LATE HOLOCENE CLIMATE, FIRE, AND VEGETATION HISTORY OF THE NORTHERN RANGE, YELLOWSTONE NATIONAL PARK

by

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ABSTRACT

Yellowstone National Park is an iconic natural landscape that encompasses unique geologic features as well as a diverse and ecologically important flora and fauna. The ecological resilience of the Northern Range of the park, home to the park’s ungulate herds, faces an uncertain future with a projected warming climate over the next century. Understanding the variability of vegetation organization in response to past changes in climate can help park managers plan for future climate scenarios. Lake sediment cores from two lakes were collected, analyzed for pollen type, charcoal accumulation and lithological components, and compared with other studies to highlight commonalities in fire-histories and vegetation trends across the Northern Range over the past 4000 cal yr BP. Foster Lake the records suggest fire-episodes and changes to lake productivity and between ~3500-2900 cal yr BP, large intense fire-episodes between ~2500-2150 cal yr BP, ~1000 cal yr BP and frequent large fire episodes from ~700 cal yr BP to the present day. Floating Island Lake records between ~4000-3000 cal yr BP suggest the site experienced infrequent, large fire episodes concurrent with periods of protracted drought and decreases in water level. Between ~3000-1500 low intensity fire episodes were common, punctuated by infrequent large fire episodes at ~2900, ~2250, ~2050 and ~1880 cal yr BP. During the last ~1ka two fire episodes were recorded at Floating Island Lake, at ~1030 cal yr BP coincident with the Medieval Climate Anomaly, and 270~ cal yr BP during the Little Ice Age. A comparison of fire histories from studies spanning the Northern Range shows that during periods of protracted drought large fire episodes are common across the landscape, and that during periods of moderate climate fire size and severity is likely modulated by local site controls such as topography and vegetation structure. This study shows that fire episodes in the Northern Range have occurred as a spatial and temporal mosaic, and are likely to continue to do so. Additionally, this study increases our understanding of how vegetation structure and fire regimes in the Northern Range have varied as a result of a range of climate conditions in the past. Such baseline information helps us anticipate some of the ecological responses that may occur in the decades ahead with global warming.

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Introduction

Current consensus in the global scientific community is that anthropogenically induced rising levels of atmospheric CO_2 and other greenhouse gases are likely to alter Earth's ecosystems worldwide over the coming century (Jansen et al., 2007, IPCC, 2013, Heyhoe et al., 2017) through changes in precipitation and increasing temperatures. Regions at high latitude and/or high elevation are particularly vulnerable to ecological reorganization due to the inability of many species to migrate beyond physiographic boundaries (Bartlein et al., 1997). In topographically complex landscapes such as the Northern Rocky Mountains, a warming climate is already resulting in non-linear effects to weather such as increasing frequency of extreme precipitation events and seasonal drought. Negative impacts to ecosystems due to shorter winters, decreased snowpack and an increase in the length and intensity of the wildfire season are expected to increase over the coming century (USGCRP, 2018).

Relative to long-term trends since the Last Glacial Maximum (LGM), late Holocene vegetation assemblages and fire regimes have been fairly stable in the Northern Rocky Mountains (Whitlock and Brunelle, 2006). Though over decadal to centennial scales, precipitation across portions of the western U.S. has varied widely from conditions at present (Herweijer et al., 2007). Paleo-climate indexes from annually resolved tree ring records show a long interval of pronounced aridity, the Medieval

Climate Anomaly, from approximately AD 900-1300 (Cook et al. 2004) as well as the Little Ice Age, roughly AD 1570-1730, a period of re-advancement of mountain glaciers and generally cooler temperatures than today (Bradley and Jones, 1993).

In the complex topography of the Intermountain West, ecological responses to future changes in climate are likely to vary with elevation, landscape hydrology and topography (Whitlock and Bartlein, 1993, McWethy et al., 2010). Recent studies focusing on the Greater Yellowstone Ecosystem (GYE) suggest that forests such as those found in Yellowstone National Park (YNP) could see significant changes in fire regimes and vegetation by the middle of this century (Turner et al., 2013,Westerling et al., 2011, Iglesias et al., 2018). Modeling of multiple fossil pollen assemblages in the region by Iglesias et al. (2015) highlights species response to past changes in temperature and precipitation through the Holocene. Their study concludes that warmer and drier winters, hotter summers, insect activity and fire management policies all could act to create novel vegetation response and assemblage in the future.

Yellowstone National Park (YNP) comprises a relatively pristine landscape and a valuable natural history laboratory where we can understand ecological change through time (Turner et al., 2016). Its rugged and remote terrain, as well as the protected status of the park, has allowed the ecological communities of the region to remain largely intact during the intensified settlement of the western United States over the last 200 years. These qualities enable close comparisons of natural conditions in the past and at present, which are necessary to understand the range of variability in ecosystem dynamics under different climate conditions (Hobbs et al., 2010). In addition, as the world's first National Park, Yellowstone is an iconic symbol of landscape conservation efforts.

Responding to concerns about the degradation of grassland ecosystems in YNP, the National Academy of Sciences reviewed the available science surrounding the ecology and management of Yellowstone's ungulate herds in its Northern Range. These grassland-steppe, open-forest parkland, and riparian corridors serve as the wintering range for Yellowstone's northern elk and bison herds. As such, information on past, current and future changes in vegetation is of high importance to park resource managers. The resultant report by the National Research Council Committee on Ungulate Management in YNP (NRC, 2002) recommended the need for more information on the range of natural variability in ecosystem dynamics, including consideration of historical variability.

In the Greater Yellowstone Ecosystem, Holocene precipitation patterns have broadly followed two separate regimes (Whitlock and Bartlein, 1993). The Northern Range of Yellowstone National Park follows a summer-wet regime where the ratio of July/January precipitation is highly influenced by monsoonal circulation caused by heating the continental interior of the United States. At higher elevations, and to the west and south in the Greater Yellowstone Ecosystem, a summer-dry pattern exists where the ratio of July/January precipitation is largely influenced by the Pacific subtropical high-pressure system suppressing summer rainfall in the Pacific Northwest. The intensity of these precipitation patterns determines in part the vegetation and fire regimes at present. Studies of fossil pollen and fire history in the Greater Yellowstone Ecosystem suggest that summer-wet and summer-dry precipitation patterns were intensified by increased summer insolation during the early Holocene, which resulted in summer-wet regions becoming wetter and summer-dry regions becoming drier than at present (Huerta et al., 2009, Millspaugh et al., 2000, 2004, Whitlock and Bartlein, 1993; Whitlock, 1993). In the late Holocene, as the contrast between summer-wet and summer-dry regimes has attenuated with decreased summer insolation, the vegetation patterns in Greater Yellowstone Ecosystem have been relatively stable (Krause & Whitlock 2013) and differences in fire occurrence have been influenced by spatial variations in topography and annual to decadal climate variability (Huerta et al., 2009). Other late-Holocene studies from the Greater Yellowstone Ecosystem (Meyer, 1995, Persico and Meyer, 2009) show temporal correlation between periods of high fire-related debris flow in the Northern Range to periods of high beaver activity in the region. Hadly (1995) shows that changes in late-Holocene mammal assemblages in the Northern Range also correspond with fluctuations in temperature and persistent drought. These studies highlight the interconnectedness of ecosystem components to changes in climate, fire and precipitation through time.

The objective of this study is to increase our understanding of the vegetation and fire history of the Northern Range based on examination of fossil pollen, charcoal, and lithologic records from two small lakes, Floating Island Lake (44.9421 N, 110.45036 W, elev. 2023 m) and Foster Lake (44.8737 N, 1101677 W, elev. 2052 m)(Fig. 1). These data were compared with previously published late-Holocene pollen and fire-history reconstructions (Whitlock et al., 2008, 2012; Huerta et al., 2008, Millspaugh et al., 2004;

Engstrom et al., 1991) to examine spatial and temporal variations in the environmental history of the Northern Range (Fig.1). Comparisons were made between the lake-sediment records and tree-ring climate reconstructions (Gray et al., 2007), regional drought reconstructions (Cook et al., 2004), and fluvial and geomorphic changes (Meyer et al., 1995, Persico and Meyer, 2009), in order to better understand of how climate variation is expressed in the vegetation and fire regime on both local and landscape scales in the Northern Range.

Specifically this study asked, what do the fire and pollen histories in these new records tell us about the local vegetation response to climate variation over the last ~4000 years? Second, when considered with other studies from the NR, under what conditions does local fire occurrence vary from regional trends over time, and how does this inform future management.

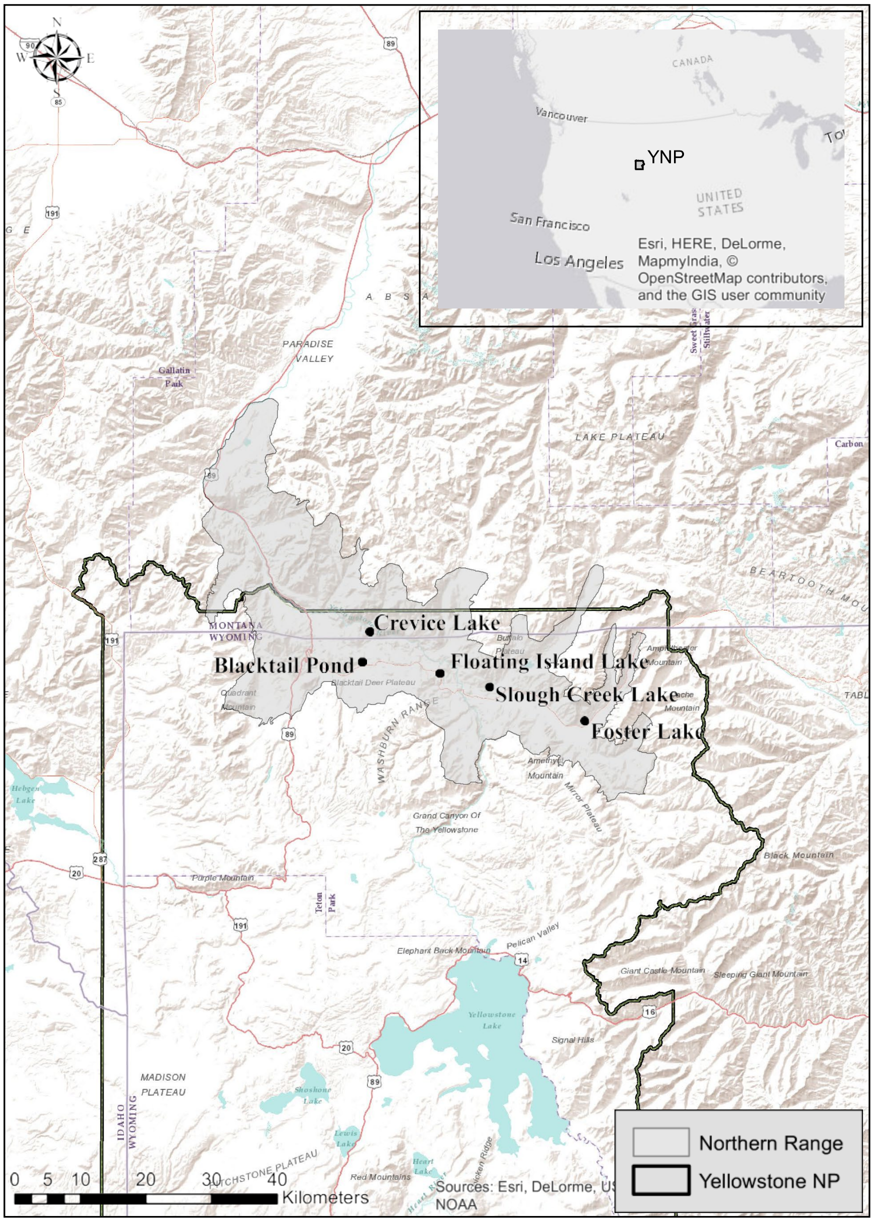

Figure 1. Study locations in the Northern range of Yellowstone National Park.

Modern Setting

The Northern Range extends from the Yellowstone River valley in southwest Montana north of Yellowstone National Park (referred to as the Paradise Valley), south and east up the Yellowstone River encompassing the Blacktail Deer Plateau, the broad grasslands of the Lamar River Valley, and its much of its' tributary rivers and streams. (Yellowstone National Park, 1997). In the Paradise Valley the Northern Range is bounded by the Absaroka-Beartooth Wilderness on the east and Gallatin Range on the west. In Yellowstone National Park the Northern Range is bounded on the north by the Absaroka-Beartooth Wilderness, it includes the Swan Lake Flat south of Mammoth Hot Springs, and is bounded on the south-east by the Washburn Range, separating it from the interior higher elevations of Yellowstone (Fig. 1).

Climate in the Northern Range can be characterized by long cold winters, and cool summers punctuated with convectional afternoon thunderstorms. Multi-decadal climate data from four weather stations located across the Northern Range (Table 1) show mean annual temperatures are stratified by elevation. Gardiner, MT (elev. 1609 m) in the West has a mean annual temperature of 7.3°C, Mammoth WY (elev. 1898) at 4.6°C, Tower Falls WY (elev. 1911) at 2.2°C and the Lamar River, WY (elev. 1972 m) climate station on the eastern portion of the range shows a mean annual temperature of 1.8°C. Data from the same locations show the Northern Range receives the majority of its precipitation during summer months, regardless of elevation or longitude. Gardiner is semi-arid with a mean annual precipitation of 24.7cm and a ratio of summer/winter (June, July, August/ December, January, March) precipitation of 2.8. Mammoth has a mean annual precipitation of 39.1 cm, Tower Falls 41.9 cm, Lamar River 36.4 cm, and summer/winter precipitation ratios are 1.7, 1.5, and 1.9 respectively. (Western Regional Climate Center, 2016)(Table.1)

Climate Station	Elevation (m)	Mean Annual Temp. (°C)	Mean Annual Precipitation (cm)	Mean Winter (D J F) Precipitation (cm)	Mean Summer (J J A) Precipitation (cm)	Ratio of Summer/Winter Precipitation	Years for Summary Record
Gardiner, MT	1609	7.3	24.7	3.1	8.7	2.8	1956-2012
Mammoth, WY	1898	4.6	39.1	7.2	12	1.7	1894-2012
Tower Falls, WY	1911	2.2	41.9	8.8	13.1	1.5	1948-2012
Lamar River, WY	1972	1.8	36.4	6.8	12.7	1.9	1881-2012

Table 1. Climate weather station data sites in northern Yellowstone National Park, from west to east. (Western Regional Climate Center)

In the Northern Range vegetation communities are stratified by elevation, and community structure is strongly related to substrate (Despain, 1990). Vegetation primarily falls within three zones as described by Lessica (2012). The Valley Zone (elev. 610 -1525 m) describes vegetation common to low-elevation northwest portions of the Northern Range, and corresponds with Merriam's Upper Sonoran/Transition. From Gardiner south and to the east, the Northern Range falls primarily within the Montane Zone (1370 – 2130 m) and to a lesser degree the lower Sub-Alpine Zone (1980-2900 m). These correspond with Merriam's Transition/Canadian and Canadian zones respectively.

Within these zones, the dominant vegetation community is sagebrush-steppe on calcareous glacial till in the mountain valleys. This transitions to open sage-conifer parkland at higher elevation and steeper aspect. Common woody shrub species of the sagebrush-steppe community are *Artemisia tridentata* ssp. *tridentata* (basin big sagebrush), *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush), *Artemisia frigida* (fringed sage), *Ericameria nauseosa* (rubber rabbit brush), *Chrysothamnus viscidiflorus* (sticky-leaf rabbit brush) and *Sarcobatus vermiculatus* (greasewood) in the Gardiner Basin. Common grasses are *Elymus cinereus* (basin wildrye), *Elymus elemoides* (bottlebrush squirrel tail), *Elymus trachycaulus* (slender wheatgrass), *Bromus porteri* (nodding brome), *Bromus carinatus* (mountain brome), *Achnatherum richardsonii* (Richardson's needlegrass), *Achnatherum hymenoides* (Indian ricegrass), *Hesperostipa comata* (needle-and-thread), and *Festuca idahoensis* (Idaho fescue). Common forbs include several species of *Lupinus* spp. (lupine), *Balsamorhiza sagittata* (arrowleaf balsamroot), *Geum triflorum* (prairie smoke), *Helianthella uniflora* (Rocky Mountain helianthella), *Madia glomerata* (cluster tarweed), *Arabis nuttallii* (Nuttall's rockcress), *Geranium viscosisimum* and *G. richardsonii* (sticky geranium and white geranium), several species in the genus *Eriogonum* (buckwheat), *Phlox hoodii* (carpet phlox), and several species in the genus *Potentilla* (cinquefoil).

Numerous riparian communities exist along rivers and wetlands throughout the Northern Range. Riparian herbaceous vegetation includes several species in the genus *Carex* (sedge), *Typha latifolia* (common cat-tail), *Juncus arcticus (wire rush),* and *Schoenoplectus acutis* (hardstem bulrush). Woody understory and arboreal species include *Rosa woodsii* (Wood's rose), *Ribes* spp. (gooseberry), *Prunus virginiana* (common chokecherry), *Amelanchier alnifolia* (serviceberry), *Rhus aromatica* var. *trilobata* (skunkbush sumac), *Betula occidentalis* (river birch), *Alnus viridus* ssp. *sinuata* (wavey-leaf alder), several members of the genus *Salix* (willow), *Populus angustifolia* (narrrowleaf cottonwood), and *Populus acuminata* (lanceleaf cottonwood). (Lesica, 2012, Whipple, 2011 unpublished, Dorn, 2001, Dorn 1984, Yellowstone National Park Resource Monitoring Program, 2013-2014). *Populus tremuloides* (quaking aspen) is associated with moist areas but is currently not a large component of the Northern Range flora (Whipple, 2011 unpublished).

As the Valley Zone transitions to Montane zone in the Northern Range, open conifer forests replace the sage-steppe vegetation of the valley floors and become dominant on the slopes. In Yellowstone, there are currently nine conifer species. Seven species represent three genera in the family Pinaceae*, Abies bifolia* (subalpine fir)*, Picea engelmannii* (Engelmann spruce)*, Picea glauca* (white spruce)*, Pinus albicaulis* (whitebark pine)*, Pinus contorta* (lodgepole pine)*, Pinus flexilis* (limber pine) *and Psuedotsuga menziesii* (Douglas fir)(Whipple, 2011 unpublished). At higher elevations and to the south, lodgepole is the dominant species on the relatively infertile ryholitic substrate. Lodgepole currently represents >80% of forested areas within Yellowstone. (Yellowstone National Park, 2014). In the Northern Range, sagebrush-conifer parkland is composed primarily of Douglas-fir, while Engelmann spruce, subalpine fir and whitebark pine occupy higher elevations (Whipple, 2011 unpublished, Despain 1990). The two other conifers found in Yellowstone are *Juniperus communis* (common juniper) and *J. scopulorum* (Rocky Mountain juniper). Common juniper is found through out the park primarily as an understory component in higher elevations (1809-2950 m). Rocky Mountain juniper is presently found primarily in lower elevation areas (1580-2011 m) of the Northern Range such as Gardiner and Mammoth (Whipple 2011, unpublished).

Site Description

Foster Lake is located at the east end of the Lamar Valley close to the convergence of Soda Butte Creek and the Lamar River. Surface area is 3.2 hectares and the lake lies in an active southeast flowing landslide. The watershed lies below the southeast face of the Druid Peak portion of the Beartooth-Absaroka Uplift, a range of Eocene andesitic and basaltic lava flows (Taylor et al, 1989). The sedimentary record is 1.75 cm long and the absence of Mazama ash layer suggests an age younger than 6700 yr BP (Engstrom et al., 1991). Foster Lake is primarily fed by ground water although currently an ephemeral stream flows in from the north. Engstrom et al., (1991) note that this stream was permanent c.1988 and supplemented by a spring on the northwest shore. Foster Lake lies at the forest/steppe boundary with dominant steppe and understory vegetation characterized by sagebrush, snowberry, wild rose, common juniper, and various bunch grasses and forbs. Forest stands consist of primarily Douglas fir, lodgepole pine and Engelmann spruce, along with scattered stands of quaking aspen at the forest edge. The aquatic vegetation includes *Myriophyllum spicatum* (water milfoil) and *Polygonum amphibium* (water smartweed), and small patches of willow grow on the northwest shore. Its relatively deep water depth (~7 m) and small surface area suggests that bottom sediments experience little bioturbation or wave action.

Floating Island Lake is located approximately 4.8 km west of Tower Junction. With a surface area of 3.2 hectares (Engstrom et al., 1991), it is nested in a north-facing depression of poorly sorted calcareous Pinedale glacial till. The watershed lies within Eocene andesitic volcaniclastic deposits, but a local outcropping of basalt abuts the north shore (Taylor et al, 1989). The lake has no inlet or outlet, relying entirely on ground water recharge and seasonal runoff. Historic photos suggest multiple age classes of willow and aspen in the riparian zone, though those stands are largely gone today (Engstrom et al, 1991). A 2014 vegetation survey showed the lake margin consisting primarily of hard-stem bulrush, cattail, horsetail (*Equisetum* spp), water sedge (*Carex aquatilus*), field mint (*Mentha arvensis)*, and tufted hairgrass (*Deschampsia cespitosa*). Floating Island Lake sits at a boundary between sagebrush steppe and parkland with forest to the south composed of Douglas fir, subalpine fir and Engelmann spruce. Emergent shorelines evident in the basalt talus and its shallow depth suggest dramatic changes in lake level in the past.

Methods

Field Methods

During the winter and fall 2010, sediment cores 1.63m and 1.53m in length were retrieved from Floating Island Lake and Foster Lake, respectively. The Floating Island Lake core (FI10A) was retrieved from the ice surface using a Klein piston corer at a water depth of 3m. A Klein piston core from Foster Lake (FL10B) was retrieved from an anchored floating platform in 6.5m of water. Both cores were capped in the field and transported to the Paleoecology Lab at Montana State University where they were placed in refrigeration. The cores were split longitudinally, photographed and described in the lab, and half of each core was stored as archive. The remaining core material was sampled at 0.5 cm intervals for analysis.

Chronology

Age-depth models were developed for Foster and Floating Island lakes based on seven (3 for Foster Lake, 4 for Floating Island Lake) calibrated AMS ^{14}C dates from terrestrial plant macrofossils and macroscopic charcoal particles (Table 2). Age determinations were processed at The National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) at Woods Hole, Massachusetts.

Radiocarbon dates for each sample were calibrated to calendar years before present (cal yr B.P.) using Clam 2.2 (Blaauw, 2010) within the open source statistical software R (R Core Team, 2014). The resultant age-depth models were created assuming a Gaussian probability distribution for calibrated dates within a 95% confidence interval. A smoothed-spline regression was used to fit models through the age distributions over 1000 iterations for each site (Figures 2 & 3).

Some of the ^{14}C samples, appearing too young or old (Table 2), were not considered for the final age-depth model based on the inconsistency of their calibrated age within a logical sediment sequence of the cores. These are particularly apparent in the Foster Lake age-depth model. The cause of the inconsistency is not known but possibilities include contamination during sample extraction, bio-perturbation and repositioning of local material prior to taking the core, contamination during processing, or for some samples using a prohibitively small piece of material with which to measure ^{14}C.

Sequential charcoal, magnetic-susceptibility and pollen data (Floating Island Lake) obtained from the cores don't show any apparent abrupt changes in the proxy record that might suggest a large-scale repositioning of sediment within the lakebed (Figures 4,5 and 6). Similarly, sedimentation rates derived from the final chronologies show them to be in-line with other studies from the area. That being said, given the level of uncertainty within the Foster Lake ^{14}C dates it was decided that for this study, time would not be well spent on a pollen reconstruction for that site.

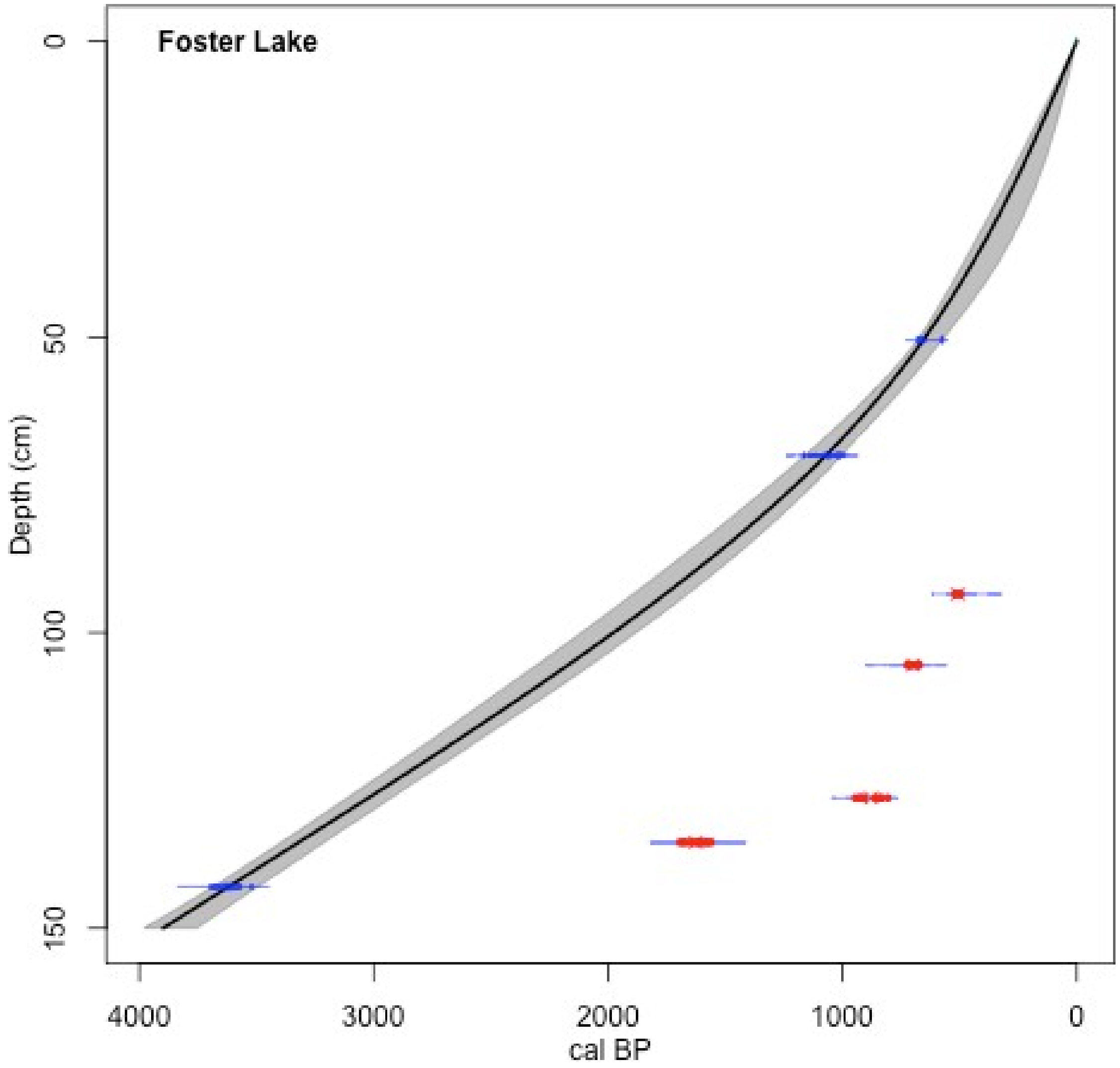

Figure 2. Smooth-spline regression age/depth model for Foster Lake, YNP.

