

Pinus balfouriana

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INTRODUCTORY

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Southern foxtail pine.



Northern foxtail pine. Photos © 1998. Charles Webber , California Academy of Sciences.

AUTHORSHIP AND CITATION:

Fryer, Janet L. 2004. Pinus balfouriana. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: <http://www.fs.fed.us/database/feis/> [2010, June 21].

FEIS ABBREVIATION:

PINBAL
PINBALA
PINBALB

SYNONYMS:

None

NRCS PLANT CODE [[101](#)]:

PIBA
PIBAA
PIBAB

COMMON NAMES:

foxtail pine
southern foxtail pine
northern foxtail pine
Sierra foxtail pine
Klamath foxtail pine

TAXONOMY:

The scientific name of foxtail pine is *Pinus balfouriana* Grev. & Balf. (Pinaceae). There are 2 subspecies [[8,32,39,47,68](#)]:

Pinus balfouriana subsp. *austrina* R.J. & J.D. Mastrogiuseppe southern foxtail pine

Pinus balfouriana subsp. *balfouriana* northern foxtail pine

Foxtail pine, [Great Basin bristlecone pine](#) (*P. longaeva*), and [Rocky Mountain bristlecone pine](#) (*P. aristata*) share a common ancestor [[83,109](#)]. Taxa within the foxtail-bristlecone pine complex (*Pinus*, subgenus *Strobus*, section *Parrya* Mayr, subsection *Balfourianae* Englm.) are distinguished by growth form, bark, and differences in chemical composition [[8,25,68,76](#)]; however, these characters intergrade [[32,39,68](#)]. Foxtail and bristlecone pines readily produce fertile hybrids in the laboratory [[93,109](#)]. Disjunct distributions, and possibly other factors, prevent natural hybridization among the 4 taxa. Southern foxtail and Great Basin bristlecone pine populations seem geographically close enough for limited pollen dispersal (see [General Distribution](#)); yet to date (2004), southern foxtail × Great Basin bristlecone pine hybrids have not been found in the field [[8,60](#)].

LIFE FORM:

Tree

FEDERAL LEGAL STATUS:

No special status

OTHER STATUS:

The World Conservation Union's Species Survival Commission (IUCB-SSC) lists foxtail pine as a lower risk, conservation-dependent species [[45](#)].

DISTRIBUTION AND OCCURRENCE

SPECIES: *Pinus balfouriana*

- [GENERAL DISTRIBUTION](#)
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GENERAL DISTRIBUTION:

Foxtail pine is endemic to California. There is a 300-mile (480-km) gap in the distributions of the 2 subspecies. Southern foxtail pine occurs in the high southern Sierra Nevada of Fresno, Tulare, and Inyo counties. Its distribution lies within Sequoia and Inyo National Forests and Sequoia-Kings Canyon National Park. Highest population concentrations are in Sequoia-Kings Canyon National Park, the center of most research on southern foxtail pine. Northern foxtail pine occurs in the high North Coast and Klamath ranges in Siskiyou, Trinity, Shasta, and Tehama counties. Northern foxtail pine's distribution lies within the Klamath, Shasta, Trinity, and Mendocino National Forests, including the Marble Mountain, Yolla-Bolly-Middle Eel, and Trinity Alps Wilderness Areas [[26,39,59,61](#)]. Southern and northern foxtail pines have probably been separated since major upliftings of the Sierra Nevada during the early Pleistocene [[8](#)]. Inyo Valley, located between the southern Sierra Nevada and the White Mountains, creates a 20-mile-wide (32-km) gap between southern foxtail and Great Basin bristlecone pine populations [[26](#)]. [The U.S. Geological Survey](#) provides a distributional map of southern and northern foxtail pines.

ECOSYSTEMS [[34](#)]:

FRES23 Fir-spruce
FRES26 Lodgepole pine

STATES/PROVINCES:

CA

BLM PHYSIOGRAPHIC REGIONS [[16](#)]:

1 Northern Pacific Border
2 Cascade Mountains
4 Sierra Mountains

KUCHLER [[53](#)] PLANT ASSOCIATIONS:

K007 Red fir forest
K008 Lodgepole pine-subalpine forest

SAF COVER TYPES [[31](#)]:

204 Mountain hemlock
207 Red fir
208 Whitebark pine
218 Lodgepole pine
219 Limber pine
256 California mixed subalpine

SRM (RANGELAND) COVER TYPES [[90](#)]:

None

HABITAT TYPES AND PLANT COMMUNITIES:

Southern foxtail pine is the dominant conifer in upper-elevation subalpine communities of the south-central Sierra Nevada [[12,80,106](#)]. It is the most abundant subalpine conifer in Sequoia-Kings Canyon National Park [[10](#)]. Southern foxtail pine often occurs in pure stands [[63](#)]. California red fir (*Abies magnifica* var. *magnifica*), Sierra juniper (*Juniperus occidentalis* ssp. *australis*), Sierra lodgepole pine (*Pinus contorta* var. *murrayana*), Jeffrey pine (*P. jeffreyi*), and limber pine (*P. flexilis*) may associate on low-elevation foxtail pine sites, while whitebark pine (*P.*

