Lichenometric Dating of Historic Inscriptions on a Rock Outcrop in Coastal Oregon

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Abstract

We estimated the age of inscriptions on a rock outcrop by estimating the ages of lichens that had overgrown the inscriptions. The inscriptions are considered to be historically important, potentially representing some of the earliest European exploration of Neahkahnie Mountain, the highest point along the Pacific coast from Baja California to Strait of Juan de Fuca, Washington. The rock bearing the inscriptions was destroyed by road construction activities in about 1970–1980, but the inscriptions had been photographed with sufficient detail to allow diameter estimates for the lichens on the rock, affording an opportunity for dating based on lichen sizes. *Aspicilia* and *Placopsis* are currently the only lichen genera that are common on similar outcrops in the area and form large light-colored discrete individuals with a radial form. We therefore derived a calibration curve for lichen size in relation to age based on *Aspicilia* and *Placopsis* sizes on nearby surfaces of known age (road cuts and stone walls), then applied that curve to the diameters of lichens in the photo. Based on the sizes of the lichens on the rock outcrop with inscriptions, the rock face had been available for lichen colonization and growth for > 100 yrs and perhaps shows a pulse of recruitment following extensive wildfires on the immediate coast in the 1840s. Calculated lichen ages are within 25 years of the expected time of US Army exploration of Neahkahnie Mountain under Captain C. C. Augur in the mid-1800s.

Keywords: *Aspicilia*, historical exploration, lichens, Neahkahnie Mountain, Pacific Northwest

Introduction

One of the most topographically and historically important features of the Oregon coast is Neahkahnie Mountain. The tallest point along the coast from Baja California to Strait of Juan de Fuca, and forming a difficult barrier to travel along the coast, it holds a special place in oral histories and legends of both European settlers and Native Americans (Berry 1960, Nehalem Valley Historical Society 1991). Furthermore, the flanks of Neahkahnie Mountain are the source for a number of historical artifacts consisting of inscribed rocks (Haramundanis and Gaposchkin 2016).

Some people, including M. Wayne Jensen Jr., former Director of the Tillamook County Pioneer Museum, have hypothesized that some of the inscriptions date back to explorations by Sir Francis Drake in 1579 (Nehalem Valley Historical Society 1991). One set of inscribed rocks includes the word AUGUR, suggesting an origin with the explorations of Captain C. C. Augur with the US Army in the mid-1800s (Haramundanis and Gaposchkin 2016). An alternative interpretation is that this inscription may be a remnant of a survey by Sir Francis Drake in 1579, the word "AUGUR" referring to Latin for "predict", and inscribed at the western point of a surveyed triangle (Costaggini 1985, Bawlf 2003, Gitzen 2016). These inscribed rocks were apparently destroyed during reconstruction of parts of Highway 101.

A photo by Jensen of these rocks while they were intact clearly shows colonization by lichens. We were inspired to use the lichens in the photo to learn something about the historical context for the inscriptions, but we are aware of no previous

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studies of lichen growth rates in this biogeographic setting. Our purposes for the research described here were, therefore, two: first, to construct the first calibration curve for lichen growth on near-coastal rocks in Oregon and Washington, and second, to estimate the ages of the lichens in the photo to inform an estimate of the age of the inscriptions. The idea is that if an inscription has been overgrown by a radially growing lichen, then the age of the lichen provides an approximate minimum age for the inscription.

Estimating ages of rock surfaces by geologists, ecologists, and anthropologists has commonly been done by lichenometric dating—using size of radially growing crustose lichens as a proxy for age, and calibrating the size-age relationship by sampling the largest lichens on surfaces of known age. The basic premise is that the diameter of the largest, free-growing lichen colonizing a surface is proportional to the amount of time the surface has been exposed to its environment (Innes 1985, Naveau et al. 2007, Matthews and Trenbirth 2011). By measuring lichen diameters on surfaces of known age (i.e., buildings, bridges, gravestones, landslides), one can calibrate a dating curve for an area of interest (Loso and Doak 2006, Jomelli et al. 2007). The method assumes that colonization by lichens occurs soon after rock is exposed and that the lichens are free to grow radially.

