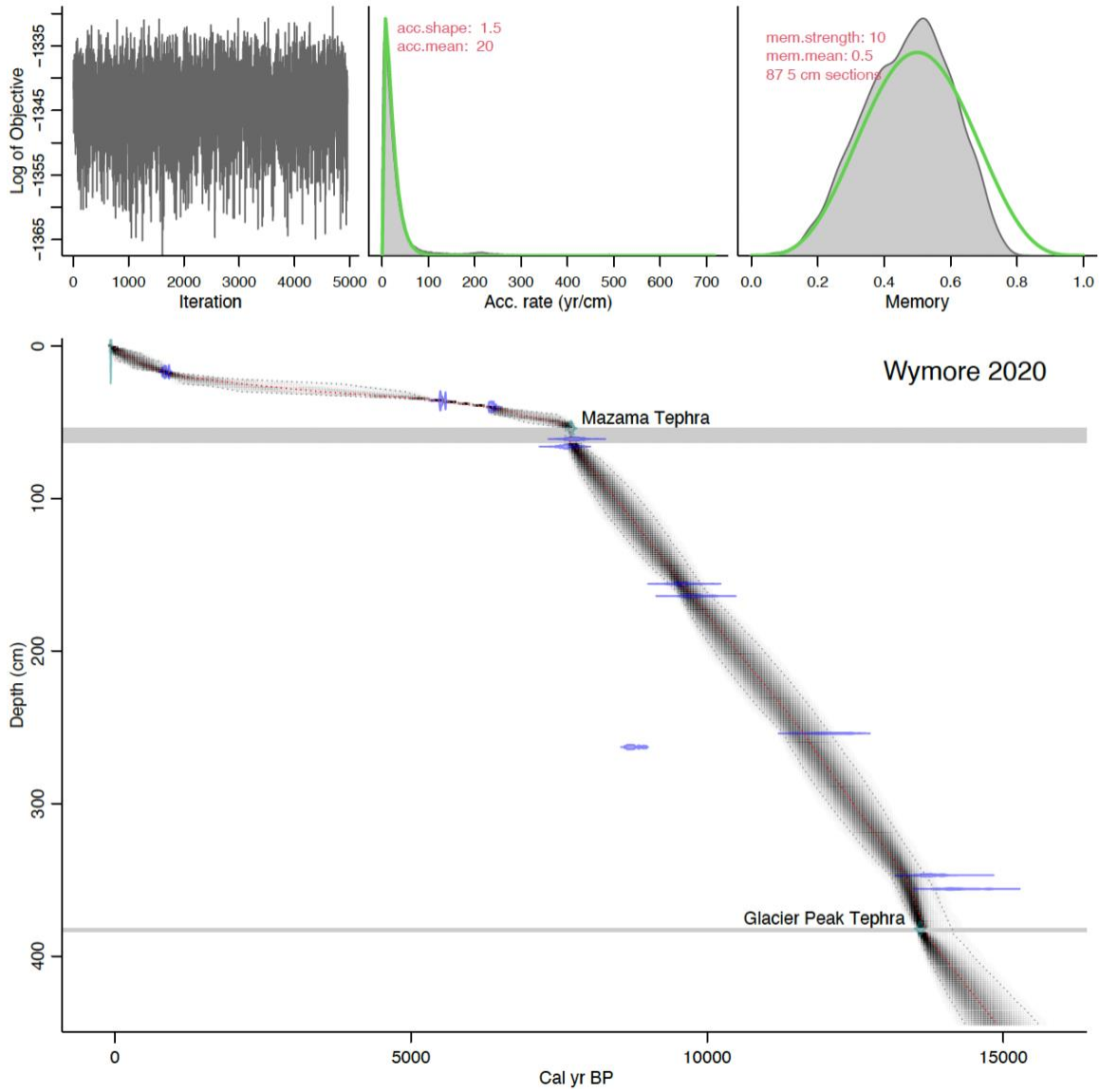


Figure 5: Age-depth model for Wymore Lake. The red dotted line represents the interpolated age for each depth of the core, with the back shading within the grey dotted lines representing the 95% confidence interval, blue dots indicating radiocarbon dates with error bars, and green dots representing tephra layers.

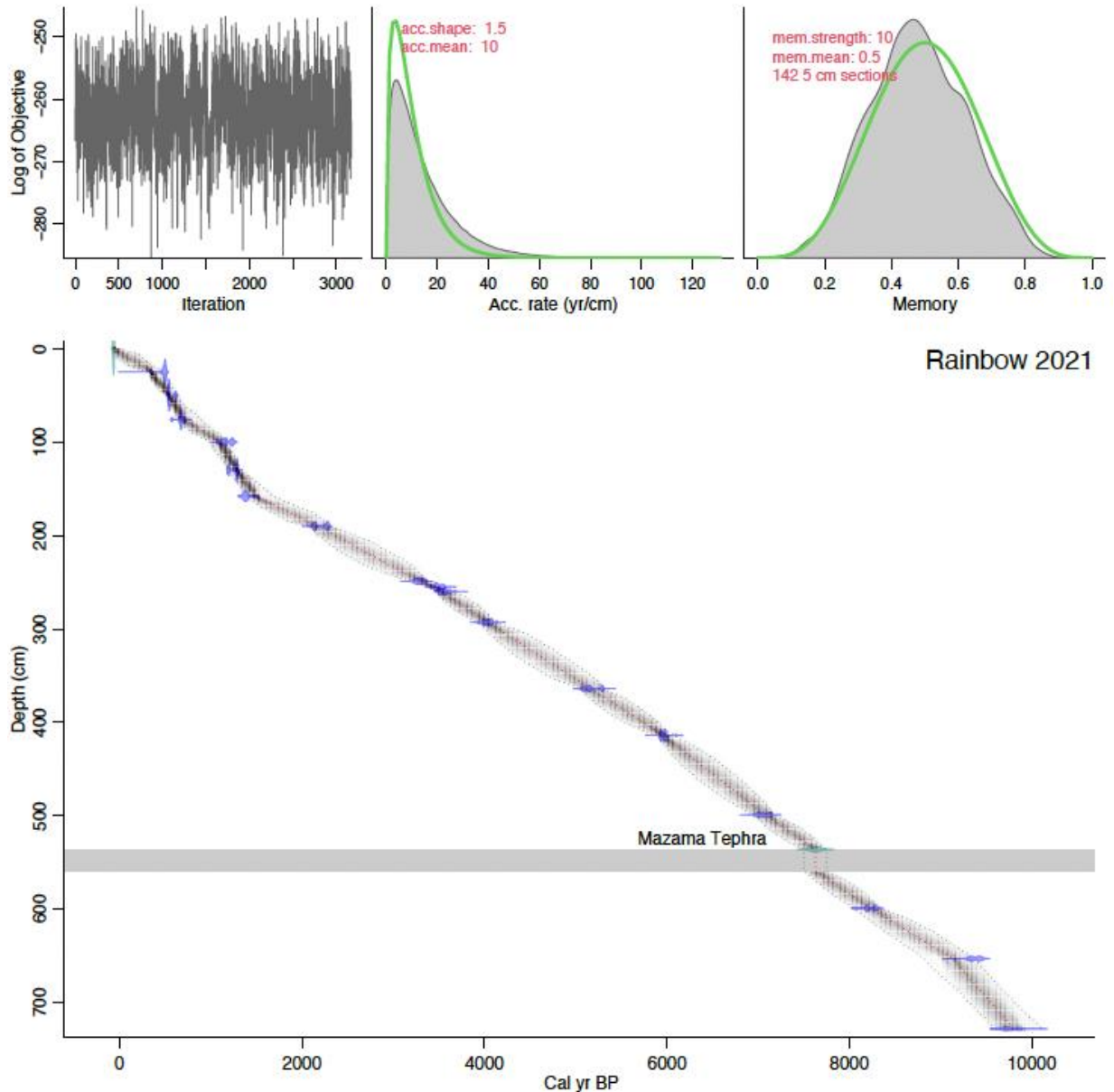


Figure 6: Age-depth model for Rainbow Lake. The red dotted line represents the interpolated age for each depth of the core, with the back shading within the grey dotted lines representing the 95% confidence interval, blue dots indicating radiocarbon dates with error bars, and green dots representing tephra layer.

Wymore Lake Pollen and Charcoal Data

WY-Z1: 399-279 cm, 14,000-12,000 cal yr. BP

Zone 1 was composed of taxa consistent with mixed-conifer forest (Iglesias et al., 2018). *Pinus* undifferentiated dominated this zone, with levels hovering between 81-95% throughout its entirety. *Abies* stayed around ~0-2% throughout most of the zone, increasing up to ~5% around 13,500 cal yr. BP. Consistently low levels of *Artemisia* (~1-3%) and Cupressaceae (~0-2%) were also represented. Low levels of Cyperaceae and the absence of aquatic taxa such as *Typha* throughout the zone are indicative of deeper, open water (Alt et al., 2018). The total pollen accumulation rate (PAR) ranged from 1,746 to 26,825 grains cm⁻² yr⁻¹, suggesting increased establishment of taxa that produce large quantities of pollen, such as *Pinus* spp. (Fig. 7). Arboreal pollen to non-arboreal pollen percentages (AP/NAP) increased throughout the zone, consistent with forest densification or increased establishment of forest patches. This zone began with fire frequencies of ~1 fires per 1000 yr⁻¹, increased to 3-3.5 fires per 1000 yr⁻¹ by ~12,500 cal yr. BP, then decreasing back to ~2 fires per 1000 yr⁻¹ by the end of the zone (Fig. 7). BCHAR was initially low, then increased as fire frequency increased, reaching the highest influx of the record c. 13,000 cal yr. BP. Peak magnitude values in this zone reached as high as 25.13 cm⁻² peak (Fig. 10). These trends are consistent with relatively high biomass-burning for the Wymore Lake site.

WY-Z2: 278-243 cm, 12,000-11,400 cal yr. BP

Dominant taxa in Zone 2 suggest a Juniper/Douglas fir parkland. Zone 2 showed a notable decrease in *Pinus* undifferentiated from 86% at the start of the zone down to 56% c. 11,900 cal yr. BP, increasing back to 89% at the end of the zone. *Artemisia* increased from 4%

up to 10%, while Cupressaceae increased from ~2% up to ~4%. *Pseudotsuga/Larix* also increased (0-6%). AP/NAP decreased until c. 11,400, where it began to increase again, consistent forest establishment (Fig. 7). Total PAR for this zone ranged from 4,796 to 12,197 grains cm⁻² yr⁻¹. Fire frequency in this zone remained ~3 fires per 1000 yr⁻¹ throughout the zone. BCHAR decreased throughout the zone. Peak magnitude values were generally low apart from one peak c. 11,700 cal yr. BP (6 cm⁻² peak⁻¹) (Fig. 10).

WY-Z3: 242-51 cm, 11,400-7,200 cal yr. BP

Zone 3 taxa indicate a dry mixed-conifer parkland consistent with the warm, dry climate of this zone, interrupted by an abrupt, short-lived shift in vegetation around the time of the eruption of Mt. Mazama c. 7,682-7,584 cal yr. BP (Egan et al., 2015; Iglesias et al., 2018). *Pinus* undifferentiated initially decreased from 86% at the start of the zone to 37% by c. 8,500 cal yr. BP, then steadily increased, reaching 57% by the end of the zone. *P. subg. strobus* remained ~1-3% throughout the zone. Cyperaceae increases up to 5% by c. 8,300, then declined to ~2% by the end of the zone. *Alnus* increased to ~7% c. 8,300, then declined to 3-4% by the end of the zone. Other taxa showed notable shifts around the eruption of Mount Mazama c. 7,682-7,584 cal yr. BP (Egan et al., 2015). *Artemisia* showed a brief but notable increase from ~2% up to 27% and began to decline shortly after to ~15% by the end of the zone, which is consistent with vegetation composition shifts associated with ash deposition (Mehring et al., 1977b; McDaniel et al., 2005; Schiller et al., 2020). Poaceae also showed a notable increase up to 17% from 3%, then declined, dropping to ~5-11% by end of the zone. Cupressaceae increased to 14% by 8,700 cal yr. BP, then began to decline to ~1-2% by the end of this zone. Amaranthaceae initially increased to ~5%, then declined to ~1%, also consistent with vegetation composition shifts

associated with ash deposition. *Pseudotsuga/Larix* increases to 7% c. 8,500 cal yr. BP, then declined to ~2% by the end of the zone. AP/NAP generally decreased throughout the zone (Fig. 7). Total PAR for the zone ranged from 2,662 to 17,221 grains cm⁻² yr⁻¹. Fire frequency began ~2-3 fires per 1000 yr⁻¹ until 10,200 cal yr. BP, when it increased to ~5 fires per 1000 yr⁻¹ by c. 8,600 cal yr. BP, then decreased steadily to 2 fires per 1000 yr⁻¹ by the end of the zone. BCHAR remained steady until c. 6,000 cal yr. BP where it abruptly increased. Peak magnitude values were variable, ranging from <1 to >13 cm⁻² peak⁻¹. Charcoal influx data indicate this period was characterized by initially frequent fires and relatively high biomass burning followed by a decline in biomass burning and fire by the end of the zone (Fig. 10).

WY-Z4: 50-36 cm, 7,200-5,300 cal yr. BP

Taxa of Zone 4 are consistent with open mixed conifer forest development as climate became cooler and wetter (Iglesias et al., 2018). *Pinus* undifferentiated increased from 71% to 82%. *Artemisia* decreased from 10% to 3%. Poaceae dropped from 8% to 3%, and Cupressaceae remained ~0%. *Pseudotsuga/Larix* remained ~1.5%. Typha increased from 0% to 1%. AP/NAP increased throughout the zone (Fig. 7). Total PAR ranged from 458 to 1,701 grains cm⁻² yr⁻¹ throughout the zone. Fire frequency decreased throughout the zone from 2 fires per 1000 yr⁻¹ to less than 1 fires per 1000 yr⁻¹, with peak magnitude values <3 cm⁻² peak⁻¹, and consistently decreasing BCHAR, indicating infrequent fires and low biomass burning (Fig. 10).

WY-Z5: 35-26 cm, 5,300-2,000 cal yr. BP

Zone 5 taxa are consistent with open mixed-conifer forest (Iglesias et al., 2018). *Pinus* undifferentiated decreased from 71% to 63% and *P. subg. strobus* decreased from 3% to 1.5%. Cyperaceae increased dramatically from 1% at the end of the previous zone to 20%, and Poaceae

increased from 3% to 10%. Asteroidae and Amaranthaceae also increased, from ~0 to 2% and 0% to 10%, respectively, then both decreased to ~1% by the end of the zone. AP/NAP generally decreased throughout the zone (Fig. 7). Total PAR ranged from 158-368 grains cm⁻² yr⁻¹. Fire frequency ranged from <0.5 to ~1.5 fires per 1000 yr⁻¹ throughout the zone. BCHAR was variable but generally low throughout the zone. Peak magnitude values were low throughout the zone (<1 cm⁻² peak⁻¹) (Fig. 10).

WY-Z6: 25-0 cm, 2,000 cal yr. BP-present

Zone 6 taxa show the development of modern mixed-conifer forests (Iglesias et al., 2018). *P. subg. pinus* decreased from ~2% to ~0.2% through the zone. *Pseudotsuga/Larix* percentages initially increased, then remained relatively stable between ~4-8%. Poaceae percentages initially increased from 6% to 15% by c. 1350 cal yr. BP, then decreased slightly, ending zone around ~4-8%. *Artemisia* increased to 1.5% by the end of the zone. *Pinus* undifferentiated levels varied between 70-88% throughout the zone. Cyperaceae levels increased (~9% to ~20%) throughout the zone, indicating the presence of a large wetland margin surrounding the lake (Alt et al., 2018). Decreased *P. subg. pinus* and increased Cyperaceae levels indicate the Wymore site was relatively dry, with low lake levels. AP/NAP increased throughout the zone, consistent with the development of closed forest (Fig. 7). PAR ranged from 230 to 6,738 grains cm⁻² yr⁻¹. Fire frequency remained low, with 0-1 fires per 1000 yr⁻¹ throughout the zone. CHAR and BCHAR levels remain low except for a brief increase c. 550 cal yr. BP, corresponding with a fire event with a peak magnitude value of 2.33 (cm⁻² peak⁻¹). Peak magnitude values remained low throughout the rest of the zone <1 cm⁻² peak⁻¹ (Fig. 10). This indicates fires were infrequent and biomass burning low during this period.

