Conserving Threatened Orchids: The Flower-Fungus Connection

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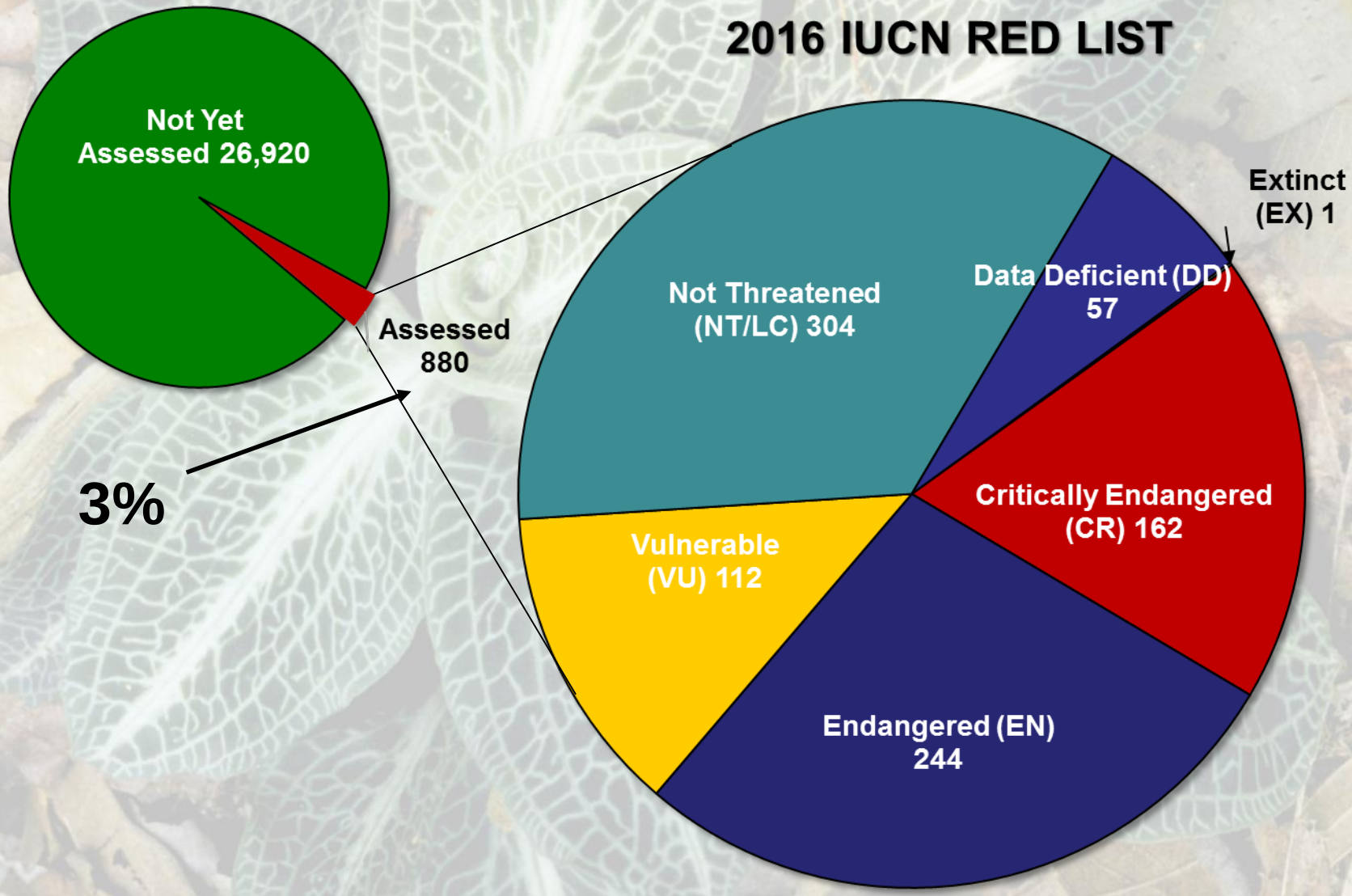
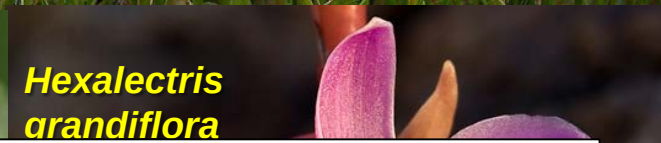
Orchids

- ~ 30,000 species (10% of all flowering plants)
- Occur on all continents except Antarctica
- Over 50 species in MD
- Widely threatened and endangered
- Complex life histories
- ‘Canary in the coal mine’ of the plant world

ORCHID SPECIES OF THE WORLD



About 220 species of native orchids in the US and Canada



57% are threatened or endangered in some part of their range of distribution

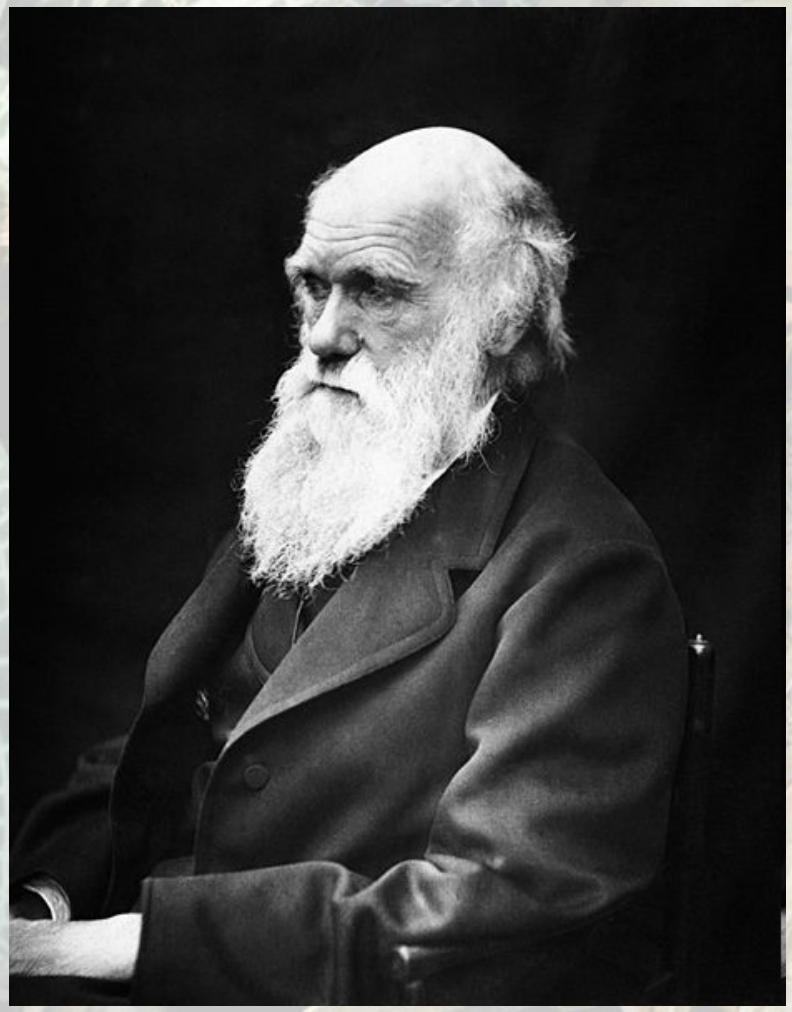
Some of our most attractive native orchids have been declining rapidly (Knapp paper)

…and it hasn't been clear what we could do to help them.

Orchid conservation has been pretty much just setting aside land.

Charles Darwin

- was fascinated by orchids' elaborate pollination and by why plants that produce so many seeds are so often rare.
- calculated that if all seeds grew into plants then the great grandchildren of a single orchid would "cover the earth in one continuous green carpet".



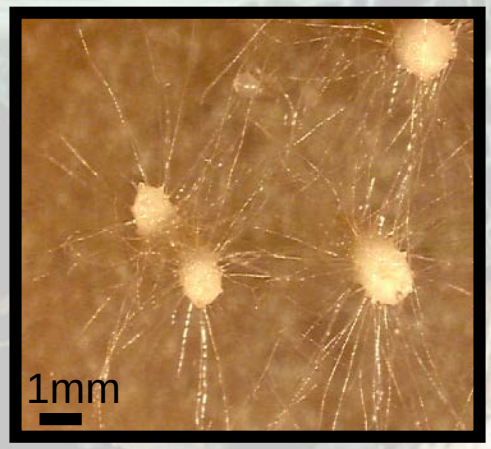
What is it about orchids?

- Why are orchids so difficult to grow and preserve?
- What does orchid research tell us?
- What will it take to apply this research to native orchids in North America?
- Where does the **North American Orchid Conservation Center** fit in?

