Understanding Disease Dynamics:

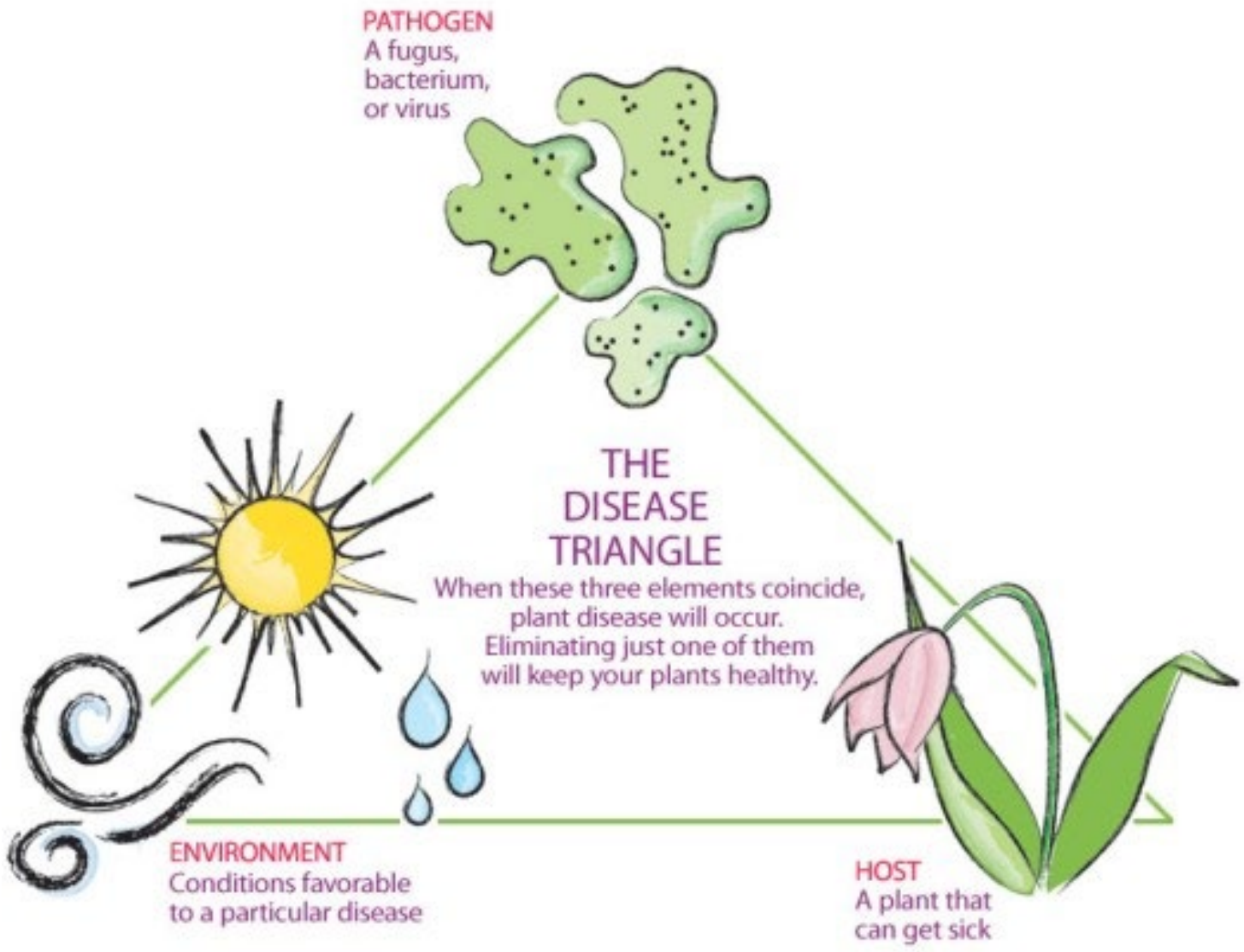
Phytophthora and Botryosphaeriaceae species in Southern California Chaparral

Dr. Sebastian Fajardo

Rizzo and Del Castillo labs

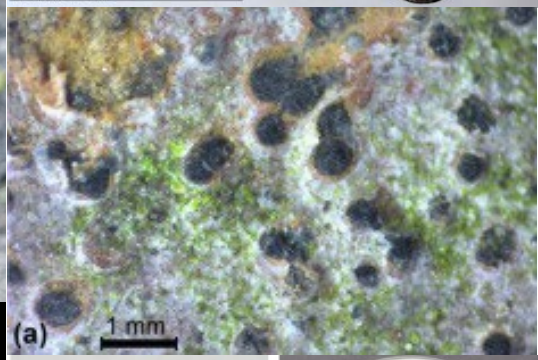
July 2025

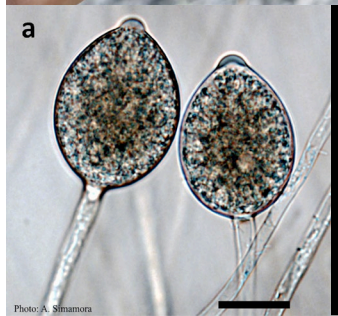
Understanding plant pathogen dynamics

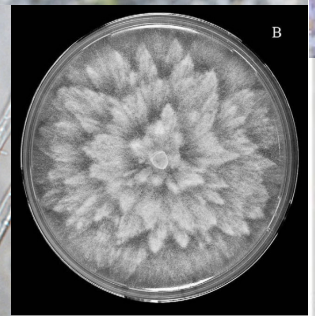


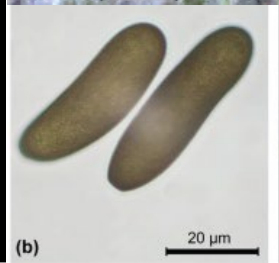
Phytophthora species vs. Botryosphaeriaceae

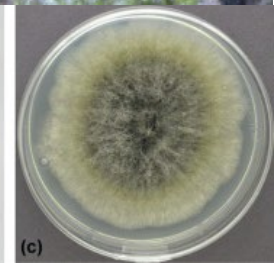
- **Similarities:**
  - Common **pathogen** of **woody** species (including many California natives)
  - Some species have a **narrow** host range; many have a **broad** host range.
  - Depending on point of infection, symptoms can vary from single branch to whole canopy **dieback**.
  - As common in natural settings as in urban landscapes.
- **Dissimilarities:**
  - *Phytophthora* thrive in **moist environments**
  - Botryosphaeriaceae generally cause disease when plant is **under stress** (i.e. drought, wounds).
  - They belong to **different** Kingdoms.
  - Different **detection methods** are needed to identify each one.











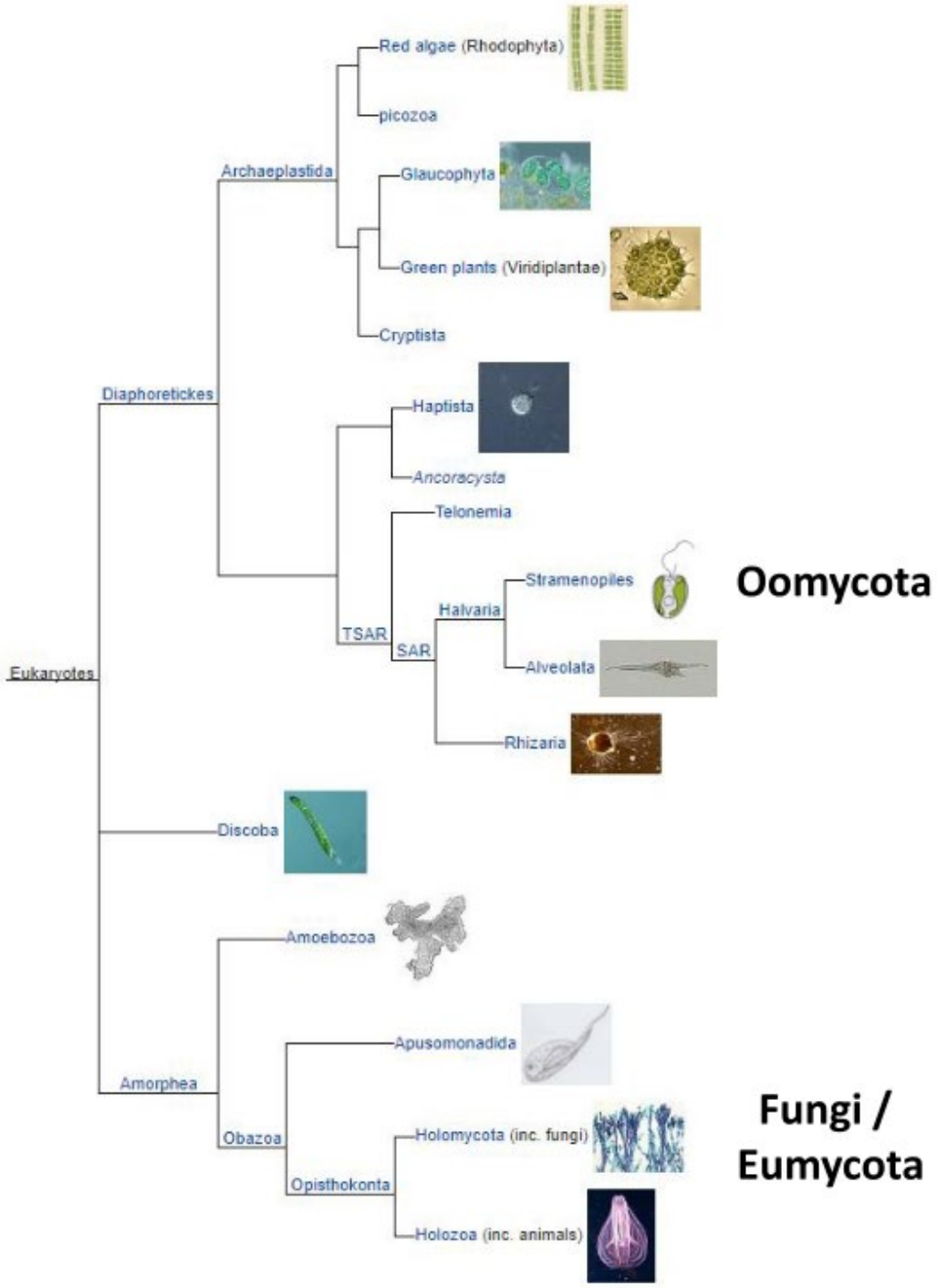
The plant destroyer- *Phytophthora* spp.

- *Phytophthora* species are renowned as **primary parasites** on thousands of **tree, shrub and crop species** across the world (Jung et al 2018).
- On a global scale, more than 66 % of all fine **root diseases** and more than 90 % of all **collar rots** of woody plants are caused by *Phytophthora* species (Tsao et al.1990).
- Morphologically they are known for having sporangia from which **zoospores** emerge (motile spores).

Bats are not Birds,

Dolphins are not Fish,

Oomycetes **<u>are not</u>** Fungi.



