Devil's in the Details: Using Archaeological and Historical Data to Refine Ecosystem Models at the Local Level

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Abstract—*The United States Forest Service is charged with managing extensive and varied ecosystems throughout the country. Under the rubric of "ecosystem management" the goal has been to provide goods and services from Forest Service lands while maintaining ecological integrity. Recognizing that ecosystems are dynamic in nature, the concept of Historical Range of Variability (HRV) has been developed to capture the range of conditions expected within ecosystems. Over the last fifteen years extensive wildfires have occurred in many parts of the western United States at a scale that has rarely been equaled during the last century. Based on the assumption that the severity of many of these fires was amplified by unnaturally high fuel loads caused by decades of fire exclusion, a program of altering forest structure on the landscape scale has been proposed. In order to implement this policy at the scale required to have a meaningful effect on wildfire behavior, the Forest Service relies on a series of increasingly sophisticated computer models. These models allow managers to quantify and visualize the effects of various restoration actions, or inaction, on wildfire behavior. Although they are extremely useful tools, there are inherent limitations to models when implementing actions in the real world. Gaps in data and the simplification of complex natural processes are obscured during modeling. A variety of plant and animal macrofossils recovered in archaeological contexts and historical data from journals, newspapers, survey notes and photographs can provide critical information concerning the HRV of specific ecosystems. Use of local archaeological and historical data can be invaluable in refining large-scale models to more accurately reflect local ecological conditions. This paper examines the types of data available in the southern Blue Mountains of eastern Oregon and provides examples of the use of these data in ecosystem planning on the Malheur National Forest.*

The United States Forest Service was established in 1905 to manage vast tracts of forest and grassland held in the public domain, particularly in the western states. The primary charge of the new agency was to manage the timber and protect the water supply on public lands. This is still the case, although in recent decades there has been less emphasis on providing timber for market and more emphasis on maintaining or restoring forest ecosystems. The Healthy Forests Initiative (HFI) and the Healthy Forests Restoration Act (HFRA) represent recent policy initiatives that direct the Forest Service to focus resources on reducing the effects of wildfire on forest ecosystems and adjacent private property. These initiatives highlight the perceived catastrophic nature of recent large-scale wildfires in the western United States and emphasize the need to move quickly to alter forest ecosystems to make them less susceptible to large scale fire events. They direct the agency to use science to develop appropriate action plans but de-emphasize the use of National Environmental Policy Act (NEPA) procedures generally used to incorporate scientific data into planning efforts. Coarse–scale modeling of Fire Regime Current Conditions (FRCC) is being utilized at the local planning level with little fine-scale "ground truthing" of the affected stands. This paper examines the potential to use existent and readily available historical and archaeological data to help fine tune FRCC.

A spat of environmental and land management legislation from the 1960s and 1970s provide the majority of the legal and regulatory framework in which the Forest Service now operates (Meidinger 1997). These include the Multiple-Use Sustained-Yield Act, the National Environmental Policy Act (NEPA), the National Forest Management Act (NFMA), the Endangered Species Act (ESA), the National Clean Water Act, and the Clean Air Act. These laws, and the social setting in which they evolved, have increased the importance of integrating scientifically valid information into forest management (Cortner and others 1999). These optimistic and sometimes conflicting mandates are expensive, at least in short term, and do not provide the immediately apparent results conducive to long term political support.

Through implementation of these mandates Federal land managers and scientists developed a process referred to as ecosystem management (Cortner and others 1999). This process provides an adaptive framework to evaluate management goals and constraints using diverse scientific information in order to estimate how various ecosystems will respond to given actions. NEPA in particular mandates interdisciplinary analysis of proposed management actions in order to evaluate the possible effects on a range of resources (Bass and others 2001). Since ecosystems are dynamic in nature, it is important to understand the variety of plant and animal communities that occur in a given area over time. One way to approach this is the concept of Historic Range of Variability (HRV). In spite of a number of difficulties in applying HRV to project planning, it is still a widely used approach to account for ecosystem variability over time (Romme and others 2003). Historical records and archaeological data can provide useful information for the determination of HRV during planning.