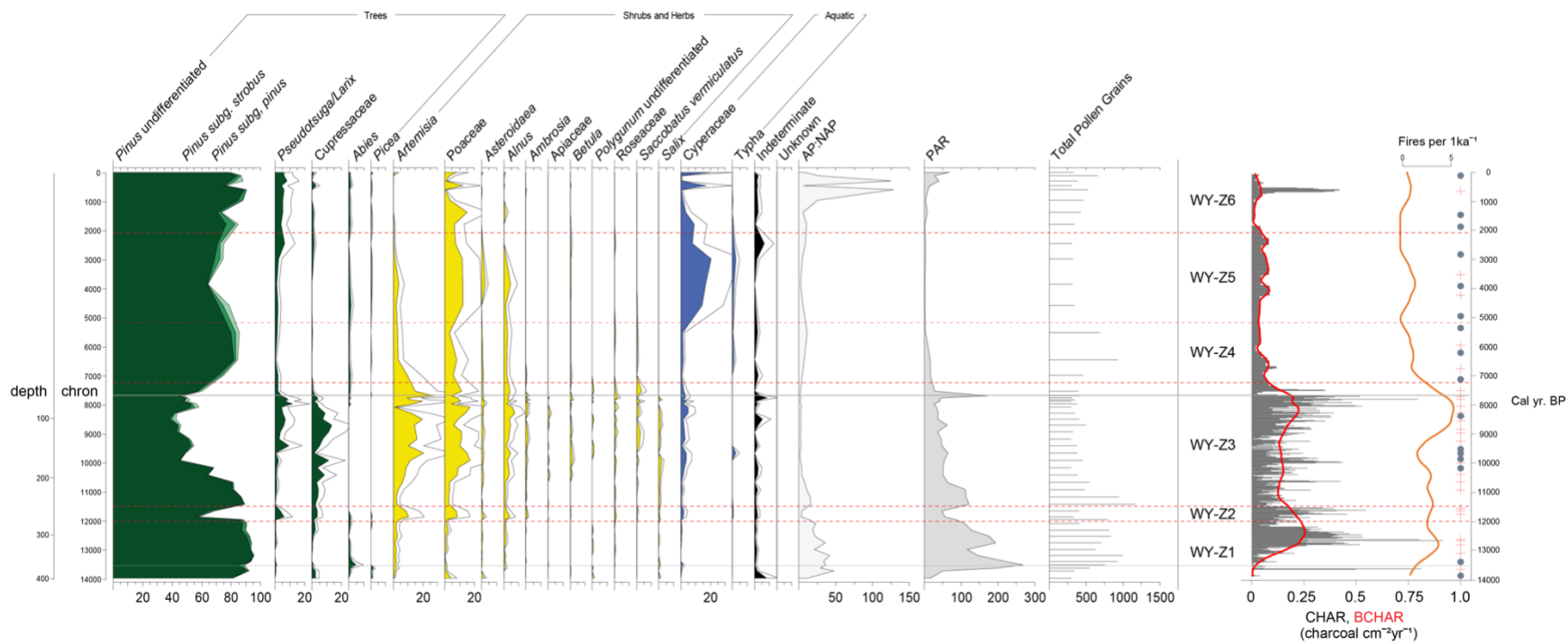


Figure 7: Pollen diagram showing major taxa and charcoal accumulation for Wymore Lake, Montana. Lines represent 2x exaggeration.

Rainbow Lake Pollen and Charcoal Data

RL-Z1: 724-374 cm, 9,800-5,300 cal yr. BP

Zone 1 taxa are consistent with an open grassland environment with some shrubs and trees. Zone 1 had the lowest *Pinus* undifferentiated percentages of the record (lowest value ~23% c. 8,200), increasing towards present to ~43% by the end of the zone. Zone 1 had the highest *Pseudotsuga/Larix* and *Artemisia* percentages of the record (~5-16% and ~3-16%, respectively). Poaceae percentages were relatively high but variable throughout the zone (5-11%). Levels of *Populus* were initially high, around 8%, then decreased to ~2% by the end of the zone. *Salix* and Amaranthaceae also hit their highest percentages of the record in zone, 10% and 5% respectively. Cyperaceae remained low around 1-2%, while *Alnus* percentages were generally high (5-12%) throughout the zone. *Pediastrum* levels rose as high as 32% early in the zone, but were variable, possibly indicating initially shallow lake levels, with fluctuating lake levels later in the zone (Dodson, 1974; Davis et al., 1977; Singh et al., 1981; Adeleye et al., 2021). AP/NAP increased throughout the zone, consistent with forest densification towards the end of the zone (Fig. 8). Total PAR ranged from 2,963 to 33,286 grains cm⁻² yr⁻¹. CHAR and BCHAR increased throughout the zone. At the beginning of the zone, fire frequency decreased from 1.7 fires per 1000 yr⁻¹ to fewer than 1 fire per 1000 yr⁻¹ around 9,300 cal yr. BP. By c. 6,500 cal yr. BP, fire frequency increased to ~8 fires per 1000 yr⁻¹, then declined to ~6.5 fires per 1000 yr⁻¹ by the end of the zone. Peak magnitude was variable but generally high with a large fire event c. 6,550 cal yr. BP (49.97 cm⁻² peak⁻¹) (Fig. 10). Charcoal influx data suggest fire frequency generally increased throughout the zone as more woody vegetation became established.

RL-Z2: 373-125 cm, 5,300-1,200 cal yr. BP

Dominant taxa present in this zone are consistent with dry mixed-conifer open forest ecosystems (Iglesias et al., 2018). *Pinus* undifferentiated levels fluctuated throughout the zone, ranging from 33-62%. *P. subg. pinus* levels increased from 7% at the start of the zone to 33% by 3,800 cal yr. BP, then decreased to ~15% by the end of the zone. *Pseudotsuga/Larix* and *Artemisia* levels ranged from 3-7% and 1-3%, respectively. Poaceae percentages began ~11%, decreased to ~5% c. 7,000 cal yr. BP, then increased to 7-10% by the end of the zone. *Populus* levels were variable (3-9%), while *Salix* levels were stable (1-2%) throughout the zone. *Pediastrum* percentages varied from ~1-19% throughout most of the zone, reaching as high as 51% c. 1,400 cal yr. BP, indicating variable lake levels (Dodson, 1974; Davis et al., 1977; Singh et al., 1981; Edwards et al., 2000; Adeleye et al., 2021). AP/NAP primarily increased throughout the zone, consistent with forest densification (Fig. 8). Total PAR ranged from 2,220 to 21,674 grains cm⁻² yr⁻¹. Fire frequency ranged from ~6-7 fires per 1000 yr⁻¹ from the beginning of the zone to until c. 3,500 cal yr. BP where it decreased to ~4-5 fires per 1000 yr⁻¹ by the end of the zone. CHAR, BCHAR, and peak magnitude were variable throughout the zone. Notably, high peak magnitude values reached as high as 125.16 cm⁻² peak⁻¹ (Fig. 10). Charcoal accumulation was generally high, likely a result of increased forest infill and the abundance of woody fuels.

RL-Z3: 124-44 cm, 1,200-500 cal yr. BP

Taxa of Zone 3 are consistent with a brief period of dry mixed-conifer parkland followed by dry mixed-conifer open forest, as arboreal percentages vary early in the zone but overall show an increasing trend of AP/NAP (Iglesias et al., 2018). *Pinus* undifferentiated levels reached the highest of the entire record (61% c. 650 cal yr. BP) with levels increasing from the start of the

zone to a high of 61% and ending the zone at 46%. *P. subg. pinus* increased from 17% to 33% by the end of the zone. *Pseudotsuga/Larix* remained stable between ~2-4%. Cyperaceae levels initially increased to 7% c. 1,100 cal yr. BP, then remained stable around 1-1.5%. Poaceae increased from 3 to 14% c. 1,100 cal yr. BP, then decreased to ~1.5% by the end of the zone. *Abies* increased from ~1% to 6%, and *Alnus* decreased from 5% to 1-2% by the end of the zone. *Pediastrum* decreased from about 12% to 3% by the end of the zone, indicating deeper, open water (Dodson, 1974; Davis et al., 1977; Singh et al., 1981; Adeleye et al., 2021). Total PAR ranged from 7,620 to 23,638 grains cm⁻² yr⁻¹ (Fig. 8). Fire frequency remained high, c. ~6 fires per 1000 yr⁻¹ for the duration of the zone while CHAR and BCHAR were variable. There was one notably high peak magnitude fire event with a value of 69.67 cm⁻² peak⁻¹ c. 700 cal yr. BP (Fig. 10).

RL-Z4:43-0 cm, 500 cal yr. BP-present

Zone 4 taxa showed the development of modern mixed-conifer forest (Iglesias et al., 2018). *Pinus* undifferentiated was variable, ranging from 42%-54%. *P. subg. pinus* decreased from 24% to 12% by the end of the zone, while *P. subg. strobus* increased from 4% to 8%. *Abies* remained within ~1-2%. Poaceae increased from 2% to 10%. Cyperaceae remained stable between ~0.5-2% and *Pseudotsuga/Larix* percentages also stable around 2-3%. *Pediastrum* decreased from 17% to 5%, indicating possibly lower lake levels (Dodson, 1974; Davis et al., 1977; Singh et al., 1981; Adeleye et al., 2021). AP/NAP generally decreased throughout the zone (Fig. 8). PAR ranged from 5,341 to 13,632 grains cm⁻² yr⁻¹. Fire frequency decreased from 5-6 fires per 1000 yr⁻¹ until c. 90 cal yr. BP, where it decreased to ~4 fires per 1000 yr⁻¹ towards the

present. Peak magnitude values remained high with a large fire event occurring c. 80 cal yr. BP (52.55 cm⁻² peak⁻¹) (Fig. 10).

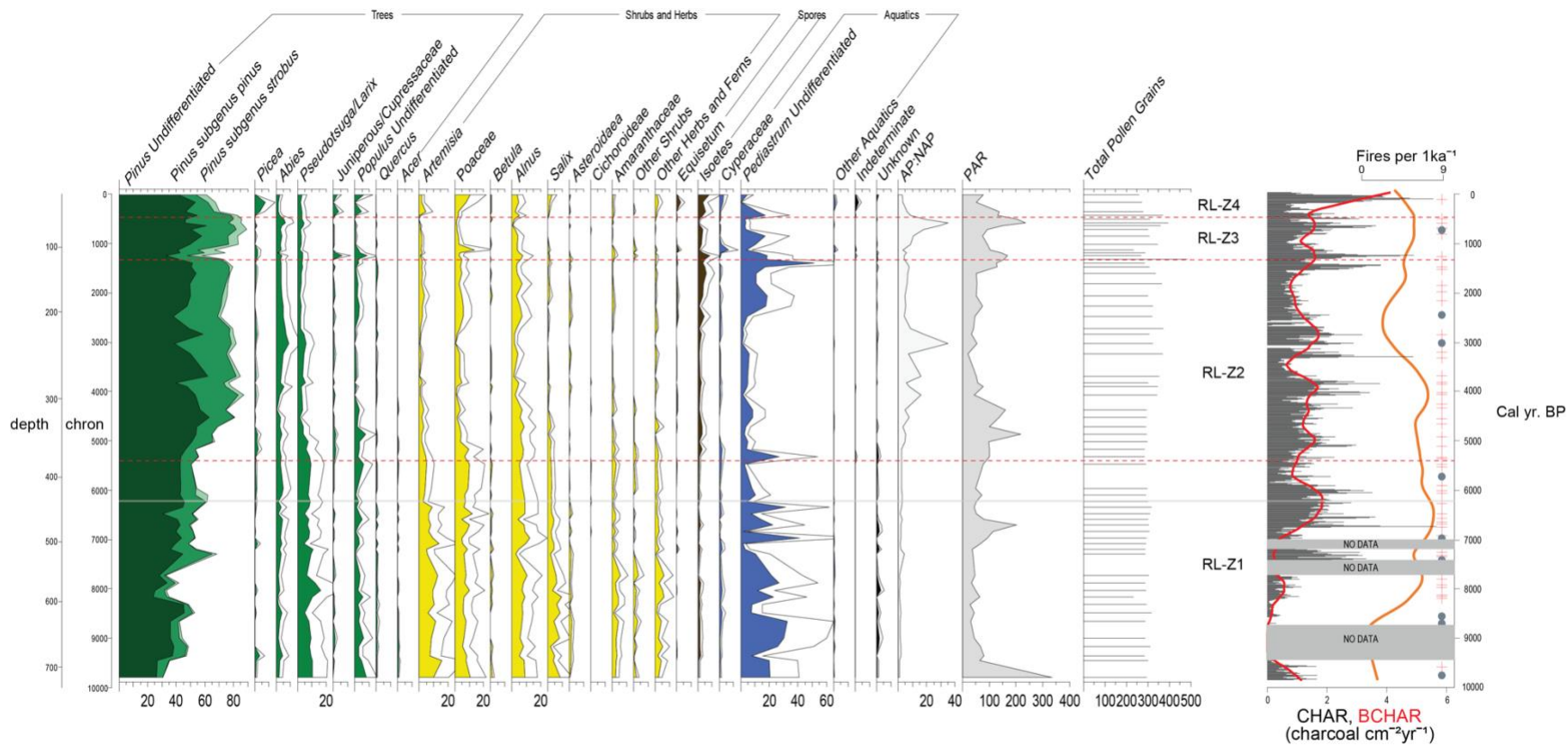


Figure 8: Pollen percentages diagram showing major taxa and charcoal accumulation for Rainbow Lake, Montana. Lines represent 2x exaggeration.

Biomarker Time Series: Rainbow Lake

An index of human presence was calculated using Coprostanol, epi-Coprostanol, and 5α Cholestanol values for Rainbow Lake. The two ratios indicating human presence (CTR1 – Coprostanol/(Coprostanol + 5α Cholestanol) and (CTRE2 – Coprostanol/(Coprostanol + epi-Coprostanol + 5α Cholestanol)) were highly correlated ($r=0.995$, $p\text{-value} < 10^{-10}$) with values ranging from 0.06 to 0.23 and 0.05 to 0.21 (mean 0.14 ± 0.02 , 0.13 ± 0.02) (Fig 9, Fig. S3). Additionally, a third ratio used to evaluate potential degradation issues (CTR3 – Coprostanol/epi-Coprostanol) was strongly correlated with CTR1 ($r=0.800$, $p\text{-value} < 10^{-6}$). Values ranged from 0.4 to 3.5 (mean 1.8 ± 0.4). The significant correlation between CTR1 and CTR3 (Fig. 9, Fig. S4) suggests that degradation did not significantly influence Coprostanol preservation.

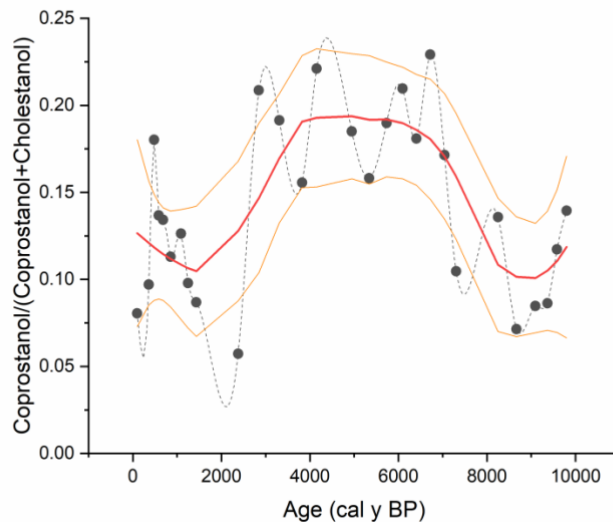


Figure 9: Rainbow Lake Coprostanol/(Coprostanol + 5α Cholestanol) ratio (CTR1), range = 0.06 to 0.23, mean = 0.14 ± 0.02 .

DISCUSSION

Multiproxy reconstructions from Wymore and Rainbow Lake suggest climate was a dominant driver of environmental change and fire activity at large spatial scales throughout much of the Holocene. The correspondence of patterns of fire frequency at Rainbow Lake during the mid-Holocene and a subtle decoupling of climate, vegetation, and fire dynamics at Wymore Lake during the late Holocene suggest a possible increased role for human and local drivers of change during these intervals.

Late Glacial Period (>14,000-11,000 cal yr. BP)

The Late Glacial period marks the beginning of the recession of the large ice sheets that covered North America during the last glacial maximum (Kutzbach et al., 1998). This recession led to a major shift in climate from a period of cold, dry conditions to warmer, and wetter conditions (Kutzbach et al., 1998). Summer insolation and increased atmospheric CO₂ concentrations accelerated climate amelioration leading to the colonization of glacial landscapes with vegetation (Kutzbach et al., 1998). Vegetation simulations from this period indicate that most of the northern latitudes not covered in ice consisted of polar desert and tundra vegetation in the early part of this period, with forests beginning to expand from warmer and wetter low latitudes after the melting of the ice sheets (Kutzbach et al., 1998).

Pollen influx was low at the beginning of the Wymore Lake record (c. 14,000 cal yr. BP) when the landscape would have been newly ice-free. As the Cordilleran ice sheet retreated, closed mixed-conifer forests were established within the Wymore Lake watershed, consistent with climate amelioration c. 14,000-12,000 cal yr. BP (Fig. 7, Fig. 11). Low percentages of

aquatic taxa indicate relatively high lake levels or abrupt transitions from open water to the upland margin during this period (Alt et al., 2018). Forests became more dense, and high biomass burning occurred as a result of warmer temperatures and increased availability of woody material (Fig. 10). A major shift in the landscape from closed forest to Juniper/Douglas fir parkland begins at Wymore Lake c. 12,000 cal yr. BP, where we see a rapid, short-lived shift to parkland vegetation coincident with the later stages of the Younger Dryas period of dry conditions c. 12,900-11,500 cal yr. BP (Alley et al., 2002) (Fig. 7, Fig. 11). Charcoal records indicate infrequent fires dominated the landscape, increasing in frequency as closed mixed-conifer forests established and more woody fuels (e.g., branches, downed trees, woody plants) became available, resulting in relatively high biomass burning by the end of the late glacial period (Fig. 10).

