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WHITEBARK PINE COMMUNITY TYPES AND THEIR PATTERNS ON THE LANDSCAPE

Stephen F. Arno
Tad Weaver

ABSTRACT

Within whitebark pine's (Pinus albicaulis) *relatively narrow zone of occurrence—the highest elevations of tree growth from California and Wyoming north to British Columbia and Alberta—this species is a member of diverse plant communities. This paper summarizes studies from throughout its distribution that have described community types containing whitebark pine and the habitat types (environmental types based on potential vegetation) it occupies.*

Whitebark pine is most abundant and widespread in the semiarid inland mountain ranges of the northwestern United States and southwestern Canada, where it occurs in a continuum of environmental situations. It can be (1) a fire-dependent, early seral component of spruce-fir forests on moist sites; (2) a persistent seral or minor climax associate in drier forest habitats; (3) a major climax species or the only tree under still drier or more wind-exposed conditions; or (4) a major component or sole dominant of krummholz communities above tree line.

The timberline landscape is a mosaic of cover types including windswept fellfields and grassy balds, wet meadows, snowdrift communities, and krummholz (shrublike conifers) and forest communities with various proportions of whitebark pine. Four factors explain much of the variation in cover types: (1) rugged topography, through its influence on microclimate; (2) differences in surface rockiness, ranging from boulder piles to moderately well-developed soils; (3) differences in substrate composition, with especially noteworthy changes occurring between calcareous and noncalcareous geologic parent materials; and (4) a patchwork of different disturbance histories in the aftermath of fires, bark beetle epidemics, blowdowns, or snow avalanches.

Whitebark pine communities also vary regionally, with changes in both climate and competing species. For example, in maritime mountain regions whitebark pine is unable to compete in the closed upper subalpine forest; it is, therefore, restricted to tree islands in the open heath parklands at timberline.

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INTRODUCTION

Whitebark pine (*Pinus albicaulis*) is a prominent species in the upper subalpine forest and timberline zones on high mountains of western North America. Here, a great variety of tree-dominated and nonarboreal communities form a complex vegetational mosaic on the rugged landscape. While few studies have provided detailed descriptions of these communities or the causes of their distributional patterns, it is possible to list the major community types and to specify the principal factors controlling the mosaic. An understanding of this environmental complex is needed to guide land management. For example, to prevent undesirable changes in water, wildlife, and recreational resources, we must be able to recognize and manage the impacts of recreation, grazing, mining, timber harvest, air pollution, greenhouse effects, and advanced forest succession linked to fire suppression.

The presence and dominance of whitebark pine depend on its environmental tolerances and on its competitive abilities. Its tolerances restrict it to relatively cool sites without extended drought. Its relatively low capacity to compete (table 1) restricts it to harsh sites where growth of more competitive trees is hampered by physical factors or, on better forest sites, by disturbance. In this paper

Table 1—Comparative tolerance of shade or competition for species associated with whitebark pine in the Inland Northwest (after Minore 1979)

Tolerance	Species
Very tolerant	Subalpine fir (*Abies lasiocarpa*)
	Mountain hemlock (*Tsuga mertensiana*)
Tolerant	Engelmann spruce (*Picea engelmannii*)
Intermediate or intolerant	Whitebark pine (*Pinus albicaulis*)
Very intolerant	Lodgepole pine (*Pinus contorta* var. *latifolia*)
	Alpine larch (*Larix lyallii*)

we examine, first, the variation in potential climax vegetation reflecting the habitat type (Daubenmire and Daubenmire 1968; Pfister and Arno 1980) as it changes locally with microclimate or substrate and regionally with macroclimate. Then, we address the role of temporal changes in the vegetation on a site after disturbance, since whitebark pine is seral in many habitat types. We conclude with a brief outline of regional classification schemes.

ENVIRONMENTAL CONTROLS

The patterns of distribution and relative dominance of whitebark pine and its associates on the mountain landscape are strongly influenced by topography (Arno and Hammerly 1984; Habeck 1987; Pfister and others 1977; Steele and others 1981, 1983). For example, slope orientation profoundly affects microclimate; north and east aspects are relatively moist and cool while south and west aspects are drier and warmer. Also, at increasingly higher elevations growing seasons become shorter and cooler.

