Études/Inuit/Studies

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Volume 36, Number 1, 2012

Les peuples de l'Arctique et le bois
Arctic peoples and wood

URI: https://id.erudit.org/iderudit/1015954ar
DOI: https://doi.org/10.7202/1015954ar

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Publisher(s)

Association Inuksiutiit Katimajiit Inc.
Centre interuniversitaire d'études et de recherches autochtones (CIÉRA)

ISSN

0701-1008 (print)
1708-5268 (digital)

Explore this journal

Cite this article

Shaw, J. D. (2012). Economies of driftwood: Fuel harvesting strategies in the Kodiak Archipelago. *Études/Inuit/Studies*, *36*(1), 63–88. https://doi.org/10.7202/1015954ar

Article abstract

Fuelwood harvesting is an integral part of the subsistence regime for many Arctic and subarctic peoples. Despite the relative paucity of woody resources in the northern tundra, charred wood fragments recovered from archaeological sites reveal a harvesting practice that is thousands of years old. Indeed, fuelwood gathering is a strategic behaviour involving a complex set of decisions beyond merely harvesting by proximity, as some have proposed. In this research, fuelwood harvesting is modeled within an economic framework. A fuel value index (FVI) is established to quantify the energetic returns of different wood species, and ethnographic interviews with Kodiak Island residents demonstrate the knowledge context that surrounds firewood acquisition. Archaeological charcoal from Kodiak Archipelago sites showcases a flexible, though increasingly selective strategy of fuelwood use by early inhabitants. For 7,500 years, maritime hunter-gatherers in the Gulf of Alaska took advantage of wood patchiness; they used a combination of exotic coniferous species in the form of driftwood and native deciduous trees such as alder to fuel their steam baths, smokehouses, and homes.

Economies of driftwood: Fuel harvesting strategies in the Kodiak Archipelago

Jennie Deo Shaw*

Résumé: Économie du bois flotté. Stratégies de ramassage du bois de feu dans l'archipel de Kodiak

Le ramassage du bois de feu fait partie intégrante de la subsistance de nombreux peuples arctiques et subarctiques. Malgré la relative rareté des ressources en bois dans la toundra nordique, les fragments de charbon de bois découverts dans des sites archéologiques révèlent que la pratique du ramassage remonte à plusieurs milliers d'années. De fait, le ramassage du bois de feu est un comportement stratégique impliquant un ensemble complexe de décisions allant au-delà de la simple récolte de proximité, comme certains l'ont suggéré. Dans cette recherche, le ramassage du bois de feu est intégré à un modèle économique. Nous avons élaboré un index de valeur énergétique quantifiant différents types de bois, et mené des entrevues ethnographiques avec des résidents de l'archipel de Kodiak, qui montrent le contexte de connaissances relatives à l'acquisition du bois de feu. Les charbons provenant des sites archéologiques de l'archipel de Kodiak illustrent une stratégie d'usage du bois de feu flexible, quoique de plus en plus sélective, par les premiers habitants. Pendant 7500 ans, les chasseurs-cueilleurs maritimes du golfe de l'Alaska ont tiré parti de la distribution irrégulière du bois; ils combinaient des conifères exotiques sous la forme du bois flotté et les feuillus locaux tels que l'aulne pour leurs bains de vapeur, leurs fumoirs et leurs maisons.

Abstract: Economies of driftwood: Fuel harvesting strategies in the Kodiak Archipelago

Fuelwood harvesting is an integral part of the subsistence regime for many Arctic and subarctic peoples. Despite the relative paucity of woody resources in the northern tundra, charred wood fragments recovered from archaeological sites reveal a harvesting practice that is thousands of years old. Indeed, fuelwood gathering is a strategic behaviour involving a complex set of decisions beyond merely harvesting by proximity, as some have proposed. In this research, fuelwood harvesting is modeled within an economic framework. A fuel value index (FVI) is established to quantify the energetic returns of different wood species, and ethnographic interviews with Kodiak Island residents demonstrate the knowledge context that surrounds firewood acquisition. Archaeological charcoal from Kodiak Archipelago sites showcases a flexible, though increasingly selective strategy of fuelwood use by early inhabitants. For 7,500 years, maritime hunter-gatherers in the Gulf of Alaska took advantage of wood patchiness; they used a combination of exotic coniferous species in the form of driftwood and native deciduous trees such as alder to fuel their steam baths, smokehouses, and homes.

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Introduction

In the frigid climes of the Arctic and subarctic, bits of charred wood (referred to herein as "charcoal") tell the tale of ancient fires that once warmed families, cooked food, fuelled steam baths, smoked fish, and aided in the many subsistence-related pursuits of daily life. Wood was not the only fuel used by high-latitude societies—archaeological and ethnographic evidence suggests bone, peat, sea mammal oil, coal, and even seaweed also were common fuel resources (Costamagno et al. 2005; Heizer 1963; Hoffecker and Elias 2007; Steffian 1992). However, wood remains are ubiquitous at northern archaeological sites, often represented by hearths and middens filled with charcoal.

Firewood is often assumed to be present at archaeological sites in direct proportion to the tree species available in the environs (e.g., Shackleton and Prins 1992). A large body of literature points, however, to a more complex method of selection, based on size and quality of different resources, on time, and energy used to harvest resources, and on species preferences (Broughton 1994a, 1994b; Cannon 2003; Grayson and Cannon 1999; Grayson and Delpech 1998; Gremillion 1997). Like other subsistence items, wood types provide variable energy returns (i.e., heat values) and require different levels of effort to harvest. Woody species, therefore, are not equally profitable. To understand the fuelwood economy of a given population, it is possible to quantify the energetic returns of fuelwood and use qualitative information on harvesting costs.

In this study, I aim to demonstrate how fuelwood harvesting can be modeled within an economic framework, rather than the usual assumption of "harvesting by proximity." I will use three lines of evidence to assess the relative importance of woody taxa to 7,500 years of Kodiak Island fuelwood harvesters: ethnographic interviews; energetic properties of fuelwoods; and taxonomic identification of archaeological charcoal. This study will address three primary questions: 1) What is the degree to which modern harvesters differentiate and target potential fuelwoods? 2) Which woods and patches were the most economically valuable through time as defined by energy available? 3) Did pre-industrial fuelwood harvesters seek to maximise heat or smoke generation, minimise handling costs, or combine these strategies when searching for wood?

Fuelwood selection is influenced not only by differences in heat content, smoke content, and harvesting costs, but also by environmental factors, such as the distribution of woody species on the landscape and the position of sites relative to wood thickets and driftwood beaches. Post-glacial vegetation histories in Alaska indicate resurgence and redistribution of woody taxa, as habitats opened and climate shifted. Driftwood beaches exhibit variable log density, depending on their orientation toward fast-moving currents or slow-moving channels. These environmental factors, as well as elusive factors like cultural preference, will be examined in this article.

