A photograph of a forest floor showing significant dieoff of sword ferns. The ground is covered with a thick layer of brown, dead fern fronds and other fallen forest debris. Some green ferns are still visible, but many are brown and brittle. The background shows more trees and foliage, suggesting a larger forest area affected by the issue.

# Emerging Forest Health Issues: Sword fern dieoff and Pacific madrone decline

Marianne Elliott  
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Extension Center  
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# Forest Declines

“Forest decline is characterized by a progressive, often rapid deterioration in the vigor of trees of one or several **species**, sometimes resulting in mass **mortality** (or dieback) within stands over a large area.”

<https://www.encyclopedia.com/>



*Phytophthora cinnamomi* on Pacific madrone in CA



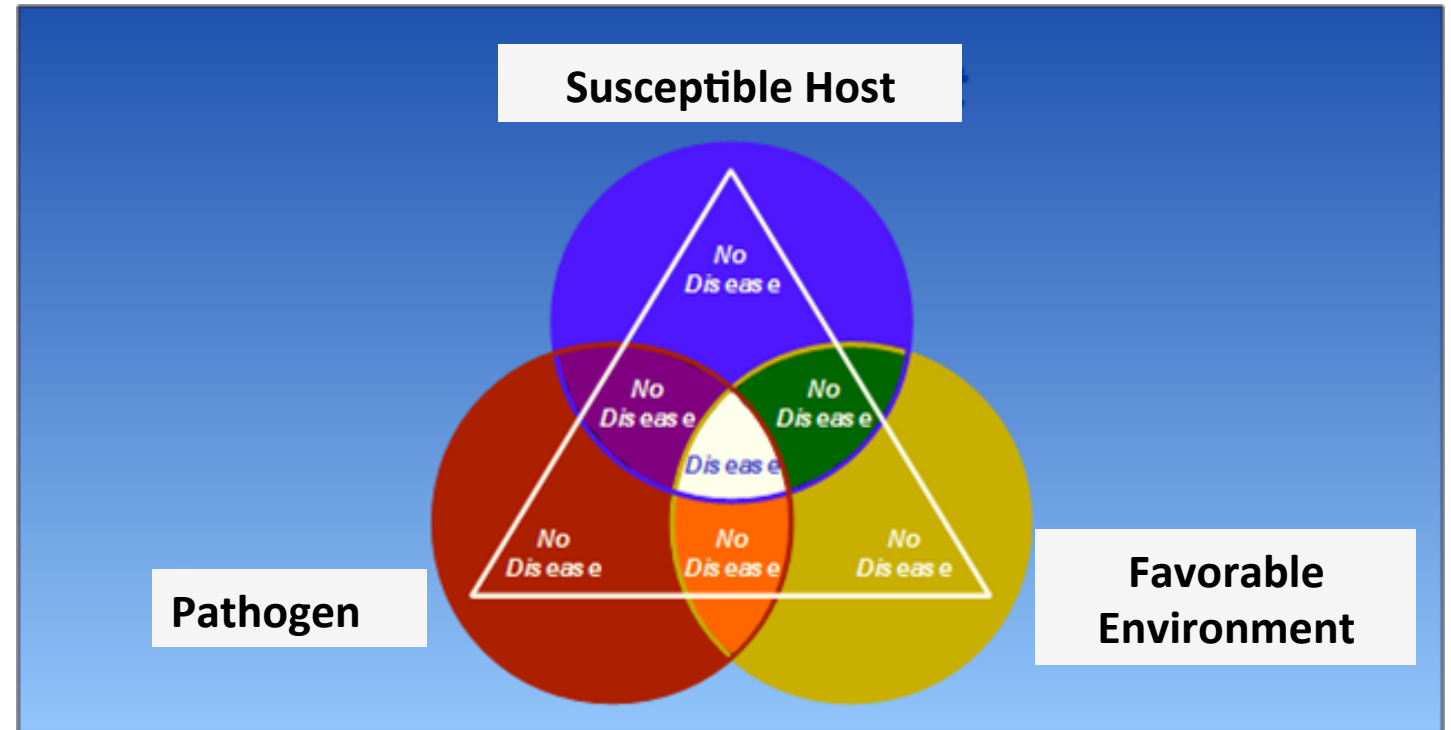
Alves et al. 2013. Decline of Mediterranean oak trees and its association with *Phytophthora cinnamomi*: A review



# Causes of forest decline

- Invasive species
- Climate change
- Management practices

Or all of the above



The Disease Triangle – you need all 3 for disease to occur



# Climate Indices

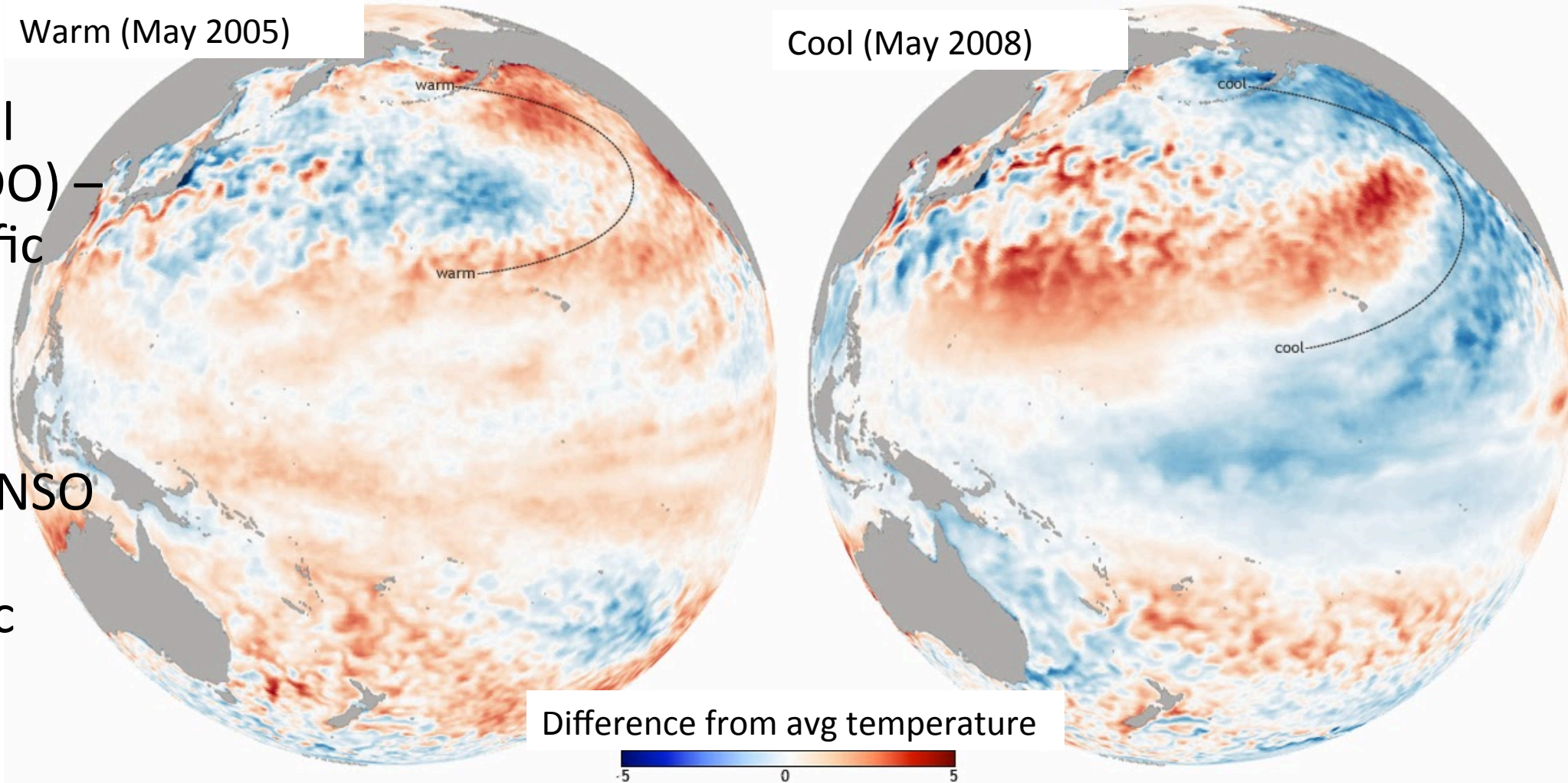
Pacific Decadal Oscillation

Warm (May 2005)