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albicaulis) may associate on high-elevation sites [81,82,106]. The most common shrub associates in southern foxtail pine communities are bush chinquapin (*Chrysolepis sempervirens*), oceanspray (*Holodiscus discolor*), wax currant (*Ribes cereum*), gooseberry currant (*R. montigenum*), Parish's snowberry (*Symphoricarpos rotundifolius* var. *parishii*), and curleaf mountain-mahogany (*Cercocarpus ledifolius*) [82,83]. Pinemat manzanita (*Arctostaphylos nevadensis*), green manzanita (*A. patula*), and bitter cherry (*Prunus emarginata*) may also be present [10,82].

In Sequoia-King Canyon National Park, Vankat [106] found less than one-fourth of southern foxtail pine communities contained shrubs. Herbaceous cover averaged around 10%, although some stands showed as much as 65% herbaceous cover. Tree cover was almost entirely foxtail pine; a few stands also had Sierra lodgepole pine. Bush chinquapin and oceanspray were the most common shrubs. Shrub associates are more common on marginal foxtail pine sites than in Sequoia-Kings Canyon, which is prime foxtail habitat. Southern monardella (*Monardella australis*) is the most consistent herbaceous associate across southern foxtail pine's range [82]. At their lowest elevations, southern foxtail pine communities merge with upper-elevation Sierra lodgepole pine or, more rarely, east-slope Jeffrey pine communities. Southern foxtail pine communities often form a mosaic with subalpine meadows [15]. At their highest elevations, southern foxtail pine communities merge into alpine meadows and fell-fields [44].

The Klamath Ranges support some of the most diverse plant communities in North America [86], and **northern foxtail pine** contributes to this diversity. Northern foxtail communities are typically more diverse compared to southern foxtail pine communities [67]. Eckert and Sawyer [30] found that along a latitudinal gradient, diversity of northern foxtail pine communities increased to the north. Lowest diversity occurred in the southern Yolla Bolly Mountains, the southernmost of the Klamath ranges, while highest diversity occurred in the Trinity and Marble mountains, the northernmost of the Klamath ranges. Northern foxtail pine generally dominates on subalpine [serpentine soils](#). Whitebark pine or mountain hemlock (*Tsuga mertensiana*) may associate on upper-elevation sites, although they are more common on nonserpentine soils [30,82]. Northern foxtail pine communities on serpentine, other [ultramafic](#), or dry soils often form a mosaic with whitebark pine-mountain hemlock or mountain hemlock-Brewer spruce (*Picea breweriana*) communities that occur on nonserpentine or wetter, north-slope soils [30,44,54,63]. Jeffrey pine and Sierra lodgepole pine may associate on dry (south and west aspects), mid-subalpine sites (<2,200 m), while Shasta red fir (*Abies magnifica* var. *shastensis*) and western white pine may associate on wetter, mid-subalpine sites [30,38,44,54,67]. Western white pine or white fir (*A. concolor*) associate on lowest-elevation subalpine sites [23,86]. Incense-cedar (*Calocedrus decurrens*) and coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) may be occasional associates at these lower elevations [67,82]. Northern foxtail pine communities merge with coast Douglas-fir, Sierra lodgepole pine, or mixed-conifer forest communities at their lowest elevations and with alpine fell-field or alpine meadow communities at highest elevations [44,63].

In the Trinity Mountains on the Siskiyou-Trinity county line, northern foxtail pine occurs in pure stands at timberline. Shasta red fir, western white pine, and Jeffrey pine associate on mid-subalpine sites. Trinity buckwheat (*Eriogonum alpinum*), pinemat manzanita, big sagebrush (*Artemisia tridentata*), and huckleberry oak (*Quercus vaccinifolia*) occur in the understory. Ground-layer associates include cobwebby paintbrush (*Castilleja arachnoidea*), Cascade aster (*Eucephalus ledophyllus*), spreading phlox (*Phlox diffusa*), and bottlebrush squirrel (*Elymus elymoides*) [23,86]. Unusually diverse northern foxtail communities exist on China and Russian peaks, where northern foxtail pine associates with Jeffrey pine, incense-cedar, and Pacific Douglas-fir [85].

