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SUMMARY REPORT

Taxonomic identification of archaeological charcoal from Č̓íxwicən for the purpose of AMS sample recommendation

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I. INTRODUCTION

The Čḯxʷicən archaeological site (45CA523) is a Lower Elwha Klallam village site unearthed in 2003 in what is now Port Angeles, Washington. This large, coastal site is situated roughly six miles east of the mouth of the Elwha River on the shores of the Strait of Juan de Fuca. Following inadvertent discovery by Washington Department of Transportation construction activities, the ensuing archaeological investigations recorded cultural strata containing over 600 features such as hearths, post-molds, structural wood, gravel features, pits, shell lenses, and living surfaces, as well as human remains and bone and lithic artifacts. These elements, along with radiocarbon ages, suggest that Čḯxʷicən was a large, ancestral village occupied for roughly 2,700 years.

From 2012 to 2015, Salix Archaeological Services (SALIX) was contracted by Dr. Virginia Butler (Portland State University), Dr. Sarah Campbell (Western Washington University), and Dr. Sarah Sterling (Portland State University) to analyze charred wood, or charcoal, recovered from Čḯxʷicən. SALIX was tasked with providing taxonomic identifications of charcoal and selecting appropriate fragments for Accelerator Mass Spectrometry (AMS) dating. This report describes the methods employed by this analysis, provides the taxonomic identifications, and assesses woody fuel use at Čḯxʷicən.

II. METHODS

The methods described in this report support the stated goal of the charcoal identification, which was to select (preferably short-lived) samples for radiometric dating. Project leaders designed and executed an extensive AMS dating program to decipher the vast palimpsest of cultural and natural deposits at Čḯxʷicən and to understand the processes that created them. As such, this analysis was not designed as a comprehensive fuel analysis, nor was it part of a greater paleoethnobotanical investigation to study plant use at Čḯxʷicən. The greater radiocarbon sample selection goal guided decisions made in the level of taxonomic identification achieved, particularly when coniferous fragments were encountered that could exacerbate the "old wood" problem, as discussed in the following sections. Caveats aside, this analysis resulted in a large body of data that is valuable in its own right and, as of this writing, it is one of the only examinations of plant material from Čḯxʷicən.

IIa. Field Recovery and Sampling

During the extensive recovery effort at Čḯxʷicən, charcoal samples were removed from the site when identified *in situ* and were collected from the water screens, as well. Since the Čḯxʷicən charcoal analysis was not designed as a thorough fuel analysis, systematic flotation and consistent, volumetric sampling were not conducted. Charcoal was removed from a myriad of feature types, including shell middens, living surfaces, hearths and other thermal features, structural remains, beach sands, and others.

Charcoal samples were sent to SALIX in seven batches over the course of four years, with target contexts predetermined by project leaders. The target contexts were identified in keeping with a greater AMS dating regime designed to provide a comprehensive site chronology. These target contexts typically were features or levels (e.g., Area A1, Unit 1, Stratum 3.0, Levels 3 and 4), within which the project leaders selected one or more samples for examination (e.g., Samples WS-531.02.04 and WS-257.02.04). The samples selected within a given target context were often prioritized.

IIb. Subsampling

The large volume of charcoal recovered from the Čḯxʷicən samples necessitated a subsampling strategy. Typically, charcoal greater than 2mm may be reliably identified by a reflected light microscope, so this study considered only the charcoal captured by a 2 mm sieve. Furthermore, AMS labs require that a charcoal fragment submitted for dating meet minimum weight requirements. The minimum weight is specified by each lab, for instance Beta Analytic requires 2 mg of charcoal (Beta Analytic Testing Laboratory 2018) and DirectAMS requires 10 mg (DirectAMS 2018). Each sample was weighed and fragments greater than 2 mm were counted. Only those fragments meeting the minimum size and weight requirements were analyzed.

IIc. The Old Wood Effect

The ultimate goal of the batch-level analysis was to select fragments for AMS that would minimize the "old wood effect." The "old wood effect" refers to the artificial inflation of radiocarbon ages when wood from the inner rings, or heartwood, of a long-lived tree species is dated and equated to the archaeological event of interest (e.g., the felling or burning of the tree). Coniferous species have negative reputations for skewing radiocarbon ages, especially on the northwest coast of North America, where some conifers can live for over 1,000 years, such as Douglas fir (*Pseudotsuga menziesii*) and Sitka spruce (*Picea sitchensis*). In the Pacific Northwest, it is best to avoid coniferous taxa for these reasons, while most angiosperms (hardwoods) are relatively short-lived and appropriate for radiocarbon dating. The best way to assure that old wood will not bias radiometric ages is to provide taxonomic identifications of wood or charcoal fragments prior to submittal.

The Čḯxʷicən charcoal analysis followed the priorities established by project leaders. Within a target context, I would select the highest priority sample for analysis, with the goal of identifying a short-lived angiosperm (hardwood), twig, or bark fragment. If the first sample yielded no short-lived options (as is common in Pacific Northwest archaeology), I would move on to the second sample, with the same goal. I then recommended specific fragments to Dr. Butler and her team as appropriate AMS candidates.

IId. Taxonomic Identification

Charcoal fragments were identified using an Olympus BX43 microscope with reflected light and up to 500x magnification (see Figures 1a and 1b for sample digital photographs). Fragments were fractured along three planes with a single-edge razor blade and mounted in a sand-filled box for easy manipulation under the microscope. Care was taken to thoroughly wash and sterilize all points of contact between identified samples and the analyst, in order to minimize cross-contamination.

Identifications were aided by the use of standard anatomical keys, namely the hardwood (dicotyledon) and softwood (conifer) keys published by Panshin and De Zeeuw (1980) and Friedman (1978), the softwood key by Kukachka (1960), and the conifer bark key by Chang (1954). I also relied on my own comparative collection to aid in identifications.

Here I will note that wood anatomists typically provide genus-level identifications for wood and charcoal samples, since individual species are difficult, if not impossible, to differentiate under the microscope. I followed this standard practice for the Čḯxʷicən samples. In some cases, groups of species may be differentiated (e.g., "hard pines" versus "soft pines"), but this distinction depends upon the degree of wood preservation and available anatomical information. In other cases, it is safe to assume a species from a genus-level identification, if the analyst is confident that that species is the only member of the genus to be indigenous to or present in the area at a given time. For instance, *Pseudotsuga menziesii* is the only member of *Pseudotsuga* native to the Pacific Northwest.

As mentioned, the Čḯxʷicən charcoal analysis is unique in that the goal of the analysis was to find and recommend fragments for AMS dating. As such, when I encountered a coniferous fragment without bark that had a high likelihood of representing "old wood," I often labeled it "unidentified conifer." This is not to say the fragments were "unidentifiable," but rather that they were not worth the time to provide a taxonomic identification, when the goal was selection of a short-lived angiosperm. Within a sample, therefore, I might analyze one fragment or twenty to arrive at a single fragment best-suited for AMS dating. This goal contrasts with a standard fuel or plant analyses, in which every fragment would be identified to taxon and only considered "unidentifiable" if poor preservation or small size precluded a genus-level identification.

IIe. Cataloguing protocol

Once identified, each fractured fragment was assigned a unique identifier, in this case the catalog number (e.g., WS-600.02.05) followed by "CH" (charcoal) and a sequential number (e.g., WS-600.02.05-CH01), or simply an alphabetical designation (e.g., WS-8097.02.04-a).

III. RESULTS OF CHARCOAL IDENTIFICATION

As summarized in Table 1 and detailed in Appendix 1, seven batches of charcoal and 409 charcoal fragments were examined for this research. All seven chronozones (CZ 1, CZ 2, CZ 3, CZ 4, CZ 4b, CZ 5, CZ 6, and CZ 7) and nine activity areas (A1, A3, A4, A5, A9, A18, A23, BX1, and BX4) are represented in the charcoal analysis.

IIIa. Overview by Genera

Fifteen named woody genera (e.g., *Thuja*, or red cedar) and four genera combinations (e.g., *Picea/Larix*, or spruce/larch) are represented in the Čḯxʷicən charcoal assemblage considered by this study (see Table 1). Genera combinations are used when a charcoal fragment has anatomical features common to two or three woody genera, but the fragment is of insufficient size or preservation to permit a more precise identification. For instance, spruce (*Picea*) and larch (*Larix*) are differentiated by a single feature under the microscope - the bordered pits on the radial section tracheids (Bartholin 1979). Unfortunately, many archaeological charcoal fragments are too small or insufficiently preserved to assess the character of the bordered pits, so they are labeled "*Picea*/*Larix*," meaning the fragment may be either spruce or larch.