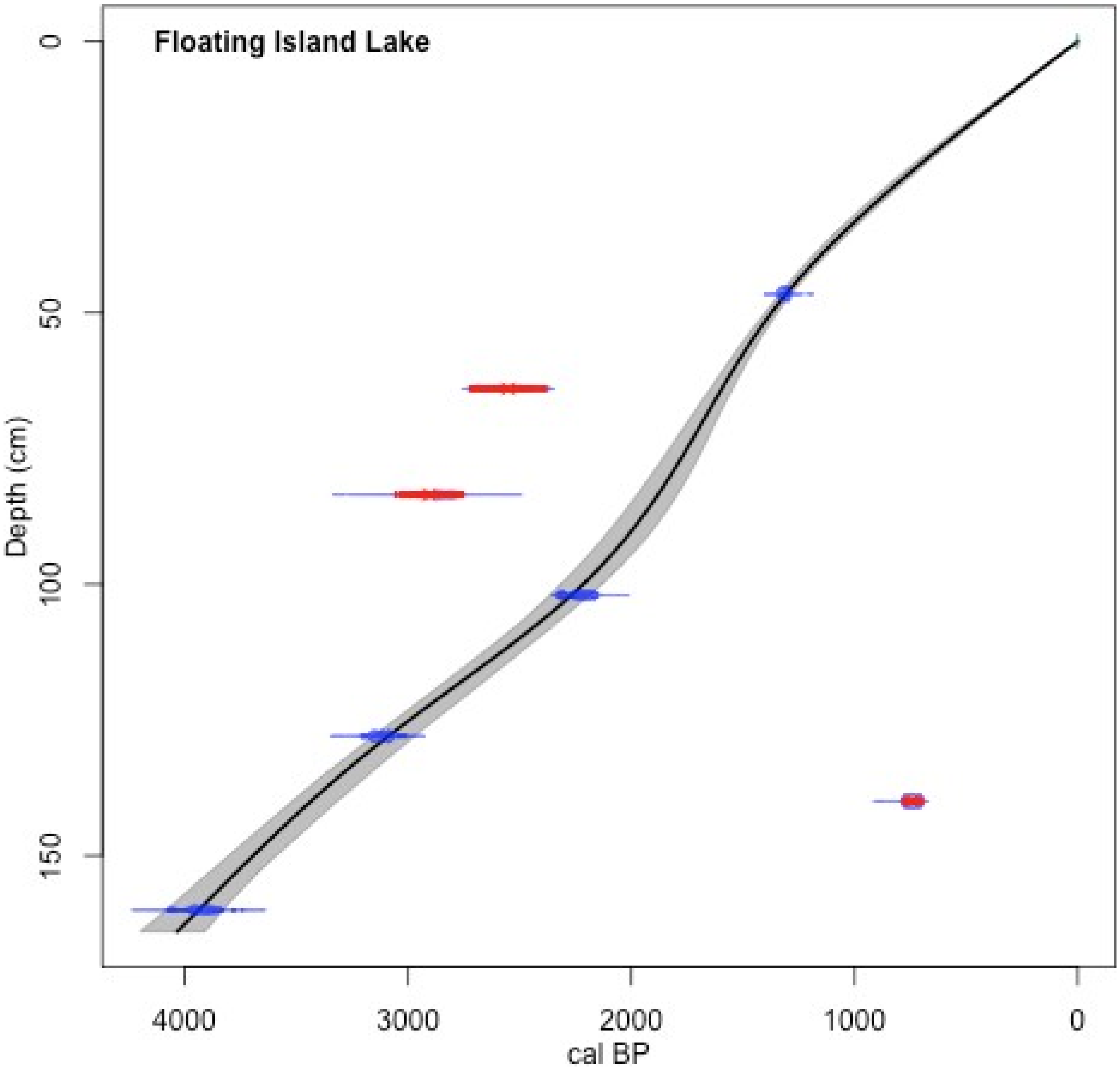

Figure 3. Smooth-spline age/depth model for Floating Island Lake, YNP

Table 2. Sample and age information used to model chronology for Foster Lake and Floating Island Lake, YNP.

Depth (cm)[a]	Core	Uncalibrated ^{14}C age (^{14}C yr BP)	Calibrated age (cal yr B.P.) with 95% CI[b]	Material Dated	Lab Id[c]	Used in Chronology	Sample Treatement Used	Sample Size (mg)	Sample Batch
50.5	Foster Lake	700 ± 25	666 (567 - 684)	wood	OS-87354	YES	Standard	2.5	Mar-11
70.0	Foster Lake	1150 ± 25	1048 (981-1173)	wood	OS-87397	YES	Standard	12.8	Mar-11
93.5	Foster Lake	450 ± 25	507 (485-530)	conifer needle	OS-92730[d]	NO	Standard	20	Oct-10
105.5	Foster Lake	765 ± 35	697 (662-733)	wood	OS-86770[d]	NO	Standard	17	Jan-11
128.0	Foster Lake	985 ± 25	927 (799-956)	wood	OS-87398[d]	NO	Standard	6	Mar-11
135.5	Foster Lake	1710 ± 35	1626 (1551-1702)	charcoal	OS-92795[d]	NO	Standard	8	Oct-10
143.5	Foster Lake	3380 ± 35	3631 (3512-3705)	wood	OS-86960	YES	Standard	7.5	Jan-11
46.5	Floating Island	1400 ± 25	1315 (1287-1343)	charcoal	OS-92778	YES	Small	5	Oct-10
64.0	Floating Island	2480 ± 40	2572 (2380-2723)	wood	OS-86963[d]	NO	Small	0.8	Jan-11
83.5	Floating Island	2760 ± 75	2894 (2751-3057)	charcoal	OS-92904[d]	NO	Small	1	Oct-10
102.0	Floating Island	2230 ± 35	2215 (2153-2333)	wood	OS-83773	YES	Standard	7.6	Sep-10
128.0	Floating Island	2960 ± 60	3133 (3006-3211)	wood	OS-86790	YES	Standard	3	Jan-11
140.0	Floating Island	835 ± 25	717 (694-786)	wood	OS-86771[d]	NO	Small	0.5	Jan-11
160.0	Floating Island	3610 ± 50	3955 (3733-4084)	charcoal	OS-92905	YES	Small	1	Oct-10

[a] Depth below mud surface

[b] Ages calibrated with CLAM 2.2

[c] National Ocean Sciences AMS Facility, Woods Hole Oceanographic Institute

[d] Date not used in age-depth mode

Lithology

Magnetic Susceptibility. Changes in the relative abundance of inorganic clastic sediment to lake systems can be inferred from sediment magnetic susceptibility. Measuring magnetic susceptibility allows us to identify times of increased erosion in a catchment (Sandgren and Snowball, 2001), and thus in conjunction with other proxies make inferences about environmental conditions through time. Magnetic susceptibility was measured at contiguous 0.5 cm intervals on the longitudinally split core from Foster Lake using a duel frequency MS2 Barington Magnetic Susceptibility Meter. The high water content and loose consistency of the core from Floating Island Lake necessitated measuring magnetic susceptibility using a cup sensor. Core material of 5 cm^3 was removed and sampled at 0.5 cm intervals through the length of the core. For both lakes, magnetic susceptibility was measured as standard CGS units.

Loss on Ignition. Lake productivity, a function of temperature, depth, nutrient and available sunlight, is inferred in relative amounts of organic and carbonate content in sediment cores (Dean, 1974). For Foster Lake, contiguous samples of 1 cm^3 were taken from the core at 0.5 cm intervals. Samples of the same volume were analyzed from the Floating Island Lake core at contiguous 1-cm intervals. All samples were dried for 24 hours at 90°C then weighed and heated to 550°C for 2 hours to remove organics. Sediment samples were then weighed and heated to 900°C for 2 hours to remove inorganic carbonates. Final weights were recorded and the weight loss at each stage was calculated to determine the proportion of organic and inorganic material in each sample.

Charcoal

Macroscopic charcoal in lake sediment is a record of local fire history (Conedera et al., 2009, Whitlock and Larsen, 2001). Sediment samples of 5 cm^3 were removed from both cores at 0.5 cm intervals and soaked for 24 hours in 30mL of 5% sodium hexametaphosphate ($(NaPO_3)_6$) and 30mL of bleach (NaClO). This process disaggregates charcoal from sediment and dissolves other organic material. Samples were gently rinsed and sieved through a 125 µm mesh screen. Macroscopic charcoal particles >125 µm in diameter were identified and counted based on criteria from Whitlock and Larsen (2001) using a stereomicroscope. Sample counts were analyzed using CharAnalysis (**http://sites.google.com/site/charanalysis/**), a free open-source statistical program that analyses charcoal counts for the purpose of peak detection. CharAnalyses uses a decomposition approach based on input parameters selecting statistical methods, raw charcoal data and an age/depth model. The program separates local "peak" fire events from regional background charcoal levels through time. For this study, a lowess smoother with a 600-year window, robust to outliers, was used in estimating background charcoal deposition levels. A Gaussian mixture model using a locally defined threshold was then used to determine peak fire events from background noise. Peaks above the 99th percentile were pronounced as fire events.

Pollen

Pollen analysis was used to reconstruct past vegetation (Bennett and Willis, 2001). Samples of 1cm volume were taken at 4-cm intervals through the length of the Floating Island Lake core, which based on the age-depth model represents an average 144 years between samples. At 50cm depth this interval represents 59 years, at 100cm depth it represents 183 years, and at 150 cm depth it represents 218 years.

Pollen preparation followed procedures outlined by Doher (1980) and Bennett & Willis (2001). Prior to processing, a known quantity of *Lycopodium* spores (13,911) was added to each sample allowing for calculation of pollen concentration and accumulation rates. Pollen was initially processed using a Shultz solution for the first 17 samples. Following a shift in lab protocol, the remaining samples were processed using an acetolysis technique. During pollen counting notable discrepancies were identified in the ratios of identified pollen grains between the two procedures, so all initial sample intervals were reprocessed using acetolysis. Pollen was identified down to the lowest possible taxonomic level based on published keys (Faegri and Iversen, 1975; Kapp et al., 2007) and modern pollen reference slides.

Results

Foster Lake Lithology and Charcoal

Sediment from the Foster Lake core was primarily brown and dark-brown fine-detritus gyttja and clay, with frequent laminations between 150-52.5cm depth. The Foster Lake core (Fig. 6) was divided into 3 units (FL1-3) based on long-term trends in magnetic susceptibility (MS), and visible patterns in sediment laminations.

The base of the core from 150-81 cm depth (FL-3, 3899-1367 cal yr BP) was predominantly laminated dark-brown and brown fine-grained detritus gyttja, with infrequent bands of clay. Large fluctuations in magnetic susceptibility and a highly variable organic component were common throughout the unit. The period between 150-133cm depth (3899-3221 cal yr BP) had MS values ranging between 15-43 CGS, with near centennial pulses between 20-25 CGS. During this time, organic sediment varied between 18-20%, and carbonate sediment varied between 14-18%. BCHAR was relatively low until 136.5 cm depth (~3368 cal yr BP). CHAR data featured small frequent fluctuations early in the unit until a prolonged increase after 136.5 cm depth (3355 cal yr BP). Two fire episodes were identified at 3754 and 3225 cal yr BP. The sediment between 133-125 cm depth (3221-2906 cal yr BP) was primarily brown fine-detritus gyttja. A spike in MS at 132.5 cm depth (3201 cal yr BP) recorded the highest value in the record at 48 CGS and coincided with a small decrease in organic and carbonate sediment. A pale-brown clay band at 125.75 cm depth (3014 cal yr BP) coincides with a decrease in MS values (16 CGS) and an increase in organics to 24%.

CHAR is relatively low during this period and fire episode is recorded at 2926 cal yr BP. The interval between 125-114 cm depth (2906-2484 cal yr BP) was a period of high MS values with a series of spikes at 124, 122.5 and 116.5cm depth (2867, 2809 and 2579 cal yr BP). Organic sediment decreased at 123.5 and 116 cm depth (2848 and 2560 cal yr BP). Between 114-103 cm depth (2484-2082 cal yr BP) sediment was brown fine-detritus gyttja with a pale-brown clay lamination from 110-109 cm depth (2335-2298 cal yr BP). MS recorded high values at 112 cm and 104 cm depth (2409 and 2117 cal yr BP). Organics were high (21% and 23%) at 112.5 cm depth and 106 cm depth (2428 and 2189cal yr BP). BCHAR was high from 2550-2100 cal yr BP and the average fire frequency reached 3.5 episodes kyr^{-1}. Fire episodes were recorded at 2474, 2315 and 2172 cal yr BP. A pale-brown clay band at 95 cm depth (1806 cal yr BP) coincided with an increase in MS (24 CGS). The sediment between 94.5-81cm depth (1789-1367 cal yr BP) was brown fine-detritus gyttja, and between 90-81 cm depth (1642-1367 cal yr BP) contained frequent laminations of dark-brown fine-detritus gyttja. MS showed a large increase between 85.5-83 cm depth (1501-1426 cal ye BP) coincident with a slight decline in organics. BCHAR was low throughout this period.

Unit FL-2 (81cm-53.5cm, 1367-710 cal yr BP) was composed of dark-brown fine-detritus gyttja from 81-69 cm depth (1367-1045 cal yr BP). MS values decreased from 24-16 CGS between 81- 79.5 cm depth (1367-1324 cal yr BP). At 78.5 cm depth (1295 cal yr BP), MS increased, organic content was 18%, and BCHAR began to increase. MS values decreased to 14 CGS at 75 cm depth (1199 cal yr BP), with a subsequent increase back to 23 CGS at 69 cm depth (1045 cal yr BP). During this interval, organic sediment decreased to 17%, and carbonates briefly increased to 20% at 73.5 cm depth (1159 cal yr BP).

From 69-53.5 cm depth (1045-710 cal yr BP), the record included frequent laminations of light-brown inorganic clay and fine-detritus gyttja, associated with a decrease in MS values. Between 69-60 cm depth (1045-840 cal yr BP), organic content increased to an average of 20%. BCHAR increased between 69.5-66 cm depth (1054-911 cal yr BP), and a fire episode occurred at 976 cal yr BP.

Unit FL-1 (53.5-0 cm depth, 710 cal yr BP- present) was dark-brown fine-detritus gyttja and with fewer laminations than before. MS values declined between 53.5 and 51.5 cm depth (710-673 cal yr BP) from 16.8 to 6.1 CGS and then fluctuated between 10-12 CGS, with brief declines at 42-40.5 cm depth (513-489 cal yr BP) and at 34.5 cm depth (402 cal yr BP). Above 34.5 cm depth, MS measurements increased steadily to the top of the core with noticeable spikes at 23 and 4 cm depth (253 and 43 cal yr BP).

Between 53.5-38.5 cm depth (710-459 cal yr BP), organic content averaged 19%, and from 38 to 3.5cm depth (452-37 cal yr BP), it increased to an average of 21%. Small declines in organic material (to 18%) were noted at 28.5 and 11 cm depth (321 and 117 cal yr BP), coincident with light-brown banding in the sediment and a fire episode at 118 cal yr BP. Above 3 cm depth, organic content declined to 18% at 1.5cm (17 cal yr BP) and then increased to the top of the core.

BCHAR was generally high throughout unit FL-1, especially between 50.5-45.5 and 37.5-30 cm depth (651-573 and 443-339 cal yr BP). Fire-episode frequency within this unit was the highest of the record averaging 8.6 episodes kyr^{-1}, and over 10 episodes kyr^{-1}

for the past 300 years. Peak fire events were recorded at 612, 521, 404, 378, 274, 222, 118, 105, 53 cal yrs BP, and 1 at the top of the core.

The lithological descriptions above use the modeled chronology from few dates and with large uncertainties in their accuracy. Based on the coherence between the lithology and charcoal record it’s possible the true chronology might better match that of the derived charcoal record age-depth than the model produced from CLAM.

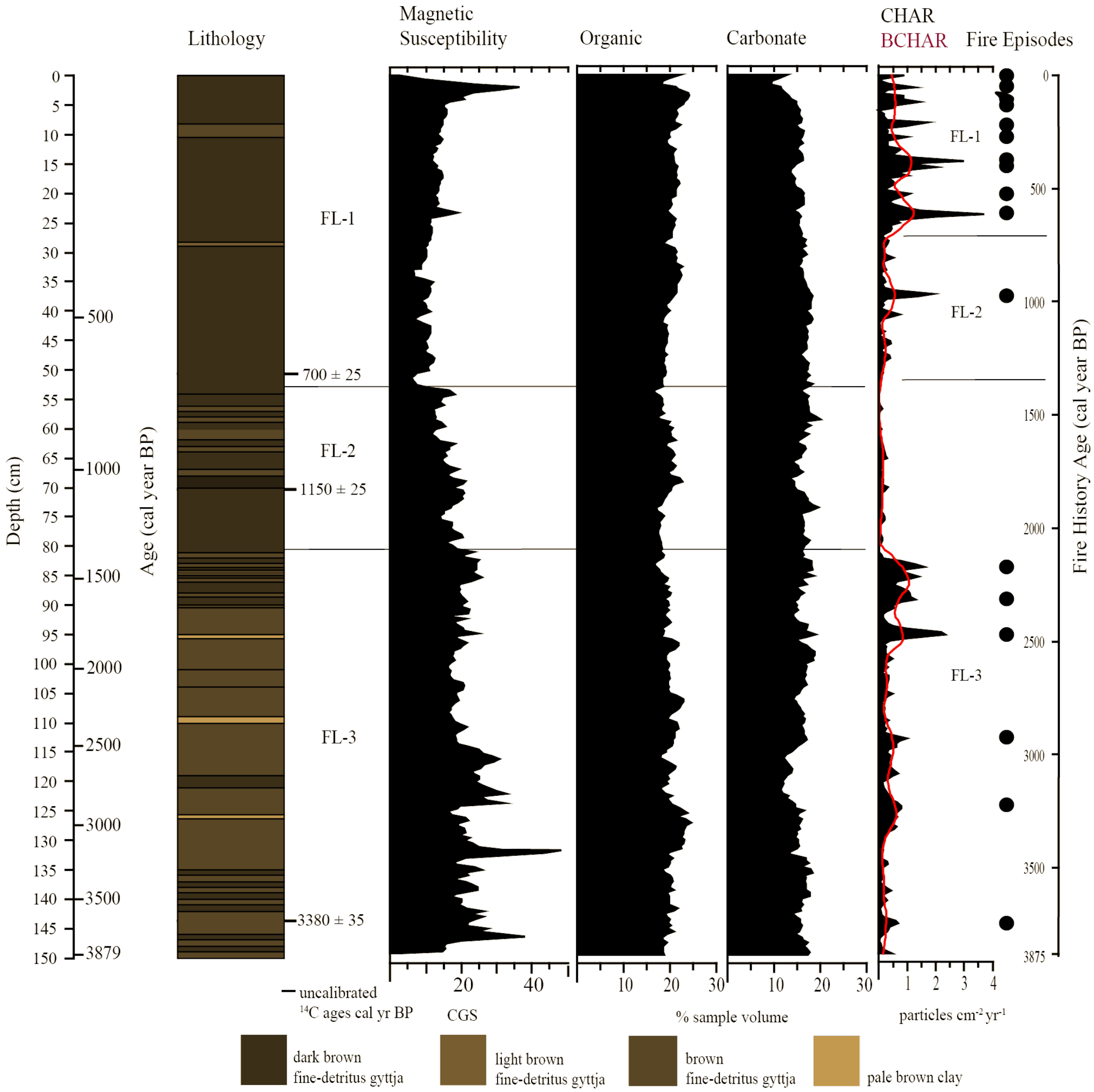

Figure 4. Lithology, radiocarbon dates, magnetic susceptibility, organic and carbonate content, and fire history for FL10B.

Floating Island Lake Lithology and Charcoal

The Floating Island sediment core was composed primarily of brown coarse-detritus gyttja, with intermittent bands of fine-detritus gytjja and sand. Root fragments and mollusk shells were ubiquitous throughout the core with a few notable exceptions of sediments at 130-143 cm depth (3150-3515 cal yr BP) and 148-150 cm depth (3643-3693 cal yr BP), where the sediments were fine-detritus gyttja. Based on the lithology, magnetic susceptibility (MS), organic and carbonate component, and charcoal data, the Floating Island record was divided into four distinct units, FI1-FI4 (Fig.4).

Unit FI-4 from 164-126cm depth (4035-3025 cal yr BP) was characterized by dark brown coarse-detritus gyttja with layers of red-brown fine-detritus gyttja between 130-143 cm depth (3150-3515 cal yr BP) and 148-150 cm depth (3643-3693 cal yr BP), stable sediment magnetic properties, fluctuating organic and carbonate content, and a generally decreasing trend in the background charcoal accumulation rate (BCHAR) (Fig. 4). MS values averaged -1.3 CGS for the unit. Positive deviations greater than 1 standard-deviation were noted at 126.5-128, 131, 141.5, 147, 158, and 159.5 cm depth. Negative deviations in MS were noted at 134.5-135.5, 136.5,138, 140.5, 143, 147.5, 156, 157, 159, 160, and 161.5 cm depth.

Organic and carbonate soil concentrations were highly variable within this unit. A low percentage (28%) of organic material was noted at 160 cm depth (3938 cal yr BP), and the organic content decreased slightly from 150-142 cm depth (3693-3489 cal yr BP), resulting in the lowest values of the record. The interval from 142-126 cm depth (3693-3025 cal yr BP) recorded a steady rise, peak and fall in organic content.

Charcoal accumulation rates (CHAR) were initially high relative to the rest of unit FI-4 at >2 particles $cm^{-2}yr^{-1}$. The record shows a peak event at 3966 cal yr BP, followed by a sharp decline to 0.6 particles $cm^{-2}yr^{-1}$ at 3927 cal yr BP, rebounding to 2 particles $cm^{-2}yr^{-1}$ by 3901 cal yr BP. CHAR declined until ~3680 cal yr BP, and accumulation then increased with a fire episode recorded at 3563 cal yr BP. From there to the top of the unit (126 cm depth, 3025 cal yr BP), the record shows two more cycles of rising CHAR followed by low intervals lasting ~150-180 years, and accumulation varying between 0.4-2.5 particles $cm^{-2}yr^{-1}$. The unit had one fire episode at 3251 cal yr BP, with an average fire frequency of 3.2 episodes kyr^{-1}.

Unit FI-3 between 126-52 cm depth (3025-1408 cal yr BP) was composed of dark brown, course-detritus gyttja and showed much less variability in organic and carbonate content than before. Organic content ranged between 30-38%. MS measurements showed little variation during this period, averaging -1.0 CGS, with the exception of a 300-year negative deviation starting at 123.5 cm depth (2945-2615 cal yr BP) that coincided with a rise and fall in BCHAR and a large fire episode at 2913 cal yr BP.

Unit FI-3 had a steady increase in CHAR and BCHAR, an increase in fire episodes, and a decrease in average fire-return interval after 2653 cal yr BP. Between 2653-2003 cal yr BP, average CHAR was 1.7 particles $cm^{-2}yr^{-1}$, up from an average of 1.1 particles $cm^{-2}yr^{-1}$ in the preceding period. Fire episodes were recorded at 2250 and 2055 cal yr BP, and mean fire frequency was 3 episodes kyr^{-1}. During the period from 2003-1418 cal yr BP, CHAR maintained a mean accumulation rate of 2.4 particles cm-

^{2}yr^{-1} and a fire frequency of 3.8 episodes kyr^{-1}. Fire episodes were recorded at 1886 and 1470 cal yr BP.

Unit FI-2 (52-12cm depth, 1408-384 cal yr BP) consisted of dark brown coarse-detritus gyttja. The organic content of the sediment increased sharply from the previous period, with values ranging from 33-48%. The periods between 48-35 cm depth (1335-1045 cal yr BP) and 33.5-23 cm depth (1007-717 cal yr BP) had high organic levels above 40%, coinciding with slight increases in BCHAR and a fire episode at 1028 cal yr BP. MS values during Unit FI-2 averaged -1 CGS. Frequent small positive deviations were noted early in the unit between 51.5-43.5 cm depth (1400-1244 cal yr BP) Three larger positive deviations occurred towards the top of the unit at 18, 16 and 13 cm depth (569, 508, 415 cal yr BP). Five negative deviations in MS were grouped in the middle of the unit between 31-22 cm depth (941, 873, 818, 804, 688 cal yr BP).

The period between 12-0 cm depth (FI-1, 384 cal yr BP – present) consisted of dark brown coarse-detritus gyttja. Organic content had another step-like increase with values ranging between 41-53%. During this period, values rarely dropped below 50% organic. MS measurements remained similar to before, with values ranging from -0.6 to -1.1. After 3 cm depth (98 cal yr BP), MS values trended strongly positive reaching 2.1 CGS at the top of the core. CHAR and BCHAR increased slightly at the top of Unit 2; however, values were generally low when compared to the core as a whole. Average CHAR was 0.3 particles cm^{-2}yr^{-1} and only one fire episode was present at 274 cal yr BP, a period of high sediment organic content and average magnetic susceptibility.

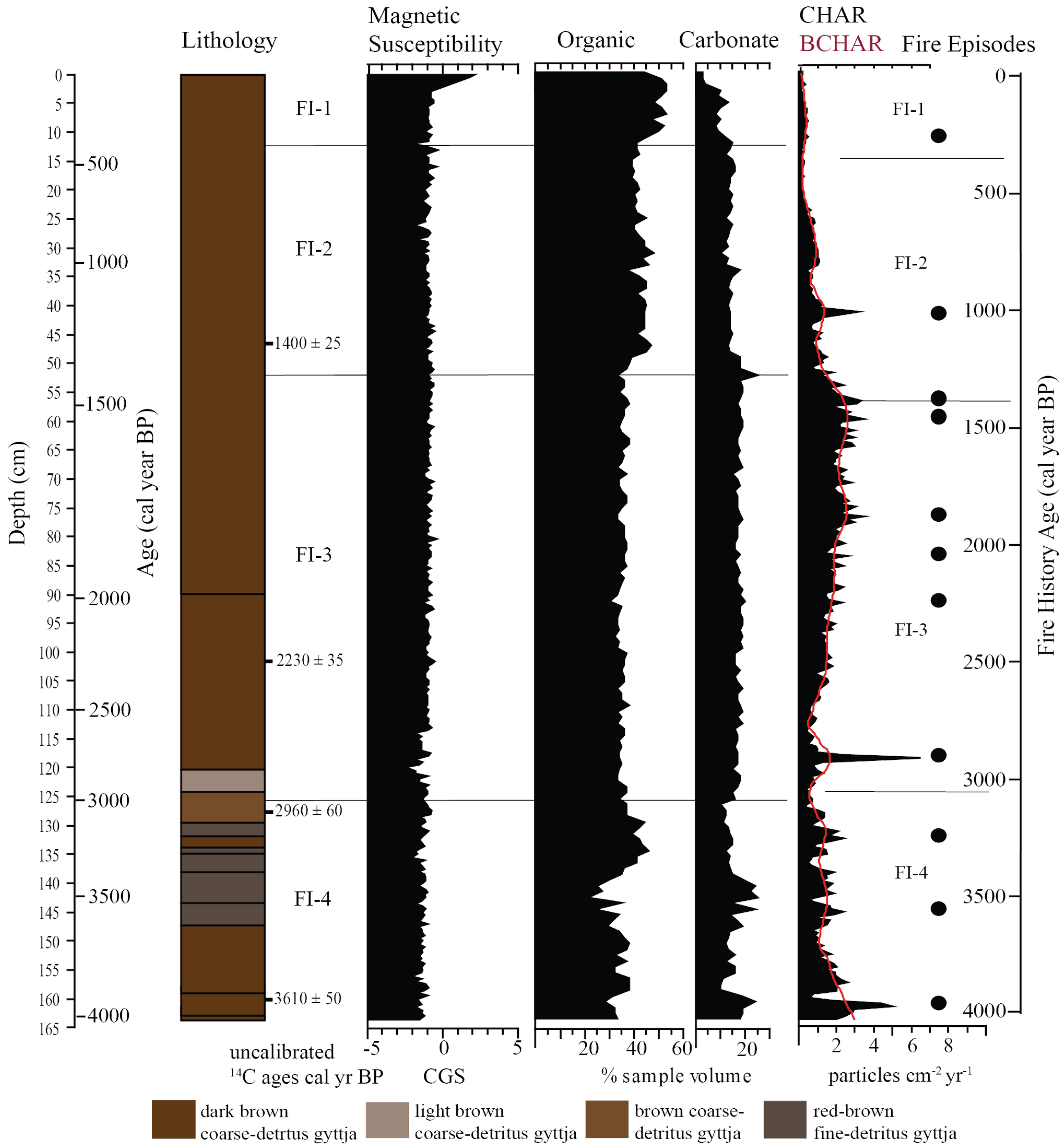

Figure 5. Lithology, radiocarbon dates, magnetic susceptibility, organic and carbonate content, and fire history for FI10A from Floating Island Lake

Floating Island Lake Pollen

The pollen record shows little significant change in the assemblage of primary taxa near Floating Island Lake in the last 4k years (Figure 6). Figure 6 shows the relative proportions of select taxa found in the pollen record, along with the ratio of arboreal to nonarboreal species, and the charcoal-derived fire record. The taxa in Figure 6 were selected by their relative abundance in the pollen record. Raw pollen counts for all taxa are available in Appendix C.

