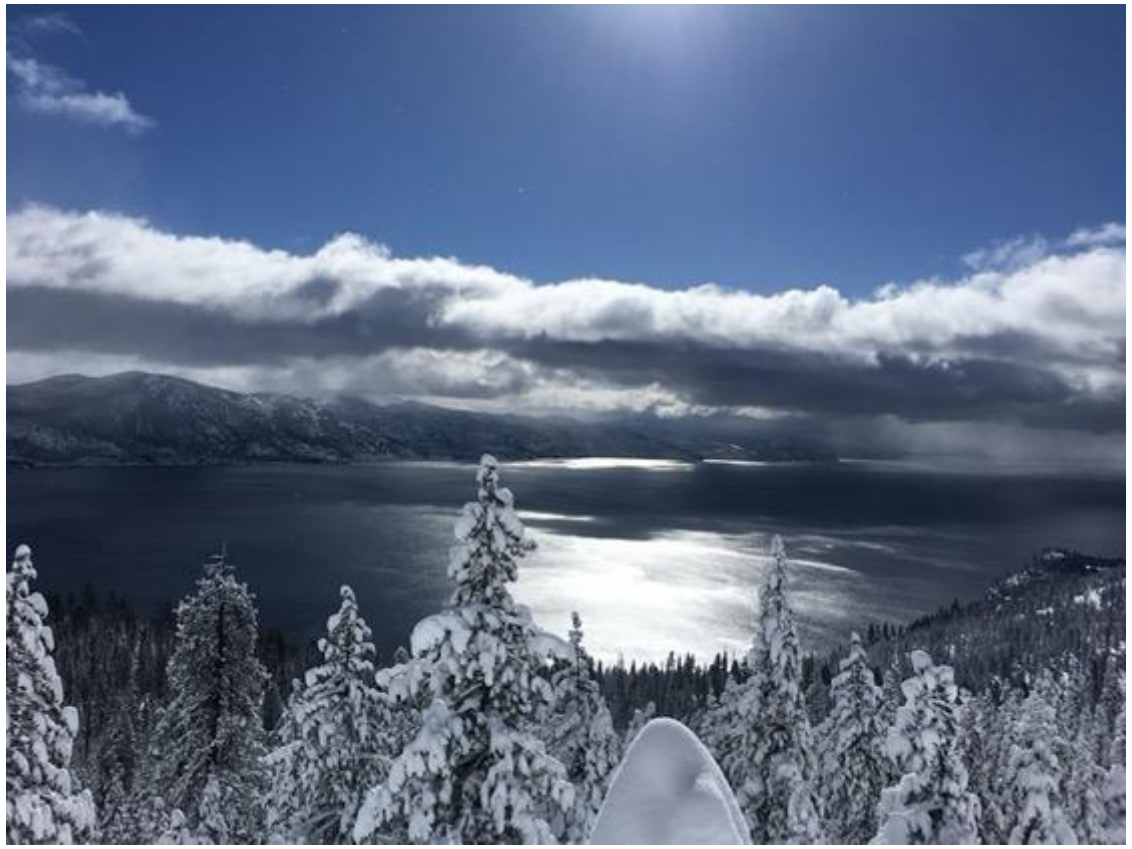
Forest Ecosystem Restoration in the Sierra Nevada

Patricia Maloney



UCDAVIS
Tahoe Environmental
Research Center

Lake Tahoe Forests

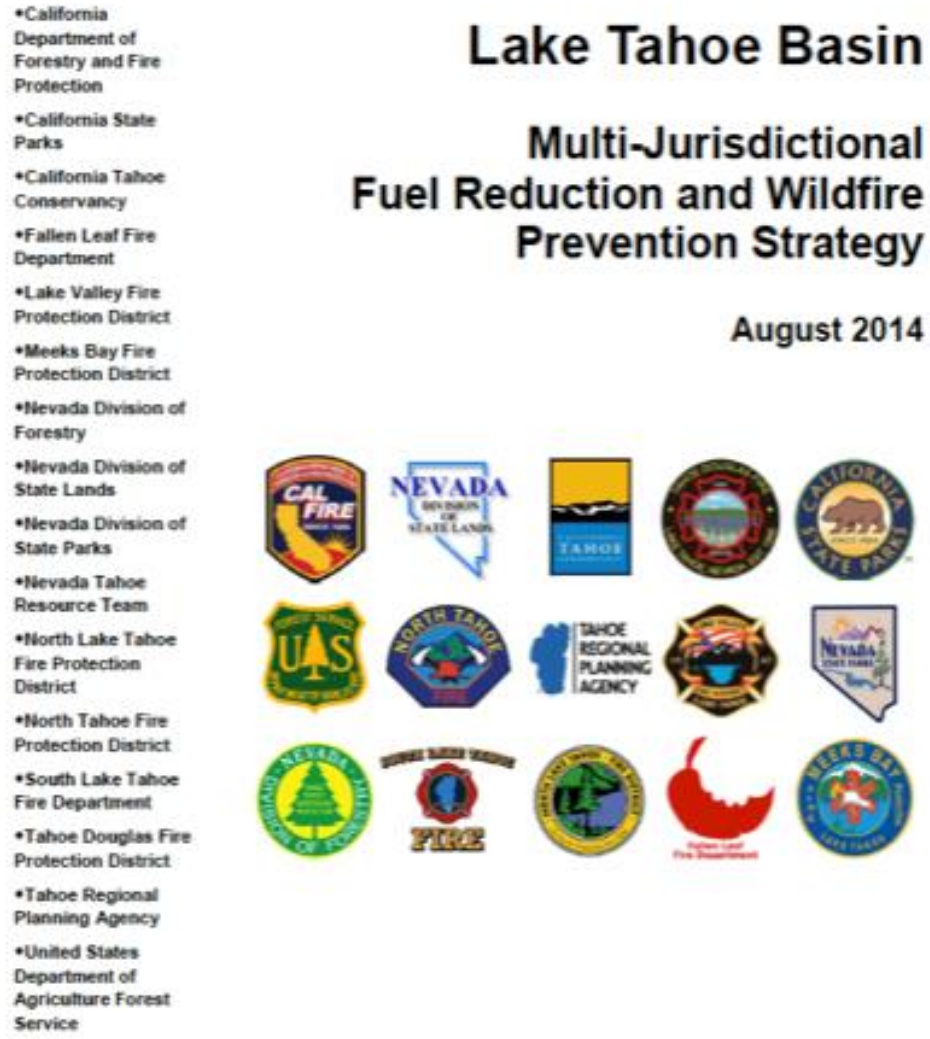
Mitigating a legacy of land-use

Active forest management

Treating over 100,00 acres in both California and Nevada

Goals of forest treatments:

1. Restore and maintain fire resilient landscapes
2. Mitigate insect and disease outbreaks
3. Increase forest resiliency to drought
4. Improve and protect carbon sequestration



