



# Applications of Niche Modeling

Makenzie Mabry  
University of Florida



**iDigBio**  
Integrated Digitized Biocollections



BiotaPhy



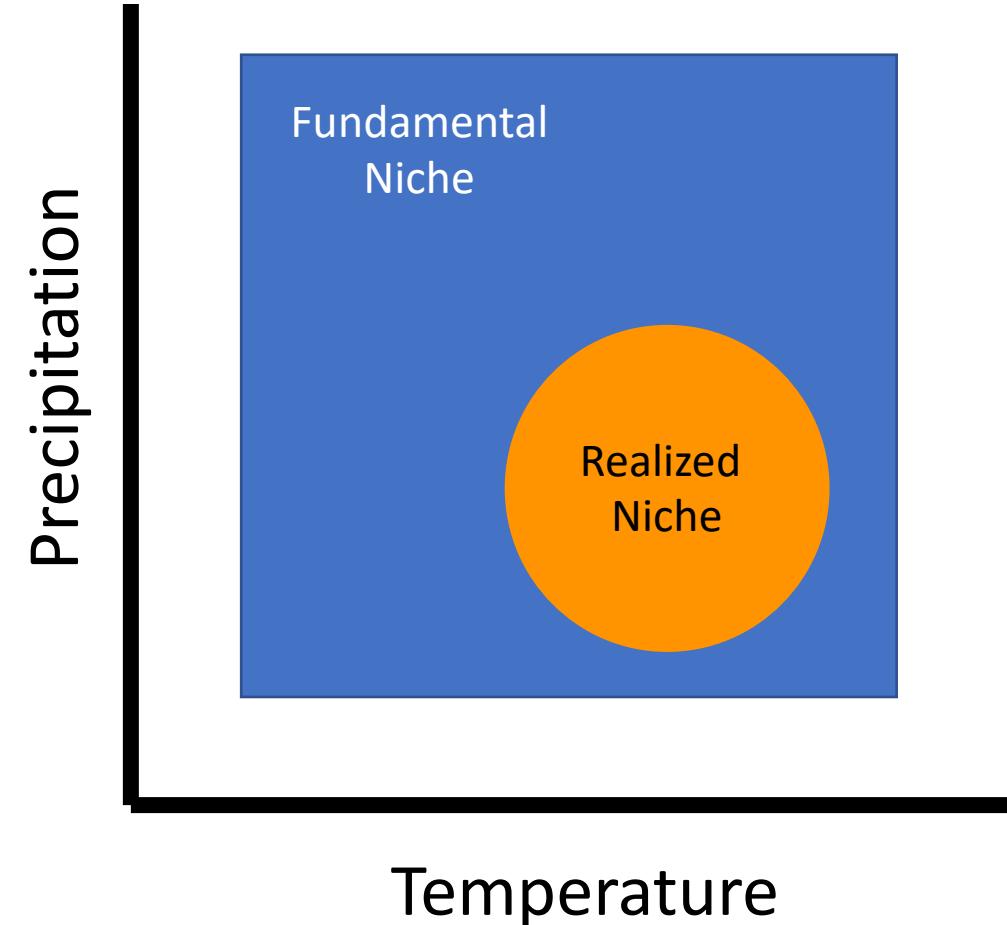
# Ecological Niche

## Fundamental Niche

- abiotic conditions a species could potentially occupy in the **absence** of biotic interactions

## Realized Niche

- abiotic conditions that a species can occupy with the **presence** of biotic interactions

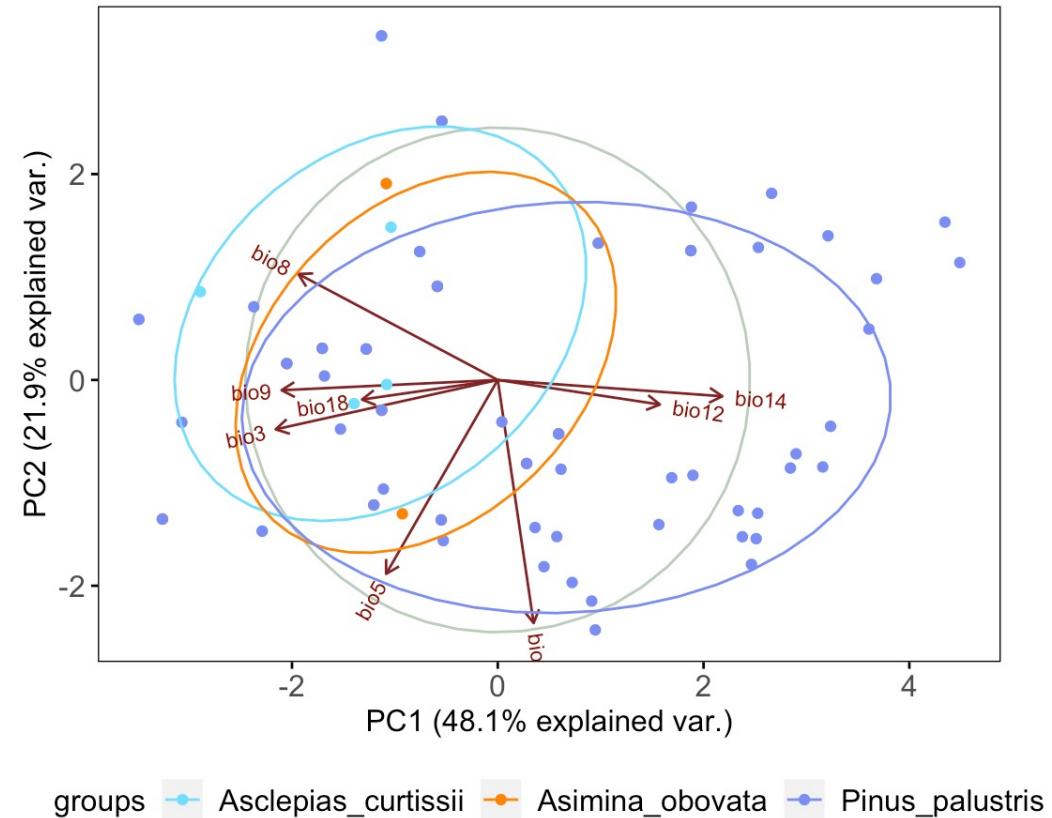


# Ecological Niche

## Fundamental Niche

- abiotic conditions a species could potentially occupy in the **absence** of biotic interactions

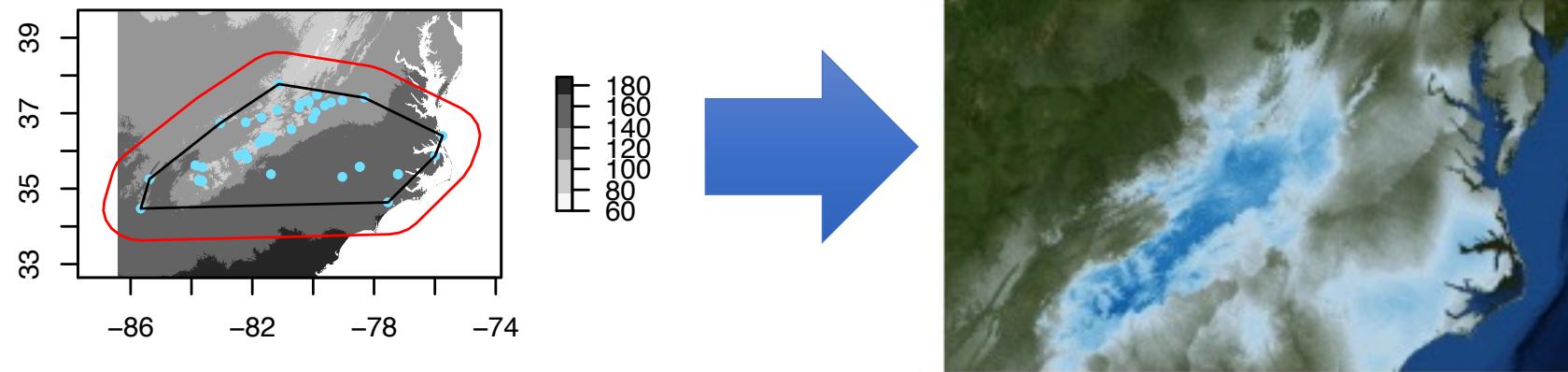
"it is defined in multidimensional ecological space  
(MacArthur 1972)." – Peterson 2001



# Ecological Niche Modeling

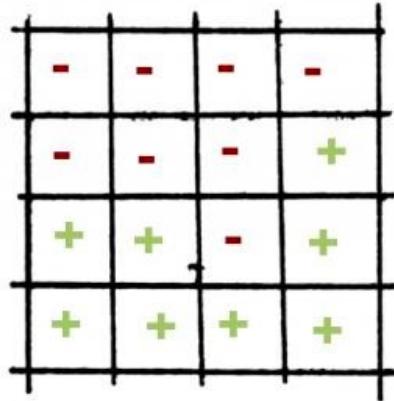
## MaxEnt

- uses the **principle of maximum entropy** on presence-only data to predict the species' potential geographic distribution (or niche)

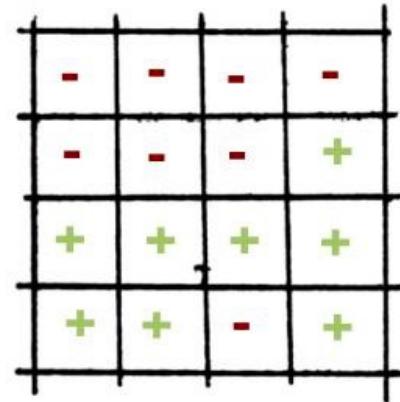


Environmental  
data

Rainfall zones  
suitability

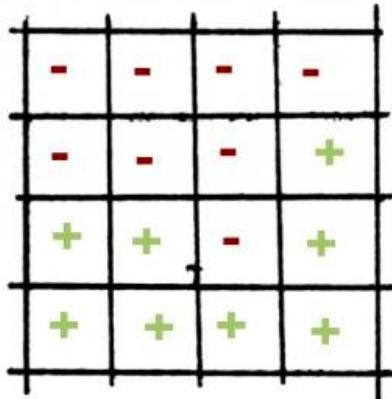


Altitude zones  
suitability

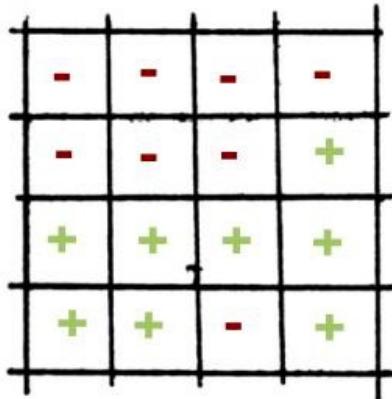


Environmental  
data

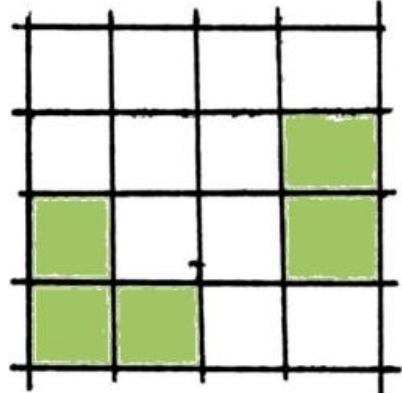
Rainfall zones  
suitability



Altitude zones  
suitability

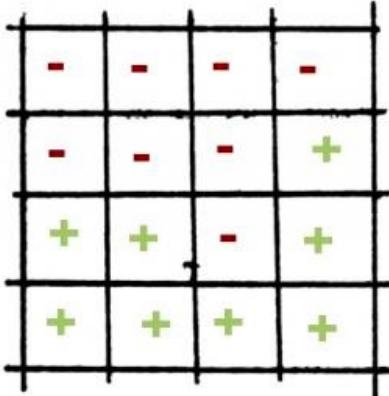


Current  
observations

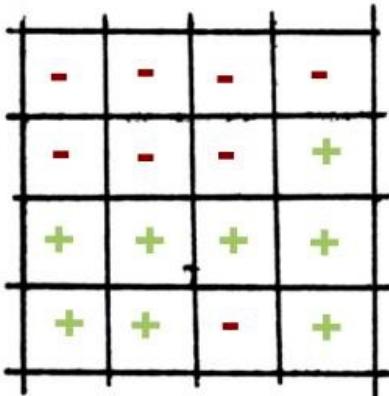


Environmental  
data

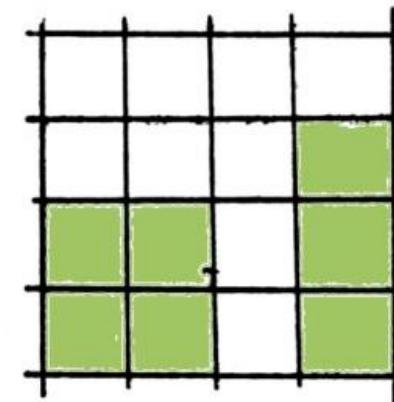
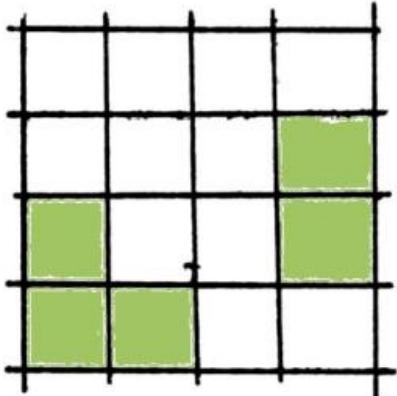
Rainfall zones  
suitability



