

A BLACK BOTANIST UNDERSTANDING *ECHINACEA* CONSERVATION  
THROUGH A PHYLOGENETIC LENS

by

CHAZZ JORDAN

(Under the Direction of Jim Leebens-Mack)

ABSTRACT

In this thesis, I combine whole plastome sequences and nuclear gene capture data to reconstruct species relationships and characterize the pace of diversification across the genus. With more sampling of intraspecific variation in both the plastome and nuclear data, I find evidence for interspecific gene flow and must reject the previously hypothesized early split between *Echinacea* lineages including species with ranges centered in the eastern and midwestern U.S. I will also use this thesis to discuss some of the experiences surrounding Black graduate students, particularly, experiences that have impacted me while performing my research on target capture sequencing to further resolve the speciation history of *Echinacea*. These experiences include: 1) Lack of social safety and isolation for Black and Brown students in a predominantly white institution (PWI) and 2) Issues for Black and Brown students regarding field safety and field work in the rural south.

INDEX WORDS: *Echinacea*, conservation genetics, phylogenetics, target capture, Black botanist, field safety, field work, predominately white institution (PWI)

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## TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS .....	iv
LIST OF FIGURES .....	viii
CHAPTER	
1 A BLACK BOTANIST UNDERSTANDING <i>ECHINACEA</i> CONSERVATION THROUGH A PHYLOGENETIC LENS.....	1
Introduction.....	1
2 UTILIZING TARGET CAPTURE SEQUENCING TO FURTHER RESOLVE THE SPECIATION HISTORY OF <i>ECHINACEA</i> (ASTERACEAE) .....	5
Abstract .....	6
Introduction.....	6
Study System .....	9
Methods.....	10
Results.....	13
Discussion.....	15
Conclusion .....	17
3 TO SUPPORT AND ACHIEVE BIODIVERSITY SCIENTIFICALLY, DIVERSITY MUST BE SUPPORTED SOCIALLY.....	27
Abstract .....	28
Introduction.....	30

Positionality Statement .....	35
Lack of social safety and isolation for Black and Brown students in a predominantly white institution (PWI) .....	36
Issues for Black and Brown students regarding field safety and field work in the rural south .....	41
Conclusion .....	46
4 A BLACK BOTANIST NOW UNDERSTANDS <i>ECHINACEA</i> CONSERVATION THROUGH A PHYLOGENETIC LENS.....	55
Conclusion .....	55
REFERENCES .....	58
APPENDIX	
Table of sampled taxa for hybridization sequencing with Compositae ParaLoss-1272 bait set .....	72

LIST OF FIGURES

	Page
Figure 2.1: <i>Echinacea</i> species and Nature Serve status rankings .....	19
Figure 2.2: Study Samples .....	20
Figure 2.3: Range map of all <i>Echinacea</i> species .....	21
Figure 2.4: Compositae-ParaLoss-1272 bait set on <i>Echinacea</i> .....	22
Figure 2.5A: <i>Echinacea</i> species tree.....	23
Figure 2.5B: <i>Echinacea</i> species tree.....	24
Figure 2.6: <i>Echinacea</i> plastome tree.....	26
Figure 3.1: Factors that can impact Black students who are part of historically marginalized groups.....	53

## CHAPTER 1

### A BLACK BOTANIST UNDERSTANDING *ECHINACEA* CONSERVATION THROUGH A PHYLOGENETIC LENS

#### Introduction

The sunflower family (Asteraceae) represents 10% of all flowering plant species encompassing more than 25,000 species (Mandel et al. 2017). The evolution of the capitulum, or flower head, is assumed to have given rise to the hyperdiversity of Asteraceae (Mandel et al. 2019). Particularly in Asteraceae, historically species are easy to hybridize, and species have rapidly diversified throughout the history of the family (Mandel et al. 2019). Due to this, it has been difficult to resolve relationships among many important lineages (Mandel et al. 2019). While many common species exist within the family, given its size, it is safe to say that, a significant fraction of species likely exhibit some form of rarity. For example, based on the NatureServe database, all *Echinacea* species exhibit some degree of rarity within state and global levels, and six of the nine species in the genus are ranked as globally G2 (imperiled) or G3 (vulnerable). In the NatureServe database, species are described globally, nationally, and sub-nationally with a rank between one (most imperiled) to five (most secure). Phylogenetic analyses can inform conservation efforts for rarer species exhibiting narrow species ranges, habitat specialization, and lower local abundances. Phylogenetic analyses can also contribute to taxonomic clarification, identification of unique and recently diverged lineages, determining species value for conservation priority, as well as, informing comparisons between rare and widespread species (Byrne 2003).

Past phylogenetic studies have been conducted to resolve evolutionary relationships in *Echinacea* but have relied heavily on variation in the plastid genome. This has resulted in many relationships remaining poorly resolved (Flagel et al. 2008) even with the use of whole plastomes (Zhang et al. 2017). While plastid genomes have been widely utilized to resolve species relationships, the plastid genome evolves slowly relative to genes in the nuclear genome, and the plastome is typically inherited as a single unit without recombination (Doyle 2022). Phylogenomic analyses using a combination of plastid data and nuclear gene data are more informative, not only with respect to resolution of species relationships, but more importantly, in yielding information on the pace and nature of diversification (Winter, Devictor, and Schweiger 2013). Such analyses can also help set conservation priorities for rare endemic species, including *E. laevigata* and *E. tennesseensis* among other *Echinacea* species listed as imperiled at the state of global level.

Given this information, in Chapter 2, my aim is to reconstruct species relationships and characterize the pace of diversification to 1) examine radiations that spawned diversification of extant *Echinacea* species found in the Southeast and Midwest (Flagel et al. 2008; Zhang et al. 2017) and 2) assess concordance and discordance between nuclear and plastid genome histories in this genus. My hypothesis is that the inclusion of nuclear data increased sampling within species in our phylogenomic analyses will more accurately resolve the evolutionary history of *Echinacea* and therefore, contribute to taxonomic clarification of the genus and add information supporting the conservation priority of *Echinacea* species.

Furthermore, while I now understand target capture and how this technique can be used for my methodology in Chapter 2, it is important to acknowledge that I am a Black botanist and a Black academic. Specifically, I am a Black, queer, female presenting scholar and scientist whose

journey to perform this research has been heavily impacted by lack of field safety during field work in the rural south as well as social safety and isolation at a predominantly white institution (PWI).

During my time in graduate school, I deliberated on why I was one of the only African Americans in my department and one of very few in my field. I learned that the first African American to receive their PhD in Evolutionary Biology was Dr. Joseph Graves in 1988 (Graves 2019), which is fairly recent. Currently, this field continues to be dominated by white scientists which is seen in demographic statistics released annually by the National Science Foundation (NSF). In 2017, the NSF released a report stating the professional biology workforce was 69.5% white, while only 3% of that workforce is Black or African American. Black women, a combination of 2 demographics that have been historically underrepresented, encompass only 2% of practicing scientists and engineers as a result of issues Black women face early in their STEM career path (Ebony O. McGee and Bentley 2017) NSF 2015). Until my last semester of graduate school, I have been the only African American graduate student in my department. I will also be the first African American graduate student in my department to receive a degree since the department's creation. The department's first African American professor did not join the department until 3 years into my graduate degree.

The need to diversify the STEM field has been prevalent for decades; however, why is there still such little diversity to where my demographic encompasses only 2% of practicing scientists? Partially, I believe that it is due to the fact that wanting diversity and actually obtaining and retaining that diversity are very different objectives. Guaranteeing both recruitment and retention of people from a diversity of backgrounds within these fields requires a focus on understanding social identities that have been historically marginalized and the

intersectionality between demographic factors (Beltran et al. 2020; Demery and Pipkin 2020; Eaton et al. 2020).

In my third chapter, my aims are to discuss literature and experiences surrounding: 1) Social safety and isolation for Black and Brown students in a PWI and 2) Issues for Black and Brown students regarding field safety and field work in the rural south. My objectives were to: 1) conduct a literature review of research surrounding field safety and social safety for Black and Brown students and 2) create a piece focused on personal experiences and perspectives regarding field safety and social safety for Black and Brown students. While I have learned many skills and life lessons in this early career stage, the journey has also been both trying and unkind. For this chapter, I thought it would be beneficial and healing to talk about my experiences as a Black scientist and botanist at a PWI.

I believe that there are systemic issues in academia, particularly higher education; however, I understand that a singular graduate student or even a group of graduate students will not solve a systemic issue. I believe that utilizing a mutual aid framework would be useful for department heads, coordinators, and administrators to utilize in order to make the culture of academia less hostile and toxic towards POC graduate students, especially Black graduate students. A mutual aid framework would allow collective coordination to meet needs of groups of people, like Black and Brown graduate students, and would signal to those students that the department and those within it have a shared understanding that the academic system in place is unjust and that most needs may not be met without intervention (Spade 2020).

## CHAPTER 2

### UTILIZING TARGET CAPTURE SEQUENCING TO FURTHER RESOLVE THE SPECIATION HISTORY OF *ECHINACEA* (ASTERACEAE)

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## Abstract

It has been difficult to resolve relationships among many important lineages within the Asteraceae family due to interspecific hybridization and rapid species diversification throughout the history of the family. Previous efforts to resolve evolutionary relationships among *Echinacea* species have relied heavily on variation in the plastid genome with limited analysis of nuclear loci. In this study, we combine whole plastome sequences and nuclear gene capture data to reconstruct species relationships and characterize the pace of diversification across the genus *Echinacea*. With more sampling of intraspecific variation in both the plastome and nuclear data, we find evidence for interspecific gene flow and reject the previously hypothesized early split between *Echinacea* lineages, including species with ranges centered in the eastern and midwestern U.S. At the same time, we find evidence for rapid radiation early in the history of *Echinacea* in agreement with previous studies. Our findings have implications for *Echinacea* conservation and trait evolution in the genus.

## Introduction

Rare plant species constitute up to a third of global plant diversity (Enquist 2019) and they are important indicators for conservation initiatives as they can perform critical ecological functions, such as contributing to community stability (Säterberg et al. 2019). Considering the three axes of rarity defined by Rabinowitz (1981), the rarest species display highly restricted geographic distributions, low local abundance, and extreme specialization to uncommon habitats (e.g. Rabinowitz et al. 1986; Broennimann et al. 2005; Anacker et al. 2013). Comparative studies, especially those employing rigorous phylogenetics approaches, can elucidate diversification history and the processes contributing to both diversification and rarity (e.g. Molina-Venegas et

al. 2020; Romeiro-Brito et al. 2023; Kress et al. 2025). For example, macroevolutionary analyses can test whether extant species diversity has been influenced by past adaptive radiations (Lunau 2004), and reveal how the diversification of trait combinations following interspecific hybridization can spur rapid speciation (Flagel et al. 2008; Jackson et al. 2000).

The sunflower family (Asteraceae) comprises more than 25,000 species representing 10% of all flowering plant species (Mandel et al. 2017). The evolution of the capitulum, or flower head, is hypothesized to have contributed to the hyperdiversity of Asteraceae (Mandel et al. 2019). Given its size, it is safe to say that while many common species exist within the family, a significant fraction of species likely exhibit some form of rarity. In the NatureServe database, species are described globally, nationally, and sub-nationally with a rank between one (most imperiled) to five (most secure). The genus *Echinacea* Moench includes nine accepted species (Plants of the World Online 2025, Flora of North America 1993+), in which all species outcross and most species having bright pink and purple ray florets within capitulum heads (Kindscher 2006, McGregor 1968). Species range sizes vary from the highly restricted range of *E. tennesseensis* (Beadle) Small, endemic to the cedar glades of 6 counties in central Tennessee, to the broad range of *E. purpurea* (L.) Moench, encompassing the eastern half of the United States (McGregor 1968). All *Echinacea* species exhibit some degree of rarity (critically imperiled (S1), imperiled (S2) or vulnerable (S3)) in at least one state within the U.S. (NatureServe), and six of the nine species in the genus are ranked as globally imperiled (G2) or vulnerable (G3) (**Fig. 2.1**). Morphologically, *Echinacea* exhibits among species variation in flower color, stem and leaf trichome density, capitulum size, and number per individual (Kindscher 2006, McGregor 1968).

It has been arduous to resolve relationships among many important lineages within the Asteraceae due to hybridization and rapid species diversification throughout the history of the family (Mandel et al. 2019). Phylogenetic analyses can inform conservation efforts for rarer species exhibiting narrow species ranges, habitat specialization, and lower local abundances (e.g. Molina-Venegas et al. 2020; Romeiro-Brito et al. 2023; Kress et al. 2025). Phylogenetic analyses also contribute to taxonomic clarification, identification of unique and recently diverged lineages, determining species value for conservation priority, as well as, informing comparisons between rare and widespread species (Byrne 2003).