Although not unusual when viewed at a time scale of multiple centuries, several fire seasons during the last 1 1/2 decades have been more severe than any since 1960 (Williams and Dellasala 2004). Increased human population and a preference for living in rural and suburban settings has resulted in a substantial increase in the number of residences built within or adjacent to forested land. Within these areas, now referred to as the Wildland/Urban Interface (WUI), thousands of homes have been lost during large wildfire events. A number of factors have contributed to the increased size and often the severity of wildfire over the last two decades. These include climatic variations, drought, disease, and heavy fuel load caused by increased vegetation density (Graham and others 2004). In many Western forests fuel loads have likely increased beyond historic levels at least partly due to almost a century of successful fire suppression actions (Romme and others 2003). This is particularly true in dry pine (*Pinus*) forest stands but less well understood in mixed conifer stands. Fire suppression has probably played an insignificant role in sub-alpine, moist fir (*Abies*) dominant and lodgepole pine (*Pinus contorta*) stands and other stands with fairly long historic fire return intervals. The current climatic situation, including "global warming" trends and several years of drought, are likely primary drivers of the current wildfire situation (McKenzie and others 2004). The overall effect of these uncontrollable climate and weather variables, versus fuel loading, which is controllable through management actions such as thinning and prescribed fire, is not well understood.

The extreme wildfire behavior during the last several years has led to significant new legislation and administrative rules/regulations aimed at expediting forest fuel reduction projects. The Healthy Forests Initiative (HFI) and the Healthy Forests Restoration Act (HFRA) are meant to guide Federal land managers out of "process predicaments" that are perceived to be delaying rapid implementation of fuels reduction projects (USDA Forest Service 2004). The interdisciplinary planning process mandated under NEPA can be time consuming and relatively expensive (Bass and others 2001). Ecosystems are complex. It takes time to consolidate and analyze the data needed in order to understand the effects of management actions on the multiple components of the ecosystems in a planning area. Fire is one of the most important disturbance processes in forests in the western United States and altering fire regimes through thinning and prescribed burning will have significant, and hopefully positive, environmental effects (McKenzie and others 2004).

Under the HFI fuels reduction projects 1000 acres or less in size and prescribed burning of 4500 acres or less can be addressed as "Categorically Excluded" under NEPA (USDA Forest Service 2004). Categorically excluded projects undergo only minimal environmental review under NEPA (Bass and others 2001). To qualify, these projects must either be in a Wildland-Urban Interface (WUI) or in an area that is rated a Fire Regime Current Condition (FRCC) Two or Three. A WUI is land that extends anywhere from ½ mile to 1½ miles from the boundary of residential land, depending on the environmental and topographic setting (USDA Forest Service 2004). FRCC is a rating of the estimated current stand fuel loading compared to its estimated historic fuel loading based on a course-scale model (GAO 2004a).

In order to consider these projects Categorical Exclusions under NEPA the HFI makes several assumptions (USDA Forest Service 2004). First, forest fuel loads are unnaturally high due primarily to 100 years of fire exclusion; second, large wildfires are catastrophic and cause significant resource damage; and third, environmental effects of prescribed fires and fuels reduction projects are well understood and generally minor. This last point is particularly significant since Categorical Exclusions under NEPA only apply to projects that do not "individually or cumulatively have a significant effect on the human environment" (Bass and others 2001). All of these assumptions are being actively debated (Beschta and others 2004, Brown and others 2004, Dombeck and others 2004, Everett and others 2000, GAO 2004, Graham 2003, Graham and others 2004, Kaufman 2004, McKenzie and others 2004, Omi and Martinson 2002, Pfilf and others 2002). As Everett and others note, "Fire regimes are site specific based on forest type, topography, microclimate, ignition sources, and past disturbance history. Land management is also site specific, requiring local information on fire regimes to manage for this important disturbance" (2000). For these reasons, among others, it is likely that most fuels reduction projects conducted on a landscape scale will be analyzed using the more complete NEPA processes of Environmental Assessments and Environmental Impact Statements (Bass and others 2001).

