POSTGLACIAL VEGETATION, FIRE, AND CLIMATE HISTORY OF BLACKTAIL POND, NORTHERN YELLOWSTONE NATIONAL PARK, WY

by

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency, and is ready for submission to the Division of Graduate Education.

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ABSTRACT

Previous studies in Yellowstone National Park (YNP) suggest intensification of the summer-dry and summer-wet patterns in Yellowstone during the early Holocene when increased summer insolation caused atmospheric circulation patterns to strengthen. To examine this hypothesis further, pollen and high-resolution charcoal records were analyzed from Blacktail Pond to reconstruct fire and vegetation histories near the present transition between summer-wet and summer-dry conditions. The site currently lies in *Pseudotsuga* parkland with *Artemisia* steppe at lower elevations around the pond. The site supported sparse tundra prior to 12,000 cal yr B.P. and fires were uncommon. Between 12,000 and 11,000 cal yr B.P, fire activity increased and *Picea-Pinus* parkland was established. These changes are consistent with increasing temperature and moisture. Between 11,000 and 7600 cal yr B.P., pollen evidence of a *Pinus-Picea-Abies* forest is consistent with increased winter moisture, while high fire activity at this time indicates that summers had lower effective moisture than at present. Between 7600 and 4000 cal yr B.P., vegetation around the site shifted to parkland dominated by *Pinus, Picea, Pseudotsuga,* and *Artemisia* indicating that effective winter moisture decreased. Fire activity continued to be high during this time suggesting summers maintained low effective moisture. The development of *Artemisia* steppe around the site over the last 4000 years indicates that effective winter moisture decreased, while decreased fire activity indicates that effective summer moisture increased during this time. Winter conditions during the early Holocene that resemble a summer-wet site along with summer conditions at the same time resembling a summer-dry site could be a result of the geographical setting of Blacktail Pond near the boundary between these two precipitation regimes. Poaceae/*Artemisia* pollen ratios were used to infer wet/dry climate oscillations during the late Holocene. The fluctuations correspond well with other paleoclimate data from northern Yellowstone National Park (Gennett and Baker, 1986; Hadly, 1996; Meyer et al., 1995), and suggest that conditions were drier from 3775-3125, 2475-2225, 1700-675, and 425-75 cal yr B.P.

INTRODUCTION

An analysis of charcoal and pollen in sediments from Blacktail Pond in northern Yellowstone National Park (YNP) was considered here and put into context with other studies that have examined postglacial fire, vegetation, and climate in northern YNP (Gennett and Baker, 1986; Millspaugh et al., 2004; Whitlock and Bartlein, 1993). The results from this study help to test hypotheses about postglacial climate, vegetation, and fire history as well as the presence of late-Holocene wet/dry oscillations in northern Yellowstone.

The western United States experiences two general circulation patterns at present, which in turn affect the seasonal distribution of precipitation (Whitlock and Bartlein, 1993). The southwestern United States receives most of its precipitation during the summer when heating of the continent causes monsoonal onshore flow of moisture from the Gulf of California and the Gulf of Mexico and is referred to as a summer-wet precipitation regime. The northwestern United States experiences a summer-dry regime as a result of the expansion of the eastern Pacific subtropical high-pressure system which suppresses precipitation. This region receives high levels of winter precipitation brought by westerly storm systems (Whitlock and Bartlein, 1993).

The boundary between summer-wet and summer-dry conditions runs through the YNP region with topography in and around the park influencing the specific distribution of these regimes (Whitlock and Bartlein, 1993). Lower areas such as the northern range of YNP are dry in winter and strongly influenced by summer-wet conditions, while orographic lifting causes areas of higher elevation (the Central Plateau of YNP) to receive abundant winter precipitation as they intercept winter storms, and summer precipitation is low. Whitlock and Bartlein (1993) plotted the annual distribution of precipitation at weather stations in Idaho, Wyoming, and Montana to show the geographical distribution of these regimes (Fig. 1).

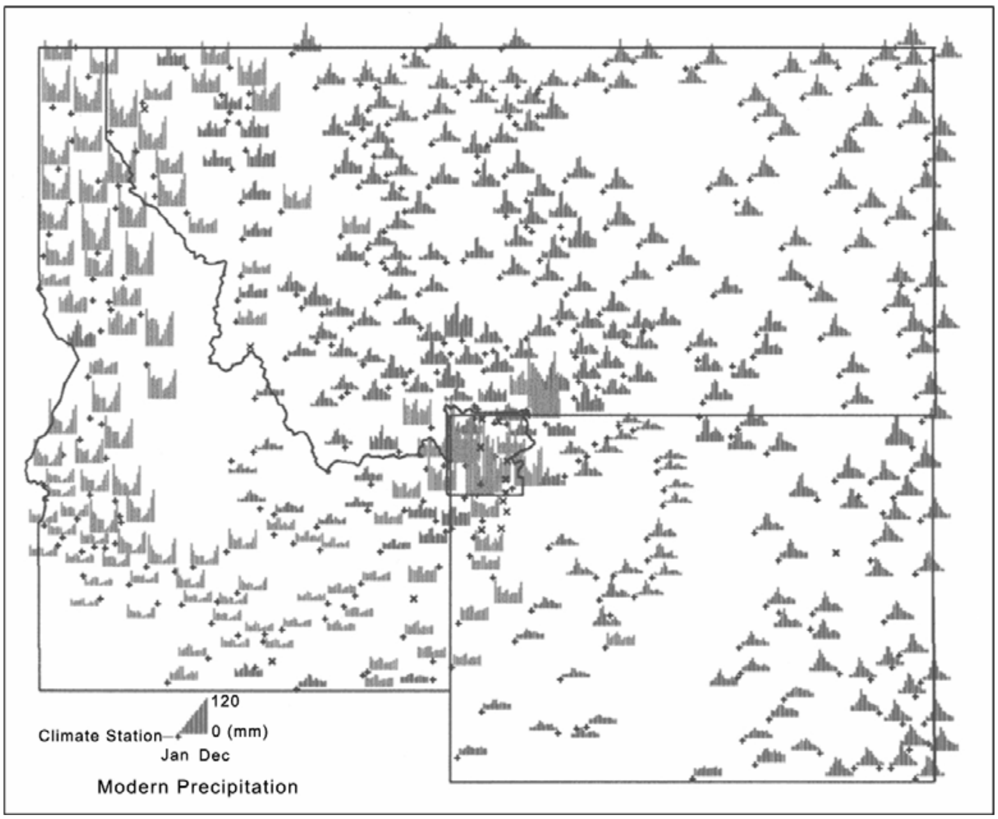

Figure 1. Map showing annual distribution of precipitation at climate stations in the Yellowstone National Park region (World WeatherDisc Associates, n.d.) (from Whitlock and Bartlein, 1993).

Pollen records suggest that the summer-wet and summer-dry conditions of the Yellowstone region were amplified during the early Holocene, when summer-wet areas became wetter and summer-dry areas became drier (Whitlock and Bartlein, 1993). The most likely cause of this amplification was the increase in northern hemisphere summer insolation between about 12,000 and 6,000 cal yr B.P. Increased summer radiation strengthened both of the major atmospheric circulation patterns that affect precipitation in this area. Millspaugh et al. (2004) compared fire and vegetation histories from sites in summer-wet and summer-dry regions of YNP to test further the hypothesis that these precipitation regimes were strengthened during the early Holocene. The first site, Slough Creek Lake (lat 44°56'N, long 110°21'W, elevation 1884 m; Fig. 2) lies in Yellowstone's northern range about 24 km east of Mammoth, WY in the summer-wet region of the park. The present vegetation around Slough Creek Lake is *Pseudotsuga* parkland, with large areas of *Artemisia* steppe. Both pollen and charcoal records from Slough Creek Lake indicate that summer-wet conditions at the site were strengthened during the early Holocene summer insolation maximum and that conditions there have become drier in the last 7000 years (Millspaugh et al., 2004; Whitlock and Bartlein, 1993).

The second site, Cygnet Lake (lat 44°39'N, long 110°36'W, elevation 2530 m; Fig. 2) lies in the Central Plateau region of YNP, an area of summer-dry conditions. Pollen data from this site suggest that the *Pinus contorta* forest of Yellowstone's Central Plateau has existed for the entirety of the Holocene, because the infertile rhyolitic substrate is incapable of sustaining other conifer species (Millspaugh et al, 2004; Whitlock, 1993). As a result, the vegetation history from this site does not show much response to past fluctuations in climate. The charcoal record from Cygnet Lake, on the other hand, was used to examine the response of fire to variations in climate over the course of the Holocene (Millspaugh et al., 2000; and Millspaugh et al., 2004). High fire frequency at Cygnet Lake during the early Holocene summer insolation maximum suggests that summer-dry conditions at the site were strengthened at that time and the site became progressively wetter with fewer fires after about 8000 cal yr B.P. (Millspaugh et al., 2004).

Whitlock and Bartlein (1993) and Millspaugh et al. (2004) considered both vegetation and fire to be affected by annual precipitation. Vegetation, however, is affected mainly by effective winter moisture in the form of snow pack (West and Young, 2000) while fires are affected by effective summer moisture (Westerling et al., 2006). Effectively wetter conditions are times when an area is cooler or receives more precipitation relative to evapotranspiration, whereas effectively drier conditions occur when an area is warmer or receives less precipitation than evapotranspiration (Etherington, 1982). In order to better understand postglacial climatic variations and to further examine the history of summer-wet vs. summer-dry precipitation regimes in the YNP region, fire and vegetation histories from a third site, Blacktail Pond, have been developed and analyzed here.

Blacktail Pond is already an important site in studies of past climate in YNP. Gennett and Baker (1986) presented a pollen record from a sediment core taken at the margin of the lake that spanned the last 14,000 years. Variations in the ratio of Poaceae to *Artemisia* pollen in their record have been used by other researchers to infer wet/dry climate oscillations over the last 4000 years in northern YNP (Meyer et al., 1995; Hadly, 1996). Higher Poaceae/*Artemisia* ratios have been interpreted as resulting from effectively wetter conditions, while lower Poaceae/*Artemisia* ratios indicate effectively drier conditions. Meyer et al. (1995) reconstructed a history of fire-related sedimentation events in the Soda Butte Creek drainage basin based on radiocarbon-dated charcoal particles in debris flow deposits. Fire-related sedimentation events were attributed to drier periods, before 3400 cal yr B.P., from 2700 to 2050, 1200 to 750, and after 150 cal yr B.P. They attributed terrace tread formation at Soda Butte Creek and overbank sedimentation at Soda Butte Creek, Slough Creek and the Lamar River, from 3400 to 2700, 2050 to 1200, and 750 to 150 cal yr B.P. to cool, effectively wetter conditions (Meyer et al., 1995).

Hadly (1996) investigated mammalian responses to climate change in the late Holocene by reconstructing faunal assemblages from fossils found in Lamar Cave in northern YNP. The chronology for this study was developed by radiocarbon dating of wood, charcoal, and bone deposits. The most common species used to infer environmental changes were the pocket gopher (*Thomomys talpoides*), montane vole (*Microtus* sp.), and Uinta ground squirrel (*Spermophilus armatus*). Higher levels of *Thomomys* and *Microtus* from 3200 to about 1200 cal yr B.P. suggested that conditions were wetter than today. After about 1200 cal yr B.P., an increase in *Spermophilus* implied drier conditions, with the driest period corresponding to the Medieval Climate Anomaly (1150 to 650 cal yr B.P). A return to mostly *Thomomys* and *Microtus* was evidence of cooler, wetter conditions occurring during the Little Ice Age (550 to 50 cal yr B.P.).

In order to determine if the Poaceae/*Artemisia* pollen ratios from Blacktail Pond used by Hadly (1996) and Meyer et al. (1995) are a robust proxy for wet/dry fluctuations, and to gain a better understanding of the late-Holocene climate of northern YNP, the ratios of these taxa were examined again in this study of Blacktail Pond.

Site Description

Blacktail Pond (lat 44°57’16” N, long 110°36’15” W, elevation 2012 m; Fig. 2) lies in a kettle-hole depression 8 km east of Mammoth, in northern YNP. Surficial geology around the site consists of late-Pinedale glacial outwash with ice-block depressions (Pierce, 1973). The Blacktail Pond valley served as a meltwater channel draining the Blacktail Deer Plateau during the Deckard Flats recessional sequence (Pierce, written comm. 2007). Farther recession of the ice permitted Blacktail Deer Creek to then drain northward to the Yellowstone River, leaving a marshy environment and a string of kettle lakes in the Blacktail Pond valley (Pierce, 1973; Pierce, 1979; Pierce, written comm. 2007). The string of kettle lakes, with a northeast-southwest orientation, is fed mainly by subterranean springs and one small stream at the extreme southwest end of the lakes. Water depth reaches 8.3 m in the deepest part, and an outlet is located at the northeast end of the lakes (Sharpe and Arnold, 1967).

Bedrock geology is late Cenozoic rhyolite tuffs and basalts. There is no limestone in the local bedrock, but limestone and dolostone fragments are present in the glacial till and gravel. Madison Group limestone and dolomite crops out at 3.5 km east of Blacktail Pond, and to a larger but minor extent farther up valley (USGS, 1972). ^{10}Be dating of moraines indicates an age of 14.3 ± 1.2 ^{10}Be ka for deglaciation in the Deckard Flats area and 15.3 ± 1.4 ^{10}Be ka for moraines up valley at Junction Butte, suggesting deglaciation occurred in the region between about 14,000 to 15,000 cal yr B.P. (Licciardi and Pierce, in press). Thus, 14,000 cal yr B.P. was used as the maximum age for the Blacktail Pond record.

Whitlock and Bartlein (1993) identified this area as lying within the summer-wet region of northern YNP, in contrast to the summer-dry region of central and southern YNP based on the summer to winter precipitation ratios at present (Western Regional Climate Center, 2007). Climate information is available from Mammoth, YNP, located 8 km west of Blacktail Pond, and from Tower Falls, 18 km southeast of Blacktail Pond (Fig. 2), for the period 1948 to 2007 (Table 1).

Since both Mammoth and Tower Falls receive more precipitation in summer than in winter, Blacktail Pond, which lies between them, is best considered a summer-wet site (Western Regional Climate Center, 2007).

Table 1. Temperature and precipitation data from climate stations near Blacktail Pond (Western Regional Climate Center, 2007)

Climate Station	**Mean Annual Temp. (°C)**	**Average Annual Precipitation (cm)**	**Ratio of Jun, July, Aug: Dec, Jan, Feb Precipitation**
Mammoth	4.6	38	1.78
Tower Falls	2	42	1.50

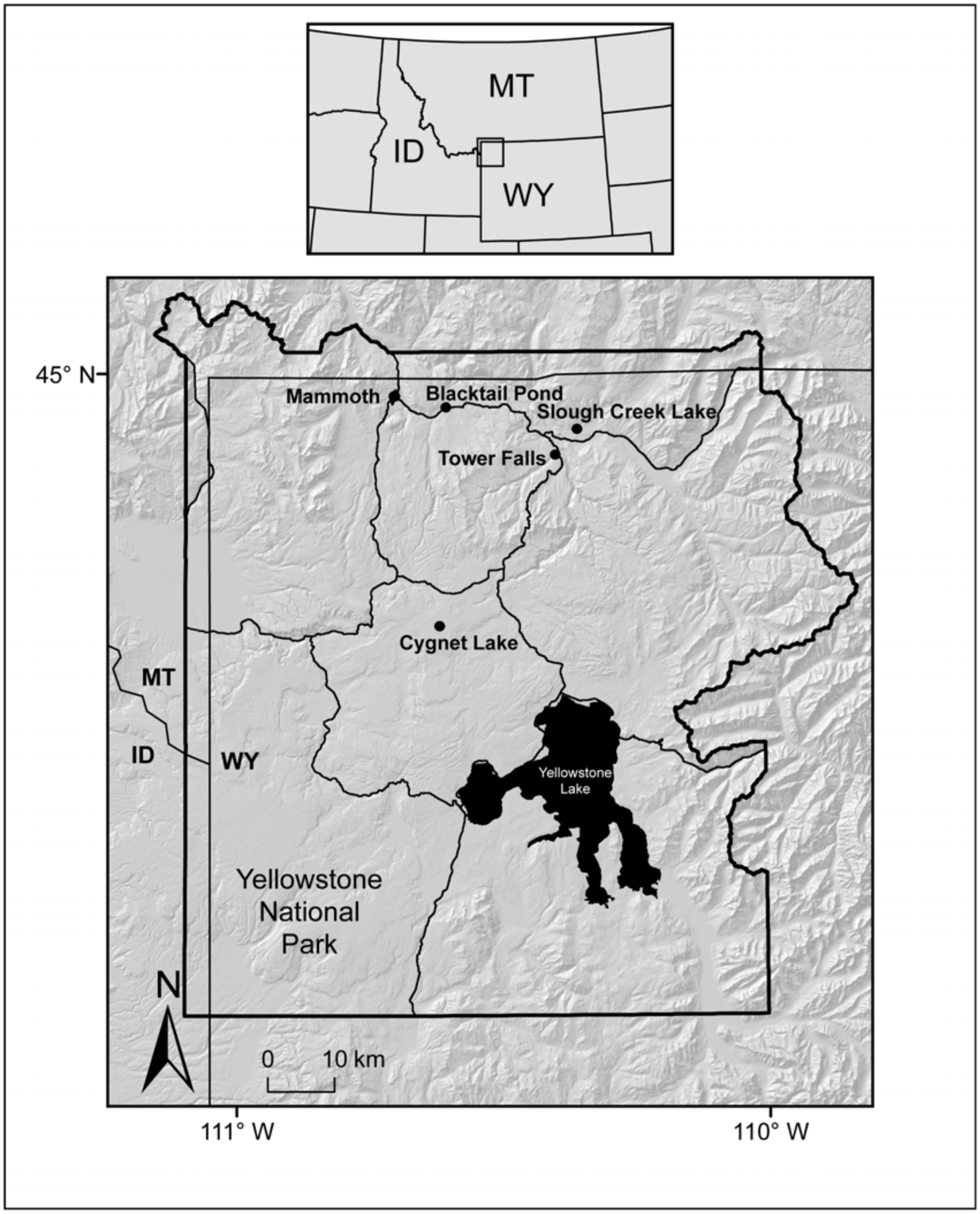

Figure 2. Map showing locations of Yellowstone National Park, Blacktail Pond, Slough Creek Lake, Cygnet Lake, Mammoth, and Tower Falls.

Vegetation in northern Yellowstone National Park is arrayed mainly by elevation, as higher areas are generally cooler and wetter (Baker, 1986). *S*teppe dominated by big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and Idaho fescue (*Fescua idahoensis*) predominates below about 1700 m elevation. Montane conifer forests occur between about 1700 and 3000 m elevation, with dominant taxa varying based upon elevation, including *Pinus flexilis* and *Juniperus scopulorum* (1700 to 1900 m elevation), *Pseudotsuga menziesii* (1900 to 2000 m elevation), *Pinus contorta* (2000 to 2400 m elevation), *Picea engelmannii* and *Abies lasiocarpa* (2400 to 2800 m elevation) and *Pinus albicaulis* (2800 to 2900 m elevation). Alpine tundra exists above about 2900 m elevation (Baker, 1986; Steele et al., 1983). Substrate is also an important control on the vegetation, with *Pinus contorta* growing on infertile rhyolitic soils, grassland and steppe on nutrient-rich calcareous glacial till, and mixed conifer forests on andesite (Despain, 1990).

Blacktail Pond is surrounded by steppe, dominated by *Artemisia tridentata* and Poaceae with herbs including those from the Asteraceae, Rosaceae, and Polygonaceae families. Stands of *Pseudotsuga menziesii* grow on the slopes around Blacktail Pond and small patches of *Abies* and *Picea* grow in moist cool gullies near the site. *Populus tremuloides* grow in isolated stands to the east of the lake, and *Salix* is present along the seasonal outlet from the Pond and in areas of springs and seepage. Cyperaceae (including *Scirpus americanus* and *Carex* sp.) as well as *Typha* grow along the boggy shoreline of the pond. The most dominant submerged aquatic plant in Blacktail Pond is *Chara* sp. and others include *Utricularia* sp. and *Myriophyllum* sp. (Sharpe and Arnold, 1967).