Although lichenometry has been widely applied and is always presented with acknowledgment of its limitations (e.g., Porter 1981, Innes 1985, Bull 1996, Bull and Brandon 1998), some authors have been critical of its application in some cases (Scuderi and Fawcett 2013, Osborn et al. 2015). Even with limited precision and accuracy, however, the estimates may help to inform dating problems on rock, depending on the goals of the inquiry (McCune et al. 2017). In this case we wanted to know broadly what lichens could tell us about the timing of rock inscriptions, without expecting precise dates for the inscriptions. Furthermore, the extrapolation needed is small and the age is relatively young (not thousands of years as attempted by many geologists). Lichenometry, despite its limitations, is apparently the only means for addressing the current problem: dating an inscription from a photograph. Other methods, such as ^{10}Be, are often used to date rock exposures, but dating an inscription on an old rock exposure differs from dating a new rock exposure. Although one might expect lichens to have been used to date inscriptions, according to Bednarik (2002), lichens have been used to date rock art only once. He wrote, "the complete lack of interest rock art researchers have shown in lichenometry is astounding, bearing in mind its reliability, simplicity and obvious economy, together with its non-intrusive nature."

Methods

Study Area

We studied exposed bedrock along Highway 101 as it traverses the steep sides of Neahkahnie Mountain in Tillamook County, Oregon at about 150 m above sea level (Figures 1 and 2). The rocks are mafic ophiolites (mainly basalt) that are relatively resistant to weathering. Below the highway, cliffs plunge into the ocean. Above the highway, cliffs and steep slopes lead to the mountain ridgetop at about 500 m. The climate is temperate oceanic with mean annual precipitation of 186 cm (based on 1961–1990 means) in the nearby town of Seaside, most of this occurring in the winter. Winters are mild and summers cool, with average temperature of 6.3 °C in January and 15.4 °C in July, and mean annual temperature of 10.9 °C. The vegetation on the steep parts of Neahkahnie Mountain is rather sparse for this climate, because of the thin soil and extensive rock exposure. Pockets of soil on the cliffs and steep slopes are dominated by patches of trees and shrubs, with extensive areas of grass and herbaceous cover.

Species Selection

Our goals were first, to determine the species of lichens most likely present in the Jensen photograph of the Augur rock (Figure 3), and second, to estimate the age of those lichens by lichenometry: building an age/size relationship by measuring lichens on surfaces of known age and using that relationship to estimate the age of the lichens in the photograph.

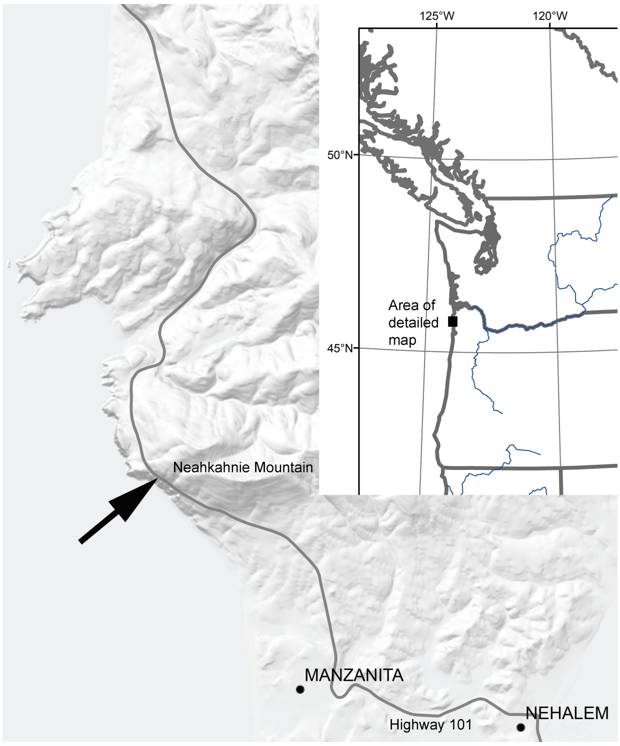

Figure 1. Location of study area along Highway 101 at Neahkahnie Mountain (arrow). Inset map shows general location.