Pinus was the dominant pollen taxa in the record, varying between 51-77% and averaging 65%. The majority of *Pinus* pollen was diploxylon type (8 - 28%) attributed to lodgepole pine. A significantly lesser amount was haploxylon type (1- 6%) attributed to limber pine and/or whitebark pine. Most of the *Pinus* pollen were lacking a distal membrane and it was not possible to identify them as haploxylon and diploxylon types ; these indeterminate *Pinus* grains accounted for 31 - 52%.

The remaining arboreal pollen types varied through the record and represent a small percentage of total pollen abundance (slightly over 10%). *Pseudotsuga-type* -type was most abundant arboreal type, averaging 3%, followed by *Picea* (2%), *Salix* (1%), *Juniperus* (1%), *Abies* (1%), *Populus* (1%), *Alnus* (1%), *Betula* (1%), and *Acer* (<1%)

Among the woody shrub and herb taxa, *Artemisia* (12%) and Poaceae (7%) were most abundant. All other woody shrubs and herbs combined account for a total average of 6% over the length of the record. Aquatic plant taxa accounted for an average 9%, with *Equisetum* (4%) and Cyperaceae (4%) as primary contributors. Algae spores (*Pediastrum* *spp.*) varied greatly in abundance through FI10A (1-56%) but averaged 7% of all terrestrial and aquatic pollen and spores.

The beginning of the record (4011 cal yr BP) had relatively high initial percentages for *Pinus* (77%) and *Picea* (4%), both decreasing to 63% and 2% respectively by ~3900 cal yr BP. *Pseudotsuga*-type (4%), *Populus* (3%) and Poaceae (13%) all increased at 3900 cal yr BP. *Pediastrum* also showed a significant spike to 56% during the same period. *Pinus* increased to 70% by 3841 cal yr BP and decreased to 64% by 3743 cal yr BP, with a corresponding slight increase in *Abies* (3%), *Juniperus* (4%), *Pseudotsuga*-type (3%), *Salix* (3%), and *Betula* (1%). From 3841-3743 cal yr BP Poaceae featured a small increase to 7%, as did *Pediastrum* (27%). At 3541 cal yr BP *Pinus, Picea*, and *Pseudotsuga*-type increased to 76%, 4% and 3% respectively, while *Artemisia* and Poaceae declined. Between 3210 and 3089 cal yr BP, *Pinus* increased to 73%, while *Pseudotsuga*-type remained 3%, *Artemsia* increased from 9-13%, and *Pediastrum* reached 19%, which was its last significant presence for the remainder of the record.

Between ~3000-2500 cal yr BP *Pinus* was less abundant than before, but recorded a slight increase to 69% at 2961 cal yr BP. During this time, *Abies* and *Pseudotsuga*-type both increased slightly to 2% at 2846 cal yr BP. *Populus* briefly rose above 2% at 2697 cal yr BP. *Artemisia* was relatively stable, rising from 9% at 2961 cal yr BP and remaining >11% until after 1652 cal yr BP. Poaceae was 9% at 2961 cal yr BP, decreased to 5% at 2846 cal yr BP and rose again to 11% by 2566 cal yr BP. *Cyperaceae* decreased slightly from 5-3%, and *Pediastrum* remained stable between 4-5% until 2566 cal yr BP.

Between ~2500-2000 cal yr BP *Pinus* pollen reached a peak of 68% at 2441 cal yr BP, followed by a decline to 62% by 2261 cal yr BP; it then increased to 67% by 2035 cal yr BP. *Abies, Salix* and *Artemisia* increased slightly to 3%, 4% and 17%, respectively, by 2216 cal yr BP. *Cyperaceae* and *Pediastrum* both show relative declines at 2216 cal yr BP.

In the period between ~2000-1400 cal yr BP, *Pinus* percentages were variable but significantly decreased from previous abundances. From 2035-1652 cal yr BP, *Pinus* declined to52%, representing the lowest *Pinus* percentages of the record. Following 1652 cal yr BP, Pinus increased until 1408 cal yr BP where it accounted for 77% of pollen grains, the highest in the record. *Picea* and *Pseudotsuga*-type declined at 1889 cal yr BP, with coincident increases in *Populus* (2%)*, Artemisia* (13.6%), *Ceanothus* (0.7%), Ericaceae (1%), *Sarcobatus* (1.6%) and Amaranthaceae (4.2%). Poaceae is generally high between 1825-1537 cal yr BP, with brief declines at 1765 and 1652 cal yr BP. *Artemisia* increased to 18% at 1652 cal yr BP. Aquatic taxa comprised a low and consistent presence in the record during this period.

Following 1408 cal yr BP, *Pinus* decreased until 1166 cal yr BP. During the same period, *Pseudotsuga*-type and *Picea* increased, reaching 6 and 3% by 968 cal yr BP. *Juniperus* briefly increased to 2% at 1166 cal yr BP, but otherwise remained >1% from 1408-860 cal yr BP. *Salix* increased after 1335 cal yr BP reaching 3% by 1255 cal yr BP. Between 1408-968 cal yr BP, peaks of *Artemisia* occurred at 1335 cal yr BP (14.5%) and 1166 cal yr BP (11.8%). Poaceae, Amaranthaceae, *Equisetum* Cyperaceae and *Pediastrum* all increased between 1335 and 1166 cal yr BP.

During last 1ky, *Pinus* decreased until 860 cal yr BP and then steadily increased until 629 cal yr BP. *Pinus* decreased to 63% at 384 cal yr BP and then increased to 70% at 257 cal yr BP. From 130 cal yr BP, *Pinus* decreased to a modern value of 59%. *Picea* increased at 968, 629 and 130 cal yr BP (3%, 2% and 3%). *Abies, Juniperus, Pseudotsuga*-type all increased at 508 and 257 cal yr BP, and following a brief decline at 130 cal yr BP, increased again to the top of the core. *Salix* followed much the same trend with increases at 860 and 384 cal yr BP (2% and 1%) and then dropped to 0% by 257 cal yr BP. After 130 cal yr BP *Salix* increased to 2% at the top of the core. *Artemisia* and Poaceae also increased at 860 and 384 cal yr BP. *Artemisia* percentages rose at the top of the core to 14%, while Poaceae decreased to 4% near present day.

Myriophyllum showed peaks at 860 and 384 cal yr BP (4 and 3%) and decreased to the top of the core. *Equisetum* also peaked at 860 and 384 cal yr BP (6 and 6%), decreased at 257 cal yr BP, increased to 8% at 103 cal yr BP, and decreased slightly to 7% at the top of the core. Cyperaceae fluctuated over the last 1ky with relatively high percentages at 968, 746, 508, 257 cal yr BP, and the top of the core (7%, 5%, 6%, 8% and 6%).

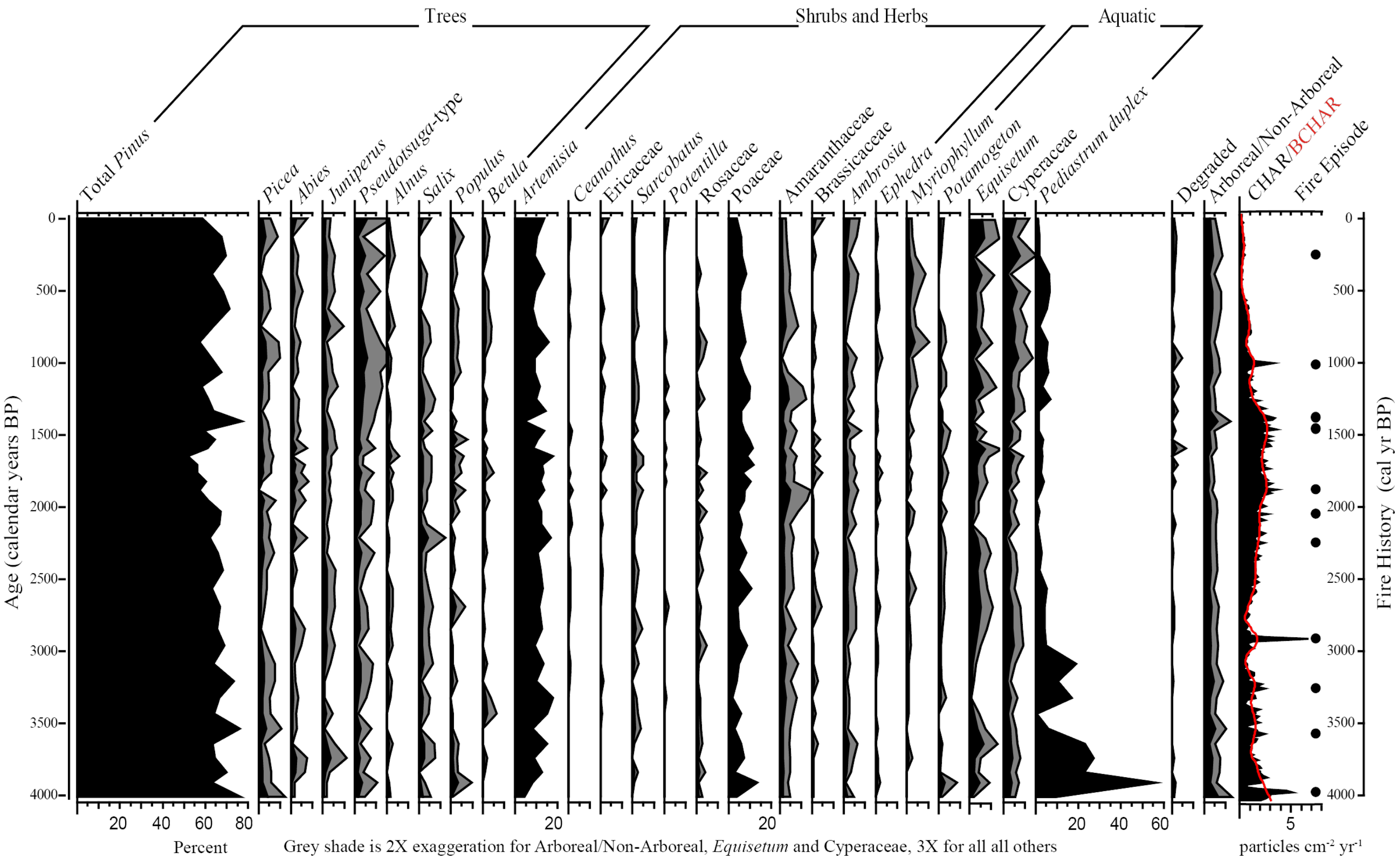

Figure 6. Pollen record of select taxa, arboreal/non-arboreal ratios, charcoal and background charcoal accumulation rates (CHAR/BCHAR), and fire episode history in core FI10A from Floating Island Lake.

Discussion

Fire, Vegetation and Climate History of the Northern Range in Yellowstone National Park During the Last 4000 Years

I compared the pollen and charcoal records from Floating Island and charcoal data from Foster Lake with fire histories from three previously studied records in the Northern Range of Yellowstone National Park; Blacktail Pond (Huerta et al., 2008), Crevice Lake (Whitlock et al., 2008, 2012), and Slough Creek Lake (Millspaugh et al., 2004). Blacktail Pond (44° 57.370 N 110° 36.071 W, elev. 2012 m) is a glacial kettle lake on Blacktail Deer Plateau. The present-day vegetation surrounding Blacktail Pond is a mixture of *Artemisia* steppe and *Pseudotsuga* parkland, with lodgepole pine forest on nearby slopes. Huerta et al. (2009) suggests that Blacktail Pond lies in a transitional area between summer-wet and summer-dry precipitation regimes. Crevice Lake (45°0.024 N, 110°34.650 W, elev. 1713 m) is a closed basin lake within the Yellowstone River canyon. Its relatively deep (>30 m) bathymetry allows for anoxic bottom water and varved sediments. The modern vegetation is an open forest of *Pseudotsuga menziesii*, *Juniperus scopulorum* and *Pinus flexilis*, with limited *Artemisia* steppe. Slough Creek Lake (44°55.497 N, 110°21.166 W, elev. 1884 m) lies in a small glacial kettle depression in the Lamar Valley south of the Buffalo Plateau. Its vegetation is a mixture of *Artemisia* steppe with *Pseudotsuga* parkland.

In interpreting the pollen and fire histories of the Northern Range (Fig. 4-8), I note the differences in sampling resolution of pollen and charcoal data among sites.

Based on the age-depth model (Fig. 3), the temporal resolution of the pollen records averaged ~100-200 years between samples, while the resolution of the charcoal records is 12 years for Floating Island, 13 years for Foster Lake, 27 years for Blacktail Pond, 13 years for Crevice Lake, and 18 years for Slough Creek Lake. Reconstructing the vegetation response to inter-annual or decadal climate variability is not possible given the resolution of the pollen data. Stegner et al. (2019) describe the limitations of using fossil pollen to capture small scale and short-term changes in vegetation structure related to fire episodes. For fossil pollen to be an effective record of fire-driven vegetation change, the sampling interval for the pollen record must be of sufficient resolution as to not obscure the driver of perceived changes.

The records of CHAR, BCHAR (Figs. 4-7) and fire episodes and fire-episode return intervals (Fig. 8) derive from statistical methods to separate local and/or large fire episodes from the continuous background accumulation of charcoal (Whitlock and Larsen, 2001, Higuera et al., 2010, Kelly et al., 2010). The charcoal records capture fire events that occur within a few kilometers of the coring site (Higuera et al., 2011), which explains why there is so much difference in the fire history among sites (Figs 6,7). Moreover, while the fire occurrence at each site is strongly influenced by climate, local site differences like ignition probability, fuel conditions, and topography determine whether a fire will occur and its characteristics.

Although observed changes in vegetation and fire histories may appear coincident when graphed, drawing correlations should be approached with caution given the differing resolution between pollen and charcoal records, and differing inherent strengths and assumptions for each proxy. The pollen record is an integration of the vegetation over a broader scale and thus shows less difference among sites or through time at a single site. I focus on comparing the higher resolution fire history reconstructions, but note that age/depth models for each lake were created independently, and have differing ranges of uncertainty, particularly the chronology used for Foster Lake interpretations.

Previous studies investigating the postglacial vegetation development of the Greater Yellowstone Ecosystem have shown that modern *Pseudotsuga* parkland and *Artemisia* steppe were largely in place by 4000 cal yr BP (Millspaugh et al., 2004, Huerta et al., 2008, Whitlock et al., 2008, 2012, Iglesias et al. 2018). The pollen record from Floating Island Lake (Fig. 6) supports that interpretation. Pollen ratios through the late Holocene period at Floating Island Lake match well with modern pollen ratios characteristic of pine forests in the Western Interior U.S. (Minckley et al., 2008) as well as in the Yellowstone region (Iglesias et al. 2018). Iglesias et al. (2018) modeled fossil conifer pollen showing that at middle elevations (2000-2400 m) mixed conifer associations were present from 12-1.5 ka BP at which point lodgepole pine expanded downslope associated with a shift from frequent low intensity fires to less frequent but more intense fires. Their models also show that at lower elevations (below 2000 m), such as those described in this comparison, short-lived submillenial no-modern-analogue steppe-forest associations likely existed as climate varied and range tolerances between species overlapped.

Between 4000-3000 cal yr BP, the pollen record from Floating Island Lake (Fig. 6) is similar to those from Crevice Lake (Whitlock et al., 2012), and Blacktail Pond

(Huerta et al., 2009). Moderate percentages of Poaceae and *Artemisia* pollen alternated with high abundance of *Pinus* pollen at all three sites. *Abies* and *Picea* generally formed a minor component of the pollen assemblage (<5%) at all sites. *Juniperus* was a minor component of the pollen record at Blacktail Pond and Floating Island Lake, and moderately represented in the record from Crevice Lake. All three sites show slight increases of *Juniperus* pollen at ~ 3700 and 3500 cal yr BP, and again at 3000 cal yr BP at Crevice Lake. *Artemisia* and Poaceae pollen show minor increases in percentages before and after ~3500 cal yr BP coincident with high levels of Cyperaceae pollen at all three sites, an indication of wetland development. This assemblage suggests a prolonged cool period between ~3600 and 3400 cal yr BP. High arboreal to non-arboreal pollen ratios at ~4000, 3500 and 3200 cal yr BP at Floating Island and Crevice Lake also suggest shifts in the abundance of forest and closer proximity of the forest boundary to the sites. Apparently, the vegetation response to decreasing summer and increasing winter insolation in the late Holocene included centennial-scale periods of expansion and contraction of the forest-steppe boundary.

The lithology at Floating Island Lake (Fig. 5) between 4000 and ~3600 cal yr BP consisted of laminations of dark brown coarse-detritus gyttja and red brown fine-detritus gyttja, and a moderate but varying organic component averaging 33%. Between ~3600-3400 cal yr BP, increasing carbonate material suggest higher lake productivity. The lithology from Foster Lake shows only minor variation in organic and carbonate content during the same period, although it recorded multiple laminations and large spikes in magnetic susceptibility between ~3650-3100 cal yr BP. After 3400 cal yr BP, the organic component at Floating Island Lake increased concurrently with an increase in *Pinus* pollen abundance.

Between ~4000-2800 cal yr BP, the fire history from Floating Island Lake (Figs. 5-7) indicates high charcoal accumulation (CHAR) and fire episodes at ~3960, ~3560, ~3250 and ~2910 cal yr BP. These fire episodes match increases in the ratio of arboreal to non-arboreal pollen and suggest that fires were associated with an expansion or infilling of forests. The fire histories from Blacktail Pond, Crevice Lake, Floating Island Lake, Slough Creek Lake (Millspaugh et al., 2004), and Foster Lake (after 3879 cal yr BP) (Fig. 7 & 8) show similar timing of fire episodes, although not all episodes are recorded at all locations simultaneously. Increased BCHAR at all sites, notably between ~3500-3200 and 3000- 2800 cal yr BP, suggest numerous fires across the Northern Range at this time. Meyer et al. (1995) describe a prolonged period with numerous fire-related sedimentation events (3300-2900cal yr BP), which overlaps in time with the period of heightened fire activity recorded in the lake-sediment records (Fig. 8).

A decrease in organic content at Floating Island Lake from ~3200-3000 cal yr BP was followed by an abrupt increase in carbonates. The organic and carbonate content then remained relatively stable until ~1400 cal yr BP. Also at ~3000 cal yr BP, the aquatic alga, *Pediastrum duplex*, abruptly declined from 20 to 5% and remained low until ~1250 cal yr BP. Coincident with the decline in *Pediastrum* was an increase in Cyperaceae and *Equisetum,* and a shift from relatively frequent laminations of red-brown fine-detritus gyttja to a homogeneous dark coarse-detritus gyttja. The lithological record of organic and carbonate content mirrors the decline, rebound and decline of *Pediastrum* in the pollen record between 3700-3000 cal yr BP. The records from Blacktail Pond (Huerta et al 2008) and Crevice Lake (Whitlock et al 2012) show slight increases in Cyperaceae at ~3000 cal yr BP, and Crevice Lake shows a sharp decrease in diatom production at that time. A lithologic reconstruction of paleo-lake levels from the larger Yellowstone region (Shuman et al., 2009) also suggests a period of aridity between 4-3.69 cal yr BP, ending concurrent with the initial decrease in *Pediastrum* at Floating Island Lake. One hypothesis is that overall this represents a time of decreasing moisture resulting in increased burning and decreasing lake levels. As water levels dropped to a low point ~3000 cal yr BP, low gradient lake margin was exposed allowing for the expansion of Cyperaceae and Equisetum at the site. Taken together, these records suggest a long-term decrease in water depth at Floating Island Lake after 3000 cal yr BP.

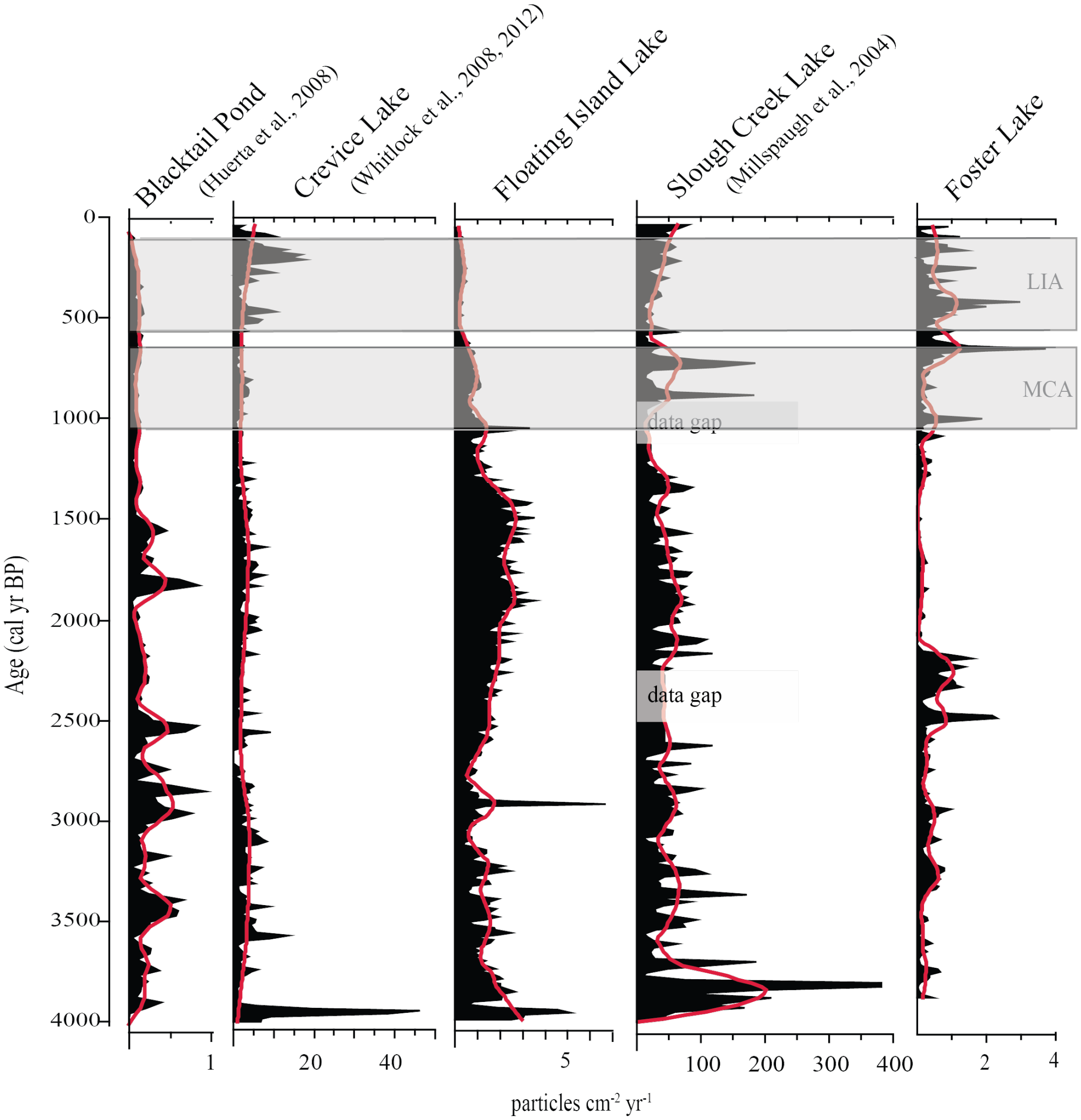

Figure 7. Late-Holocene charcoal accumulation rates (CHAR, black silhouette) and background charcoal accumulation rates (BCHAR, red line) for five lakes in the Northern Range of Yellowstone National Park. Gray shading marks timing of Little Ice Age (LIA) and Medieval Climate Anomaly (MCA)

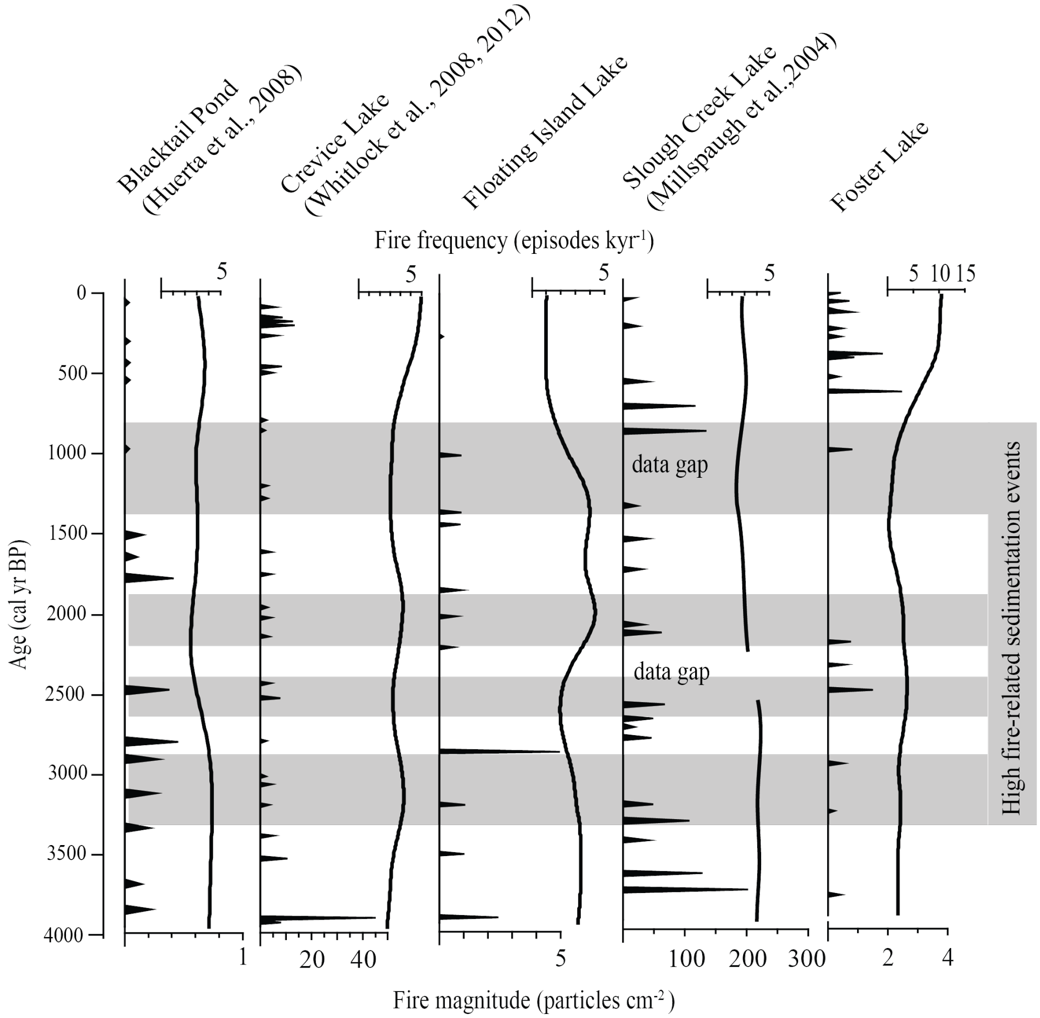

Figure 8. Late-Holocene fire episodes from five lakes in the Northern Range of Yellowstone National Park. The size of the charcoal peak indicates fire magnitude or proximity. Fire-episode frequency is based on a 1000-year running average. Times of high levels of fire-related sedimentation events identified by Meyer et al. (1995) are marked in gray.

After ~2700 cal yr BP, all five fire histories suggest a brief period of lower charcoal accumulation rates suggesting a widespread decrease in fire activity. Between 2600 and 2450 cal yr BP, fire episodes were recorded at all sites, except Floating Island Lake. This period also coincided with another time of high fire-related sedimentation (Meyer et al., 1995). Missing data from the Slough Creek record in two intervals, ~2580-2220 and 1020-890 cal yr BP, prohibit interpretation during those periods; however, Foster Lake recorded large fire episodes at 2471, 2315, and 2172 cal yr BP.

