RESEARCH ARTICLE

Ancient Bark-peeled Trees in the Bitterroot Mountains, Montana: Legacies of Native Land Use and Implications for Their Protection

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ABSTRACT: Culturally modified trees (CMTs) are trees with scars that reflect human utilization of forested ecosystems. Some CMTs can reveal unique knowledge of native cultures and insight to peoples' subsistence and land use in the past, and are mostly to be found in protected areas since they contain very old trees. In this study, we examine attributes and the spatial and temporal distribution of bark-peeled trees, and present forest structure in two remnant ponderosa pine forests (*Pinus ponderosa* P. & C. Lawson) in western Montana. We also wanted to use an alternative method of dating CMTs and initiate a broader discussion of threats to such trees and needs for sustaining and protecting them. In total, 343 bark-peelings were recorded on 274 living and dead trees. Our results show that only certain trees were selected for harvest. Nearby trees of similar size and age were not used. The age estimation indicates that the bark-peelings were performed from the mid 1600s until the early 1900s. Today the forest at both study areas is generally low in density and all-aged with very old individual trees. They consist of a mosaic of uneven-aged tree groups and individual trees of various ages. We conclude that the abundance and density of bark-peeled trees at the study areas exceed values reported in most other North American studies (formally protected forests included), that the two areas represent different harvest areas for ponderosa pine inner bark, and that CMTs need to be recognized both as ecologically and culturally valuable features of old ponderosa pine forests.

Index terms: bark-peeling, Culturally Modified Trees, forest history, native people, *Pinus ponderosa*

INTRODUCTION

The cultural history of forests and how people traditionally have interacted with forest ecosystems worldwide has been receiving increasing attention during recent decades (Agnoletti and Andersen 2000; Agnoletti 2006). An important advance in this field is the study of culturally modified trees (CMTs; i.e., trees with scars, marks, or carvings that reflect past human utilization of forested ecosystems) that are found in many old forests worldwide (Östlund et al. 2003; Turner et al. 2009). Since CMTs are old, living artifacts, they eventually die and disintegrate – lately at an accelerating rate. One specific type of CMT found in North America and northern Europe is bark-peeled trees. Just as the people encountered by the Lewis and Clark expedition in 1805 along the Lolo Trail in western Montana (Moulton et al. 1988), many native groups throughout the northern hemisphere have made use of the nutritious inner bark from coniferous trees up to the early 20th century (Krashennikov 1972; Swetnam 1984; Zackrisson et al. 2000; Prince 2001; Östlund et al. 2004; Mobley and Lewis 2009). The inner bark was collected in a manner non-lethal to the trees, but leaving a distinctive, permanent scar which can be dated using dendrochronological (tree ring) methods (Swetnam 1984; Zackrisson et al. 2000).

In North America, perhaps the most commonly used trees were ponderosa pine (*Pinus ponderosa* P. & C. Lawson), found in relatively dry forest habitats throughout much of the western United States (Oliver and Ryker 1990). Several studies have been carried out on bark-peeled ponderosa pines, most of them emphasizing their importance as a food source (see Martorano 1981; Swetnam 1984; Merrell 1988; Reddy 1993; Kaye and Swetnam 1999). Other studies underline their value as unique living artifacts, reminding us about related means of subsistence, such as the use of fire to clear away undergrowth around camping grounds and travel routes, and to attract game to certain areas – activities that may have had a substantial impact on the forest ecosystem (Östlund et al. 2005; Arno et al. 2008). At present, the survival of ponderosa pines with bark-peeling scars as well as other CMTs is threatened by declining tree vigor related to competition from ingrowth of younger trees, bark beetle outbreaks, wildfires, decay, and timber and firewood harvesting (Arno et al. 2008). This is unfortunate, if not tragic, because study of CMTs in situ reveals unique knowledge of native cultures and insight to people's subsistence and land-use activities in the past. It might also be viewed as neglect or abandonment of readily recognizable artifacts of native cultures.

CMTs in the United States are protected by law and regulation, and research performed on them must conform to those laws and regulations. CMTs are protected by the National Historic Preservation Act, and must be treated as if they were on the National Registry of Historic Places. In land management planning, under the National Environmental Policy Act, the protection of CMTs is defined under the Archeological Resource Protection Act. Additionally, the American Indian Religious Freedom Act, Protection and Enhancement of Cultural Environment (EO 11593), Indian Sacred Sites (EO 130007), and other regulations all direct federal agencies to preserve and protect traditional properties such as bark-peeled trees. However, not all personnel involved in land management activities are aware of CMTs; so, for example, in wildfire suppression CMTs may be damaged. Many federal lands are part of many Tribes' traditional use areas, and before any research can be undertaken, the proposal is frequently reviewed by a Tribal council to consider the acceptability and value of the proposed research to the Tribe.

A typical method to determine the bark-peeling dates is by using an increment borer to extract a series of pencil-size cores of the growth-ring sequence at the edge of the original scar. The cores are then examined to find the position of the bark-peeling scar in the annual rings. This allows accurate dating of bark-peelings (Swetnam 1984). Even though increment coring of coniferous trees, such as ponderosa pines, is not dangerous to the trees (the small holes rapidly fill with pitch), coring is unquestionably a physical invasion of the tree. Some Native peoples find the research activities acceptable, and the resulting detailed historical information about their ancestors valuable, and some do not. Descendents of native people are increasingly aware of the relationship between CMTs and use of them by their ancestors. Thus, some may object to any invasive sampling, such as increment boring. Accordingly, an alternative means of dating the CMTs must be developed.

In this paper, we examine the occurrence of bark-peeled trees in two remnant ponderosa pine forests in western Montana. The aims of the study were to: (1) identify and describe attributes and the spatial and temporal distribution of bark-peelings; (2) analyze the present forest structure; (3) attempt an alternative method of dating CMTs by measuring injury depth; and (4) to initiate a broader discussion of threats to CMTs and needs for sustaining and protecting them.