Life cycle

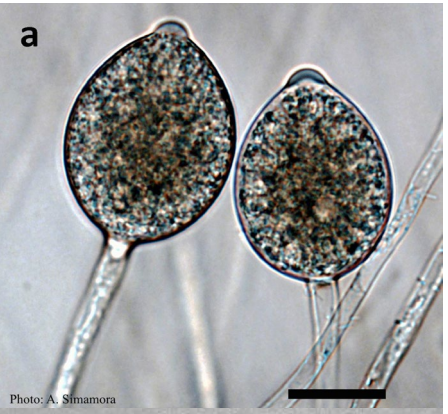

a
Photo: A. Simamora


Photo: Paul Reeser

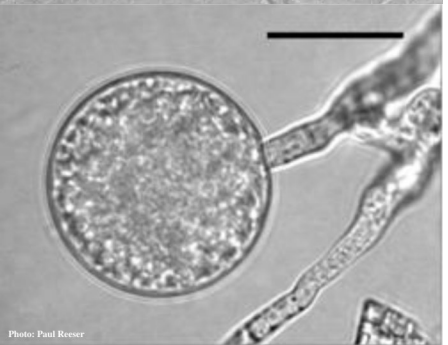
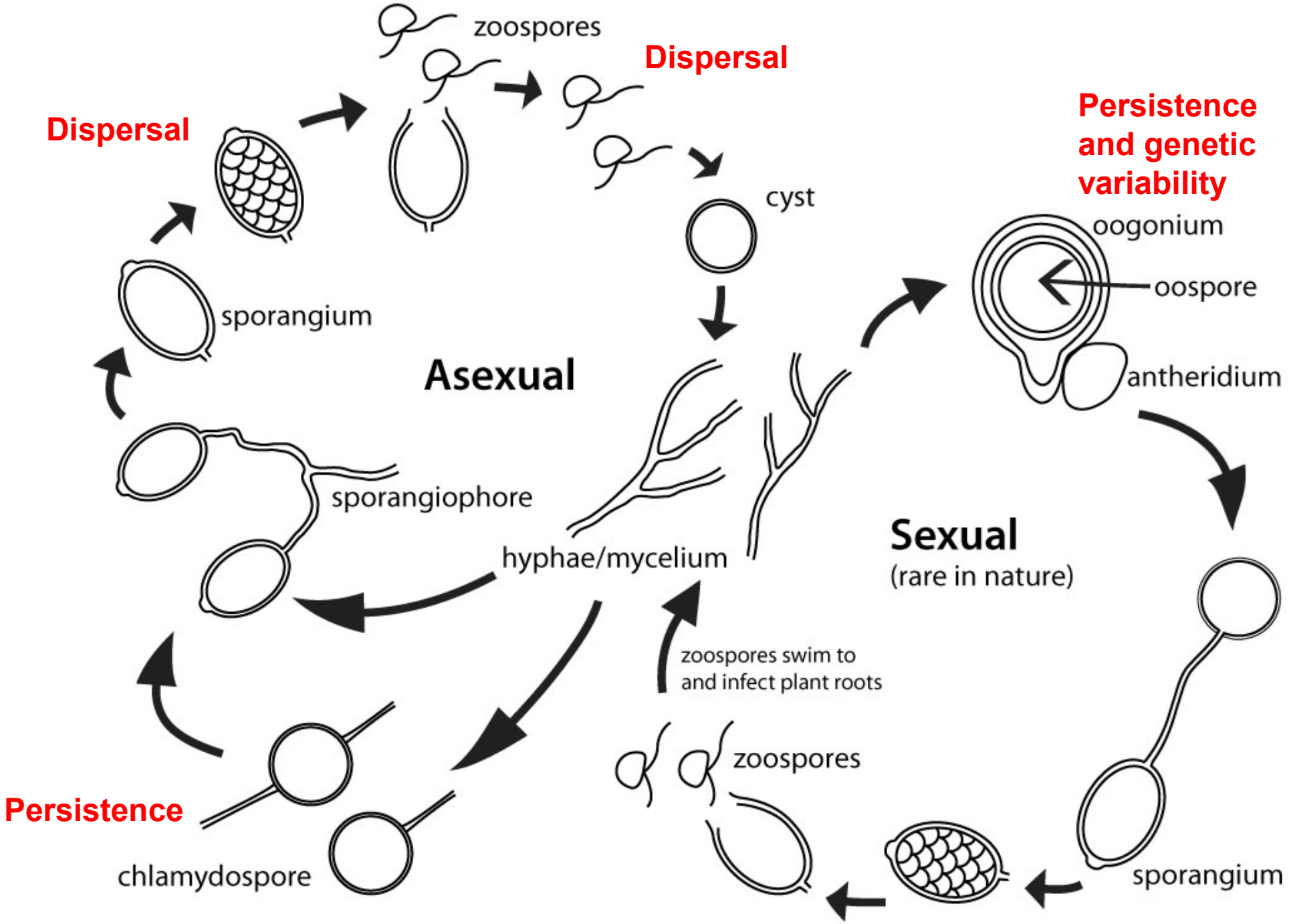


Photo: Paul Reeser


zoospores
Dispersal
Dispersal
Persistence and genetic variability
cyst
oogonium
oospore
antheridium
sporangium
Asexual
sporangiophore
hyphae/mycelium
Sexual
(rare in nature)
zoospores swim to and infect plant roots
zoospores
Persistence
chlamydospore
sporangium

Favorable abiotic conditions

- **Moisture:**
  - They are commonly known as **water molds**
  - *Phytophthora* species thrive in **wet and waterlogged** conditions.
- **Temperature:**
  - Favored by mild to warm temperatures.
  - The optimal T° **range vary** depending on the species of *Phytophthora* **(59° to 74°F)**
- **Soil Type:**
  - **High clay** content (heavy, fine-textured soils), **poor drainage, over-irrigation.**