From ~2500 to ~1900 cal yr BP, BCHAR gradually increased at Floating Island Lake and Crevice Lake and remained high until ~1400 cal yr BP. The fire history at Slough Creek Lake likewise shows high BCHAR during this time. Between ~2300 to ~1850 cal yr BP, fire-episode frequency was high at Crevice Lake and Floating Island Lake, and at ~2000 cal yr BP, fire episodes were recorded at Crevice Lake, Floating Island Lake and Slough Creek Lake. Preceding the episodes at ~2000 cal yr BP, the pollen record from Floating Island indicates a brief increase in *Pinus* and *Pseudotsuga* and decrease in *Artemisia*. Following the fire episodes at ~2000 cal yr BP, the pollen record from Floating Island Lake features a large decrease in *Pinus* and increases in Poaceae and Amaranthaceae, possibly showing the effects of stand-replacement fires near the lake. The vegetation history at Crevice Lake (Whitlock et al., 2012) records a slight increase in Amaranthaceae (Chenopodiineae) and *Juniperus,* and a decrease in Poaceae suggests more xeric conditions following the fire episodes at ca. 2000 cal yr BP. Meyer et al. (1995) describe the interval 2200-1800 cal yr BP as a period of high fire-related sedimentation in the Northern Range (Fig. 8).

Whitlock et al. (2008) found that the forests near Crevice Lake generally became more closed in the last 2650 years than they were before. They found that, although the pollen record showed little change in dominant conifer and steppe composition, the charcoal record registered marked increases in fire occurrence between 562-462 cal yr BP with an overall trend toward higher frequency after 362 cal yr BP. In addition, the diatom record from Crevice Lake reveals periods of rapid fluctuations in lake stratification and water column mixing over the last 2650 years, suggesting a dynamic response to decadal-scale climate variations.

The fire history from Foster Lake between ~2200 and 1200 cal yr BP is difficult to interpret. If the chronology used to derive the charcoal record is correct, there was a 1000-yr-long period of no significant fire episodes near the lake. The lithology preserves frequent laminations of brown and light-brown fine-detritus gyttja suggesting fluctuating productivity and lake temperature, and variations in magnetic susceptibility that suggest changes in allochthonous inputs from the watershed. The period corresponds with high BCHAR and multiple fire episodes at the other sites. It is possible that the decomposition parameters used to separate charcoal peaks from background charcoal accumulation (99th percentile) underestimate the number of fires during this period. Alternatively, the lack of distinctive charcoal peaks may indicate the occurrence of frequent low-intensity fires near Foster Lake.

Cook et al. (2004) describe periods of protracted drought in the western U.S. based on reconstructed PDSI (Palmer Drought Severity Index) and comparison with other environmental proxies. The results show a period of intense drought from ~1100-700 cal yr BP, with severe events at ~1060, 960, 850 and 750 cal yr BP.

Gray et al. (2007) developed a detailed hydrologic reconstruction for the Yellowstone National Park area from the period AD 1173 to 1998, based on tree-ring data. When considered with other hydrologic reconstructions from the western U.S., such as Cook et al. (2004), they found that wet and dry years and decadal to multi-decadal trends in precipitation were synchronous across regions. However, response to interannual and decadal variability was not consistent across basins. Their reconstruction suggests decadal dry periods in the Yellowstone region at 570-580, 490-505, 190-220 cal yr BP and during the AD 1950s. The fire histories from the Northern Range five-lake comparison suggest charcoal peaks during each of these decadal droughts in at least one record. The period between 490-505 cal yr BP shows high fire-episodes occurring at Blacktail Pond ~480 cal yr BP, at Crevice Lake 510 cal yr BP, at Slough Creek Lake ~500 cal yr BP, and at Foster Lake ~521 cal yr BP.

The Northern Range-records show that these dry periods described by Cook et al., (2004) and Gray et al., (2007) coincided with times of heightened fire activity, but the record of fire-return intervals, fire-episodes and BCHAR have diverged from one another in a few prominent ways over the last millennia. At Blacktail Pond, fire-episode frequencies were relatively stable over the last millennia (3-4 ky^{-1}), and CHAR and BCHAR decreased over the last several centuries. At Crevice Lake and Foster Lake, fire-episode frequency gradually increased from ~1000 to 500 cal yr BP and then reached high levels (5-6 kya^{-1} at Crevice Lake, 1-10 kya^{-1} at Foster Lake) from the onset of the

Little Ice Age (LIA) and to the present day. Fire episodes and BCHAR from Crevice Lake and Foster Lake records also show increased burning near those locations during the LIA and into modern times. Oxygen isotope and diatom records from Crevice Lake (Whitlock et al., 2008, 2012) suggest dry winters and protracted warm summer temperatures near the onset of the MCA. From 1100-850 cal yr BP, precipitation increased and temperatures remained high. Proxy reconstructions of spring duration, and pollen accumulation rates from the Crevice Lake study suggest a shift towards cooler moister conditions after 850 cal yr BP that lasted until 250 cal yr BP. Their data suggest that environmental conditions at Crevice Lake were highly variable at the multi-decadal and multi-centennial time scales, and that the seasonality of both precipitation and temperature anomalies influences ecological response.

At Slough Creek Lake, the charcoal record shows several large fire episodes at ~820 and 660 cal yr BP and a fire-episode frequency interval that increased from 2-3 kya^{-1}. Similar to Foster Lake and Crevice Lake, CHAR and BCHAR at Slough Creek Lake gradually increased during the LIA and into modern times. At Floating Island Lake, the charcoal record shows fire episodes at ~1028 cal yr BP near the onset of the MCA, followed by lower CHAR and BCHAR, and decreasing fire-episode frequency (to 1 kya^{-1}). Since 1028 cal yr BP multiple fire-episodes were recorded at all sites except Floating Island. This lack of peak fire episodes in the record suggests that fires near Floating Island in recent centuries have been infrequent, of low-intensity, or both.

The five Northern Range lakes show connections between long-term climate variations and regional fire activity. On multi-decadal to centennial timescales, the five records show similar trends in fire activity that suggest a shared response to long-term influences governing vegetation, available moisture and seasonal temperature anomalies. The records also highlight similar fire activity during times of persistent drought that correlate well with periods of fire-related sedimentation events in the Northern Range. Times of widespread fire-episodes occurred at ~4000, ~3500-3200, ~3000-2800, ~2000, ~1500, ~1300-900, and ~500 cal yr BP. On annual to decadal scales, the five-lake comparison suggests that fire occurrence was modulated by local controls (slope, aspect, elevation, local vegetation structure) and the simple probability of ignition and spread given suitable environmental conditions.

The mismatch in spatial resolution between the pollen and charcoal records explains why during times of increased fire episodes at multiple sites, such as ~2900 cal yr BP (Fig. 8), we don’t see large shifts in the pollen spectra from Floating Island (Fig 6). The charcoal record from Floating Island shows a period of heightened local fire activity between ~2250-1000 cal yr BP. The vegetation history during the same interval shows little change By the same measure, the long-term trend of increasing *Pinus* (large woody fuels) regionally during the last millennia, isn’t evidenced by an increase in peak fire episodes in the charcoal record from Floating Island Lake. This highlights the need for conservative interpretations when analyzing intrinsically different types of proxy data.

Conclusions

Fire has been a frequent and integral component of the Greater Yellowstone Ecosystem for thousands of years. New pollen and charcoal data from Floating Island Lake and Foster Lake add to our understanding of late-Holocene vegetation and fire history of the Northern Range of Yellowstone National Park. The comparison of pollen records from Floating Island Lake with previous studies from Blacktail Pond (Huerta et al., 2009), Crevice Lake (Whitlock et al., 2008, 2012), and Slough Creek Lake (Millspaugh et al., 2004) allows for a more comprehensive interpretation of vegetation response to wet and dry periods over the last 4000 years. Comparing and contrasting the fire-histories from different locations within the Northern Range allows for a more nuanced understanding of how variations in landscape topography have modulated fire dynamics through time, even at relatively similar and nearby sites.

During the last 4000 years, the vegetation composition in the Northern Range has remained relatively constant, though the overall trend at some locations has been a gradual increase in forest cover (Whitlock et al., 2008). Periods of drought have promoted widespread burning across the landscape with increased fire activity at ~4000, ~3500-3200, ~3000-2800, ~2000, ~1500, ~1300-900, and ~500 cal yr BP. The pollen record from Floating Island indicates short-term vegetation changes in relative amounts of arboreal and non-arboreal species coincident with drought and burning, although the overall composition remains remarkably stable through the record. The records from Floating Island also show long term changes in lake levels after ~3000 cal yr BP.

After ~1000 cal yr BP, the charcoal data from the five Northern Range lakes suggest more divergent trajectories in fire expression across the landscape. At Blacktail Pond and Floating Island Lake fire becomes less frequent and episodes decrease in intensity than before. At Crevice Lake and Foster Lake burning becomes more frequent in the area, and fire-episodes become more intense. The record from Slough Creek Lake shows a few large fire events coincident with the Medieval Climate Anomaly, but no clear trend that would suggest a change in conditions modulating fire activity over the past millennia.

As the science of climate change advances, higher-resolution spatial and temporal projections of future conditions will become possible. Multi-proxy paleo-reconstructions, such as these from Yellowstone's Northern Range, can aid land managers, policy makers and the public in better understanding how landscapes might respond to projected variability in temperature and moisture availability under future conditions. The comparison of past fire records from several sites across a landscape also highlights an important aspect of fire and vegetation response to climate change in dry forest settings. The fire history shows that fire is an intrinsic component of the ecosystem, and fire episodes are relatively common at a landscape scale. While times of prolonged drought can increase the frequency fire events, fire occurrence is likely to be both spatially heterogeneous and temporally variable. On both landscape and local scales, the vegetation response to this mosaic of area-burned will be the development of differing age cohorts in the in-situ forest communities. This complexity adds a level of resiliency in vegetation communities to single climate events or individual fire episodes, as evidenced by the relative complacency in the pollen records from the Northern Range over the last ~4000 cal yr BP. Thus, this study increases our understanding of how vegetation structure and fire regimes in the Northern Range have varied as a result of a range of climate conditions in the past. Such baseline information helps us anticipate some of the ecological responses that may occur in the decades ahead with global warming.

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APPENDICES

APPENDIX A

FLOATING ISLAND LAKE POLLEN COUNTS AND PERCENTAGES

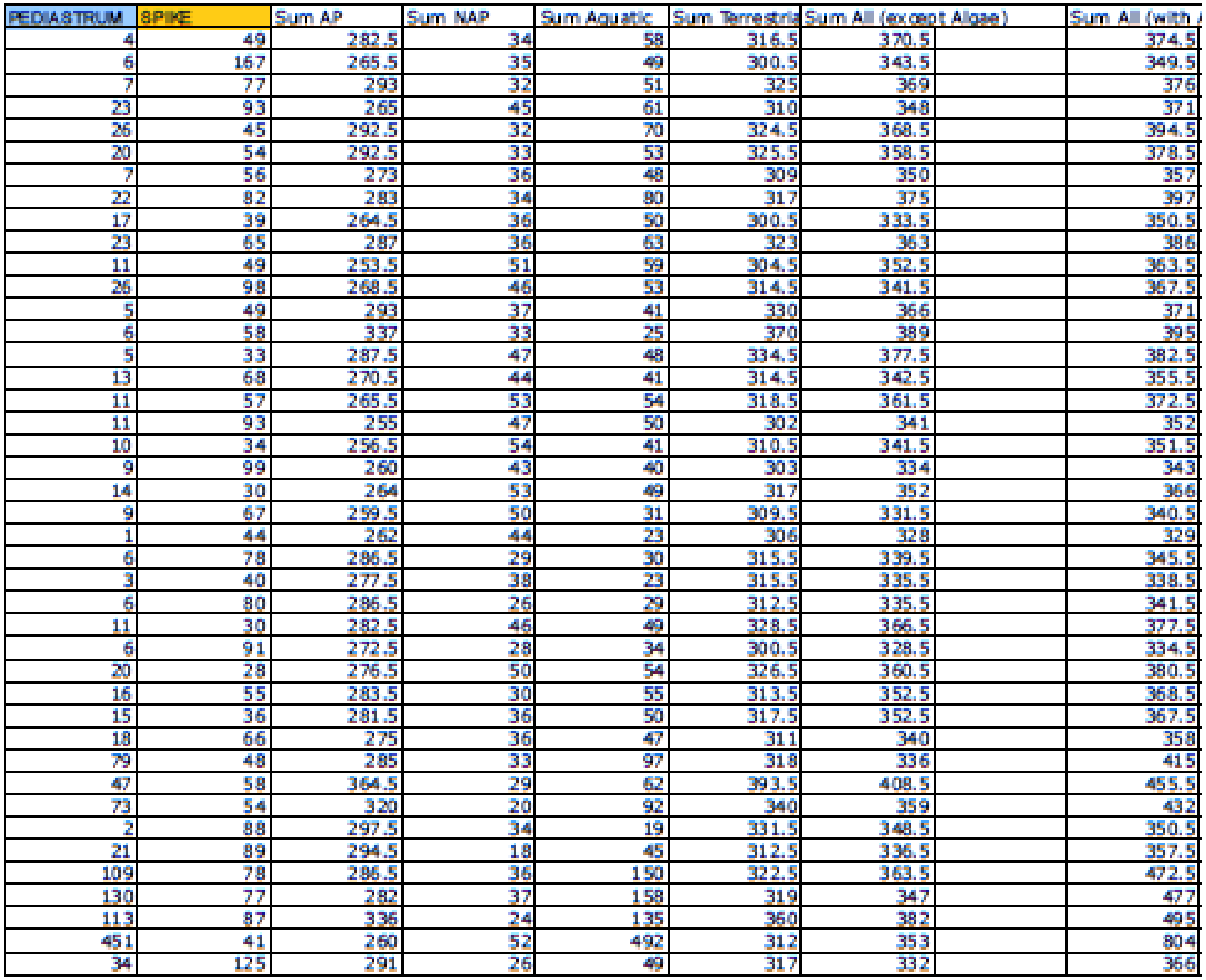
Depth	Age	HALF	Undiff	HAPLOX	DIPLOXY	Pinus Undiff	Total Pinus	PICEA	ABIES	JUNIPER	PSEUDOTSUG	ALNUS	SALIX
0	1	141	39	5	71	109.5	185.5	6	8	4	18	1	6
4	130	177	48	9	58	136.5	203.5	9	1	3	4	2	0
8	257	172	31	9	100	117	226	3	4	6	15	4	0
12	384	158	55	13	49	134	196	1	3	5	6	1	4
16	508	169	29	4	104	113.5	221.5	5	6	6	13	0	3
20	629	201	36	14	82	136.5	232.5	6	3	3	6	2	1
24	746	140	49	9	69	119	197	1	2	10	9	4	5
28	860	148	33	16	59	107	182	10	5	2	13	0	6
32	968	167	41	6	58	124.5	188.5	10	3	4	17	2	2
36	1070	190	60	10	53	155	218	5	4	5	13	2	2
40	1166	149	20	7	76	94.5	177.5	5	1	7	13	0	5
44	1255	147	46	5	69	119.5	193.5	5	4	3	12	1	8
48	1335	190	30	5	81	125	211	2	4	2	11	2	7
52	1408	302	56	17	61	207	285	5	4	5	11	2	3
56	1475	195	24	3	74	121.5	198.5	6	5	6	8	1	7
60	1537	201	37	8	57	137.5	202.5	5	3	6	6	1	2
64	1595	207	20	6	65	123.5	194.5	6	8	7	10	3	3
68	1652	162	43	9	23	124	156	7	1	4	4	6	6
72	1708	187	17	7	57	110.5	174.5	6	7	4	4	1	6
76	1765	200	32	4	34	132	170	6	5	3	9	3	6
80	1825	222	30	3	47	141	191	2	9	4	6	2	6
84	1889	189	47	5	31	141.5	177.5	0	4	3	5	3	4
88	1959	184	52	10	34	144	188	8	7	4	9	3	4
92	2035	221	53	14	35	163.5	212.5	4	3	3	9	1	2
96	2121	255	36	15	32	163.5	210.5	6	1	2	8	0	4
100	2216	227	39	11	31	152.5	194.5	5	8	3	2	1	13
104	2323	253	38	14	38	164.5	216.5	8	1	2	10	1	4
108	2441	193	56	8	45	152.5	205.5	4	3	6	5	0	3
112	2566	229	32	9	51	146.5	206.5	4	1	6	3	3	5
116	2697	215	42	7	53	149.5	209.5	3	1	6	6	3	7
120.5	2846	259	32	5	42	161.5	208.5	1	7	4	7	2	5
124	2961	192	26	10	82	122	214	4	5	6	2	3	5
128	3089	188	27	18	64	121	203	8	2	4	9	0	7
132	3210	239	44	13	112	163.5	288.5	10	3	1	10	3	2
136	3325	210	33	14	74	138	226	6	4	1	6	2	6
140	3435	211	43	7	57	148.5	212.5	6	3	5	2	0	5
144	3541	113	53	16	112	109.5	237.5	11	3	1	8	0	1
148	3643	199	56	13	36	155.5	204.5	3	1	6	3	3	8
152	3743	134	37	8	94	104	206	5	8	12	8	1	8
156	3841	214	60	11	74	167	252	7	8	4	5	0	0
159	3914	150	42	8	72	117	197	6	2	2	11	1	3
163	4011	166	60	11	89	143	243	13	2	2	5	2	6

POPULUS UND	BETULACEA	ACERACEA	ARTEMISIA	AMELANCHIER	CEANOTHUS	ERICACEA	SARCOBATUS	POTENTILLA	ROSACEA UND	POACEAE
1	1	0	43	0	1	4	2	2	0	12
6	3	0	31	0	1	0	1	1	0	18
2	2	0	30	0	0	0	1	0	0	20
3	0	0	43	0	0	0	1	0	2	26
1	3	0	31	0	1	0	2	0	0	18
4	3	0	27	0	0	2	2	0	1	17
3	4	1	32	0	1	0	3	0	1	20
4	4	0	50	0	0	0	1	1	5	25
3	1	0	28	0	0	2	1	0	3	15
5	1	0	30	0	0	0	2	0	0	22
1	0	0	36	0	0	2	3	2	1	30
1	2	0	31	0	0	1	3	0	4	30
0	1	0	48	0	0	1	2	2	0	19
3	1	0	16	0	0	0	1	0	1	22
1	2	0	46	0	2	1	3	0	1	24
8	0	0	33	0	1	1	0	0	2	30
1	2	0	27	0	0	0	2	1	1	36
6	1	1	54	0	0	3	5	0	1	26
4	3	0	39	0	0	2	5	1	0	36
5	5	0	40	0	1	0	2	0	5	20
1	1	0	38	0	0	0	2	1	1	33
7	1	0	42	0	2	3	5	0	3	24
2	3	0	31	0	0	0	3	0	0	22
4	1	0	39	0	1	0	2	0	5	14
0	1	0	39	0	2	1	2	0	1	20
2	1	1	52	0	0	0	1	0	3	15
1	2	0	35	0	0	0	1	0	1	27
2	0	0	36	0	1	1	3	0	3	14
0	1	0	43	0	1	1	2	0	0	35
7	0	0	35	0	1	0	1	2	2	13
0	1	0	40	0	0	0	5	0	1	15
1	0	0	29	0	0	0	1	0	5	27
1	2	1	42	1	1	0	3	0	1	16
4	0	0	39	0	1	2	0	0	1	15
0	4	0	60	0	0	0	2	1	2	6
1	7	0	50	0	0	1	3	0	2	20
1	0	0	26	0	0	0	4	0	2	9
4	0	1	49	0	0	0	1	0	3	19
3	2	0	28	0	0	0	0	0	1	23
4	1	1	46	0	0	0	3	0	5	10
10	0	0	26	0	0	0	1	0	1	42
1	0	0	14	0	0	0	0	0	3	12

TUBULIFLORA	AMARANTHACE	UMBELLIFERA	POLYGONUM C	BRASSICACEA	URTICA	CORNUS	BIDENS TYPE	AMBROSIA	EPHEDRA	GALIUM
1	3	2	0	6	0	0	0	8	0	0
1	3	0	0	0	0	3	1	6	1	0
1	4	0	0	2	0	0	0	3	0	0
0	5	0	0	0	0	2	0	7	1	0
1	5	0	0	0	0	0	0	6	1	0
0	7	0	0	0	0	0	1	4	2	0
0	9	0	1	2	0	0	0	2	0	0
0	4	0	0	1	0	1	0	1	1	0
0	1	1	0	2	0	0	0	6	3	0
0	4	0	1	0	0	3	0	4	1	0
0	11	0	0	1	0	0	0	5	0	0
0	13	0	1	0	0	0	0	2	0	0
1	6	0	0	1	0	0	0	5	1	0
0	6	0	0	2	0	0	0	2	1	0
2	9	0	0	0	0	0	0	9	1	0
0	7	0	0	4	0	0	0	3	0	0
1	5	0	0	1	0	0	0	3	0	0
0	8	0	0	4	0	1	0	5	2	0
1	7	0	0	1	0	0	0	5	1	0
0	7	1	0	5	0	0	0	6	3	0
1	7	1	0	2	0	0	0	5	1	0
0	15	1	0	0	2	0	0	7	1	0
0	13	0	0	1	0	0	0	5	2	0
0	9	0	0	1	0	0	0	4	0	0
1	5	0	0	1	0	0	0	6	1	0
0	7	0	0	1	0	0	0	2	0	0
2	6	1	0	3	0	0	0	5	0	0
0	6	0	0	1	0	0	0	6	1	0
0	7	0	0	2	0	0	0	5	0	0
0	3	0	0	5	0	0	0	6	2	0
2	8	0	1	0	0	0	0	6	0	0
0	4	0	0	1	0	0	0	2	1	0
0	9	0	0	1	0	0	1	3	1	0
0	7	0	0	4	0	0	0	2	0	0
0	9	0	0	0	0	0	1	3	0	0
0	7	0	0	2	0	0	0	3	0	1
0	5	0	1	0	0	0	0	2	1	0
0	5	0	0	3	0	0	0	7	0	0
0	5	0	0	1	0	0	0	5	1	0
0	6	0	1	1	0	0	0	4	1	0
0	4	0	0	1	0	0	0	1	2	0
0	5	0	0	1	0	1	0	5	0	0

PLANTAGO	ONAGRACEAE	SCROPHULARI	SAXIFRAGACE	RANUNCULACE	CARYOPHYLLA	HYPERICUM	FABACEAE	LAMIACEAE	THALICTRUM	UNKNOWN
0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	2	0	1	1
0	0	0	0	0	0	0	0	0	0	1
1	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	1
0	0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	2	0	0	5
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	1	0	3
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	3
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	7
1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	3
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	1	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0
0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	2
0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	2	0	0	1	0	0	1
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	2	0	0	0
0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	1	0	0	0	0
0	0	0	1	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	1	0	0	0	0	1

	NUPHAR	MYRIOPHYLLU	POTAMOGETO	PEDIASTRUM S	EQUISETUM	UTRICULARIA	SELAGINELLA	TYPHA	CYPERACEAE	HIPPURIS
0	0	3	3	1	24	1	0	0	22	0
0	0	3	2	0	26	0	0	0	12	0
0	0	5	1	3	6	0	0	0	28	1
0	0	10	0	0	22	0	0	0	6	0
0	0	7	0	2	11	0	0	1	23	0
0	0	4	0	0	13	2	0	0	14	0
0	2	5	3	1	11	0	0	0	19	0
0	0	13	4	0	22	1	0	0	18	0
0	0	3	1	0	6	0	0	0	23	0
0	0	5	4	0	17	0	0	0	14	0
0	0	6	4	2	24	0	0	0	12	0
0	0	3	0	0	8	0	0	0	16	0
0	0	1	2	0	13	2	0	0	18	0
0	0	2	2	0	5	1	0	0	9	0
0	0	4	7	1	16	0	0	0	15	0
0	0	1	5	0	9	0	0	0	13	0
0	0	2	4	2	29	1	0	0	5	0
0	0	2	2	0	17	0	0	2	16	0
0	0	1	4	0	13	0	0	1	12	0
0	0	3	5	0	13	0	0	0	10	0
0	0	2	4	0	16	0	0	0	13	0
0	0	2	2	0	12	0	0	0	6	0
0	0	0	1	0	8	0	0	3	10	0
0	0	4	4	0	8	0	0	0	8	0
0	0	3	1	0	3	0	0	1	12	0
0	0	0	3	0	14	1	1	0	4	0
0	0	2	4	0	20	0	0	1	11	0
0	0	1	3	0	13	0	0	0	11	0
0	0	5	3	0	17	0	0	0	9	0
0	0	1	3	0	21	0	0	0	14	0
0	0	2	2	0	16	0	0	0	15	0
0	0	2	1	0	10	0	0	0	16	0
0	0	1	1	1	6	0	0	0	9	0
0	0	1	2	0	5	0	0	0	7	0
0	0	1	4	0	2	0	0	0	12	0
0	0	1	0	0	9	0	0	0	7	0
0	0	0	0	0	14	0	0	0	10	0
0	0	1	2	0	26	0	0	0	12	0
0	0	3	1	0	10	0	0	0	14	0
0	0	0	1	0	9	1	0	0	11	0
0	0	0	10	0	18	0	0	0	13	0
0	0	0	2	0	4	0	0	0	9	0



PEDIASTRUM	SPIKE	Sum AP	Sum NAP	Sum Aquatic	Sum Terrestria	Sum All (except Algae)		Sum All (with
4	49	282.5	34	58	316.5	370.5		374.5
6	167	265.5	35	49	300.5	343.5		349.5
7	77	293	32	51	325	369		376
23	93	265	45	61	310	348		371
26	45	292.5	32	70	324.5	368.5		394.5
20	54	292.5	33	53	325.5	358.5		378.5
7	56	273	36	48	309	350		357
22	82	283	34	80	317	375		397
17	39	264.5	36	50	300.5	333.5		350.5
23	65	287	36	63	323	363		386
11	49	253.5	51	59	304.5	352.5		363.5
26	98	268.5	46	53	314.5	341.5		367.5
5	49	293	37	41	330	366		371
6	58	337	33	25	370	389		395
5	33	287.5	47	48	334.5	377.5		382.5
13	68	270.5	44	41	314.5	342.5		355.5
11	57	265.5	53	54	318.5	361.5		372.5
11	93	255	47	50	302	341		352
10	34	256.5	54	41	310.5	341.5		351.5
9	99	260	43	40	303	334		343
14	30	264	53	49	317	352		366
9	67	259.5	50	31	309.5	331.5		340.5
1	44	262	44	23	306	328		329
6	78	286.5	29	30	315.5	339.5		345.5
3	40	277.5	38	23	315.5	335.5		338.5
6	80	286.5	26	29	312.5	335.5		341.5
11	30	282.5	46	49	328.5	366.5		377.5
6	91	272.5	28	34	300.5	328.5		334.5
20	28	276.5	50	54	326.5	360.5		380.5
16	55	283.5	30	55	313.5	352.5		368.5
15	36	281.5	36	50	317.5	352.5		367.5
18	66	275	36	47	311	340		358
79	48	285	33	97	318	336		415
47	58	364.5	29	62	393.5	408.5		455.5
73	54	320	20	92	340	359		432
2	88	297.5	34	19	331.5	348.5		350.5
21	89	294.5	18	45	312.5	336.5		357.5
109	78	286.5	36	150	322.5	363.5		472.5
130	77	282	37	158	319	347		477
113	87	336	24	135	360	382		495
451	41	260	52	492	312	353		804
34	125	291	26	49	317	332		366

APPENDIX B

FLOATING ISLAND LAKE CHARCOAL COUNTS

date: 11-11-2010
site: Floating Island Lake, YNP core: FI10A prep: 50ml NaPO3 - 50ml bleac

Depth	total volume	sample volume cc	grass	>250 u	> 125 u
0		5			7
0.5		5			6
1		5			4
1.5		5			12
2		5			4
2.5		5			4
3		5			8
3.5		5			7
4		5			13
4.5		5			7
5		5			17
5.5		5			11
6		5			13
6.5		5			17
7		5			9
7.5		5			13
8		5			9
8.5		5			17
9		5			11
9.5		5			12
10		5			4
10.5		5			8
11		5			5
11.5		5			5
12		5			12
12.5		5			6
13		5			7
13.5		5			3
14		5			11
14.5		5			2
15		5			7
15.5		5			7
16		5			6
16.5		5			7
17		5			9
17.5		5			13
18		5			11
18.5		5			20
19		5			13
19.5		5			14
20		5			29
20.5		5			NA
21		5			19
21.5		5			NA
22		5			27
22.5		5			NA
23		5			22
23.5		5			NA
24		5			31