METHODS AND MATERIAL

Location of study areas

The study was carried out in two areas situated along two tributaries of the West Fork of the Bitterroot River in southwestern Ravalli County, Montana (Figure 1). The study areas are located on the West Fork Ranger District of the Bitterroot National Forest. They are subject to an "inland Pacific-influenced climate" with mean annual precipitation of about 550 to 600 mm and mean January and July temperatures of about -4 ˚C and 18 ˚C (Arno 1979). Summers are typically dry with low relative humidity. The terrain is heavily forested and consists of highly dissected steep mountain slopes and narrow canyons and valleys. Soils are coarse, rocky, and shallow, and are derived from granite and a mixture of volcanic strata (Alt and Hyndman 1986). The composition and structure of the conifer-dominated forest was historically shaped by wildfires of variable frequency and severity. Since the early 20th century, fire suppression has altered historic fire patterns (Arno et al. 1995). The two sites were chosen because they are known to contain large concentrations of bark-peeled trees and, judging from the scarcity of old stumps, the forest has been subjected to only a minor amount of tree cutting.

The first study area is located on the steep slopes above Fales Flat, a native camping area along the Nez Perce Fork of the West Fork Bitterroot River. Large, old ponderosa pine trees border a stream-side meadow (Fales Flat) and extend up the south- and west-facing mountain slopes that rise above (Figure 2a). Up to the mid 19th century, Fales Flat was used as a camp site by Nez Perce people travelling eastward across the vast expanse of rugged ridges and canyons on their way to the buffalo (*Bison bison* L.) hunting grounds on the high plains east of the Continental Divide (Koeppen 1996). The actual study area encompasses approximately 85 ha of steep slopes rising from 1550 m at the campsite to about 1780 m in elevation. The second study area is situated in the flat bottom of a narrow valley at Hughes Creek, about 20 km southeast of Fales Flat (Figure 2b). It consists of about 90 ha of semi-open forest at an elevation of about 1550 m. This vicinity was historically utilized by native peoples, probably for subsistence and as part of the travel route up the West Fork valley to mountain passes providing access to the Salmon River canyon to the south. The area was subjected to considerable prospecting and

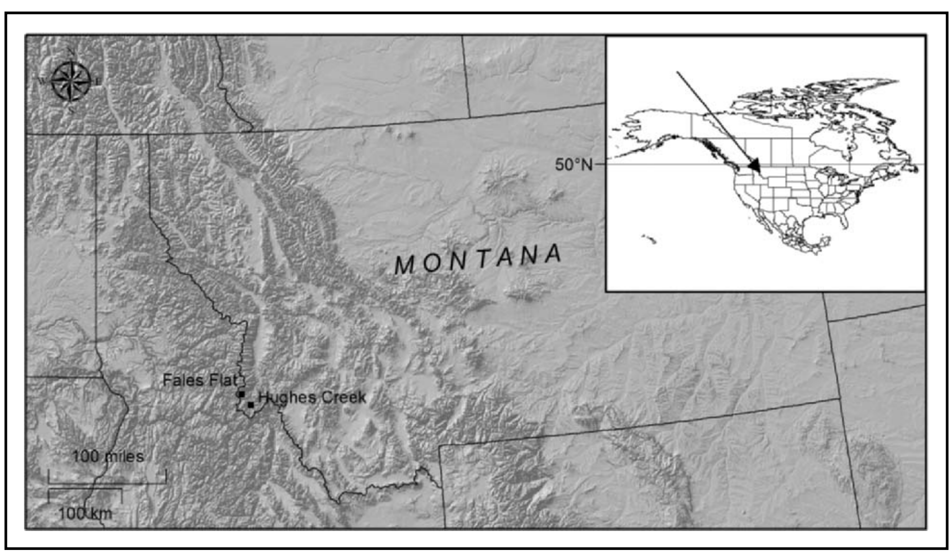

Figure 1 Location and topographic map of the West Fork Ranger District, southwest Montana showing the positions of the study areas Fales Flat and Hughes Creek.

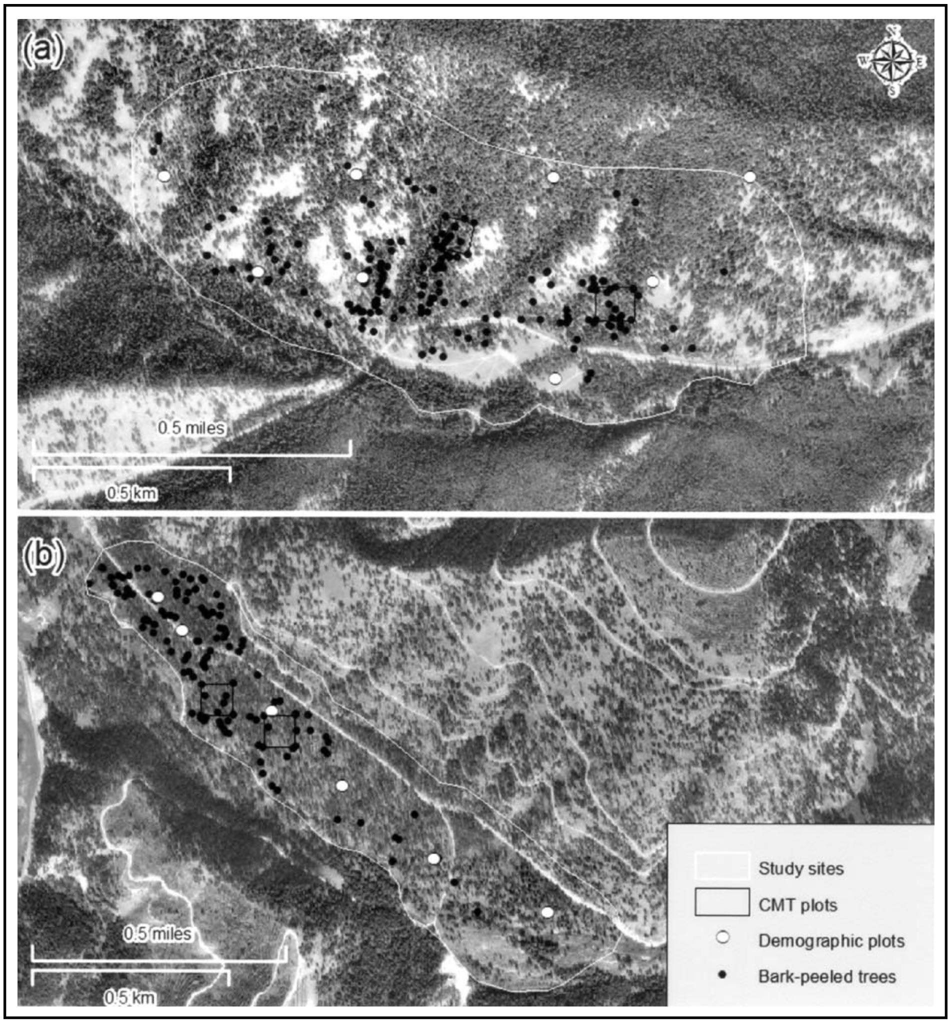

Figure 2. Spatial distributions of bark-peeled trees in (a) Fales Flat and (b) Hughes Creek. Each circle represents one bark-peeled tree. Location and boundaries of study areas, demographic plots and CMT plots. Source of aerial photography: U.S. Geological Survey.

mining activity in the late 1800s.

