# Documenting ancient plant management in the northwest of North America[1]

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**Abstract:** Ethnographic literature documents the pervasiveness of plant-management strategies, such as prescribed burning and other kinds of cultivation, among Northwest Peoples after European contact. In contrast, definitive evidence of precontact plant management has been elusive. Documenting the nature and extent of precontact plant-management strategies has relevance to historians, archaeologists, managers, conservationists, forest ecologists, and First Nations. In this paper, we summarize the various lines of evidence that have been, or could be, used to document ancient cultivation in the northwest of North America. We organize this discussion by the ecological consequences of ancient plant-management practices and their documented or potential visibility in the paleo-, neo-ecological, and archaeological records. Our review demonstrates that while finding evidence of ancient plant management can be difficult, such evidence can be found when innovative research methods are applied. Further, when various independent lines of evidence are compiled, reconstructions of past plant-management strategies are strengthened considerably.

*Key words:* traditional ecological knowledge, resource management, northwest, cultivation, prescribed burning.

**Résumé :** La littérature ethnographique fait état de l'ubiquité des stratégies d'aménagement de la végétation, comme le brûlage contrôlé et autres types de culture, chez les populations du Nord-ouest, après le contact avec les Européens. Au contraire, on retrace plus difficilement les preuves d'aménagement de la végétation avant le contact. La documentation sur la nature et l'étendue des stratégies d'aménagement des végétaux avant le contact intéresse les historiens, les archéologistes, les aménagistes, les écologistes forestiers et les Premières Nations. Les auteurs résument les divers éléments de preuves qui ont été ou ont pu servir à documenter l'agriculture ancienne, dans le nord-ouest de l'Amérique du Nord. Les auteurs présentent une discussion selon les conséquences écologiques des anciennes pratiques d'aménagement des végétaux et leur visibilité documentée ou potentielle dans les archives paléo-, néo-écologiques, et archéologiques. Cette revue démontre qu'en dépit de la difficulté de trouver des preuves d'aménagements anciens de la végétation, on peut y arriver en utilisant des méthodes de recherche innovantes. De plus, l'utilisation de diverses lignées de preuves indépendantes, renforce considérablement les reconstructions des anciennes stratégies d'aménagement de la végétation.

*Mots-clés :* connaissances écologiques traditionnelles, aménagement des ressources, nord-ouest, culture, brûlage contrôlé.

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## Introduction

Though deeply embedded in anthropological literature, the term "hunter–gatherer" has recently undergone a major re-evaluation. Once thought to characterize mobile peoples with simple social and economic systems and who foraged for wild plants and animals (e.g., Lee and Devore 1968), we now understand that so-called hunter–gatherer societies encompass a wider range of socio-economic behaviours (e.g., Arnold 1996; Ames and Maschner 1999). As part of this re-evaluation, the role of "wild" foods in the diet, the very foundation of the traditional definition of hunter–gatherers, is being revisited. Many hunter–gatherer societies manipulated their environment to some degree to increase the availability and productivity of desired resources (e.g., Hallam 1989; Blackburn and Anderson 1993; Anderson 2005). For some groups this manipulation was casual, but for others it was reflected in intensive and regular management activities (e.g., Smith 2005). The complexity of this mosaic of economic behaviours has led some researchers to reconsider the usefulness of the term hunter–gatherers and, indeed, whether it is fruitful to even try and categorize societies by their subsistence practices (e.g., Terrell et al. 2003).

Nowhere is the reassessment of hunter–gatherer societies more relevant than in northwest North America (Fig. 1). Anthropologists have long recognized the high degree of social complexity of Northwest coast peoples (e.g., Boas 1897; Wissler 1917), but recent re-evaluations of the anthropological and archaeological literature demonstrate that many peoples of the interior northwest were similarly complex (Hayden 1992, 2000*a*; Prentiss and Kuijt 2005). Concurrent

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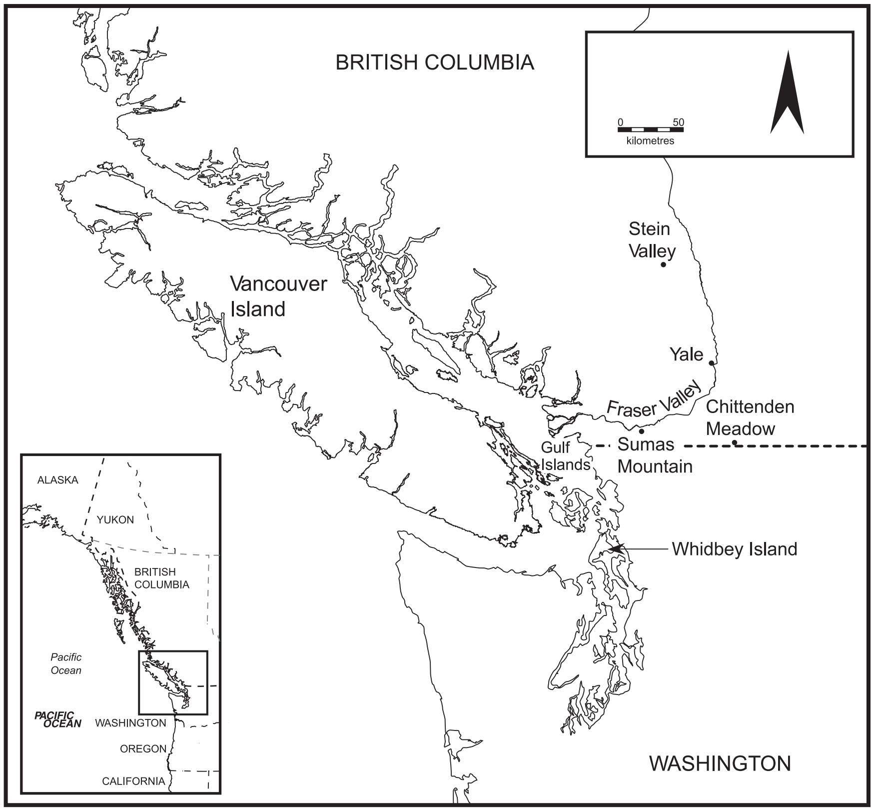
**Fig. 1.** The northwest (shown in the inset) is the region encompassing the Pacific coast and the adjacent Interior Plateau. The Pacific coast extends from southeast Alaska through British Columbia to southern Oregon. The Interior Plateau extends eastward from the eastern slopes of the coastal ranges. Its eastern boundary is roughly the crests of the Cariboo and Monashee mountains in British Columbia and the eastern state lines of Washington and Oregon (Lepofsky 2004). The enlarged section illustrates place names mentioned in the text.




with this re-evaluation of social complexity is an increasing awareness that northwest foragers did not rely solely on wild resources gathered from an untended environment. Rather, an extensive ethnobiological literature indicates that many of the hundreds of plants and animals used for food, technology, and rituals were actively managed to ensure ongoing productive harvests (e.g., Boyd 1999*a*; Peacock and Turner 2000; Jones 2002; Hunn et al. 2003; Turner and Peacock 2005; White 2006; Williams 2006). The degree of management, particularly associated with plants, forces the question whether the label of hunter–gatherer is indeed appropriate for some Northwest Peoples (cf. Deur and Turner 2005).

While the ethnobiological literature clearly documents the pervasiveness of plant-management strategies among Northwest Peoples after European contact, definitive evidence of *precontact* plant management has been elusive. This stems in large part from the challenges posed by the nature of the potential evidence. Since many of the plant-management activities were small in scale by design, and likely had subtle ecological consequences, they did not often result in obvious or long-lasting evidence in the paleo-, neo-ecological, and archaeological records. Furthermore, as several researchers have noted, the cultivation of root crops (e.g., corms, rhizomes, bulbs, etc.) specifically, may be hard to track since vegetative propagation may not result in easily identified morphological changes in the plants themselves (e.g., Smith 2005; Turner and Peacock 2005). Additionally, the impacts of such changes on population or community structure may be short-lived and difficult or impossible to detect in the modern ecosystem.