24.5		5			NA
25		5			29
25.5		5			33
26		5			31
26.5		5			30
27		5			19
27.5		5			13
28		5			19
28.5		5			21
29		5			16
29.5		5			16
30		5			16
30.5		5			20
31		5			17
31.5		5			25
32		5			22
32.5		5			36
33		5			35
33.5		5			22
34		5			116
34.5		5			26
35		5			35
35.5		5			26
36		5			16
36.5		5			16
37		5			19
37.5		5			32
38		5			25
38.5		5			30
39		5			16
39.5		5			18
40		5			21
40.5		5			22
41		5			28
41.5		5			27
42		5			35
42.5		5			27
43		5			33
43.5		5			19
44		5			10
44.5		5			24
45		5			39
45.5		5			26
46		5			16
46.5		5			48
47		5			30
47.5		5			46
48		5			34
48.5		5			29
49		5			39
49.5		5			33
50		5			51
50.5		5			43

51		5			59
51.5		5			67
52		5			46
52.5		5			31
53		5			37
53.5		5			37
54		5			41
54.5		5			74
55		5			27
55.5		5			62
56		5			48
56.5		5			38
57		5			38
57.5		5			30
58		5			36
58.5		5			37
59		5			43
59.5		5			21
60		5			37
60.5		5			61
61		5			33
61.5		5			30
62		5			29
62.5		5			40
63		5			44
63.5		5			42
64		5			34
64.5		5			27
65		5			27
65.5		5			29
66		5			35
66.5		5			26
67		5			26
67.5		5			42
68		5			28
68.5		5			21
69		5			25
69.5		5			50
70		5			22
70.5		5			40
71		5			34
71.5		5			28
72		5			33
72.5		5			36
73		5			29
73.5		5			35
74		5			18
74.5		5			46
75		5			23
75.5		5			32
76		5			29
76.5		5			29
77		5			28

77.5		5			41
78		5			34
78.5		5			42
79		5			35
79.5		5			48
80		5			40
80.5		5			34
81		5			36
81.5		5			51
82		5			43
82.5		5			46
83		5			34
83.5		5			78
84		5			44
84.5		5			46
85		5			46
85.5		5			55
86		5			47
86.5		5			31
87		5			36
87.5		5			39
88		5			52
88.5		5			25
89		5			40
89.5		5			40
90		5			41
90.5		5			49
91		5			36
91.5		5			29
92		5			40
92.5		5			24
93		5			56
93.5		5			35
94		5			44
94.5		5			45
95		5			62
95.5		5			26
96		5			42
96.5		5			48
97		5			43
97.5		5			48
98		5			37
98.5		5			60
99		5			62
99.5		5			46
100		5			35
100.5		5			42
101		5			42
101.5		5			75
102		5			29
102.5		5			62
103		5			38
103.5		5			41

104		5			33
104.5		5			64
105		5			47
105.5		5			57
106		5			32
106.5		5			47
107		5			40
107.5		5			45
108		5			48
108.5		5			45
109		5			49
109.5		5			57
110		5			40
110.5		5			56
111		5			54
111.5		5			26
112		5			44
112.5		5			56
113		5			47
113.5		5			NA
114		5			32
114.5		5			37
115		5			39
115.5		5			25
116		5			19
116.5		5			19
117		5			25
117.5		5			32
118		5			27
118.5		5			16
119		5			15
119.5		5			21
120		5			29
120.5		5			16
121		5			33
121.5		5			36
122		5			27
122.5		5			228
123		5			18
123.5		5			29
124		5			29
124.5		5			43
125		5			20
125.5		5			29
126		5			28
126.5		5			11
127		5			18
127.5		5			15
128		5			27
128.5		5			15
129		5			10
129.5		5			33
130		5			43

130.5		5			40
131		5			33
131.5		5			14
132		5			38
132.5		5			60
133		5			48
133.5		5			75
134		5			42
134.5		5			18
135		5			29
135.5		5			57
136		5			20
136.5		5			20
137		5			15
137.5		5			16
138		5			31
138.5		5			54
139		5			41
139.5		5			40
140		5			35
140.5		5			52
141		5			37
141.5		5			43
142		5			54
142.5		5			24
143		5			11
143.5		5			25
144		5			54
144.5		5			43
145		5			74
145.5		5			35
146		5			13
146.5		5			54
147		5			37
147.5		5			27
148		5			18
148.5		5			27
149		5			22
149.5		5			26
150		5			22
150.5		5			32
151		5			26
151.5		5			32
152		5			47
152.5		5			23
153		5			38
153.5		5			40
154		5			61
154.5		5			38
155		5			31
155.5		5			65
156		5			36
156.5		5			64

157		5			64
157.5		5			47
158		5			51
158.5		5			49
159		5			20
159.5		5			13
160		5			34
160.5		5			96
161		5			150
161.5		5			74
162		5			83
162.5		5			56
163		5			64
163.5		5			41

APPENDIX C

FLOATING ISLAND LAKE MAGNETIC SUSCEPTIBILITY

Bartington Instruments Multisus File		
————————————————————		
12/1/11 14:40	C:\Documents and Settings\whitlock\Desktop\Firmage\Floating_10A_2\Fl10A_final.txt	Multisus 32/2.31
————————————————————		
Fl10A_2		
————————————————————		
Sensor	MS2B	
Range	0.1	
Units	CGS	
Frequency	LF	
Drift Limit	1.5	
Volume Correction	0	
Container volume	5	
Container Correction	0	
Container sus SI	0	
Container sus CGS	0	
————————————————————		
Depth	Volume	LF Sus
0	5	2.1
0.5	5	1.8
1	5	0.8
1.5	5	0.7
2	5	0.6
2.5	5	-0.1
3	5	-0.8
3.5	5	-0.9
4	5	-0.8
4.5	5	-0.6
5	5	-0.6
5.5	5	-1
6	5	-0.9
6.5	5	-0.9
7	5	-0.9
7.5	5	-1
8	5	-0.9
8.5	5	-0.9
9	5	-0.7
9.5	5	-1
10	5	-1.1
10.5	5	-0.7
11	5	-0.9
11.5	5	-0.9
12	5	-2.1
12.5	5	-1.1
13	5	-0.3
13.5	5	-0.8
14	5	-1.2
14.5	5	-0.9
15	5	-0.9
15.5	5	-1
16	5	-0.4
16.5	5	-0.9
17	5	-1
17.5	5	-0.8
18	5	-0.6
18.5	5	-1
19	5	-0.8
19.5	5	-1
20	5	-1.2
20.5		
21	5	-0.9
21.5		
22	5	-1.3
22.5		
23	5	-0.8
23.5		
24	5	-0.9
24.5		
25	5	-1.2
25.5	5	-1.1
26	5	-1.9
26.5	5	-1.3
27	5	-0.9
27.5	5	-0.8
28	5	-1
28.5	5	-1.8
29	5	-1
29.5	5	-0.9
30	5	-1.2
30.5	5	-0.9
31	5	-1.3
31.5	5	-1
32	5	-0.9
32.5	5	-1
33	5	-1.1
33.5	5	-1.1
34	5	-1.1
34.5	5	-0.9
35	5	-0.9

35.5	5	-1.2
36	5	-0.9
36.5	5	-1.1
37	5	-0.9
37.5	5	-0.8
38	5	-0.8
38.5	5	-1
39	5	-0.8
39.5	5	-0.9
40	5	-0.8
40.5	5	-0.9
41	5	-0.9
41.5	5	-1
42	5	-1.2
42.5	5	-0.9
43	5	-1
43.5	5	-0.6
44	5	-0.9
44.5	5	-0.5
45	5	-0.9
45.5	5	-1.1
46	5	-0.8
46.5	5	-0.7
47	5	-0.9
47.5	5	-1.2
48	5	-0.7
48.5	5	-1
49	5	-1
49.5	5	-1
50	5	-0.7
50.5	5	-0.8
51	5	-0.6
51.5	5	-0.7
52	5	-1
52.5	5	-0.8
53	5	-0.9
53.5	5	-0.6
54	5	-0.6
54.5	5	-0.9
55	5	-0.7
55.5	5	-0.7
56	5	-0.8
56.5	5	-0.9
57	5	-0.7
57.5	5	-1
58	5	-0.7
58.5	5	-0.9
59	5	-0.9
59.5	5	-0.9
60	5	-1.1
60.5	5	-1
61	5	-0.6
61.5	5	-0.8
62	5	-0.9
62.5	5	-0.8
63	5	-1
63.5	5	-0.9
64	5	-0.9
64.5	5	-0.8
65	5	-1
65.5	5	-0.9
66	5	-1
66.5	5	-0.9
67	5	-0.9
67.5	5	-0.8
68	5	-1.1
68.5	5	-0.9
69	5	-1.2
69.5	5	-1.2
70	5	-1
70.5	5	-0.6
71	5	-0.9
71.5	5	-0.7
72	5	-1
72.5	5	-1.1
73	5	-0.7
73.5	5	-0.8
74	5	-0.9
74.5	5	-1.1
75	5	-0.9
75.5	5	-0.7
76	5	-1
76.5	5	-0.8
77	5	-1.1
77.5	5	-1
78	5	-0.8
78.5	5	-1
79	5	-0.9
79.5	5	-1.1

80	5	-0.9
80.5	5	-0.4
81	5	-1.2
81.5	5	-0.8
82	5	-1
82.5	5	-0.8
83	5	-0.8
83.5	5	-0.8
84	5	-1
84.5	5	-1
85	5	-1.1
85.5	5	-0.8
86	5	-1.1
86.5	5	-0.9
87	5	-1
87.5	5	-1
88	5	-0.7
88.5	5	-1
89	5	-1
89.5	5	-1
90	5	-0.7
90.5	5	-1.1
91	5	-0.9
91.5	5	-1.3
92	5	-0.7
92.5	5	-0.6
93	5	-0.9
93.5	5	-1.2
94	5	-1.2
94.5	5	-1
95	5	-0.9
95.5	5	-0.9
96	5	-1
96.5	5	-1
97	5	-0.9
97.5	5	-0.8
98	5	-0.9
98.5	5	-0.9
99	5	-1.1
99.5	5	-1.1
100	5	-1
100.5	5	-1.1
101	5	-0.9
101.5	5	-0.5
102	5	-0.7
102.5	5	-1
103	5	-0.9
103.5	5	-1.1
104	5	-1.1
104.5	5	-1.1
105	5	-0.9
105.5	5	-0.9
106	5	-1.1
106.5	5	-0.9
107	5	-1.1
107.5	5	-1
108	5	-1
108.5	5	-1
109	5	-1
109.5	5	-1.1
110	5	-0.9
110.5	5	-1
111	5	-1.1
111.5	5	-0.9
112	5	-0.9
112.5	5	-1
113	5	-0.7
113.5	5	-1
114	5	-1.8
114.5	5	-1.4
115	5	-1.7
115.5	5	-1.4
116	5	-1.4
116.5	5	-1.4
117	5	-1.4
117.5	5	-0.8
118	5	-0.9
118.5	5	-1.9
119	5	-1.3
119.5	5	-1.5
120	5	-2.5
120.5	5	-1.8
121	5	-1.8
121.5	5	-1
122	5	-1.5
122.5	5	-1.5
123	5	-0.9
123.5	5	-1.2
124	5	-1

124.5		5	-1
125		5	-1.2
125.5		5	-1.3
126		5	-1.1
126.5		5	-1
127		5	-0.9
127.5		5	-0.7
128		5	-0.8
128.5		5	-1.5
129		5	-1.2
129.5		5	-1.1
130		5	-1.5
130.5		5	-1.3
131		5	-0.9
131.5		5	-1.2
132		5	-1.4
132.5		5	-1.5
133		5	-1.4
133.5		5	-1.2
134		5	-1.5
134.5		5	-1.8
135		5	-1.7
135.5		5	-2.1
136		5	-1.2
136.5		5	-1.6
137		5	-1.4
137.5		5	-1.2
138		5	-1.6
138.5		5	-1.2
139		5	-1.1
139.5		5	-1.1
140		5	-1.3
140.5		5	-1.6
141		5	-1.1
141.5		5	-1
142		5	-1.2
142.5		5	-1.1
143		5	-1.4
143.5		5	-1.8
144		5	-1.3
144.5		5	-1.1
145		5	-1.3
145.5		5	-1.2
146		5	-1.3
146.5		5	-1.5
147		5	-1
147.5		5	-1.6
148		5	-1.4
148.5		5	-1.3
149		5	-1.2
149.5		5	-1.5
150		5	-1.3
150.5		5	-1.5
151		5	-1.2
151.5		5	-1.4
152		5	-1.3
152.5		5	-1.5
153		5	-1.4
153.5		5	-1.5
154		5	-1.2
154.5		5	-1.4
155		5	-1.3
155.5		5	-1.4
156		5	-2.1
156.5		5	-1.4
157		5	-1.9
157.5		5	-1.1
158		5	-0.9
158.5		5	-1.2
159		5	-1.7
159.5		5	-1
160		5	-1.7
160.5		5	-1.5
161		5	-1.4
161.5		5	-1.8
162		5	-1.3
162.5		5	-1.4
163		5	-1.2
163.5		5	-1.5

APPENDIX D

FLOATING ISLAND LAKE LOSS ON IGNITION

Cruc. ID number	Depth	Wt. Cruc.	Wt Cruc + Wet Sed	Wt Cruc + Dry Sed	Wt. Cruc + Heated 550°C wt.	Wt. Cruc+Heated 900° C wt.	Wet sed	Dry Sed	Organic Loss	Inorganic Loss	% Organic	% Carbonate
6	0.0-0.5cm	5.6719	6.3809	5.752	5.7165	5.7143	0.709	0.0801	0.0355	0.0022	44.3196	2.746567
9	1.0-1.5cm	5.1503	6.0888	5.2239	5.1861	5.1836	0.9385	0.0736	0.0378	0.0025	51.3587	3.396739
7	2.0-2.5cm	4.9131	5.8977	4.9783	4.9436	4.9408	0.9846	0.0652	0.0347	0.0028	53.22086	4.294479
8	3.0-3.5cm	5.4317	6.1598	5.4673	5.4484	5.445	0.7281	0.0356	0.0189	0.0034	53.08989	9.550562
11	4.0-4.5cm	5.4029	6.064	5.4305	5.4163	5.4137	0.6611	0.0276	0.0142	0.0026	51.44928	9.42029
10	5.0-5.5cm	4.6927	5.5725	4.72	4.7069	4.7034	0.8798	0.0273	0.0131	0.0035	47.98535	12.82051
13	6.0-6.5cm	5.8512	7.0189	5.8947	5.8723	5.8679	1.1677	0.0435	0.0224	0.0044	51.49425	10.11494
14	7.0-7.5cm	5.513	6.219	5.5691	5.5394	5.535	0.706	0.0561	0.0297	0.0044	52.94118	7.843137
15	8.0-8.5cm	5.4618	6.5074	5.5136	5.489	5.4837	1.0456	0.0518	0.0246	0.0053	47.49035	10.23166
16	9.0-9.5cm	4.9938	6.1479	5.0499	5.0208	5.0162	1.1541	0.0561	0.0291	0.0046	51.87166	8.199643
17	10.0-10.5cm	4.6054	5.594	4.6614	4.6336	4.6284	0.9886	0.056	0.0278	0.0052	49.64286	9.285714
31	11.0-11.5cm	5.448	6.5346	5.5223	5.4892	5.4802	1.0866	0.0743	0.0331	0.009	44.54913	12.11306
36	12.0-12.5cm	5.192	6.1048	5.2548	5.2289	5.2194	0.9128	0.0628	0.0259	0.0095	41.24204	15.12739
33	13.0-13.5cm	5.1317	6.01	5.2034	5.1742	5.164	0.8783	0.0717	0.0292	0.0102	40.72524	14.22594
51	14.0-14.5cm	5.3347	6.4053	5.4149	5.3813	5.3713	1.0706	0.0802	0.0336	0.01	41.89526	12.46883
12	15.0-15.5cm	5.1313	6.1902	5.219	5.1847	5.1716	1.0589	0.0877	0.0343	0.0131	39.1106	14.93729
27	16.0-16.5cm	4.841	5.9475	4.922	4.8905	4.8777	1.1065	0.081	0.0315	0.0128	38.88889	15.80247
29	17.0-17.5cm	5.1478	6.2286	5.2454	5.2068	5.1915	1.0808	0.0976	0.0386	0.0153	39.54918	15.67623
21	18.0-18.5cm	4.6539	6.8508	4.747	4.7103	4.697	2.1969	0.0931	0.0367	0.0133	39.41998	14.28571
1	19.0-19.5cm	4.4285	5.4878	4.535	4.4917	4.4772	1.0593	0.1065	0.0433	0.0145	40.65728	13.61502
2	20.0-20.5cm	5.3974	6.2754	5.5258	5.4724	5.4552	0.878	0.1284	0.0534	0.0172	41.58879	13.39564
3	21.0-21.5cm	5.535	6.4836	5.6807	5.6227	5.6015	0.9486	0.1457	0.058	0.0212	39.80782	14.55045
4	22.0-22.5cm	5.3059	6.3997	5.4716	5.4037	5.3808	1.0938	0.1657	0.0679	0.0229	40.97767	13.82016
5	23.0-23.5cm	4.8124	5.7907	4.9564	4.8988	4.8771	0.9783	0.144	0.0576	0.0217	40	15.06944
40	24.0-24.5cm	5.2347	6.1635	5.3559	5.306	5.2894	0.9288	0.1212	0.0499	0.0166	41.17162	13.69637
41	25.0-25.5cm	4.2701	5.2414	4.4003	4.342	4.3262	0.9713	0.1302	0.0583	0.0158	44.77727	12.13518
42	26.0-26.5cm	4.9182	5.9813	5.0572	5.001	4.9808	1.0631	0.139	0.0562	0.0202	40.43165	14.53237
43	27.0-27.5cm	5.1538	6.2951	5.2912	5.2359	5.2162	1.1413	0.1374	0.0553	0.0197	40.24745	14.3377
44	28.0-28.5cm	5.0493	6.0575	5.1625	5.1151	5.1008	1.0082	0.1132	0.0474	0.0143	41.87279	12.63251
65	29.0-29.5cm	5.6872	6.7209	5.8073	5.7542	5.7399	1.0337	0.1201	0.0531	0.0143	44.21316	11.90674
66	30.0-30.5cm	5.6256	6.7696	5.7584	5.6995	5.6821	1.144	0.1328	0.0589	0.0174	44.35241	13.10241
67	31.0-31.5cm	4.7965	5.8458	4.8983	4.849	4.8385	1.0493	0.1018	0.0493	0.0105	48.42829	10.31434
68	32.0-32.5cm	5.4386	6.4067	5.5522	5.5031	5.488	0.9681	0.1136	0.0491	0.0151	43.22183	13.29225
69	33.0-33.5cm	5.0451	6.0646	5.1526	5.103	5.0905	1.0195	0.1075	0.0496	0.0125	46.13953	11.62791
115	34.0-34.5cm	3.8999	4.9979	4.0477	3.9928	3.9657	1.098	0.1478	0.0549	0.0271	37.14479	18.33559
116	35.0-35.5cm	4.0244	5.1274	4.1344	4.0881	4.072	1.103	0.11	0.0463	0.0161	42.09091	14.63636
117	36.0-36.5cm	3.8998	5.1041	4.0208	3.9664	3.9499	1.2043	0.121	0.0544	0.0165	44.95868	13.63636
118	37.0-37.5cm	4.1476	5.399	4.2906	4.2269	4.2079	1.2514	0.143	0.0637	0.019	44.54545	13.28671
119	38.0-38.5cm	4.0354	4.9693	4.1423	4.098	4.0817	0.9339	0.1069	0.0443	0.0163	41.4406	15.2479
100	39.0-39.5cm	3.9258	4.8973	4.0442	3.9923	3.9762	0.9715	0.1184	0.0519	0.0161	43.83446	13.59797
101	40.0-40.5cm	3.8812	5.0371	4.0211	3.9588	3.9407	1.1559	0.1399	0.0623	0.0181	44.53181	12.93781
102	41.0-41.5cm	4.0792	5.2302	4.2421	4.1706	4.1482	1.151	0.1629	0.0715	0.0224	43.89196	13.75077
103	42.0-42.5cm	4.2136	5.3708	4.3919	4.3129	4.2879	1.1572	0.1783	0.079	0.025	44.30735	14.02131
104	43.0-43.5cm	4.1767	5.4154	4.3631	4.2804	4.255	1.2387	0.1864	0.0827	0.0254	44.36695	13.62661
105	44.0-44.5cm	4.1493	5.169	4.2826	4.2238	4.2054	1.0197	0.1333	0.0588	0.0184	44.11103	13.80345
106	45.0-45.5cm	4.1145	5.3771	4.3015	4.2245	4.1965	1.2626	0.187	0.077	0.028	41.17647	14.97326
107	46.0-46.5cm	4.0262	5.1989	4.2232	4.1351	4.1079	1.1727	0.197	0.0881	0.0272	44.72081	13.80711
108	47.0-47.5cm	4.0732	5.2086	4.2671	4.1759	4.1505	1.1354	0.1939	0.0912	0.0254	47.03455	13.09954
109	48.0-48.5cm	4.1456	5.283	4.3424	4.2545	4.227	1.1374	0.1968	0.0879	0.0275	44.66463	13.97358
110	49.0-49.5cm	4.0462	5.0804	4.2277	4.1561	4.1236	1.0342	0.1815	0.0716	0.0325	39.44904	17.90634
111	50.0-50.5cm	4.1873	5.2565	4.4003	4.32	4.2815	1.0692	0.213	0.0803	0.0385	37.69953	18.07512
112	51.0-51.5cm	4.0058	5.1237	4.2175	4.1393	4.1006	1.1179	0.2117	0.0782	0.0387	36.93906	18.28059
113	52.0-52.5cm	4.0362	5.1838	4.2729	4.1943	4.1344	1.1476	0.2367	0.0786	0.0599	33.20659	25.30629
114	53.0-53.5cm	4.1307	5.2891	4.3216	4.252	4.2172	1.1584	0.1909	0.0696	0.0348	36.45888	18.22944
52	54.0-54.5cm	5.1549	6.2653	5.3582	5.286	5.2467	1.1104	0.2033	0.0722	0.0393	35.51402	19.33104
53	55.0-55.5cm	5.2213	6.3534	5.4112	5.3459	5.3098	1.1321	0.1899	0.0653	0.0361	34.38652	19.01001
54	56.0-56.5cm	5.4053	6.5562	5.5855	5.5196	5.4864	1.1509	0.1802	0.0659	0.0332	36.57048	18.42397
55	57.0-57.5cm	4.6325	6.6506	4.7877	4.7293	4.7033	2.0181	0.1552	0.0584	0.026	37.62887	16.75258
56	58.0-58.5cm	5.1071	6.0698	5.2416	5.1938	5.1691	0.9627	0.1345	0.0478	0.0247	35.53903	18.36431
1	59.0-59.5cm	4.4786	5.5074	4.605	4.5408	4.5091	1.0288	0.1264	0.0642	0.0317	50.79114	25.07911
63	60.0-60.5cm	4.6299	5.7242	4.8196	4.7529	4.7177	1.0943	0.1897	0.0667	0.0352	35.16078	18.55561
3	61.0-61.5cm	5.5353	6.5918	5.7145	5.6536	5.6196	1.0565	0.1792	0.0609	0.034	33.98438	18.97321
4	62.0-62.5cm	5.3062	6.3179	5.4664	5.4106	5.3814	1.0117	0.1602	0.0558	0.0292	34.83146	18.22722
5	63.0-63.5cm	4.8125	5.8494	4.9831	4.9189	4.8899	1.0369	0.1706	0.0642	0.029	37.63189	16.99883