Early Holocene (11,000-6,000 cal yr. BP)

During the early Holocene, increased summer insolation and warmer, drier conditions intensified summer drought at lowland NRM sites (Bartlein et al., 1998; Kutzbach et al., 1998; Whitlock et al., 2008). Winter conditions were cooler than present due to seasonally low insolation during winter months (DJF) (Kutzbach et al., 1998). Additionally, the intensification of the Pacific sub-tropical high-pressure system and blocking of summer storms from the Pacific led to a decrease in summer precipitation in the northwestern US (Bartlein et al., 1998; Kutzbach et al., 1998). These conditions led to the expansion of more open grasslands/woodlands throughout NRM forest ecosystems, especially at lower elevation valley margins (Kutzbach et al., 1998; Carter et al., 2017; McWethy et al. 2020).

The pollen record at Wymore Lake suggests a transition from a dry mixed-conifer parkland to mixed-conifer woodland, indicating a pronounced response to the increased summer insolation during the early Holocene (Fig. 11). Xerophytic taxa including *Artemisia* (sagebrush), Cupressaceae (Juniper) and Poaceae (grass) were abundant from c. 11,000-6,000 cal yr. BP, assemblages that are consistent with the presence of a dry parkland prior to ~7,500 cal yr. BP (Fig. 7). Interestingly, the early Holocene increase in pollen abundance of *Pseudotsuga/Larix* increased much earlier than other NRM sites (Alt et al., 2018). The warm, dry conditions likely facilitated this pronounced expansion of *Pseudotsuga/Larix* during the early Holocene.

Similar to Wymore Lake, the pollen record at Rainbow Lake indicates an open grassland environment existed early in the period (Fig. 8). Towards the end of the early Holocene, the Rainbow Lake landscape transitioned to a dry mixed-conifer forest (Fig. 8, 11).

Changes in pollen percentages for key taxa at Wymore Lake following the eruption of Mount Mazama 7682-7584 cal yr. BP (Egan et al., 2015) suggest ash deposition may have had a short-term (multi-decadal) impact on vegetation composition. Steppe taxa (e.g., *Artemisia*, Poaceae) show a brief but notable increase immediately after the Mazama eruption (Fig. 7). Other studies in the NRM have also reported a brief increase in *Artemisia* (sagebrush) pollen and a decrease in *Pinus* undifferentiated pollen following the Mazama eruption (Mehring et al., 1977a; Mack et al., 1978; Brant, 1980; Power et al., 2011; Alt et al., 2018), as have studies in the Greater Yellowstone Ecosystem (GYE) (Schiller et al., 2020). Prior research has also shown that the composition of the Mazama ash favors steppe species such as *Artemisia*, as it creates a “mulching effect”, trapping moisture and enhancing growing conditions (Mehring et al., 1977b; McDaniel et al., 2005; Schiller et al., 2020). This steppe landscape was short-lived,

however, and mixed-conifer parkland vegetation, returned to dominate through the end of the early Holocene (Fig. 7, Fig. 11).

At the beginning of the early Holocene c. 11,000 cal yr. BP, fire frequency increased at Wymore Lake, peaking c. 8,600 cal yr. BP, likely resulting from the combination of mid-Holocene summer insolation intensification and an increase in the availability of abundant woody fuels. Warm, dry conditions associated with high summer insolation, and the short-lived vegetation shift back to steppe associated with the Mazama eruption allowed for abundant fine fuels and fuel drying during this period (Fig. 7, 11). Fire frequency declined at the end of the mid-Holocene c. 7,000 cal yr. BP and persisted for millennia. This persistent decline in charcoal influx coincides with a rapid decline in sediment accumulation. As a result, we propose that either intermittent hiatuses in sediment accumulation at the site, and/or a preponderance of low-severity fires associated with mid-Holocene drying and shifts from woody to more herbaceous (primarily grasses) vegetation could be responsible for this decline (Fig. 7, 10-11).

The fire record at Rainbow Lake includes several gaps where data is missing, therefore few interpretations can be made about fire activity during the beginning of the early Holocene at this site. By the mid early-Holocene, our record indicates woody biomass burning increased c. 7,500 yr. BP as forests expanded and became denser with frequent large fires occurring by the end of the zone (Fig. 10). This corresponds with increasing charcoal accumulation throughout this period. Fire frequency remains high and relatively stable between 7,000 cal yr. BP and 3,000 cal yr. BP, the highest frequency of our record.

Late Holocene (6,000 cal yr. BP-Present)

During the late Holocene, summer insolation levels declined to present-day levels. This decline resulted in reduced seasonality and an overall cooling trend with cooler summers and warmer and wetter winters in the NRM. Reduced summer drought, cooler summers, warmer and wetter winters, and a weakening high-pressure system all contributed to the changes in vegetation seen during this period in the NRM (Bartlein et al., 1998; Kutzbach et al., 1998).

In general, pollen records from both Wymore and Rainbow Lakes show that forests transitioned from drier, open mixed-conifer forest to wetter, more dense mixed-conifer forests that occur today within the watersheds (Fig. 7).

During the mid-late Holocene, several notable short-term shifts in vegetation occur. Evidence that the warmer drier conditions during the Medieval Climate Anomaly (MCA) and the cooler climatic conditions during the Little Ice Age (LIA) resulted in a multi-centennial change in vegetation at Rainbow Lake (Mann et al., 2009). From c. 1000-700 cal yr. BP, there was an abrupt increase in *P. subg. pinus* (Ponderosa and/or Lodgepole pine) *Pinus subg. strobus* (Western white pine), and Poaceae, indicating a brief period of warmer, drier conditions. At c. 650-100 cal yr. BP we see a decrease in all pines and *Abies grandis* (Grand fir), while Poaceae and *Artemisia* increased, indicating cooler, drier climate at Rainbow Lake during the LIA (Fig. 8, Fig. 11).

Sedimentation rates were very low throughout the late Holocene at Wymore Lake (Fig. 5). This decline in sedimentation and pollen and charcoal influx could have resulted from extended periods of localized drying (perhaps elevation-dependent), a slowdown in the

production of water input from the spring feeding Wymore Lake, or changes in surface and shallow subsurface hydrology related to changes in terrestrial vegetation.

One explanation for a decrease in surface or subsurface hydrology providing water to the spring feeding Wymore Lake is that increased forest infill (and subsequent transpiration) that occurred during the generally cooler and wetter conditions of the later Holocene could have reduced surface water and spring flow to significantly dry the very shallow (1-2 meters deep) Wymore Lake pan. Whatever the driver, pollen percentages for semi-arid taxa (e.g., *Amaranthaceae*, *Poaceae*, *Asteroidae*, and *Cyperaceae*) increased significantly c. 3,500 cal yr. BP to present (Fig. 7, 11). At c. 2,000 cal yr. BP, we see the modern mixed-conifer forest begin to develop at Wymore Lake. *Cyperaceae* (sedges) increased, indicating lowering lake levels and large wetland margin surrounding the lake, consistent with conditions at the site today (Alt et al., 2018). Pollen percentages of *Poaceae* (grasses) and *Pseudotsuga/Larix* (Douglas fir/Western Larch) were highly variable from c. 1,000 cal yr. BP to present (Fig. 8). This variability could potentially be associated with increased ENSO events or pronounced oscillations between wet and dry conditions at lower elevations in the Mission Valley.

Differences in levels of woody versus non-woody biomass between Wymore Lake and Rainbow Lake likely contributed to their differing fire histories during the late Holocene. Fire occurrence was infrequent during the late Holocene at Wymore Lake, with large alternating peaks between grassland and forest pollen dominance coinciding with large (Fig. 7). These large fluxes could indicate alternating forest to non-forest taxa in response to disturbances and highlight the sensitivity of this site to these transitions in the late Holocene (Fig. 10). Relatively high late-Holocene fire activity at Rainbow Lake despite cooler and wetter conditions indicates

some decoupling of climatic controls on fire and vegetation and a possible role for human-set fires during the least 1-2 millennia.

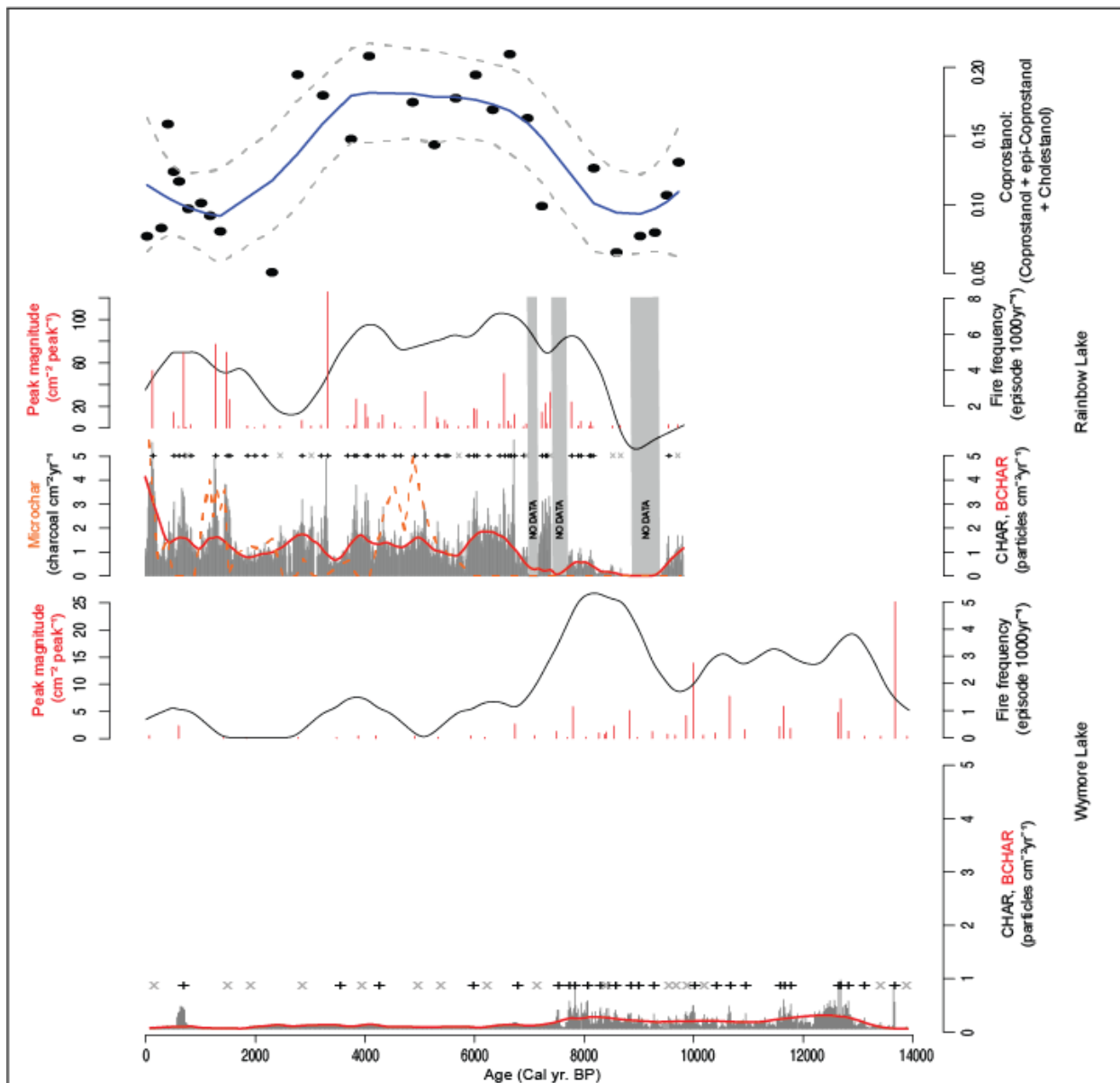


Figure 10: Coprostanol ratio (Coprostanol/(Coprostanol + *epi*-Coprostanol + Cholestanol), fire episode frequency, peak magnitude, microchar, and Char influx data for Rainbow Lake; fire episode frequency, peak magnitude, and Char influx data for Wymore Lake.

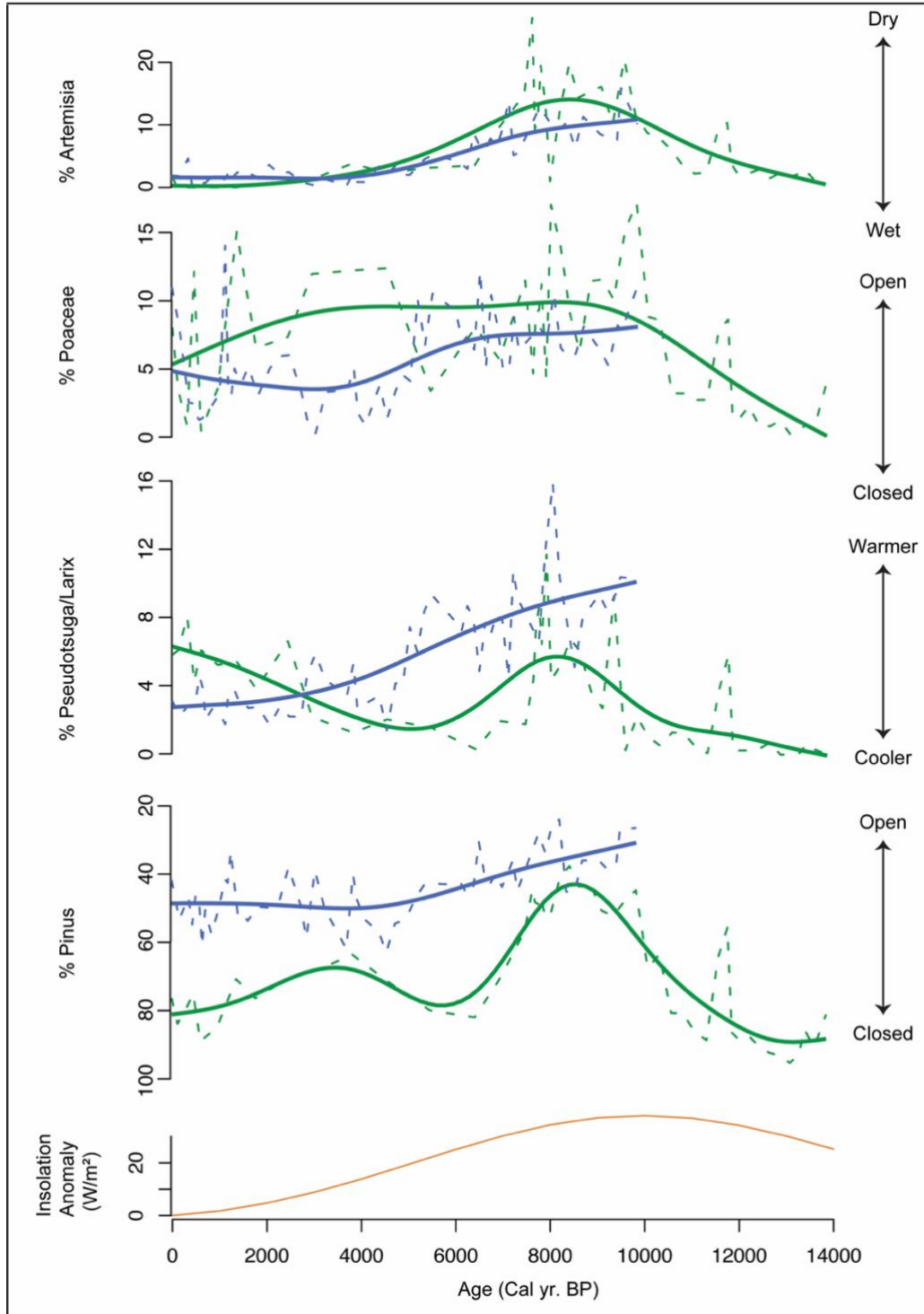


Figure 11: Summary of major taxa at Wymore Lake (green) and Rainbow Lake (blue), shown as pollen percentages, plotted both as raw data (dotted line) and using a GAM smoother (solid line), with July Insolation Anomaly for 45° North (Laskar et. al, 2004). Arrows on the left y-axis show implications for moisture, temperature, and landscape coverage.

Regional Comparison

Fire Activity Across NRM Biophysical Gradients

High-elevation forests in the NRM tend to be most responsive to changes in growing season temperature because they are moisture-limited systems, where extended growing seasons and increased growing season temperatures allow fuels to dry sufficiently to promote fire spread. Warmer spring temperatures can also lead to reduced spring snowpack and accelerated snowmelt, resulting in longer fire seasons. Infrequent, high-severity fire regimes dominate at these sites (Peet, 2000; Veblen, 2000; Schoennagel et al., 2004; Power et al., 2011). Stand-replacing fires typically occur infrequently – as seldom as once every 200-300 years (Romme 1982; Kipfmüller and Baker, 2000; Veblen, 2000; Schoennagel et al., 2003; Schoennagel et al., 2004) – and are associated with persistent high-pressure systems promoting extremely dry climate (Romme and Despain 1989; Renkin and Despain 1992; Bessie and Johnson, 1995; Nash and Johnson, 1996; Schoennagel et al., 2004). Long-term droughts (40 or more days with no precipitation) caused by persistent high-pressure systems allow for large fuels to dry sufficiently enough to be at risk of burning (Schoennagel et al., 2004). Unlike low-elevation forests, high-elevation forests are predominantly composed of dense, continuous forest canopies with abundant ladder fuels (such as saplings and lateral branches), an abundance of large fuels (such as fallen trees) and very few fine fuels (such as herbaceous plants) in the understory (Schoennagel et al., 2004).