Because it is relatively cold tolerant and relatively noncompetitive, whitebark pine's importance increases with elevation. In the lower subalpine habitat types (fig. 1) whitebark pine occurs in small amounts and primarily as suppressed saplings. In the colder, upper subalpine habitat types the establishment and growth of competing conifers are reduced. This allows whitebark pine to assume dominance on many sites.

In moist sites of the upper subalpine zone (for example, cirque basins) whitebark pine is a minor component of subalpine fir-spruce (*Abies lasiocarpa-Picea engelmannii*) stands except where it becomes a pioneer dominant after a severe fire, avalanche, or other major disturbance. Its early seral success is possible because of whitebark pine's superior hardiness in the harsh microclimate of the disturbed site and its introduction by the seed caching Clark's nutcracker (Tomback and others, this proceedings). Within 150 to 200 years, vigorous fir and spruce begin to replace the pine.

Conversely, on relatively dry sites in the upper subalpine forest, whitebark pine is a long-persisting seral associate in the subalpine fir habitat types (potential climax; fig. 1). Lodgepole pine (*Pinus contorta* var. *latifolia*) is also a seral associate in many of these stands. On the driest sites, subalpine fir is absent, lodgepole pine is seral, and whitebark pine assumes the climax role (Steele and others 1983).

In the alpine timberline zone, above the upper limit of continuous forest, whitebark pine often occurs in pure or mixed groves or tree islands. Any trees that can survive are considered part of the climax community (Arno and Hammerly 1984; Pfister and others 1977). Whitebark pine and its arboreal associates occur in a continuum of lifeforms at timberline. These range from large, single-stem trees to stunted multistemmed trees to flagged krummholz (tall shrub form) and cushion krummholz. Because whitebark pine is hardier, it often produces a taller life form than the associated subalpine fir.

In addition to cold timberlines, whitebark pine occurs at dry timberlines, which are subalpine forest-herbland ecotones. At dry timberlines, it may be associated with inland Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) or limber pine (*Pinus flexilis*).

Rugged topography adds small-scale site variations to the general zonal patterns. For example, sharp ridge crests in the upper subalpine forest are exposed to severe wind, which favors whitebark pine relative to fir and spruce. Rugged topography and resulting vegetation patterns influence the distribution of snow, which in turn affects soil moisture, soil development, and potential

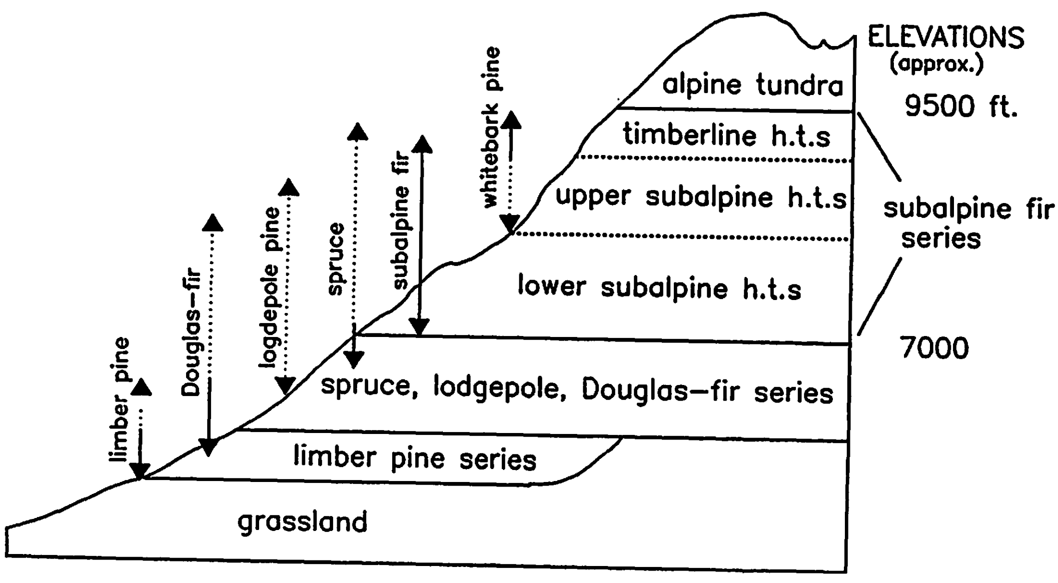

Figure 1—General elevational distribution of forest trees (arrows) and habitat type series (potential climax) on noncalcareous geologic types in south-central Montana. Solid portion of arrow indicates where a species is the potential climax, and dotted portion shows where it is seral. (Modified from Pfister and others 1977).

vegetation. Microsites receiving excessive snow often support wet meadow vegetation rather than trees. In contrast, microsites with deficient snow support semiarid grassland or other dry nonforest types. Sometimes contrasting snowdrift and dry microsites lie close to each other with a strip of whitebark pine in between, as in the "ridgetop ribbon forest" described by Arno and Hammerly (1984).

