VEGETATION CHANGE IN THE UPPER SNAKE, YELLOWSTONE, AND GREEN RIVER DRAINAGES: THE LAST 14,000 YEARS

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ABSTRACT

Compiled pollen data from 28 cores indicate that the proportions of some plant species in Eastern Idaho and Western Wyoming have varied dramatically over the last 14,000 years. This information was used to examine how vegetation communities change over time. Discriminant analysis was used to determine the most influential species in community composition. The proportion of each discriminating species was interpolated for areas between cores using cokriging which allowed us to employ elevation. The general pattern of distribution in the predicted vegetation map for the historical period was comparable to the modern GAP data and provided the model for creating predictive maps for the notable vegetation peaks of the late Pleistocene and early and late Holocene.

Keywords: pollen coring, GIS, Idaho, historic.

INTRODUCTION

Humans have been exploiting the resources of eastern Idaho and western Wyoming for over ten thousand years. Near the center of our project area at Wasden Cave (Miller 1982), Folsom projectile points were found along with mammoth remains in deposits dating to 10,640 ± 85 BP, (AA-6833 accelerator date, Miller personal communication, 1997). Near the southwestern edge of the area, a twenty year old woman was buried with a spear point and bone needle 10,675 ± 95 years ago (Green, et al. 1998). In Yellowstone National Park near the eastern edge of the area, archaeological surveys and excavations have discovered large obsidian points which have provided hydration dates of 9,850 ± 278 years ago and 9,650 ± 248 years ago (Cannon 1993:8). These points are part of a broad collection of artifacts that document the exploitation of mammoth, bison, antelope, deer, and elk. To gain a better understanding of the resources available to early hunters and their prey from the Late Pleistocene into historic times, archaeologists attempt to reconstruct the environment in which they lived (Grayson 1998, Rhode 1999). Over the past several years, pollen cores have been collected from cave deposits on the Idaho National Engineering and Environmental Laboratory (INEEL) and from mountain lakes in eastern Idaho, Yellowstone National Park, Grand Teton National Park, and the Wind River Range (Figure 1).

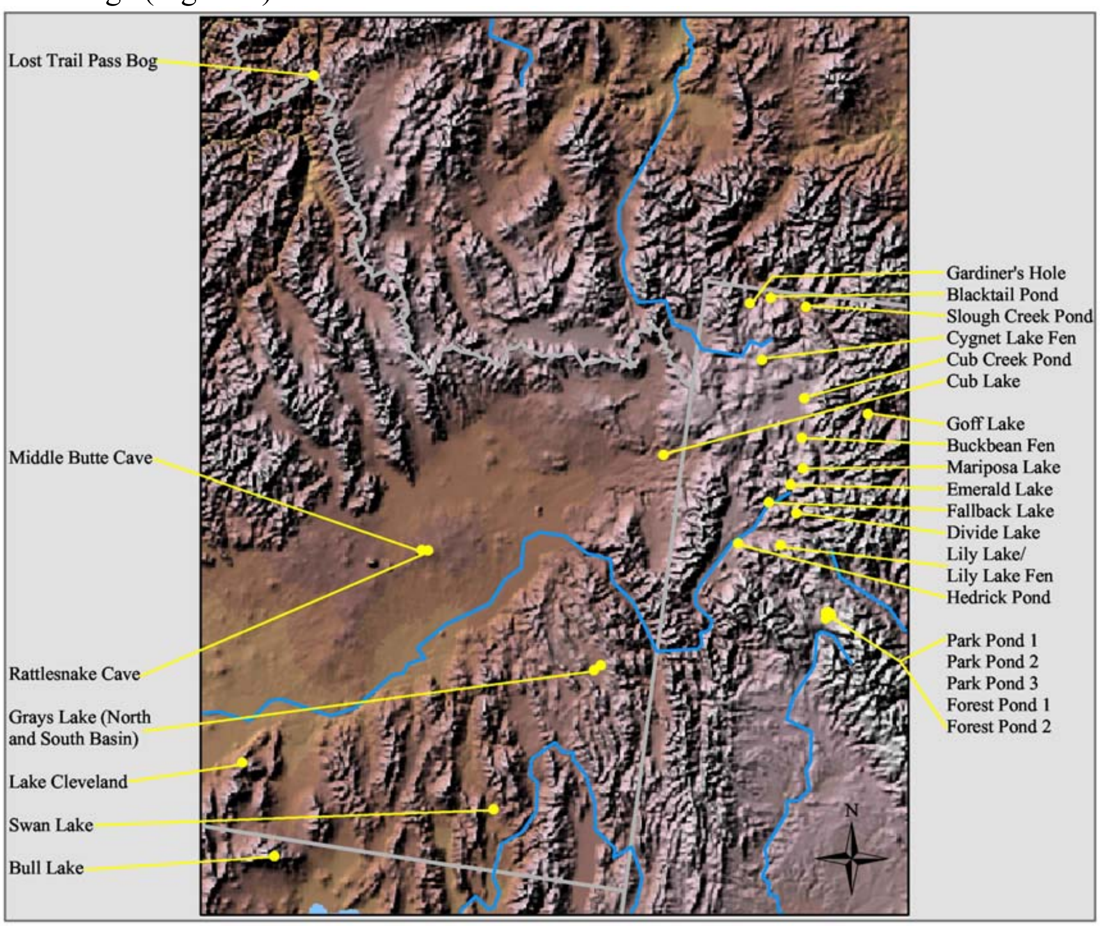


Figure 1. Shaded relief of the project area with core locations identified. The shaded relief was created by John Sterner at John Hopkins University Applied Physics Laboratory (Sterner 1995).