A larger stumbling block to documenting ancient plant management, however, has been the lack of concerted research effort focused on finding such evidence. As with other regions (e.g., Lepofsky 1999), the biases against documenting the extensiveness and intensity of plant-management systems in the northwest have deep historical roots (Deur 2000; Deur and Turner 2005). More recently, this research topic has largely been eclipsed by the dominant focus on animal resources, in particular on the importance of salmon (Lepofsky 2004). These preconceptions about the relative unimportance of plant resources, combined with the problem of the "light footprint" of many traditional management activities (Lepofsky et al. 2003) means that we have little collective knowledge about plant-management activities in the past — what activities were undertaken, the intensity of those activities, where they were practiced, or over what time periods.

There are good reasons why we should be concerned with documenting plant-management strategies in the precontact period specifically. Although the compiled ethnographic evidence based on oral traditions documents a rich legacy of plant management, we often lack the details about specific management practices in particular ecosystems. For instance, Stó:lō elders in the Fraser Valley recount that prescribed fires were used to enhance berries in high-elevation meadows. They tell us that fires were set every 3 years or thereabouts, yet there is little memory about exactly where the burned patches were, whether it was the same patches over the years, or if they shifted slightly, whether only the edges of the patches were burned to reduce tree encroachment, or the size of the burned areas (Lepofsky et al. 2005*a*). Given the huge disruptions in traditional northwest cultures in the postcontact era (e.g., Boyd 1990), extracting evidence from the archaeological and ecological records may be the only way to reconstruct some of these lost details about plant management. Studying the precontact archaeological and ecological records has significant potential to tell us about practices that are not reflected in more modern sources.

Further, the codevelopment of social complexity and the intensification of resource production is a common theme of northwest archaeological research (e.g., Matson and Coupland 1995). Although much of this discussion has focused on animal resources, researchers also recognize the importance of the intensification of plant production in the development of northwest social systems (e.g., Peacock 1998; Lepofsky and Peacock 2004; Ames 2005). Among the many pathways to intensification (Lepofsky and Peacock 2004), cultivation to enhance productivity is central. In this context, documenting when plants began to be actively managed is a fundamental question about the development of northwest societies.

The role of past peoples in influencing the dynamics of the ecosystems in which they participated is also a critical input to developing ecosystem-based systems of management today. Understanding the natural or historical range of variability in ecosystem parameters (Landres et al. 1999) is necessary for charting a management path that has a high likelihood of maintaining desired species, ecosystem services, and products into the future. In most cases, however, there was a component of that range of variability that had an anthropogenic origin (e.g., Vale 2002; Whitlock and Knox 2002; Heckenberger et al. 2003, 2007; Willis et al. 2004). In many cases, the anthropogenic component is dealt with by declaring precontact or pre-industrial peoples to be part of the "natural dynamics" (Landres et al. 1998, 1999), but this approach begs the question of understanding the human role in past dynamics. This issue also relates directly to the broader philosophical debates about the sustainability of indigenous societies and their resource management practices (e.g., Kay 1994; Broughton 1997; Krech 1999; Butler 2000; Vale 2002; Hunn et al. 2003; Turner 2005; Berkes and Turner 2006) — and the current intense interest in how past societies have interacted with changing resources and climate (e.g., de Menocal 2001; Diamond 2005; Lepofsky et al. 2005*b*).

In this paper, we summarize the various lines of evidence that have been, or could be, used to document ancient cultivation in the northwest. Given the early stage in the development of this area of research, many of these examples represent hypotheses about the nature of the evidence that remain to be evaluated. Following Deur and Turner (2005) and others, we use the term cultivation to mean "the repeated and intentional manipulation of both plants *and* their environments as a means toward plant resource enhancement". Cultivation includes activities such as transplanting propagules, soil enhancement, and prescribed burning. We are particularly concerned with evaluating which of these activities may leave evidence in the paleo- and neo-ecological and archaeological records.

We use the rich ethnographic evidence of ecological knowledge among northwest indigenous peoples as a starting point for understanding the role of humans in past ecosystems of the region. This evidence demonstrates the range of management techniques used by peoples of the northwest to maintain and encourage certain plants and ecosystems. We then review the kinds of data that have been or could be used to find evidence of plant management in the past. Since finding such evidence can be difficult, we advocate an explicitly interdisciplinary approach that brings together multiple lines of evidence to tease out the roles of humans in past ecosystems.

## Plant management in the northwest: the ethnographic evidence

Cultivation to enhance the productivity of plants used for rituals, food, and materials was widely practiced among Northwest Peoples in the postcontact era (e.g., Boyd 1999*a*; Turner 1999; Peacock and Turner 2000; Blukis Onat 2002; Deur and Turner 2005; Turner and Peacock 2005). Management strategies were applied to many of the hundreds of plants used by Northwest Peoples (Turner 1995, 1997, 1998), across a range of ecosystems. Cultivation was directed both towards influencing the structure and productivity of individual plants (e.g., by pruning or separating bulbs) and the structure and productivity of plant communities as a whole (e.g., through tilling or prescribed burning).

While the ethnobiological literature about traditional plant management in the northwest is extensive and detailed, we present only a brief summary to provide context for our exploration into the possible evidence of ancient management strategies. Our review of these practices is taken from the more extensive literature cited above. We highlight practices that have the potential to leave lasting signatures in the ecological and archaeological records.

Cultivation of plants by Northwest Peoples included a wide range of behaviours that are commonly associated with any gardening or farming enterprise. Preferred areas for plant collecting were known, and many of these locations were owned and managed by family groups. In some cases, the ownership of these resource locales was conveyed to others by demarcating plot boundaries with stones or fences (Turner et al. 2005). The productivity of desired plants in areas where they were gathered was often enhanced by applying mulch, tilling, removing rocks, burning individual plants, weeding, and by selectively harvesting or replanting plants with desired attributes. Finally, particularly desirable plants (especially root crops) were sometimes transported to new locales and replanted there. As is typical of gardening, transplanting often meant subtly changing local ecosystems to create and maintain suitable growing conditions for the transplant.

Setting prescribed fires was a commonly used way to manipulate local ecosystems to increase the productivity of desired plants. Given the potentially profound effects of fires, this aspect of plant management has received substantial attention from northwest ecologists and managers (e.g., Boyd 1999*b*; Vale 2002; Storm and Shebitz 2006). Abundant ethnographic evidence suggests that the use of prescribed fires as a cultivation technique was widespread in the northwest in the early postcontact era. Fire was used to enhance the productivity of economically important early seral or disturbance-dependent vegetation and to increase forage for game to be hunted. In addition, several groups mention that fire was used to control unwanted pests associated with economically important plants. While details about the nature of prescribed burning are often missing from oral accounts, we know that areas maintained through prescribed fires were typically small in spatial extent and were burned repeatedly, at least once per decade.

A case can be made, based solely on these ethnographic sources, that plant cultivation practices had their origins long before European contact. First, collectively, these historic sources indicate that plant management was a fundamental part of the yearly cycle of many indigenous peoples distributed widely across the region. The early occurrence of the management and control of other resources (e.g., via fish weirs, clam gardens) throughout the northwest (Moss et al. 1990; Eldridge and Acheson 1992; Williams 2006) strongly suggests that resource management, in general, has long been practiced in this region. Second, numerous indigenous linguistic terms associated with specific management techniques provide other clues as to the long-term practice of plant management. This linguistic evidence includes place names that refer to modified landscapes (e.g., Hunn 1996; Norton et al. 1999; Deur 2005; Storm and Shebitz 2006) and rituals and oral traditions associated with plant management (Table 1; e.g., Turner 1999; Deur 2005). The integration of plant management in language, in descriptions of the cultural landscape, and in ritual, reflects a deep, in situ cultural development of these practices among northwest indigenous peoples. What remains largely missing, however, is direct evidence for the presumed ancient origins of the management practices and their consequences for plants and ecosystems. The circumstantial evidence is convincing, but it would be useful to have direct evidence of the antiquity of the practices and a more detailed knowledge of the ecological changes they produced.