Table 1. Summary of woody taxa examined from the Čǐx́ʷicən site (45CA523)

Scientific Name (*conifer)	***Common Name***	***NISP***	***% of Total (n=409)***	***% of Identified Genera (n=153)***
*Pseudotsuga**	Douglas fir	75	19%	49%
*Pseudotsuga/Taxus**	Douglas fir/yew	15	4%	10%
Alnus	alder	14	3%	9%
*Picea/Larix**	spruce/larch	9	2%	6%
Salix	willow	7	2%	5%
Sambucus	elderberry	6	2%	4%
Rubus	brambles/raspberry	4	1%	3%
Malus	crabapple	4	1%	3%
*Tsuga**	hemlock	3	1%	2%
*Pinus**	pine	3	1%	2%
Holodiscus	oceanspray	3	1%	2%
Acer	maple	2	<1%	1%
*Thuja**	cedar	2	<1%	1%
Arbutus	madrone	1	<1%	<1%
*Chamaecyparis**	false cypress/yellow cedar	1	<1%	<1%
Oplopanax	devil's club	1	<1%	<1%
*Picea**	spruce	1	<1%	<1%
*Abies/Tsuga**	true fir/hemlock	1	<1%	<1%
Alnus/Betula	alder/birch	1	<1%	<1%
Unidentified conifer	unidentified	173	42%	-
Unidentified wood	unidentified	48	12%	-
Unidentified plant material	unidentified	18	4%	-
Unidentified angiosperm	unidentified	15	4%	-
Unidentified bark	Unidentified	2	<1%	-
	TOTAL	**409**	**100%**	**100%**

At Čǐx́ʷicən, the identified taxa encompass both angiosperms, or "hardwoods," and conifers, or "softwoods." In addition, five categories represent the "unidentified" fragments: unidentified angiosperms, unidentified conifers, unidentified bark, unidentified wood, and unidentified plant material. Unidentified categories are a standard part of any charcoal analysis and reflect the inadequate preservation of wood anatomy, either due to small fragment size or structural damage. As previously mentioned, the number of unidentified fragments in this study is artificially large, due to the priority of selecting angiosperm fragments that originated from presumably shorter-lived species than the average conifer.

Site wide, 69% of the charcoal fragments are conifers (n=283), 14% are angiosperms (n=58), and the remaining 17% of fragments (n=68) are unidentified wood, bark, or plant material. Figure 1 displays the relative abundances of conifers, angiosperms, and unidentified wood and plant across the site.

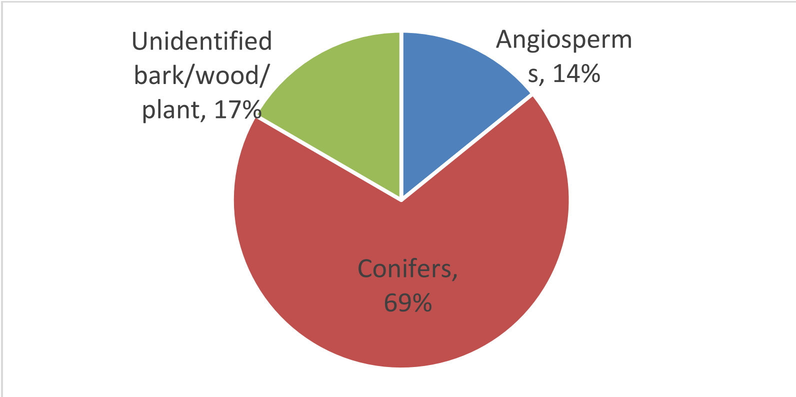

Figure 1. Site-wide representation of conifers, angiosperms, and unidentified fragments (NISP=409)

The most dominant woody taxon at Čḯxʷicən is *Pseudotsuga*, certainly *Pseudotsuga menziesii* (Douglas fir), representing 18% (n=75) of the total assemblage, or 49% (n=75) of the identified fragments (note: any taxon preceded by a "cf." is combined with its regular taxon for counting purposes, so *Pseudotsuga* and cf. *Pseudotsuga* fragments will be summed into a single category). The *Pseudotsuga* totals may in fact be even larger if the undifferentiated *Pseudotsuga*/*Taxus* (yew) category is considered (n=15); however, *Taxus* is also a possibility in this region.

The second most abundant taxon is *Alnus* (alder), with n=14 and 9% of the identified assemblage. Other notable woody genera at Čḯxʷicən include: *Picea/Larix* (undifferentiated spruce/larch, 6%); *Salix* (willow, 5%); *Sambucus* (elderberry, 4%); *Malus* (crab apple, 3%); and *Rubus* (brambles, 3%); *Holodiscus* (oceanspray, 2%); *Pinus* (pine, 2%); *Tsuga* (hemlock, 2%); *Acer* (maple, 1%); and *Thuja* (cedar, 1%) (all percentages represent the identified portion of the assemblage). Other woods are present in quantities less than 1% of the total assemblage: include: *Arbutus* (madrone), *Chamaecyparis* (yellow cedar), *Oplopanax* (devil's club), *Picea* (spruce), and possibly *Abies* (true fir) and *Betula* (birch).

IIIb. Woody Taxa Represented at Čḯxʷicən

Conifers. Six genera of conifers, also called softwoods, are evident in the Čḯxʷicən charcoal assemblage: *Pseudotsuga*, *Tsuga*, *Pinus*, *Thuja*, *Chamaecyparis* and *Picea*. Other conifers may or may not be present, as they are part of a combined identification (e.g., the "*Larix*" in *Picea*/*Larix,* also *Abies* and *Taxus*) and are not confirmed as stand-alone identifications. As indicated previously, conifers dominate the Čḯxʷicən assemblage (69%, n=283). The percentages and counts below indicate whole site representation. Ethnographic context for the use of these woods by Klallam Tribes and other Olympic Peninsula Peoples is presented within this section and in a subsequent section of this report.

Pseudotsuga (false fir*;* n=75). In the Pacific Northwest, the only species of false hemlock is *Pseudotsuga menziesii*, or Douglas fir, further differentiated as a coastal subspecies (ssp. *menziesii*) and an interior subspecies (ssp. *glauca*). Douglas fir is a subclimax species within the *Tsuga heterophylla* vegetation zone and is widespread throughout western Washington (Franklin and Dyrness 1973). It typically has a lifespan of 750 years and occasionally lives up to 1300 years (Pojar and MacKinnon 1994).

The wood has long been sought as a high-quality fuel (Pojar and MacKinnon 1994:32), and "everywhere the bark was considered to be a top quality fuel because it burned with a hot smokeless flame" (Turner & Bell 1971:71). Gunther (1945:19) recorded Douglas fir as a primary fuelwood and many tribes (including the Klallam, Quinault, Cowlitz, Skagit, Lummi, Swinomish, Chehalis, and Green River) prized the bark, which required less work to collect. Eells (1985:50) also cited "red fir" and its bark as a major firewood, as well as used for lumber, masts, spear handles, oars, and the pitch for fastening arrow and spear heads.

Tsuga (hemlock*;* n=3). Hemlock is represented by two species in the Pacific Northwest: *Tsuga heterophylla* (western hemlock) and *Tsuga mertensiana* (mountain hemlock). Today, western hemlock is a dominant species in the Pacific coastal forest, growing from low elevations up to 3,500 feet, and lives up to 500 years (Arno and Hammerly 1999:75-79). Mountain hemlock, as its name suggests, primarily grows from 3,500 to 6,000 feet, and has a maximum lifespan comparable to western hemlock (Arno and Hammerly 1999: 80-85). Given these ecological niches, it is likely that the hemlock found in the Čḯxwicən charcoal assemblage is western hemlock.

Western hemlock was a frequently used fuelwood by Pacific Northwest tribes (Gunther 1945:18), and was used to make halibut hooks (Eells 1985:51). The Klallam tribes boiled the bark for a red-brown dye and to stop hemorrhages, and they used saplings to reinforce fish traps (Gunther 1945:18).

Pinus (pine; n=3). On the Olympic Peninsula, the primary native pine species are *Pinus contorta* (lodgepole or shore pine) and *Pinus monticola* (western white pine) (Pojar and McKinnon 1999). One fragment exhibits dentate ray tracheids, which is characteristic of certain pines, including *Pinus contorta* (Kukachka 1960); the other fragments are indeterminate. The likely subspecies in the Čḯxʷicən vicinity is *Pinus contorta contorta*, shore pine, a relatively short-lived conifer that thrives along the coast (Cope 1993).

Northwest native peoples used shore pine pitch to waterproof canoes and to treat open sores. They also fashioned the roots into rope and chewed the buds to cure sore throats (Arno and Hammerly 1999:40; Gunther 1945:27; Pojar and MacKinnon 1994:38).

Thuja (cedar*;* n=2). *Thuja plicata* (western redcedar) is the only *Thuja* species native to the Pacific Northwest. Today, western red cedar is one of the keystone species within the *Tsuga heterophylla* vegetation zone (Franklin and Dyrness 1973), which characterizes landscapes throughout western Washington. Like many Northwest conifers, western red cedar may be extremely long-lived, with old-growth trees reaching 1,000 to 1,400 years (Pojar and MacKinnon 1994).