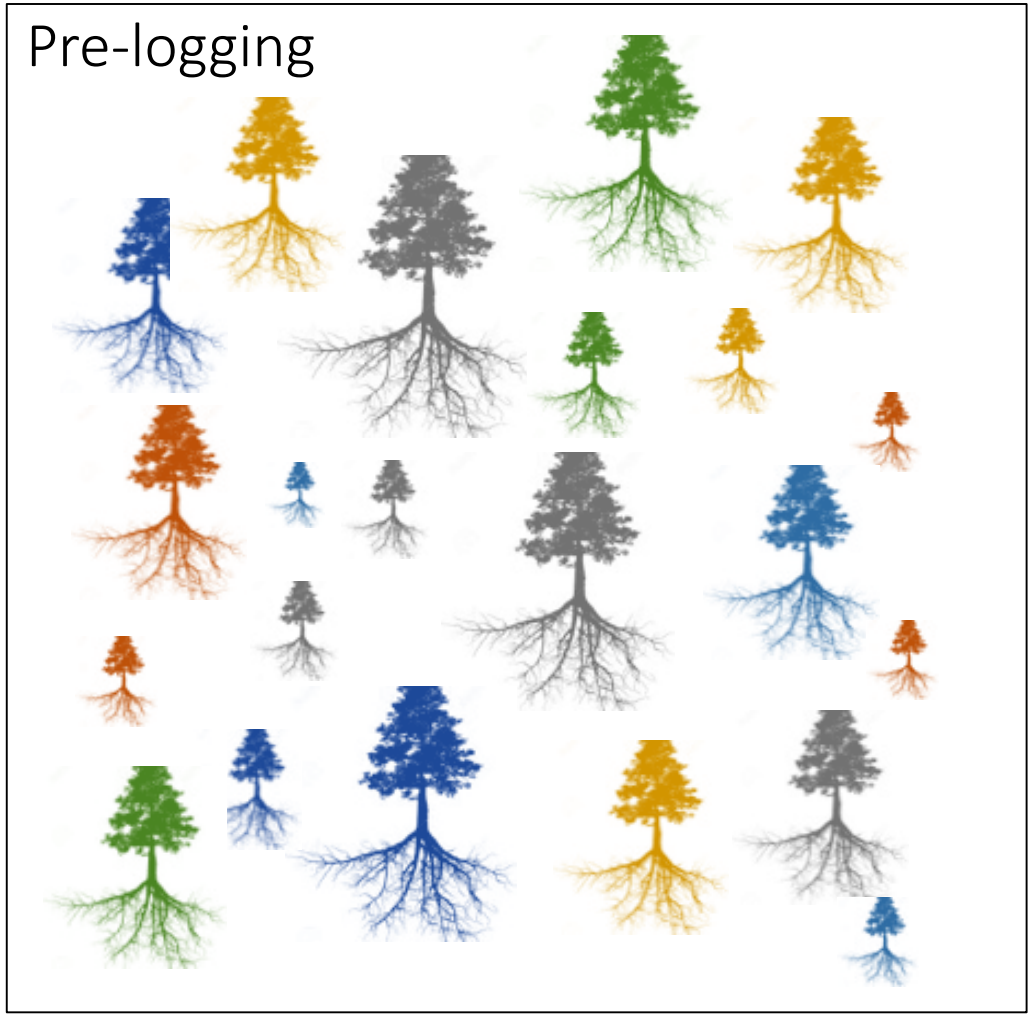
Historical Land-Use


+

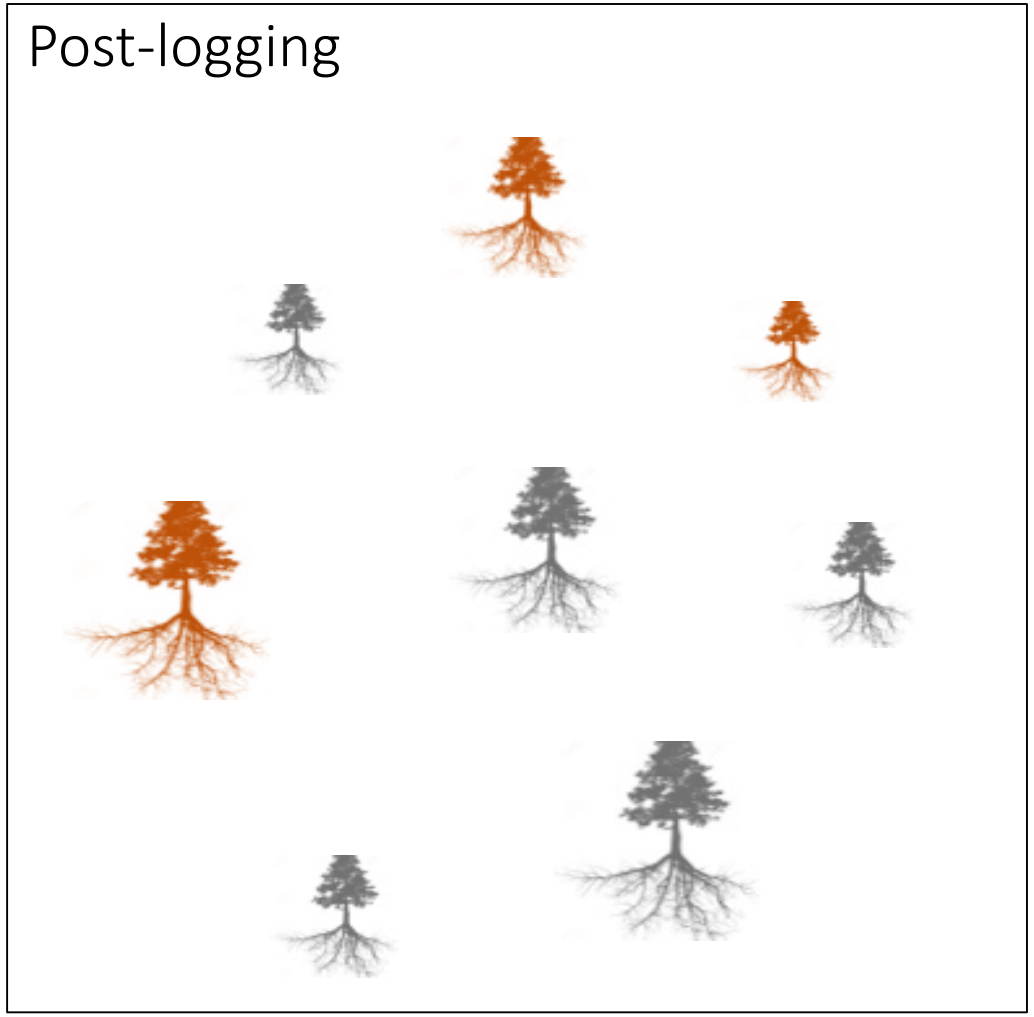
=


Genetic consequences of Comstock-era logging on sugar pine populations in the Lake Tahoe Basin