The local environment has fluctuated greatly as a result of global and regional weather fluctuations (regardless of human impacts) and there is no single "normal " or pristine environment that defines the Upper Snake River Basin. Therefore compiling what is known about "natural" fluctuations will provide a baseline to interpret the actual effects of past and modern societies and to appreciate what the immediate and long-term prospects are for environmental fluctuation. While pollen cores are typically used to recreate local vegetation change (Beiswenger 1991, Bright 1966, and Whitlock 1993), this research project explores the possibility of reconstructing how plant communities change over time on a regional scale.

Study Area

The study area (see Figure 1) extends 265 miles N-S by 230 miles E-W and encompasses an area of 60,950 square miles or nearly 40 million acres. The shaded relief shows the dramatic variation in topographic relief that characterizes the area which impacts its climate and consequent vegetation cover (Wigand 2003). The locations of the pollen cores are broadly dispersed across southeastern Idaho with one core from southwestern Montana and one from northern Utah. The pollen cores from western Wyoming are in closer proximity to one another with the five cores in the Wind River Range (Park Pond and Forest Pond locations) separated by only .9 to 2.3 miles. The furthest distance between pollen cores is 263 miles between Lost Trail Pass and Bull Lake with Bull Lake 259 miles from Slough Creek Pond and Lost Trail Pass 253 miles from the Wind River cores. This separation distance presents a number of difficulties when attempting to interpolate the vegetation between pollen cores, but it was anticipated that the Wind River Range cores would provide important information for modeling short-range spatial autocorrelation.

Pollen Database

We have compiled all published pollen data for the Upper Snake River and adjacent regions (see Table 1). Much of this data is available on the internet from the North American Pollen Database. When the raw pollen data was not available, data was extrapolated from published pollen diagrams. Two additional previously uninvestigated cores were included: a core from Bull Lake in northern Utah was analyzed by Van de Water and another core from the northern Grays Lake Basin was examined by Wigand (2003). Although the analysis varies among the locales, pollen was removed from the drilled cores at approximately every 10 cm. Plants were identified to family and genus and either raw counts or percentage of total pollen were recorded. All pollen counts have been converted to proportions to provide comparative data.

The pollen cores have been analyzed to varying degrees. For some cores, different species within a genus have been identified, such as *Pinus contorta* and *Pinus flexilis*, while in other cores, *Pinus* species were not differentiated. While the compiled database lists each core's raw data in the manner it was initially presented, additional variables have been added to combine species which were not consistently differentiated. Combined species include *Acer*, *Alnus*, *Ambrosia*, *Asteraceae*, *Ceanothus*, *Cercocarpus*, *Chenopodiaceae*/*Amaranthaceae*, *Ephedra*, *Eriogonum*, *Fraxinus*, *Galium*, *Juglans*, *Juniperus*, *Pinus*, *Populus*, *Potentilla*, *Prunus*, *Pseudotsuga*, *Ranunculus*, *Rosaceae*, *Sambucus*, *Sarcobatus*, *Saxifragaceae*, *Scrophulariaceae*, *Shepherdia*, *Spiraea*, *Tsuga*, *Valeriana*, and *Xanthium*. In addition, all species of grass (*Gramineae*, *Poaceae*, and *Phragmites*) were combined. The following discussion refers to these combinations and the general patterns of their distribution. It should also be noted that this analysis deals only with terrestrial pollens which reflect changes in species distribution: aquatic pollens, spores and algae are included in some of the pollen analyses, but provide information regarding changes in aquatic systems.

Table 1. Locations of the pollen cores and the investigators that contributed data for this project. The number of sources that were used to interpolate each pollen cores chronology, as well as its age range in radiocarbon years BP are provided.

Core Location	**State**	**Investigator**	**Dates**	**Min. Age**	**Max. Age**
*Blacktail Pond	WY	Gennett 1977	4	0	11752
*Buckbean Fen	WY	Baker 1977	8	0	11500
Bull Lake	UT	Van de Water	5	2719	13398
*Cub Creek Pond	WY	Wright n.d.	3	128	11947
*Cub Lake	ID	Baker 1983	3	0	14096
*Cygnet Lake Fen	WY	Whitlock 1993	9	0	16484
*Divide Lake	WY	Whitlock 1993	5	0	12392
*Emerald Lake	WY	Whitlock 1993	6	459	12730
*Fallback Lake	WY	Whitlock 1993	3	8609	12173
*Forest Pond 1	WY	Lynch 1995	5	0	8703
*Forest Pond 2	WY	Lynch 1995	5	0	8687
*Gardiner's Hole	WY	Baker 1983	3	0	13850
*Goff Lake	WY	Wright n.d.	2	142	3710
Grays Lake - north	ID	Wigand 2003	4	72	4250
Grays Lake - south	ID	Beiswenger 1991	18	0	20717
*Hedrick Pond	WY	Whitlock 1993	6	0	17408
Lake Cleveland	ID	Davis, et al. 1986	5	0	12503
*Lily Lake	WY	Whitlock 1993	4	0	7507
*Lily Lake Fen	WY	Whitlock 1993	6	6286	12891
Lost Trail Pass Bog	MT	Mehringer, et al. 1977	16	0	15327
*Mariposa Lake	WY	Whitlock 1993	5	0	13369
Middle Butte Cave	ID	Davis, et al. 1986	6	2871	30407
*Park Pond 1	WY	Lynch 1995	3	180	4533
*Park Pond 2	WY	Lynch 1995	5	0	10328
*Park Pond 3	WY	Lynch 1995	5	394	10451
Rattlesnake Cave	ID	Davis, et al. 1986	6	0	13991
*Slough Creek Pond	WY	Whitlock and Bartlein 1993	6	0	13362
Swan Lake	ID	Bright 1966	4	0	12090

* Data is available from the North American Pollen Database.