In contrast, fire activity in low-elevation forests in the NRM is highly varied with frequent, low-mixed severity fires (Carter et al., 2017). These forests tend to be open with abundant fine fuels in the understory, particularly herbaceous plants and grasses (Swetnam and

Baisan, 1996; Schoennagel et al., 2004). An increase in the number of large wildfires at low-elevation sites tends to be associated with above-average spring temperatures, and warm, dry summers (Kitzberger et al., 2007; Heyerdahl et al., 2008; Carter et al., 2017). Wetter than average years can promote fuel buildup in low-elevation ecosystems, which, when followed by subsequent year(s) of dry conditions, creates abundant and continuous dry fuels, promoting larger wildfires (Morgan et al., 2008; Carter et al., 2017).

NRM Fire Activity and Environmental Change

Early-mid Holocene

High-elevation sites throughout the NRM experienced high biomass burning at the beginning of the early Holocene due to a strengthened Pacific high-pressure system in the NRM region, decreasing precipitation and increasing summer temperatures (Bartlein et al., 1998; Power et al., 2011). Additionally, multi-decadal droughts in forests that had become more dense led to increased fire activity (Alt et al., 2018; Power et al., 2011). By the end of the mid-Holocene, peak summer insolation began to decline, leading to wetter spring and early summer climate at high-elevation sites, resulting in a decrease in biomass burned (Power et al., 2011).

As summer insolation levels increased, low-elevation ecosystems in the NRM experienced frequent burning during the early Holocene (Bartlein et al., 1998; Kutzbach et al., 1998; Whitlock et al., 2008; Power et al., 2011). Alt et al. (2018) report a regional increase in xerophytic taxa at Twin Lake as warm, dry conditions dominate, which supported low biomass burning regionally. The Black Lake and Foy Lake (Power et al., 2011; McWethy et al., 2020) records also report xerophytic taxa during the early to mid-Holocene as a result of warm, dry summers and low-severity fire activity (Braconnot et al., 2019; McWethy et al., 2020). Our

record at Wymore and Rainbow Lakes shows a similar trend of xerophytic taxa and shrub-steppe/parkland landscapes during the early Holocene, and fire activity was of generally low-intermediate frequency due to the abundance of open woodland and grassland understory fuel matrix (Fig. 11).

During the mid-Holocene, cooler and wetter climatic conditions led to a decrease in fire activity at most low-elevation sites (Power et al., 2011; Alt et al., 2018). Wymore Lake and Rainbow Lake transitioned to mixed-conifer forests with intermediate-high frequency fires by the end of the mid-Holocene. Additionally, the deposition of ash from the eruption of Mt. Mazama c. 7,682-7,584 cal yr. BP (Egan et al., 2015) significantly impacted the vegetation, fire regimes, and chemistry of several NRM sites including Foy Lake (Power et al., 2011), Twin Lake (Alt et al., 2018), and Wymore Lake. Pollen and charcoal accumulation rates decreased post-Mazama, signaling that ash deposition may have disrupted vegetation growth and reproduction as well as suppressed wildfire activity (Mehring et al., 1977b; McDaniel et al., 2005; Power et al., 2011; Schiller et al., 2020). Wymore and Rainbow Lake showed decreasing xerophytic vegetation and increasing tree cover throughout this period. While Wymore experienced declining fire frequency, Rainbow Lake saw the highest fire frequencies of the Holocene, corresponding with the highest coprostanol ratios c. 7,000-3,000 cal yr. BP (Fig. 10, 11). Fire frequency throughout the NRM generally decreased as cooler temperatures and increased precipitation allowed for woody vegetation forest establishment and densification during the end of the mid-Holocene.

Late Holocene

During the late Holocene, modern NRM forests developed at all elevations. While cooler and wetter conditions generally prevailed throughout the NRM, climate variability led to wide oscillations between warm/dry and cool/wet conditions promoting highly variable fire activity at different elevations (Jansen et al., 2007; Heyerdahl et al., 2008; Shuman et al., 2009; Whitlock et al., 2011; Carter et al., 2017; Alt et al., 2018). Forest density increased at high-elevations during the late Holocene and these sites experienced a decrease in biomass burning up until recent centuries (Alt et al. 2018).

By the late Holocene, low-elevation mixed-conifer forests expanded and became denser at many NRM sites including Rainbow Lake, Wymore Lake, Black Lake, Twin Lake, and Power et al. (2011) sites, yet fire activity was highly variable (Alt et al., 2018; McWethy et al., 2020). Vegetation and fire frequency at low-elevation sites in the NRM were more dynamic and variable when compared with high-elevation sites during the late Holocene. High levels of biomass burned within some watersheds, and fire frequency was high at most low-elevation forests despite cool, wet conditions, possibly indicating human use of fire may have been an important driver of fire dynamics during this period (see Vale, 2002 and chapters therein; Lepofsky et al., 2005; Power et al., 2011; McWethy et al., 2020). Modern day mixed-conifer forests established during the late Holocene at Wymore and Rainbow Lake and fire activity remained high at these sites, indicating a departure from what might be expected during a period of cooler and wetter climate (Fig. 9-11). Archaeological records show indigenous populations increased to their highest levels during the last 2,000 cal yr. BP in the region. Both higher population numbers and evidence that fire activity were decoupled from climate suggest human

activity may have played a larger role in mediating fire activity over the last several millennia (Peros et al., 2010; Gajewski et al., 2011; MacDonald, 2012; McWethy et al., 2020).

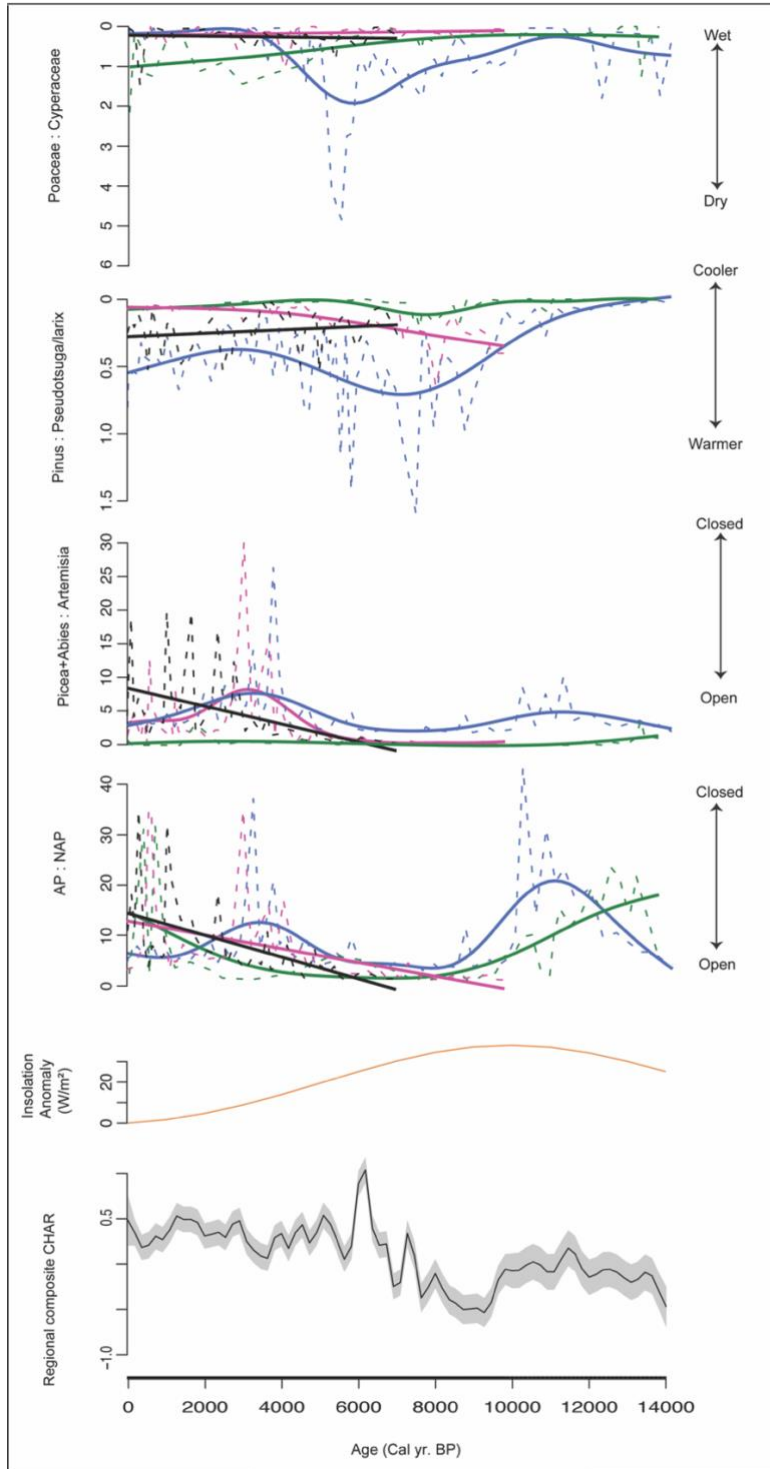


Figure 12: Select pollen percent ratios for Wymore Lake (green), Twin Lake (Alt et al., 2018) (blue), Rainbow Lake (pink), and Black Lake (McWethy et al., 2020) (black), with a GAM smoother, July Insolation Anomaly for 45° North (Laskar et al., 2004), and regional composite char influx (Wymore Lake, Twin Lake, Rainbow Lake, and Black Lake).

HUMAN INFLUENCE

The Flathead Indian Reservation, located in the Mission Valley, is home to the confederated Salish (Bitterroot Salish and Pend d'Oreille tribes) and Kootenai tribes. These tribes, among others, have lived in the NRM region and closely interacted with the landscape for millennia (Malouf, 1969). Indigenous populations throughout western North America used fire to manage the landscapes including clearing land around settlements to safeguard communities from severe fires, maintaining travel routes, facilitating the expansion of cultural plants, promoting conditions for hunting and agriculture, and preparing land for ceremonial use among many others (Stewart, 2002; Williams, 2002; Trauernicht et al., 2015; Lake et al., 2017; Long et al., 2021). Humans also used savvy management of fuels following years of unusually wet or dry conditions. For example, populations often set more fires in the cool-season during years when fuels had built up to protect communities (Bliege et al., 2016; Roos et al., 2018).

Disentangling human influence on fire activity is challenging because human use of fire often modestly amplifies or dampens climatic controls on the factors that drive fire activity (e.g., fuel type, abundance, condition, lightning). Additionally, humans often modify the frequency of low-severity fires, which are often not well represented in paleoecological charcoal records from lake sediments (Baker, 2002). Low-elevation sites may have the best chance of registering human influence on fire and the landscape, as low elevation sites are less susceptible to lightning strikes than mid or high elevation sites (Baker, 2002). Regional archaeological records and the accessibility of these low-elevation sites in the NRM indicate the potential for human presence throughout the Holocene (Peros et al., 2010; Gajewski et al., 2011; MacDonald, 2012; McWethy et al., 2020). The presence of humans in these watersheds raises the question whether humans

actively used fire to manage these ecosystems and if so, whether the scale of management in these drier forests can be detected via traditional paleoecological methods and approaches (Bliege et al, 2016; Roos et al., 2018).

Analysis of biomarker data serves as an independent record of human presence and land-use, providing new insights into possible human influence on fire and ecosystem change (Leeming et al., 1996; Meyers, 1997; McWethy et al., 2020). The biomarker data from our record suggests a long period of human presence at the Rainbow Lake site, and biomarker data from a site within ~14 kilometers of Wymore Lake (Black Lake) also documented over 7,000 years of human presence (McWethy et al., 2020). Rainbow Lake biomarker data suggest less human use of the watershed prior to 7,000 cal yr. BP. Lower values do not necessarily exclude the presence of humans at the site yet the clear increase of coprostanol levels between 7,000 and 3,000 cal yr. BP correspond to increasing fire frequency trends at Rainbow Lake suggesting humans were likely managing fire and vegetation within this watershed.

CONCLUSIONS

The paleoenvironmental reconstructions from the low-elevation NRM Wymore Lake and Rainbow Lake watersheds highlight shifts in vegetation and fire regimes throughout the Holocene in response to millennial-scale climate variability and human influence. Notable transitions include:

- As the ice sheets began to retreat during the end of the Late Glacial period, cool, wet conditions allow closed mixed conifer forests to expand, interrupted c.12,000 cal yr. BP by a brief shift to Juniper/Douglas fir parkland in response to the Younger Dryas period of dry conditions, with closed mixed-conifer forest returning immediately after the end of the Younger Dryas as climate amelioration returned. Fuels were limited and fires infrequent at the beginning of the late glacial, but rising levels of charcoal accumulation through the end of this period indicate biomass burning increased as woody vegetation expanded and became more abundant.
- The early Holocene brought warmer, drier conditions allowing for early dry parkland/open grasslands to expand. A short-lived vegetation shift towards shrub-steppe occurred post-Mazama eruption c. 7,700 cal yr. BP. Drier conditions and more abundant fuels allow for fire frequency to increase throughout the period, with Wymore Lake seeing the highest fire frequencies during the early part of the period (c. 11,000-6,000 cal yr. BP), and Rainbow Lake seeing the highest fire frequencies c. 7,000-3000 cal yr. BP, an interval which corresponds with an increase in human presence in the watershed.

- In the late Holocene, summer insolation levels decline towards present day levels and climate becomes cooler in the summer with warmer and wetter winters. Some short-lived vegetation shifts occur, but the cooler and generally wetter conditions of the late Holocene facilitated the development of the mixed-conifer forests that occur at both sites today.

During the last 3,000 years of our record, the mixed-conifer forests at Wymore Lake and Rainbow Lake have remained relatively stable. The persistence of more open mixed-conifer forests with a large component of Douglas fir/Larch may indicate an increased use of fire by humans to maintain more open forests that would have been favored by ungulates. Fire suppression in US forests was widespread by the 1930s (Arno, 1980) and coupled with livestock grazing, development, and modern forestry, led to a significant decrease in fire activity and indigenous management of western ecosystems through fire. This had a dramatic impact on lands inhabited and managed by the Confederated Salish and Kootenai Tribes, effectively removing fire from "...fire dependent ecosystems" (CSKT, 2007).

Over a hundred years of fire suppression and decades of climate warming have altered the natural fire regimes and ecosystem dynamics of forests throughout the NRM. This may be especially true for low-elevation forests that have accumulated fuels and densified. In recent years, this shift has resulted in an increase in the frequency of stand-replacing fires in ecosystems that have rarely seen such intense fire events, including the low-elevation mixed-conifer open forests found today within the Wymore Lake and Rainbow Lake watersheds. Tribes and agencies are increasingly calling for a return of fire to these landscapes to address the current state of fuels in these lower elevation mixed-conifer forests (CSKT 2007; Long et al., 2021). More research is

needed to expand our understanding of how low elevation forests respond to changes in climate, human use, and fire regime to guide these efforts.

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APPENDICES

APPENDIX A

Supplementary Materials

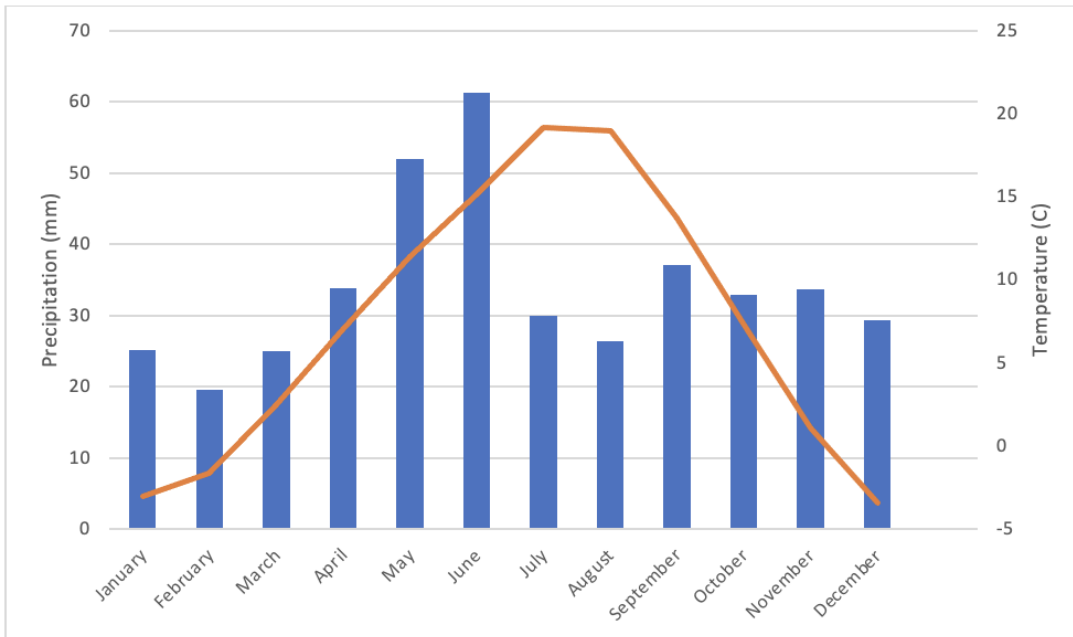


Figure S1: Average monthly precipitation and average monthly temperature from 1981-2010 for Wymore Lake, MT (PRISM Climate Group, 2021).