METHODS

Field Methods

Sediment cores, approximately 6.2 m in length, were retrieved from the southwestern basin of Blacktail Pond with a 5-cm-diameter Livingstone square-rod piston sampler (Wright et al., 1984) from the ice surface in January, 2006. The cores, BTP06A and BTP06B were extruded in the field, wrapped in plastic wrap and aluminum foil and transported to the Paleoecology Lab at Montana State University where they were refrigerated. All analyses were performed on core BTP06A, and gaps in recovery from 50-54 cm, 150-154 cm, 245-250 cm, and 348.5-350 cm depths were filled in with sediment from core BTP06B following careful stratigraphic correlation. An 85 cm-long short core was retrieved using a 7-cm-diameter Klein piston corer to recover intact the mud-water interface and the upper meter of sediment. The short core was sampled in the field at 1-cm intervals into plastic bags and refrigerated.

Loss on Ignition and Magnetic Susceptibility

In order to determine organic and carbonate contents of the core, which serve as proxies for lake productivity, 1-cm^3 samples were collected at 4 cm intervals to a depth of 5.44 m for loss-on-ignition analysis (LOI) (Dean, 1974). Samples were dried at 90°C for 24 hours and weight loss was measured after heating to 550°C for 2 hours to remove organics to and 900°C for 2 hours to remove carbonates.

Measurement of sediment magnetic susceptibility, a function of allochthonous magnetic mineral content, was undertaken to determine variations in the amounts of erosion into Blacktail Pond (Gedye et al., 2000; Thompson and Oldfield, 1986). Samples of 3-cm^3 volume were measured at 1-cm intervals from 0 to 2.7 m depth and 0.5 cm intervals from 2.7 to 4.7 m depth using a Bartington MS2 dual frequency susceptibility meter (Dearing, 1999). The results are presented in CGSx10^{-6}.

Pollen

Pollen analysis was undertaken in order to reconstruct a local vegetation history at Blacktail Pond. Sediment samples of 1-cm^3 were collected at 8-cm intervals to a depth of 444 cm. Pollen was extracted using the methods of Bennett and Willis (2002), apart from the acetolysis procedure, which was replaced by the use of Schultze's solution (Doher, 1980). A tablet containing a known concentration of *Lycopodium* spores was added to each sample in order to calculate pollen concentration (grains cm^{-3}) and pollen accumulation rates (PAR; grains cm^{-2} yr^{-1}). Pollen residues were mounted in silicone oil and observed at 400x magnification. Between 300 and 500 pollen grains were identified per sample to the lowest taxonomic level possible by comparison with reference slides and published pollen identification keys (e.g. Kapp et al., 2000; Moore and Webb, 1978). Percentages of pollen taxa at each depth were based on the sum of total terrestrial pollen grains at that depth.

Based on modern phytogeography, diploxylon-type *Pinus* grains were attributed to *Pinus contorta* and haploxylon-type *Pinus* grains were attributed to *Pinus albicaulis* or

Pinus flexilis (Baker, 1986). *Pinus* grains lacking distal membranes were identified as *Pinus* Undifferentiated. Grains that were unidentifiable because of damage were counted as ‘Degraded’. The record was divided into 5 zones, using a constrained cluster analysis of the pollen percentages (Grimm, 1987). Past vegetation was reconstructed based on changes in pollen percentages of total terrestrial grains and accumulation rates. Pollen percentages in each zone were compared to modern pollen rain from four studies (Baker, 1976; Bright, 1966; Fall, 1994; Whitlock, 1993) and pollen accumulation rates (PAR) compared to modern PAR from two published studies (Fall, 1992; Ritchie and Lichti-Federovich, 1967).

Charcoal

To reconstruct a local fire history at Blacktail Pond, macroscopic charcoal was isolated from the sediment by soaking each sample in 20 ml of 5% sodium metaphosphate and 20 ml of 6% bleach for 24 hours and rinsing it through nested 250µm and 125µm sieves. Charcoal particles were tallied at 1-cm intervals from 0 to 2.7 m depth and 0.5 cm intervals from 2.7 to 4.7 m depth. These sizes were chosen because particles >250µm um are not transported far from their source and thus provide information on local fire history (Whitlock and Millspaugh, 1996; Whitlock and Larsen, 2001). The counts from the two size fractions were later combined, because they showed the same trends. Grass charcoal was also distinguished from wood charcoal, but changes in the grass charcoal/total charcoal ratio followed changes in the abundance of grass pollen throughout the record suggesting that it did not provide additional information on past fire regimes.

Statistical treatment of charcoal data in this study was done using CharAnalysis software (Higuera, 2007a) and follows the principles described in Long et al. (1998). Charcoal counts were re-sampled in contiguous 25-year bins (the median resolution of the record) in order to provide equally spaced samples over time through the record. The re-sampled values were based on the proportion that each overlapping count had within the 25-year bin. Charcoal accumulation rates (CHAR; particles cm^{-2} yr^{-1}) were determined by dividing concentrations (particles cm^{-3}) by deposition time (yr cm^{-1}). The CHAR data were separated into two components: a slowly varying trend in the data, which is attributed to millennial-scale changes in fuel biomass (Marlon et al., 2006), and positive CHAR values above a prescribed threshold, which were inferred to represent fire episodes (Long et al., 1998). A fire episode may represent one or more fires occurring within the time span of the bin. Slowly varying trends in CHAR, referred to as background charcoal (BCHAR), were determined using a 500-year lowess smoother, robust to outliers. This value was selected because it has been used to standardize charcoal records from other sites in the northwestern United States (Marlon et al., 2006). To determine charcoal episodes, BCHAR was subtracted from CHAR, leaving a residual, referred to here as RCHAR. The noise distribution of RCHAR within a 500-year window around every sample was plotted and fitted with a Gaussian mixture model. For every sample, the 95th percentile of the noise distribution was used to define a threshold value. Threshold values throughout the record were smoothed with a 500-year lowess smoother following previous studies in YNP (Marlon et al., 2006) and fire events were identified as times when RCHAR values exceeded this smoothed 95% threshold. Fire-episode frequencies (episodes 1000 yr $^{-1}$) were smoothed with a 2000 year window (lowess smoother) following previous studies in YNP (Marlon et al., 2006). CHAR episodes that had a >5% chance of coming from the same Poisson distribution as minimum CHAR in a surrounding 150 year window were disqualified from consideration as episodes. Fire-episode magnitudes (particles cm^{-2} episode^{-1}) are dependent upon the amount of charcoal produced during an episode, and vary based upon the size, severity, and proximity of the fires (Whitlock et al., 2006; Whitlock and Millspaugh, 1996).

Because the long core did not recover the uppermost centimeters of sediment, the charcoal stratigraphy from the short core was used to extend the record up to the present day. The short core charcoal stratigraphy was correlated with that from the long core for this purpose. Charcoal concentrations (particles cm^{-3}) in the Blacktail Pond short core were calculated from charcoal counts at 1-cm intervals and sedimentation rates were determined from the ^{210}Pb chronology. Charcoal accumulation rates (CHAR; particles cm^{-2} yr^{-1}) were determined by dividing concentrations (particles cm^{-3}) by deposition time (yr cm^{-1}) (J. Yale, unpublished data).

Charcoal records from Slough Creek Lake and Cygnet Lake were re-analyzed using the same parameters as at Blacktail Pond, which caused them to look slightly different from the original published records. The differences arise from the use of a local threshold, rather than a global threshold, and determination of episodes based on residuals of CHAR minus BCHAR rather than using a threshold ratio of 1. Slough Creek

Lake was re-sampled in 26-year bins and Cygnet Lake was re-sampled in 20-years bins because these were the median resolutions of the records.

Chronology

The Blacktail Pond chronology was based on four AMS ^{14}C dates of terrestrial plant material and identification of a 0.5 cm thick ash deposit at a depth of 2.68 m as the Mazama Ash (Table 2). Glacier Peak Ash was reported deep in a Blacktail Pond sediment core from Gennett and Baker (1986) but was not found in either core BTP06A or BTP06B.

Table 2. Uncalibrated radiocarbon dates and calibrated ages for Blacktail Pond

Depth (cm)[a]	**Core**[b]	**Depth in BTP06A (cm)**[c]	**Uncalibrated ^{14}C age (^{14}C yr B.P.)**	**Calibrated age (cal yr B.P.) with 2 sigma range**[d]	**Material dated**	**Lab number**[e]
85	BTP06A	same	2138±39	2126 (2199-2201)	wood	AA70023
181-184	BTP06A	same	8010±60	8870 (8682-9021)	Insect chitin or aquatic plant	N76635
268	BTP06A	same	6730±40	7597 (7560-7667)	Mazama Ash	Znadowicz et al., 1999
343	BTP06A	same	8485±40	9501 (9450-9537)	charcoal	N76636
384	BTP06B	386.7	9444±57	10,683 (10,515-10,799)	charcoal	AA0024
410	BTP06B	412.5	10,414±71	12,317 (12,061-12,422)	twig	AA70025

[a] Depth below mud-water interface.
[b] Core from which sample was taken.
[c] Depth of sample in BTP06A following stratigraphic correlation.
[d] Calibrated ages derived from CALIB 5.0.1 (Stuvier et al., 2005). The two sigma range is given in parentheses.
[e] AA-University of Arizona AMS Faclility; N-Lawrence Livermore AMS facility.

Five macrofossils were submitted for radiocarbon dating, but one date was excluded from the age-depth model because it was out of sequence and judged to be too old based upon its position stratigraphically above the Mazama Ash. The material was originally thought to be insect chitin but may have been from aquatic zooplankton or macrophytes that incorporated ancient carbon. Blacktail Pond lies in a watershed containing carbonate till and gravel, which would result in depleted levels of ^{14}C for the water and its inhabitants when compared to terrestrial organisms existing at the same time.

A range of possible calibrated dates with probability distributions were determined for every radiocarbon date using Calib 5.0.1 (Stuiver et al., 2005). Monte Carlo sampling was used to generate a cubic smoothing spline through all the dates 2000 times, and the final age-depth model was based on the median of all the runs (Higuera, 2007b) (Fig. 3). Because cosmogenic exposure ages from boulders in recessional moraines indicate that deglaciation in the area occurred around 14,000 cal yr B.P. (Licciardi and Pierce, in press), I considered this to be the likely age for the bottom of the core, at 6.2 m depth. Lack of ^{14}C dates below the clay/gyttja boundary (ca. 12,000 cal yr B.P.), however, prevents direct determination of basal age.

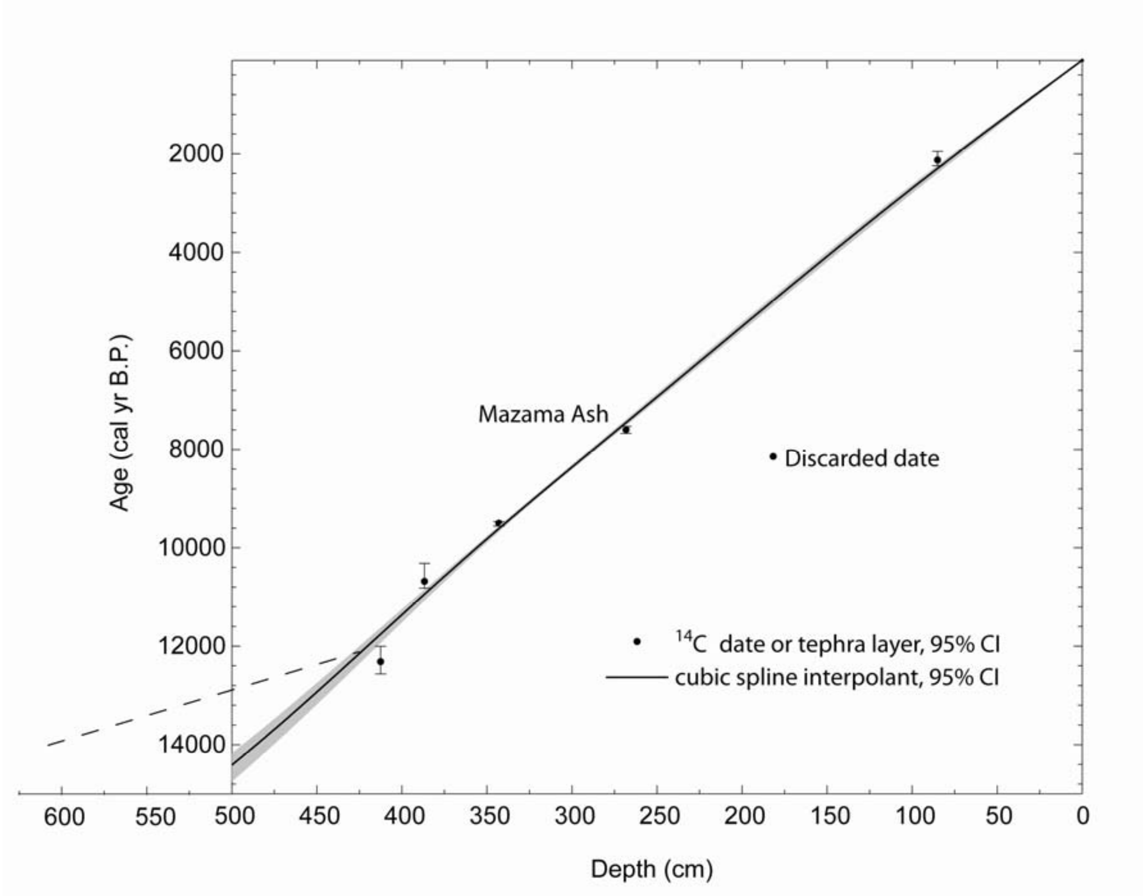

Figure 3. Age depth model for Blacktail Pond core BTP06A. Dashed line represents inferred but unconfirmed curve below 12,000 cal yr B.P. More rapid sedimentation below 12,000 cal yr B.P. is likely based on high allochthonous content, as well as low organic, pollen, and charcoal content in sediment below this depth. Inferred age for base of core at 6.2 m depth is 14,000 cal yr B.P. based on age of local deglaciation (Licciardi and Pierce, in press).

In order to compare the Cygnet Lake and Slough Creek Lake records with the data from Blacktail Pond, new age models were developed for those sites, based on the original radiocarbon dates calibrated to current standards (Calib 5.0.1; Stuiver et al., 2005) and the Monte Carlo age-depth model described earlier (Higuera, 2007b). The new chronologies were similar to the original published ones, with the Slough Creek Lake chronology differing less than 400 years at all depths and that from Cygnet Lake differing less than 550 years at all depths.

Samples for ^{210}Pb dating were submitted from the short core at contiguous 1-cm intervals to 20 cm depth in order to develop a chronology for use with charcoal analysis performed on the core. Age determinations from the short core were based on a second-order polynomial (Table 3) (J.Yale, unpublished data).

Table 3. Short core ^{210}Pb concentrations, age determinations, and age model for Blacktail Pond

Depth (top cm)[a]	**^{210}Pb dpm g^{-1}[b]**	**Age (cal yr B.P.)**
0	-	-56
1	24.75	-54
2	20.37	-52
3	15.74	-49
4	14.06	-46
5	13.24	-42
6	11.67	-38
7	12.15	-34
8	10.86	-29
9	11.59	-24
10	9.18	-18
11	7.45	-12
12	7.37	-6
13	6.18	1
14	7.71	8
15	5.36	15
16	6.3	23
17	7.01	31
18	5.51	40
19	7.3	49
20	7.36	59
21	5.25	68

Blacktail Pond short core age model (cal yr B.P.)
Age = 0.1959 * depth^2 + 1.8103 * depth - 56
[a] Depth below mud surface.
[b] Concentrations provided by Dr. James Budahn at the U.S. Geological Survey, Denver, CO.

RESULTS

<u>Lithology</u>

The freshwater carbonate-rich sediment (i.e., marl) at Blacktail Pond was likely precipitated authigenically from the Charophytes (*Chara*) living in the water. Most growth and photosynthesis of *Chara* occurs in shallow water during the summer months. Increased carbonate content implies warmer, longer summers, increased alkalinity, and possibly decreased lake levels through greater evaporation (Pentecost et al., 2006).

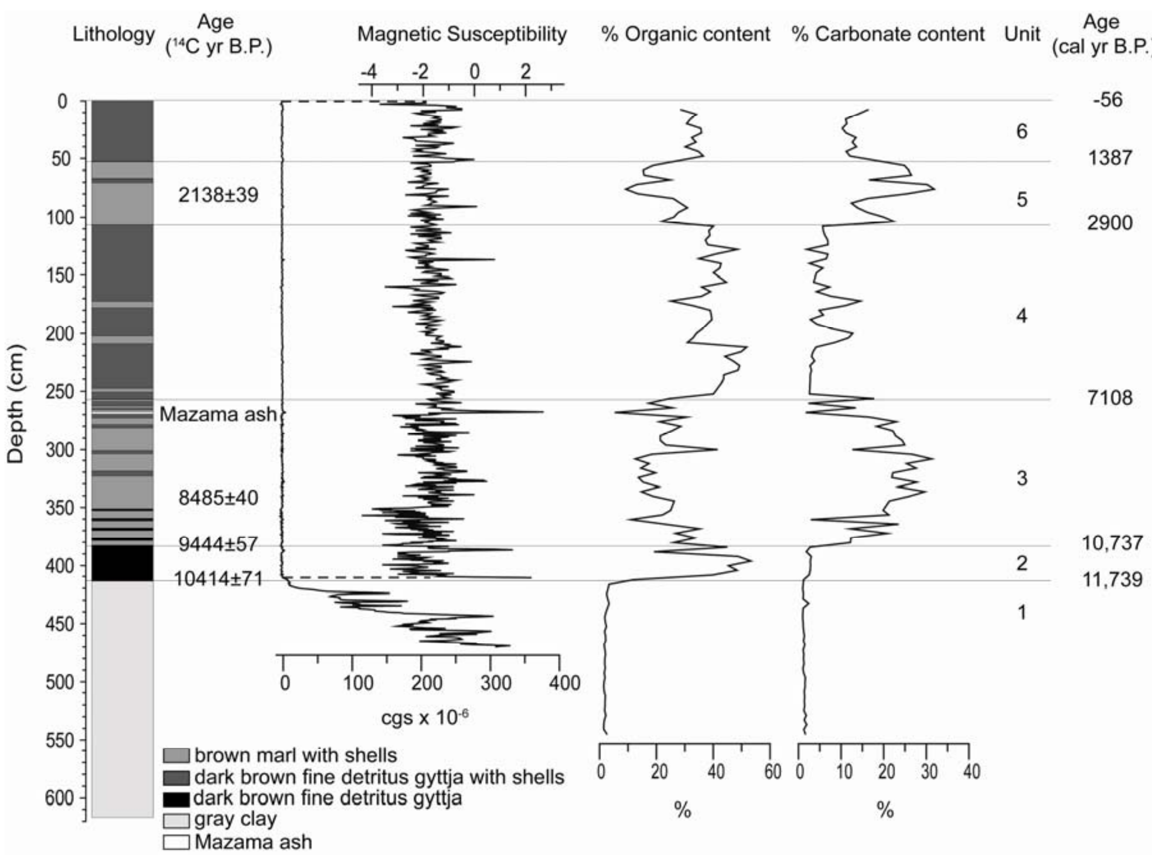

Figure 4. Lithology, magnetic susceptibility, organic content, and carbonate content in Blacktail Pond core BTP06A.