Fuelwood availability and distribution on the Kodiak Archipelago

Kodiak lies at the boundary of the forested and unforested regions of the North, and as a subarctic case study it perhaps defines the southern limits of fuel harvesting in tundra-dominated ecosystems. The southern portion of the Kodiak Archipelago is a natural location to conduct fuel-related research not only because of its well-documented record of human habitation, but also because of its position at a vegetational crossroads—the northern third of Kodiak is forested (but only has been for the last 1,000 years), while the southern two-thirds is a mixture of alpine and lowland tundra devoid of large trees (Figure 1). Also, since Kodiak is adjacent to the powerful Alaska Coastal Current and the Alaskan Stream, driftwood "catcher beaches" (Adams 1998) have been historically, and I would argue prehistorically, integral to the greater fuelwood subsistence strategy. In his excavations of Saqqaq sites in Greenland, Grønnow (1996) demonstrated that their residents depended upon driftwood for tool manufacture, construction, and fuel. Similarly, to evaluate the fuelwood harvesting strategies on Kodiak, it is important to understand the background of two critical variables: the people and the fuel resources.

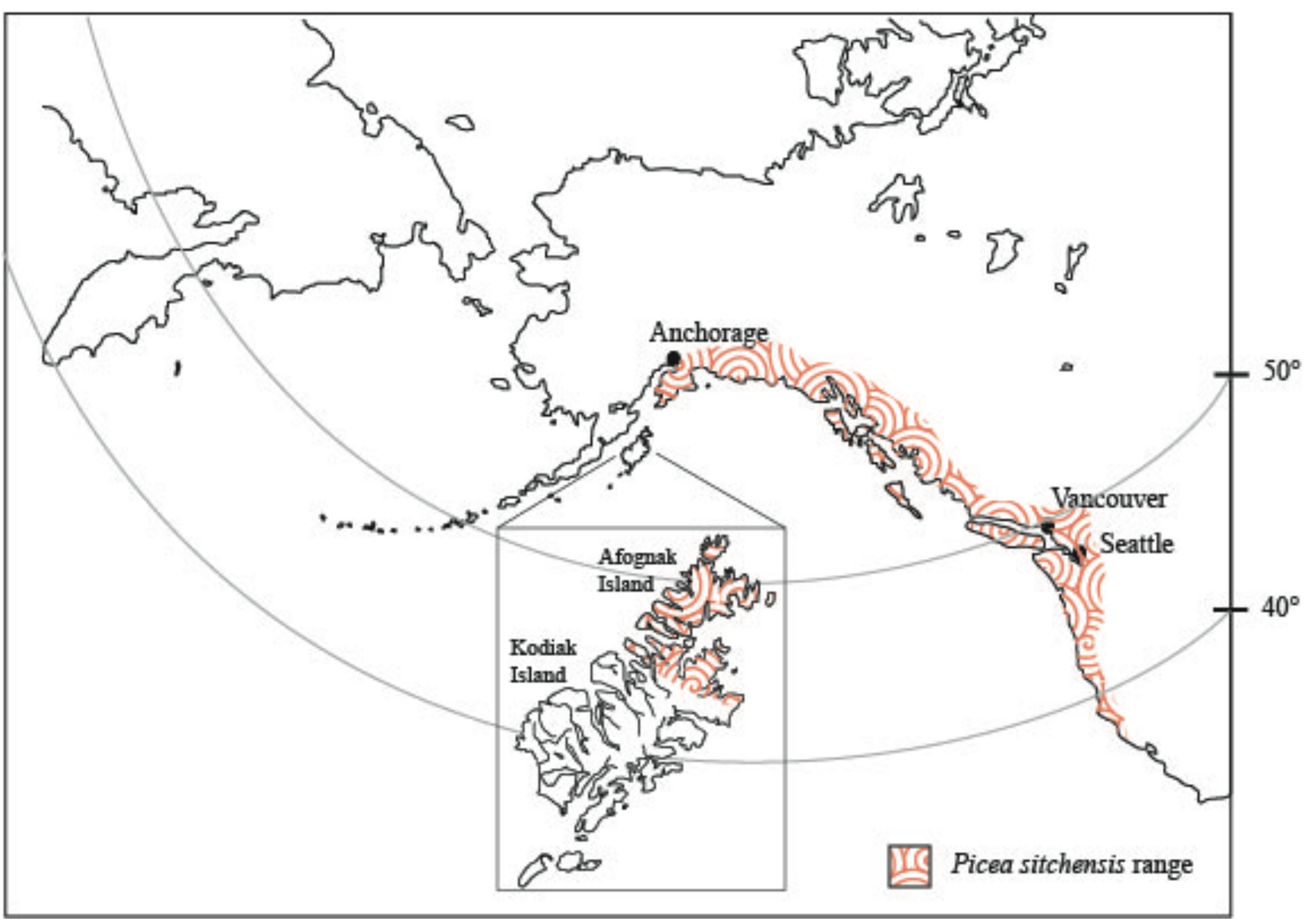

Figure 1. Location of Kodiak Archipelago and modern distribution of Sitka spruce (*Picea sitchensis*) (after Viereck and Little 1975).

Traditional use of fuelwood on Kodiak

Many Kodiak-area residents identify themselves as Alutiiq—referring to both the language and the people who traditionally have inhabited portions of the Alaska Peninsula, the Kodiak Archipelago, the Kenai Peninsula, and Prince William Sound. Archaeological research has documented at least 7,500 years of human habitation on Kodiak, culminating in the complex hunter-gatherer society encountered by Russian explorers in 1784 (Fitzhugh 2003).

Today, fuelwood harvesting on Kodiak includes collection of standing wood as well as driftwood, and the importance of wood permeates all aspects of island culture. In fact, driftwood collection has been critical enough to warrant a specific Alutiiq word, *kapilaaq*, as well as a host of related terms: *pukilaaq* (small driftwood); *tep'aq* (driftwood log); and *napaq* (spruce tree) (Drabek and Adams 2004). Modern village residents use wood for many purposes, but the *banya* (the commonly used Russian word for steam baths) is an especially important tradition on Kodiak (Figure 2). Written records highlight the role of banyas as social and medicinal venues where extended families and neighbours would convene (Holmberg 1985 [1855-1863]). Archaeological investigations have uncovered rooms that contain large quantities of fire-cracked rocks, charcoal, and water-dipping tools, thus extending the use of such baths back several thousand years (Steffian 2001).

The practice of smoking and storing fish for winter consumption is at least 3,300 years old in Kodiak (Steffian et al. 2006) and represents another end-use category for fuelwood. Large charcoal accumulations start to appear in the archaeological record at Early Kachemak tradition sites, such as the Zaimka Mound, Outlet, and Horseshoe Cove sites, dated between 4000 and 2700 cal BP. The accumulations are presumed to represent fish drying or smoking sites, based on the intermingling of faunal and wood remains (Saltonstall and Steffian 2006; Tennessen 2000).

Driftwood and standing wood have long been harvested for non-fuel-related purposes such as construction, tool manufacture, and kayak and umiak production. This study, however, considers only fuel-related activities and their associated signature in the archaeological record.

The resource

Archaeological research and ethnohistoric records show that the primary fuel used by Indigenous Kodiak Island residents was wood (Knecht 1995; Steffian et al. 2006; Tennessen 2000). Stone lamps fuelled by sea mammal oil were commonly used to produce heat and light, but abundant charcoal deposits suggest that wood was the staple fuel that heated semi-subterranean sod homes, smoked salmon, and warmed the all-important banya. Woody biomass on Kodiak is concentrated in two patches: terrestrial and littoral.