Previous phylogenetic analyses of *Echinacea* have relied heavily on variation in the plastid genome. This has resulted in many relationships remaining poorly resolved (Flagel et al. 2008) even in analyses of whole plastomes (Zhang et al. 2017). Plastid genomes have been widely utilized to resolve species relationships, but the plastid genome evolves slowly relative to genes in the nuclear genome, and the plastome is typically inherited as a single unit without recombination (Doyle 2022). Moreover, evolving as a single locus, the evolutionary history of the plastid genome may not match the history of speciation due to incomplete lineage sorting (ILS) (Degnan and Rosenberg, 2009) and interspecific gene flow (e.g. Baldwin et al. 2023). Genome scale multispecies coalescence analyses using many nuclear gene loci can improve resolution of species relationships while providing insights into the pace and nature of diversification (Winter, Devictor, and Schweiger 2013). Such phylogenomic investigations can also help set conservation priorities for rare endemic species (Rokas et al. 2005), including *E. laevigata* (C.L. Boynton & Beadle) S.F. Blake and *E. tennesseensis* among other *Echinacea* species listed as imperiled at the state of global level (**Fig. 2.1**).

Few studies have utilized nuclear data to resolve relationships among all *Echinacea* species, and species relationships have not been well supported in studies that have used nuclear loci AFLP markers (Still, Kim, and Aoyama 2005); *Adh* + *CesA* + *GPAT* (Flagel et al. 2008); *ITS* + *trnH-psbA* (Zhang et al. 2017); SCoT markers (Jedrzejczyk 2020)). Robust understanding of species relationships is critical given conservation concerns for *Echinacea* species (**Fig. 2.1**). The primary objective of this study is to reconstruct *Echinacea* species relationships under the multispecies coalescent and assess whether internal branch lengths in the estimated species tree imply periods of rapid diversification in the genus (Flagel et al. 2008; Zhang et al. 2017). In addition, we assess the degree of concordance between species tree estimated using nuclear loci and the plastid genome tree. We hypothesize that our phylogenomic analyses will elucidate the evolutionary history of *Echinacea* and contribute to conservation management plans for species across the genus.

### Study System

*Echinacea* is a genus of outcrossing plants endemic to the United States with species known for their bright floral colors, generalist pollinators, and medicinal properties ( **Fig. 2.1**; McKeown 1999). While there is much research surrounding the medicinal and ecological attributes of *Echinacea* (Hensel et al. 2020; Manayi, Vazirian, and Saeidnia 2015), there are fewer phylogenetic investigations of species relationships across the genus (Flagel et al. 2008; Jedrzejczyk 2020; Zhang et al. 2017). At the same time, the relatively small size of the genus enables genus-wide investigations of *Echinacea* speciation (Flagel et al. 2008; Zhang et al. 2017). There are nine *Echinacea* species (Flagel et al., 2008, Plants of the World Online 2025,

Flora of North America 1993) that vary in flower size and flower color (Wagenius and Lyon 2010) (**Fig 2.1**). All *Echinacea* species outcross, have the ability to hybridize where species ranges overlap (McGregor 1968; Sassana et al. 2014), and rely on flying insect pollinators for reproduction (McGregor 1968; Kindscher 2006). Moreover, *Echinacea* populations are important components of threatened prairie ecosystems throughout the eastern half of the United States, including tallgrass, mixed-grass, short grass prairie communities, as well as open habitats like limestone glades and hill sides (Wagenius and Lyon 2010, Kindscher 2006, McGregor 1968).

## **Methods**

### **Taxon sampling**

Samples for all *Echinacea* species – *E. angustifolia* DC., *E. atrorubens* (Nutt.) Nutt., *E. laevigata*, *E. pallida* (Nutt.) Nutt., *E. paradoxa* Britton, *E. purpurea*, *E. sanguinea* Nutt., *E. simulata* McGregor, and *E. tennesseensis* – were included in our phylogenomic analyses (**Fig. 2.2, Fig. 2.3**) along with available sequences for three closely related species in the Heliantheae Cassini tribe – *Helianthus annuus* L., *H. argophyllus* Torr. & A.Gray, and *Parthenium argentatum* A.Gray (Mandel et al. 2019) serving as outgroup taxa for phylogenomic analyses. Sequence data for the three outgroup samples were extracted from NCBI's sequence read archive (SRA) database (**Appendix 1**).

### **DNA isolation and library creation**

DNA was extracted from silica-dried, snap frozen, and herbarium leaf tissue samples (**Appendix 1**) using QIAGEN Plant Pro Kits and a Qubit 2.0 fluorometer broad-range assay was used to

assess DNA concentrations. Shotgun sequencing libraries were constructed using Roche KAPA HyperPlus Library Kits with universal Y-yoke stub adapters (30 Mm) and dual indexed iTru primers (Glenn et al. 2019). Double stranded DNA was fragmented for 6 min and kept at 4°C for 5 min, aiming for an average fragment size between 500 – 600 bp for sequencing preparation. The DNA is then end-repaired using an A-tailing reaction for 30 minutes at 35 °C before ligation. Universal stub adapters were then ligated to the A-tailed overhangs in an overnight incubation at 20°C, followed by a post-ligation 0.8X KAPA HyperPure bead cleanup. The cleaned ligation product was then amplified for 6 PCR cycles with the Roche Company KAPA HiFi HotStart Ready Mix and dual ended primers (i5, i7) followed by a post amplification 1x bead cleanup using KAPA HyperPure Beads (Roche) to remove free oligonucleotides and smaller fragments. Library fragment size distributions were measured using Bioanalyzer High Sensitivity DNA Kits (Agilent Technologies) and DNA concentration (mean nM) were quantified through real-time PCR (qPCR), using KAPA Library Quantification kits and KAPA SYBR Fast qPCR Master Mix (Roche). Concentration estimates of each library were size corrected using the following formula:

$$x = \frac{452}{\frac{\text{mean fragment size}}{\text{mean nM}}}$$

They were then converted from nM to ng/uL using the following formula:

$$x = \frac{660 * \text{mean fragment size} * \text{size corrected nM}}{1,000,000}$$

### **Hybridization and sequencing**

Libraries were pooled (10 – 13 libraries per pool), with a target input of 150 – 200 ng from each library, and pools were bead-cleaned using 0.8x using KAPA HyperPure Beads (Roche). Pools were eluted from the beads in 100 uL of H<sub>2</sub>O and SpeedVac™ (Savant) concentrated to 7 uL as described in the Arbor Biosciences Hybridization Capture protocol. Each pool was incubated at 60 °C for 24 hours with 5.5 uL of the Compositae-ParaLoss-1272 target capture baits (Moore-Pollard, Jones, and Mandel 2023). Following bait capture, hybridization reactions were amplified for 14 PCR cycles to enrich for targets, followed by a 0.8x bead cleanup for purification.

Fragment size distributions for target-enriched libraries were assessed using Bioanalyzer High Sensitivity DNA chips (Agilent Technologies) and qPCR. Hybridization pools were combined for a final concentration of 10mM for sequencing. Sequencing on the Illumina NovaSeq X Plus platform was performed through the SeqCenter (Pittsburgh, PA) sequencing service provider.

### **Target sequence recovery and assembly**

All HybSeq reads were quality-trimmed using Fastp v.0.23.2 (Chen et al. 2018). Reads that were shorter than 21 bp after trimming were removed. The HybPiper v.2.1.6 pipeline (Johnson et al. 2016) was used to map the filtered reads to target sequences in the Compositae target file (Mandel et al. 2019) and create “supercontig” assemblies for each target locus for each sample.

### **Phylogenomic analysis**

Multiple sequence alignments for each locus were constructed for each target locus using MAFFT v.7.505 (Katoh and Standley 2013) with the “—auto” flag, instructing MAFFT to choose the best alignment strategy to best fit the data. Misaligned sequences were identified and

trimmed using trimAl v.1.4.1 (Capella-Gutiérrez, Silla-Martínez, and Gabaldón 2009).

Maximum Likelihood gene trees with support values were estimated using IQTree v.1.6.12 (Nguyen et al. 2015) with the “-- mfp and -bb ” flags to implement ModelFinder optimization (Kalyaanamoorthy et al. 2017) and the ultrafast bootstrap (Minh, Nguyen, and Von Haeseler 2013) respectively. Species tree estimation was performed using the summary method ASTRAL v.5.7.8 (Mirarab et al. 2014) with the unrooted gene trees as input. The “-t” flag was used to assess quartet scores for each node. Quartet frequencies were visualized as pie diagrams using the R packages GGTree, Ape, and TidyVerse.

### **Utilizing plastome sequences from off-target reads for phylogenetic analysis**

Using a plastome gene target file plastome-encoded genes were extracted from the trimmed target-enriched sequence data as bycatch. Hybpiper v.2.1.6, MAFFT v.7.505, and Trimal v.1.4.1 were used as described above to capture assemble and align plastome sequences. Multiple sequence alignments for 76 plastome-encoded genes were concatenated in Geneious v.2023.2.1 (Kearse et al. 2012) to construct a super matrix. A Maximum Likelihood tree and ultrafast bootstrap support values were estimated on the concatenated alignment using IQTree v.1.6.12 (Nguyen et al. 2015).

1

## **Results**

### **Phylogenomic analysis**

Target capture efficiency ranged between 9–24% for the Compositae-Paraloss-1272 bait set resulting in 1,234 – 1,272 recovered genes per sample (**Fig. 2.4**), and gene trees for all targeted

loci were estimated for the ASTRAL species tree analysis. The species tree inferred from analysis of 1272 nuclear gene trees placed a clade of *E. purpurea* samples as sister to all other *Echinacea* species (**Fig. 2.5**). Most species were found to be monophyletic in the species tree analysis with local posterior probabilities ranging from 0.8 to 1 (**Fig. 2.5**). At the same time, high quartets frequencies for alternative resolutions of each node (Q2 and Q3) implicated a high degree of gene tree - species tree discordance, suggesting rapid diversification and incomplete lineage sorting, particularly along the spine of the species tree (**Fig. 2.5**). Alternative quartet frequencies (Q2 and Q3) are generally balanced as would be expected with incomplete lineage sorting (ILS) (**Fig. 2.5**). Two species, *E. pallida* and *E. angustifolia*, were not recovered as monophyletic. An *E. angustifolia* individual appeared in a clade with *E. paradoxa*, while *E. pallida* samples were scattered among clades containing, *E. sanguinea*, *E. atrorubens* and *E. angustifolia*, and *E. simulata* (**Fig. 2.5**).

### **Utilizing plastome sequences from off-target reads for phylogenetic analysis**

Plastome genes were assembled using off-target reads from the bait capture sequence data. The plastome tree revealed extensive polyphyly for each species (**Fig. 2.6**) and the branch lengths for internodes along the spine were very short (**Fig. 2.6**). Most bootstrap support values along the spine of the plastome tree were low despite the massive length of the concatenated plastome gene alignment including 67,743 bases (**Fig. 2.6**). Interestingly, samples E\_purpurea\_CJ18, E\_angustifolia\_CJ23, and the outgroup species exhibited much longer branch lengths compared to all other ingroup samples.

## Discussion

### High gene recovery with lower percentage of on-target sequence assembly

Here, we analyzed *Echinacea* species relationships based on an analysis of single-copy target capture genes (Mandel et al. 2019; Moore-Pollard, Jones, and Mandel 2023). The large number of recovered genes for this genus indicates that the Compositae-Paraloss-1272 bait set is effective for sunflower family taxa beyond those originally tested (Moore-Pollard, Jones, and Mandel 2023).

### Phylogenomic analysis shows extensive gene tree - species tree discordance

Previous plastome phylogenomic analysis with single samples per species (Zhang et al. 2017) provided an misleading view of *Echinacea* relationships and diversification. A common theme in the findings of our plastome and multispecies coalescence analysis of low-copy nuclear genes is that the evolutionary history of *Echinacea* includes an early burst of rapid diversification and some degree of interspecific hybridization. In contrast to the plastome tree presented by Zhang et al. (2017), our species tree (**Fig. 2.5**) place the cosmopolitan *E. purpurea* as sister to a clade with the remainder of the genus, and most southeastern species form a grade with a clade dominated by midwestern species arising later in the evolutionary history of *Echinacea*. A rapid rate of early diversification is indicated by the short internodes along the spine of the *Echinacea* species tree (**Fig. 2.5A**) and extensive signal for incomplete lineage sorting as seen in the high frequency of alternative quartets in the species tree analysis (**Fig. 2.5B**). The lack of monophyly among samples of each species in the plastome tree (**Fig. 2.6**) may also be a consequence of ILS. At the same time polyphyly of *E. pallida* and *E. angustifolia* in both the ASTRAL (**Fig. 2.5**) and plastome (**Fig. 2.6**) trees implicate hybridization and interspecific gene flow.

Nearly even quartet frequencies for many nodes in the species tree estimation, shown in **Fig. 2.5B** as pie charts, indicate high levels of gene tree-species tree discordance. Given the low posterior probabilities for many nodes on the spine of the clade dominated by midwestern species (**Fig. 2.5A**), we cannot discount the possibility of polytomies in the *Echinacea* species tree (i.e. ancestral species spawning more than two daughter species). In support of this hypothesis, a number of nodes exhibit quartets with equal frequencies for all three resolutions of nodes on the spine of the Midwest-dominated clade (**Fig. 2.5B**). This pattern would be expected in the face of rapid radiation and rampant incomplete lineage sorting (ILS). At the same time, the polyphyly of some species implicates post-diversification interspecific gene flow.