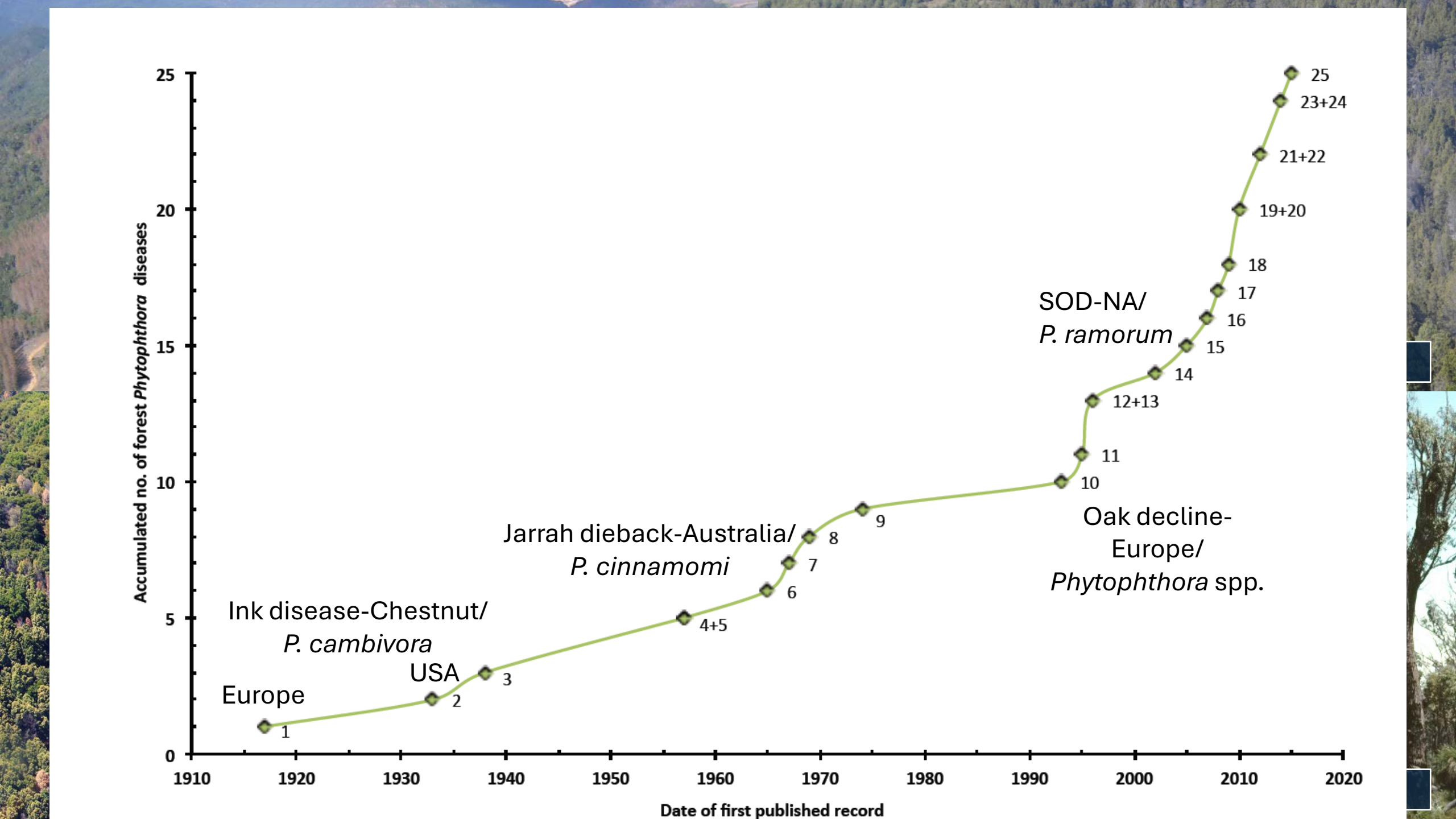
Root rots and wilting

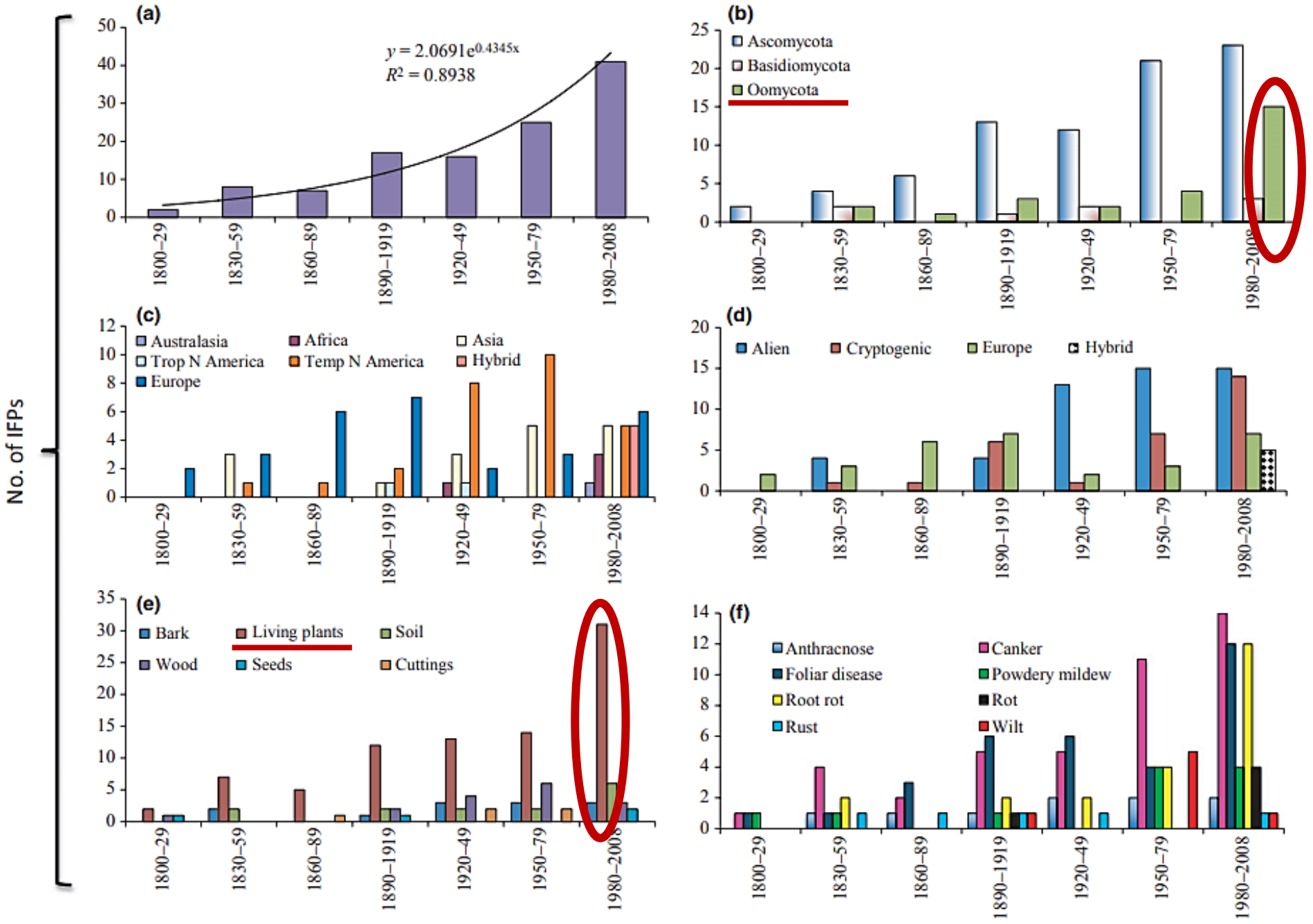
Stem and branch Cankers

Yellowing and rapid browning

Landscape dieback

Leaf blights

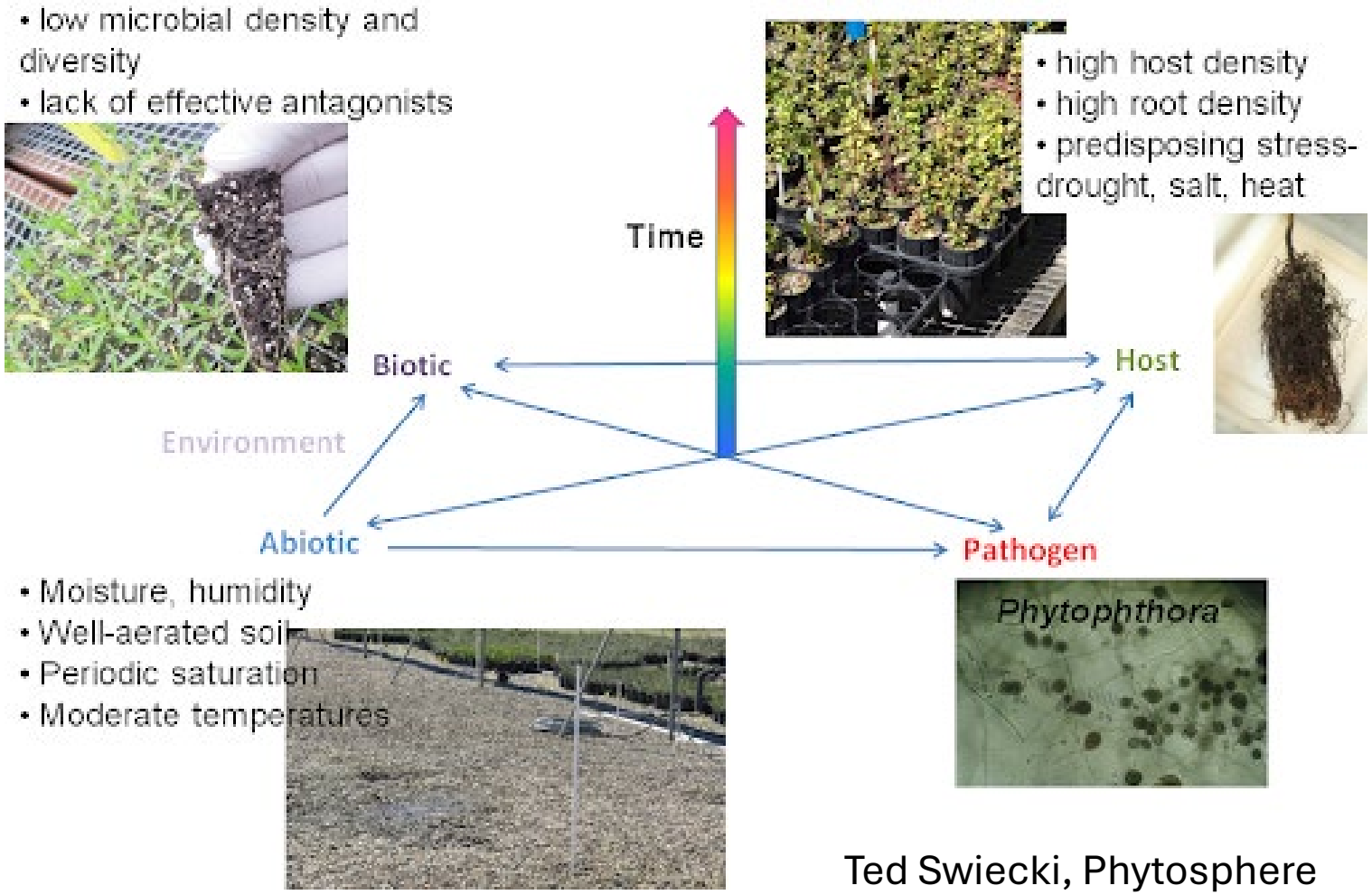

Accumulated no. of forest *Phytophthora* diseases
Date of first published record
0
5
10
15
20
25
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Europe
1
Ink disease-Chestnut/
P. cambivora
USA
2
3
4+5
Jarrah dieback-Australia/
P. cinnamomi
6
7
8
9
Oak decline-
Europe/
Phytophthora spp.
10
11
12+13
14
SOD-NA/
P. ramorum
15
16
17
18
19+20
21+22
23+24
25



A. Santini *et al.* *New Phytologist* (2013) 197: 238–

Unwanted and undetected in nurseries

- Conditions for *Phytophthora* **reproduction and dispersal** may be present.
- Fungicides may be restricted, not oomycete specific, or **not able to eradicate**.
- Plant and soil are in a **constant flux**.
- Many nurseries provide plants for **restoration purposes**.



Ted Swiecki, Phytosphere

Plant Disease • 2019 • 103:448-455 • https://doi.org/10.1094/PDIS-01-18-0167-RE

e-Xtra*

Phytophthora Species Are Common on Nursery Stock Grown for Restoration and Revegetation Purposes in California

S. Rooney-Latham,[1,†] C. L. Blomquist,[1] K. L. Kosta,[2] Y. Y. Gou,[1] and P. W. Woods[1]

[1]California Department of Food and Agriculture, Plant Pest Diagnostics Center, Sacramento, CA 95832; and [2]California Department of Food and Agriculture Nursery Program, Sacramento, CA 95814

Food and Agriculture, Plant Pest Diagnostics Laboratory (CDFA-PPDC), Sacramento 95832

Biol Invasions
https://doi.org/10.1007/s10530-021-02496-6

ORIGINAL PAPER

Phytophthora species repeatedly introduced in Northern California through restoration projects can spread into adjacent sites

Laura Lee Sims · Matteo Garbelotto

P. crassamura on *Frangula californica*

Photo: Phytosphere Research

Phytophthora diversity in Angeles NF

- **Restoration:** Nursery-grown native plants are used for restoration after disturbances (fires, invasives, recreation).
- **Prior Contamination:** Nursery plants and ANF restoration sites were found to be contaminated with *Phytophthora* species.
- **Collaboration:** A NFWF-funded project between USFS, ANF, PSW, and UC Davis Plant Pathology was initiated.
- **Goal:** Inform monitoring, prevention, and best management practices.
- **Study Objective:** Determine *Phytophthora* distribution and diversity within ANF to establish a baseline and assess potential damage from introductions.

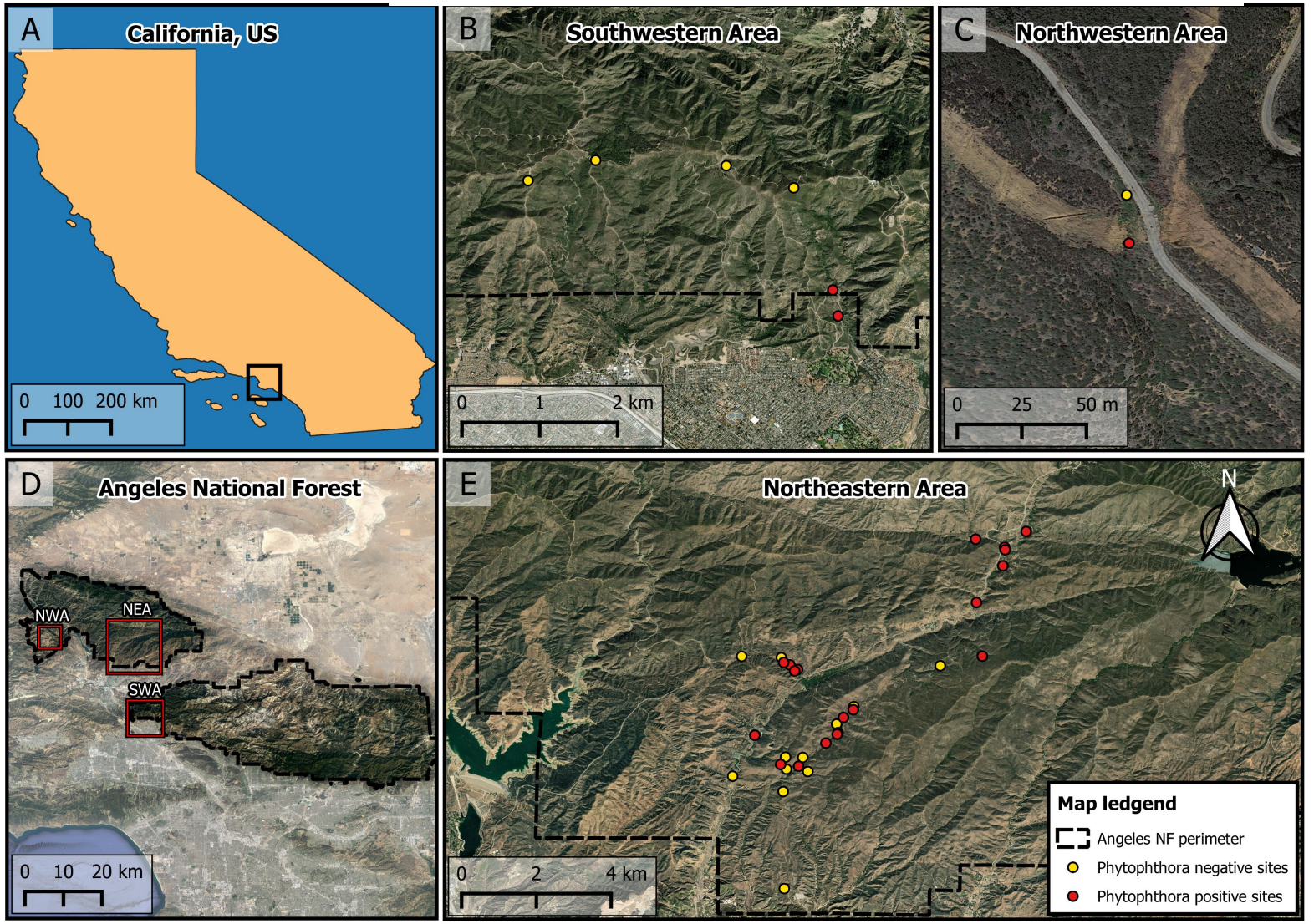
Journal of Fungi

MDPI

Article

Phytophthora Species and Their Associations with Chaparral and Oak Woodland Vegetation in Southern California

Sebastian N. Fajardo [1,*], Tyler B. Bourret [1,2], Susan J. Frankel [3] and David M. Rizzo [1]




A
Transition chaparral oak wood land


B
High montane chaparral


C
Perennial and ephemeral stream beds

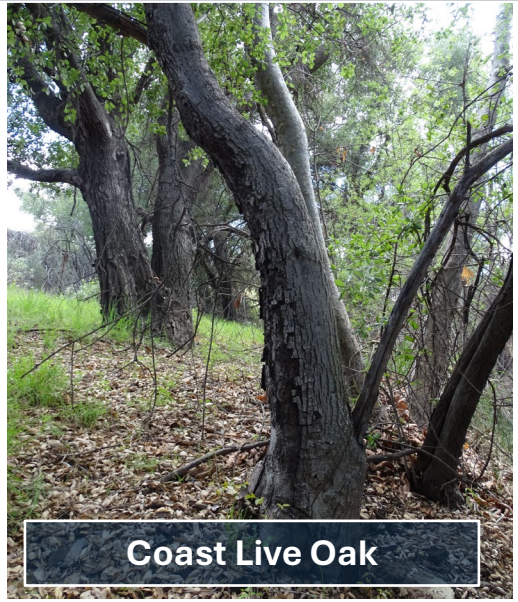

D
Oak woodlands

Black sage

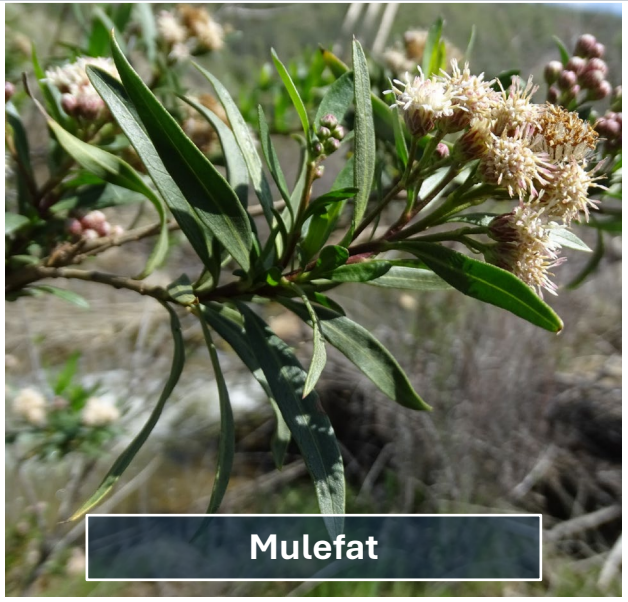
ly leaf yerba santa

48 plant species were sampled from 24 plant families in oak woodland and chaparral areas!