Figure 2. a) (top) interior and b) (bottom) exterior of the banya on the Mary Haakanson property, Old Harbor, Kodiak Island, Alaska, 2004. Photo by Jennie Deo Shaw.

Terrestrial patches simply contain living, or standing, woody shrubs and trees, and their associated deadwood. The extreme variation of vegetation in terrestrial wood patches across the archipelago deserves emphasis. The northeastern portions of Kodiak are dominated by forests of Sitka spruce (*Picea sitchensis*) and occasional stands of black cottonwood (*Populus trichocarpa*) (Peteet and Mann 1994; Viereck and Little 1975). Sitka spruce has spread into the northern third of the region only within the last 1,000 years (Heusser 1960), as shown in Figure 1. In contrast, the southwestern end is unforested and tundra-dominated, exhibiting rolling meadows of grasses, sedges, heaths, berries, and wildflowers, as well as thickets of shrubby Sitka alder (*Alnus sinuata*), willows (*Salix* spp.), and Kenai birch (*Betula kenaica*) that dot the low-elevation zones (Peteet and Mann 1994; Viereck and Little 1972). Black cottonwood and balsam poplar (*Populus balsamifera*) may also be found along river valleys and in other low-lying areas in the south.

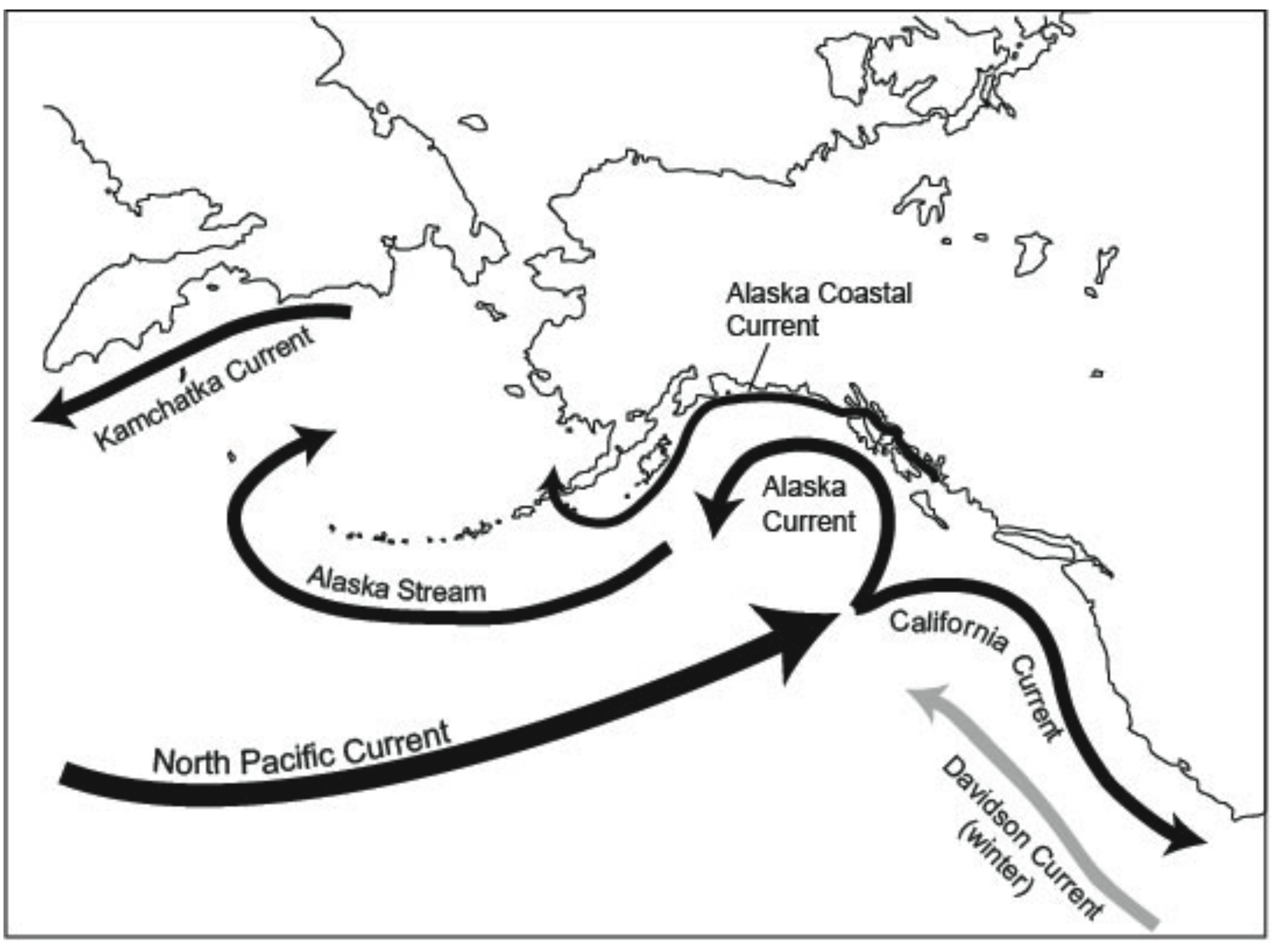

Figure 3. Dominant ocean surface currents in the Northeast Pacific.

Littoral patches are beach catchments; they contain only dead wood in the form of driftwood. Certain "catcher beaches" trap large quantities of driftwood that have washed in from local rivers and from the mainland (Adams 1998). The type and character of driftwood found in Kodiak depends largely upon the trajectories of ocean currents, and the dominant North Pacific circulation pattern is shown in Figure 3 (Reed and Schumacher 1986; Thomson 1981: 230). Given these current patterns, British

Columbia, Southeast Alaska, Prince William Sound, the Kenai Peninsula, and the Kodiak Islands themselves have been the source areas for most of the driftwood gathered by Kodiak residents for 7,500 years. Washington, Oregon, and California must be added, since the California Current is blown offshore during winter months and gives way to the Davidson Current, thus reversing the coastal current from southbound to northbound (Thomson 1981: 232).

Several researchers have documented the dynamics of driftwood abundance and distribution as they relate to past coastal economies in other regions of the Arctic and subarctic (Alix 2001, 2005, 2009; Alix and Koester 2002; Dyke and Savelle 2000; Eggertsson and Laeyendecker 1995; Fitzhugh 1996; Lepofsky et al. 2003). Table 1 lists every woody taxon that a) attains tree or tall shrub height and b) is or was found at any time during the Holocene between the California and Kodiak coastlines, since all are potential driftwood source areas. These taxa are and were potential candidates for driftwood arriving on Kodiak beaches. I have not included palaeoecological or abundance information here, but see Shaw (2008 Tables 2.1, 2.3) for a summary of modern and past species' distributions.

Modern fuelwood harvesters of Kodiak

Ethnographic information, in the form of interviews with modern fuelwood gatherers from Old Harbor, on the southeast coast of Kodiak Island, was used to answer the first question of this research: what is the degree to which modern harvesters differentiate and target potential fuelwoods? My assumption was that wood harvesters have developed a sensory "key" to identify and differentiate woods, which aids them in targeting the most appropriate wood for the desired end use. This assumption must be validated with modern harvesters before being applied to the archaeological charcoal record and the people who produced it.