*E. angustifolia* and *E. pallida* are polyphyletic in the species tree based on analysis of 1272 nuclear genes. While most *E. angustifolia* samples were grouped together in the species tree (**Fig. 2.5**), one individual was placed in a clade with *E. paradoxa*. *E. pallida* samples exhibited a higher degree of polyphyly with samples being placed in several clades with *E. sanguinea*, *E. atrorubens*, *E. angustifolia*, and *E. simulata* – all with ranges in the Midwest. Previous work has documented that all species that have overlapping ranges can hybridize (Kindscher 2006; McGregor 1968; McKeown 1999). We hypothesize that more extensive range overlap among Midwestern species has resulted in higher rates of introgressive hybridization. Additional sampling across the ranges of *E. simulata* and the midwestern species (**Figs. 2.3 and 2.5**) is required to gain deeper understanding of the influence of interspecific gene flow among these species.

### **Plastome sequences also suggests rapid diversification and the possibility of interspecific gene flow**

Most nodes on the plastome tree have bootstrap robust support values, but as seen in the species tree analysis some nodes on the spine of the tree are poorly supported, suggesting rapid early diversification of sampled plastome lineages. Whereas Zhang et al. 2017 inferred distinct clades for eastern and western species in their whole-plastome analysis, this interpretation of the plastome history does not hold up when we sampled more than a single individuals per species. Whereas Zhang et al. (2017) identified distinct eastern and midwestern species clades, our plastome tree (**Fig. 2.6**) suggests rapid diversification early in the history of the genus and multi-gene species tree estimation (**Fig. 2.5**) suggests that *E. purpurea*, with the broadest range of all *Echinacea* species, is sister to a clade with the remainder of the genus. The lack of species monophyly in the plastome tree and poor correspondence between the species and the plastome trees (**Fig. 2.5** vs. **Fig. 2.6**) is consistent with the hypothesis that species lineages retained ancestral variation in plastome haplotypes as they were diversifying. Hybridization resulting in interspecific exchange of plastomes may have also contributed to the polyphyly of species tree (**Fig. 5**) in the plastome phylogeny (**Fig. 2.6**).

### **Conclusions**

The purple coneflower is known for its vibrant fluorescence and ethnobotanical significance. Being a part of the Asteraceae family, this genus has had a complex evolutionary history, including but not limited to, a history of rapid radiation, variation in ploidy, and high potential for hybridization. With heavier sampling, we must reject the previously hypothesized early split between eastern and western species clades (Zhang et al. 2017). It is interesting that the most

widespread species, *E. purpurea*, is sister to all other *Echinacea* species (**Fig. 2.5**). In agreement with previous work (Flagel et al. 2008; Zhang et al. 2017), we found very short internode branch lengths along the spine of the tree implying rapid diversification (**Fig. 2.5**). Evidence for some interspecific gene flow is not surprising given the ability of *Echinacea* species to hybridize (McGregor 1968) and their overlapping ranges (**Fig. 2.1**).

Given the results of our phylogenomic analyses, we hypothesize that *Echinacea* originated in the Southeast and expanded its range into the Midwest. Geographic isolation and adaptation to local environmental conditions (Baskauf, McCauley, and Eickmeier 1994) likely contributed to the speciation process. For example, extant *Echinacea* species exhibit variation in soil characteristics (Baskauf and Eickmeier 1994) and climate niches (Boyd et al. 2022). The persistence of clearly distinguishable species despite the ability of all *Echinacea* species to hybridize is also suggestive of ecological divergence in the speciation process. Nonetheless, actively hybridizing populations may be of conservation concern (Sassana et al. 2014).

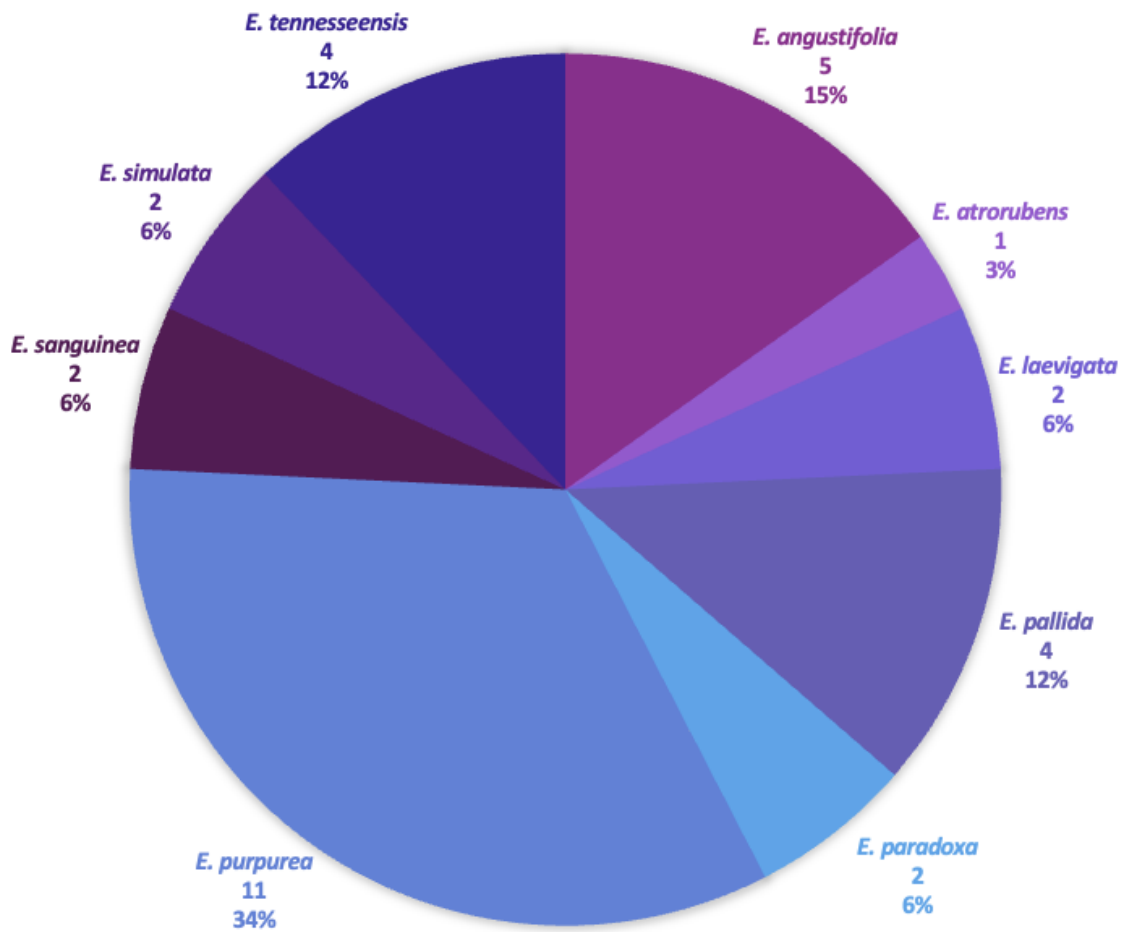
Phylogenetics can be used as an asset to aid conservation efforts. In the case of this study, we aimed to utilize phylogenetic inferences to improve understanding of *Echinacea* diversity and speciation. Our findings should inform *Echinacea* conservation effort and priorities. For example, the narrow endemic *E. tennesseensis* is phylogenetically distinct and the polyphyly of *E. angustifolia* and *E. pallida* (**Fig. 2.5, Fig. 2.6**) implicate hybridization as a potential threat.

## FIGURES



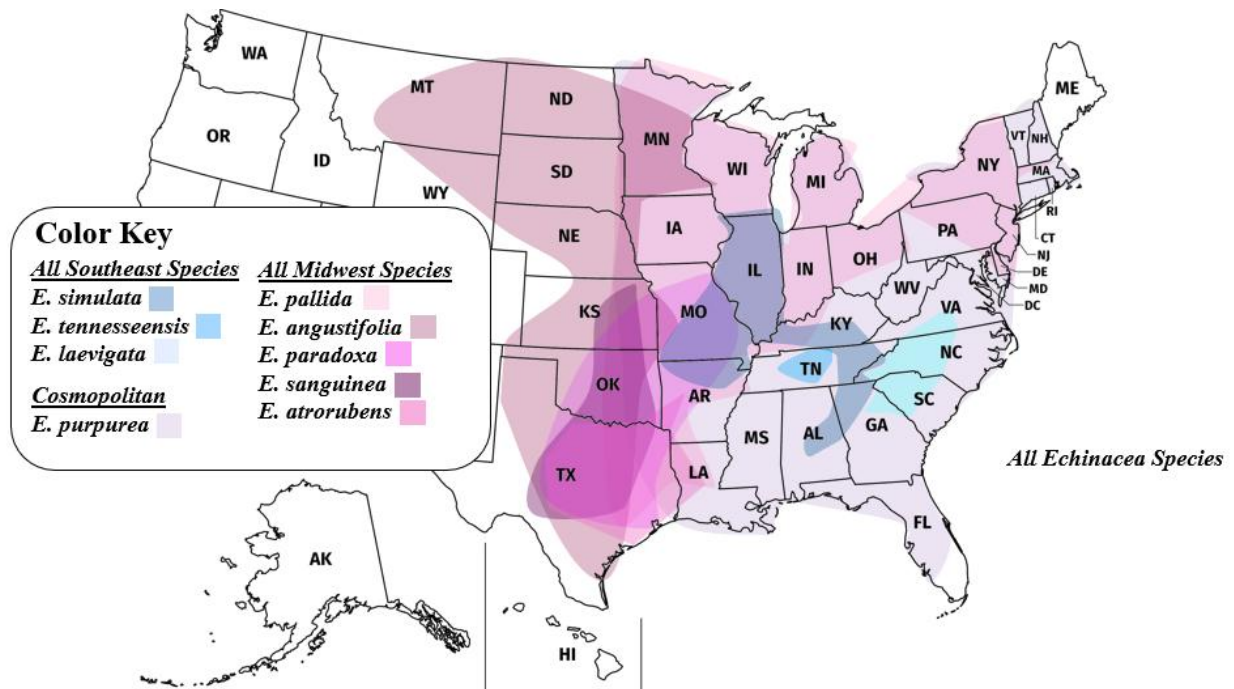
**FIGURE 2.1. *Echinacea* species and Nature Serve status rankings.**

All species of *Echinacea*, except for *E. purpurea*, *E. angustifolia*, and *E. pallida*, rank as G2 and G3. This indicates that most *Echinacea* species are imperiled or vulnerable. All species are ranked imperiled or critically imperiled in one or more states.



**FIGURE 2.2. *Echinacea* Study Samples.**

Each species used in the study are displayed, as well as the number of samples per species and the species percentage used within the study.



**FIGURE 2.3.** Range map of all *Echinacea* species.

Southeastern *Echinacea* species (Blue shades) have geographic ranges that generally lay side by side with minimal overlapping. In comparison, midwestern *Echinacea* species (Pink shades) have increased overlap in their geographic ranges.