Regardless of the type of NEPA analysis to be conducted, FRCC modeling is still the tool used to estimate the priority for treatment for forest stands (GAO 2004a). In a resent review of the analysis of effects from wildfire and fuels reduction projects by the General Accounting Office it was made clear that there is a lack of consensus on how to describe and analyze potential effects (GAO 2004). The report lists 19 existing models and similar tools used in planning and managing fires (GAO 2004b). Most of these look at a limited range of effects and were not designed for extensive effects analysis. All ecosystem models are abstractions of reality and they intentionally simplify complex natural processes. This is an inherent limitation of modeling and does not invalidate the use of models so long as the assumptions used and data gaps present are made explicit.

The model used to generate FRCC was devised to estimate the condition of ecosystems on a national scale and is not intended for identifying condition class by watershed or stand at the local level. The team that developed the model has clearly laid out the assumptions they used and limitations of their data. "To assess fire regime current conditions, we needed a baseline of conditions from which to compare. A critical data layer developed to assess current conditions and departure from historic conditions was the 'Historic Natural Fire Regime' layer" (Schmidt and others 2002). This data layer was completed "using expert knowledge to assign fire regimes to General Land Cover Classes" and was refined by integrating "expert knowledge, remote sensing, and biophysical data to map fire regimes" (Schmidt and others 2002). "Expert knowledge" while certainly useful for many things, is difficult to quantify or verify in this context.

Their methodology was described as "similar to that used by Brown and others (1994), who integrated site characteristics, habitat types, topographic attributes, and vegetation to map fire regimes" (Schmidt and others 2002). In spite of being perhaps difficult to replicate, this methodology and the use of unspecified "expert knowledge" was perfectly valid for the stated goal of providing generalized national-scale data. It is only when this model is applied at the local project level, against the specific advice of the model's authors, that problems can arise. To compensate for this, "the Forest Service and the Department of the Interior are developing a project-level analysis tool [that] requires the field office staff to conduct a field visit to examine vegetation conditions, to consider them in context of past and current fire regimes, and to estimate the alteration of fire regimes and fire intensity if a fire were to burn in the current conditions" (GAO 2004a).

In to understand the ecological effects of modern wildfire, prescribed fires or mechanical treatment of fuels, an understanding of the historic fire regime is necessary (Everett and others 1999, Graham and others 2004, Romme and others 2003). Fire ecologists have developed a number of ways to estimate historic fire regimes for specific stands. The most accurate of these involve compiling fire histories from fire scarred trees and stumps or using data on stand age classes in situations (Everett and others 1999). Although accurate, these processes can be time consuming and relatively expensive. Since fire scars are a finite resource that is reduced as trees and stumps containing scars deteriorate from rot and fire, this expense may be worthwhile. Historic fire regimes for specific stands are often estimated from stands with known fire histories that appear similar in type and topographic setting. This often becomes a matter of applying "expert knowledge" in ways that are often inexact and difficult to explain. Estimates of FRCC, whether identified from course-scale models or extrapolation from similar stands, can often be checked against existing historical, archaeological and paleo-ecological data.

A wide range of historical, archaeological and paleo-ecological data can be used to provide important clues as to the veracity of estimated FRCC (Sullivan and others 1999). As with any data, it must be used critically and with an awareness of limitations in accuracy, completeness, and scale. It is important to bear in mind that ecosystems are in constant flux and most historical data provides only a brief snapshot of the ecological conditions at a given point in time. Understanding the source of the information can be useful in identifying potential reporter or transcriber errors. Some historic and archaeological data is specific to a given stand, but more frequently it is based on sources within the same or neighboring watersheds. When working with information that originated from stands other than those being analyzed it is necessary to consider the similarity in the environmental setting between the stands. Modern stand composition, aspect, elevation, soils type, and related environmental attributes can be used to determine how relevant the data is to the stand being studied. The greater the distance and the greater the variation in environmental settings between the data source and the study stand, the less confidence can be placed in the data.