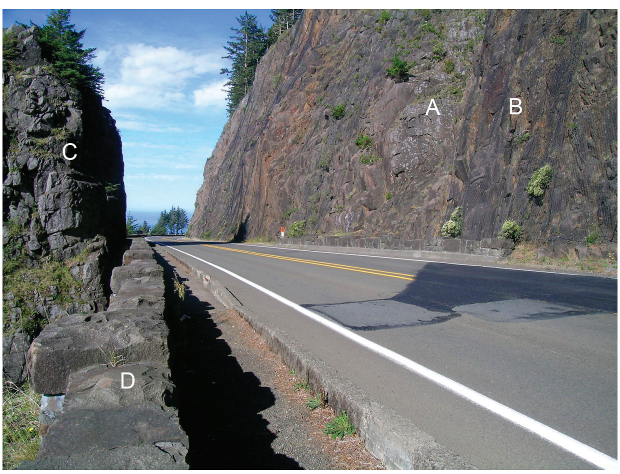

Figure 2. Highway 101 traversing cliffs at Neahkahnie Mountain, Tillamook County, Oregon, near the site of now-demolished historic inscriptions. A) Colonies of *Aspicilia* on a part of the cliff bearing lichen communities that established before the road was built. B) Recently exposed bedrock. Portions covered by a metal screen were not sampled. C) Rock spire known as "The Tooth" (not sampled). D) Part of the rock wall used as a calibration surface. Photo by Michael Goff, October 2010, with his permission.

Exploring the area on foot revealed only two lichen species in the current communities that formed large, pale individuals on old rock exposures: *Aspicilia* sp. (Figure 4) and *Placopsis lambii*, two crustose lichens. The latter was restricted to somewhat sheltered, moist sites, while *Aspicilia* was common on large exposed rock faces, similar to that pictured in the 1968 photo of the inscription. We therefore emphasized *Aspicilia* as a basis for dating, being the most likely species in the photo, although we also used *Placopsis* as a backup, because it was readily available. We cannot say with certainty which of the many species of *Aspicilia* was present, because our voucher specimens lacked mature spores and pycnidia, characters needed for identification to species (McCune 2017). The material falls in the difficult group of norstictic acid-deficient, rimose to areolate, pale gray species formerly lumped broadly under the name *A. caesiocinerea*. Henceforth we refer to the species just by its genus, *Aspicilia*. Nomenclature of lichens follows the North American checklist (Esslinger 2018).

Lichen Diameters in the 1968 Photo

A photo of the inscribed rock was taken by M. Wayne Jensen Jr. in 1968 (Figure 3), consisting of a man pointing out the inscriptions, with numerous roughly circular lichen thalli in the photo. An age estimate for the individuals overgrowing the inscription would provide an approximate minimum age for the inscription, assuming that the largest lichens had established around the time of the inscription or later. Small nearby individuals might have survived the process of inscription, thus the largest lichens could be somewhat older than the inscription. Estimating the size of the back of the hand touching the rock as 10.2 cm (4 inches) yielded a pixel size of 3 per cm, with an uncertainty of 5–10%. Applying this conversion factor to the largest lichen overgrowing and roughly

Figure 3. Inscriptions *in situ* at Neahkahnie Mountain in 1968 before they were destroyed by road work. The photo is of low resolution but was the best copy available to us. Lichen outlines have been superimposed on the photos and assigned letters. Lichens A and B have overgrown the word "AUGUR" (barely visible in the photo), presumably inscribed by C. C. Augur or his men during explorations by the US Army in mid-1800s. Sizes were estimated by calibrating a digital copy of the photo with the size of the man and the man's hand. Photo by Wayne Jensen Jr. from the Tillamook County Pioneer Museum.

centered on the inscription ("A" in Figure 3) yielded an estimated maximum diameter of 13.7 cm. A smaller lichen ("B" in Figure 3), about 8.4 cm in diameter, also overgrew and was roughly centered on the inscription.

Growth Curve Derivation

No lichenometric growth curves are available for coastal regions of Oregon, Washington, or northern California. We therefore derived our own relationship between lichen size and minimum age.

Calibrating a new lichen diameter-age relationship requires measuring lichen sizes on surfaces of known age. We found only two such groups of surfaces in the study area within 1 km of the original site: a rock wall along the highway (Figure 2D), and relatively fresh surfaces of bedrock exposed by highway improvement (Figure 2B).