Field sampling and measurements

In each study area, the occurrence of bark-peeled trees was examined using the approach of Anderson et al. (2008) based on strip-surveying. A transect running in a north-south direction was established at the center of each area. Parallel transects were then laid out eastwards and westwards (mean distance between transects was approximately 30 m) enabling a complete survey of the area containing bark-peeled trees and ending where these trees ceased to occur. Along each transect, all trees with bark-peelings were geo-positioned with a GPS receiver. Each of these trees was recorded as to species, diameter at breast height (dbh), and status (living, standing dead, and fallen dead). The size (height and width), shape, and compass orientation of the scar were measured and any tool marks were noted. The curvature of the scarred surface was measured using a profile gauge. For bark-peeled trees found on slopes, the position of the scar (upper or lower side, or perpendicular to the slope) was recorded.

To characterize the present forest structure, we used an *n*-tree density-adapted sampling method (see Jonsson et al. 1992; Lessard et al. 2002). Demography plots were arranged on a grid to systematically sample forest structure in areas containing bark-peeled trees. In total, eight demography plots were laid out on the slopes above Fales Flat and six at Hughes Creek. By using a GPS to find the pre-determined gridpoint coordinates as the plot center, and correcting for slope, we sampled up to 30 trees (≥ 10 cm dbh) within a maximum radius of 30 m. Thus, the demography plots varied in area with tree density (depending on the number of trees within a circular plot of variable radius), but could never exceed 0.3 ha. For each tree, we recorded the species, status (alive or standing dead), dbh, and diameter at sampling height (dsh). Increment cores were taken approximately 10 cm above the ground using a bit powered from a chain saw, when possible, and with manual increment borers when not possible. We cored 201 living and dead trees at Fales Flat study area and 170 from Hughes Creek, for a total of 371. To estimate the maximum tree age, we also cored approximately 20 trees with an old appearance in each study area (Stokes and Smiley 1968; Fritts 1976).

For later determination of the approximate period when the bark peeling was done (i.e., by measuring the depth of a bark-peeling in relation to present tree diameter), we also collected increment cores from trees of comparable size (> 40 cm dbh) without visible bark-peelings. These samples were collected at Hughes Creek in two randomly placed 1 hectare square plots (hereafter referred to as CMT plots) containing both trees with and without bark-peelings. Rarely the pith is in the centre of the stem (Bakker 2005). Therefore, each tree was cored twice from opposite sites using a manual increment corer (diameter 10 mm). All samples were taken at breast height to avoid rot and irregularities in ring sequences that may be present in the earliest years of a tree's development (cf., Josefsson et al. 2010). A total of 80 cores were collected from 40 trees. GPS-position, bark thickness, and dbh for all the cored trees were recorded. In addition, the occurrence of cut stumps was recorded inside the CMT plots.

Laboratory procedures

To determine tree basal area within demography plots, we converted dsh measurements on remnant trees to dbh using regression equations by species, derived from dbh/dsh measurements on living trees across the study area. We determined tree ages of 114 ponderosa pines (36 trees from the Fales Flat area and 78 trees from

Hughes Creek). Cores from trees with rot were discarded. Cores were mounted and surfaced using increasingly fine grades of sandpaper (100 – 400 grit). Ring widths of the ponderosa pine cores were visually cross-dated using tree-ring chronologies for the southern part of the Bitterroot Mountains, established by Sutherland et al. (unpubl. data), and measured using a tree-ring measuring station with a resolution of 1/1000 mm (VELMEX sliding stage micrometer) with the J2X software (Version 4.2 – VoorTech Consulting, accessed 2009). The numbers of rings in cores of other tree species were counted under the microscope. When increment cores failed to intersect the pith, we estimated the number of missing annual rings to the pith by matching the curvature of the innermost rings on the core to concentric circles drawn on a transparent plastic sheet (see Applequist 1958; Barrett and Arno 1988). To determine the approximate year of tree establishment, we then added the number of rings offset from the pith. The pith date of each tree was interpreted as its establishment date. Tree age was not corrected for the number of years it took the tree to reach the height at which it was cored (approximately 10 cm above ground). All cross-dating was quality checked, both visually and using COFECHA software (Holmes 1983).

To estimate the approximate period of time when a bark-peeling was made, we measured and compared the injury depth on the bark-peeled tree with the radial increment of unscarred trees of similar size growing nearby. We assumed that, on average, trees of similar size growing on the same site to have similar radial increment pattern, especially since the forest structure was comparatively open in the original ponderosa pine forests of this area (Arno and Sneck 1977; Arno et al. 1995).

Injury depth was calculated by subtracting the radius of the tree inside the bark when the bark-peeling was produced (r) from the present radius of the tree inside the bark (R). Radius r was estimated from the curvature of the scarred surface (which was obtained in the field by using a profile gauge). Radius R was estimated by dividing the present dbh of the bark-peeled tree by two and subtracting a value for bark thickness (3.84 cm) – representing mean bark thickness of the 40 cored trees within the two CMT plots. Radial increment was estimated by establishing a model for age/stem radius relationship (taking into account that ring width typically decreases in a curvilinear relationship with tree age) of the overstory ponderosa pines. Out of the 40 cored trees inside the two CMT plots, 14 that had clear ring sequences and intersected the pith were used to establish the model. First, mean number of years for each cm ($\bar{Y}_i$) from the outermost tree ring to the pith, based on data from a number of trees (n – here 14) and calculated from the mean value of two cores ($\bar{y}_i$) from each tree, was estimated according to the following formula:

[1] $$\bar{Y}_i = \frac{\sum_{i=1}^{n} y_i}{n}$$

Secondly, an age/stem radius relationship (the cumulative number of years per cm) was established by fitting a quadratic polynomial to the mean number of years for each cm derived from all 14 trees using PASW statistics 18 for Windows:

[2] $Age = 3.765 + 12.452\ Injury\ depth + 0.080\ Injury\ depth^2$

We used root mean square error of prediction (RMSEP) for judging the performance of our model.