Altitude zones  
suitability



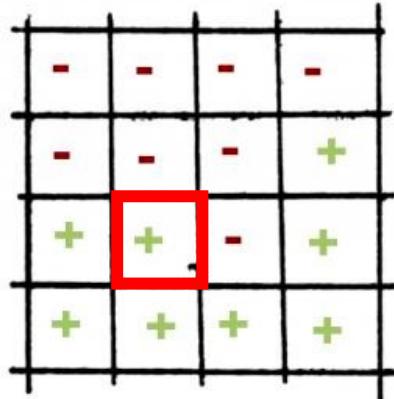
Current  
observations



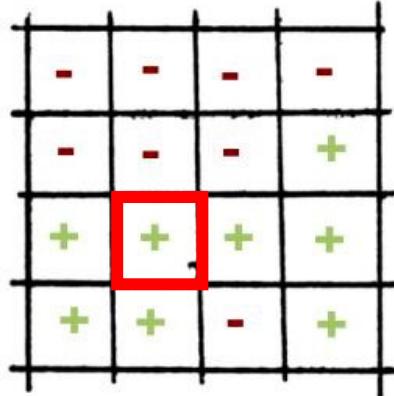
Habitat model based  
on suitable rainfall and  
altitude zones in  
combination with  
current observations

Environmental  
data

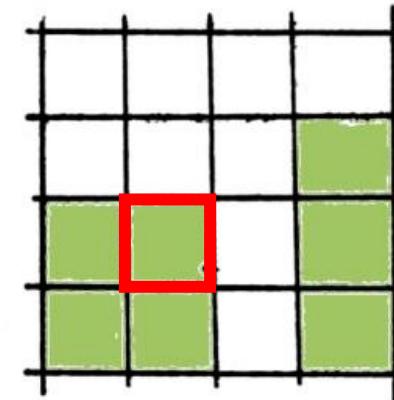
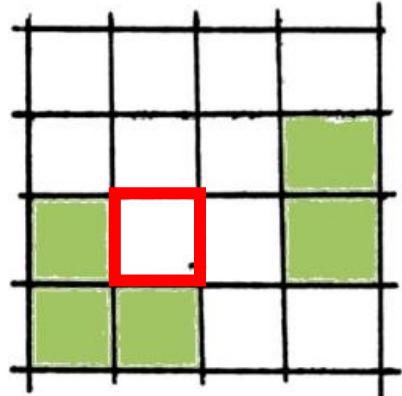
Rainfall zones  
suitability



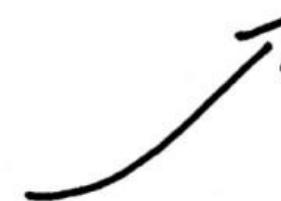
Altitude zones  
suitability

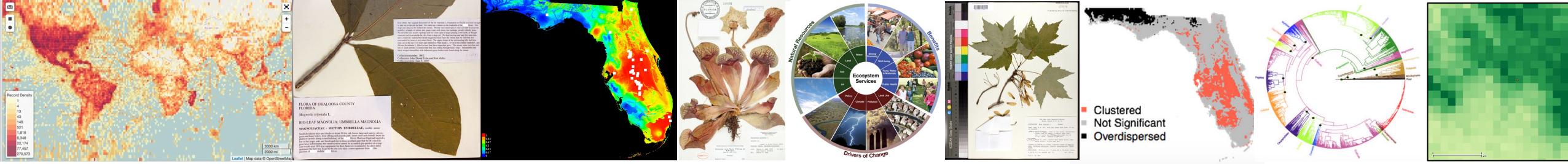


Current  
observations



Habitat model based  
on suitable rainfall and  
altitude zones in  
combination with  
current observations





# Applications of Ecological Niche Modeling

# Applications of Ecological Niche Models

- Estimate current distribution
- Predict future distributions
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- Niche of polyploid compared to its diploid progenitor(s)
- Invasives--projections

Allen, J., Folk, R.A., P.S. Soltis, D.E. Soltis, R.P. Guralnick.  
2019. Biodiversity synthesis across the green  
branches of the tree of life. *Nature Plants* 5:11-13.

# Applications of Ecological Niche Models

- Estimate current distribution
- Predict future distributions
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- Niche of polyploid compared to its diploid progenitor(s)
- Invasives--projections

# Florida Plant Diversity in a Changing Climate: Present & Future



Julie Allen, Charlotte Germain-Aubrey,

K. Neubig, L. Majure, R. Abbott, M. Whitten, N. Barve, H. Owens,  
B. Mishler, S. Laffan, R. Guralnick, D. Soltis, P. Soltis



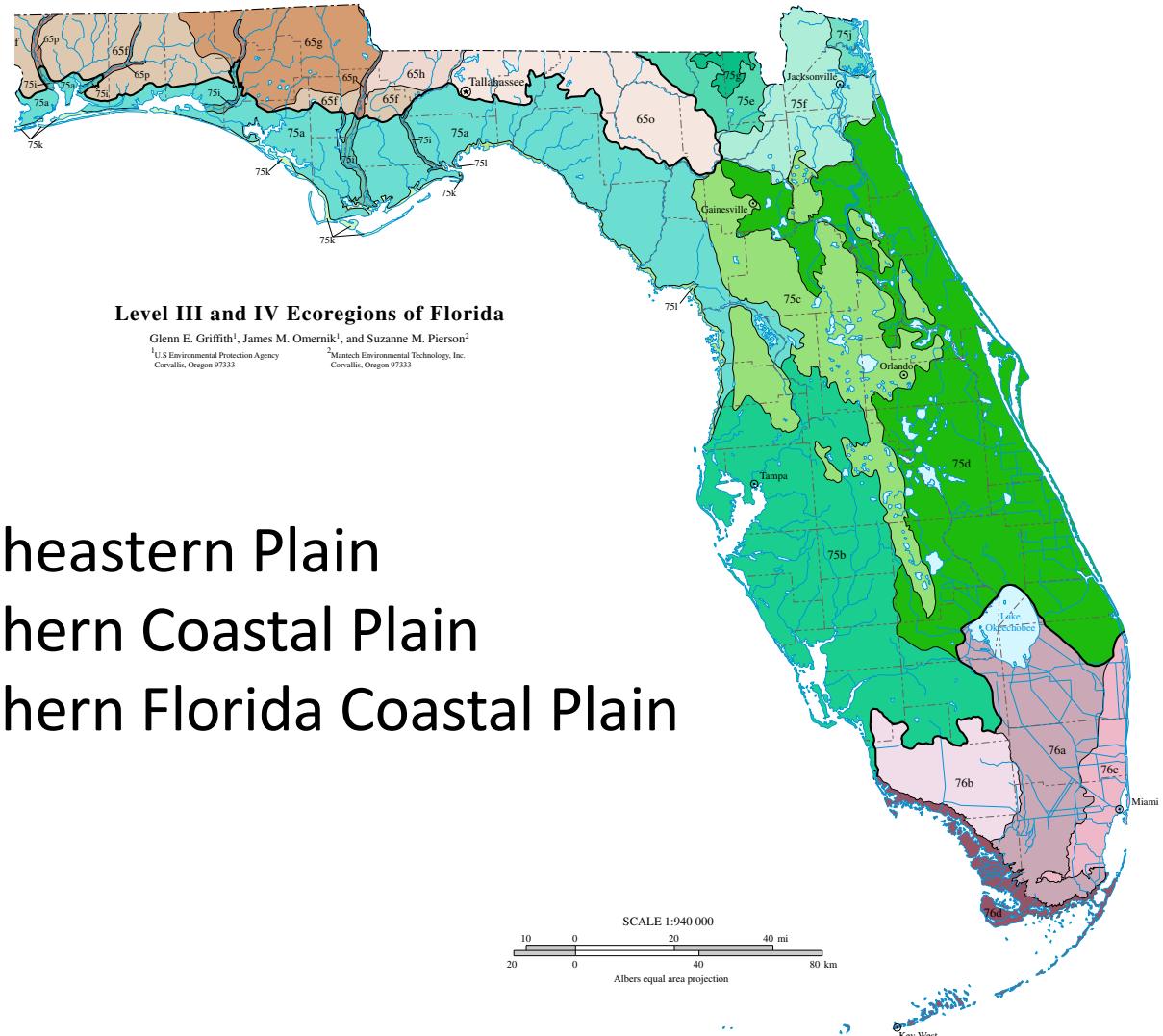
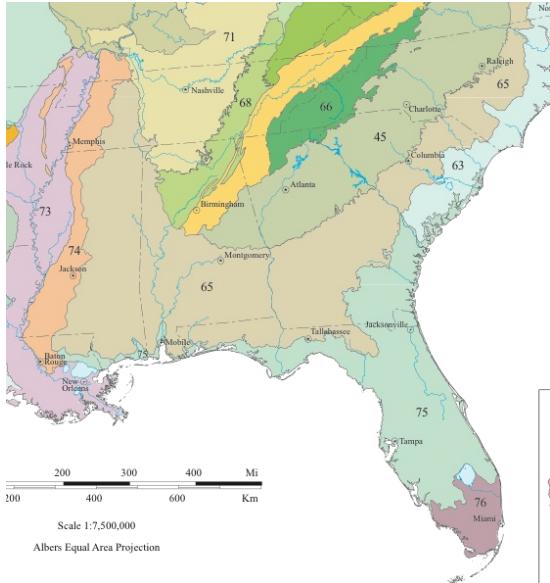
Rob Guralnick

Allen, Germain-Aubrey et al. 2019. *iScience*11: 57–70  
<https://doi.org/10.1016/j.isci.2018.12.002>

Julie Allen



# Florida Ecoregions



~4,100 vascular plant species

# Modeling the Distribution of Species

- Location information from herbarium labels
- Environmental data:
  - Temperature, precipitation, soil, etc.
- Software to model the range of each species
- For Florida plants:
  - ~2700 plant species (of 4100 species)



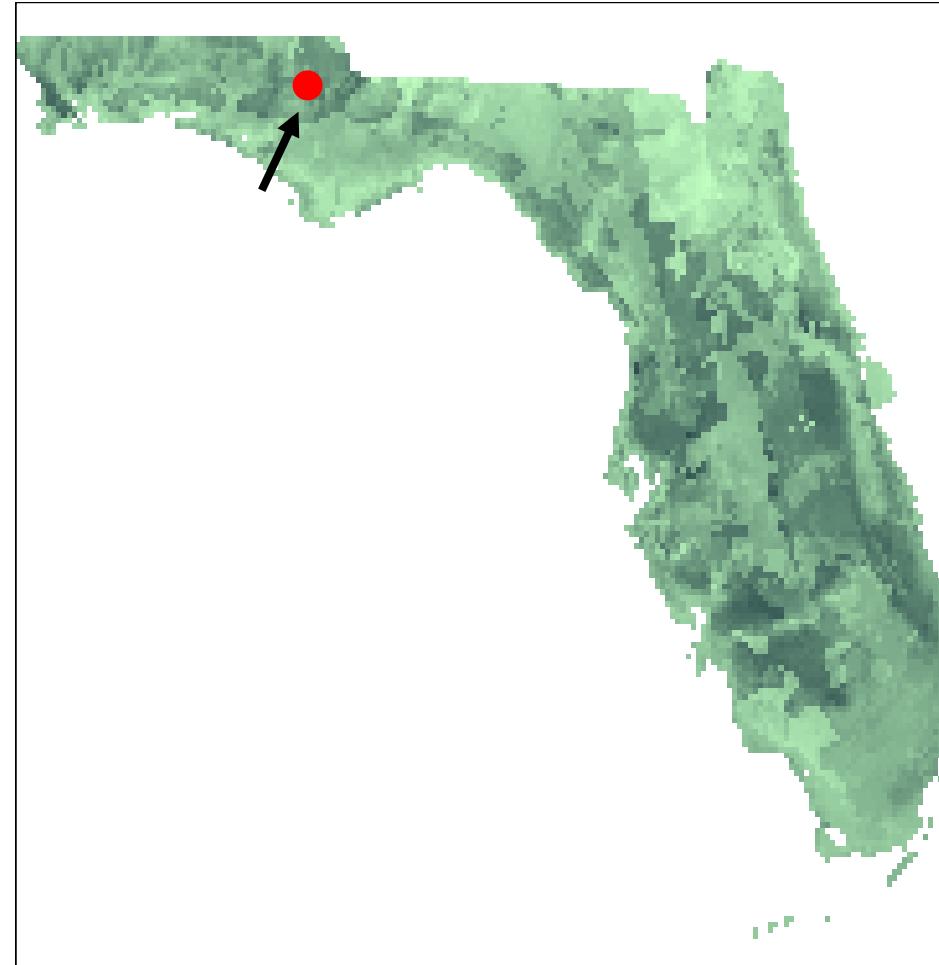
Charlotte  
Germain-Aubrey



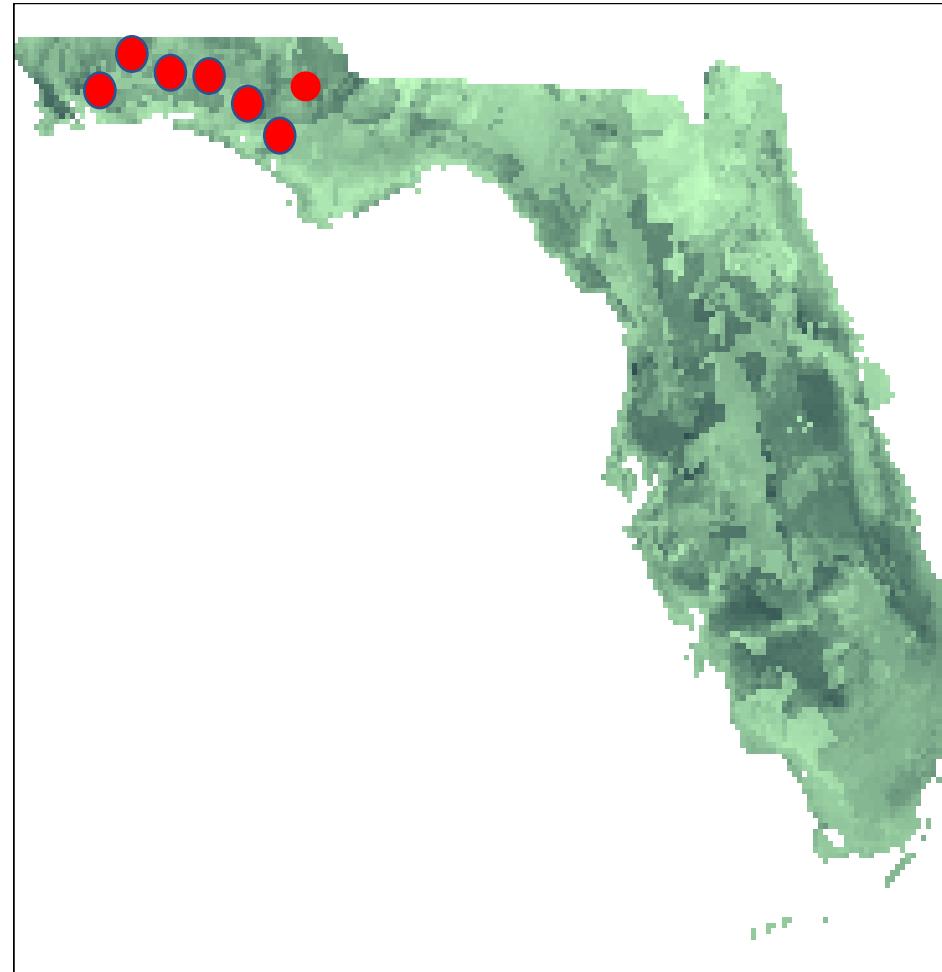
# Modeling the Distribution of Species: Present