Cotton wood



Coast Live Oak



Mulefat

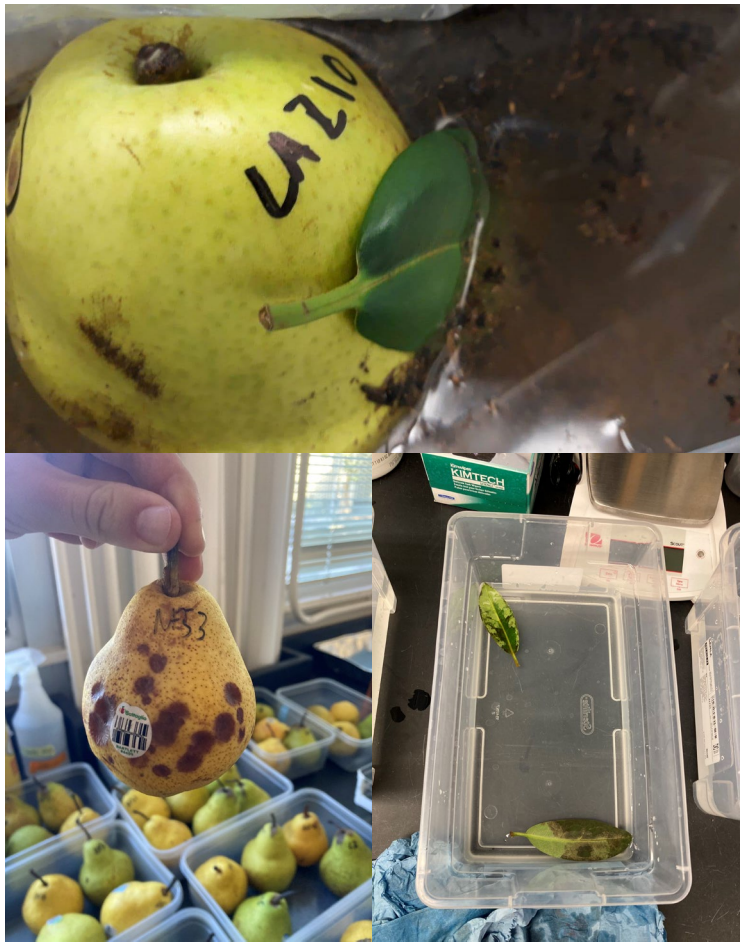
Other shrubs and herbs

Phytophthora baiting

Soil sampling

- Rhizosphere or bulk composite
- Plant health rating
- GPS point
- Plant species

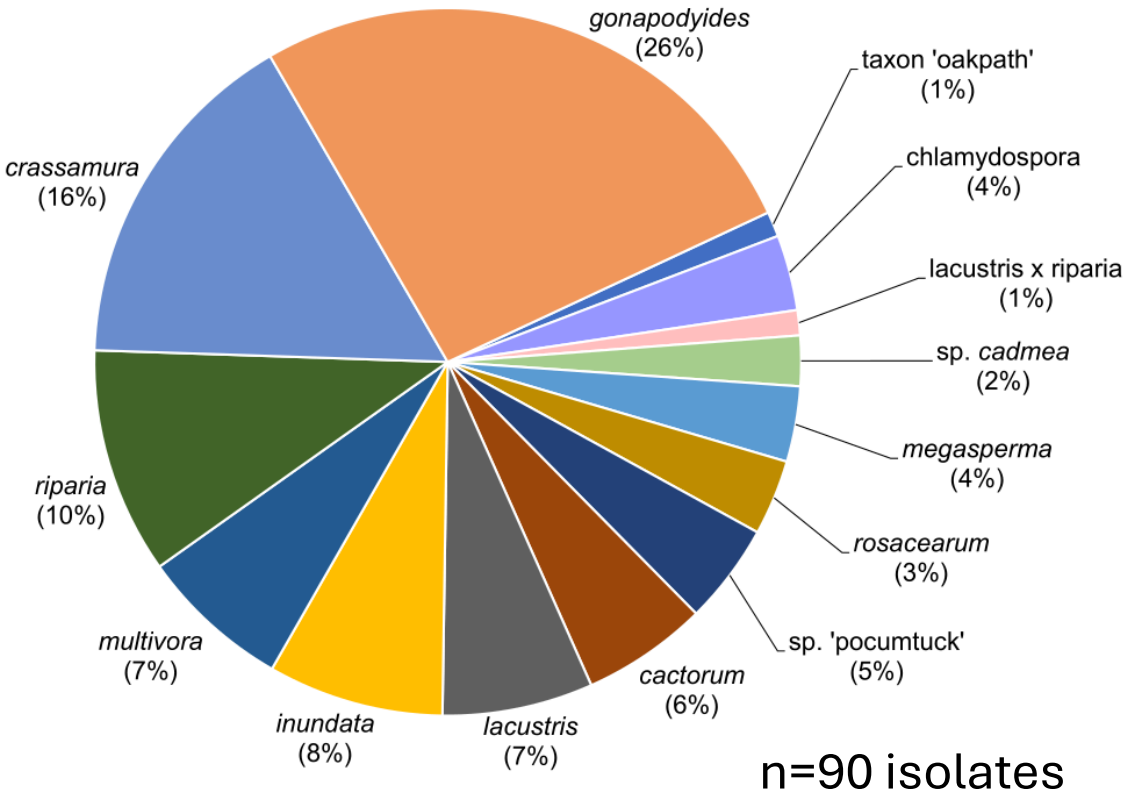
Transport samples to lab



Soil samples processed through baiting (Pears and Rhododendron leaves)

Isolate oomycetes in selective media and identified through sequencing of ITS region

Phytophthora spp. frequency



n=90 isolates

Phytophthora Species	Sub Clade	No. of Isolates	Vegetation Type	Sample	Source/Host	ANF Area
cactorum (CAC3)	1a	3	Oak woodland	Rhizosphere	*Quercus agrifolia*, *Hazardia squarrosa*	NEA
cactorum (CAC1)	1a	2	Chaparral	Rhizosphere	*Salix* sp., *Eriodictyon crassifolium*	NEA, SWA
chlamydospora	6b	3	Chaparral	Bulk	Riverbed	NEA, SWA
crassamura	6b	14	Chaparral, Oak woodland	Rhizosphere, Bulk	*Artemisia californica*, *B. salicifolia*, Grass [1], OHV tracks [2], *Q. agrifolia*, *Salvia mellifera*, Riverbed [3],	NEA, SWA, NWA
gonapodyides	6b	23	Chaparral, Oak woodland	Rhizosphere, Bulk	*Adenostoma fasciculatum*, *B. salicifolia*, Grass, OHV tracks, *Populus fremontii*, *Q. agrifolia*, Riverbed	NEA, SWA
inundata	6a	7	Chaparral, Oak woodland	Rhizosphere, Bulk	*B. salicifolia*, Riverbed,	NEA
lacustris	6d	6	Chaparral, Oak woodland	Bulk	Riverbed, *Salix* sp.	NEA
lacustris x riparia	6d	1	Oak woodland	Rhizosphere, Bulk	*B. salicifolia*, Riverbed	NEA
megasperma	6b	3	Oak woodland	Rhizosphere, Bulk	*Diplacus auricantus*, Riverbed	NEA
multivora	2c	6	Chaparral	Rhizosphere, Bulk	*E. crassifolium*, *Eriogonum fasciculatum*, Riverbed, *S. mellifera*, *Toxicodendron diversilobum*	SWA
riparia	6d	9	Oak woodland	Rhizosphere, Bulk	Grass, OHV, *Q. agrifolia*, Riverbed, *Salix* sp.	NEA
rosacearum	6a	3	Chaparral	Rhizosphere, Bulk	Grass, Riverbed	NEA
sp. *cadmea*	7a	2	Chaparral, Oak woodland	Rhizosphere, Bulk	Grass, Riverbed	NEA
sp. 'pocumtuck'	6b	4	Chaparral, Oak woodland	Rhizosphere, Bulk	*B. salicifolia*, OHV, Riverbed	NEA
taxon 'oakpath'	8e	1	Oak woodland	Bulk	OHV	NEA

[1] Native and exotic grasses (*Bromus* spp., *Avena* spp.). [2] Tracks left by off-highway vehicles (OHV). [3] Areas with evidence that water passes through, ephemerally or perennially.


Thinning *E. crassifolium* x
site with ***P. crassamura***


Thinning *A. fasciculatum* x
P. gonapodyides + site with ***P. crassamura***


Dead *Quercus* sp. x
site with *P. multivora*


Dead *Quercus* sp. x
with ***P. gonapodyides***


Dead *S. mellifera* x
P. multivora


Yellowing *E. crassifolium* x
P. cactorum

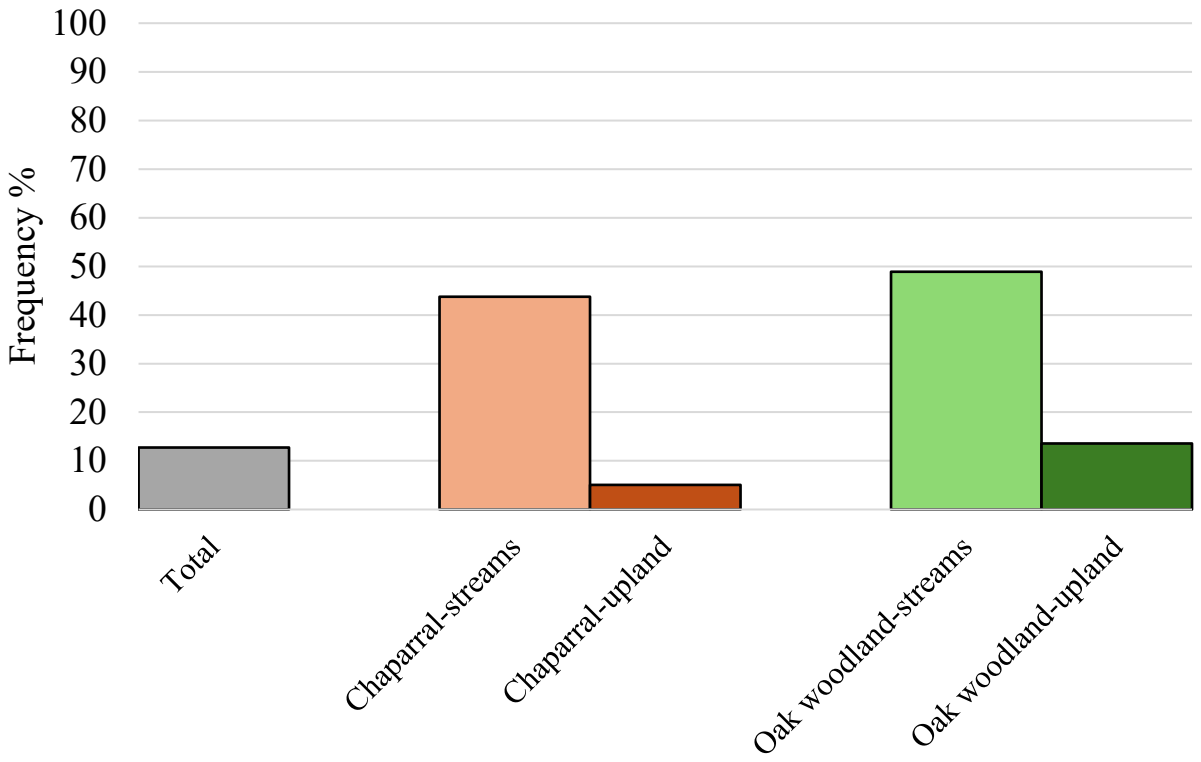


Table. Sørensen similarity measurements between the *Phytophthora* communities based on vegetation and sampling context.