Western redcedar was crucial to the existence of Coast Salish people – its wood, bark, and roots providing the raw material for canoes, paddles, house planks, bentwood boxes, basketry, rope, harpoon floats, spears, fishing weirs, clothing, and medicine, among many other uses (Stewart 1984; Gunther 1945). The wood also makes excellent fuel (Turner & Bell 1971: 72). Western redcedar is easy to split and resistant to rot – two properties valued in the Pacific Northwest. In addition, western redcedar heartwood possesses toxic components to fungi and insects, so it is durable when subject to water and sediments. As compared to other Northwest conifers, western redcedar typically is straight-grained, free of knots, light-weight, resistant to shrinkage, a good insulator, and very pliable when steamed – all desirable characteristics in canoes, house planks, bentwood boxes and other household items (Friedman 2005:135-136). Tools like adzes, wedges, and mauls are found in Northwest Coast archaeological sites as old as 5,000 yr BP (Stewart 1984:26-27), but were widespread by roughly 3,500 yr BP, indicating the existence of a healthy woodworking industry by this time (Ames and Maschner 1999:92-94).

Chamaecyparis (false cypress; n=1). Two species of *Chamaecyparis* (false cypress) exist in the Pacific Northwest: *Chamaecyparis nootkatensis* (Alaska yellow cedar) and *Chamaecyparis lawsonia* (Port Orford cedar). *C. lawsonia's* native range stretches along the border between southwest Oregon and northwest California, making it an unlikely candidate for the Čḯxwicən *Chamaecyparis* fragment. C. *nootkatensis*, on the other hand, is found in western Washington – albeit usually 2,500 to 6,500 feet above sea level – including on the Olympic Peninsula (Arno and Hammerly 1999:124). Alaska yellow cedars can attain 1,000 to 1,500 years in age and are not commonly found in Northwest Coast archaeological sites, likely due to the distance required to transport wood from live stands. Alaska yellow cedar was a favored wood for bows (either manufactured or traded) and was also used to fashion paddles, masks, pendants, bowls (Pojar and MacKinnon 1994:43).

Picea (spruce; n=1). In the Pacific Northwest, the dominant spruce species is *Picea sitchensis* (Sitka spruce), which thrives in low to mid-elevation sites, rarely occurring above 1,500 feet (Arno and Hammerly 1999:53). Other spruces found in the Northwest include *Picea engelmannii* (Engelmann spruce), commonly found at mid- to high elevations, and *Picea glauca* (white spruce), which is adapted to interior sites (Pojar and MacKinnon 1994:37). Based on ecology, Sitka spruce is the likely candidate for the Čḯxʷicən fragments. Sitka spruce commonly lives for 400 to 700 years.

Northwest peoples used all parts of Sitka spruce trees: Makah and Quinault people chewed the pitch as gum and used it to caulk canoe, most Pacific Coast tribes used spruce root for basketry and hats and to make twine, and many tribes used the inner bark as medicine (Gunther 1945:17). In addition, spruce wood makes an excellent fuel (Arno and Hammerly 1999:58; Eells 1985:52).

Possible conifers. Three additional conifers may be represented in the Čḯxʷicən charcoal assemblage – *Abies*, *Larix*, and *Taxus*. Each were unable to be distinguished individually, but rather are grouped with one other genera with similar anatomical features. These specimens were too small or too poorly preserved to enable precise identification.

Abies (true fir, as *Abies/Tsuga;* n=1). Four species of true fir are represented in western Washington forests: *Abies lasiocarpa* (sub-alpine fir), *Abies amabilis* (Pacific silver fir), *Abies grandis* (grand fir, or lowland white fir), and *Abies procera* (noble fir). If true fir is present in the Čı́xʷicən charcoal, the most likely species is *Abies grandis*, a shade-tolerant tree which currently grows between sea level and mid-elevations, prefers drier climates, and reaches lifespans of 250 to 300 years (Arno and Hammerly 1999). Gunther (1945:19) reports the Chehalis as using *Abies grandis* for fuel and Straits Salish tribes boiled the bark for brown and pink dyes (Pojar and MacKinnon 1994:34).

Larix (larch, as *Picea/Larix*, n=9). Larch in the Northwest occurs as *Larix occidentalis* (western larch) and *Larix lyallii* (alpine larch), both deciduous conifers that drop their needles in autumn and can live 500 to 900 years. Despite the claim that *Larix occidentalis* "has a high heating value and splits readily, yielding one of the finest fuel woods available in the Northwest" (Arno and Hammerly 1999:44), larch is an unlikely candidate for fuel wood at Čı́xʷicən. In Washington, *Larix occidentalis* is found east of the Cascades and *Larix lyallii* is found only in the highest elevations of the northern Washington Cascades (Arno and Hammerly 1999:41-52). The *Picea*/*Larix* charcoal fragments are more likely *Picea* (spruce).

Taxus (yew, as *Pseudotsuga/Taxus*; n=15). The only yew native to the Pacific Northwest is *Taxus brevifolia* (Pacific yew), which grows as a shrub or small tree in mature and old growth forests throughout the Pacific Northwest and Olympic Peninsula. Pacific yew wood is hard, strong, and flexible, and has been a preferred wood for Northwest tribes, including the Klallam, who carved and bent the wood into bows, arrows, wedges, clubs, harpoon shafts, drum frames, and many other tools (Gunther 1945:16; Pojar and MacKinnon 1994:40). Gunther (1945:16) cited the Klallam as drying and crushing yew needles, and smoking them instead of tobacco. The Klallam also used yew for canoe paddles.

Angiosperms. Nine angiosperms, sometimes called broad-leaved trees or hardwoods, are represented in the Čı́xʷicən charcoal assemblage: *Alnus* (alder), *Salix* (willow), *Sambucus* (elderberry), *Malus* (crab apple), *Rubus* (brambles/salmonberry), *Holodiscus* (oceanspray), *Acer* (maple), *Arbutus* (madrone), and *Oplopanax* (devil's club).

Alnus (alder*;* n=14). In western Washington, the native alder species are *Alnus rubra* (red alder) and *Alnus crispa sinuata* (Sitka alder). Red alder is one of the most prevalent hardwoods in the *Tsuga heterophylla* vegetation zone and is often found along rivers and shorelines (Franklin and Dyrness 1973:72). Both species of alder are relatively short-lived deciduous trees or shrubs; *Alnus rubra* lives typically 100 years or less, and often no more than 50 years (Favorite and Immel 2006; Pojar and McKinnon 1994). *Alnus sinuata* attains 25 to 50 year lifespans (Darris 2011). As is typical in charcoal analysis, the Čı́xʷicən alder fragments cannot be identified to species.

Alder has been widely documented by ethnobotanists working in the Northwest Coast and Alaska as a preferred fuel for smoking fish, among many other uses (Russell 1991:21-22; Turner & Bell 1971:79). Erna Gunther (1945:27) stated: "Uniformly in this area [western Washington] alder wood is preferred for smoking salmon. It is also used for firewood in the open because it does not spark." On the Olympic Peninsula, the Makah and Nitinaht used red alder for smoking and drying fish, as well as for barbecuing seal meat (Gill 2005:377). Eells (1985:50) reported the Straits Salish tribes as using alder for making many household implements, as well as paddles, bailers, masks, fish traps, and for medicine and dyes.

Salix (willow; n=7). Over 30 species of willow are native to western Washington, including Scouler's willow (*Salix scoulriana*), Hooker's willow (*Salix hookeriana*), Pacific willow (*Salix lasiandra*), and Sitka willow (*Salix sitchensis*) (Arno and Hammerly 1999:140). All are classified as shrubs or small trees, rarely exceed 12 m in height (Pojar & MacKinnon 1994:88-89), and usually are considered old at 30 years. Willows typically grow in moist sediments, alongside streams, rivers, and lakes. Willows make decent fuelwood and the Klallam have used willow wood and bark as twine and as a tea to cure sore throats and tuberculosis (Arno and Hammerly 1999:143; Gunther 1945:26).

Sambucus (elderberry; n=6). Several elderberry species are native to the Olympic Peninsula, including *Sambucus racemosa* ssp. *pubens* var. *arborescens* (red elderberry), *Sambucus racemosa* ssp. *pubens* var. *melanocarpa* (black elderberry), and various subspecies, such as *Sambucus caerulea* (blue elderberry). *Sambucus* species are deciduous and typically grow as short-lived shrubs to small trees in the Northwest (Pojar and McKinnon 1994:70), making them ideal candidates for radiometric dating. Red and blue elderberries are and have been extensively consumed throughout the region; historically, they were steamed on rocks and stored in water or underground for the winter. The Klallam also boiled the bark into tea as treatment for diarrhea (Gunther 1945:47).