METHODS

The project's objective was to produce vegetation maps for time periods identified as peak transitions by the data. If we could successfully predict modern vegetation based on our pollen core samples, we felt we could use the model to predict vegetation in earlier time periods. The pollen data indicate that some species, particularly sage, pine and grass, show dramatic fluctuations over time (Figure 2), while other species, particularly *Populus*, show almost no change even though *Populus* differentiates some plant communities from others. Therefore, we felt it was important to identify which species within our pollen samples were the most influential in distinguishing between the modern GAP vegetation classifications, rather than only using species that showed variation over time.

In selecting the most recent data for the last 200 years, only 22 pollen cores contributed data. Therefore, we included the most recent data from four more cores, Emerald Lake, Park Pond 3, Middle Butte, and Bull Lake to obtain data representative of the entire area. As some of the pollen cores have been analyzed at finer scales than others, they may contribute two or more data values for ages that fall within this range. Discriminant analysis indicated that 33 species had the most discriminating power. However, nine of these were not considered as they were present at four or less pollen locales. The remaining species determined to have the most predictive power were *Abies*, *Alnus*, *Ambrosia*, *Artemisia*, *Aster*, *Betula*, *Cercocarpus*, *Chenopodiaceae/Amaranthaceae*, *Ephedra*, *Eriogonum*, *grass*, *Juniperus*, *Picea*, *Pinus*, *Populus*, *Pseudotsuga*, *Quercus*, *Ranunculus*, *Rhamnaceae*, *Rosaceae*, *Rumex*, *Salix*, *Sarcobatus*, and *Thalictrum*.

Several interpolating methods were explored with the Wyoming data in an effort to find the best method for predicting vegetation between sampled locales. Unfortunately, the paucity of the data severely limits employing any interpolation method with any degree of accuracy. Relationships between species and other environmental variables were examined and elevation was found to have a weak correlation. As this project focused on determining general patterns of distribution, we felt that accuracy could be compromised to create a smooth surface and the capability of cokriging allowed us to capitalize on the correlation of species with elevation. In performing cokriging, we accepted the default coefficients calculated within ArcMap's Geostatistical Analyst. While adjustments were made to the search radius and the number of neighbors to include, these were attempted in an effort to produce predictions for the entire area and to smooth contours, not to improve accuracy or manipulate the distribution.

The shear size of the study area determined the resolution at which the analysis could be conducted. To comply with the limitations of our statistical software, we resampled concatenated digital elevation models (DEM) to produce a number of cells that would be manageable. This resulted in an image with a cell resolution of 316.683 m. Elevations associated with each cell's center point were used with the pollen data to create prediction maps for the 24 most influential species of the recent period.

The ISU GIS Training and Research Center had previously merged the GAP data for the center's specific area of concern (AOC) which includes Idaho, Montana, Wyoming, and Utah. As the AOC extends across four states, it was necessary to recode the GAP vegetation data from each state into a uniform system. We used the recoded vegetation coverage, which will be referred to as rcGAP, to distinguish it from each state's GAP analysis (Gap Analysis Program). For each cell, the rcGAP category was derived. Although, we refer to this as the historic map, we were really interested in how the vegetation landscape looked prior to Euro-American expansion into the area. Therefore we treated cells with rcGap codes such as agriculture or urban as missing data. Discriminant analysis was conducted based on the rcGAP vegetation categories using the predicted species distributions and elevation. Our first attempt produced a rather complex vegetation distribution simply because there were so many categories. In an attempt to simplify classifications into more general categories, we further combined the rcGAP classes into the following distinctive groups. All subsequent predicted classifications were based on these generalized vegetation groups which are organized by approximate elevation from highest to lowest.

Mixed Subalpine: Alpine fir, lodgepole pine, spruce, and whitebark pine are included in this classification in Idaho's GAP data. Within our predicted category, 37%