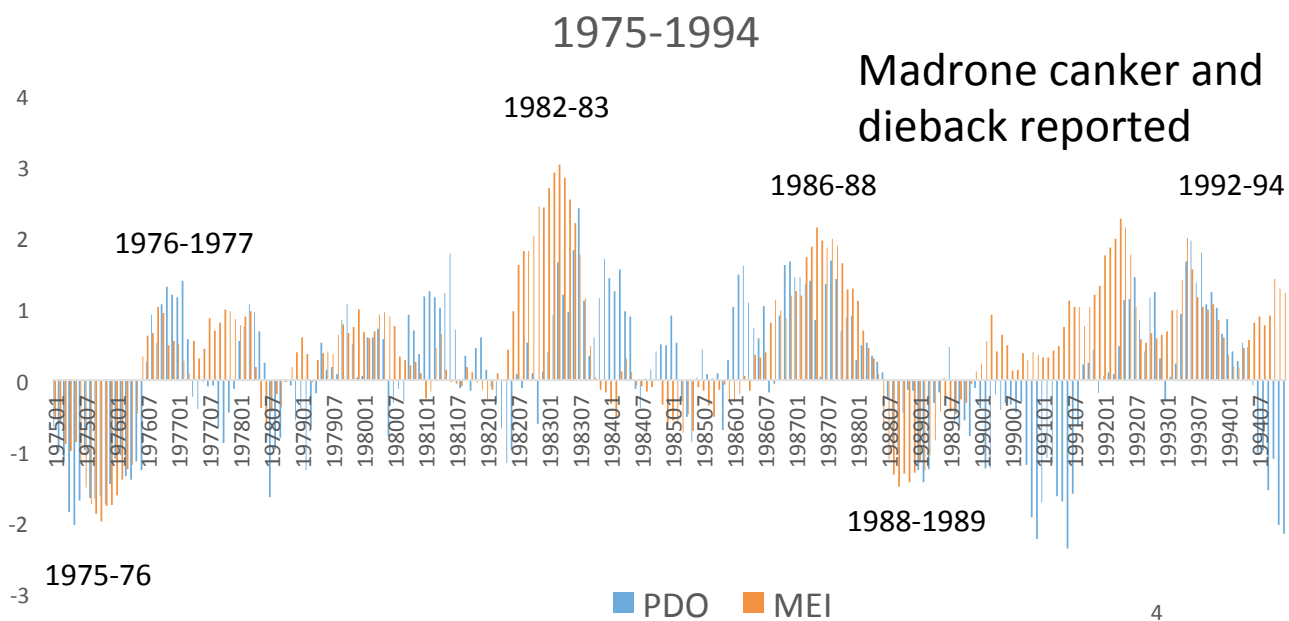
Cool (May 2008)

Pacific Decadal  
Oscillation (PDO) –  
Northern Pacific

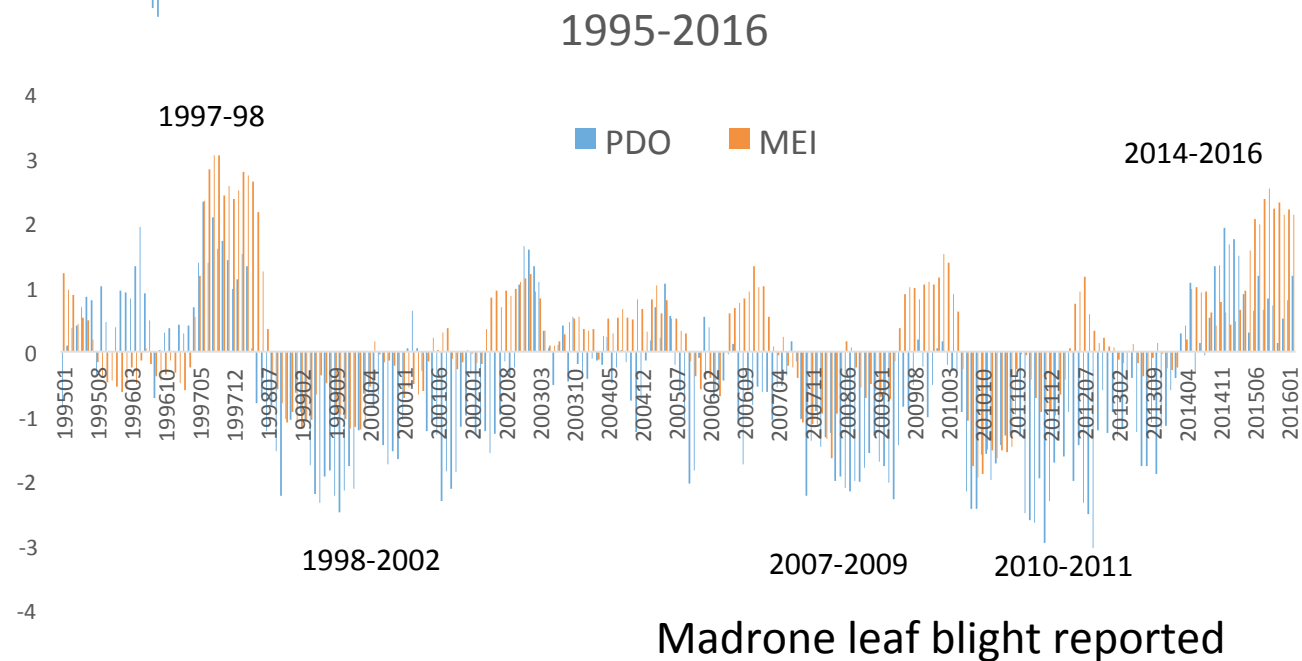
Multivariate ENSO  
Index (MEI) –  
Tropical Pacific







When both indices are in phase the effects are stronger





# PNW species in decline

Bigleaf maple  
(*Acer macrophyllum*)

Pacific madrone  
(*Arbutus menziesii*)

Western red cedar  
(*Thuja plicata*)

Red alder (*Alnus rubra*)

Pacific sword fern  
(*Polystichum munitum*)





# Western swordfern (*Polystichum munitum*)

- Distribution – Pacific coast (Alaska to Baja CA) low elevation forests
- Moist and nutrient rich soils, high OM content
- Reproduction by spores
- Ferns colonize open ground and do not reproduce under a closed canopy
- Individual plants can live for hundreds of years.





# Wildlife

Animals such as mountain beavers, elk, black-tailed deer feed on swordfern

Low palatability for slugs

Habitat (cover) for birds, small mammals



Photo courtesy of <https://shawncita.wordpress.com/>.