Historical data can be found in a wide variety of forms (table 1). Journals, letters, and diaries of explorers and

Table 1. Sources of historical and archaeological data from the Malheur National Forest.

Type	Examples	Dates
Historic photo	long term family collections	1860's-present
Historic photo	FS silvic	1908-present
Historic photo	FS admin, misc	1908-present
Historic photo	Osborn lookout panoramic	1935-1940
Historic photo	range photo plots	1938-present
Historic photo	aerial photos	1939-present
Historic documents	Hudson's bay journal	1825-1831
Historic documents	army letters and journals	1865-1880
Historic documents	settler's letters, diaries, histories	1862-1940
Historic documents	general land office survey notes and maps	1870's-1960's
Historic documents	FS silvic reports and maps	1906-present
Historic documents	FS fire reports and maps	1909-present
Historic documents	FS range reports and maps	1915-present
Historic documents	FS misc admin reports and maps	1905-present
Historic documents	Indian agency records and maps	1868-1880
Historic documents	American Indian ethnographic records and histories	1860-present
Historic documents	newspaper articles	1870's-present
Archaeological	carbon 14 dating	7,000-200BP
Archaeological	botanical remains from excavation	7,000-100BP
Archaeological	faunal remains from excavation	3,000-100BP
Archaeological	land use inferred from site type	7,000-100BP
Paleoecological	pollen and plant macrofossils from sediment cores	7,000-100BP
Paleoecological	packrat midden analysis	3,000BP-present
Paleoecological	fire histories from scarred trees	1600-present
Paleoecological	fire histories from sediment charcoal	10,000BP-present
Paleoecological	geomorphological analysis	10,000BP-present
Paleoecological	relic plant communities	1900-present

early settlers can contain descriptions of general, and occasionally quite specific, environmental settings. The earliest sources of historical information for the Malheur National Forest in eastern Oregon are daily journals kept by the Hudson's Bay Company fur trappers in the 1820s and 1830s (Davies 1961). Although specific locations can be difficult to identify, there are descriptions of forest type and condition in the journals. Several locations entries record forest stands thick with downed timber. For example on October 9th 1826 Ogden reported that "all along our road this day we came over a woody country, Norway pines, and from the number of fallen trees, our progress was very slow, course east, distance nine miles" (Davies 1961). Clearly this was not an "open park-like stand" like those often generalized as occurring through eastern Oregon before the advent of active fire suppression (Campbell and others 2003).

Early newspaper accounts and later published interviews with longtime residents likewise contain a variety of information about forest conditions and cultural practices that affected them. For instance in the late 1800s there were several accounts of Indian hunting parties setting extensive fires as they left the mountains in the Fall. A variety of government records contain a wide range of environmental data. General Land Office survey notes and maps often provide the earliest landscape scale environmental descriptions in the western United States (fig. 1). In the Blue Mountains the earliest of the surveys took place in the 1860s. The surveyors mapped out the landscape in a one mile wide grid pattern. Physical markers were left every ¼ mile and brief descriptions of the terrain and vegetation were recorded. The quality of the descriptions varied considerably with the interests and skills of the individual surveyors but at a minimum the extent and general types of vegetation were recorded and mapped. Internal Forest Service records dating back to 1905 can provide much information. These can be found in local or regional offices although many of the earliest records have been discarded over the years. Many of these records can be found in the United States National Archives. Some real gems are hidden in the archives but searching for records from this source can be time consuming. On the Malheur we have located early silvicultural survey reports, maps of forest stand types, early wildfire records, and grazing records.

Historic photographs can provide some of the cleanest data since they do not rely on the judgment of recorders of indeterminate ability. Any photograph with visible vegetation can be used as long as the approximate photo point and date can be determined. Re-photographic surveys, where modern photos are taken from the same location as historic photos, are effective records of ecosystem change (Gruell 2001). Many early agency photographs include information on location, date, time, and weather.