Pre-logging



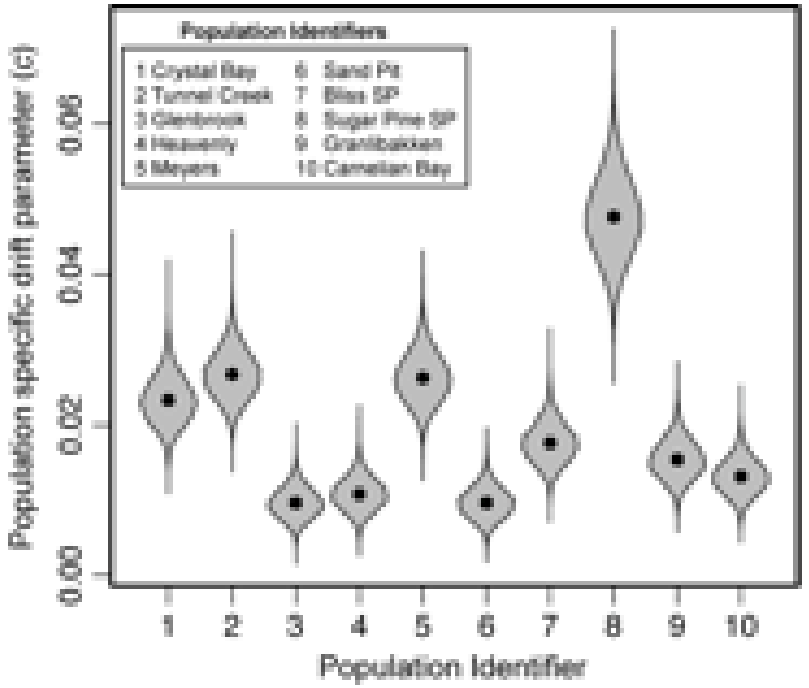
Post-logging



Tree image source - http://www.123rf.com/clipart-vector/conifers.html

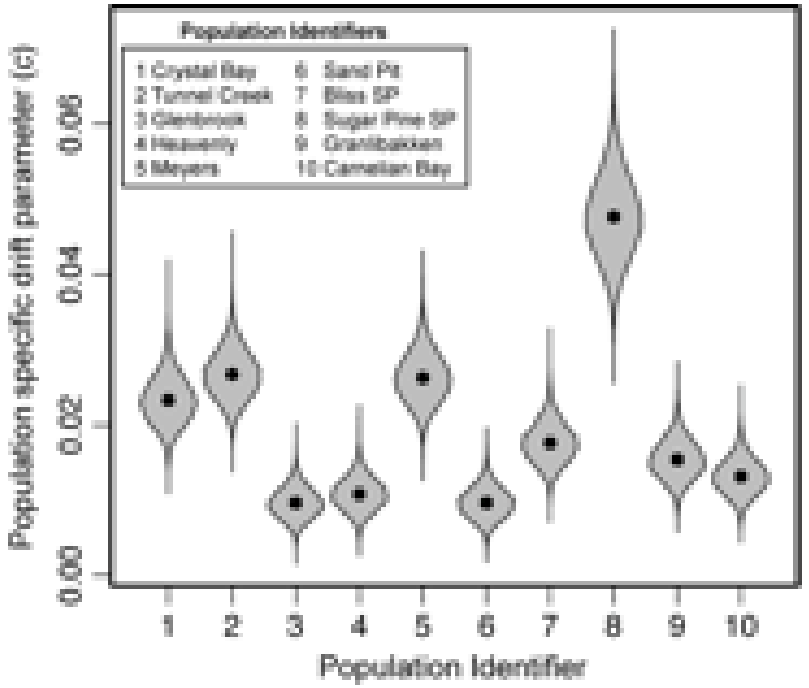
What are the genetic consequences of historical logging in the Lake Tahoe Basin?

- **High genetic drift in some sugar pine populations in the LTB. Genetic drift can result in important traits being lost from a population without respect to survival and fitness.**
- Effects of drift are greater in small populations and can act faster to reduce genetic variation.
- Populations at Tunnel Creek, Crystal Bay, & Sugar Pine Point SP, have “0” heritability for water-use efficiency. Essentially these populations have lost their “memory” to pass this trait on to the next generation.
- Such genetic losses could affect sugar pine’s resilience and ability to respond and adapt to environmental change.



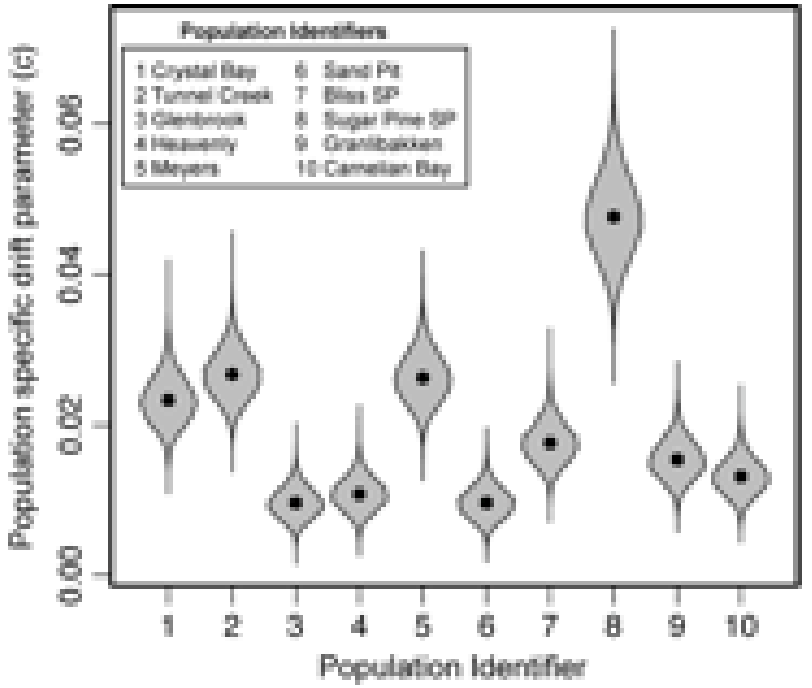
What are the genetic consequences of historical logging in the Lake Tahoe Basin?

- High genetic drift in some sugar pine populations in the LTB. Genetic drift can result in important traits being lost from a population without respect to survival and fitness.
- **Effects of drift are greater in small populations and can act faster to reduce genetic variation.**
- Populations at Tunnel Creek, Crystal Bay, & Sugar Pine Point SP, have “0” heritability for water-use efficiency. Essentially these populations have lost their “memory” to pass this trait on to the next generation.
- Such genetic losses could affect sugar pine’s resilience and ability to respond and adapt to environmental change.



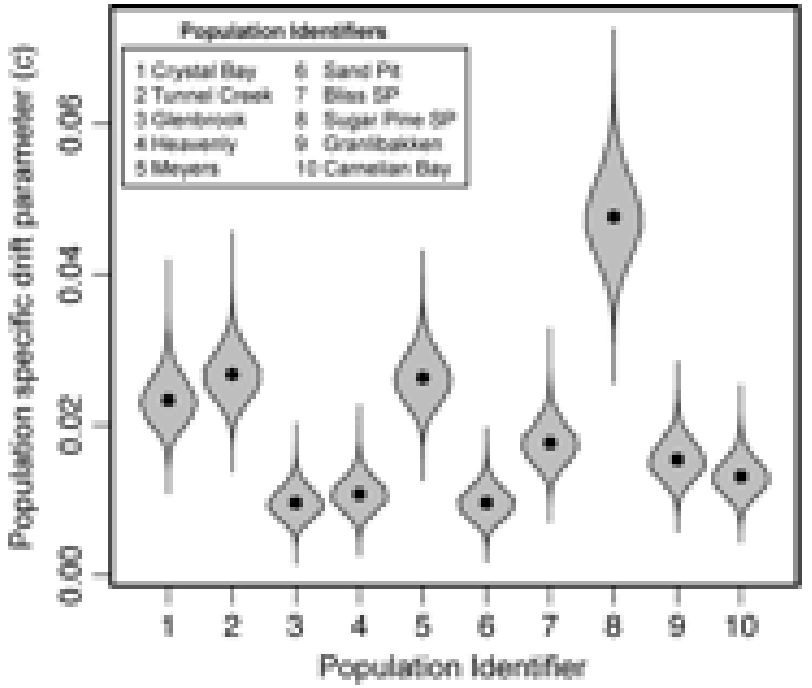
What are the genetic consequences of historical logging in the Lake Tahoe Basin?