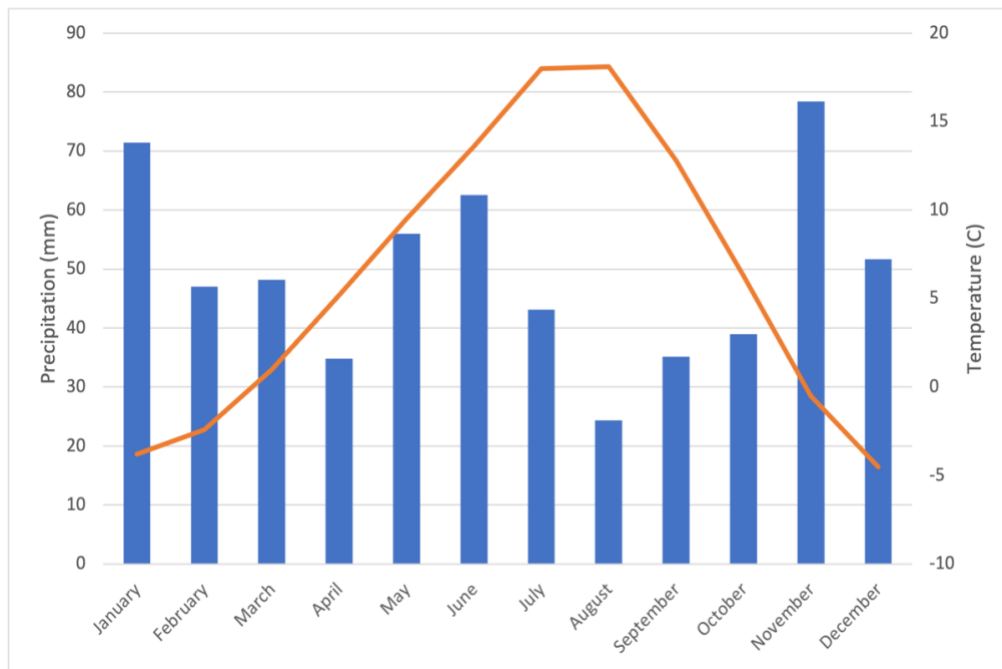


Figure S2: Average monthly precipitation and average monthly temperature from 1981-2010 for Rainbow Lake, MT (PRISM Climate Group, 2021).

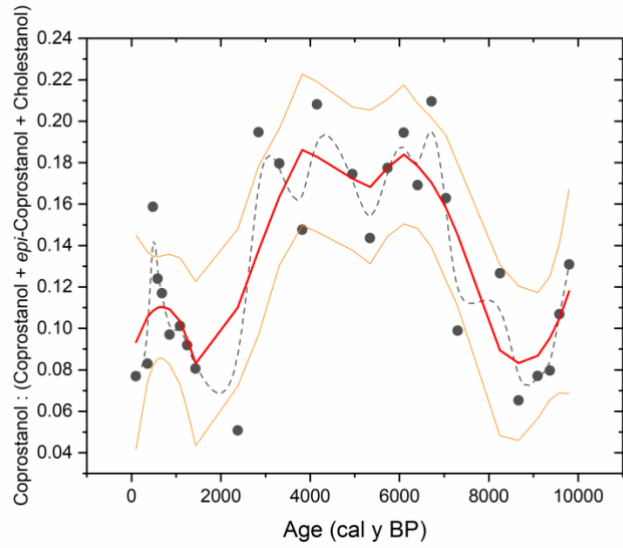


Figure S3: Rainbow Lake Coprostanol/(Coprostanol+*epi*-Coprostanol+5 α Cholestanol ratio (CTR2), ranges from 0.4 to 3.5, with a mean value of 1.8 ± 0.4

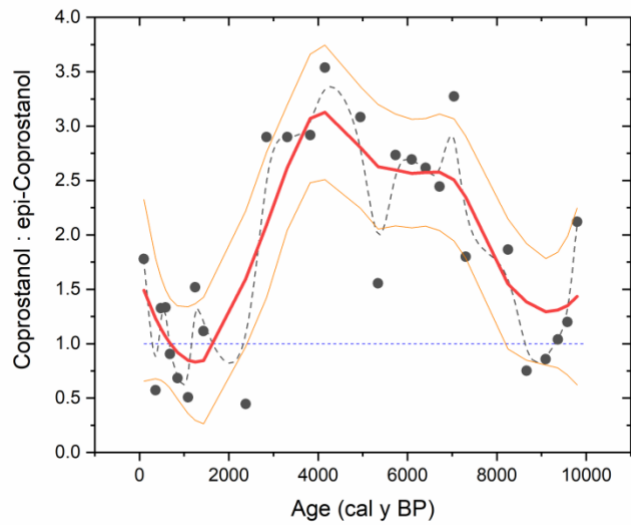


Figure S4: Rainbow Lake Coprostanol/*epi*-Coprostanol (CTR3), ranges from 0.4 to 3.5, with a mean value of 1.8 ± 0.4

Table S1 – Radiocarbon Dates for Wymore Lake

Core	Depth (cm)	Lab Number	Material Dated	Uncalibrated age (C yr BP)	Calibrated Age range (Cal yr. BP)
WY-1A-20	36	169640	Sediment Organic Carbon	4,810 ± 20	5,502.5-5,727.2
WY-1A-20	40	169641	Sediment Organic Carbon	5,600 ± 25	6,404.7-6,474.9
WY-1B-20	55	Egan et al., 2015	Mazama Ash	7,627 ± 50	7,682-7584
WY-1B-20	61	169642	Sediment Organic Carbon	7,910 ± 40	79,16.9-8,046.8
WY-1B-20	66	169643	Sediment Organic Carbon	7,780 ± 30	8,492.4-8,539.4
WY-1B-20	156	169644	Sediment Organic Carbon	9,560 ± 40	11,025.9-11,051.1
WY-1C-20	164	169645	Sediment Organic Carbon	9,740 ± 40	11,226.2-11,250.8
WY-1C-20	254	169646	Sediment Organic Carbon	11,300 ± 50	13,245.6-13,267.6
WY-1C-20	263	169647	Sediment Organic Carbon	7,920 ± 30	13,480.7-13,506.6
WY-1D-20	347	169648	Sediment Organic Carbon	12,900 ± 65	15,605.5-15,631.1
WY-2B-20	382	Kuehn et al., 2009	Glacier Peak Ash	11,600± 50	13,410-13,710
WY-2B-20	443	169649	Sediment Organic Carbon	31,000 ± 830	20,096.9-20,151.5

Table S2 – Radiocarbon Dates for Rainbow Lake

Core	Depth (cm)	Lab Number	Material Dated	Uncalibrated age (C yr BP)	Calibrated Age range (Cal yr. BP)
Poly 2015 (surface)	0	surface	Sediment Organic Carbon	-66 ± 5	N/a
Poly 2015	25	145859	Sediment Organic Carbon	425 ± 20	469-516
Poly 2015	50	145860	Sediment Organic Carbon	545 ± 15	612-623
Poly 2015	76	D-AMS014429poly	Sediment Organic Carbon	736 ± 32	651-724
Poly 2015	100	145861	Sediment Organic Carbon	1,240 ± 20	1,207-1,267
Poly 2015	130	145862	Sediment Organic Carbon	1,340 ± 20	1,263-1,300
Poly 2015	158	D-AMS014426poly	Sediment Organic Carbon	1,514 ± 28	1,490-1,511
2016 A	190	142469	Plant/Wood	2,170 ± 15	2,234-2,301
2016 B	249	142470	Plant/Wood	3,070 ± 20	3,219-3,356
2016 B	255	D-AMS014428liv	Sediment Organic Carbon	3,267 ± 31	3,443-3,564
2016 B	260	142471	Plant/Wood	3,340 ± 20	3,600-3,635
2016 B	260	142471b	Sediment Organic Carbon	3,470 ± 20	3,787-3,829
2016 B	293	145853	Plant/Wood	3,690 ± 20	4,123-4,139
2016 C	364	142472	Plant/Wood	4,530 ± 20	5,261-5,311
2016 D	414	145855	Sediment Organic Carbon	5,200 ± 20	5,916-5,994
2016 D	494	D-AMS014425liv	Plant/Wood	4,800 ± 28	5,546-5,589
2016 D	499	145858	Sediment Organic Carbon	6,150 ± 25	7,093-7,157
2016 E	532	142474	Plant/Wood	4,790 ± 25	5,602-5,744
N/a		Egan et al., 2015	Mazama Ash	7,627 ± 50	7,682-7,584
2016 F	599	145856	Sediment Organic Carbon	7,390 ± 30	8,165-8,329
2016 F	653	145857	Sediment Organic Carbon	8,360 ± 35	9,286-9,474
2016 G	728	142473	Sediment Organic Carbon	8,750 ± 35	9,660-9,782

Table S3: Concentrations of each fecal sterol for Rainbow Lake, MT.

Depth	Cal yr BP	Coprostanol	<i>epi</i> - coprostanol	Cholesterol	Cholestanol	Sitosterol	Stigmastanol
10	99	16	9	131	183	604	488
25	361	52	91	1084	484	3846	3638
40	479	53	40	569	241	2320	1550
55	587	32	24	517	202	1380	918
70	684	38	42	512	245	2309	1062
85	851	26	38	1275	204	1765	793
100	1087	36	71	536	249	1931	1013
125	1250	41	27	339	378	1271	829
150	1436	29	26	1320	305	1534	884
200	2379	32	72	2665	527	2727	3259
225	2848	29	10	499	110	934	538
250	3309	58	20	361	245	1168	587
275	3823	35	12	278	190	781	473
300	4151	46	13	403	162	967	537
350	4947	37	12	364	163	871	700
375	5343	28	18	1324	149	568	454
400	5733	41	15	1281	175	892	486
425	6096	35	13	494	132	747	579
450	6406	34	13	703	154	720	549
475	6719	44	18	550	148	821	662
500	7041	36	11	410	174	699	500
525	7304	27	15	653	231	710	687
600	8251	41	22	854	261	819	960
625	8665	6	8	26	78	142	269
650	9097	36	42	359	389	1055	1535
675	9367	53	51	528	561	1257	2044
700	9583	36	30	756	271	1031	1686
725	9800	53	25	401	327	1170	1310

APPENDIX B

Raw Pollen Data

Wymore Lake

Core Sample #	WY-1A-20	WY-1A-20	WY-1A-20	WY-1A-20	WY-1A-20
Adj. Depth	1	4	8	11	14
Pinus undiff.	248.5	550.5	305.5	229.5	467.5
Pinus subg. Strobos	9	17	13	3	6
Pinus subg. Pinus	1	3	21	0	3
Abies	2	3	4	4	2
Cyperaceae	84	4	2	64	3
Artemisia	6	0	0	0	0
Roseaceae	0	0	0	0	0
Ambrosia	0	0	0	0	1
Alnus	2	1	0	1	0
Betula	0	0	0	1	0
Poaceae	26	22	3	37	2
Aster	1	0	0	0	1
Typha	0	0	0	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	0	0	0	0	0
Acer	0	0	0	0	0
Cupressaceae	5	3	0	8	0
Indeterminate	0	15	7	6	9
Picea engelmanni	2	0	1	1	2
Apiaceae	0	0	0	0	0
Amaranthaceae	4	2	0	2	0
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0
Polygonum	0	0	0	0	0
Bistorta	0	0	0	0	0
Ligulaflorae	0	0	0	0	0
Campanulaceae	0	0	0	0	0
Salix	0	0	0	0	0
Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	19	40	31	13	32
Quercus	0	0	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0

Rhus	0	0	0	0	0
Total Pollen Grains	409.5	660.5	387.5	369.5	528.5

Core Sample #	WY-1A-20	WY-1A-20	WY-1A-20	WY-1A-20	WY-1A-20
Adj. Depth	18	21	23	26	28
Pinus undiff.	389.5	301.5	259	214	219.5
Pinus subg. Strobilus	12	9	21	5	11
Pinus subg. Pinus	3	1	7	7	7
Abies	3	3	4	0	1
Cyperaceae	7	15	33	26	85
Artemisia	0	0	2	2	4
Roseaceae	0	0	0	1	0
Ambrosia	0	0	0	0	0
Alnus	0	6	0	0	5
Betula	0	0	1	2	1
Poaceae	16	64	22	22	38
Aster	0	0	0	1	3
Typha	1	0	1	3	10
Unknown	0	0	0	0	0
Saccobatus vermiculatus	0	0	0	0	0
Acer	0	0	0	0	0
Cupressaceae	0	4	2	4	2
Indeterminate	10	10	1	20	5
Picea engelmanni	0	2	2	0	1
Apiaceae	0	0	0	0	0
Amaranthaceae	1	2	5	4	14
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0
Polygonum	0	0	0	0	0
Bistorta	0	0	0	0	0
Liguliflorae	0	0	0	1	1
Campanulaceae	0	0	0	0	0
Salix	0	0	0	0	0
Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	24	23	13	20	7
Quercus	0	0	0	0	0

Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	0	0	0
Total Pollen Grains	466.5	440.5	373	332	414.5

Core Sample #	WY-1A-20	WY-1A-20	WY-1A-20	WY-1A-20	WY-1A-20
Adj. Depth	31	33	36	41	46
Pinus undiff.	198.5	242	554.5	760.5	327
Pinus subg. Strobilus	1	11	23	11	12
Pinus subg. Pinus	1	14	15	10	5
Abies	2	5	2	4	5
Cyperaceae	64	57	9	14	2
Artemisia	12	8	22	33	44
Roseaceae	0	0	3	0	0
Ambrosia	0	0	0	0	1
Alnus	14	5	18	18	10
Betula	1	1	2	2	3
Poaceae	38	42	23	74	26
Aster	7	0	1	3	3
Typha	4	3	1	11	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	0	1	3	7	0
Acer	0	0	0	0	0
Cupressaceae	0	0	1	0	0
Indeterminate	0	3	13	0	12
Picea engelmanni	1	1	0	2	0
Apiaceae	0	0	0	0	0
Amaranthaceae	32	0	2	0	2
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0
Polygonum	0	0	0	0	0
Bistorta	0	0	0	0	0
Liguliflorae	2	0	0	0	0
Campanulaceae	0	0	0	0	0
Salix	0	0	0	0	0
Mryiophyllum	0	0	4	0	1
Malvaceae	0	0	0	0	0
Pseudotsuga	4	7	11	3	9

Quercus	0	0	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	0	0	0
Total Pollen Grains	381.5	400	707.5	952.5	462

Core Sample #	WY-1A-20	WY-1B-20	WY-1B-20	WY-1B-20	WY-1B-20
Adj. Depth	51	54	64	68	71
Pinus undiff.	224	184.5	149.5	169	138
Pinus subg. Strobos	5	1	4	0	4
Pinus subg. Pinus	8	10	2	10	6
Abies	2	1	2	1	0
Cyperaceae	9	14	9	6	13
Artemisia	59	113	29	41	58
Roseaceae	3	6	6	1	0
Ambrosia	0	5	0	5	0
Alnus	16	14	10	8	13
Betula	0	3	3	4	0
Poaceae	45	19	28	32	33
Aster	2	3	2	2	4
Typha	0	0	0	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	13	4	1	4	8
Acer	0	0	0	0	0
Cupressaceae	3	9	12	12	5
Indeterminate	0	16	26	13	1
Picea engelmanni	0	1	0	0	0
Apiaceae	0	0	1	0	0
Amaranthaceae	4	5	7	9	5
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0
Polygonum	2	0	1	0	1
Bistorta	0	0	0	0	0
Liguliflorae	0	0	0	0	0
Campanulaceae	0	0	0	0	0
Salix	0	0	1	4	0
Mryiophyllum	0	1	0	1	0
Malvaceae	0	0	0	0	0

Pseudotsuga	7	18	23	30	19
Quercus	0	0	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	1	0	0
Total Pollen Grains	402	427.5	317.5	352	308

Core Sample #	WY-1B-20	WY-1B-20	WY-1B-20	WY-1B-20	WY-1B-20
Adj. Depth	76	81	91	101	111
Pinus undiff.	199	156.5	142	152	217.5
Pinus subg. Strobus	4	9	3	8	4
Pinus subg. Pinus	10	9	4	11	5
Abies	3	0	0	0	0
Cyperaceae	7	15	18	7	11
Artemisia	52	3	42	80	72
Roseaceae	3	4	0	3	2
Ambrosia	5	3	4	0	4
Alnus	8	17	25	15	23
Betula	2	1	0	2	3
Poaceae	16	51	48	36	31
Aster	7	2	2	2	3
Typha	0	0	0	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	2	4	6	1	7
Acer	0	0	0	0	0
Cupressaceae	13	13	30	29	67
Indeterminate	7	3	2	22	12
Picea engelmanni	0	0	0	0	0
Apiaceae	0	1	4	1	2
Amaranthaceae	2	9	8	5	5
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	1	0	0
Polygonum	0	0	0	2	1
Bistorta	0	0	0	0	0
Liguliflorae	0	0	0	0	1
Campanulaceae	0	0	0	0	0
Salix	0	1	4	4	7
Mryiophyllum	1	0	0	1	0

Malvaceae	0	0	0	0	0
Pseudotsuga	44	13	18	27	30
Quercus	0	0	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	0	1	0
Total Pollen Grains	385	314.5	361	409	507.5
Core Sample #	WY-1B-20	WY-1B-20	WY-1B-20	WY-1C-20	WY-1C-20
Adj. Depth	123	135	147	159	171
Pinus undiff.	139	150	198.5	184	201.5
Pinus subg. Strobos	6	4	4	3	3
Pinus subg. Pinus	0	0	5	0	0
Abies	0	0	0	0	0
Cyperaceae	8	9	4	15	17
Artemisia	50	48	39	79	52
Roseaceae	4	1	2	0	3
Ambrosia	3	4	2	1	3
Alnus	12	10	6	18	11
Betula	3	1	3	5	7
Poaceae	37	34	38	58	77
Aster	4	2	2	3	3
Typha	0	0	0	10	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	8	7	7	0	4
Acer	0	0	0	1	0
Cupressaceae	37	21	19	6	50
Indeterminate	0	2	7	0	5
Picea engelmanni	0	0	0	0	0
Apiaceae	0	0	1	0	2
Amaranthaceae	5	1	3	21	6
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0
Polygonum	0	0	2	2	0
Bistorta	0	0	0	0	0
Ligulaflorae	0	0	0	9	0
Campanulaceae	0	0	0	0	0
Salix	2	2	3	0	8

Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	12	8	35	1	10
Quercus	2	0	1	0	1
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	1	0	2
Total Pollen Grains	332	304	382.5	416	465.5

Core Sample #	WY-1C-20	WY-1C-20	WY-1C-20	WY-1C-20	WY-1C-20
Adj. Depth	183	195	207	219	231
Pinus undiff.	200	246.5	435.5	388	813.5
Pinus subg. Strobus	1	2	5	4	7
Pinus subg. Pinus	1	0	0	1	0
Abies	0	0	0	0	0
Cyperaceae	7	7	3	6	6
Artemisia	26	31	33	17	21
Roseaceae	1	1	0	2	3
Ambrosia	1	1	1	1	3
Alnus	10	14	8	6	11
Betula	1	3	0	0	0
Poaceae	26	33	17	15	25
Aster	1	3	3	1	0
Typha	0	0	0	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	1	0	4	1	1
Acer	0	1	0	0	0
Cupressaceae	11	32	18	21	36
Indeterminate	7	8	1	10	7
Picea engelmanni	0	0	0	0	0
Apiaceae	0	3	0	0	0
Amaranthaceae	0	3	2	3	4
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	1	0
Caryophyllaceae	1	0	0	0	0
Polygonum	0	0	0	0	0
Bistorta	0	0	1	0	0
Liguliflorae	0	0	0	1	0
Campanulaceae	0	0	0	0	0

Salix	4	4	4	3	7
Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	3	2	7	6	4
Quercus	0	0	0	0	1
Rhamnus	1	0	0	0	0
Epilobium	0	0	2	0	0
Rhus	0	0	0	0	0
Total Pollen Grains	303	394.5	544.5	487	949.5

Core Sample #	WY-1C-20	WY-1D-20	WY-1D-20	WY-1D-20	WY-1D-20
Adj. Depth	243	255	267	272	279
Pinus undiff.	1031	261.5	182	688	359.5
Pinus subg. Strobus	9	13	2	7	10
Pinus subg. Pinus	0	2	5	9	0
Abies	0	0	3	7	4
Cyperaceae	7	9	6	2	1
Artemisia	28	36	34	30	9
Roseaceae	2	2	2	4	1
Ambrosia	0	2	3	0	0
Alnus	11	9	13	6	3
Betula	0	1	1	0	0
Poaceae	31	31	28	11	5
Aster	4	1	5	2	1
Typha	1	1	1	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	1	3	1	3	0
Acer	0	0	0	0	0
Cupressaceae	26	14	12	13	7
Indeterminate	8	7	6	5	4
Picea engelmanni	0	0	1	1	2
Apiaceae	1	0	0	1	0
Amaranthaceae	2	3	8	2	0
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	1
Polygonum	0	0	0	0	0
Bistorta	0	0	0	0	0
Liguliflorae	1	0	0	0	0

Campanulaceae	0	0	0	0	0
Salix	8	1	1	4	0
Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	1	15	19	3	1
Quercus	0	2	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	0	0	0
Total Pollen Grains	1172	413.5	333	798	408.5

Core Sample #	WY-1D-20	WY-1D-20	WY-1D-20	WY-1D-20	WY-1D-20
Adj. Depth	291	303	315	327	339
Pinus undiff.	711.5	757.5	648.5	582	943
Pinus subg. Strobos	16	16	10	1	1
Pinus subg. Pinus	7	4	0	0	0
Abies	2	0	4	4	6
Cyperaceae	3	2	1	0	0
Artemisia	18	24	10	14	17
Roseaceae	0	1	1	2	1
Ambrosia	1	0	0	0	0
Alnus	7	11	9	1	7
Betula	1	1	0	0	0
Poaceae	18	6	5	7	1
Aster	1	3	1	1	1
Typha	0	0	0	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	1	1	0	0	0
Acer	0	0	0	0	0
Cupressaceae	18	5	1	1	0
Indeterminate	9	5	5	9	10
Picea engelmanni	0	0	0	0	0
Apiaceae	0	0	0	0	0
Amaranthaceae	1	0	0	0	2
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	1	1
Polygonum	2	0	2	2	0
Bistorta	0	0	0	0	0

Liguliflorae	1	0	0	0	0
Campanulaceae	0	0	0	0	0
Salix	0	1	1	0	0
Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	2	3	5	0	0
Quercus	0	0	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	1	0	1	0
Rhus	0	0	0	0	0
Total Pollen Grains	819.5	841.5	703.5	626	990

Core Sample #	WY-1D-20	WY-2B-20	WY-2B-20	WY-2B-20	WY-2B-20
Adj. Depth	351	363	375	387	399
Pinus undiff.	858	647	488	307.5	245.5
Pinus subg. Strobus	3	24	6	6	0
Pinus subg. Pinus	0	7	7	0	0
Abies	21	36	6	3	0
Cyperaceae	0	9	3	1	0
Artemisia	20	10	12	4	2
Roseaceae	0	2	0	0	0
Ambrosia	1	0	0	0	0
Alnus	4	6	6	0	0
Betula	0	0	1	1	0
Poaceae	4	6	4	3	12
Aster	2	1	0	0	5
Typha	0	0	0	0	0
Unknown	0	0	0	0	0
Saccobatus vermiculatus	0	0	0	0	0
Acer	0	0	0	0	0
Cupressaceae	0	6	4	8	7
Indeterminate	7	4	7	5	25
Picea engelmanni	0	0	8	2	2
Apiaceae	0	1	0	0	0
Amaranthaceae	0	0	0	0	0
Fabaceae	0	0	0	0	0
Ranunculaceae	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0
Polygonum	0	0	2	0	2

Bistorta	0	0	0	0	0
Liguliflorae	0	0	0	1	0
Campanulaceae	0	0	0	0	0
Salix	3	4	1	0	2
Mryiophyllum	0	0	0	0	0
Malvaceae	0	0	0	0	0
Pseudotsuga	1	4	1	1	0
Quercus	0	0	0	0	0
Rhamnus	0	0	0	0	0
Epilobium	0	0	0	0	0
Rhus	0	0	0	0	0
Total Pollen Grains	924	767	556	342.5	302.5

Rainbow Lake:

depth (sed)	5	15	25	35	44
Pinus Undiff	108	145	130	202	144.5
Pinus subg. Strobus	31	24	55	88	103
Pinus subg. Pinus	20	14	11	15	19
Picea	1	19.5	9.5	1	0
Abies	6	4	4.5	8.5	17.5
Pseudotsuga/Larix	8	6	8	11	10
Juniperous/Cupressaceae	7	0	10	2	0
Betulacea	1	1	1	0	2
Alnus	10	13	6	18	6
Populus Undiff	16	0	13	2	0
Acer	0	0	0	0	0
Quercus	0	0	0	1	0
Salix	8	4	2	2	0
Artemisia	5	5	13	2	0
Other Shrubs	0	0	2	0	0
Poaceae	28	21	7	9	5
Tubuliflorae	1	0	1	0	0
Liguliflorae	0	0	0	0	0
Amaranthaceae	3	2	3	3	1
Other Herbs and Ferns	4	7	3	3	1
Indeterminate	1	6	0	1	0
Unknown	2	0	0	0	1
Equisetum	1	9	0	1	1
Cyperaceae	9	7	2	2	2
Isoetes	25	10	18	16	3
Other Aquatics	2	4	0	0	0
Pediastrum Undiff	14	0	39	80	10
Pollen Sum	311	301.5	338	467.5	326
depth (sed)	54	64	74	85	95
Pinus Undiff	183	220	152	176.5	172
Pinus subg. Strobus	121	70	95	56	94
Pinus subg. Pinus	34	24	21	22	24
Picea	1	3	0	2	0
Abies	24.5	14	9.5	11.5	11
Pseudotsuga/Larix	18	14	6	8	8

Juniperous/Cupressaceae	0	1	1	1	1
Betulacea	0	0	0	0	1
Alnus	2	1	6	13	12
Populus Undiff	2	3	1	3	1
Acer	0	0	0	0	0
Quercus	1	1	0	0	1
Salix	0	0	0	0	2
Artemisia	2	3	2	5	6
Other Shrubs	0	0	0	0	2
Poaceae	5	5	5	7	11
Tubuliflorae	0	2	0	0	0
Liguliflorae	0	0	1	0	0
Amaranthaceae	2	0	1	1	0
Other Herbs and Ferns	0	1	1	0	0
Indeterminate	0	0	0	0	0
Unknown	0	0	0	0	1
Equisetum	0	0	0	0	1
Cyperaceae	0	2	2	1	7
Isoetes	2	6	11	11	11
Other Aquatics	1	1	0	0	0
Pediastrum Undiff	14	12	11	65	43
Pollen Sum	412.5	383	325.5	383	409

depth (sed)	105	115	125	135	145
Pinus Undiff	96	122.5	89	204	146.5
Pinus subg. Strobis	33	49	40	140	67

Pinus subg. Pinus	26	43	27	10	5
Picea	5	6	5	4	0.5
Abies	8	2.5	11	15.5	10.5
Pseudotsuga/Larix	4	10	10	18	9
Juniperous/Cupressaceae	0	4	16	0	0
Betulacea	0	0	0	1	0
Alnus	8	15	20	29	11
Populus Undiff	6	11	23	12	8
Acer	0	0	0	0	0
Quercus	0	0	0	1	1
Salix	2	1	2	4	4
Artemisia	3	6	2	9	7
Other Shrubs	3	0	4	1	0
Poaceae	32	10	8	24	12
Tubuliflorae	0	1	1	7	1
Liguliflorae	0	0	0	0	0
Amaranthaceae	3	5	5	4	1
Other Herbs and Ferns	2	1	3	6	2
Indeterminate	1	0	2	0	0
Unknown	0	2	1	2	0
Equisetum	5	0	1	2	4
Cyperaceae	18	3	2	1	1
Isoetes	3	12	30	33	21
Other Aquatics	4	0	1	2	0
Pediastrum Undiff	11	45	68	117	330
Pollen Sum	273	349	371	646.5	641.5
depth (sed)	154	164	173	184	194
Pinus Undiff	154.5	181	180.5	150.5	155
Pinus subg. Strobis	81	78	91	67	77
Pinus subg. Pinus	7	2	6	11	7
Picea	3	3	2	0	0
Abies	11	12.5	13.5	12	15.5
Pseudotsuga/Larix	10	9	10	5	9
Juniperous/Cupressaceae	2	0	1	2	0
Betulacea	0	1	0	2	0
Alnus	9	12	25	10	18
Populus Undiff	2	5	9	6	10

Acer	0	0	0	0	0
Quercus	2	2	1	0	1
Salix	2	2	3	5	0
Artemisia	6	8	6	11	7
Other Shrubs	0	0	0	0	0
Poaceae	12	17	11	15	19
Tubuliflorae	2	0	1	3	2
Liguliflorae	0	0	0	0	0
Amaranthaceae	1	1	2	3	4
Other Herbs and Ferns	1	3	2	2	1
Indeterminate	0	0	0	0	0
Unknown	2	0	1	0	1
Equisetum	1	1	2	4	2
Cyperaceae	4	4	0	5	2
Isoetes	19	24	17	13	5
Other Aquatics	0	0	0	0	0
Pediastrum Undiff	69	43	46	75	71
Pollen Sum	400.5	408.5	430	401.5	406.5
depth (sed)	204	218	224	234	245
Pinus Undiff	122	182	180.5	126	185
Pinus subg. Strobus	99	105	56	128	91
Pinus subg. Pinus	6	8	9	11	6
Picea	2	4	4	2	1
Abies	16	23	21.5	28	19
Pseudotsuga/Larix	7	8	14	19	16
Juniperous/Cupressaceae	3	0	1	1	3
Betulacea	0	0	0	0	1
Alnus	22	11	6	6	16
Populus Undiff	9	2	3	0	3
Acer	0	0	0	0	0
Quercus	1	1	2	0	2
Salix	2	2	1	0	1
Artemisia	8	4	2	1	5
Other Shrubs	0	0	0	0	0
Poaceae	19	12	4	1	12
Tubuliflorae	4	0	0	0	3
Liguliflorae	0	0	0	0	0

Amaranthaceae	2	2	0	0	1
Other Herbs and Ferns	3	5	1	0	5
Indeterminate	0	0	0	0	0
Unknown	0	1	2	1	1
Equisetum	3	0	0	0	1
Cyperaceae	3	4	3	0	2
Isoetes	16	4	8	5	5
Other Aquatics	0	0	0	1	0
Pediastrum Undiff	16	6	7	3	24
Pollen Sum	363	384	325	333	403
depth (sed)	264	275	282	295	314
Pinus Undiff	219	120.5	163.5	183	167.5
Pinus subg. Strobus	70	101	93	104	52
Pinus subg. Pinus	10	10	14	12	1
Picea	4.5	0	2.5	4	0
Abies	11.5	9	19	8	2
Pseudotsuga/Larix	12	16	9	10	10
Juniperous/Cupressaceae	0	1	0	2	0
Betulacea	1	0	2	0	0
Alnus	4	14	15	8	21
Populus Undiff	4	0	5	0	10
Acer	0	0	0	0	1
Quercus	1	1	1	1	0
Salix	2	1	3	2	1
Artemisia	1	7	3	3	10
Other Shrubs	0	0	0	0	3
Poaceae	12	15	6	3	11
Tubuliflorae	0	1	3	1	0
Liguliflorae	0	1	0	0	1
Amaranthaceae	1	2	3	2	5
Other Herbs and Ferns	0	3	4	1	0
Indeterminate	0	0	1	0	0
Unknown	0	1	0	0	0
Equisetum	1	0	1	2	2
Cyperaceae	2	3	3	4	1
Isoetes	5	8	7	5	4
Other Aquatics	0	0	0	0	0
Pediastrum Undiff	18	17	17	5	28

Pollen Sum	379	331.5	375	360	330.5
depth (sed)	324	335	345	354	364
Pinus Undiff	186	158.5	157	151	131.5
Pinus subg. Strobus	51	42	33	43	20
Pinus subg. Pinus	2	0	0	4	0
Picea	1	0	6.5	4	7
Abies	9.5	7	12	8	6.5
Pseudotsuga/Larix	4	12	12	22	17
Juniperous/Cupressaceae	1	1	5	2	5
Betulacea	1	0	0	0	1
Alnus	17	24	18	19	23
Populus Undiff	6	5	22	10	9
Acer	0	0	0	1	1
Quercus	0	0	1	1	0
Salix	4	7	2	7	6
Artemisia	6	10	6	6	9
Other Shrubs	1	1	1	1	4
Poaceae	4	10	13	12	28
Tubuliflorae	0	0	1	0	1
Liguliflorae	0	0	0	0	0
Amaranthaceae	0	2	4	3	7
Other Herbs and Ferns	1	9	0	2	5
Indeterminate	0	0	0	0	0
Unknown	0	2	0	0	3
Equisetum	0	1	0	0	0
Cyperaceae	0	0	0	2	6
Isoetes	6	9	9	3	9
Other Aquatics	1	1	0	0	0
Pediastrum Undiff	28	11	8	16	12
Pollen Sum	329.5	312.5	310.5	317	311
depth (sed)	374	384	415	425	435
Pinus Undiff	123.5	124	127.5	125	137.5
Pinus subg. Strobus	35	22	32	31	45
Pinus subg. Pinus	1	0	1	25	3
Picea	1	2	2.5	1.5	2
Abies	10	9	15	11.5	4.5
Pseudotsuga/Larix	24	27	23	21	26

Juniperous/Cupressaceae	3	1	1	0	0
Betulacea	0	2	0	1	0
Alnus	22	15	23	25	27
Populus Undiff	7	18	5	3	8
Acer	0	1	0	0	0
Quercus	0	1	1	0	0
Salix	6	7	8	7	8
Artemisia	13	15	13	11	9
Other Shrubs	5	2	4	0	0
Poaceae	19	30	27	20	22
Tubuliflorae	0	0	1	0	1
Liguliflorae	0	1	0	0	1
Amaranthaceae	3	8	3	5	2
Other Herbs and Ferns	7	5	8	3	6
Indeterminate	2	0	0	0	0
Unknown	4	1	2	2	0
Equisetum	0	1	0	0	0
Cyperaceae	7	4	1	3	2
Isoetes	4	3	2	4	2
Other Aquatics	0	0	0	0	1
Pediastrum Undiff	108	7	25	35	15
Pollen Sum	404.5	306	325	334	322
depth (sed)	445	455	465	474	484
Pinus Undiff	141.5	94.5	122	130	121.5
Pinus subg. Strobus	37	63	41	19	37
Pinus subg. Pinus	1	2	3	3	1
Picea	1.5	1	0	0	1
Abies	11.5	5	13.5	12	10
Pseudotsuga/Larix	25	15	23	21	25
Juniperous/Cupressaceae	0	2	1	0	1
Betulacea	0	3	1	1	1
Alnus	29	28	12	26	28
Populus Undiff	4	10	15	8	3
Acer	1	0	1	0	0
Quercus	1	3	0	2	0
Salix	7	9	13	12	8
Artemisia	28	21	20	24	20