In November 2004, I interviewed 15 Old Harbor residents who actively harvest driftwood and local deciduous woods for fuel consumption, or who did so in the past. As the largest of the six Aboriginal villages existing today on Kodiak, Old Harbor's population hovers just above 200 and many current residents were born and raised here. Old Harbor is the closest inhabited village to the archaeological locus of this research—Sitkalidak Island (Figure 4). My questions were intended to elicit information on harvesting locations, quantities, methods, and preferred species (for the entire ethnographic analysis, see Shaw 2008: 94-124). Based on open-ended questions, I evaluated three assumptions about fuel harvesting:

1) Fuelwood harvesters can differentiate woody taxa;
2) Fuelwoods are selected according to known energetic properties; and
3) Handling costs (e.g., distance, mode of transport, degree of processing) are a critical component of fuelwood harvesting.

Table 1. Trees and tall shrubs found in the Northwest Coast and Gulf of Alaska, during the Holocene.

Scientific name	**Common name**
Coniferous	
Abies amabilis	Pacific silver fir
Abies grandis	Grand fir
Abies lasiocarpa	Subalpine fir
Chamaecyparis lawsoniana	Port Orford cedar
Chamaecyparis nootkatensis	Alaska yellow cedar
Picea glauca	White spruce
Picea mariana	Black spruce
Picea sitchensis	Sitka spruce
Pinus contorta	Lodgepole pine
Pinus monticola	Western white pine
Pseudotsuga menziesii	Douglas fir
Sequoia sempervirens	Redwood
Taxus brevifolia	Pacific yew
Thuja plicata	Western red cedar
Tsuga heterophylla	Western hemlock
Tsuga mertensiana	Mountain hemlock
Deciduous	
Acer circinatum	Vine maple
Acer glabrum var. *douglasii*	Douglas maple
Acer macrophyllum	Bigleaf maple
Alnus rubra	Red alder
Alnus sinuata	Sitka alder
Alnus tenuifolia	Thinleaf alder
Arbutus menziesii	Pacific madrone
Betula papyrifera	Paper birch
Betula papyrifera var. *kenaica*	Kenai birch
Castanopis chrysophylla	Golden chinkapin
Cornus nuttallii	Pacific dogwood
Echinopanax horridum	Devil's club
Fraxinus latifolia	Oregon ash
Malus fusca	Pacific crab apple
Menziesia ferruginea	Rusty menziesia
Populus balsamifera	Balsam poplar
Populus tremuloides	Quaking aspen
Populus trichocarpa	Black cottonwood
Prunus emarginata	Bitter cherry
Quercus garryana	Garry oak
Rubus spectabilis	Salmonberry
Salix spp.	Willows
Sambucus racemosa	Red elderberry
Sorbus sitchensis	Sitka mountain ash

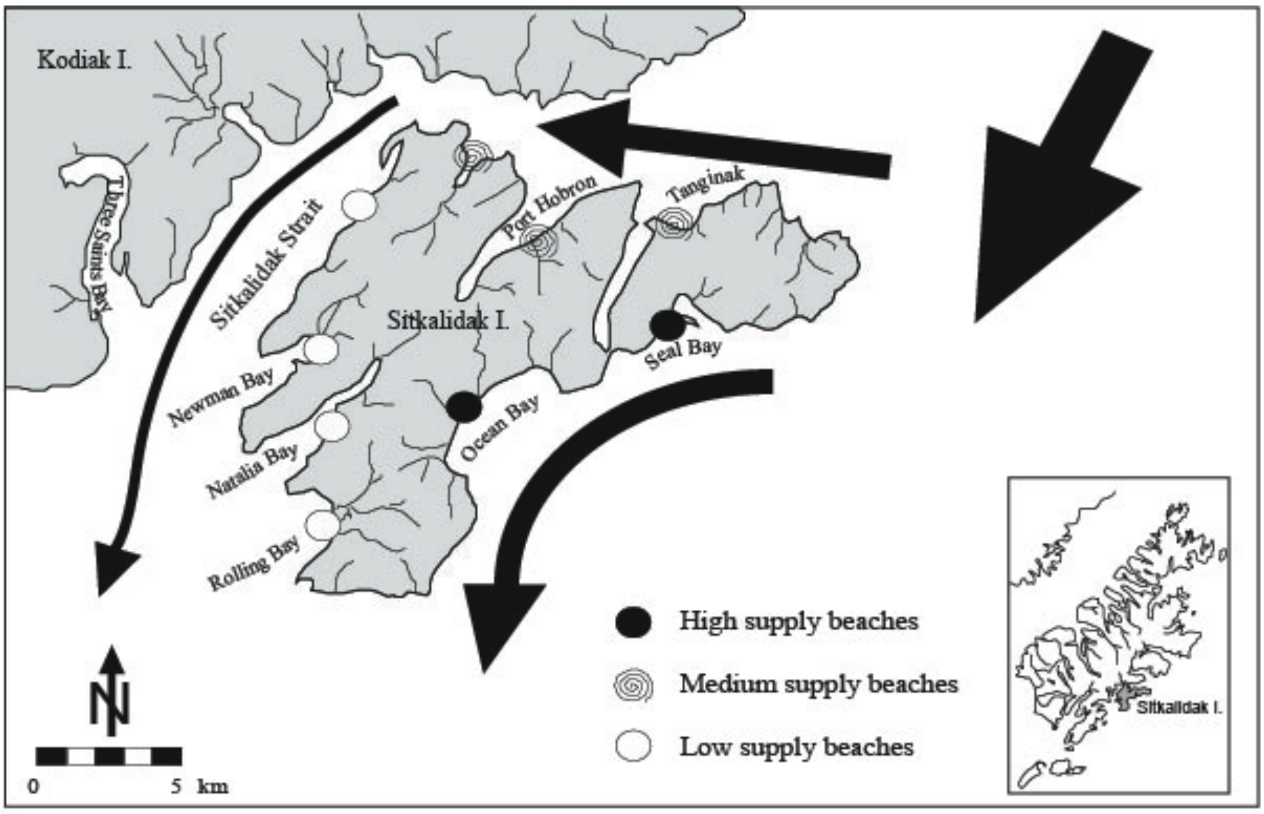

Figure 4. Sitkalidak Island high, medium, and low driftwood supply beaches. Arrow thickness represents relative speed of the ocean current.

Assumption #1: Fuelwood harvesters can differentiate woody taxa.

I asked various questions to try and determine each interviewee's ability to differentiate woody species. I started with general questions and proceeded to more specific ones. Results are presented in Table 2.

What kind of driftwood do you target?

Many individuals answered this question by naming a specific species or, if they did not know the name, by describing it. The most frequent answer was "any kind," but there were several mentions of specific taxa like cedar, spruce, hemlock, pine, and fir. Two participants mentioned qualitative characteristics like dry or short pieces. Interestingly, one reported that people used to be more selective in their driftwood preferences. He alluded to the fact that, today, people think "wood is wood" and do not know the difference between woods. His grandfather taught him how to choose good woods for burning and said, "if you just go and use any kind of wood, you'll be cleaning your smokestack a lot more… [to remove the] soot." Another gentleman said that he was not particular, but that his uncle was "choosy," preferring small-grained wood.