Orchid reproduction depends on other species

Pollinators

Fungi



Fungi

Pollinators

King-in-His Carriage Orchid

Drakaea glyptodon

What do fungi do for plants?

A mycorrhiza is a symbiotic association between a plant root and a fungus

- Most plants in most ecosystems
- All plant families
- Essential for access to nutrients and water
- Protect against pathogens

Read 1997

Orchids take mycorrhizae to an extreme

- Orchids cheat their mycorrhizal fungi.
- Orchids eat their fungi.
- Orchids are entirely dependent on fungi for all their nutrition at least early in life.
- This early life stage may last only a few months or many years.

Orchid mycorrhizal fungi:

Tulasnella violacea

- Ecologically diverse

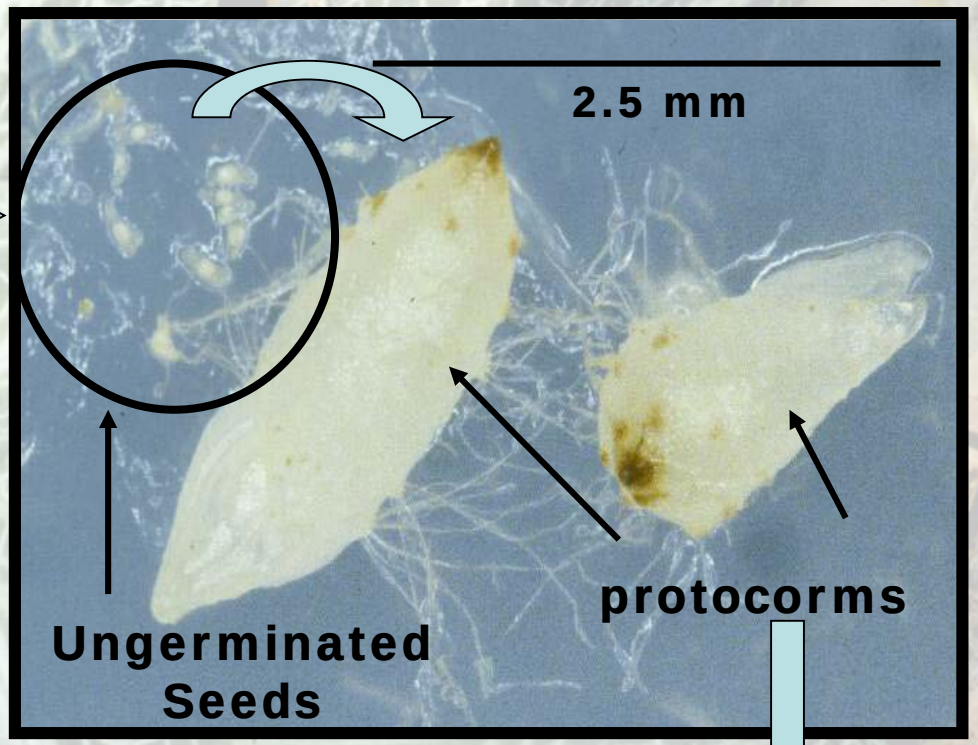
  Ectomycorrhizae,
  Mycoparasites,
  Pathogens,
  Decomposers

Tulasnella violea

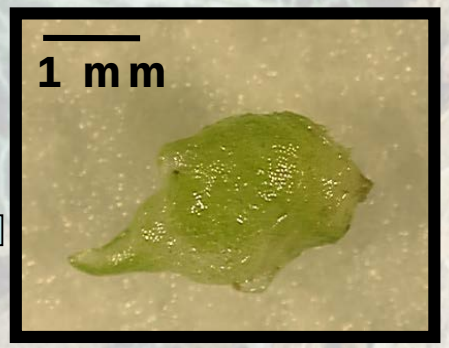
- Widespread and common
- Poorly-studied
- Morphologically indistinguishable

Images from J. Breitenbach “Fungi of Switzerland” 1986

Orchid seeds and fungi:

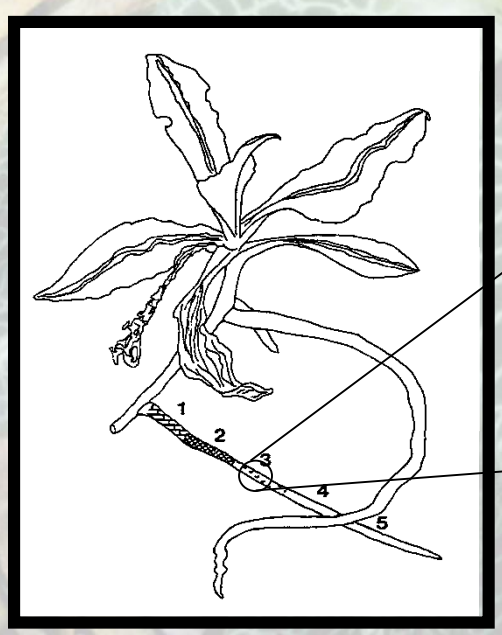


- Seeds have no nutrients.
- Germination requires specific fungi.
- Fungi provide all nutrients, including carbon.

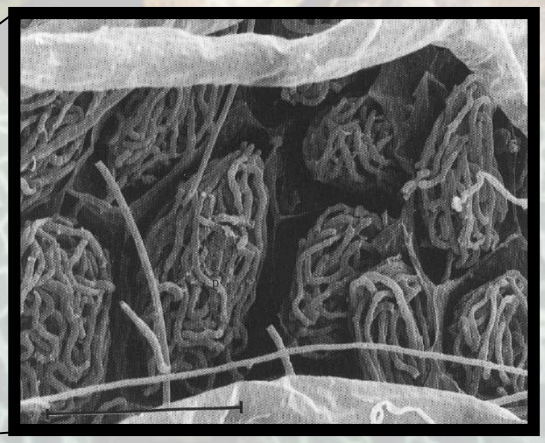


Adult orchids and fungi:

- Fungi form pelotons in root cells.
- Most orchids continue to get nutrients from fungi as adults.
- Fungi help orchids tolerate stress.



Adult *Goodyera* showing below-ground parts. (Zelmer 1994)



Pelotons (fungal coils) in an orchid root (Beyrle et al. 1995).

Orchid life history

Seeds

Protocorms

Seedlings

Vegetative Plants

Dormant Plants

Sexual Plants

How do fungi affect orchid performance?

Isotria medeoloides

Where are these fungi and when do they support orchids?

- There are LOTS of fungi in the soil!
- Up to 150 species in 0.5g of soil.
- Extract DNA from soil
- 2 samples 15cm apart may share only 25% of their species.
- We design specific probes to look only at the DNA from the fungi we are interested in and tell us how much is there.

Soil core

↓

Fungal DNA

When do fungi support seed germination?

Seed packets tell us when conditions are right for orchids

A test with three orchids:

Liparis liliifolia
mauve twayblade

Tipularia discolor
cranefly orchid

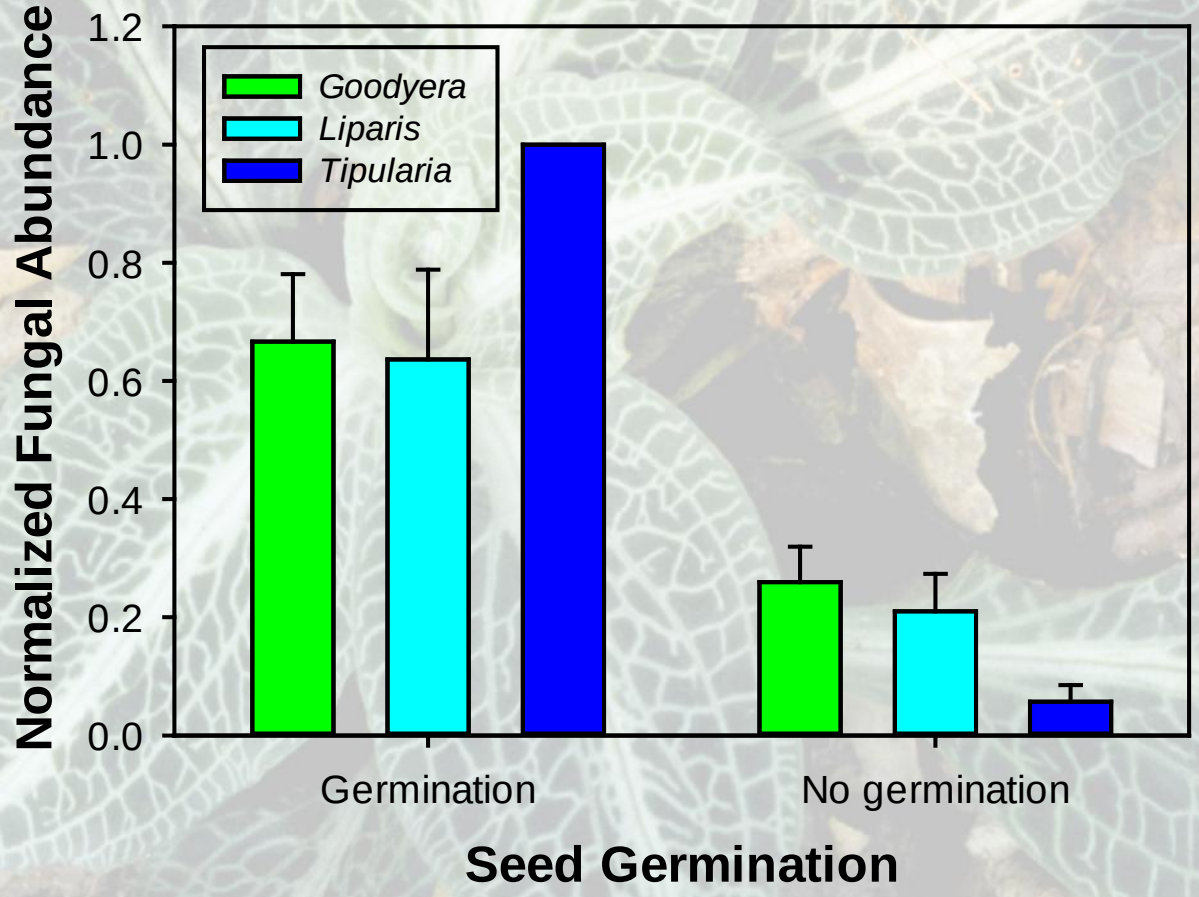
Goodyera pubescens
rattlesnake plantain

Different orchids need different fungi

MD101
GA243
Tulasnella bifrons[H]
MD109
MD141
MD144p
MD145p
MD148p
MD150p
MD154p
MD179
NC245
MI230
NC239
NC241
NC244
NC247
NC248
NC249
MD169
MD186
MD213-2
MD219
GA253
Tulasnella calospora[C]
Tulasnella deliquescens[C]
MD120
MD196
MD197
MD191
MD192
MD140
MD166p
MI193
IA233
VA234
IA238
VA258
MD128
MD170
MD181
MD175
MD188
MD213-1
MD184
MD183
MD218
GA254
Ceratobasidium obscurum[G]
Ceratobasidium cornigerum[C]
Ceratorhiza goodyerae-repentis[C]
Sistotrema brinkmani[C]
MD121p
MD138p
MD207
Tomentella punicea[G]
NC259
Suillus cavipes[G]
Chroogomphus vinicolor[G]
Scutellospora castanea[G]
Brauniella albidipes[G]
Gomphidius glutinosus[G]
Serpula himantioides[G]
10 changes

McCormick *et al.* 2004

More fungus more germination

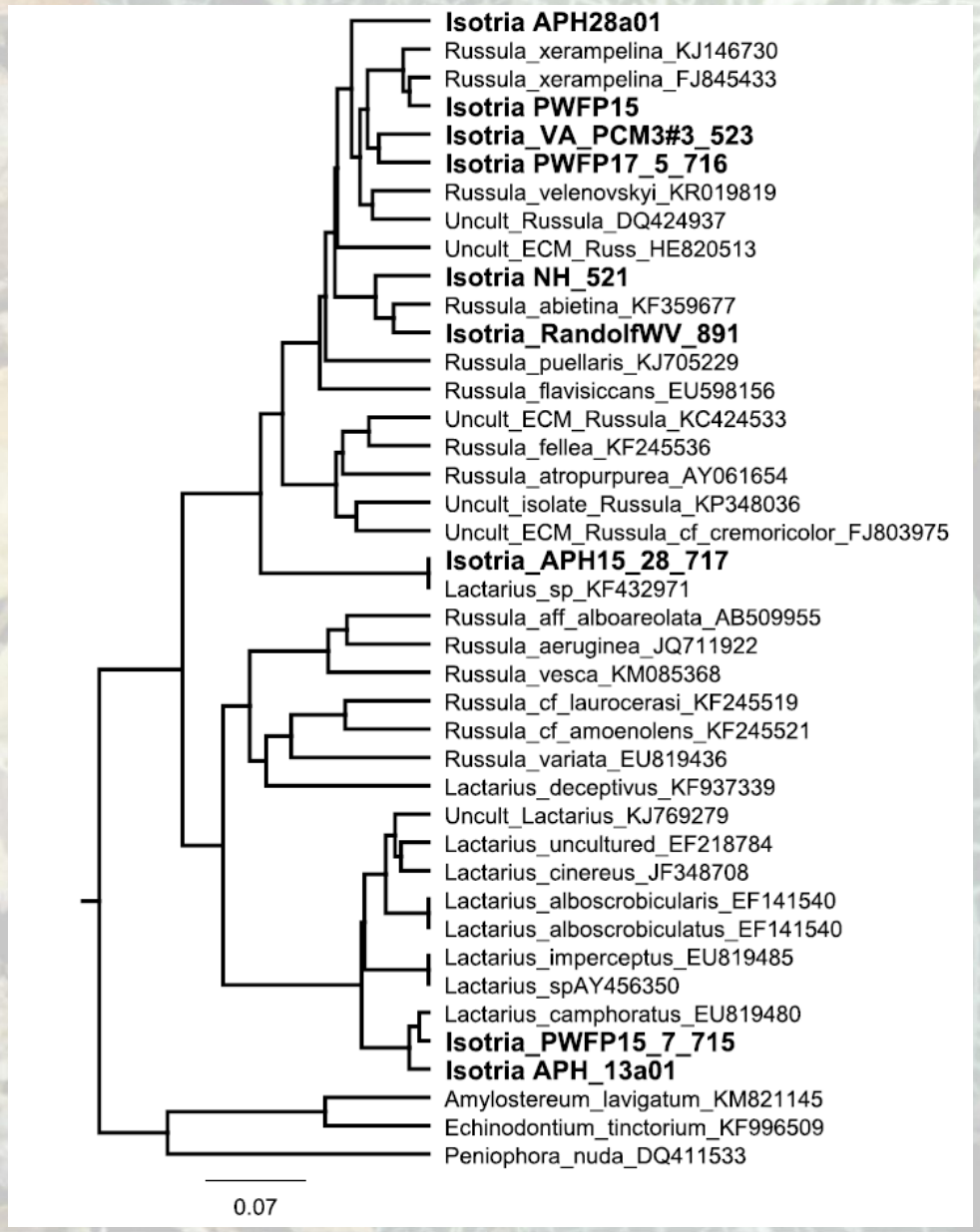


Isotria fungi are all ectomycorrhizal

All *Lactarius* and *Russula* are considered obligately ectomycorrhizal (ECM)

ECM hosts we have identified are:
Fagus grandifolia
Quercus falcata
Quercus alba
Carya cordiformis
Carya ovata
Betula alleghaniensis

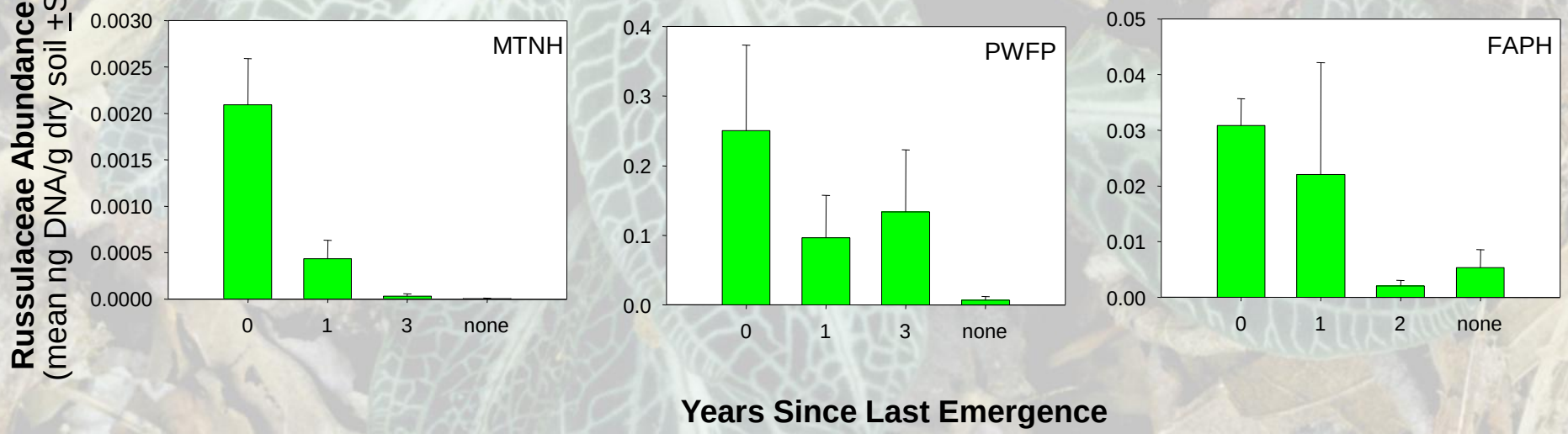
Mycorrhizal fungi



Russula xerampelina

Mycorrhizal fungus abundance

More fungus means plants are more likely to emerge and less likely to become dormant.