Holland [44], Rundel and others [81], and Sawyer and Thornburgh [86] provide vegetation typings describing foxtail pine communities.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: *Pinus balfouriana*



Southern foxtail. © 1998. Charles Webber ,
California Academy of Sciences

- [GENERAL BOTANICAL CHARACTERISTICS](#)
- [RAUNKIAER LIFE FORM](#)
- [REGENERATION PROCESSES](#)
- [SITE CHARACTERISTICS](#)
- [SUCCESSIONAL STATUS](#)
- [SEASONAL DEVELOPMENT](#)



Southern foxtail. © 1995. Br. Alfred
Brousseau , St. Mary's College

GENERAL BOTANICAL CHARACTERISTICS:

Foxtail pine is a native conifer. It is a low-growing pine, generally 20 to 50 feet (6-15 m) tall, but occasionally reaching 72+ feet (22+ m) in height [39,76]. The champion tree is a northern foxtail pine on the Trinity National Forest that measures 76 feet (23 m) in height, 34 feet (10 m) in spread, and 26.3 feet (8 m) in circumference [2]. Foxtail pine's trunk is usually single-stemmed. Unlike other North American conifers, foxtail pine rarely assumes krummholz form at high elevations; instead, it retains a straight bole [8,10,82,83]. Bark of mature foxtail pine is "exceptionally thick" [8]: nearly as thick as that of ponderosa pine (*Pinus ponderosa*). Bark thickness measurements of 1.85 inches (4.70 cm) [45] and 2.4 to 3.1 inches (6-8 cm) [8] are reported for mature foxtail pines. Mature tree crowns are 8.5 feet (2.6 m) or less in diameter. Branches are short and thick in diameter [39,76]. Branching habit is sparse in southern foxtail pine [59]; southern foxtail pine also tends to be self-pruning. Northern foxtail pine branches tend to be thicker, and may extend to the ground [6,39,67] (the photos in the [Introductory](#) section illustrate this difference). Foxtail is a 5-needle pine. The *Balfourianae* complex is unique among pines in that about half of their branches originate from within the needle fascicles [24,59]. Needle clusters are thickly set toward the branch ends, resembling foxtails [58]. Needles persist for 5 to 7+ years [64,70]; trees at lower elevations tend to retain needles longer than trees at timberline [64]. Female cones are 2.4 to 7.5 inches (6-19 cm) long, dehiscent, and have tiny prickles. Seeds are small (~0.3 inch (8 mm) long), with detachable seed wings about 3 times longer than the seeds [39,76]. Northern foxtail pines tend to have heavier cones and larger seeds with longer seed wings than southern foxtail pines [66].

Morphological differences between southern foxtail pine, northern foxtail pine, and Great Basin bristlecone pine are slight. Southern foxtail pine has thinner bark that tends to grow in square plates (pictured above right) compared to northern foxtail pine, which has relatively thicker bark that tends to grow in narrow ridges. Southern foxtail pine retains its needles longer than northern foxtail pine [39]. Northern foxtail pine tends to have a fuller crown and suffer from less cambial die-back than southern foxtail pine [59]. Great Basin bristlecone pine is distinguished from foxtail pines by having relatively longer cone prickles (2-6 mm) compared to foxtail pines (<1mm). Distributions of Great Basin, southern foxtail, and northern foxtail pines do not overlap [39,61], so distinguishing among them in the field is easy.

Stand structure: Foxtail pine communities are typically open, with a sparse understory and scattered woody debris. Arid, high-elevation conditions allow woody debris to persist for many years without decaying [44]. In Sequoia-Kings Canyon National Park, southern foxtail pine grows in widely spaced woodlands in its upper elevational range and is often the only tree species. At lower elevations it forms a more dense forest, either in mixed or monospecific stands

[10,12,81,82]. The foxtail pine-alpine ecotone is usually abrupt as a result of foxtail pine's inability to form krummholz [63]. Northern foxtail pine communities tend toward greater density than southern foxtail pine communities [82]. In the Klamath Ranges, stand densities of northern foxtail pine communities ranged from a minimum of 51 trees/ha in the Yolla Bolly Mountains to a maximum of 381 trees/ha in the Trinity Mountains [30]. Stand densities of southern foxtail pine communities in Sequoia-Kings Canyon National Park range from 50 trees/ha to 600 trees/ha [30,63,80,82]. Ryerson [82] found a mean stand density of 100 trees/ha on sites across southern foxtail pine's distribution.

Age class: Age class structure within foxtail pine stands appears mixed [30,68]. Few studies have been conducted on age class distributions in foxtail pine. In a study across the Klamath Ranges, Eckert and Sawyer [30] found northern foxtail pines less than 100 years of age were most common ($\geq 50\%$ relative density). A few very old trees (around 1,000 years of age) were scattered within all the study sites. In a study across southern foxtail pine's distribution in the Sierra Nevada, Ryerson [82] found most trees were in the 350- to 500-year-old class, followed by trees less than 200 years old, and trees older than 800 years, respectively.

Foxtail pine is a very long-lived conifer, although it does not approach the extreme ages of bristlecone pines. Foxtail pine occurs on wetter sites than bristlecones; consequently, foxtail pines show relatively faster growth, develop heart rot, and die more quickly than bristlecone pines [8]. Foxtail pine has advanced heart rot by 1,000 years of age. The oldest foxtail pine on record (as of 2004) is a 3,400-year-old southern foxtail pine [82]. Northern foxtail pines occur in wetter habitats than southern foxtail pines and are shorter lived, attaining maximum ages of about 1,600 years [30,68,82].