- High genetic drift in some sugar pine populations in the LTB. Genetic drift can result in important traits being lost from a population without respect to survival and fitness.
- Effects of drift are greater in small populations and can act faster to reduce genetic variation.
- **Populations at Tunnel Creek, Crystal Bay, & Sugar Pine Point SP, have "0" heritability for water-use efficiency. Essentially these populations have lost their "memory" to pass this trait on to the next generation.**
- Such genetic losses could affect sugar pine's resilience and ability to respond and adapt to environmental change.



What are the genetic consequences of historical logging in the Lake Tahoe Basin?

- High genetic drift in some sugar pine populations in the LTB. Genetic drift can result in important traits being lost from a population without respect to survival and fitness.
- Effects of drift are greater in small populations and can act faster to reduce genetic variation.
- Populations at Tunnel Creek, Crystal Bay, & Sugar Pine Point SP, have “0” heritability for water-use efficiency. Essentially these populations have lost their “memory” to pass this trait on to the next generation.
- **Such genetic losses could affect sugar pine’s resilience and ability to respond and adapt to environmental change.**



Ecological & Evolutionary Consequences of Environmental Change

- Shifts in species composition & structure
- Genetic shifts within existing species
- Is climate change exerting a selective pressure for drought resilient forest trees?

Climate Change Induced Drought

From 2012 to 2016 drought and bark beetles killed more than 126 million trees in California and 72,000 in the Lake Tahoe Basin.

Drought – Bark Beetle Interactions

- Bark beetles, such as mountain pine beetle (MPB), are known to preferentially attack drought-stressed trees.
- Trees have a physical-based defense by producing resin.
- Host chemistry can either defend against bark beetle attack or aid in locating a suitable host.
- When trees, such as those here in the Sierra Nevada are drought-stressed, they can emit chemicals such as ethylene that can signal tree vulnerability and detection by bark beetles such as MPB.

Drought – Bark Beetle Interactions

- Bark beetles, such as mountain pine beetle (MPB), are known to preferentially attack drought-stressed trees.

- Trees have a physical-based defense by producing resin.

- Host chemistry can either defend against bark beetle attack or aid in locating a suitable host.

- When trees, such as those here in the Sierra Nevada are drought-stressed, they can emit chemicals such as ethylene that can signal tree vulnerability and detection by bark beetles such as MPB.

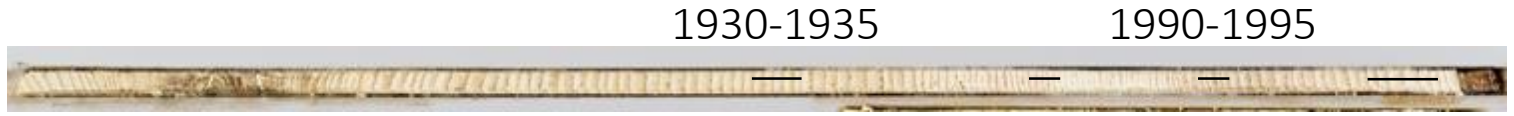
Drought – Bark Beetle Interactions

- Bark beetles, such as mountain pine beetle (MPB), are known to preferentially attack drought-stressed trees.
- Trees have a physical-based defense by producing resin.
- Host chemistry can either defend against bark beetle attack or aid in locating a suitable host.
- When trees, such as those here in the Sierra Nevada are drought-stressed, they can emit chemicals such as ethylene that can signal tree vulnerability and detection by bark beetles such as MPB.

Drought – Bark Beetle Interactions

- Bark beetles, such as mountain pine beetle (MPB), are known to preferentially attack drought-stressed trees.
- Trees have a physical-based defense by producing resin.
- Host chemistry can either defend against bark beetle attack or aid in locating a suitable host.
- When trees, such as those here in the Sierra Nevada are drought-stressed, they can emit chemicals such as ethylene that can signal tree vulnerability and detection by bark beetles such as MPB.

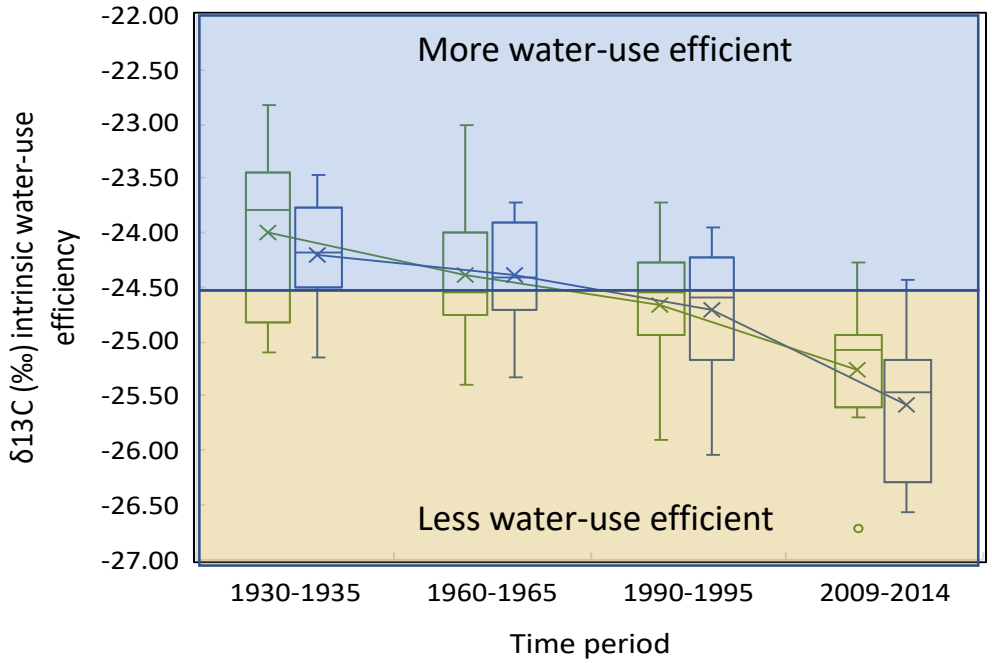
TERC's forest and conservation biology lab cored from 100 live and 100 mountain pine beetle-killed sugar pine trees to conduct a retrospective analysis of their tree rings.



Retrospective analysis of water-use efficiency over the last 90 years

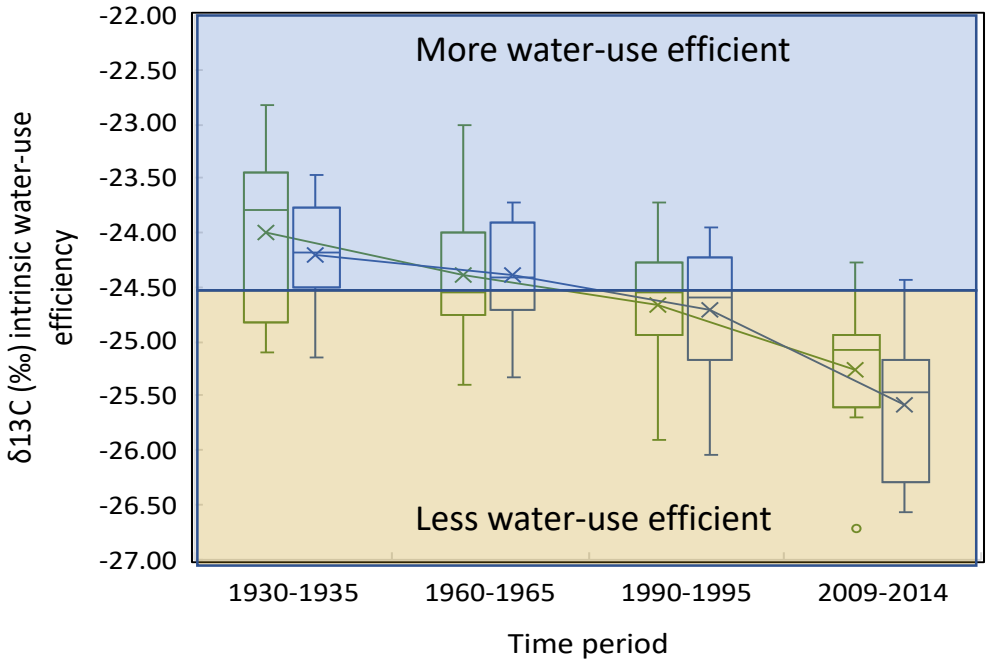
Drought stress and susceptibility to MPB

- Sugar pine trees that were more water-use efficient, and perhaps better adapted to drought, survived the 2012-2016 MPB outbreak.
- In contrast those sugar pines killed by MPB utilized water less efficiently and were most susceptible to MPB attack.
- Trees under high drought stress often have reduced host defenses to bark beetle attack.