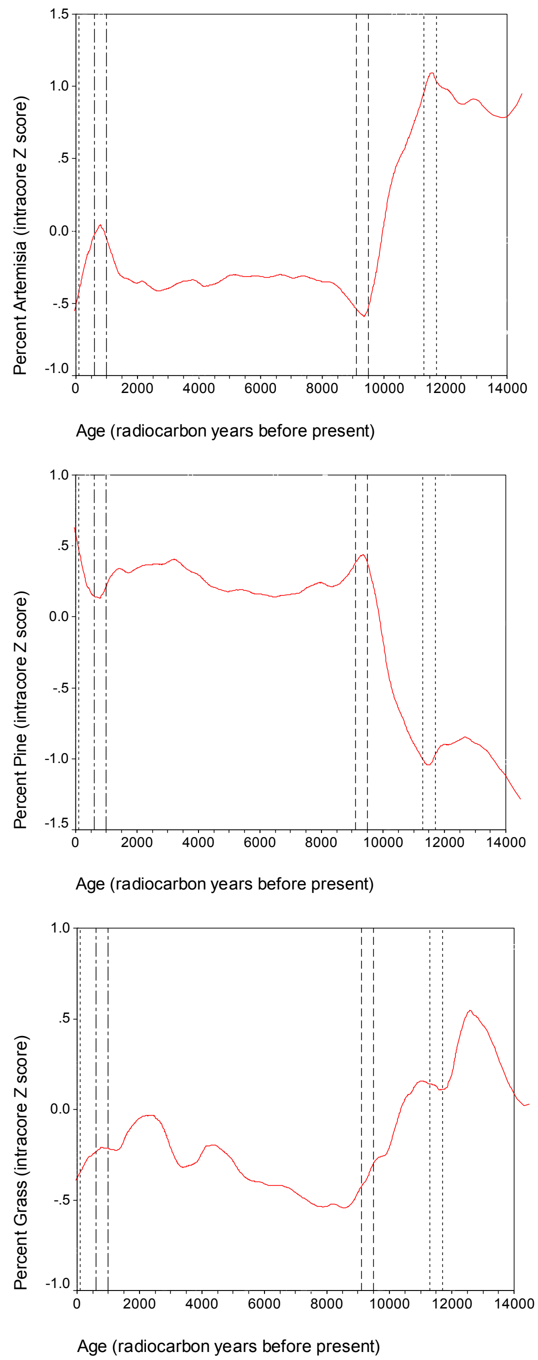


Figure 2. Fluctuations in the percent of sage, pine and grass over the last 14,000 years. Lines bracket the peak transition periods examined: single dotted line – present historic period; double dot and dash lines – late Holocene; double dash lines – early Holocene; and double dotted lines – late Pleistocene.

of the area was classed in the rcGAP as mixed subalpine, 21.7% was classed as whitebark pine, and 19.2% was classed as grassland. According to the discriminant analysis, this category has a comparatively small amount of grass and sagebrush cover.

Subalpine Meadow: Almost one third (29.3%) of the predicted subalpine meadow category was classified as subalpine meadow by the rcGAP with significant areas classed as mixed spruce and fir (23.4%), douglas-fir (7.3%), and lodgepole pine (23.3%). While the Idaho GAP Analysis defines this class as predominantly perennial montane or subalpine grass species, our predicted category includes more montane forbs and shrubs along with pine, spruce and fir which is consistent with the other rcGAP categories. Idaho's lodgepole pine class includes subalpine fir, Englemann spruce, whitebark pine, aspen and douglas-fir, as well as *Artemisia* spp. This is similar to what is found in the douglas-fir category with the addition of grand fir, ponderosa pine, and limber pine and shrubs such as serviceberry, snowberry, chokecherry, Oregon grape, and spirea. While *Asteraceae* and *Picea* occur in small amounts in each of the predicted categories, the subalpine meadow class contains the largest proportion.

Mixed Conifers: A number of different categories of the rcGAP comprise the predicted group mixed conifers. This is apparent when looking at how areas within the predicted group were formerly classed: 29.6% of predicted mixed conifer was classed as lodgepole pine in the rcGAP, 11.3% was classed as mixed subalpine, 10.1% was classed as douglas-fir, 7.7% was classed as grassland, and 9.2% was classed as big sagebrush. Our predicted group contains the third highest proportion of pine and fourth highest proportion of spruce within the pollen cores. Additional species include spruce, *Artemisia* spp., chenoams (*Chenopodeaceae*/*Amaranthaceae*), and various grasses.

Mixed Aspen/Conifer: *Populus* spp. occur in relatively small proportions within the pollen cores, yet we were able to differentiate this group with a relative degree of success. While areas within the predicted mixed aspen/conifer category were classed as mixed subalpine, douglas-fir, and lodgepole pine in the rcGAP, 23.4% of the area was classed as aspen and 26.7% was classed as big sagebrush. Perhaps the differentiating characteristic is that a 'median' amount of the discriminating species occurs in the mixed aspen/conifer group, except for juniper; it contains the highest proportion of J*uniperus* spp. of any of our predicted groups.

Mountain Sage: Within our predicted groups, the mountain sage category contains the highest proportions of *Artemisia* spp., *Betula*, *Ephedra* spp., *Eriogonum* and chenoams. This is the category referred to as montane shrub in the rcGAP, but we selectively named it mountain sage due to the dominance of sage and the fact that less than one percent of the predicted group was classed as montane shrub in the rcGAP. Within the mountain sage class, 33.6% of the area was formerly classed as big sagebrush, 17.8% as aspen, and 20.9% as douglas-fir. The Idaho GAP defines a warm mesic shrub category for southern Idaho as containing alder, serviceberry, Oregon grape, snowberry, willow, rose and various fruit-bearing shrubs: understory plants found in the douglas-fir category.

Riparian: The predicted riparian class has a high proportion of *Picea* and *Pinus* species and is most similar to the needleleaf dominated riparian class as defined in the Idaho GAP. This category includes douglas-fir, Englemann spruce, subalpine fir, maple, lodgepole pine, aspen and cottonwood. Comparatively, this predicted class has lower proportions mountain mahogany, chenoams, grass and juniper.

Grassland: In addition to various grasses, the predicted grassland class contains pine, spruce and some sagebrush, although it has the least amount of sage when other classes are compared. Discriminant analysis did reasonably well: 46.9% of the predicted grassland was classed by the rcGAP as grassland and 23.9% of the area was classed as sagebrush. Other grassland areas were classed as mixed xeric conifer, mixed subalpine and Douglas-fir. Interestingly, its proportion of pine is the highest compared to the other predicted categories, however, it is only slightly lower than in the mixed subalpine class. This is possibly due to the broad airborne distribution of pine pollen rather than stands of pine within the grassland.

Pinyon Pine/Juniper: The Idaho GAP defines the pinyon pine/juniper class as dominated by these two species, although mountain mahogany, serviceberry, *Artemisia* spp., bitterbrush, chokecherry, and snowberry may also occur. Only 8.4% of the area within predicted pinyon pine/juniper was classed as pinyon pine/juniper in the rcGAP; 16.8% of the area was classed as grassland and 53.2% of the area was classed as big sagebrush. The predicted class has a comparatively low proportion of pine, but its proportion of juniper is somewhat higher than average. The highest percent of mountain mahogany and *Abies* spp. occurs in this category.