An approximate point in time when a tree was scarred (i.e., when a bark-peeling was made) was then estimated by comparing the injury depth of such scars with our estimated age/stem radius model. To provide an indication of the degree of dispersion around each dating, we calculated the confidence interval (CI) of the mean increment of the 14 trees that were used to produce the model. Radial increment of the 40 trees cored in the CMT plots were measured using a tree-ring measuring station with a resolution of 1/100 mm (LINTAB 5, RINNTECH Technologies) and the TSAPWin software and statistics (Version 0.59).

RESULTS

Occurrence and attributes of bark-peeled trees

In total, 343 bark-peelings were recorded on 274 living and dead trees at the two study areas (Table 1). Three different sizes-classes of bark-peelings could be discerned: (1) small scars 15 – 25 cm in height (vertical dimension of the scar itself); (2) medium sized scars 26 – 70 cm; and (3) large scars >70 cm (Figure 3). Large bark-peelings are most abundant and small ones least common (Table 1). The Fales Flat area, which has been least affected by tree cutting (a few cut stumps occur along the road to the camping ground), contains 158 trees (1.9 per ha) with bark-peelings. The bark-peeled trees are somewhat aggregated and all but eight trees were found below 1700 m in elevation (Figure 2a). Most bark-peelings (43%) were recorded on the side of a tree perpendicular to the slope, and 31% were situated on the upper side of the tree, while 26% were on the lower side. Approximately one-fourth of the trees that contain bark-peelings were dead. The Hughes Creek site has 116 trees (1.3 per ha) with bark-peelings (Table 1), although selective logging in the past has removed a number of large trees. Cut stumps are most common in the central portion of the study area, at about 14 per ha. The bark-peeled trees occur scattered throughout the study area but concentrated in the western part (Figure 2b). At Hughes Creek about 95% of the bark-peeled trees are alive.

Age estimation of bark peelings

Fourteen bark-peeled trees were selected for estimation of the period when bark-peelings were made. These trees are situated in or adjacent to the CMT plots used for producing our age/stem radius model. The overall difference between the values predicted by our age/stem radius model (RMSEP) was ca. 57 years (Figure 4).Two of the bark-peelings were 6 – 7 cm inside the level of the surrounding unscarred stem wood. Based on the model, these scars were estimated to have been made 76 and 88 years earlier; (outermost tree ring) minus 76 – 88 equals an estimated period of 1919 to 1931 (Figure 4). One bark-peeling had an injury depth of 36 cm and was estimated to have occurred about 350 years earlier (~1650s) based on the model (Figure 4). The remaining 11 bark-peelings had injury depths between 10 and 21 cm, corresponding to model dates of about 120 to 235 years earlier (~1770s to 1880s) (Figure 4).

Present forest characteristics

On the steep slopes of the Fales Flat study area, the forest structure is patchy with inland Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) A.E. Murray making up 62% of stems), and ponderosa pine 23%, and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) 12%. Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), whitebark pine (*Pinus albicaulis* Engelm.), and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) also occur rarely. About 8% of the standing stems are dead trees, and the majority of these are large and old ponderosa pines. The forest at Hughes Creek is largely ponderosa pine (54% of stems) along with Douglas-fir (30%) and lodgepole pine (16%). Standing dead trees, mostly lodgepole pines, account for about 5% of the standing stems.

At the Fales Flat area, number of trees is right-skewed towards younger dbh classes with most trees in the 10 to 40 cm dbh classes and few trees in diameter classes over 60 cm (Figure 5a). While lodgepole pine occurs sparsely in dbh classes 10 to 50 cm, Douglas-fir appears abundantly in all dbh classes up to 90 cm (Figure 5a). Ponderosa pine occurs in dbh classes up to 60 cm and very sparsely in the highest dbh class (101-110 cm) (Figure 5a). A similar diameter distribution was recorded at Hughes Creek, but with fewer trees in the 30 to 50 cm dbh classes (Figure 5b). Here lodgepole pine is more abundant and occurs in dbh classes up to 40 cm, while Douglas-fir is less common and appears in dbh classes up to 50 cm (Figure 5b). Ponderosa pine is by far most abundant and appears in most dbh classes up to 110 cm (Figure 5b). Mean dbh is slightly higher at the Fales Flat area (28.9 cm) than at Hughes Creek (26.1 cm) (Table 2), and the overall mean is 27.6 cm.

Average basal area is similar at the Fales Flat area (16.5 m^2 ha^{-1}) and at Hughes Creek (14.2 m^2 ha^{-1}), and tree density (number of stems $\geq$ 10 cm dbh) ranges from 25 to 730 per ha at the Fales Flat area (mean = 328 per ha) and from 92 to 549 per ha at Hughes Creek (mean = 311 per ha) (Table 2). Ponderosa pine and Douglas-fir occur throughout the Fales Flat area, while lodgepole pine has an uneven distribution and was recorded in only two of the eight demography plots (Table 2). At Hughes Creek, ponderosa pine and lodgepole pine were recorded in all six demography plots, while Douglas-fir is less evenly distributed (Table 2). At Fales Flat, the majority of the cored ponderosa pine trees are 50 to 100 years old (mean = 83 years); thus a minority of ponderosa pines are old enough to have bark peelings (Table 2, Figure 6), but the oldest cored trees are over 300 years old. The ponderosa pine trees at Hughes Creek are considerably older (mean = 157 years) and most are between 125 and 175 years old (Table 2, Figure 6). The oldest cored tree germinated in the mid 15th century.

Table 1. Number and type of bark-peelings recorded at each study site and in total.