What kind of wood do you harvest for your smokehouse/wood stove/banya?

Cottonwood is by far the preferred wood for use in smokehouses, as mentioned by all individuals who responded (Table 2). A few also mentioned that they would harvest alder or Kenai birch (local birch). Out of fourteen respondents, nine cited alder as their preferred wood stove fuel, although six also mentioned (undifferentiated) driftwood as a good fuelwood for heating and four mentioned birch. A few interviewees preferred to mix the woods, usually alder mixed with driftwood. All of them preferred driftwood for "making banya," and only a few specified taxa like spruce, hemlock, or yellow cedar (Table 2).

Most respondents were able to differentiate some types of wood—whether by physical properties or by name—especially alder and cottonwood. It follows that most of them had a "key" by which they named or described wood, whether it was taught to them or learned by observation. Assumption #1 appears to be upheld.

Table 2. Responses to question, "What kind of wood do you harvest for your smokehouse/wood stove/banya?"

	No. of responses[1]		
	Smokehouse	**Wood stove**	**Banya**
Type of wood harvested	8	14	11
Cottonwood	8	-	-
Scrap wood – kindling	1	-	-
Alder	1	9	-
Birch	1	4	-
Driftwood (undifferentiated)	-	6	11
Mix	-	2	-
Driftwood – kindling	-	1	-
Not spruce	-	1	-
"Red ones"	-	1	-
Spruce	-	-	2
Dry pieces	-	-	2
Damp and dry	-	-	1
Yellow cedar	-	-	1
Hemlock	-	-	1

[1]Some interviewees offered multiple answers.

Assumption #2: Fuelwoods are selected according to known energetic properties.

Why do you target certain kinds of wood?

This question likewise flows from Assumption #1, but when interviewees were asked why they preferred certain species, another level of detail emerged. At least eight individuals selected cottonwood as their favoured smokehouse wood because it smokes the fish better and longer, and because it burns slower. Wet cottonwood was often targeted as driftwood on the beaches and creek banks because it does not burn as hot as other woods or, in the words of one participant, "if you get the dry stuff, it'll burn too hot and cook your fish." Others liked cottonwood for the good flavour it imparts to the fish, and one person specified that drift cottonwood results in saltier fish (also documented by Mishler [2001:172] in the villages of Old Harbor and Ouzinkie).

Alders, Kenai birch, and driftwood were targeted for fuelling wood stoves. Many individuals cited alder as a long and slow-burning wood that burns hot. Degree of heat was an issue inside the house, though, and one individual preferred alder heat because it is not too hot. Harvesting costs were among the selection criteria, as indicated by interviewees' claims that alder is accessible, abundant, and softer than Kenai birch to chop down. Four individuals added that alder ash is the best-tasting ash for making *iqmik* or snuff/chew. Traditional iqmik includes tobacco, black tea, and alder ash, among other ingredients, and according to one elder it used to be mixed in a hollowed-out whale vertebra called *culusuq*. Birch was also a desirable fuelwood for heating because it burns very hot (some say hotter than alder) and smells nice, although some participants claimed Kenai birch trees are hard to cut down and the ash is too strong for iqmik. One participant believed the Kenai birches are worth the greater effort to chop down.

One individual cited driftwood as a favourite heating wood because it does not "carbon up the stacks" like alder, which deposits a residue. For the wood stove, one gentleman preferred alder and Kenai birch before turning to driftwood, although he claimed driftwood had been used frequently in the past but burned faster. Another individual claimed that he would not burn spruce in the wood stove because it burns too hot. Some harvested driftwood for the wood stove when deep snow made harvesting alder and Kenai birch difficult. Many interviewees preferred red cedar for kindling, which only arrives as driftwood.

Several participants harvested driftwood to fuel their banyas, and a broad "driftwood" category was often described in terms of its heat value. One individual said that driftwood "burned better, or makes it hotter" and that alders "don't have as much heat as that regular wood." Interestingly, two gentlemen used the term "regular wood" to mean driftwood. Some individuals named certain species that have good fuel qualities: spruce burns hot because of the pitch content; hemlock leaves a nice coal; yellow cedar leaves a coal; and red cedar does not get that hot but burns quickly and is therefore good for kindling. Some individuals preferred driftwood because it comes in ready-to-go, short pieces or because its bulk reduces the number of pieces that need to be fed into a banya stove.

Assumption #3: Handling costs are a critical component of fuelwood harvesting.

"Handling costs" refer to round-trip travel time, mode of transport, search time, chopping effort, and curing time. Differences do exist between modern and past fuelwood harvesters, especially in the technology used to transport and process wood.

Today, gas-fuelled skiffs or fishing boats are used to access driftwood beaches, whereas human-powered skin and wood-framed boats were the only transport options in the past. I would suggest that significant costs exist in both transport categories—a monetary cost of filling a gas tank and an energetic cost of paddling a kayak or umiak—resulting in high costs to the forager in both scenarios. Chopping and cutting technology has also changed from the stone adzes and mauls of the past to the chainsaws of the present. Nevertheless, different handling costs must be ranked by relative importance to create a larger economic model of fuelwood harvesting.

If you arrive on a driftwood beach, how do you decide which logs you want to take?

Most interviewees answered with observations about the condition, size, or grain of the wood. Some of them cited only one criterion, but most based their log selection on several. The criteria mentioned include: dry (8 votes); no knots (5); small, i.e., pieces called pukilaaq that will fit in the banya or stove (3); close/fine grain (2); straight (1); easy to split (1); large (1); and high sap content (1).

The most commonly cited criterion was degree of dryness. Specifically, participants claimed they looked for logs that had been recently deposited (“new”), were lightweight, or appeared to float high in the water. One individual said wood that has been on the beach for a while is called “white wood” and is often ignored because it is rotten underneath. Low moisture content appears to be a desirable log quality, presumably because such logs are lighter to transport and require less seasoning time before use. Many harvesters hit the log with an axe and listen to the sound produced to determine dryness.

In addition to dryness, other criteria were important. A lack of knots or straight grain was a favourable quality, since knots can result in slow and unsafe chainsaw cutting. Many respondents noted that small pieces were desirable, thereby minimising the need for sawing and chopping. Ethnographic interviews clearly demonstrated that handling costs guided fuelwood selection, as seen in criteria that reduce the time and energy spent seasoning the wood (moisture content) and chopping the wood (size of log, knots).

Applying ethnographic information

By validating model assumptions with ethnographic information, we can make very general statements about fuelwood harvesting, such as: 1) fuelwood gatherers can differentiate woody taxa; 2) fuelwoods are selected for their known energetic properties; and 3) handling costs are a critical component of fuelwood harvesting. There is no reason to believe that past fuelwood gatherers did not recognise differences or inherent costs and benefits between different woods, as they do today, especially since research on other subsistence items indicates long-standing awareness of differences between resource attributes. Another step is needed, however, to link current ethnographic behaviour to the archaeological record.