	Chaparral-upland	Oak woodlands-upland	Oak woodlands-streams
Oak woodlands-upland	0.47	-	-
Oak woodlands-streams	0.53	0.77	-
Chaparral-streams	0.66	0.44	0.5

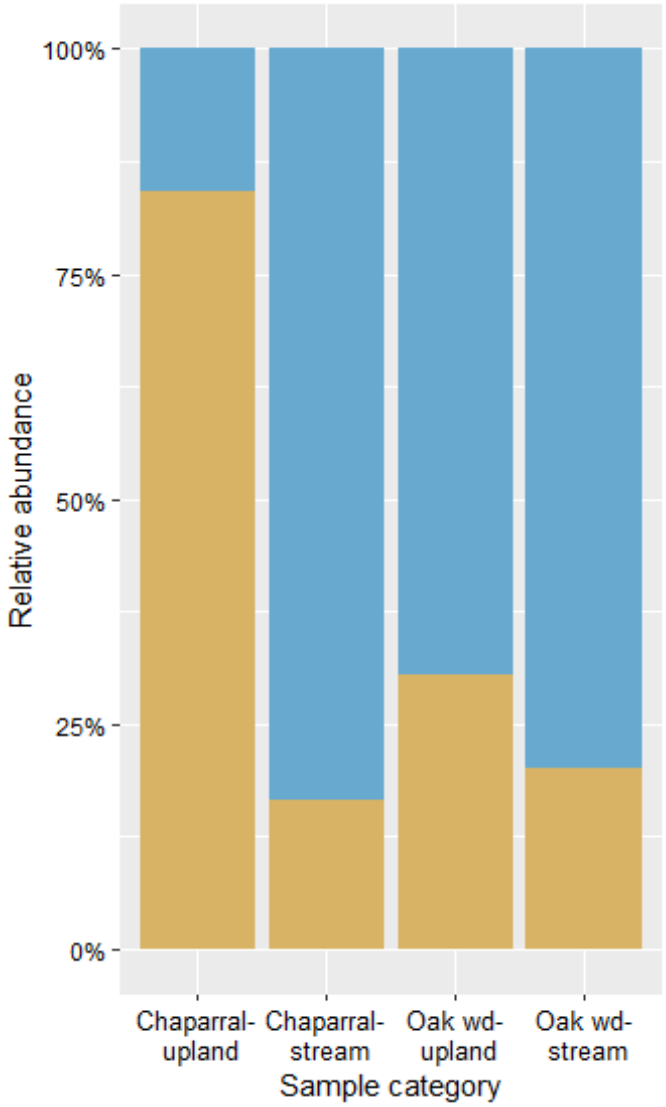
Chaparral

Upland

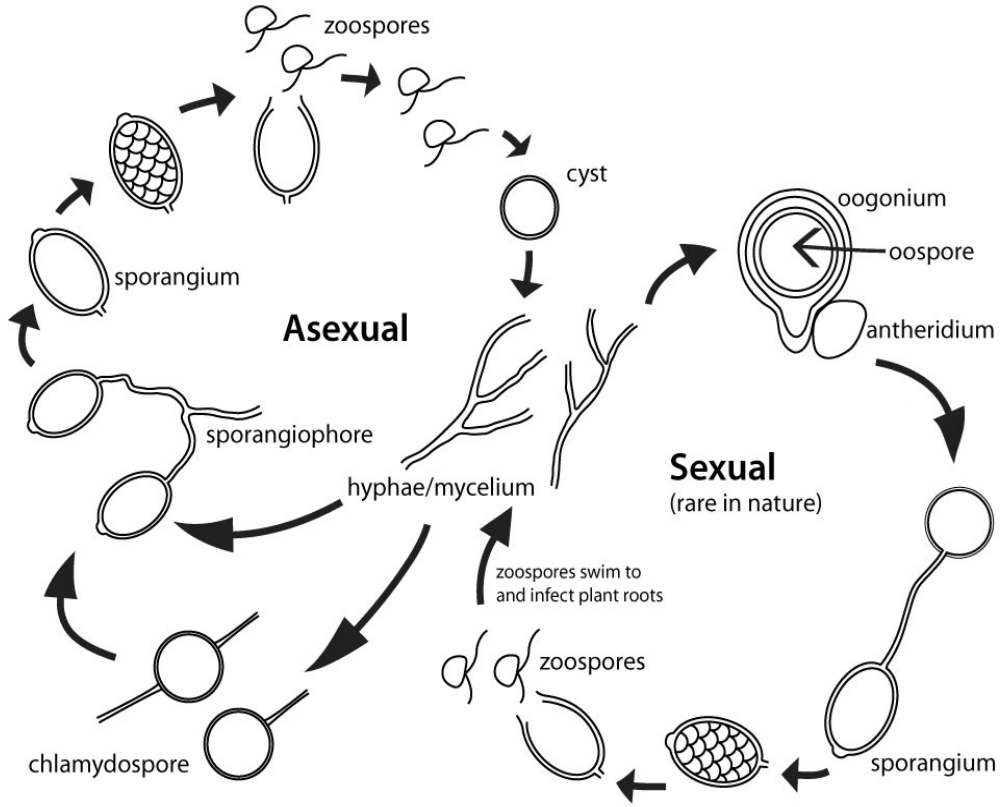
Stream

Oak Woodland

Persistence in adverse conditions



Homothallic: self fertile, readily produce oospores.
Sterile/heterothallic: Requires mating types. Oospores rare in nature.



OHV trails

- **Prevalence:** Off-highway vehicle (OHV) tracks were observed in 20 sites across three study areas (motorbikes, heavy machinery, and hiking trails).
- **Sampling:** 63 samples were taken from OHV tracks (54 chaparral, 9 oak woodland).
- **Positivity:** 11% (7 samples) tested positive for *Phytophthora*.
- **Species:** *P. crassamura* was most frequent, followed by *P. gonapodyides*, *P*. sp. ‘pocumtuck’, *P. riparia*, and P. taxon ‘oakpath’.
- **Implication:** OHV tracks may contribute to the spread of *Phytophthora* in these ecosystems.

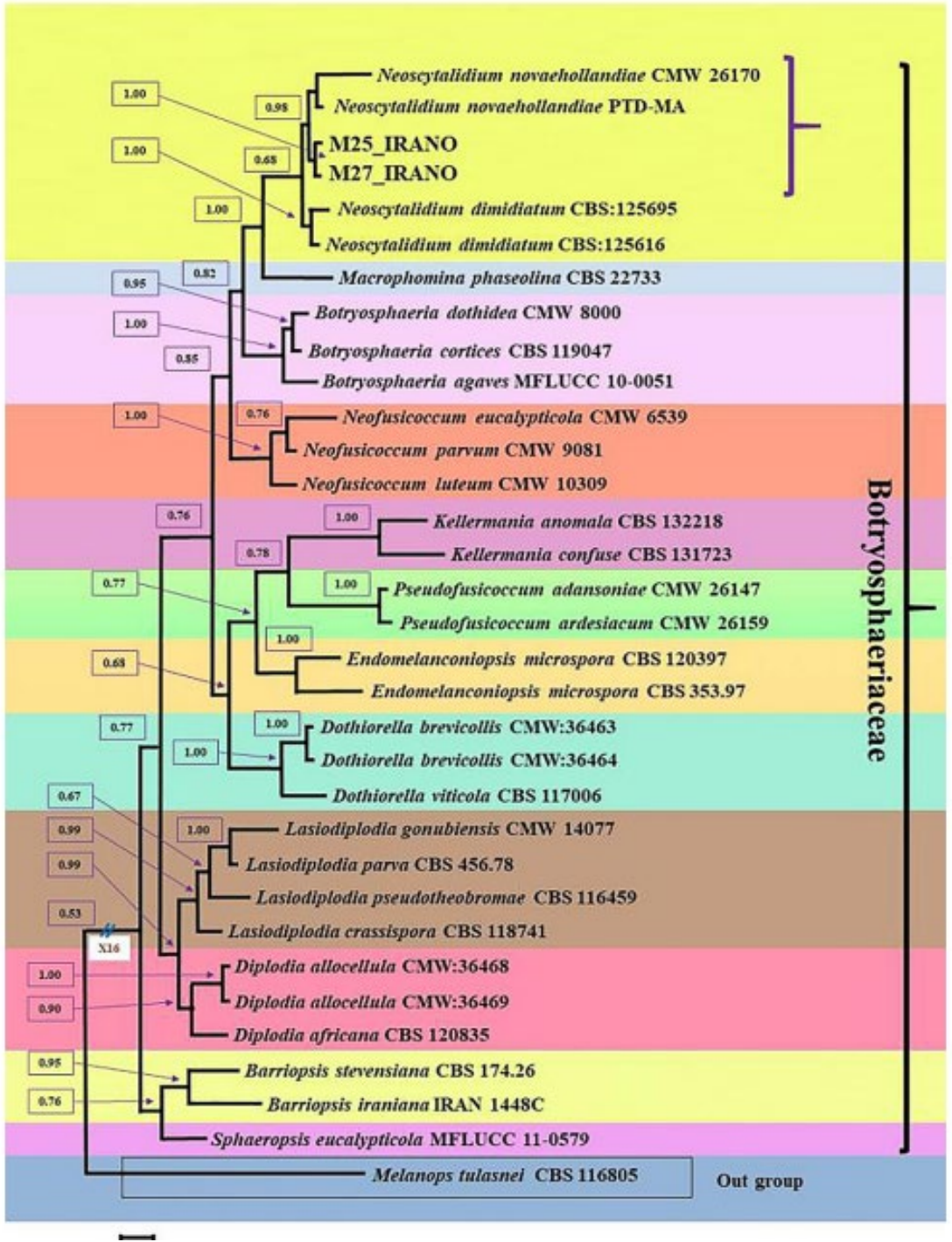
Unexpected Distribution and Implications

- This study revealed **higher diversity** than previously thought, including new host associations and potentially novel taxa.
- **Homothallic *Phytophthora*** species are more **prevalent in uplands** areas.
- **Waterways**, season **flooding** and Off-highway vehicle **(OHV) tracks** may act as routes of **dispersal**.
- *Phytophthora* detected under both symptomatic and healthy-looking plants, suggests **potential for overlooking** infections.
- **Further research is needed** to develop effective **prevention** and **management strategies**, including expanded **surveys** and **pathogenicity tests**.