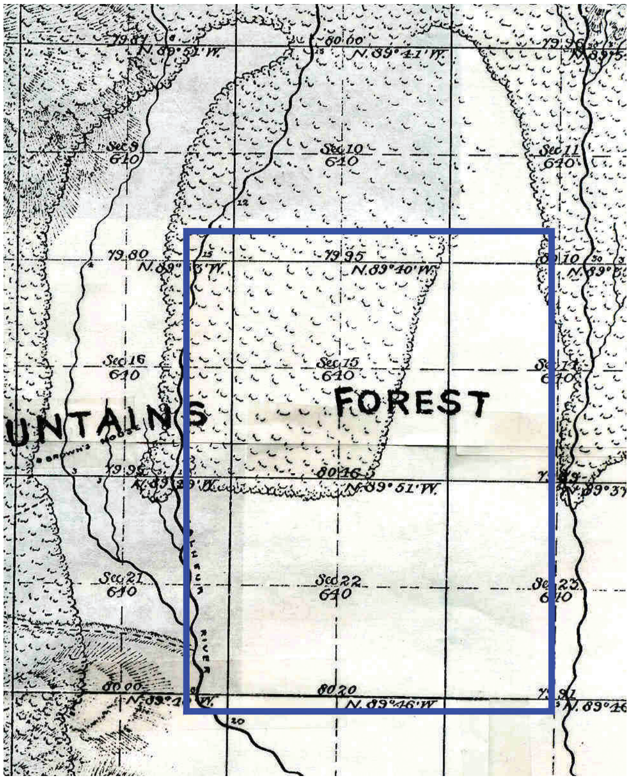

Figure 1. 1884 General Land Office map of Logan Valley. Box shows area of photo in figure 2.

Figure 2. Comparison photos from Antelope Lookout. Bottom photo 1935, top photo 1996. Note significant increase in tree density and loss of meadow.

Some of these are located in local and regional files but copies of many are also located in the National Archives. Range evaluation plot and silvicultural report photographs are extremely useful but relatively uncommon. The backgrounds from photographs depicting general project work, recreation, or buildings can also show significant landscape and vegetation information and are more common. Aerial photographs from the Malheur date back to the 1930s and provide detailed information on stand composition and density. In the Pacific Northwest a series of panoramic photos were taken from fire lookouts between 1929 and 1942. These Osborne photographs were completed at 999 locations in the region including 41 on the Malheur. They provide excellent overviews of several watersheds from each location. The photo points are easy to relocate and photograph in order to compare historic and current stand composition (fig. 2).

Archaeological and paleo-ecological data is more esoteric and frequently less readily available but it can be very useful in evaluating stand conditions over longer time periods. Wood charcoal recovered from archaeological sites and sediment cores can often be identified as to species and accurately dated (Sullivan and others 1999). In settings where an intact sediment core can be recovered a detailed fire history can often be constructed. Once wood has been converted to charcoal it preserves quite well and could be recovered from sediment in forest stands to develop site specific fires histories. Charcoal fragments as small as .3 grams can now be dated, but cost will likely limit this application since numerous samples would be needed.

A sediment core recovered from Lost Lake, just north of the Malheur National Forest, has produced a 7,600 year record of major wildfire events in a basin dominated by mixed conifer forest stands (Mehringer 1995). Sixteen charcoal lenses ranging from .2cm to 20cm thick were identified in the cores. Thickness of the charcoal lens is viewed as indicative of the size and intensity of the fire with the thicker layers of charcoal representing larger and/or more intense episodes. The largest fire by far took place immediately following the deposition of volcanic ash from the eruption of Mount Mazama at circa 7,600BP. The charcoal from this deposit is 20cm thick, compared with 3cm for the next thickest deposit and 1cm or less for the rest. It appears that the fine volcanic ash caused a major vegetation die-off that provided fuel for a truly catastrophic wildfire. Overall this core produced a record of amazing consistency of stand composition and long fire return intervals across seven millennia.

