



Evolutionary Perspectives on North American Pondweeds: New Insights with Implications for Conservation

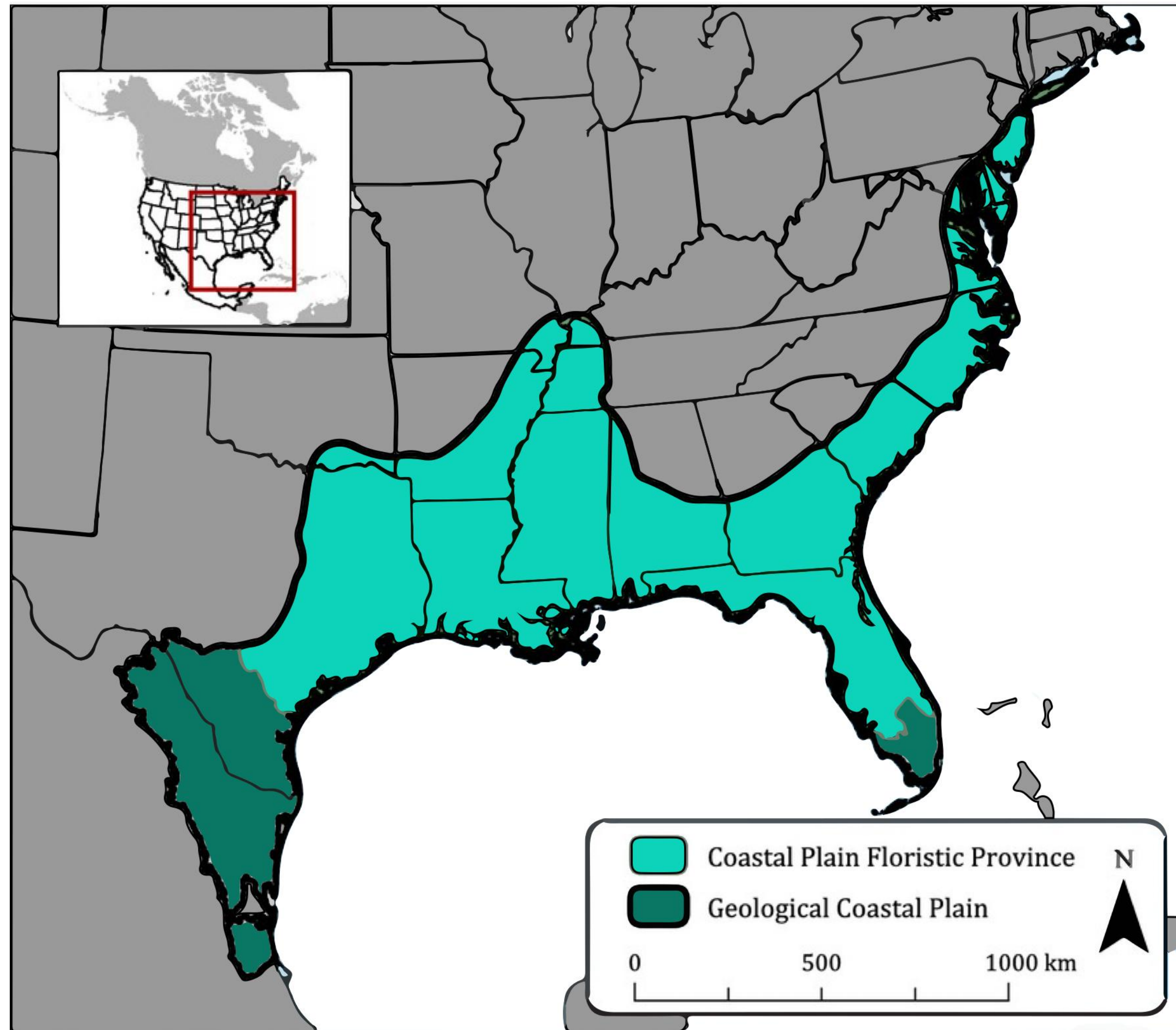
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U. of South Alabama



BIOLOGY
MOLECULES TO ECOSYSTEMS



The North American Coastal Plain



The NACP is one of the larger terrestrial biodiversity hotspots and considered to be one of the most sharply defined floristic provinces in North America

The NACP was overlooked as a hotspot

Despite recognition of high animal diversity and endemism, especially in freshwater ecosystems, the NACP was bypassed as a global biodiversity hotspot due to:

- poor understanding/collation of plant diversity data
- Misconceptions about geology and ecology



Zacc
Ramm

Kaitlyn
Sampson



Our contribution

Pondweeds!

We aim to resolve taxonomy and understand diversification dynamics in North American pondweeds.



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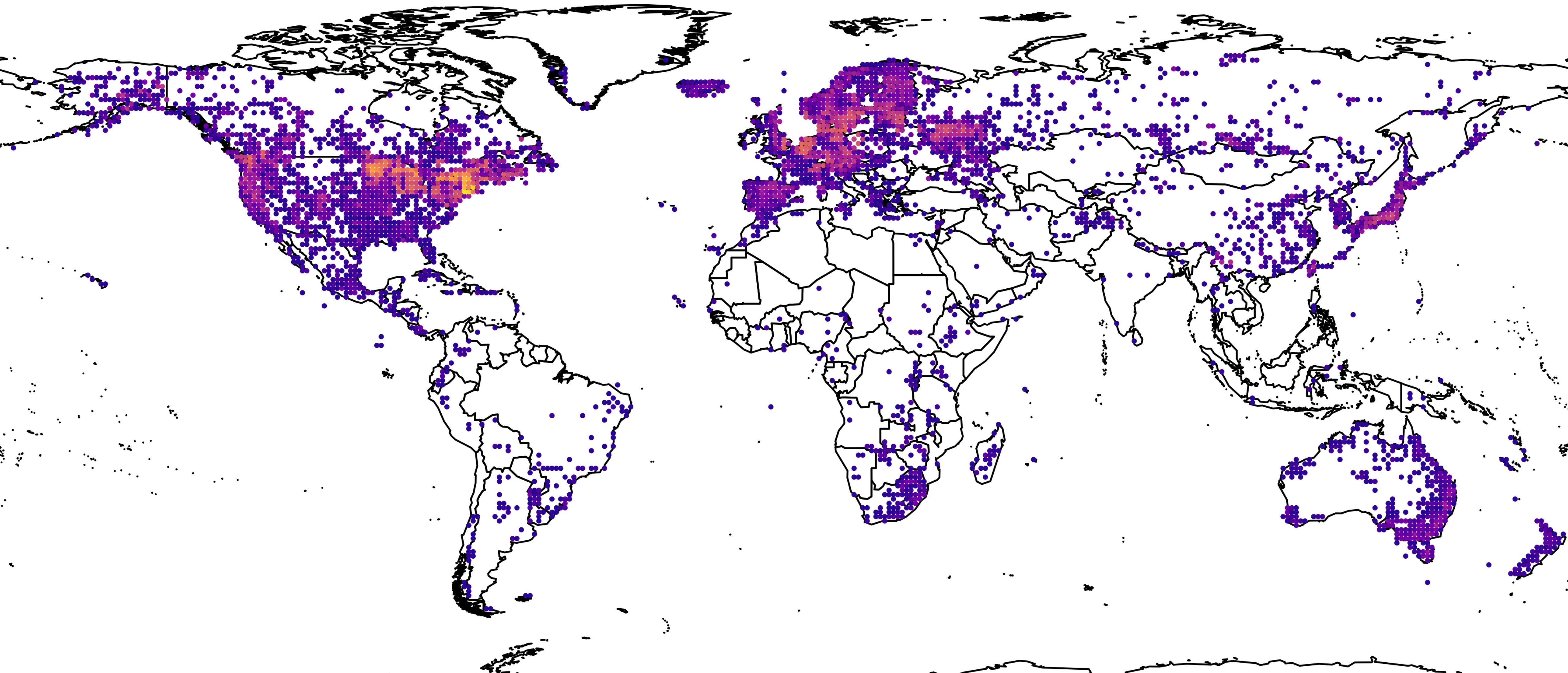
Our contribution

Despite being ecologically important, aquatic plants are under-collected and understudied compared to terrestrial plants.

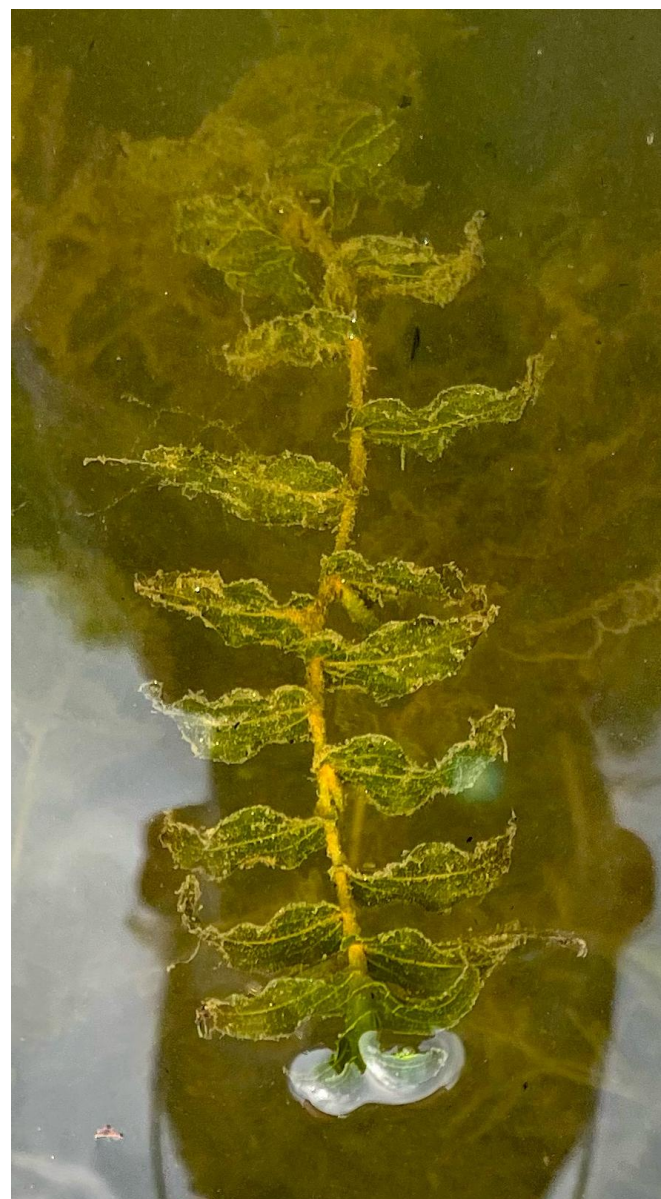
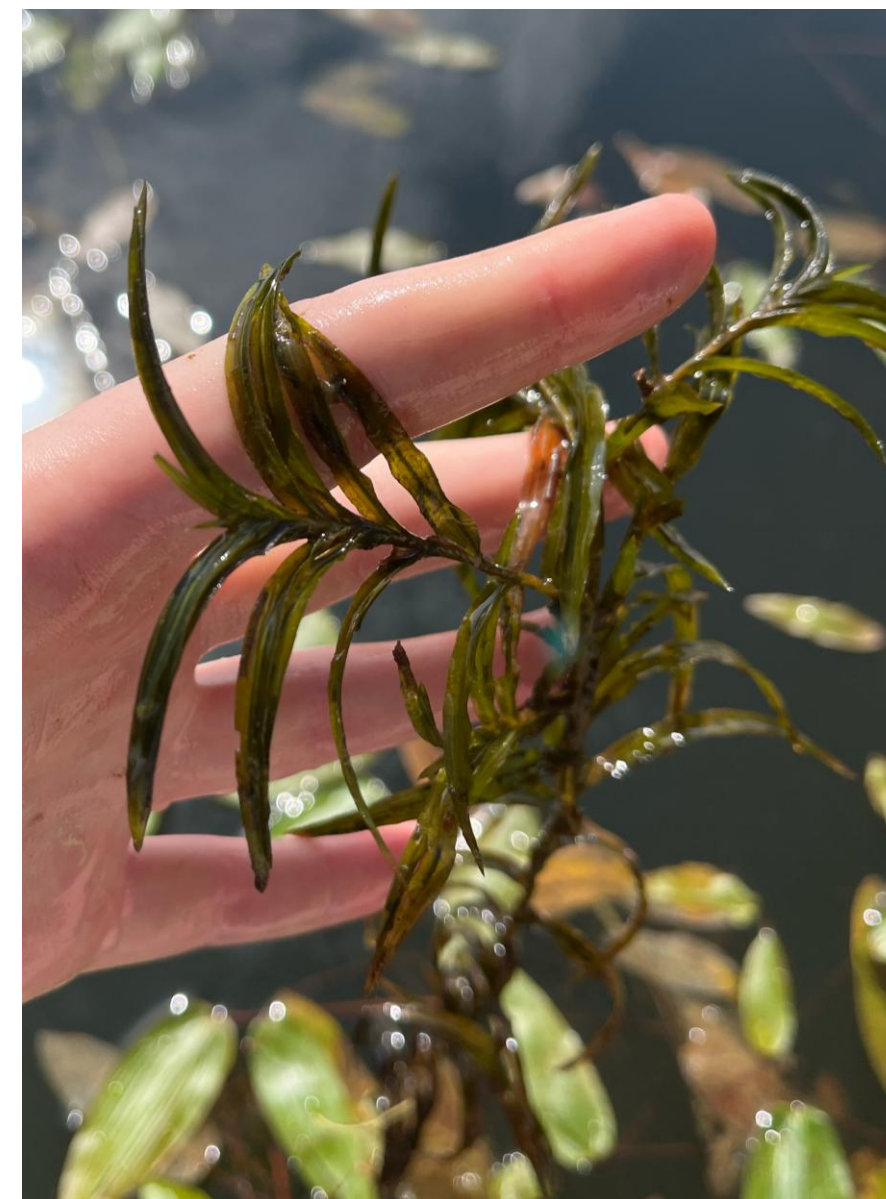
We know relatively little about the organisms that support the extraordinary animal diversity in our freshwater ecosystems.

Potential for large knowledge gains about plant biodiversity and freshwater ecology in the NACP.

The pondweed family (Potamogetonaceae)



The pondweed family (Potamogetonaceae)



The pondweed family (Potamogetonaceae)

Taxonomic difficulty stems from (2) low between species variation,

These are four species (*P. bicupulatus*, *P. diversifolius*, *P. spirillus*, *P. vaseyi*):



The pondweed family (Potamogetonaceae)

Taxonomic difficulty stems from (3) rampant hybridization,

$P. \text{ gramineus} \times P. \text{ perfoliatus} = P. \times \text{nitens}$



×



=



The pondweed family (Potamogetonaceae)

Global diversity:

Althenia (10 spp.)

Groenlandia (1 spp.)

Potamogeton (90 spp.; 75+ hybrids)

Stuckenia (7 spp.; 3 hybrids)

Zannichellia (6 spp.)



The pondweed family (Potamogetonaceae)

North American diversity:

Althenia (0 spp.)

Groenlandia (0 spp.)