Sagebrush Steppe: We combined the rcGAP sagebrush categories into one class, the sagebrush steppe. Following the descriptions given in the Idaho GAP, a variety of other plants could be found in association with *Artemisia* spp. depending on available moisture and elevation. These include grand fir, subalpine fir, mountain mahogany, lodgepole pine, ponderosa pine, douglas-fir, juniper, bearberry, Ceonothus, ninebark, chokeberry, snowberry, bitterbrush, greasewood, and bluebunch wheatgrass. Within the predicted sagebrush steppe group, 57.7% of the area was classed as big sagebrush in the rcGAP and 9.5% of the area was classed as grassland. The proportion of *Artemisia* spp. in the predicted sagebrush stepped is significant; however, it is not the highest compared to the other categories. Interestingly, there is almost as much pine as sagebrush, but again this is most likely a factor of the proliferation of *Pinus* pollen.

Sage/Grassland: Our predicted sage/grassland category contains the highest proportions of *Populus* spp., *Pseudotsuga* spp., *Quercus*, *Ranunculus*, and *Rosaceae* spp. when compared to the other categories. There is also a particularly high percent of grass and a comparatively high percent of *Artemisia* spp. and chenoams. This may account for the fact that 62.7 % of the area within predicted sage/grasslands was classed as big sagebrush within rcGAP.

Greasewood/Desert: Discriminant analysis repeatedly separated this category. Predicted greasewood/desert has the highest proportion of *Sarcobatus,* ragweed, and grasses and the lowest proportion of pine. It also contains a significant amount of *Artemisia* spp. and chenoams. Comparing the predicted to rcGAP, 70.1% was classed as grassland in rcGAP, 10.1% was classed as big sagebrush, and 16.3% was classed as salt desert shrub. The Idaho GAP defines salt-desert shrub as budsage (*Artemisia spinescens*), shadscale (*Atriplex confertifolia*), 4-wing saltbush (*Atriplex spinosa*) and greasewood (*Sarcobatus vermiculatus*). As our pollen core data do not differentiate *Atriplex* spp., we elected to name the category greasewood/desert.

Using our combined classifications produced a generalized vegetation map (Figure 3) which we felt was comparative, at least visually, to the modern GAP data. Natural landscape features, such as sand dunes and lava, were recoded to match the reGAP data. In addition to the reconstructed historic vegetation distribution, we selected three earlier time periods in which to create vegetation maps because they appear to represent extremes in vegetation fluctuation (Figure 2). The three periods are:

Late Holocene Extreme: This period is generally known as the Medieval climate optimum or anomaly (Bettinger 1999:68) and dates to approximately 1100 – 600 years ago. It was a warm-dry period marked by a reduced distribution of pine when compared to earlier and later periods in the Holocene. Much of what today is coniferous forest was then subalpine meadowland, which also contained considerable amounts of sagebrush. The amount of grass was significantly greater than today but not as great as the Holocene peak around 2500 years ago.

Early Holocene Extreme: This period, dating to 9100 – 9500 years ago, was marked by a dramatic expansion of pine growth over earlier times spurred by the rapid warming at the onset of the Holocene but prior to the long-term drying effects of prolonged heat. The quantity and distribution of sagebrush, grass and pine is similar to historic vegetation cover. This period is probably equivalent to interstadial number seven recognized in millennial-scale climatic cycles throughout the northern hemisphere (Bond et. al 1997:1262).

Late Pleistocene Extreme: This period is probably the well-known Younger Dryas (10,000 – 11,200 years ago, Madsen 1999:79) although it seems to date a little earlier in our study area (11,300 – 11,700). This discrepancy may result from the interpolation of radiocarbon dates in pollen cores and the resultant averaging of many cores to produce the summary graphs shown in Figure 2. This period was marked by restricted and sparse pine distributions because most of the higher country was under ice and snow. Peripheral to the snow cover were coniferous forests although they did not extend into the lower elevations of the Snake River Plain, which supported much more grass than later climates making them ideal habitats for Pleistocene megafauna herbivores.

For each of the three earlier periods, pollen data was selected from age ranges that bracketed the noted extreme fluctuations. As for the recent historic period, it was sometimes necessary to either include a pollen core whose most recent date fell outside of the time range or extend the time range to include more core samples. Twenty-five cores contributed to the Late Holocene, 24 to the Early Holocene, and 22 to the Late

Pleistocene. Cokriging was used to create prediction maps for each of the 24 species within each of the time periods, with the exception of *Rhamnaceae*. This species did not occur in any of the cores during the Early Holocene or Late Pleistocene. However, we considered this to be an important factor and included its zero value in the discriminant function.

RESULTS

Vegetation maps for the four time periods are presented in Figure 3. The historic map shows what the eastern Snake River Plain and Yellowstone Plateau may have looked like prior to the urbanization, agriculture, forestry and mining impacts indicated in the modern GAP. Sagebrush steppe covered much of the lower elevations with mixed conifers extending across the Yellowstone Plateau and into the Island Park caldera region. A mixed subalpine forest was confined to the higher elevations of the Rocky Mountains while extensive grasslands dominated southwestern Montana. A mixed aspen/conifer forest surrounded what are now the Palisades and Blackfoot Reservoirs and pinyon/juniper forest extended northward from the Idaho/Utah border south of the Lake Walcott Reservoir. Jackson Lake was surrounded by an arc of mixed conifers but much of the landscape to the east and west was covered by subalpine meadow.