Malus (crab apple; n=4). The crab apple species native to the Pacific Northwest is *Malus fusca*, also called *Pyrus fusca* (Pacific crab apple). *Malus fusca* is deciduous and typically grows as a shrub or small tree in the Northwest, reaching ages of 100 to 150 years (Arno and Hammerly 1999:185-186). Northwest tribes have variously used crab apple wood for seal spears and mauls and have consumed the berries for food and medicinal purposes; the Klallam reportedly boiled the bark into an eye wash (Gunther 1945:38).

Rubus (brambles/salmonberry; n=4). On the Olympic Peninsula, there are many native species of *Rubus*, including *Rubus spectabilis* (salmonberry), *Rubus ursinus* (Pacific blackberry), *Rubus parviflorus* (thimbleberry), and *Rubus leucodermis* (blackcap raspberry). All of these species grow as deciduous shrubs and are very short-lived, often less than two years (Pojar and McKinnon 1994). Eells (1985:50-51,62) reported that the Straits Salish ate berries of many *Rubus* species, also drying them into cakes for the winter. They also used blackberry root as cold medicine, as well as using blackberry and raspberry juice as paint.

Holodiscus (oceanspray; n=3). The species native to the Pacific Northwest is *Holodiscus discolor*, also known as oceanspray, creambush, or ironwood. *Holodiscus discolor* grows as a deciduous shrub, and rarely lives more than 30 years (Fryer 2010), rendering it an ideal species for radiocarbon dating. Gunther (1945:33) cited ironwood as widely used among western Washington tribes for roasting tongs, digging sticks, spears, arrow shafts and other tools. Ironwood bark and leaves were also boiled for medicinal purposes (Eells 1985:51). To my knowledge, there is no ethnobotanical information indicating *Holodiscus* was a common firewood.

Acer (maple; n=2). On the Northwest Coast, *Acer* may take the form of a large tree such as *Acer macrophyllum* (bigleaf maple), or smaller shrubs/trees like *Acer circinatum* (vine maple) and *Acer glabrum* (Douglas maple). Vine maple is the most common *Acer* species on the Olympic peninsula, but bigleaf maple is a consistent part of the *Tsuga heterophylla* vegetation zone and may be found covered in moss in the rainforest or in open sites. Vine maple prefers shade, is often found in the shrubby understory of western hemlock and Douglas fir forests, and turns a vibrant shade of red or yellow in the summer and fall. Douglas maple, on the other hand, may be found on rocky, open slopes, forest edges, and floodplains, and does not turn vibrant red. Bigleaf maple may live up to 200 years, while the vine maple is considerably shorter lived, around 20 years (Arno and Hammerly 1999).

Maples were and are culturally important trees. Bigleaf maple was used for firewood and the Klallam carved it into canoe paddles and boiled the bark into a treatment for tuberculosis. Vine maple shoots were commonly used in basketry and the wood also was widely used as fuel (Gunther 1945:39-40). Maples were also used by the Straits Salish to make paddles, oars, bailers, bobbins, combs, fish clubs, and other tools (Eells 1985:51).

Arbutus (madrone; n=1). *Arbutus menziesii*, Pacific madrone, is the only species of madrone native to the Northwest Coast. The tree is a deciduous evergreen and has been recorded to live 200 to 250 years, with some conjecture of 400 to 500 year old trees (Sudworth 1908). Madrone is a very hard, dense wood, and was used as firewood and its roots for spoons and dippers by local peoples (Arno and Hammerly 1999:209-213).

Oplopanax (devil's club; n=1). The species native to the Northwest is *Oplopanax horridus*, or Devil's club, a relatively short-lived deciduous shrub. This small shrub is covered with spines and may be found near streams and wetlands, especially in low to mid elevation sites. It has been used medicinally by Pacific Northwest tribes, as well as fashioned into fish lures by Klallam people. Straits Salish tribes mixed devil's club charcoal with bear grease for ceremonial face paint and as a tattoo dye (Gunther 1945:41; Pojar and MacKinnon 1994:82).

Possible angiosperms. One additional angiosperm may be represented in the Č̓ix̣wicən charcoal assemblage – *Betula*, or birch.

Betula (birch, as *Alnus/Betula;* n=1). One fragment was identified as *Alnus/Betula* due to shared anatomical features between the two genera. This specimen was too small or too poorly preserved to enable precise identification. Birch is not widespread on the Olympic Peninsula, but individual *Betula papyrifera* (paper birch) trees may be found in clearings and in moist woods (Pojar and MacKinnon 1994:47). Inland tribes made more use of the tree, many fashioning canoes and baskets from birch bark and wood, as well as for fuelwood. This specimen is more likely an alder fragment.

IV. DATA EXPLORATION

IVa. Modern and Historic Plant Use by Coast Salish Peoples

It is useful and important to recognize that the Lower Elwha Klallam Tribe and the tribes of the Olympic Peninsula and the Salish Sea have been using the woody plants found in the Č̓íxʷicən charcoal assemblage for a very long time. Table 2 presents just some of those important uses of plants for food, fuel, tools, and medicine, but it is by no means an exhaustive list.

Table 2. Select Plant Uses among the Klallam and Straits Salish Tribal Communities

Genus	***Common Name***	***Food plant?***	***Fuel plant?***	***Medicinal plant?***	***Tool plant?***	***Comments***
CONIFERS						
Chamaecyparis	yellow cedar		X			fuel[4]
Picea	spruce	X	X	X	X	food, roots for baskets, pitch for caulk, tea[2]
Pinus	pine			X		medicinal, chewing gum, tea[2]
Pseudotsuga	Douglas fir		X	X	X	bark fuel, spear & harpoon shafts, tea [1,2], torches, pitch[3]
Thuja	red cedar		X	X	X	construction, tools, boxes; tea[2]; fuel[4]; fire drill[5,6], baskets, clothes[3,6]
ANGIOSPERMS						
Acer	maple		X	X	X	smoke salmon; firewood; fish clubs, ladles, digging sticks, split pole racks to cook salmon, canoe paddles[3], tb tea[4]
Alnus	alder	X	X	X	X	smoking/drying salmon & deer, dye, serving platters, medicine [2,3,7]
Arbutus	madrone			X	X	medicinal tea[2]; tool handle[4]
Holodiscus	oceanspray			X	X	roasting tongs, spears, digging sticks, arrow shafts, etc. [2]
Malus	crabapple	X		X	X	berries[3], eye wash[2]; wedges[4]
Oplopanax	devil's club			X	X	bass lines; medicinal
Rubus	salmonberry, blackberry, thimbleberry	X		X	X	berries[3]; also pipe stem, plugs for floats, bark as astringent; roots as cold medicine [2,7]
Salix	willow			X	X	bark: string, tea
Sambucus	elderberry	X		X	X	berries[3] steamed on rocks; tea for diarrhea; combs[4]

[1]Turner and Bell 1971; [2]Gunther 1945; [3] Mapes 2009; [4]Turner and Peacock 2005; [5]Friedman 1976; [5]Gunther 1927; [6]Eells 1887; [7]Gill 2005.

IVb. Trends in Wood Use at Čı́xwicən

The Čı́xʷicən charcoal was collected from 9 areas within the site, 8 of them mapped in Figure 2. Furthermore, charcoal was recovered from all 7 chronozones (CZ) represented at the site, spanning more than 2,000 years of site occupation. Data exploration of the Čı́xʷicən charcoal assemblage is tentative, because of the previously stated project goal to provide charcoal identifications to inform AMS recommendations, rather than seeking to understand broader plant use and fire function. Still, the assemblage can be assessed for cursory patterns, some of which are presented here.

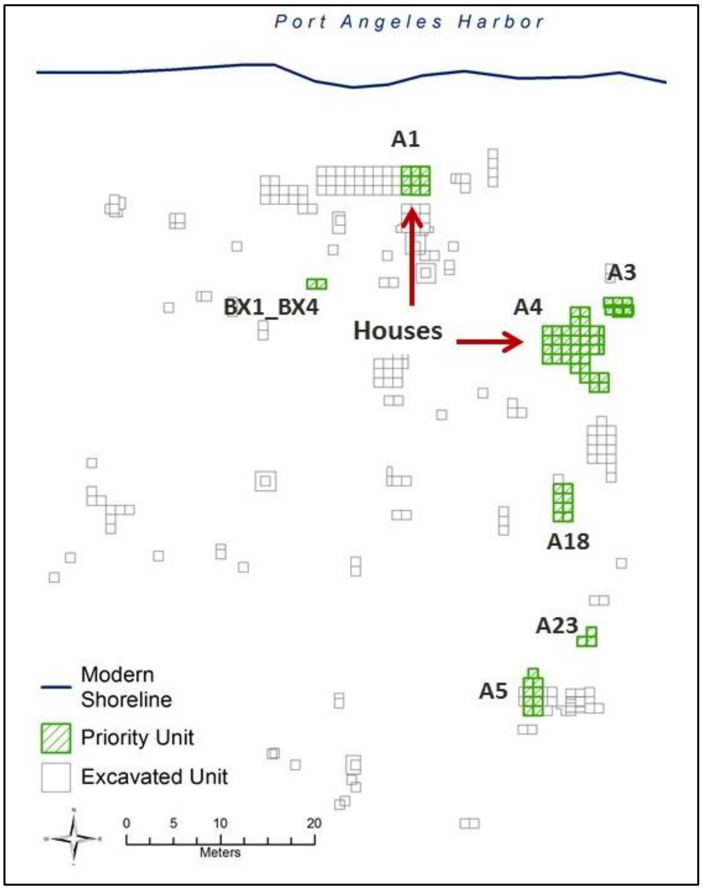

Figure 2. Map of Čı́xʷicən site, indicating excavation areas and Houses A1 and A4. Figure (modified) courtesy of Kaitlin Dempsey.