Energetic values of Southern Alaskan fuelwoods

To address the second question in this research—which woods and patches were the most economically valuable through time?—it is necessary to determine what "value" woods may have had to the user. One assumption is that the most desirable woods for heating and cooking would be those that have high energy content or that give the highest realised heat output. I used a measure called the Fuel Value Index (FVI) to rank the energetic return of woods that may be found in the study area. The FVI (Jain 1992; Jain and Singh 1999) is calculated from four physical properties of wood, namely the calorific return, density, moisture content, and ash content, and is represented by a simple equation:

$$\text{Fuel Value Index (FVI)} = \frac{\text{(calorific return x density)}}{\text{(moisture content x ash content)}}$$

The calorific return and density positively affect the FVI, while the moisture and ash contents detract from the FVI. Therefore, a wood with high density and low moisture content will produce a higher FVI than a wood with low density and high moisture content. I ranked 20 woods according to the FVI system, as indicated in Table 3 (see Shaw 2008 for a full discussion of the FVI calculations). The woods represent the most common local deciduous woods and driftwoods on Kodiak. Douglas fir and Sitka spruce have the highest FVI, while western hemlock and black cottonwood have the lowest.

Quantifying the relative energetic returns of different woods is important because it provides a standard measure of realised heat. FVIs can then be used to help interpret the motivation behind fuelwood selection, past and present. For instance, I would interpret an archaeological charcoal assemblage that is dominated by Douglas fir, the highest-ranking wood in this study, as indicating a desire for heat production—perhaps banya or home heating. Similarly, I would interpret a charcoal assemblage composed primarily of cottonwood as indicative of low-heat fires—perhaps created for smoking or drying. Encountering large quantities of a mid-ranked wood on the FVI list, such as alder or willow, does not suggest a fire constructed for heat maximisation, nor one constructed for smoke generation. Rather, large quantities of alder or willow may suggest that higher FVI woods (for heat) or lower FVI woods (for smoke) were too costly to obtain, perhaps too distant or too difficult to chop. Following this logic, alder was selected because it was locally available and because harvesters sought to minimise the handling costs associated with more desirable woods.

The FVI method does assume that high energy content and high density are the primary characteristics valued by fuelwood foragers; however, we know that other criteria matter, such as the taste a smoky wood imparts to fish or the rapid burn of kindling. Although I have used simplified assumptions to model fuel value and do not discount the value of other qualitative criteria, I expect that these factors will enrich subsequent iterations of this research.

Table 3. Fuel value rankings for 20 woody taxa.

Tested species[1]			
Common name	**Fuel Value Index (kJ/cm^3)**	**Fuelwood rank**	**Comments**
Douglas fir	298,423	1	lowest ash
Sitka spruce	152,853	2	
Coast redwood	139,320	3	low ash, highest caloric
Lodgepole pine	77,461	4	highest moisture
Pacific yew	61,278	5	high caloric
Alaska yellow cedar	59,928	6	
Mountain spruce	49,843	7	
Kenai birch	48,897	8	
Red alder[2]	36,962	9	
Hooker willow	34,685	10	
Scouler willow	34,107	11	
Pacific silver fir	32,281	12	
Western red cedar	27,892	13	low density
Bigleaf maple	27,822	14	
Quaking aspen	26,917	15	
Devil's club	22,265	16	
Pacific madrone	21,507	17	highest density, high ash
Black cottonwood	20,657	18	
Western hemlock	13,199	19	high ash
Red elderberry	indet.	(20?)[2]	highest ash, high moisture

[1]Species in **bold** are native to Kodiak and Sitkalidak Islands today and have been present throughout much of the Holocene
[2]The density for red elderberry could not be determined due to small sample size. It is tentatively listed here as rank #20 due to its extremely high ash and moisture contents.

Archaeological charcoal from the Kodiak Archipelago

Sitkalidak Island case study

Sitkalidak Island, on the southeastern shore of Kodiak Island and southwest of the Sitka spruce forests, is devoid of large trees but still offers residents a choice of harvesting either native trees and shrubs or driftwood. The island also exhibits all intensity levels for driftwood-supplied beaches (Figure 4). High driftwood supply beaches exist on the eastern side of Sitkalidak Island where the Alaskan Stream parallels the land, whereas medium supply beaches occur on the northern shores, and low supply beaches are removed from the main trajectory of the Alaskan Stream and are located on the western side of Sitkalidak Strait (as defined by Fitzhugh 1996).

Ben Fitzhugh's (1996) Sitkalidak Archaeological Survey identified more than 150 archaeological sites, which collectively span the 7,500-year history of the Kodiak region. I chose six of the sites for charcoal analysis: KOD106, KOD112, KOD122, KOD379, KOD530, and KOD555. The sites crosscut spatial and temporal boundaries and, together, represent high, medium, and low driftwood supply bays (Figure 4 and Table 4), as well as the majority of cultural traditions on Kodiak: Ocean Bay I (7500-5500 cal BP) and II (5500-4000 cal BP); Late Kachemak (2700-800 cal BP); Koniag (800-200 cal BP); and Alutiiq (1784-present). The Early Kachemak tradition (4000-2700 cal BP) is quite elusive on Sitkalidak Island and is the one tradition in 7,500 years of prehistory that is not represented in this study.

Sitkalidak Island archaeological sites form a perfect testing ground for questions posed in this research: did pre-industrial fuelwood harvesters seek to maximise heat or smoke generation, to minimise handling costs, or to combine these strategies when searching for wood? In this case, woods with high FVIs likely maximised heat generation, woods with low FVIs maximised smoke generation, and woods with middling FVIs required less travel time, chopping, sawing, or curing, thereby minimising handling costs.

Table 4. Overview of archaeological sites chosen for this research.

Site name	Site number	SAS number[1]	Habitat	Driftwood supply rate	Cultural affiliation
Natalia Point Cove	KOD106	126	Coast of peninsula	Low	Koniag-Alutiiq transition
McCord Bay	KOD112	31	Inner bay	Medium	Late Kachemak, Koniag
Ocean Beach	KOD122	71	Exposed outer bay	High	Alutiiq
Outer Fox Lagoon	KOD379	34	Active spit	Medium	Late Kachemak, Koniag
Ocean Bay Stream	KOD530	82	Stream-side	High	Ocean Bay I-II transition
Barling Spit 4	KOD555	121	Sheltered spit	Low	Ocean Bay I

[1]The Sitkalidak Archaeological Survey (SAS) was conducted by Ben Fitzhugh in 1993, 1994, and 1995 and is published in Fitzhugh 1996.

Methods

During the Sitkalidak Archaeological Survey, Fitzhugh collected large quantities of archaeological charcoal from hearths, postholes, floors, middens, and other features. Although most of these samples are discrete "grab" samples and not bulk samples intended for flotation, care was taken to collect all visible charcoal fragments (Ben Fitzhugh, pers. comm. 2005). Detailed notes accompany the samples, including provenance information and descriptions of notable sediment or associated artifacts/features.

As is common in palaeoethnobotanical analyses, it was critical to separate the charcoal into size classes prior to sub-sampling the collection. Charcoal was passed through a set of nested geological sieves and separated into a maximum of five size classes per sample bag: >16 mm; 8-16 mm; 4-8 mm; 2-4 mm; and <2 mm. A random sub-sampling strategy resulted in the removal and analysis of 20 charcoal fragments from each size class in a given sample bag, for a total of 1,113 analysed fragments. The provenance information for each sample bag is presented in Table 5. Charcoal fragments were fractured with a single-edged razor in order to expose three planes: transverse (or cross); tangential; and radial. The fractured specimens were then mounted for microscopy. Charcoal fragments were taxonomically assigned to a genus, where possible, using a Leica reflected-light microscope in the University of Washington Archaeological Microscopy Laboratory.