Botryosphaeriaceae complex

- They cause **severe damage to woody** agricultural hosts like grapevines and walnuts.
- These fungi are almost **ubiquitous** in Mediterranean areas of the world.
- In **California**, they have been associated with causing **shoot dieback** in forest settings, affecting Oaks, Manzanitas, Madrones, Redwood and others, especially during **drought years**.
- Over 26 genera and 1500 species belong to this family, hence the complex.

Fig. 9 Phylogenetic tree of Botryosphaeriaceae taxa based on *TEF-1a+LSU* sequences obtained with Bayesian analysis using the GTR + G model. Branch values of ≥ 50% for Bayesian probability and type species used for the present genera. Each genus is separated by a different colour. The newly generated sequences with related genera and species are indicated in yellow. *Melanops tulasnei* was utilized as an outgroup species



Alizadeh et al. 2023

UC IPM Jack Kelly Clark

Lakeside Ceanothus **decline**

- In **2023, a decline** was reported in the rare and endemic species Lakeside Ceanothus (***Ceanothus cyaneus***) in San Diego County.
- In various sites a significant decline was observed in a span of a **four-year period**.
- Individuals exhibited general decline, with severe symptoms of **thinning and dieback**. Abnormal growths on branches were present.
- In 2024, Folks from the San Diego River Park Foundation and the San Diego Zoo reported a similar situation occurring at El Capitan Mountain in San Diego County.
- Dr. Johanna Del Castillo, a UCCE Nursery Extension Specialist from UC Davis, was asked to assess the situation.

Photos: from Lakeside Ceanothus Comparison.docx

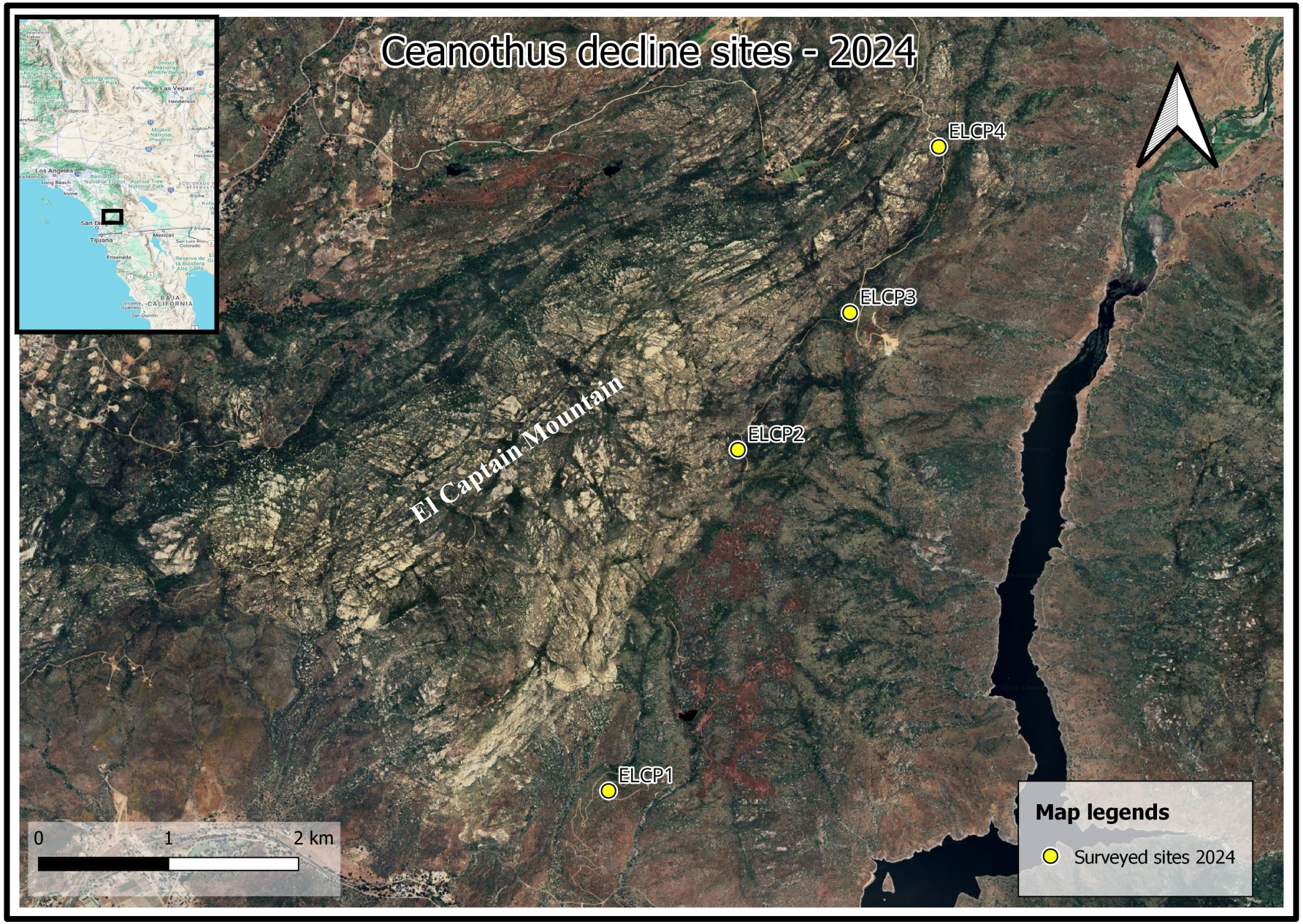
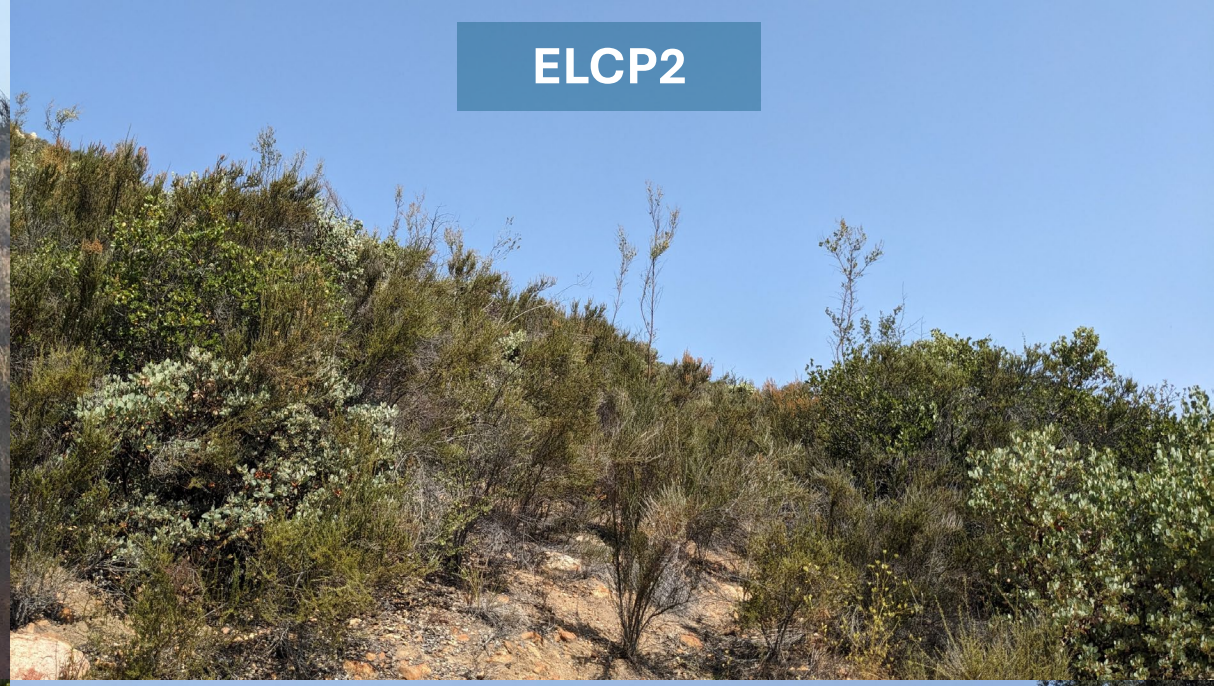


Figure. Sites visited during the July 24, 2024, survey trip to observe declining *Ceanothus cyaneus* in San Diego County.


ELCP1


ELCP2


ELCP3

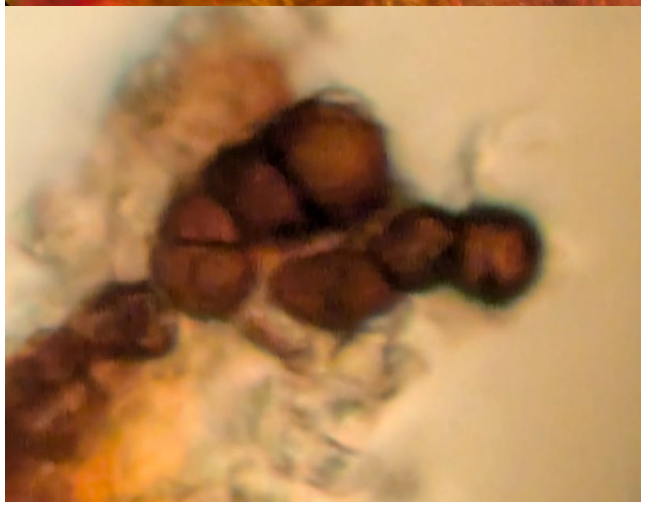

ELCP4

Thinning



Thinning was the **most frequent** symptoms observed across all four sites in the El Capitan Mountain San Diego, Co. Thinning varied in severity, with complete defoliated branches, **partial defoliation and yellowing**. Noticeable other chaparral species seem not to be severely affected.

“Abnormal growths”, Resin exudates



Abnormal growths on *Ceanothus cyaneus* as seen in the field, dry and hard texture. Post moist chamber, growths became soft and brittle. Under the microscope, growths appear to be hardened resin. Resin vacuoles can be observed.

Branch cankers

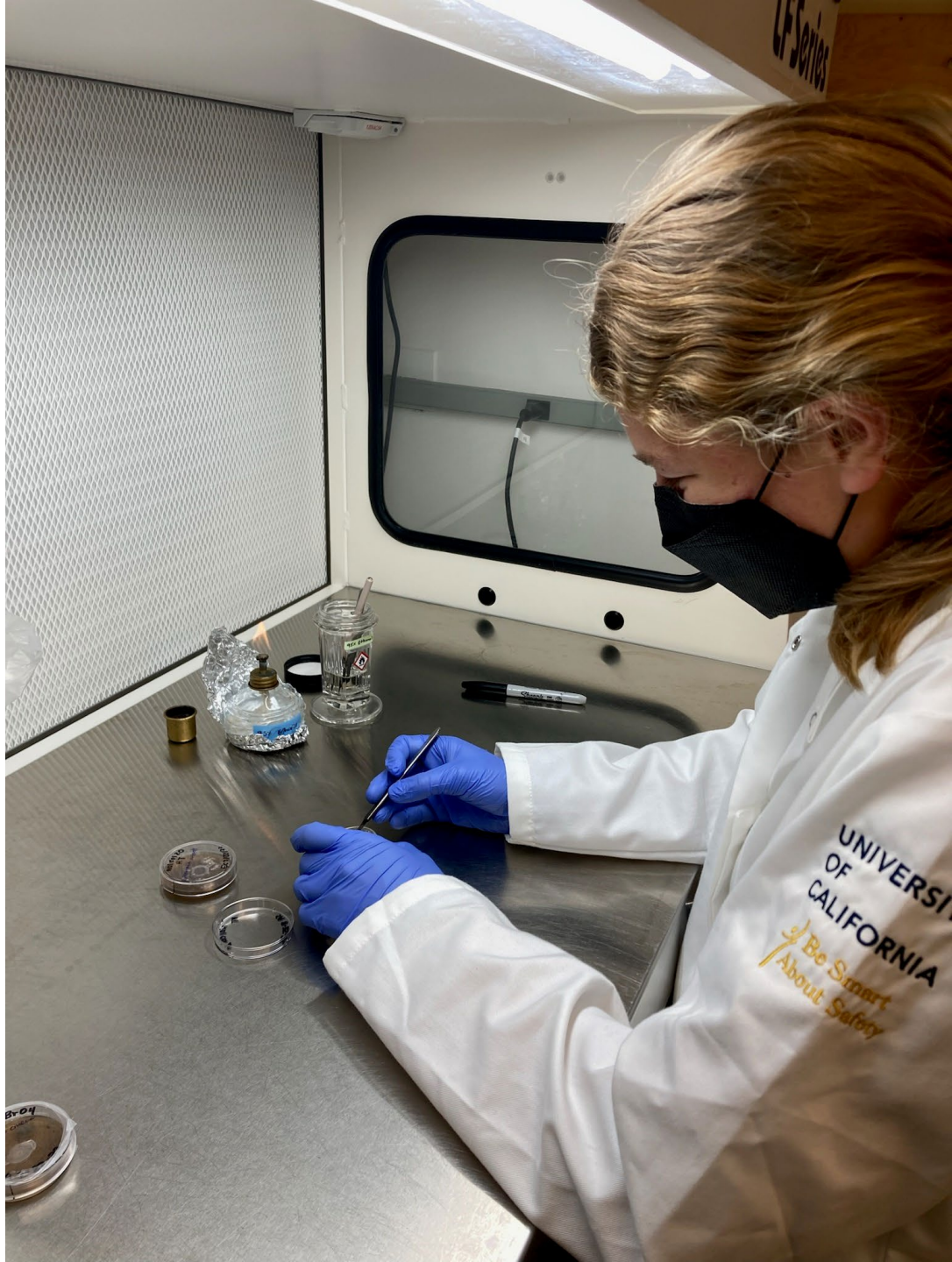
Underneath harden resin, small and delimited cankers were observed.