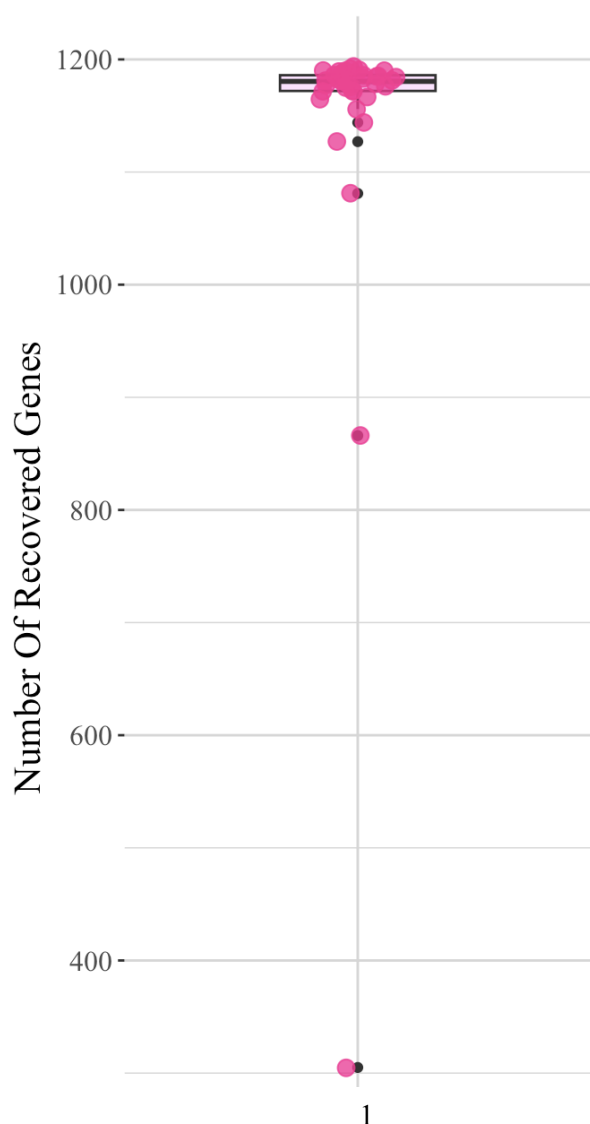


Fig. 2.4A

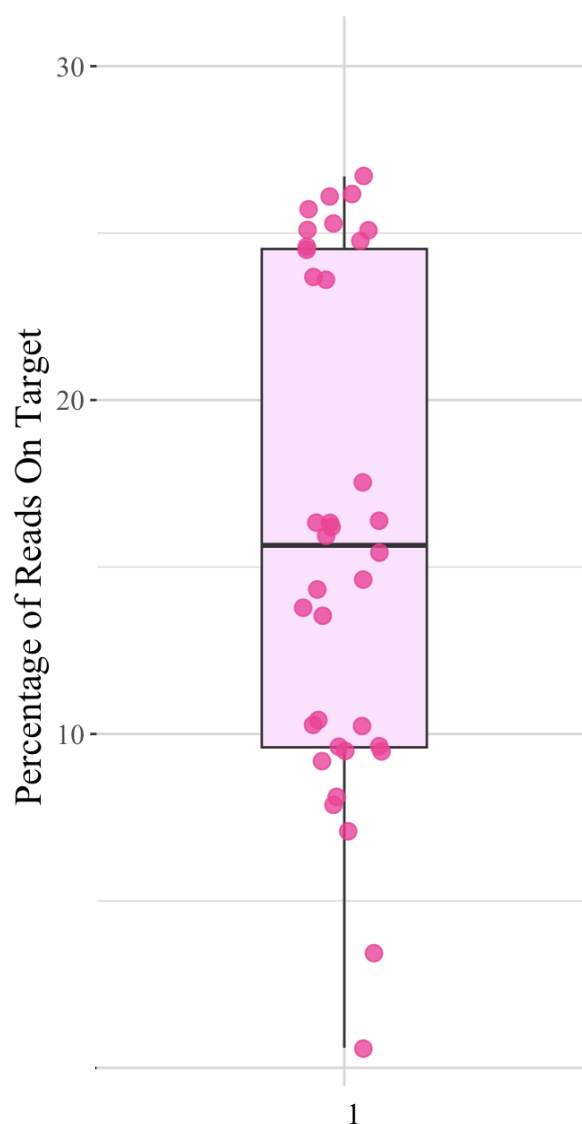


Fig. 2.4B

**FIGURE 2.4. Compositae-ParaLoss-1272 bait set on *Echinacea*.**

Boxplots show (A) **the number of recovered genes** i.e. the number of targeted genes that were successfully enriched, sequenced and assembled; and (B) **the percentage of reads on target** i.e. the percentage of sequenced read that were successfully bound to the targeted regions of interest, which mapped to the reference target sequences from Mandel et al. 2019 using the Compositae – Paraloss – 1272 baits on the *Echinacea* data set.

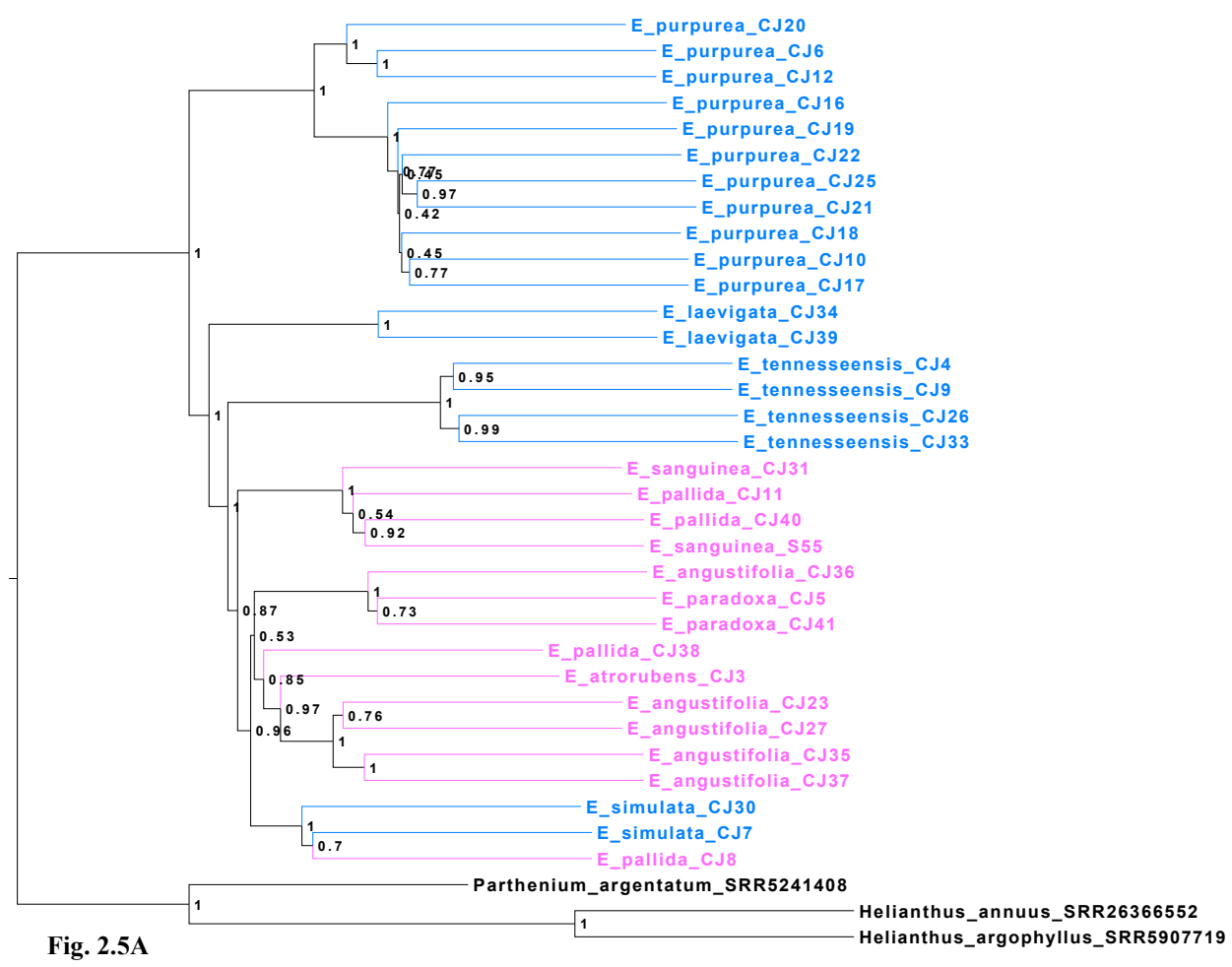


Fig. 2.5A

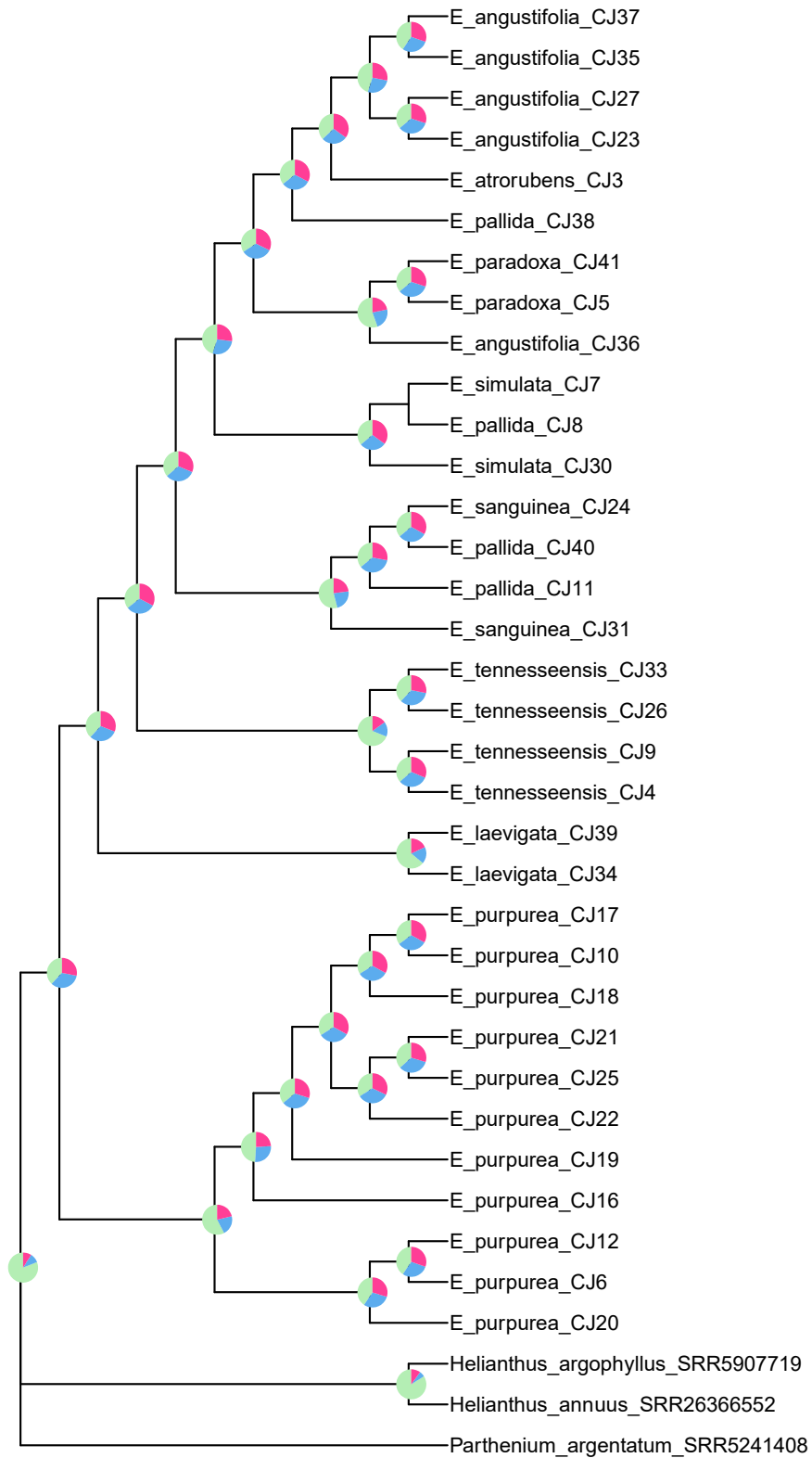
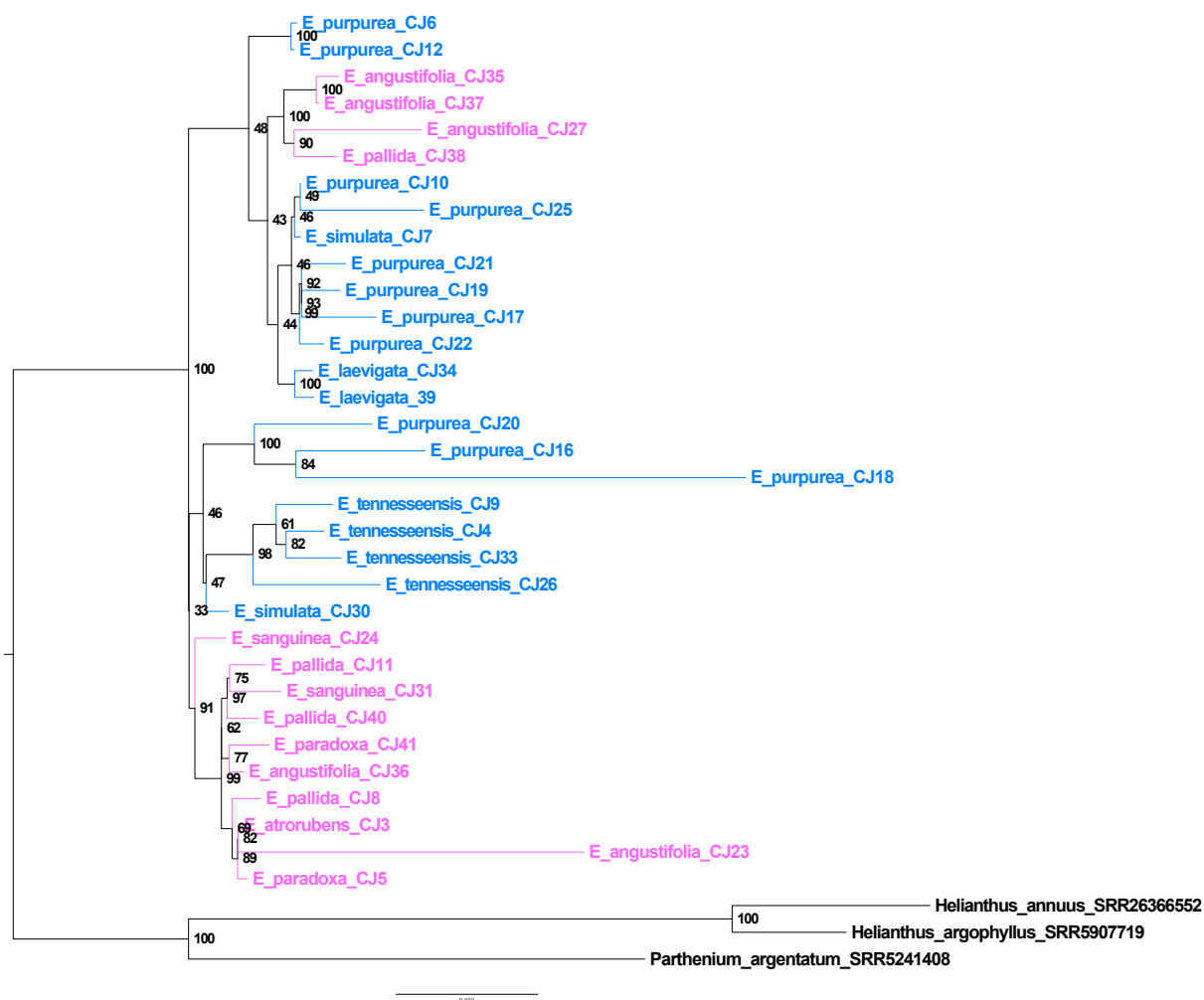


Fig. 2.5B

**FIGURE 2.5. *Echinacea* species tree based on nuclear loci. A) *Echinacea* species tree.**

Species in blue indicate southeastern species and cosmopolitan *E. purpurea*, while species in pink indicate midwestern species. Aside from *E. simulata*, eastern species are placed in a grade leading to a clade with all midwestern species. **B) *Echinacea* nuclear tree with quartet frequencies.** Quartet frequencies on each node of the ASTAL tree reveal extensive gene tree discordance due to rapid diversification leading to incomplete lineage sorting. For most nodes, quartets supporting alternative resolutions (q2 and q3) are balanced as expected with incomplete lineage sorting.