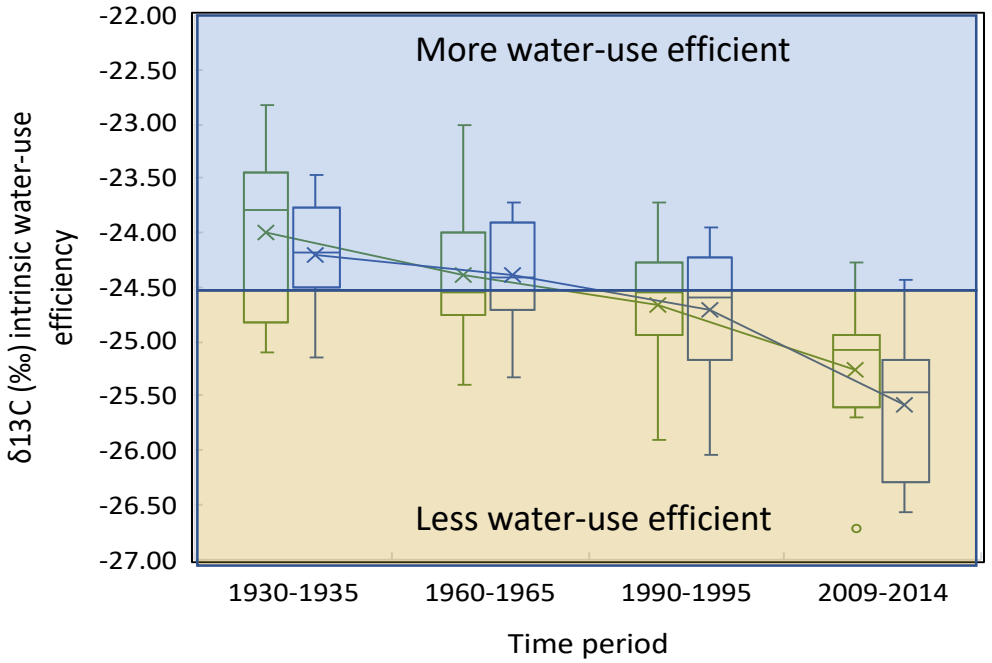
Drought stress and susceptibility to MPB

- Sugar pine trees that were more water-use efficient, and perhaps better adapted to drought, survived the 2012-2016 MPB outbreak.
- In contrast those sugar pines killed by MPB utilized water less efficiently and were most susceptible to MPB attack.
- Trees under high drought stress often have reduced host defenses to bark beetle attack.



Drought stress and susceptibility to MPB

- Sugar pine trees that were more water-use efficient, and perhaps better adapted to drought, survived the 2012-2016 MPB outbreak.
- In contrast those sugar pines killed by MPB utilized water less efficiently and were most susceptible to MPB attack.
- Trees under high drought stress often have reduced host defenses to bark beetle attack.



Amplifying within-population resilience to drought –
Collections from local drought “survivors”

Collected from 100 surviving sugar pines in 2017 & 2021

Amplifying within-population resilience to drought

Los Angeles Times

Leader of Navy is ousted in clash

Pentagon chief fires Richard V. Spencer, giving Trump a win in SEAL controversy.

Nunes dodges query about meeting

Lawmaker threatens to sue CNN over report on allegation he sought info from ex-Ukrainian official.

A bet on Sierra survivors

In climate race, scientists are propagating trees with staying power

Forest scientists bet on hardiest trees

In 2019-2020 UCD & the CCC out-planted the progeny of 100 local and diverse sugar pine trees, essentially those trees that survived drought & a MPB outbreak.

We consider this approach as “assisted regeneration” of local and diverse seed sources.

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

- **Scientifically study the survivors / "winners"**
- Out-plant progeny of drought "survivors"
- Use remote sensing technologies, geospatial datasets, and high resolution microtopographic maps to improve microsite selection for restoration plantings and increase seedling survivorship.
- Monitor seedling survival as well as track the fate of 100 genetic individuals.
- Common garden study
- Measure a suite of ecologically important traits (e.g., water-use efficiency, chemical defense, disease resistance, growth, resource allocation, etc.)

Current Work

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

- Scientifically study the survivors / "winners"
- **Out-plant progeny of drought "survivors"**
- Use remote sensing technologies, geospatial datasets, and high resolution microtopographic maps to improve microsite selection for restoration plantings and increase seedling survivorship
- Monitor seedling survival as well as track the fate of 100 genetic individuals
- Common garden study
- Measure a suite of ecologically important traits (e.g., water-use efficiency, chemical defense, disease resistance, growth, resource allocation, etc.)

Current Work

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

- Scientifically study the survivors / "winners"
- Out-plant progeny of drought "survivors"
- **Use remote sensing technologies, geospatial datasets, and high resolution microtopographic maps to improve microsite selection for restoration plantings and increase seedling survivorship**
- Monitor seedling survival as well as track the fate of 100 genetic individuals
- Common garden study
- Measure a suite of ecologically important traits (e.g., water-use efficiency, chemical defense, disease resistance, growth, resource allocation, etc.)

Current Work

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

- Scientifically study the survivors / "winners"
- Out-plant progeny of drought "survivors"
- Use remote sensing technologies, geospatial datasets, and high resolution microtopographic maps to improve microsite selection for restoration plantings and increase seedling survivorship.
- **Monitor seedling survival as well as track the fate of 100 genetic individuals**
- Common garden study
- Measure a suite of ecologically important traits (e.g., water-use efficiency, chemical defense, disease resistance, growth, resource allocation, etc.).

Current Work

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

- Scientifically study the survivors / "winners"
- Out-plant progeny of drought "survivors"
- Use remote sensing technologies, geospatial datasets, and high resolution microtopographic maps to improve microsite selection for restoration plantings and increase seedling survivorship.
- Monitor seedling survival as well as track the fate of 100 genetic individuals
- Common garden study
- Measure a suite of ecologically important traits (e.g., water-use efficiency, chemical defense, disease resistance, growth, resource allocation, etc.)

Current Work

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

- Scientifically study the survivors / "winners"
- Out-plant progeny of drought "survivors"
- Use remote sensing technologies, geospatial datasets, and high resolution microtopographic maps to improve microsite selection for restoration plantings and increase seedling survivorship.
- Monitor seedling survival as well as track the fate of 100 genetic individuals
- Common garden study
- Measure a suite of ecologically important traits (e.g., water-use efficiency, chemical defense, disease resistance, growth, resource allocation, etc.)