Potamogeton (29 spp.; 30+ hybrids)

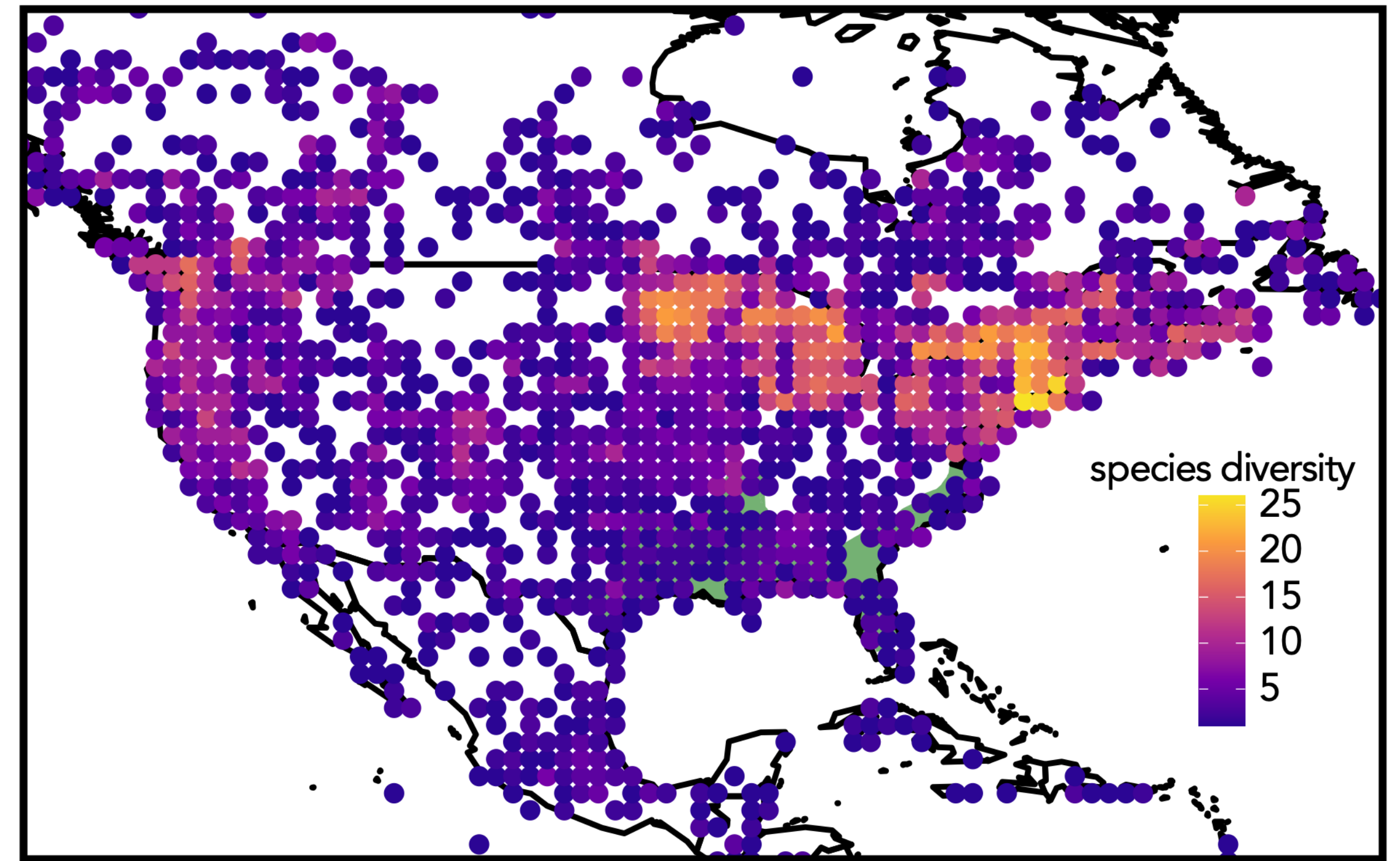
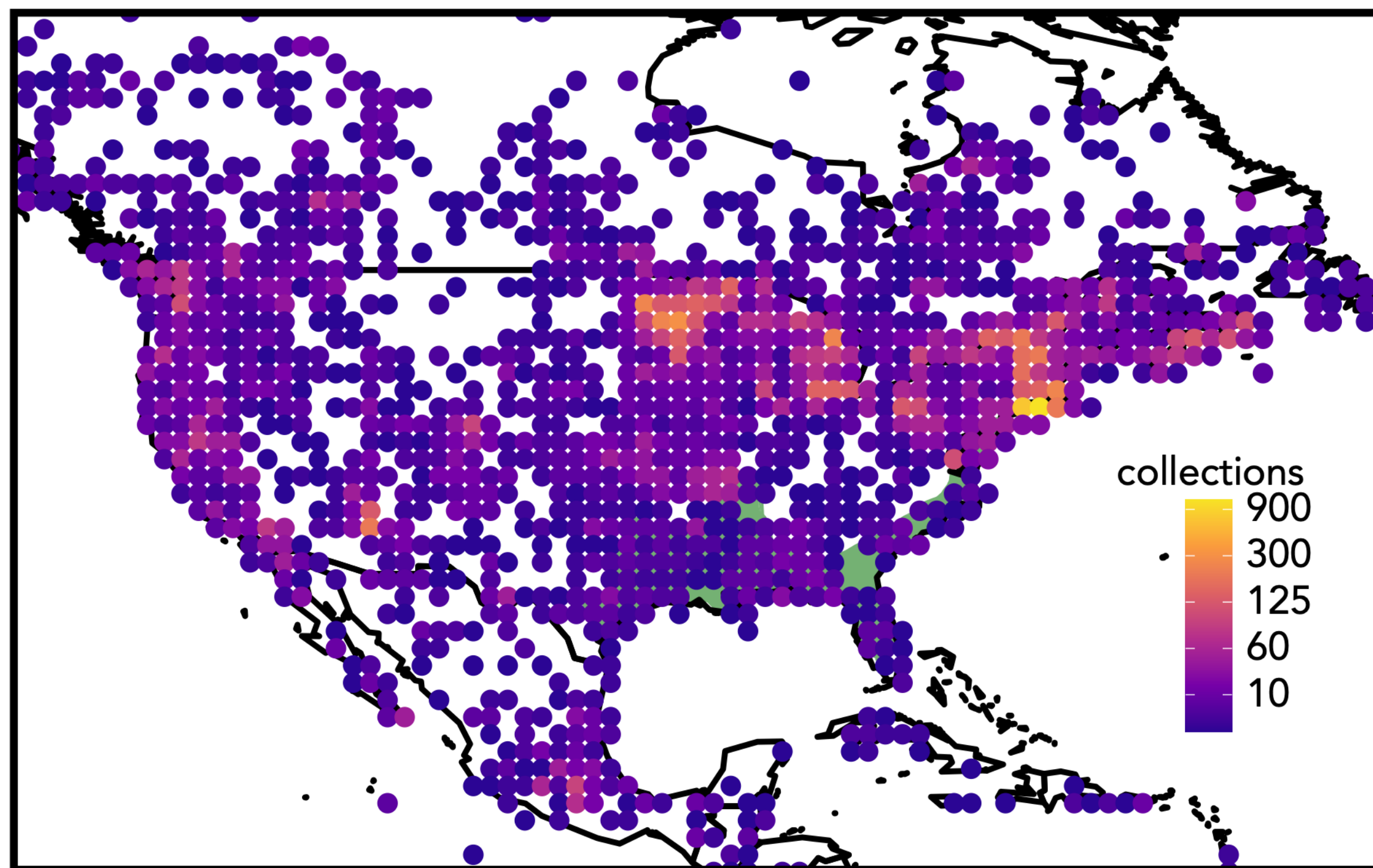
Stuckenia (3 spp.; 0 hybrids)

Zannichellia (1 spp.)



The pondweed family (Potamogetonaceae)

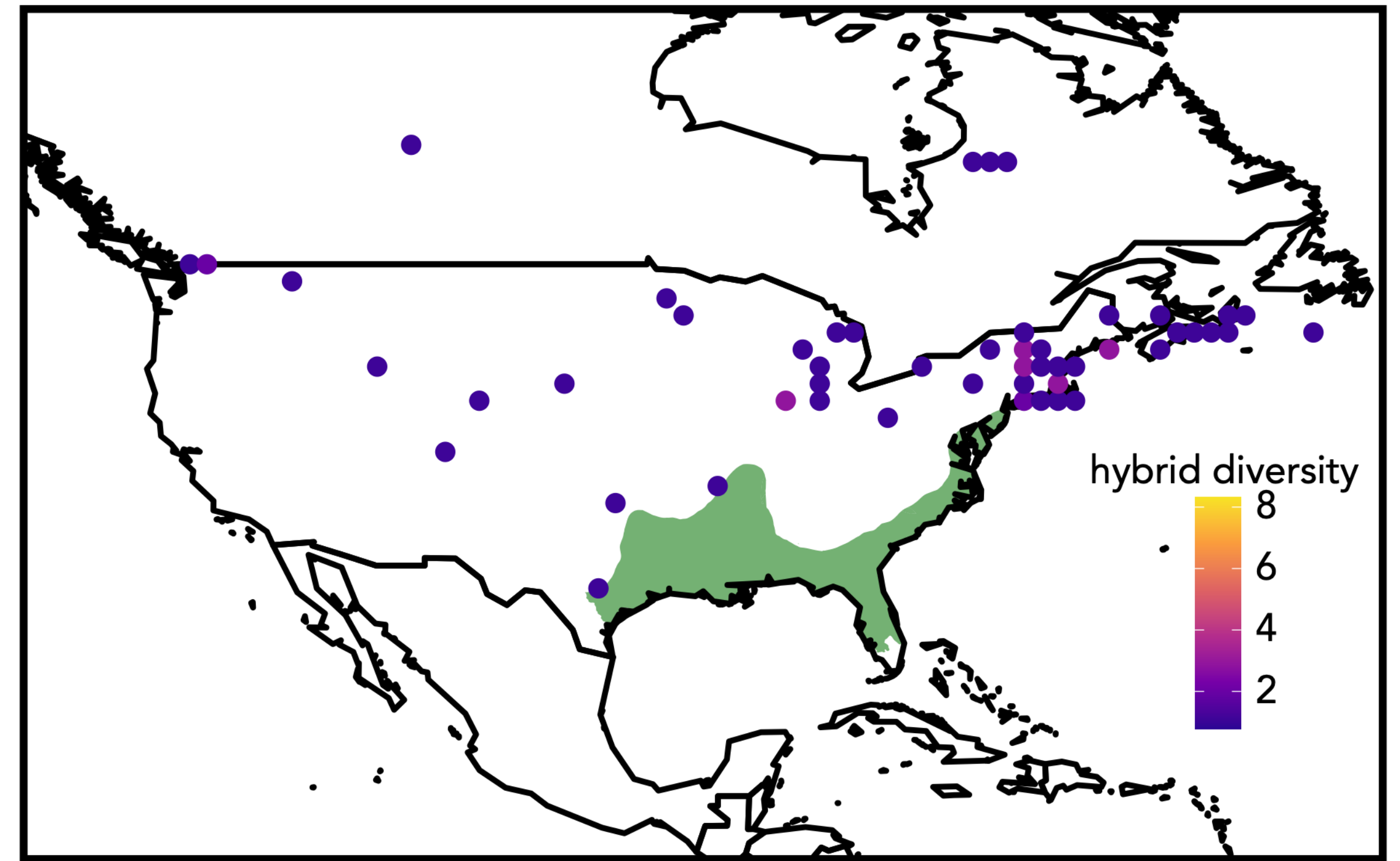
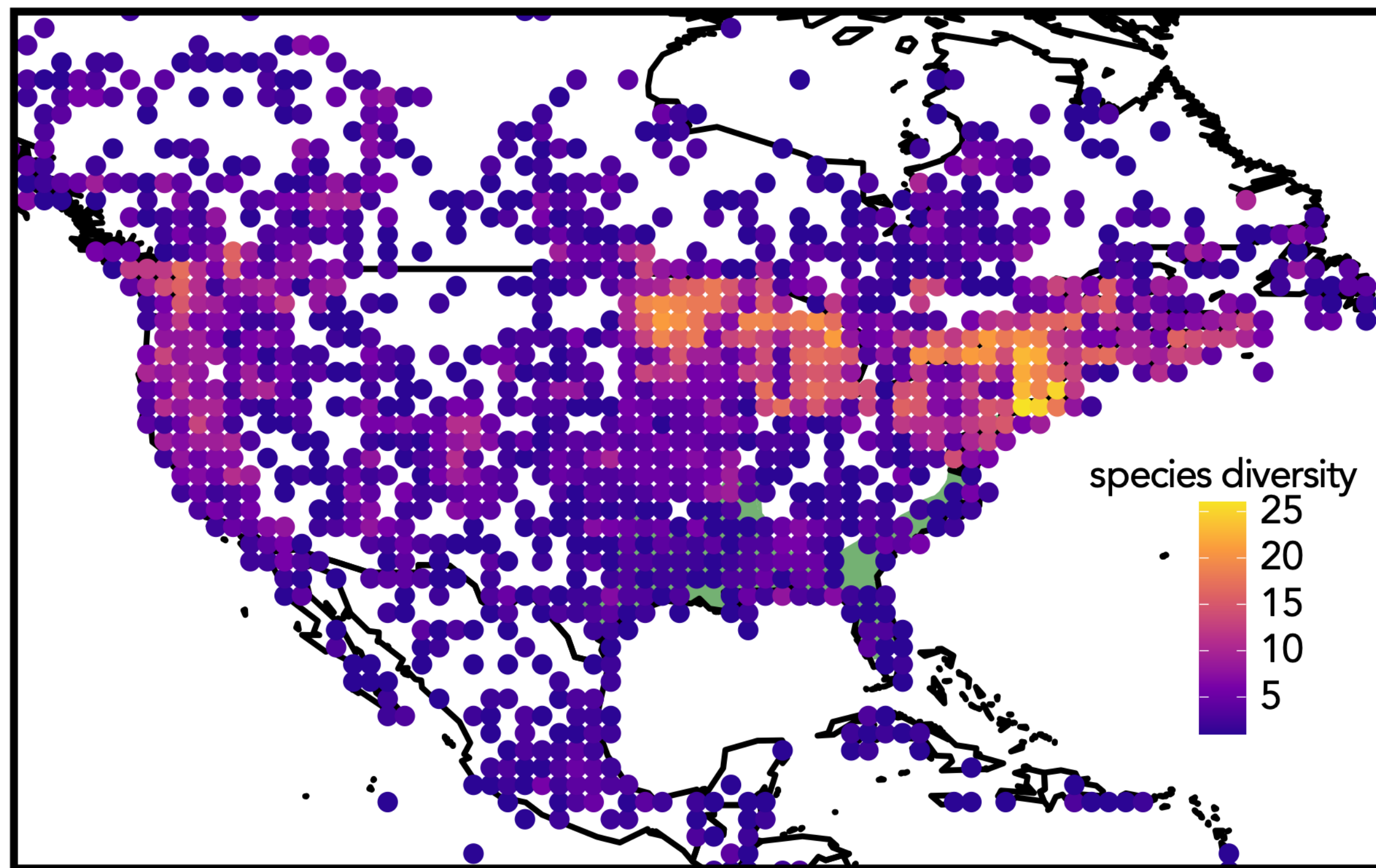
North American diversity:



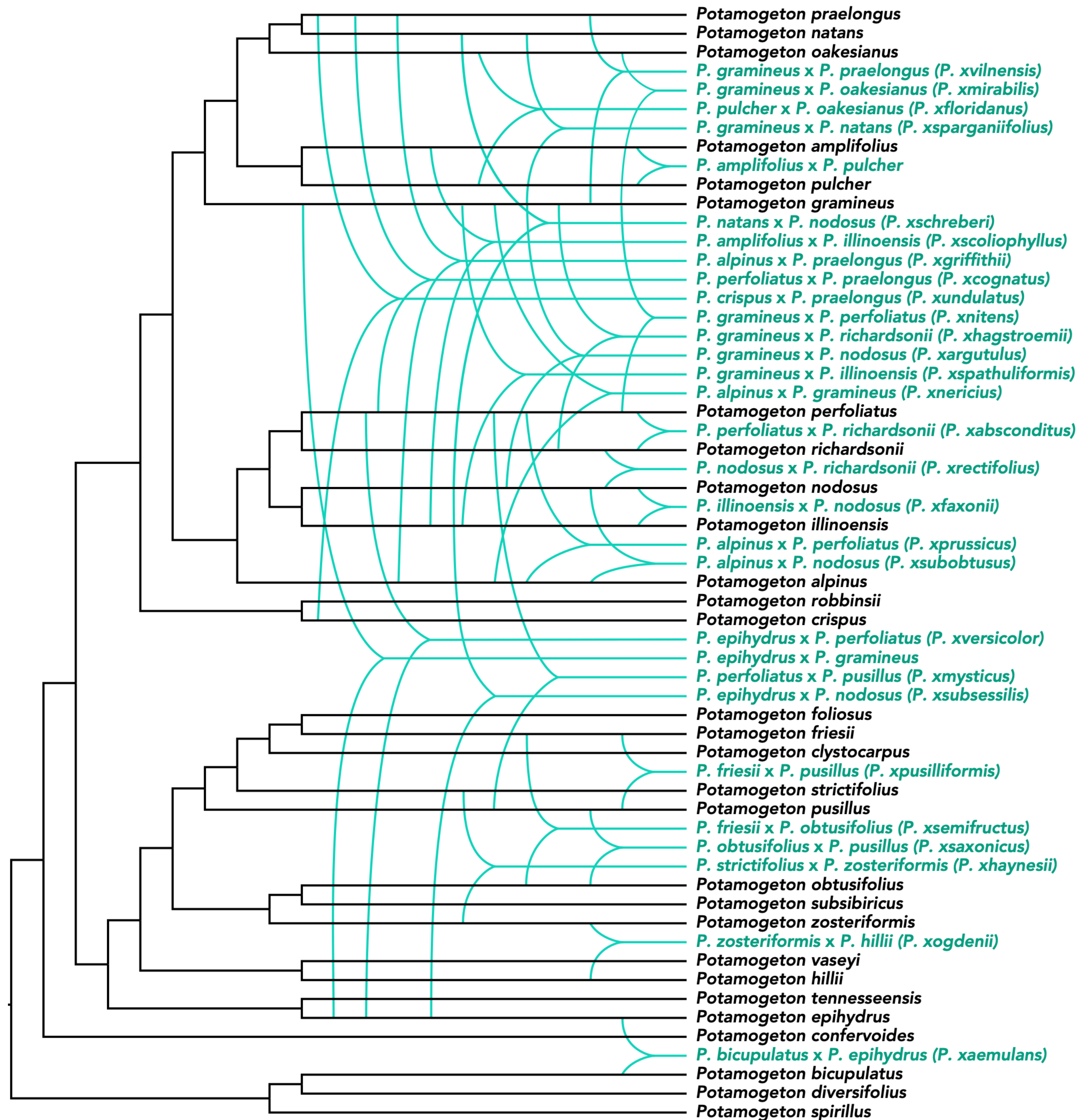
Described species diversity is correlated with collections/research effort

The pondweed family (Potamogetonaceae)

North American diversity:



Hybrids tend to be described where collections/research effort are highest and where parent species co-occur



This is the current hypothesis for discrete species and hybrid diversity in North America and the relationships among them.