6	64.0-64.5cm	5.673	6.7166	5.8424	5.7781	5.7497	1.0436	0.1694	0.0643	0.0284	37.9575	16.76505
7	65.0-65.5cm	4.9138	5.8878	5.0718	5.0164	4.9875	0.974	0.158	0.0554	0.0289	35.06329	18.29114
8	66.0-66.5cm	4.4324	6.4921	5.612	5.5465	5.5153	2.0597	1.1796	0.0655	0.0312	5.55273	2.644964
9	67.0-67.5cm	5.1507	6.1262	5.2944	5.2445	5.2193	0.9755	0.1437	0.0499	0.0252	34.72512	17.53653
10	68.0-68.5cm	4.693	5.7666	4.8594	4.8044	4.7726	1.0736	0.1664	0.055	0.0318	33.05288	19.11058
11	69.0-69.5cm	5.4034	6.436	5.5566	5.4996	5.4762	1.0326	0.1532	0.057	0.0234	37.20627	15.27415
12	70.0-70.5cm	5.132	6.1402	5.2851	5.2325	5.207	1.0082	0.1531	0.0526	0.0255	34.35663	16.65578
14	71.0-71.5cm	5.5141	6.5816	5.6786	5.6234	5.594	1.0675	0.1645	0.0552	0.0294	33.55623	17.87234
15	72.0-72.5cm	5.4629	6.4971	5.6075	5.557	5.5338	1.0342	0.1446	0.0505	0.0232	34.92393	16.04426
16	73.0-73.5cm	4.9955	6.0198	5.1511	5.0928	5.0666	1.0243	0.1556	0.0583	0.0262	37.46787	16.83805
17	74.0-74.5cm	4.6064	5.669	4.7606	4.7042	4.6781	1.0626	0.1542	0.0564	0.0261	36.57588	16.92607
18	75.0-75.5cm	5.3836	6.3168	5.5148	5.4684	5.4455	0.9332	0.1312	0.0464	0.0229	35.36585	17.45427
21	76.0-76.5cm	4.6542	5.6222	4.7979	4.7501	4.7238	0.968	0.1437	0.0478	0.0263	33.26374	18.30202
19	77.0-77.5cm	5.3431	6.4043	5.5059	5.4519	5.4216	1.0612	0.1628	0.054	0.0303	33.16953	18.61179
22	78.0-78.5cm	5.3789	6.3406	5.5198	5.469	5.4449	0.9617	0.1409	0.0508	0.0241	36.05394	17.10433
30	79.0-79.5cm	5.0385	6.1886	5.2083	5.1476	5.1186	1.1501	0.1698	0.0607	0.029	35.74794	17.07892
31	80.0-80.5cm	5.449	6.5274	5.5918	5.5401	5.5157	1.0784	0.1428	0.0517	0.0244	36.20448	17.08683
32	81.0-81.5cm	5.7921	6.8113	5.9353	5.8819	5.8587	1.0192	0.1432	0.0534	0.0232	37.2905	16.20112
33	82.0-82.5cm	5.132	6.1818	5.2988	5.2364	5.2095	1.0498	0.1668	0.0624	0.0269	37.41007	16.1271
35	83.0-83.5cm	5.6148	6.6752	5.7738	5.7173	5.6894	1.0604	0.159	0.0565	0.0279	35.53459	17.54717
36	84.0-84.5cm	5.1928	6.2904	5.3747	5.3084	5.2785	1.0976	0.1819	0.0663	0.0299	36.4486	16.4376
37	85.0-85.5cm	5.0212	6.074	5.1848	5.1242	5.0968	1.0528	0.1636	0.0606	0.0274	37.04156	16.74817
38	86.0-86.5cm	5.5698	6.7304	5.7582	5.6939	5.6595	1.1606	0.1884	0.0643	0.0344	34.12951	18.25902
39	87.0-87.5cm	5.0792	6.1377	5.2474	5.1871	5.1585	1.0585	0.1682	0.0603	0.0286	35.85018	17.00357
120	88.0-88.5cm	4.1808	5.2952	4.3619	4.2984	4.2672	1.1144	0.1811	0.0635	0.0312	35.0635	17.22805
65	89.0-89.5cm	5.6875	6.8138	5.8592	5.8012	5.7693	1.1263	0.1717	0.058	0.0319	33.77985	18.57892
1	90.0-90.5cm	4.4289	5.5182	4.6003	4.5441	4.5124	1.0893	0.1714	0.0562	0.0317	32.7888	18.49475
3	91.0-91.5cm	5.5354	6.5574	5.6985	5.6492	5.616	1.022	0.1631	0.0493	0.0332	30.22685	20.35561
4	92.0-92.5cm	5.3061	6.3604	5.4683	5.4118	5.3832	1.0543	0.1622	0.0565	0.0286	34.83354	17.63255
5	93.0-93.5cm	4.8124	5.7895	4.9652	4.9138	4.8858	0.9771	0.1528	0.0514	0.028	33.63874	18.32461
6	94.0-94.5cm	5.6722	6.8472	5.8508	5.7921	5.759	1.175	0.1786	0.0587	0.0331	32.86674	18.53303
7	95.0-95.5cm	4.9134	5.9331	5.0709	5.0184	4.9882	1.0197	0.1575	0.0525	0.0302	33.33333	19.1746
8	96.0-96.5cm	5.4323	6.455	5.587	5.5342	5.5065	1.0227	0.1547	0.0528	0.0277	34.13058	17.90562
9	97.0-97.5cm	5.1512	6.2256	5.3109	5.2601	5.2291	1.0744	0.1597	0.0508	0.031	31.80964	19.4114
10	98.0-98.5cm	4.6926	5.7267	4.846	4.7944	4.7673	1.0341	0.1534	0.0516	0.0271	33.63755	17.66623
11	99.0-99.5cm	5.4029	6.382	5.5498	5.5013	5.4741	0.9791	0.1469	0.0485	0.0272	33.01566	18.516
12	100.0-100.5cm	5.1318	6.1947	5.2885	5.2307	5.2056	1.0629	0.1567	0.0578	0.0251	36.88577	16.01787
13	101.0-101.5cm	5.8513	6.9411	6.0116	5.9545	5.9288	1.0898	0.1603	0.0571	0.0257	35.62071	16.03244
14	102.0-102.5cm	5.5128	6.5684	5.6676	5.6125	5.587	1.0556	0.1548	0.0551	0.0255	35.59432	16.47287
15	103.0-103.5cm	5.4627	6.5303	5.6273	5.5693	5.5402	1.0676	0.1646	0.058	0.0291	35.23694	17.67922
16	104.0-104.5cm	4.9943	6.0445	5.1501	5.0944	5.0692	1.0502	0.1558	0.0557	0.0252	35.75096	16.17458
101	105.0-105.5cm	3.8814	4.9504	4.042	3.9842	3.9576	1.069	0.1606	0.0578	0.0266	35.99004	16.56289
102	106.0-106.5cm	4.0799	5.1665	4.257	4.1988	4.1646	1.0866	0.1771	0.0582	0.0342	32.86279	19.31112
103	107.0-107.5cm	4.214	5.2919	4.3695	4.3153	4.2882	1.0779	0.1555	0.0542	0.0271	34.85531	17.42765
104	108.0-108.5cm	4.1772	5.2552	4.3403	4.2832	4.2555	1.078	0.1631	0.0571	0.0277	35.0092	16.98345
105	109.0-109.5cm	4.1499	5.2245	4.3148	4.2515	4.2225	1.0746	0.1649	0.0633	0.029	38.3869	17.58642
106	110.0-110.5cm	4.115	5.0823	4.2762	4.2224	4.192	0.9673	0.1612	0.0538	0.0304	33.37469	18.85856
107	111.0111.5cm	4.0263	5.0138	4.173	4.1212	4.096	0.9875	0.1467	0.0518	0.0252	35.31016	17.17791
108	112.0-112.5cm	4.0739	5.1283	4.2359	4.1825	4.1523	1.0544	0.162	0.0534	0.0302	32.96296	18.64198
109	113.0-113.5cm	4.1459	5.168	4.301	4.2458	4.2211	1.0221	0.1551	0.0552	0.0247	35.58994	15.92521
110	114.0-114.5cm	4.0464	5.1007	4.2124	4.1531	4.1256	1.0543	0.166	0.0593	0.0275	35.72289	16.56627
111	115.0-115.5cm	4.1875	5.245	4.3542	4.2977	4.2691	1.0575	0.1667	0.0565	0.0286	33.89322	17.15657
112	116.0-116.5cm	4.0065	5.037	4.1677	4.1108	4.0844	1.0305	0.1612	0.0569	0.0264	35.29777	16.37717
113	117.0-117.5cm	4.0361	5.1339	4.2014	4.1455	4.1182	1.0978	0.1653	0.0559	0.0273	33.8173	16.51543
114	118.0-118.5cm	4.1311	5.15	4.2858	4.2325	4.2059	1.0189	0.1547	0.0533	0.0266	34.45378	17.19457
115	119.0-119.5cm	3.9006	4.8967	4.0518	3.9986	3.9734	0.9961	0.1512	0.0532	0.0252	35.18519	16.66667
1	120.0-120.5cm	4.429	5.4171	4.5768	4.5267	4.5049	0.9881	0.1478	0.0501	0.0218	33.89716	14.74966
3	121.0-121.5cm	5.5354	6.5065	5.6951	5.642	5.613	0.9711	0.1597	0.0531	0.029	33.24984	18.15905
4	122.0-122.5cm	5.3061	6.3717	5.4871	5.4275	5.3942	1.0656	0.181	0.0596	0.0333	32.92818	18.39779
5	123.0-123.5cm	4.8122	5.8533	4.9798	4.9174	4.8894	1.0411	0.1676	0.0624	0.028	37.2315	16.70644
6	124.0-124.5cm	5.6722	6.6941	5.8134	5.7618	5.7406	1.0219	0.1412	0.0516	0.0212	36.54391	15.01416
7	125.0-125.5cm	4.9134	5.9704	5.054	5.0064	4.984	1.057	0.1406	0.0476	0.0224	33.85491	15.93172
8	126.0-126.5cm	5.4318	6.4248	5.5564	5.5101	5.4973	0.993	0.1246	0.0463	0.0128	37.15891	10.27287
9	127.0-127.5cm	5.1507	6.1469	5.2789	5.231	5.2153	0.9962	0.1282	0.0479	0.0157	37.36349	12.24649
10	128.0-128.5cm	4.6925	5.7096	4.8287	4.778	4.7612	1.0171	0.1362	0.0507	0.0168	37.22467	12.3348
11	129.0-129.5cm	5.4026	6.3382	5.5014	5.4584	5.4473	0.9356	0.0988	0.043	0.0111	43.52227	11.23482
12	130.0-130.5cm	5.1316	6.1351	5.2404	5.1948	5.1812	1.0035	0.1088	0.0456	0.0136	41.91176	12.5
14	131.0-131.5cm	5.512	6.5089	5.6261	5.5817	5.566	0.9969	0.1141	0.0444	0.0157	38.91323	13.75986
102	132.0-132.5cm	4.0796	5.1637	4.1904	4.1442	4.128	1.0841	0.1108	0.0462	0.0162	41.69675	14.62094

44	133.0-133.5cm	5.0491	6.0687	5.1479	5.1057	5.0913	1.0196	0.0988	0.0422	0.0144	42.71255	14.5749
114	134.0-134.5cm	4.1306	5.1434	4.2425	4.1907	4.1769	1.0128	0.1119	0.0518	0.0138	46.29133	12.33244
109	135.0-135.5cm	4.1457	5.1525	4.261	4.2136	4.1979	1.0068	0.1153	0.0474	0.0157	41.11015	13.61665
43	136.0-136.5cm	5.1528	6.1365	5.2712	5.2227	5.2076	0.9837	0.1184	0.0485	0.0151	40.96284	12.75338
42	137.0-137.5cm	4.9173	5.9865	5.0741	5.0178	4.9956	1.0692	0.1568	0.0563	0.0222	35.90561	14.15816
15	138.0-138.5cm	5.4619	6.4516	5.6052	5.5554	5.5332	0.9897	0.1433	0.0498	0.0222	34.75227	15.49197
46	139.0-139.5cm	5.5222	6.5626	5.6768	5.6305	5.6004	1.0404	0.1546	0.0463	0.0301	29.94825	19.4696
105	140.0-140.5cm	4.1498	5.2023	4.3495	4.2993	4.2516	1.0525	0.1997	0.0502	0.0477	25.13771	23.88583
41	141.0-141.5cm	4.2696	5.309	4.4538	4.4047	4.3639	1.0394	0.1842	0.0491	0.0408	26.65581	22.14984
101	142.0-142.5cm	3.8817	4.9403	4.0776	4.0371	3.9877	1.0586	0.1959	0.0405	0.0494	20.67381	25.21695
118	143.0-143.5cm	4.1475	5.1884	4.2688	4.2264	4.2097	1.0409	0.1213	0.0424	0.0167	34.95466	13.76752
31	144.0-144.5cm	5.4483	6.4948	5.6229	5.5807	5.5392	1.0465	0.1746	0.0422	0.0415	24.16953	23.76861
103	145.0-145.5cm	4.2139	5.2373	4.3484	4.3023	4.2837	1.0234	0.1345	0.0461	0.0186	34.27509	13.829
116	146.0-146.5cm	4.0241	4.9964	4.1616	4.1188	4.0952	0.9723	0.1375	0.0428	0.0236	31.12727	17.16364
117	147.0-147.5cm	3.8978	4.9173	4.0479	4.0039	3.9749	1.0195	0.1501	0.044	0.029	29.31379	19.32045
56	148.0-148.5cm	5.1075	6.0664	5.2258	5.185	5.1679	0.9589	0.1183	0.0408	0.0171	34.48859	14.45478
38	149.0-149.5cm	5.5706	6.564	5.6929	5.6488	5.6324	0.9934	0.1223	0.0441	0.0164	36.05887	13.40965
100	150.0-150.5cm	3.9272	4.9799	4.0669	4.014	3.9973	1.0527	0.1397	0.0529	0.0167	37.86686	11.95419
52	151.0-151.5cm	5.1554	6.1437	5.2789	5.2332	5.2167	0.9883	0.1235	0.0457	0.0165	37.00405	13.36032
66	152.0-152.5cm	5.6255	6.7241	5.778	5.7286	5.7038	1.0986	0.1525	0.0494	0.0248	32.39344	16.2623
112	153.0-153.5cm	4.006	5.0694	4.1317	4.0847	4.0695	1.0634	0.1257	0.047	0.0152	37.39061	12.09228
54	154.0-154.5cm	5.4056	6.4361	5.5503	5.5037	5.4799	1.0305	0.1447	0.0466	0.0238	32.20456	16.44782
106	155.0-155.5cm	4.115	5.1266	4.252	4.2075	4.1852	1.0116	0.137	0.0445	0.0223	32.48175	16.27737
22	156.0-156.5cm	5.3784	6.4095	5.5017	5.455	5.4417	1.0311	0.1233	0.0467	0.0133	37.8751	10.7867
17	157.0-157.5cm	4.6057	5.6882	4.7446	4.6917	4.6777	1.0825	0.1389	0.0529	0.014	38.08495	10.07919
53	158.0-158.5cm	5.2218	6.2562	5.358	5.3069	5.2932	1.0344	0.1362	0.0511	0.0137	37.51836	10.05874
55	159.0-159.5cm	4.6322	5.7117	4.8115	4.7568	4.723	1.0795	0.1793	0.0547	0.0338	30.50753	18.85109
1	160.0-160.5cm	4.429	5.4196	4.5911	4.5454	4.5065	0.9906	0.1621	0.0457	0.0389	28.19247	23.99753
3	161.0-161.5cm	5.5353	6.6431	5.6986	5.6463	5.6152	1.1078	0.1633	0.0523	0.0311	32.02694	19.0447
4	162.0-162.5cm	5.306	6.2787	5.4576	5.4084	5.3801	0.9727	0.1516	0.0492	0.0283	32.45383	18.66755
5	163.0-163.5cm	4.8124	5.9062	4.9597	4.9112	4.8852	1.0938	0.1473	0.0485	0.026	32.926	17.65105

APPENDIX E

FOSTER LAKE CHARCOAL COUNTS

date: 06-20-11
site: Foster Lake, WY core: FL10B prep: 50ml NaPO3 - 50ml bleach -24hrs
Dave Firmage

depth	sample volume/cc	soak date	rinse date	count date	> 125 u	CHAR
0	5	2/28/11	3/1/11	4/21/11	9	1.8
0.5	2	2/28/11	3/1/11	4/21/11	3	1.5
1	2	2/28/11	3/1/11	4/21/11	0	0
1.5	5	2/28/11	3/1/11	4/21/11	2	0.4
2	5	2/28/11	3/1/11	4/21/11	2	0.4
2.5	5	2/28/11	3/1/11	4/21/11	1	0.2
3	2	2/28/11	3/1/11	4/21/11	2	1
3.5	5	2/28/11	3/1/11	4/21/11	7	1.4
4	5	2/28/11	3/1/11	4/21/11	1	0.2
4.5	5	2/28/11	3/1/11	4/21/11	13	2.6
5	5	2/28/11	3/1/11	4/21/11	15	3
5.5	5	2/28/11	3/1/11	4/21/11	8	1.6
6	5	2/28/11	3/1/11	4/21/11	4	0.8
6.5	5	2/28/11	3/1/11	4/21/11	2	0.4
7	5	2/28/11	3/1/11	4/21/11	2	0.4
7.5	2	2/28/11	3/1/11	4/21/11	1	0.5
8	2	2/28/11	3/1/11	4/21/11	0	0
8.5	5	2/28/11	3/1/11	4/21/11	13	2.6
9	5	2/28/11	3/1/11	4/21/11	4	0.8
9.5	5	2/28/11	3/1/11	4/21/11	7	1.4
10	5	2/28/11	3/1/11	4/21/11	11	2.2
10.5	5	2/28/11	3/1/11	4/21/11	6	1.2
11	5	2/28/11	3/1/11	4/21/11	14	2.8
11.5	5	2/28/11	3/1/11	4/21/11	26	5.2
12	5	2/28/11	3/1/11	4/21/11	11	2.2
12.5	5	2/28/11	3/1/11	4/21/11	2	0.4
13	5	2/28/11	3/1/11	4/21/11	8	1.6
13.5	5	2/28/11	3/1/11	4/21/11	6	1.2
14	5	2/28/11	3/1/11	4/21/11	2	0.4
14.5	5	2/28/11	3/1/11	4/21/11	0	0
15	5	5/4/11	5/5/11	5/6/11	0	0
15.5	5	5/4/11	5/5/11	5/6/11	3	0.6
16	5	5/4/11	5/5/11	5/6/11	1	0.2
16.5	5	5/4/11	5/5/11	5/6/11	1	0.2
17	5	5/4/11	5/5/11	5/6/11	2	0.4
17.5	5	5/4/11	5/5/11	5/6/11	2	0.4
18	5	5/4/11	5/5/11	5/6/11	3	0.6
18.5	5	5/4/11	5/5/11	5/6/11	3	0.6
19	5	5/4/11	5/5/11	5/6/11	33	6.6
19.5	5	5/4/11	5/5/11	5/6/11	8	1.6
20	5	5/4/11	5/5/11	5/6/11	5	1
20.5	5	5/4/11	5/5/11	5/6/11	12	2.4
21	5	5/4/11	5/5/11	5/6/11	3	0.6
21.5	5	5/4/11	5/5/11	5/6/11	2	0.4
22	5	5/4/11	5/5/11	5/6/11	4	0.8
22.5	5	5/4/11	5/5/11	5/6/11	3	0.6
23	5	5/4/11	5/5/11	5/6/11	8	1.6
23.5	5	5/4/11	5/5/11	5/6/11	2	0.4
24	5	5/4/11	5/5/11	5/6/11	6	1.2
24.5	5	5/4/11	5/5/11	5/6/11	15	3
25	5	5/4/11	5/5/11	5/6/11	10	2
25.5	5	5/4/11	5/5/11	5/6/11	3	0.6
26	5	5/4/11	5/5/11	5/6/11	5	1
26.5	5	5/4/11	5/5/11	5/6/11	8	1.6
27	5	5/4/11	5/5/11	5/6/11	2	0.4
27.5	5	5/14/11	5/15/11	5/16/11	4	0.8
28	5	5/14/11	5/15/11	5/16/11	4	0.8
28.5	5	5/14/11	5/15/11	5/16/11	10	2
29	5	5/14/11	5/15/11	5/16/11	10	2
29.5	5	5/14/11	5/15/11	5/16/11	12	2.4
30	5	5/14/11	5/15/11	5/16/11	7	1.4
30.5	5	5/14/11	5/15/11	5/16/11	8	1.6
31	5	5/14/11	5/15/11	5/16/11	5	1
31.5	5	5/14/11	5/15/11	5/16/11	18	3.6
32	5	5/14/11	5/15/11	5/16/11	13	2.6

32.5	5	5/14/11	5/15/11	5/17/11	63	12.6
33	5	5/14/11	5/15/11	5/17/11	26	5.2
33.5	5	5/14/11	5/15/11	5/17/11	17	3.4
34	5	5/14/11	5/15/11	5/17/11	10	2
34.5	5	5/14/11	5/15/11	5/17/11	28	5.6
35	5	5/14/11	5/15/11	5/17/11	28	5.6
35.5	5	5/14/11	5/15/11	5/17/11	16	3.2
36	5	5/14/11	5/15/11	5/17/11	18	3.6
36.5	5	5/14/11	5/15/11	5/17/11	9	1.8
37	5	5/14/11	5/15/11	5/17/11	21	4.2
37.5	5	5/14/11	5/15/11	5/17/11	13	2.6
38	5	5/14/11	5/15/11	5/17/11	7	1.4
38.5	5	5/14/11	5/15/11	5/17/11	4	0.8
39	5	5/14/11	5/15/11	5/17/11	4	0.8
39.5	5	5/14/11	5/15/11	5/17/11	17	3.4
40	5	5/14/11	5/15/11	5/17/11	8	1.6
40.5	5	5/14/11	5/15/11	5/17/11	5	1
41	5	5/14/11	5/15/11	5/17/11	5	1
41.5	5	5/14/11	5/15/11	5/17/11	3	0.6
42	5	5/14/11	5/15/11	5/17/11	3	0.6
42.5	5	5/14/11	5/15/11	5/17/11	17	3.4
43	5	5/14/11	5/15/11	5/17/11	19	3.8
43.5	5	5/14/11	5/15/11	5/17/11	12	2.4
44	5	5/14/11	5/15/11	5/17/11	6	1.2
44.5	5	5/14/11	5/15/11	5/17/11	13	2.6
45	5	5/16/11	5/17/11	5/18/11	5	1
45.5	5	5/16/11	5/17/11	5/18/11	10	2
46	5	5/16/11	5/17/11	5/18/11	8	1.6
46.5	5	5/16/11	5/17/11	5/18/11	16	3.2
47	5	5/16/11	5/17/11	5/18/11	23	4.6
47.5	5	5/16/11	5/17/11	5/18/11	26	5.2
48	5	5/16/11	5/17/11	5/18/11	69	13.8
48.5	5	5/16/11	5/17/11	5/18/11	51	10.2
49	5	5/16/11	5/17/11	5/18/11	21	4.2
49.5	5	5/16/11	5/17/11	5/18/11	10	2
50	5	5/16/11	5/17/11	5/18/11	15	3
50.5	5	5/16/11	5/17/11	5/18/11	12	2.4
51	5	5/16/11	5/17/11	5/18/11	8	1.6
51.5	5	5/16/11	5/17/11	5/18/11	8	1.6
52	5	5/16/11	5/17/11	5/18/11	9	1.8
52.5	5	5/16/11	5/17/11	5/18/11	7	1.4
53	5	5/16/11	5/17/11	5/18/11	2	0.4
53.5	5	5/16/11	5/17/11	5/18/11	6	1.2
54	5	5/16/11	5/17/11	5/18/11	1	0.2
54.5	5	5/16/11	5/17/11	5/18/11	7	1.4
55	5	5/16/11	5/17/11	5/18/11	7	1.4
55.5	5	5/16/11	5/17/11	5/18/11	5	1
56	5	5/16/11	5/17/11	5/18/11	5	1
56.5	5	5/16/11	5/17/11	5/18/11	2	0.4
57	5	5/16/11	5/17/11	5/18/11	3	0.6
57.5	5	5/16/11	5/17/11	5/18/11	2	0.4
58	5	5/16/11	5/17/11	5/18/11	10	2
58.5	5	5/16/11	5/17/11	5/18/11	10	2
59	5	5/16/11	5/17/11	5/18/11	4	0.8
59.5	5	5/16/11	5/17/11	5/18/11	4	0.8
60	5	5/16/11	5/17/11	5/18/11	4	0.8
60.5	5	5/16/11	5/17/11	5/18/11	5	1
61	5	5/16/11	5/17/11	5/18/11	6	1.2
61.5	5	5/16/11	5/17/11	5/18/11	2	0.4
62	5	5/16/11	5/17/11	5/18/11	2	0.4
62.5	5	6/6/11	6/7/11	6/9/11	4	0.8
63	5	6/6/11	6/7/11	6/9/11	4	0.8
63.5	5	6/6/11	6/7/11	6/9/11	6	1.2
64	5	6/6/11	6/7/11	6/9/11	2	0.4
64.5	5	6/6/11	6/7/11	6/9/11	5	1
65	5	6/6/11	6/7/11	6/9/11	13	2.6
65.5	5	6/6/11	6/7/11	6/9/11	42	8.4
66	5	6/6/11	6/7/11	6/9/11	41	8.2
66.5	5	6/6/11	6/7/11	6/9/11	9	1.8

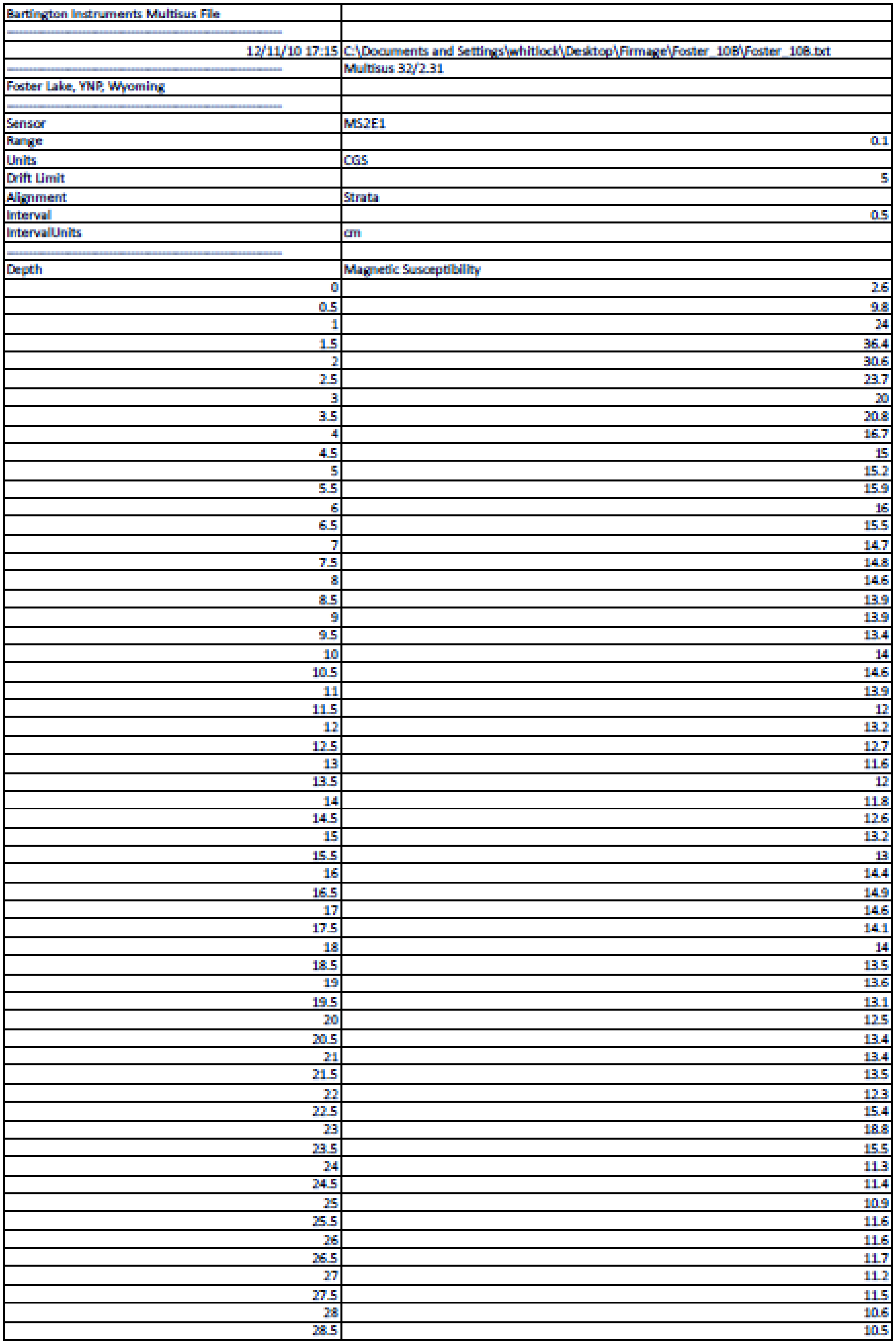
67	5	6/6/11	6/7/11	6/9/11	2	0.4
67.5	5	6/6/11	6/7/11	6/9/11	5	1
68	5	6/6/11	6/7/11	6/9/11	4	0.8
68.5	5	6/6/11	6/7/11	6/9/11	1	0.2
69	5	6/6/11	6/7/11	6/9/11	10	2
69.5	5	6/6/11	6/7/11	6/9/11	20	4
70	5	6/6/11	6/7/11	6/9/11	9	1.8
70.5	5	6/6/11	6/7/11	6/9/11	1	0.2
71	5	6/6/11	6/7/11	6/9/11	0	0
71.5	5	6/6/11	6/7/11	6/9/11	1	0.2
72	5	6/6/11	6/7/11	6/9/11	1	0.2
72.5	5	6/6/11	6/7/11	6/9/11	6	1.2
73	5	6/6/11	6/7/11	6/9/11	0	0
73.5	5	6/6/11	6/7/11	6/9/11	4	0.8
74	5	6/6/11	6/7/11	6/9/11	12	2.4
74.5	5	6/6/11	6/7/11	6/9/11	11	2.2
75	5	6/6/11	6/7/11	6/9/11	6	1.2
75.5	5	6/6/11	6/7/11	6/9/11	2	0.4
76	5	6/6/11	6/7/11	6/9/11	4	0.8
76.5	5	6/6/11	6/7/11	6/9/11	13	2.6
77	5	6/6/11	6/7/11	6/9/11	9	1.8
77.5	5	6/6/11	6/7/11	6/9/11	4	0.8
78	5	6/6/11	6/7/11	6/9/11	3	0.6
78.5	5	6/6/11	6/7/11	6/9/11	3	0.6
79	5	6/6/11	6/7/11	6/9/11	5	1
79.5	5	6/6/11	6/7/11	6/9/11	3	0.6
80	5	6/6/11	6/7/11	6/9/11	3	0.6
80.5	5	6/6/11	6/7/11	6/9/11	2	0.4
81	5	6/8/11	6/10/11	6/13/11	2	0.4
81.5	5	6/8/11	6/10/11	6/13/11	1	0.2
82	5	6/8/11	6/10/11	6/13/11	1	0.2
82.5	5	6/8/11	6/10/11	6/13/11	0	0
83	5	6/8/11	6/10/11	6/13/11	0	0
83.5	5	6/8/11	6/10/11	6/13/11	0	0
84	5	6/8/11	6/10/11	6/13/11	1	0.2
84.5	5	6/8/11	6/10/11	6/13/11	4	0.8
85	5	6/8/11	6/10/11	6/13/11	1	0.2
85.5	5	6/8/11	6/10/11	6/13/11	1	0.2
86	5	6/8/11	6/10/11	6/13/11	1	0.2
86.5	5	6/8/11	6/10/11	6/13/11	0	0
87	5	6/8/11	6/10/11	6/13/11	1	0.2
87.5	5	6/8/11	6/10/11	6/13/11	3	0.6
88	5	6/8/11	6/10/11	6/13/11	0	0
88.5	5	6/8/11	6/10/11	6/13/11	1	0.2
89	5	6/8/11	6/10/11	6/13/11	2	0.4
89.5	5	6/8/11	6/10/11	6/13/11	4	0.8
90		6/8/11	6/10/11	6/13/11		#DIV/0!
90.5		6/8/11	6/10/11	6/13/11		#DIV/0!
91		6/8/11	6/10/11	6/13/11		#DIV/0!
91.5	5	6/8/11	6/10/11	6/13/11	9	1.8
92	2	6/8/11	6/10/11	6/13/11	0	0
92.5	5	6/8/11	6/10/11	6/13/11	7	1.4
93	5	6/8/11	6/10/11	6/13/11	1	0.2
93.5	5	6/8/11	6/10/11	6/13/11	4	0.8
94	5	6/8/11	6/10/11	6/13/11	4	0.8
94.5	5	6/8/11	6/10/11	6/13/11	6	1.2
95	5	6/8/11	6/10/11	6/13/11	3	0.6
95.5	5	6/8/11	6/10/11	6/13/11	12	2.4
96	5	6/8/11	6/10/11	6/13/11	5	1
96.5	5	6/8/11	6/10/11	6/13/11	2	0.4
97	5	6/8/11	6/10/11	6/13/11	5	1
97.5	5	6/8/11	6/10/11	6/13/11	1	0.2
98	5	6/8/11	6/10/11	6/13/11	3	0.6
98.5	5	6/8/11	6/10/11	6/13/11	2	0.4
99	5	6/8/11	6/10/11	6/13/11	6	1.2
99.5	5	6/8/11	6/10/11	6/13/11	9	1.8
100	5	6/9/11	6/10/11	6/14/11	3	0.6
100.5	5	6/9/11	6/10/11	6/14/11	1	0.2
101	5	6/9/11	6/10/11	6/14/11	0	0