Physiology: Its relative inability to withstand cold may partially explain foxtail pine's narrow distribution compared to its more widely distributed high-elevation associate, whitebark pine. Poor ability to form krummholz limits foxtail pine's ability to withstand ice blasting [13]. Its seedlings are less resistant to freezing than whitebark pine seedlings [82].

RAUNKIAER [78] LIFE FORM:

[Phanerophyte](#)

REGENERATION PROCESSES:

Environmental interactions that foster foxtail pine recruitment are poorly understood. Climate and water balance may be the primary factors driving foxtail pine establishment, with best recruitment during periods of warm, wet winters and cool summer temperatures [33,36,37,62]. Dendrochronologists studying a 3,500-year history of southern foxtail pine recruitment and death rates in Sequoia-Kings Canyon National Park found 2 periods of poor southern foxtail pine recruitment. The 1st was during a drought lasting decades (950-550 years BP); the other was an extended period of below-average temperatures (450-50 years BP). Death rate was relatively stable over the last 1,000 years, averaging about 0.05% per capita. Death appeared to be due to local or endogenous factors except during periods of extreme climate fluctuation. Mortality spiked during the periods of extended drought and extended cold. Overall recruitment rate was slightly higher than death rate, averaging around 0.06% per capita [62,63]. As of this writing (2004), field studies on the seed germination and seedling establishment stages of foxtail pine's life cycle are lacking. Further studies are needed on the regeneration requirements and life cycle of foxtail pine.

Barriers to regeneration: Domestic livestock grazing may adversely affect foxtail pine regeneration in areas where grazing is still practiced. Vankat [106] found southern foxtail pine in Sequoia-Kings Canyon National Park showed a pulse of recruitment from 1890-1895. That period coincides with a period of reduced domestic sheep grazing in the southern Sierra Nevada.

White pine blister rust (*Cronartium ribicola*) affects the ability of 5-needle pines to reproduce by killing cone-bearing branch tips. An infected northern foxtail pine population on the Klamath National Forest (see [Other Management Considerations](#)) shows poor recruitment, although it is uncertain at this time if blister rust is responsible. Levels of blister rust infection in foxtail pine are being monitored [99].

Breeding system: Allozyme surveys show that genetic diversity is low in foxtail pine compared to other pine

species. There is more genetic differentiation among than within populations. Interpopulation genetic diversity is particularly pronounced in northern foxtail pine, which tends to have small (300-600 individuals), isolated populations, and restricted between-population gene flow. Natural selection for serpentine tolerance, global warming (see Other Management Considerations, [Climate](#)), and genetic drift have likely contributed to northern foxtail pine's low genetic diversity [[77](#)].

Pollination: Foxtail pine is wind pollinated [[59](#)].

Seed production: Foxtail pine 1st produces cones at 20 to 50 years of age [[52,82](#)]. The cone cycle (development through maturity) takes 5 to 6 years [[28](#)]. There is usually a 5- to 6-year interval between large cone crops [[52](#)]. Environmental conditions promoting large crops are undocumented (as of 2004).

Seed dispersal: Foxtail pine seed is dispersed by wind [[58,59](#)]. How long seed is retained in the cone, and whether it survives fire and disperses from cones onto burns, is poorly documented (as of 2004). Likewise, average range of dispersal for wind-blown foxtail pine seed is unknown, making it difficult to predict the potential for long-range foxtail pine seed dispersal onto burns or other open seedbeds.

Although [Clark's nutcrackers](#) disperse bristlecone pine seeds, there have been no sightings of the birds dispersing the smaller seeds of foxtail pine [[60,70](#)]. Trees growing from Clark's nutcracker caches often have multiple, genetically distinct stems [[58,59](#)]. The typical single-stemmed habit [[8,10,82](#)] of foxtail pine suggests that Clark's nutcracker dispersal and caching is unusual. Ryerson [[83](#)], however, noted the presence of a few multiple-stemmed trees throughout foxtail pine's distribution, suggesting the possibility of Clark's nutcracker seed dispersal and caching. Genetic identities of multiple-stemmed foxtail pine "individuals" have not been determined. Further investigation is needed on mechanisms of seed dispersal for foxtail pine.

Seed banking: No information is available on this topic.

Germination: Seeds require stratification [[25,28](#)]. Fresh, stratified southern foxtail pine seed collected in Sequoia-Kings Canyon National Park showed 86% germination. After 9.4 years in cold storage, the same seed lot showed 72% germination [[75](#)].

Seedling establishment/growth: Based on limited information, foxtail pine seedling establishment appears to be episodic, occurring during periods of mild, wet winters [[62,82](#)].