But we think this is incomplete!



The Florida pondweed (*Potamogeton floridanus*)

P. floridanus is a rare endemic known from few populations in the Blackwater River drainage in Santa Rosa Co., FL

Assumed to be a blackwater river specialist and of federal interest for protection under the Endangered Species Act

Determined to be a hybrid between *P. oakesianus* and *P. pulcher* using genetic data (Kaplan et al., 2018)

The Florida pondweed (*Potamogeton floridanus*)

P. oakesianus

Lanceolate to ovate floating leaves

Acicular-linear submersed leaves

Acidic bogs, ponds, and lakes

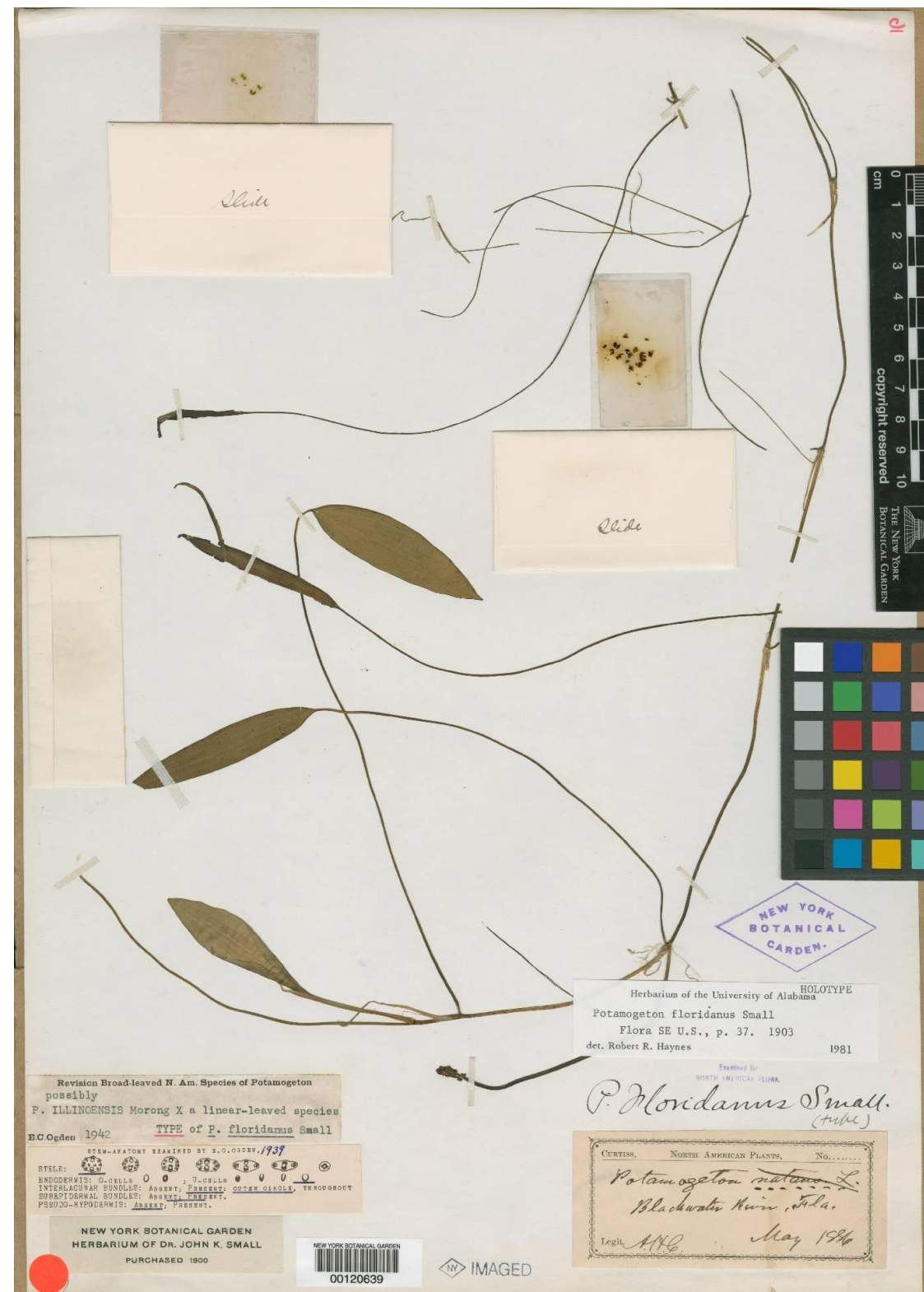


P. floridanus

Lanceolate floating leaves

Acicular-linear submersed leaves

Shallow, slow-flowing blackwater streams

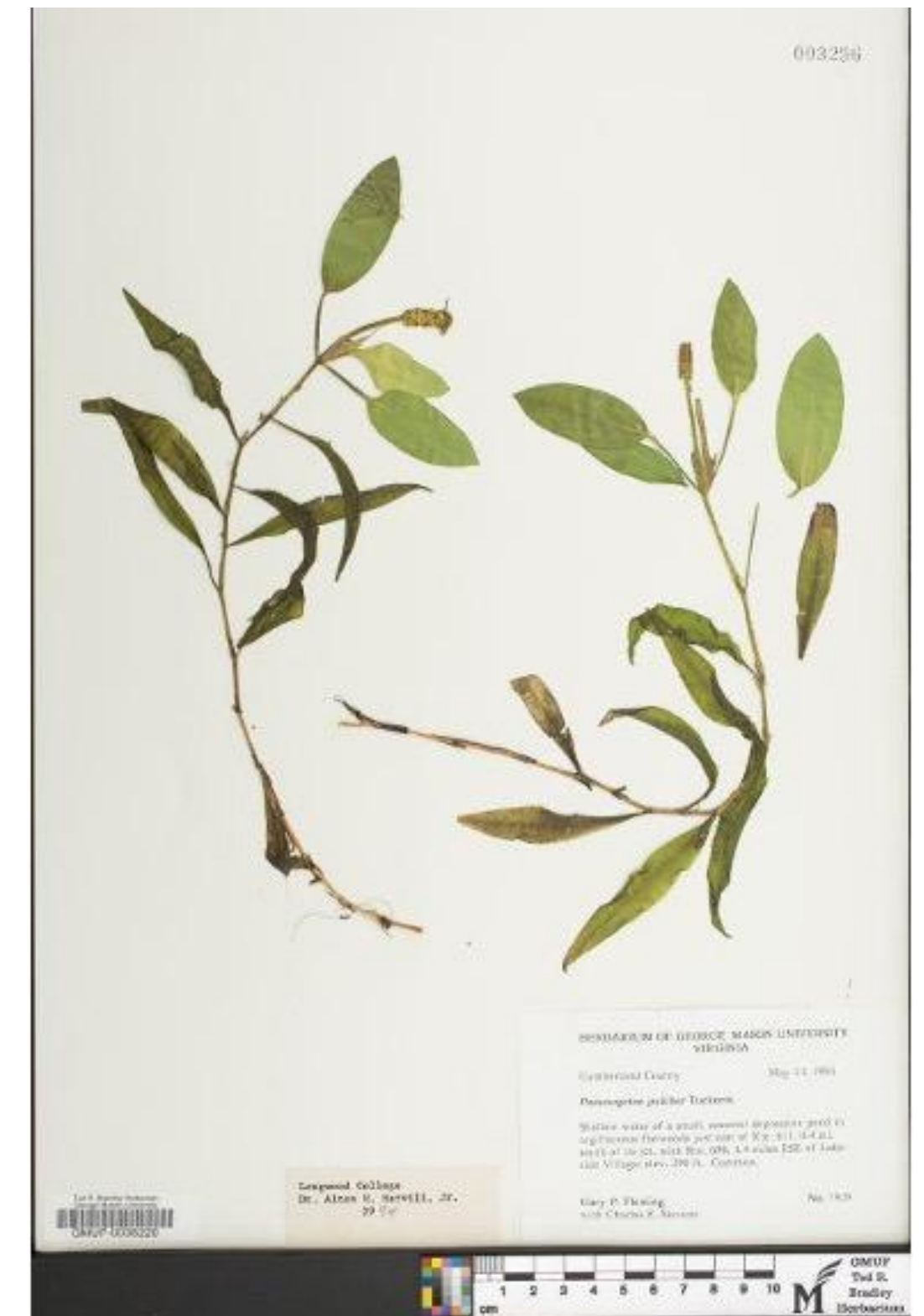


P. pulcher

Lanceolate to ovate floating leaves

Lanceolate submersed leaves

Stagnant to slow-moving streams, ponds and lakes



The Florida pondweed (*Potamogeton floridanus*)

P. oakesianus

Lanceolate to ovate floating leaves

Acicular-linear submersed leaves

Acidic bogs, ponds, and lakes

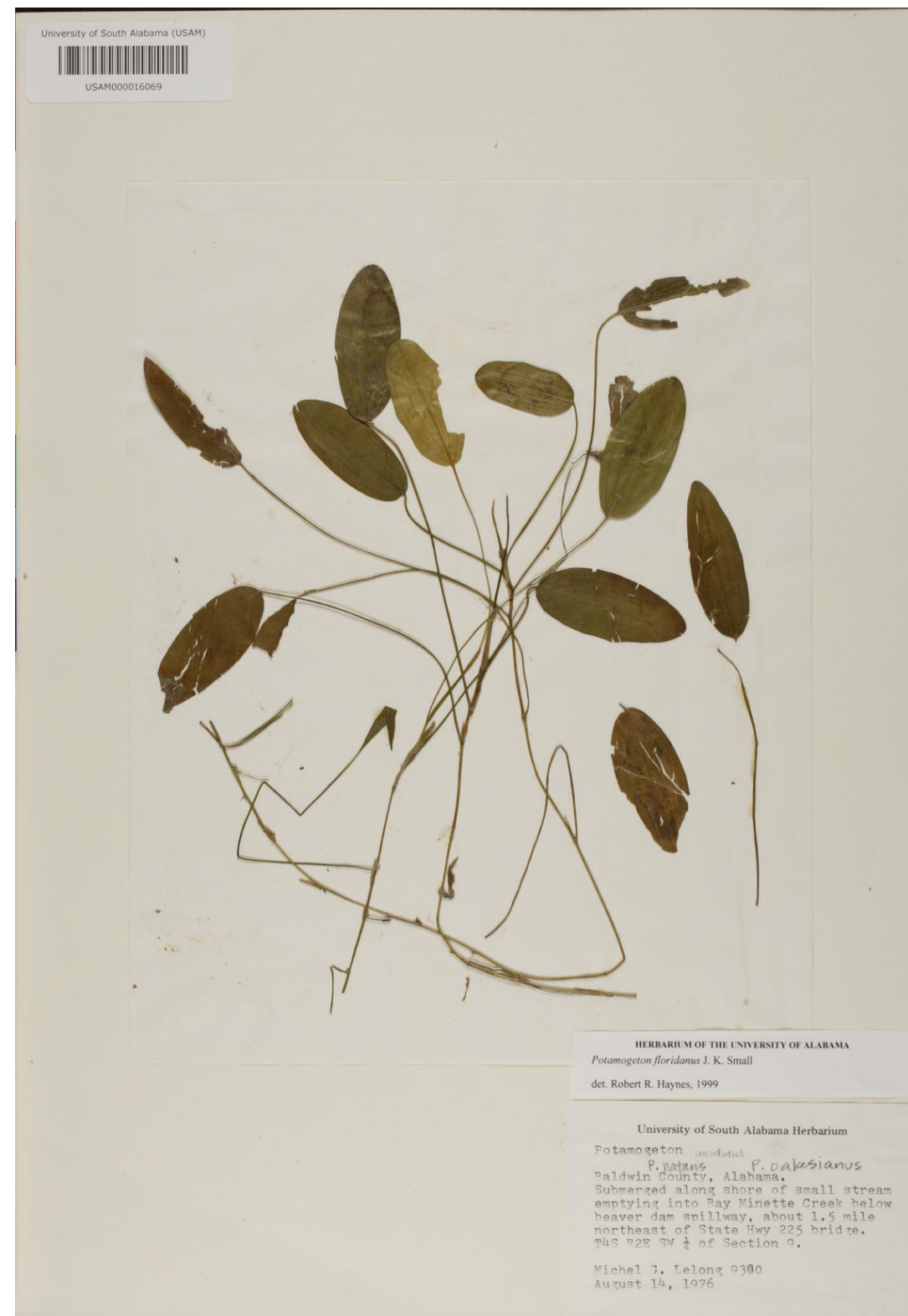


P. sp. Bay Minnette Creek

Ovate floating leaves

Acicular-linear submersed leaves

Shallow, slow-flowing blackwater streams

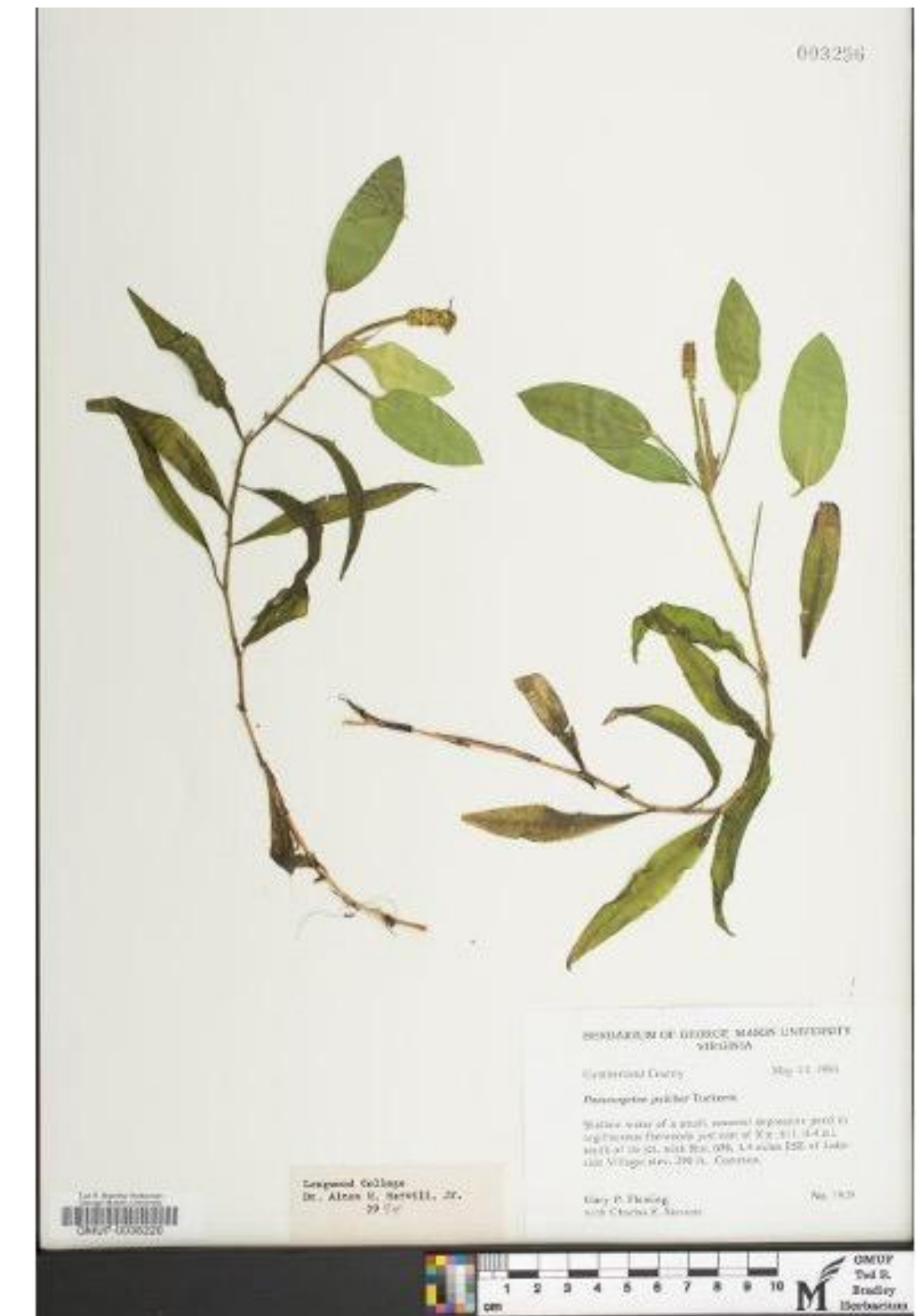


P. pulcher

Lanceolate to ovate floating leaves

Lanceolate submersed leaves

Stagnant to slow-moving streams, ponds and lakes



The Florida pondweed (*Potamogeton floridanus*)