Other botanical remains recovered from archaeological sites on the Malheur National Forest include charred roots and seeds, phytolyths and pollens. Camas (*Camassia quamash*) bulbs recovered from steaming ovens dated to 600 years ago strongly suggest that the valley where they were recovered was wetter and supported more camas plants at that time than currently. Mortar bases recovered at sites dating to the last 1200 years contained significant amounts of pollen from Lomatium sp which were an import Indian root crop (Varney and others 2003). *Lomatium* sp. plants are still common on the dry ridges associated with these sites. This suggests a broadly similar ecological setting at this location over the last 1200 years. Pollen recovered from the soil adhering to the mortars, and analyzed as a control, indicate that the pine tree line has retreated upslope at one location. Pollen recovered from sediment cores, especially from springs, bogs or lakes, can be used to complete quite detailed local vegetation histories.

Additional archaeological and paleo-ecological data that can be useful for determining aspects of ecosystem history include faunal remains from archaeological sites, floral material from packrat nests, geomorphological analysis of sediments and landforms, and artifacts such as mortars and grinding slabs. The location of sites across the landscape can also provide general information about changes in the environment over time. For instance, the presence of sites in dense lodgepole or young ponderosa pine (*Pinus ponderosa*) thickets suggest that these locations were much more open when they were occupied. Similarly, subsurface testing at archaeological sites located in and adjacent to meadows often demonstrates that sites were restricted to margins or low ridges out of the lower parts of the meadows proper. This suggests that many of the dry upland meadows on the Malheur were much wetter historically.

None of the preceding examples of historical and archaeological data is sufficient to independently determine HRV for forest stands but they can provide an important piece of the puzzle when used in conjunction with other evidence. An example from a meadow "rehabilitation" project on the Malheur National Forest demonstrates how disparate historical and archaeological evidence can be used to verify, or in this case modify, the proposed model of HRV for this location. Logan Valley is a large upland meadow located at the headwaters of the Malheur River. It is a mix of dry, moist and wet meadows surrounded by pine dominated mixed conifer stands and bisected by several creeks with their associated riparian communities. The northern fringe of the meadow has fingers of mature ponderosa and lodgepole pine feathering into

Figure 3. 2001 aerial photo of Logan Valley section from box in figure 1. Horizontal road at center line on map. Note difference in tree line and "new" riparian in center of photo created by ditch. White boxes indicate pollen collection sites.

the meadow with a dense growth of young lodgepole pine occurring as a lower story within and between the mature stands. The young pine filling once open spaces between the mature stands fits the generally held model of aggressive meadow encroachment by lodgepole as a result of wildfire exclusion. For several years the Forest has conducted thinning and burning projects to remove the pine to improve sandpiper nesting habitat.

This was a perfectly logical, if primarily intuitive, model of the HRV for Logan Valley based on "expert knowledge." Figure 2 illustrates similar meadow encroachment at another location south of Logan Valley which provides tentative support for this model. However, while doing historical background research for an unrelated project, employees with the Heritage program came across some site specific data that seemed to contradict the pine encroachment model. Figure 1 illustrates the 1884 General Land Office survey map for the area where the pine eradication projects were taking place. Figure 3 is a 2001 aerial photograph of the same location. A comparison of the map and photograph show that the pine "encroachment" north of the road in the