Core BTP06A was divided into six lithologic units (Fig. 4). The lowest unit from 6.20 to 4.12 m depth was composed of gray clay. Loss on ignition analysis of sediment from 5.44 to 4.12 m depth indicates low organic content (~2%) and low carbonate content (~1.3%), and magnetic susceptibility of sediment from 4.70 to 4.12 m depth was higher than the rest of the core (5.8 to 329.0 cgs x 10^{-6}). The low organic and carbonate content of this unit suggests that the lake was unproductive at the time it was deposited or that organic matter was flushed out of system before deposition. The elevated magnetic susceptibility indicates a high influx of allochthonous clastic material, which was composed mostly of clay-sized particles. The second unit from 4.12 to 3.80 m depth contained dark brown fine detritus gyttja with low to moderate magnetic susceptibility (-3.6 to 6.3 cgs x 10^{-6}), high organic content (~40%), and low carbonate content (~2.5%). The highly organic composition of this unit suggests a productive environment. The decrease in magnetic susceptibility implies a reduction in clastic mineral input to the lake, and most of the sediment came from autochthonous material. The weakly negative (diamagnetic) susceptibility of sediment samples in and above this unit is likely the result of varying amounts of carbonate minerals in the material (Dearing, 1999). The third lithologic unit from 3.80 to 2.56 m depth consisted of light brown marl with shells, interbedded with layers of dark brown fine detritus gyttja with and without shells. Sediment magnetic susceptibility was low (-3.2 to 0 cgs x 10^{-6}) with the exception of the layer at 2.68 m depth containing Mazama Ash (2.7 cgs x 10^{-6}). Organic content and carbonate content (~22% and 20%) were relatively high and suggest increased lake productivity and precipitation of marl from dissolved $CaCO_3$. The fourth unit from 2.56

to 1.08 m depth consisted of dark brown fine detritus gyttja with shells, interbedded with light brown marl with shells. Magnetic susceptibility was low (-3.5 to 0.8 cgs x 10^{-6}), organic content was high (~40%), and carbonate content was low (~6%), implying that the lake was productive but authigenic precipitation of $CaCO_3$ decreased. The fifth unit, from 1.08 to 0.52 m depth, contained light brown marl with shells along with interbedded dark brown fine detritus gyttja with shells. Magnetic susceptibility was low (-2.7 to 0.1 cgs x 10^{-6}), organic content was moderate (~22%), and carbonate content was moderate (~21%). The upper unit from 0.52 m depth to the top of the long and short cores was composed of watery gyttja with shells, with low magnetic susceptibility (-3.7 to 0 cgs x 10^{-6}), high organic content (~33%) and moderate carbonate content (~13%).

Pollen

The Blacktail Pond vegetation reconstruction was based on the interpretation of five pollen zones: Zone BP-1, alpine tundra; Zone BP-2, *Picea, Pinus* parkland with *Betula*; Zone BP-3, mixed conifer forests dominated by *Pinus*, *Picea*, and *Pseudotsuga*; Zone BP-4, parkland dominated by *Pinus, Picea*, and *Pseudotsuga*; and Zone BP-5, *Pinus contorta*, *Pseudotsuga* parkland and *Artemisia* steppe (Fig. 5). Percentages of pollen taxa and pollen accumulation rates (PAR) for each zone are listed as mean values unless otherwise noted.

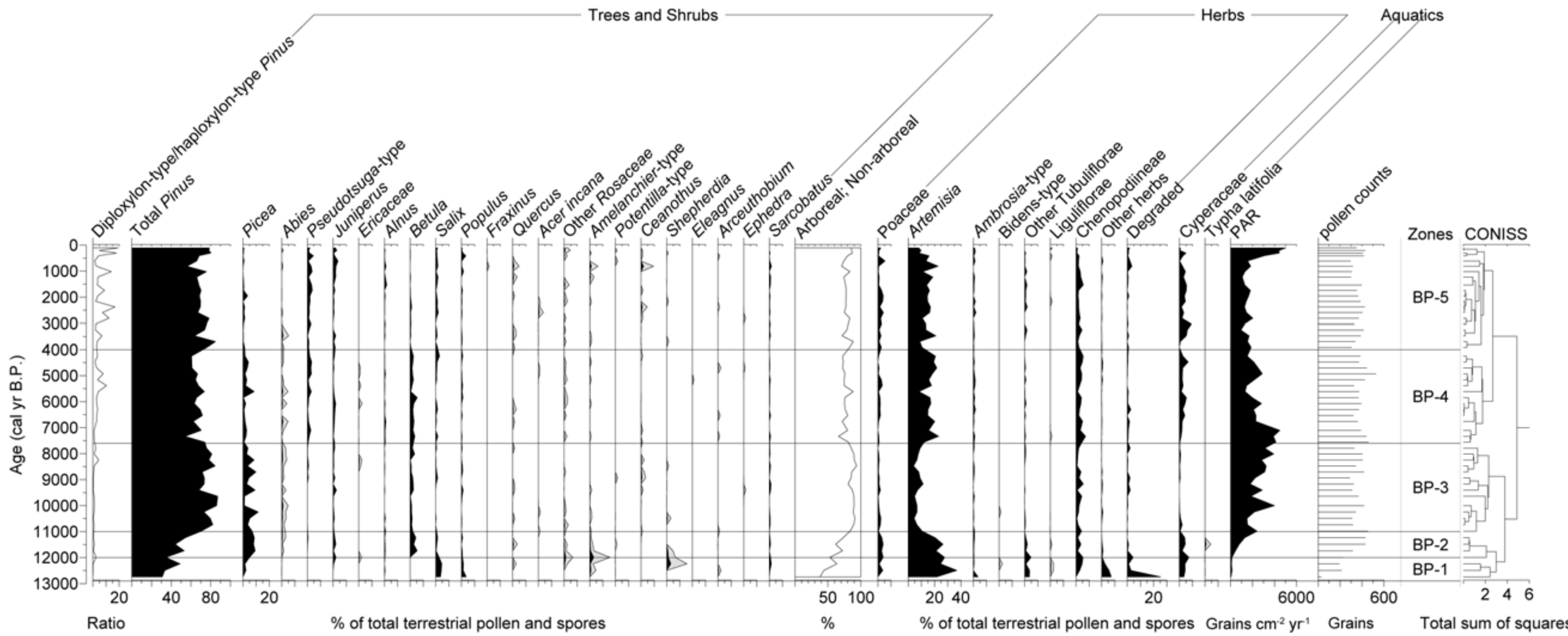

Figure 5. Pollen percentages at Blacktail Pond over the last 13,000 cal yr B.P.

Zone BP-1 (4.44-4.28 m depth; 13,000-12,000 cal yr B.P.): Percentages of Poaceae (1.6%), *Artemisia* (28%), other herbs (5.2%), and Cyperaceae (4.1%) were high, and *Pinus* (38%, mostly haploxylon-type) was moderate in this zone. *Picea* (1.3%), *Salix* (4.2%), *Populus* (2.2%), Rosaceae (0.5%) Asteraceae Tubiliflorae (2.8%), and Chenopodiineae (2.5%) were present in low amounts. This zone contained an especially high percentage (10%) of degraded grains, possibly the result of surface exposure prior to deposition. Total nonarboreal pollen percentages were high (52%) and PAR for this zone was low (87 grains cm^{-2} yr^{-1}).

PAR for Zone BP-1 fits within the range of values for modern PAR from tundra in arctic-subarctic Canada (5 - 762 grains cm^{-2} yr^{-1}) (Ritchie and Lichti-Federovich, 1967). The pollen assemblage in this zone resembles modern pollen rain from alpine tundra in the Wind River Range, WY, except that in modern assemblages, Poaceae is more abundant (7.7%), and *Salix* (1.3%) and *Artemisia* are less abundant (19%) than in Zone BP-1 (Fall, 1994). Pollen rain from alpine tundra in Yellowstone National Park has lower percentages of Poaceae (3-5%) and more closely matches this record (Whitlock, 1993). High *Salix* values suggest the presence of willow in riparian settings (Fall, 1994). Modern pollen assemblages from alpine tundra in the Wind River Range and YNP are dominated by diploxylon-type *Pinus* grains rather than haploxylon-type grains (Fall, 1994; Whitlock, 1993), reflecting the input of *Pinus contorta* pollen from lower elevations (Fall, 1994). The haploxylon-type *Pinus* growing below Blacktail Pond was most likely *Pinus albicaulis* since it grows in modern high-elevation environments in YNP; *P. flexilis* is predominantly a lower elevation (<2000 m elevation) taxa (Baker, 1986), but it also grows in exposed settings and may also have contributed to the pollen type. *Populus tremuloides* stands most likely grew near the site, since 1 to 2% *Populus* pollen shows up in *Artemisia* steppe when *Populus tremuloides* grows within a few hundred meters of the site (Bright, 1966). *Polygonum bistortoides*-type pollen is a common component of pollen rain from modern tundra environments (Fall, 1994), but it was insignificant in this record. Based on these components, the vegetation around Blacktail Pond between 13,000-12,000 cal yr B.P. was likely alpine tundra with patches of *Salix* and *Populus* nearby.

Zone BP-2 (4.20-3.96 m depth; 12,000-11,000 cal yr B.P.): Percentages of *Picea* (7.8%), *Juniperus* (1.5%), *Betula* (3.1%), Poaceae (3.4%), *Artemisia* (24%) and Cyperaceae (4.6%) were high. *Pinus* values (47%) were moderate with equal amounts of diploxylon-type and haploxylon-type identified. Pollen of *Salix* (1.3%), *Populus* (0.6%), *Rosaceae* (0.5%), Asteraceae Tubiliflorae (2.2%), and Chenopodiineae (3%) were present in low amounts. Nonarboreal pollen percentages were moderate, about 35%, and PAR averaged 663 grains cm^{-2} yr^{-1}.

PAR from this zone falls within the range of values from the modern forest-tundra ecotone of arctic-subarctic Canada (5-762 grains cm^{-2} yr^{-1}) (Ritchie and Lichti-Federovich, 1967). Pollen percentages resemble those from modern *Pinus albicaulis* parkland between alpine tundra and mixed conifer forest in the Wind River Range, WY (Fall, 1994). Zone BP-2, however, contained higher *Picea* and Cyperaceae percentages than modern parkland samples. Modern samples from *Pinus albicaulis* parkland also feature higher percentages of diploxylon-type than haploxylon-type *Pinus* grains (63-

93%) than this record. *Betula* was especially high in this zone when compared to values from modern *Pinus albicaulis* parkland, since the taxa was not even mentioned in the modern study (Fall, 1994). Vegetation around Blacktail Pond during the time of Zone BP-2 most likely resembled parkland at the forest-tundra ecotone. *Picea engelmannii* and *Pinus albicaulis* would have grown in scattered stands among open meadows dominated by *Artemisia* and Poaceae. *Betula glandulosa* and Cyperaceae would have occupied wet areas. *Pinus contorta* and *Pinus flexilis* may also have been present or their pollen could have blown from lower elevations or from areas farther south on the Central Plateau (Fall, 1994).

Zone BP-3 (3.88-2.80 m depth; 11,000-7600 cal yr B.P.) contained the highest percentages of *Pinus* (85%) and identifiable pine grains were composed of approximately equal amounts of diploxylon-type and haploxylon-type. *Picea* pollen, most likely from *Picea engelmannii*, was also well represented (5%), and pollen of *Abies* (0.5%), *Betula* (1.5%), *Salix* (0.3%), *Populus* (0.4%), and Poaceae (1%) were present in low amounts. *Artemisia* was lower (7%) in this zone than any other, as was nonarboreal pollen (12%). PAR was relatively high (2620 grains cm^{-2} yr^{-1}).

PAR from Zone BP-3 falls within the range (2216-4903 grains cm^{-2} yr^{-2}) from modern montane forests in the Colorado Rocky Mountains (Fall, 1992). Pollen from this zone resembles modern surface samples from *Picea*-*Abies*-*Pinus albicaulis* forest in YNP, but contains lower levels of *Abies* (0.5% rather than 1.5%) and haploxylon-type *Pinus* (50% rather than 75% of the total *Pinus* component) (Baker, 1976). It is likely that the pollen in Zone BP-3 came from forests dominated by *Pinus albicaulis* or *P. flexilis* and *Picea* with *Abies* and *Pinus contorta* as subdominants.

Zone BP-4 (2.72-1.56 m depth; 7600-4000 cal yr B.P.) included high *Pinus* percentages (66%) with a high representation of diploxylon-type grains. *Picea* percentages decreased (2.46%), *Abies* decreased slightly (0.3%), *Pseudotsuga* was present for the first time in low but steady amounts (up to 1.6%), *Artemisia* percentages were relatively high (17%), *Betula* values were moderate (2.5%), and Chenopodiineae percentages were moderate (4%) but higher than in Zone BP-3. Poaceae also increased slightly (1.2%). Nonarboreal pollen increased to 24% and PAR averaged 2534 grains cm^{-2} yr^{-1}.

PAR in Zone BP-4 fits within the low end of the range of PAR from modern montane forests in the Colorado Rocky Mountains (2216-4903 grains cm^{-2} yr^{-2}) (Fall, 1992). Percentages of taxa from this zone resemble the modern pollen rain of montane forest communities in the Wind River Range, WY. This modern forest is dominated by *Picea engelmannii* with lower amounts of *Abies lasiocarpa*, *Pinus contorta*, and *P. albicaulis* (Fall, 1994). The decrease in PAR and percent arboreal pollen from Zone BP-3 to this one, the establishment of *Pseudotsuga*, and the increase in *Artemisia, Betula*, Chenopodiineae, and Poaceae suggest that the vegetation shifted to *Pinus, Picea engelmannii*, and *Pseudotsuga* forests on the slopes around Blacktail Pond, and *Artemisia* steppe likely existed in low-lying areas. Diploxylon-type *Pinus contorta* replaced haploxylon-type *Pinus* as the dominant taxa.

Zone BP-5 (1.44-0 m depth; 4000 cal yr B.P. to present) consisted of moderate *Pinus* percentages (24%) with mostly diploxylon-type *Pinus* grains. *Artemisia* decreased slightly (14%), *Abies* decreased slightly (0.1%), and *Betula* decreased to 0.3%. *Picea* percentages were lowest (0.7%) and *Pseudotsuga* percentages were highest (2%) in this zone. *Poaceae* percentages were relatively high (2%) as was total nonarboreal pollen (21%). PAR averaged 2050 grains cm^{-2} yr^{-1}.

PAR from Zone BP-5 fits within the range from modern *Artemisia* steppe in the Colorado Rocky Mountains (858-4484 grains cm^{-2} yr^{-1}) (Fall, 1992). This pollen assemblage is similar to modern pollen rain from *Artemisia* steppe environments in YNP, but with lower *Pinus* percentages (32-70% *Pinus* pollen was observed in the modern study) (Whitlock, 1993). In addition, *Pseudotsuga* pollen percentages were slightly higher than in the modern steppe environment, which contained approximately 1.3% *Pseudotsuga* pollen (Whitlock, 1993). The pollen rain in this zone suggests an open steppe environment dominated by *Artemisia* and Poaceae in the lowlands around Blacktail Pond and patches of *Pseudotsuga* and *Pinus contorta* growing in parkland type vegetation on adjacent rocky outcrops in the watershed. This vegetation reconstruction resembles the modern environment around Blacktail Pond.

Charcoal

At Blacktail Pond (Fig. 6), BCHAR was negligible until 12,000 cal yr B.P. when it increased to 0.04 particles cm^{-2} yr^{-1}. BCHAR values increased to 0.43 particles cm^{-2} yr^{-1} by about 11,000 cal yr B.P., and after about 11,000 cal yr B.P., remained relatively consistent, averaging 0.18 particles cm^{-2} yr^{-1} until 1500 cal yr B.P., after which it decreased to an average of 0.10 particles cm^{-2} yr^{-1}.

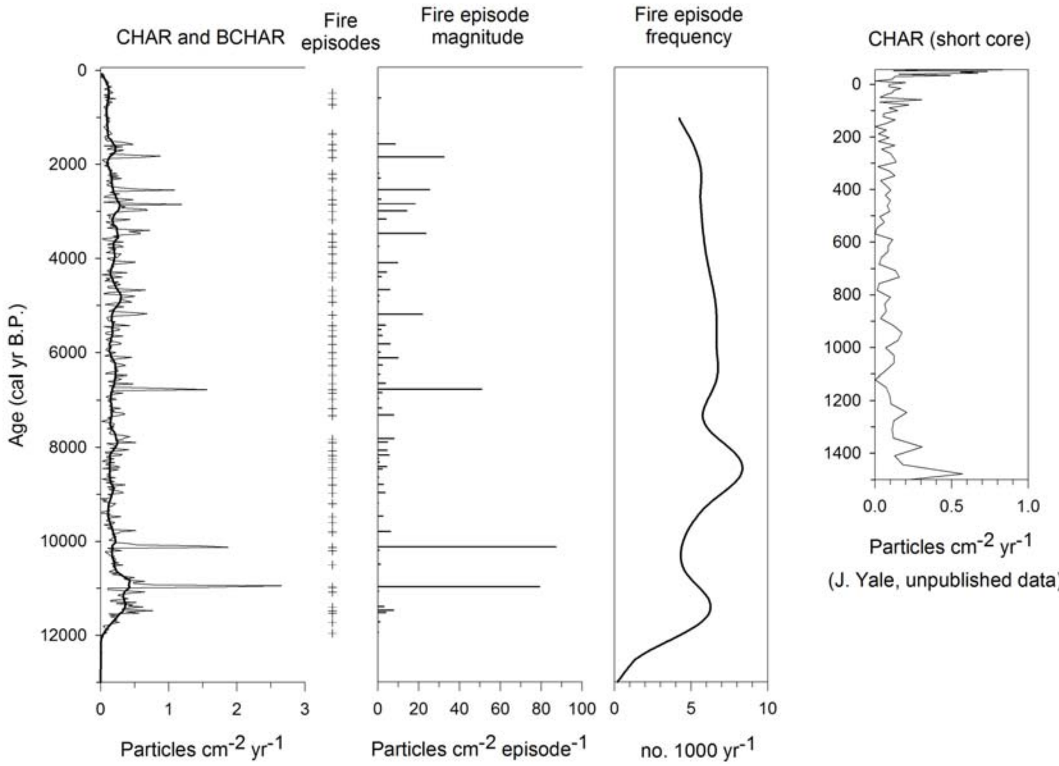

Figure 6. Charcoal results from Blacktail Pond core BTP06A over the last 13,000 cal yr B.P. (this study) and CHAR values from Blacktail Pond short core extending back 1500 cal yr B.P. (J. Yale, unpublished data). Because fire-episode frequency was based on a 2000 year window, values younger than 1000 cal yr B.P. were discarded.

CHAR values were negligible before 12,000 cal yr B.P. at which point they increased to 0.03 particles cm^{-2} yr^{-1}. They increased to 2.66 particles cm^{-2} yr^{-1} at about 11,000 cal yr B.P. and then decreased somewhat to average 0.23 particles cm^{-2} yr^{-1} until 1500 cal yr B.P. CHAR was low from 1500 to 0 cal yr B.P., with a mean of 0.10 particles cm^{-2} yr^{-1}.

Eleven fire episodes were identified between 13,500 and 12,000 cal yr B.P. but determined as insignificant because their counts were not statistically different from nearby low counts. After 12,000 cal yr B.P., sixty-four significant episodes were identified, along with four in the last 2500 cal yr that were determined as insignificant. The two largest episodes in the record occurred between 11,000 and 10,000 cal yr B.P. and had magnitudes of 87 and 79 particles cm^{-2} $episode^{-1}$. Other episodes in the record averaged 4.5 particles cm^{-2} $episode^{-1}$.

Fire-episode frequency was negligible before about 12,000 cal yr B.P. after which it increased and was elevated averaging 6 events 1000 yr^{-1} between 12,000 and 11,000 cal yr B.P. Fire-episode frequency dipped to 4 events 1000 yr^{-1} at about 10,500 cal yr B.P. and then increased to a maximum of 8 events 1000 yr^{-1} at about 8,500 cal yr B.P., after which it decreased to 6 events 1000 yr^{-1} by 7600 cal yr B.P. Fire-episode frequency averaged 6 events 1000 yr^{-1} between 7600 and 4000 cal yr B.P. and between 4000 cal yr B.P and present day decreased from 6 events 1000 yr^{-1} to 3 events 1000 yr^{-1}.

