TITLE: Natural and anthropogenic threats to California's endemic foxtail pine (*Pinus balfouriana)*

LOCATION: California

DURATION: Year 2 of 2-year project **FUNDING SOURCE:** Base Plan

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PROJECT OBJECTIVES:

(1) To increase the number of long-term monitoring plots in foxtail pine stands.
(2) To develop demographic models for foxtail pine.
(3) To supplement current data on the status of white pine blister rust in foxtail pine with data on other stressors such as mountain pine beetle and climatic factors.

JUSTIFICATION:

a. Linkage to FHM Detection Monitoring: White pine blister rust is an exotic invasive fungal pathogen that entered California in 1929. Since that time it has infected sugar pine as far south as the southern Sierra and Mt. Breckenridge. Permanent plots are in place (via FIA) and the infection in sugar pine is well documented. Prior to 2004, blister rust infection on the other five-needled pines (also called white pines) was not well-known or documented, with the exception of data collected by Duriscoe and Duriscoe[1] in Sequoia and Kings Canyon NPs and Maloney[2] in the Lake Tahoe Basin region. In 2004, FHM funding was obtained to assess the distribution and levels of blister rust on all five high-elevation white pines of California, including foxtail pine. The data from that survey documented the presence of blister rust in all six plots established in the northern foxtail pine stands[3, 4]. In that survey, specific areas were not intensively sampled within the species' ranges since the objective was to distribute plots so broad regional patterns would be revealed, especially in the widely-distributed whitebark and western white pines. As a result, a small number of plots were established for the remaining three species (foxtail, limber, and Great Basin bristlecone pine) having more limited distributions in the State. Additional plots are needed to better understand the impact of blister rust on the endemic foxtail pine, especially in the northern stands, because current information on the health of this species is very limited: FIA plots are virtually non existent and no risk model has been developed for this species (Mike Bohne, pers. comm.). Bioclimatic models developed by Warwell et al. (unpub. data) predict that, by 2030, climatic conditions suitable for foxtail pine, especially in the north, virtually diminish with the exception of conditions in the Mt. Shasta area, where foxtail is not currently found (but where whitebark and western white pine are found). Bioclimatic predictions are useful tools to identify populations at risk, and can guide us in managing tree species in light of anthropogenic effects such as white pine blister rust and climate change.

b. Significance in geographical scale, biological impact and political importance:
Climate change, insects, and pathogens are three major threats to high-elevation white pines. In California, temperatures are projected to increase 2 to 6°C from the year 2000 to 2100.[5] These increases may lead to tree species migrating to cooler sites, latitudinally or elevationally, if possible. Moreover, warmer temperatures may also elevate mountain pine beetle activity in these high-elevation forests.[6] The non-native pathogen, white pine blister rust (*Cronartium ribicola*), remains a serious threat to these high-elevation species, as it continues to spread over North American forests containing white pines.[7] In California, the pathogen has been found in four of the six white pine species, including California's endemic foxtail pine.

Noteworthy of foxtail pine is its limited, disjunct distribution at high elevations in the northern coast-interior and southern Sierra Nevada mountains. This geographic separation also corresponds to significant genetic differences with the recognition of a northern and a southern ecotype.[8] In the north, foxtail stands are also genetically diverse from one another, have small population sizes, are at their ecological limits, and located in a distinctive geological-vegetation complex of California. Both ecotypes occupy the highest elevations where they are adapted to harsh mountain climates. Foxtail pine has similar ecological values as other high-elevation white pines, e.g., stabilizing soils, providing habitat and forage for wildlife, and having cultural value.

Data from the 2004-2006 survey documented that statewide the highest rust levels were found on the Six Rivers and Klamath NFs, in the north-central Sierra, and in lower levels on the west-slope of the southern Sierra. For foxtail pine, rust infection averaged 15% and varied from 2 to 32% in the six northern long-term monitoring plots. Given the continuous nature of the forests with white pines, i.e., lower elevation sugar pine, mid- to high-elevation western white pine, and high-elevation foxtail pine, it is expected that blister rust will have an increasing impact on foxtail over time. Northern populations already at their ecological margins are under threat by blister rust; in addition, a rapidly changing climate, e.g., increased temperatures and protracted summer drought, can elevate mountain pine activity and reduce foxtail populations with greater mortality and limited regeneration. In the Klamath mountains, a recent mountain pine beetle outbreak has been observed at Box Camp Mountain in one of the monitoring plots where no activity was documented in 2004 (Deems Burton, pers. comm.). In the southern foxtail populations, rust has not yet been observed[1,4] although one rust-infected tree was observed in Sequoia & Kings Canyon NP in 1995 by a forest pathologist[1]. Both sugar and western white pines have been impacted, suggesting that with time blister rust may enter the high-elevation foxtail populations. In addition, a changing climate, i.e., warmer, drier conditions, may be affecting seedling recruitment in the southern foxtail stands: data from the 2004-2006 plots revealed substantially lower regeneration (25 seedlings/ha) in the south than in the north (120 seedlings/ha). Current information on the status of foxtail pine relies on anecdotal observations and a relatively small number of plots. Supplementing with additional plots would provide more information on the rust, beetle activity, and recruitment dynamics of this endemic white pine species. Such information is basic to developing conservation and management strategies, as this species is part of the larger concern about health of all high-elevation white pine species (Samman et al. 2003).[9] Given foxtail's limited distribution, the risk of significant, more rapid loss of trees (or populations) may be higher than in the widely-distributed high-elevation white pines of California. More information is needed to adequately develop recommendations that mitigate against adverse impacts and maintain or restore foxtail pine populations as a response to public concerns about the health of these high-elevation forest ecosystems.