Rock-Blake *et al.* 2017

Field Conclusions

Some orchids need specific fungi, while others can use many different ones.

More abundant fungi are better able to support orchid seed germination and emergence from dormancy.

Maybe improving conditions for the fungi would also improve conditions for orchids.

What can we do to make fungi more abundant?

Tipularia discolor

Liparis liliifolia

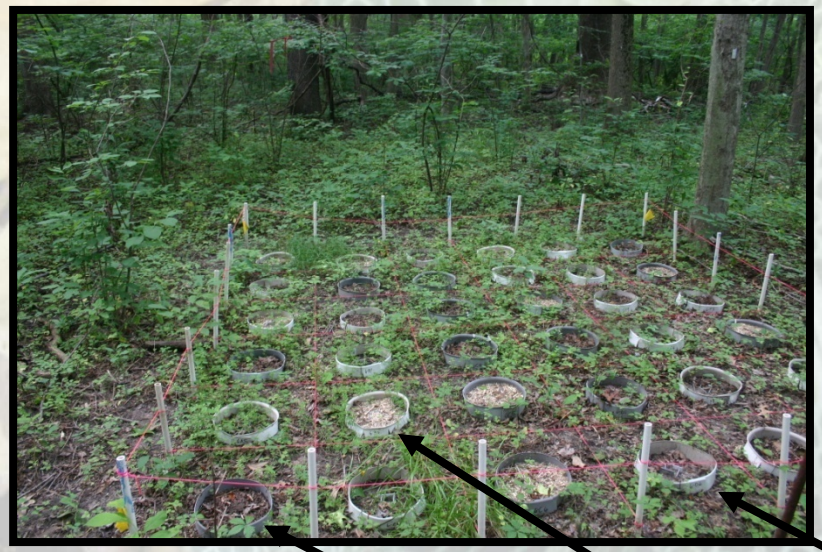
Goodyera pubescens

- Seed packets of 3 species.
- With and without appropriate fungi for germination added.

What makes these fungi abundant?

6 forest sites: 3 old (150+ years), 3 young (50-70 years)

36 subplots in each: 1/3 got chipped wood, 1/3 crushed leaves, 1/3 control



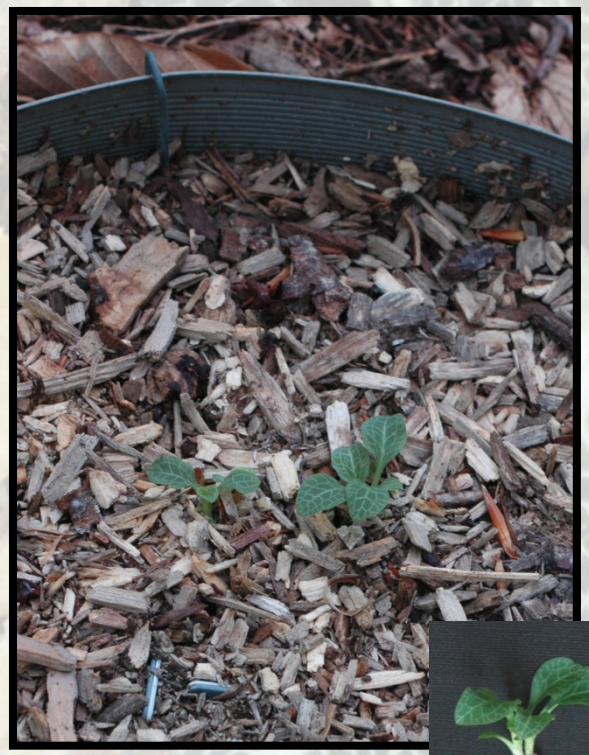
wood

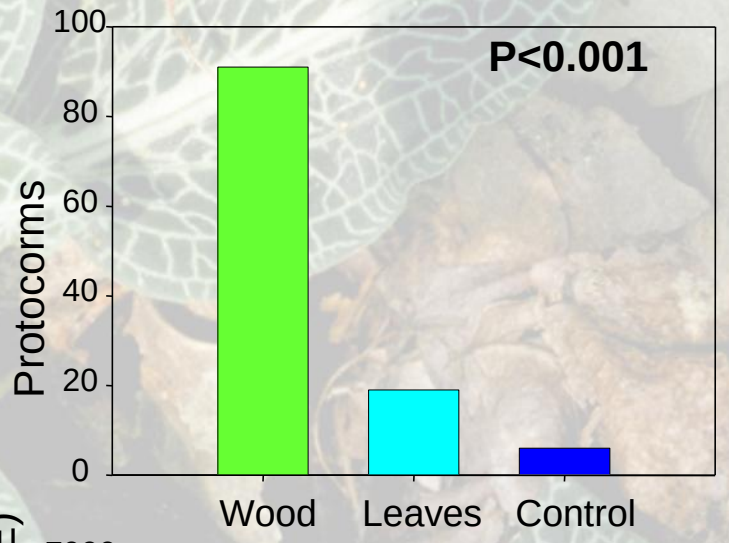
leaves

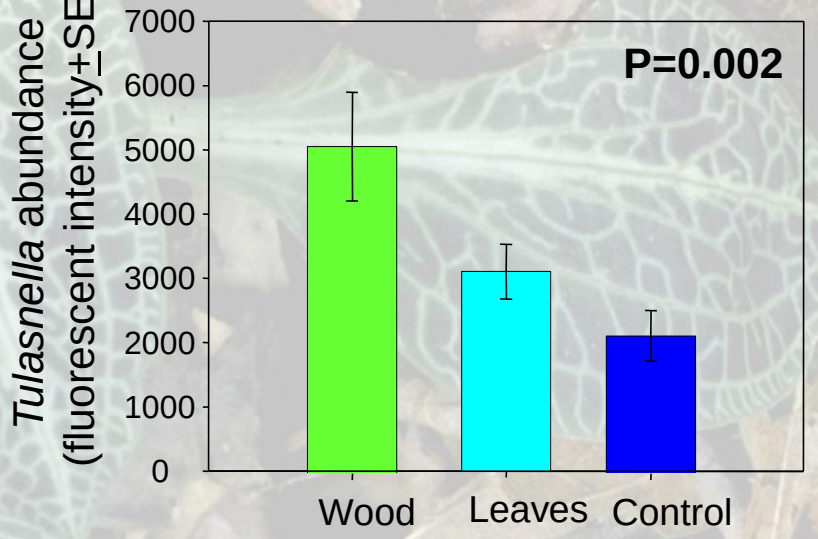
control

Goodyera pubescens
Rattlesnake plantain

Did amendments affect host fungi and protocorm development?