The area around Blacktail Pond burned in 1988 although the charcoal record from the long core does not show evidence of this. The short core does in fact show increased charcoal at the top of the record likely from the 1988 fires. CHAR values from the short core averaged 0.14 particles cm^{-2} $year^{-1}$, and relatively high values above 5 cm depth (averaging 0.53 particles cm^{-2} $episode^{-1}$) are likely from the fires of 1988 that burned around the site (Fig. 6) (J. Yale, unpublished data).

Although statistical re-analysis of charcoal data from Slough Creek Lake and Cygnet Lake yielded somewhat different results from the original studies, their general trends were the same and did not substantially change the interpretations. Fire-episode frequency at Slough Creek Lake was lowest at the bottom of the record, ca. 15,000 cal yr B.P., and increased through the Holocene to present day. Fire-episode frequency at

Cygnet Lake was lowest during the late-glacial between 16,000 and 11,000 cal yr B.P., increased during the early and middle Holocene with the exception of a drop at ca. 8500 cal yr B.P., and decreased during the late Holocene, after ca. 4000 cal yr B.P (Fig. 7).

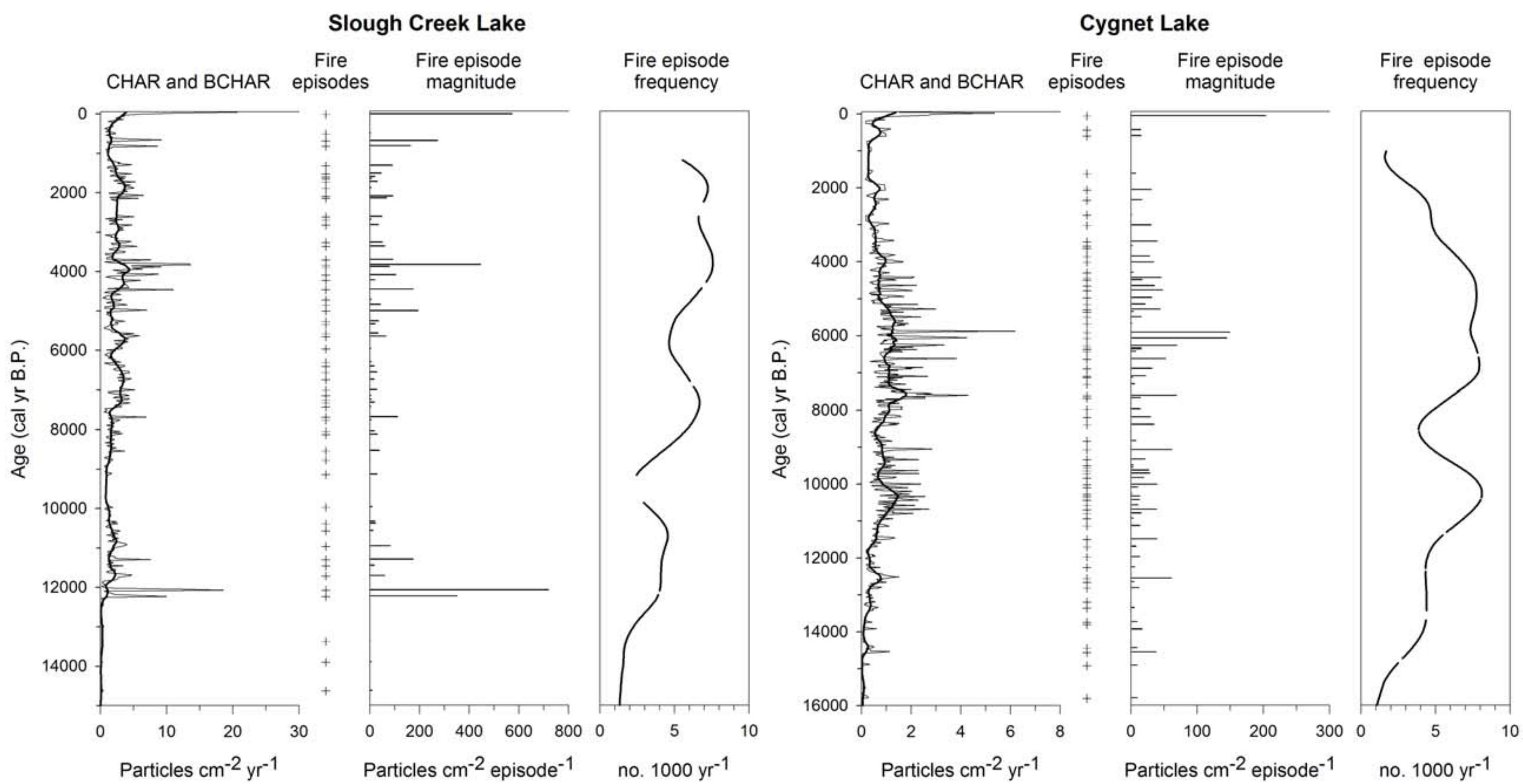

Figure 7. Results from re-analysis of charcoal data from Slough Creek Lake and Cygnet Lake (from Millspaugh, 1997). Because fire-episode frequency was based on a 2000 year window, values younger than 1000 cal yr B.P. were discarded.

DISCUSSION

Lithologic, charcoal, and pollen data from Blacktail Pond provide information on the environmental history near the site for the last 14,000 cal yr B.P. The vegetation reconstruction was based on pollen percentages and pollen accumulation rates, and a fire history was inferred from charcoal accumulation rates, background charcoal accumulation rates, fire-episode frequency, and episode magnitude. The climate interpretation inferred from these proxies was compared with those from Cygnet Lake and Slough Creek Lake, where similar high-resolution studies were undertaken (Millspaugh et al., 2000; Millspaugh et al., 2004; Whitlock and Bartlein, 1993). This comparison provides a better understanding of the environmental history in YNP during postglacial time and enabled examination of paleoclimate hypotheses posed by Whitlock and Bartlein (1993) that concern the effect of the early-Holocene summer insolation maximum on Yellowstone's precipitation regimes. In addition, Poaceae/*Artemisia* ratios from this study were compared with wet/dry intervals determined by Gennett and Baker (1986), Meyer et al. (1995) and Hadly (1996), in order to determine the dependability of this proxy for determining wet/dry fluctuations.

Late-glacial Period (>11,000 cal yr B.P.)

In its early stages, Blacktail Pond was an unproductive lake subject to considerable allochthonous clastic input from the recently deglaciated landscape. The low organic content and high magnetic susceptibility suggest that soils and vegetation around the site were poorly developed. The vegetation around Blacktail Pond between

13,000-12,000 cal yr B.P. was likely alpine tundra with patches of *Salix* and *Populus* nearby, which in turn implies cool but wet conditions. Fires at the site were insignificant at this time based on the fact that CHAR was very low.

Between 12,000 and 11,000 cal yr B.P., Blacktail Pond became more productive and stable A-horizon soils likely developed, based on the increased organic content of the sediment and the decreased magnetic susceptibility. The pollen data suggest that vegetation was parkland of *Picea engelmannii* and *Pinus albicaulis,* with open meadows of *Artemisia*, and Poaceae, and wet areas of *Betula glandulosa* and Cyperaceae. Subalpine parkland vegetation occurs about 500 m above the site today and the pollen record indicates cooler-than-present conditions but warmer than before. Fires increased significantly in this zone with BCHAR and CHAR values both increasing (to 0.26 particles cm^{-2} yr^{-1}). Fire frequency averaged 6 episodes 1000 yr^{-1} with episode magnitude averaging 3 particles cm^{-2} $peak^{-1}$. This jump in fire activity reflects both increasing woody fuels for fires and warmer conditions. Both the pollen and charcoal data imply warmer wetter conditions than before, but still cooler than at present in the Blacktail Pond region (Fig. 8).

This reconstruction is consistent with the large-scale controls of climate at this time. Climate simulations indicate an increase in summer temperatures beginning ca. 16,000 cal yr B.P. as summer insolation increased and the North American continental ice sheet began to decrease in size. Winter temperatures, on the other hand, likely remained lower than present until after 6000 cal yr B.P. (Bartlein et al., 1998).

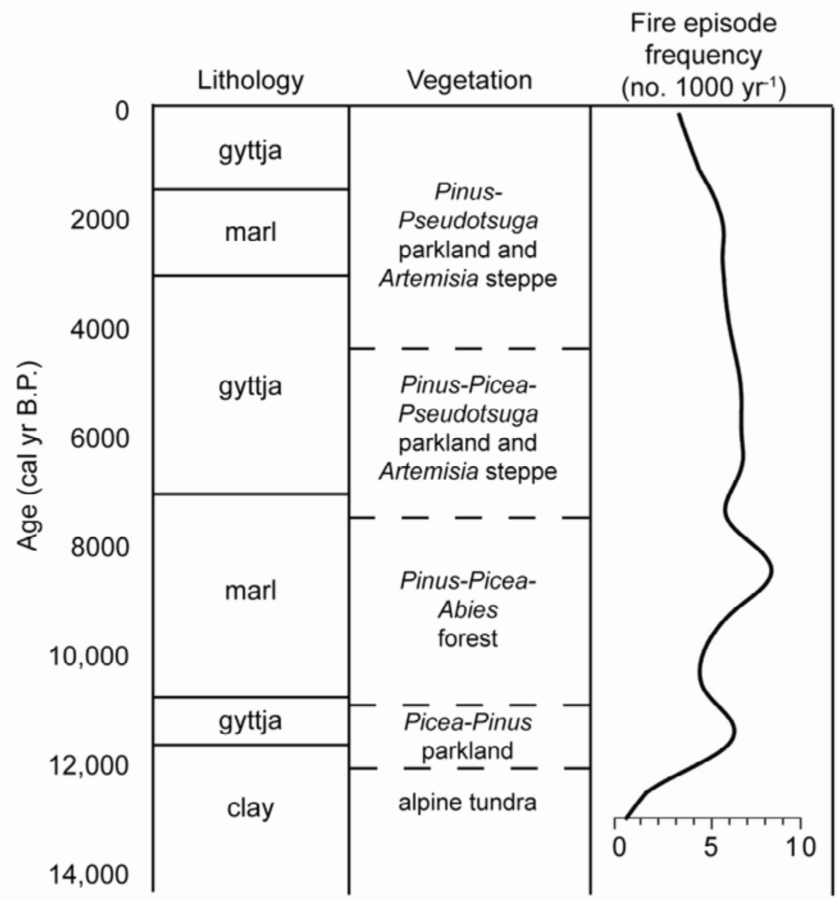

Figure 8. Summary of postglacial lithology, vegetation, and fire frequency at Blacktail Pond.

Early Holocene Period (ca. 11,000-7600 cal yr B.P.)

Between 11,000 and 7600 cal yr B.P., the sediments of Blacktail Pond became carbonate rich (~20% carbonates), indicating that Charophytes (*Chara*) in the lake became more productive during the early Holocene than before as a result of strengthened summer conditions (i.e. more sunlight, warmer temperatures, lower lake levels). Pollen data indicate that the area around Blacktail Pond was dominated by forests of *Pinus albicaulis* and/or *P. flexilis* with *Picea engelmannii*, *Abies lasiocarpa*, and *Pinus contorta* subdominants. The shift from subalpine parkland to forest indicates that the climate became warmer and that winters were effectively wetter, providing more snow pack and soil moisture to support conifer development.

The charcoal record from Blacktail Pond suggests elevated fire activity during the early Holocene as BCHAR (0.19 particles cm^{-2} yr^{-1}) and CHAR (0.25 particles cm^{-2} yr^{-1}) were high. Fire-episode frequency was decreased during the first half of the early Holocene between 11,000 and about 9,500 cal yr B.P., (reaching a low of 4 episodes 1000 yr^{-1} between 10,600 and 10,000 cal yr B.P.) while at the same time fire episode magnitudes reached record maximums (79 particles cm^{-2} $episode^{-1}$ at 10,975 cal yr B.P. and 87 particles cm^{-2} $episode^{-1}$ at 10,125 cal yr B.P.) and averaged 87 particles cm^{-2} $peak^{-1}$. As the fire regime shifted to high-severity, low-frequency events, *Pinus, Picea, Abies* forests became established in the area. Such mesophytic vegetation requires low-frequency fire regimes in order to become established (Romme and Knight, 1981). Although the vegetation suggests that winters were effectively wetter than before, the charcoal data imply that summers were likely warmer and drier than before.

During the second half of the early Holocene (ca. 9500 to 7600), fire-episode magnitude decreased (average 3 particles cm^{-2} $peak^{-1}$) while fire-episode frequency increased, reaching a record maximum of 8 episodes 1000 yr^{-1} at 8500 cal yr B.P. These data suggest that fires became more frequent and less severe than during the first half of the early Holocene, a shift that occurred as summer insolation, while still high relative to the rest of the Holocene, was decreasing. Weakening monsoons, bringing less moisture to the region during the summer months could result in drier annual conditions allowing for more frequent, less severe fires. Nonetheless, the early Holocene at Blacktail Pond was a period of elevated fire activity, suggesting the site exhibits summer conditions resembling a summer-dry environment.

Taken together, the pollen and charcoal data from Blacktail Pond imply that effective moisture levels during winter and summer were divergent. Winters were effectively wetter supporting the expansion of conifers while summers were effectively drier and warmer than today allowing for increased marl production and less-frequent but more severe fires between ca. 11,000 and 8500 cal yr B.P. and more frequent but less-severe fires between ca. 8500 and 7600 cal yr B.P. This fire regime shift does not correspond to any major changes in vegetation and thus is likely a direct result of a change in seasonality (Fig. 8).

This reconstruction is consistent with the large-scale controls of climate and their expression in summer-dry regions. Climate simulations indicate that during the early Holocene, much of North America was subject to a strengthened subtropical high-pressure system and hence decreased precipitation in summer months (summer-dry conditions), whereas the Southwest experienced strengthened monsoonal flow and hence increased precipitation (summer-wet conditions) (Bartlein et al., 1998). The high incidence of fire at Blacktail Pond during the early Holocene indicates that summer precipitation was minimal at this time suggesting the influence of summer-dry conditions on the site.

Increased seasonality during the early Holocene is also consistent with climate simulations that indicate that divergent summer and winter temperatures were at a maximum as a result of January temperature increases lagging behind July temperature increases (Bartlein, 1998).

Middle Holocene Period (7600-4000 cal yr B.P.)

From 7600 to 4000 cal yr B.P., sediment in Blacktail Pond had decreased levels of authigenic carbonates and increased accumulation of dark-brown fine-detritus gyttja with shells. It is possible that lower *Chara* production was a result of cooler, shorter summers and/or higher lake levels than during the early Holocene. Decreased summer temperatures and evaporation would be expected as summer insolation decreased from its early-Holocene maximum to present day levels (Bartlein et al., 1998).

Pollen data indicate that vegetation around Blacktail Pond between 7600 and 4000 cal yr B.P. consisted of forests of *Pinus contorta* and *Picea engelmannii*, likely growing above the pond and in moist gullies, *Pseudotsuga* probably growing on the slopes around the pond, and *Artemisia* steppe, probably on low-lying areas around the pond. Increased levels of *Pinus contorta* and *Pseudotsuga* along with decreased PAR imply a reduction in the amount of moisture available for vegetation, possibly a result of winters that were effectively drier.

Fire activity at Blacktail Pond was reduced somewhat from the previous zone, but still high. BCHAR and CHAR decreased very slightly to averages of 0.18 and 0.22 particles cm^{-2} yr^{-1} respectively. Fire frequency was lower than before and remained relatively constant in this zone, averaging 6 episodes 1000 yr^{-1}. Fire-episode magnitude was variable in this zone which contained the third largest peak of the record with 51 particles at 6775 cal yr B.P. Fires were apparently frequent and varied in intensity during this time, suggesting a persistence of warm, effectively dry summer conditions compared to present, although less so than in the previous zone.

The lithology, vegetation, and fire data together imply considerable seasonality during the middle Holocene but not as extreme as the previous period. Summers were sufficiently dry and warm to allow carbonate production and frequent fires of varying intensity. Vegetation in this zone, on the other hand, implies considerable winter moisture to allow *Pinus* and *Picea* to grow on rocky slopes around Blacktail Pond (Fig. 8).

This reconstruction is consistent with an increase in summer precipitation and a decrease in the seasonality of temperature and effective moisture between summer and winter, both of which are consistent with paleoclimate model simulations for 6000 cal yr B.P. (Bartlein et al., 1998). As summer insolation decreased, resulting in a weakening of the subtropical high-pressure system over much of the continent, areas influenced by summer-dry conditions would have experienced an increase in precipitation. Simulated January temperatures increased at 6000 cal yr B.P. (Bartlein et al., 1998), leading to less seasonality as compared to the early Holocene.

Late Holocene Period (4000 cal yr B.P. to present)

Between 4000 cal yr B.P. and present day, Blacktail Pond continued to deposit primarily dark brown fine detritus gyttja with shells. Low carbonate production at this time suggests cooler, less alkaline conditions (Meyers and Ishiwatari, 1993). A divergence from this overall trend likely existed from ca. 3000 to 1400 cal yr B.P., when the sediment shifted to light brown marl with shells, suggesting increased *Chara* activity at that time, possibly because of warmer temperatures, increased sunlight, and increased evaporation.

Pollen data suggest that during the late Holocene, *Artemisia* steppe with forest patches of *Pseudotsuga* and *Pinus contorta* developed in the Blacktail Pond area. This shift from predominantly forest to steppe, along with a decline in PAR from the middle Holocene to the late Holocene, suggests effectively drier conditions in winter than before.

The charcoal data indicate that fire activity at Blacktail Pond decreased over the last 4000 years. Fire frequency, which maintained a value of 6 episodes 1000 yr^{-1} between 4000 and about 2000 cal yr B.P. declined over the last 2000 years to a value of 3 episodes 1000 yr^{-1} by the present. Fire episode magnitude increased between 4000 and 2000 cal yr B.P. (average 7 particles cm^{-2} $episode^{-1}$), and then decreased (average 5 particles cm^{-2} $episode^{-1}$) as fire frequency decreased over the past 2000 years. CHAR and BCHAR decreased to 0.20 and 0.16 particles cm^{-2} yr^{-1} on average during the late Holocene, suggesting a decrease in fuel availability. This decline in fire activity implies a decrease in convectional storms or generally cooler wetter summers than before.

Lithology, pollen and charcoal records suggest that during the late Holocene, winters became effectively drier than before, and summers became effectively wetter than before as modern climatic conditions became established. A brief return to warm/dry conditions occurred between ca. 3000 to 1400 cal yr B.P., when marl deposition increased (Fig. 8).

The shift to wetter summers and decreased seasonality between summer and winter is consistent with climate simulations (Bartlein et al., 1998). As summer insolation continued to decrease through the late Holocene, the subtropical high-pressure system was weakened, allowing for more summer moisture in summer-dry environments. Additionally, summer and winter temperatures became more similar, which would have resulted in more comparable effective moisture in summer and winter (Bartlein et al., 1998).

Comparison of Vegetation and Fire Reconstruction at Blacktail Pond with Other Sites in Yellowstone National Park

The vegetation and fire history inferred at Blacktail Pond are different from the Slough Creek Lake and Cygnet Lake reconstructions discussed in Millspaugh et al. (2004), and provide new insights into the nature of the summer-wet/summer-dry precipitation regions in YNP during the Holocene. Pollen records from Slough Creek Lake indicate that conditions were cold and dry with tundra vegetation before ca. 13,000, and became warmer and wetter with a shift to *Picea* parkland between ca. 13,000 and 11,000 cal yr B.P. The climate was likely wetter during the early Holocene (ca. 11,000 to 7000 cal yr B.P.) when the area was dominated by *Pinus-Juniperus* forest and *Betula* was significant, probably existing in riparian areas. After ca. 7000 cal yr B.P., the area became drier with a shift to *Pseudotsuga* parkland. At Cygnet Lake, the initial vegetation was alpine tundra, and after 11,000 cal yr B.P. it was replaced by *Pinus contorta* forest (Millspaugh et al., 2004).