Foxtail pine is a slow-growing conifer [[59,70](#)]. Best growth of southern foxtail pine occurs in years with relatively warm, wet winters and cool summers [[33,36,37,62](#)]. Studies on growth rates of foxtail pine are limited. One study found relative height growth rates of 0.2 to 0.9 inch (0.5-2.3 cm) per year for seedlings in Sequoia-Kings Canyon National Park. Seedlings in open, high-elevation sites tended to grow taller than seedlings in lower-elevation, forested areas [[92](#)]. For mature trees, another Sequoia-Kings Canyon study found trees at lower elevations (<8,200 feet (2,500 m)) had greater relative growth rates compared to trees at high elevations (>9,800 feet (3,000 m)). Relative growth rates were 6.7-9.1 inches/100 years compared to 2.4-3.1 inches/100 years (17-23 cm/100 yrs vs. 6-8 cm/100 yrs), at low and high elevations, respectively [[82](#)].

SITE CHARACTERISTICS:

Foxtail pine is adapted to harsh environmental conditions [[59,70](#)]. Its long life span, slow growth, and persistent needles are typical of conifer species adapted to stressful habitats [[70](#)]. Foxtail pine holds an ecological position between whitebark pine and limber pine: it is less tolerant of cool, short growing seasons than whitebark pine and less tolerant of warm, arid growing conditions than limber pine [[44,86](#)]. North of southern foxtail pine's distribution in the Sierra, freezing temperatures occur all year long [[82](#)]. Foxtail pine communities are most common on "safe sites," such as ultramafic soils and dry granite fields, that few other conifer species can tolerate [[30,59](#)]. Slope varies from gentle to as much as 55% [[82,83](#)].

Southern foxtail pine grows on well-drained, decomposed granite and granite boulder fields. Southern foxtail pine

does not occur on serpentine or other ultramafic soils, which are rare in the high Sierra Nevada [51,54,82]. It is more common on the drier, eastern side of the Sierra Nevada, while whitebark pine is more common on the west slope [10,82]. Climate in the southern Sierra Nevada is mediterranean, with cold winters and warm, dry summers [67,86]. Annual precipitation on the east slope ranges from 20 to 30 inches (500-750 mm) [13]. Southern foxtail pine occurs from 8,900 to 12,000 feet (2,700-3,700 m) elevation [39]. Tree damage from ice- and sandstorms is common [67]. Highest density of southern foxtail pine occurs on north-facing slopes; least density is on south slopes. Percent slope across southern foxtail pine's range averages less than 33% [82].

Habitat of **northern foxtail pine** is even more restricted than that of southern foxtail pine. The Klamath Ranges are geologically complex, consisting of steep elevational gradients and a variety of parent rock materials that strongly influence plant community boundaries [51]. Climate is mediterranean, but is strongly moderated by the maritime influence of the nearby Pacific Ocean [67]. Annual precipitation averages from 49 to 60 inches (1,250-1,750 mm) [13]. Northern foxtail pine occurs from 6,900 to 8,200 feet (2,100-2,500 m) elevation [39]. There are relatively few high-elevation peaks in the Klamath Ranges; therefore, northern foxtail pine tends to segregate into small populations on isolated "sky islands" [77]. Substrates on which northern foxtail pine grows include gabbro, granodiorite, limestone, schist, and most commonly, serpentine [51,54,59,86]. Because most associated conifers (except Jeffrey pine) are less tolerant to them, serpentine soils can partially ameliorate the elevational restriction and lower northern foxtail pine's elevational distribution. Northern foxtail pine tends to grow in large, monospecific stands when on serpentine soils. On other substrates it is generally found in small stands (a few hundred trees) on ridge crests, mountain tops, and steep, south- or west-facing slopes [30,68,77,86]. Populations on serpentine soils are more likely to occur on all aspects, including valley bottoms and lake shores [77]. Percent slope ranged from 15-32% on 4 sites in the Klamath Ranges [82].

SUCCESSIONAL STATUS:

Foxtail pine is shade intolerant, requiring open, sunny locations throughout its life cycle [8,9,82,86]. Foxtail pine pioneers on serpentine and high-elevation subalpine sites [30]. It competes poorly on nutrient-rich, mesic, and low-subalpine sites [77,86]. Foxtail pine is generally noninvasive [79]; however, it has extended its distribution into the California red fir zone in times of global cooling [82]. On high-elevation, ultramafic or dry granitic sites, foxtail pine is not threatened by successional replacement by shade-tolerant conifers such as California red fir and mountain hemlock because no other tree is as well adapted to the harsh sites that foxtail pine occupies [14,30]. On more favorable sites, successional replacement of foxtail pine by mountain hemlock and firs may be occurring. Research is needed on successional patterns in foxtail pine communities on mesic, nonserpentine sites.

A resurvey in Sequoia-Kings Canyon National Park showed that in 27 years, southern foxtail pine basal area and cover increased 8% and 16%, respectively. The changes were entirely due to foxtail pine diameter growth; in 27 years there had been no foxtail pine mortality, and no ingrowth of foxtail pine or other tree species, on the study plots [80]. To date (2004), there are no studies of succession in foxtail pine communities following fire, avalanche, or other disturbances. Studies documenting postdisturbance recruitment and succession in foxtail pine communities are needed.