Other Shrubs	0	2	1	0	2
Poaceae	20	37	15	31	25
Tubuliflorae	2	4	0	1	3
Liguliflorae	0	0	0	0	1
Amaranthaceae	3	8	8	2	7
Other Herbs and Ferns	5	5	8	7	9
Indeterminate	0	0	0	0	0
Unknown	1	1	2	5	6
Equisetum	0	1	0	0	2
Cyperaceae	5	5	0	3	1
Isoetes	1	2	3	8	2
Other Aquatics	0	0	1	0	0
Pediastrum Undiff	146	25	51	90	7
Pollen Sum	470.5	346.5	354.5	405	321.5
depth (sed)	494	504	514	524	564
Pinus Undiff	129	115	103.5	128.5	85
Pinus subg. Strobos	27	27	50	58	11
Pinus subg. Pinus	2	0	4	9	3
Picea	0	6	0	0	0
Abies	8.5	11	7	10	5
Pseudotsuga/Larix	23	13	31	26	20
Juniperous/Cupressaceae	1	0	0	0	3
Betulacea	0	1	3	0	3
Alnus	36	27	13	7	32
Populus Undiff	8	9	4	1	11
Acer	1	0	1	0	0
Quercus	0	2	0	2	1
Salix	9	12	13	6	17
Artemisia	28	41	15	16	39
Other Shrubs	2	0	0	1	11
Poaceae	14	15	25	18	24
Tubuliflorae	0	1	3	4	3
Liguliflorae	0	0	0	0	0
Amaranthaceae	2	6	5	2	17
Other Herbs and Ferns	4	5	9	2	19
Indeterminate	0	0	0	0	0
Unknown	0	1	5	0	2
Equisetum	0	0	3	0	0

Cyperaceae	2	5	6	2	4
Isoetes	3	1	5	3	1
Other Aquatics	1	1	0	1	2
Pediastrum Undiff	209	5	10	34	86
Pollen Sum	509.5	304	315.5	330.5	399
depth (sed)	574	584	594	604	614
Pinus Undiff	96.5	73	55.5	132	144
Pinus subg. Strobilus	17	19	22	9	18
Pinus subg. Pinus	6	4	4	1	5
Picea	0	3	0	0	2
Abies	6.5	7.5	2	4.5	12.5
Pseudotsuga/Larix	35	46	24	23	16
Juniperous/Cupressaceae	0	0	1	1	2
Betulacea	1	2	1	2	0
Alnus	23	21	21	20	23
Populus Undiff	9	6	13	6	11
Acer	1	1	0	0	1
Quercus	1	2	1	3	1
Salix	18	10	23	18	27
Artemisia	33	28	22	31	20
Other Shrubs	0	6	3	4	2
Poaceae	20	30	15	17	19
Tubuliflorae	2	3	3	1	3
Liguliflorae	0	0	0	0	0
Amaranthaceae	7	8	10	13	3
Other Herbs and Ferns	9	15	15	6	4
Indeterminate	0	0	0	0	0
Unknown	4	8	0	2	5
Equisetum	0	1	0	0	0
Cyperaceae	6	7	5	2	8
Isoetes	8	6	3	5	4
Other Aquatics	1	0	0	1	0
Pediastrum Undiff	112	41	73	25	27
Pollen Sum	416	347.5	316.5	326.5	357.5
depth (sed)	624	644	654	674	684
Pinus Undiff	103.5	103.5	119	107	80
Pinus subg. Strobilus	16	18	28	25	24

Pinus subg. Pinus	2	6	4	2	2
Picea	0	0	0	10	3
Abies	7.5	5	8.5	12.5	8
Pseudotsuga/Larix	23	27	26	27	31
Juniperous/Cupressaceae	0	4	2	0	1
Betulacea	0	0	3	1	1
Alnus	20	16	25	15	25
Populus Undiff	8	18	9	8	14
Acer	1	1	2	1	3
Quercus	3	1	3	1	1
Salix	13	23	6	14	11
Artemisia	33	25	25	22	48
Other Shrubs	8	1	4	1	1
Poaceae	23	18	16	23	23
Tubuliflorae	5	4	4	4	4
Liguliflorae	0	0	0	0	0
Amaranthaceae	12	9	9	10	8
Other Herbs and Ferns	13	7	16	6	13
Indeterminate	0	0	0	0	0
Unknown	2	6	4	0	2
Equisetum	0	0	1	1	0
Cyperaceae	6	3	3	3	2
Isoetes	7	7	6	6	3
Other Aquatics	2	0	2	0	0
Pediastrum Undiff	148	130	112	25	77
Pollen Sum	456	432.5	437.5	324.5	385

depth (sed) 724

Pinus Undiff	77
Pinus subg. Strobus	13
Pinus subg. Pinus	0
Picea	2
Abies	6.5
Pseudotsuga/Larix	30
Juniperous/Cupressaceae	0
Betulacea	4
Alnus	26
Populus Undiff	23
Acer	1

Quercus	1
Salix	25
Artemisia	30
Other Shrubs	6
Poaceae	32
Tubuliflorae	1
Liguliflorae	0
Amaranthaceae	7
Other Herbs and Ferns	7
Indeterminate	0
Unknown	2
Equisetum	0
Cyperaceae	3
Isoetes	3
Other Aquatics	1
Pediastrum Undiff	77
Pollen Sum	377.5

APPENDIX C

Raw Charcoal Data

Wymore Lake:

Top	Depth	volume (cc)	Char count
0	1	5	0
1	2	5	8
2	3	5	6
3	4	5	4
4	5	5	6
5	6	5	4
6	7	5	7
7	8	5	14
8	9	5	9
9	10	5	10
10	11	5	8
11	12	5	74
12	13	5	105
13	14	5	100
14	15	5	27
15	16	5	26
16	17	5	17
17	18	5	5
18	19	5	12
19	20	5	6
20	21	5	12
21	22	5	16
22	23	5	1
23	24	5	44
24	25	5	52
25	26	5	106
26	27	5	58
27	28	5	87
28	29	5	97
29	30	5	107
30	31	5	80
31	32	5	155
32	33	5	71
33	34	5	68
34	35	5	59
35	36	5	42

36	37	5	41
37	38	5	47
38	39	5	21
39	40	5	51
40	41	5	37
41	42	5	41
42	43	5	32
43	44	5	58
44	45	5	34
45	46	5	33
46	47	5	37
47	48	5	47
48	49	5	51
49	50	5	73
50	51	5	98
51	52	1	3
52	53	3	4
53	54	3	21
54	55	3	12
55	56	3	9
56	57	3	11
57	58	3	3
58	59	3	7
59	60	3	4
60	61	3	10
61	62	2	0
62	63	2	7
63	64	2	4
64	65	2	12
65	66	2	5
66	67	2	15
67	68	2	29
68	69	2	16
69	70	2	11
70	71	2	17
71	72	2	6
72	73	2	9
73	74	2	20

74	75	2	12
75	76	2	10
76	77	2	14
77	78	2	10
78	79	2	17
79	80	2	26
80	81	2	7
81	82	2	8
82	83	2	3
83	84	2	13
84	85	2	4
85	86	2	4
86	87	2	13
87	88	2	4
88	89	2	6
89	90	2	9
90	91	2	14
91	92	2	16
92	93	2	10
93	94	2	3
94	95	2	14
95	96	2	7
96	97	2	17
97	98	2	7
98	99	2	18
99	100	2	7
100	101	2	7
101	102	2	5
102	103	2	6
103	104	2	9
104	105	2	15
105	106	2	14
106	107	2	7
107	108	2	7
108	109	2	7
109	110	2	4
110	111	2	5
111	112	2	4

112	113	2	5
113	114	2	10
114	115	2	5
115	116	2	7
116	117	2	14
117	118	2	7
118	119	2	14
119	120	2	10
120	121	2	2
121	122	2	5
122	123	2	8
123	124	2	5
124	125	2	4
125	126	2	9
126	127	2	12
127	128	2	6
128	129	2	6
129	130	2	11
130	131	2	1
131	132	2	3
132	133	2	4
133	134	2	4
134	135	2	2
135	136	2	0
136	137	2	1
137	138	2	5
138	139	2	4
139	140	2	13
140	141	2	4
141	142	2	6
142	143	2	7
143	144	2	5
144	145	2	2
145	146	2	5
146	147	2	1
147	148	2	4
148	149	2	6
149	150	2	0

150	151	2	6
151	152	2	4
152	153	2	0
153	154	2	9
154	155	2	8
155	156	2	4
156	157	2	7
157	158	2	3
158	159	2	3
159	160	2	6
160	161	2	10
161	162	2	2
162	163	2	8
163	164	2	3
164	165	2	3
165	166	2	4
166	167	2	5
167	168	2	5
168	169	2	14
169	170	2	13
170	171	2	8
171	172	2	7
172	173	2	14
173	174	2	11
174	175	2	17
175	176	2	19
176	177	2	16
177	178	2	4
178	179	2	5
179	180	2	6
180	181	2	3
181	182	2	3
182	183	2	2
183	184	2	8
184	185	2	4
185	186	2	12
186	187	2	4
187	188	2	8

188	189	2	9
189	190	2	2
190	191	2	5
191	192	2	8
192	193	2	9
193	194	2	7
194	195	2	3
195	196	2	12
196	197	2	3
197	198	2	0
198	199	2	1
199	200	2	2
200	201	2	6
201	202	2	4
202	203	2	2
203	204	2	2
204	205	2	1
205	206	2	7
206	207	2	12
207	208	2	18
208	209	2	12
209	210	2	4
210	211	2	3
211	212	2	6
212	213	2	4
213	214	2	2
214	215	2	6
215	216	2	6
216	217	2	5
217	218	2	6
218	219	2	6
219	220	2	8
220	221	2	3
221	222	2	13
222	223	2	2
223	224	2	6
224	225	2	3
225	226	2	5

226	227	2	3
227	228	2	2
228	229	2	1
229	230	2	6
230	231	2	6
231	232	2	6
232	233	2	4
233	234	2	4
234	235	2	6
235	236	2	7
236	237	2	5
237	238	2	5
238	239	2	9
239	240	2	7
240	241	2	1
241	242	2	4
242	243	2	6
243	244	2	3
244	245	2	3
245	246	2	4
246	247	2	3
247	248	2	3
248	249	2	1
249	250	2	8
250	251	2	7
251	252	2	15
252	253	2	16
253	254	2	3
254	255	2	9
255	256	2	19
256	257	2	15
257	258	2	10
258	259	2	8
259	260	2	7
260	261	2	10
261	262	2	10
262	263	2	6
263	264	2	21

264	265	2	12
265	266	2	7
266	267	2	4
267	268	2	5
268	269	2	9
269	270	2	7
270	271	2	11
271	272	2	4
272	273	2	4
273	274	2	7
274	275	2	3
275	276	2	10
276	277	2	4
277	278	2	1
278	279	2	8
279	280	2	8
280	281	2	2
281	282	2	5
282	283	2	4
283	284	2	5
284	285	2	1
285	286	2	4
286	287	2	0
287	288	2	13
288	289	2	9
289	290	2	9
290	291	2	11
291	292	2	10
292	293	2	14
293	294	2	8
294	295	2	11
295	296	2	10
296	297	2	12
297	298	2	17
298	299	2	14
299	300	2	13
300	301	2	19
301	302	2	12

302	303	2	21
303	304	2	17
304	305	2	13
305	306	2	16
306	307	2	13
307	308	2	23
308	309	2	14
309	310	2	16
310	311	2	8
311	312	2	33
312	313	2	9
313	314	2	36
314	315	2	7
315	316	2	17
316	317	2	7
317	318	2	14
318	319	2	19
319	320	2	15
320	321	2	13
321	322	2	21
322	323	2	7
323	324	2	10
324	325	2	7
325	326	2	9
326	327	2	2
327	328	2	6
328	329	2	3
329	330	2	2
330	331	2	2
331	332	2	4
332	333	2	3
333	334	2	7
334	335	2	4
335	336	2	4
336	337	2	6
337	338	2	8
338	339	2	3
339	340	2	1

340	341	2	1
341	342	2	2
342	343	2	0
343	344	2	1
344	345	2	1
345	346	2	4
346	347	2	1
347	348	2	2
348	349	2	1
349	350	2	2
350	351	2	1
351	352	2	1
352	353	2	0
353	354	2	2
354	355	2	1
355	356	2	2
356	357	2	0
357	358	2	3
358	359	2	3
359	360	2	0
360	361	2	1
361	362	2	1
362	363	2	0
363	364	2	0
364	365	2	0
365	366	2	0
366	367	2	1
367	368	2	0
368	369	2	0
369	370	2	0
370	371	2	0
371	372	2	0
372	373	2	0
373	374	2	2
374	375	2	0
375	376	2	1
376	377	2	2
377	378	2	0

378	379	2	0
379	380	2	0
380	381	2	0
381	382	2	0
382	383	2	0
383	384	2	0
384	385	2	1
385	386	2	3
386	387	2	43
387	388	2	1
388	389	2	0
389	390	2	0
390	391	2	0
391	392	2	0
392	393	2	0
393	394	2	0
394	395	2	0
395	396	2	0
396	397	2	0
397	398	2	2
398	399	2	1
399	400	2	0
400	401	2	0
401	402	2	3
402	403	2	0
403	404	2	0
404	405	2	0
405	406	2	1
406	407	2	0
407	408	2	0
408	409	2	0
409	410	2	0
410	411	2	0
411	412	2	0
412	413	2	0
413	414	2	0
414	415	2	0
415	416	2	0

416	417	2	0
417	418	2	0
418	419	2	0
419	420	2	0
420	421	2	0
421	422	2	0
422	423	2	1
423	424	2	0
424	425	2	0
425	426	2	0
426	427	2	0
427	428	2	0
428	429	2	0
429	430	2	0
430	431	2	0
431	432	2	0
432	433	2	0
433	434	2	0
434	435	2	0
435	436	2	0
436	437	2	0
437	438	2	0
438	439	2	0
439	440	2	0
440	441	2	0
441	442	2	0
442	443	2	0
443	444	2	0
444	445	2	0

Rainbow Lake:

top depth	bottom depth	volume (cc)	grass	>125	notes	total
0.0	0.5	3	0	29	one deciduous leaf fragment	29
0.5	1.0	3	0	37	possibly a small seed	37
1.0	1.5	3	0	44	Large PC piece potentially contributing fragments	44
1.5	2.0	3	0	49	FLF	49
2.0	2.5	3	0	34	FLF x3	34
2.5	3.0	3	0	42		42
3.0	3.5	3	0	52		52
3.5	4.0	3	0	78		78
4.0	4.5	3	0	107	FLF x2	107
4.5	5.0	3	0	131		131
5.0	5.5	3	0	201	large seed present	201
5.5	6.0	3	1	184		185
6.0	6.5	3	0	202		202
6.5	7.0	3	0	215		215
7.0	7.5	3	0	162		162
7.5	8.0	3	0	167	FLF	167
8.0	8.5	3	1	257		258
8.5	9.0	3	0	217		217
9.0	9.5	3	2	314		316
9.5	10.0	3	0	269	FLF x4	269
10.0	10.5	3	0	161		161
10.5	11.0	3	1	160		161
11.0	11.5	3	0	186	seed present	186
11.5	12.0	3	0	180		180
12.0	12.5	3	0	166	FLF x2	166
12.5	13.0	3	0	117		117
13.0	13.5	3	0	182		182
13.5	14.0	3	2	98		100
14.0	14.5	3	0	72		72
14.5	15.0	3	0	58		58
15.0	15.5	3	1	36		37
15.5	16.0	3	0	35		35
16.0	16.5	3	0	49		49
16.5	17.0	3	0	59		59
17.0	17.5	3	1	42		43

17.5	18.0	3	0	48		48
18.0	18.5	3	0	39		39
18.5	19.0	3	0	58		58
19.0	19.5	3	1	71		72
19.5	20.0	3	1	60		61
20.0	20.5	3	0	65	FLF	65
20.5	21.0	3	0	72	potential seed present BPM; sediment was dry when sampled, faulty whirlpack.	72
21.0	21.5	3	1	91		92
21.5	22.0	3	0	45		45
22.0	22.5	3	0	36		36
22.5	23.0	3	0	39		39
23.0	23.5	3	0	15		15
23.5	24.0	3	0	36		36
24.0	24.5	3	0	37		37
24.5	25.0	3	1	33		34
25.0	25.5	3	1	30		31
25.5	26.0	3	0	33		33
26.0	26.5	3	2	38	FLF	40
26.5	27.0	3	1	40		41
27.0	27.5	3	0	59		59
27.5	28.0	3	6	60	possible deciduous leaf charcoal	66
28.0	28.5	3	3	46		49
28.5	29.0	3	1	42		43
29.0	29.5	3	0	32		32
29.5	30.0	3	1	26		27
30.0	30.5	3	3	47	large charcoal fragment	50
30.5	31.0	3	5	32		37
31.0	31.5	3	0	24		24
31.5	32.0	3	5	35		40
32.0	32.5	3	3	43	lots of columnar alga/diatoms	46
32.5	33.0	3	5	52		57
33.0	33.5	3	0	33		33
33.5	34.0	3	2	30		32
34.0	34.5	3	1	24		25
34.5	35.0	3	2	48		50
35.0	35.5	3	0	25		25