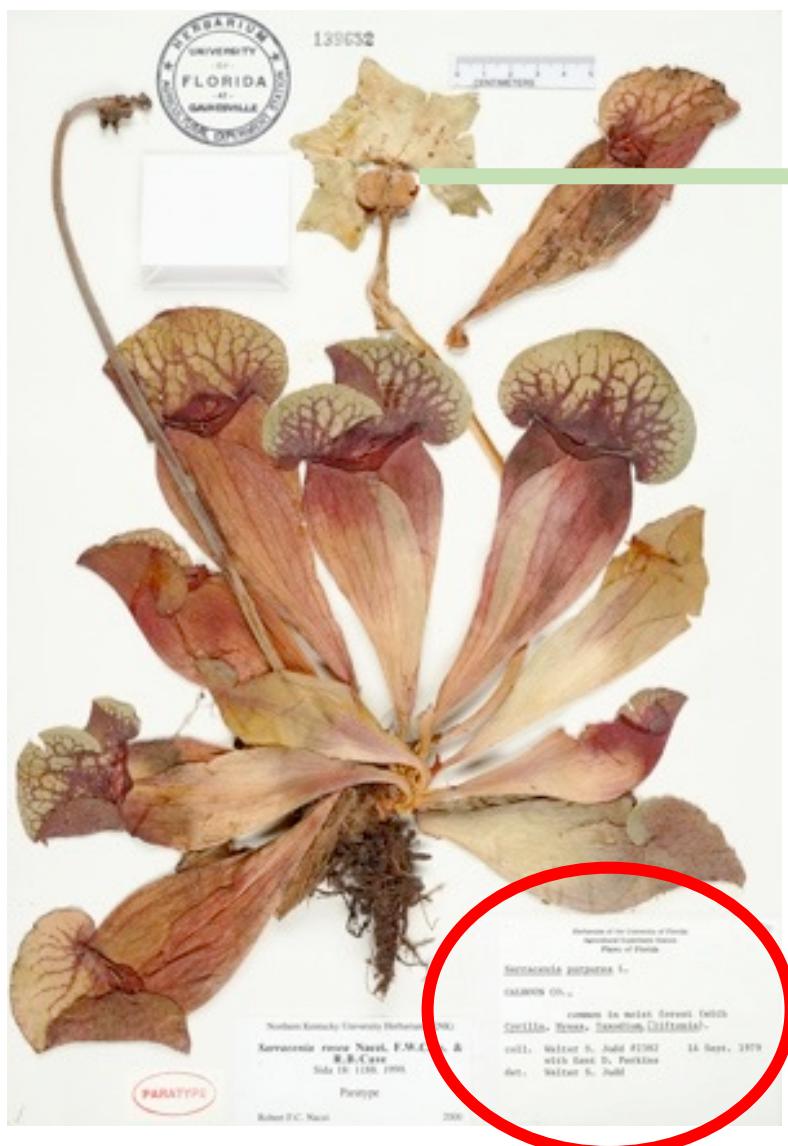
# Modeling the Distribution of Species: Present



# Modeling the Distribution of Species: Present



# Modeling the Distribution of Species: Present



The image features a map of Florida with red dots representing collection sites. Below the map are five herbarium specimens of *Sarracenia* plants, each with a small label. The background transitions from green at the top to yellow and orange at the bottom.

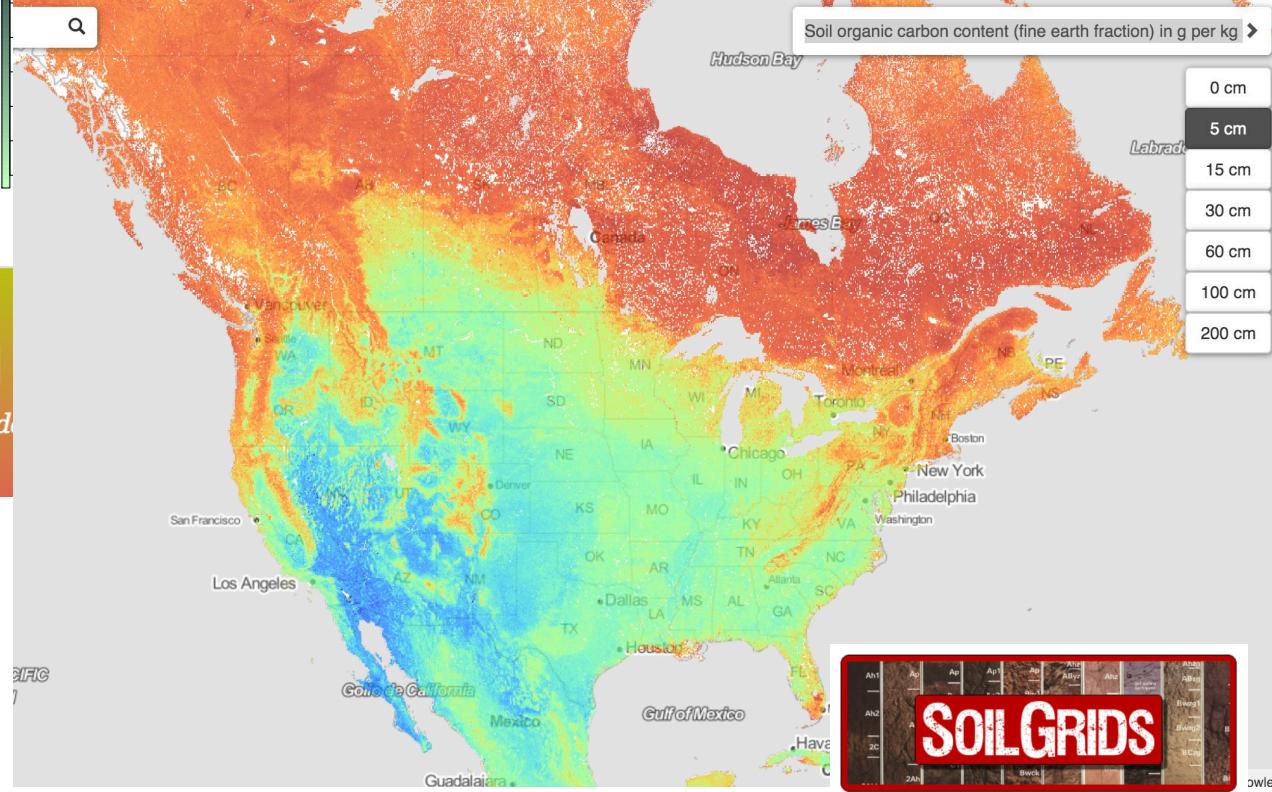
WorldClim - Global Climate Data

*Free climate data for ecological modeling and GIS*

19 Bioclimatic variables  
temperature  
rainfall



# Modeling the Distribution of Species: Present

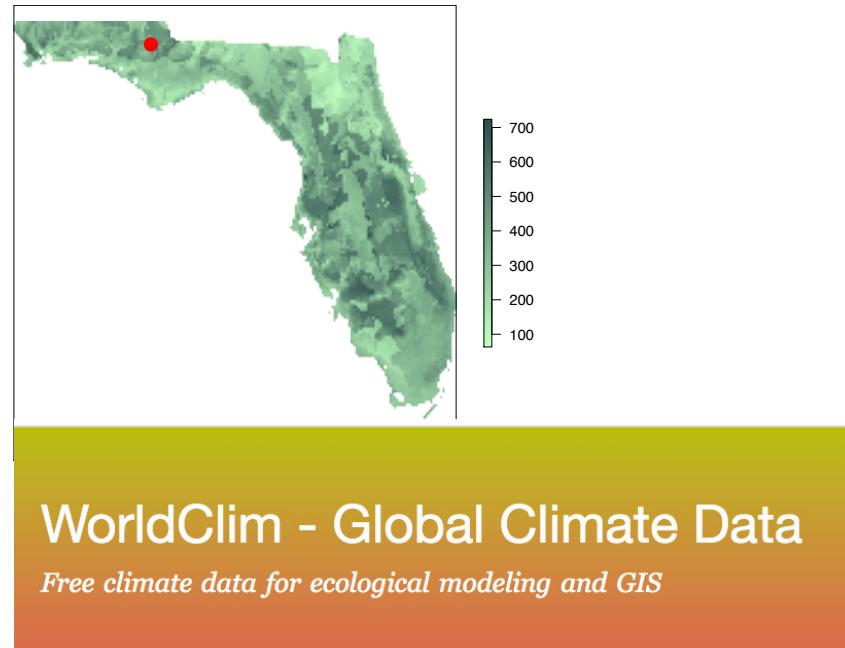


Global maps of soil properties at multiple depths

b cycle background maps    a geolocate    m open layer menu  
i open SoilInfo (works only when location is selected)

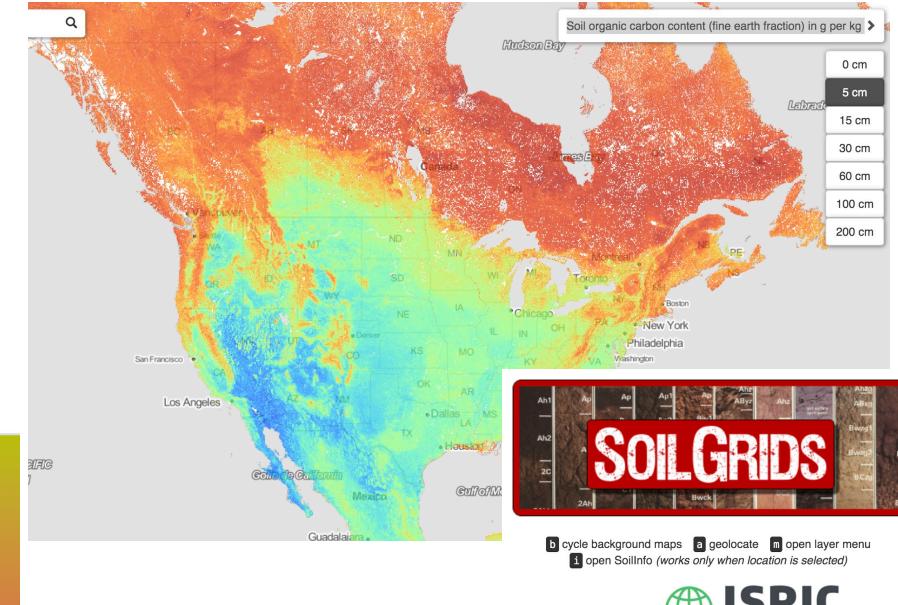
Powered by  **ISRIC**  
World Soil Information

# Modeling the Distribution of Species: Present



WorldClim - Global Climate Data

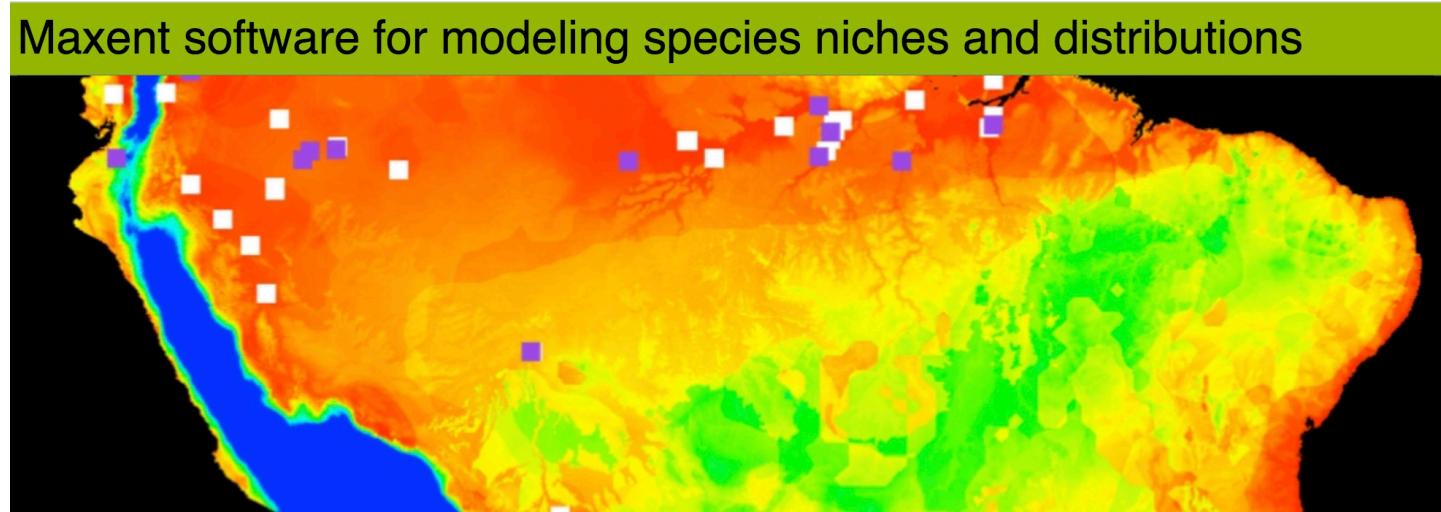
Free climate data for ecological modeling and GIS