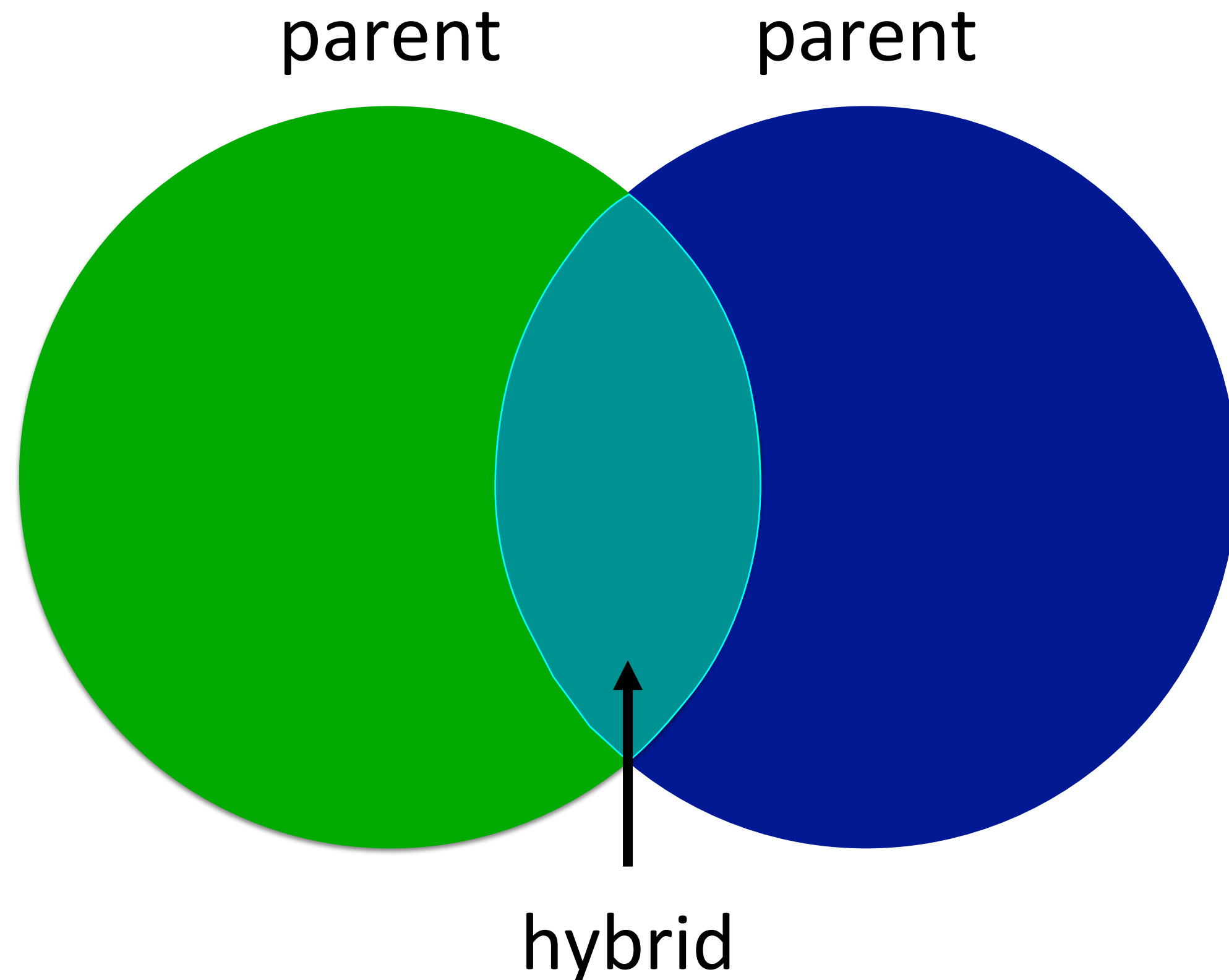


Determine if Bay Minette Creek pondweed is *P. floridanus*

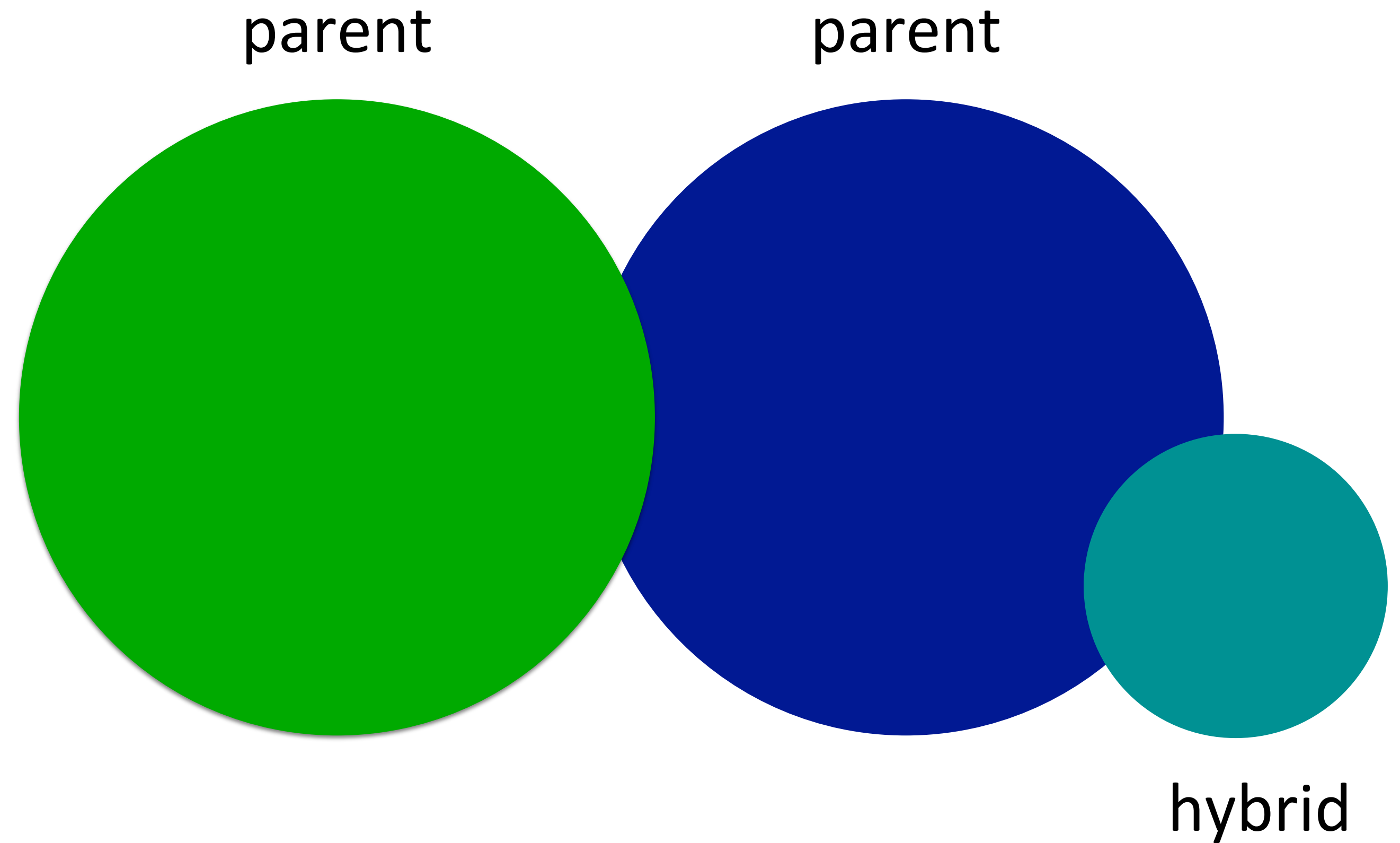
If so, is it from the same or a different hybridization event?

The Florida pondweed (*Potamogeton floridanus*)

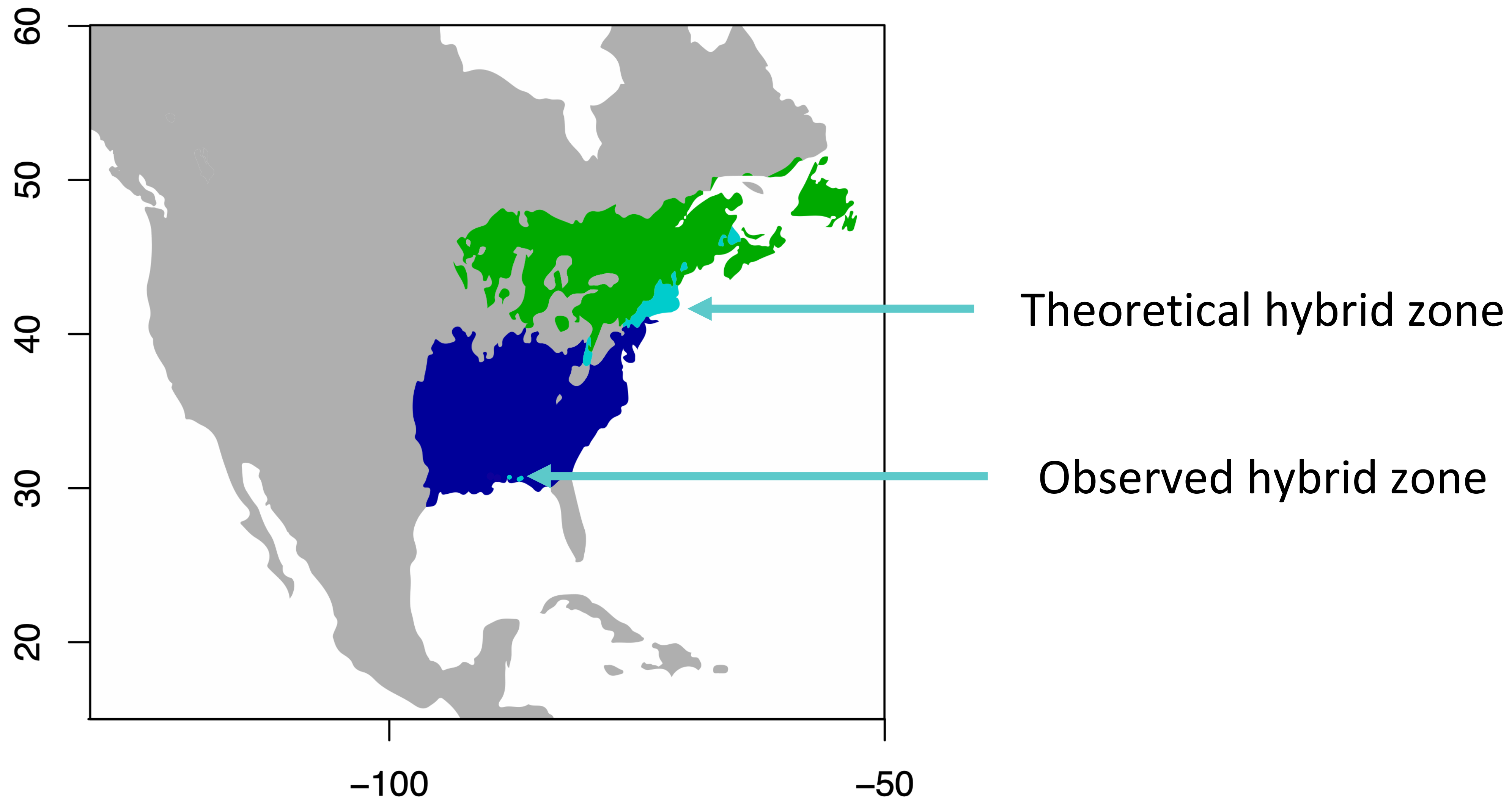
Typical theoretical model of hybrid zones



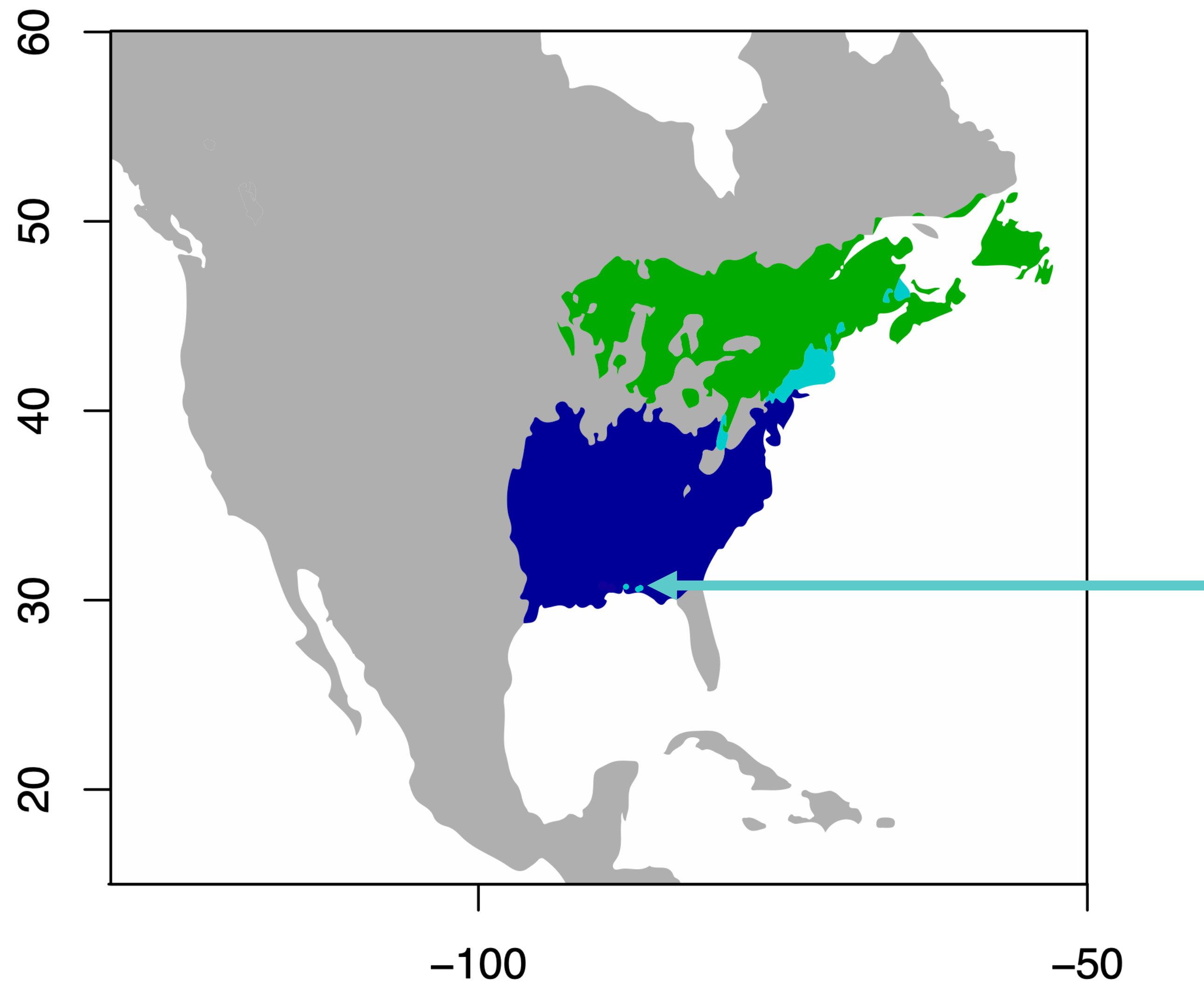
Observed model for *P. floridanus*



The Florida pondweed (*Potamogeton floridanus*)

