LONG-TERM MONITORING OF HIGH-ELEVATION WHITE PINE COMMUNITIES IN PACIFIC WEST REGION NATIONAL PARKS

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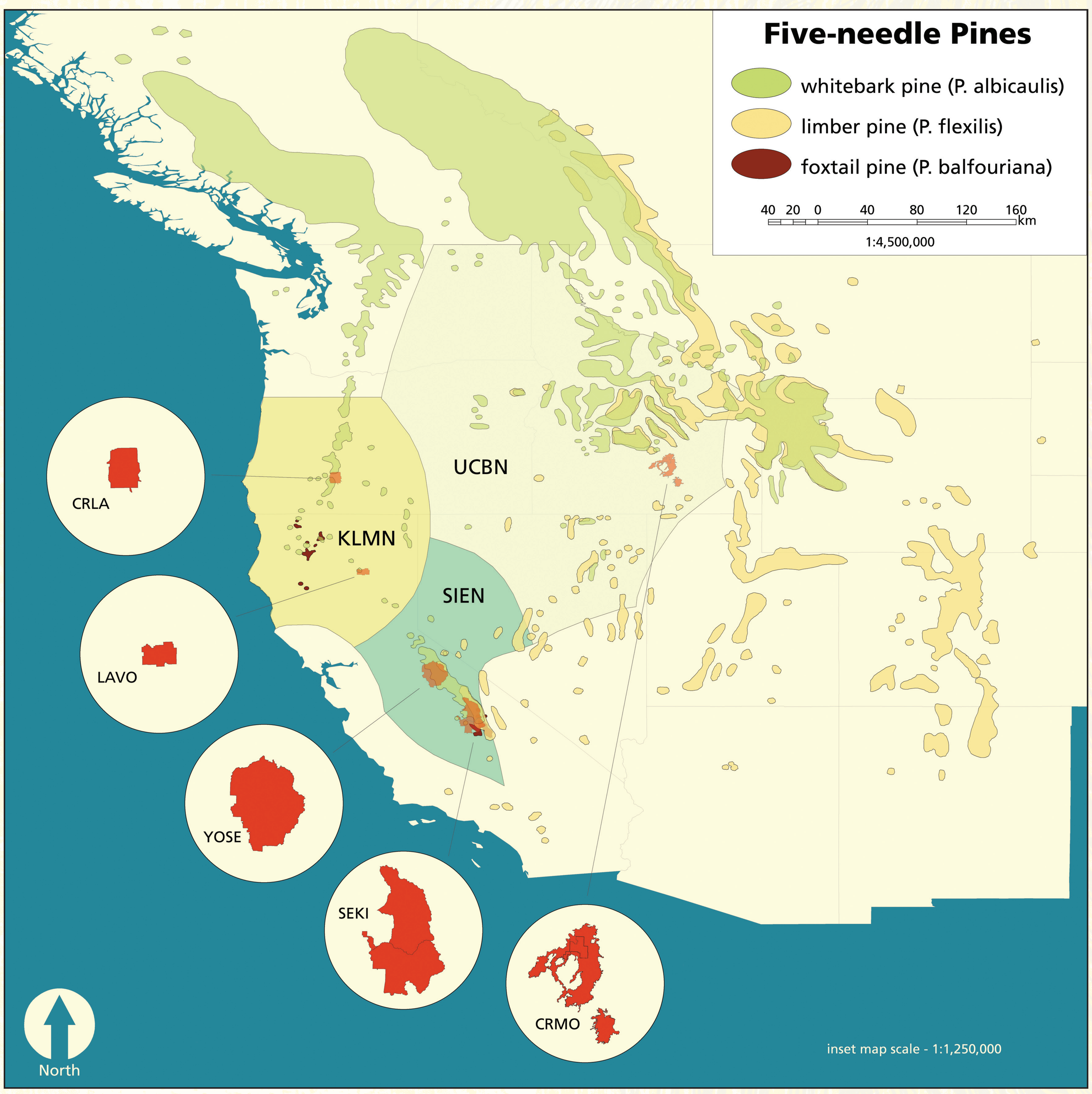
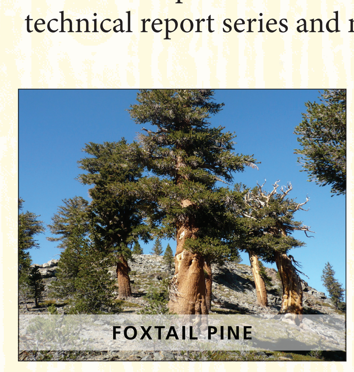