Powered by



ISRIC  
World Soil Information



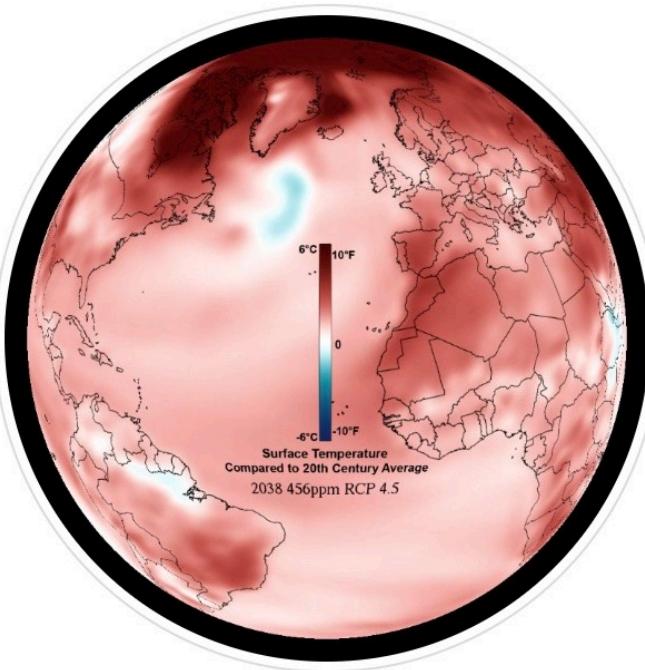
Maxent software for modeling species niches and distributions

# Applications of Ecological Niche Models

- Estimate current distribution
- **Predict future distributions**
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- Niche of polyploid compared to its diploid progenitor(s)
- Invasives--projections

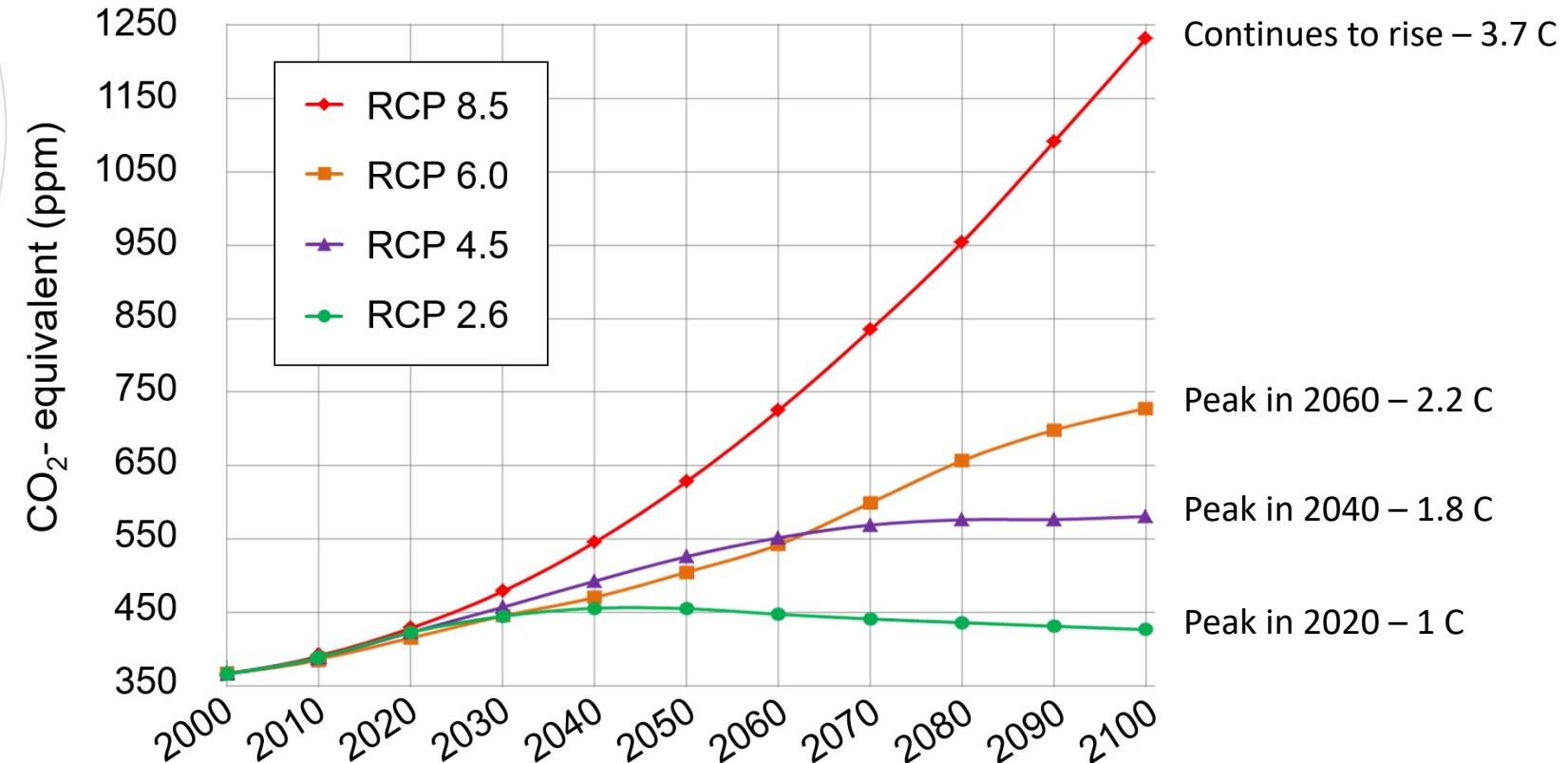
# Modeling the Distribution of Species: Future

## Representative Concentration Pathways: Models for Future Temperatures



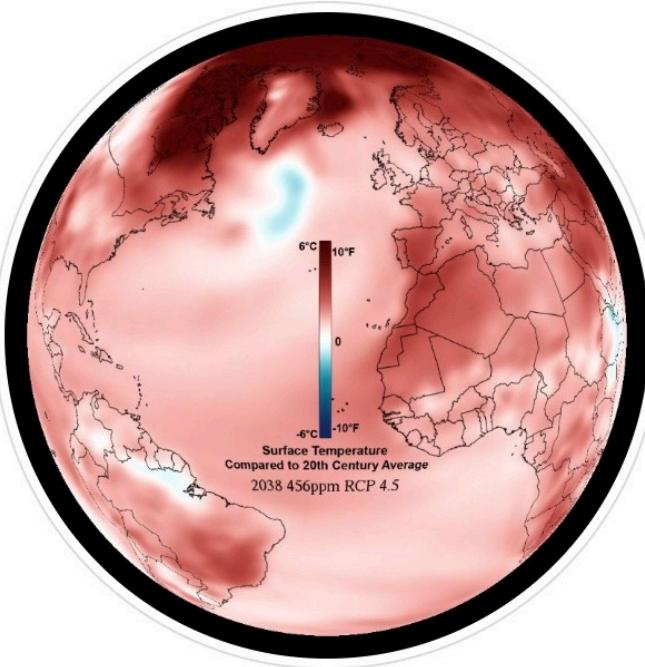
### IPCC AR5 Greenhouse Gas Concentration Pathways

Representative Concentration Pathways (RCPs) from the fifth Assessment Report by the International Panel on Climate Change



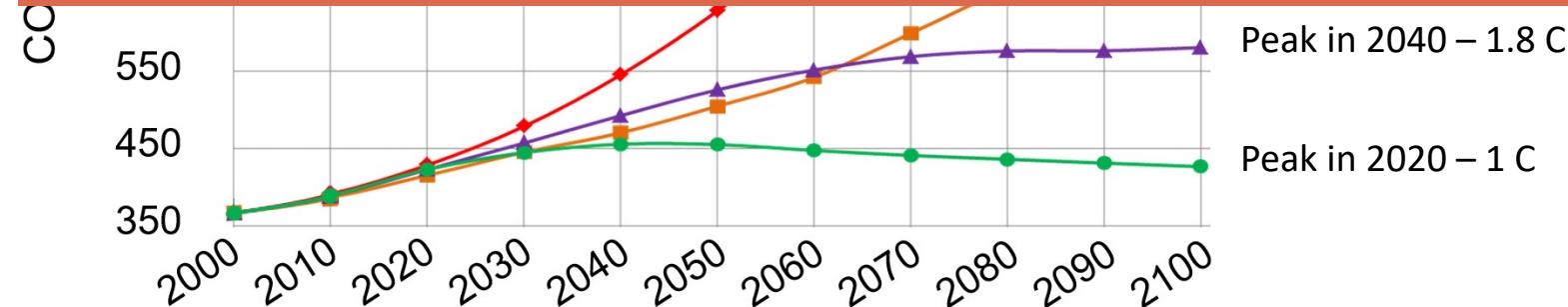
# Modeling the Distribution of Species: Future

## Representative Concentration Pathways: Models for Future Temperatures



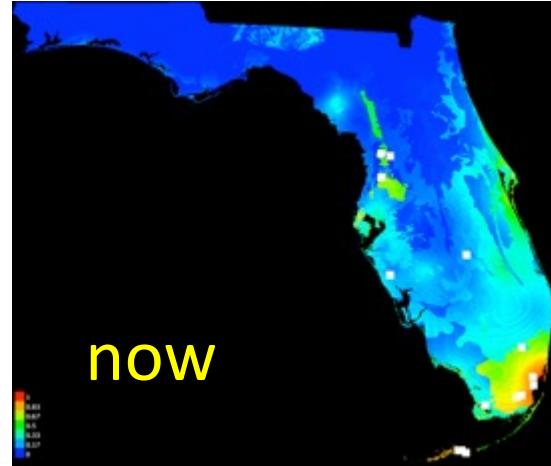
### IPCC AR5 Greenhouse Gas Concentration Pathways

Representative Concentration Pathways (RCPs) from the fifth Assessment Report by the International Panel on Climate Change



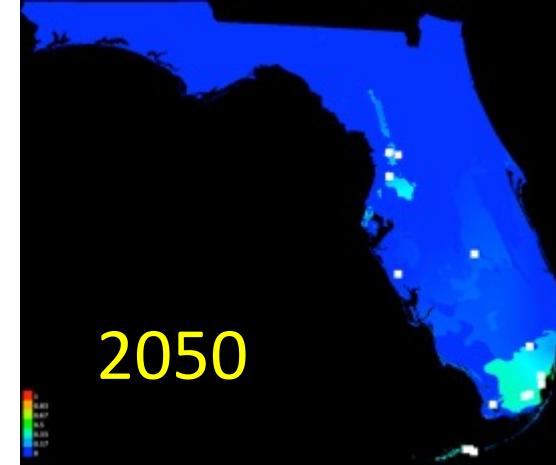
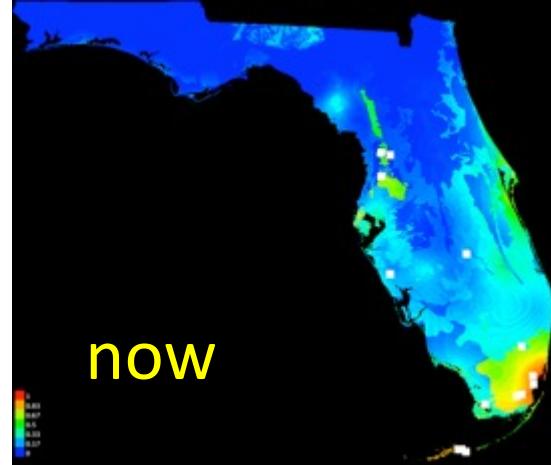
# Response to Climate Change: Models for Present & Future

*Abildgaardia ovata* (flatspike sedge)



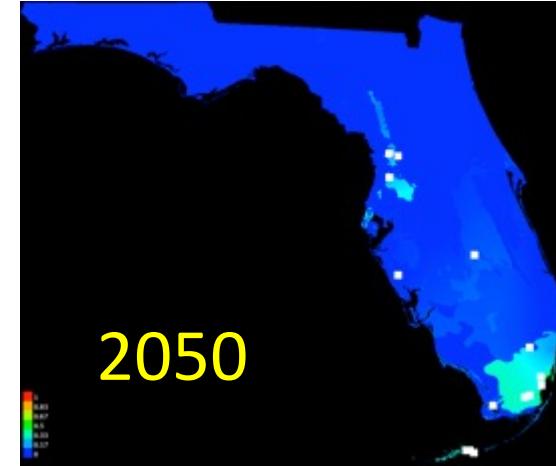
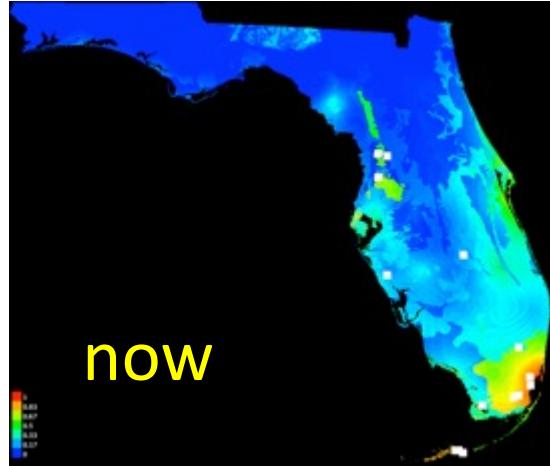
# Response to Climate Change: Models for Present & Future