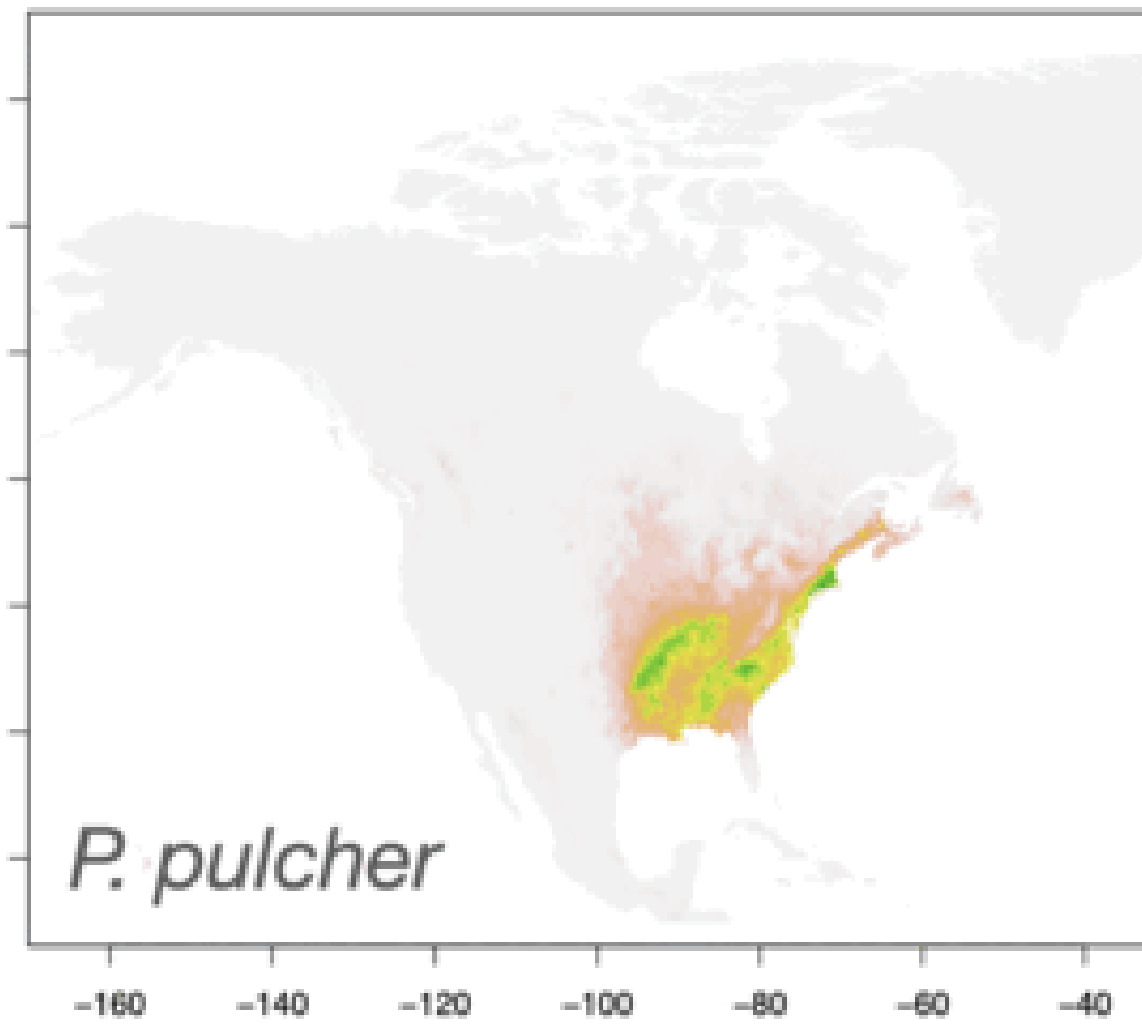
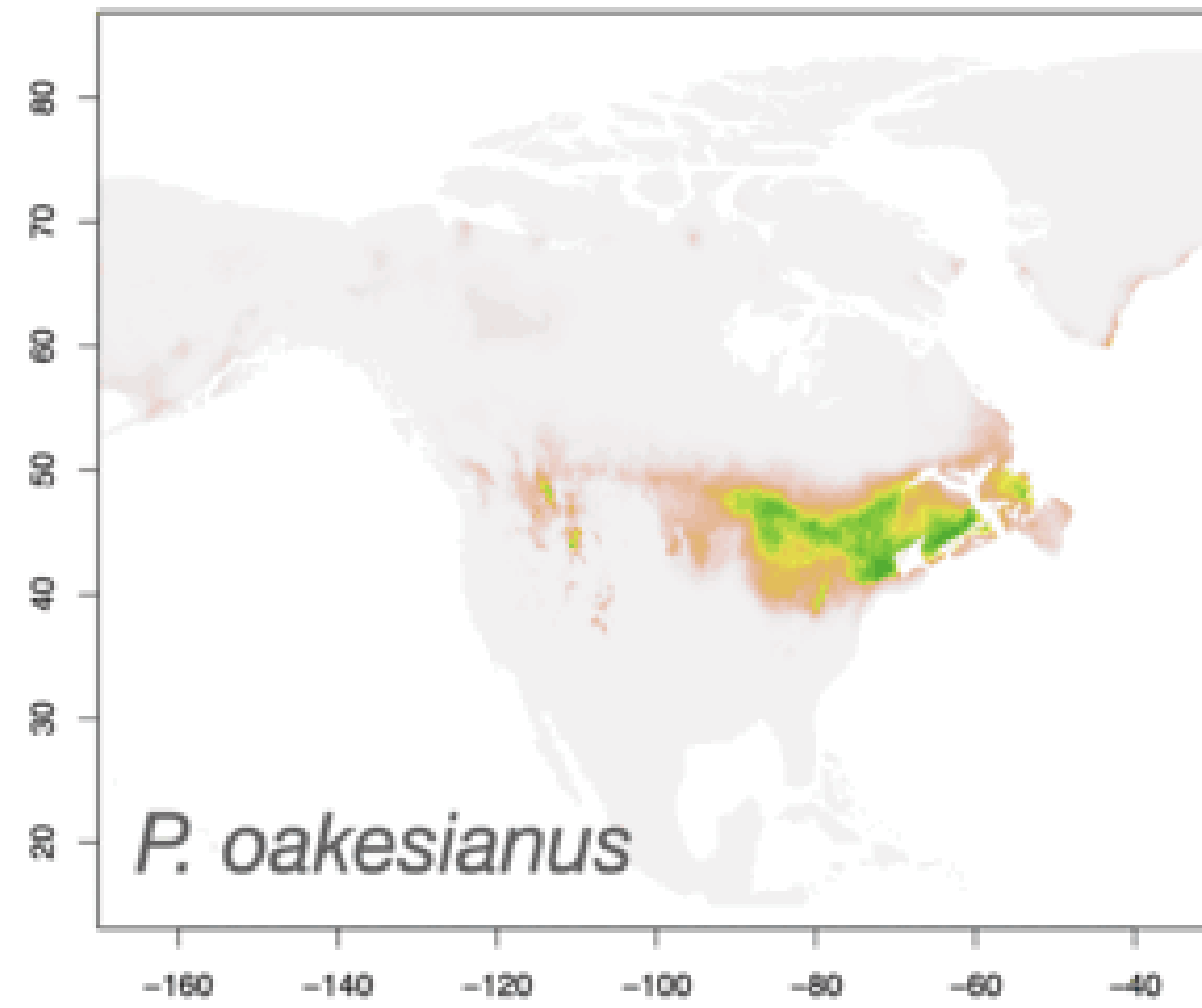


The Florida pondweed (*Potamogeton floridanus*)

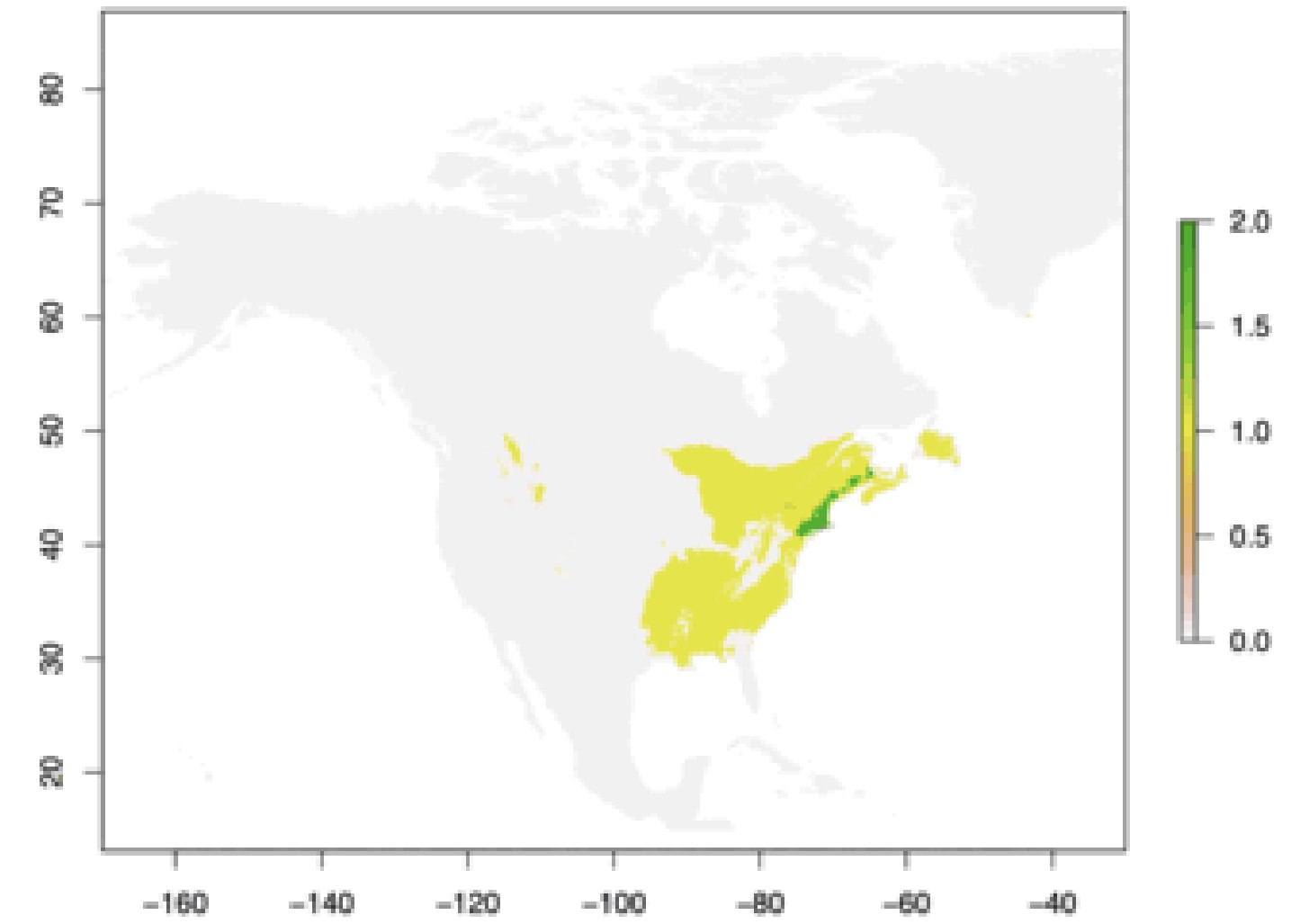


How did *P. floridanus* get here?

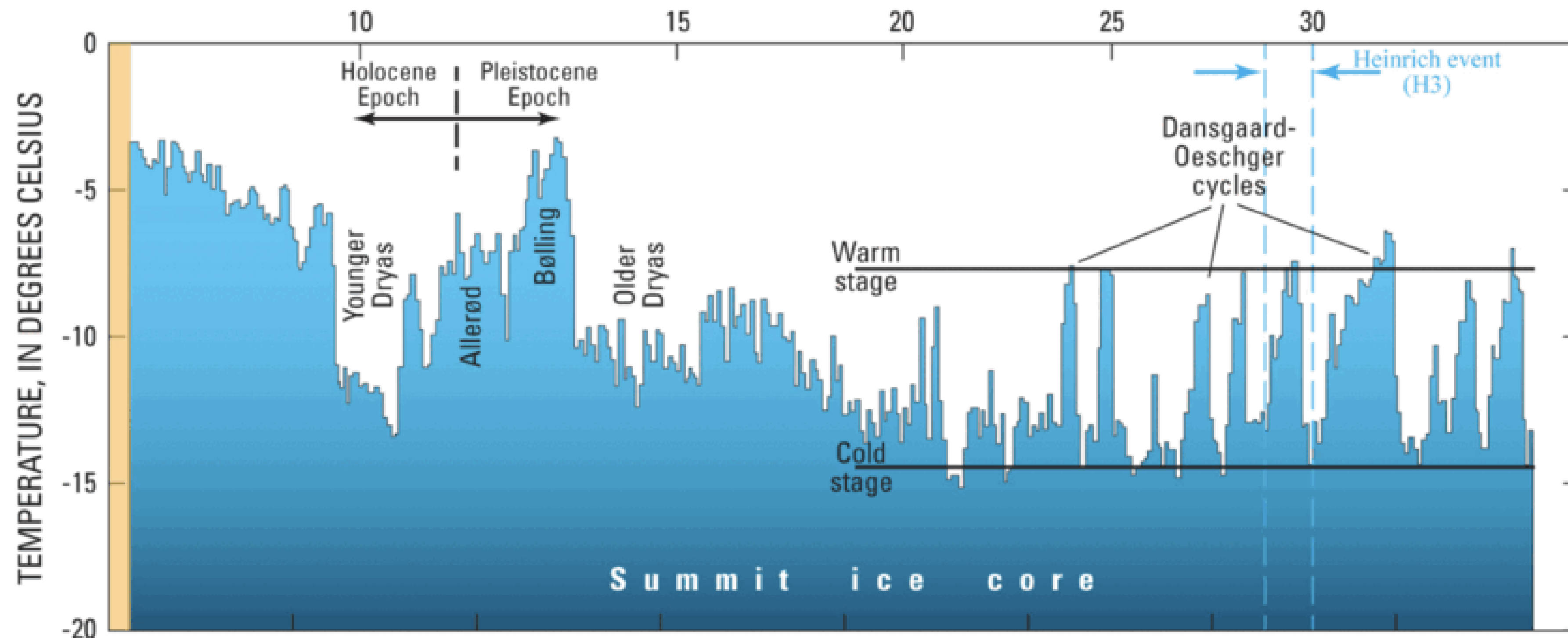
Suitability



Overlap

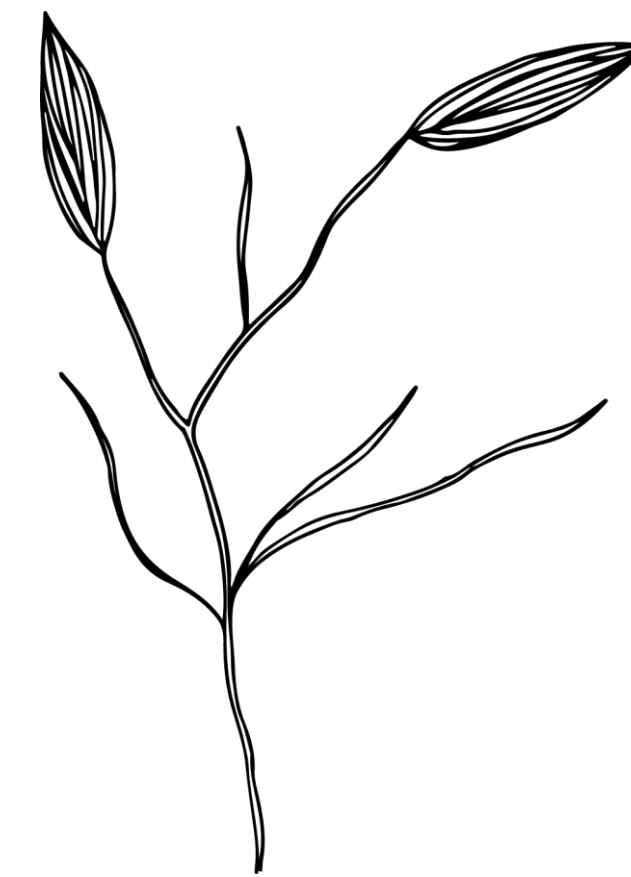
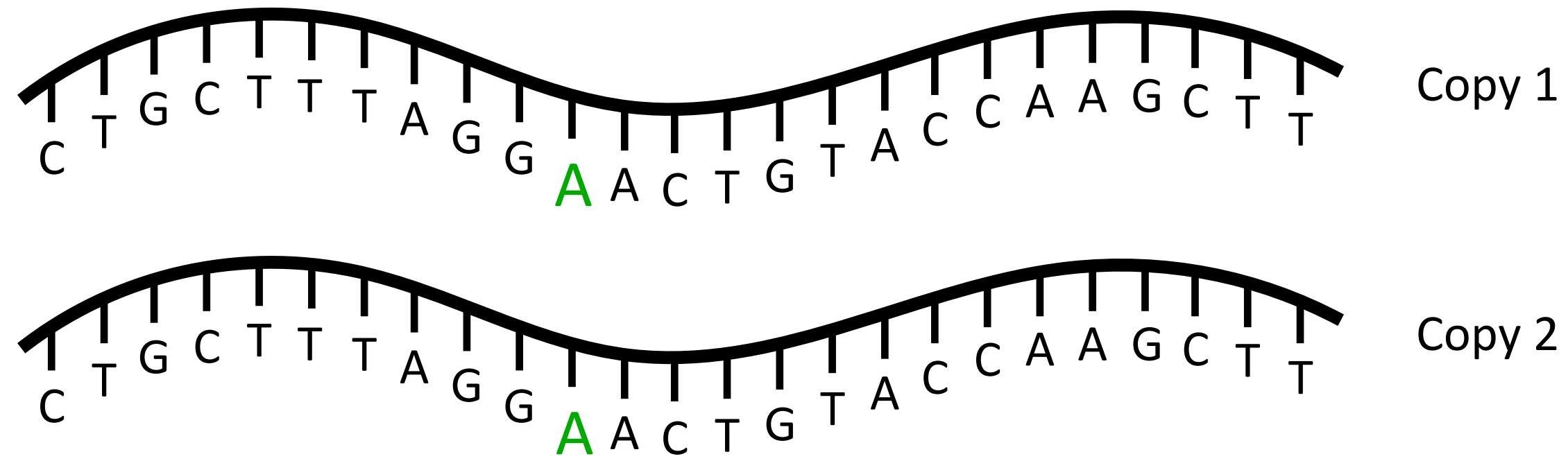