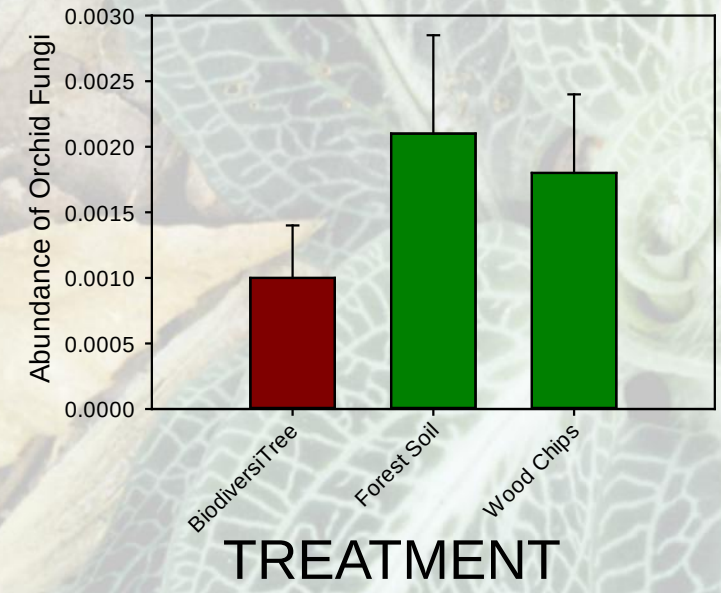


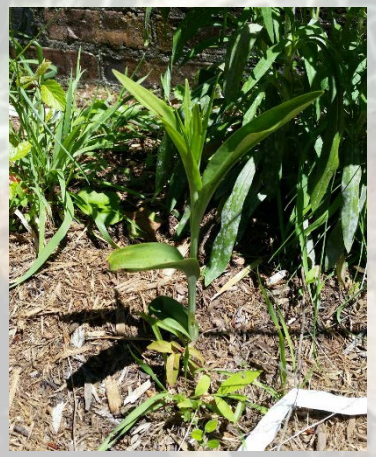


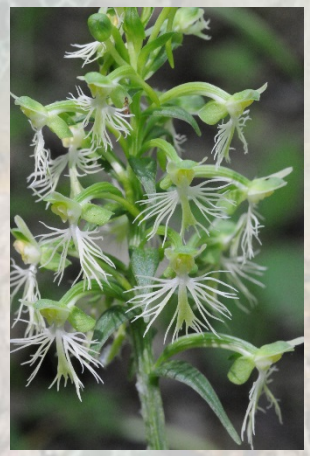


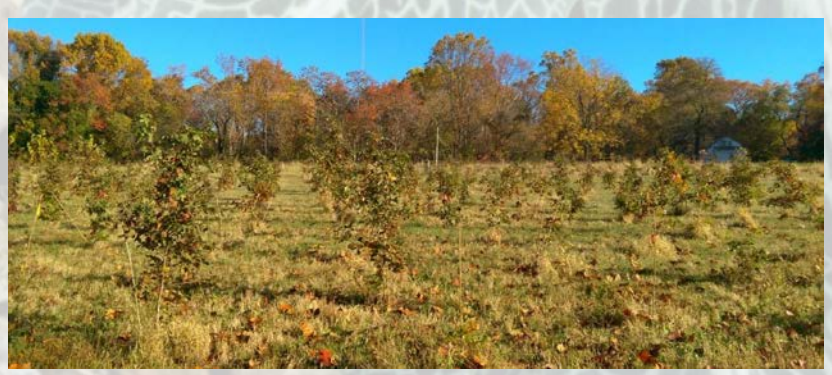
McCormick et al. 2012

Applications









Orchids and host fungi

- *A*ll three orchids were limited by the abundance of the fungi they needed, but the fungi were all limited by different things.
- Adding wood and leaves increased host fungus abundance and germination for *Goodyera*.
- Adding wood inoculated with orchid fungi or adding forest soil that had the fungi helped to increase those fungi in new soils, but only somewhat.