*Abildgaardia ovata* (flatspike sedge)

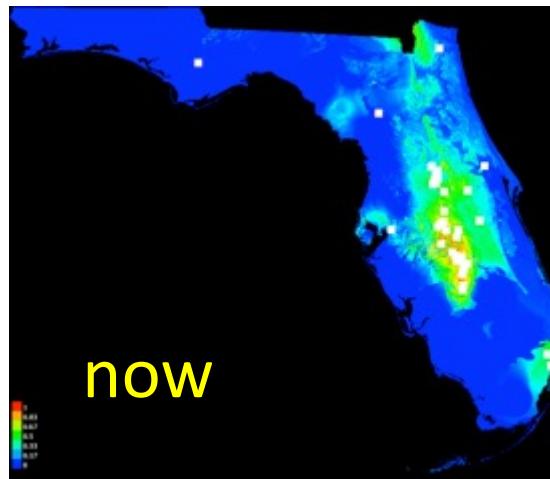


# Response to Climate Change: Models for Present & Future

*Abildgaardia ovata* (flatspike sedge)

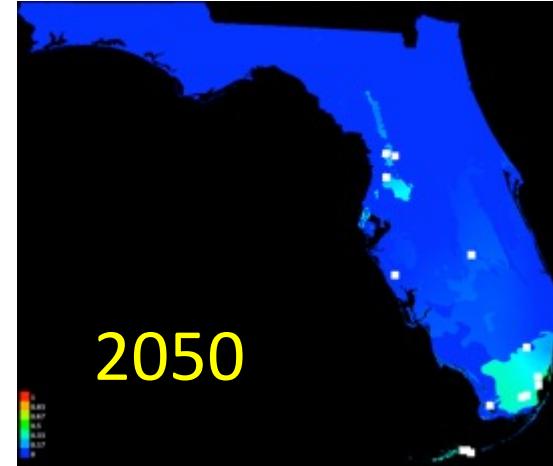
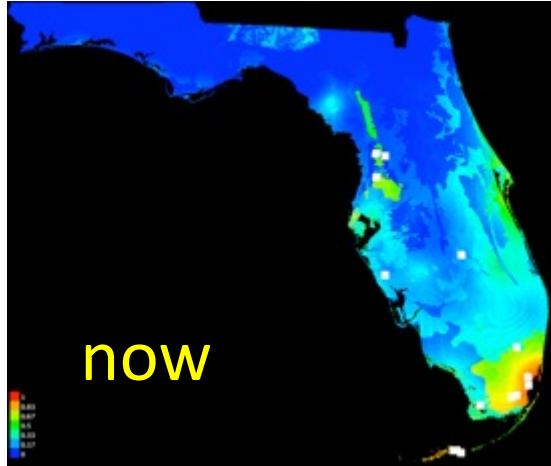


*Prunus geniculata* (scrub plum)

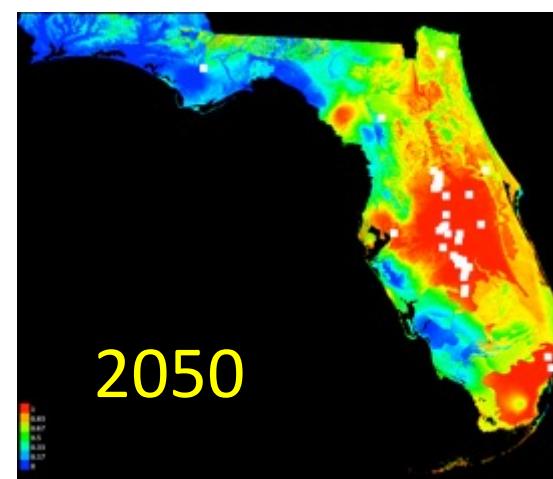
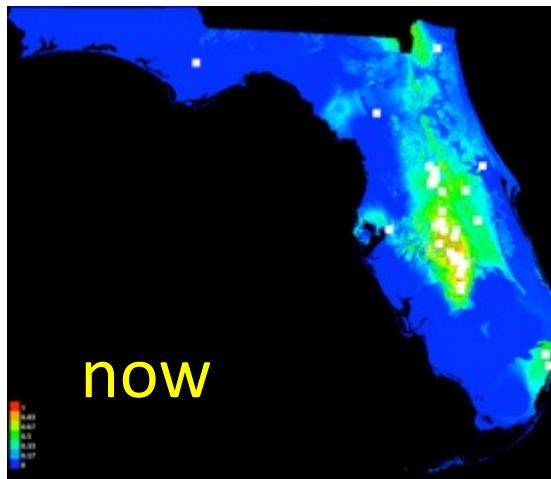


# Response to Climate Change: Models for Present & Future

*Abildgaardia ovata* (flatspike sedge)

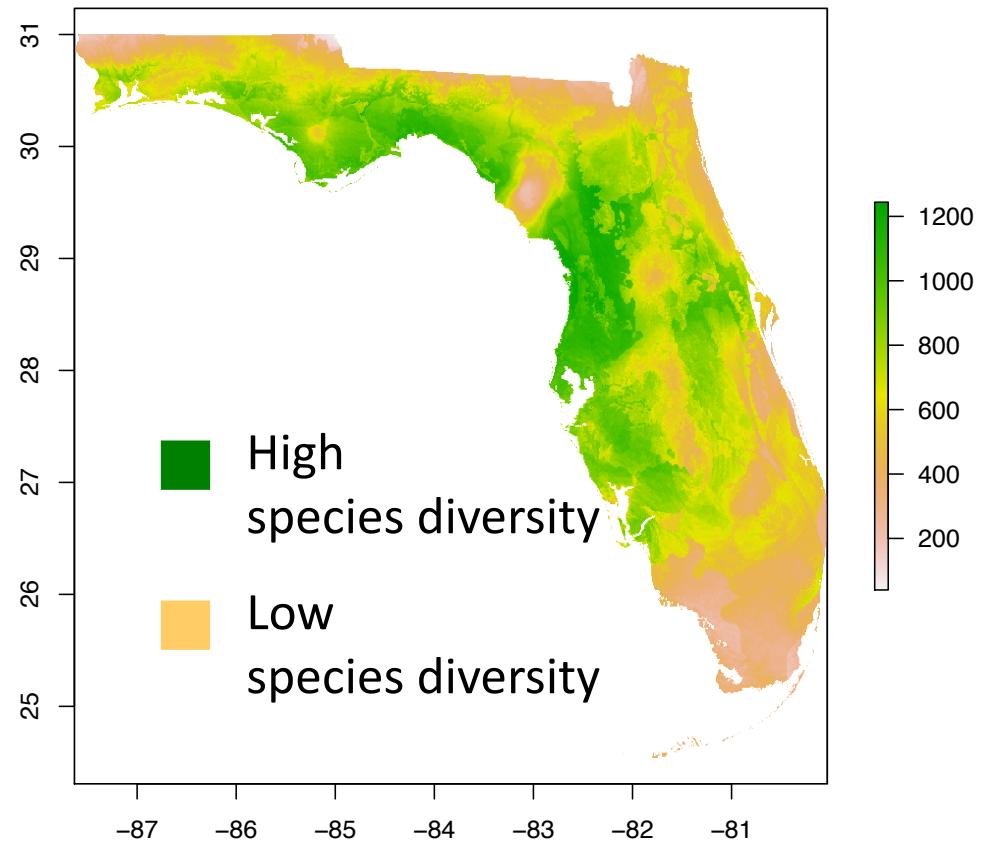


*Prunus geniculata* (scrub plum)