## Documenting past management techniques

In this section, we review several possible lines of evidence that could be used to document past plant-management activities (Table 1). We organize this discussion around the ecological consequences of management activities and the evidence those practices might leave on the landscape, rather than on the management techniques themselves (e.g., tilling, burning, etc.). We do this because different management actions can produce similar patterns in the archaeological and neo- and palaeo-ecological records — the data are the most parsimonious organizing feature. As well, we emphasize the fundamental importance to progress in this area of research of developing our body of primary biophysical data on these practices.

Each section below discusses a specific kind of evidence that could be used to assess whether a particular type of ancient plant management occurred. We begin each section with a brief description of the management activities that could have produced distinct evidence for that practice. We then review examples of previous research or potential research that could be used to document these activities. In general, this review demonstrates both the difficulties of finding evidence of pre-European plant cultivation, and the striking lack of concerted research effort put towards exploring this topic: many lines of evidence remain unexplored.

## Changes in plant morphology and genetics

### *The practices*

Several tools of traditional plant management have the potential to result in morphological or genetic changes over time in the plant populations themselves. These practices include the selective harvesting, replanting, and tending of individual specimens of preferred plants (Table 1). Such practices are particularly well documented for root vegetables, such as wapato (*Sagittaria latifolia* Willd.), camas (*Camassia* spp.), springbank clover (*Trifolium wormskioldii* Lehm.), and arrowleaved balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.). Larger sizes of these foods were selectively harvested, while smaller bulbs and tubers were left or replanted for future harvests. In some cases, particularly large bulbs were left in order that plants would go to seed (e.g., Deur 1999, 2000, 2005). The tending of root vegetables may have led to rapid phenotypic change in the tended populations (e.g., larger roots). In addition, we expect that the replanting of roots with desired traits or encouraging the dispersal of seeds from desired individuals would, over time, have resulted in directional selection for preferred characters.

Although not explicitly documented in the ethnographic literature, Northwest Peoples may have also tended plant foods other than root crops. These are typically naturally occurring varieties of wild fruits with distinctive and preferred attributes, such as taste and color. For instance, among both northwest coast and Interior Peoples, fruits with preferred attributes, such as distinctive colour and flavour, including salmonberries (*Rubus spectabilis* Pursh), Saskatoon berries (*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer), or Pacific crabapples (*Malus fusca* (Raf.) Schneid.) are recognized and named (Turner 1997; Turner and Peacock 2005, p. 147). The initial occurrence of these preferred "varieties" would have been part of the natural variation in the plant population. The fact that plants bearing these preferred fruits can be found in high concentrations in particular known plant-collecting areas (Turner and Peacock 2005, p. 147) suggests that plants bearing desired fruits may have been selectively tended or even planted in those locations.

Our discussion in this paper focuses on activities that are expressed at the population, community, or landscape scale. However, the removal of bark or cambium, for technology or for food, respectively, from individual trees is a notable special case of indigenous plant management involving modifications to the morphology of individual trees. The use of products made from the bark of red cedar (*Thuja plicata* Donn ex D. Don) and yellow cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) was a cornerstone of indigenous technology (e.g., Stewart 1984), and the Holocene history of cedar biogeography is intimately connected to First Nations culture (Hebda and Mathewes 1984). The ethnographic records, oral history, and historical records provide abundant evidence for the use of cedar technology and cultural practices related to the trees from which bark was harvested. We consider these practices as plant management,

**Table 1.** Lines of evidence for documenting ancient plant management.

| Ecological consequence | Associated activities | Potential evidence | Current state of evidence |
| --- | --- | --- | --- |
| Not applicable | Cultivation generally | Place names reflecting importance of plants no longer there or management of plants | Abundant, e.g, Nuu-Chah-Nulth and Kwakwaka'wakw terms associated with estuarine gardens (Deur 2000, 2004); burned landscapes among Gitksan and Chehalis (Gottesfeld-Johnson 1994, Storm and Shebitz 2006); anthropogenic landscapes in Interior Plateau (Norton et al.1999) |
| | | Oral traditions describing plant management | Abundant, e.g, Kwakwaka'wakw prayer to burning berry bush (Turner 1999). |
| Changes in plant morphology and genetics | Selective harvesting and tending | Archaeobotanical evidence of increase or standardization in size | Kramer (2000) found no evidence of increase in camas bulbs in Willamette Valley, but study may be limited by sample size and mixing of species<br>Vegetatively propagated perennials may not display subtle morphological changes (Turner and Peacock 2005; Smith 2005) |
| | | Reduced genetic variation in tended populations | No research on either herbarium or archaeological specimens |
| | | Multiple ages classes of bark stripping on individual trees; larges stands of trees with single scars | Some evidence, but limited antiquity in part owing to limited application of formal dendrochronological methods |
| Modification of soil | Mulching, tilling, removal of large rocks, improvement of drainage, laying of plot boundaries | Increased nitrogen, phosphorous, etc. in specific areas from mulching | Deur (2000, 2005) noted some differences in soil within garden plots consistent with anthropogenic modifications |
| | | Reduction in sediment size | Ditto |
| | | Evidence of plot boundaries | Stone plot boundaries in estuarine environments (Deur 2000, 2004); other ecosystems not explored |
| Geographic and ecological range extensions | Transplanting of propagules and maintenance of appropriate habitats | Historical records of plant distributions | Camas documented in regions where it no longer grows |
| | | Archaeobotanical evidence of nonlocal taxa | Archaeobotanical samples rarely collected from archaeological sites. Need to control for climatically-induced shifts in plant distributions |
| | | Pollen evidence of nonlocal taxa | No research; detailed study of nonarboreal pollen needed |
| | | Other archaeological evidence of harvesting and processing of nonlocal taxa (residues, distinctive features or artifacts) | None; evidence for "tobacco stone mortar bowls" and pipe residues not conclusive (Hayden 2000b:197) |
| | | Genetic evidence of nonlocal plants | Genetics of one Garry oak population in Fraser Valley consistent with human origins |
| | | Nonlocal varieties in archaeobotanical or herbarium specimens | No research, aDNA not yet applied to plant remains |
| | | The co-occurrence of disjunct populations of economic species | No research |
| Changes in fire regimes (seasonality, frequency, patch size) | Prescribed burning | Greater frequency of charcoal in soil and lake records than expected for natural fires | Existing studies suggest natural burns swamp the record (Lepofsky et al. 2003, 2004; Whitlock and Knox 2002) |
| | | Radiocarbon dates of charcoal from soil profiles and lake cores indicating shorter fire return intervals than expected for natural fire regimes | Ditto; may not be able to detect small scale fires |

**Table 1** (*concluded*).

| Ecological consequence | Associated activities | Potential evidence | Current state of evidence |
|---|---|---|---|
| | | Fire scars indicate greater fire frequency than expected for natural fires | Hadley (1999) evidence consistent with prescribed fires in Willamette Valley |
| | | Fire scars indicate fires outside of natural fire season | Very early season fires in the Stein Valley are consistent with human-set fires prior to ~A.D. 1900 |
| | | Fires on wetter sites more than expected naturally | No research |
| Shifts in vegetation mosaics | Prescribed burning, weeding and selective propagation | Changes in pollen and (or) archaeobotanical record | Previous pollen studies from large catchment basins not likely to represent small-scale, localized prescribed fires |
| | | | No evidence that cannot be accounted for by climatic changes (Hallett 2001; Whitlock and Knox 2002); finer woods may burn to ash |
| | | | Detailed study of nonarboreal pollen needed, as well as large sample of macrobotanical remains |
| Geographic and ecological range contractions | Cessation of management, particularly prescribed burning | Encroachment of fire intolerant and (or) shade-tolerant plants | Chittenden Meadow recent encroachment is climate-driven, but previous maintenance of parkland may be due to prescribed fires |
| | | Archaeobotanical evidence of plants not growing today | Archaeological evidence of camas and other parkland vegetation where no longer growing today (Weiser 2006) consistent with prescribed burning; need to control for climate-driven vegetation shifts |

rather than just harvesting of wild-plant resources because of the common pattern of multiple scars on individual trees and the well established cultural proscriptions against removing too much bark from an individual tree, or stripping the bark too frequently from a single tree (Turner and Peacock 2005). Both of these proscribed practices would ultimately kill the tree.