101.5	5	6/9/11	6/10/11	6/14/11	2	0.4
102	5	6/9/11	6/10/11	6/14/11	5	1
102.5	5	6/9/11	6/10/11	6/14/11	3	0.6
103	5	6/9/11	6/10/11	6/14/11	1	0.2
103.5	5	6/9/11	6/10/11	6/14/11	0	0
104	5	6/9/11	6/10/11	6/14/11	3	0.6
104.5	5	6/9/11	6/10/11	6/14/11	6	1.2
105	5	6/9/11	6/10/11	6/14/11	41	8.2
105.5	5	6/9/11	6/10/11	6/14/11	60	12
106	5	6/9/11	6/10/11	6/14/11	14	2.8
106.5	5	6/9/11	6/10/11	6/14/11	54	10.8
107	5	6/9/11	6/10/11	6/14/11	39	7.8
107.5	5	6/9/11	6/10/11	6/14/11	16	3.2
108	5	6/9/11	6/10/11	6/14/11	27	5.4
108.5	5	6/9/11	6/10/11	6/14/11	40	8
109	5	6/9/11	6/10/11	6/14/11	41	8.2
109.5	5	6/9/11	6/10/11	6/14/11	47	9.4
110	5	6/9/11	6/10/11	6/14/11	18	3.6
110.5	5	6/9/11	6/10/11	6/14/11	19	3.8
111	5	6/9/11	6/10/11	6/14/11	6	1.2
111.5	5	6/9/11	6/10/11	6/14/11	5	1
112	5	6/9/11	6/10/11	6/14/11	9	1.8
112.5	5	6/9/11	6/10/11	6/14/11	14	2.8
113	5	6/9/11	6/10/11	6/14/11	37	7.4
113.5	5	6/9/11	6/10/11	6/14/11	111	22.2
114	5	6/9/11	6/10/11	6/14/11	39	7.8
114.5	5	6/9/11	6/10/11	6/14/11	5	1
115	5	6/9/11	6/10/11	6/14/11	10	2
115.5	5	6/9/11	6/10/11	6/14/11	9	1.8
116	5	6/9/11	6/10/11	6/14/11	10	2
116.5	5	6/9/11	6/10/11	6/14/11	21	4.2
117	5	6/9/11	6/10/11	6/14/11	5	1
117.5	5	6/16/11	6/17/11	6/19/11	13	2.6
118	5	6/16/11	6/17/11	6/19/11	1	0.2
118.5	5	6/16/11	6/17/11	6/19/11	15	3
119	5	6/16/11	6/17/11	6/19/11	13	2.6
119.5	5	6/16/11	6/17/11	6/19/11	11	2.2
120	5	6/16/11	6/17/11	6/19/11	7	1.4
120.5	5	6/16/11	6/17/11	6/19/11	19	3.8
121	5	6/16/11	6/17/11	6/19/11	8	1.6
121.5	5	6/16/11	6/17/11	6/19/11	4	0.8
122	5	6/16/11	6/17/11	6/19/11	8	1.6
122.5	5	6/16/11	6/17/11	6/19/11	7	1.4
123	5	6/16/11	6/17/11	6/19/11	4	0.8
123.5	5	6/16/11	6/17/11	6/19/11	13	2.6
124	5	6/16/11	6/17/11	6/19/11	6	1.2
124.5	5	6/16/11	6/17/11	6/19/11	10	2
125	5	6/16/11	6/17/11	6/19/11	5	1
125.5	5	6/16/11	6/17/11	6/19/11	37	7.4
126	5	6/16/11	6/17/11	6/19/11	25	5
126.5	5	6/16/11	6/17/11	6/19/11	23	4.6
127	5	6/16/11	6/17/11	6/19/11	10	2
127.5	5	6/16/11	6/17/11	6/19/11	16	3.2
128	5	6/16/11	6/17/11	6/19/11	14	2.8
128.5	5	6/16/11	6/17/11	6/19/11	14	2.8
129	5	6/16/11	6/17/11	6/19/11	18	3.6
129.5	5	6/16/11	6/17/11	6/19/11	26	5.2
130	5	6/16/11	6/17/11	6/19/11	15	3
130.5	5	6/16/11	6/17/11	6/19/11	5	1
131	5	6/16/11	6/17/11	6/19/11	7	1.4
131.5	5	6/16/11	6/17/11	6/19/11	10	2
132	5	6/16/11	6/17/11	6/19/11	14	2.8
132.5	5	6/16/11	6/17/11	6/19/11	19	3.8
133	5	6/16/11	6/17/11	6/19/11	32	6.4
133.5	5	6/16/11	6/17/11	6/19/11	32	6.4
134	5	6/16/11	6/17/11	6/19/11	20	4
134.5	5	6/16/11	6/17/11	6/19/11	28	5.6
135	5	6/16/11	6/17/11	6/19/11	15	3
135.5	5	6/16/11	6/17/11	6/19/11	27	5.4

136	5	6/16/11	6/17/11	6/19/11	12	2.4
136.5	5	6/16/11	6/17/11	6/19/11	7	1.4
137	5	6/16/11	6/17/11	6/19/11	6	1.2
137.5	5	6/16/11	6/17/11	6/19/11	3	0.6
138	5	6/16/11	6/17/11	6/19/11	6	1.2
138.5	5	6/16/11	6/17/11	6/19/11	4	0.8
139	5	6/16/11	6/17/11	6/19/11	5	1
139.5	5	6/16/11	6/17/11	6/19/11	15	3
140	5	6/16/11	6/17/11	6/19/11	4	0.8
140.5	5	6/16/11	6/17/11	6/19/11	4	0.8
141	5	6/16/11	6/17/11	6/19/11	7	1.4
141.5	5	6/16/11	6/17/11	6/19/11	1	0.2
142	5	6/16/11	6/17/11	6/19/11	6	1.2
142.5	5	6/16/11	6/17/11	6/19/11	19	3.8
143	5	6/16/11	6/17/11	6/19/11	3	0.6
143.5	5	6/16/11	6/17/11	6/19/11	12	2.4
144	5	6/16/11	6/17/11	6/19/11	5	1
144.5	5	6/16/11	6/17/11	6/19/11	2	0.4
145	5	6/16/11	6/17/11	6/19/11	3	0.6
145.5	5	6/16/11	6/17/11	6/19/11	7	1.4
146	5	6/16/11	6/17/11	6/19/11	33	6.6
146.5	5	6/16/11	6/17/11	6/19/11	14	2.8
147	5	6/16/11	6/17/11	6/19/11	14	2.8
147.5	5	6/16/11	6/17/11	6/19/11	4	0.8
148	5	6/16/11	6/17/11	6/19/11	0	0
148.5	2	6/16/11	6/17/11	6/19/11	3	1.5
149	5	6/16/11	6/17/11	6/19/11	4	0.8
149.5	5	6/16/11	6/17/11	6/19/11	14	2.8

APPENDIX F

FOSTER LAKE MAGNETIC SUSCEPTIBILITY



Bartington Instruments Multisus File	
--	
12/11/10 17:15	C:\Documents and Settings\whitlock\Desktop\Firmage\Foster_10B\Foster_10B.txt
--	Multisus 32/2.31
Foster Lake, YNP, Wyoming	
--	
Sensor	MS2E1
Range	0.1
Units	CGS
Drift Limit	5
Alignment	Strata
Interval	0.5
IntervalUnits	cm
--	
Depth	Magnetic Susceptibility
0	2.6
0.5	9.8
1	24
1.5	36.4
2	30.6
2.5	23.7
3	20
3.5	20.8
4	16.7
4.5	15
5	15.2
5.5	15.9
6	16
6.5	15.5
7	14.7
7.5	14.8
8	14.6
8.5	13.9
9	13.9
9.5	13.4
10	14
10.5	14.6
11	13.9
11.5	12
12	13.2
12.5	12.7
13	11.6
13.5	12
14	11.8
14.5	12.6
15	13.2
15.5	13
16	14.4
16.5	14.9
17	14.6
17.5	14.1
18	14
18.5	13.5
19	13.6
19.5	13.1
20	12.5
20.5	13.4
21	13.4
21.5	13.5
22	12.3
22.5	15.4
23	18.8
23.5	15.5
24	11.3
24.5	11.4
25	10.9
25.5	11.6
26	11.6
26.5	11.7
27	11.2
27.5	11.5
28	10.6
28.5	10.5

29	9.7
29.5	10
30	10
30.5	10.2
31	9.9
31.5	9.2
32	8.5
32.5	8.5
33	6.5
33.5	6.6
34	6.7
34.5	9.8
35	12.1
35.5	11.1
36	11.2
36.5	11.5
37	10.9
37.5	10.5
38	8.8
38.5	9.9
39	10.3
39.5	10
40	11.2
40.5	8.4
41	7.2
41.5	6.5
42	9.5
42.5	11.4
43	11.4
43.5	11.3
44	11
44.5	10.6
45	9.9
45.5	10.2
46	10.7
46.5	9.8
47	10.1
47.5	11.6
48	12.4
48.5	12.1
49	11
49.5	10.5
50	11
50.5	7.5
51	6.9
51.5	6.1
52	6.5
52.5	7.5
53	10.5
53.5	16.8
54	18
54.5	14.7
55	14.4
55.5	14
56	15.1
56.5	12.2
57	12.4
57.5	12.3
58	13
58.5	12.3
59	14.3
59.5	15.4
60	12.8
60.5	11.9
61	11.8
61.5	13
62	13.9
62.5	18.3
63	16.7
63.5	16.5
64	15
64.5	16
65	14.8

65.5	14.6
66	15.7
66.5	16.8
67	19.4
67.5	16.7
68	16.1
68.5	17.7
69	21.2
69.5	20.3
70	17.3
70.5	20.6
71	20.8
71.5	20.1
72	20.3
72.5	19
73	17.6
73.5	16.9
74	15
74.5	15.1
75	13.9
75.5	14.5
76	17.6
76.5	17.5
77	17
77.5	17.7
78	20.2
78.5	20.3
79	17.6
79.5	15.7
80	17.3
80.5	19.1
81	23.6
81.5	21
82	20.8
82.5	25
83	24.4
83.5	24.3
84	24.1
84.5	23
85	24.1
85.5	25.8
86	22.9
86.5	19.8
87	19.5
87.5	19.7
88	19.3
88.5	19.9
89	20.9
89.5	21.5
90	20.6
90.5	20
91	22.3
91.5	22.1
92	15.2
92.5	21.1
93	18.1
93.5	18.4
94	20.4
94.5	20.9
95	24.5
95.5	18.7
96	18.8
96.5	21.6
97	20.3
97.5	19.8
98	17.9
98.5	17.7
99	17.6
99.5	18.2
100	17.2
100.5	16.2
101	16.2
101.5	17

102	16.8
102.5	17
103	17.8
103.5	20.6
104	20.8
104.5	20.3
105	18.4
105.5	18.7
106	18.9
106.5	19.4
107	18.1
107.5	17.1
108	17
108.5	16.4
109	17.1
109.5	17.4
110	18.2
110.5	19.6
111	21.7
111.5	20.4
112	19
112.5	18.3
113	18.5
113.5	18.5
114	19.2
114.5	22.4
115	25.2
115.5	26
116	28.7
116.5	30.7
117	29.2
117.5	26.5
118	25.3
118.5	23.3
119	23.7
119.5	24.9
120	24.9
120.5	23.8
121	26.1
121.5	28
122	30.1
122.5	32.5
123	25.3
123.5	27.3
124	31.9
124.5	19.6
125	18.9
125.5	16.1
126	17.6
126.5	21.2
127	21.9
127.5	19.4
128	19.1
128.5	21
129	21.3
129.5	19.5
130	22.2
130.5	20.7
131	23
131.5	25
132	31.7
132.5	48.2
133	43.4
133.5	21.2
134	18.2
134.5	18.4
135	23.9
135.5	25.9
136	21.3
136.5	22.1
137	17.3
137.5	21.3
138	23.2

138.5	24.5
139	24.8
139.5	18.7
140	17
140.5	20.2
141	20
141.5	19.3
142	21.5
142.5	26.1
143	22.4
143.5	26.2
144	23.9
144.5	21.9
145	21.5
145.5	27.5
146	24.1
146.5	31.1
147	37.9
147.5	20.1
148	15.8
148.5	15.3
149	15.7
149.5	14.7
150	2.8

APPENDIX G

FOSTER LAKE LOSS ON IGNITION

Cruc. ID number	Depth	Wt. Cruc.	Wt Cruc + Wet Sed	Wt Cruc + Dry Sed	Wt. Cruc + Heated 550°C wt.	Wt. Cruc+Heated 900° C wt.	Wet sed	Dry Sed	Organic Loss	Inorganic Loss	% Organic	% Carbonate
1	0	4.4292	5.4717	4.6943	4.6355	4.6013	1.0425	0.2651	0.0588	0.0342	22.18031	12.90079
3	0.5	5.5356	6.69	5.8044	5.7513	5.7215	1.1544	0.2688	0.0531	0.0298	19.75446	11.08631
4	1	5.3062	6.484	5.5986	5.5447	5.5166	1.1778	0.2924	0.0539	0.0281	18.43365	9.610123
5	1.5	4.8126	5.9122	5.081	5.0326	5.0072	1.0996	0.2684	0.0484	0.0254	18.03279	9.463487
6	2	5.6725	6.8177	5.94	5.8834	5.8528	1.1452	0.2675	0.0566	0.0306	21.15888	11.43925
7	2.5	4.9136	6.0852	5.1926	5.132	5.0993	1.1716	0.279	0.0606	0.0327	21.72043	11.72043
8	3	5.4321	6.5257	5.6787	5.62	5.589	1.0936	0.2466	0.0587	0.031	23.80373	12.57097
9	3.5	5.1507	6.2892	5.3906	5.3326	5.3011	1.1385	0.2399	0.058	0.0315	24.17674	13.13047
10	4	4.6931	5.8025	4.9245	4.8699	4.838	1.1094	0.2314	0.0546	0.0319	23.59551	13.78565
11	4.5	5.4051	6.4662	5.6205	5.571	5.539	1.0611	0.2154	0.0495	0.032	22.9805	14.85608
39	5	5.08	6.188	5.3122	5.2592	5.2246	1.108	0.2322	0.053	0.0346	22.82515	14.90095
113	5.5	4.0373	5.1309	4.2808	4.2282	4.1909	1.0936	0.2435	0.0526	0.0373	21.60164	15.31828
24	6	5.1239	6.2617	5.3777	5.3241	5.2841	1.1378	0.2538	0.0536	0.04	21.11899	15.76044
102	6.5	4.0808	5.2193	4.3427	4.2862	4.2457	1.1385	0.2619	0.0565	0.0405	21.57312	15.46392
103	7	4.2151	5.3275	4.4733	4.418	4.3776	1.1124	0.2582	0.0553	0.0404	21.41751	15.64679
22	7.5	5.3791	6.5679	5.6541	5.5965	5.5524	1.1888	0.275	0.0576	0.0441	20.94545	16.03636
19	8	5.3436	6.491	5.606	5.551	5.5095	1.1474	0.2624	0.055	0.0415	20.96037	15.81555
41	8.5	4.272	5.4376	4.5371	4.4783	4.4387	1.1656	0.2651	0.0588	0.0396	22.18031	14.93776
49	9	5.6049	6.8319	5.884	5.825	5.7821	1.227	0.2791	0.059	0.0429	21.13938	15.37083
38	9.5	5.5722	6.8458	5.8695	5.8105	5.7616	1.2736	0.2973	0.059	0.0489	19.84527	16.44803
123	10	4.0389	5.2151	4.3184	4.2632	4.2178	1.1762	0.2795	0.0552	0.0454	19.74955	16.24329
71	10.5	5.1798	6.3975	5.4585	5.403	5.3582	1.2177	0.2787	0.0555	0.0448	19.91389	16.07463
46	11	5.5226	6.7963	5.8211	5.7635	5.7164	1.2737	0.2985	0.0576	0.0471	19.29648	15.77889
18	11.5	5.3848	6.5802	5.6644	5.6105	5.5648	1.1954	0.2796	0.0539	0.0457	19.27754	16.34478
33	12	5.1329	6.3605	5.4194	5.3631	5.3187	1.2276	0.2865	0.0563	0.0444	19.65096	15.49738
117	12.5	3.8983	5.0936	4.1524	4.0986	4.0602	1.1953	0.2541	0.0538	0.0384	21.17277	15.11216
120	13	4.1807	5.3955	4.4495	4.394	4.3516	1.2148	0.2688	0.0555	0.0424	20.64732	15.77381
35	13.5	5.616	6.8243	5.8822	5.8274	5.7847	1.2083	0.2662	0.0548	0.0427	20.58603	16.04057
119	14	4.036	5.2388	4.3068	4.2504	4.2062	1.2028	0.2708	0.0564	0.0442	20.82718	16.32201
110	14.5	4.0468	5.2475	4.3185	4.2619	4.2177	1.2007	0.2717	0.0566	0.0442	20.8318	16.26794
117	15	3.8983	4.9726	4.1418	4.0907	4.0547	1.0743	0.2435	0.0511	0.036	20.98563	14.78439
66	15.5	5.6262	6.8941	5.9002	5.8409	5.8016	1.2679	0.274	0.0593	0.0393	21.64234	14.34307
120	16	4.1807	5.3934	4.4504	4.3929	4.3555	1.2127	0.2697	0.0575	0.0374	21.31999	13.86726
30	16.5	5.0382	6.2778	5.3371	5.2737	5.2329	1.2396	0.2989	0.0634	0.0408	21.21111	13.65005
105	17	4.15	5.3073	4.4207	4.3629	4.3252	1.1573	0.2707	0.0578	0.0377	21.35205	13.92686
113	17.5	4.0373	5.1944	4.2993	4.2441	4.2058	1.1571	0.262	0.0552	0.0383	21.0687	14.61832
25	18	5.1312	6.3904	5.4212	5.3582	5.3166	1.2592	0.29	0.063	0.0416	21.72414	14.34483
38	18.5	5.572	6.7131	5.8402	5.7812	5.7424	1.1411	0.2682	0.059	0.0388	21.99851	14.46682
18	19	5.3846	6.5356	5.6629	5.6037	5.5625	1.151	0.2783	0.0592	0.0412	21.27201	14.80417
7	19.5	4.9143	6.1945	5.2342	5.1667	5.1162	1.2802	0.3199	0.0675	0.0505	21.10034	15.78618
64	20	5.4935	6.7414	5.807	5.7406	5.6889	1.2479	0.3135	0.0664	0.0517	21.18022	16.49123
9	20.5	5.151	6.5112	5.4792	5.41	5.3568	1.3602	0.3282	0.0692	0.0532	21.0847	16.20963
37	21	5.0221	6.3456	5.3384	5.2745	5.2222	1.3235	0.3163	0.0639	0.0523	20.20234	16.53494
10	21.5	4.6935	5.9497	4.9912	4.9314	4.8824	1.2562	0.2977	0.0598	0.049	20.08734	16.45952
104	22	4.1792	5.4615	4.4905	4.4274	4.3763	1.2823	0.3113	0.0631	0.0511	20.26984	16.41503
28	22.5	5.2167	6.4268	5.509	5.4506	5.406	1.2101	0.2923	0.0584	0.0446	19.97947	15.2583
58	23	5.6532	6.8545	5.9414	5.8856	5.8446	1.2013	0.2882	0.0558	0.041	19.36155	14.22623
110	23.5	4.0468	5.3788	4.3649	4.3024	4.2541	1.332	0.3181	0.0625	0.0483	19.64791	15.1839
11	24	5.4053	6.7747	5.7225	5.6573	5.6071	1.3694	0.3172	0.0652	0.0502	20.55485	15.82598
13	24.5	5.852	7.0318	6.1268	6.0684	6.026	1.1798	0.2748	0.0584	0.0424	21.25182	15.4294
68	25	5.4408	6.7432	5.754	5.6887	5.6401	1.3024	0.3132	0.0653	0.0486	20.8493	15.51724
39	25.5	5.081	6.3217	5.3646	5.3049	5.2619	1.2407	0.2836	0.0597	0.043	21.05078	15.1622
8	26	5.4334	6.7028	5.7249	5.6653	5.6197	1.2694	0.2915	0.0596	0.0456	20.44597	15.64322
35	26.5	5.6166	6.9259	5.9243	5.8615	5.8128	1.3093	0.3077	0.0628	0.0487	20.40949	15.8271
14	27	5.5134	6.7315	5.805	5.746	5.6992	1.2181	0.2916	0.059	0.0468	20.2332	16.04938
55	27.5	4.6332	5.9124	4.956	4.8907	4.8393	1.2792	0.3228	0.0653	0.0514	20.22924	15.92317
6	28	5.6734	6.9813	6.0034	5.9396	5.8834	1.3079	0.33	0.0638	0.0562	19.33333	17.0303
108	28.5	4.0751	5.327	4.3969	4.3377	4.2849	1.2519	0.3218	0.0592	0.0528	18.39652	16.40771
12	29	5.133	6.4358	5.4626	5.3979	5.3423	1.3028	0.3296	0.0647	0.0556	19.62985	16.86893
49	29.5	5.6047	6.834	5.9049	5.842	5.7941	1.2293	0.3002	0.0629	0.0479	20.9527	15.95603
46	30	5.5231	6.746	5.8215	5.758	5.7083	1.2229	0.2984	0.0635	0.0497	21.28016	16.6555
1	30.5	4.4296	5.6419	4.7154	4.6555	4.6063	1.2123	0.2858	0.0599	0.0492	20.95871	17.21484
15	31	5.4627	6.7799	5.768	5.7028	5.6543	1.3172	0.3053	0.0652	0.0485	21.35604	15.88601
33	31.5	5.1328	6.3419	5.4127	5.3533	5.3084	1.2091	0.2799	0.0594	0.0449	21.22186	16.04144

22	32	5.3793	6.7145	5.694	5.6271	5.5774	1.3352	0.3147	0.0669	0.0497	21.25834	15.79282
19	32.5	5.3438	6.572	5.6324	5.5673	5.523	1.2282	0.2886	0.0651	0.0443	22.55717	15.34997
40	33	5.2359	6.5745	5.5505	5.4818	5.431	1.3386	0.3146	0.0687	0.0508	21.83725	16.14749
29	33.5	5.1482	6.516	5.4465	5.38	5.3313	1.3678	0.2983	0.0665	0.0487	22.29299	16.32585
103	34	4.2154	5.3764	4.4831	4.4232	4.3793	1.161	0.2677	0.0599	0.0439	22.37579	16.39895
51	34.5	5.3358	6.6533	5.6478	5.5782	5.5271	1.3175	0.312	0.0696	0.0511	22.30769	16.37821
102	35	4.081	5.3242	4.3868	4.3203	4.2691	1.2432	0.3058	0.0665	0.0512	21.74624	16.74297
71	35.5	5.1803	6.4333	5.4793	5.4155	5.3649	1.253	0.299	0.0638	0.0506	21.33779	16.92308
42	36	4.9181	6.1808	5.2121	5.1492	5.099	1.2627	0.294	0.0629	0.0502	21.39456	17.07483
48	36.5	5.8032	7.0916	6.1132	6.0469	5.9925	1.2884	0.31	0.0663	0.0544	21.3871	17.54839
67	37	4.7974	6.0882	5.1058	5.0402	4.9854	1.2908	0.3084	0.0656	0.0548	21.27108	17.76913
24	37.5	5.1245	6.3489	5.4173	5.3566	5.303	1.2244	0.2928	0.0607	0.0536	20.73087	18.30601
123	38	4.0394	5.2514	4.3252	4.2673	4.2155	1.212	0.2858	0.0579	0.0518	20.25892	18.12456
5	38.5	4.8134	6.1113	5.1067	5.049	4.9963	1.2979	0.2933	0.0577	0.0527	19.67269	17.96795
47	39	4.9909	6.306	5.3081	5.2474	5.1901	1.3151	0.3172	0.0607	0.0573	19.13619	18.06431
26	39.5	5.0661	6.3549	5.3869	5.3251	5.2674	1.2888	0.3208	0.0618	0.0577	19.26434	17.98628
7	40	4.9139	5.9852	5.191	5.1356	5.0888	1.0713	0.2771	0.0554	0.0468	19.99278	16.88921
64	40.5	5.4935	6.7027	5.8157	5.7538	5.6972	1.2092	0.3222	0.0619	0.0566	19.21167	17.56673
60	41	5.151	6.4368	5.4965	5.4317	5.3687	1.2858	0.3455	0.0648	0.063	18.75543	18.23444
37	41.5	5.022	6.2932	5.3773	5.3119	5.2463	1.2712	0.3553	0.0654	0.0656	18.40698	18.46327
10	42	4.6937	5.9278	5.0348	4.9725	4.9115	1.2341	0.3411	0.0623	0.061	18.26444	17.88332
8	42.5	5.4324	6.6252	5.768	5.7031	5.6469	1.1928	0.3356	0.0649	0.0562	19.3385	16.74613
35	43	5.616	6.9275	5.9566	5.8916	5.8337	1.3115	0.3406	0.065	0.0579	19.08397	16.99941
117	43.5	3.8983	5.228	4.2423	4.1762	4.1165	1.3297	0.344	0.0661	0.0597	19.21512	17.35465
66	44	5.6263	6.9539	5.9605	5.8954	5.8384	1.3276	0.3342	0.0651	0.057	19.47935	17.05566
120	44.5	4.1808	5.5629	4.5471	4.4765	4.4127	1.3821	0.3663	0.0706	0.0638	19.27382	17.41742
30	45	5.0381	6.2116	5.3557	5.2944	5.2398	1.1735	0.3176	0.0613	0.0546	19.30101	17.19144
105	45.5	4.1499	5.3197	4.4751	4.4124	4.3576	1.1698	0.3252	0.0627	0.0548	19.28044	16.85117
113	46	4.0375	5.3536	4.3952	4.3277	4.2663	1.3161	0.3577	0.0675	0.0614	18.87056	17.16522
25	46.5	5.131	6.4332	5.4923	5.425	5.3629	1.3022	0.3613	0.0673	0.0621	18.62718	17.18793
38	47	5.5719	6.8185	5.9245	5.8584	5.8012	1.2466	0.3526	0.0661	0.0572	18.74645	16.22235
18	47.5	5.3843	6.6241	5.7342	5.6667	5.6117	1.2398	0.3499	0.0675	0.055	19.29123	15.71878
14	48	5.5122	6.8143	5.853	5.7892	5.7336	1.3021	0.3408	0.0638	0.0556	18.72066	16.31455
104	48.5	4.1786	5.4306	4.5121	4.4499	4.3933	1.252	0.3335	0.0622	0.0566	18.65067	16.97151
55	49	4.6322	5.782	4.9465	4.8882	4.833	1.1498	0.3143	0.0583	0.0552	18.54916	17.56284
28	49.5	5.2162	6.4747	5.5575	5.493	5.4339	1.2585	0.3413	0.0645	0.0591	18.89833	17.31614
58	50	5.6527	6.8765	5.9849	5.9225	5.8649	1.2238	0.3322	0.0624	0.0576	18.78387	17.33895
6	50.5	5.6728	6.9791	6.025	5.9575	5.8978	1.3063	0.3522	0.0675	0.0597	19.16525	16.9506
110	51	4.0465	5.3275	4.3883	4.3238	4.2633	1.281	0.3418	0.0645	0.0605	18.87068	17.70041
108	51.5	4.0741	5.3878	4.4211	4.3576	4.2981	1.3137	0.347	0.0635	0.0595	18.29971	17.14697
11	52	5.4047	6.668	5.7536	5.6896	5.6309	1.2633	0.3489	0.064	0.0587	18.34336	16.8243
12	52.5	5.132	6.4969	5.5045	5.4363	5.3677	1.3649	0.3725	0.0682	0.0686	18.30872	18.41611
13	53	5.8516	7.1039	6.1946	6.1314	6.071	1.2523	0.343	0.0632	0.0604	18.42566	17.60933
68	53.5	5.4404	6.782	5.8243	5.7604	5.6995	1.3416	0.3839	0.0639	0.0609	16.64496	15.86351
39	54	5.0803	6.47	5.4657	5.4016	5.3385	1.3897	0.3854	0.0641	0.0631	16.63207	16.3726
49	54.5	5.6048	6.9519	5.9718	5.9065	5.8419	1.3471	0.367	0.0653	0.0646	17.79292	17.60218
41	55	4.2717	5.4646	4.6131	4.5506	4.4922	1.1929	0.3414	0.0625	0.0584	18.30697	17.10603
24	55.5	5.1243	6.4165	5.4931	5.426	5.3624	1.2922	0.3688	0.0671	0.0636	18.19414	17.24512
19	56	5.3438	6.5889	5.693	5.6287	5.5678	1.2451	0.3492	0.0643	0.0609	18.41352	17.43986
123	56.5	4.039	5.3019	4.416	4.3476	4.2815	1.2629	0.377	0.0684	0.0661	18.14324	17.53316
67	57	4.7969	6.0723	5.1792	5.1106	5.0433	1.2754	0.3823	0.0686	0.0673	17.94402	17.60398
22	57.5	5.3793	6.5634	5.7231	5.6587	5.5979	1.1841	0.3438	0.0644	0.0608	18.73182	17.6847
51	58	5.3359	6.5745	5.7235	5.6566	5.5822	1.2386	0.3876	0.0669	0.0744	17.26006	19.19505
48	58.5	5.803	7.1623	6.216	6.1424	6.0592	1.3593	0.413	0.0736	0.0832	17.82082	20.14528
40	59	5.2356	6.391	5.5737	5.5067	5.4518	1.1554	0.3381	0.067	0.0549	19.81662	16.2378
33	59.5	5.133	6.3874	5.5086	5.4363	5.3687	1.2544	0.3756	0.0723	0.0676	19.2492	17.99787
71	60	5.1801	6.433	5.551	5.4749	5.412	1.2529	0.3709	0.0761	0.0629	20.51766	16.95875
47	60.5	4.9905	6.205	5.3225	5.2564	5.203	1.2145	0.332	0.0661	0.0534	19.90964	16.08434
29	61	5.1482	6.4549	5.5066	5.4346	5.3715	1.3067	0.3584	0.072	0.0631	20.08929	17.60603
106	61.5	4.1158	5.3245	4.4512	4.3838	4.328	1.2087	0.3354	0.0674	0.0558	20.09541	16.63685
52	62	5.1566	6.3091	5.4801	5.4118	5.3618	1.1525	0.3235	0.0683	0.05	21.11283	15.45595
114	62.5	4.1317	5.3322	4.468	4.4031	4.3524	1.2005	0.3363	0.0649	0.0507	19.29825	15.07583
46	63	5.5229	6.7587	5.8618	5.7968	5.7401	1.2358	0.3389	0.065	0.0567	19.1797	16.7306
103	63.5	4.2155	5.4415	4.5412	4.4764	4.4215	1.226	0.3257	0.0648	0.0549	19.89561	16.856
112	64	4.0076	5.2221	4.3318	4.2653	4.2119	1.2145	0.3242	0.0665	0.0534	20.51203	16.47131
119	64.5	4.0365	5.2492	4.3517	4.2856	4.2352	1.2127	0.3152	0.0661	0.0504	20.97081	15.98985
56	65	5.1072	6.3611	5.4342	5.3672	5.3151	1.2539	0.327	0.067	0.0521	20.4893	15.93272
42	65.5	4.9177	6.1098	5.233	5.17	5.1252	1.1921	0.3153	0.063	0.0448	19.98097	14.20869
63	66	4.631	5.8619	4.9639	4.8953	4.847	1.2309	0.3329	0.0686	0.0483	20.60679	14.50886