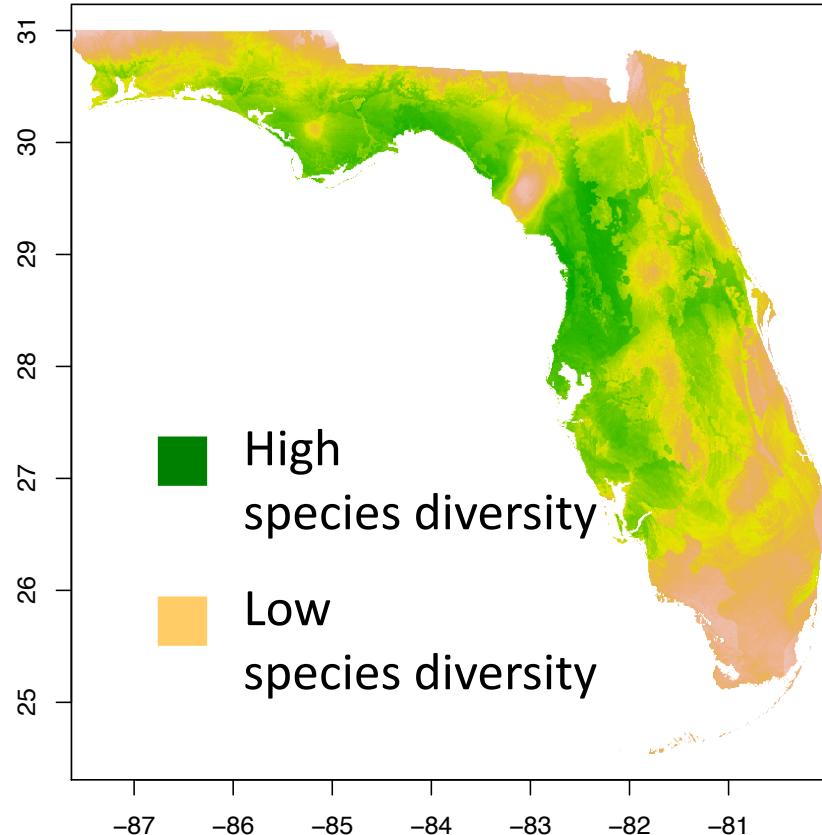
# Florida Plant Diversity: Now & 2050

Present

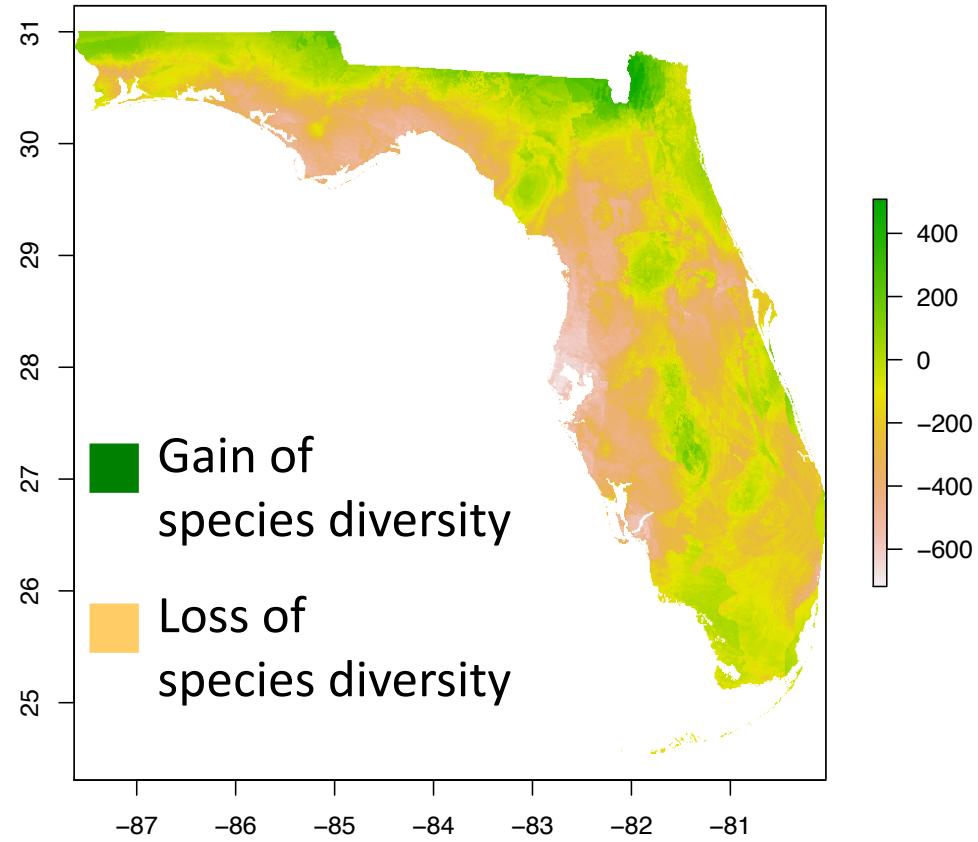


# Florida Plant Diversity: Now & 2050

Present



2050

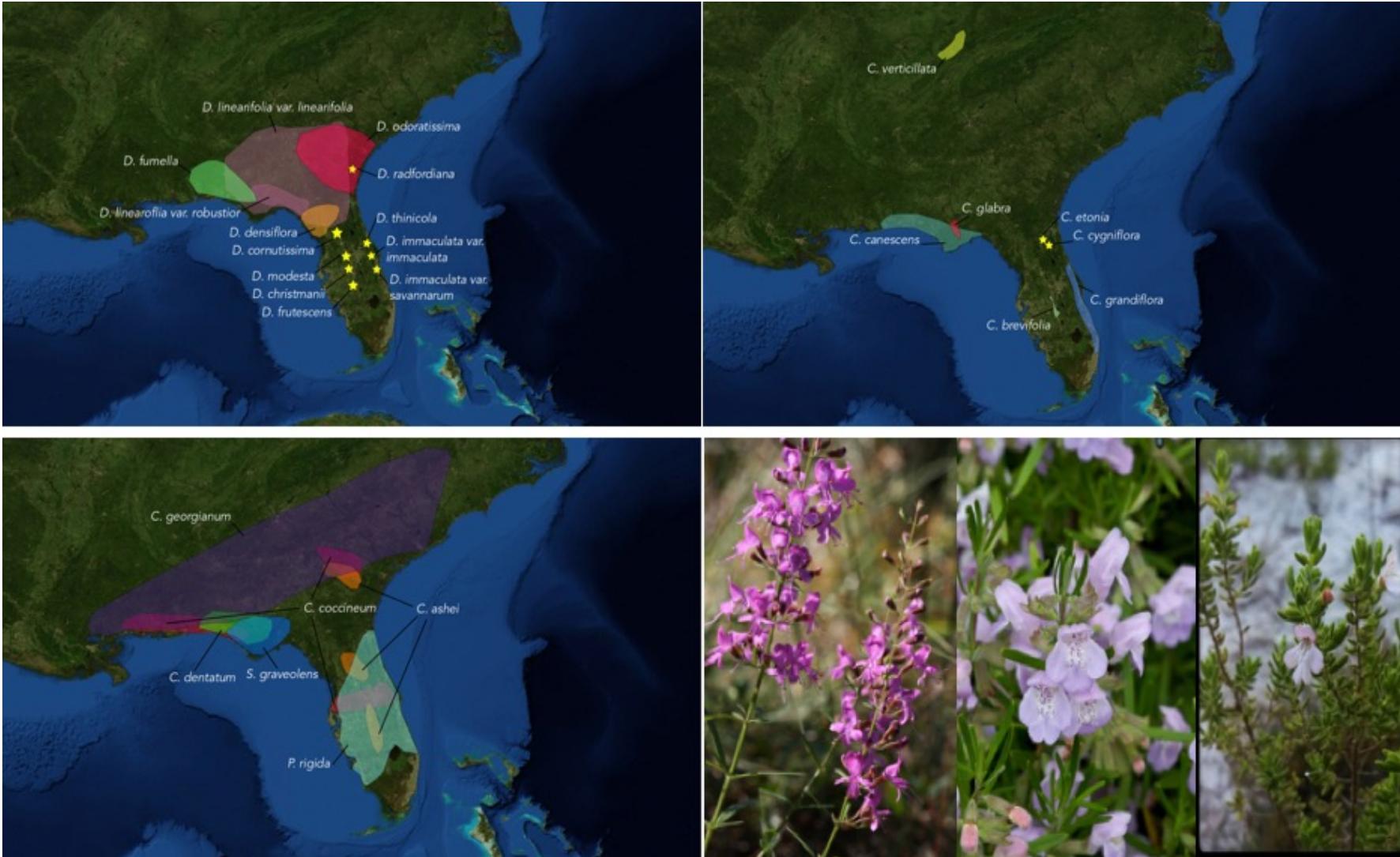


# spp 2050 - #spp now

# Applications of Ecological Niche Models

- Estimate current distribution
- Predict future distributions
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- Niche of polyploid compared to its diploid progenitor(s)
- Invasives--projections

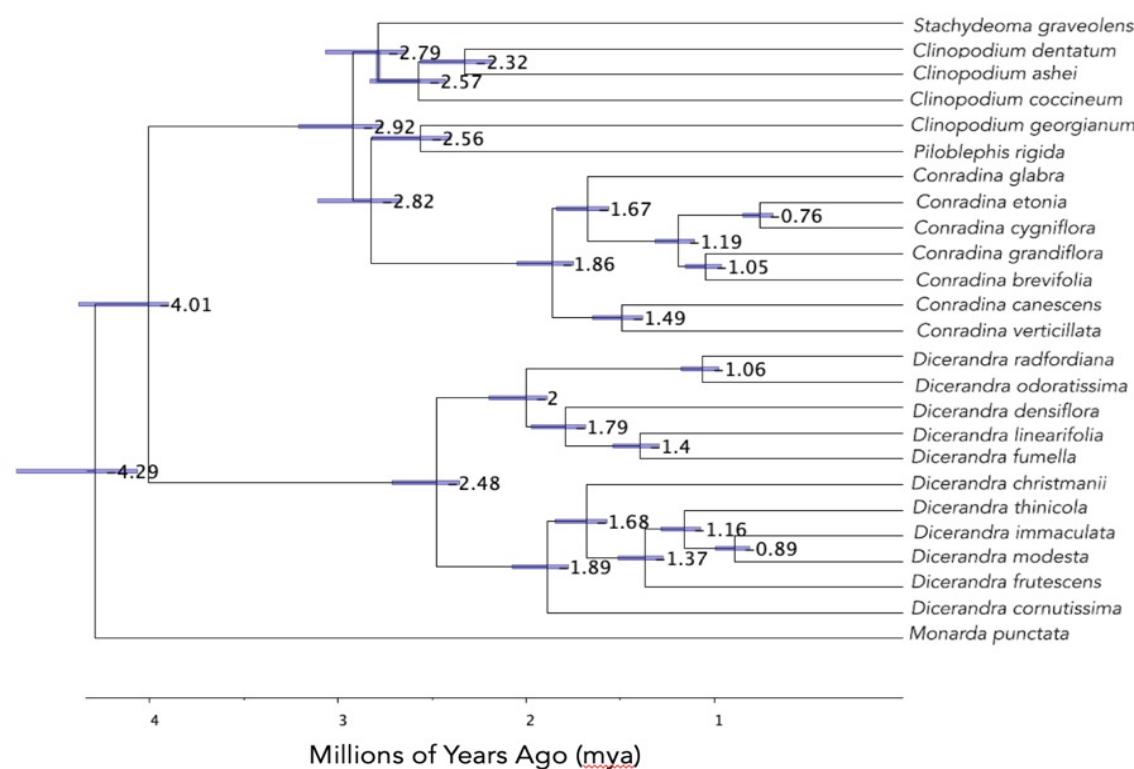
# Past Distribution: Scrub Mint Clade



Naranjo. 2020

Naranjo et al. unpubl.

# Past Distribution

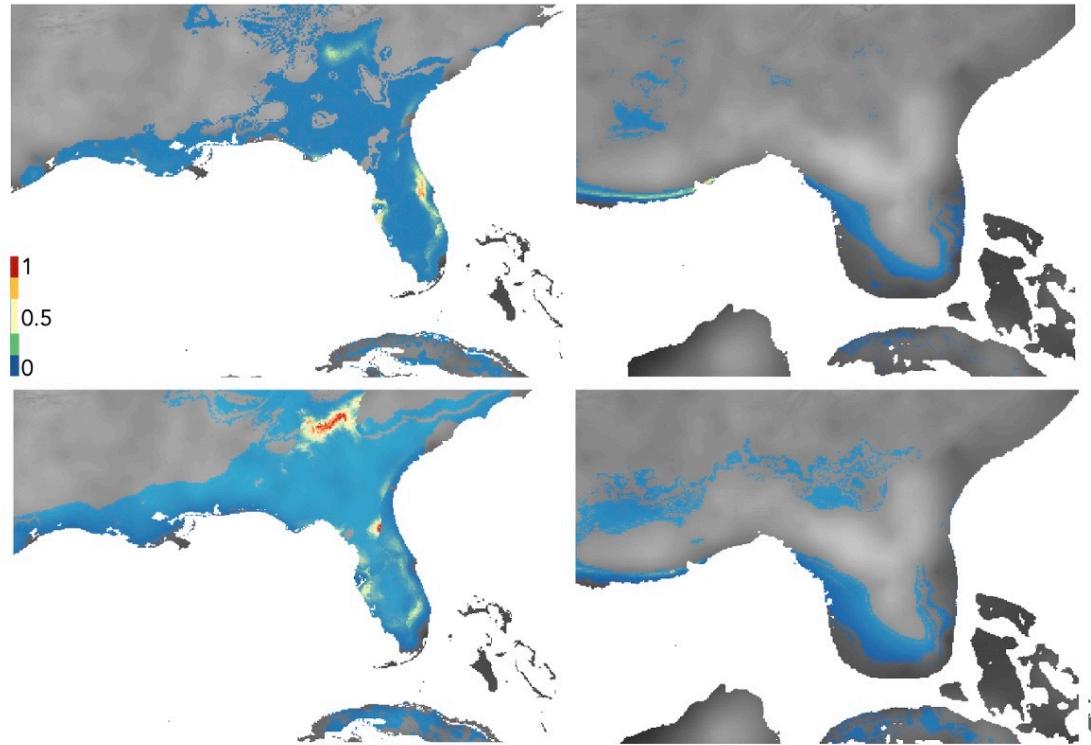


MRCA of SMC

MRCA of Dicerandra

Interglacial

Glacial Maxima



PaleoClim:  
paleoclim.org

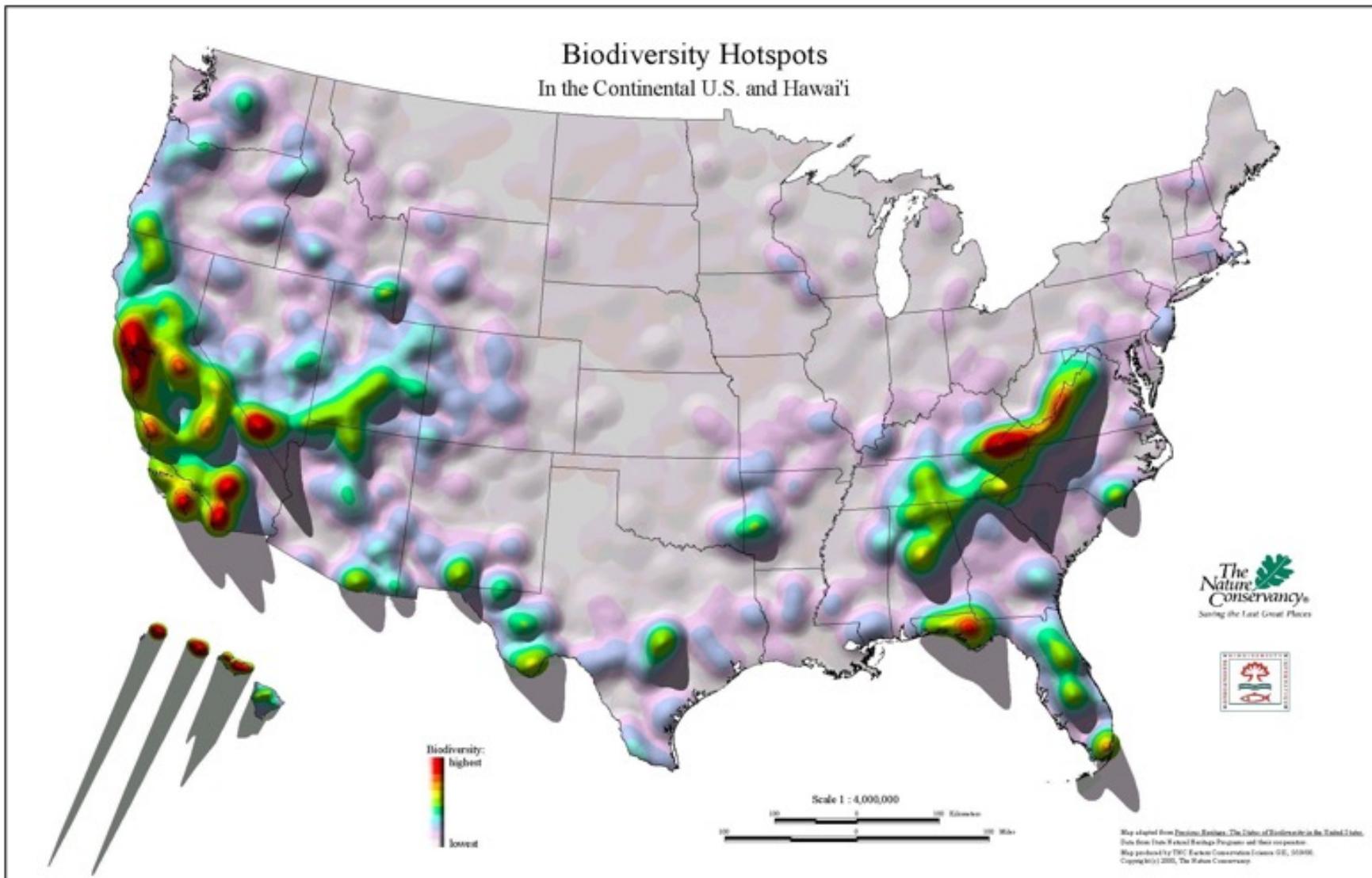


Naranjo. 2020  
Naranjo et al. unpubl.  
Folk et al. 2018. *American Naturalist*

# Applications of Ecological Niche Models

- Estimate current distribution
- Predict future distributions
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- Niche of polyploid compared to its diploid progenitor(s)
- Invasives--projections

# What to Protect?

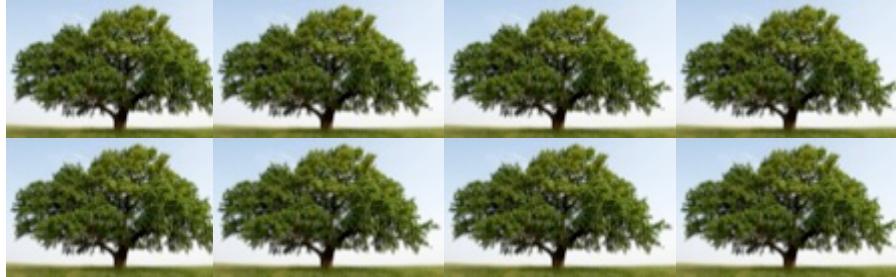


# Phylogenetic Diversity:

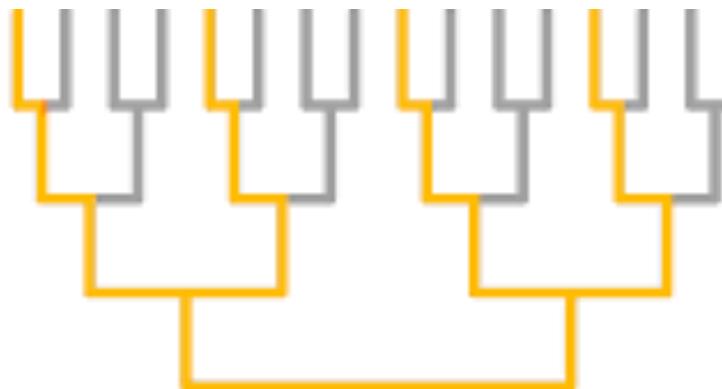
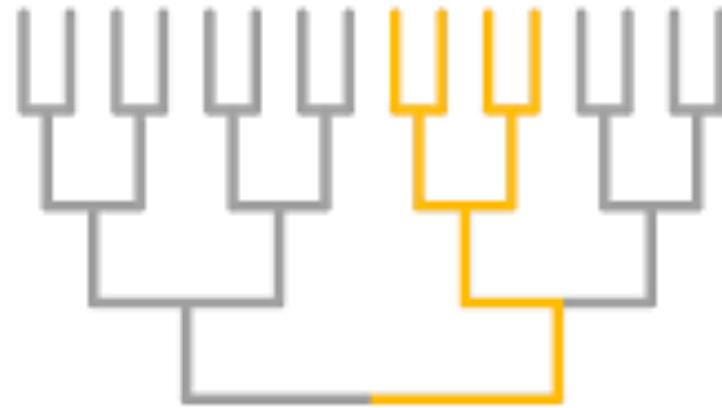
How much of the Tree of Life is present in a geographic area?