**FIGURE 2.6.** *Echinacea* plastome tree.

Species in blue indicate southeastern species and cosmopolitan *E. purpurea*, while species in pink indicate midwestern species. The lack of monophyly for most species is striking, and samples do not fall into eastern and midwestern clades as found in an earlier study (Zhang et al. 2017).

### CHAPTER 3

TO SUPPORT AND ACHIEVE BIODIVERSITY SCIENTIFICALLY,  
DIVERSITY MUST BE SUPPORTED SOCIALLY

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<sup>2</sup> Jordan, C.M. and Williams, T.M. To be submitted to the American Journal of Botany.

## **Abstract**

The Oxford Review defines cultural diversity as encompassing a variety of backgrounds, languages, traditions, and beliefs within a community. In the fields of science, technology, engineering, and mathematics (STEM), the need to increase cultural diversity has been prevalent since the 1990s (Gainen 1995), however, wanting diversity and obtaining and retaining that diversity are two very different objectives. Recognizing and nurturing cultural diversity is vital for promoting a culture of inclusion, mutual respect, and social unity. Ensuring diversity within these fields requires a focus on understanding how certain identities are marginalized in science and society and how different demographic factors intersect. However, how can scientists, academics, professors, advisors, grant writers, and the like claim to want to increase diversity and discuss diversity, but continually not create or have systems in place to support culturally diverse students? Which in turn, leads to low retention of people from different backgrounds in scientific fields and workplaces. How can so many academic studies be premised on the benefits of biodiversity, but the culture within these academic spheres seems to devalue cultural and social diversity within their own groups?

Currently in my graduate degree program, not only am I the only African American student in my cohort, I will also be the first African American student in my department to receive a graduate degree. I want to acknowledge that, before me, 1 African international student and 1 Caribbean international student have graduated from my program. It is important to recognize that these past students, now professors, may have experienced racism and anti-blackness. I want to recognize that they may also have had negative experiences in the program. However, it is important to understand that Blackness is not a monolith. While my academic journey has provided opportunities to learn many worthwhile lessons, it has also been arduous

and wounding. In this reflective essay, I will discuss some of the experiences surrounding Black graduate students, particularly, experiences that have impacted me while performing my research on target capture sequencing to further resolve the speciation history of *Echinacea*. These experiences include:

- I. Lack of social safety and isolation for Black and Brown students in a predominantly white institution (PWI)
- II. Issues for Black and Brown students regarding field safety and field work in the rural south

### **Disclaimer**

I understand that reading this document may cause discomfort for readers from dominant backgrounds, particularly white readers who are department heads, department coordinators, advisors, and students (Russo-Tait 2022). I invite you to push through the discomfort that you might experience to understand and be conscious of the experiences of those from different backgrounds and learn how to make field work, research, and social settings safer and more supportive for all. Throughout the paper, there will also be capitalization of Black, but not white in reference to groups in racial ethnic, and/or cultural terms. Black can refer to a shared sense of identity and community, while white carries a different connotation and meaning, especially in the United States (Columbia Journalism Review).

## Introduction

In the article, *Dilemma of a Black Intellectual*, Cornel West describes being an African American academic as an “act of self-imposed marginality” (West 1985). In the book *The Black Academic’s Guide to Winning Tenure – Without Losing Your Soul*, authors Kerry Ann Rockquemore and Tracey Laszloffy further detail this quote as being a Black academic, in a way, requires a disconnect from the larger African American community while also acknowledging that you, as a Black academic, will never be fully welcomed into the professoriate (Rockquemore and Laszloffy 2008).

As a new graduate student, I was not privy to these thought processes. I was previously at a minority serving undergraduate institution (MSI) where African Americans were the most predominant demographic, followed by other persons of color (POCs), and then white people. At this institution, I did not scrutinize how I showed up to a space or how I was perceived prior to people talking with or to me. I was able to witness people of color, specifically Black women, in highly influential research and teaching positions for the first time in my life.

I was unaware that moving to a predominately white institution (PWI) would be such a culture shock (Shavers and Moore 2019), ranging from realizing that the issues I would raise, how I showed up to a space, and the way that I talked made many of my white counterparts visibly uncomfortable and sometimes combative. While it is an unsaid expectation, I realized that to navigate the system that I stepped into would require three primary tasks: I) publish research, II) teach well, and III) serve your institution as a good departmental citizen, without stirring the pot too much (Rockquemore and Laszloffy 2008). Exposed to this new academic culture, I decided to look into the history of African Americans in my current field. Through my studies, I learned that the first African American that received their PhD in Evolutionary Biology

was Dr. Joseph Graves in 1988 (Graves 2019). More recently, this field continues to be dominated by white scientists which is displayed in demographic statistics released by the National Science Foundation (NSF) annually. In 2017, the National NSF released a report stating the professional biology workforce was 69.5% white, while only 3% of that workforce is Black or African American. In 2021, there were about 52K doctoral research recipients, when the last NSF census survey was taken (“Doctorate Recipients from U.S. Universities: 2021 | NSF - National Science Foundation,” n.d.). In that year, 2,431 African American individuals and 2,831 Hispanic individuals received doctoral degrees in research related fields. This was in comparison to 21,333 white individuals. Black women, a combination of 2 demographics that have been historically marginalized, comprise only 2% of practicing scientists and engineers as a result of issues Black women face early in their STEM career path (Ebony O. McGee and Bentley 2017; NSF 2015). The problem is even more stark in evolutionary biology, which is the field in which I currently house my research. Without going into full detail of the problematic and sordid history of research institutions within the United States (Graves 2019) demographics in STEM fields have remained mostly white and male, while having significantly less Black and Brown individuals, as well as women (NSF Demographic Surveys 2023; <https://nces.nsf.gov/pubs/nsf24336/table/1-8>).

As stated previously, the need to diversify STEM has been clear to many for decades (Gainen 1995). However, wanting diversity and actually obtaining and retaining that diversity are very different objectives. Guaranteeing both recruitment and retention of people from a diversity of backgrounds within these fields requires a focus on understanding social identities that have been historically marginalized and the intersectionality between demographic factors (Beltran et al. 2020; Demery and Pipkin 2020; Eaton et al. 2020). However, how can

departments, scientists, academics, professors, advisors, grant writers, and the like claim to want to increase diversity and discuss diversity, but continually fail to create or have systems in place to support culturally diverse students? In turn, this failure leads to low retention of cultural diversity in scientific fields and workplaces. How can so many academic studies be premised on biodiversity, while the culture within these academic spheres seems to devalue cultural and social biodiversity within their own groups?

Until my last semester of graduate school, I have been the only African American graduate student in my department. I will also be the first African American graduate student in my department to receive a degree since the department's creation. The department's first African American professor did not join the department until 3 years into my graduate degree. I want to acknowledge that, prior to me, there has been 1 African international student and 1 Caribbean international student who have graduated from my program. It is important to recognize that these past students may have experienced racism and anti-blackness. I want to recognize their struggles that may have occurred during their time in the program. However, it is important to understand that Blackness is not a monolith. These students were not African American or from the African diaspora. For example, when meeting with one of these individuals, who is now a professor, they stated that they are not "Black". They stated that they do not identify with the African American experience in academia, even though I may have been directed their way as a factor of Blackness being monolithic in white America.

While the journey has been a space for me to learn many worthwhile lessons, I will also describe the journey as both arduous and wounding. It has been key for me to remember that the professors and researchers of color are "co-conspirators" (Love 2019) and have continued to inspire me and push me forward to pursue a scientific future. In particular, this support system

has helped me to realize that institutions that foster a diverse community of researchers generate high quality science. In this paper, I will discuss some of the experiences surrounding Black graduate students, particularly, experiences that have impacted me while performing my research (Fig. 3.1) on target capture sequencing to further resolve the speciation history of *Echinacea* (Jordan et al. 2025, *Frontiers in Plant Science*, in review). These experiences include:

- I. Lack of social safety and isolation for Black and Brown students in a predominantly white institution (PWI)
- II. Issues for Black and Brown students regarding field safety and field work in the rural south

While these are two main issues that I have dealt with during my research, it is important to acknowledge that there are a myriad of issues that impact students, especially students of color. Some of these issues include, but are not limited to: low pay with lack of outside financial support or generational wealth, supporting dependents, harassment from white faculty and their white graduate students, etc. In contrast, a number of students come to graduate school with more privilege compared to others. Personally, this was a realization that I had to come to terms with. Many of my white counterparts within my department only had to worry about their research and qualifications to obtain their degree. A multitude of POC students (graduate and undergraduate), professors, and research professionals usually have to think about many aspects that are separate from their academic prowess and ambitions (Rockquemore and Laszloffy 2008; Solorzano 2000).

While in graduate school, I have witnessed and experienced a number of people (faculty and students) that perpetuate a culture of competitiveness and, at times, self-centeredness. I have learned that, unfortunately, people who perpetuate this culture are usually part of the white supremacist culture that academia, also known as the Ivory Tower, is shrouded in. As stated in RightsViews, a blog from Columbia University, some of the characteristics that overlap between academic culture, particularly at a PWI, and white supremacist culture include: prioritizing individualism, power hoarding, prioritizing white comfort, quantity over quality, defensiveness, and urgency. At times, I have felt that graduate school is an “intellectual fishbowl” and a “white man’s academic playground.” I do not feel as though it is a welcoming or healthy place for people who are not cisgendered, heterosexual white men. I have also experienced some of the dangers of trusting white women who knowingly or unknowingly may perpetuate the same issues as the cisgendered, heterosexual white men. It seems like the closer proximity to whiteness, the higher the likelihood of a person to perpetuate that culture of whiteness, instead of promoting a culture of inclusivity.

I believe that there are systemic issues in academia, particularly higher education; however, I understand that a singular graduate student or even a group of graduate students will not solve a systemic issue. A mutual aid framework would be useful for department heads, coordinators, and administrators to utilize in order to make the culture of academia less hostile and toxic towards POC graduate students, especially Black graduate students. This framework can be defined as a community led and oriented approach, where people collaborate voluntarily to share resources and services for the benefit of the whole. The aim is to recognize, meet needs, and overcome barriers. A mutual aid framework would allow collective coordination to meet needs of groups of people, like Black and Brown graduate students, and would signal to those students that the

department and those within it have a shared understanding that the academic system in place is unjust and that most needs may not be met without intervention (Spade 2020).

### **Positionality Statement**

In this piece, I will be talking about myself and my experiences, as those experiences are intertwined in the spaces where I have been located as a student and as an employee. I am a Black, queer, woman-adjacent plant biologist with training in conservation genetics and phylogenetics. I have experience outside of and within Predominantly White Institutions (PWIs), as I received my bachelor's degree from a Minority Serving Institution (MSI) and will receive my Master's degree from a PWI. Careerwise, I have extensive experience in plant identification, monitoring rare species and southeast endemics, database curation and maintenance, protocol creation and design, research analysis and science communication. I also have experience in grant writing and reporting, as I am a recipient of two fellowships during my time in graduate school, one of which is the National Science Foundation's Graduate Research Fellowship Program. During the course of my academic career, I have accrued 7 years of experience designing and managing research projects and assessing sites for monitoring plant communities in several research laboratories, herbariums, and botanical gardens.

Currently, I have had the privilege of creating, nurturing, and funding a phylogenetics and conservation focused thesis pertaining to the *Echinacea* genus. I have found that this genus has shaped much of how I research and study floristic traits in the southeast. All species of *Echinacea* are rare to some degree (NatureServe); specifically, I have been able to work with *E. tennesseensis* and *E. laevigata*, which are endemic to the southeast, have narrow species ranges, and have been or are currently under protected status. Due to this, I have critical experience as a

black field biologist working in the rural south working with the public and state authorities in these areas.