c. Feasibility or probability that the project will be successfully completed: From 2004 to 2006, Region 5 established 123 long-term monitoring plots to examine levels of blister rust over a broad regional scale on the five high-elevation white pines. The Region's blister rust resistance program will take the lead in coordinating efforts to obtain additional information on foxtail pine. Personnel on the Klamath National Forest already have knowledge about accessible sites where additional plots could be established in the north. More plots may be established and some existing plots in Sequoia and Kings Canyon National Parks may be re-visited to increase the number in the southern foxtail. Dr. Patricia Maloney (collaborator affiliated with UC Davis) is currently working on the 2004-2006 white pine survey report and is interested in extending her expertise to this project. Other individuals who contributed to the previous survey may also be interested in this work.

DESCRIPTION:

a. Background: This project will focus on the impact of white pine blister rust on foxtail pine in California and will add to the current number of 12 foxtail plots (6 in the north and 6 in the south) established in the 2004-2006 field survey described previously. Long-term monitoring plots following protocols of the 2004-2006 field survey will be established in both areas, but some areas from a previous study (Duriscoe & Duriscoe 2002) may be revisited as part of the southern plot additions. Typically, field observations also have been made while approaching the plot sites. Transect plots will be established with the collection of tree, *Ribes*, blister rust, and other pest, forest, and landscape data. The plot protocol is a modified version of the Whitebark Ecosystem Foundation's protocols for evaluating whitebark and limber pine.

b. Methods:
Foxtail pine plots will be 30 by 50 m, with size being adjusted to accommodate site factors, and contain at least 30 live foxtail out of 50 total. For each tree, data will be collected on diameter, tree status (live, dead), crown condition (≤10% dead, dying, damaged, infected; 11-20%, etc.), and incidence of WPBR. Canker location, number, and status will be recorded along with notes on other traits typical of rust-infection. In addition, data will be taken on "unknown" flagging, pests or pathogens such as mountain pine beetle (*Dendroctonus ponderosae*), and on cone production. At the plot level, seedlings/saplings will be counted, live or dead, and whether infected with WPBR. *Ribes* species, percent cover, and WPBR infection will be noted. Information will be recorded on plot conditions, location, slope characteristics, other tree species, aecia phenology, and presence/absence of *Castilleja*, *Pedicularis*, and Clark's nutcrackers. A subset of populations are planned for more intensive sampling in order to develop demographic population data to project population dynamics, i.e., are populations increasing, decreasing, or maintaining.

c and d. Products and Schedule of Activities:
Year 1: (Summer 2008) Establish long-term monitoring plots and collect data in the northern and southern foxtail pine stands.
Year 2: (Fall 2008 - Summer 2009) Enter and analyze data. Develop demographic models and a report on the status of foxtail pine in the plots established from this project and the previous 2004-2006 survey.

e. Progress/Accomplishments to Date – Year One of a Two-Year Project (2008):
Below is a table of plots that were established this summer or will be established in the summer of 2009. Note that all locations in bold are survey and demographic plots that have been completed. Also, plots in the left column were established in the previous California high-elevation white pine – rust survey (2004-2006).

Established Plot Locations (2004 – 2006 survey)	New Survey Plot Locations (this project)	Demographic Plot Locations (this project)
Northern stands		
Box Camp Mountain	North Yolla Bolly – 2008	Box Camp – 2008
Boulder Lakes	**Southern Trinity Alps - 2008**	Deadfall/Mt Eddy – 2008
Lake Mountain	**China Mountain - 2008**	North Yolla Bolly – 2008
Deadfall Foxtail	Telephone Lake - 2008	
South Yolla Bolly	Caribou Lake/Trinity Alps - 2009	
Wildcat Peak		
Southern Sierra stands		
Tharp's Rock	**Red Lake - 2008**	**Onion Valley – 2008**
Horseshoe Meadow	**Shepherd's Pass - 2008**	Cottonwood Pass – 2008
Franklin Lake	**Meysan Lake - 2008**	Crabtree Meadows - 2009
Guyot Creek	**Siberian Pass – 2008**	
Crabtree Meadows	Coyote Pass – 2009	
Onion Valley		

Because of the active fire season in California this year, field work that was scheduled for July in the north could not be completed because of access issues and fire danger. A trip to the area in early September allowed for the establishment of two survey plots, but access was still restricted in the Yolla Bolly Wilderness and would be for the rest of the season. Additional work will be done in October in the southern Sierra Nevada and possibly in the northern foxtail stands, if time and weather allow.