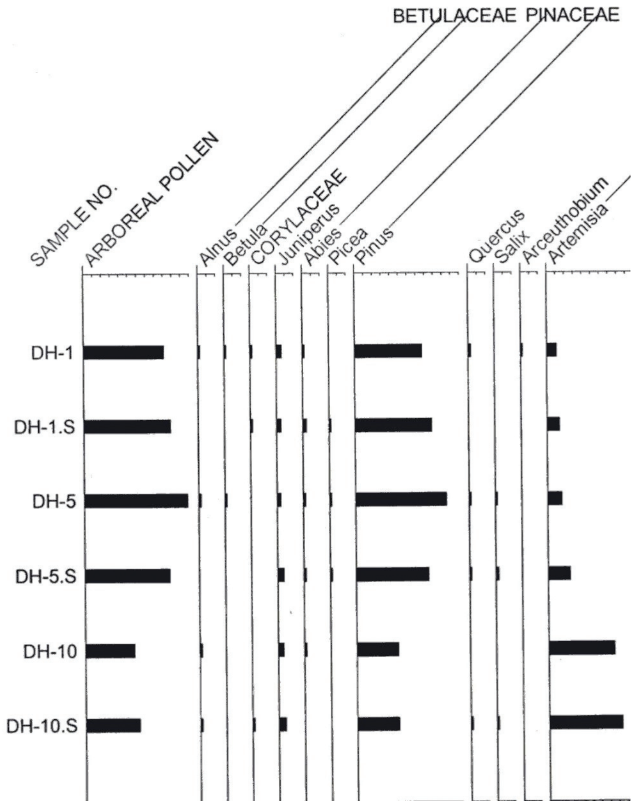

Figure 4. Chart showing pollen from three mortars and associated soil. Difference between pine (*Pinus*) and sagebrush (*Artemisia*) indicate DH-1 and DH-5 historically pine forest while DH-10 historically open sagebrush meadow. (Varney and others 2003).

center of the 2001 photo, is within the tree line as it is drawn on the 1884 map. This is compelling but it is possible that the tree line in the map either was in error or shows an anomalous expansion into the meadow.

During archaeological survey conducted during this same time three hopper mortar bases were collected sent to a lab for pollen analysis (Varney and others 2003). The artifacts were collected from three locations separated by one half mile (fig. 3, white boxes labeled dh1, dh5 and dh10). The chart in figure 4 shows that the ratio of pine (*Pinus*) pollen to sagebrush (*artemisia*) pollen from each of the mortars provides evidence that the 1884 tree line is accurate. The northern sample (dh1), which was recovered at the edge of the modern tree line, produced much more pine pollen than it did sagebrush. The middle sample (dh5), which was within the 1884 tree line but is now in open grass/sagebrush, had virtually the identical pine to sagebrush pattern. The southern most sample (dh10), well south of both the modern and 1884 tree line, produced almost twice as much sagebrush pollen as it did pine pollen.

The historic and archaeological evidence from Logan Valley does suggest that the pine "encroaching" into the meadow may be part of a natural process moving the valley closer to its HRV than it is at present. By applying the principles of adaptive management we can respond to this new information and alter our stand treatment as appropriate (Bass and others 2001). It is important to recognize that the new evidence has not "proven" that the original model of pine encroachment was wrong. It simply suggests that a different model better explains the existing data. New data could be found, or an alternative explanation of the existing data could be developed, that might convince us that pine is indeed encroaching. This is not meant to suggest that we should simply give up and either do no management at all or do anything we want since it won't matter anyway. The important lesson is that we should approach ecosystem management with an open mind and a reasonable dose of humility. Ecosystems are extraordinarily complex and we need to learn as we go.

The history of Federal land management contains notable cases where land managers, with the best of intensions, and using the best available science, made large-scale changes to western forests that we now regret (Langston 1995). One example is the heavy buildup of fuels in dry pine forests, much of which is the direct effect of decades of very successful fire suppression efforts (Graham and others 2004). There was an active scientific debate in the first part of the 20th Century as to whether total fire suppression or "light burning" was the proper way to treat pine stands. In one of several similar publications Snow and Kotok argued persuasively that repeated light burning killed most trees and rendered sites unproductive for decades (1924). The photographs of dense young pine that they used to illustrate "the return of the forest- when fire is kept out" are the same types of photos used today to illustrate dangerous fuel buildup. Cronon eloquently summed up the challenge (1995). "Even well intentioned management can have disastrous consequences if it is predicated on the wrong assumptions, and yet testing those assumptions is always much harder than people realize. To do so we must realize that ecosystems are profoundly historical, meaning that they exist in time and are the products as much of there own past as of the timelessly abstract process we think we see going on in them." Hopefully we can remain open, humble and adaptive as we search for the proper ways to implement the Healthy Forest Initiative and the Healthy Forests Restoration Act.

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