35.5	36.0	3	0	32		32
36.0	36.5	3	5	38		43
36.5	37.0	3	2	33		35
37.0	37.5	3	3	44		47
37.5	38.0	3	1	48		49
38.0	38.5	3	6	44		50
38.5	39.0	3	8	81	VERY large fragment (~1cm)	89
39.0	39.5	3	6	70		76
39.5	40.0	3	7	113		120
40.0	40.5	3	0	64		64
40.5	41.0	3	0	23		23
41.0	41.5	3	0	19		19
41.5	42.0	3	2	13		15
42.0	42.5	3	1	14		15
42.5	43.0	3	1	22		23
43.0	43.5	3	1	25		26
43.5	44.0	3	2	22		24
44.0	44.5	3	2	24	FLF	26
44.5	45.0	3	0	26		26
45.0	45.5	3	1	20		21
45.5	46.0	3	0	28		28
46.0	46.5	3	5	14		19
46.5	47.0	3	0	9	sample patially spilled after counting	9
47.0	47.5	3	1	23		24
47.5	48.0	3	2	33		35
48.0	48.5	3	4	30		34
48.5	49.0	3	3	35		38
49.0	49.5	3	2	18		20
49.5	50.0	3	0	36		36
50.0	51.0	3	6	70		76
51.0	52.0	3	4	44		48
52.0	53.0	3	0	43		43
53.0	54.0	3	2	45		47
54.0	55.0	3	3	27		30
55.0	56.0	3	2	12		14
56.0	57.0	3	2	34		36
57.0	58.0	3	10	31		41

58.0	59.0	3	6	31		37
59.0	60.0	3	3	60		63
60.0	61.0	3	3	93		96
61.0	62.0	3	4	72		76
62.0	63.0	3	1	55		56
63.0	64.0	3	2	58		60
64.0	65.0	3	0	55		55
65.0	66.0	3	3	79	sample spilled after counting	82
66.0	67.0	3	2	39		41
67.0	68.0	3	3	26		29
68.0	69.0	3	1	17		18
69.0	70.0	3	7	51		58
70.0	71.0	3	1	35		36
71.0	72.0	3	1	29		30
72.0	73.0	3	1	47		48
73.0	74.0	3	4	34		38
74.0	75.0	3	4	41		45
75.0	76.0	3	3	53		56
76.0	77.0	3	2	35		37
77.0	78.0	3	3	46		49
78.0	79.0	3	1	42		43
79.0	80.0	3	7	52		59
80.0	81.0	3	22	73		95
81.0	82.0	3	5	49		54
82.0	83.0	3	7	35		42
83.0	84.0	3	2	34		36
84.0	85.0	3	14	35		49
85.0	86.0	3	9	37		46
86.0	87.0	3	14	38		52
87.0	88.0	3	4	41		45
88.0	89.0	3	9	34		43
89.0	90.0	3	16	24		40
90.0	91.0	3	6	31		37
91.0	92.0	3	4	30		34
92.0	93.0	3	6	28		34
93.0	94.0	3	9	76		85
94.0	95.0	3	8	83		91
95.0	96.0	3	2	47		49

96.0	97.0	3	6	36	42
97.0	98.0	3	8	71	79
98.0	99.0	3	12	36	48
99.0	100.0	3	5	31	36
100.0	101.0	3	8	38	46
101.0	102.0	3	7	25	32
102.0	103.0	3	11	50	61
103.0	104.0	3	2	18	20
104.0	105.0	3	6	32	38
105.0	106.0	3	8	41	49
106.0	107.0	3	2	40	42
107.0	108.0	3	3	31	34
108.0	109.0	3	3	21	24
109.0	110.0	3	5	23	28
110.0	111.0	3	5	35	40
111.0	112.0	3	2	31	33
112.0	113.0	3	10	34	44
113.0	114.0	3	1	13	14
114.0	115.0	3	10	34	44
115.0	116.0	3	4	49	53
116.0	117.0	3	9	43	52
117.0	118.0	3	15	39	54
118.0	119.0	3	7	75	82
119.0	120.0	3	6	87	93
120.0	121.0	3	1	122	123
121.0	122.0	3	10	62	72
122.0	123.0	3	3	60	63
123.0	124.0	3	3	62	65
124.0	125.0	3	5	60	65
125.0	126.0	3		35	35
126.0	127.0	3	8	42	50
127.0	128.0	3	10	33	43
128.0	129.0	3	4	45	49
129.0	130.0	3	5	46	51
130.0	131.0	3	7	30	37
131.0	132.0	3	1	26	27
132.0	133.0	3	2	21	23
133.0	134.0	3	6	41	47

134.0	135.0	3	4	23	27
135.0	136.0	3	2	28	30
136.0	137.0	3	2	24	26
137.0	138.0	3	6	16	22
138.0	139.0	3	8	26	34
139.0	140.0	3	1	19	20
140.0	141.0	3	5	39	44
141.0	142.0	3	6	35	41
142.0	143.0	3	4	15	19
143.0	144.0	3	1	36	37
144.0	145.0	3	9	28	37
145.0	146.0	3	4	62	66
146.0	147.0	3	13	82	95
147.0	148.0	3	7	70	77
148.0	149.0	3	14	79	93
149.0	150.0	3	9	63	72
150.0	151.0	3	8	70	78
151.0	152.0	3	21	94	115
152.0	153.0	3	5	23	28
153.0	154.0	3	4	24	28
154.0	155.0	3	14	76	90
155.0	156.0	3	16	49	65
156.0	157.0	3	8	66	74
157.0	158.0	3	18	64	82
158.0	159.0	3	7	44	51
159.0	160.0	3	4	42	46
160.0	161.0	3	12	29	41
161.0	162.0	3	12	32	44
162	163	3	3	60	63
163	164	3	9	85	94
164	165	3	1	79	80
165	166	3	1	56	57
166	167	3	3	66	69
167	168	3	0	51	51
168	169	3	0	61	61
169	170	3	2	49	51
170	171	3	6	37	43
171	172	3	5	46	51

172	173	3	0	33	33
173	174	3	12	72	84
174	175	3	0	42	42
175	176	3	3	61	64
176	177	3	4	36	40
177	178	3	3	35	38
178	179	3	2	58	60
179	180	3	5	64	69
180	181	3	3	34	37
181	182	3	1	46	47
182	183	3	2	56	58
183	184	3	1	72	73
184	185	3	2	67	69
185	186	3	2	44	46
186	187	3	4	52	56
187	188	3	6	81	87
188	189	3	2	49	51
189	190	3	5	51	56
190	191	3	7	69	76
191	192	3	5	70	75
192	193	3	8	40	48
193	194	3	6	49	55
194	195	3	1	35	36
195	196	3	3	50	53
196	197	3	7	50	57
197	198	3	3	58	61
198	199	3	1	37	38
199	200	3	8	74	82
200	201	3	1	42	43
201	202	3	10	107	117
202	203	3	4	95	99
203	204	3	1	38	39
204	205	3	3	88	91
205	206	3	1	73	74
206	207	3	3	79	82
207	208	3	2	41	43
210	211	3	33	57	90
211	212	3	7	39	46

212	213	3	4	48	52
214	215	3	8	85	93
215	216	3	10	102	112
216	217	3	11	75	86
217	218	3	8	87	95
218	219	3	6	98	104
219	220	3	5	96	101
220	221	3	9	89	98
221	222	3	10	114	124
222	223	3	6	125	131
223	224	3	13	178	191
224	225	3	1	64	65
225	226	3	0	118	118
226	227	3	3	60	63
227	228	3	1	35	36
228	229	3	3	82	85
229	230	3	2	57	59
230	231	3	2	110	112
231	232	3	5	93	98
232	233	3	3	148	151
233	234	3	6	116	122
234	235	3	4	89	93
238	239	3			113
239	240	3	0	52	52
240	241	3	1	43	44
241	242	3	1	61	62
242	243	3	1	142	143
243	244	3	5	60	65
244	245	3	6	80	86
245	246	3	5	153	158
246	247	3	1	102	103
247	248	3	3	232	235
248	249	3	2	99	101
249	250	3	2	50	52
250	251	3	6	35	41
251	252	3	2	49	51
252	253	3	3	30	33
253	254	3	11	62	73

254	255	3	1	55	56
255	256	3	2	45	47
256	257	3	2	53	55
257	258	3	5	54	59
258	259	3	3	94	97
259	260	3	6	77	83
260	261	3	4	43	47
261	262	3	1	49	50
262	263	3	5	77	82
263	264	3	2	20	22
264	265	3	4	40	44
265	266	3	2	38	40
266	267	3	3	46	49
267	268	3	5	70	75
268	269	3	4	45	49
269	270	3	2	54	56
270	271	3	4	114	118
271	272	3	8	87	95
272	273	3	13	61	74
273	274	3	9	55	64
274	275	3	7	144	151
275	276	3	7	82	89
276	277	3	3	61	64
277	278	3	5	52	57
278	279	3	2	55	57
279	280	3	2	63	65
280	281	3	7	54	61
281	282	3	3	47	50
282	283	3	1	72	73
283	284	3	7	92	99
284	285	3	0	59	59
285	286	3	4	51	55
286	287	3			49
287	288	3	3	61	64
288	289	3	5	120	125
289	290	3	12	115	127
290	291	3	1	58	59
291	292	3	0	78	78

292	293	3	2	117	119
293	294	3	0	88	88
294	295	3	1	62	63
295	296	3	1	56	57
296	297	3	1	28	29
297	298	3	1	50	51
298	299	3	0	55	55
299	300	3	1	56	57
300	301	3	0	25	25
301	302	3	1	39	40
302	303	3	2	35	37
303	304	3	1	61	62
304	305	3	2	64	66
305	306	3	2	103	105
306	307	3	2	61	63
307	308	3	3	84	87
308	309	3	1	57	58
309	310	3	4	43	47
310.0	311.0	3	15	129	144
311.0	312.0	3	9	86	95
312.0	313.0	3	7	80	87
313.0	314.0	3	2	66	68
314.0	315.0	3	5	48	53
315.0	316.0	3	3	61	64
316.0	317.0	3	11	50	61
317.0	318.0	3	2	64	66
318.0	319.0	3	1	35	36
319.0	320.0	3	7	59	66
320.0	321.0	3	3	71	74
321.0	322.0	3	1	59	60
322.0	323.0	3	4	46	50
323.0	324.0	3	2	86	88
324.0	325.0	3	9	71	80
325.0	326.0	3	8	44	52
326.0	327.0	3	3	38	41
327.0	328.0	3	6	36	42
328.0	329.0	3	7	39	46
329.0	330.0	3	3	67	70

330.0	331.0	3	7	81	88
331.0	332.0	3	3	57	60
332.0	333.0	3	1	55	56
333.0	334.0	3	3	48	51
334.0	335.0	3	1	42	43
335.0	336.0	3	1	54	55
336.0	337.0	3	6	60	66
337.0	338.0	3	2	65	67
338.0	339.0	3	3	50	53
339.0	340.0	3	4	63	67
340.0	341.0	3	1	45	46
341.0	342.0	3	7	45	52
342.0	343.0	3	4	78	82
343.0	344.0	3	6	64	70
344.0	345.0	3	7	73	80
345.0	346.0	3	5	63	68
346.0	347.0	3	2	108	110
347.0	348.0	3	2	84	86
348.0	349.0	3	2	50	52
349.0	350.0	3	1	45	46
350.0	351.0	3	2	105	107
351.0	352.0	3	1	89	90
352.0	353.0	3	2	58	60
353.0	354.0	3	2	67	69
354.0	355.0	3	3	95	98
355.0	356.0	3	2	85	87
356.0	357.0	3	2	65	67
357.0	358.0	3	4	130	134
358.0	359.0	3	3	127	130
359.0	360.0	3	11	108	119
360.0	361.0	3	2	51	53
361.0	362.0	3	3	69	72
362.0	363.0	3	0	50	50
363.0	364.0	3	2	70	72
364.0	365.0	3	2	54	56
365.0	366.0	3	0	34	34
366.0	367.0	3	0	34	34
367.0	368.0	3	0	66	66

368.0	369.0	3	2	40	42
369.0	370.0	3	1	36	37
370.0	371.0	3	1	35	36
371.0	372.0	3	3	43	46
372.0	373.0	3	1	53	54
373.0	374.0	3	8	94	102
374.0	375.0	3	5	31	36
375.0	376.0	3	2	91	93
376.0	377.0	3	3	23	26
377.0	378.0	3	1	40	41
378.0	379.0	3	0	23	23
379.0	380.0	3	2	30	32
380.0	381.0	3	3	49	52
381.0	382.0	3	3	84	87
382.0	383.0	3	1	65	66
383.0	384.0	3	2	52	54
384.0	385.0	3	2	36	38
385.0	386.0	3	0	85	85
386.0	387.0	3	0	21	21
387.0	388.0	3	1	34	35
388.0	389.0	3	3	15	18
389.0	390.0	3	0	18	18
390	391	2			25
391	392	2			36
392	393	2			25
393	394	2			18
394	395	2			8
395	396	2			20
396	397	2			23
397	398	2			48
398	399	2			68
399	400	2			34
400	401	2			27
401	402	2			22
402	403	2			46
403	404	2			16
404	405	2			30
406	407	2			38

407	408	2		22
408	409	2		29
409	410	2		81
410	411	2		54
411	412	2		42
412	413	2		50
413	414	2		40
414	415	2		73
415	416	3	22	112
416	417	3	20	133
417	418	3	11	94
418	419	3	15	98
419	420	3	24	157
420	421	3	14	84
421	422	3	6	64
422	423	3	12	62
423	424	3	10	80
424	425	3	9	68
425	426	3	8	50
426	427	3	5	51
427	428	3	9	55
428	429	3	9	41
429	430	3	8	72
430	431	3	14	75
431	432	3	15	83
432	433	3	6	68
433	434	3	4	67
434	435	3	3	55
435	436	3	12	106
436	437	3	4	103
437	438	3	3	81
438	439	3	5	44
439	440	3	3	80
440	441	3	6	79
441	442	3	3	85
442	443	3	7	67
443	444	3	4	56
444	445	3	5	59

445	446	3	3	78
446	447	3	7	73
447	448	3	5	80
448	449	3	5	58
449	450	3	5	59
450	451	3	3	81
451	452	3	3	48
452	453	3	19	55
453	454	3	11	104
454	455	3	3	64
455	456	3	1	53
456	457	3	1	66
457	458	3	11	52
458	459	3	18	141
459	460	3	12	131
460	461	3	10	110
461	462	3	4	70
462	463	3	3	48
463	464	3	6	39
464	465	3	3	37
465	466	3	8	46
466	467	3	26	95
467	468	3	12	98
468	469	3	15	44
469	470	3	5	68
470	471	3	7	86
471	472	3	3	42
472	473	3	14	104
473	474	3	17	145
474	475	3	10	212
475	476	3	0	82
476	477	3	3	21
477	478	3	1	16
478	479	3	0	31
479	480	3	1	43
480	481	3	4	15
481	482	3	0	23
482	483	3	4	41

483	484	3	0	12
484	485	3	0	11
485	486	3	5	28
486	487	3	2	22
487	488	3	1	44
488	489	3	2	50
489	490	3	0	44
490	491	3	1	36
491	492	3	0	17
492	493	3	3	44
493	494	3	0	44
494	495	5	3	26
512	513	3	6	74
513	514	3	3	32
514	515	3	1	51
515	516	3	2	45
516	517	3	2	65
517	518	3	3	48
518	519	3	11	106
519	520	3	2	56
520	521	3	1	30
521	522	3	4	79
522	523	3	0	63
523	524	3	1	57
524	525	3	1	162
525	526	3	1	41
526	527	3	3	61
527	528	3	4	101
528	529	3	0	14
529	529.5	3	5	64
529.5	530	3	7	56
530	530.5	3	14	113
530.5	531	3	23	85
531	531.5	1	1	36
531.5	532	2	10	83
532	532.5	2	8	90
532.5	533	2	3	21
533	533.5	2	1	51

533.5	534	2	2	49
534	534.5	2	2	32
561	562	2		10
562	563	2		13
563	564	2		12
564	565	2		32
565	566	2		26
566	567	2		20
567	568	2		34
568	569	2		15
569	570	2		14
570	571	2		13
571	572	2		3
572	573	2		18
573	574	2		7
574	575	2		14
575	576	3	0	41
576	577	3	0	25
577	578	3	0	33
578	579	3	0	54
579	580	3	1	29
580	581	3	1	17
581	582	3	0	10
582	583	3	0	16
583	584	3	0	27
584	585	3	0	26
585	586	3	0	28
586	587	3	0	22
587	588	3	0	16
588	589	3	1	30
589	590	3	3	36
590	591	3	0	18
591	592	3	1	47
592	593	3	0	20
593	594	3	2	31
594	595	3	2	23
595	596	3		10
596	597	3		10

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604	605	3	7
605	606	3	6
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611	612	3	9
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613	614	3	8
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617	618	2	10
625	626	2	8
681	682	3	5
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684	685	3	4
685	686	3	3
686	687	3	5
687	688	3	7
688	689	3	8
689	690	3	18
690	691	3	5
691	692	3	17
692	693	3	21
693	694	3	16
694	695	3	43
695	696	3	54
696	697	3	21

697	698	3	29
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699	700	3	9
700	701	3	10
701	702	3	20
702	703	3	16
703	704	3	22
704	705	3	26
705	706	3	12
706	707	3	6
707	708	3	13
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709	710	2	14
710	711	3	28
711	712	2	17
712	713	2	21
713	714	2	8
714	715	2	19
715	716	3	25
716	717	2	37
717	718	0.5	3
718	719	2	27
719	720	2	21
720	721	2	9
721	722	2	9
722	723	2	12
723	724	2	9
724	725	1	18
725	726	3	37
726	727	2	33
727	728	1	16