### *The evidence*

While shifts in the size or character of plants under cultivation are well described elsewhere, finding evidence of human-induced morphological or genetic changes in northwest perennials, including root crops, may require using innovative techniques. Whereas seed-propagated annuals respond relatively quickly to selection and cultivation with noticeable morphological changes (e.g., Gremillion 1993; Smith 2006), changes in vegetatively propagated perennials may be more subtle and less immediate (Smith 2005). Tracking morphological changes will require analyses of large samples of well-dated plant remains from single archaeological sites (e.g., Thoms 1989) and innovative ways of assessing subtle metric changes through time (e.g., Lepofsky et al. 1998).

To our knowledge, a study by Kramer (2000) is the only example from the northwest of research targeted at tracking potential morphological or genetic changes in plant foods as a result of cultivation. Based on the assumption that selective harvesting and propagation would result in larger bulbs through time, Kramer measured charred camas bulbs recovered from archaeological sites in the Willamette Valley (ranging in age from 8000 to 140 years ago). She found no noticeable trend in bulb size, but argues that a larger and better dated sample is needed to evaluate these results fully. Kramer also points out that if her sample included the two native species of camas (*Camassia leichtlinii* (Baker) Wats., *Camassia quamash* (Purch) Greene), which vary greatly in size, any morphological changes through time would be masked. Methods which distinguish between the two species of bulbs, such as an analysis of their ancient DNA (aDNA), or the compilation of species-specific morphological attributes, would considerably refine such an analysis in the future. Furthermore, a comparison of average bulb size at various times in the past against specimens from modern populations that are no longer tended could be used as a measure of whether any of the ancient populations were ever cultivated (i.e., the ancient populations should be, on average, larger than the modern one).

Genetic analyses of archaeobotanical specimens have the potential to reveal whether plants have undergone genetic shifts as a result of human selective pressures. Analysis of the genetic character of populations over relatively long periods of time (e.g., thousands of years) from a time-series of archaeobotanical samples is a relatively untapped source of evidence in the attempts to understand human interaction with their environment. Economic botanists have long recognized the potentially complex patterns of genetic variation in populations of plants influenced by human selection (e.g., Harlan 1975); both high and low genetic diversity have been postulated for cultivated-crop populations. In the case of the northwest coast, we expect a reduction in genetic variation in populations that have been subject to long-term management, as cultivators started with natural populations with whatever endemic levels of diversity they represented and then selected for cultivation subsets of the populations with preferred characteristics. This should be evident in genetic analyses of archaeological specimens, as well as in modern plant populations that have been established through selective tending and perhaps planting (e.g., stands of Saskatoon or crabapple). Conversely, we might expect a pattern of rapid increase in diversity as a result of long-distance trade in propagules (e.g., between peoples of Oregon and British Columbia, who traded materials for stone tool manufacture; e.g., Carlson 1994). Species of tobacco (*Nicotiana quadrivalvis* Pursh, and *Nicotinia attenuata* Torr. ex S. Wats.), for example, were spread extensively through regional trade (Turner and Loewen 1998) and might make a good case study for this problem.

The archaeological record of the northwest provides abundant evidence of the removal of tree bark and cambium in the form of "culturally modified trees" (CMTs). Such trees, from which bark or cambium has been removed, have a distinctive harvesting scar, the morphological details of which change over time as it heals or as rot sets in (e.g., Stryd and Eldridge 1993; Prince 2001; Marshall 2002). Different kinds of management choices by indigenous people are evidenced where some areas show multiple age-classes of bark-stripping scars on individual single trees (e.g., Lepofsky and Pegg 1996; Garrick 1998), and elsewhere, large stands of CMTs bear only a single removal scar on each tree (e.g., Prince 2001). The antiquity of cedar-bark harvesting is also shown by the abundant record of the products of cedar technology (e.g., baskets, cordage, mats, and clothing) in archaeological sites dating back thousands of years (Bernick 1991, 1998).

CMT scars can be aged reliably via standard dendrochronological methods (i.e., via the use of cross-dated chronologies; Stokes and Smiley 1968; Holmes 1983), though such methods have been applied in relatively few cases. Thus, although CMTs can be ubiquitous, the database of well established scarring dates is relatively small. There are many CMTs that have been dated to the early contact and historic periods; fewer have been dated to the precontact era. Partially, this reflects the increasing challenge of finding, identifying, and ageing CMT scars as they heal and (or) rot. However, since cedars often live to be many hundreds of years old, decay slowly once they die, and the antiquity of cedar technology is well established, we suspect it also reflects the lack of a concerted effort to find older scars and to apply formal dendrochronological methods to them. The increased use of cross-dating should allow firm dates to be established for archaeological samples which could not otherwise be dated with any degree of accuracy.

## Modifications of soil

### *The practices*

Direct enhancement and modifications to soils were common elements of plant management in the northwest. These activities included fertilization, mulching, tilling, and the removal of larger rocks from plant harvesting areas (e.g., Deur 2002*a*, 2002*b*, 2005). As a result of these activities, soil in tended patches would have been both finer and more enriched than in untended areas. Such changes in soil chemistry and texture may still be detectable in the soils, although soil-nutrient characteristics may change rapidly in some areas.

### *The evidence*

Elsewhere in the world, archaeologists use texture and elevated levels of selected elements to identify ancient agricultural soils (e.g., Clark and Tamimi 1984). In the northwest, however, Deur's (2002*a*, 2002*b*, 2005) research is the sole application of soil analyses to distinguish cultivation. He used soil chemistry as one of several lines of evidence to characterize estuarine gardens where indigenous peoples of the central coast of British Columbia cultivated silverweeds (*Potentilla anserina* L. and *Potentilla pacifica* Howell) and springbank clover. His preliminary results suggest there are detectable differences in soils inside and outside garden plots.

As was the case in Deur's study (Deur 2002*a*, 2002*b*, 2005), this approach requires a priori knowledge of the location of some cultivated plots, either via local knowledge or through remnant boundary markers. With this knowledge, differences between cultivated and noncultivated soils could be characterized. If consistent differences were found, other cultivated sites might be able to be identified using those data.

A potentially longer-lasting and more easily identified modification of soils is the demarcation of garden plots with stones, stakes, or trenches (Deur 2005; Suttles 2005; Turner et al. 2005), or the piling of cobbles as markers of plot ownership (Beckwith 2004, p. 71). While wooden stakes are unlikely to preserve, except in extraordinary conditions (e.g., anaerobic preservation in mudflats), these circumstances do occur on occasion. In Deur's (2000, 2002*a*) studies of estuarine gardens, stone boundary markers survived from their time of establishment to the present, in relatively undisturbed environments. His dating of carbon samples trapped between the original estuarine surface and the deposits lain down after the plots were constructed demonstrates that at least some of the features date just prior to European contact. Dates from this single feature are the only direct evidence for precontact plant cultivation in the northwest.