SEASONAL DEVELOPMENT:

Pollen dispersal and pollination of new foxtail pine cones occurs in July and August. Mature cones open and disperse seed in September and October [27,52]. Common garden studies show foxtail and bristlecone pines open their cones later in the season than other North American pine species [25]. Little is known of foxtail pine's seed biology and the phenological development of seedlings. Further work is needed in this area.

FIRE ECOLOGY

SPECIES: *Pinus balfouriana*

- [FIRE ECOLOGY OR ADAPTATIONS](#)
- [POSTFIRE REGENERATION STRATEGY](#)

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations: Foxtail pine has many characteristics of a fire survivor [87]. Some of its morphological characteristics are similar to ponderosa pine, a highly fire-adapted species [4]. Like ponderosa pine, foxtail pine is a long-lived tree with a large-diameter bole, thick bark, and large-diameter branches [8,45]. Branches are generally sparse and self-pruning in southern foxtail pine, although thin branching and a self-pruning habit are less common in northern foxtail pine [39,59,67]. Few fire studies on foxtail pine have been conducted; however, Ryerson [82] found mature, fire-scarred southern foxtail pines throughout the tree's distribution. As further evidence of foxtail pine's ability to survive fire, Keifer [48] reported that in the Sierra lodgepole pine-southern foxtail pine ecotone in Sequoia-Kings Canyon National Park, foxtail pines were uneven-aged and showed multiple fire scars, while Sierra lodgepole pines were even-aged and showed no evidence of scarring. More fire history studies are needed on foxtail pine.

Foxtail pine seedlings pioneer on burned sites. The seeds are small, light, and have large wings [39,70,76], suggesting the possibility of foxtail pine seed dispersal onto burns from on- and off-site parent trees. In Sequoia-Kings Canyon National Park, Ryerson [82] found southern foxtail pine seedlings on 2 burned sites. On the 1st burn, seedlings established near 4 lightning-killed, mature trees. On the 2nd burn, foxtail pine seedlings grew in openings created when fire burned across a ridgetop. Further studies are needed on patterns of foxtail pine seed dispersal and seedling establishment after fire.

Fire regimes: Fires are infrequent, and are generally of low severity, in subalpine regions of the southern Sierra Nevada. Scant litter production and discontinuous fuels do not promote fire spread in foxtail pine communities. Fire intensity tends to decrease when lower-elevation fires burn into southern foxtail pine. Fire spread slows; or, fires may extinguish due to lack of fuels [10,20,21,49,65]. Although foxtail pine sites receive more lightning strikes than lower-elevation forests, ignitions are uncommon [102,103]. Rocky, highly dissected foxtail pine habitats rarely sustain large fires. In a fire history study, Keifer [48] found frequent fire in Sierra lodgepole pine, but only occasional fires in southern foxtail pine sites. The National Park Service [101] classifies fire occurrence as "very low" in subalpine conifer zones of Sequoia-King Canyon National Park, with a mean fire-return interval of 187 years and a maximum recorded fire-return interval of 508 years. Caprio and Lineback [21] found southern foxtail and whitebark pine communities of Sequoia-Kings Canyon National Park had the longest return fire intervals of all plant communities in the Park. Estimated area burned in southern foxtail pine communities averaged 145 acres/year (168 ha/yr) with a mean fire-return interval of 187 years. Estimated burn area extended to 153 acres/year (62 ha/year) under the maximum mean fire-return interval of 508 years. Fire scar data from 2 watersheds show few fires in foxtail-whitebark pine communities of Sequoia-Kings Canyon National Park from 1700 to 2000: 7 on north aspects and 3 on south aspects [19]. Differences in fire-return intervals between aspects were not significant [18].

The fire ecology of upper subalpine zones of California is poorly understood [101]. This is particularly true for northern foxtail pine, for which fire ecology and fire regime information are nearly absent. Thornburgh [95] found white fir-mountain hemlock communities of the Marble Mountains, where northern foxtail pine is an associate, experience a regime of mixed low- and moderate-severity fires. Fire effects and postfire recruitment of foxtail pine were not reported. Further documentation and research are needed on the fire ecology of foxtail pine and other subalpine communities of California.

Occasionally, large, stand-replacing fires occur in southern foxtail pine [91]. For example, The 1949 Kern Canyon 2 Fire burned 1,100 acres (445 ha) of southern foxtail and Jeffrey pine habitat in Sequoia-Kings Canyon National Park. Ignited by lightning on 13 July, it was controlled by 31 July. Southwesterly winds up to 40 mph (64 km/hr) caused crowning and spotting. Steep, rugged terrain contributed to fast fire spread and resistance to control [10].