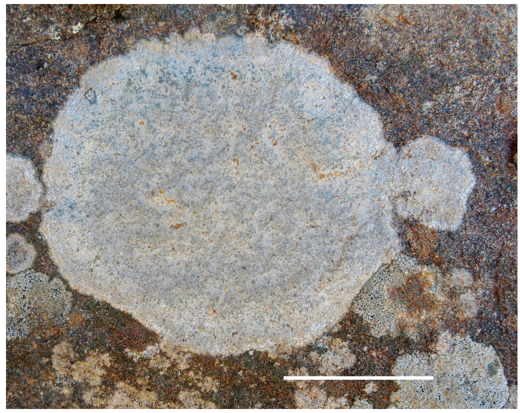

Figure 4. Example of *Aspicilia* on a cliff at Neahkahnie Mountain (scale bar 10 cm). The largest individual shown has a major diameter of 23.7 cm, with an estimated age of 225 yr, based on an extrapolation of our regression, and corresponding to a birth year of 1788. Smaller individuals to the right and left are also *Aspicilia*, although smaller individuals with black speckles (apothecia) in lower right and lower left are a *Rhizocarpon* species in the *R. cinereovirens* group. Also present in the photo but not forming conspicuous discrete individuals are *Pertusaria chiodectonoides* and *Acarospora fuscata*.

The rock wall along the highway (Figure 2D) we estimate to have been built in 1940, based on an informational sign at a pullout along Highway 101 and a photo of highway construction dated 1940. The rock wall appears to be basalt, similar to the rock outcrops along the road. The rock wall is partially heavily shaded and partially in full sun; we avoided the shaded areas because the 1968 Jensen photo is clearly of a large exposed outcrop. We measured major and minor axes of elliptical approximations of 10 and 7 individuals of *Aspicilia* and *Placopsis*, respectively, chosen as the largest discrete individuals on several segments of the rock wall. No individuals appeared to predate the wall, based on their small sizes.

The more recent rock removal on the rock cuts along the highway has a distinct stepped structure, with a grid of retaining rods and plates. This activity happened either post-1968 or post 1975, according to different sources, so we used dates of 1970 and 1980 in our regressions to determine the sensitivity of the results to that choice of date.

These rock faces were clearly more recent than much of the exposed rock along the highway, based on lichen sizes. We measured lichens on well-exposed faces away from the metal retaining rods, plates, or wire that might suppress lichen growth by metallic leachates. We again measured major and minor axes of elliptical approximations of 40 and 14 individuals of *Aspicilia* and *Placopsis*.

Lichenometry typically assumes that when rock is freshly exposed, no lichens exist on it, and thus the maximum lichen diameter would be zero for rocks of age zero. We presume, however, that even the largest lichens on a rock face would have had a variable, but unknown lag time between exposure of the rock and colonization. We therefore introduced 10 points into the age/diameter regression with ages 1 to 10 yr and size = 0, simulating a variable (but unknown) lag time to colonization. Ideally we would instead measure a set of small lichens on recently exposed rock surfaces of known age, but we saw no obvious dated surfaces like that. These zero-diameter points helped to control the slope of the line, given that we know that the line should cross both axes near zero.

Examining a scatterplot of diameter against age for the calibration data points revealed an approximately straight-line relationship. We therefore did not evaluate nonlinear curves, instead using simple least-squares regression with diameter as the dependent variable. Using just the major axis of the elliptical approximations yielded better fits (higher R^2) than either the minor axis alone or the average of the major and minor axes. Our final models thus used only the major axes.

Results and Discussion

Regression of diameters of *Aspicilia* and *Placopsis lambii* against age of rock surfaces were sufficiently strong to provide a basis for lichen dating with either species in the study area (Table 1; Figure 5). Growth rate estimates (0.11–0.12 cm yr^{-1}) were similar to those of crustose species in other studies. As in all lichenometry however, a number of assumptions limits the accuracy of the estimates. Our calibration curve extends to 73 years, so extrapolations beyond that have increasing error from unmeasured sources, such as climate change.

Estimates of the lichen ages overgrowing the word "AUGUR" were consistent with establishment of those lichens near the time of exploration of the Neahkahnie Mountain area by Captain C. C. Augur with the US Army in the mid-1800s. Our best estimate for the age of the largest lichen in the photo, lichen A, with diameter of 13.7 cm, coincides with establishment around 1835, based on applying the regression equation to the size estimate of the lichen (first row of Table 1). If we assume a date of 1980 rather than 1970 for the more recent road cut (second row of Table 1), then the approximate establishment year of the lichen is 1833. Unfortunately any estimate of error around those dates is incomplete, because the measured error around the regression line omits other sources of error, and we have no good way to estimate the true error associated with the method. We would not be surprised, however, if the true establishment date was more than ± 15 yr from our point estimate. This suggests that the lichen may have been very small or not present at the time that the rock was inscribed.