# Uses

- Floral greens
- Landscapes
- Slope stabilization



## Native American uses

Medicines

Household

Food

Rituals





# Swordfern dieoff at Seward Park, Seattle

2010



2016



<http://sewardparkswordferndieoff.blogspot.com>

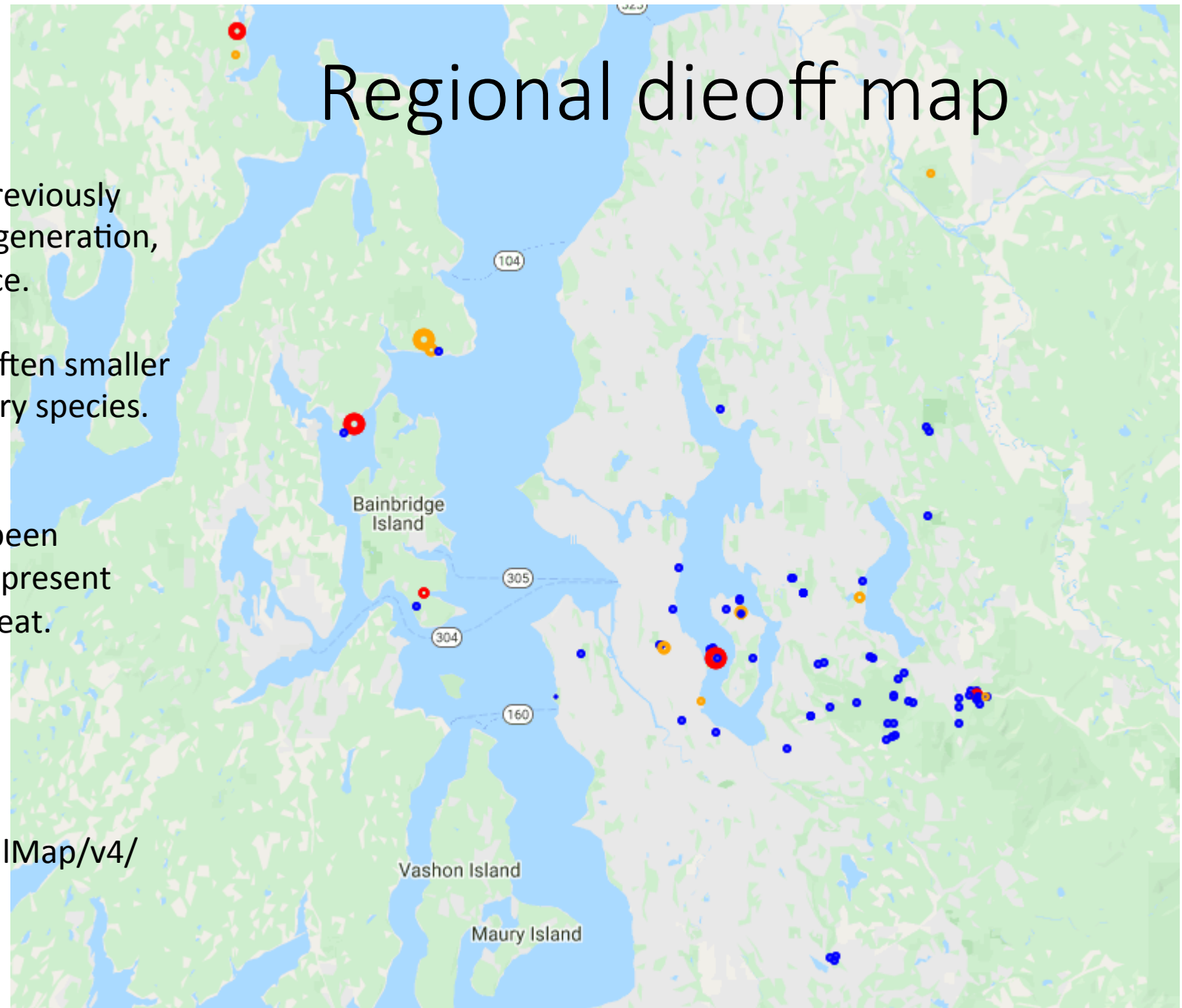


# Regional dieoff map

**Red** sites are large (1 acre or more), were previously dominated by sword ferns, have seen no regeneration, and now constitute an ecological disturbance.

**Orange** sites exhibit moderate die-off, are often smaller in size, and with mixed unaffected understory species. Probably minor ecological impact.

**Blue** sites are provisional. Dead ferns have been observed, but without much spread, and at present apparently posing little or no ecosystem threat.



<http://pshannon.net/swordFerns/regionalMap/v4/>



## Early Stage of Decline

Isolated fronds show signs of stress. Affected fronds may display pale color similar to bleaching, curling fronds and leaflets, brown rotting, general loss of vigor.



## Middle Stage of Decline

Most fronds display characteristics of stress related to the decline and are completely wilted and dry



## Late Stage of Decline

Complete loss of fronds, leaving a crown stump that may remain intact for several years without regenerating



- Unhealthy fronds have twisted or wrinkled, browning pinnae and can lack sori.
- Symptoms start at the tip and work downward

This is consistent with water stress



<https://www.fs.fed.us/database/feis/plants/fern/polmun/all.html>

Healthy

Chlorophyll measurements showed that symptomatic fronds were experiencing water stress



Symptomatic

Healthy crowns will have fiddleheads that expand into fronds in the spring.

Fronds in the lower crown die off naturally

Unhealthy ferns do not produce new fiddleheads.

Occasionally a few are produced on declining stumps, suggesting that there may be possible resistance or recovery



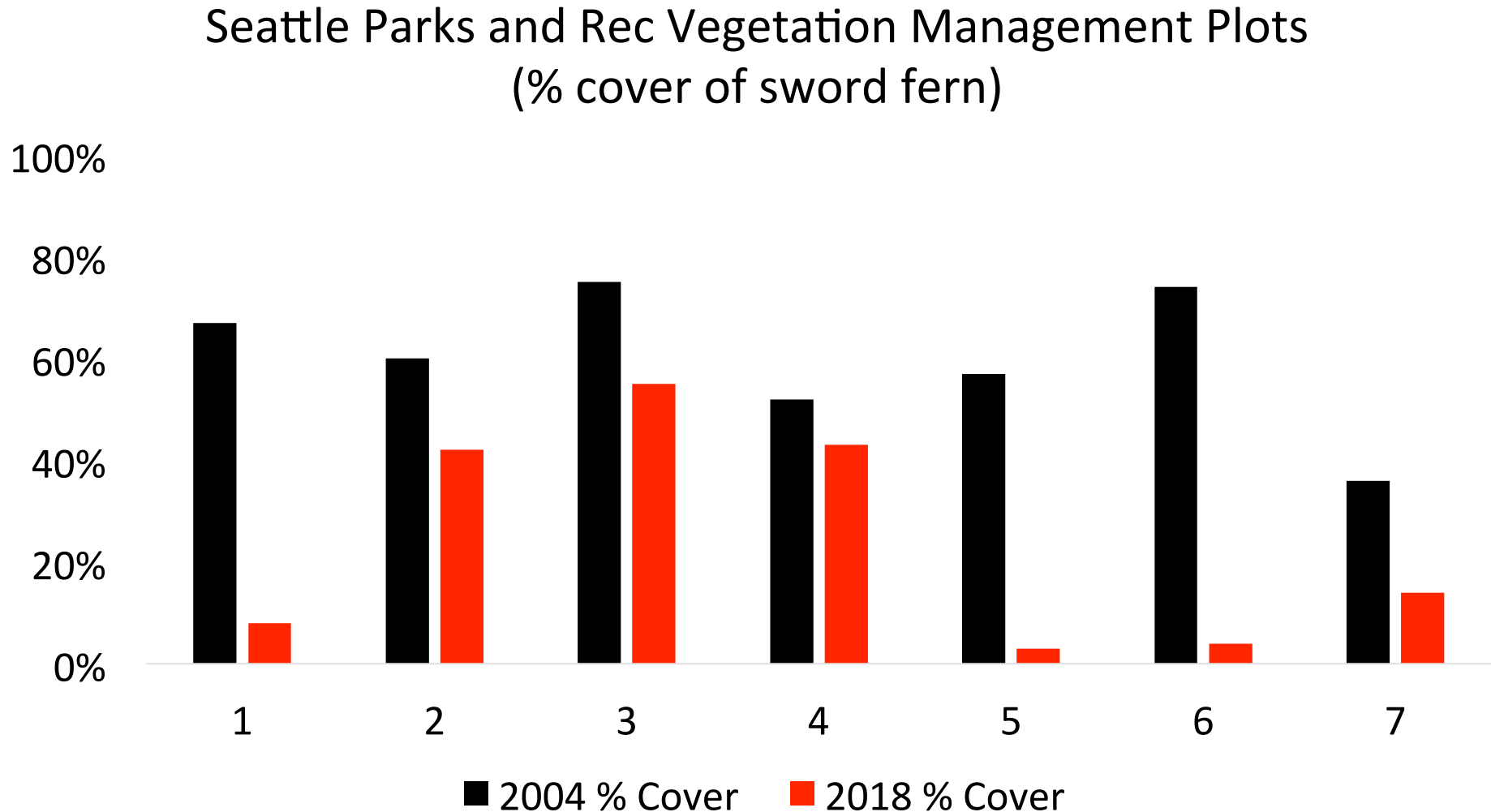
<https://www.fs.fed.us/database/feis/plants/fern/polmun/all.html>



<http://sewardparkswordferndieoff.blogspot.com/>



# Impact at Seward Park



# Hypotheses

- Soilborne pathogen (fungus, Phytophthora)
- Sapborne pathogen (bacteria, phytoplasma, virus)
- Nutrient deficiency
- Drought
- Thrips or other insect
- Mountain beavers
- Earthworms
- Blue Angels
- Herbicide or other chemical



# Soilborne pathogen

Does *Phytophthora* survive outplanting in restoration sites?

## Seward Park



No *Phytophthora* in sword fern dieoff sites

Some *Phytophthora* in 2017 restoration plantings,  
mostly endemic species



# Water transmission experiments support the vascular pathogen hypothesis

A frond from a symptomatic fern was paired with one from a healthy fern in water and monitored for 3 weeks.

The healthy frond became symptomatic.