The data from Slough Creek Lake, in the northern, summer-wet part of YNP suggest that conditions at the site were generally wetter in the early Holocene than at present, as a result of increase monsoonal precipitation. Decreased summer insolation in the middle and late Holocene resulted in weakened monsoonal flow and decreased summer precipitation. The vegetation history at Cygnet Lake in the central, summer-dry region of YNP was so strongly affected by substrate that pollen data there are not useful for inferring changes in climate. In contrast, the fire history reconstruction from the site indicates that summer conditions were effectively drier during the early Holocene than at present allowing for fire frequencies to reach their highest levels. During the late Holocene, decreased summer insolation and weakening of the subtropical high-pressure system allowed for increased precipitation during the summer months, resulting in lower fire activity (Fig. 9). A pollen record from Divide Lake, south of YNP in a summer-dry region of the Teton National Forest (lat 43° 57’ N, long 110° 14’ W, elevation 2624 m) confirms that winter conditions were drier during the early Holocene, but does not include a charcoal record to reveal summer conditions (Whitlock and Bartlein, 1993).

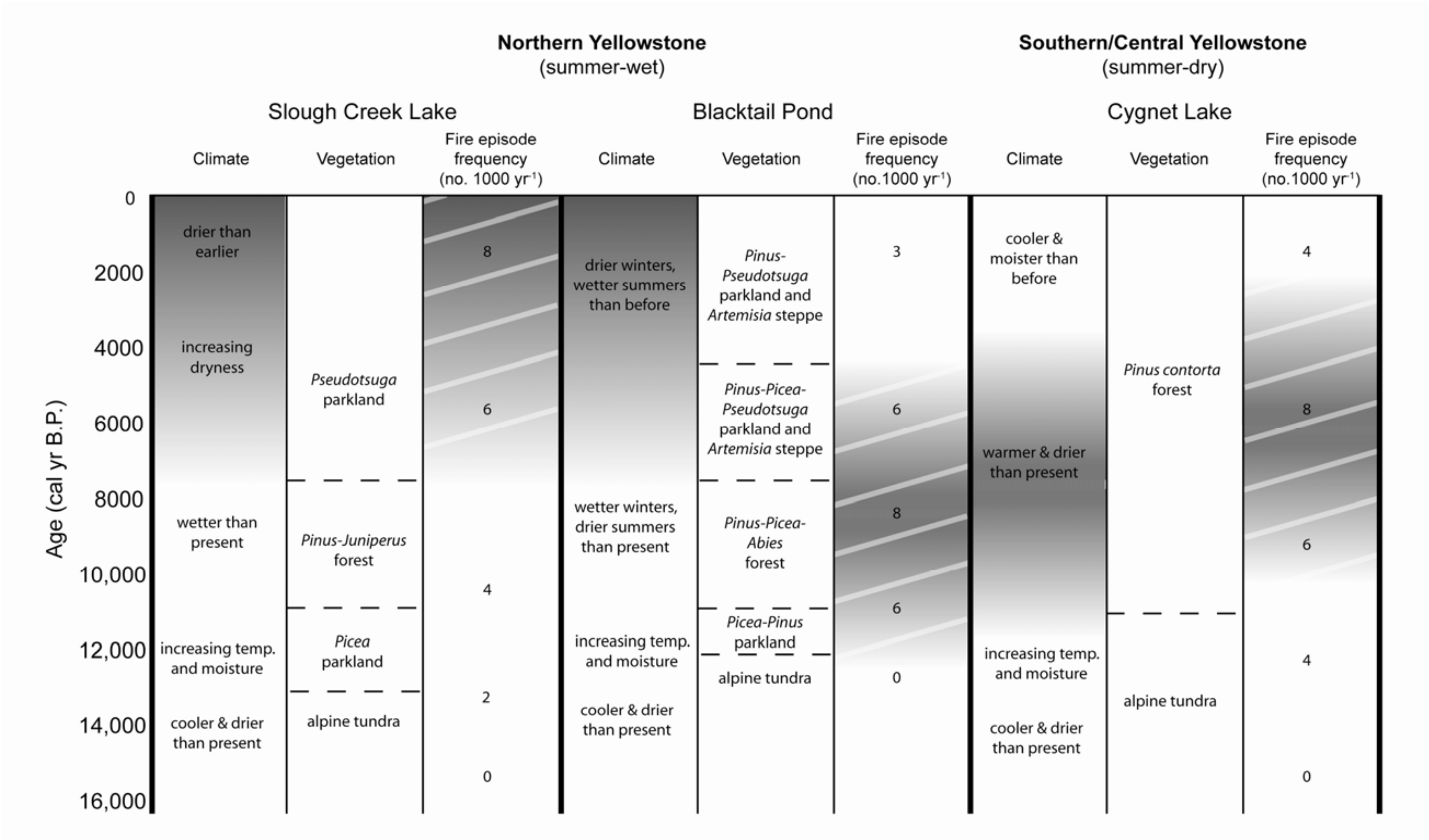

Figure 9. Comparison of vegetation, climate, and fire histories at Slough Creek Lake, Blacktail Pond, and Cygnet Lake. Shading indicates greater aridity and hachured shading indicates the time of highest fire activity (modified from Millspaugh et al., 2004).

The vegetation history at Blacktail Pond is similar to that at Slough Creek Lake. Although the timing is slightly different, both sites experienced a shift from alpine tundra to parkland during the late-glacial, development of conifer forest in the early Holocene, and replacement by parkland in the middle and late Holocene. Both sites suggest wetter winter conditions in the early Holocene, followed by effectively drier winter conditions in the middle and late Holocene as vegetation became more open. This series of climate changes does not fit neatly into either precipitation regime proposed by Whitlock and Bartlein (1993), which focuses on summer conditions. Climate simulations in Bartlein et al. (1998), however, indicate a steady rise in winter temperatures throughout the course of the Holocene, which could in turn have resulted in a steady decrease in effective winter moisture.

The fire history at Blacktail Pond, on the other hand, resembles that of Cygnet Lake, with increased fire activity during the early and middle Holocene when a strengthened subtropical high-pressure system limited precipitation in summer-dry environments, and decreased fire activity during the late Holocene when weakening of the subtropical high-pressure system allowed for increased summer precipitation. This suggests that Blacktail Pond shows close affinities with a summer-dry response to Holocene insolation changes.

This juxtaposition of responses at Blacktail Pond could be partly a result of its transitional setting between the summer-wet and summer-dry climate regions. The vegetation histories at Slough Creek Lake and Blacktail Pond reflect the underlying control of changes in winter precipitation on vegetation during the Holocene. Winter precipitation may have been greater in the early Holocene when winter insolation levels were lower. The fire histories at Cygnet Lake and Blacktail Pond, on the other hand, show a similar fire response to drier summer conditions in the early Holocene, and reduced fires in the late Holocene when summers were cooler and wetter. This similarity suggests that both sites responded to a strengthening of the subtropical high-pressure system in the early Holocene and its weakening in the late Holocene.

Centennial-scale Wet/Dry Oscillations in Northern Yellowstone National Park

In order to determine if ratios of Poaceae/*Artemisia* pollen from core BTP06A correspond to ratios of Poaceae/*Artemisia* from Gennett and Baker (1986), and to wet/dry intervals determined by Meyer et al. (1995) and Hadly (1996), the pollen ratios from both studies of Blacktail Pond are plotted side by side with effectively drier intervals, along with the geomorphic and vertebrate fossil information from the other studies (Fig. 10).

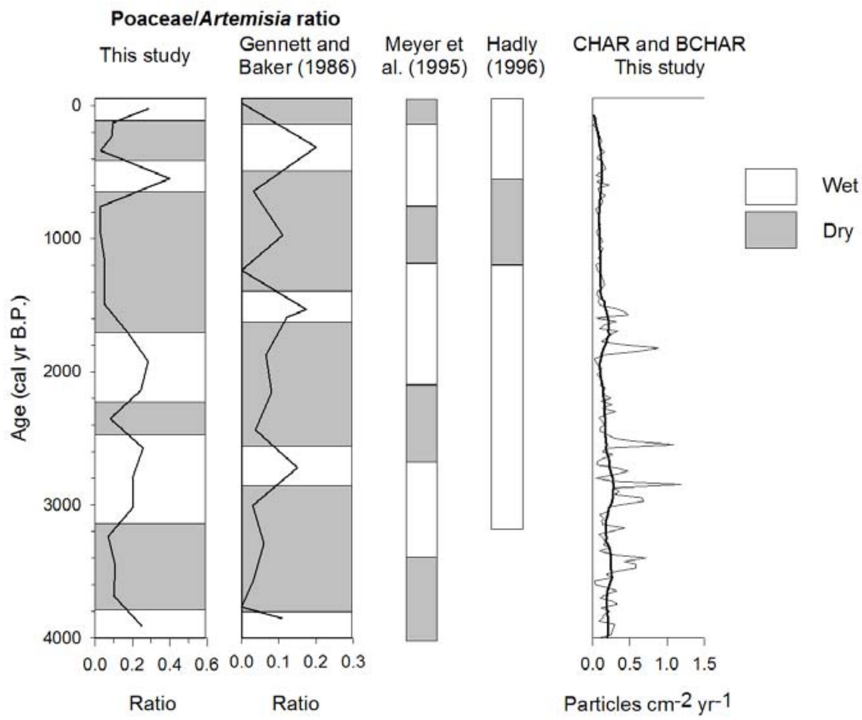

Figure 10. Comparison of late Holocene wet/dry oscillations inferred from various proxies in northern Yellowstone National Park, and CHAR values from Blacktail Pond core BTP06A.

Data from this study, Gennett and Baker (1986), and Meyer et al. (1995) all show four dry intervals during the late Holocene occurring ca. 3775-3125, 2475-2225, 1700-675, and 425-75 cal yr B.P. The record from Hadly (1996) does not extend as far back as the other three records, but the one dry interval inferred from their data (ca. 1200-500 cal yr B.P.) does correspond with a dry interval found in the other three records, broadly between 1700 and 675 cal yr B.P.

The fact that timing of the dry intervals inferred from Poaceae/*Artemisia* ratios in this study and Gennett and Baker (1986), are somewhat offset is not surprising. The chronologies for of each of these records are constrained by the mud-water interface, Mazama Ash, and one ^{14}C date between these two values. The ^{14}C date in Gennett and Baker (1986) was obtained on bulk carbonate-rich sediment, and the likelihood that ancient carbon contamination yielded a spuriously old date is high. In addition, the core from which the date was obtained was taken along the lake margin, and the sediments changed abruptly from marl to peat at around 0.5 m depth as fen developed at the site. This date, the only one above Mazama Ash is located in the peat just above this lithologic change, and it is likely that this shift in depositional environment and sediment type is associated with an unconformity. Comparison of the pollen data also point to a possible unconformity in the Gennett and Baker (1986) record, given the late increase of diploxylon-type *Pinus* pollen just above the change in lithology at ca. 1480 cal yr B.P. as compared to 4000 cal yr B.P. in the continuous lake-sediment core presented here. Variations in sedimentation rate, the possibility of unconformities, and inaccuracies with the ^{14}C date that was used would have a large impact on the Gennett and Baker (1986) Poaceae/*Artemisia* ratios, and it is not surprising that they do not match the other records perfectly. The new Blacktail Pond ratios and independent climate proxies (Meyer et al., 1995; Hadly, 1996) are a better approximation of wet/dry periods in northern YNP during the late Holocene. Additional ^{14}C dates on the Blacktail Pond core would help better constrain the chronologies and refine the timing of these events.

When considering these climate oscillations in the context of established regional events, it becomes apparent that the Medieval Climate Anomaly (~1150-650 cal yr B.P.; Cronin et al., 2003) corresponds generally with the second to last dry interval inferred from these records (1700-675 cal yr B.P.) The Little Ice Age (~550-50 cal yr B.P.;

Cronin et al., 2003) corresponds with the most recent dry interval inferred from these records (425-75 cal yr B.P.).

When CHAR and BCHAR values from core BTP06A were compared with the wet/dry intervals inferred from pollen data (this study) and sedimentary data (Meyer et al., 1995), overall charcoal abundance was highest during wet periods (3500-2500, 1900-1400, 700-100 cal yr B.P.) (Fig. 10). This relation likely reflects an increase in fuel biomass during wet periods, resulting in higher BCHAR and CHAR overall (Marlon et al., 2006). In other areas of steppe and xeric forest, wet periods have been shown to be associated with higher fire activity (Mensing et al., 2006; Pierce et al., 2004), because the buildup of fine fuel biomass makes the vegetation highly flammable during dry seasons or years within the wet period. At Blacktail Pond, wet periods occurring on centennial time scales must have allowed for more fuels, and, within these periods, intermittent droughts were times of frequent fires.

CONCLUSIONS

From this analysis of the vegetation, fire, and climate history of Blacktail Pond, and the comparison of its record to that of Slough Creek Lake in the summer-wet environment and Cygnet Lake in the summer-dry environment of YNP, several conclusions can be drawn:

1. The vegetation at Blacktail Pond sometime after 14,000 and before 12,000 cal yr B.P. consisted of alpine tundra growing on weakly-developed soils. Fire activity was initially low but increased between 12,000 and 11,000 cal yr B.P. as fuels became more abundant with the establishment of *Picea-Pinus* parkland vegetation. Early Holocene forests of *Pinus, Picea,* and *Abies* along with high fire activity indicate that the overall conditions were warmer than before, winters were effectively wetter, and summers were effectively drier than at present. The middle Holocene at Blacktail Pond was a period of *Pinus, Picea,* and *Pseudotsuga* parkland with areas of *Artemisia* steppe. Fire activity around the site decreased somewhat but still remained high. This vegetation suggests that winters were still effectively wet but becoming drier. The fire history indicates that summers remained effectively dry. The late Holocene saw a shift to *Artemisia* steppe with patches of *Pseudotsuga* and *Pinus contorta* suggesting winter moisture around the site decreased. Fire activity at Blacktail Pond decreased over the last 4000 years, with a sharp decline occurring after 2000 cal yr B.P. indicating that summers became cooler and/or wetter than before.

2. Wet/dry climate oscillations during the late Holocene, inferred from Poaceae/*Artemisia* pollen ratios in this record correspond well with similar climate

signals determined from other late Holocene studies in northern YNP, including a previous study of Blacktail Pond (Gennett and Baker, 1986; Meyer et al., 1995; Hadly, 1996). Dry intervals occurred between ca. 3775-3125, 2475-2225, 1700-675, and 425-75 cal yr B.P. The second to last dry interval corresponds generally with the Medieval Climate Anomaly, and the Little Ice age unexpectedly fits with the most recent dry interval. Charcoal values from Blacktail Pond were somewhat higher during wetter intervals and it is likely that fuel build-up during these periods led to higher production of charcoal during fire events.

3. The Holocene vegetation history at Blacktail Pond is similar to that from Slough Creek Lake, a summer-wet site in northern YNP, whereas the fire history more closely resembles that from Cygnet Lake, a summer-dry site in central YNP. This could be a result of the transitional setting of Blacktail Pond between these two precipitation regimes.

4. Additional postglacial records of fire and vegetation from more summer-wet and summer-dry sites in YNP, particularly in non-rhyolitic summer-dry environments would be beneficial by providing a greater network of data for generating conclusions about postglacial climate change in YNP.

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APPENDICES

APPENDIX A:

KEY TO POLLEN TAXA

ABI	Abies
ACE	Acer incana
ALN	Alnus
AMB	Ambrosia-type
AME	Amelanchier-type
AP	Arboreal pollen
ARC	Arceuthobium
ART	Artemisia
BET	Betula
BID	Bidens-type
BRA	Brassicaceae
CAR	Caryophyllaceae
CEA	Ceanothus
CHE	Chenopodiineae
CYP	Cyperaceae
DEG	Degraded
DRY	Dryopteris-type
ELE	Eleagnus
EPH	Ephedra
ERC	Ericaceae
ERG	Erigonium
FAB	Fabaceae
FRX	Fraxinus
GAL	Galium
JUN	Juniperus
LIG	Liguliflorae

LYC	Lycopodium
MLV	Malvaceae sphaeralcea
NAP	Non-arboreal Pollen
OTH	Other herbs
PIC	Picea
PND	Pinus diploxylon-type
PNH	Pinus haploxylon-type
PNU	Pinus undifferentiated
POA	Poaceae
POL	Polygonaceae
POP	Populus
POT	Potentilla-type
PS	Pollen sum
PSE	Pseudotsuga-type
PS-T	Pollen sum-terrestrial
QUE	Quercus
RAN	Ranunculaceae
ROS	Other Rosaceae
SAL	Salix
SAR	Sarcobatus
SEL	Selaginella densa-type
SHE	Shepherdia
THA	Thalictrum
TUB	Other Tubuliflorae
TYP	Typha latifolia
UMB	Umbelliferae

APPENDIX B:

RAW POLLEN COUNTS

Blacktail Pond Raw Pollen Counts																		
Depth (cm)	Age (cal yr B.P.)	PND	PNH	PNU	PIC	ABI	PSE	JUN	ERC	ALN	BET	SAL	POP	FRX	QUE	ACE	ROS	AME
0	23	48.5	2.5	223	2.5	0	7	6	0	0	0	5	2	0	0	0	2	0
4	127	40.5	8.5	286.5	2.5	1	4	12	0	2	0	3	2	0	0	0	4	0
8	232	18	1	308.5	2	0	7	2	0	1	1	4	5	0	0	0	1	1
12	336	17.5	4	262.5	0.5	0	19	5	0	1	1	4	14	0	0	0	2	0
20	545	24.5	20	149.5	2.5	0	2	11	0	1	0	4	1	0	1	0	0	0
28	755	20	7.5	150	1	0.5	9	7	0	4	0	5	1	1	3	0	0	4
36	965	14	1	217	0	0	11	6	0	0	0	1	5	0	0	0	0	0
44	1176	28.5	7.5	161	0.5	0	3	6	0	2	1	5	0	0	2	0	0	2
56	1494	20.5	6	243.5	2.5	0	13	2	0	7	0	4	0	0	0	0	3	0
64	1707	22	2.5	223	2	0	13	5	0	0	1	1	3	0	0	0	0	0
72	1921	20.5	5.5	224	13	0	7	1	0	2	1	3	1	0	1	0	1	0
80	2136	26	12	231	0.5	0	8	3	0	1	3	5	2	0	0	1	2	1
88	2353	33.5	2	260.5	5.5	0	6	2	0	1	5	5	1	0	0	1	0	0
96	2571	36	5	229.5	3.5	0.5	6	3	0	1	2	8	2	0	0	3	0	0
104	2791	24.5	2	262.5	5	0	4	1	0	0	2	2	1	0	0	0	1	0
112	3012	21	9	219.5	1.5	0	9	0	0	2	2	0	0	0	0	0	0	0
120	3234	21.5	11	274	1	2	5	1	0	1	2	3	1	0	2	0	1	0
128	3457	34	5	208	1	4	1	8	0	2	2	4	2	0	2	0	0	1
136	3682	40	12.5	234.5	1	0	4	2	0	0	0	0	2	0	0	0	1	1
144	3907	39.5	14	179	4	1	3	5	0	0	2	4	0	0	1	0	0	0
156	4247	27	8	198.5	6.5	1	7	4	0	1	10	11	4	0	0	0	0	0
164	4474	11	7	208.5	15.5	1	12	1	0	1	8	4	1	0	0	0	1	1
172	4702	50	17.5	202.5	15	0	12	3	1	1	7	4	0	0	0	1	1	0
180	4930	39	5	308	9	0	16	1	1	4	10	3	2	0	0	1	1	0
188	5159	19.5	5.5	251	12.5	1	3	1	0	1	11	3	2	0	0	0	2	1
196	5388	41	4	176	7	1	4	1	1	1	5	0	3	0	0	0	0	0
204	5618	56	13.5	205.5	32	3.5	11	2	0	1	2	0	2	0	0	0	1	0
212	5847	12	4.5	225	1.5	0	4	4	0	0	20	0	4	0	0	0	2	0