Oaks

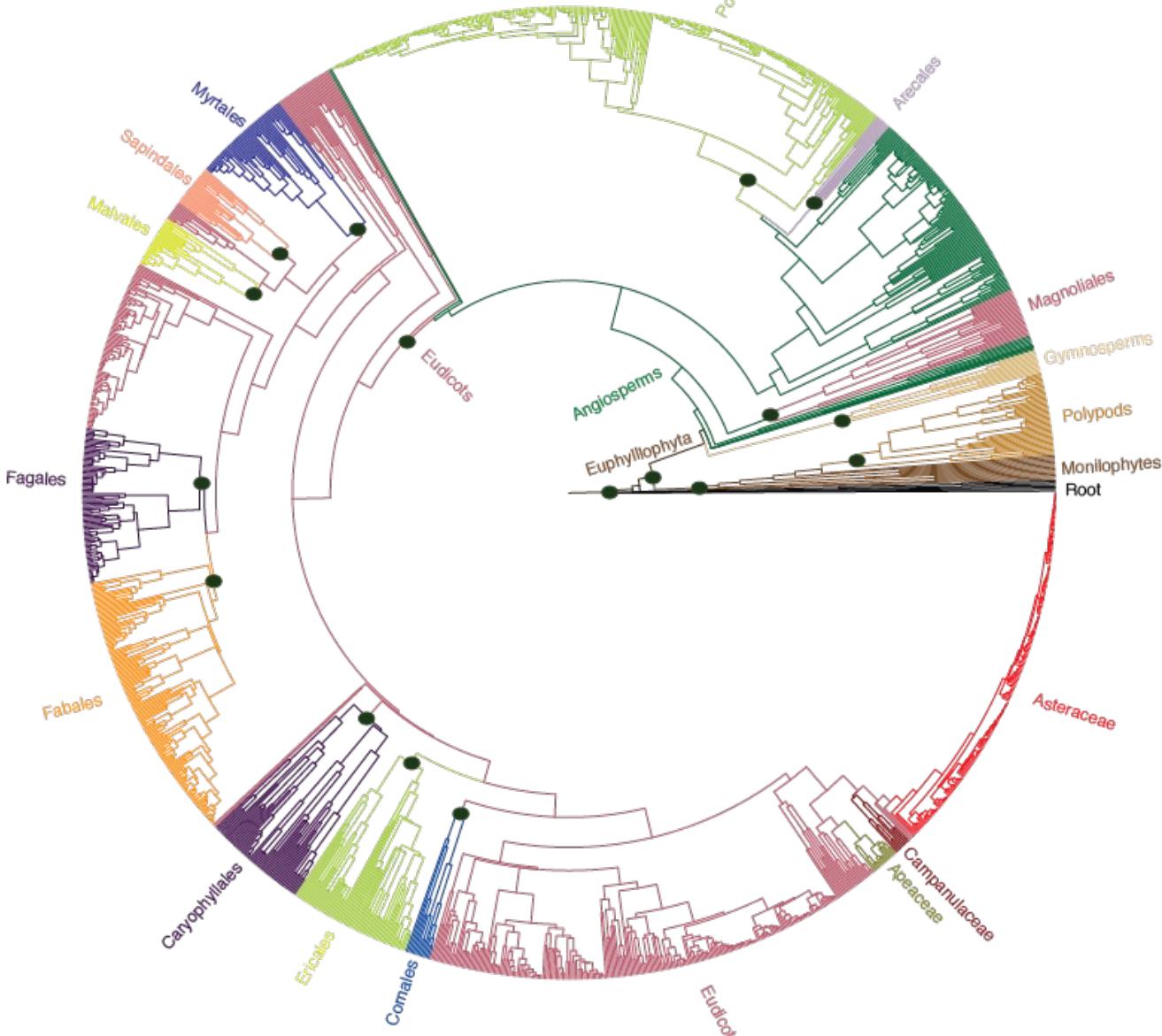


Vs.



# Phylogenetic Diversity

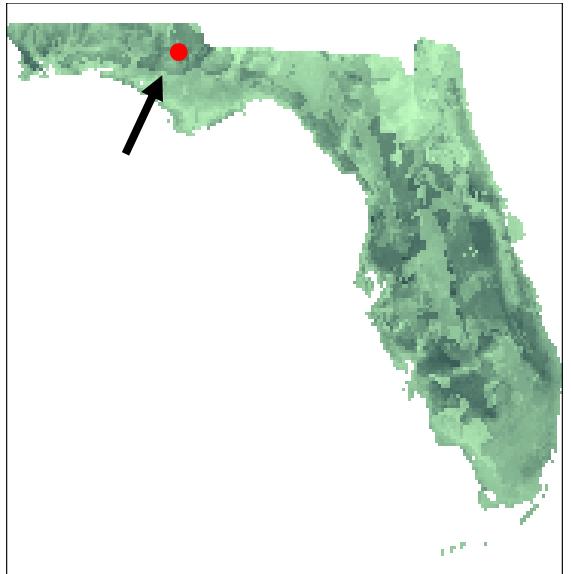
## Florida Plant Phylogeny



# Computing Phylogenetic Diversity

## Phylogenetic Diversity:

How much of the Tree of Life is present in a geographic area?



8,045 pixels/communities  
16 km<sup>2</sup> per pixel

*Species A*  
*Species B*  
*Species C*  
*Species D*  
*Species E*

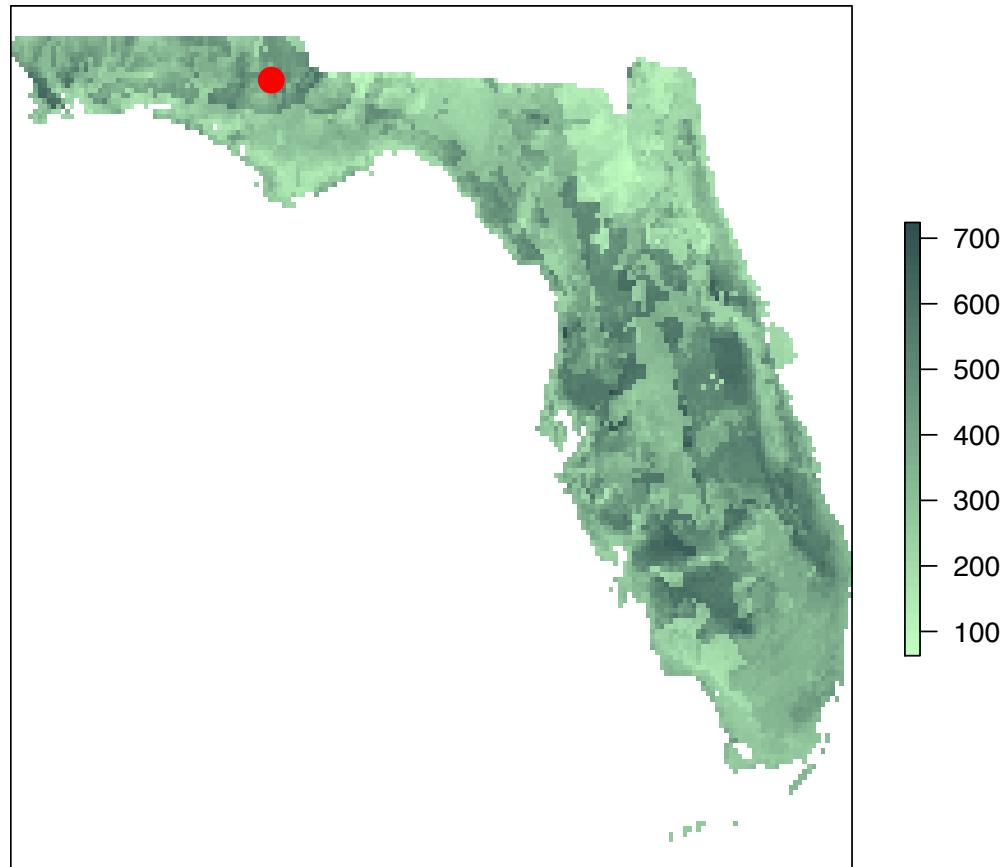
...



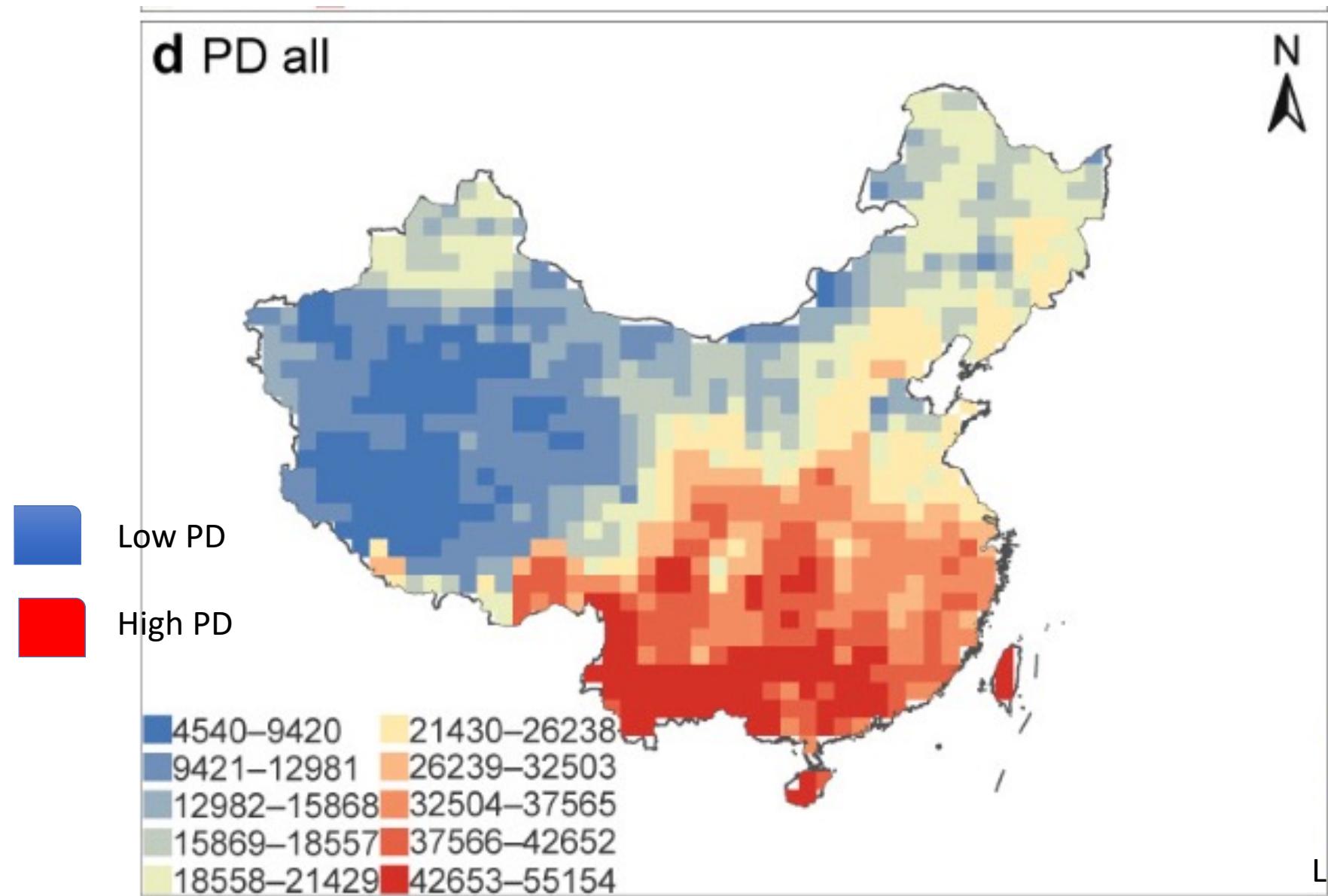
# Computing Phylogenetic Diversity

## Phylogenetic Diversity:

How much of the Tree of Life is present in a geographic area?