Current Work

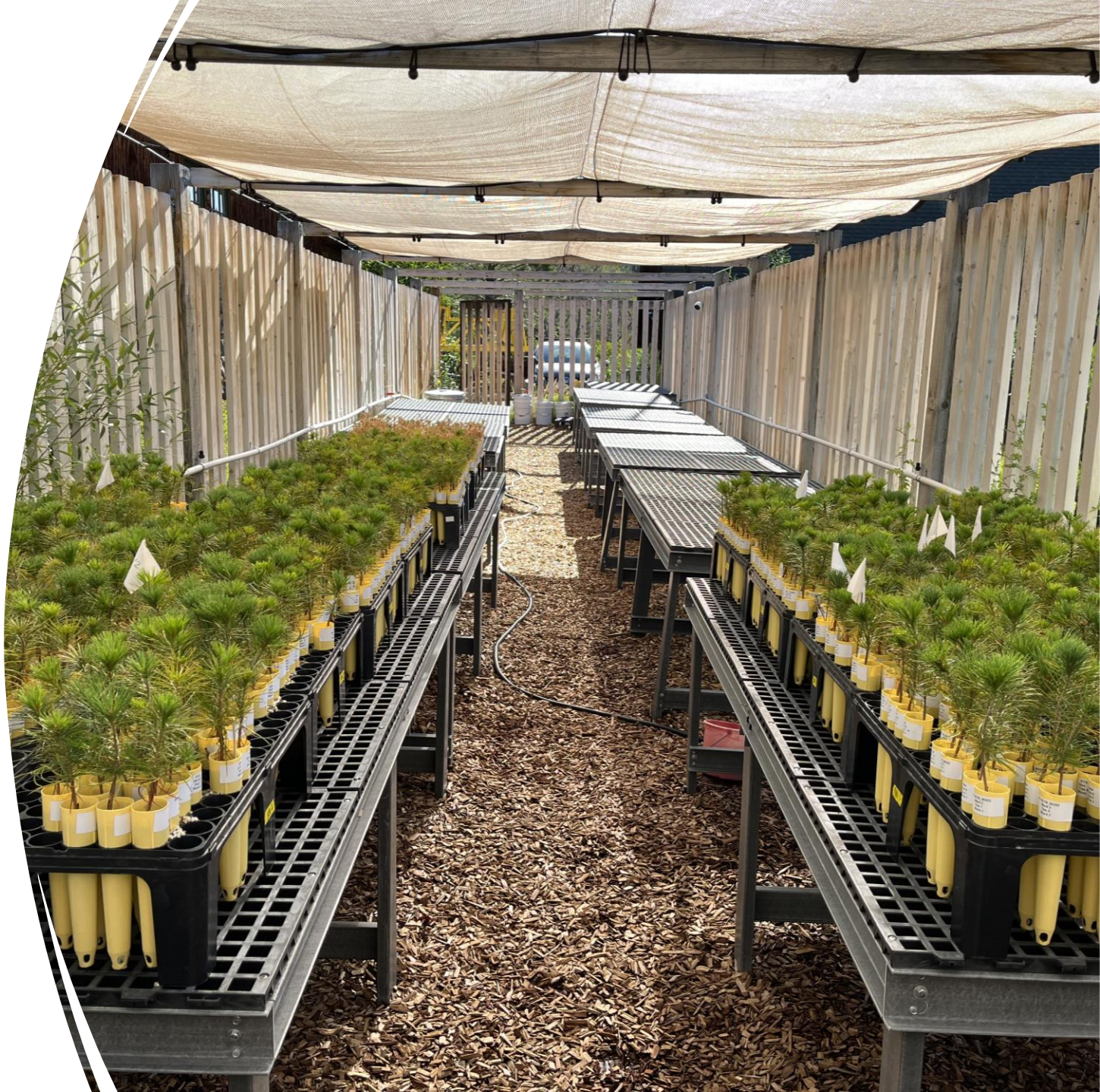
Trait-based approach

Seed are collected from many sources (families). This can be local e.g., the Tahoe Basin or range-wide.

Families are grown in a common environment.

Measure a variety of adaptive traits.

Determine relationships between traits and environment of the source locations.



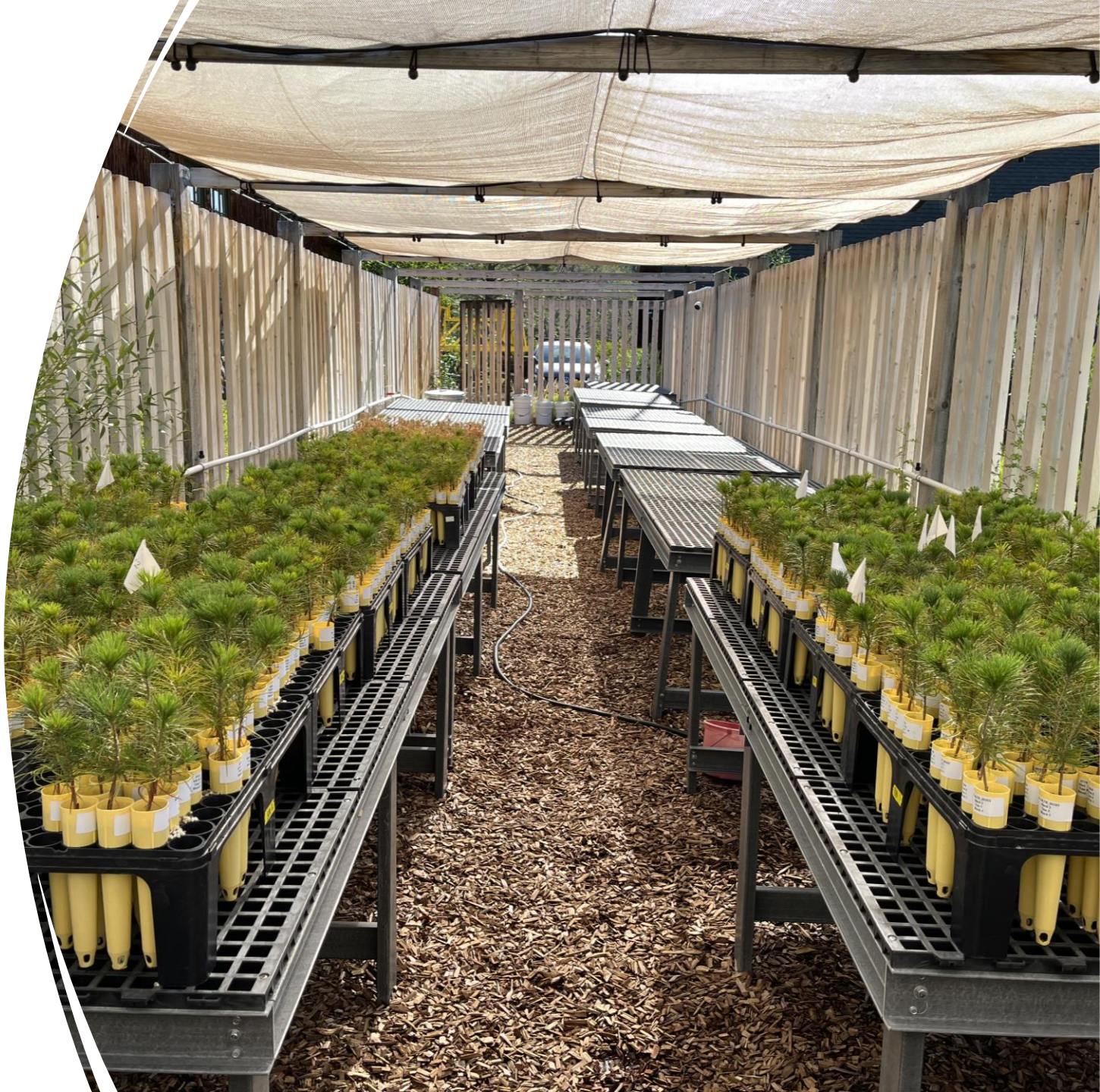
Trait-based approach

Seed are collected from many sources (families). This can be local e.g., the Tahoe Basin or range-wide.