Healthy

Healthy



Photos — Paul Shannon

Healthy

Symptomatic



# Nutrient deficiency

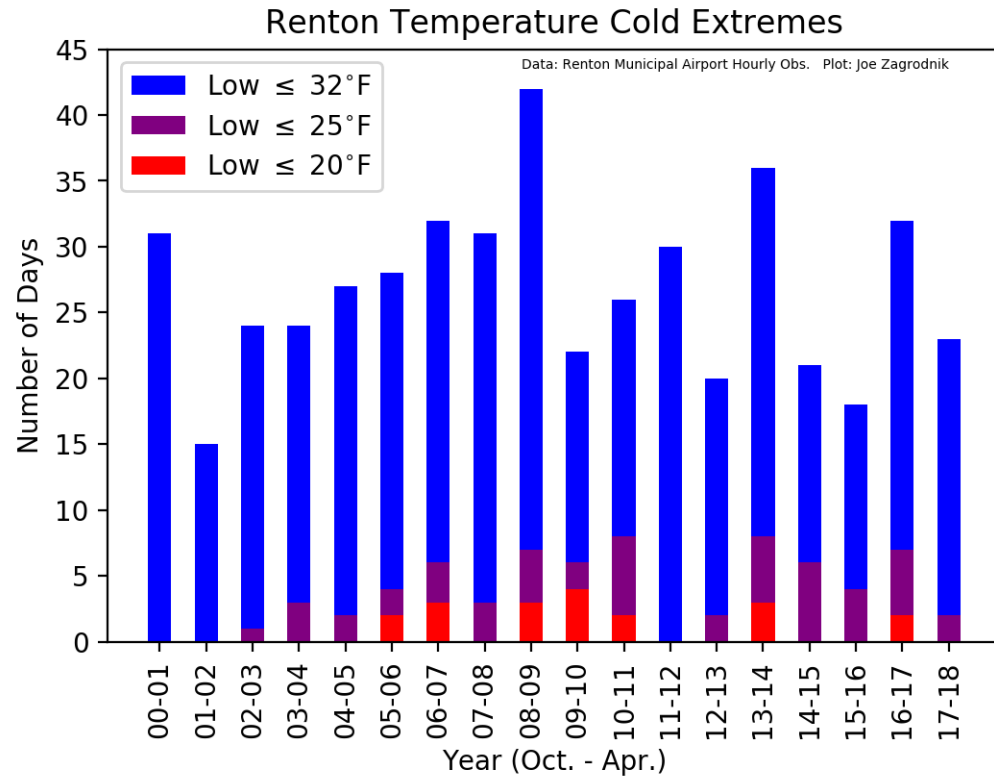
Pollution in the city has led to loss of nitrogen fixing lichens. Are soils deficient in N?

Soil nutrient testing is negative for this hypothesis.

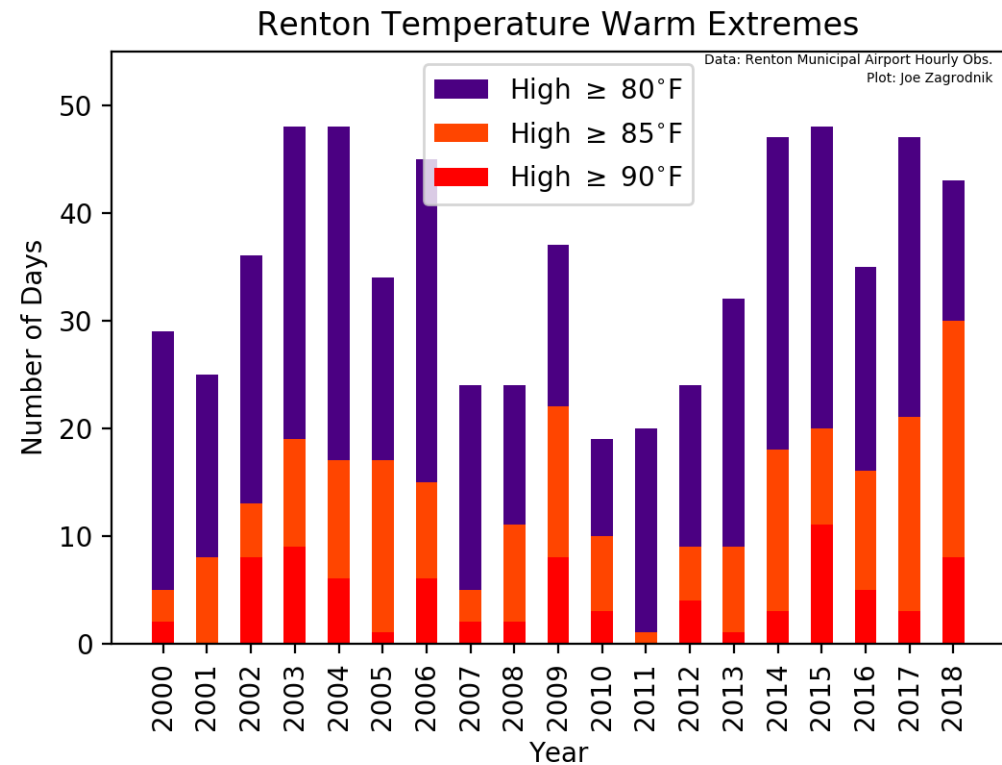
Also does not account for spread of dieoff patches.



# Extreme weather



Within normal range of variability,  
probably a contributing factor



<https://atmos.uw.edu/blog/jzagrod/2019/01/30/are-extreme-temperatures-causing-the-seward-park-sword-fern-die-off/>



# Climate change/Drought

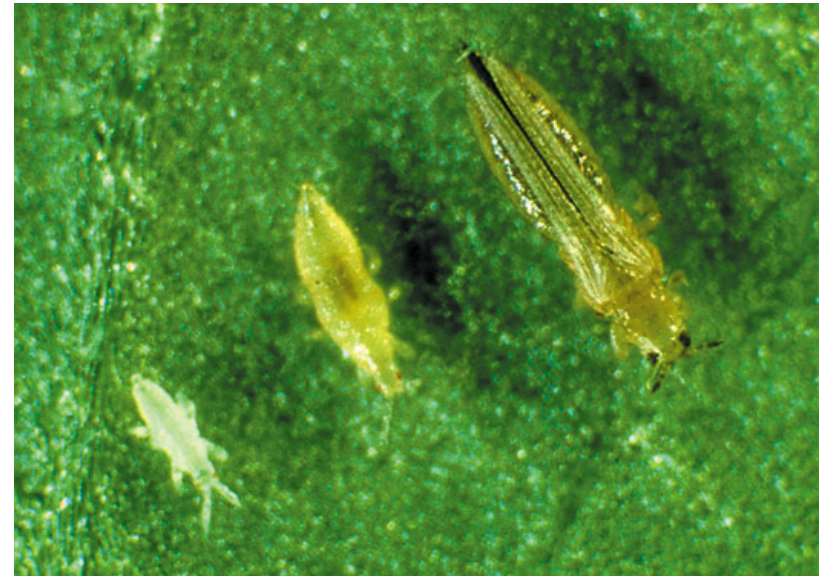
Fog frequency has declined over the past 50+ years along the Pacific Coast of the western United States (Johnstone 2008, as cited by [\[134\]](#)), which has reduced the frequency of summertime leaf-wetting events. Considering the demonstrated importance of fog water for redwood forest plants, including western swordfern (see [Climate](#) in the Site Characteristics section), it seems likely that levels of plant water stress will increase in coastal communities as this important water subsidy is lost [\[134\]](#).

# Thrips

Small insects that feed on sap

Patrick Tobin (UW) and student, found one thrips in a large sample with Berlese traps. Although thrips have devastated ferns in CA, seems unlikely here.