# Phylogenetic Diversity: China



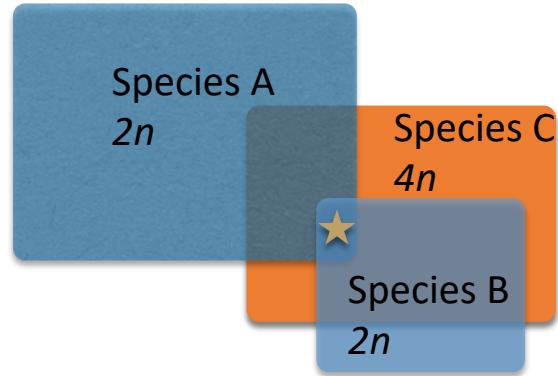
# Applications of Ecological Niche Models

- Estimate current distribution
- Predict future distributions
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- **Niche of polyploid compared to its diploid progenitor(s)**
- Invasives--projections

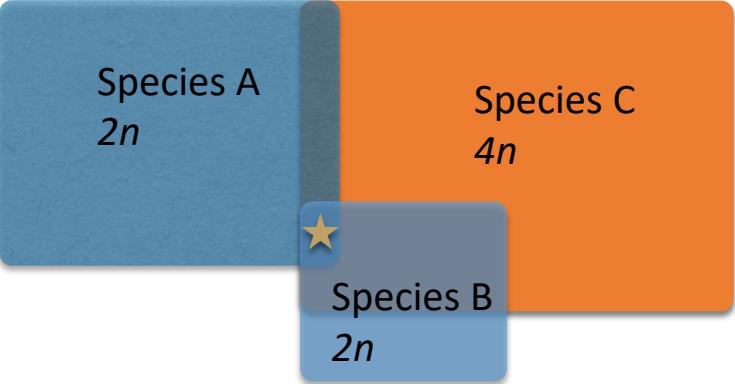
# Niche Evolution in Allopolyploids



## Niche Intermediacy

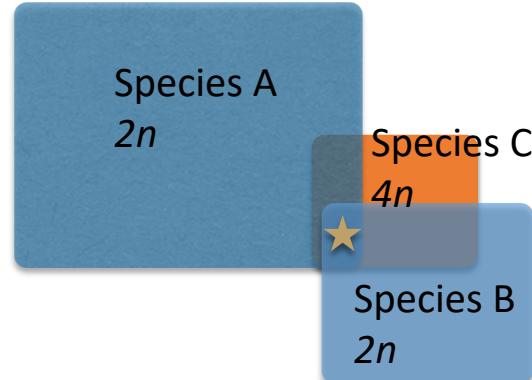


## Niche Expansion

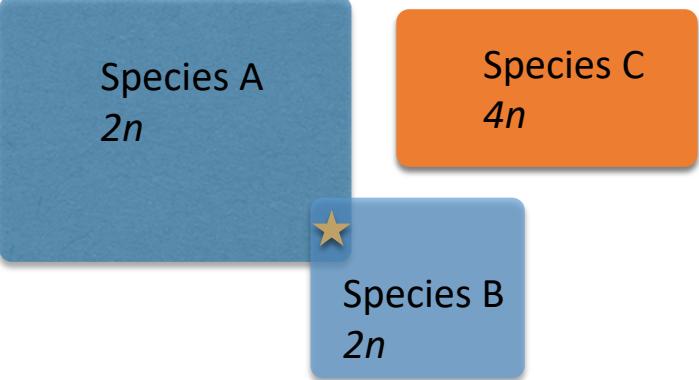


Blaine  
Marchant

## Niche Contraction



## Niche Novelty





# Niche Evolution in Allopolyploids

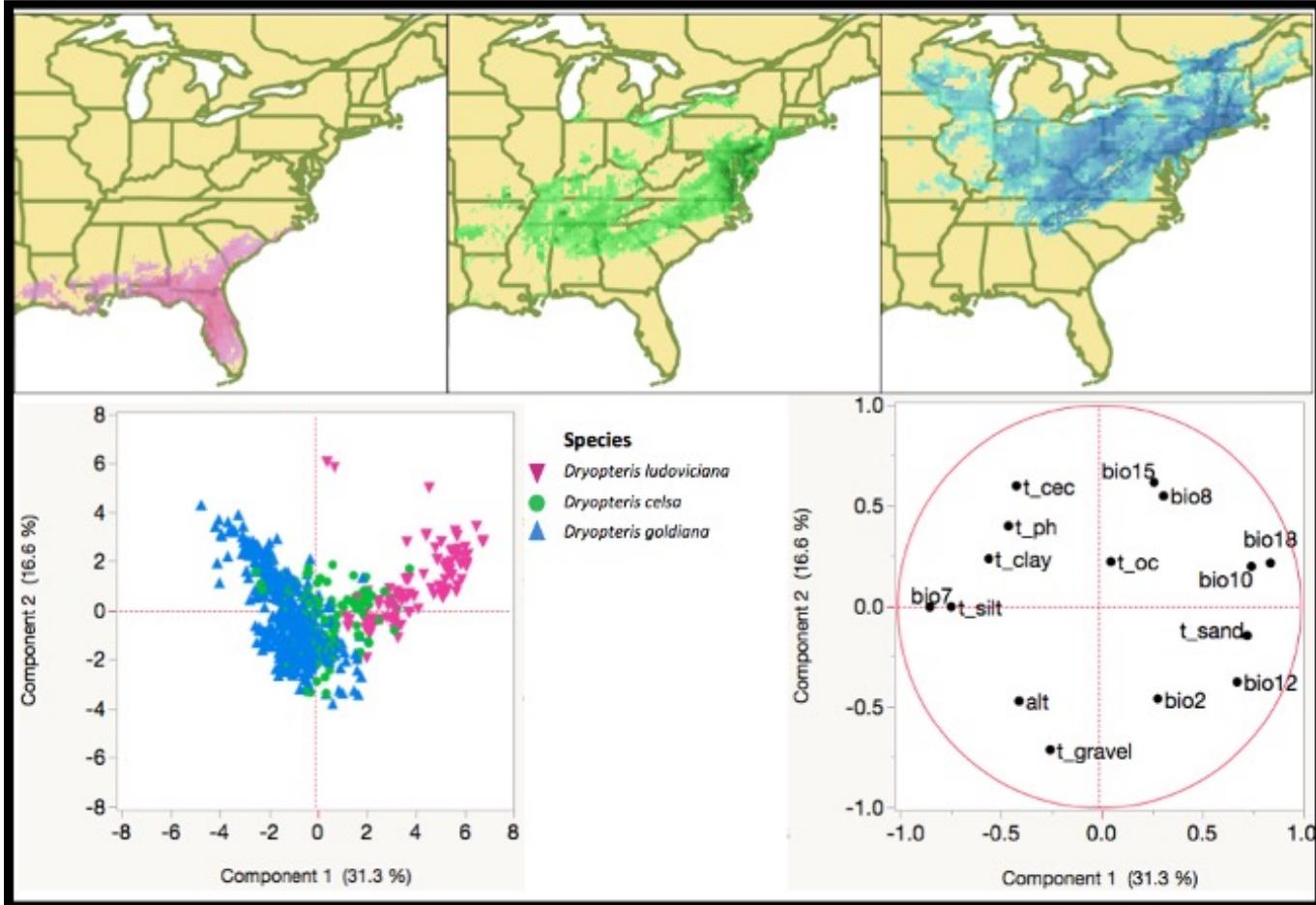


## Niche Intermediacy

Breadth: Parent < Polyloid < Parent

Overlap: Polyloid > 0.3

Blaine  
Marchant



*Dryopteris celsa*

Nickrent, D.L. et al. 2006  
onwards. *Phytoimages*.  
<http://www.phytoimages.siu.edu>

Marchant et al. 2016. *New Phytologist*

# Niche Evolution in Allopolyploids



13 allopolyploids & parents

- Niche intermediacy: 8
- Niche contraction: 2
- Niche expansion: 2
- Niche novelty: 1
- More cases are needed!



# Niche Evolution in Autopolyploids



AMERICAN JOURNAL OF BOTANY

## Niche divergence between diploid and autotetraploid *Tolmiea*<sup>1</sup>

Clayton J. Visger<sup>2,3,5</sup>, Charlotte C. Germain-Aubrey<sup>3</sup>, Maya Patel<sup>3</sup>, Emily B. Sessa<sup>2,4</sup>, Pamela S. Soltis<sup>3,4</sup>, and Douglas E. Soltis<sup>2,4</sup>



*Tolmiea menziesii*



*Galax urceolata*

American Journal of  
Botany



RESEARCH ARTICLE

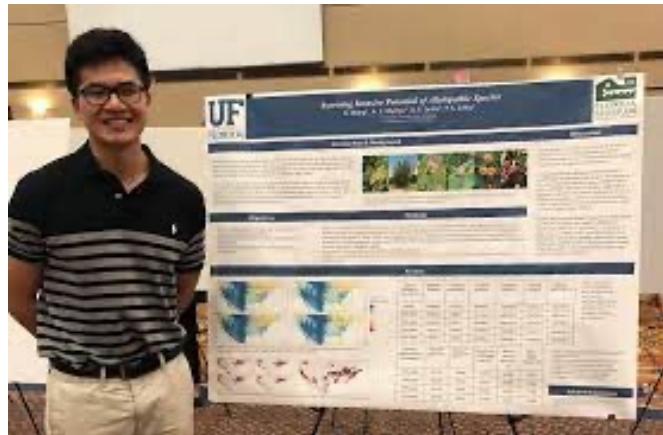
## Climatic niche comparison among ploidal levels in the classic autopolyplloid system, *Galax urceolata*

Michelle L. Gaynor<sup>1,4</sup> , D. Blaine Marchant<sup>2,3</sup>, Douglas E. Soltis<sup>2,3</sup>, and Pamela S. Soltis<sup>3</sup>

# Applications of Ecological Niche Models

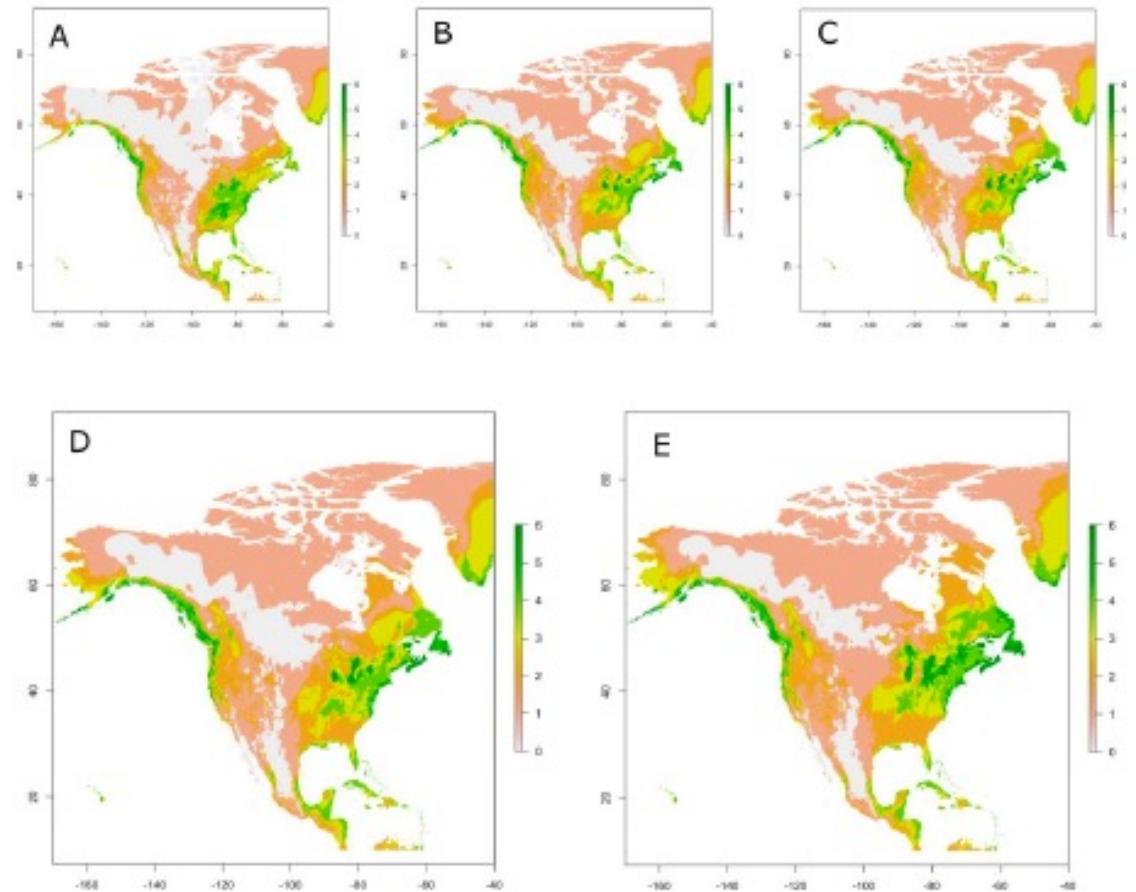
- Estimate current distribution
- Predict future distributions
- Infer past distributions
- Use as foundation for phylogenetic diversity studies
- Niche of polyploid compared to its diploid progenitor(s)
- **Invasives--projections**

# Potential Distributional Shifts Under Climate Change Models



Anson  
Wang

*Ailanthus altissima*  
*Casuarina equisetifolia*  
*Centaurea stoebe* ssp. *micranthos*  
*Dioscorea bulbifera*  
*Lantana camara*  
*Schinus terebinthifolia*



**Figure 2.** Heat maps showing areas at risk constructed by combining projections of the six species. Projections are (A) current, (B) 2050 rcp4.5, (C) 2050 rcp8.5, (D) 2070 rcp4.5, and (E) 2070 rcp8.5. Species occupation of an area can range from 0 to 6, with 0 representing no suitable climate for any of the six species investigated present and 6 representing predicted suitable climate for all six species.