To our knowledge, no archaeological surveys have been explicitly targeted at finding and dating ancient gardens (but see Moss 2005 for postcontact gardens). Following Deur (e.g., Deur 2000), estuaries elsewhere on the coast should be explored for archaeological evidence for garden plots. While we recognize the importance of traditional knowledge for focusing the locations of such archaeological surveys, we advocate that such surveys also be conducted in places where oral traditions do not specifically mention estuarine gardens. In addition, thorough surveys of other ecosystems in which plants were known to have been tended in owned plots (e.g., camas meadows; Suttles 1951) are likely to produce remains of ancient plot boundaries. Priority should be given to determining the antiquity of such features.

## Geographic and ecological range extensions

### *The practices*

Ethnographic information indicates it was relatively common practice to transplant propagules with desired traits (e.g., Suttles 1951, p. 147; Turner and Loewen 1998; Deur 2005). As a result, nonlocal species of economically valued plants, or nonlocal genetic strains, could be introduced into a region, sometimes from across substantial distances. In addition to such *geographic* range extensions, Northwest Peoples extended the *ecological* ranges of plants by modifying poor or uninhabitable habitats within the plant's natural distribution, so that they become more productive or habitable. In both cases, ongoing management was often required (e.g., via prescribed burning, weeding, etc.) for the introduced plants to flourish in these extended habitats.

***The evidence***

Comparisons of historical records with current plant distributions are one avenue for documenting geographic and ecological range extensions as a result of ancient plant management (Table 1). For instance, the historical presence of camas (*C. quamash*, *C. leichtlinii*) in Alaska (Pojar and MacKinnon 1994, p. 108), western Vancouver Island, northern Oregon (Deur 2005), and the central Fraser Valley (Gould 1942; Duff 1952) — where it no longer grows today, are possible examples of such range extensions. The presence of camas in places well out of its current range, or in ecosystems that would be naturally unsuitable (e.g., too densely vegetated), suggests both transplanting of nonlocal bulbs and the maintenance of habitats suitable for the introduced plants through the setting of prescribed fires (Deur 2005; see below).

Plant remains from archaeological sites could also be used to document shifts in plant ranges as a result of transplanting (Table 1). Identifying nonlocal plant remains recovered from archaeological sites may constitute such evidence if the remains could be shown to be local and not received via trade. Mass processing of plant foods via drying or cooking in earth ovens would constitute evidence of local harvesting, since unprocessed plant foods were generally too heavy to transport any great distances. Such processing leaves distinctive archaeological features that could be easily sampled for the recovery of ancient plant remains (e.g., Thoms 1989; Peacock 1998). Unfortunately, collecting and analyzing plant remains is not yet common practice among northwest archaeologists (Lepofsky 2004; Lepofsky and Peacock 2004). A more indirect line of evidence would be the recovery of artifacts used for processing nonlocal taxa (e.g., seed grinding implements in locales where seed crops are no longer present). Elsewhere, archaeologists conduct residue analyses to determine the original function of artifacts (e.g., Piperno 2006). However, such approaches have not been widely applied in the northwest.

A special and dramatic case of geographic range extension in the northwest is that of tobacco. Tobacco is not native to the northwest. In postcontact times it was cultivated by many Northwest Peoples for its leaves, which were chewed or smoked in pipes (Turner and Taylor 1972; Turner 2004; Moss 2005). However, there is no archaeological evidence of its use in the more distant past. Conclusive proof of precontact domestication and use of tobacco would require the recovery of the highly distinctive tobacco seeds in the archaeological record, or the positive identification of nicotine residues in pipes or other artifacts (Lepofsky 2004).

A region-wide study of the population genetics of Garry oak (*Quercus garryana* Dougl. ex Hook.) (Ritland et al. 2005) provides an example both of potential geographic range extension, of intriguing variation in genetic characters among populations, and of the value of adding an archaeological context to studies which intend to distinguish anthropogenic from other origins of plant populations. Garry oak is distributed from California through British Columbia, and is the only oak native to British Columbia. Today, Garry oak in British Columbia, like camas, is largely restricted to the dry habitats of the Gulf Islands and southeast Vancouver Island (Fig. 1). However, two small, isolated populations of Garry oak occur on the British Columbia mainland in the Fraser Valley. One is located on a lower slope of Sumas Mountain above the north shore of the Fraser River. There are no archaeological remains known to be associated with this population. The other population is upriver in the Fraser Canyon, north of the town of Yale. While more distant in linear measure from the main British Columbia population centres for Gary oak, it is on a riverside bench on the primary ancient regional travel route and is associated with a complex and rich archaeological record extending to the early Holocene (Mitchell and Pokotylo 1996) and with modern First Nations reserves.

Ritland et al. (2005) found that the oaks exhibit a complex pattern of genetic variation, with two broad groups or clades emerging, one on Vancouver Island and the adjacent Gulf Islands and one on the American San Juan islands and mainland extending southward into Oregon. The two British Columbia mainland populations are genetically distinct from each other, and the Sumas population doesn't group significantly with either broad clade. The Yale population, while not significantly associated with the island populations with which it was most similar, groups with the British Columbia islands clade. Ritland et al. (2005) use this genetic distinctness to suggest that both populations originated either via nonhuman animal dispersal events or as relictual populations from a broader earlier distribution. Oaks may have had a wider distribution in southern British Columbia during a warm period in the mid-Holocene — and there is evidence for a local increase in fires during this time (Hallett et al. 2003). Ritland et al. (2005) discounted a hypothesis of origins via indigenous people because oak populations of "recent anthropogenic origin" should have had a closer genetic affinity to their group of origin. McIntosh and Sadler (2001) completed a botanical and ecological survery of the Yale oak stand and also concluded, based many on the presence of a variety of plant species with disjunct distributions, including Garry oaks, that this stand is more likely a remnant of a previously extensive Garry oak community in the mid-Holocene. However, with a knowledge of the long duration of human activity in the area, the strong and ancient cultural connections between people of the coastal islands and the Upper Fraser Valley (Lepofsky et al. 2000), and of the water-based travel patterns of those people, we suggest that an ancient human origins hypothesis for the Yale, but not the Sumas oak population, may also be consistent with the genetic data. What is needed to resolve these hypotheses is a concerted effort to combine archaeological and palaeoecological evidence with further genetic analyses. More communitylevel research might also help resolve the role of humans in explaining distributional oddities: the co-occurrence of disjunct populations of economically important plants would lend support to cultural hypotheses for population distribution.

The analysis of aDNA of archaeological plant specimens also has the potential to provide insights into the movement of plant propagules in ancient times (e.g., Brown 1999). As with modern studies, with a large sample of ancient plant remains, DNA can be used to identify distinct cultivated populations and trace their movement through time. We expect the pathways of plant transport, as we suggest for the Garry oak case above, followed established routes of cultural interaction. In addition, analyses of herbarium specimens of locally extirpated plant species (e.g., tobacco, camas) should allow a similar tracking of plant movement across space and perhaps through time.

### *Prescribed burning*

Prescribed burning is a practice that was widespread geographically and culturally. Because prescribed burning is associated with a broad range of ecological consequences, we address the practices once here, and then discuss the evidence individually for three main classes of consequence below.

### *The practices*

Early historical European records and First Nation oral traditions describe the setting of prescribed fires throughout the northwest (e.g., Norton 1979; Boyd 1999*b*, Turner 1999). Such fires were set to maintain open ecosystems, to discourage the encroachment of less economically important plants, and sometimes to discourage pests on culturally important plants. There is evidence of indigenous peoples' use of prescribed fires across a broad range of ecosystem types, from dry ponderosa pine parklands and grasslands to cold, snowy, subalpine coastal and interior forests. The range of plant groups targeted by management in these ecosystems is equally diverse. In many cases, the timing and location of prescribed burns were carefully planned and often managed by specialists knowledgeable in fire ecology.