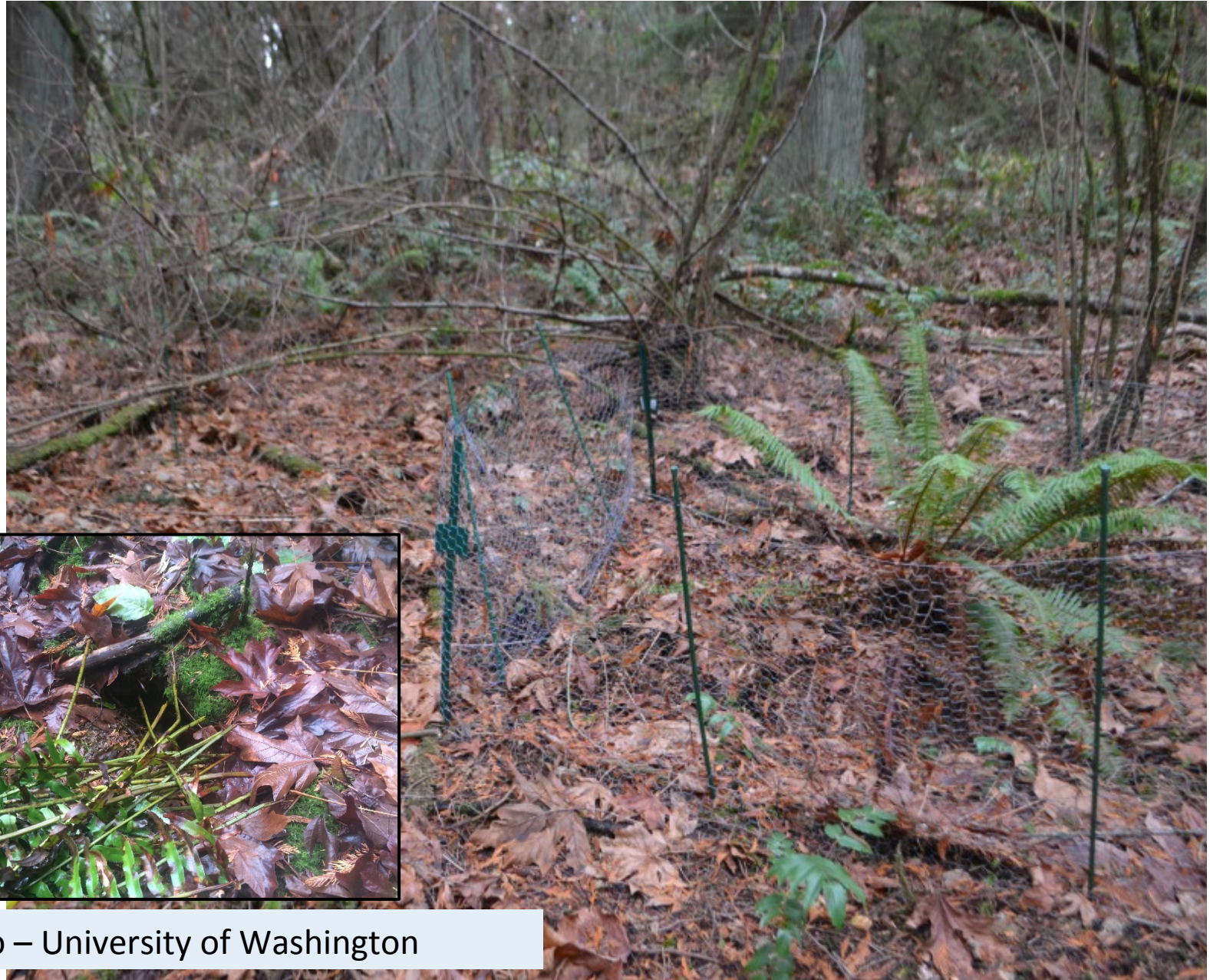
However, sucking insects can be a vector for sapborne diseases.





# Mountain beaver

- Exclosure study was inconclusive – damage both inside and outside the plots.
- Does not account for sites with dieoff and no mountain beaver population.



Tim Billo – University of Washington



# Earthworms

Invasive earthworm damage in a deciduous forest in NE US



**NO EARTHWORMS**



**HEAVY EARTHWORM INVASION**

[https://westernforestry.org/wp-content/uploads/2016/10/SeventhNativePlants\\_Antieau.pdf](https://westernforestry.org/wp-content/uploads/2016/10/SeventhNativePlants_Antieau.pdf)



# Chemical damage

Ferns are very sensitive to damage from chemicals, such as oils



<http://www.missouribotanicalgarden.org/>



Paraffin smoke oil used in air show

# Hypotheses

- Soilborne pathogen (fungus, Phytophthora) – probably not
- Sapborne pathogen (bacteria, phytoplasma, virus) - possibly
- Nutrient deficiency
- Drought
- Thrips or other insect
- Mountain beavers
- Earthworms – maybe
- Blue Angels
- Herbicide or other chemical
- Your ideas ???

Many of these do not account for spread of dieoff areas.



# How you can help

**If you are interested in volunteering to help with field work efforts to monitor, map, and research sword fern decline at Seward Park, or to join the mailing list to keep up with the latest developments please email [lisa.ciecko@seattle.gov](mailto:lisa.ciecko@seattle.gov).**

## **Report possible sword fern dieoff sites using iNaturalist**

- <https://www.inaturalist.org/projects/western-sword-fern-decline-in-washington-state>












https://www.inaturalist.org/projects/western-sword-fern-decline-in-washington-state

OBSERVATIONS



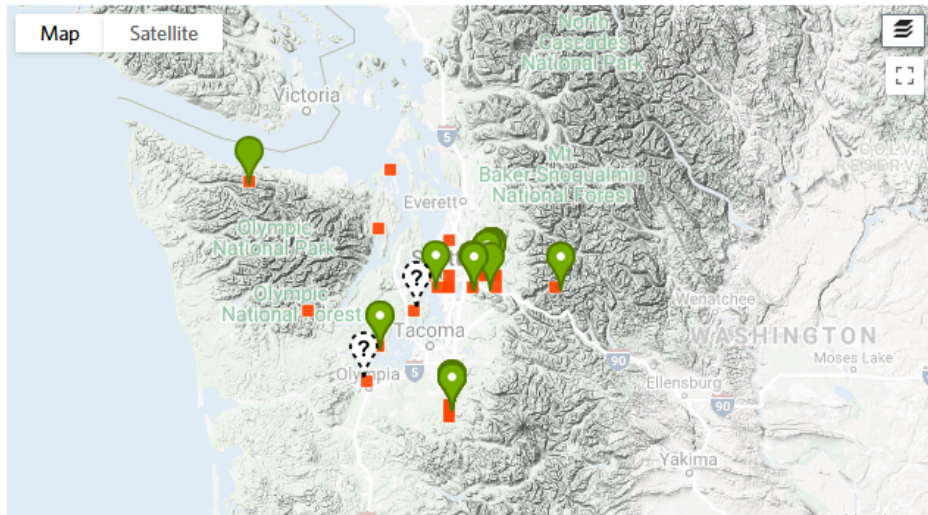
## Western Sword Fern Decline in Washington State




### Stats

Totals	Most Observations	Most Species	Most Observed Species
<b>44</b> Observations »	 <b>breannaspence</b> 12 observations	 <b>jakepool_natureboy</b> 1 species	 <b>Western Sword Fern</b> 41 observations
<b>1</b> Species »	 <b>jakepool_natureboy</b> 9 observations	 <b>paul-shannon</b> 1 species	
<b>18</b> People »	 <b>joestormer</b> 4 observations	 <b>momalusk</b> 1 species	
	 <b>n5jrn</b> 3 observations	 <b>timbillo</b> 1 species	
	 <b>paul-shannon</b> 3 observations	 <b>brewbooks</b> 1 species	

**Report possible sword fern dieoff sites using iNaturalist**  
<https://www.inaturalist.org/projects/western-sword-fern-decline-in-washington-state>

Map Satellite



**Members** 44 members  
    
[View All Members »](#)

**Export Observations**  
[Atom / CSV](#)

**About**  
What could be more iconic of the PNW than a lush fern understory? Unfortunately, previously healthy stands of western sword fern (*Polystichum munitum*) have been declining throughout the Puget Sound Region (western U.S.) in the course of the past

Possible dieoff site:  
5 or more dead ferns  
in a contiguous patch



# Pacific madrone (*Arbutus menziesii*)



- Distribution – Pacific coast (BC to southern CA) low elevation forests
- Dry, open sites, low fertility soils
- Early successional species
- Seedling regeneration in open sites.
- Resprouts after fire



# CONIFER BROADLEAF EVERGREEN

## PSME-ARME/GASH

Douglas-fir- Pacific  
madrone /salal

## PSME-ARME/HODI/ LOHI

Douglas-fir- Pacific  
madrone / oceanspray /  
honeysuckle

## PSME-ARME/VAOV

Douglas-fir- Pacific





# Value to humans

- Not commercially valuable as timber
- Slope stabilization
- Landscapes
- Art – woodworking, etc.
- Firewood
- Native American uses – medicinal, food, wood



[arbutusarts.com](http://arbutusarts.com)

# Uses by wildlife

- Winter food (berries) for birds, other animals – seed dispersal
- Animal pollinated
- Nesting sites for cavity nesters, other birds in canopy, also small mammals.