TIME, IN THOUSANDS OF YEARS BEFORE COMMON ERA

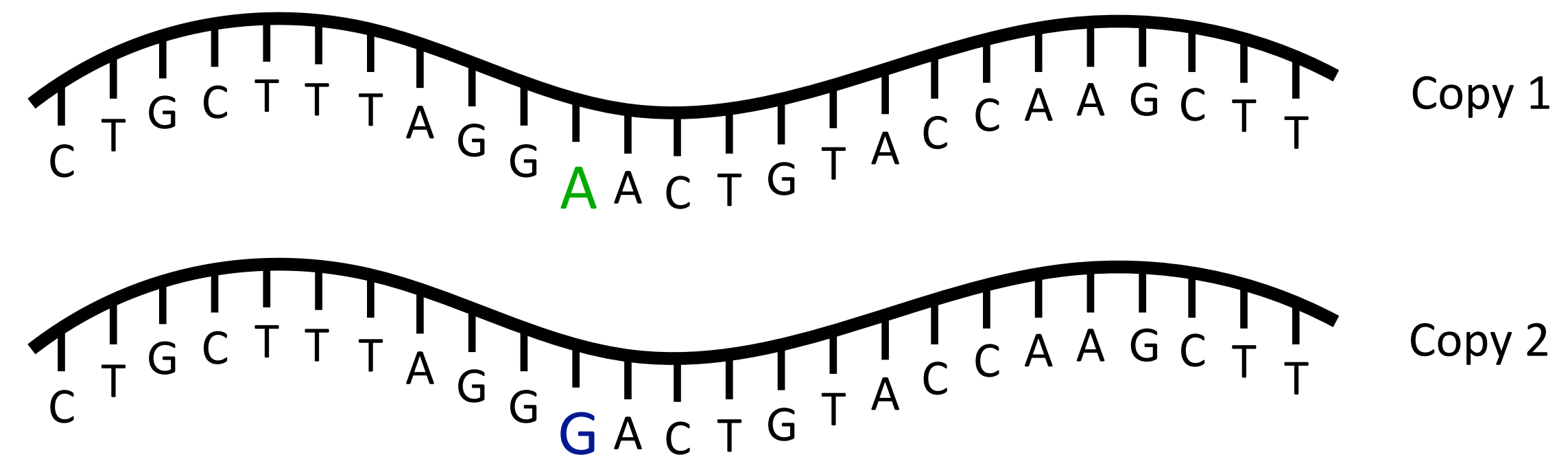




P. oakesianus



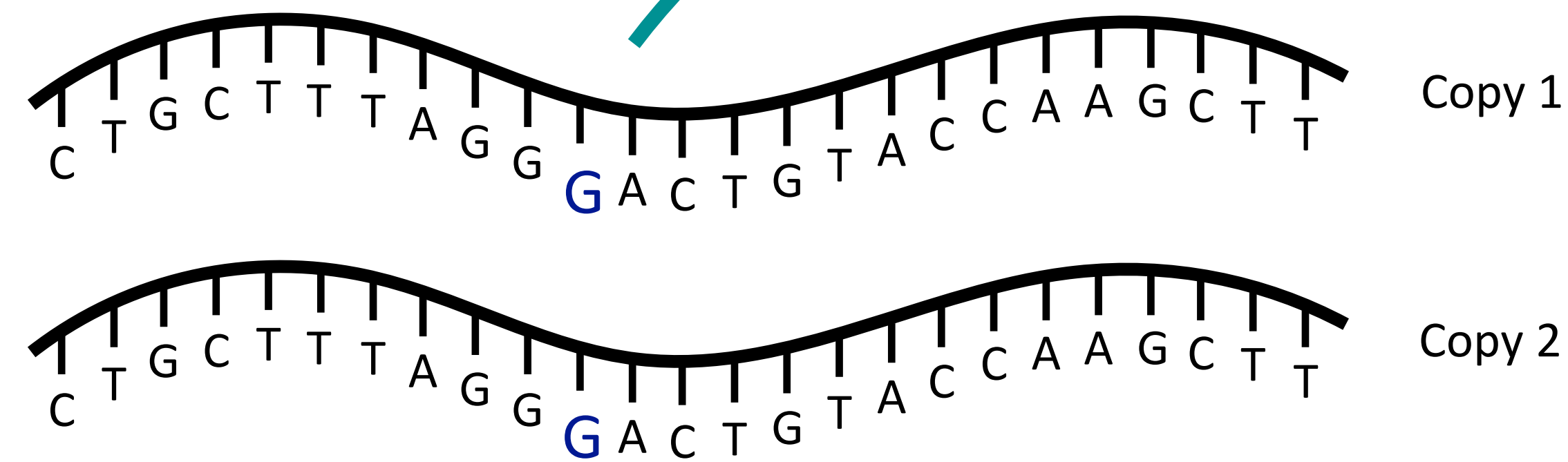
P. floridanus



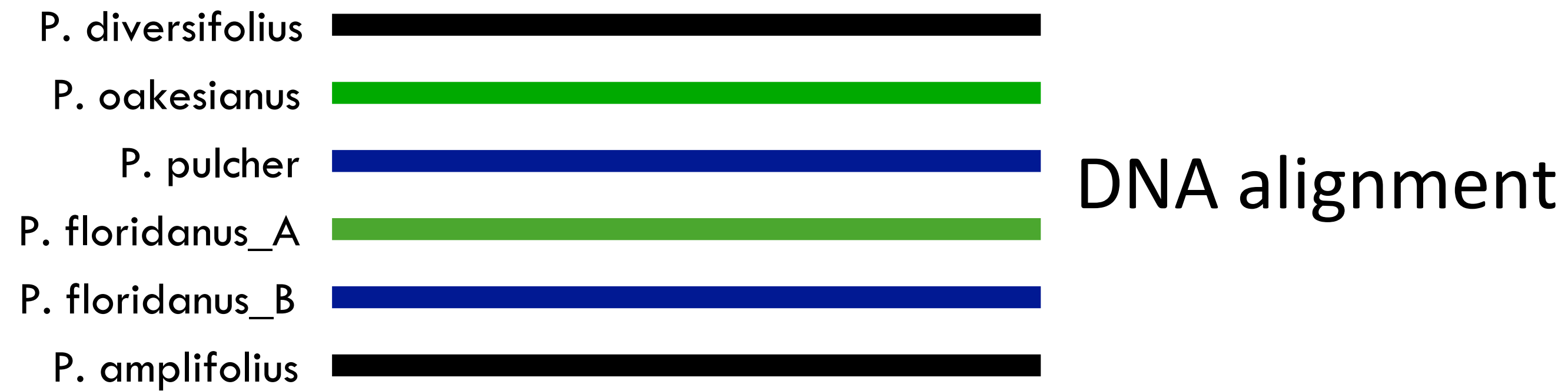
hybridization



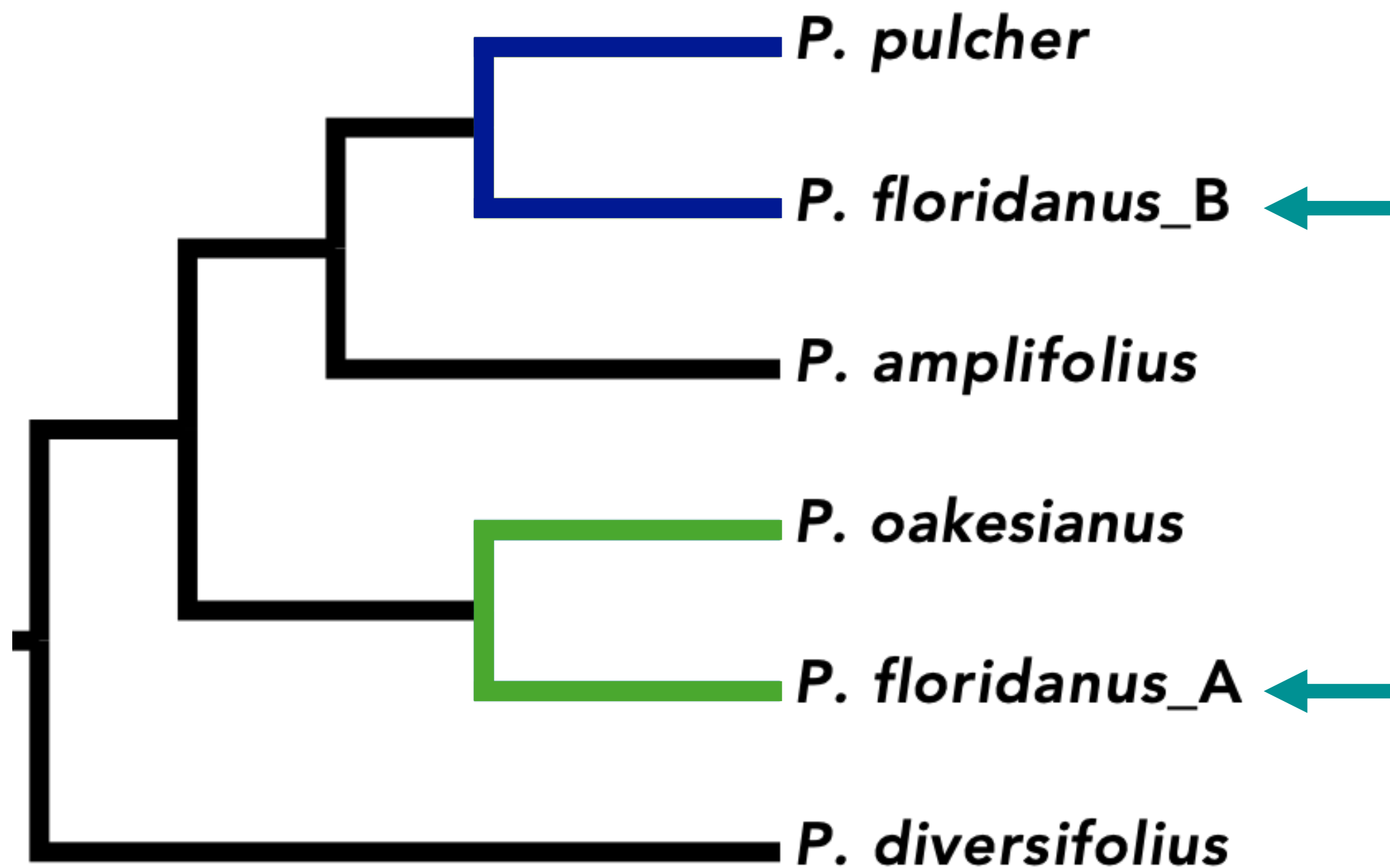
P. pulcher



Genetic signatures of hybridization

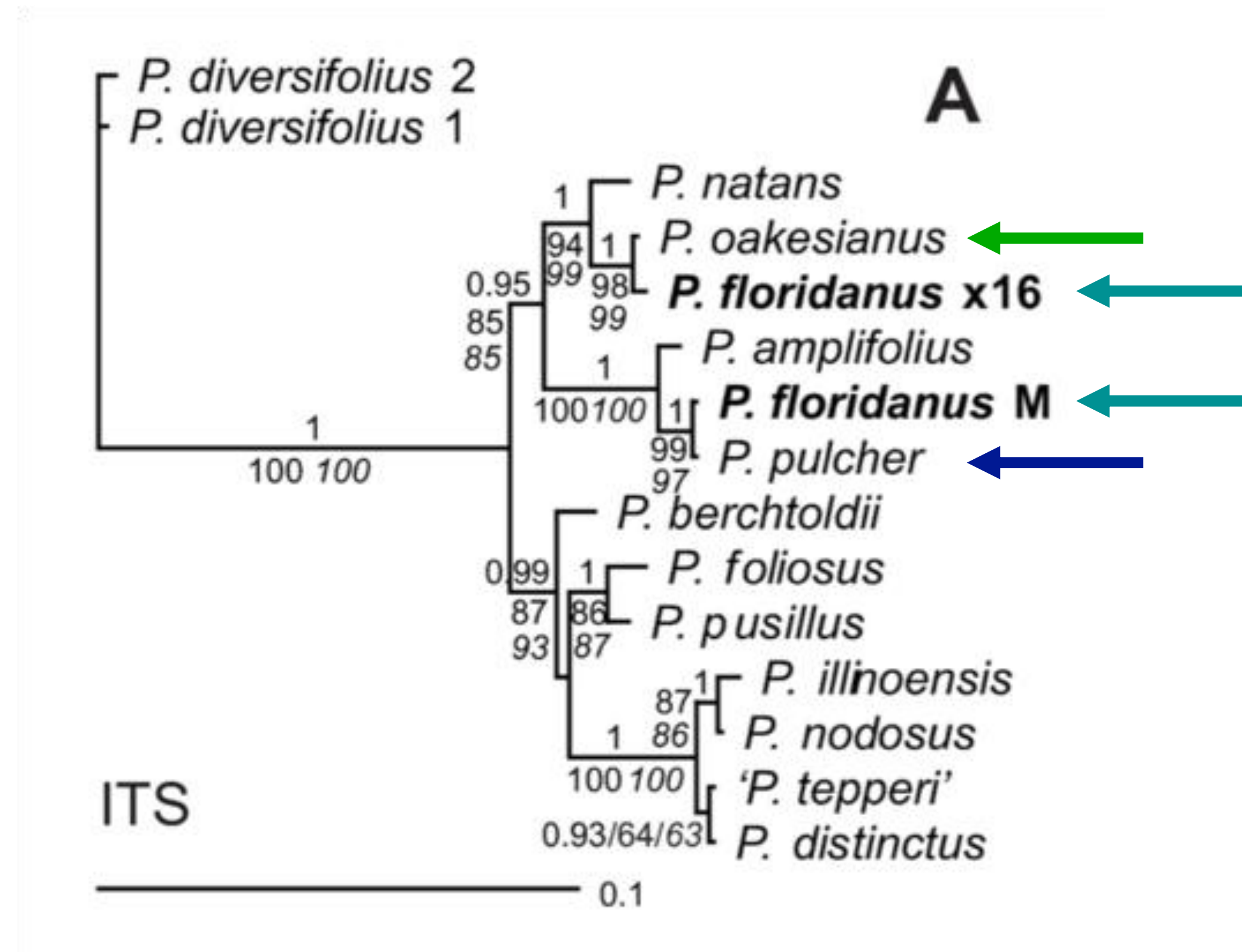


gene tree analysis

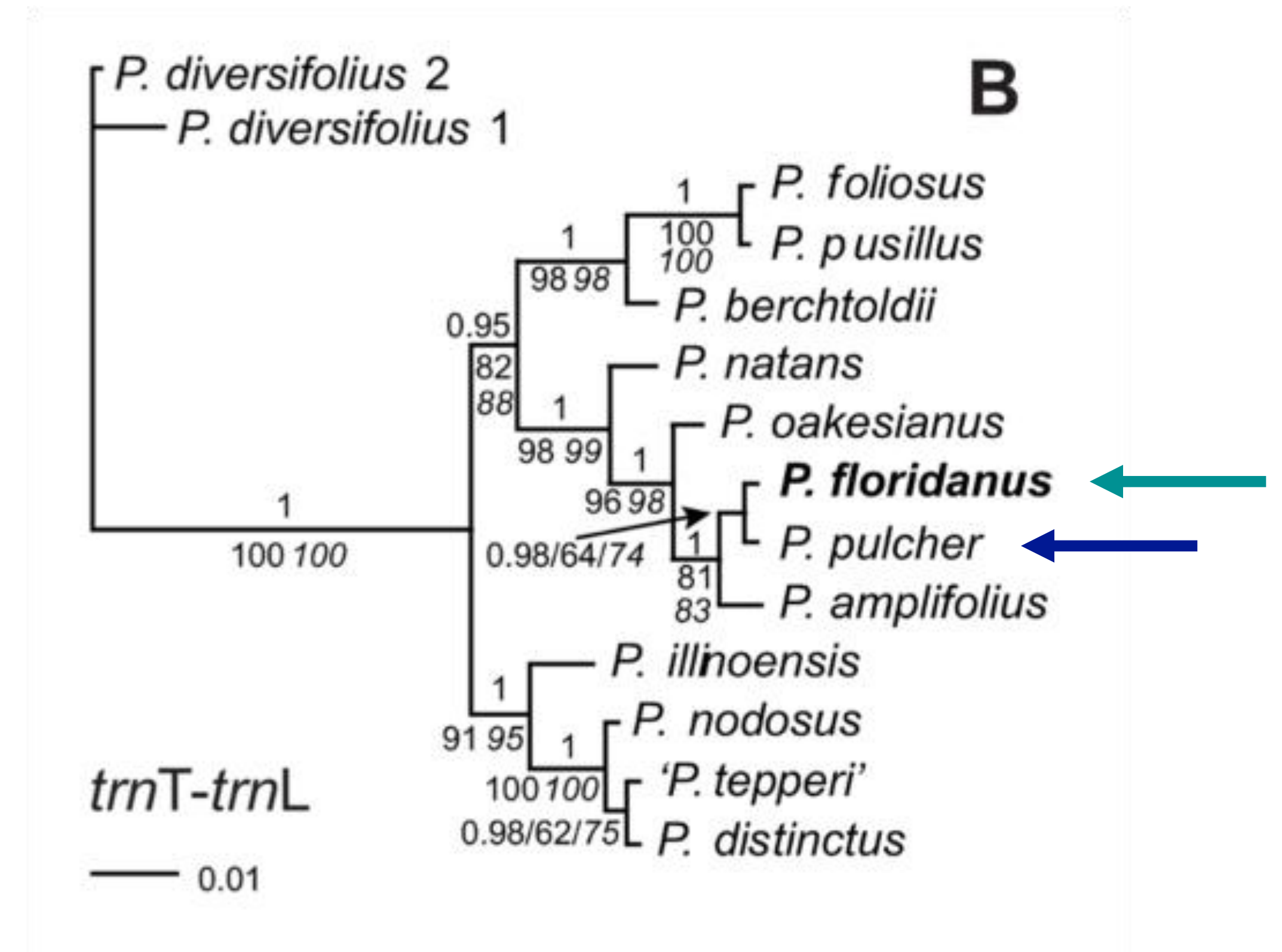


← In a hybrid species, different copies from the same sample will have different relationships to other species in the phylogeny. The closest relative of each copy provides information about the parental lineages.