Table 5. Provenance information for charcoal samples used in taxonomic analyses.

Site name	Sample bag no.	Provenance[1]
Natalia Point Cove	KOD106#399	House 1 (multi-room house pit), TP1, 13-24 cm, hearth
	KOD106#400	House 1, TP1, 28-38 cm, hearth
	KOD106#401	House 1, TP1, 62 cm, base of FCR zone
	KOD106#402	House 9 (small house pit), TP2, 20-25 cm, floor
	KOD106#403	House 9, TP3, 14-21 cm, hearth
	KOD106#404	House 9, TP3, 30-41 cm, hearth
McCord Bay	KOD112#76	TP3, 30-38 cm, clay-lined pit, greasy black FCR
	KOD112#75	TP3, 62 cm, clay-lined pit, greasy black soil
Ocean Beach	KOD122#171	House pit, TP3, 10-20 cm, roof sod
	KOD122#172	House pit, TP3, 28-31 cm, floor
	KOD122#173	House pit, TP3, 38 cm, black greasy layer
Outer Fox Lagoon	KOD379#84	House pit 1, TP1, 33 cm, dark brown soil w/ FCR
	KOD379#85	House pit 1, TP1, 72-77 cm, shell midden pockets
	KOD379#86	House pit 1, TP1, 84 cm, shell midden pockets
	KOD379#249	House w/ side room, TP4, 20-50 cm, sandy w/ FCR
	KOD379#250	House w/ side room, TP4, 49-57 cm, FCR pavement
	KOD379#251	House w/ side room, TP4, 57-72 cm, clay-rich sediment
Ocean Bay Stream	KOD530#411	TP2, layered charcoal/red ochre surfaces
	KOD530#412	TP2, 50 cm, red ochre surface
	KOD530#414	TP3, 65 cm
	KOD530#413	TP3, 70 cm
	KOD530#415	TP3, 65-70 cm
Barling Spit 4	KOD555#383	Locus 1, TP1, 20-55 cm, charcoal & gravel
	KOD555#384	Locus 1, TP1, 55-58 cm, 1st floor
	KOD555#385	Locus 1, TP1, 74-76 cm, 2nd floor
	KOD555#386	Locus 1, TP1, 91 cm, fill above 3rd floor
	KOD555#387	Locus 1, TP1, 91-99 cm, 3rd floor

[1]All samples were collected and described by Dr. Ben Fitzhugh, in conjunction with his 1996 dissertation research. TP = test pit, FCR = fire-cracked rock.

Overview of charcoal analysis

The abundance percentages presented here reflect the number of fragments assigned to a genus divided by the total number of identified specimens (NISP), which is 1,113. They were calculated according to many different scales: entire assemblage; archaeological site; driftwood supply site (low, medium, high); and cultural tradition, as presented in this article, as well as by sample bag and test pit, as described in Shaw (2008: 169-184).

Overall, alder (*Alnus*) is the most abundant wood in the assemblage, representing 43% of the total analysed charcoal fragments. The aggregated assemblage is also 17% spruce (*Picea*), 11% cottonwood (*Populus*), 2% Douglas fir (*Pseudotsuga menzeisii*), 2% birch (*Betula*), and 2% hemlock (*Tsuga*). Seven other woody genera are present in trace amounts (*Salix*, *Sambucus*, *Thuja*, *Chamaecyparis*, *Abies*, *Acer*, and *Prunus*). As native deciduous taxa, alder, cottonwood, and Kenai birch may be indicative of either terrestrial or littoral patch exploitation, although harvesting of alder and Kenai birch from terrestrial patches would entail lower handling costs than harvesting of the same woods as driftwood (for handling-cost comparisons, see Shaw 2008: Tables 5.6-5.11). Cottonwood may have been equally expensive to obtain from terrestrial and littoral patches, but for simplification I will consider cottonwood fragments as a product of terrestrial harvesting. Coniferous woods like spruce, Douglas fir, and hemlock, on the other hand, were almost certainly gathered as driftwood. The taxonomic results are neither temporally nor spatially homogenous but rather show real differences between Sitkalidak area sites and across cultural traditions.

Temporal patterning in wood harvesting strategies

During the earliest Ocean Bay phases on Sitkalidak Island (7500-4000 cal BP), local deciduous woods dominated the assemblages and the charcoal reflects a high degree of wood specialisation, especially during Ocean Bay I (OBI). OBI sites adhere to a handling-cost-only selection strategy, based on high alder representation (71%; OBI NISP=204), although high-fuel value coniferous driftwoods were harvested and burned in small quantities during the time of this early cultural tradition. The Ocean Bay II (OBII) assemblage has 50% relative abundance of cottonwood (OBII NISP=217). This low-fuel-value preference (Table 3) may represent early evidence for fish smoking and/or drying. It is likely no coincidence that the major OBII site, KOD530, is located on a rise above the largest salmon run on Sitkalidak Island—the Ocean Bay Stream. Throughout Kodiak, the OBII tradition marks the incipient stages of large-scale fishing and the associated practice of processing fish for storage.

The Early Kachemak (4000-2700 cal BP) is not represented in this study. The analysis resumes with Late Kachemak-era sites (2700-800 cal BP), which contain over 50% coniferous wood, or driftwood, and exhibit the least specialised wood assemblages (Late Kachemak NISP=131). This increased reliance on spruce may be explained by the northwest expansion of *Picea* ranges on the mainland and a concomitant increase in spruce driftwood travelling to Kodiak. Late Kachemak tradition sites indicate that inhabitants sought to maximise heat generation, as demonstrated by use of the highest-ranking woods in the FVI study: Douglas fir and spruce.

Koniag sites (800-200 cal BP) returned to alder-dominated assemblages (54%; Koniag NISP=423) and, presumably, to a handling-cost-guided selection strategy. The reduction in Koniag-era spruce use is puzzling (only 14%), especially since spruce was more available than ever on Sitkalidak Island. A combination of territorial circumscription and preservation of the largest, straightest driftwood logs for use in construction may have contributed to the decline in spruce firewood.

The single Alutiiq-era site (200-0 cal BP) exhibits nearly 80% coniferous driftwood charcoal (Alutiiq NISP=138) and once again supports a strategy of heat maximisation. Spruce would have provided very efficient heat; perhaps not a coincidence, as this period is associated with the Little Ice Age. More analysis is needed in order to accurately interpret Alutiiq period fuelwood harvesting strategies, since interpretations presented here are based on a solitary site.

Spatial patterning in wood harvesting strategies

Taxonomic results were also broken down into low, medium, and high supply sites of Sitkalidak Island, since field observations indicate that the driftwood supply fluctuates radically in line with the proximity to faster driftwood-bearing currents (after Fitzhugh 1996) (Figure 4). For instance, alder is the dominant wood appearing at low supply side sites (68% of total), and its presence seems to indicate that residents were willing to make do with a moderate-FVI wood to reduce handling costs. Low supply site charcoal assemblages possess very little coniferous wood (10% of total). Coniferous wood (e.g., spruce, hemlock, cedar) is found only as driftwood on Sitkalidak. These large-diameter driftwood logs are unlikely to be transported by slow currents—also known as low-competency currents—suggesting that low supply side residents occasionally travelled to or traded for wood from higher supply catcher beaches, although in far smaller quantities than for wood from alder patches.