The widespread historical records and oral traditions of prescribed burning in the northwest, while compelling, are not alone sufficient evidence for the precontact use of this management technique. Furthermore, as researchers have noted (e.g., Whitlock and Knox 2002), it is hard to gauge from these records the actual extent and pervasiveness of such practices in any given place or time: typically, few details are provided by the records that would allow such conclusions. Thus, independent lines of evidence are needed to document the timing and nature of this management technique. We propose three classes of such evidence: first, shifts in the parameters of fire regimes (such as fire interval or fire seasonality) as the result of the initiation or cessation of prescribed fires (Table 1); second, changes in local vegetation mosaics as a result of changing fire regimes; and third, more specifically, ecological range contractions associated with the encroachment of fire-intolerant plants after the cessation of prescribed fires.

## Changes in fire regimes

### *The evidence*

Analysis of fire regimes focuses on several key parameters: frequency, severity, spatial extent, seasonality, landscape position, and internal heterogeneity (e.g., Lertzman et al. 1998; Cissel et al. 1999; Heyerdahl et al. 2001; Gavin et al. 2003*b*). Potentially, if other factors could be accounted for, changes in any of these temporal or spatial parameters could be used as indicators of anthropogenic influence. However, it can be difficult to accurately reconstruct these parameters for past fire regimes (e.g., Lertzman and Fall 1998) and "accounting for other factors" is often not trivial. Despite the methodological challenges, seeking an anthropogenic signal in palaeocological data on fire regimes is an active line of enquiry for both ecologists and archaeologists.

Ethnographic information suggests that the seasonality and frequency of prescribed fires, as well as the size of burns, varied with cultural groups and across ecological zones. However, there are commonalities that allow us to make general statements about the differences between fires that are natural in origin (lightning-ignition) versus cultural (human-ignition; Lepofsky et al. 2005*a*). In general, whereas natural fires can vary substantially in severity and over many orders of magnitude in temporal frequency and spatial extent, cultural fires represented only a small portion of this variability. They were typically of low severity and limited spatial extent (Beckwith 2004). Furthermore, intervals between past natural fires varied from as little as 10–20 years in dry regions such as the dry interior of British Columbia, Washington, or Oregon (e.g., Heyerdahl et al. 2001, 2007), to thousands of years in wet coastal rainforests of the British Columbia coast (Lertzman et al. 2002; Gavin et al. 2003*a*, 2003*b*). In contrast, while cultural fires probably varied in frequency, managed patches were likely burned every 10 years or less (e.g., Beckwith 2004; Lepofsky et al. 2005*a*). Finally, natural fires were typically restricted to the "fire season" — late summer and early fall for the Pacific northwest, whereas cultural fires wouldn't necessarily be limited to this period.

Low severity fires can leave scars in the wood of surviving trees that can be accurately dated with standard dendrochronological techniques (e.g., Heyerdahl et al. 2001, 2007). There is no direct evidence, however, of whether the ignition source for a fire in such a record was human or lightning. To identify an anthropogenic signal, something must stand out in the record in contrast to other periods or nearby "control" areas. For instance, if prescribed fires were more frequent than natural ones, fire scarred trees in landscapes maintained by prescribed fires should exhibit shorter fire intervals than in control areas without the anthropogenic influence. While this approach has been successful elsewhere (e.g., Barrett and Arno 1999), Hadley's (1999) analyses of fire-scars in a Willamette Valley meadow is, to our knowledge, the only study from the northwest which successfully used fire scars explicitly to identify a signal of prescribed aboriginal burning. Based on fire scar data, Hadley demonstrated that fires in Willamette Valley were more frequent prior to European arrival and more frequent in the meadow than the surrounding forest. The greater frequency of fires in the meadow suggests that the meadow was maintained through prescribed burning. The decline in fire frequency postcontact is consistent with the suppression of prescribed fires.

Analysis of charcoal from lake sediments and forest soils (Brown and Hebda 2002; Gavin et al. 2003*a*, 2003*b*; Hallett et al. 2003) is another approach to understanding past fire regimes that has some potential to identify cultural fire signals. In our research in the subalpine forests of the coast Mountains of southwestern British Columbia, we have tried using soil and lake sediment charcoal as a way of tracking shifts in fire frequency that may be the result of aboriginal burning practices (Lepofsky et al. 2005*a*). However, despite the fact that we sampled at a very fine scale, and dated extensively, we found little direct evidence for prescribed fires. The frequency of fires from the charcoal records was consistent with a natural fire history of infrequent (centennial to millennial scale fire intervals) rather than human-set fires (decadal scale intervals). This was the case even when we examined locations where the oral traditions indicated that burning had been practiced. As a result, we have had to modify our expectation for the kind of signal produced by prescribed fire in these forests (Table 1). As with dendrochronological evidence, teasing out an anthropogenic signal when there is one present will be difficult.

Shifts in the seasonal distribution of fires could represent evidence of anthropogenic fires. Management choices about the season of burning can influence both fire behaviour (and thus the ease of controlling fires) and the nature of the fire effects on vegetation. For instance, fires are typically easier to control early in the season, when fuels are moist and fire weather less extreme. However, much of the ethnographic evidence from the northwest suggests that prescribed burns were conducted in the fall (e.g., Lepofsky et al. 2005*a*). The season of burning can be identified from fire scars in low severity fire regimes, however it is only recently that such data has been collected (e.g., Kaye and Swetnam 1999). Heyerdahl et al. (2007), studied low severity fire regimes in the Stein Valley in the southwest interior of British Columbia (Fig. 1) using tree ring analyses of fire scars. The fire record over the past 250 years is dominated by fires during what we consider today to be "the fire season" — midsummer to early fall. However, early in the record there was also a minor component of very early season fires (E. Heyerdahl and K. Lertzman, unpublished data). This early season component dropped out of the record around 1900. An hypothesis of aboriginal prescribed fires that ceased after European settlement could explain this pattern.

Finally, examining the landscape positions of past fires may also provide evidence of prescribed fires. Although many First Nations in the coastal northwest set fires on drier south-facing slopes (Deur 1999; Lepofsky et al. 2005*a*), cultural fires likely have been less limited to such fire-prone locations than would natural fires. Rather, we expect prescribed fires could potentially occur wherever people owned and (or) managed plant harvesting areas. For instance, in our work on the ethnography of prescribed fires in subalpine coastal forests (Lepofsky et al. 2005*a*), we found that fire was used as a management tool on cold, snowy sites that seemed initially very improbable. Indeed, since one of the outcomes of plant management was to increase plant productivity and extend ecological ranges, patches managed through prescribed fires could, in principle, be widespread on the landscape. Ecological knowledge gathered from local First Nations should be used as a guide to locations which may have been managed with prescribed fires.

As with other lines of evidence, studies that rely on the location of fires as an indicator of prescribed burning need to control for changes in climate that might modify the likelihood of fire in different positions on the landscape over time. For instance, Gavin et al. (2003*a*) showed that in a rainforest watershed on the west coast of Vancouver Island, varying portions of the landscape were susceptible to burning at different times during the Holocene. This was due not to anthropogenic factors, but rather to shifts in the strength of large-scale climatic control of fire regimes relative to control by local topographic factors.

## Shifts in vegetation mosaics

### *The evidence*

Changes in the various parameters of fire regimes will exert a broad influence on plant communities across affected portions of the landscape. With increasing incidence of fire, we would expect an overall shift towards early seral or disturbance tolerant species and younger age-classes of intolerant species, with the opposite trends under a regime of reduced fire incidence. These various changes would, for the most part, have been expressed though shifting the dominance of native plant species that were already present in communities. This differs from what is observed classically in agricultural landscapes, where new species or combinations of species become the dominant elements of the landscape, and thus where the signal of cultivation is much more distinct. In agricultural landscapes, pollen analyses are commonly used to track such changes in vegetation through time (e.g., Delcourt et al. 1986; Parkes and Flenley 1990). In such studies, pollen is usually extracted from lake catchments that collect pollen rain representing a broad, regional summary of vegetation. Pollen collected from such large catchments is dominated by wind-pollinated vegetation, primarily from trees.