The Florida pondweed (*Potamogeton floridanus*)

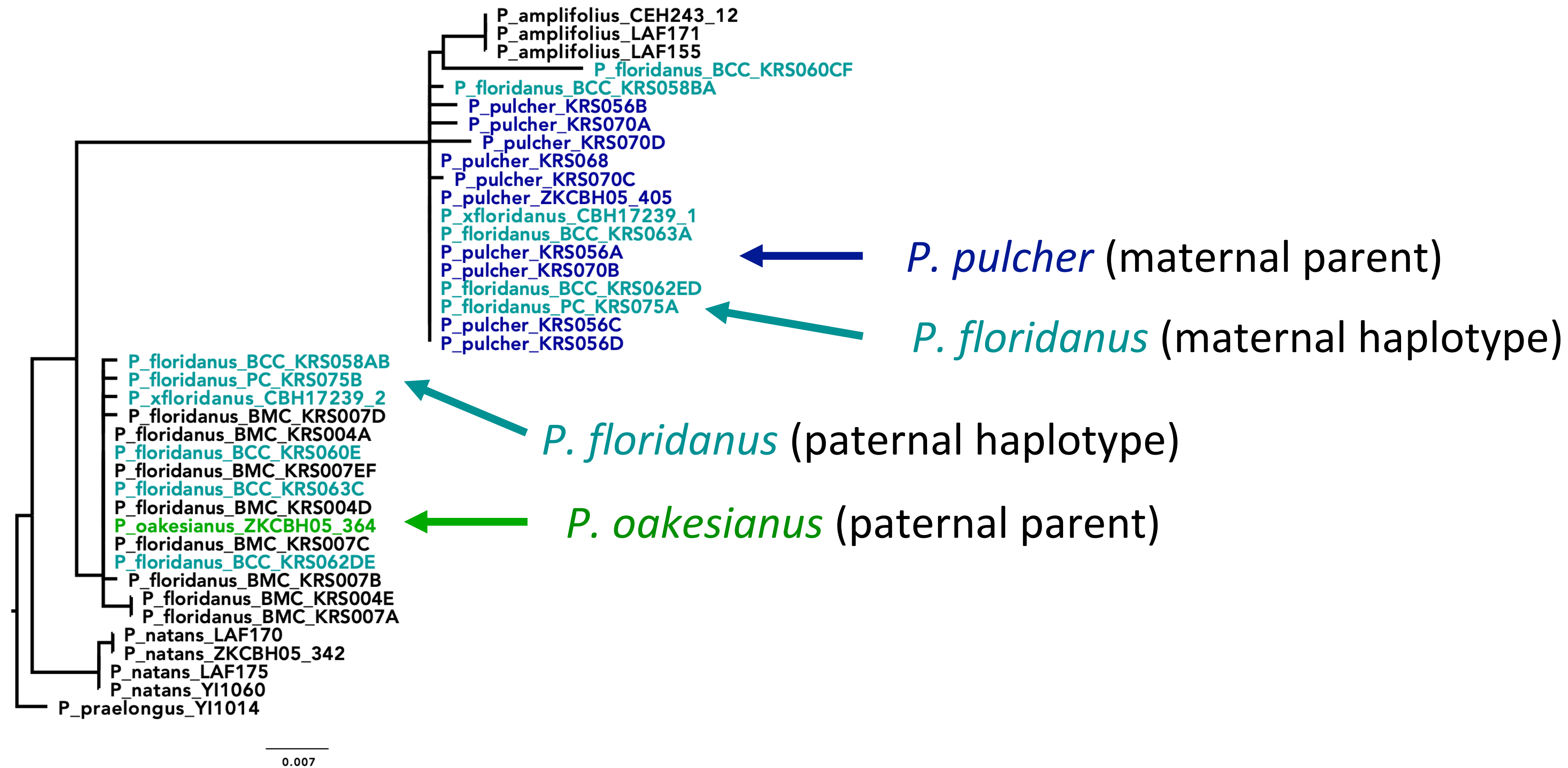


nuclear DNA
bi-parentally inherited



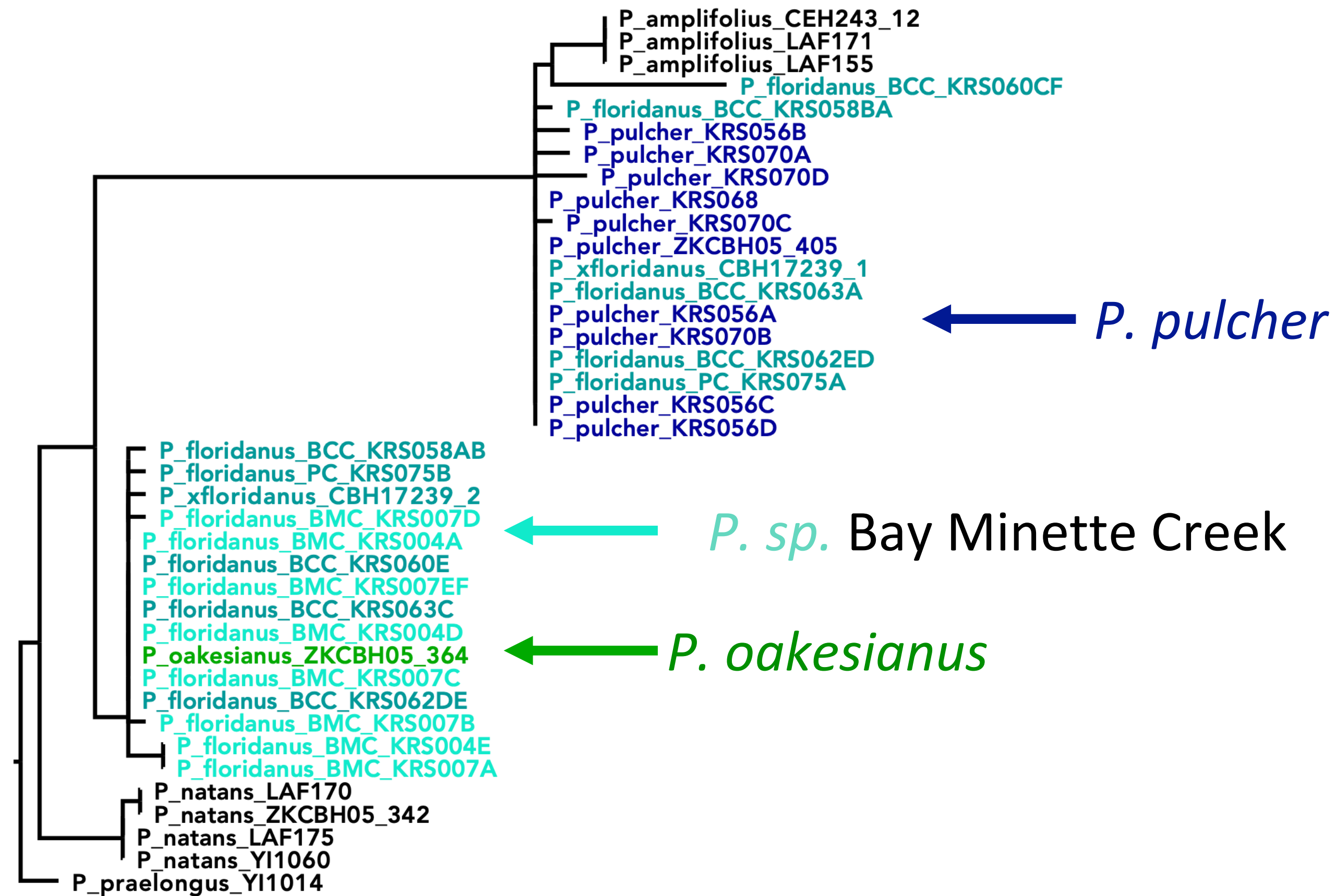
chloroplast DNA
maternally inherited

The Florida pondweed (*Potamogeton floridanus*)



ITS (nuclear DNA)
bi-parentally inherited

The Florida pondweed (*Potamogeton floridanus*)

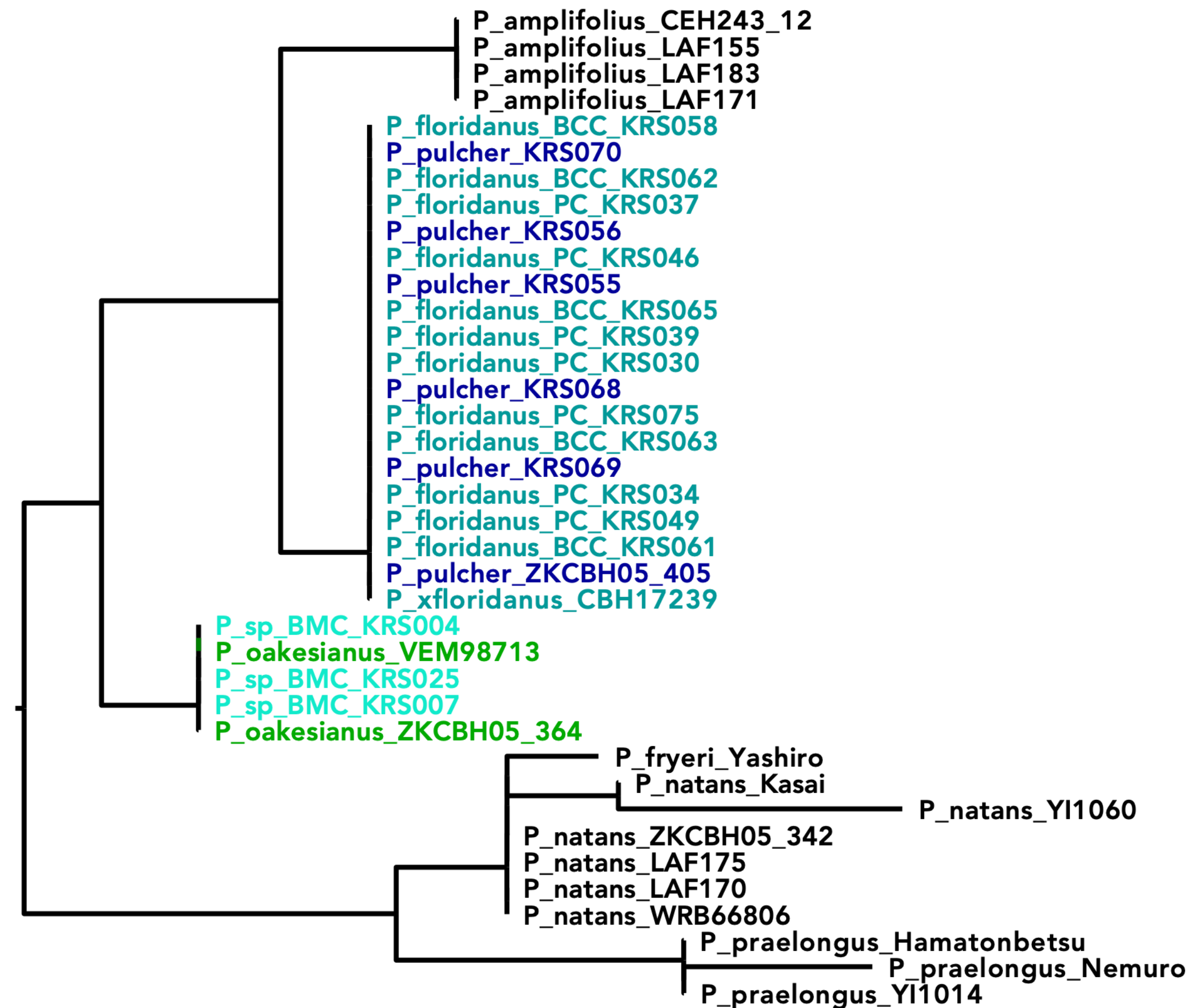


The Bay Minette Creek pondweed does not exhibit the same pattern we saw in populations of *P. floridanus*.

All haplotypes are most closely related to *P. oakesianus*.

ITS (nuclear DNA)
bi-parentally inherited

The Florida pondweed (*Potamogeton floridanus*)

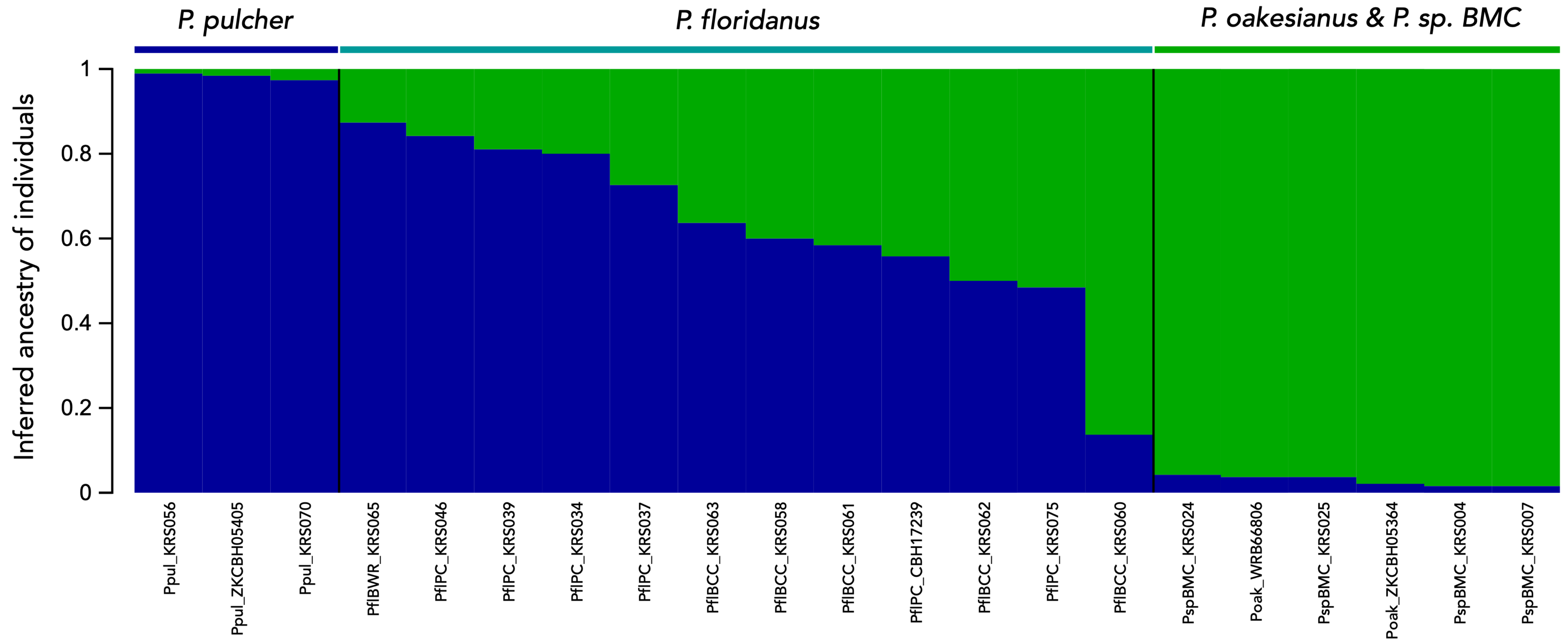


0.002
trnT-L (chloroplast DNA)
maternally inherited

Relationships inferred from chloroplast data for all populations of *P. floridanus* are consistent with *P. pulcher* being the maternal parent.

The Bay Minette Creek pondweed again shows affinity for *P. oakesianus*. If it is a hybrid, it could represent a separate hybridization event.

The Florida pondweed (*Potamogeton floridanus*)



The Bay Minette Creek pondweed is genetically indistinguishable from *P. oakesianus*

The Florida pondweed (*Potamogeton floridanus*)

Summary:

The Bay Minette Creek pondweed is unlikely to be a hybrid, but may be a relict population of *P. oakesianus* from Pleistocene glacial movement.

It is possible that the Bay Minette Creek population is the paternal parent of *P. floridanus*. More fine-scale genetic research of *P. oakesianus* and the Bay Minette Creek population is needed to address this.