Families are grown in a common environment.

Measure a variety of adaptive traits.

Determine relationships between traits and environment of the source locations.



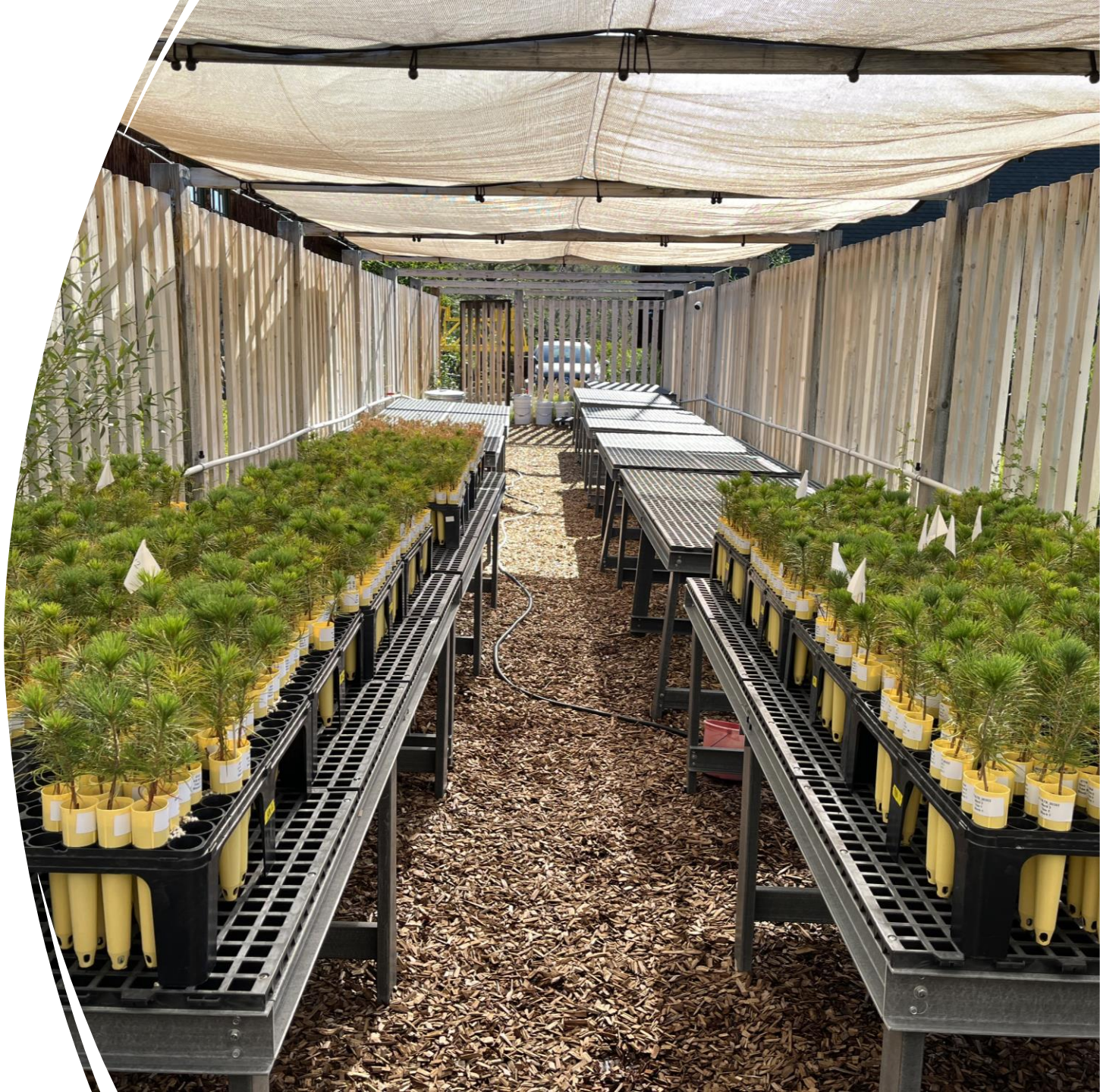
Trait-based approach

Seed are collected from many sources (families). This can be local e.g., the Tahoe Basin or range-wide.

Families are grown in a common environment.

Measure a variety of adaptive traits.

Determine relationships between traits and environment of the source locations.