Orchid life history

Seeds

Protocorms

Seedlings

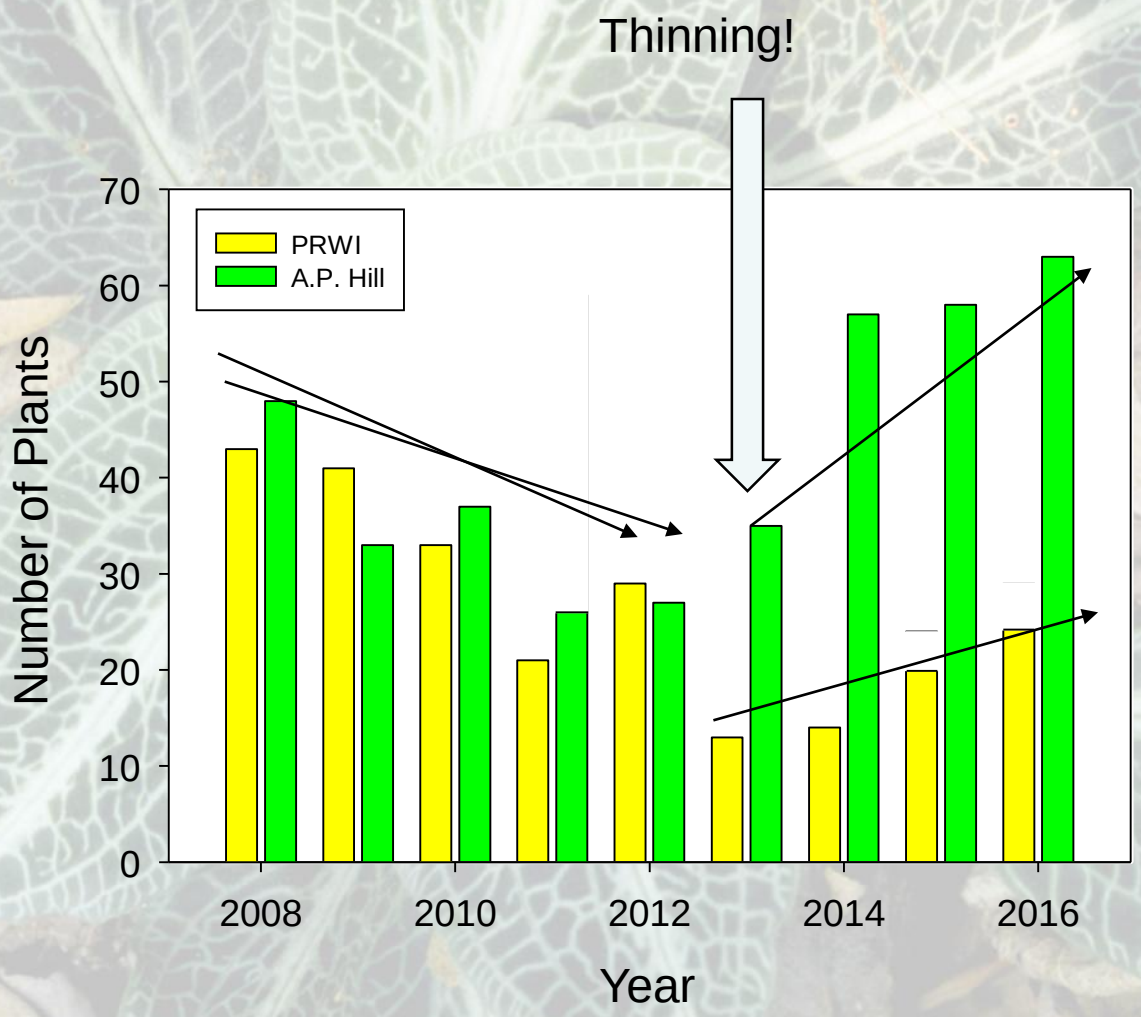
Vegetative Plants

Dormant Plants

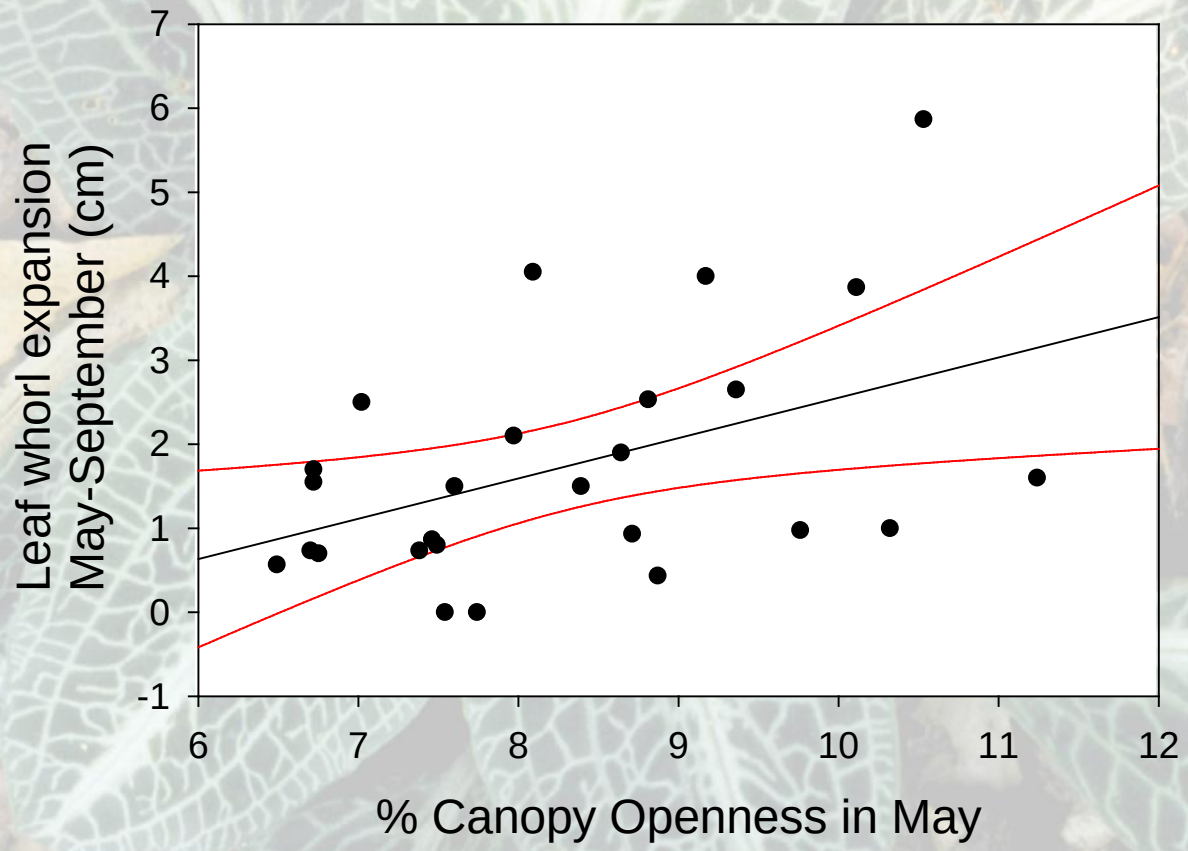
Sexual Plants

Canopy Thinning Experiment – Increase light

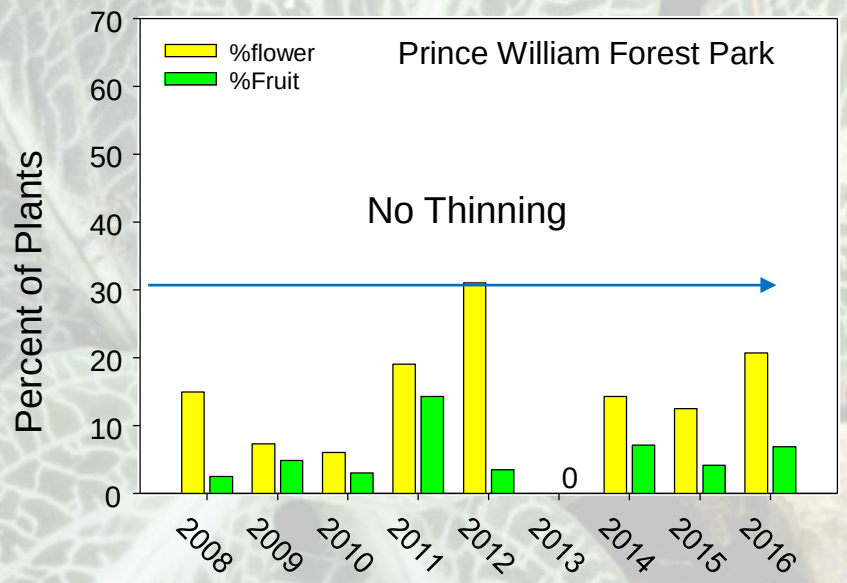
Thinning increased emergent plants

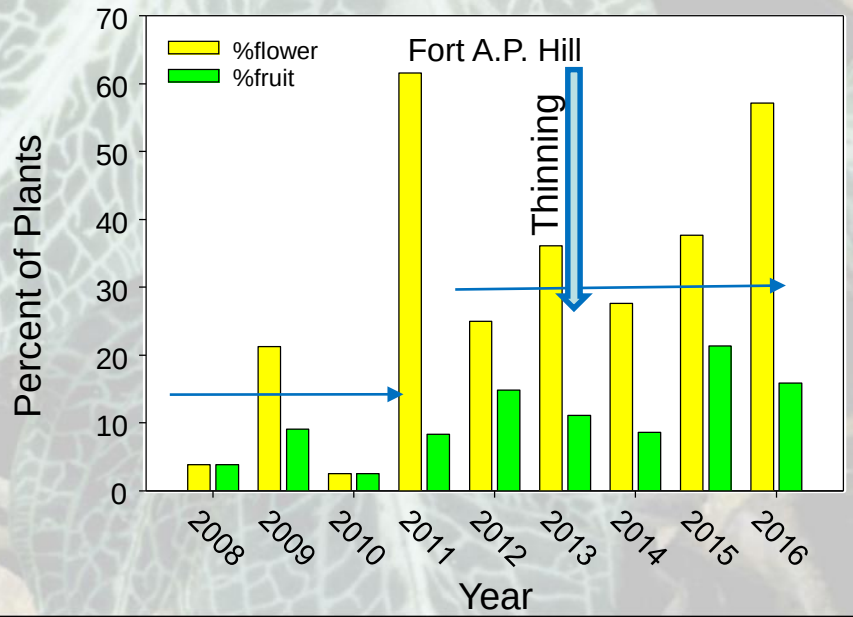


Individual plants also grew bigger



Flowering and Fruiting increased





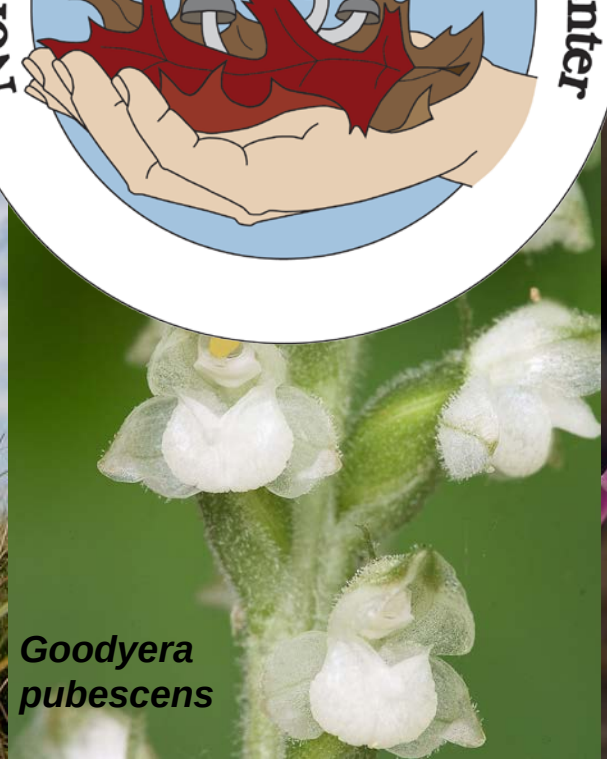
Cypripedium parviflorum

Spiranthes cernua

North American Orchid Conservation Center

Platanthera praeclara

Photos courtesy of Hal Horwitz



Goodyera pubescens

Hexalectris grandiflora

Our mission:

Conserve our native orchid heritage

Photos courtesy of Hal Horwitz

Goodyera pubescens

NAOCC Model

Propagation

Fungal Banks

Seed Banks

Education

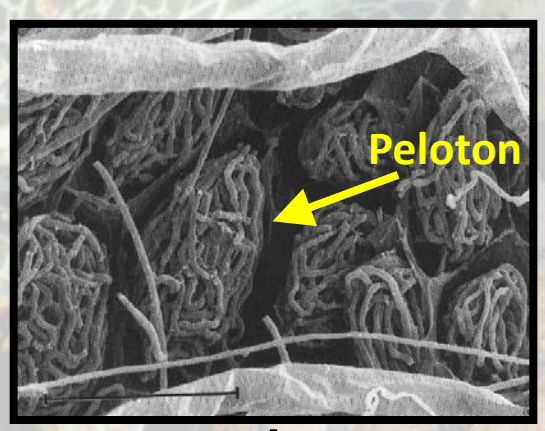
Longwood Gardens
Pollinator Partnership
UC Berkley
Virginia Native Plant Society
Minnesota Landscape Arboretum
Ridges Sanctuary

Orchid Conservation Coalition
Seeds for Success
UC Santa Cruz
Wabash College
NatureServe
University of Wisconsin-Green Bay

Old Dominion University
University of Florida
US Forest Service
Wintergreen Nature Foundation
Grand Traverse Regional Land Conservancy
Naples Orchid Society