Edaphic factors also influence the distribution of whitebark pine in the rugged high-mountain terrain. For example, whitebark pine may be abundant on talus slopes or bedrock outcrops, but scarce on surrounding sites with deeper soils, where other conifers are more competitive.

Changes in substrate (surface geologic type) can also have a profound effect on whitebark pine communities. The contrast between calcareous (usually limestone) and noncalcareous substrates provides a dramatic example. Limestone often weathers to produce an excessively well-drained soil that limits growth of conifers (Goldin 1976; Pfister and others 1977). In especially dry regions (for example, in northern Nevada and eastern California), whitebark pine is largely confined to noncalcareous substrates (Harlow and Harrar 1958; Weaver and Dale 1974). In most regions, however, whitebark pine occurs on both calcareous and noncalcareous substrates. Calcareous sites support open pine stands with herbaceous undergrowth, while adjacent noncalcareous sites have dense mixed conifer stands with seral whitebark pine and an undergrowth of low *Vaccinium* (huckleberry or whortleberry) shrubs (Arno and Hammerly 1984; Pfister and others 1977).

REGIONAL VARIATIONS

On a larger scale, the composition and distribution of whitebark pine communities vary based on regional differences in climate, topography, and competitive relationships of subalpine tree floras. Whitebark pine communities are extensive and diverse in the drier inland mountain ranges. However, their abundance declines southward in California, perhaps in response to increasing length of summer drought. In wet regions, such as the crest of the northern Cascade Range and the British Columbia coastal ranges, whitebark pine occurs only in open timberline habitats and it is a minor constituent there. In these wet oceanic mountains, whitebark pine's growth is slow and its ultimate tree sizes are small. It is essentially absent from the dense upper subalpine forest, apparently because of an inability to compete with the shade-tolerant mountain hemlock (*Tsuga mertensiana*), subalpine fir, and Pacific silver fir (*Abies amabilis*). At these timberlines, dense heath (*Phyllodoce* and *Cassiope*) hinders conifer regeneration. Whitebark pine is a minor component of the conifer invasion that does occur in timberline heathlands during especially dry summers (Brink 1959; Franklin and others 1971).

Whitebark pine is abundant in regions having humid, snowy winters and long dry periods in summer, such as California's high Sierra Nevada and the inland mountains of the northwestern United States. Its abundance and vigorous growth in semiarid regions and on topographically dry sites suggest that it is more drought resistant than other northwestern subalpine trees.

The abundance of whitebark pine decreases as summer precipitation increases northward in the inland Northwest. For example, July-August precipitation in the upper subalpine zone averages about 2 inches (5 cm) in central Idaho, where the species is very abundant, and 5 to 6 inches in the latitude of Kootenay and Banff National Parks, where it is generally a minor component of the high-country vegetation (Arno 1970). Presumably this occurs because whitebark pine's competitors—subalpine fir, spruce, mountain hemlock (in the Selkirks), and (locally) alpine larch (*Larix lyallii*)—are more vigorous in the more humid environment. Physiological investigations of drought-sensitive alpine larch (Richards 1981; Richards and Bliss 1986) explain its inverse distribution. Despite extensive timberline habitat, alpine larch occurs only north of latitude 45.5° N., where it is confined to moist north-facing slopes. In contrast, northward into Canada it becomes abundant on southern exposures (Arno and Hammerly 1984).

Whitebark pine is absent from the high-desert mountains east and south of the Sierra Nevada, at least in part because this species is not as tolerant of year-round aridity as are limber pine and Great Basin bristlecone pine (*Pinus longaeva*). The current southern distributional limits of whitebark pine from California to the central Rockies may also result in part from inadequate seed distribution to isolated mountain habitats during alternating glacial and warm climates of the Pleistocene.