Blacktail Pond Raw Pollen Counts																		
Depth (cm)	Age (cal yr B.P.)	PND	PNH	PNU	PIC	ABI	PSE	JUN	ERC	ALN	BET	SAL	POP	FRX	QUE	ACE	ROS	AME
220	6077	21.5	7.5	221.5	8.5	3	3	8	2	2	11	3	1	0	1	0	2	1
228	6307	37.5	10.5	210	3	0	1	6	0	1	8	5	0	0	2	0	0	0
236	6536	26	9	195	4	0	2	4	0	1	8	1	2	0	0	0	1	0
244	6766	29.5	10.5	185.5	6	3.5	3	3	0	4	11	2	0	0	1	0	0	0
256	7109	21	24.5	230	11	1	10	3	0	2	9	0	0	0	0	0	0	0
264	7337	13.5	15	209	10.5	0	6	1	0	2	16	7	2	0	0	0	2	1
272	7565	31	25.5	284	4	0.5	3	5	0	3	12	1	1	0	0	0	0	0
280	7793	51.5	23.5	174	12.5	2	1	4	0	0	6	2	2	0	1	0	0	0
288	8021	48	47	233	11.5	2.5	0	2	0	1	14	0	0	0	0	0	0	0
296	8248	75.5	17	225.5	34.5	3	2	2	2	0	1	1	1	0	0	0	0	0
304	8477	43	47.5	200	12	1	3	2	1	1	3	1	3	0	0	0	0	0
312	8706	33	48	218	41.5	1	1	1	0	1	4	3	4	0	0	0	1	0
320	8937	23.5	70.5	118.5	13	1	2	4	0	0	6	4	0	0	0	0	0	0
328	9170	31	80	127.5	9.5	0	0	0	0	0	8	1	0	0	1	0	0	0
336	9404	24	90.5	97.5	29	2	0	8	0	1	8	0	4	0	1	0	0	1
344	9641	18	20	282	4.5	0	0	1	0	0	1	0	2	0	0	0	0	0
356	10001	56	54	250	4.5	4	0	1	0	0	5	0	0	0	0	0	1	0
364	10245	37	41.5	172	40	2	0	2	0	0	4	0	0	0	0	1	1	1
372	10490	29	64.5	152.5	16	2	0	3	0	2	5	1	1	0	1	0	0	1
380	10737	39	50.5	170.5	11.5	1	0	1	0	0	4	0	1	0	0	0	2	0
388	10986	31	47	241	32	2.5	1	3	0	4	9	3	0	0	0	1	1	1
396	11236	22.5	46	166	37.5	2.5	2	6	0	1	19	6	4	0	0	0	0	1
404	11487	17	17	156.5	35	0.5	1	9	0	2	12	4	0	0	3	0	2	2
412	11739	14	33	121.5	29.5	1	0	1	0	2	17	1	2	0	0	0	1	2
420	11991	18	7.5	53.5	11.5	0	0	5	1	1	0	6	2	0	0	0	3	7
428	12242	5	40	50.5	3	0	0	1	0	0	0	9	3	0	1	0	1	1
436	12492	3	24	44.5	5	0	0	0	0	1	0	9	3	0	0	0	0	2
444	12741	0	2	6.5	0	0	0	0	0	0	0	1	1	0	0	0	0	0
456	13111	0	2	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Blacktail Pond Raw Pollen Counts																		
Depth (cm)	Age (cal yr B.P.)	POT	CEA	SHE	ELE	ARC	EPH	SAR	POA	ART	AMB	BID	TUB	LIG	CHE	RAN	THA	UMB
0	23	0	0	0	0	0	0	0	8	28	3	0	0	1	4	0	0	0
4	127	1	1	0	0	0	0	0	4	42	6	0	0	0	4	0	0	0
8	232	0	1	1	0	0	0	2	3	34	5	0	3	0	3	0	0	0
12	336	0	1	0	0	1	0	0	2	66	1	0	1	1	10	0	0	0
20	545	1	0	0	0	0	0	1	16	40	4	0	1	0	6	0	3	0
28	755	0	6	0	0	0	0	5	2	72	0	0	1	0	6	0	0	0
36	965	0	0	0	0	0	0	0	1	34	0	0	5	0	10	0	0	0
44	1176	0	0	0	0	0	0	3	3	56	3	0	0	0	11	0	2	0
56	1494	0	0	0	0	0	0	3	3	56	2	0	7	0	22	0	0	0
64	1707	0	1	0	0	0	0	0	10	57	2	0	3	0	7	0	0	0
72	1921	0	0	0	0	0	0	2	15	53	0	0	3	0	6	0	0	0
80	2136	0	0	1	0	0	0	1	14	57	6	0	2	1	8	0	0	0
88	2353	0	4	0	0	1	0	1	6	72	1	0	8	0	9	0	0	0
96	2571	0	1	0	0	0	0	2	17	66	8	0	0	0	10	0	0	0
104	2791	0	1	0	0	0	1	0	8	40	0	0	0	0	12	0	0	0
112	3012	0	0	0	0	0	0	2	9	44	1	0	0	0	7	0	0	0
120	3234	0	0	0	0	0	0	1	4	56	2	0	7	0	19	0	0	0
128	3457	0	0	0	0	0	0	3	9	82	3	0	3	0	10	0	0	0
136	3682	0	0	1	0	0	0	0	3	30	1	0	0	0	5	0	0	0
144	3907	0	0	0	0	0	0	0	8	32	1	0	0	0	7	0	0	0
156	4247	0	1	0	0	0	0	0	2	80	1	0	0	0	21	0	0	0
164	4474	0	0	0	0	0	0	1	0	72	3	0	1	0	18	0	0	0
172	4702	0	0	0	0	2	1	2	4	96	1	0	3	0	14	0	0	0
180	4930	0	0	0	0	0	0	0	2	97	4	0	0	0	23	0	0	0
188	5159	0	0	0	1	0	0	3	11	67	6	0	4	0	18	0	0	0
196	5388	0	0	0	0	0	0	1	11	58	4	0	0	0	9	0	0	0
204	5618	0	0	0	0	0	0	1	2	31	1	0	1	0	5	0	0	0
212	5847	0	0	0	0	0	0	1	6	61	4	0	1	0	15	0	0	0

Blacktail Pond Raw Pollen Counts																		
Depth (cm)	Age (cal yr B.P.)	POT	CEA	SHE	ELE	ARC	EPH	SAR	POA	ART	AMB	BID	TUB	LIG	CHE	RAN	THA	UMB
220	6077	0	0	0	0	0	0	1	7	68	2	0	4	0	15	0	0	0
228	6307	0	0	0	0	0	0	0	6	56	6	0	0	0	10	0	0	0
236	6536	0	0	0	0	1	0	3	6	48	1	0	2	0	7	0	0	0
244	6766	0	0	0	0	0	0	0	2	73	2	0	0	0	18	0	1	0
256	7109	0	1	0	0	0	0	0	0	61	0	0	1	0	13	0	0	0
264	7337	0	0	0	0	1	0	4	3	102	5	0	3	1	32	0	0	0
272	7565	0	1	0	0	0	0	1	4	56	3	0	1	0	21	0	0	0
280	7793	0	0	0	0	0	0	1	0	30	2	0	2	0	7	0	0	0
288	8021	0	0	0	0	0	0	2	3	31	0	0	3	0	6	0	0	0
296	8248	0	2	0	0	0	0	0	4	27	0	0	2	0	5	0	0	0
304	8477	0	0	1	0	0	0	3	2	14	2	0	0	0	3	0	0	0
312	8706	0	2	0	0	0	0	2	2	34	3	0	0	0	16	0	0	0
320	8937	1	2	0	0	0	0	0	3	26	1	0	0	0	7	0	0	0
328	9170	0	0	0	0	0	0	4	3	37	0	0	0	0	18	0	0	0
336	9404	0	1	0	0	0	1	3	6	22	0	0	1	0	3	0	1	0
344	9641	0	0	0	0	0	0	0	1	18	3	0	0	0	16	0	0	0
356	10001	0	0	0	0	0	0	0	3	28	0	0	0	0	10	0	0	0
364	10245	0	0	0	0	0	0	1	4	23	1	1	1	0	7	0	1	1
372	10490	0	0	2	0	0	0	2	7	14	1	0	1	0	2	0	1	0
380	10737	0	0	0	0	0	0	2	6	21	0	0	2	0	5	0	0	0
388	10986	0	1	0	0	1	0	0	2	48	4	0	0	0	19	0	0	0
396	11236	0	0	0	0	0	0	2	13	88	4	0	4	0	6	0	0	0
404	11487	1	0	0	0	0	0	4	17	114	2	0	9	1	16	0	1	0
412	11739	0	0	3	0	0	0	0	9	67	1	0	3	0	4	0	0	0
420	11991	0	0	3	0	0	0	2	9	63	1	0	11	0	12	0	1	0
428	12242	0	0	6	0	0	0	3	2	48	1	1	2	1	9	0	0	0
436	12492	0	0	0	0	1	0	1	8	79	0	0	8	1	6	1	0	0
444	12741	0	0	0	0	0	0	0	0	6	1	0	1	0	0	0	0	0
456	13111	0	0	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0

Blacktail Pond Raw Pollen Counts																	
Depth (cm)	Age (cal yr B.P.)	BRA	CAR	POL	ERG	GAL	FAB	OTH	DRY	SEL	MLV	DEG	CYP	TYP	LYC	PS-T	PS
0	23	0	0	0	0	0	0	0	0	0	0	6	3	0	93	348.5	351.5
4	127	0	0	0	0	0	0	0	0	0	0	4	3	0	108	428	431
8	232	0	0	0	0	0	0	0	0	0	0	4	22	0	88	407.5	429.5
12	336	0	0	0	0	0	0	0	0	0	0	2	12	0	108	415.5	427.5
20	545	0	0	0	0	0	0	0	0	0	0	6	1	0	127	294.5	295.5
28	755	0	0	0	0	0	0	0	0	0	0	11	8	0	101	316	324
36	965	0	0	0	0	0	0	0	0	0	0	1	15	0	123	306	321
44	1176	0	0	0	0	0	0	0	0	0	0	2	10	0	133	298.5	308.5
56	1494	0	0	0	0	0	0	0	0	0	0	2	23	0	135	396.5	419.5
64	1707	0	0	0	0	0	0	0	0	0	0	0	20	0	82	352.5	372.5
72	1921	0	0	0	0	1	0	0	0	0	0	4	15	0	90	364	379
80	2136	0	0	0	0	0	0	0	0	0	0	0	19	0	107	385.5	404.5
88	2353	0	0	0	0	0	0	0	0	0	0	1	7	0	130	425.5	432.5
96	2571	0	0	0	0	0	0	0	0	0	0	0	14	0	107	403.5	417.5
104	2791	0	1	0	0	0	0	0	0	0	0	1	8	0	70	369	377
112	3012	0	0	0	0	0	0	0	0	0	0	2	33	0	99	329	362
120	3234	0	0	0	0	0	0	0	0	0	0	0	27	0	169	414.5	441.5
128	3457	0	0	0	0	0	0	0	0	0	0	4	22	0	90	388	410
136	3682	0	0	0	0	0	0	0	0	0	0	0	3	0	87	338	341
144	3907	0	0	0	0	0	0	0	0	0	1	3	0	0	66	304.5	304.5
156	4247	0	0	0	0	0	0	0	0	0	0	2	11	0	106	385	396
164	4474	0	1	0	0	0	0	2	0	0	0	2	27	0	76	372	399
172	4702	0	0	0	0	0	2	1	0	0	0	1	12	0	78	442	454
180	4930	0	0	0	0	0	0	0	0	0	0	1	13	0	84	527	540
188	5159	0	0	0	0	0	2	1	0	0	0	0	10	0	94	426.5	436.5
196	5388	0	0	0	0	0	0	0	0	0	0	0	10	0	111	327	337
204	5618	0	0	0	0	0	0	0	0	0	0	3	6	0	145	373.5	379.5
212	5847	0	0	0	0	0	0	0	0	0	0	2	21	0	99	367	388

Blacktail Pond Raw Pollen Counts																	
Depth (cm)	Age (cal yr B.P.)	BRA	CAR	POL	ERG	GAL	FAB	OTH	DRY	SEL	MLV	DEG	CYP	TYP	LYC	PS-T	PS
220	6077	0	0	0	0	0	0	0	0	0	0	2	18	0	78	395	413
228	6307	0	0	0	0	0	0	0	0	0	0	10	10	0	103	372	382
236	6536	0	0	0	0	0	0	0	0	0	0	0	14	0	83	321	335
244	6766	0	0	0	0	0	0	0	0	0	0	6	8	0	98	361	369
256	7109	0	0	0	0	0	0	0	0	0	0	3	8	0	56	390.5	398.5
264	7337	0	0	0	0	0	0	0	0	0	0	3	6	0	74	439	445
272	7565	0	0	0	0	0	0	0	0	0	0	2	2	0	74	459	461
280	7793	0	0	0	0	0	0	0	0	0	0	7	1	0	70	328.5	329.5
288	8021	0	0	0	0	0	0	0	0	0	0	0	4	0	68	404	408
296	8248	0	0	0	0	0	0	0	0	0	0	2	3	0	94	406.5	409.5
304	8477	0	0	0	0	0	0	0	0	0	0	1	1	0	67	343.5	344.5
312	8706	0	0	0	0	0	2	0	0	0	0	1	2	0	82	418.5	420.5
320	8937	0	0	0	0	0	0	0	0	0	0	6	2	0	75	288.5	290.5
328	9170	1	0	1	0	0	0	0	0	0	0	3	0	0	100	325	325
336	9404	0	0	0	0	0	0	0	0	0	0	7	0	0	55	311	311
344	9641	0	0	0	0	0	0	0	0	0	0	1	0	0	92	367.5	367.5
356	10001	0	0	0	0	0	0	0	0	0	0	2	1	0	44	418.5	419.5
364	10245	0	0	0	0	0	0	1	0	0	0	0	1	0	61	342.5	343.5
372	10490	0	0	0	0	0	0	0	0	0	0	1	3	0	73	309	312
380	10737	0	0	0	0	0	0	0	0	0	0	0	7	0	66	316.5	323.5
388	10986	0	0	0	0	0	0	0	0	0	0	1	3	0	55	452.5	455.5
396	11236	0	0	0	0	0	0	0	0	0	0	0	19	0	89	430.5	449.5
404	11487	0	0	0	0	0	0	0	1	0	0	4	21	4	132	431	456
412	11739	0	1	0	0	0	0	0	0	2	0	1	7	0	158	316	323
420	11991	0	0	0	0	0	0	0	0	0	0	10	18	0	366	227.5	245.5
428	12242	0	0	0	0	0	0	5	0	0	0	2	9	0	445	194.5	203.5
436	12492	0	0	0	1	0	0	10	0	0	0	6	10	0	258	213.5	223.5
444	12741	0	0	0	0	0	0	2	0	0	0	7	1	0	101	27.5	28.5
456	13111	0	0	0	0	0	0	0	0	0	0	1	0	0	100	11.5	11.5

APPENDIX C:

POLLEN PERCENTAGES

Blacktail Pond Pollen Percentages																		
Depth (cm)	Age (cal yr B.P.)	PND	PNH	PNU	PIC	ABI	PSE	JUN	ERC	ALN	BET	SAL	POP	FRX	QUE	ACE	ROS	AME
0	23	13.9	0.7	64.0	0.7	0.0	2.0	1.7	0.0	0.0	0.0	1.4	0.6	0.0	0.0	0.0	0.6	0.0
4	127	9.5	2.0	66.9	0.6	0.2	0.9	2.8	0.0	0.5	0.0	0.7	0.5	0.0	0.0	0.0	0.9	0.0
8	232	4.4	0.2	75.7	0.5	0.0	1.7	0.5	0.0	0.2	0.2	1.0	1.2	0.0	0.0	0.0	0.2	0.2
12	336	4.2	1.0	63.2	0.1	0.0	4.6	1.2	0.0	0.2	0.2	1.0	3.4	0.0	0.0	0.0	0.5	0.0
20	545	8.3	6.8	50.8	0.8	0.0	0.7	3.7	0.0	0.3	0.0	1.4	0.3	0.0	0.3	0.0	0.0	0.0
28	755	6.3	2.4	47.5	0.3	0.2	2.8	2.2	0.0	1.3	0.0	1.6	0.3	0.3	0.9	0.0	0.0	1.3
36	965	4.6	0.3	70.9	0.0	0.0	3.6	2.0	0.0	0.0	0.0	0.3	1.6	0.0	0.0	0.0	0.0	0.0
44	1176	9.5	2.5	53.9	0.2	0.0	1.0	2.0	0.0	0.7	0.3	1.7	0.0	0.0	0.7	0.0	0.0	0.7
56	1494	5.2	1.5	61.4	0.6	0.0	3.3	0.5	0.0	1.8	0.0	1.0	0.0	0.0	0.0	0.0	0.8	0.0
64	1707	6.2	0.7	63.3	0.6	0.0	3.7	1.4	0.0	0.0	0.3	0.3	0.9	0.0	0.0	0.0	0.0	0.0
72	1921	5.6	1.5	61.5	3.6	0.0	1.9	0.3	0.0	0.5	0.3	0.8	0.3	0.0	0.3	0.0	0.3	0.0
80	2136	6.7	3.1	59.9	0.1	0.0	2.1	0.8	0.0	0.3	0.8	1.3	0.5	0.0	0.0	0.3	0.5	0.3
88	2353	7.9	0.5	61.2	1.3	0.0	1.4	0.5	0.0	0.2	1.2	1.2	0.2	0.0	0.0	0.2	0.0	0.0
96	2571	8.9	1.2	56.9	0.9	0.1	1.5	0.7	0.0	0.2	0.5	2.0	0.5	0.0	0.0	0.7	0.0	0.0
104	2791	6.6	0.5	71.1	1.4	0.0	1.1	0.3	0.0	0.0	0.5	0.5	0.3	0.0	0.0	0.0	0.3	0.0
112	3012	6.4	2.7	66.7	0.5	0.0	2.7	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	3234	5.2	2.7	66.1	0.2	0.5	1.2	0.2	0.0	0.2	0.5	0.7	0.2	0.0	0.5	0.0	0.2	0.0
128	3457	8.8	1.3	53.6	0.3	1.0	0.3	2.1	0.0	0.5	0.5	1.0	0.5	0.0	0.5	0.0	0.0	0.3
136	3682	11.8	3.7	69.4	0.3	0.0	1.2	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.3	0.3
144	3907	13.0	4.6	58.8	1.3	0.3	1.0	1.6	0.0	0.0	0.7	1.3	0.0	0.0	0.3	0.0	0.0	0.0
156	4247	7.0	2.1	51.6	1.7	0.3	1.8	1.0	0.0	0.3	2.6	2.9	1.0	0.0	0.0	0.0	0.0	0.0
164	4474	3.0	1.9	56.0	4.2	0.3	3.2	0.3	0.0	0.3	2.2	1.1	0.3	0.0	0.0	0.0	0.3	0.3
172	4702	11.3	4.0	45.8	3.4	0.0	2.7	0.7	0.2	0.2	1.6	0.9	0.0	0.0	0.0	0.2	0.2	0.0
180	4930	7.4	0.9	58.4	1.7	0.0	3.0	0.2	0.2	0.8	1.9	0.6	0.4	0.0	0.0	0.2	0.2	0.0
188	5159	4.6	1.3	58.9	2.9	0.2	0.7	0.2	0.0	0.2	2.6	0.7	0.5	0.0	0.0	0.0	0.5	0.2
196	5388	12.5	1.2	53.8	2.1	0.3	1.2	0.3	0.3	0.3	1.5	0.0	0.9	0.0	0.0	0.0	0.0	0.0
204	5618	15.0	3.6	55.0	8.6	0.9	2.9	0.5	0.0	0.3	0.5	0.0	0.5	0.0	0.0	0.0	0.3	0.0
212	5847	3.3	1.2	61.3	0.4	0.0	1.1	1.1	0.0	0.0	5.4	0.0	1.1	0.0	0.0	0.0	0.5	0.0
220	6077	5.4	1.9	56.1	2.2	0.8	0.8	2.0	0.5	0.5	2.8	0.8	0.3	0.0	0.3	0.0	0.5	0.3