### **Lack of social safety and isolation for Black and Brown students in a predominantly white institution (PWI)**

In previous research, several issues have been explored related to Black students' experiences attending PWIs or historically white institutions (**Fig. 3.1**): 1) isolation and loneliness, 2) racial hostility, 3) persistence, 4) psychological distress, 5) stereotyping, 6) surplus invisibility, 7) invisibility, 8) bias in grading, and 9) indifference/lack of sensitivity (Jason, Richardson, and Dennis 2023; Shavers and Moore 2019; Juanita Johnson-Bailey et al. 2009; Solorzano 2000). Seeing as POC students are extremely underrepresented at historically white institutions (HWIs) (Yosso et al. 2004), the need to diversify STEM has been prevalent for many decades (Jason, Richardson, and Dennis 2023; Gainen 1995), however, retaining this diversity in these fields are two very different goals. Ensuring diversity within these fields requires a focus on understanding marginalized identities and how different demographic factors intersect (Beltran et al. 2020; Demery and Pipkin 2020; Eaton et al. 2020). Research in this area has indicated that an aspect of the HWI/PWI experience that stood out for Black graduate students was the “passive and quietly hostile environment”, in which these students expressed that they experienced an unwelcoming environment where they felt like intruders that were only being tolerated in the academic space (Juanita Johnson-Bailey et al. 2009; Solorzano 2000). For Black graduate students there is a direct correlation between their connection to their program and their ability to finish their graduate studies (Lynch and Jennifer 2010; Juanita Johnson-Bailey et al. 2009; Astin and Oseguera 2005; Feagin 1992).

At my own institution, some examples of experiences that I have had and/or witnessed that have negatively impacted mine and others' connection with my graduate program include, but are not limited to:

1. Invalidation of micro aggressive reported to the home department
2. Invalidation of racist experiences reported to the home department
3. A lack of support from the home department resulting in a departmental transfer
4. Experiencing hostile tenured faculty who lack accountability resulting in a lab transfer

As a result of these experiences, these graduate students transferred to different labs and/or different departments, dropped out of the program entirely, or if they had already passed their qualifying exams, they decided to leave with a Master's degree instead of the PhD, of which the PhD was their original goal.

In the literature, factors identified as contributing to the negative correlation between institutional alienation and program retention include, but are not limited to:

1. A lack of hiring STEM faculty of color and/or seeking them out for departmental seminars or symposiums (Ebony O. McGee and Bentley 2017; Vinnicombe and Singh 2003; Reddick 2015; Palmer and Holmes 2010) (National Center for Educational Statistics 2007)
2. Normalization of being seen as an imposture despite high academic achievements (Ebony O. McGee and Bentley 2017; Vinnicombe and Singh 2003)

3. A lack of POC STEM role models, mentors, or alumna for Black students to network with and find support (Ebony O. McGee and Bentley 2017; Cole and Espinoza 2008; Reddick 2015; Palmer and Holmes 2010) (National Center for Educational Statistics 2007)
4. Increased numbers of Black peers dropping out of STEM programs (Ebony O. McGee and Bentley 2017; Cole and Espinoza 2008; Malone and Barabino 2009; Robinson et al. 2016)

When a Black graduate student is disconnected from their program and institution, it can lead to I) higher likelihood of not reaching graduation (Shavers and Moore 2019; Juanita Johnson-Bailey et al. 2009) and II) an increase of the distancing between students and the institutions, to combat a lack of support, and therefore increase self-reliance (Jason, Richardson, and Dennis 2023). While I have been at my southern PWI, I have watched every single student who has looked like me leave with a master's from the PhD program, transfer out of the program, or drop out whether they had secured funding or not. I have also experienced the death of a friend, a Black female graduate student while in my program. Death of black students and professors is another separate issue in academia (Thomas, Johnson, and Clark 2024) worth mentioning, but on which I will not elaborate here. Black graduate students, especially those at the intersection of multiple marginalized identities, can fall through the cracks within their programs and this in turn perpetuates a leaky pipeline in academia, where they leave the academic and/or academic adjacent career path (Jason, Richardson, and Dennis 2023; Ysseldyk et al. 2019).

When settled in their graduate work, many Black graduate students, like myself, start to process the multiple and compounding disadvantages of being Black with several other marginalized identities, such as being a woman and being queer, at a PWI (Jason, Richardson, and Dennis 2023). Ultimately, Black graduate students start to decide whether the degree is worth the turmoil that they may experience while getting the degree and the physical and psychological impacts that may occur after degree completion (Ysseldyk et al. 2019; Shavers and Moore 2019; Solorzano 2000). Graduate programs, particularly the faculty, department heads, and coordinators at PWIs, will need to actually make considerations and be intentional in their efforts to support Black graduate students. I have found that graduate programs, whether intentionally or not, tend to adopt an approach of color blindness and meritocracy, which can negate experiences of students who have been marginalized by the academic system and perpetuate structural racism dismissing acknowledgement of differences in life experiences (Ebony O. McGee and Bentley 2017; Basile and Lopez 2015; Lopez, Casane, and Philippe 2002; Martin 2009; Russo-Tait & Rodgers, in press). They will need to make efforts to positively impact the social experiences of their POC graduate students. Specifically, efforts to aid their Black and Brown graduate students, rather than perpetuating similar cycles and issues that continue to be ignored and/or pushed under the rug (Juanita Johnson-Bailey et al. 2009). These efforts should go hand in hand with tangible results, which could include an academic culture prioritizing a mutual aid framework (Spade 2020) to aid retention and promoting and incentivizing accountable leadership (Spade 2020) versus hierarchical leadership.

Black and POC graduate students within these graduate programs have different backgrounds and life experiences, qualitatively and quantitatively, compared to their white counterparts (Juanita Johnson-Bailey et al. 2009). So it is understandable that they will need

more than strictly graduate school support to complete their studies. Being a graduate student in STEM requires scientific support to perform my research well. However, being a Black graduate student requires emotional support, social support, safety support, mental support. Some examples of different types of support for Black and Brown graduate students include, but are not limited to, access to Black and Brown therapists and psychiatrists (Ebony O. McGee and Bentley 2017), providing networking opportunities with alumna from identities within groups that have been historically marginalized, providing logistical aid and technicians to increase safety for Black and Brown students who need to do field work. Without those other aspects of support included in the graduate experience, I believe that it is a disservice to students who look like me and increases difficulty to stay within a program that is already difficult from the start. I also believe that faculty, department heads, and coordinators that do not recognize, understand, or help with these aspects of support for their POC students when they join the program may in fact perpetuate the low retention of Black and Brown graduate students who choose to stay within the program. When I graduate, I will be the first African American graduate student to leave with a degree in my department in its existence and I believe that speaks volumes, being that this is happening in 2025. There are very limited spaces to nurture and aid Black graduate students, especially those with intersections between race and gender (Jason, Richardson, and Dennis 2023). As a result, it is seen personally and through research, that marginalized graduate students will begin to depend less on their graduate programs and more so on themselves to find support, generate academic achievement, and outside positive mentorship (Jason, Richardson, and Dennis 2023; Ebony Omotola McGee 2020; Ebony O. McGee and Bentley 2017; Robinson et al. 2016; Ebony O. McGee and Martin 2011).

As a Black graduate student, I have been told that I possess a large amount of “resilience” (Morton and Nkrumah 2021). I am continuing to learn that many other Black students have similar narratives, in which “resilience” is characterized as grit, perseverance, and mental toughness (Ebony O. McGee and Bentley 2017; Ebony O. McGee and Stovall 2015). Despite outside forces, Black students often cultivate high academic esteem, support systems, perseverance and optimism over time as they navigate otherwise unsupportive academic environments (Ebony O. McGee and Bentley 2017; O’Connor 1997). Knowing that there is a collective struggle at the intersection of race, gender, and class can serve as a source of comfort and determination (Ebony O. McGee and Bentley 2017; O’Connor 1997). As a Black graduate student, there is some resentment I feel regarding the need for excessive amounts of “grit” and “resilience” to attempt to reach degree completion. Graduate school is generally difficult; however, my white counterparts do not experience the same level of need for grit and resilience in the same way as Black and POC students. In the colorblind and meritocratic culture of academia, there is a tendency to only recognize Black students' academic success and the success this merit brings to their respective departments while ignoring the ways that these students can be placed at unacknowledged risk (Ebony O. McGee and Bentley 2017).

### **Issues for Black and Brown students regarding field safety and field work in the rural south**

If the supposed “safe spaces” of the ivory tower are exclusionary and harmful to Black people, it is no surprise that field work, especially in the white rural south, can present its own risk. A large fraction of graduate student projects in the plant sciences require field work to collect samples and parameters from field sites, design and perform experiments, and also record

natural history observations and demographic data (Ramírez-Castañeda et al. 2022). While field work is foundational for collecting plant material and voucher specimens, it is also vital for providing field site statistics (ex. plant distribution and abundance), habitat characteristics (ex. plant community and community structure), environmental metrics (ex. soil texture and topography), and ecological interactions (ex. plant - pollinator and mutualism) (Ramírez-Castañeda et al. 2022).

Field work is highly valued as robust research in graduate school and beyond; however, there are still power imbalances (Ramírez-Castañeda et al. 2022) and safety measures that continue to be overlooked as the workforce and student body in this field attempt to become more diverse (Demery and Pipkin 2020). The risk of a student may pertain to their race or ethnicity, sexual orientation, disability, gender identity, and/or their religion (Demery and Pipkin 2020). Some individuals are more likely to experience conflict and violence while working in the field, solely based on how they exist in the world due to identity prejudice (Demery and Pipkin 2020). Conflict in regard to prejudice, can be detrimental to a student's physical wellbeing, as well as their mental health, productivity, and even their career and career prospects (Demery and Pipkin 2020). Over the course of my time in graduate school, I have learned that safety in field research is heavily dependent on an individual's identity, their physical location, and whether or not the student has received training.

As someone with multiple marginalized identities in STEM, the fact that field work was a large component of my graduate degree was a major concern. My study sites are located in the rural south of the United States, where physical safety, as well as social safety with local white people have been challenging as a Black, queer woman presenting individual. While designing my dissertation project, I assumed that there would be systems in place within my department

and the graduate school, to inform, protect, and train new students on how to conduct research in the field. Unfortunately, that was not a reality for me when I started graduate school. In fact, it seemed as if I needed to have an instance of danger, during my first summer of field work, to start being taken seriously regarding the risks and liabilities that I experience through field research.

The thought process of sending students into the field alone is normalized in my department. At the time, I did not have an extensive background in field work and was trained in molecular work during my undergraduate degree. It wasn't until I talked to my family that I realized how dangerous this actually was. They said "this is dangerous, and you will not be doing this" verbatim and at the time I tried to level with my family to say that "this is what I have to do" to get my degree. I didn't understand the gravity of the situation until my family and other POCs in the scientific community communicated how dangerous it was to go into the field alone. When I tried to discuss my safety issues with my PI at the time, prior to my transferring labs, the issues I brought up were ignored and when I asked her what could be done, I was given very unhelpful and unthoughtful suggestions. One of the suggestions was that I could text her when I go into and out of the field; however, the major issue was that her research is in Colorado and so she was half a country away. When I asked her lab for help, not a single person helped me, and I was told the massive amount of work they themselves had to do and so they were unable to help me. It felt so horrible to not have your advisor or your lab mates have your back in regard to safety, which should be non-negotiable.

In the eyes of some, the research product is more important than having field safety and protocols. From my personal experience, I have been in a situation where an authority figure struggling to get their own accolades had the mentality that all those lower on the hierarchical

structure should also struggle to “build character” as if to perpetuate hazing rituals for pre-career individuals. It seems as if data collection is more important than the researcher who is actually collecting the data. I attempted to navigate this mindset in graduate school; however, it is very difficult to go against the grain.

I remember having to stand up to my past advisor and saying “no” even though she disapproved. Unfortunately, she did not help me at all finding people to go with me to add safety to my trips even though I informed her of every list I made of field help. This list of field help resulted from me going to different faculty and friends in different departments to ask students for field work assistance and help with logistical planning because I had no help from my home lab. While it would have been safer to have a field team, instead of just me and one other technician, I went with at least one other person to my field sites because that was what I was able to do alone.

While it was difficult to source team members for field safety and planning purposes, I continued to stay firm in my decision to not go alone on field site trips. For a time, I was deterred from field work after an encounter where one of the white Tennessee locals had called the local rangers on me for trespassing, even though I provided the park with documentation and let them know ahead of time the duration that a team member and I would be there. It was a fairly big site with me on one side of the plot and my team member on the other side, so I was approached separately. I remember seeing that they had guns and thinking “wow, this is honestly horrifying – what do I do right now? What if this doesn’t go well?” I tried talking to the rangers and several locals and no one would listen to me. This was an experience that deterred me and many others with similar experiences from field work. When I relayed this experience to my past advisor, I

was met with “Sorry you experienced that... now moving on to the research.” The lack of care surrounding this was jarring and I knew from that reaction that I needed to transfer labs.