Thus, in the wettest mountain regions whitebark pine is narrowly confined to the timberline zone and to open rocky subalpine sites. In contrast, in drier regions where drought hampers competitors (notably in the dry-summer inland mountains of the northwestern United States), whitebark pine is often a major component of both the upper subalpine forest and the timberline zone, encompassing about 2,500 ft (760 m) in elevation. In the Sierra Nevada whitebark pine is generally confined to timberline but is often abundant there.

ROLE OF DISTURBANCE

Disturbances are important in shaping the structure of all whitebark pine communities, and natural disruptions are vital to the perpetuation of whitebark pine in the habitat types where it is seral. In the timberline zone, the climate is so harsh and limiting for tree growth that climatic disturbances (such as damaging winds, ice storms, snowloads, summer frost, and winter desiccation) prevent stand closure and thereby allow competition-intolerant species like whitebark pine to coexist indefinitely with their tolerant competitors (Arno and Hammerly 1984; Franklin and Dyrness 1973; Pfister and others 1977). Conversely, in subalpine forest habitats, whitebark pine's perpetuation depends upon occasional disturbances. Without disturbance, succession will lead to dominance by subalpine fir, spruce, or mountain hemlock.

In large portions of the inland northwestern United States, the area covered by seral whitebark pine communities has diminished in recent decades. Its decline is due to successional replacement linked to fire suppression and aggravated by epidemics of mountain pine beetle and white pine blister rust (Arno 1986; Kendall and Arno, this proceedings).

Prior to 1900, fires at intervals averaging between 50 and 350 years were widespread and were important in perpetuating seral whitebark pine communities (Arno 1986; Morgan and Bunting, this proceedings). These often burned in a patchy pattern with differential severities. Both light surface fires and stand replacing fires favor whitebark pine in relation to its shade-tolerant competitors. High-intensity, stand-replacing fires in thick subalpine fir-spruce forests often allow whitebark pine to become established as a result of nutcracker seed caching. After establishment, some of these seral whitebark pine communities have been perpetuated by low-intensity fires that killed understory fir and spruce.

As a result of fire suppression during the 1900's, natural fire cycles in seral whitebark pine communities have been postponed (Arno 1986), so this species is being replaced by its competitors. Even management programs that allow some natural fires to burn are probably insufficient for mimicking whitebark pine fire cycles of the past. The most effective fires in the highly discontinuous whitebark pine habitats (atop isolated high ridges) were ones that spread over large expanses—hundreds of thousands of acres. However, most whitebark pine habitats lie near developed or commercially utilized lands where such massive fires are not tolerable politically, even in wilderness areas or National Parks.

Fire suppression during this century has no doubt resulted in a decrease in the establishment of new whitebark pine communities. These young stands are needed to compensate for aging stands in which whitebark pine is being replaced successionally. Avalanches and severe blowdowns also create open microenvironments that allow whitebark pine to enter as a pioneer species. These disturbances are no substitute for fire, however, because they produce only small areas suitable for seral whitebark pine forests and they fail to reduce competition from understory trees and shrubs.

Mountain pine beetle epidemics are another influential natural disturbance that tends to kill overstory whitebark pines and enhance succession toward domination by subalpine fir (Bartos and Gibson, this proceedings; Kendall and Arno, this proceedings). Similarly, white pine blister rust, an introduced disease, severely injures and kills whitebark pine, hastening succession toward dominance by shade-tolerant conifers (Hoff and Hagle, this proceedings; Kendall and Arno, this proceedings).

COMMUNITY TYPES AND HABITAT TYPES

A variety of reports describe whitebark pine communities of almost every State and Province occupied by the tree (table 2). Whitebark pine habitats are abundant, diverse, and best documented in the inland northwestern United States (Cole 1982; Forcella 1977, 1978; Pfister and others 1977; Steele and others 1981, 1983; Weaver and Dale 1974; and other studies listed in table 2). Three remarkably consistent community complexes appear repeatedly in this region—extending from western Wyoming and northeastern Oregon to the southernmost portions of British Columbia and Alberta.