5	66.5	4.8129	6.1273	5.1437	5.0737	5.0233	1.3144	0.3308	0.07	0.0504	21.16082	15.23579
3	67	5.5365	6.752	5.863	5.7959	5.7457	1.2155	0.3265	0.0671	0.0502	20.5513	15.37519
15	67.5	5.463	6.7891	5.8251	5.7542	5.6949	1.3261	0.3621	0.0709	0.0593	19.58023	16.37669
1	68	4.4298	5.6846	4.7817	4.7111	4.6581	1.2548	0.3519	0.0706	0.053	20.06252	15.0611
102	68.5	4.0812	5.3082	4.4043	4.3334	4.2899	1.227	0.3231	0.0709	0.0435	21.94367	13.46332
26	69	5.0655	6.317	5.391	5.3172	5.27	1.2515	0.3255	0.0738	0.0472	22.67281	14.50077
43	69.5	5.1538	6.399	5.5087	5.4346	5.3832	1.2452	0.3549	0.0741	0.0514	20.87912	14.48295
7	70	4.914	6.1992	5.2743	5.2013	5.1495	1.2852	0.3603	0.073	0.0518	20.26089	14.37691
64	70.5	5.4936	6.7933	5.8569	5.7836	5.7286	1.2997	0.3633	0.0733	0.055	20.17616	15.139
60	71	5.1505	6.352	5.5022	5.4339	5.3761	1.2015	0.3517	0.0683	0.0578	19.41996	16.43446
37	71.5	5.0216	6.2588	5.3914	5.3206	5.2583	1.2372	0.3698	0.0708	0.0623	19.14548	16.84694
10	72	4.6931	5.9218	5.0774	5.0053	4.9385	1.2287	0.3843	0.0721	0.0668	18.76138	17.38225
8	72.5	5.4322	6.7133	5.8253	5.7525	5.684	1.2811	0.3931	0.0728	0.0685	18.51946	17.42559
35	73	5.6157	6.9102	6.0194	5.9467	5.8726	1.2945	0.4037	0.0727	0.0741	18.00842	18.35521
117	73.5	3.8982	5.1528	4.2908	4.2243	4.147	1.2546	0.3926	0.0665	0.0773	16.93836	19.68925
66	74	5.6261	6.8879	6.0217	5.9533	5.8833	1.2618	0.3956	0.0684	0.07	17.29019	17.69464
120	74.5	4.1805	5.4303	4.5618	4.4927	4.4319	1.2498	0.3813	0.0691	0.0608	18.12221	15.94545
58	75	5.6527	6.8699	6.0072	5.9407	5.8837	1.2172	0.3545	0.0665	0.057	18.75882	16.07898
6	75.5	5.6725	6.846	6.013	5.9518	5.8961	1.1735	0.3405	0.0612	0.0557	17.97357	16.3583
110	76	4.0464	5.1568	4.3792	4.3206	4.2656	1.1104	0.3328	0.0586	0.055	17.60817	16.52644
108	76.5	4.0739	5.3329	4.4336	4.3698	4.3105	1.259	0.3597	0.0638	0.0593	17.737	16.48596
11	77	5.4042	6.6466	5.7617	5.6985	5.6404	1.2424	0.3575	0.0632	0.0581	17.67832	16.25175
12	77.5	5.1319	6.3701	5.4711	5.4117	5.3555	1.2382	0.3392	0.0594	0.0562	17.51179	16.5684
13	78	5.8519	7.1643	6.2206	6.1561	6.0965	1.3124	0.3687	0.0645	0.0596	17.4939	16.1649
68	78.5	5.4404	6.7183	5.794	5.7318	5.6734	1.2779	0.3536	0.0622	0.0584	17.5905	16.51584
39	79	5.0805	6.278	5.4267	5.3653	5.3035	1.1975	0.3462	0.0614	0.0618	17.73541	17.85095
49	79.5	5.6048	6.8733	5.972	5.9058	5.8418	1.2685	0.3672	0.0662	0.064	18.02832	17.42919
30	80	5.0384	6.2874	5.4102	5.3432	5.2807	1.249	0.3718	0.067	0.0625	18.02044	16.81011
105	80.5	4.1501	5.4086	4.5158	4.4494	4.3899	1.2585	0.3657	0.0664	0.0595	18.15696	16.27017
113	81	4.0375	5.2557	4.3899	4.3274	4.2705	1.2182	0.3524	0.0625	0.0569	17.73553	16.14642
25	81.5	5.1313	6.3216	5.4708	5.4072	5.3509	1.1903	0.3395	0.0636	0.0563	18.73343	16.58321
38	82	5.5723	6.675	5.8919	5.8332	5.7826	1.1027	0.3196	0.0587	0.0506	18.36671	15.83229
18	82.5	5.3849	6.6644	5.744	5.6822	5.6172	1.2795	0.3591	0.0618	0.065	17.20969	18.10081
14	83	5.5124	6.7122	5.8576	5.8007	5.7379	1.1998	0.3452	0.0569	0.0628	16.4832	18.19235
104	83.5	4.1791	5.3416	4.5112	4.4551	4.3947	1.1625	0.3321	0.0561	0.0604	16.8925	18.18729
55	84	4.6326	5.7718	4.974	4.9141	4.851	1.1392	0.3414	0.0599	0.0631	17.5454	18.48272
28	84.5	5.2166	6.4806	5.5809	5.5156	5.4565	1.264	0.3643	0.0653	0.0591	17.92479	16.22289
41	85	4.2714	5.4623	4.6321	4.5651	4.4983	1.1909	0.3607	0.067	0.0668	18.57499	18.51955
24	85.5	5.1243	6.3484	5.479	5.4097	5.3525	1.2241	0.3547	0.0693	0.0572	19.53764	16.1263
19	86	5.3436	6.555	5.7055	5.6358	5.5768	1.2114	0.3619	0.0697	0.059	19.25946	16.30285
123	86.5	4.0389	5.2758	4.4233	4.3528	4.2873	1.2369	0.3844	0.0705	0.0655	18.34027	17.03954
67	87	4.7971	5.9859	5.1412	5.0733	5.022	1.1888	0.3441	0.0679	0.0513	19.73264	14.90846
22	87.5	5.3794	6.5928	5.7316	5.6644	5.609	1.2134	0.3522	0.0672	0.0554	19.08007	15.7297
51	88	5.336	6.6076	5.7101	5.6351	5.5737	1.2716	0.3741	0.075	0.0614	20.04812	16.41272
48	88.5	5.8031	6.9865	6.1269	6.0626	6.012	1.1834	0.3238	0.0643	0.0506	19.85794	15.62693
40	89	5.2358	6.4369	5.581	5.5167	5.4641	1.2011	0.3452	0.0643	0.0526	18.62688	15.23754
33	89.5	5.1329	6.247	5.4544	5.3918	5.3452	1.1141	0.3215	0.0626	0.0466	19.47123	14.49456
71	90	5.18	6.5045	5.5291	5.4601	5.4072	1.3245	0.3491	0.069	0.0529	19.76511	15.15325
47	90.5	4.9902	6.1995	5.3161	5.2542	5.2056	1.2093	0.3259	0.0619	0.0486	18.99356	14.91255
29	91	5.1479	6.4499	5.4977	5.429	5.3758	1.302	0.3498	0.0687	0.0532	19.63979	15.20869
106	91.5	4.1152	5.4537	4.4878	4.4176	4.3645	1.3385	0.3726	0.0702	0.0531	18.84058	14.25121
52	92	5.1564	6.3324	5.5138	5.4467	5.396	1.176	0.3574	0.0671	0.0507	18.77448	14.18579
114	92.5	4.1313	5.3752	4.499	4.4268	4.3725	1.2439	0.3677	0.0722	0.0543	19.63557	14.76747
46	93	5.5225	6.7426	5.8864	5.8134	5.7569	1.2201	0.3639	0.073	0.0565	20.06046	15.52624
103	93.5	4.2152	5.4647	4.5878	4.5153	4.4509	1.2495	0.3726	0.0725	0.0644	19.45786	17.28395
112	94	4.0071	5.294	4.4102	4.3363	4.2673	1.2869	0.4031	0.0739	0.069	18.33292	17.11734
119	94.5	4.036	5.3998	4.47	4.3886	4.3163	1.3638	0.434	0.0814	0.0723	18.75576	16.65899
56	95	5.1072	6.4833	5.5376	5.4578	5.3764	1.3761	0.4304	0.0798	0.0814	18.54089	18.91264
42	95.5	4.9178	6.1568	5.3001	5.232	5.1664	1.239	0.3823	0.0681	0.0656	17.81324	17.1593
63	96	4.6312	5.9048	4.9855	4.9135	4.8607	1.2736	0.3543	0.072	0.0528	20.32176	14.90262
5	96.5	4.813	6.1869	5.1999	5.116	5.0545	1.3739	0.3869	0.0839	0.0615	21.68519	15.89558
3	97	5.5365	6.8486	5.9149	5.8325	5.7674	1.3121	0.3784	0.0824	0.0651	21.7759	17.20402
15	97.5	5.4632	6.6738	5.8245	5.7491	5.6839	1.2106	0.3613	0.0754	0.0652	20.86908	18.04595
1	98	4.4295	5.7512	4.8227	4.7455	4.6718	1.3217	0.3932	0.0772	0.0737	19.63377	18.74364
102	98.5	4.0809	5.3253	4.4582	4.386	4.315	1.2444	0.3773	0.0722	0.071	19.13597	18.81792
26	99	5.0653	6.3062	5.4488	5.3758	5.3049	1.2409	0.3835	0.073	0.0709	19.0352	18.48761
43	99.5	5.1532	6.322	5.5264	5.4555	5.386	1.1688	0.3732	0.0709	0.0695	18.99786	18.62272
18	100	5.3846	6.6517	5.7435	5.673	5.613	1.2671	0.3589	0.0705	0.06	19.64335	16.71775
14	100.5	5.5124	6.7117	5.8618	5.7931	5.7333	1.1993	0.3494	0.0687	0.0598	19.66228	17.11505

104	101	4.1788	5.4064	4.5344	4.4659	4.4055	1.2276	0.3556	0.0685	0.0604	19.26322	16.98538
49	101.5	5.6049	6.8134	5.9556	5.8867	5.8281	1.2085	0.3507	0.0689	0.0586	19.64642	16.70944
30	102	5.0382	6.2799	5.3818	5.3142	5.256	1.2417	0.3436	0.0676	0.0582	19.67404	16.9383
66	102.5	5.6265	6.8046	5.9598	5.8936	5.8385	1.1781	0.3333	0.0662	0.0551	19.86199	16.53165
64	103	5.4936	6.7835	5.853	5.7827	5.7228	1.2899	0.3594	0.0703	0.0599	19.56038	16.66667
113	103.5	4.0374	5.2918	4.3862	4.3182	4.2581	1.2544	0.3488	0.068	0.0601	19.49541	17.2305
68	104	5.4408	6.8003	5.8244	5.7491	5.6869	1.3595	0.3836	0.0753	0.0622	19.62982	16.21481
105	104.5	4.1502	5.5134	4.5244	4.4511	4.3917	1.3632	0.3742	0.0733	0.0594	19.58846	15.87386
55	105	4.6324	5.9246	4.9799	4.911	4.857	1.2922	0.3475	0.0689	0.054	19.82734	15.53957
37	105.5	5.0219	6.2264	5.3301	5.2641	5.2188	1.2045	0.3082	0.066	0.0453	21.41467	14.69825
8	106	5.4326	6.7136	5.7565	5.6824	5.6364	1.281	0.3239	0.0741	0.046	22.87743	14.20191
25	106.5	5.1314	6.3256	5.4111	5.3473	5.3055	1.1942	0.2797	0.0638	0.0418	22.81015	14.94458
35	107	5.616	6.8533	5.9183	5.8506	5.8048	1.2373	0.3023	0.0677	0.0458	22.39497	15.15051
110	107.5	4.0467	5.2973	4.3674	4.2971	4.247	1.2506	0.3207	0.0703	0.0501	21.9208	15.62208
10	108	4.6935	5.9833	5.033	4.9604	4.9064	1.2898	0.3395	0.0726	0.054	21.38439	15.90574
39	108.5	5.0809	6.4187	5.4396	5.3675	5.3086	1.3378	0.3587	0.0721	0.0589	20.10036	16.42041
120	109	4.1811	5.4792	4.5356	4.4659	4.4089	1.2981	0.3545	0.0697	0.057	19.6615	16.07898
58	109.5	5.6531	6.9377	6.0162	5.9461	5.8855	1.2846	0.3631	0.0701	0.0606	19.30598	16.68962
12	110	5.1324	6.4002	5.4901	5.4134	5.3542	1.2678	0.3577	0.0767	0.0592	21.44255	16.55018
117	110.5	3.8988	5.1813	4.2281	4.1569	4.1044	1.2825	0.3293	0.0712	0.0525	21.62162	15.94291
13	111	5.852	7.1603	6.1833	6.1112	6.0575	1.3083	0.3313	0.0721	0.0537	21.76275	16.20887
28	111.5	5.2169	6.5036	5.5558	5.4845	5.4288	1.2867	0.3389	0.0713	0.0557	21.03865	16.43553
60	112	5.1512	6.4319	5.4799	5.4111	5.357	1.2807	0.3287	0.0688	0.0541	20.93094	16.45878
108	112.5	4.0747	5.3692	4.4127	4.3418	4.2848	1.2945	0.338	0.0709	0.057	20.97633	16.86391
7	113	4.9144	6.2624	5.265	5.1929	5.1325	1.348	0.3506	0.0721	0.0604	20.56475	17.22761
38	113.5	5.5725	6.8166	5.9002	5.8329	5.7799	1.2441	0.3277	0.0673	0.053	20.53708	16.17333
11	114	5.4049	6.6151	5.7205	5.6562	5.6083	1.2102	0.3156	0.0643	0.0479	20.37389	15.17744
6	114.5	5.6733	7.0477	6.036	5.9671	5.9146	1.3744	0.3627	0.0689	0.0525	18.99642	14.47477
27	115	4.8418	5.9746	5.1592	5.0984	5.0548	1.1328	0.3174	0.0608	0.0436	19.15564	13.73661
115	115.5	3.9008	5.0887	4.2421	4.1806	4.1368	1.1879	0.3413	0.0615	0.0438	18.01934	12.83328
101	116	3.8827	5.1228	4.2377	4.1744	4.131	1.2401	0.355	0.0633	0.0434	17.83099	12.22535
16	116.5	4.9951	6.0511	5.2926	5.2365	5.1989	1.056	0.2975	0.0561	0.0376	18.85714	12.63866
121	117	4.0641	5.2498	4.3828	4.3181	4.2764	1.1857	0.3187	0.0647	0.0417	20.30122	13.08441
65	117.5	5.6879	6.7712	5.9845	5.9219	5.8813	1.0833	0.2966	0.0626	0.0406	21.10587	13.68847
36	118	5.1929	6.3386	5.492	5.4295	5.3875	1.1457	0.2991	0.0625	0.042	20.89602	14.04213
54	118.5	5.4056	6.4685	5.7065	5.6464	5.605	1.0629	0.3009	0.0601	0.0414	19.97341	13.75872
31	119	5.449	6.5583	5.7491	5.691	5.6521	1.1093	0.3001	0.0581	0.0389	19.36021	12.96235
21	119.5	4.6548	5.7468	4.9624	4.9016	4.8634	1.092	0.3076	0.0608	0.0382	19.76593	12.41873
53	120	5.2223	6.3381	5.5329	5.4736	5.4367	1.1158	0.3106	0.0593	0.0369	19.09208	11.88023
44	120.5	5.0501	6.1534	5.355	5.2958	5.2588	1.1033	0.3049	0.0592	0.037	19.4162	12.13513
107	121	4.0272	5.1488	4.3432	4.286	4.2488	1.1216	0.316	0.0572	0.0372	18.10127	11.77215
32	121.5	5.7926	6.9774	6.1285	6.0679	6.0291	1.1848	0.3359	0.0606	0.0388	18.04108	11.55106
69	122	5.0453	6.248	5.3801	5.3168	5.2772	1.2027	0.3348	0.0633	0.0396	18.90681	11.82796
118	122.5	4.1489	5.3177	4.4653	4.4013	4.3599	1.1688	0.3164	0.064	0.0414	20.22756	13.0847
116	123	4.0246	5.231	4.3753	4.3077	4.2626	1.2064	0.3507	0.0676	0.0451	19.27573	12.85999
109	123.5	4.1469	5.2689	4.4629	4.4002	4.3559	1.122	0.316	0.0627	0.0443	19.84177	14.01899
111	124	4.1887	5.4301	4.5475	4.4742	4.4216	1.2414	0.3588	0.0733	0.0526	20.42921	14.65998
23	124.5	5.3586	6.4845	5.6588	5.593	5.5488	1.1259	0.3002	0.0658	0.0442	21.91872	14.72352
5	125	4.8128	5.9469	5.1128	5.0441	4.9947	1.1341	0.3	0.0687	0.0494	22.9	16.46667
3	125.5	5.5364	6.6902	5.8429	5.7702	5.7227	1.1538	0.3065	0.0727	0.0475	23.71941	15.49755
15	126	5.4629	6.6627	5.8043	5.7316	5.6804	1.1998	0.3414	0.0727	0.0512	21.29467	14.99707
1	126.5	4.4297	5.6659	4.7672	4.6888	4.6347	1.2362	0.3375	0.0784	0.0541	23.22963	16.02963
102	127	4.0808	5.2653	4.3921	4.3156	4.2668	1.1845	0.3113	0.0765	0.0488	24.57437	15.6762
26	127.5	5.0654	6.1583	5.3743	5.3017	5.2544	1.0929	0.3089	0.0726	0.0473	23.50275	15.3124
40	128	5.2355	6.3959	5.5488	5.4766	5.4272	1.1604	0.3133	0.0722	0.0494	23.045	15.76763
43	128.5	5.1533	6.2768	5.4513	5.3835	5.3394	1.1235	0.298	0.0678	0.0441	22.75168	14.79866
112	129	4.0069	5.1784	4.273	4.2125	4.1724	1.1715	0.2661	0.0605	0.0401	22.73581	15.06952
33	129.5	5.1329	6.2765	5.4345	5.3666	5.3224	1.1436	0.3016	0.0679	0.0442	22.51326	14.65517
103	130	4.2151	5.3458	4.4999	4.4342	4.391	1.1307	0.2848	0.0657	0.0432	23.06882	15.16854
29	130.5	5.148	6.3442	5.4668	5.3938	5.3451	1.1962	0.3188	0.073	0.0487	22.89837	15.27604
106	131	4.1151	5.2253	4.4372	4.3654	4.3154	1.1102	0.3221	0.0718	0.05	22.29121	15.52313
56	131.5	5.1072	6.2856	5.4749	5.3921	5.3367	1.1784	0.3677	0.0828	0.0554	22.51836	15.06663
119	132	4.036	5.2717	4.4368	4.3569	4.3035	1.2357	0.4008	0.0799	0.0534	19.93513	13.32335
24	132.5	5.1243	6.2528	5.5037	5.4306	5.3791	1.1285	0.3794	0.0731	0.0515	19.26726	13.57406
123	133	4.039	5.1851	4.3786	4.3092	4.2518	1.1461	0.3396	0.0694	0.0574	20.43581	16.90224
52	133.5	5.1561	6.381	5.5249	5.4516	5.3894	1.2249	0.3688	0.0733	0.0622	19.87527	16.86551
67	134	4.7972	5.9401	5.1368	5.0694	5.0098	1.1429	0.3396	0.0674	0.0596	19.84688	17.55006
22	134.5	5.3796	6.5127	5.7484	5.6764	5.6175	1.1331	0.3688	0.072	0.0589	19.52278	15.97072
51	135	5.336	6.4855	5.7058	5.6383	5.572	1.1495	0.3698	0.0675	0.0663	18.25311	17.92861

19	135.5	5.3436	6.5426	5.7248	5.6532	5.5828	1.199	0.3812	0.0716	0.0704	18.78279	18.468
63	136	4.6308	5.8197	4.9839	4.9139	4.8551	1.1889	0.3531	0.07	0.0588	19.82441	16.65251
114	136.5	4.1315	5.3891	4.5115	4.4345	4.37	1.2576	0.38	0.077	0.0645	20.26316	16.97368
71	137	5.1802	6.3745	5.5429	5.4684	5.4076	1.1943	0.3627	0.0745	0.0608	20.54039	16.76317
42	137.5	4.9177	6.0548	5.2738	5.2025	5.1421	1.1371	0.3561	0.0713	0.0604	20.02247	16.96153
48	138	5.803	6.9969	6.1755	6.1015	6.0382	1.1939	0.3725	0.074	0.0633	19.86577	16.99329
46	138.5	5.5224	6.6169	5.861	5.7906	5.7334	1.0945	0.3386	0.0704	0.0572	20.79149	16.89309
41	139	4.2716	5.4292	4.6393	4.5687	4.5035	1.1576	0.3677	0.0706	0.0652	19.20044	17.73185
47	139.5	4.9902	6.1567	5.3484	5.2778	5.2145	1.1665	0.3582	0.0706	0.0633	19.70966	17.67169
12	140	5.1323	6.3668	5.514	5.4387	5.3773	1.2345	0.3817	0.0753	0.0614	19.72753	16.08593
117	140.5	3.8985	5.1491	4.2843	4.2082	4.1466	1.2506	0.3858	0.0761	0.0616	19.72525	15.96682
13	141	5.8519	7.0726	6.204	6.1349	6.0776	1.2207	0.3521	0.0691	0.0573	19.62511	16.27379
28	141.5	5.2168	6.3808	5.5578	5.4844	5.4309	1.164	0.341	0.0734	0.0535	21.52493	15.68915
60	142	5.1511	6.3309	5.508	5.4339	5.3774	1.1798	0.3569	0.0741	0.0565	20.76212	15.83076
108	142.5	4.0745	5.3295	4.5012	4.4209	4.3613	1.255	0.4267	0.0803	0.0596	18.81884	13.96766
7	143	4.9141	6.1372	5.2927	5.2199	5.1639	1.2231	0.3786	0.0728	0.056	19.22874	14.79134
38	143.5	5.5722	6.7934	5.9285	5.8573	5.8012	1.2212	0.3563	0.0712	0.0561	19.98316	15.74516
11	144	5.4047	6.6319	5.7791	5.7058	5.647	1.2272	0.3744	0.0733	0.0588	19.57799	15.70513
6	144.5	5.6729	6.9029	6.0391	5.9655	5.9063	1.23	0.3662	0.0736	0.0592	20.09831	16.16603
55	145	4.6327	5.8228	5.0002	4.9296	4.8712	1.1901	0.3675	0.0706	0.0584	19.21088	15.89116
37	145.5	5.022	6.2464	5.3862	5.3108	5.2541	1.2244	0.3642	0.0754	0.0567	20.70291	15.56837
8	146	5.4325	6.6171	5.8	5.7288	5.675	1.1846	0.3675	0.0712	0.0538	19.37415	14.63946
25	146.5	5.1314	6.3267	5.5122	5.4425	5.3809	1.1953	0.3808	0.0697	0.0616	18.30357	16.17647
35	147	5.6162	6.8314	5.9845	5.9168	5.8565	1.2152	0.3683	0.0677	0.0603	18.38175	16.37252
110	147.5	4.0467	5.2964	4.4238	4.3512	4.2861	1.2497	0.3771	0.0726	0.0651	19.25219	17.26333
10	148	4.6933	5.8858	5.0587	4.9913	4.9307	1.1925	0.3654	0.0674	0.0606	18.44554	16.58456
39	148.5	5.081	6.3807	5.4746	5.4017	5.3339	1.2997	0.3936	0.0729	0.0678	18.52134	17.22561
120	149	4.1811	5.4335	4.5694	4.498	4.4293	1.2524	0.3883	0.0714	0.0687	18.38784	17.69251
58	149.5	5.6531	6.8075	6.0182	5.9499	5.8865	1.1544	0.3651	0.0683	0.0634	18.7072	17.36511