Conifer Use. Conifers were certainly important at Čı́xʷicən, in particular Douglas fir. With a site-wide abundance of 49% of identified charcoal fragments (and perhaps 59% if undifferentiated Douglas fir/yew fragments are actually Douglas fir), it is reasonable to assume that Douglas fir wood was intentionally burned as fuel, which is in keeping with many other archaeological sites across the region, since the wood is “pitchy” and burns hot, as well as the bark. It is also possible that Douglas fir abundance is artificially high, since this taxon has spiral thickenings - a dramatic anatomical feature that is instantly obvious when observed under the microscope. Most species are not as easily recognizable.

The second most represented conifer is a combined spruce/larch category, which is likely spruce, since larch does not grow in proximity to the study area. Often abundant in Northwest Coast archaeological sites, spruce is likely under-represented at Č̕íxʷicən because of the high "unidentified" portion of the assemblage. Spruce does not have a dramatic anatomical feature, like the spiral thickenings of Douglas fir, and many conifers were labeled "unidentified conifer" to continue the hunt for short-lived taxa.

Hardwood Use. Alders were the most combusted angiosperm, or hardwood, at Č̕íxʷicən, although they comprise only 9% of the identified charcoal. Alder presence is not surprising, since it was regarded as a good fuelwood for smoking salmon and for spark-free burning in open areas (Gunther 1945:27). After alder, willows are the most represented hardwood, but at only 5% of identified fragments, it is difficult to comment on their importance. More attention will be given to hardwoods as fuel in a subsequent section.

Berry Associations. Two charcoal samples were analyzed from some of the deeper sediments in Area A4. The samples were removed from Area A4 Unit 8 (see Figure 3) and, following taxonomic identification, I recommended two charcoal fragments for AMS dating. The fragments were identified as *Sambucus* sp. and *Rubus* sp. This layer is part of Chronozone 2 (CZ 2) - spanning 1900 to 1550 cal BP, it is the second deepest chronozone. This association of *Sambucus* and *Rubus*, in combination with *Holodiscus*, is interesting and deserves further exploration.

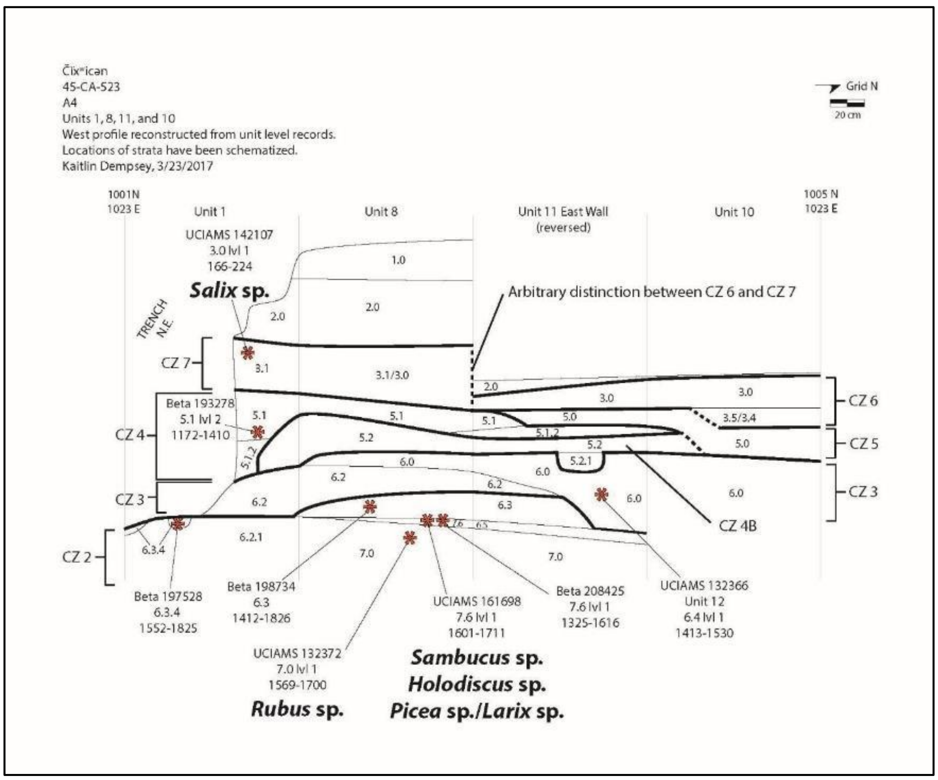

Figure 3. Area A4, Units 1, 8, 11, and 10, West Profile. Map (modified) courtesy of Kaitlin Dempsey.

As previously mentioned, several elderberry species are native to the Olympic Peninsula, but *Sambucus racemosa* (red elderberry) is perhaps the most recognizable. Species of *Rubus* native to the area include salmonberry, Pacific blackberry, thimbleberry, and blackcap raspberry; however, *Rubus* species are not able to be differentiated under the microscope.

The *Sambucus*, *Rubus*, and *Holodiscus* charcoal fragments were found in close proximity to each other in Feature 191 (see Figure 4). *Sambucus* and *Rubus* are both berry-producing shrubs or small trees and it is tempting to interpret these charcoal fragments as the byproducts of food consumption.

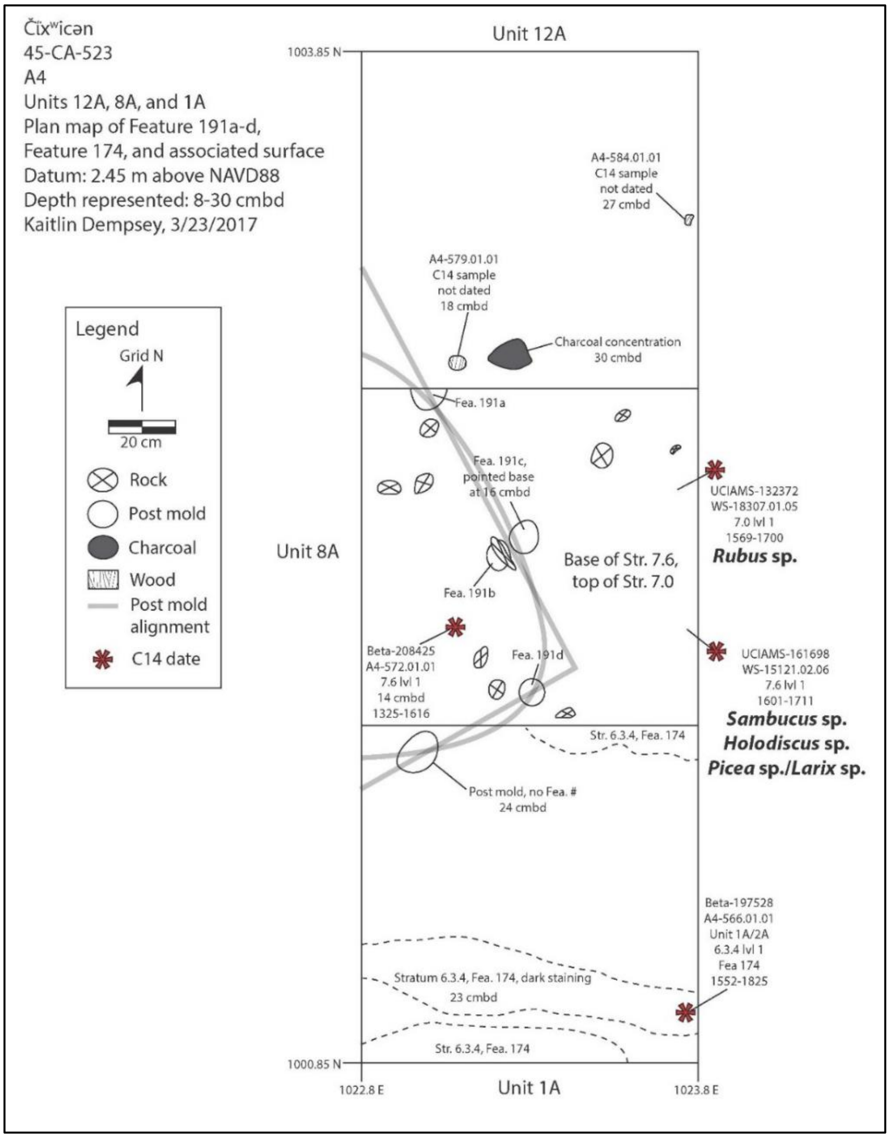

Figure 4. Plan view of Feature 191, Area A4, Units 12A, 8A, and 1A, 8-30 cmbd. Figure (modified) courtesy of Kaitlin Dempsey.