	Fales Flat	Hughes Creek	Total
Number of bark-peeled trees	158	116	274
living trees	120	110	230
dead standing trees	18	2	20
lying dead trees	20	4	24
Number of bark-peelings	206	137	343
small scars [a]	17	16	33
middle sized scars [b]	67	60	127
large scars [c]	122	61	183

[a] 15 – 25 cm in height
[b] 26 – 70 cm in height
[c] > 70 cm in height

DISCUSSION AND CONCLUSIONS

Bark-peeling characteristics and spatial patterns

The abundance and density (stems per ha) of bark-peeled trees at the Fales Flat and Hughes Creek areas (Table 1) exceed values reported in most other North American studies. On the Nechako Plateau in British Columbia, Prince (2001) and Marshall (2002) also found several hundreds of bark-peelings on lodgepole pine, but more often lower numbers have been recorded of ponderosa pines; for example Alldredge (1995) 45 trees and, Östlund et al. (2005) 138 trees in Montana, Swetnam (1984) 20 trees in New Mexico, and Kaye and Swetnam (1999) 45 trees also in New Mexico. The numbers of bark-peelings documented at Fales Flat and Hughes Creek, and in contrast to many other areas, indicates intensive native land use in the past. Still, we suspect that the study areas at Fales Flat and Hughes Creek previously contained even higher quantities of bark-peeled trees since some live trees were selectively logged, other bark-peeled trees probably died and crumbled in decay, and scarred standing dead trees may have been removed for firewood. Still others may contain bark-peelings that have completely closed over and are no longer visible.

The observed spatial pattern at the Fales Flats area (Figure 2a) indicates a typical harvest area (see Prince 2001) around a major transitory campground on a small

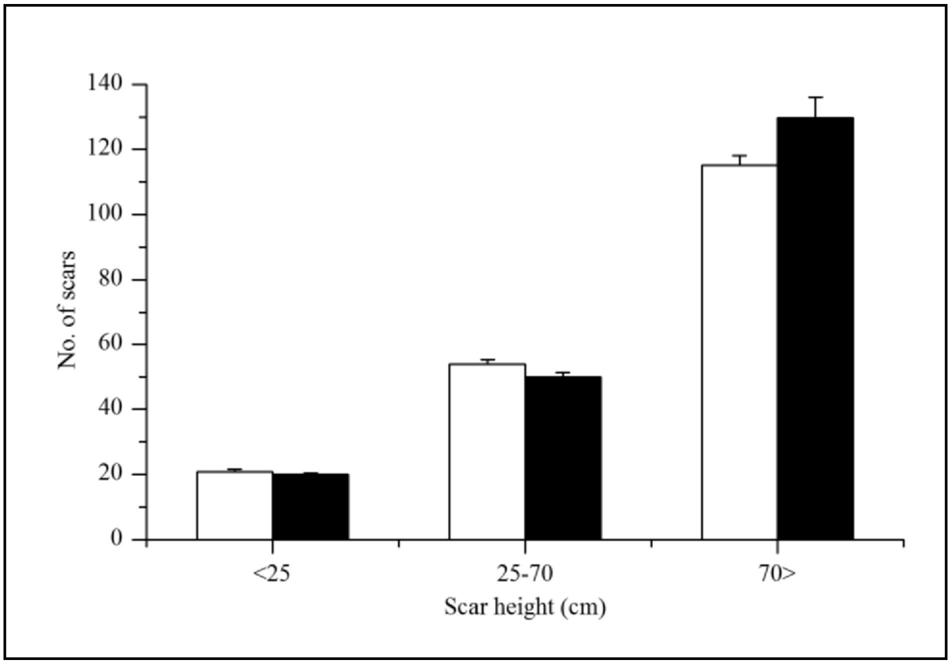

Figure 3. Differences in height (vertical dimension) of bark-peeling scars between three size-classes. Data are means and standard error.

meadow along the Nez Perce Fork. Native peoples camped in the valley bottom and collected inner bark from ponderosa pines on the south- and west-facing slopes above. This spatial pattern suggests concentrations in two subareas, which most likely correspond to an eastern and a western camp-site complex. Trees with scars thin out above around 1700 m in elevation, which we interpret as a result of increasingly difficult access up the steep slopes, since the collected inner bark was heavy to carry (cf., Östlund et al. 2009). The Fales Flat area was an important travel corridor for several native groups, including the Nez Perce and Salish. When the ponderosa pine inner bark could be collected in late spring, different groups were visiting or passing through this area. Possibly the harvest of inner bark was also connected to the important harvest of the Bitterroot plant (*Lewisia rediviva* Pursh) also conducted in late spring (cf., Hitchcock and Cronquist 1964; Kuhnlein and Turner 1991; Moerman 1998).

The spatial pattern of bark-peeled trees at Hughes Creek (Figure 2b) is more difficult to interpret. No particular areas have been identified as native campsites. However,