First, on the driest sites and in arid mountain ranges, communities dominated by whitebark pine (both seral and potential climax) are abundant. At the highest elevations, in cold-moist situations, the undergrowth is usually dominated by *Vaccinium scoparium*. Under progressively

Table 2—Principal publications and theses describing whitebark pine communities, listed by State and Province. Complete citations appear in the References section

Alberta	Achuff 1989; Baig 1972; Ogilvie, this proceedings
British Columbia	Achuff 1989; Brink 1959; McAvoy 1931; Ogilvie, this proceedings; Selby and Pitt 1984
California	Barbour 1988; Cooke 1940, 1955; Klikoff 1965; Sawyer and Thornburgh 1977; Taylor 1976; Vale 1977
Idaho	Steele and others 1981, 1983; USDA Forest Service 1989
Montana	Arno 1970; Craighead and others 1982; Forcella 1977, 1978; Pfister and others 1976, 1977; USDA Forest Service 1989; Weaver and Dale 1974
Nevada	Loope 1969
Oregon	Cole 1982; Franklin and Dyrness 1973; Hall 1973; Hopkins 1979; Jackson and Faller 1973; Lueck 1980
Washington	Agee and Kertis 1987; Arno 1970; del Moral 1979; Franklin and Dyrness 1973; Williams and Lillybridge 1983
Wyoming	Forcella 1977; Gruell 1980; Steele and others 1983;

drier conditions, the characteristic undergrowth changes to *Carex geyeri, Juncus parryi, Arnica cordifolia*, and, finally, *Festuca idahoensis*.

Second, in average mountain habitats of the inland Northwest, whitebark pine stands are codominated by subalpine fir and, at lower elevations, by lodgepole pine. The characteristic undergrowth ranges from *Phyllodoce empetriformis* and *Luzula hitchcockii* in moist situations to *Xerophyllum tenax, Vaccinium scoparium, Carex geyeri*, and *Ribes montigenum* on increasingly drier sites.

Third, moist subalpine forest sites often have whitebark pine as a seral component mixed with Engelmann spruce (*Picea engelmannii*), subalpine fir, and, at lower elevations, lodgepole pine. Alpine larch and mountain hemlock can be constituents in certain localities. Characteristic undergrowth includes numerous wet-meadow forbs and sedges, and the shrubs *Ledum glandulosum, Phyllodoce empetriformis, Menziesia ferruginea*, and *Rhododendron albiflorum*.

In the continental climate of western Wyoming and central Montana, whitebark pine is the potential climax tree in several subalpine forest habitat types as well as being a seral associate in several others (table 3). In the inland maritime climate found west of the continental divide in Montana, whitebark pine is seral except in the timberline zone (table 4).

Northward in the Rocky Mountains of Alberta and British Columbia, whitebark pine remains widespread but is less often a dominant species. Achuff (1989) and Ogilvie (this proceedings) provide detailed descriptions of whitebark pine communities in Canada. In Alberta, whitebark pine is most common in the timberline zone as a codominant with subalpine fir, spruce, and sometimes with alpine larch (Baig 1972). Characteristic undergrowth includes *Phyllodoce empetriformis* in moist sites along or near the Continental Divide (inland-maritime zone); *P. glanduliflora* in comparable sites in mountains farther inland (east); *Vaccinium scoparium* on well-drained sites, and *Juniperus communis* on the driest south-facing slopes.

The importance of whitebark pine increases from wet to dry sites in the Cascade Range. In the rain shadow of the Washington Cascades on the granitic Stuart Range, whitebark pine is abundant in the upper subalpine forest and the timberline zone. Timberline communities are dominated by whitebark pine on dry sites and warm aspects and by alpine larch in moist-cool situations (del Moral 1979) as they are in some moist mountain ranges of western Montana (Arno and Habeck 1972). In the Stuart Range, relatively moist whitebark pine-alpine larch communities have an undergrowth of *Vaccinium*

Table 3—High-elevation habitats of western Wyoming arranged approximately on a gradient of decreasing site moisture. Competitive status and abundance of whitebark pine and its associates are shown (modified from Steele and others 1983)