Photo: Michael Macor, The Chronicle



# Wood decay

Often associated with insects  
– wood borers and  
dampwood termites

Cavity nesting birds prefer  
trees colonized by wood decay  
fungi

Large Pacific madrones often  
have heart rot





Serious decline problems first noticed in the 1990s

American Forests “Famous and Historic Tree” at Magnolia Bluffs, Seattle, WA





# Fungal diseases can attack any part of the tree

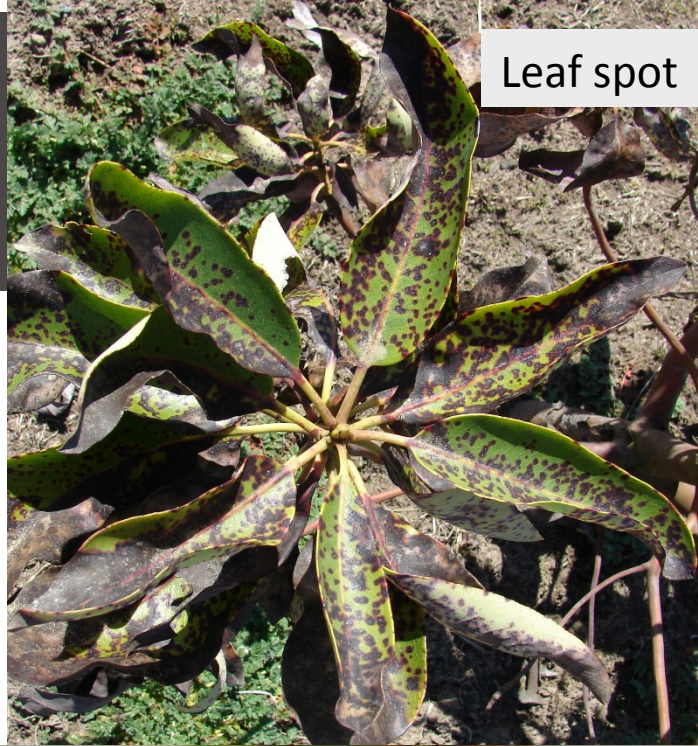
- Root disease
- Stem and branch cankers
- Wood decay
- Branch dieback
- Foliar blight
- Leaf spots
- Fruit mummies





# Foliar fungi

- Leaf spot
- Leaf blight
- Blister blight
- Rust
- Sooty mold



Leaf spot



Rust



*Exobasidium  
vaccinii* on fruit

“At least 19 different fungi  
are associated with leaf  
spots on madrone”  
Byther, 1999



# Shoot and leaf blight



“Large, dying branches appear to have a necrotic leading front similar to a cambial killing canker...Limited isolations from such cankers have yielded a species of *Phacidiopycnis*. This fungus was not pathogenic in healthy madrone.”  
Hunt, 1999.

*Phacidiopycnis washingtonensis*

The fungus was also isolated from leaf spots on emerging foliage, lesions on green shoots, and the petiole and leaf blade of dead, attached leaves.