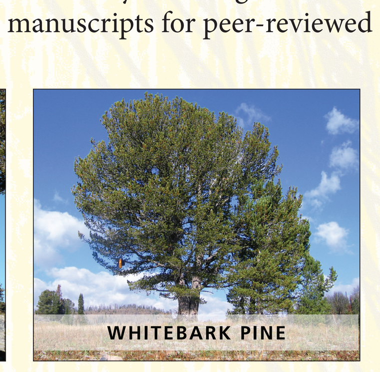
ABSTRACT –

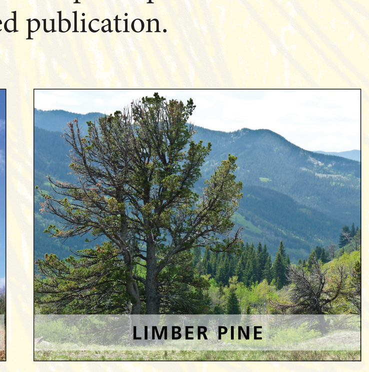
BACKGROUND – National Park Service Inventory and Monitoring (I&M) networks conduct long-term monitoring to provide park managers information on the status and trends in key biological and environmental attributes (vital signs). Here we present an overview of a collaborative approach to long-term monitoring of high-elevation white pine forest dynamics among three Pacific West Region I&M networks: Klamath (KLMN), Sierra Nevada (SIEN), and Upper Columbia Basin (UCBN). Whitebark pine (*Pinus albicaulis*) is monitored in five national parks: Lassen Volcanic and Crater Lake in the KLMN, and Yosemite, Sequoia, and Kings Canyon in the SIEN. Foxtail pine (*P. balfouriana*) is monitored in Sequoia and Kings Canyon, and limber pine (*Pinus flexilis*) is monitored in Craters of the Moon in the UCBN. Previous but limited sampling efforts report relatively low levels of blister rust infection and tree mortality. In KLMN, 30% of whitebark pine trees were infected, while less than 5% of sampled whitebark were infected in SIEN. Rust was not found on foxtail or limber pine within plots in our parks. However, one infected foxtail pine was identified in Sequoia in 1995, and several infected limber pines were found in Craters of the Moon in 2006.

APPROACH – Permanent plots are allocated to random locations using an equal-probability spatially-balanced approach using the Generalized Random Tessellation Stratified (GRTS) algorithm. A serially alternating panel design is used with a three-year rotation for re-surveying permanent plots. Tree- and plot-level data are collected to determine the status and trends in forest structure, species composition, demographic rates, cone production, incidence and severity of white pine blister rust (*Cronartium ribicola*), occurrence of mountain pine beetle (*Dendroctonus ponderosae*), and dwarf mistletoe (*Arceuthobium spp*) infection.

APPLICATION – Blister rust and mountain pine beetle occurrence within several of the network parks, coupled with projections of increased temperature and decreased precipitation in the region, portend future declines in white pine communities, underscoring the need for broad-scale collaborative monitoring. Our joint efforts will provide comparable data on rust infection rates and tree damage, pine beetle outbreaks, and tree mortality across a large region with diverse forest types. Collaborative monitoring will also create opportunities to share information to better understand the effects of modern stressors on the dynamics of high-elevation forest ecosystems, and add to our knowledge of blister rust spread and epidemiology. This information can help park managers adapt to anticipated short- and long-term changes in ecosystem structure and function. Annual reports will be published through the NPS Natural Resources Technical Report series and through NPS websites. Resource briefs will be produced and updated each year to provide a quick overview on the status of high-elevation white pine communities in each park. Trend analyses will occur at the end of each panel rotation ultimately resulting in more in-depth reports for the NPS technical report series and manuscripts for peer-reviewed publication.