Field work should be accessible to everyone (Demery and Pipkin 2020; Clancy et al. 2014). Especially if field work is required for their dissertation research, a field safety team and field safety protocols should be standard. As a student researcher, I should not have to question whether my field work is merit based, or safety based. Being able to operate out of this mindset comes from a place of privilege and/or seniority. Over the course of my time in graduate school, I have learned that safety in field research is heavily dependent on an individual’s identity, their physical location, and whether or not the student has received training. I made attempts to create departmental field safety protocols. However, I realized that reliving my negative experiences and teaching white graduate students and faculty about the dangers and hesitations that I and many Black graduate students in ecology and plant biology related departments experience was very emotionally tiring and triggering. This task was even more burdensome because I) I felt that I had to justify why I needed to be kept safe at field sites and II) for many white faculty members and students’ this was their first introductory course to how their Black and Brown students may not be safe while trying to do their field research. It was disheartening to know that before my efforts to develop a field safety guide for POC students, many had never even thought for a second about these topics, which really showed how the lack of diversity and diversity training can harm Black and Brown students.

There is limited research on the impact of field work experiences on POC graduate students, particularly Black graduate students. However, this makes sense given the fact that white people dominate the field and Black and Brown students may experience I) less exposure to the fields of ecology and botany, II) a lack of same-race role models in ecology, botany, and

evolutionary biology, and III) discomfort in outdoor spaces due to issues with social and physical safety (O'Brien, Bart, and Garcia 2020). Historically, Black people were not able to access recreation, education, and other benefits that their white counterparts were able to generationally due to Jim Crow laws that were in effect until 1968 (O'Brien 2022). During this time, there were segregated "Black" beaches, like Highland Beach in Maryland and "Black" parks (such as Paradise Park in Florida. However, many black parents, including mine, did not experience these beaches and parks, as they were part of the Black population that flocked to the cities during the Great Migration attempting to find better employment opportunities (National Archives 2021). It is interesting to realize that while my parents and grandparents were not able to give me those experiences and exposure to botany, white individuals in the same age bracket as my parents, such as my advisor, were able to experience these aspects of nature, ecology, and plant biology from childhood onward.

## **Conclusion**

While I now understand target capture, also known as hybridization sequencing (Jordan et al. 2025, in review) and how this technique can be used to further understand the evolutionary relationships within the *Echinacea* genus, particularly those with qualities of rarity, as a Black, queer, female presenting scholar my journey to perform this research has been heavily impacted by lack of field safety during field work in the rural south as well as social safety and isolation at a PWI (**Fig. 3.1**).

It is important to also mention that while I have been heavily impacted by these two factors, there are a number of other struggles, some of which have impacted me, and others that impact students of color such as: low pay, with lack of outside financial support or generational

wealth, supporting dependents, harassment from white faculty and students, etc. One aspect of the degree experience that I had to make peace with was the realization that many of my white counterparts within my department only had to think about their research and qualifications to obtain their degree. Many POC students (graduate and undergraduate) as well as POC professors and research professionals may have to think about many aspects that are separate from their academic prowess and ambitions to succeed in an exclusionary culture such as academia and professorship. (Rockquemore and Laszloffy 2008; Solorzano 2000).

During my time in graduate school, I have experienced a plethora of people (faculty and students) that perpetuate a culture of competitiveness and self-centeredness. At times graduate school seems to be a “fishbowl” and a “white man’s academic playground.” I do not feel as though it is a welcoming or healthy place for people who are not cisgendered, heterosexual white men, or those who can successfully assimilate into that culture. I have also experienced some of the dangers of trusting white women who knowingly or unknowingly may perpetuate the same issues and feel like snakes in sheep’s clothing. My personal experience is mirrored in research that convincingly shows that there are systemic issues in academia, particularly higher education; however, I understand that a singular graduate student or even a group of graduate students will not solve a systemic issue. I believe that a mutual aid framework would be helpful for department heads, coordinators, and administrators to utilize in order to make the culture of academia less hostile and toxic towards POC graduate students, especially Black graduate students. A mutual aid framework would allow collective coordination to meet needs of groups of people, like Black and Brown graduate students, and would signal to those students that the department and those within it have a shared understanding that the academic system in place is unjust and that most needs may not be met without intervention (Spade 2020). In his book,

Mutual Aid: Building Solidarity Through Crisis (and the next), Dean Spade discussed three key elements of mutual aid (Spade 2020):

- I. The goal of mutual aid is to meet survival needs and build a shared understanding about why others may not have what they need.
- II. Mutual aid mobilizes individuals, increases solidarity, and shapes movements.
- III. Mutual aid is participatory and aims to solve issues through collective action rather than waiting for a savior to appear.

This reframe utilizing mutual aid methodology would be beneficial for 1) increasing emotional support, social support, safety support, and mental support for Black and Brown students and 2) graduate programs attempting to increase retention of graduate students of color. To be a successful graduate program, department, advisor, etc., there has to be an understanding that graduate students are not a monolith. Each student that a program and advisor agree to teach, and mentor is different based on their previous and current life experiences, and their degree of academic knowledge for that particular graduate program. So, while it seems obvious that each student will need different levels and types of support in order to succeed, many graduate programs, intentionally or not, may ignore what seems obvious and blatant.

It is also important to note that needing more support compared to others (ex. Black students vs. white students) is not a weakness, but an act of awareness in a system that was not built for them and was, and in many cases still is, built to actively exclude them. There should not be an expectation placed on communities that have been historically marginalized to assimilate to a standard that has failed them repeatedly. Standards should be edited to

accommodate a more diverse community of students and faculty. The key is to teach, learn, and work to dismantle a non-inclusive system (Halsey et al. 2020).

Another important aspect that may be useful for reframing academic culture and mentorship within a department is promoting and incentivizing accountable leadership versus hierarchical leadership. Spade's book lists qualities that categorize hierarchy versus accountability (Spade 2020, Reddick 2025, Ted X Talks). Hierarchical leaders have qualities that include, but are not limited to:

- Successful by dominating others
- Concern with maintaining reputation
- Winning support through status
- Fosters competition in groups
- Impulsivity
- Sense of self through status
- Insensitive to feelings of others
- Gossips rather than being direct
- Defensive and closed to feedback

Accountable leaders have qualities that include, but are not limited to:

- Growth mindset
- Willingness to admit mistakes
- Good communicator
- Fosters compassion in groups
- Holds group decisions – reliable
- Cultivates authenticity

- Sensitive and responsive
- Gives direct feedback with care
- Open to feedback
- Can ask for help
- Interested in learning from discomfort

While I can picture faculty during my graduate experience that have been hierarchical leaders, which in general is the culture that I feel is perpetuated commonly amongst faculty at PWIs, I can also picture faculty that have been accountable leaders for myself and other graduate students who have struggled during their time in higher education. Personally, those are the faculty members who have listened and been receptive to my experiences, have taken the time to repeatedly check in on me and my mental health, and have consistently been there to help me and talk through difficult social issues that I have faced while here. Over the years, they have also shared their own personal experiences with me in hopes that I would not feel so alone and isolated during this journey. It is also important to state that almost all of these people have been faculty members who were POCs, as well as women, of which they themselves fall within the intersections of race and gender.

So, while I now have a vast repertoire of skills related to computational datasets, project management, grant writing, genetic and sequencing work, and field work, I also recognize the amount of stress, emotional distress, harm, and fear this degree has given me. In this paper, I have discussed topics ranging from several issues that have been explored related to Black students' experiences attending PWIs or historically white institutions (**Fig. 3.1**): 1) isolation and loneliness, 2) racial hostility, 3) persistence, 4) psychological distress, 5) stereotyping, 6) surplus

invisibility, 7) invisibility, 8) bias in grading, and 9) indifference/lack of sensitivity (Jason, Richardson, and Dennis 2023; Shavers and Moore 2019; Juanita Johnson-Bailey et al. 2009; Solorzano 2000). I have discussed and given personal and literature examples of how a lack of social safety and isolation can impact Black and POC students at a PWIs. I have also discussed issues and examples that can and have arisen for Black and POC students regarding field safety and field work in the rural south. I hope that this paper serves as a lesson for academics, especially white academics, in my field of how experiences can drastically change when you are culturally and racially different compared to those within your field. I hope this will be a moment where white academics will not solely “think” about the work and “intellectualize” the work, but will actually do the work required to show up for Black and POC students and support those students even when it is not in the white academics’ best interest to do so. Understanding the racial, mental, and social hardships that many Black students undergo as a result of their experiences in higher education is pivotal to limiting risk for students, especially when attending a PWI. Increasing access to POC STEM faculty, mentors, advisors, and other POC graduate students can aid in providing safety to students who may be placed in areas of increased risk, such as at PWIs and HWIs. It is the responsibility of all faculty and staff; therefore, the institution, to ensure that everyone is properly educated, safe, and has the ability to contribute to cultural diversity.

In a study from McGee and Bentley 2017, a Black female undergraduate student, “Nia”, was concerned about attending an HBCU and the fear of that attendance limiting her career endeavors. Her mom said, “If you want diversity, you’ll get diversity for the rest of your life, but right now it’s important to love yourself.” Her mom supported her attending a HBCU because she knew that her daughter would have much more support there, even though HBCUs tend to be

looked down upon by the white academic majority. When making choices about your future, you need to make choices that will have you at the center and focus on you only. You have an entire lifetime to bridge the gap between white and Black academia, for example. However, it is important to have a strong foundation where you know you will be supported and surrounded by people who have your best interest at heart. While at a PWI, I have found that it is hard to trust white people, especially faculty, as I have been burned in the past. Many times my “diversity” and my own success has been used to benefit them and their own accolades as a white person showing the facade of allyship.

I will end with a message of guidance for Black and POC academics, as Nia’s mother did for her in the paper above. It is important to make your choices for yourself and not for others or how others view you. This is your journey, and you have the autonomy to decide where you want to get your education, who you want to learn from, and also the impact you decide to have after. Your success will be your own, and it does not belong to any department, professor, etc.

### FIGURES

To be marginalized in graduate school at a PWI...

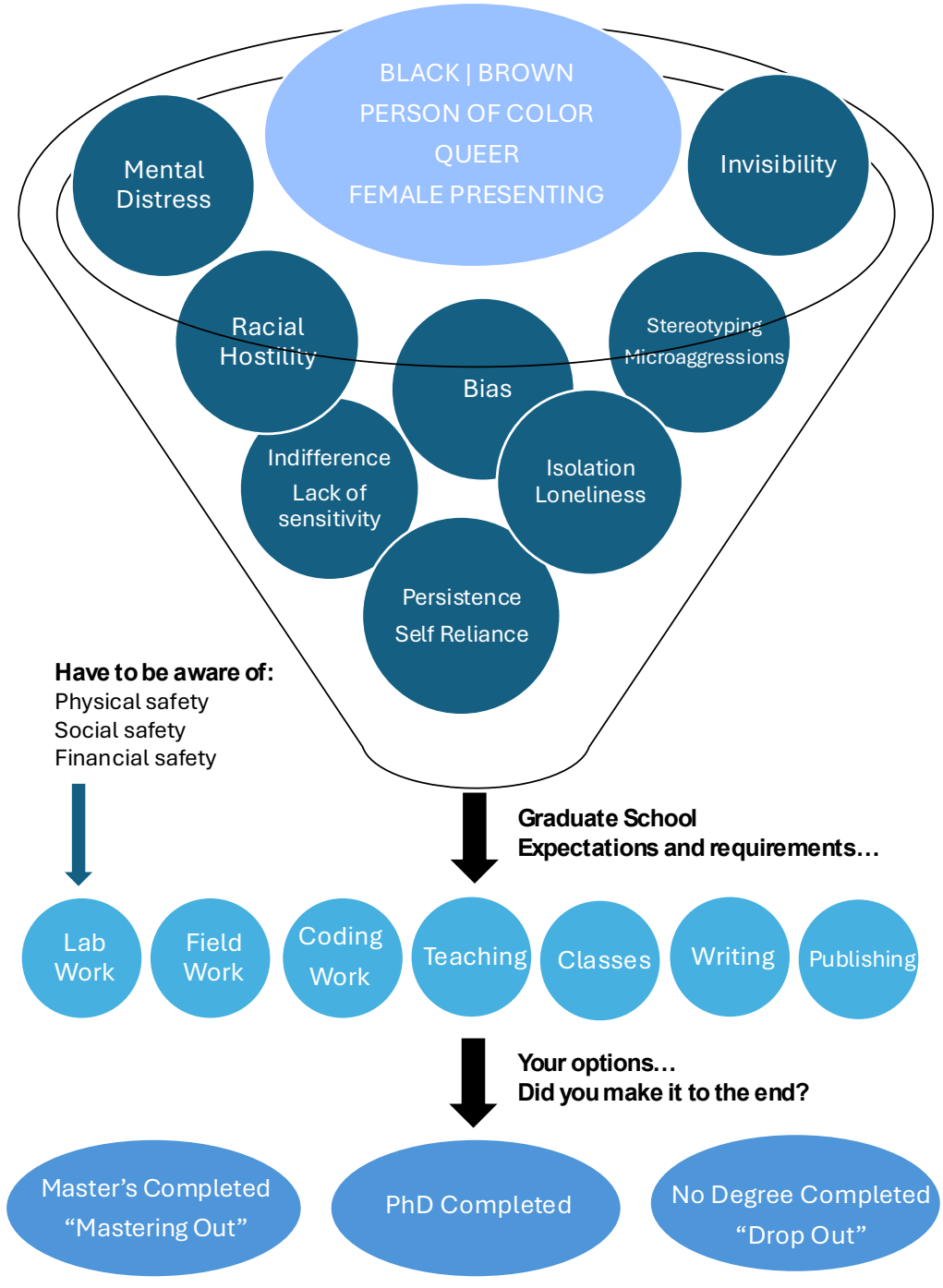


Figure 3.1: Factors that can impact Black students who are part of historically marginalized groups

## CHAPTER 4

### A BLACK BOTANIST NOW UNDERSTANDS *ECHINACEA* CONSERVATION THROUGH A PHYLOGENETIC LENS

#### Conclusion

The *Echinacea* genus is known for its vibrant capitulum inflorescences and ethnobotanical/medicinal significance. Similar to much of the Sunflower family (Asteraceae), Being a part of the Asteraceae family, including but not limited to, a history of rapid radiation, variation in ploidy, and high potential for hybridization. Heavier sampling was resulted in informative data and, as a result, we must reject the previously hypothesized early split between eastern and western species clades (Zhang et al. 2017). It is interesting that the most widespread species, *E. purpurea*, is sister to all other *Echinacea* species (**Fig. 2.5**). However, consistent with previous work (Flagel et al. 2008; Zhang et al. 2017), we found very short internode branch lengths along the spine of the tree implying rapid diversification (**Fig. 2.5**). In addition, given the ability of *Echinacea* species to hybridize and their overlapping ranges, evidence for some interspecific gene flow is not unexpected (**Fig. 2.1**). In the future, we suggest additional sampling across the ranges of *E. simulata* and the midwestern species (**Fig. 2.3, Fig. 2.5**). This would allow a deeper understanding of the influence of interspecific gene flow among these species.