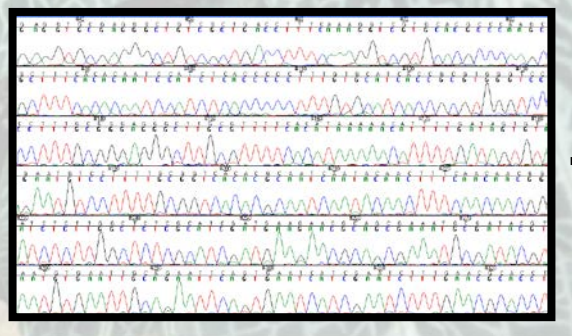
Fungus banks

Conserving the diversity of fungi that orchids need



Beyrle et al. 1995

DNA Extraction



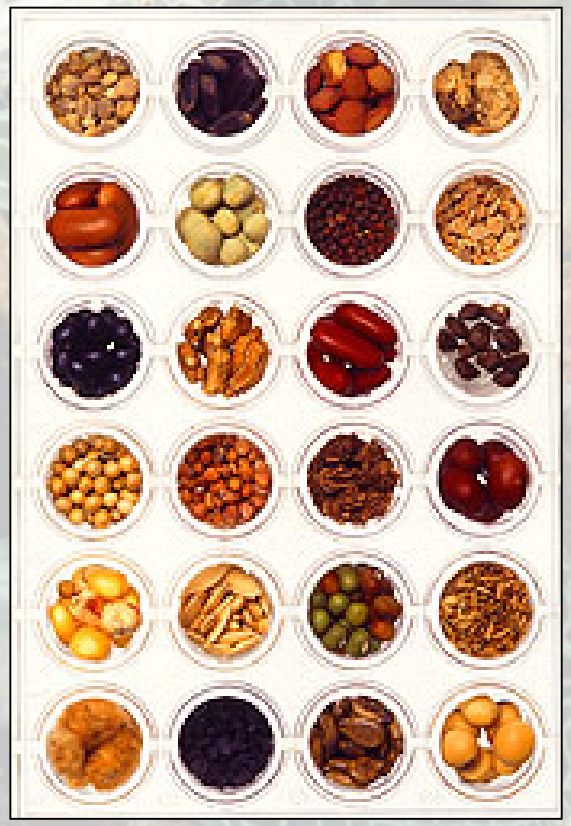
Cryopreservation

Seed banks

Conserving orchid genetic diversity

Nationally

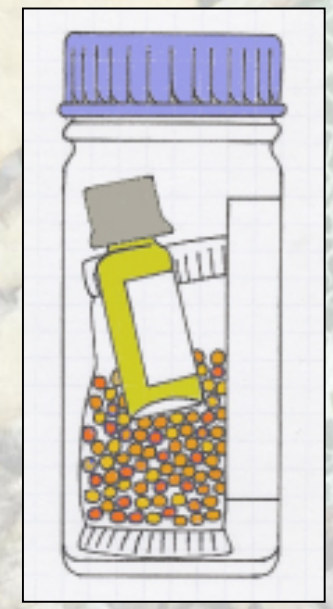
USDA - Agricultural Research Service
National Seed Storage Laboratory
in Fort Collins, Colorado



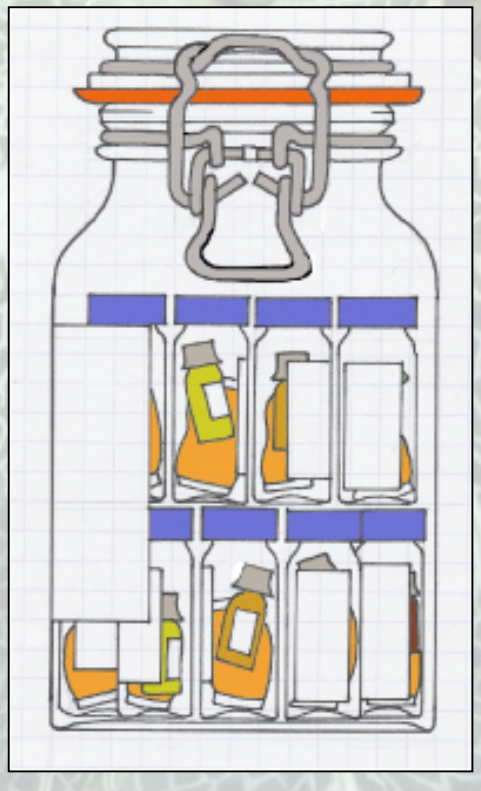
(Source: USDA Image Gallery)

Regionally

- **Storage in individual laboratories**
- **Storage in regional facilities**

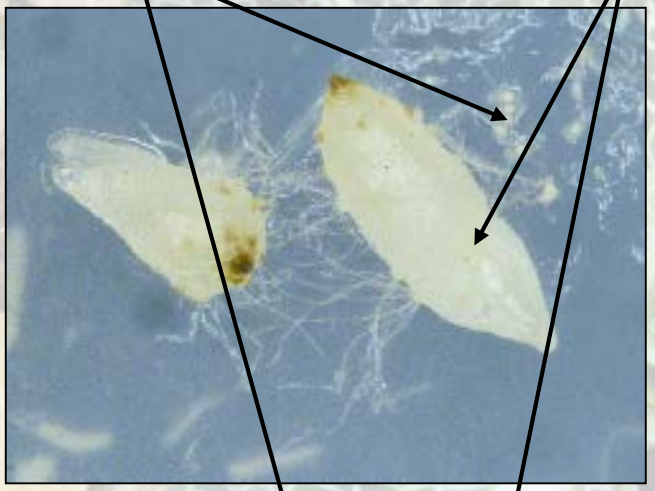


(Source: Phil Seaton)



Propagation to establish sustainable populations

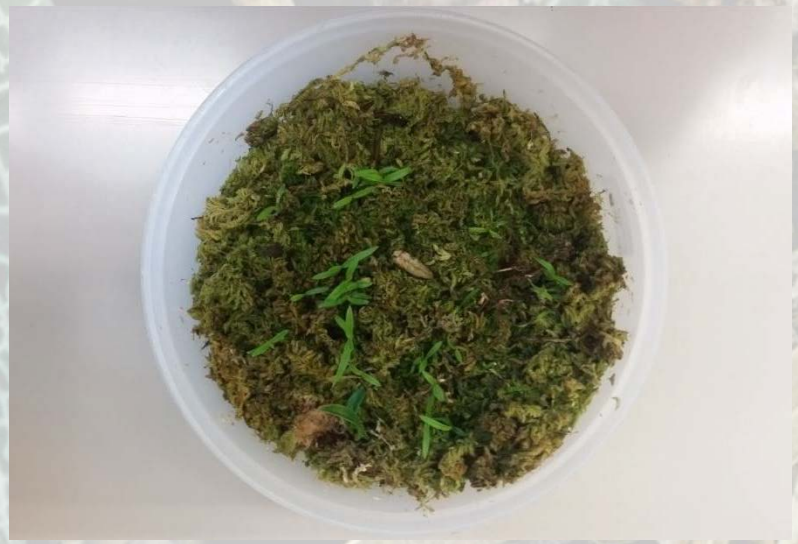
Seeds and Protocorms



Liparis liliifolia

Corallorhiza odontorhiza

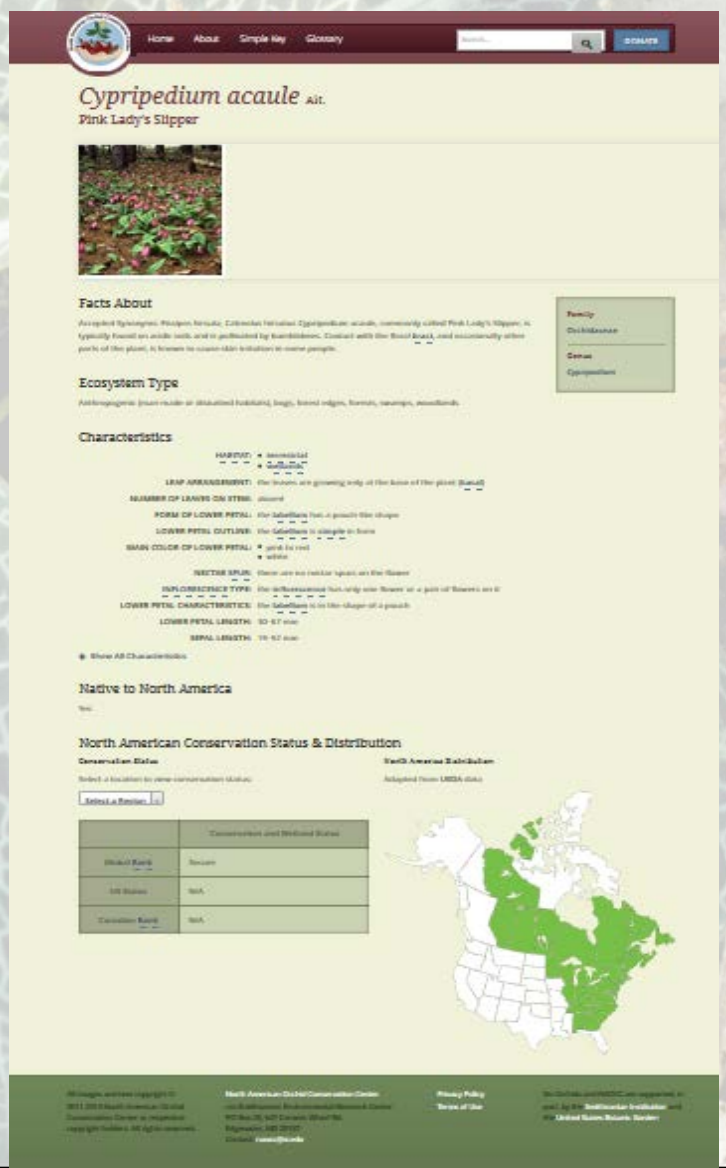
Seedlings



Education: increasing botanical literacy and engaging citizen scientists in hands-on conservation