Site moisture	Habitat type[1]	Tree species[2] *Pinus albicaulis*	*Abies lasiocarpa*	*Picea engelmannii*	*Pinus contorta*	*Pinus flexilis*	*Pseudotsuga menziesii*	*Populus tremuloides*
Wet ↑	PIEN/VASC	(S)	c	C	(S)	(s)		
	PIEN/CALE	s	c	C	s			
	ABLA/VAGL, VASC	s	C	S	S			
	ABLA/VASC, PIAL	C	C	S	S		(s)	
	ABLA/VASC, VASC	s	C	S	S			
	ABLA/ARLA	(S)	C	S	(S)		(S)	(S)
	ABLA/THOC	s	C	S	S		S	(S)
	ABLA/JUCO	s	C	(S)	S	s	(S)	
	ABLA/RIMO, RIMO	s	C	S	(s)			
	ABLA/RIMO, PIAL	C	C	c				
	ABLA/ARCO, SHCA	s	C	s	S	s	s	s
	PIAL/VASC	C	c	c	C			
	PIAL/CAGE				(C)			
	PIAL/JUCO	C			C	s		
	PIAL/CARO	C	(c)	(c)	(C)	(s)		
↓ Dry	PIAL/FEID	C						

[1]Abbreviations consist of the first two letters of the genus and species names. Undergrowth species are: ARCO = *Arnica cordifolia;* ARLA = *A. latifolia;* CAGE = *Carex geyeri;* CALE = *Caltha leptosepala;* CARO = *Carex rossii;* FEID = *Festuca idahoensis;* JUCO = *Juniperus communis;* RIMO = *Ribes montigenum;* SHCA = *Shepherdia canadensis;* THOC = *Thalictrum occidentale;* VAGL = *Vaccinium globulare;* VASC = *V. scoparium.*
[2]C = climax dominant; S = seral dominant; c = minor climax species; s = minor seral species; () = in part of the habitat type only.

Table 4—Typical high-elevation forest zonation in west-central Montana showing the competitive status and abundance of whitebark pine and its associates (modified from Pfister and others 1977)

Elevational zone	Moisture	Habitat types[1]	Stand components[2]					
			Pinus albicaulis	*Abies lasiocarpa*	*Picea engelmannii*	*Larix lyallii*	*Pinus contorta*	*Pseudotsuga menziesii*
Timberline zone	Dry sites	PIAL	C	—	—		—	—
		PIAL-ABLA	C	C	c			
	Moist sites	LALY-ABLA	C	C	c	C		
Upper subalpine forest	Dry sites	ABLA-PIAL/VASC	S^{300y}	C	s		—	—
		ABLA/LUHI	S^{250y}	C	s		S^{200y}	—
	Moist sites		S^{200y}	C	S^{400y}	s	s	—
Lower subapline forest	Dry sites	ABLA/XETE, VASC	s	C	s	—	S	s

[1]Abbreviations consist of the first two letters of the genus and species names. Undergrowth species are: LUHI = *Luzula hitchcockii*; VASC = *Vaccinium scoparium*; XETE = *Xerophyllum tenax*.
[2]C = climax dominant; S = seral dominant for number of years (as indicated) after fire or other disturbance; c = minor climax species; s = minor seral species.

myrtillus, which is ecologically similar to *V. scoparium* (del Moral 1979). With increasing dryness, whitebark pine communities have undergrowths characterized by *Lewisia columbiana*, *Phlox diffusa*, *Juniperus communis*, and *Penstemon davidsonii*.

In the excessively well-drained pumice of the Oregon Cascades, whitebark pine communities are characterized by sparse undergrowth. On sites with average moisture conditions, undergrowth is typically *Penstemon davidsonii*; in wetter microsites *Vaccinium scoparium* and *Luzula hitchcockii* are characteristic (Jackson and Faller 1973; Lueck 1980). On coarse volcanic substrates in south-central Oregon, Hopkins (1979) described two community types (= habitat types) in which whitebark pine and lodgepole pine are the climax dominants and the principal undergrowth is *Carex pensylvanica*, *Poa nervosa*, and *Penstemon laetus*.

Southward on the Cascade-Sierra Nevada axis, whitebark pine is common but largely confined to timberline communities in northern and central California. Subalpine fir and Engelmann spruce are essentially absent, and the timberline communities tend to be quite open, with only sparse, scattered undergrowth (Barbour 1988). These communities consist of mixtures of whitebark pine with mountain hemlock on moist sites and with Sierra lodgepole pine (*Pinus contorta* var. *murrayana*), western white pine (*Pinus monticola*), and foxtail pine (*P. balfouriana*) on drier sites.