To acquire this data, I attended graduate school at a predominantly white institution (PWI) and an extensive amount of field work was also required. I now understand target capture (Jordan et al. 2025, in review) and how this technique can be used to further understand the evolutionary relationships within the *Echinacea* genus. However, as a Black, queer, female

presenting student my journey to perform this research has been heavily impacted by lack of field safety during field work in the rural south as well as social safety and isolation at a PWI (Fig. 3.1).

My personal experience is mirrored in research and persuasively shows that there are systemic issues in academia, particularly higher education. Unfortunately, I understand that a singular graduate student or even a group of graduate students will not solve a systemic issue. Due to that, I believe that 1) most of the work is the responsibility of department heads, coordinators, and administrators due to their longevity in academia and 2) a mutual aid framework would be helpful for said individuals to utilize in order to make the culture of academia less hostile and toxic towards POC graduate students, especially Black graduate students. A mutual aid framework would allow collective coordination to meet needs of groups of people, like Black and Brown graduate students, and would signal to those students that the department and those within it have a shared understanding that the academic system in place is unjust and that most needs may not be met without intervention (Spade 2020).

Truthfully, to be an effective graduate program, department, advisor, etc., there has to be an understanding that graduate students are not a monolith. So, while it seems blatant that each student will need different levels and types of support in order to succeed, many graduate programs, intentionally or not, may disregard what seems obvious and plain to see. It is foolish and unkind to place an expectation of assimilation on historically marginalized communities. Historically as a society, we should have learned that the standard of assimilation is wrong and has also failed underrepresented groups. However, in many ways, repeated and mirrored experiences by Black and Brown students may show us that not much has been learned. Standards should be edited to accommodate a more diverse community of students and faculty.

The key is to teach, learn, and work to dismantle a non-inclusive system (Halsey et al. 2020). That is the answer to how you diversify and retain students of color. However, this requires many senior and supervising members of departments like faculty, staff, department heads, and administrators to actually do the internal work with actionable steps and not solely intellectualize the internal work in their heads.

So, while I now have a vast repertoire of skills related to computational datasets, project management, grant writing, genetic and sequencing work, and field work, I also recognize the amount of stress, emotional distress, harm, and fear this degree has given me. I truly I hope that this thesis serves as a lesson for academics, especially white academics, in my field of how experiences can drastically change when you are culturally and racially different compared to those within your field. I personally hope that this thesis will have an impact on the department I am graduating from. Hopefully, this thesis inspires faculty to do better in the near future for students of different backgrounds who are coming into the program. Currently, I have taken the responsibility off of myself and the massive amount of stress I feel hoping for an academic environment that will do better and protect those who are at increased risk. I have spent the last 5 years looking out for those around me, from historically marginalized communities, because I was not protected or looked out for prior to transferring labs. Many of the incidents in this thesis that have been my own experience have been swept under the rug by my own department, and I never received an apology or acknowledgement from the responsible parties. I know now that I deserved better, specifically the Chazz who started graduate school with a spark in their eyes, deserved better. The passion and love I had for science has slowly died over the last 5 years, not because I cannot do the work, but because of interpersonal issues and trauma that has resulted in incidents with white faculty during my time in graduate school and academia at large. However,

I still have a small inkling of hope that academia and my graduate program in particular will do better in the near future, especially for Black students who have an interest and love for plant biology.

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## APPENDIX

**Appendix 1. Sampled taxa for hybridization sequencing with Compositae-ParaLoss-1272 bait set.** This data will also be available on the Sequence Reads Archive (SRA, NIH). This has been submitted separately as an excel data sheet file to the SRA on the NIH database.

<i>sample name</i>	sample ID	organism	geo loc name	collection year	voucher ID	SRA accession	bioproject accession	collector name
<i>Allison4_IL_Pall_S67_L008_CJ8</i>	CJ8	Echinacea pallida	USA: Illinois	2023	GA280733	SRR31904110	PRJNA1207049	Stuart Allison
<i>Ames25106_Purp_S65_L008_CJ6</i>	CJ6	Echinacea purpurea	USA: Georgia	1998	GA280729	SRR31904109	PRJNA1207049	NCRPIS: GRIN Repository
<i>Black6423_Sang_CJ24_S55</i>	CJ24	Echinacea sanguinea	USA: Texas	2023	GA280720	SRR31904098	PRJNA1207049	Adam Black
<i>CJ3_CLTN_Tenn_S68_L008_CJ9</i>	CJ9	Echinacea tennesseensis	USA: Tennessee	2023	GA280738	SRR31904087	PRJNA1207049	Chazz Jordan, Philip Bentz
<i>CJ6LH_TNTenn_CJ33_S61</i>	CJ33	Echinacea tennesseensis	USA: Tennessee	2023	GA280739	SRR31904083	PRJNA1207049	Chazz Jordan, Philip Bentz
<i>CJ9LH_Tntenn_CJ26_S57</i>	CJ26	Echinacea tennesseensis	USA: Tennessee	2023	GA280739	SRR31904082	PRJNA1207049	Chazz Jordan, Philip Bentz
<i>CJ_MvgGA_Tenn_S63_L008_CJ4</i>	CJ4	Echinacea tennesseensis	USA: Tennessee	2023	GA280732	SRR31904081	PRJNA1207049	Chazz Jordan, Philip Bentz
<i>CLF006EA212023_Ang_CJ35_S63</i>	CJ35	Echinacea angustifolia	CN: Saskatchewan	2021	GA280723	SRR31904080	PRJNA1207049	Sarah Vinge-Mazer
<i>Dunn91721_Purp_S69_L008_CJ10</i>	CJ10	Echinacea purpurea	USA: New York	2021	GA280730	SRR31904079	PRJNA1207049	Amara Dunn
<i>E019HA8_Laev_CJ34_S62</i>	CJ34	Echinacea laevigata	USA: Georgia	2023	GA280736	SRR31904078	PRJNA1207049	Emily Laske
<i>E026_12_Laev_CJ39_S67</i>	CJ39	Echinacea laevigata	USA: Georgia	2023	GA280735	SRR31904108	PRJNA1207049	Emily Laske
<i>ENTSo_CJPB_Tnpurp_CJ25_S56</i>	CJ25	Echinacea purpurea	USA: Tennessee	2022	GA280731	SRR31904107	PRJNA1207049	Chazz Jordan, Philip Bentz
<i>Elk8212_purp_CJ21_S52</i>	CJ21	Echinacea purpurea	USA: Michigan	2021	All sample used	SRR31904106	PRJNA1207049	Marcel El Kouri
<i>Gostel831_Ang_CJ23_S54</i>	CJ23	Echinacea angustifolia	USA: Texas	2023	GA280722	SRR31904105	PRJNA1207049	Morgan Gostel
<i>Gostel832_Atro_S62_L008_CJ3</i>	CJ3	Echinacea atrorubens	USA: Texas	2024	GA280721	SRR31904104	PRJNA1207049	Morgan Gostel

<i>PI631251_Sim_CJ3 0_S59</i>	CJ30	Echinacea simulata	USA: Missouri	1996	GA280725	SRR31904103	PRJNA1207049	NCRPIS: GRIN Repository - PI631251
<i>PI631263_Para_CJ 41_S69</i>	CJ41	Echinacea paradoxa	USA: Oklahoma	1997	All sample used	SRR31904102	PRJNA1207049	NCRPIS: GRIN Repository
<i>PI631264_Para2_S 64_L008_CJ5</i>	CJ5	Echinacea paradoxa	USA: Oklahoma	1997	GA280734	SRR31904101	PRJNA1207049	NCRPIS: GRIN Repository
<i>PI631308_Sim2_S6 6_L008_CJ7</i>	CJ7	Echinacea simulata	USA: Tennessee	1997	GA280726	SRR31904100	PRJNA1207049	NCRPIS: GRIN Repository
<i>PI649040_purp_CJ 20_S51</i>	CJ20	Echinacea purpurea	USA: Alabama	1998	All sample used	SRR31904099	PRJNA1207049	NCRPIS: GRIN Repository
<i>Pizza9211_purp_CJ 22_S53</i>	CJ22	Echinacea purpurea	USA: Michigan	2021	All sample used	SRR31904097	PRJNA1207049	Riley Pizza
<i>SLCGA2_purp_CJ19 _S50</i>	CJ19	Echinacea purpurea	USA: Georgia	2021	All sample used; public property - extirpated	SRR31904096	PRJNA1207049	Chazz Jordan
<i>UTEP15876_Ang_C J37_S65</i>	CJ37	Echinacea angustifolia	USA: South Dakota	1980	UTEPH672 9	SRR31904095	PRJNA1207049	William J. Hess
<i>UTEP18125_Ang_C J36_S64</i>	CJ36	Echinacea angustifolia	USA: Oklahoma	1981	UTEPC1806	SRR31904094	PRJNA1207049	Larry K. Magrath
<i>UTEP20792_Pall_S 70_L008_CJ11</i>	CJ11	Echinacea pallida	USA: Louisiana	1982	UTEPH672 5	SRR31904093	PRJNA1207049	Roy Dale Thomas
<i>UTEP34215_Ang_C J27_S58</i>	CJ27	Echinacea angustifolia	USA: Oklahoma	1984	UTEPC1804	SRR31904092	PRJNA1207049	Larry K. Magrath
<i>UTEP50934_Sang2 _CJ31_S60</i>	CJ31	Echinacea sanguinea	USA: Texas	1982	UTEP50934	SRR31904091	PRJNA1207049	Royal D. Suttkus
<i>UTEP53433_Pall_C J38_S66</i>	CJ38	Echinacea pallida	USA: Texas	No Date	UTEPC1807	SRR31904090	PRJNA1207049	Unknown
<i>UTEP65581_Pall_C J40_S68</i>	CJ40	Echinacea pallida	USA: Louisiana	1975	UTEPH673 0	SRR31904089	PRJNA1207049	Roy Dale Thomas
<i>VR1_TazTN_Purp_ S71_L008_CJ12</i>	CJ12	Echinacea purpurea	USA: Tennessee	2022	GA280727	SRR31904088	PRJNA1207049	Chazz Jordan, Vanessa Raditz
<i>ent_south13_purp _CJ17_S48</i>	CJ17	Echinacea purpurea	USA: Tennessee	2022	All sample used	SRR31904086	PRJNA1207049	Chazz Jordan

<i>ladwig10211_purp_CJ16_S47</i>	CJ16	Echinacea purpurea	USA: Wisconsin	2021	GA280728	SRR31904085	PRJNA1207049	Laura Ladwig
<i>lohman9211_purp_CJ18_S49</i>	CJ18	Echinacea purpurea	USA: New York	2021	All sample used	SRR31904084	PRJNA1207049	Rowena Lohmen
<i>SRR5241408_Parthenium_argentatum</i>	Parthenium argentatum_SRR5241408	Parthenium argentatum	USA: Arizona	1942	Reference collector	SRR5241408	PRJNA369535	William Belknap
<i>SRR26366552_Helianthus_annuus</i>	Helianthus annuus_SRR26366552	Helianthus annuus	USA: Iowa	2020	Reference collector	SRR26366552	PRJNA1027349	Brian Smart
<i>SRR5907719_Helianthus_argophyllus</i>	Helianthus argophyllus_SRR5907719	Helianthus argophyllus	USA: Texas	2016	Reference collector	SRR5907719	SRR5907719	Gregory Owens