Fuels: Foxtail pine snags and woody debris are highly resinous, and are slow to decay in high-elevation habitats. In Sequoia-Kings Canyon National Park, downed foxtail pines that have been dead for over 1,000 years still retain medium-sized (>0.8-inch (2-cm) diameter) or larger branches [62]. Foxtail pine communities are not typically highly flammable though, because woody fuels are limited and discontinuous [65,91], and litter is sparse [81]. Live fuels are also scant. A 1978 fuel inventory in Sequoia-Kings Canyon National Park showed a mean of 10 tons/acre in foxtail and other subalpine types [10]. Basal area and litter quantity decreased with elevation, although litter quality (N:C ratio) increased with elevation [64]. The live understory is typically sparse in foxtail pine communities. Lloyd and

Graumlich [63] found less than 1 plant/m² in southern foxtail pine understories in Sequoia-Kings Canyon National Park. Van Wagtenonk and others [105] reported the following fuelbed characteristics for southern foxtail pine:

Woody fuel depth	Litter depth	Duff depth	Litter & duff depth
1.24 cm	0.19 cm	1.60 cm	1.79 cm

Quantitative measures of physical fuel properties such as surface-to-volume ratios are used in fuel models. By fuel size class, van Wagtenonk and others [104] provide mean surface-to-volume ratio, diameter and squared quadratic mean diameter, and angles of inclination tables for southern foxtail pine and other Sierra Nevada conifers.

The following table provides fire-return intervals for plant communities where foxtail pine occurs. For further information, see the FEIS summary on the dominant species listed below.

Community or Ecosystem	Dominant Species	Fire-Return Interval Range (years)
whitebark pine	<i>Pinus albicaulis</i>	50-200 [1,3]
Sierra lodgepole pine	<i>Pinus contorta</i> var. <i>murrayana</i>	35-200 [5]
mountain hemlock	<i>Tsuga mertensiana</i>	35 to > 200 [5]

Fire-return intervals for these species vary widely; trends in variation are noted in the species reviews.

POSTFIRE REGENERATION STRATEGY [94]:

Tree without adventitious bud/root crown

Initial off-site colonizer (off-site, initial community)

FIRE EFFECTS

SPECIES: *Pinus balfouriana*

- [IMMEDIATE FIRE EFFECT ON PLANT](#)
- [DISCUSSION AND QUALIFICATION OF FIRE EFFECT](#)
- [PLANT RESPONSE TO FIRE](#)
- [DISCUSSION AND QUALIFICATION OF PLANT RESPONSE](#)
- [FIRE MANAGEMENT CONSIDERATIONS](#)

IMMEDIATE FIRE EFFECT ON PLANT:

Lightning damage to foxtail pines is common, especially to trees in the upper subalpine zone [82]. Low-severity surface fire leaves basal scars on foxtail pines and kills some trees [48,82].

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:

Fire and climate may play an interactive role in determining the California red fir-foxtail pine ecotone. California red firs (*Abies magnifica* var. *magnifica* and *A. m.* var. *shastensis*) have thicker bark and are more fire-tolerant than most firs [7], but are not as fire-tolerant as foxtail pine. Warming climate and more frequent fires may promote foxtail pine invasions into lower-elevation California red fir communities [82].

PLANT RESPONSE TO FIRE:

Foxtail pine's thick bark helps protect it from damage from surface fires. Sparse, large-diameter branches discourage

torching and fire spread. Little is known about foxtail pine's response after the fire has passed. In the 1979 Fire Management Plan for Sequoia-Kings Canyon National Park, Bancroft [10] wrote "Very little research has been conducted on the effect of fire on natural regeneration in subalpine forests." This remains true of foxtail pine and other subalpine forests today. Research is needed on the fire ecology of foxtail pine.

Kiefer [48] found foxtail pine recruitment in Sequoia-Kings Canyon National Park was uneven-aged and did not appear to be correlated with fire history. This was in sharp contrast to associated Sierra lodgepole pine, whose recruitment dated from past fires. Kiefer suggested that climate may play a more important role in foxtail pine recruitment than fire.

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:

No additional information is available on this topic.

FIRE MANAGEMENT CONSIDERATIONS:

Southern foxtail pine communities are managed with prescribed natural fire (wildland fire for resource benefit) [91]. Fire may extend foxtail pine's distribution downslope on some sites [48], although the postfire interactions of California subalpine conifers have had too little study to predict postfire results with confidence. Fire may encourage foxtail pine recruitment and growth on existing foxtail pine sites by releasing nutrients from slow-decaying woody debris. On those relatively rare foxtail pine sites with closed canopies, fire would encourage foxtail pine recruitment by creating an open mineral seedbed.

MANAGEMENT CONSIDERATIONS

SPECIES: *Pinus balfouriana*

- [IMPORTANCE TO LIVESTOCK AND WILDLIFE](#)
- [VALUE FOR REHABILITATION OF DISTURBED SITES](#)
- [OTHER USES](#)
- [OTHER MANAGEMENT CONSIDERATIONS](#)

IMPORTANCE TO LIVESTOCK AND WILDLIFE:

Foxtail pine boughs probably provide shelter for wildlife. Chipmunks and birds probably eat the seeds, but little is known about wildlife use of foxtail pine habitats. Research is needed on the ecology of foxtail pine communities.