Blacktail Pond Pollen Percentages																		
Depth (cm)	Age (cal yr B.P.)	PND	PNH	PNU	PIC	ABI	PSE	JUN	ERC	ALN	BET	SAL	POP	FRX	QUE	ACE	ROS	AME
228	6307	10.1	2.8	56.5	0.8	0.0	0.3	1.6	0.0	0.3	2.2	1.3	0.0	0.0	0.5	0.0	0.0	0.0
236	6536	8.1	2.8	60.7	1.2	0.0	0.6	1.2	0.0	0.3	2.5	0.3	0.6	0.0	0.0	0.0	0.3	0.0
244	6766	8.2	2.9	51.4	1.7	1.0	0.8	0.8	0.0	1.1	3.0	0.6	0.0	0.0	0.3	0.0	0.0	0.0
256	7109	5.4	6.3	58.9	2.8	0.3	2.6	0.8	0.0	0.5	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
264	7337	3.1	3.4	47.6	2.4	0.0	1.4	0.2	0.0	0.5	3.6	1.6	0.5	0.0	0.0	0.0	0.5	0.2
272	7565	6.8	5.6	61.9	0.9	0.1	0.7	1.1	0.0	0.7	2.6	0.2	0.2	0.0	0.0	0.0	0.0	0.0
280	7793	15.7	7.2	53.0	3.8	0.6	0.3	1.2	0.0	0.0	1.8	0.6	0.6	0.0	0.3	0.0	0.0	0.0
288	8021	11.9	11.6	57.7	2.8	0.6	0.0	0.5	0.0	0.2	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
296	8248	18.6	4.2	55.5	8.5	0.7	0.5	0.5	0.5	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
304	8477	12.5	13.8	58.2	3.5	0.3	0.9	0.6	0.3	0.3	0.9	0.3	0.9	0.0	0.0	0.0	0.0	0.0
312	8706	7.9	11.5	52.1	9.9	0.2	0.2	0.2	0.0	0.2	1.0	0.7	1.0	0.0	0.0	0.0	0.2	0.0
320	8937	8.1	24.4	41.1	4.5	0.3	0.7	1.4	0.0	0.0	2.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0
328	9170	9.5	24.6	39.2	2.9	0.0	0.0	0.0	0.0	0.0	2.5	0.3	0.0	0.0	0.3	0.0	0.0	0.0
336	9404	7.7	29.1	31.4	9.3	0.6	0.0	2.6	0.0	0.3	2.6	0.0	1.3	0.0	0.3	0.0	0.0	0.3
344	9641	4.9	5.4	76.7	1.2	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0
356	10001	13.4	12.9	59.7	1.1	1.0	0.0	0.2	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0
364	10245	10.8	12.1	50.2	11.7	0.6	0.0	0.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.3	0.3	0.3
372	10490	9.4	20.9	49.4	5.2	0.6	0.0	1.0	0.0	0.6	1.6	0.3	0.3	0.0	0.3	0.0	0.0	0.3
380	10737	12.3	16.0	53.9	3.6	0.3	0.0	0.3	0.0	0.0	1.3	0.0	0.3	0.0	0.0	0.0	0.6	0.0
388	10986	6.9	10.4	53.3	7.1	0.6	0.2	0.7	0.0	0.9	2.0	0.7	0.0	0.0	0.0	0.2	0.2	0.2
396	11236	5.2	10.7	38.6	8.7	0.6	0.5	1.4	0.0	0.2	4.4	1.4	0.9	0.0	0.0	0.0	0.0	0.2
404	11487	3.9	3.9	36.3	8.1	0.1	0.2	2.1	0.0	0.5	2.8	0.9	0.0	0.0	0.7	0.0	0.5	0.5
412	11739	4.4	10.4	38.4	9.3	0.3	0.0	0.3	0.0	0.6	5.4	0.3	0.6	0.0	0.0	0.0	0.3	0.6
420	11991	7.9	3.3	23.5	5.1	0.0	0.0	2.2	0.4	0.4	0.0	2.6	0.9	0.0	0.0	0.0	1.3	3.1
428	12242	2.6	20.6	26.0	1.5	0.0	0.0	0.5	0.0	0.0	0.0	4.6	1.5	0.0	0.5	0.0	0.5	0.5
436	12492	1.4	11.2	20.8	2.3	0.0	0.0	0.0	0.0	0.5	0.0	4.2	1.4	0.0	0.0	0.0	0.0	0.9
444	12741	0.0	7.3	23.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	3.6	0.0	0.0	0.0	0.0	0.0
456	13111	0.0	17.4	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Blacktail Pond Pollen Percentages																	
Depth (cm)	Age (cal yr B.P.)	POT	CEA	SHE	ELE	ARC	EPH	SAR	POA	ART	AMB	BID	TUB	LIG	CHE	RAN	THA
0	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	8.0	0.9	0.0	0.0	0.3	1.1	0.0	0.0
4	127	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.9	9.8	1.4	0.0	0.0	0.0	0.9	0.0	0.0
8	232	0.0	0.2	0.2	0.0	0.0	0.0	0.5	0.7	8.3	1.2	0.0	0.7	0.0	0.7	0.0	0.0
12	336	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.5	15.9	0.2	0.0	0.2	0.2	2.4	0.0	0.0
20	545	0.3	0.0	0.0	0.0	0.0	0.0	0.3	5.4	13.6	1.4	0.0	0.3	0.0	2.0	0.0	1.0
28	755	0.0	1.9	0.0	0.0	0.0	0.0	1.6	0.6	22.8	0.0	0.0	0.3	0.0	1.9	0.0	0.0
36	965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	11.1	0.0	0.0	1.6	0.0	3.3	0.0	0.0
44	1176	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	18.8	1.0	0.0	0.0	0.0	3.7	0.0	0.7
56	1494	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	14.1	0.5	0.0	1.8	0.0	5.5	0.0	0.0
64	1707	0.0	0.3	0.0	0.0	0.0	0.0	0.0	2.8	16.2	0.6	0.0	0.9	0.0	2.0	0.0	0.0
72	1921	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.1	14.6	0.0	0.0	0.8	0.0	1.6	0.0	0.0
80	2136	0.0	0.0	0.3	0.0	0.0	0.0	0.3	3.6	14.8	1.6	0.0	0.5	0.3	2.1	0.0	0.0
88	2353	0.0	0.9	0.0	0.0	0.2	0.0	0.2	1.4	16.9	0.2	0.0	1.9	0.0	2.1	0.0	0.0
96	2571	0.0	0.2	0.0	0.0	0.0	0.0	0.5	4.2	16.4	2.0	0.0	0.0	0.0	2.5	0.0	0.0
104	2791	0.0	0.3	0.0	0.0	0.0	0.3	0.0	2.2	10.8	0.0	0.0	0.0	0.0	3.3	0.0	0.0
112	3012	0.0	0.0	0.0	0.0	0.0	0.0	0.6	2.7	13.4	0.3	0.0	0.0	0.0	2.1	0.0	0.0
120	3234	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	13.5	0.5	0.0	1.7	0.0	4.6	0.0	0.0
128	3457	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.3	21.1	0.8	0.0	0.8	0.0	2.6	0.0	0.0
136	3682	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.9	8.9	0.3	0.0	0.0	0.0	1.5	0.0	0.0
144	3907	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	10.5	0.3	0.0	0.0	0.0	2.3	0.0	0.0
156	4247	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5	20.8	0.3	0.0	0.0	0.0	5.5	0.0	0.0
164	4474	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	19.4	0.8	0.0	0.3	0.0	4.8	0.0	0.0
172	4702	0.0	0.0	0.0	0.0	0.5	0.2	0.5	0.9	21.7	0.2	0.0	0.7	0.0	3.2	0.0	0.0
180	4930	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	18.4	0.8	0.0	0.0	0.0	4.4	0.0	0.0
188	5159	0.0	0.0	0.0	0.2	0.0	0.0	0.7	2.6	15.7	1.4	0.0	0.9	0.0	4.2	0.0	0.0
196	5388	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.4	17.7	1.2	0.0	0.0	0.0	2.8	0.0	0.0
204	5618	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	8.3	0.3	0.0	0.3	0.0	1.3	0.0	0.0
212	5847	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.6	16.6	1.1	0.0	0.3	0.0	4.1	0.0	0.0
220	6077	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.8	17.2	0.5	0.0	1.0	0.0	3.8	0.0	0.0

Blacktail Pond Pollen Percentages																	
Depth (cm)	Age (cal yr B.P.)	POT	CEA	SHE	ELE	ARC	EPH	SAR	POA	ART	AMB	BID	TUB	LIG	CHE	RAN	THA
228	6307	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	15.1	1.6	0.0	0.0	0.0	2.7	0.0	0.0
236	6536	0.0	0.0	0.0	0.0	0.3	0.0	0.9	1.9	15.0	0.3	0.0	0.6	0.0	2.2	0.0	0.0
244	6766	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	20.2	0.6	0.0	0.0	0.0	5.0	0.0	0.3
256	7109	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	15.6	0.0	0.0	0.3	0.0	3.3	0.0	0.0
264	7337	0.0	0.0	0.0	0.0	0.2	0.0	0.9	0.7	23.2	1.1	0.0	0.7	0.2	7.3	0.0	0.0
272	7565	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.9	12.2	0.7	0.0	0.2	0.0	4.6	0.0	0.0
280	7793	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	9.1	0.6	0.0	0.6	0.0	2.1	0.0	0.0
288	8021	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	7.7	0.0	0.0	0.7	0.0	1.5	0.0	0.0
296	8248	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.0	6.6	0.0	0.0	0.5	0.0	1.2	0.0	0.0
304	8477	0.0	0.0	0.3	0.0	0.0	0.0	0.9	0.6	4.1	0.6	0.0	0.0	0.0	0.9	0.0	0.0
312	8706	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	8.1	0.7	0.0	0.0	0.0	3.8	0.0	0.0
320	8937	0.3	0.7	0.0	0.0	0.0	0.0	0.0	1.0	9.0	0.3	0.0	0.0	0.0	2.4	0.0	0.0
328	9170	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.9	11.4	0.0	0.0	0.0	0.0	5.5	0.0	0.0
336	9404	0.0	0.3	0.0	0.0	0.0	0.3	1.0	1.9	7.1	0.0	0.0	0.3	0.0	1.0	0.0	0.3
344	9641	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.9	0.8	0.0	0.0	0.0	4.4	0.0	0.0
356	10001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	6.7	0.0	0.0	0.0	0.0	2.4	0.0	0.0
364	10245	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2	6.7	0.3	0.3	0.3	0.0	2.0	0.0	0.3
372	10490	0.0	0.0	0.6	0.0	0.0	0.0	0.6	2.3	4.5	0.3	0.0	0.3	0.0	0.6	0.0	0.3
380	10737	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.9	6.6	0.0	0.0	0.6	0.0	1.6	0.0	0.0
388	10986	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.4	10.6	0.9	0.0	0.0	0.0	4.2	0.0	0.0
396	11236	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.0	20.4	0.9	0.0	0.9	0.0	1.4	0.0	0.0
404	11487	0.2	0.0	0.0	0.0	0.0	0.0	0.9	3.9	26.5	0.5	0.0	2.1	0.2	3.7	0.0	0.2
412	11739	0.0	0.0	0.9	0.0	0.0	0.0	0.0	2.8	21.2	0.3	0.0	0.9	0.0	1.3	0.0	0.0
420	11991	0.0	0.0	1.3	0.0	0.0	0.0	0.9	4.0	27.7	0.4	0.0	4.8	0.0	5.3	0.0	0.4
428	12242	0.0	0.0	3.1	0.0	0.0	0.0	1.5	1.0	24.7	0.5	0.5	1.0	0.5	4.6	0.0	0.0
436	12492	0.0	0.0	0.0	0.0	0.5	0.0	0.5	3.7	37.0	0.0	0.0	3.7	0.5	2.8	0.5	0.0
444	12741	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.8	3.6	0.0	3.6	0.0	0.0	0.0	0.0
456	13111	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.1	0.0	0.0	0.0	0.0	17.4	0.0	0.0

Blacktail Pond Pollen Percentages																	
Depth (cm)	Age (cal yr B.P.)	UMB	BRA	CAR	POL	ERG	GAL	FAB	OTH	DRY	SEL	MLV	DEG	CYP	TYP	AP	NAP
0	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.9	0.0	85.7	14.3
4	127	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.7	0.0	86.0	14.0
8	232	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.1	0.0	87.2	12.8
12	336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.8	0.0	80.0	20.0
20	545	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.3	0.0	74.2	25.8
28	755	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	2.5	0.0	70.9	29.1
36	965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.7	0.0	83.3	16.7
44	1176	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.2	0.0	74.2	25.8
56	1494	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.5	0.0	76.8	23.2
64	1707	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	0.0	77.6	22.4
72	1921	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.1	4.0	0.0	77.5	22.5
80	2136	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	77.2	22.8
88	2353	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6	0.0	77.2	22.8
96	2571	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	75.0	25.0
104	2791	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.1	0.0	83.2	16.8
112	3012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	9.1	0.0	80.9	19.1
120	3234	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	78.8	21.2
128	3457	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.4	0.0	71.4	28.6
136	3682	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	88.5	11.5
144	3907	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.0	0.0	82.9	17.1
156	4247	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.8	0.0	72.5	27.5
164	4474	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	6.8	0.0	73.4	26.6
172	4702	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.2	2.6	0.0	72.4	27.6
180	4930	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.4	0.0	75.9	24.1
188	5159	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.0	2.3	0.0	74.4	25.6
196	5388	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	74.9	25.1
204	5618	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.6	0.0	88.5	11.5
212	5847	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.4	0.0	75.7	24.3
220	6077	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.4	0.0	75.2	24.8

Blacktail Pond Pollen Percentages																	
Depth (cm)	Age (cal yr B.P.)	UMB	BRA	CAR	POL	ERG	GAL	FAB	OTH	DRY	SEL	MLV	DEG	CYP	TYP	AP	NAP
228	6307	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.6	0.0	76.3	23.7
236	6536	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	80.1	19.9
244	6766	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	2.2	0.0	71.7	28.3
256	7109	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	0.0	80.0	20.0
264	7337	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.3	0.0	66.1	33.9
272	7565	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	81.0	19.0
280	7793	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.3	0.0	85.4	14.6
288	8021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	89.4	10.6
296	8248	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.0	90.2	9.8
304	8477	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	93.6	6.4
312	8706	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.2	0.5	0.0	86.1	13.9
320	8937	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.7	0.0	85.1	14.9
328	9170	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	80.6	19.4
336	9404	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	87.1	12.9
344	9641	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	89.4	10.6
356	10001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	89.7	10.3
364	10245	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	88.3	11.7
372	10490	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.0	91.3	8.7
380	10737	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	89.3	10.7
388	10986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.0	83.6	16.4
396	11236	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	73.3	26.7
404	11487	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.9	4.6	0.9	61.7	38.3
412	11739	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.3	2.2	0.0	72.2	27.8
420	11991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	7.3	0.0	53.0	47.0
428	12242	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	1.0	4.4	0.0	63.5	36.5
436	12492	0.0	0.0	0.0	0.0	0.5	0.0	0.0	4.7	0.0	0.0	0.0	2.8	4.5	0.0	43.8	56.2
444	12741	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0	0.0	25.5	3.5	0.0	38.2	61.8
456	13111	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	47.8	52.2

APPENDIX D:

CHARCOAL CONCENTRATIONS AND ACCUMULATION RATES

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
2.0	75	2.00	0.08
3.0	101	1.60	0.06
4.0	127	0.00	0.00
5.0	153	0.33	0.01
6.0	179	1.67	0.06
7.0	206	2.33	0.09
8.0	232	2.33	0.09
9.0	258	3.33	0.13
10.0	284	3.00	0.11
11.0	310	1.33	0.05
12.0	336	4.00	0.15
13.0	362	4.33	0.17
14.0	388	0.00	0.00
15.0	415	3.67	0.14
16.0	441	3.33	0.13
17.0	467	5.00	0.19
18.0	493	4.00	0.15
19.0	519	0.67	0.03
20.0	545	4.00	0.15
21.0	572	1.00	0.04
22.0	598	6.00	0.23
23.0	624	2.00	0.08
24.0	650	2.33	0.09
25.0	676	4.67	0.18
26.0	703	3.00	0.11
27.0	729	3.67	0.14
28.0	755	2.67	0.10
29.0	781	0.67	0.03
30.0	808	2.00	0.08
31.0	834	2.00	0.08
32.0	860	2.00	0.08
33.0	886	3.00	0.11
34.0	913	2.33	0.09
35.0	939	1.67	0.06
36.0	965	1.33	0.05
37.0	991	2.67	0.10
38.0	1018	4.00	0.15
39.0	1044	2.00	0.08
40.0	1070	3.67	0.14
41.0	1097	3.33	0.13
42.0	1123	2.67	0.10
43.0	1150	2.00	0.08
44.0	1176	3.00	0.11
45.0	1202	1.00	0.04
46.0	1229	1.67	0.06
47.0	1255	2.00	0.08

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
48.0	1282	3.67	0.14
49.0	1308	3.33	0.13
50.0	1334	4.33	0.16
51.0	1361	4.33	0.16
52.0	1387	2.33	0.09
53.0	1414	1.00	0.04
54.0	1440	2.67	0.10
55.0	1467	2.00	0.08
56.0	1494	1.67	0.06
57.0	1520	7.33	0.28
58.0	1547	11.00	0.41
59.0	1573	12.67	0.48
60.0	1600	1.33	0.05
61.0	1627	9.00	0.34
62.0	1653	3.67	0.14
63.0	1680	2.33	0.09
64.0	1707	11.33	0.42
65.0	1733	4.00	0.15
66.0	1760	5.67	0.21
67.0	1787	1.33	0.05
68.0	1813	25.33	0.95
69.0	1840	20.67	0.77
70.0	1867	5.33	0.20
71.0	1894	0.67	0.02
72.0	1921	1.00	0.04
73.0	1948	1.67	0.06
74.0	1974	3.33	0.12
75.0	2001	3.00	0.11
76.0	2028	1.33	0.05
77.0	2055	3.00	0.11
78.0	2082	3.67	0.14
79.0	2109	2.33	0.09
80.0	2136	6.33	0.23
81.0	2163	1.67	0.06
82.0	2190	8.67	0.32
83.0	2217	1.67	0.06
84.0	2244	7.67	0.28
85.0	2271	3.33	0.12
86.0	2299	8.33	0.31
87.0	2326	4.67	0.17
88.0	2353	2.00	0.07
89.0	2380	4.00	0.15
90.0	2407	4.33	0.16
91.0	2435	1.67	0.06
92.0	2462	3.67	0.13
93.0	2489	7.67	0.28

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
94.0	2516	8.33	0.30
95.0	2544	34.00	1.24
96.0	2571	5.67	0.21
97.0	2599	3.67	0.13
98.0	2626	7.67	0.28
99.0	2653	4.00	0.15
100.0	2681	1.00	0.04
101.0	2708	1.67	0.06
102.0	2736	14.33	0.52
103.0	2763	11.67	0.42
104.0	2791	1.00	0.04
105.0	2818	2.00	0.07
106.0	2846	34.33	1.24
107.0	2874	7.67	0.28
108.0	2901	10.00	0.36
109.0	2929	8.00	0.29
110.0	2957	22.00	0.79
111.0	2984	17.33	0.63
112.0	3012	4.00	0.14
113.0	3040	8.00	0.29
114.0	3067	2.33	0.08
115.0	3095	4.33	0.16
116.0	3123	3.33	0.12
117.0	3151	3.67	0.13
118.0	3178	13.33	0.48
119.0	3206	5.00	0.18
120.0	3234	0.67	0.02
121.0	3262	6.33	0.23
122.0	3290	2.67	0.10
123.0	3318	7.67	0.27
124.0	3346	2.33	0.08
125.0	3374	7.33	0.26
126.0	3402	21.00	0.75
127.0	3429	9.67	0.35
128.0	3457	19.00	0.68
129.0	3485	14.33	0.51
130.0	3513	3.00	0.11
131.0	3541	9.33	0.33
132.0	3570	0.67	0.02
133.0	3598	1.00	0.04
134.0	3626	5.00	0.18
135.0	3654	10.00	0.36
136.0	3682	3.00	0.11
137.0	3710	2.67	0.09
138.0	3738	13.33	0.47
139.0	3766	2.00	0.07