This was a significantly different landscape than that which characterized the late Holocene extreme. Subalpine meadow dominated areas which would later be dominated by sagebrush steppe, mixed aspen/conifer, and mixed conifers. Grasslands extended from Bear Lake northwest to the present American Falls Reservoir and across much of the region of the Henry’s Fork. Mixed aspen/conifer forests were confined to the higher elevations of the Rockies and were bordered by mixed conifer and mountain sage vegetation. The mixed subalpine zone doesn’t even occur. While the pinyon/juniper forest is still prevalent on the Idaho/Utah border a broad sage/grassland community surrounds the Lake Walcott Reservoir.

The predicted vegetation landscape for the early Holocene extreme is similar to the historic map. This is exactly what the data predict. Figure 2 shows the percent of pine, sage, and grass were at levels equivalent to recent data. The notable difference is that a sage/grassland zone doesn’t occur in the early Holocene, indicating that this period may have been slightly drier or warmer than today.

The late Pleistocene was dramatically different. The predicted map indicates the entire Yellowstone Plateau, extending southwest into the area around Island Park, and including much of the Teton Range was in subalpine meadow. Much of this area was most likely under permanent snow, although the last vestiges of the Pinedale Glacier may have been visible in the Rocky Mountains. The mixed subalpine zone is extensive encompassing the mountain ranges of southeast Idaho except for the area around Bear Lake that is surrounded by subalpine meadow. The mixed aspen/conifer community is not as extensive as the subalpine zone, but drapes the mountain ranges to the northwest of the Snake River Plain. Sage/grasslands occupy the ranges south of the Snake River Plain while grasslands dominate the Plain. The distribution reflects a vegetation landscape adapted to considerably colder temperatures.

The paucity of data is apparent in the geometric boundaries of some of the vegetation zones, particularly visible in the Late Pleistocene which was based on data from only 22 pollen cores. These are also due to a violation of the assumption when using a kriging method that closely spaced data are more similar than data separated by greater distance. Within the compiled pollen data, this was often not the case. However, no effort has been made to make the maps more "realistic": the maps reflect the purely objective computation of probabilities for vegetation zone distribution.

In spite of these limitations, the general patterns appear to correlate with modern vegetation distribution and with what is known about the area from pollen and archaeological research. The percentage of land that falls within each of the vegetation zones is given in Table 2. While this helps to quantify vegetation change over time, again we are not implying any measure of accuracy. What is important is that, to our knowledge, this is the first attempt to produce a map, based on empirical data, of what the regional vegetation landscape may have looked like during the documented Late Pleistocene and Holocene extremes. The table shows that while the area within our vegetation zones may be similar in different time periods, the actual distribution as reflected in the predictive maps is significantly different.

Table 2. Area percentage of vegetation zones within each of the time periods mapped in Figure 3.

Classification	**Historic Period**	**Late Holocene Extreme**	**Early Holocene Extreme**	**Late Pleistocene Extreme**
Subalpine Meadow	5.4	44.9	3.3	41.8
Grassland	8.7	17.7	8.9	9.7
Mountain Sage	1.1	1.4	0	2.4
Greasewood/Desert	.4	1.7	.3	.2
Sagebrush Steppe	45.3	7.9	48.5	3.3
Pinyon/Juniper	3.4	5.7	3.6	0
Mixed Aspen/Conifer	7.2	6.0	4.8	.4
Mixed Coniferous	20.5	6.5	23.0	14.1
Mixed Subalpine	2.4	0	2.3	17.0
Riparian	0	.1	0	0
Sage/Grassland	.3	2.8	0	5.8
Barren or Open Water	5.3	5.3	5.3	5.3
Total Percent	100	100	100	100

CONCLUSIONS

The goal of this project was to gain an appreciation of how past climate changes are reflected in the landscape vegetation. We initiated this project without any preconception about the distribution of prehistoric vegetation other than it would correlate somewhat with elevation. The maps solely reflect co-kriged predictions: the numbers speak for themselves.

Our pollen core samples are so few and the distances between most are so great, there is no way to know how well our maps represent the actual distribution of vegetation at these time periods. The only way to improve on this is to acquire more data, either with additional pollen cores, particularly along the Snake River Plain and in the ranges that border it, or with the analysis of unexamined existing cores from the project area. However, the predictive maps are much more revealing that we thought possible. We now have a model by which we can test additional time periods, perhaps exploring the millennial cycles noted by other researchers within the Great Basin (Madsen 1999). We have snapshots of the Holocene landscape and can begin to test these against the archeological data to address questions regarding how earlier inhabitants adapted to a changing environment and exploited and manipulated its resources. We may never have all the answers, but each gives us more insight into not only the past, but also the influence we have on our present environment.