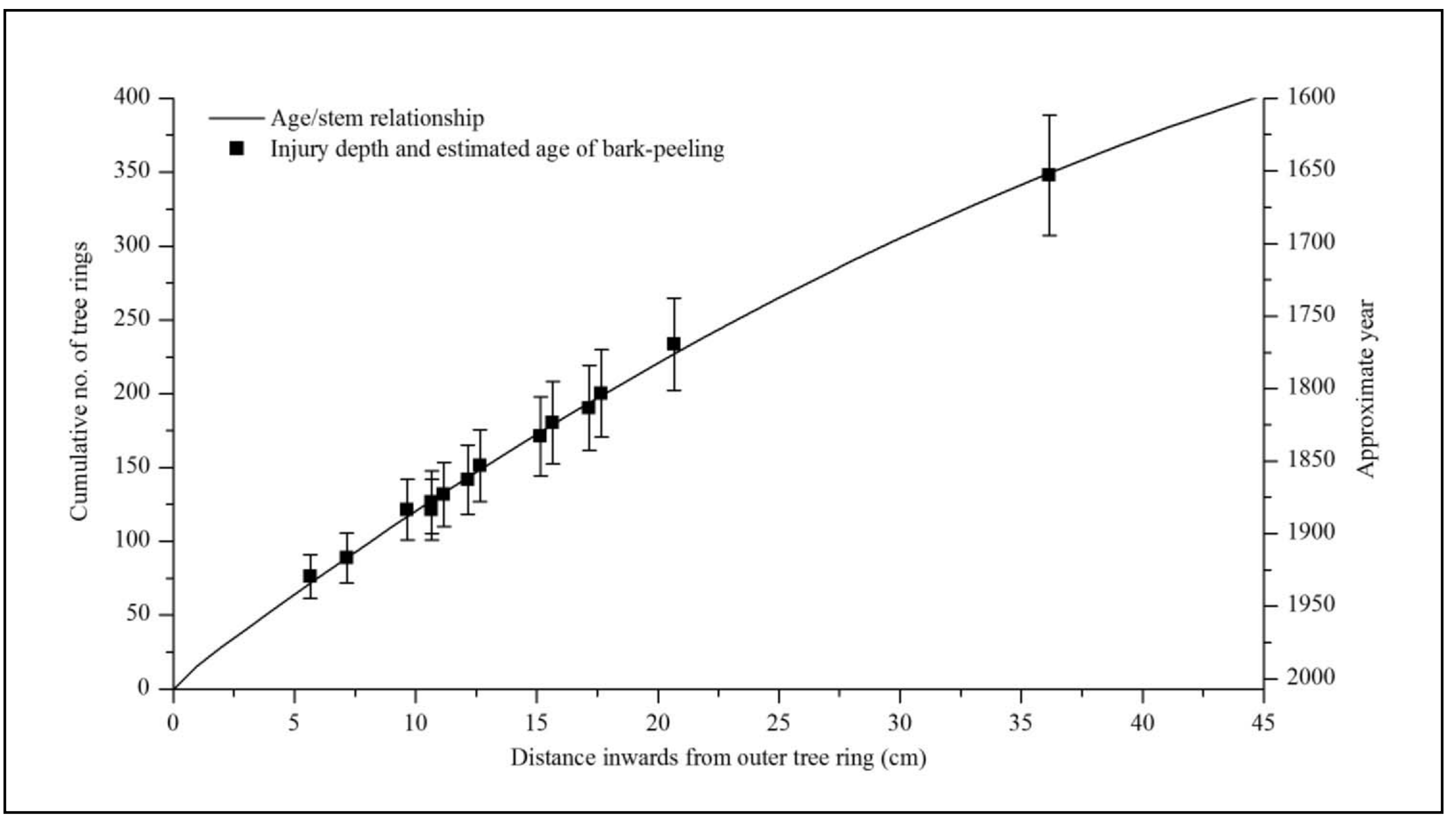

Figure 4. Number of tree rings (left y-axis) and age estimation (right y-axis) of bark-peeling scars (■), based on injury depth related to the age/stem radius model for sampled trees without bark-peelings (–). The degree of dispersion around each point in time when a bark-peeling was made was derived from the CI (95%) of the mean increment of the 14 trees used to produce the model. RMSEP of the age/stem radius model was 57.14.

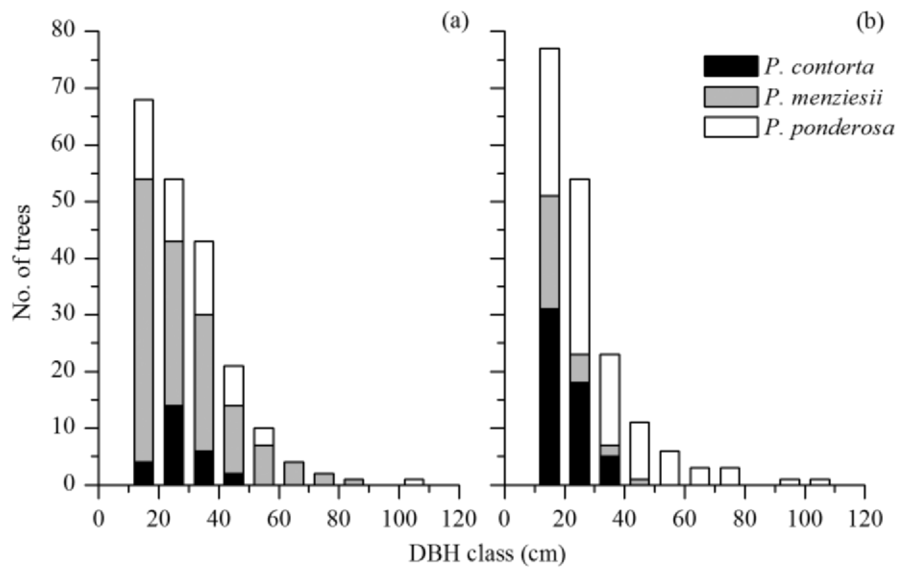

Figure 5. Diameter distributions for trees (the three major tree species) at (a) Fales Flat and (b) Hughes Creek.

this area is situated along a travel corridor providing access to the Salmon River canyons (to the south) – well-known for major runs of anadromous fish and resident native cultures. The higher concentration of trees in the northwestern part of the study site may suggest that people had campsites here, but past mining and logging on these privately-owned properties make it impossible to reconstruct the historic pattern of bark-peeled trees in the Hughes Creek and adjacent West Fork valleys.

In both study areas, there is an intriguing pattern of harvest of inner bark within the forest. Only certain trees were used for harvest. Nearby trees of similar size and age were not used. This efficient pattern of resource use has been documented in many previous studies in north America (Swetnam 1984; Kaye and Swetnam 1999; Östlund et al. 2005) and in Europe (Bergman et al. 2004; Josefsson et al. 2010). A possible explanation relates to differences in taste or other qualities of the inner bark among different trees (Östlund et al. 2009). The very small scars on some trees that we

Table 2. Forest characteristics of the two study areas – segregated on the three major species and for all measured trees.

