Proactive Use of Genetic Resistance to Pathogens to Sustain Ecological Function of Threatened Ecosystems

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Mountain Top Tree Species: Symbols of Perseverance and Tolerance

Define the very limits of the tree growth form

Remote but not beyond reach of anthropogenic influences
High Elevation Five-Needle Pines – Challenged by new stresses

Playing out on the high elevation landscape right now

White pine blister rust

Climate change

Mountain Pine Beetle
Whitebark Pine gives us a Preview

Whitebark pine has been exposed to white pine blister rust for over 50 years.

Mountain pine beetle is active.

Whitebark Pine is now a candidate species for Endangered Status under the Endangered Species Act.

We don’t want the other species to follow the same trajectory as whitebark pine.
Healthy ecosystems still exist but are threatened

- Disease continues to spread
- Risk analysis reveals that >50% of the five-needle pine habitat in the Southern Rockies regularly has conditions suitable for the disease (Kearns, Jacobi, et al)
- In 2001 we started to build the science foundation for management to sustain these southern populations

**Legend**
- Foxtail Pine
- Great Basin Bristlecone Pine
- Limber Pine
- Rocky Mountain Bristlecone Pine
- Whitebark Pine
We have an opportunity to choose a path

Proactive Strategy

Data gathering → Informed Intervention → Modified Natural Ecosystem

Natural Ecosystem

Restoration Strategy

Invasion → Data gathering → Informed Intervention → Modified Natural Ecosystem → Functional Ecosystem in the Presence of WPBR

Late Invasion

Impaired Ecosystem → Restoration → Recovering Ecosystems

Goal: prepare the landscape to promote self-sustaining resilient populations and sustained ecosystem function into the future in the presence of the rust.

(Schoettle and Sniezko 2007, Keane and Schoettle 2011)
Sustaining population resiliency requires maintenance of:

(1) Population recovery capacity after disturbances
(2) Adaptive capacity
(3) Multi-generational persistence

Requires a long-term and evolutionary perspective.
Life History – High Elevation Five-Needle Pines

Regeneration Cycle

Delayed maturation 50 to 70 years

Seedling establishment

Immature trees

Seed

Reproductive trees

Long-lived, stress tolerant

Not prolific; infrequent

Response to native stressors → tolerance, perseverance
Not well equipped for rapid adaptation to novel stressors
White Pine Blister Rust compromises the regeneration cycle - kills trees of all ages

**Regeneration Cycle**

- Seedling establishment
- Immature trees
- Seed
- Reproductive trees
- Top-kill Mortality
- Reduced dispersal
- Low production Mortality
- Mortality

Resistance and regeneration opportunities are key to keeping the regeneration cycle intact and supporting a viable population.
Preparation for invasion

Preparation Toolkit = Resistance, Natural and Artificial Regeneration

**Regeneration Cycle**

- **Prepare site** → **Seed** → **Immature trees** → **Plant resistant seedlings** → **Top-kill mortality** → **Reproductive trees** → **Low production** → **Reduced dispersal** → **Seedling establishment** → **Mortality** → **Prepare site**

(Schoettle et al 2011)
Exploring Interactions: Predicting Population Outcomes

For high elevation five-needle pine populations:
- What frequency of resistance is enough to sustain a population?
- Under what conditions?
- Will stimulating regeneration accelerate selection for resistance?
- How does the probability of infection affect selection and population dynamics?

Need to understand the interaction of life history traits of the high elevation pines with:
- ✓ Probability of rust infection
- ✓ Regeneration capacity
- ✓ Heritable rust resistance
- ✓ Management
Population Genetic Infection Model

Population projections under different:
Initial conditions; Rust hazard conditions; Rust resistance allele frequencies; Management scenarios

Field et al, in press, Ecol Appl., Schoettle et al. in prep
Model Parameterizations

For each of the 6 stages we define:

- Initial density
- Initial resistance allele frequency
- Survivorship probability
- Transition probability to next stage
- Fecundity
- Rust infection probability
- Cost of infection on fecundity and survivorship

Fecundity and seed germination are density dependent

- Relationships and parameters derived from the literature and field datasets for high elevation pines
- Three genotypes (RR, Rr, rr) – simply inherited disease resistance
- Random mating
- No co-evolution of the pathogen

Field et al, in press, Ecol Appl., Schoettle et al, in prep

SEE POSTER FOR MORE DETAILS
Effect of resistance in the natural population

More resistance $\rightarrow$ less decline in density $\rightarrow$ faster rebound
Uncertain if there is a threshold beyond which rebound is unlikely
Management may still be necessary
Generate: Mosaic of stands with different time courses of selection

Manipulate selection rate through demographics:
   Selection is fast for young trees
   Slower for older larger trees

Generate young stands via disturbance if regeneration cycle is healthy

Plant resistant seedlings if:
   • regeneration cycle is impaired or
   • resistance in base population is too low

(Schoettle and Sniezko 2007)
Stimulating Regeneration Accelerates Selection for Resistance

Requires:
- Functioning regeneration cycle
- Resistance in the base population

Remove competing vegetation at the time of rust introduction
Maintain structural change over time
200 year projection after rust infection

Increase regeneration → Increase selection for resistance
For multi-generational sustainability:

- **Resistance is key**: Frequency in natural population
- **Manage demographics and colonization dynamics**: Accelerate selection for resistance and population resilience
- **Manage the ecosystem before processes are impaired**: Utilize the natural processes to increase effectiveness of intervention; Retain adaptive capacity during pathogen naturalization.
Proactive Strategy in the Southern Rockies – Putting it into practice

Interdisciplinary team: ecologists, geneticists, pathologists, silviculturalists, and economists

Natural Populations:
   Rocky Mountain bristlecone pine (*Pinus aristata*)
   Limber pine (*Pinus flexilis*)

✓ Rust resistance testing – families and natural populations
   ▪ Complete resistance
   ▪ Partial resistance
✓ Regeneration dynamics and requirements
✓ Pilot scale silvicultural treatments
✓ Gene conservation

Integrate to develop management plans
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