Lichen colonies on rock faces can be reset by disturbance. In this case, the most likely disturbance factors prior to European settlement would be exfoliation or mass wasting of the rock, clearing of a surface by human activity, or mortality of rock communities by fire.

Fire history could have resulted in a pulse of lichen recruitment in the mid-1800s in one of two ways. First, Native Americans frequently burned areas along the coast (Sauter and Johnson 1974), so it seems possible that reduction of burning coincident with European settlement would have resulted in a pulse of lichen recruitment on rock outcrops along the coast. Tillamook County was established in 1853.

Second, large intense fires in the 1840s killed many forests in some areas of the coastal landscape in northern Oregon (Munger 1944, Teensma et al. 1991, Zobel 2002). These fires reportedly drove Native Americans into the sea in some places (Morris 1934). Although we know of no fire history studies on Neahkahnie Mountain, we have

TABLE 1. Simple linear regression models for growth in major diameter (cm) of *Aspicilia* and *Placopsis lambii* against age (years) since substrate exposure at Neahkahnie Mountain, Oregon. Models are based on calibration dates to 73 years (Figure 5). "Roadcut assumption" refers to two estimates of the year that road work exposed new surfaces; n is the sample size. The prediction equation reverses the regression equation to estimate age from major diameter.

	Roadcut Assumption	Slope	Intercept	R^2	n	Prediction Equation
Aspicilia	1970	0.108	–0.641	0.88	60	age = 9.24(diam + 0.641)
Aspicilia	1980	0.103	–0.167	0.87	60	age = 9.72(diam + 0.167)
Placopsis	1970	0.118	–0.742	0.88	31	age = 8.47(diam + 0.740)

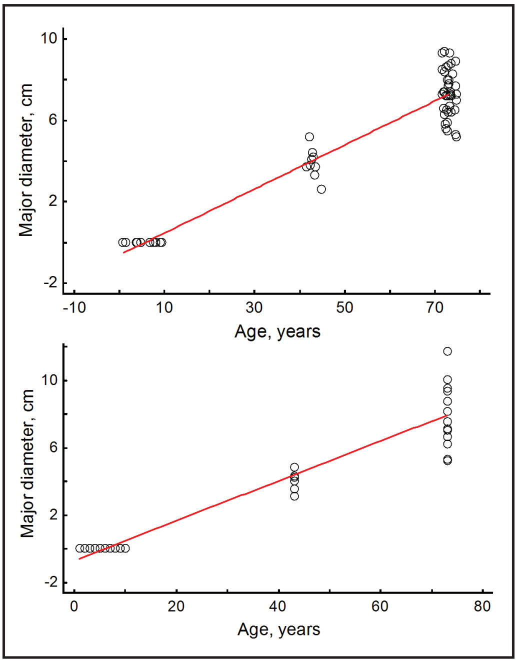

Figure 5. Simple linear regressions of major lichen diameters against age of rock surface for *Aspicilia* (upper graph) and *Placopsis* (lower graph). Points in the upper graph have been jittered horizontally to reduce overlap. Regression equations are in Table 1.

observed many forests in the area with few signs of logging but that are clearly not old-growth.

Two alternative hypotheses should be considered: First, the inscription of AUGUR might not be authentic if it had been placed there in relatively recent years. In this case, we would have expected considerable damage to the lichens overgrowing the inscription, rather than smooth, continuous individuals.

Second, different parts of the inscription could have been made at different times, specifically the word AUGUR could have been added later to some existing inscriptions. While we cannot rule that out, the consistency of the appearance of the lichen colonies, the inscriptions, and the rock face give no support to that hypothesis.

Last, the lichen ages lend no support to Jensen's hypothesis that some of the inscriptions date to the Drake exploration in 1579. Neither can the lichen ages refute that hypothesis; however, all of the lichens covering the area of the inscriptions appear to be much younger than that.

It is impossible to draw firm conclusions concerning the age of the inscriptions given the numerous assumptions involved, but our results are consistent with a near coincidence of three events: exploration and inscriptions by C. C. Augur's company of the US Army, extensive wildfires in the 1840s, and a pulse of lichen colonization in the mid-1800s.