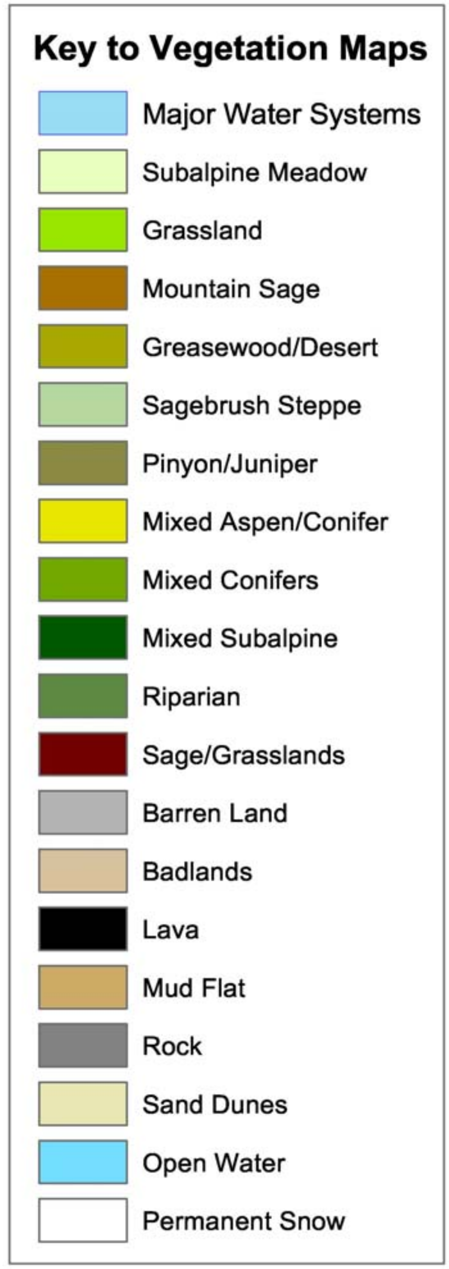
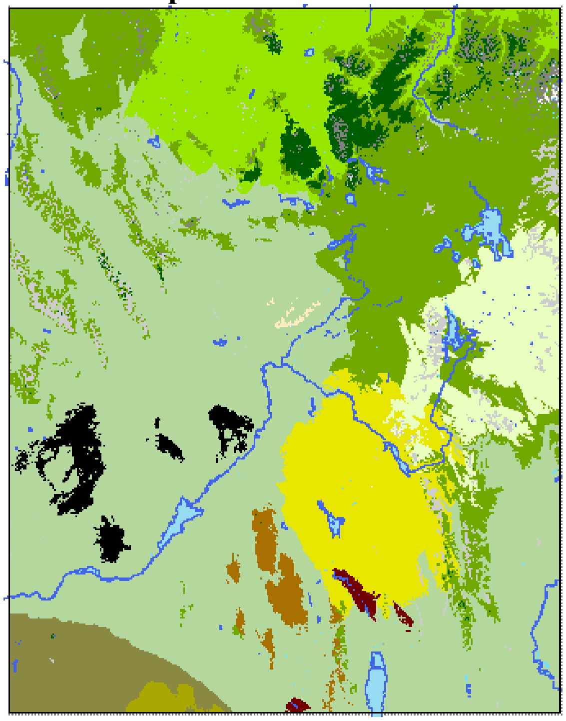
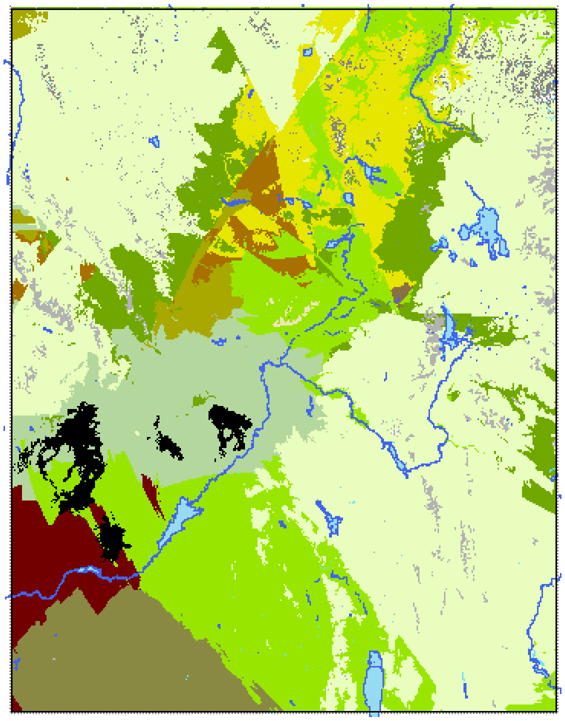


Figure 3. This legend is associated with the four maps on the following page. Each of the maps represents the general distribution of vegetation zones for a particular time period. The reader is cautioned that these are only generalized maps.