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
140.0	3794	6.67	0.24
141.0	3823	4.33	0.15
142.0	3851	4.00	0.14
143.0	3879	2.00	0.07
144.0	3907	11.00	0.39
145.0	3935	5.67	0.20
146.0	3964	9.33	0.33
147.0	3992	2.33	0.08
148.0	4020	4.00	0.14
149.0	4048	6.00	0.21
150.0	4077	15.00	0.53
151.0	4105	10.00	0.35
152.0	4133	2.33	0.08
153.0	4162	6.33	0.22
154.0	4190	4.33	0.15
155.0	4218	4.67	0.16
156.0	4247	3.00	0.11
157.0	4275	2.67	0.09
158.0	4303	12.33	0.43
159.0	4332	1.00	0.04
160.0	4360	0.33	0.01
161.0	4389	12.33	0.43
162.0	4417	2.00	0.07
163.0	4445	4.00	0.14
164.0	4474	1.67	0.06
165.0	4502	8.00	0.28
166.0	4531	4.67	0.16
167.0	4559	10.33	0.36
168.0	4588	3.33	0.12
169.0	4616	2.00	0.07
170.0	4645	8.67	0.30
171.0	4673	18.67	0.65
172.0	4702	10.00	0.35
173.0	4730	1.33	0.05
174.0	4759	1.33	0.05
175.0	4787	15.33	0.54
176.0	4816	12.67	0.44
177.0	4844	8.00	0.28
178.0	4873	8.33	0.29
179.0	4902	10.67	0.37
180.0	4930	13.67	0.48
181.0	4959	1.67	0.06
182.0	4987	2.00	0.07
183.0	5016	10.67	0.37
184.0	5045	6.33	0.22
185.0	5073	6.00	0.21

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
186.0	5102	4.00	0.14
187.0	5130	3.33	0.12
188.0	5159	19.33	0.68
189.0	5188	19.67	0.69
190.0	5216	7.00	0.24
191.0	5245	2.67	0.09
192.0	5274	2.67	0.09
193.0	5302	3.33	0.12
194.0	5331	3.33	0.12
195.0	5360	8.00	0.28
196.0	5388	2.00	0.07
197.0	5417	14.67	0.51
198.0	5446	1.33	0.05
199.0	5474	5.33	0.19
200.0	5503	8.33	0.29
201.0	5532	7.67	0.27
202.0	5560	3.00	0.10
203.0	5589	1.67	0.06
204.0	5618	3.00	0.10
205.0	5646	9.33	0.33
206.0	5675	5.00	0.17
207.0	5704	3.00	0.10
208.0	5732	2.00	0.07
209.0	5761	5.00	0.17
210.0	5790	8.67	0.30
211.0	5819	8.67	0.30
212.0	5847	3.33	0.12
213.0	5876	4.67	0.16
214.0	5905	2.67	0.09
215.0	5933	2.33	0.08
216.0	5962	2.00	0.07
217.0	5991	6.67	0.23
218.0	6019	5.00	0.17
219.0	6048	3.33	0.12
220.0	6077	1.67	0.06
221.0	6106	16.33	0.57
222.0	6134	5.67	0.20
223.0	6163	3.67	0.13
224.0	6192	4.67	0.16
225.0	6220	6.00	0.21
226.0	6249	8.67	0.30
227.0	6278	10.67	0.37
228.0	6307	7.00	0.24
229.0	6335	5.00	0.17
230.0	6364	7.00	0.24
231.0	6393	8.00	0.28

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
232.0	6421	3.00	0.10
233.0	6450	2.00	0.07
234.0	6479	12.67	0.44
235.0	6507	3.00	0.10
236.0	6536	8.33	0.29
237.0	6565	9.33	0.33
238.0	6594	3.00	0.10
239.0	6622	5.33	0.19
240.0	6651	14.00	0.49
241.0	6680	3.67	0.13
242.0	6708	3.67	0.13
243.0	6737	8.33	0.29
244.0	6766	56.67	1.98
245.0	6794	5.67	0.20
246.0	6823	4.00	0.14
247.0	6851	9.67	0.34
248.0	6880	3.67	0.13
249.0	6909	4.00	0.14
250.0	6937	0.67	0.02
251.0	6966	7.67	0.27
252.0	6995	3.00	0.10
253.0	7023	3.33	0.12
254.0	7052	4.67	0.16
255.0	7080	4.67	0.16
256.0	7109	4.33	0.15
257.0	7138	3.00	0.10
258.0	7166	9.67	0.34
259.0	7195	3.67	0.13
260.0	7223	5.67	0.20
261.0	7252	4.00	0.14
262.0	7280	11.00	0.39
263.0	7309	9.67	0.34
264.0	7337	5.33	0.19
265.0	7366	2.67	0.09
266.0	7394	4.33	0.15
267.0	7423	2.33	0.08
268.0	7452	0.33	0.01
269.0	7480	4.00	0.14
270.0	7508	6.67	0.23
270.5	7523	5.33	0.19
271.0	7537	6.00	0.21
271.5	7551	4.67	0.16
272.0	7565	4.33	0.15
272.5	7580	6.00	0.21
273.0	7594	5.33	0.19
273.5	7608	1.00	0.04

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
274.0	7622	3.67	0.13
274.5	7637	5.33	0.19
275.0	7651	5.33	0.19
275.5	7665	2.33	0.08
276.0	7679	5.33	0.19
276.5	7693	3.33	0.12
277.0	7708	3.67	0.13
277.5	7722	4.00	0.14
278.0	7736	4.67	0.16
278.5	7750	11.33	0.40
279.0	7765	6.67	0.23
279.5	7779	18.33	0.64
280.0	7793	3.00	0.11
280.5	7807	15.33	0.54
281.0	7821	4.00	0.14
281.5	7836	13.33	0.47
282.0	7850	5.33	0.19
282.5	7864	7.67	0.27
283.0	7878	6.00	0.21
283.5	7893	10.00	0.35
284.0	7907	19.67	0.69
284.5	7921	5.00	0.18
285.0	7935	0.67	0.02
285.5	7949	4.33	0.15
286.0	7964	7.00	0.25
286.5	7978	7.33	0.26
287.0	7992	2.33	0.08
287.5	8006	7.33	0.26
288.0	8021	7.33	0.26
288.5	8035	1.00	0.04
289.0	8049	13.33	0.47
289.5	8063	10.00	0.35
290.0	8077	11.33	0.40
290.5	8092	2.33	0.08
291.0	8106	2.00	0.07
291.5	8120	1.00	0.04
292.0	8134	1.67	0.06
292.5	8149	15.33	0.54
293.0	8163	2.33	0.08
293.5	8177	12.00	0.42
294.0	8191	3.00	0.11
294.5	8206	2.33	0.08
295.0	8220	2.67	0.09
295.5	8234	2.00	0.07
296.0	8248	9.00	0.32
296.5	8263	2.00	0.07

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
297.0	8277	2.00	0.07
297.5	8291	1.33	0.05
298.0	8305	0.67	0.02
298.5	8320	0.33	0.01
299.0	8334	10.00	0.35
299.5	8348	1.67	0.06
300.0	8362	3.33	0.12
300.5	8377	1.67	0.06
301.0	8391	2.67	0.09
301.5	8405	6.33	0.22
302.0	8420	10.67	0.37
302.5	8434	7.33	0.26
303.0	8448	0.00	0.00
303.5	8463	1.67	0.06
304.0	8477	7.00	0.24
304.5	8491	9.33	0.33
305.0	8505	4.00	0.14
305.5	8520	1.00	0.03
306.0	8534	5.33	0.19
306.5	8548	2.33	0.08
307.0	8563	6.00	0.21
307.5	8577	1.33	0.05
308.0	8591	4.33	0.15
308.5	8606	2.33	0.08
309.0	8620	3.67	0.13
309.5	8634	1.67	0.06
310.0	8649	11.67	0.41
310.5	8663	0.00	0.00
311.0	8678	0.33	0.01
311.5	8692	1.33	0.05
312.0	8706	2.67	0.09
312.5	8721	4.33	0.15
313.0	8735	7.00	0.24
313.5	8749	4.00	0.14
314.0	8764	0.33	0.01
314.5	8778	0.67	0.02
315.0	8793	17.33	0.60
315.5	8807	9.00	0.31
316.0	8822	1.67	0.06
316.5	8836	8.33	0.29
317.0	8850	2.00	0.07
317.5	8865	4.00	0.14
318.0	8879	6.67	0.23
318.5	8894	7.00	0.24
319.0	8908	1.67	0.06
319.5	8923	2.67	0.09

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
320.0	8937	9.33	0.32
320.5	8952	4.00	0.14
321.0	8966	18.33	0.63
321.5	8981	8.33	0.29
322.0	8995	3.33	0.11
322.5	9010	2.67	0.09
323.0	9024	7.33	0.25
323.5	9039	0.67	0.02
324.0	9053	4.67	0.16
324.5	9068	7.67	0.26
325.0	9082	4.33	0.15
325.5	9097	0.00	0.00
326.0	9111	0.00	0.00
326.5	9126	4.00	0.14
327.0	9140	1.00	0.03
327.5	9155	0.67	0.02
328.0	9170	1.67	0.06
328.5	9184	4.00	0.14
329.0	9199	7.67	0.26
329.5	9213	5.00	0.17
330.0	9228	5.00	0.17
330.5	9243	6.33	0.22
331.0	9257	4.33	0.15
331.5	9272	4.67	0.16
332.0	9287	1.67	0.06
332.5	9301	4.67	0.16
333.0	9316	0.67	0.02
333.5	9331	5.33	0.18
334.0	9345	1.67	0.06
334.5	9360	5.67	0.19
335.0	9375	1.00	0.03
335.5	9389	0.33	0.01
336.0	9404	0.00	0.00
336.5	9419	1.00	0.03
337.0	9434	6.33	0.21
337.5	9448	0.67	0.02
338.0	9463	5.00	0.17
338.5	9478	9.33	0.32
339.0	9493	9.00	0.30
339.5	9508	1.67	0.06
340.0	9522	6.00	0.20
340.5	9537	1.00	0.03
341.0	9552	3.67	0.12
341.5	9567	1.33	0.04
342.0	9582	3.67	0.12
342.5	9596	2.67	0.09

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
343.0	9611	9.00	0.30
343.5	9626	6.00	0.20
344.0	9641	4.00	0.13
344.5	9656	0.33	0.01
345.0	9671	2.00	0.07
345.5	9686	6.00	0.20
346.0	9701	7.33	0.25
346.5	9716	2.33	0.08
347.0	9731	2.67	0.09
347.5	9746	5.33	0.18
348.0	9761	5.00	0.17
348.5	9776	19.67	0.66
349.0	9791	9.67	0.32
349.5	9806	9.00	0.30
350.0	9821	6.00	0.20
350.5	9836	9.67	0.32
351.0	9851	7.33	0.24
351.5	9866	1.00	0.03
352.0	9881	7.67	0.25
352.5	9896	4.33	0.14
353.0	9911	9.00	0.30
353.5	9926	4.67	0.15
354.0	9941	5.67	0.19
354.5	9956	5.00	0.17
355.0	9971	4.00	0.13
355.5	9986	3.33	0.11
356.0	10001	6.33	0.21
356.5	10017	8.33	0.28
357.0	10032	5.00	0.17
357.5	10047	9.00	0.30
358.0	10062	15.33	0.51
358.5	10077	9.00	0.30
359.0	10092	29.67	0.98
359.5	10107	43.00	1.42
360.0	10123	104.33	3.43
360.5	10138	6.33	0.21
361.0	10153	2.33	0.08
361.5	10168	3.33	0.11
362.0	10184	7.00	0.23
362.5	10199	12.33	0.40
363.0	10214	5.67	0.19
363.5	10229	1.67	0.05
364.0	10245	0.33	0.01
364.5	10260	4.33	0.14
365.0	10275	5.33	0.17
365.5	10290	1.00	0.03

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
366.0	10306	4.33	0.14
366.5	10321	7.00	0.23
367.0	10336	5.67	0.18
367.5	10352	2.00	0.07
368.0	10367	10.00	0.33
368.5	10382	4.67	0.15
369.0	10398	10.67	0.35
369.5	10413	2.67	0.09
370.0	10428	2.67	0.09
370.5	10444	14.67	0.48
371.0	10459	4.33	0.14
371.5	10474	5.00	0.16
372.0	10490	4.33	0.14
372.5	10505	13.00	0.42
373.0	10521	6.33	0.21
373.5	10536	4.67	0.15
374.0	10551	1.33	0.04
374.5	10567	14.00	0.45
375.0	10582	4.00	0.13
375.5	10598	3.00	0.10
376.0	10613	12.00	0.39
376.5	10629	3.00	0.10
377.0	10644	5.67	0.18
377.5	10660	2.67	0.09
378.0	10675	7.67	0.25
378.5	10690	8.67	0.28
379.0	10706	4.00	0.13
379.5	10721	4.33	0.14
380.0	10737	11.67	0.38
380.5	10752	6.33	0.20
381.0	10768	23.33	0.75
381.5	10783	11.67	0.38
382.0	10799	4.67	0.15
382.5	10815	19.33	0.62
383.0	10830	9.33	0.30
383.5	10846	17.00	0.55
384.0	10861	22.67	0.73
384.5	10877	15.33	0.49
385.0	10892	12.00	0.39
385.5	10908	17.67	0.57
386.0	10923	4.33	0.14
386.5	10939	49.00	1.57
387.0	10955	87.00	2.79
387.5	10970	101.67	3.26
388.0	10986	9.67	0.31
388.5	11001	3.67	0.12

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
389.0	11017	2.00	0.06
389.5	11033	2.33	0.07
390.0	11048	16.00	0.51
390.5	11064	1.67	0.05
391.0	11079	24.00	0.77
391.5	11095	25.33	0.81
392.0	11111	7.00	0.22
392.5	11126	12.00	0.38
393.0	11142	3.33	0.11
393.5	11158	9.67	0.31
394.0	11173	15.00	0.48
394.5	11189	4.67	0.15
395.0	11205	11.00	0.35
395.5	11220	13.33	0.43
396.0	11236	12.33	0.39
396.5	11252	3.00	0.10
397.0	11267	8.67	0.28
397.5	11283	0.67	0.02
398.0	11299	23.67	0.75
398.5	11314	6.33	0.20
399.0	11330	7.00	0.22
399.5	11346	9.00	0.29
400.0	11362	19.67	0.63
400.5	11377	14.00	0.45
401.0	11393	7.67	0.24
401.5	11409	26.33	0.84
402.0	11424	9.67	0.31
402.5	11440	14.00	0.45
403.0	11456	4.67	0.15
403.5	11471	25.67	0.82
404.0	11487	22.67	0.72
404.5	11503	4.33	0.14
405.0	11519	25.00	0.80
405.5	11534	13.33	0.42
406.0	11550	2.33	0.07
406.5	11566	6.33	0.20
407.0	11582	8.33	0.26
407.5	11597	4.67	0.15
408.0	11613	4.33	0.14
408.5	11629	4.67	0.15
409.0	11644	15.33	0.49
409.5	11660	2.33	0.07
410.0	11676	5.33	0.17
410.5	11692	11.67	0.37
411.0	11707	3.00	0.10
411.5	11723	6.67	0.21

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
412.0	11739	11.00	0.35
412.5	11755	4.00	0.13
413.0	11770	5.00	0.16
413.5	11786	4.33	0.14
414.0	11802	1.00	0.03
414.5	11818	0.67	0.02
415.0	11833	2.00	0.06
415.5	11849	2.00	0.06
416.0	11865	2.33	0.07
416.5	11880	4.67	0.15
417.0	11896	2.00	0.06
417.5	11912	1.67	0.05
418.0	11928	1.00	0.03
418.5	11943	5.00	0.16
419.0	11959	1.67	0.05
419.5	11975	0.33	0.01
420.0	11991	1.67	0.05
420.5	12006	0.00	0.00
421.0	12022	0.00	0.00
421.5	12038	0.00	0.00
422.0	12053	0.00	0.00
422.5	12069	0.00	0.00
423.0	12085	0.33	0.01
423.5	12101	0.33	0.01
424.0	12116	0.00	0.00
424.5	12132	0.00	0.00
425.0	12148	0.00	0.00
425.5	12163	0.33	0.01
426.0	12179	0.00	0.00
426.5	12195	0.33	0.01
427.0	12210	0.00	0.00
427.5	12226	0.33	0.01
428.0	12242	0.00	0.00
428.5	12257	0.33	0.01
429.0	12273	0.33	0.01
429.5	12289	0.00	0.00
430.0	12305	0.00	0.00
430.5	12320	0.00	0.00
431.0	12336	0.67	0.02
431.5	12351	0.33	0.01
432.0	12367	0.00	0.00
432.5	12383	1.00	0.03
433.0	12398	0.00	0.00
433.5	12414	0.00	0.00
434.0	12430	0.00	0.00
434.5	12445	0.67	0.02

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
435.0	12461	0.33	0.01
435.5	12477	0.00	0.00
436.0	12492	0.00	0.00
436.5	12508	0.00	0.00
437.0	12523	0.67	0.02
437.5	12539	0.00	0.00
438.0	12555	0.33	0.01
438.5	12570	0.00	0.00
439.0	12586	0.33	0.01
439.5	12601	0.33	0.01
440.0	12617	0.00	0.00
440.5	12632	0.00	0.00
441.0	12648	0.00	0.00
441.5	12664	0.33	0.01
442.0	12679	0.00	0.00
442.5	12695	0.00	0.00
443.0	12710	0.00	0.00
443.5	12726	0.00	0.00
444.0	12741	0.00	0.00
444.5	12757	0.33	0.01
445.0	12772	0.00	0.00
445.5	12788	0.33	0.01
446.0	12803	0.00	0.00
446.5	12819	0.00	0.00
447.0	12834	0.00	0.00
447.5	12850	0.33	0.01
448.0	12865	0.00	0.00
448.5	12880	0.00	0.00
449.0	12896	0.00	0.00
449.5	12911	0.00	0.00
450.0	12927	0.00	0.00
450.5	12942	0.00	0.00
451.0	12958	0.33	0.01
451.5	12973	0.00	0.00
452.0	12988	0.00	0.00
452.5	13004	0.33	0.01
453.0	13019	0.33	0.01
453.5	13034	0.33	0.01
454.0	13050	0.00	0.00
454.5	13065	0.00	0.00
455.0	13081	0.00	0.00
455.5	13096	0.00	0.00
456.0	13111	0.00	0.00
456.5	13126	0.00	0.00
457.0	13142	0.00	0.00
457.5	13157	0.33	0.01

Blacktail Pond Charcoal Concentrations and Accumulation Rates			
Depth (cm)	Age (cal yr B.P.)	Concentration (# cm^{-3})	Accumulation Rate (# cm^{-2} yr^{-1})
458.0	13172	0.00	0.00
458.5	13188	0.00	0.00
459.0	13203	0.00	0.00
459.5	13218	0.33	0.01
460.0	13233	0.00	0.00
460.5	13249	0.33	0.01
461.0	13264	0.00	0.00
461.5	13279	0.00	0.00
462.0	13294	0.00	0.00
462.5	13309	0.00	0.00
463.0	13324	0.00	0.00
463.5	13340	0.33	0.01
464.0	13355	0.00	0.00
464.5	13370	0.33	0.01
465.0	13385	0.00	0.00
465.5	13400	0.33	0.01
466.0	13415	0.00	0.00
466.5	13430	0.00	0.00
467.0	13445	0.00	0.00
467.5	13460	0.00	0.00
468.0	13475	0.00	0.00
468.5	13491	0.00	0.00
469.0	13506	0.00	0.00
469.5	13521	0.00	0.00