Rob Losey and colleagues (2003) analyzed the use of red elderberry (*Sambucus racemosa*) fruit in Northwest Coast archaeological sites. They reference ethnobotanical information from Makah territory up into the British Columbia Coast that states, because of red elderberry's tartness, it was often mixed with berries like "salmonberry, red, blue, or black huckleberry, salal, blueberry, crabapples, and with fish and mammal oils to make it more palatable…." (Losey et al. 2003:701). In fact elderberry seeds are found in association with *Rubus*, or salmonberry, seeds at Ozette, Hoko River, and the Duwamish No. 1 archaeological sites.

In addition, since elderberry fruit and seeds are toxic, Losey and colleagues state that "The berries are nearly always described as being cooked prior to consumption, which renders the fruit less toxic. People cooked red elderberry fruit through steaming on rocks, pit-baking, and boiling. The cooked mass was sometimes dried on a rack over a fire or in the sun to produce dried berry cakes that were rehydrated for consumption" (Losey et al. 2003:701-703).

Within Feature 191 (see Figure 4), the *Sambucus* and *Rubus* fragments were found in close proximity to one another and to an alignment of stones, fire-modified rock, and five postmolds, one of which terminates in a point. Shell, faunal material, and charcoal are in abundance in this stratum, which is recognized as an occupation surface. The wood analysis supports preliminary conclusions that this feature is a berry-drying feature or a multi-purpose smoking/drying area, an interpretation bolstered also by the presence of *Holodiscus* sp., addressed next.

Holodiscus discolor - called oceanspray, creambush, or ironwood – is represented at Č̕íxʷicən by only three charcoal fragments. Oceanspray is a very dense wood and so it is no surprise that ethnographic evidence has documented its use for roasting sticks or tongs ("Because it won't burn" [Swinomish informant; Gunther 1945]), but also for digging sticks, spear shafts, and canoe paddles. For these reasons, it was likely not a preferred fuelwood – were these oceanspray pieces originally part of a roasting rack and inadvertently made their way into the fire?

It is interesting that two out of three oceanspray fragments co-occur with fruit trees – elderberry in Area A4 (Figure 4) and crab apple in Area A3 (*Malus* sp.) (Figure 5). Could this association indicate that these locations were used to dry fruit? Or make tea? These conjectures are based on a very small sample, but it might be worth a closer look at any seeds contained in bulk samples.

Wood Use through Space and Time. Some spatial trends are worth pointing out: such as the highest taxonomic richness is found in Area A4 (R=12), while the lowest richness exists in Area BX4 (R=2). When examined chronologically, richness varies from R=2 (in CZ 7, the youngest chronozone) to a high of R=10 for the deeper CZ 3 and CZ 4 (see Figure 6). There appears to be a very strong correlation, however, between NTAXA (richness) and NISP (number of identified specimens) for both trends, so sample size is certainly at work here. With the higher sample sizes, genera like maple (*Acer*), madrone (*Arbutus*), and devil's club (*Oplopanax*) are picked up in small numbers.

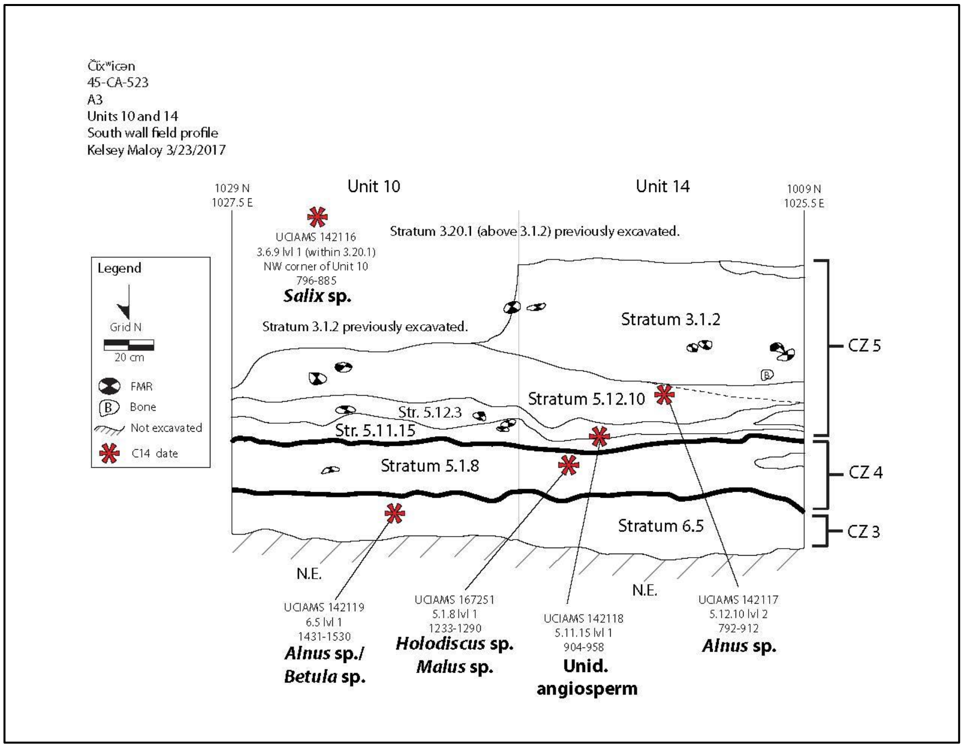

Figure 5. Area A3, Units 10 and 14, South profile with locations of select charcoal fragments removed for identification. Figure (modified) courtesy of Kelsey Maloy.

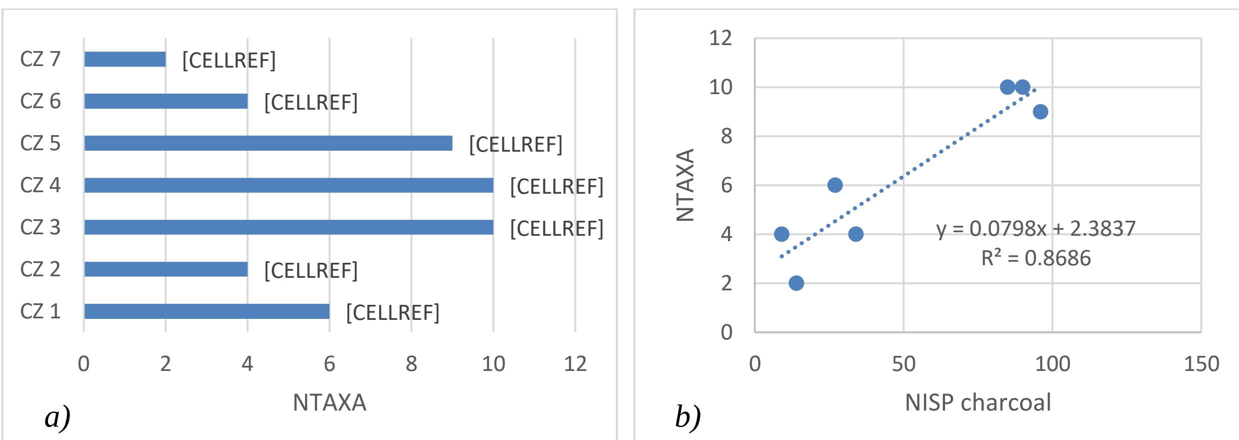

Figure 6. a) Richness (NTAXA) by chronozone; b) Richness vs. number of identified specimens (NISP) by chronozone.

IVc. Fuelwood Management

Another area of plant use at Č̓ix̣ʷicən that we may cautiously explore is fuelwood management. As anybody who has made a fire in a fireplace or fire pit knows, woods have very different burning properties. Oak and birch may produce a hot, long burning fire, cottonwood produces a low heat, very smoky fire, cedar is great for kindling, etc.