On the medium driftwood supply side of Sitkalidak Island, the taxonomic analyses suggest that residents were harvesting from driftwood-supplied beaches, as indicated by a 47% coniferous wood representation, primarily spruce and Douglas fir. Although alder represents 37% of the assemblage at medium supply sites, the overall harvesting strategy made heat production the priority.

On Sitkalidak Island's high driftwood supply side, charcoal assemblages are 28% spruce, 25% cottonwood, and 20% alder, although in actuality the two high supply sites display very different charcoal patterns. One high supply site (KOD530) is dominated by cottonwood, while the other site (KOD122) shows a bias toward spruce. Based on the charcoal data, KOD530 fuelwood was gathered for smoke generation, while KOD122 fuelwood was collected for heat generation. The data indicate different fire functions were pursued at each locale; therefore, these sites should be considered separately.

It follows that the fuel value parameter proposed by this research may not have been a selection criterion in driftwood-limited coastal areas, as it was at certain medium and high supply sites. There appears to be a wood supply threshold at which fuel value becomes a wood selection criterion and, on Kodiak, that threshold is met along coastlines that face and are directly adjacent to the Alaska Coastal Current. In other words, where choice is available, residents appear more likely to select wood according to fuel value. The taxonomic results presented here suggest that Sitkalidak Island inhabitants were not selecting wood capriciously but rather had particular strategies and end use categories in mind when harvesting fuelwood. Wood harvesting strategies generally became less specialised over time and one of the highest-ranking fuelwoods from an FVI perspective, spruce, emerged as a dominant fuelwood choice by historic times. As wood needs diversified with the addition of banyas and mass-processing of fish for storage and increased with house size and population, it is natural that the Alutiiq people would have adapted their fuelwood harvesting strategies accordingly.

Trends in Sitkalidak Island charcoal

Increasing spruce exploitation through time

One of the most significant trends in this research is an increase in spruce abundance from the earliest occupation of Kodiak, around 7,500 years ago, through the historic Alutiiq phase. This trend is partially attributable to the increasing availability of spruce, as its habitat spread north and west, eventually being harvested on Sitkalidak Island as driftwood. Spruce availability, however, is only a part of the story. I believe that spruce's high FVI ranking indicates that this woody taxon offered a fuel efficiency that exceeded that of any native wood. Indigenous harvesters would have recognised this advantage and targeted spruce whenever possible, especially when temperatures dipped. Spruce and another high-FVI wood, Douglas fir, were indeed preferred during at least two cool intervals. Site KOD530 shows an increase in relative spruce abundance from ca. 5900 to 5000 cal BP, coincident with a major cooling episode in the Gulf of Alaska (Mann et al. 1998: Figure 2). This site is located near Ocean Beach, where the largest driftwood accumulations in the study area occur today. In addition, the dominance of spruce during the historic Alutiiq period overlaps with the widely studied Little Ice Age ca. 1350-1900 in the Gulf of Alaska (Mann et al. 1998). This study offers tantalising evidence that Kodiak Islanders recognised fuel value differences and adjusted their wood harvesting strategies to maximise heat efficiency in cold times. Further research is needed to tease out the influence of site function and features associated with charcoal samples (hearth, house floor, banya, etc.) on potential temporal trends.

Avoidance of birch?

Given the emphasis on heat generation at several sites and during at least two cultural traditions, the virtual absence of birch in the overall charcoal assemblage is puzzling. Birch is shown in Fuel Value Index studies (Table 3) to exhibit a higher heat value than alder, although alder was clearly the most widely-used native deciduous wood. One explanation may be the higher handling costs required to exploit birch thickets, due to their more limited distribution. Modern wood harvesters also claim that birch trees are difficult to chop down, and such difficulty would certainly have influenced those who used stone tools to process trees. Other explanations by Alix and Brewster (2005: 5-6) are based on their study of Interior Alaska driftwood, specifically that fallen birch (*Betula papyrifera*) is rarely found along river banks and is nearly absent in driftwood accumulations. They also cite birch's low resistance to decay—a taphonomic effect that may further reduce the encounter rates with drift birch. A last possible explanation relates to aesthetic qualities of burning. Osgood (1958) writes that the Ingalik of the Yukon and Kuskokwim rivers disliked burning birch because offensive black smoke was released when the bark burned. If indeed Kenai birch (*Betula papyrifera* var. *kenaica*) exhibits similar phenomena in the Kodiak region, then these avenues provide rich potential for future research.

Conclusion

This article has considered the economic tradeoffs of fuelwood harvesting at northern latitudes. Ethnographic information from Old Harbor, Alaska, was successfully used to test assumptions about fuelwood selection criteria. A Fuel Value Index (FVI) was employed as a means to rank woody taxa on the basis of measurable physical properties. The Sitkalidak Island archaeological charcoal study demonstrated that past fuelwood harvesting strategies considered both heat value and handling costs. Some interesting patterns emerged that warrant further investigation. First, coastal areas that receive at least moderate supplies of driftwood can support fuel-value-based wood selection, rather than simply "harvesting by proximity." Second, hunter-gatherers may have targeted high-energy fuelwoods like spruce in response to cooling Gulf of Alaska temperatures during at least two phases of the Holocene.

Charcoal assemblages are useful far beyond mere presence/absence or radiocarbon purposes. Palaeo-fuel studies are a rich source of behavioural and environmental information when performed rigorously and integrate such diverse topics as wood science, oceanography, palaeoclimatology, and ethnography. Furthermore, charcoal often persists in acidic sedimentary environments while other botanical and faunal materials do not. For this reason, charcoal can allow archaeologists to access subsistence strategies otherwise obscured by taphonomic processes.

The results of the research presented here contribute to a body of emerging studies on human use of driftwood and other fuelwood at high latitudes (Alix 2001, 2005, 2009; Alix and Brewster 2004; Dyke and Savelle 2000; Grønnow 1996; Simpson et al.

2003; Tennessen 2000) and at middle-latitudes (Lepofsky et al. 2001, 2003). These investigations suggest that fuelwood was a strategically-harvested subsistence resource across North America and, like other subsistence resources, compelled its users to adapt to the ever-changing environmental and social context in which it was imbedded.

Acknowledgments

I am extremely indebted to the people and Tribal Council of Old Harbor, Alaska, and the staff at the Alutiiq Museum and Archaeological Repository in Kodiak for their insight, expertise, and hospitality. In particular, I thank Mary Haakanson, Phyllis and Glen Clough, Sven Haakanson, Jr., April Laktonen Counsellor, Patrick Saltonstall, and Amy Steffian. The original research was supported by the National Science Foundation, Office of Polar Programs (OPP#0425349), and guided by Ben Fitzhugh, Julie Stein, Donald Grayson, and Carol Jolles. Thanks also go to Claire Alix, Stephanie Jolivette, and two anonymous reviewers for commenting on this manuscript and to Anne-Hélène Kerbiriou for translating the abstract.

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