No white pine blister rust was observed in the northern or southern plots. In the southern Sierra Nevada evidence of recent mountain pine beetle activity and mortality was observed at Meysan Lake. Other forest insects were also observed in the southern Sierra Nevada: pine needle miner, scale, and the white pine weevil. To confirm the weevil observation, next year we will sample foliage and send it to the

regional and/or zone entomologist for confirmation. While fire is considered very infrequent in these high elevation systems, basal fire scars were noted in 4 of the 5 locations in the southern Sierra Nevada. Overall, stand conditions were good.

f. Summary:
The project is progressing satisfactorily. Fire activity in the northern stands limited our work, so only a few plots were established there this year. Additional field work is planned for the summer of 2009 to complete all plot establishment and data collection. We are requesting $12,850 in second-year funds to be used for analyses and reporting on the information from this assessment.

COSTS:

	Item	Requested FHM EM Funding	Other-Source Funding	Source
YEAR ONE				
Administration	Salary		7,592	R5 Genetics
	Overhead @ 15%		1,139	R5 Genetics
	Travel		1,000	R5 Genetics
	Vehicle (.415 per mile)		830	R5 Genetics
	Supplies		300	R5 Genetics
Procurements	Contracting:			
	1 field pathologist @$1475/wk, 7 wks	10,325		
	1 field crew @$830/wk, 7 wks	5,810		
	Travel ($500/wk, 7 wks)	3,500		
	Vehicle ($250/wk, 7 wks)	1,750		
	Equipment/Supplies	1,000		
TOTAL		22,385	10,861	
YEAR TWO				
Administration	Salary		4,366	R5 Genetics
	Overhead @ 15%		655	R5 Genetics
	Travel		500	R5 Genetics
	Vehicle (.415 per mile)		415	R5 Genetics
	Supplies		300	R5 Genetics
Procurements	Contracting:			
	1 field pathologist @$1475/wk, 8 wks	11,800		
	Travel ($500/wk, 1 wk)	500		
	Vehicle ($250/wk, 1 wk)	250		
	Supplies	300		
TOTAL		12,850	6,236	

ENDNOTES:

[1] Duriscoe, D.M. and C.S. Duriscoe. 2002. Survey and monitoring of white pine blister rust in Sequoia and Kings Canyon National Parks—Final report of 1995-1999 survey and monitoring plot network. Science and Natural Resources Management Division, Sequoia and Kings Canyon National Parks.

[2] Maloney, P.E. 2000. Topics in forest pathology and ecology in the Sierra Nevada and the Sierra San Pedro Martir, Baja. Ph.D. Dissertation, University of California, Davis.

[3] One plot had non-aecial evidence of blister rust only.

[4] Maloney, P., J. Dunlap, D. Duriscoe, R. Smith, J. Pickett, D. Davis, D. Burton, and J. Kliejunas. 2007. White pine blister rust and high elevation five-needle pines in California. Poster, 2007 Forest Health Monitoring Working Group Meeting, San Diego, California.

[5] Cayan, D., A. Luers, M. Hanemann, G. Franco, and B. Croes. 2006. Scenarios of climate change in California: an overview. California Climate Change Center, publication CEC-500-2005-186-SF. 53 p.

[6] Logan, J.A., and J.A. Powell. 2001. Ghost forests, global warming, and the mountain pine beetle (Coleoptera: Scolytidae). American Entomologist 47: 160-172.

[7] Schwandt, J.W. 2006. Whitebark Pine in Peril: A case for restoration. USDA Forest Service. Intermountain Region Forest Health Protection Report# R1-06-28. 24p.

[8] Oline, D.K., J.B. Mitton, and M.C. Grant. 2000. Population and subspecific genetic differentiation in the foxtail pine (*Pinus balfouriana*). Evolution 54(5): 1813-1819.

[9] Samman, S., J. Schwandt, and J. Wilson. 2003. Managing for healthy white pine ecosystems in the United States to reduce the impacts of white pine blister rust. Forest Service Report R1-03-118. Missoula, MT: Department of Agriculture, Forest Service. 10p.