Go Orchids website

goorchids.northamericanorchidcenter.org







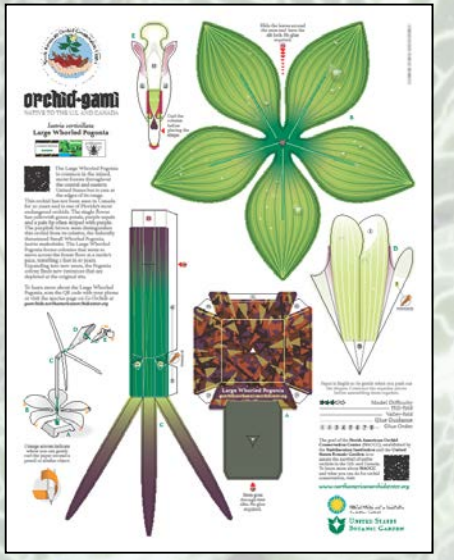



orchid-gami
NATIVE TO THE U.S. AND CANADA
North American Orchid Conservation Center






Photos: Maarten Janssens and Jay O’Neill



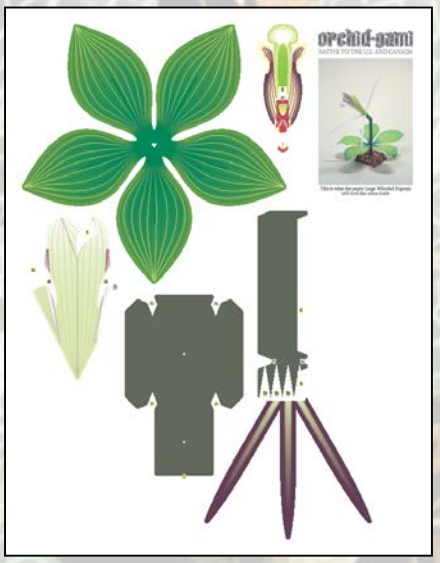


Photo: University of Wisconsin-Madison

Photo: University of Wisconsin-Madison

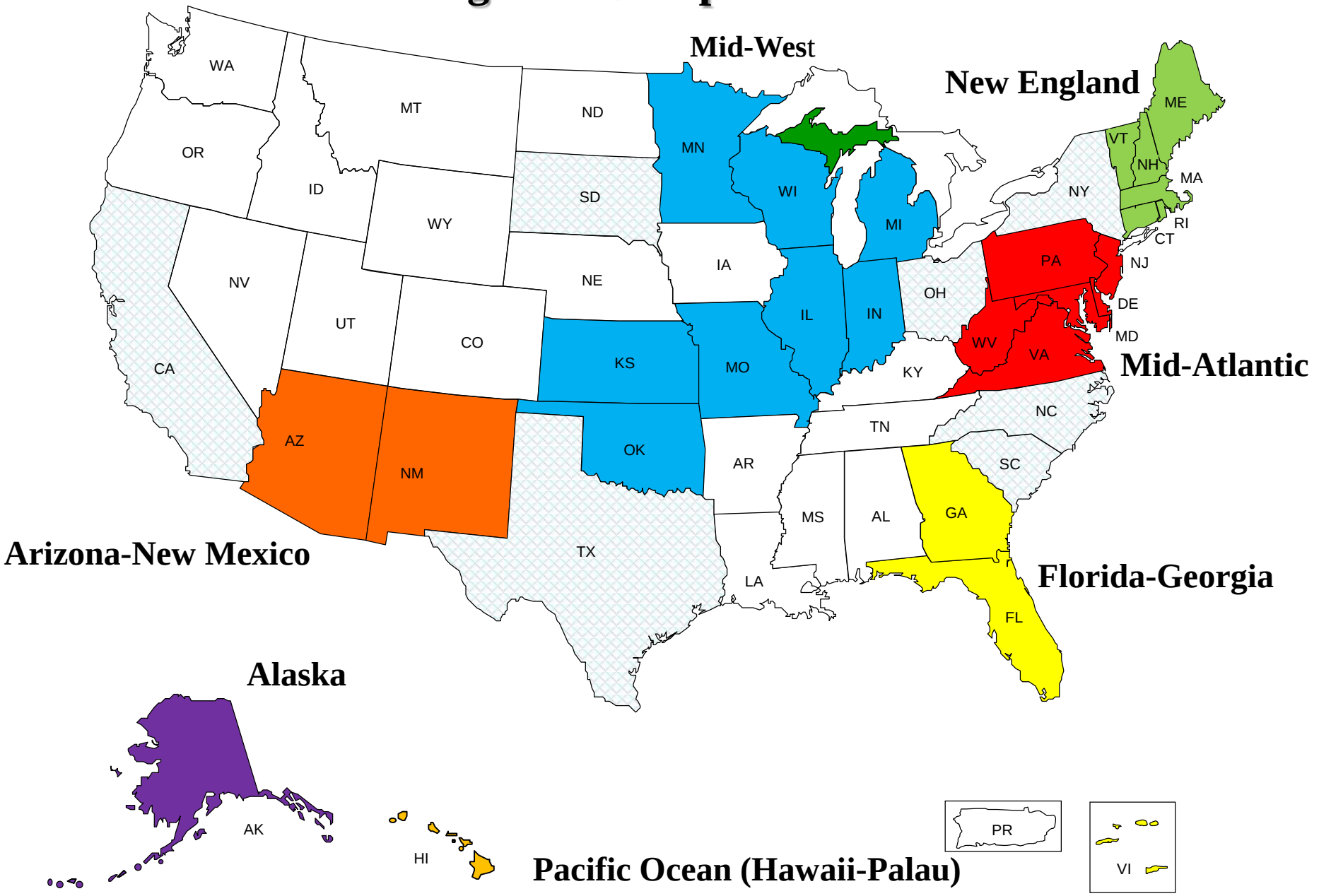
Dr. Ken Cameron – University of Wisconsin – using models with students at the Mater Grove Academy as part of “Read Across America” day

Implementing the model

Regional groups:

- Collect mycorrhizal fungi
- Collect seeds
- Initiate propagation
- Initiate educational efforts

Regional Groups – March 2017



Where the effort stands

- More than 50% of US covered with regional groups
- Secured funds to support Development Coordinator
- First endowment received – still seeking major endowment to assure long-term success
- Visits to NAOCC and Go Orchids web site increasing regularly (Thanks to National Geographic for the great ‘shout-out’)
- Model moving beyond US (Palau – USFS, 9 western European countries, Greece-Turkey, Australia)

Optimism abounds

- NAOCC model based on ecological concepts and citizen science is robust and is rapidly gaining acceptance with an ever increasing number of collaborators
- Goal of collecting samples from all species in the U.S. and Canada in the next five years can be reached
- The NAOCC concept is already reaching out globally and is easily adapted to any environment/country
- Like all efforts of this sort, long-term success depends on development of a sustainable funding base

Acknowledgments

- Dennis Whigham – SERC
- Jay O'Neill – SERC
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- Ari Novy, Ray Mims, Susan Pell – US Botanic Garden
- Hanna Rasmussen – University of Copenhagen
- Funding: NSF, DOD, USDA, NPS, WV Department of Transportation, Contributors to SERC/NAOCC (Chicago Botanic Garden, SI Gardens, US Botanic Garden, Minnesota Landscape Arboretum, Biophilia, Hal and Helen Horwitz Orchid Conservation Fund)

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http://northamericanorchidcenter.org/

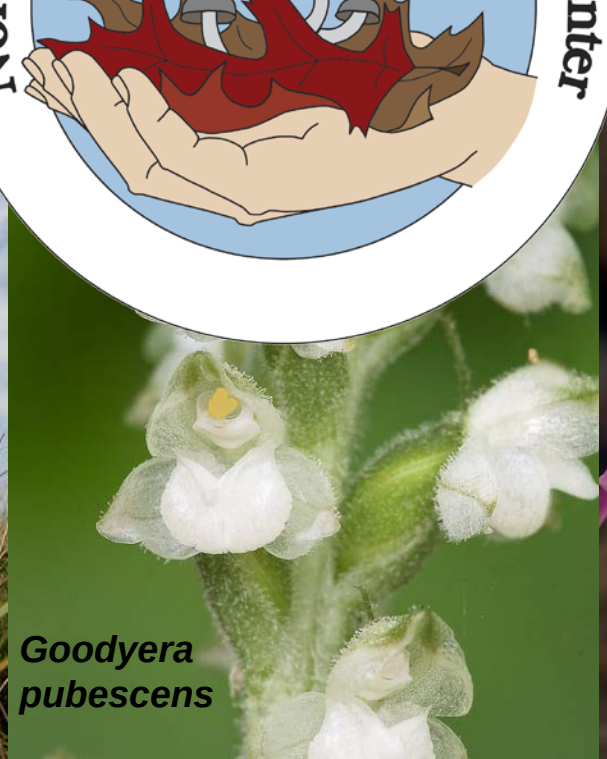
Cypripedium parviflorum

Spiranthes cernua

North American Orchid Conservation Center

Platanthera praeclara

Photos courtesy of Hal Horwitz



Goodyera pubescens

Hexalectris grandiflora