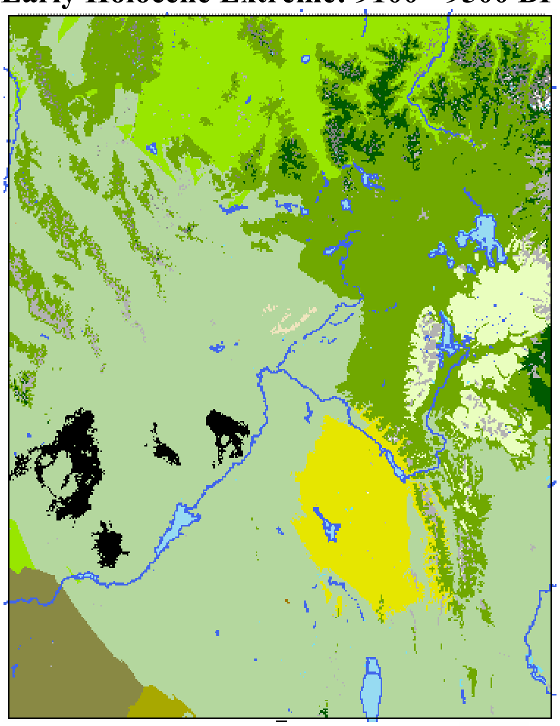
Historic Map 150 - 250 BP



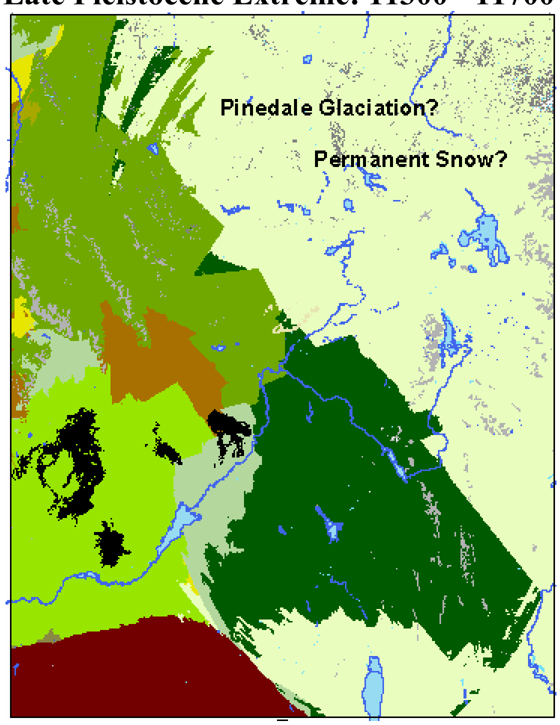
Late Holocene Extreme: 600 - 1000 BP



Early Holocene Extreme: 9100 - 9500 BP



Late Pleistocene Extreme: 11300 - 11700



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LITERATURE CITED

Baker, R.G., 1976, Late Quaternary vegetation history of the Yellowstone Lake Basin, Wyoming. *United States Geological Survey Professional Paper* 729_E.

Baker, R.G., 1983, Holocene vegetational history of the western United States. *in* Wright, H.E., Jr., ed., Late-Quaternary environments of the United States, Volume 2 The Holocene. Minneapolis, University of Minnesota Press.

Beiswenger, J.M., 1991, Late Quaternary vegetational history of Grays Lake, Idaho: Ecological Monographs, v. 61, no.2, p.165-182.

Bettinger, R.L., 1999, What happened in the Medithermal. Beck, C., ed., Models for the Millennium: Great Basin Anthropology Today. Salt Lake City, UT, The University of Utah Press.

Bond, G., Showers, W., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I., Bonani, G., 1997, A pervasive millennial-scale cycle in North Atlantic Holocene and glacial climates: Science, v. 278, p. 1257-1266.

Bright, R.C., 1966, Pollen and seed stratigraphy of Swan Lake, Southeastern Idaho: Its relation to regional vegetational history and to Lake Bonneville history: Tebiwa, v. 9, no. 2, p.1-47.

Cannon, K.P., 1993, Paleoindian use of obsidian in the greater Yellowstone area: new evidence of the mobility of early Yellowstone people: Yellowstone Science, v. 1, no. 4, p.6-9.

Davis, O.K., Sheppard, P.S., and Robertson, S., 1986, Contrasting climatic histories for the Snake River Plain result from multiple thermal maxima: Quaternary Research, v. 23, p. 321-339.

Gap Analysis Program, http://www.gap.uidaho.edu/Projects/FTP.htm

Gennet, J.A., 1977, Palynology and paleoecology of sediments from Blacktail Pond, northern Yellowstone Park, Wyoming [M.S. thesis]: University of Iowa.

Grayson, D.K., 1998, The Desert's Past: A Natural Prehistory of the Great Basin: Washington, D.C., Smithsonian Institution.

Green, T.J., Cochran, B., Fenton, T.W., Woods, J.C., Titmus, G.L., Tieszen, L., Davis, M.A., Miller, S.J., 1998, The Buhl burial: a Paleoindian woman from Southern Idaho: American Antiquity, v. 63, no. 3, p. 437-456.

Idaho State University GIS Training and Research Center, http://giscenter.isu.edu/

Lynch, E.A., 1995, Origin of park-forest vegetation mosaic in the Wind River Range, Wyoming [dissertation]: University of Minnesota.

Madsen, D.B., 2000, Late Quaternary paleoecology in the Bonneville Basin: Utah Geological Survey Bulletin 130, 190 p.

Madsen, D.B., 1999, Environmental change during the Pleistocene-Holocene transition and its impacts on human populations. *in* Beck, C., ed., Models for the Millennium: Great Basin Anthropology Today. Salt Lake City, UT, The University of Utah Press.

Mehringer, P.J., Jr., Arno, S.F., and Peterson, K.L., 1977, Postglacial history of Lost Trail Pass Bog, Bitterroot Mountains, Montana: Artic and Alpine Research, v. 9, no. 4, p. 345-368.

Miller, S.J., 1982, The archaeology and geology of an extinct megafauna/fluted point association at Owl Cave, the Wasden site, Idaho: a preliminary report. *in* Ericson, J.E., Taylor,R.E., and Berger, R., eds., Peopling of the New World. Los Altos, CA, Ballena Press, Anthropological Papers No. 23, p.81-95.

Rhode, D., 1999, The role of paleoecology in the development of Great Basin archaeology, and vice-versa: *in* Beck, C., ed., Models for the Millennium: Great Basin Anthropology Today. Salt Lake City, UT, The University of Utah Press.

Sterner, R., 1995, Color landform atlas of the United States: John Hopkins University Applied Physics Laboratory.

Whitlock, C., 1993, Postglacial vegetation and climate of Grand Teton and southern Yellowstone National Parks: Ecological Monographs, v. 63, no. 2, p. 173-198.

Whitlock, C. and Bartlein, P.J., 1993, Spatial variations of Holocene climatic change in the Yellowstone region: Quaternary Research, v. 39, p. 231-238.

Wigand, P.E., 2003, Southeastern climatic transition region in the Northern Rockies, unpublished manuscript.

Wigand, P.E. and Rhode, D., 2002, Great Basin vegetation history and aquatic systems: the last 150,000 years: *in* Hershler, R., Madsen, D.B., and Currey, eds., Great Basin Aquatic Systems History. Smithsonian Contributions to Earth Sciences 33, Washington, D.C., Smithsonian Institution Press.

Wright, H.E., Jr., n.d., Pollen analyses at Mummy Cave and nearby areas, Northeastern Wyoming, [unpublished manuscript]: University of Minnesota.