Given the sparse documentation of the inscriptions, and the fact that they have already been destroyed, is difficult to see how further work on this specific case could provide more definite dates. We do, however, believe that lichenometric dating may be worthwhile for other inscriptions or structures in the area, particularly if the rock exposure is still intact.

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Literature Cited

Bawlf, S. 2003. The Secret Voyage of Sir Francis Drake: 1577-1580. Penguin Books, New York, NY.

Bednarik, R. G. 2002. The dating of rock art: a critique. Journal of Archaeological Science 29: 1213-1233.

Berry, D. 1960 (reprinted 2004). Trask. Oregon State University Press, Corvallis.

Bull, W. B. 1996. Dating San Andreas fault earthquakes with lichenometry. Geology 24:111-114.

Bull, W. B., and M. T. Brandon. 1998. Lichen dating of earthquake-generated regional rockfall events, southern Alps, New Zealand. Geological Society of America Bulletin 110:60-84.

Costaggini, P. A. 1985. Sir Francis Drake's northwest exploration: an historical discussion and survey of artifacts at Neahkahnie Mountain, Oregon. M.S. Thesis, Department of Civil Engineering, Oregon State University, Corvallis.

Esslinger, T. L. 2018. A cumulative checklist for the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada. Version 22, 29 January 2018. North Dakota State University, Fargo. Available online at http://www.ndsu.edu/pubweb/~esslinge/chcklst/chcklst7.htm (accessed 04 February 2019).

Gitzen, G. D. 2016. The treasure rocks of Neah-kah-nie Mountain. Fort Nehalem Publishing, Wheeler, OR.

Haramundanis, K., and E. M. Gaposchkin. 2016. Mystery Rocks in Oregon. Unpublished report on file at Tillamook County Pioneer Museum, Tillamook, OR.

Innes, J. 1985. Lichenometry. Progress in Physical Geography 9:187-254.

Jomelli, V., D. Grancher, P. Naveau, D. Cooley, and D. Brunstein. 2007. Assessment study of lichenometric methods for dating surfaces. Geomorphology 86:131-143.

Loso, M. G., and D. F. Doak. 2006. The biology behind lichenometric dating curves. Oecologia 147:223-229.

Matthews, J. A., and H. E. Trenbirth. 2011. Growth rate of a very large crustose lichen (*Rhizocarpon* subgenus) and its implications for lichenometry. Geografiska Annaler 93A:27-39.

McCune, B. 2017. Microlichens of the Pacific Northwest. Volumes 1 and 2. Wild Blueberry Media, Corvallis, OR.

McCune, B., N. Ali, R. J. Hartley, and W. J. Hunt. 2017. Estimating age of rock cairns in southeast Alaska by combining evidence from successional metrics, lichenometry, and carbon dating. Arctic Science 3:698-715.

Morris, W. G. 1934. Forest fires in Oregon and Washington. Oregon Historical Quarterly 35:313-339.

Munger, T. T. 1944. Out of the ashes of Nestucca. American Forests 50:342-345, 367-368.

Naveau, P., V. Jomelli, D. Cooley, D. Grancher, and A. Rabatel. 2007. Modeling uncertainties in lichenometry studies. Arctic, Antarctic and Alpine Research 39:277-285.

Nehalem Valley Historical Society. 1991. Tales of the Neahkahnie Treasure. Unpublished report of the Treasure Committee, on file at Tillamook County Pioneer Museum, Tillamook, OR.

Osborn, G., D. McCarthy, A. Labrie, and R. Burke. 2015. Lichenometric dating: science or pseudo-science? Quaternary Research 83:1-12.

Porter, S. C. 1981. Lichenometric studies in the Cascade Range of Washington: establishment of *Rhizocarpon geographicum* growth curves at Mount Rainier. Arctic and Alpine Research 13:11-23.

Sauter, J., and B. Johnson. 1974. Tillamook Indians of the Oregon Coast. Binfords and Mort, Portland, OR.

Scuderi, L. A., and P. J. Fawcett. 2013. Holocene environmental change resets lichen surface dates on Recess Peak glacial deposits in the Sierra Nevada, California. Quaternary Research 80:180-188.

Teensma, P. D. A., J. T. Rienstra, and M. A. Yeiter. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon Coast Range from 1850 to 1940. Technical Note OR-9, USDI Bureau of Land Management, Portland, OR.

Zobel, D. 2002. Ecosystem use by indigenous people in an Oregon coastal landscape. Northwest Science 76:304-314.

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