# Shoot dieback and canker fungi



Madrone canker

*Fusicoccum arbuti* = *Neofusicoccum arbuti*



*Botryosphaeria* dieback  
Several species

Branches look “burned” or sooty



Canker caused by *Neofusicoccum arbuti*

Canker

Can have multiple layers

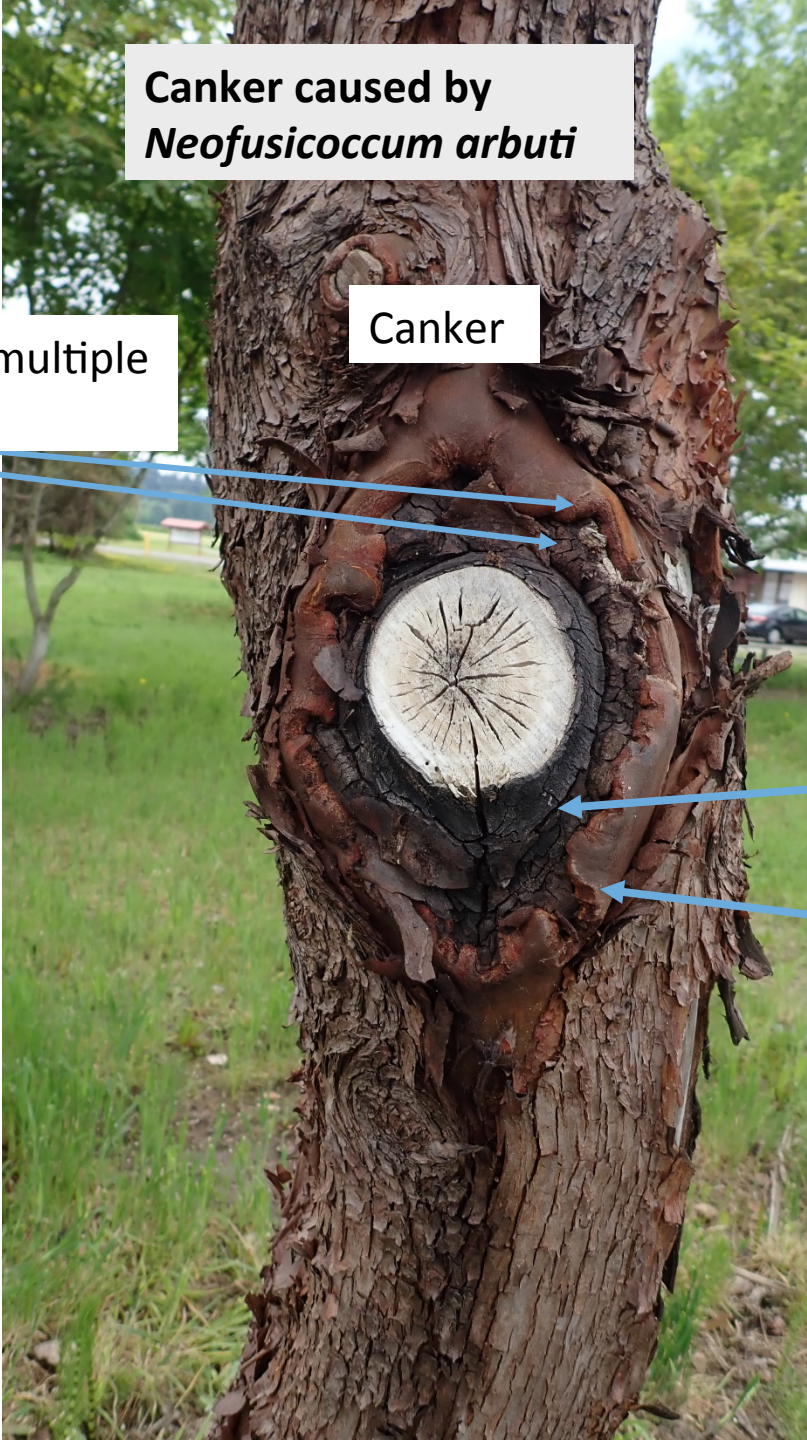
Healthy tissue, not black

Smooth margin

Blackened, sunken area

Irregular margin

Mechanical damage





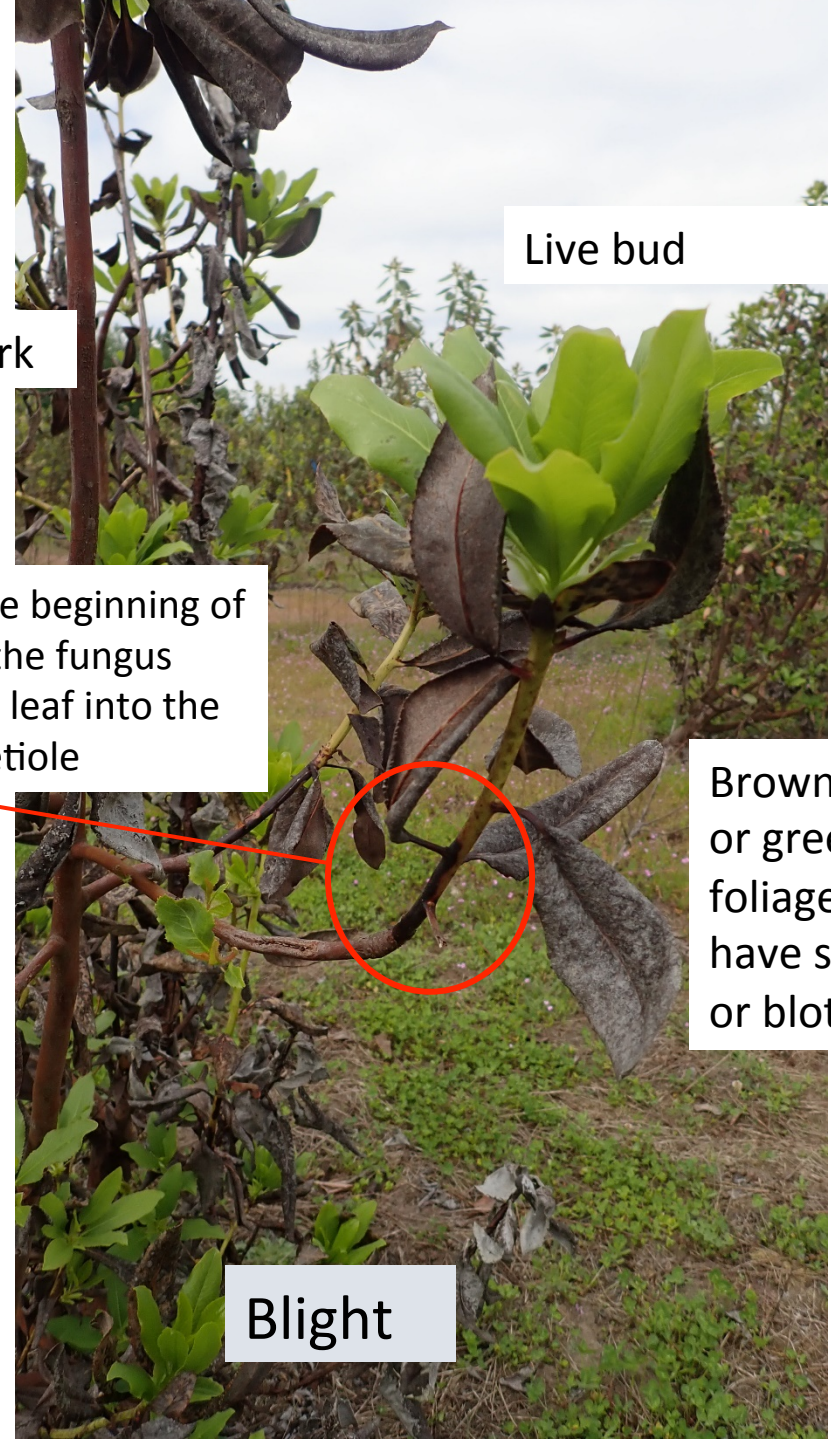


Sooty bark

Dead bud

Silver-grey foliage

Dieback



Live bud

Brown bark

This could be the beginning of shoot blight as the fungus moves from the leaf into the shoot via the petiole

Brown, grey, or green foliage, can have spots or blotches

Blight



# Root disease

- *Phytophthora* (*P. cactorum*, *P. cinnamomi*)
- *Armillaria* (*A. gallica*, *A. mellea*)
- *Heterobasidion occidentale*



Mushrooms of *Armillaria* spp.  
inside a madrone tree.

[www.shroomery.org](http://www.shroomery.org)



*Phytophthora* root  
disease



# Fungal diseases are affected by climate conditions

Cold, wet winter/spring:

Symptom expression – cold damage, foliar blight



Warm, wet spring:

Fungal sporulation, germination, infection

Temperature and precipitation are expected to increase in PNW. This will affect insect pollinators and diseases of Pacific madrone.

Warm, dry summer:

Drought  
Symptom expression – canker, dieback, root disease





# Causes of decline in Pacific madrone

## Climate-related

1975-1998: warm phase – drought, canker, dieback, *Armillaria* root disease, *P. cinnamomi* root disease

1999-2014: cool phase – leaf blight, cold damage, *Phytophthora* root disease

2014 – present: warm phase

## Anthropogenic

Urbanization

Fire suppression

Exotic pests and pathogens (*P. cinnamomi*, *P. ramorum*, others)





# For best results

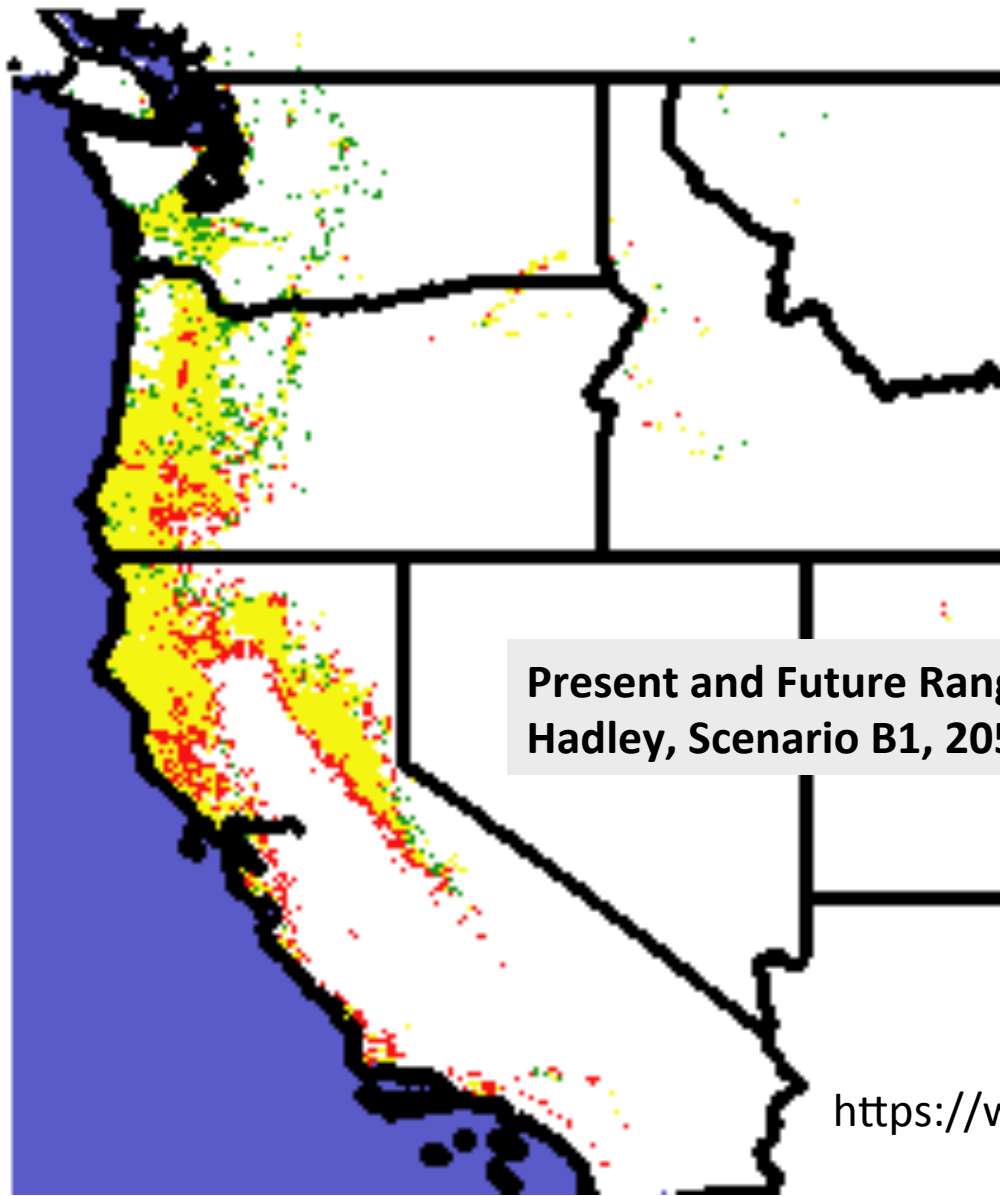
- Plant from container grown stock.
- Focus on sites with **well-drained soils**, rocky soils, south and west aspects.
- In the absence of fire – try **thinning** to reduce canopy competition + **controlling** invasive species.
- Choose sites with **compatible woody vegetation** & mycorrhizal associations.
- **Avoid** soil compaction/alteration, irrigation, fertilization, pollution, and physical damage.