The whitebark pine zone is often made up of an intricate pattern of community types dominated variously by tall or dwarf trees, shrubs, subalpine herbs, or alpine tundra plants. These community mosaics and their microenvironmental controls are little studied. One exception is del Moral's (1979) work in the Stuart Range. Another is Pfister and others' (1976) quantitative description and map of an extensive whitebark pine community mosaic in the Scapegoat Wilderness of northwestern Montana. Their map (fig. 17 in Craighead and others 1982) differentiated six habitat types and phases containing major amounts of whitebark pine and several habitat types in which whitebark pine is a minor component. The map units were characterized with constancy and coverage data for forest community types (both postfire and mature) as well as associated subalpine grassland, wet meadow, and avalanche community types (table 5). The topographic and edaphic controls of the major whitebark pine types (table 6) were identified as a guide for vegetation mapping throughout the study area. Many more similar studies are needed before we hope to understand the dynamics of whitebark pine community mosaics.

Table 5—Constancy (in percent ÷ 10)—and average percent canopy cover, in (), for six habitat types in the Scapegoat Wilderness, MT, containing whitebark pine (from Pfister and others 1976; habitat types from Pfister and others 1977) (LUHI = *Luzula hitchcockii*; MEFE = *Menziesia ferruginea*; VASC = *Vaccinium scoparium*)

Habitat type and phase:	ABLA-PIAL/ VASC	ABLA/LUHI- VASC	ABLA/LUHI- MEFE	PIAL-ABLA	PIAL-ABLA snowdrift	LALY-ABLA
Computer map code:	820	831	832	850	850D	860
No. of sample stands:	13	8	2	4	2	3
TREES						
Abies lasiocarpa	9(39)	10(48)	10(65)	10(44)	5(4)	10(15)
Larix occidentalis						10(27)
Picea spp.	8(18)	8(27)	10(16)	8(7)	5(2)	7(13)
Pinus albicaulis	10(36)	10(30)	10(25)	10(47)	5(5)	10(15)
Pinus contorta	4(4)	1(10)				
Pseudotsuga menziesii	4(4)					
SHRUBS						
Alnus sinuata			5(4)			
Juniperus communis	4(7)			5(2)		
Ledum glandulosum		1(40)	10(10)			
Menziesia ferruginea	2(2)	4(3)	10(30)			
Ribes lacustre	3(1)	1(0)		2(0)		
Shepherdia canadensis	1(0)			2(0)		
Vaccinium caespitosum	1(0)					
Vaccinium globulare	2(30)	1(0)				
Vaccinium scoparium	7(38)	10(54)	10(45)	5(75)	5(10)	10(47)
PERENNIAL GRAMINOIDS						
Calamagrostis rubescens	2(10)					
Festuca idahoensis	1(20)			5(1)		
Luzula hitchcockii		10(11)	10(10)	8(2)		10(18)
PERENNIAL FORBS						
Cirsium foliosum	5(1)			8(1)		
Fragaria spp.	4(3)					
Heracleum lanatum	1(2)			2(0)		
Lomatium dissectum	1(0)					
Senecio triangularis	3(1)	1(0)		2(2)		
Thalictrum occidentale	4(22)	1(0)		8(17)		
Valeriana sitchensis	3(3)	3(2)		5(1)		
Viola orbiculata	1(0)		5(2)			
Xerophyllum tenax	8(38)	6(30)	5(30)			8(5)

Table 6—Topographical distribution of habitat types containing whitebark pine on noncalcareous and calcareous (limestone) substrates in the Scapegoat Wilderness, synthesized from Pfister and others (1976)

Environmental gradient	Habitat type and phase (Pfister and others 1977)	Geologic substrate			
		Noncalcareous		Calcareous	
		Elevation	Aspect	Elevation	Aspect
		Feet		*Feet*	
Warm/dry	PIAL and subalpine grasslands	[1]—	—	7,000-7,800	S
↑	ABLA-PIAL/VASC	—	—	7,000-8,000	all
	ABLA/LUHI-VASC	7,300-7,800	all	—	—
	ABLA/LUHI-MEFE	7,300-7,500	N&E	—	—
↓	PIAL-ABLA	7,800-8,300	NW,W, S, SE	8,000-8,500	all
Cold/wet	LALY-ABLA	7,700-8,600	N&E	—	—

[1]— = absent or scarce.

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