Palatability/nutritional value: Foxtail pine seeds are palatable and nutritious, but they are not large compared to most 5-needle pines [98]:

<u>Species</u>	<u>Mean seed weight</u>
Great Basin bristlecone pine	25 mg
foxtail pine	27 mg
limber pine	93 mg
whitebark pine	175 mg

Cover value: No information is available on this topic.

VALUE FOR REHABILITATION OF DISTURBED SITES:

No information is available on this topic.

OTHER USES:

Foxtail pine is an ecologically important species. The open structure of foxtail pine stands slows snowmelt and helps retain snowpack. Foxtail pine also helps stabilize soil on steep subalpine slopes [84,92].

As a long-lived conifer, foxtail pine is a valuable species for dendrochronological and related climate studies [33,36,37,88,89].

Wood Products: Foxtail pine is rarely harvested [82] and is not commercially important [92].

OTHER MANAGEMENT CONSIDERATIONS:

Damaging bioagents: Foxtail pine is highly susceptible to **white pine blister rust**, a usually fatal fungal disease that affects 5-needle pines [40,71,84]. In the greenhouse, Hoff and others [40] inoculated 18 species of Eurasian and North American 5-needle pine seedlings with blister rust. Of the 18 species, foxtail and southwestern white pine (*Pinus strobiformis*) showed least resistance to blister rust. All of the 92 inoculated foxtail pines became infected. Other studies show a 75-100% seedling infection rate [93]. Although the mediterranean climate of California once protected all but the northernmost populations of 5-needle pines from blister rust, that is no longer true. Some northern foxtail pines on the Scott River District of the Klamath National Forest have blister rust [96,97,99]. As of this writing (2004), blister rust has not been detected in southern foxtail pine, although western white pine and sugar pine (*P. lambertiana*) in Sequoia-Kings Canyon National Park are infected [84,99].

Blister rust-infected trees may take from 2 years to decades to succumb, but infection is always fatal [41,42]. Gooseberries and currants (*Ribes* spp.) are the primary host of white pine blister rust. Life cycle of white pine blister rust is complex. Gitzendanner and others [35] and McDonald and Hoff [71] provide details of the rust's life history and ecology. Hoff [41] provides a diagnostic guide to aid managers in recognizing symptoms of blister rust infection in white pines. There are no known methods of [controlling blister rust](#) [47]. Fungicide application, pruning infected tree branches, and/or removing *Ribes* spp. have neither eliminated nor controlled white pine blister rust [22,71], and such treatments have undesirable ecological effects [47]. For further information on management of white pine blister rust, see Samman and others [84].

Some northern foxtail pines on the Scott River District show phenological resistance to blister rust. Identification and breeding programs for these genetically valuable, blister-rust resistant individuals are crucial to an integrated strategy for protecting and restoring foxtail and other white pines [40,71,84]. Breeding programs for blister rust-resistant foxtail pines are being implemented [99].

Other damaging bioagents: Foxtail pines are susceptible to mountain pine beetle attacks [107]. Two rare species of *Pityophthorus* bark beetles may feed primarily on foxtail pine [17]. While contributing to biodiversity, little is known of the impacts of these *Pityophthorus* bark beetles to foxtail pine. Limber pine dwarf-mistletoe (*Arceuthobium cyanocarpum*) occasionally infects foxtail pine [50,69,73]. A fungal needle cast (*Lophodermium durilabrum*) has caused minor damage to northern foxtail pines in the Marble Mountains [72].

Climate affects foxtail pine's elevational range. For most of the period for which tree records are available ($\approx 3,500$ years), southern foxtail pine has existed above present treeline [62,63]. For example, Vankat [106] found dead stands of foxtail pine above present timberline (10,800- 11,200 feet (3,300-3,400 m)) on the Kern River Watershed in Sequoia-Kings Canyon National Park. These "ghost forests" may be relicts of foxtail pines that died during a period of global warming [56]. Lloyd and Graumlich [63] documented 3 episodes where southern foxtail pine expanded upslope. Although the data are somewhat unclear [55,89], these expansions appear to have occurred during relatively warm, wet periods. Presently, southern foxtail pine is expanding its range both upslope and laterally into subalpine meadows and previously untreed east slopes. This expansion has been explained as a response to global warming [62,64], or due to a combination of factors including global warming, low conifer diversity (and consequent lack of growth interference for foxtail pine in the upper elevations of the southern Sierra Nevada), and stochasticity [68,82,88].

Northern foxtail pine is threatened by global warming. Already restricted to a relatively few high-elevation peaks, there are no higher-elevation refugia for the Klamath Mountains subspecies to migrate to. Many northern foxtail pine populations are being "squeezed off the tops of mountains that are insufficiently high to provide suitable habitat" [77].

Pinus balfouriana: References

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