Photo: Michael Yadrick



# *Arbutus menziesii*



Present and Future Ranges -  
Hadley, Scenario B1, 2050

## Expected range shift under climate change

- New habitat in 2050
- Habitat overlap, current and 2050
- Current habitat gone in 2050

Number of Suitable Ecoregions (Niche Breadth)	60
Area in Present Suitable Range	222,507 km <sup>2</sup>
Area in Future Suitable Range (Had B1 2050)	195,199 km <sup>2</sup>
Area of Overlap of Future Suitable Range with Present Suitable Range (Had B1 2050)	160,225 km <sup>2</sup>



# Common garden study



Redwood Valley (CA)  
leaves expanded

Veneta, OR  
leaves emerging

Port Angeles, WA  
buds elongating

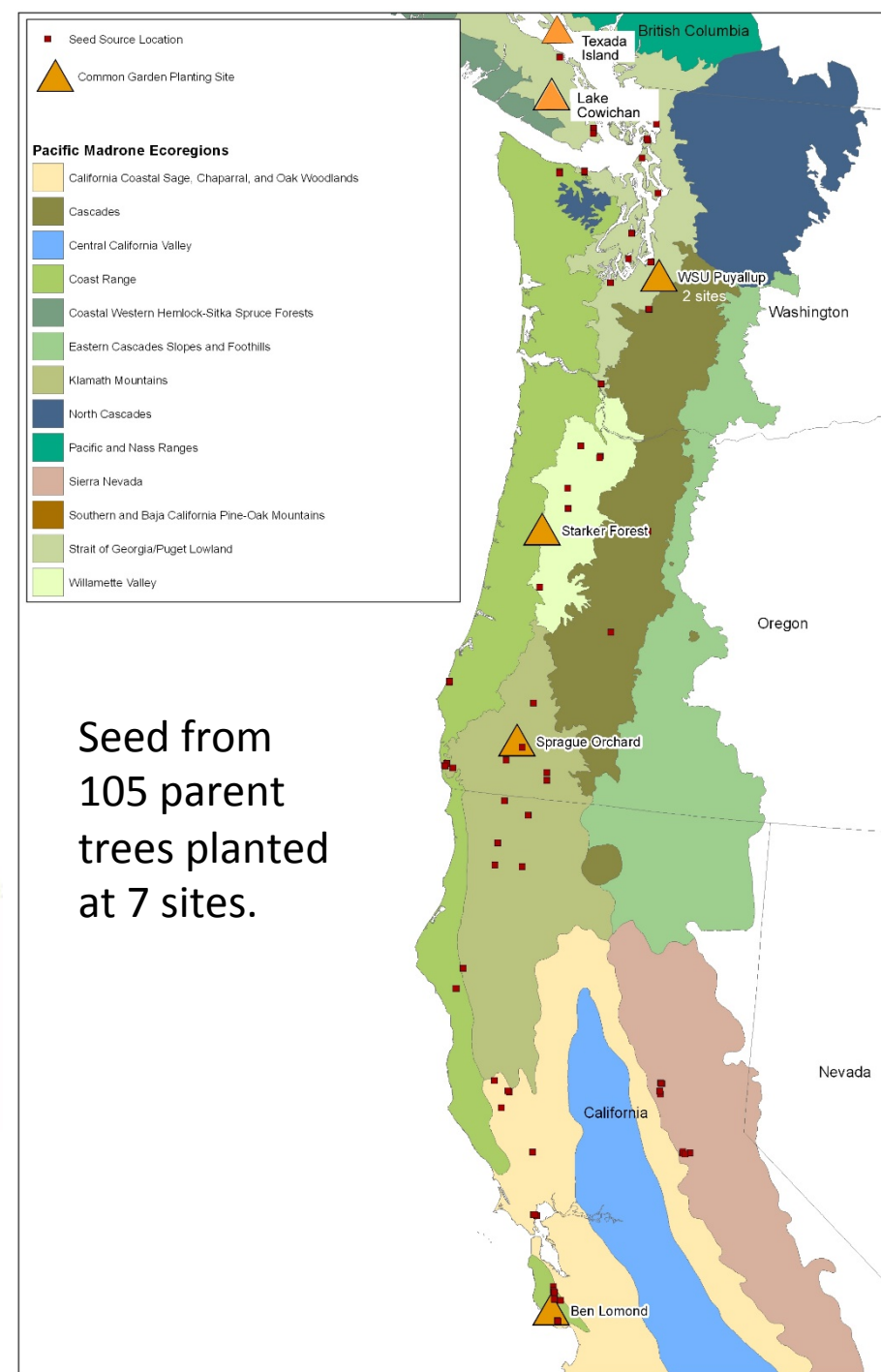
Bremerton, WA  
buds swelling

**Fig. 7. Variation in bud burst on May 8, 2018 at Starker Forest**

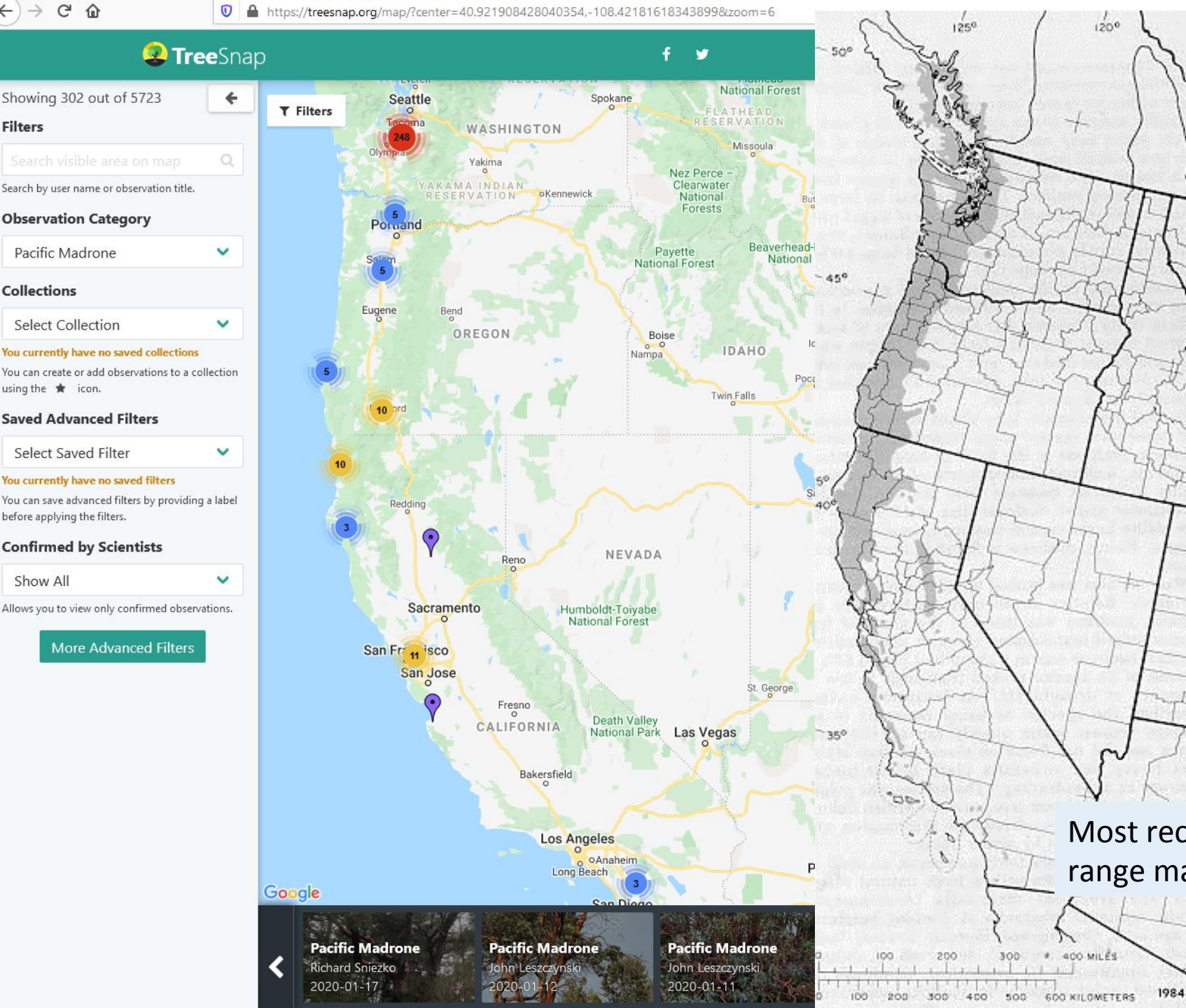
**Timing of flushing in the spring (and budset in the fall) are strong indicators of local adaptation**

- ✓ Bud burst began April 3 but some sources did not flush until May 29
- ✓ Sources from southern latitudes (CA) flushed first at Starker Forest
- ✓ More northerly sources (WA and OR) flushed last at Starker Forest

DeWald, L.E., Kamakura, R.P., Snieszko, R.A., Elliott, M., and Chastagner, G.A. 2020. Decline in Pacific madrone: Assessing health and future persistence using common garden sentinel tests.







# Madrone survey using TreeSnap app

<https://treesnap.org/>

- Update range map.
- Data on growth, health condition, effects of management, etc.



# How to get involved

- Use TreeSnap to help us map the range and health condition
- Join the Arbutus ARME mailing list
- Contribute to newsletter – share your madrone stories!

[ppo.puyallup.wsu.edu/pmr/](http://ppo.puyallup.wsu.edu/pmr/)

Other ideas? email us  
arbutusarme@gmail.com



@arbutusarme



# Questions?

Sword fern

<https://www.swordferndieoff.org/>

Madrone

<https://ppo.puyallup.wsu.edu/pmr/>

email me [melliott2@wsu.edu](mailto:melliott2@wsu.edu)