Basal cankers

Basal cankers were found on two of the six sampled individuals. Underneath the sunken lesions, visible cambium necrosis was observed.

Sample processing

- **Plant tissue and soil samples** were transported to Del Castillo Lab at UC Davis and assessed for fungal and oomycete plant pathogens.
- Plant tissue was **surface sterilized** and plated on **1/3 PDA** (Potato dextrose Agar) with antibiotics.
- Soil samples were processed for *Phytophthora* through common **oomycete baiting techniques.**
- All isolated strains were **identified** through sequencing of the **ITS** region. Samples were sent for sequencing at Psomagen, Inc., Rockville, MD.



Site ELCP2, sample ELCP2-1. This individual *Ceanothus cyaneus* had severe die back on multiple branches, including completely dead branches. Highly severe branches had dried up resin exudates. Cankers underneath exudations and basal cankers were also observed. ***Dothiorella iberica*** and ***Botryosphaeria dothidea*** were frequently isolated.

Table. *Ceanothus cyaneus* survey summary. In total four sites were visited taking symptomatic plant and soil rhizosphere samples. An additional soil sample from a dry creek bed was taken from site ELCP3. GPS point and elevation for site ELCP1 are missing due to GPS tracker issues.

Site	Vegetation type	Lat, Long	Elevation (m)	Sample ID	Type of sample	Symptoms	Isolations
ELCP1	Chaparral	NA	NA	ELCP1-1	Plant tissue	Resin exudations, thinning, branch death	***Botryosphaeria dothidea, Neofusicoccum vitifusiforme****, Pringsheimia chamaecyparis*
ELCP1	Chaparral	NA	NA	ELCP1-2	Plant tissue	Resin exudations, dead branches, thinning and basal canker	***Botryosphaeria dothidea, Neofusicoccum vitifusiforme***
ELCP2	Chaparral	32.92425, -116.80422	754.86	ELCP2-1	Plant tissue	Resin exudations, dead branches, thinning and basal canker	*Botryosphaeria dothidea Dothiorella iberica*
ELCP2	Chaparral	32.92425, -116.80422	754.86	ELCP2-2	Plant tissue	Thinning and yellowing	***Botryosphaeria dothidea*** *Opportunistic molds: Stromatinia sp., Biscogniauxia sp. Paracamarosporium sp.*
ELCP3	Oak woodland	32.93551, -116.795	664.23	ELCP3-1	Plant tissue	Mechanical damage, dead branches.	***Botryosphaeria dothidea***
ELCP3	Oak woodland	32.93551, -116.795	664.23	CLP3-3	Soil from dry riverbed	NA	*Phytophthora thermophila*
ELCP4	Chaparral	32.94915, -116.7877	660.39	ELCP4-1	Plant tissue	Resin exudations, dead branches, thinning.	*Opportunistic molds: Roselinia sp., Soradriomycetes sp.*

Botryosphaeriaceae and *Ceanothus* spp.

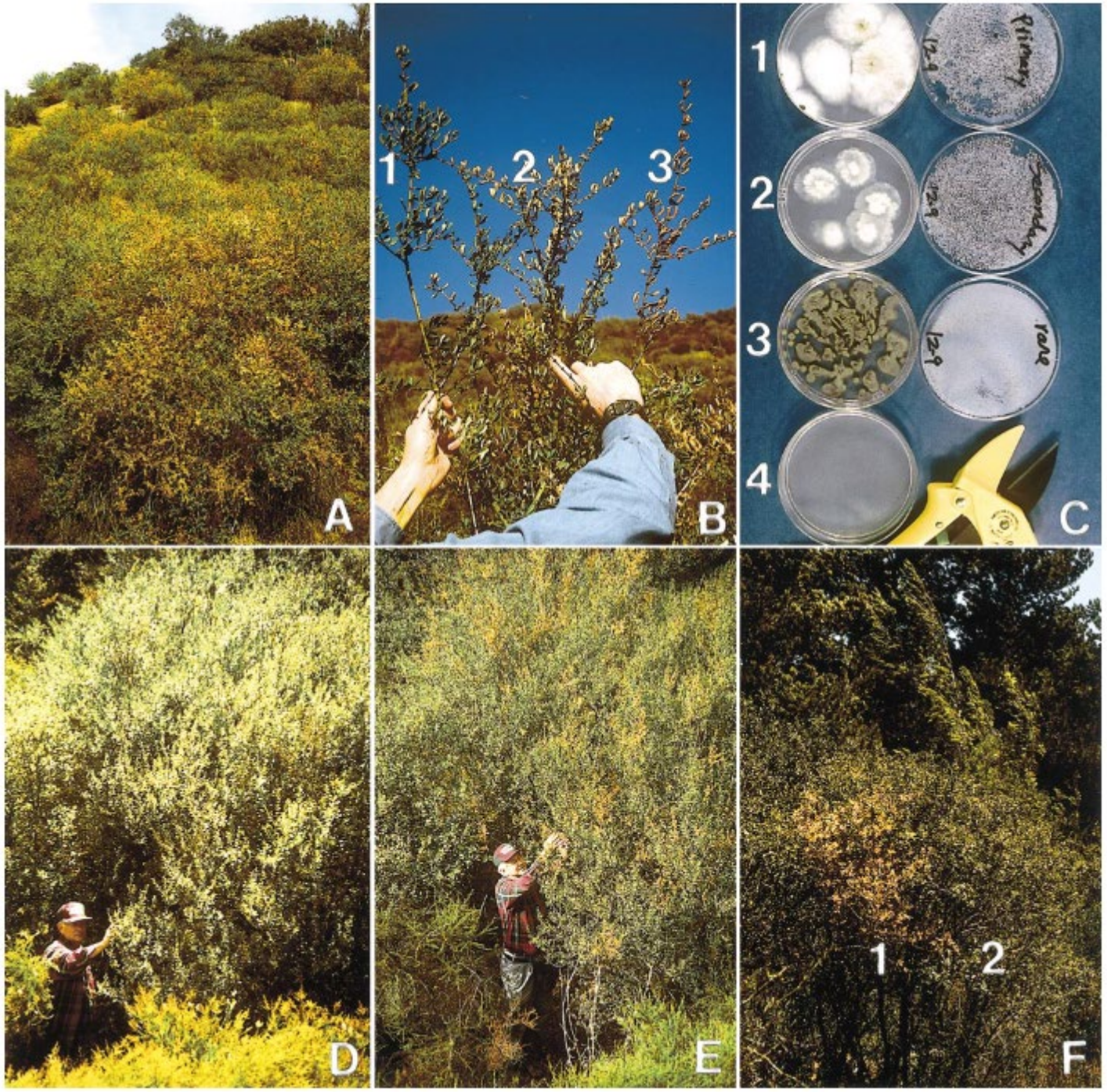
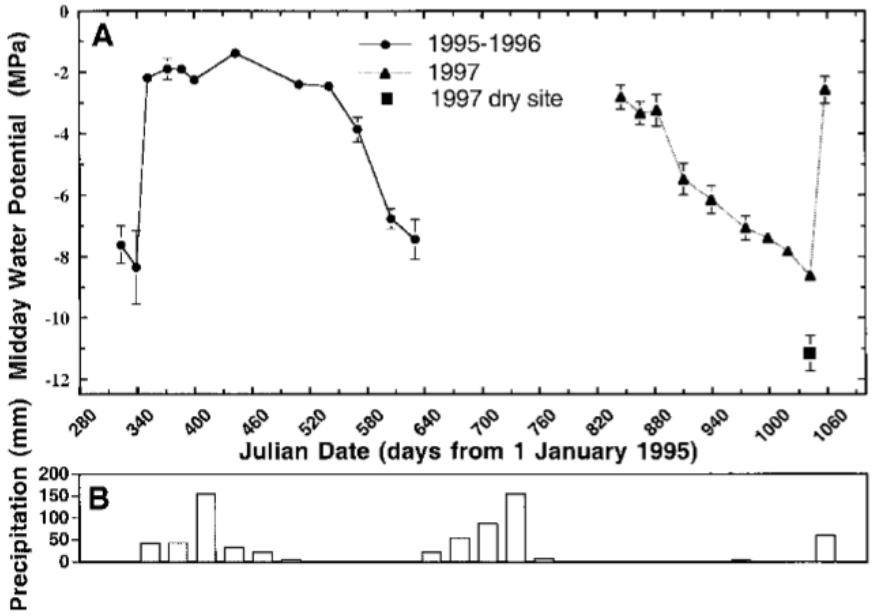


Fig. 1. (A**) Mixed stand of *Ceanothus crassifolius*** growing at the Malibu Forestry Unit of Los Angeles County in the Santa Monica Mountains of southern California, USA. **Note dieback, predominately among terminal, outer canopy branchlets**. (B) Individual *C. crassifolius* shrub in November of 1997, at the peak of seasonal drought with close-up view of outer canopy branchlets: (1) healthy, (2) recently dead, and (3) month-old dead. (C) **Three species of fungi isolated** from C. *crassifolius* growing at our study site and used for inoculation treatments: (1) ***Botryosphaeria* dothidea,** (2) ***Botryosphaeria* sp.**, (3) ***Sclerophoma* sp.**,and (4) control—agar only. (D) Healthy *C. crassifolius* canopy in midsummer: (E) Same view as in panel D but in late fall after the onset of branchlet dieback.(F) Example of a healthy shrub in midsummer 15 d after the basal stem of one branch was notched (1) adjacent to remaining branches and (2) that were not notched (control).

Davis et al. 2002

Botryosphaeriaceae and *Ceanothus* spp.

- Reggina et al. 1994 and Davis et al. 2001 reported **shoot die back** of several species of Ceanothus: *C. crassifolius*, *C. oliganthus*, *C. megacarpus*, *C. spinosus* and *C. leucodemis* in SoCal.
- The results suggest that the observed dieback was **not caused by a fungus** but was consistent with insufficient water transport to foliage associated with prolonged drought.
- Apparently **endophytic fungi were widely present**, occurring in at least half of the healthy stems. However, upon death of the branchlets, they proliferated and were present in 100% of dead branchlets.