Northwest researchers have observed shifts in pollen frequencies representing relative greater abundance of open-canopy vegetation and suggested that this may be evidence of the onset of prescribed burning practices in the past (e.g., Gottesfeld et al. 1991; Pellatt et al. 2001). However, in those cases where pollen samples were collected from large catchments, the observed shifts in pollen may represent regional-scale, climatically driven vegetation changes rather than the subtle, local shifts we would expect from prescribed burning. Based on our current understanding of prescribed burning practices in the northwest, such fires were typically of low intensity and small in spatial extent. They would most likely have resulted only in local, small-scale shifts in vegetation abundances that would be a small portion of a regional signal. To track these potentially more subtle ecological changes requires sampling small catchments that are more likely to (*i*) collect pollen originating from economically important, insect pollinated local plants and, (*ii*) thereby provide a record dominated by local-scale vegetation dynamics. Few pollen studies in the northwest are sufficiently fine-grained, either spatially or temporally, to identify with certainty shifts in vegetation mosaics resulting from prescribed fires.

Regardless of the sampling context, if we wish to draw conclusions about the role of human-set fires in past vegetation dynamics, we need to be able to control for climatically-driven changes that may confound such observations. For instance, we studied fire history in the coastal subalpine forests of southwest British Columbia (Hallett et al. 2003; Lepofsky et al. 2005*a*) using charcoal from lake sediments and soils. This revealed a period of increased fire frequency between 2400 and 1200 BP, the Fraser Valley Fire Period (FVFP). In these cool, snowy forests, fire weather is associated with extended periods of drought in the summer and early fall — conditions that not only increase the likelihood of wildfires, but would make prescribed burning more feasible as well.

Strongly coincident with the FVFP is a period of intensification of many cultural practices in the Gulf of Georgia and the Fraser Valley (Lepofsky et al. 2005*b*). Indeed, throughout much of the southern portion of the region, this is a time of cultural intensification, some aspects of which may be linked to climate (Prentiss et al. 2003, 2005; Lepofsky et al. 2005*b*). We cannot distinguish from the fire record whether all the fires represent natural ignition sources or if some are "climate-enabled prescribed burning." However, it is consistent with the cultural changes at that time that people began setting prescribed fires to augment the harvest of economically and socially valued plant resources. This coincident timing of the FVFP and a period of cultural intensification highlights the challenges of teasing out the human signal in past vegetation dynamics. Others working in coastal British Columbia have found significant changes in both the pollen and charcoal records during the time of the FVFP and attributed them directly to prescribed burning, rather than climate (e.g., Gottesfeld et al. 1991; Brown and Hebda 2002). We remain unconvinced, however, by the evidence for a hypothesis of solely human causation and argue instead for an overall climatic driver for fire during this time (e.g., solar forcing, Hallett 2001). Clearly however, climatic change and human activities can drive fire incidence simultaneously, and we suspect that climatic facilitation of the use of fire as a management tool is likely to be important in very wet coastal environments.

## Geographic and ecological range contractions

### *The evidence*

Earlier, we discussed the inference of ancient plant management from ecological range *extensions*, here we consider the idea that ecological range *contractions* can provide indirect evidence of the cessation of plant-management practices. The encroachment of fire-intolerant species into what were believed to be previously more open plant communities maintained by fire is the most common application of this idea. We consider it an ecological range contraction because of the reduction in area or loss of the plant communities maintained or enhanced by prescribed burning. Encroachment by, and increasing density of, young and fire-intolerant trees are predictable responses to a cessation of prescribed burning, but also to modern fire suppression and to climatic shifts that might lead to a reduced incidence of fire in the absence of changes in management practices. For instance, several researchers have suggested that the cessation of prescribed burning is responsible for the recent encroachment of other vegetation (e.g., Douglas-fir; *Pseudotsuga menziesii* (Mirbel) Franco) into Garry oak – camas meadows of southeast Vancouver Island (Fuchs 2001). The hypothesis that the cessation of prescribed burning is a causal factor in vegetation change, however, is complicated by the co-occurrence of settlement by Europeans, fire suppression, and recent climate changes.

Controlling for the effects of climatically driven, natural versus cultural fires on shifts in vegetation is a critical step in using plant distributions as evidence of past prescribed fires. For instance, the recent contraction of ecosystems that historically were managed through prescribed fires (e.g., *Vaccinium* spp. patches in subalpine meadows throughout the northwest, and Garry oak meadow communities in southeastern Vancouver Island, parts of Puget Sound in Washington State, and the Willamette Valley of western Oregon) has been cited as possible evidence of the cessation of prescribed fires (e.g., Johanessen et al. 1971; Norton 1979; White 1980; Agee 1993; Boyd 1999*a*; Deur 1999). However, since policies have restricted both natural and cultural fires since the early to mid-twentieth century, it is difficult to separate the roles that either natural or cultural fires alone would have played in maintaining these communities. The effects of concurrent changes in climate over the past century challenge our ability to distinguish the direct effects of the cessation of traditional management practices (e.g., Lepofsky et al. 2003).

Our research in Chittenden Meadow in southwest British Columbia (Fig. 1) provides an instructive example of the challenge of distinguishing climatic from human causes of apparent ecological range contractions, in particular, distinguishing the cessation of prescribed fires from climatic shifts as drivers of change (Lepofsky et al. 2003). Chittenden Meadow is an open patch of herbaceous and shrub-dominated vegetation in a largely forested landscape. It has a mix of ponderosa pines (*Pinus ponderosa* P.& C. Lawson) and meadow vegetation that is unusual in coastal British Columbia, but shows evidence of significant encroachment of young woody vegetation along the margins of the meadow. Throughout its range, ponderosa pine is associated with frequent, low severity, surface fires, while the surrounding forest is more typical of the coastal-–interior transition with a history of higher-severity, stand replacing fires.

Historical, ethnographic, and archaeological sources describe long (e.g., early Holocene) and extensive use of the area surrounding Chittenden Meadow. Our own archaeological evidence from the meadow itself corroborates this, indicating Chittenden Meadow was an important ecosystem to First Nations in the past. The historical record also documents extensive burning by First Nations early in the period of European settlement in the region. These data, combined with the recent in-filling of the meadow by early seral species led us to hypothesize that the meadow was maintained as an open ecosystem in the past through regular prescribed fires, but is now being colonized by woody vegetation in response to the cessation of burning, an example of ecological range contraction. We hypothesized that the recent encroachment was due to the cessation of these prescribed fires.

The actual historical dynamics of the meadow reflect a more complex mix of climatic and anthropogenic drivers than this hypothesis suggests. We combined analyses of soils, dendrochronology, historical climate records, ethnography, and archaeology, to construct an alternative hypothesis for the meadow's history. We were able to show that the meadow itself has existed as a distinct element of the vegetation mosaic for a long time, at least hundreds of years. Over most of its ecological history, the meadow was an open ponderosa pine parkland, with more pines than are currently present, but much more open than the surrounding forest. However, the encroachment appears to be a response to a recent period of climatic warming. Its establishment is correlated with low spring snowpack in the 1970s — clearly much more recent than, and not at all related to, the cessation of burning earlier in the 20th century. The major change in meadow vegetation occurred around 1890 when most of the pines in the meadow, along with much of the surrounding forest, burned in a higher severity fire, probably associated with the early European settlement of the area. Ecological range expansion and contraction had occurred, but in response to a more complex set of drivers than simply cessation of prescribed burning or climate variation.

While we documented use of the meadow by ancient people, we failed to find direct evidence of their use of prescribed fires to maintain the meadow — most of the tree-ring evidence we had hoped to find would have burned in the late 19th century fire. However, we were also unable to find any other hypothesis that could explain the existence and persistence of the meadow over such a long period. The hypothesis of aboriginal prescribed fires as a factor in Chittenden Meadow's history remains unrejected, but only supported by circumstantial evidence. Partially in response to this work, B.C. Parks has initiated a restoration program in Chittenden Meadow intended to reduce encroachment of woody vegetation and to enhance meadow plants with First Nations cultural significance (Witt 2006).