Similarly, more genetic markers are needed to produce a time-calibrated phylogeny to test if hybridization occurred during the Pleistocene or more recently

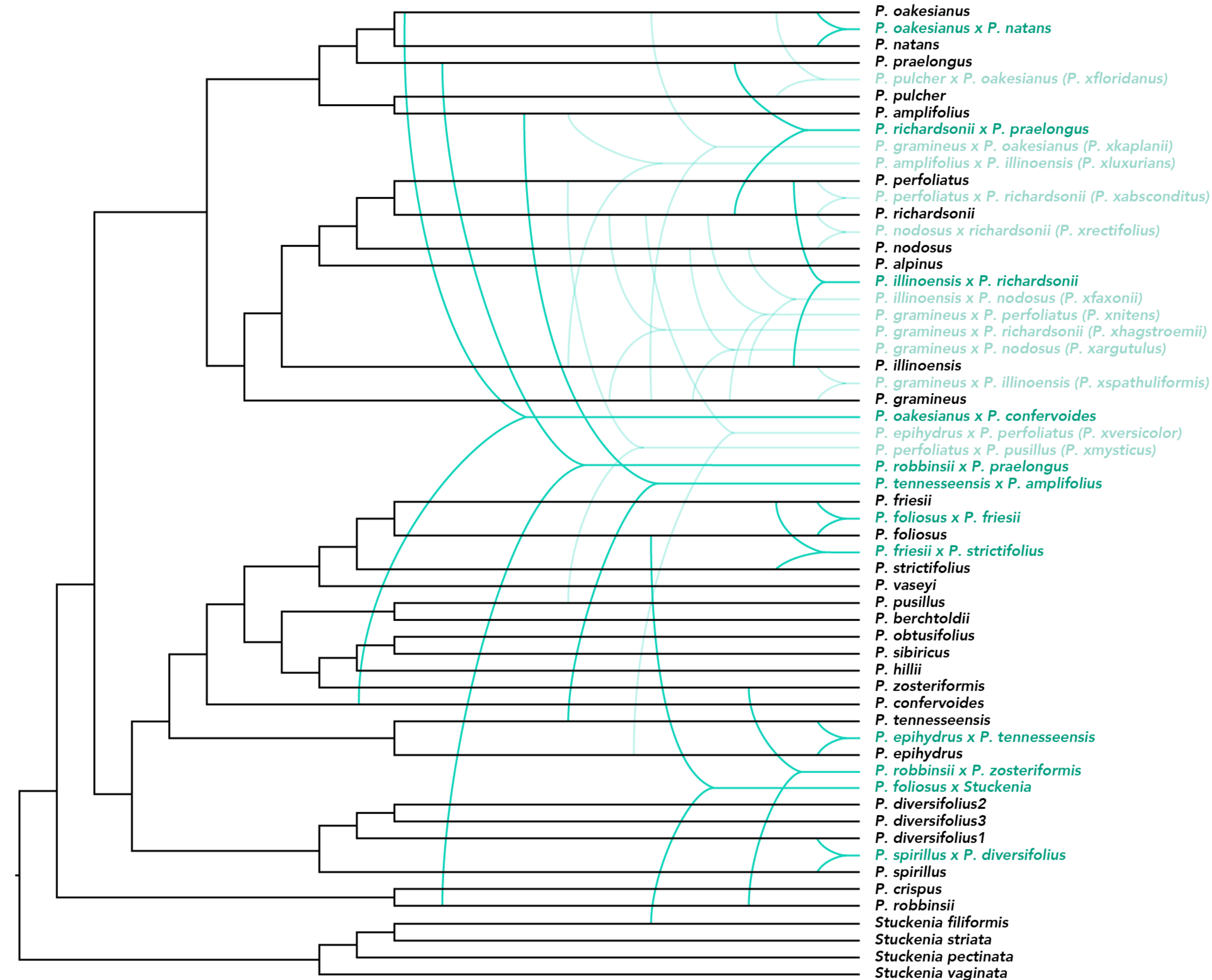
Phylogenomic Data Collection

- 288 samples of North American pondweeds representing 29 discrete species and 9 described hybrids
- 2 runs on an Illumina NextSeq 2000: 1 run for target-enriched libraries, 1 genome skimming run for unenriched libraries
- HybPiper and HybPhaser to assemble target capture data, identify putative hybrids, and phase reads
- Captus to assemble high-copy, off-target regions: cpDNA, nrDNA spacers

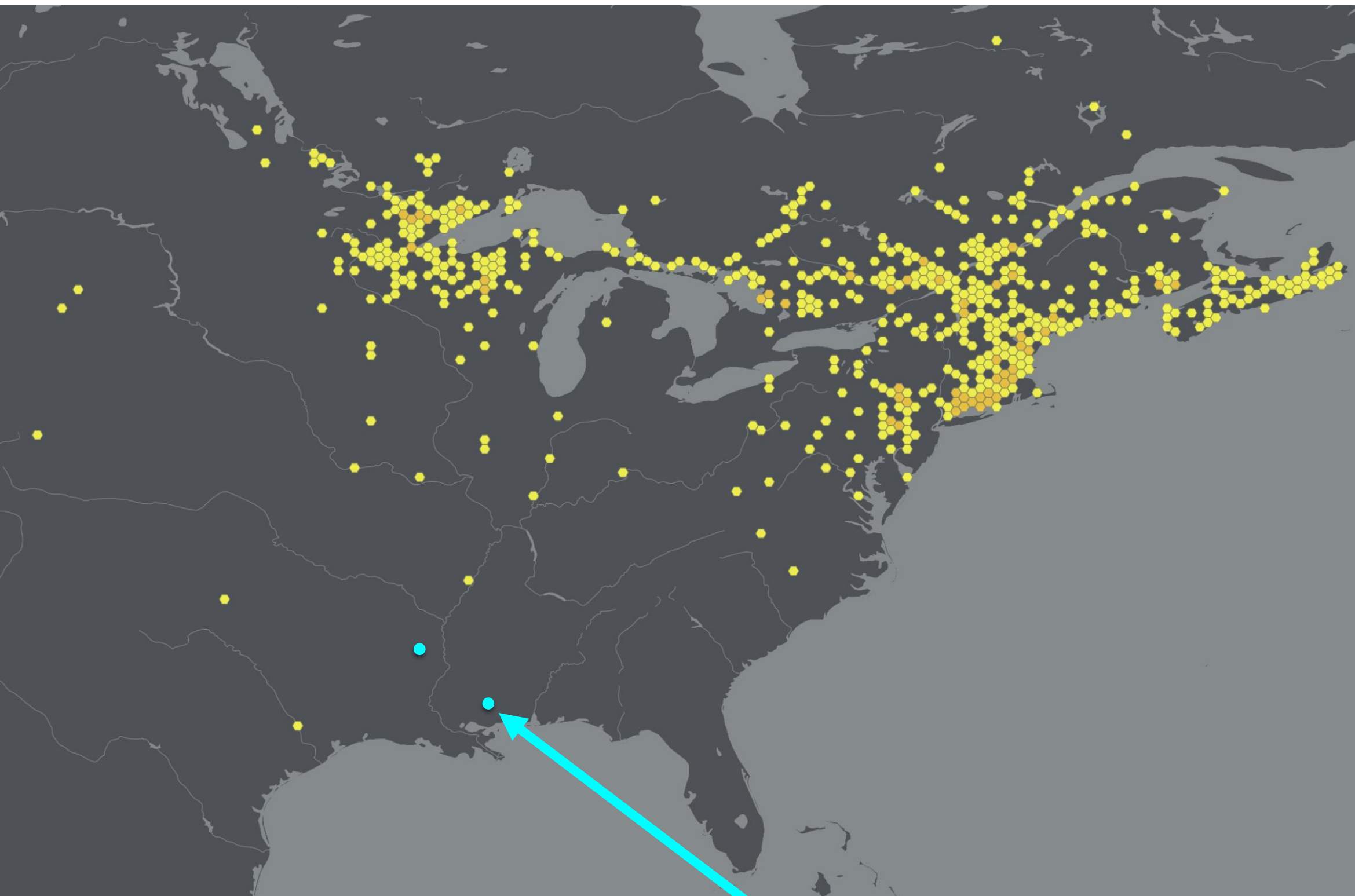
HybPhaser

We identified 24 putative
hybrid combinations

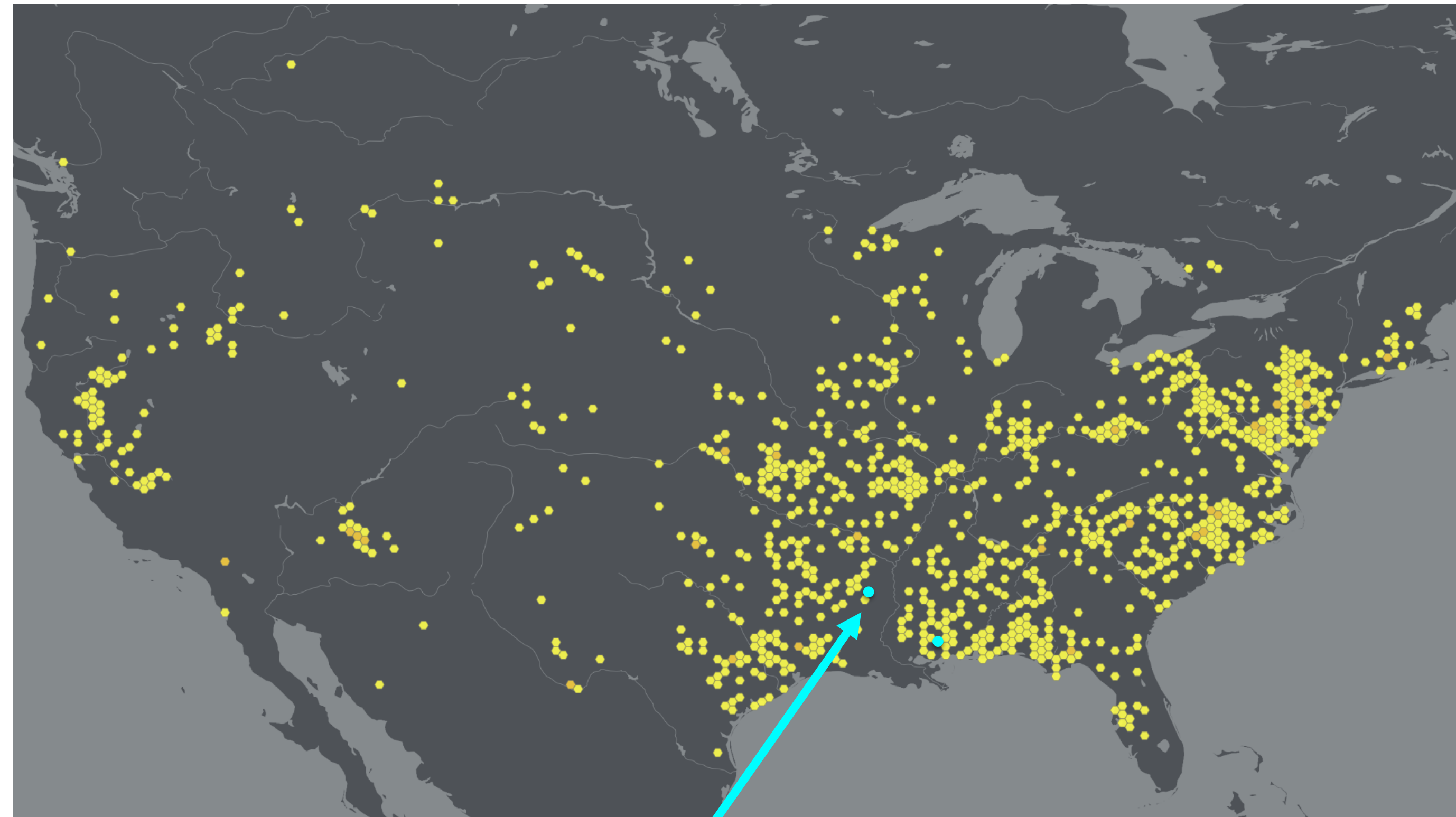
Including 12 novel hybrid
combinations!



P. spirillus distribution

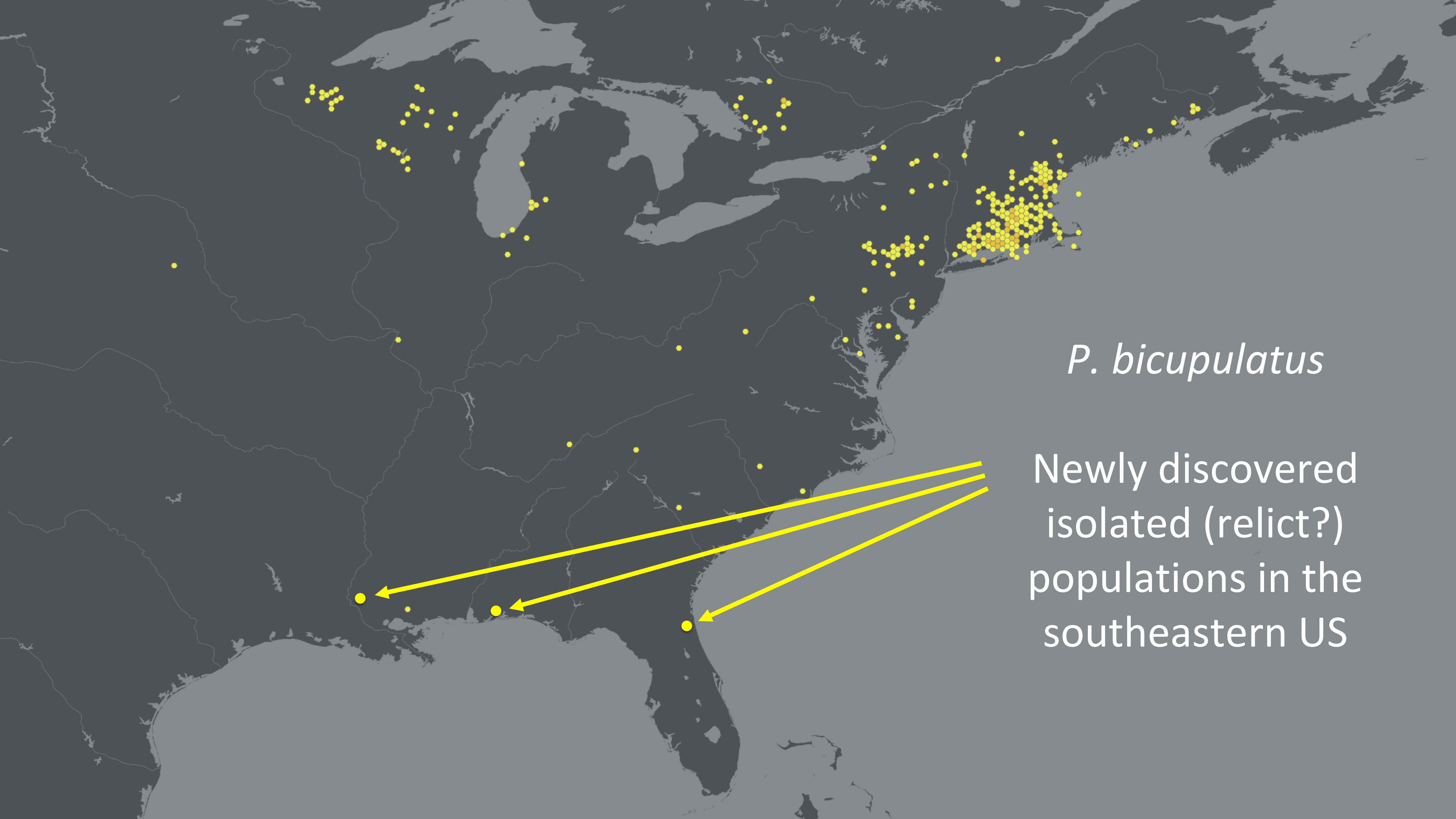


P. diversifolius distribution



P. spirillus x *P. diversifolius*

Newly discovered (possibly orphaned) hybrid in the southeastern US



P. bicupulatus

Newly discovered
isolated (relict?)
populations in the
southeastern US

Conclusions

We have a lot to learn about pondweeds!

Pondweed diversity is likely under-described in the southeastern US

In addition to filling knowledge gaps about biodiversity in the NACP, this research provides the opportunity to learn more about broad-scale evolutionary patterns and processes that contribute to the high diversity in the NACP.

Implications for conservation

Pondweed hybrids are numerous and can be ecologically important, but are not eligible for many types of protection due to their hybrid status. Policies should consider hybrids for protection.

As the climate warms, relict populations of discrete species in the southeastern US may provide gene pools adapted to warmer waters.

Anecdotally, we have observed that pondweed populations seem to be outcompeted by *Myriophyllum spicatum*. Narrowly-distributed, orphaned hybrids and relict populations are increasingly threatened as we just begin to discover them.

Thank you!

Kaitlyn Mitchell
Haley Nichols
Laymon Ball

Howard Horne
Ana Maria Bedoya
Jeremiah Henning



NYBG