FOXTAIL PINE


WHITEBARK PINE


LIMBER PINE

LONG-TERM MONITORING OBJECTIVES –

Determine the status and trends in the following:

1. Tree species composition and structure.
2. Tree species birth, death, and growth rates.
3. Incidence of white pine blister rust and level of crown kill.
4. Incidence of pine beetle and severity of tree damage.
5. Incidence of dwarf mistletoe and severity of tree damage.
6. Cone production of white pine species.

DESIGN AND FIELD METHODS –


NUTCRACKER WITH SEED
SEEDS EXTRACTED FROM CONE
REGENERATION

- Plot locations are assigned using an equal-probability spatially-balanced approach using the Generalized Random Tessellation Stratified (GRTS) algorithm.
- Permanent macro- (50 m x 50 m) and sub-plots (3 m x 3 m) are established.
- Each plot is visited once every three years (Table 1).
- Plot-level data are collected on slope, elevation, aspect, and temperature in certain plots.
- Tree-level data are collected on status (live/dead), species name, diameter, height, cone production, rust infection and crown kill, pine beetle occurrence, and mistletoe infection.
- Regeneration data are collected on seedling counts by species and height class (20 - <50, 50 - <100, 100 - <137 cm) from multiple subplots and averaged for plot-level values.

ANALYSIS METHODS –

DESCRIPTIVE –

- Estimate the proportion of trees and plots affected by blister rust, pine beetle, and mistletoe.
- Quantify seedling density and cone production.
- Construct stand tables by combinations of species composition, size class (diameter and height), tree status (live or dead), and health status (infected or healthy).

TREND MODELING –

Analyze trends through time in demographic (birth and death), reproductive (regeneration and cone production), growth (diameter and height), and infection (rust, beetle, mistletoe) rates. A mixed model is used to test the null hypothesis that the trend coefficient β_1 is equal to zero (H_0: $\beta_1 = 0$), with type I error $\alpha = 0.1$ and type II error $\beta = 0.2$ (and power $(1-\beta) = 0.8$). The model (equation 1) includes fixed effects, which contribute to the mean of the outcome of interest, and random effects, which contribute to the variance. Random effects estimate variation that can affect the ability to detect trend, such as site-to-site and year-to-year variation.

NETWORK COMPARISONS –

Mixed linear models are used to estimate trends in the response variables across the three networks. Comparisons of rates of change among the networks are made using F-tests to test for differences in slope and intercept coefficients. Descriptive statistics are compared among the networks using standard uni- and multivariate approaches.

$$y_{ijk} = \mu + w_j \beta + b_j + a_i + w_j t_i + c_{ij} + e_{ijk} \qquad (1)$$

where $i = 1,\ldots,m_a$; $j = 1,\ldots,m_b$; $k = 1,\ldots,m$ and
m_a = the number of sites in the sample;
m_b = the number of consecutive years in the sample;
m = the number of measurements taken within a site and year;
w_j = constant representing the j[th] year (covariate);
μ and β = fixed intercept and slope of the linear time trend;
b_j = random effect of the j[th] year;
a_i = random intercept of the i[th] site, independent and identically distributed as $N(0, \sigma^2_a)$;
t_i = random slope of the i[th] site, independent and identically distributed as $N(0, \sigma^2_t)$;
c_{ij} = random effect of site by year, independent and identically distributed as $N(0, \sigma^2_c)$;
e_{ijk} = residual error, independent and identically distributed as $N(0, \sigma^2_e)$.

Table 1. Revisit design for monitoring white pine species in Pacific West Region networks a) Klamath, **b)** Sierra Nevada, and **c)** Upper Columbia Basin.

a. KLMN. This panel design is followed in both LAVO and CRLA for a total KLMN n = 60 unique plots.

	YEAR												
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1 (n=10)	deferred			x			x			x			x
2 (n=10)		x			x			x			x		
3 (n=10)			x			x			x			x	

b. SIEN. This panel design is followed in both YOSE and SEKI for a total SIEN n = 108 unique plots.

PANEL	YEAR												
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1 (n=12)	x			x			x			x			x
2 (n=12)		x			x			x			x		
3 (n=12)			x			x			x			x	

c. UCBN. This panel design is followed in CRMO for a total UCBN n = 90 unique plots.

PANEL	YEAR												
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1 (n=30)	x			x			x			x			x
2 (n=30)		x			x			x			x		
3 (n=30)			x			x			x			x	