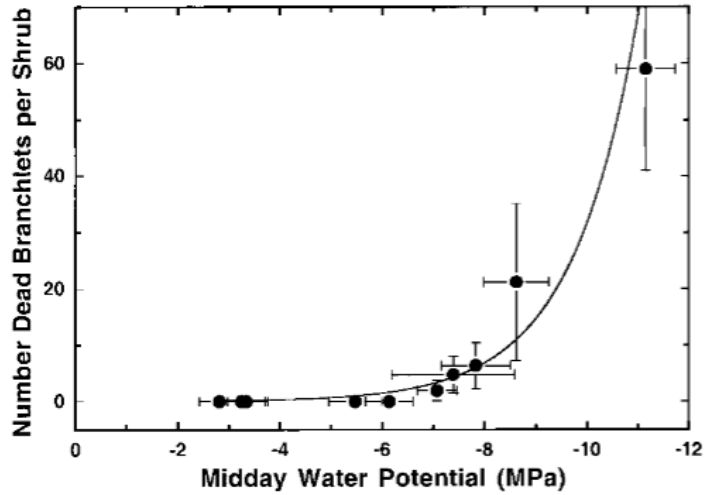


Fig. 3. Relationship between midday leaf xylem pressure (P_L) and the number of dead branchlets per shrub for *Ceanothus crassifolius* during the summer/fall drought of 1997 (9 mo without significant rainfall; see Fig. 2B). Individuals were growing in a mixed chaparral stand at the Malibu Forestry Unit of Los Angeles County in the Santa Monica Mountains of California. The datum for the lowest mean water potential of −11.2 MPa ($N = 22$) was taken from an adjacent stand 200 m away from the original 12 individuals.

Endophytes

- From the Greek words: *Endo* (within), *Phyto* (plant)
- Fungus that **lives inside** a plant, typically within its tissues, without causing any immediate harm or disease to the host.
- Many fungal endophytes form **beneficial relationships** with plants, helping them with stress tolerance, nutrient uptake, or defense against pests and pathogens.

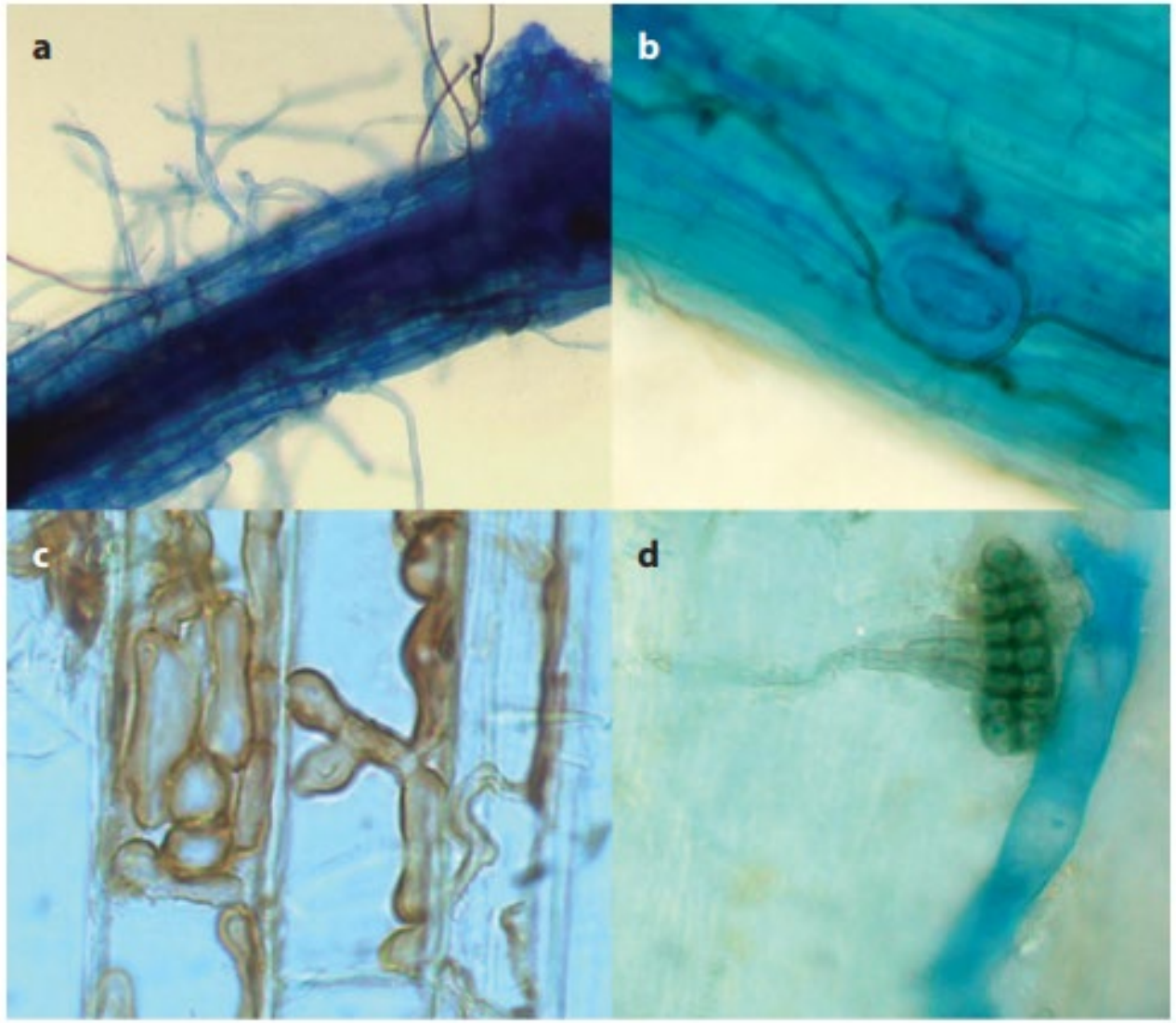


Figure 6

Dark septate endophytes (DSEs). (*a*) Stained root section of the grass *Bouteloua gracilis* showing internal and extraradical hyphae; (*b*) DSE hyphae encircling a mycorrhizal vesicle (AMF) in a *Geum rossii* root; (*c*) hyphal proliferation in plant cells; and (*d*) germinating DSE spore in *G. rossii* root. (Photos courtesy of J. Herrera and A. Porras-Alfaro.)

Porras-Alfaro and Bayman, 2011

Endophytes

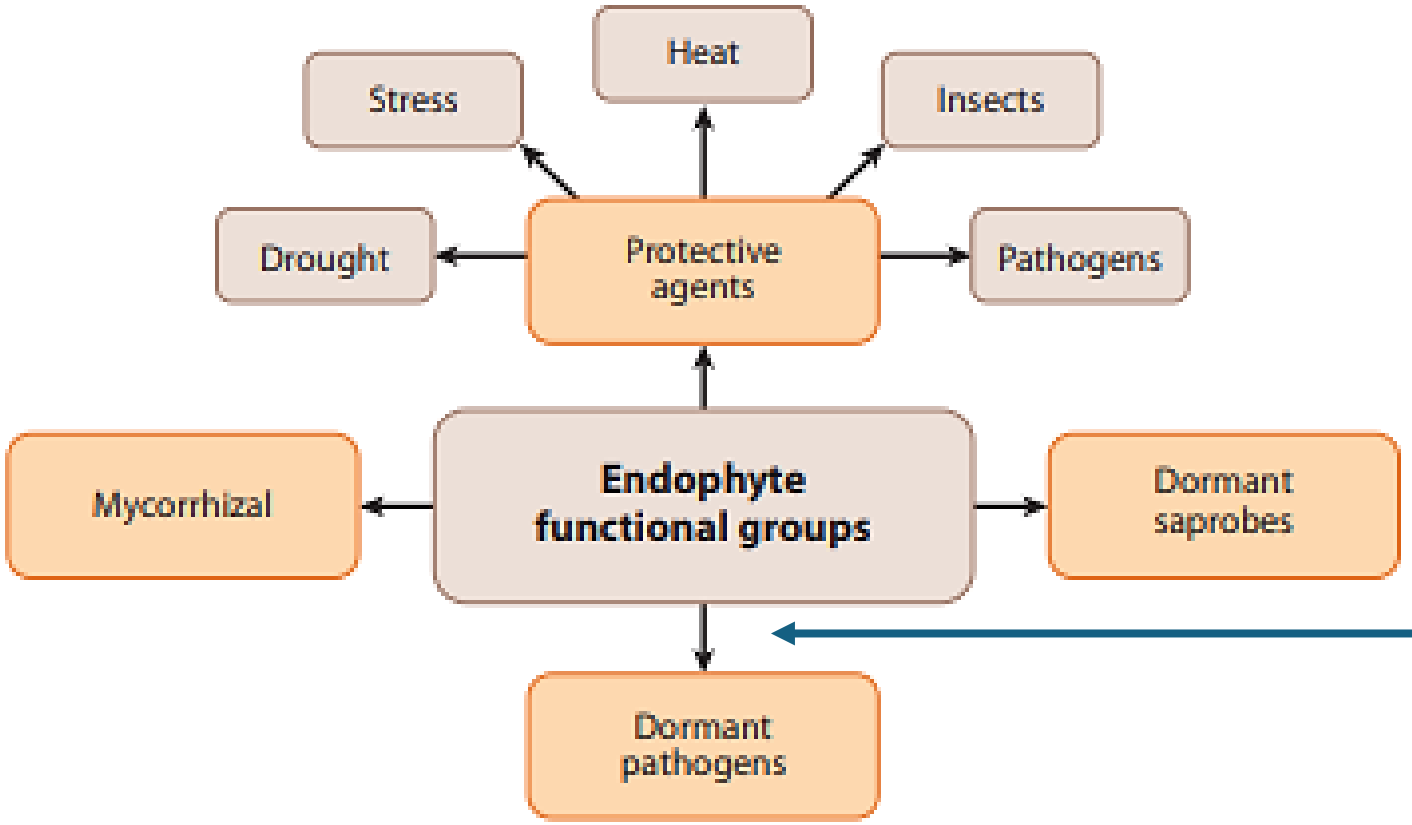


Figure 1

The mycobiome. As part of a fungal community, endophytic fungi may have one or multiple functional roles during their life cycles or in reponse to plant or environmental cues.

A change in the host or environment may **trigger pathogenicity** in an endophyte that was previously asymptomatic.

Conclusions

- **Drought** in combination with **Botryosphaeriaceae** are probably contributing to the observed symptoms.
- Both cases can relate to the concept of **plant predisposition**. Disease as on set from drought stress
- **Future studies** are needed to gain insights into the risk posed by stress and Botryosphaeriaceae species, this will aid to assess the long-term health of Lakeside Ceanothus in the face of environmental pressures.

Recommendations

- **Periodic Monitoring:** Regular monitoring of the Lakeside Ceanothus population at El Capitan Mountain is highly recommended to track potential issues.
- **Expanded Surveying:** Collecting samples from various locations, including adjacent areas in the El Capitan Mountain will help to determine the presence and prevalence of these pathogens through out the season.
- **Sanitary Measures:** Minimize human-mediated spread, including removing plant and soil debris from tools, boots and vehicles.
- **Pathogenicity Testing:** Inoculating healthy *C. cyaneus* with the Botryosphaeriaceae fungi isolated in this survey will help evaluate their pathogenic potential.
- **Exclusion:** In the meantime, avoid collecting seeds or any propagating material from these areas.

Integrated Tree Disease Management

- **Understanding Pathogens is Key:** Managing tree diseases, especially those caused by *Phytophthora* and Botryosphaeriaceae species, requires knowing how these different pathogens operate.
- **Prevent Phytophthora Spread:** Avoid moving contaminated soil or plants. Always use clean tools and manage irrigation carefully.
- **Control Botryosphaeriaceae with Pruning:** Prune diseased branches and sanitize your tools between cuts to prevent fungal spread.
- **Monitoring:** Regularly check your trees for symptoms. Early detection allows for quick intervention, which can save your trees from further decline.


Questions???