One way to better understand the fuel wood choices available to the residents of the Č̓ix̣ʷicən site is to compare the energetic output, or returns, of different woods. Energetic returns provide the basis for constructing a fuelwood ranking system using the assumption that the woods with the highest net energetic returns would be preferred for activities when high heat is desired (*e.g.*, heating and boiling) and those woods with the lowest net energy returns would be preferred when low heat is desired (*e.g.*, smoking and drying). Four wood properties relevant to the energetic output of wood are: moisture (water) content, ash content, calorific value, and density. The Fuel Value Index (FVI) uses these characteristics, which may be measured and combined into the equation detailed here:

$$\text{FVI} = \frac{\text{Calorific value (KJ/g) x density (g/cm}^3\text{)}}{\text{Ash content (g/g) x water content (g/g)}}$$

This index was developed in India and has been used in rural Africa as well, where wood is the primary source of fuel (Jain 1992; Jain and Singh 1999). The highest quality fuelwoods, or those with the highest FVI, match up with those most desired by the rural population and have been recommended for large tracts of cultivation.

My own fuel value work in the Alaskan sub-Arctic (Kodiak Archipelago) is appropriate to the Pacific Northwest as well, since many of the woody species I assessed originate in the PNW and arrive as driftwood on Kodiak. I submitted samples from twenty woody taxa native to the PNW and Alaska to the University of Idaho Forest Products Laboratory for calorific value, density, ash content, and water content measurements. The results from these analyses assist in predicting the ideal woody taxa for heating or cooking activities (low moisture, high caloric value, high fuelwood rank) versus smoking and drying activities (high moisture, low fuelwood rank).

The FVI rankings in Table 3 (adapted from Shaw 2008:Table 4.2) consolidate the analyses conducted on twenty woody species native to the Northwest Coast and southern Alaska. The relative ranks of each taxon show that many low heat, high moisture woods, such as black cottonwood, are near the bottom of the chart. Not coincidentally, many Kodiak fishermen and women consider some of these to be excellent woods for smoking and drying. Other good smoking woods are found in the middle ranks, such as alder and willow, and their use may depend on the moisture content of the wood piece. Some woods rank very high on the FVI table, like top-ranked Douglas fir, which is double the value of next highest ranking wood, Sitka spruce. These woods are better for high heat activities like heating and cooking.

Table 3. Fuel Value Index (FVI) of select woody taxa from the Pacific Northwest and Alaska

Common Name	Scientific Name	Fuel Value Index (kJ/cm^3)	Fuelwood Rank
Douglas fir	***Pseudotsuga menziesii***	**298,423**	**1**
Sitka spruce	*Picea sitchensis*	152,853	2
Coast redwood	*Sequoia sempervirens*	139,320	3
Lodgepole pine	*Pinus contorta*	77,461	4
Pacific yew	*Taxus brevifolia*	61,278	5
Alaska yellow cedar	*Chamaecyparis nootkatensis*	59,928	6
Mountain spruce	*Picea mariana*	49,843	7
Kenai birch	*Betula papyrifera var. kenaica*	48,897	8
Red alder	***Alnus rubra***	**36,962**	**9**
Hooker willow	*Salix hookeriana*	34,685	10
Scouler willow	*Salix scouleriana*	34,107	11
Pacific silver fir	*Abies amabilis*	32,281	12
Western redcedar	*Thuja plicata*	27,892	13
Bigleaf maple	*Acer macrophyllum*	27,822	14
Quaking aspen	*Populus tremuloides*	26,917	15
Devil's club	*Oplopanax horridus*	22,265	16
Pacific madrone	*Arbutus menziesii*	21,507	17
Black cottonwood	*Populus trichocarpa*	20,657	18
Western hemlock	*Tsuga heterophylla*	13,199	19
Red elderberry	*Sambucus racemosa*	indeterminate	(20?)

IVd. Douglas Fir and Alder Fuel Use

This FVI research gives context to several of the genera found in the Čí̓xʷicən charcoal assemblage and we might make some tentative interpretations about fire function. The highest ranked fuel on the FVI list is Douglas fir, which also happens to be a consistent component of the Čí̓xʷicən charcoal assemblage across all areas of the site, representing up to 25% of charcoal from a given area (see Figure 7). Douglas fir is ideal for creating hot fires, perhaps for cooking food or for heating rocks to be used in boiling, or for creating warmth. This measurement may also extend to Douglas fir bark, but unfortunately I did not assess bark in my FVI research.

For instance, in Feature 12 (located in Area A1, roughly 1000 yr cal BP) (see Figure 8), I identified high ranked taxa, including Douglas fir and spruce – the first and second ranked taxa in the FVI table, respectively. These species may indicate a preference for high heat, perhaps heating or cooking. This hearth was surrounded by modified and unmodified bone, antler, lithics, and shellfish, and indeed may be a central hearth used for heating and cooking. The relative abundance of Douglas fir across the site is affected by sample size, however, so it's not worth making further spatial or temporal interpretations here.

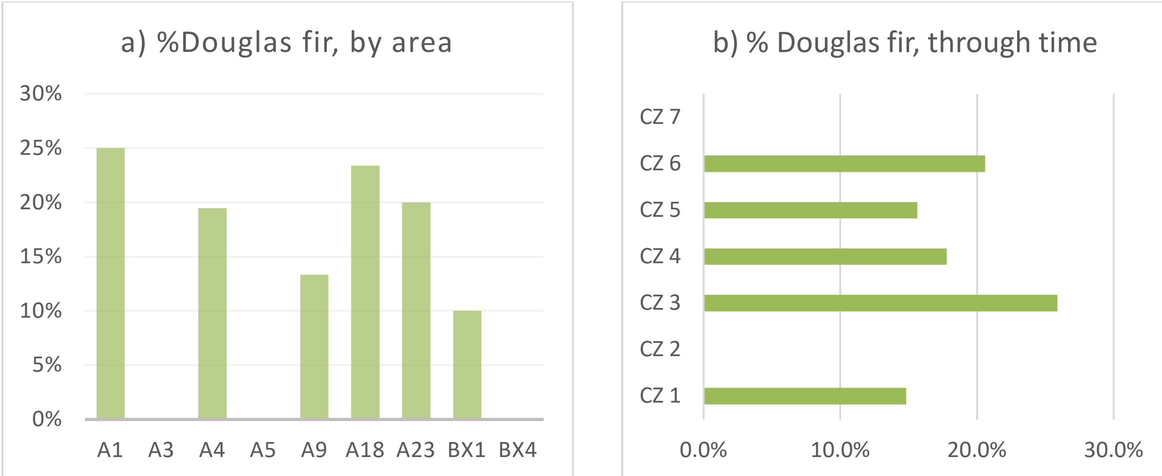

Figure 7. a) Representation of Douglas fir, by area; b) Representation of Douglas fir, by chronozone (CZ 1=oldest, CZ 7=most recent).

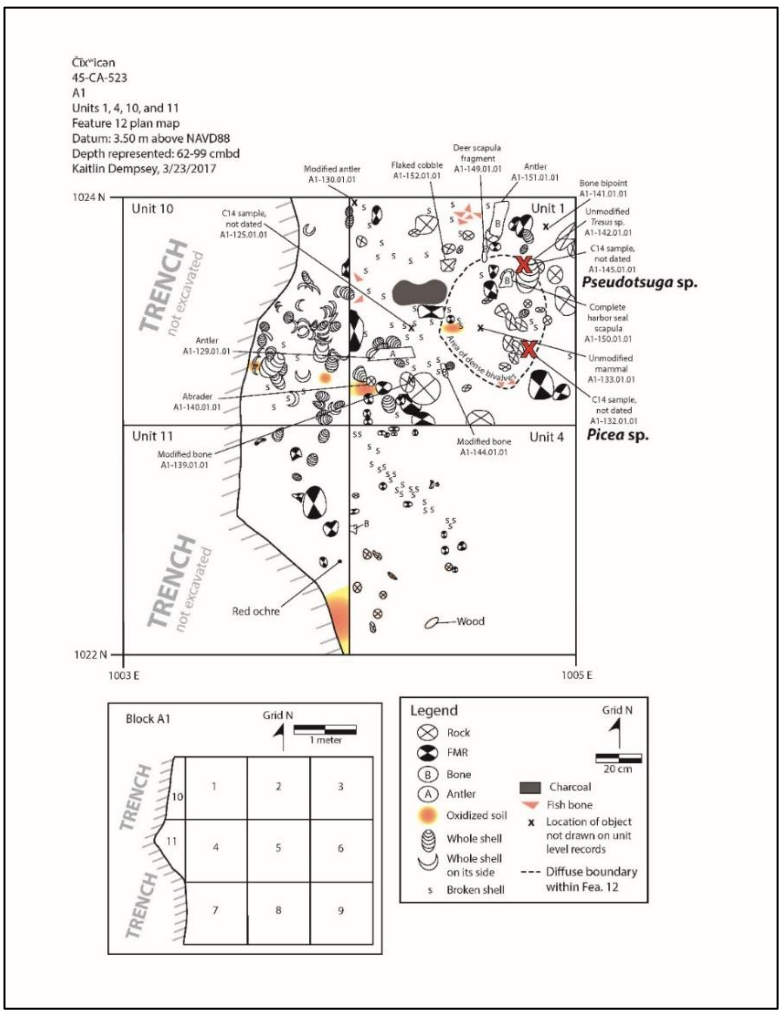

Figure 8. Plan map of Feature 12. Figure courtesy of Kaitlin Dempsey.