Analysis of plant remains in archaeological contexts is a potentially powerful, but under-utilized tool to examine shifting relations between human activities and the ecological range of plant species and communities. For example, Weiser (2006) studied a complex of archaeological features associated with Ebey's Prairie, Whidbey Island, Washington State (Fig. 1), which was known to be an anthropogenic meadow, maintained through prescribed fires at the time of European settlement (Weiser 2006). Records of the time indicate abundant camas, bracken (*Pteridium aquilinum* (L.) Kuhn), and other culturally important plants. Ethnographic sources indicate that in addition to setting fires, indigenous peoples tilled the soil with digging sticks to encourage camas (Weiser 2006). By the late 1850s, fires were discouraged and many areas were claimed by homesteaders. Settlers took control of Ebey's Prairie and it has been in agricultural production since then; however, small remnants of native vegetation, including culturally important species, exist in uncultivated refugia. Today, the prairie is surrounded by mature forest and would clearly succeed to forest in the absence of continued human intervention.

Weiser (2006) examined archaeological features from the area that was formerly aboriginally maintained prairie. She identified the remains of camas, onions (*Allium* sp.), and other plants typical of open meadow or parkland conditions from these sites. These plant remains had radiocarbon dates ranging in age from several hundred years ago (late in the precontact era) to 3000 years ago. Weiser concluded that some aboriginal management activities had begun shaping Ebey's Prairie by around 2400 years ago when a large assemblage of meadow species were present in her samples and when there was an increase in the number of archaeological features at the site. Collectively, these data provide a convincing case for the antiquity of plant-management practices and their continuity with our understanding from the ethnographic record. The hypothesis of an open ecosystem maintained through prescribed burning over a period of millennia is consistent with the data. With the cessation of prescribed burning and conversion of land to modern agriculture, however, there was a contraction of the ecological range of camas and other culturally important meadow taxa.

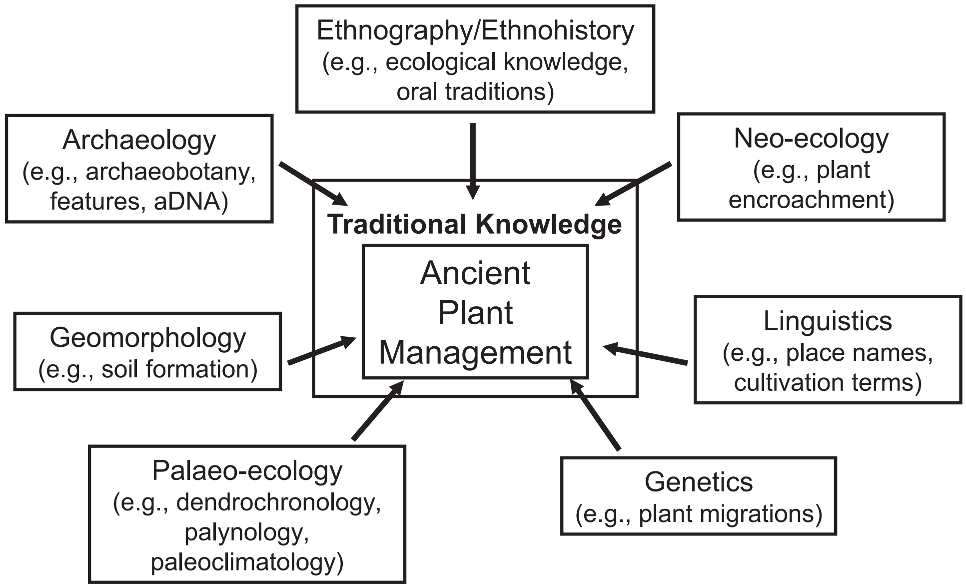
## Discussion

Many plant-management strategies used by Northwest Peoples have the potential to leave lasting and measurable evidence in the archaeological and ecological records (Table 1). However, the very nature of traditional plant management in the northwest — which it is often small in scale, patchy in space and time, and may not leave impacts that emerge from natural background variation — means that the traces of such practices will often be subtle. This subtlety, combined with preconceived biases about the minor importance of plants in indigenous subsistence generally, and plant-management activities in particular, has meant that little concerted effort has focused on finding evidence of plant management in the past. A number of approaches that have been used successfully elsewhere in the world, such as exploring the genetic basis of morphological changes in cultivated food plants (e.g., Brown 1999), have not yet been tried in the northwest. We are convinced that there is considerable potential for this kind of research to lead to an understanding of both the antiquity and the complexity of indigenous peoples' active roles in managing their environments.

Despite the paucity of research focused on elucidating the antiquity of traditional management practices, and the inherent challenges of the field, there have been some successes in documenting ancient plant management. In fact, in most studies where the research was designed explicitly to examine such practices (e.g., Deur 2000; Lepofsky et al. 2003; Weiser 2006), some evidence for ancient plant management was found. As well, such studies reinforce the complexity of the mix of social and ecological relationships expressed in the indigenous management systems. The most successful approaches to understanding ancient plant management typically combine multiple lines of evidence from diverse disciplines (e.g., Fig. 2; Storm 2002). For instance Deur (2000) and Lepofsky et al. (2003) combined traditional ecological knowledge, archaeological data, ecological analyses of modern plant communities, and sediment analyses.

The confounding effects of changing climate over

**Fig. 2.** Diverse lines of evidence needed to document ancient plant management.




archaeological and palaeoecological time scales emerge repeatedly as an issue. This can be exacerbated by the coincident timing of climate change with significant changes in culture. The recent description of the Fraser Valley Fire Period (Hallett et al. 2003) and its cultural correlate, the Marpole Phase (Lepofsky et al. 2005*b*) provide an excellent example of this. The best approach to dealing with these issues is to combine independent lines of evidence, develop spatial or temporal controls whenever possible, sample the temporal record at as fine a scale as possible, and generate models with testable predictions.

## Conclusions

We can identify four key issues that are raised by our review and merit significant attention.

1. Exploring the genetic basis of morphological changes in modern and archaeological specimens of culturally important plants is a significant, but largely unexplored, avenue of research. This should involve comparisons of genetic and morphological features among archaeological samples over time and with modern populations across space. Ethnographic information and traditional knowledge regarding areas that were known to be cultivated should be incorporated into these research designs.
2. Currently, a major stumbling block to documenting range extensions and contractions is the lack of systematic collection of archaeological plant remains in the northwest region. Distributional records of ancient plants could then be compared to both historical and modern distributional records. Our ability to proceed with this kind of research ties in to problems related to surveying and monitoring biological diversity more generally. It also raises the issue of insufficient resources being allocated to maintaining herbaria collections and to systematics in general.
3. We suspect that the study of ancient management practices is confounded both by a tendency not to recognize potential anthropogenic signals when they may be present, and by a willingness to accept a hypothesis of aboriginal management activities (especially burning) when, in fact, the evidence is weak. Progress will require rigorous data collection and evaluation which combines disciplinary strengths more broadly than has been the norm. This synthesis should include the systematic combination of ethnographic, archaeological, modern, and palaeo-ecological information by multi-disciplinary teams of researchers as well as modern First Nations whose ancestors' practices are the subject of the research (Fig. 2). In our experience, such teams are more likely to recognize meaningful interactions between cultural and ecological phenomena (e.g., Lepofsky et al. 2003, 2005b) than more narrowly constituted research groups.
4. Current knowledge of northwest plant management supports the continuing re-evaluation of the nature of "hunter–gatherer" subsistence activities and social organization. Even with large gaps in our understanding, there are a broad range of activities that illustrate both the active involvement of Northwest Peoples in managing their plant resources and the likely antiquity of many of those practices. This recognition has implications for our understanding of northwest societies, for the historical dynamics of northwest ecosystems, and for management decisions informed by that understanding.

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