	Douglas-fir Mean ± SE	Lodgepole pine Mean ± SE	Ponderosa pine Mean ± SE	All trees Mean ± SE	Range
Fales Flat					
Diameter [b]	28.6 ± 1.42	27.7 ± 1.63	30.6 ± 2.35	28.8 ± 1.05	10.0 – 105.4
Basal area [c]	10.2 ± 2.67	1.8 ± 1.71	4.2 ± 1.57	16.5 ± 2.41	2.9 – 24.1
Stem density [d]	202.6 ± 63.63	40.4 ± 38.62	75.9 ± 32.62	327.5 ± 73.41	24.9 – 729.7
Tree age [e]	–	–	82.7 ± 2.47	–	34 – 106
Hughes Creek					
Diameter [b]	19.5 ± 1.65	19.4 ± 0.99	31.7 ± 1.94	26.1 ± 1.21	10.0 – 107.4
Basal area [c]	0.8 ± 0.46	2.7 ± 1.12	10.7 ± 2.03	14.2 ± 2.79	4.2 – 22.2
Stem density [d]	40.2 ± 26.35	127.0 ± 62.26	143.6 ± 28.28	310.8 ± 67.93	91.5 – 549.0
Tree age [e]	–	–	157.3 ± 10.36	–	35 – 543

[a] Range is the variation within all sample plots
[b] Diameter at breast height in cm
[c] Basal area in $m^2\ ha^{-1}$
[d] Stem density in number of stems per ha
[e] Mean tree age of all cored trees within demography plots

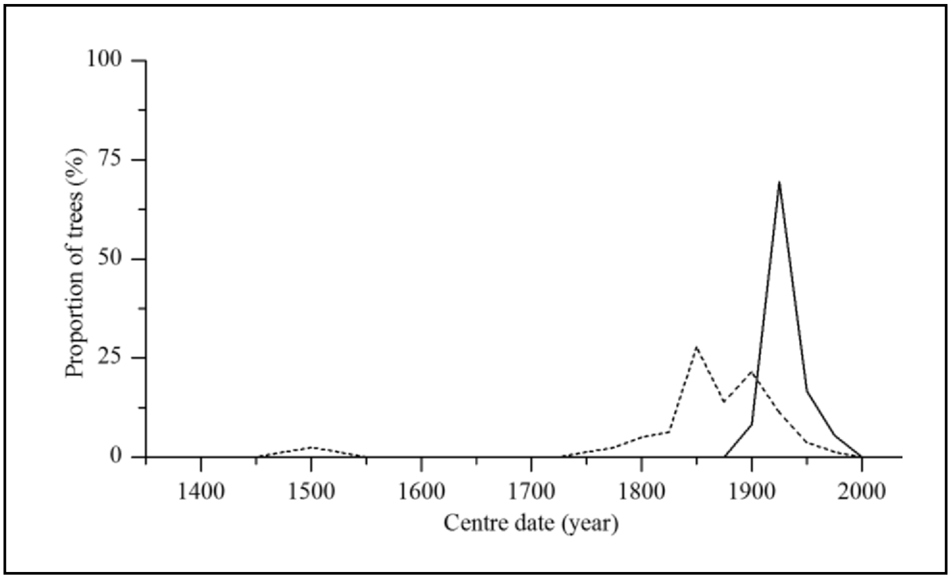

Figure 6. Age distribution for trees (ponderosa pine) at Fales Flat (–) and Hughes Creek (---).

found at both sites might be "tasting-scars" to test the suitability of a tree's inner bark before harvesting (Figures 3 and 7a-c).

Alternative method of dating bark-peelings

There are conflicting views on how to treat CMTs, which causes a dilemma for researchers who would like to determine the precise date (year) of each scar in order to interpret temporal patterns in land use. This can be done with minimal damage to trees by using increment corers (see Swetnam 1984; Barrett and Arno 1988). However, some native peoples consider CMTs sacred and important to their cultural heritage; and some may oppose or prohibit sampling of such trees, although others favor careful sampling that provides further information about their ancestors' traditions (cf., Bergman et al. 2004; Lewis and Sheppard 2005). Since CMTs die and decay over time, there is an urgent need to develop alternative methods for gleaning information from them without the use of increment boring. The relatively simple method applied in this study provides one example.

Our results indicate that bark was harvested at Hughes Creek from the mid 17th century to the early 20th century, and more intensively between the late 18th and late 19th century (Figure 4). This temporal pattern in harvesting of inner bark corresponds well with other studies on utilization of inner bark from ponderosa pine in this region by Alldredge (1995) and by Östlund et al. (2005). Beginning with the Lewis and Clark Expedition through this area in 1805 and 1806, a rich assortment of historical accounts describes the extensive seasonal land use, travels, and migrations of Nez Perce, Salish, and other native peoples in these mountains; these activities were disrupted and virtually eliminated with the slaughter of bison herds and displacement of natives to reservations in the 1870s and soon thereafter (Moulton et al. 1988, 1993; Moore 1996; Farr 2003).

Our estimated degree of uncertainty around each dating is about ±25 years for the youngest bark-peelings (76 and 88 years old, approximately 1930) and ±40 years for the oldest (~350 years old, approximately 1660). This lack of precision is, however, of lesser concern if the goal is to provide a general estimate of temporal patterns of CMTs. The dating technique presented and evaluated here relies on a robust age/stem radius relationship. Allometric relationships are complex and have only been methodically analyzed for a few tree species (e.g., some pine species) (Climent et al. 2002; Landis and Bailey 2006) and some neotropical tree species (O'Brien et al. 1995). For ponderosa pine, several previous studies indicate a moderate to strong age/stem radius relationship of ponderosa pine (cf. Morgan et al. 2002; Youngblood et al. 2004; Taylor 2010). We suggest that building a model of age/stem radius relationship must take the following aspects into account: (1) a large number of trees need to be sampled since many cores will need to be discarded because of tree ring irregularities (see Schweingruber 1988); (2) cores might not reach the pith; and (3) it is crucial that cores are sampled right-angled (90°) to the stem.

Resemblance to other old ponderosa pine forests

In both study areas, the forest is a mosaic of uneven-aged tree groups and individual trees of various ages (Figure 2a,b), which is typical of many old ponderosa forests (cf., White 1985; Covington and Moore 1994; Arno et al. 1995; Arno et al. 1997; Youngblood et al. 2004; Abella 2008; Taylor 2010). The forests are generally low in density and all-aged with very old individual trees – two additional features of what is commonly referred to as old growth or pre-settlement forests (Covington and Moore 1994; Fule et al. 1997; Kaufmann et al. 2000). Although the majority of trees at Fales Flat now post-date the last severe fire in 1889, trees which germinated in the 15th and 16th centuries also exist here (Arno et al. 1995; Sutherland, unpubl. data). Most certainly, this forest was much more open historically. Prior to 1900, fires occurred at average intervals of about 50 years (Arno et al. 1995) – an unusually long interval for ponderosa pine forests apparently related to the dry conditions and sparse undergrowth on these slopes but often enough to kill many of the small trees.