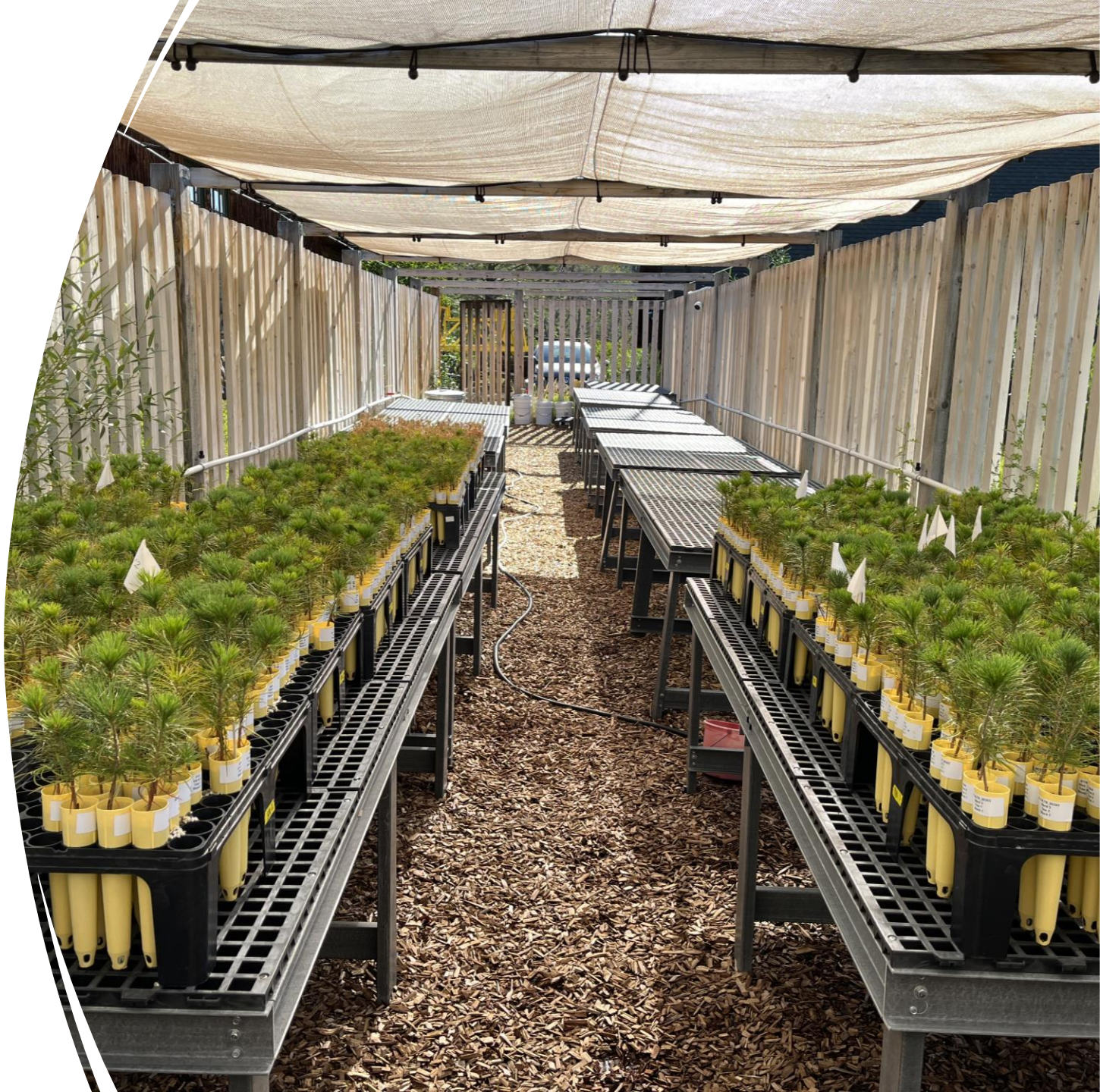
Trait-based approach

Seed are collected from many sources (families). This can be local e.g., the Tahoe Basin or range-wide.

Families are grown in a common environment.

Measure a variety of adaptive traits.

Determine relationships between traits and environment of the source locations.



Amplifying within-population resilience to drought – **Take 2**


Los Angeles Time

Leader of Navy is ousted in clash

Pentagon chief fires Richard V. Spencer, giving Trump a win in SEAL controversy.

A bet on Sierra survivors

In climate race, scientists are propagating trees with staying power


orest scientists bet on hardiest tree

Develop climate resilient forest restoration strategies

Funded by CalFire's Forest Health Program & California Climate Investments

Workforce Development with the CCC

Los Angeles Times

Leader of Navy is ousted in clash

Pentagon chief fires Richard V. Spencer, giving Trump a win in SEAL controversy.

Nunes dodges query about meeting

Lawmaker threatens to sue CNN over report on allegation he sought info from ex-Ukrainian official.

A bet on Sierra survivors

In climate race, scientists are propagating trees with staying power

VOLUNTEERS with the California Conservation Corps head into the thicket to begin planting thousands of sugar pine seedlings near Kings Beach this month.

Forest scientists bet on hardest trees

ARTURO GARCIA of the Conservation Corps plants seedlings during the "assisted regeneration" effort.

The goal is to develop a pipeline with the California Conservation Corps (CCC) that recruits and integrates a diverse and equitable workforce into conservation and forest health-related careers

Fir mortality

Currently we are seeing moderate to high fir mortality on the west shore of Lake Tahoe but this is also being observed more broadly across the Sierra Nevada, particularly on the western slopes.

Trends in Ecology & Evolution

CellPress

Opinion

Who Should Pick the Winners of Climate Change?

Michael S. Webster,[1,*] Madhavi A. Colton,[1] Emily S. Darling,[2] Jonathan Armstrong,[3] Malin L. Pinsky,[4] Nancy Knowlton,[5] and Daniel E. Schindler[6]

Many conservation strategies identify a narrow subset of genotypes, species, or geographic locations that are predicted to be favored under different scenarios of future climate change. However, a focus on predicted winners, which might not prove to be correct, risks undervaluing the balance of biological diversity from which climate-change winners could otherwise emerge. Drawing on ecology, evolutionary biology, and portfolio theory, we propose a conservation approach designed to promote adaptation that is less dependent on uncertain predictions about the identity of winners and losers. By designing actions to facilitate numerous opportunities for selection across biological and environmental conditions, we can allow nature to pick the winners and increase the probability that ecosystems continue to provide services to humans and other species.

Trends

Predict-and-prescribe management may erode diversity by focusing on 'winners'.

Conservation strategies based on portfolio theory reduce risk by protecting diversity.

Adaptation networks are a new approach to conservation based on portfolio theory.

Diverse, connected, and large adaptation networks maximize the adaptive capacity of species.

Causes

Fir engraver beetle

Beetle photo source: http://www.padil.gov.au/pests-and-diseases/pest/image/46019

Causes

Heterobasidion root disease

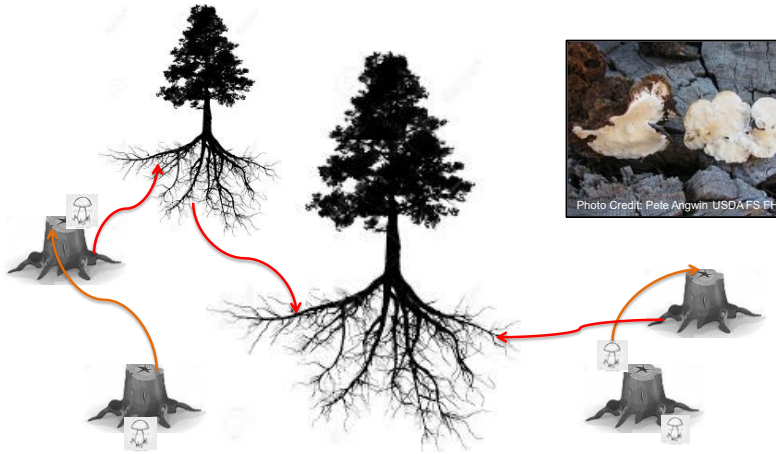


Image sources: Tree with roots - http://www.123rf.com/clipart-vector/conifers.html;
stump: http://www.123rf.com/photo_39847089_stock-vector-illustration-of-a-cartoon-funny-pine-tree-stump-with-roots-and-some-blades-of-grass.html;
mushroom: http://www.shutterstock.com/s/mushroom+cartoon/search.html?page=1&inline=164488733

Causes

Dwarf Mistletoe – Parasitic Plant

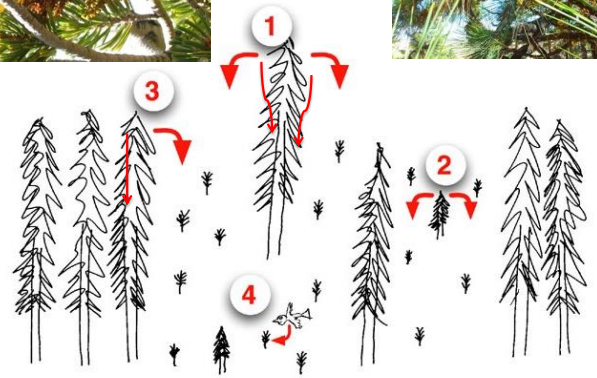


Figure source: Worral and Geils 2006. Dwarf mistletoes. *The Plant Health Instructor*. DOI: 10.1094/PHI-I-2006-1117-01

Causes

Drought & Overstocked stands

Thank You

Acknowledgements: Tom Burt, Camille Jensen, Aaron Vanderpool, Shannon Lynch, Tom Smith, Susan Ustin, Mui Lay, Sean Hogan,Elisa Marini, Anne Liston, Sheri Smith, Carmen Woods, Geoff Schladow, John Gleason, Lora Richards, Annette Delfino Mix, Detlev Vogler, Roland Shaw, Annabelle Monti, Rich Adams, Dan Shaw, Brian Hirt, Rita Mustatia, Bruce Saito, California Conservation Corp (CCC)

Funding Sources: California Tahoe Conservancy, Tahoe Fund, USFS Forest Health Protection & Pacific Southwest Research Station, CalFire.