While Douglas fir dominates the conifers at Čǐxʷicən, alder is the most represented angiosperm. Fortunately, alder abundances are not biased by sample size, so Area 5 may represent an intense use of alder fuel (see Figure 9). These alder fragments occur primarily in Chronozones 5 and 6, dating between 1000 and 300 yr cal BP. As a mid-ranking fuelwood, alder may have been collected dry for a higher heat or cooking fire, or collected green or "unseasoned" to optimize for a smoky fire. The Lower Elwha Klallam tribe use alder wood to smoke salmon and deer meat, so the fragments found at Čǐxʷicən may have been burned for this purpose. It would be interesting to examine the potential increased use of alder after 1000 cal BP with a larger sample.

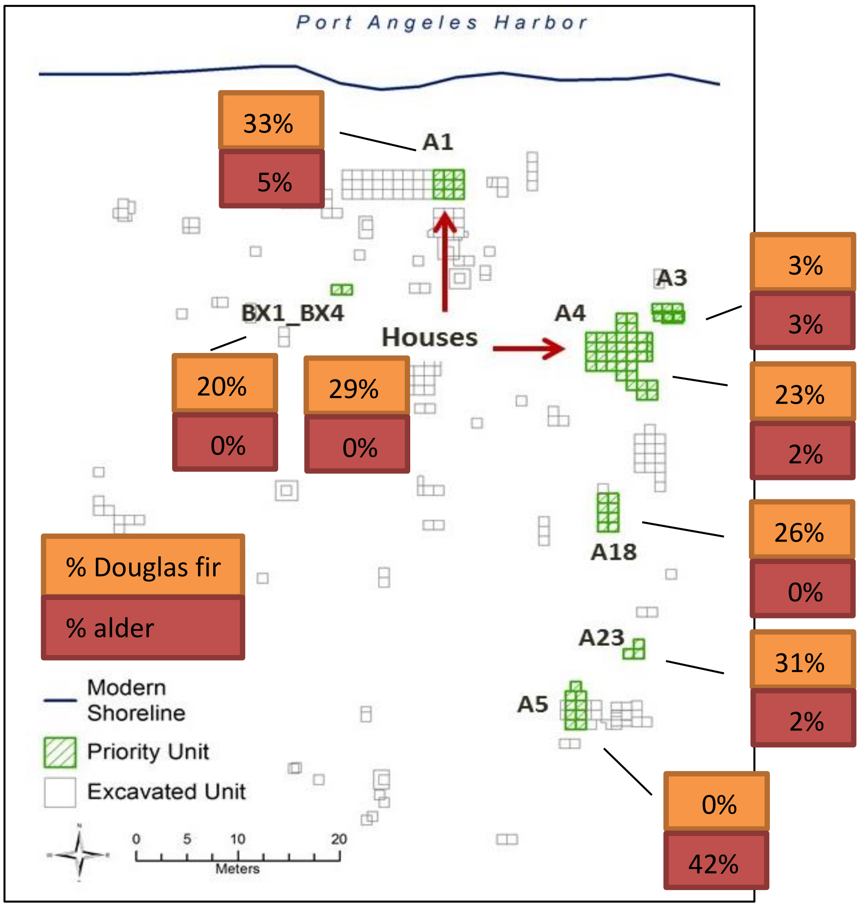

Figure 9. Relative abundance of Douglas fir and alder, by area. Figure (modified) courtesy of Kaitlin Dempsey.

IVe. Deadwood and Driftwood Harvesting

As previously mentioned, FVI rankings can be affected by the amount of moisture in a piece of wood – so, collecting green wood (high moisture) or deadwood/driftwood (low moisture/already seasoned) can make a difference in the fuel value. Unfortunately, moisture content is a property that is difficult to access in archaeological charcoal.

Fuel remains can, occasionally, exhibit signs that they were collected as deadwood or driftwood. Nancy Turner and Sandra Peacock (2015:108), in the book "Keeping It Living," state that

Northwest Coast native peoples often collected fuelwood from dead or downed trees, as driftwood, and sometimes as branches from living trees. This makes sense, since using deadwood or driftwood removes the need to process a huge tree and, many times, the pieces are already seasoned.

Anatomical features that may support a deadwood or driftwood designation include:

1. Spiral checking in the wood (see Figure 10) – this feature is indicative of compression wood in conifers (found on the underside of branches or leaning wood, also found on twigs and small branch pieces); this feature by itself does not indicate deadwood, but it is useful in combination with other features;
2. Fungal hyphae (Figure 11) and vegetative spores – these fungi are evidence of pre-combustion degradation and they usually penetrate wood where bark is absent, especially in humid environments.

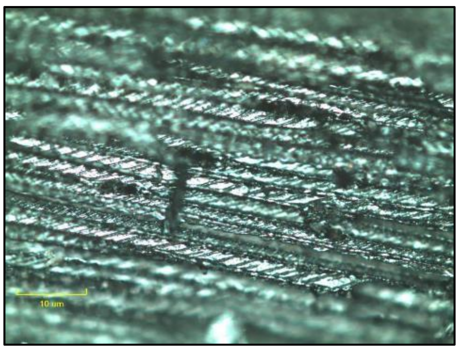

Figure 10. Spiral checking.

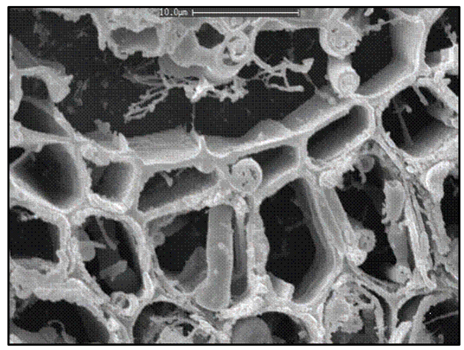

Figure 11. Fungal hyphae.

At Č̓íxʷicən, there are several examples that wood may have been collected as deadwood from the forest floor, or as driftwood. For instance:

- At least fourteen charcoal fragments exhibit spiral checking. They are all conifers, and likely represent branch or twig wood.
- At least four fragments show fungal hyphae – indicative of deadwood or driftwood.

Further research questions on the topic of deadwood and driftwood gathering may be possible with a larger, more comprehensive charcoal sample. For instance, earthquakes can trigger co-seismic subsidence, which can drown forests, and tsunamis have the potential to create significant quantities of driftwood. It is possible that a shift in the balance of fuelwood use may occur after a seismic event, thereby affecting the balance of wood collected from forests versus from a driftwood catchment area.

V. CONCLUSION

This study places the taxonomic identifications of archaeological charcoal into greater cultural context by using a fuel value ranking of local woods and examining ethnobotanical information from western Washington tribes. These lines of inquiry suggest a rich history of tree and shrub use at Čí̓xʷicən, one that made use of the diverse resources offered by the Pacific Coastal Forest. In particular, Douglas fir, spruce, and alder, were widely used throughout the more than 2,000 year occupation of the village. Other woods were also used and were likely important, such as cedar, hemlock, and maple, but may be underestimated in the assemblage due to the priority of identifying short-lived hardwoods for AMS dating.

Small-batch charcoal assemblages, like the one investigated here, may begin as a radiocarbon "pre-analysis," but they can inform larger resource acquisition and use topics. This study suggests that Čí̓xʷicən inhabitants employed a sophisticated understanding of wood and burning properties to suit their needs. The combustion features at Čí̓xʷicən were constructed for a variety of purposes - fires may have been lit to smoke or dry foods, as well as to provide high temperature fires for heating or boiling. For instance, the charcoal record indicates that Douglas fir was very important to Čí̓xʷicən residents, possibly as a fuelwood for cooking and heating hearths. Alder wood was also burned, and may have been used to smoke or dry raw foods. In addition, there is some evidence for berry drying and preservation at the Čí̓xʷicən site.

Many paleoethnobotanical research opportunities could be pursued with the Čí̓xʷicən charcoal assemblage, including: 1) fuel management – is there more to learn about wood fuel management generally, and specifically about use of deadwood and driftwood?; 2) is increased fuel efficiency apparent in the archaeological charcoal record during colder times?; and 3) can we see increased use of degraded wood (possibly driftwood) following a seismic event? These research directions would be bolstered by information from the Lower Elwha Klallam Tribe pertaining to traditional knowledge of woody taxa, as well as a reexamination of the "unidentified" portion of the charcoal assemblage. In addition, faunal and non-woody botanical data have the potential to provide corroborating information, especially on the subject of the smoking and/or drying of shellfish, fish, and berries at Čí̓xʷicən.

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