Present threats to CMTs

CMTs such as the bark-peeled trees of the upper Bitterroot drainage constitute important links to the culture and natural resource uses of native people. The trees are valued by the descendants of the people that made these distinctive, living artifacts and by those who study anthropology, archeology, and forest ecology. Even under ideal

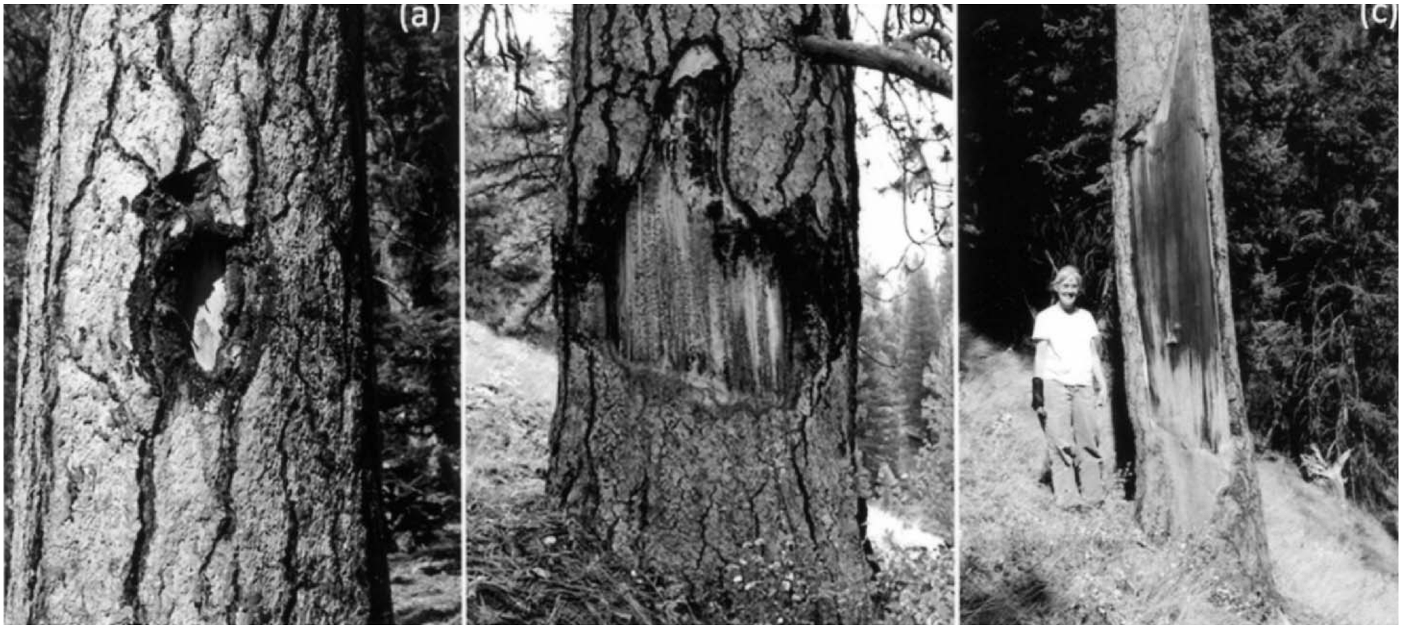

Figure 7. Three types of bark-peelings scars recorded at both study sites; (a) small scar, (b) medium sized scar, and (c) large scar. Photos by Lars Östlund.

circumstances, the bark-peeled ponderosa pines would die, decay, and disappear over the next few centuries. However the rate of attrition is hastened by several factors that to some extent could be mitigated. Critical threats to the existence to CMTs in the western United States are insect and disease outbreaks, modern wildfires that are more destructive than historic fires, and loss of vigor due to competition from ingrowth of younger trees as a result of disrupting historic low-intensity fires (Keane et al. 2006). Bark-beetle infestations are particularly hazardous to ponderosa pine stands with low vitality (Six and Skov 2009). Trees with bark-peeled trees are also in danger because the exposed dry wood on the scarred surface makes them more susceptible to injury from fire, resulting in high mortality of old trees (Keane et al. 2006). Because of long-term absence of forest fire, drier forests types, such as ponderosa pine, often have accumulated fuel loads and are susceptible to more intensive fire once they happen (Arno and Petersen 1983). Consequently, when trying to restore old-growth ponderosa pine forests, not only the ecological aspects of the forest must be taken into account (Wagner et al. 2000; Allen et al. 2002) but also cultural resources. CMTs must be identified and safeguarded, for example, when prescribed burning is performed. Managing fire intensity and removing litter and ladder fuel around CMTs increases chances that such trees will survive and benefit from fuel reduction and ecological restoration treatments.

Another major threat to ancient bark-peeled trees in western North America is lack of knowledge and recognition of them often contributing to inadequate protection from human impacts (land exploitation, construction of roads and houses, but also logging and firewood harvest). As shown in this study, many CMTs occur near roads, in camping areas, etc. In fact, similar bark-peeled trees are found in varying numbers in several other parts of the Bitterroot National Forest and elsewhere along the Rocky Mountains (White 1954; Munger 1993; Reddy 1993; Alldredge 1995; Koeppen 1996; Östlund et al. 2005). We suggest that, in principal, all CMTs on public lands should be registered and data on concentrations of such trees be included in management plans. This is a first step towards an overall protection of CMTs and strongly increases the awareness among forest managers of their value.

In conclusion, CMTs need to be recognized both as ecologically and culturally valuable features of old ponderosa pine forests. Attention needs to be drawn to the unique educational value of ancient CMTs, since they greatly contribute to the scientific knowledge about past utilization of natural resources and native peoples' affiliation to land (Östlund et al. 2002; Andersson 2005; Turner et al. 2009). We also need improved tools to help protect them from logging on privately-owned land, but perhaps the most important factor is still to increase the general awareness and knowledge of these trees and their values.

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