Mondamin Sickened

Human & Climate Effects on the Survival of Miami Ethnobotany

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I. Introduction

Once home to the Shawnee, Potawatomi, Delaware, and Miami people, Indiana's contemporary culture and institutions have had their indigenous history wiped from public memory, in many cases advertently. What has remained, however, is the foundation of indigenous culture, not only in the United States but across the world–the existence of native ecosystems. It is possible with even a cursory understanding of indigeneity to identify the critical human-ecosystem relationship that characterizes indigenous cultures and knowledge systems. The link between humans and the environment within the Miami system can be seen throughout the legends and myths passed down within the community over generations. The story of Mondamin, a Miami corn deity and the title of this thesis, is said to have manifested himself in the form of an ill and aging man as a physical demonstration of the maltreatment of the season's corn harvest. Mondamin is encountered weak and hungry in a lodge, and he reveals that the Miami would face a poor fall hunt as a result of their irresponsibility (Raffert, 1996). This story carries the critical, underlying assumption that community health is directly related to environmental health and is one that can be found in many indigenous storytelling traditions. It is a characteristic that, in recent decades, has increasingly been considered a crucial part of developing a sustainable environmental ethic in the modern day (Johnson et al., 2016)--take the 1992 Rio Declaration at the United Nations Conference on Environment and Development (UNCED), for example, which declared the importance of indigenous peoples, land rights, and their knowledge systems towards sustainable development (Higgins, 1998).

Despite these strides in management, it will take much more than international agreements to secure and diffuse indigenous environmental ethic. Paradoxically, we must also ensure the survival of the ecosystems in which the ethic was born. In essence, we must listen to the natural world and its original protectors in order to understand how to protect it. It is paramount that this mission occur in every community across the country through the participation of both indigenous and non-indigenous actors alike, particularly as the threat of climate change has become a closer reality than a distant uncertainty. Already Indiana has begun to see more precipitation, higher temperatures, and a greater incidence of extreme weather events. Exacerbated by a predicted increase in the frequency and intensity of spring floods and summer droughts, an increase in average temperatures, shorter frost seasons, and greater presence of invasive species, diseases, and pests, Indiana's forests will change (Phillips et al., 2019). It is with this in mind that this thesis asks: *How will future human and climate plant stressors affect the survival of ethnobotanical plants important to the Miami of southern Indiana?*

Ethnobotany, the study of how people use and integrate plant species into their culture and identity, has widely been used to document indigenous plant use for medicinal, commercial, ceremonial, food, and construction purposes across the world. The prevailing sentiment that arises from these studies is the critical need to push ethnobotany past documentation and into practical use, marrying scientific understandings of the environment with the practical knowledge gained from centuries of living in mutualistic relationships with the land. This thesis focuses on the Miami people specifically due to a lower degree of displacement compared to other Indiana native peoples–the Miami were the only nation to have a segment of its population successfully resist forced exodus despite the 1830 Indian Removal Act and land cession treaties in the following decades (Rafert, 1996). Because of this, it can be argued that Miami ethnobotany is generally reflective of native Indiana ecosystem use and its study can produce relevant Hoosier plant use applications.

The question is primarily inspired by the environmental rehabilitation work done by the Yurok Tribe of northern California. In 2014, the Environmental Protection Agency awarded the Yurok Tribe the Science to Achieve Results (STAR) grant to finance the implementation of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources. The adaptation plan, created in response to worsening river health and salmon population decline, integrated tribal knowledge and community engagement with input from state and federal agencies (Maldonado, 2019). Cultural responsibility for one's environment and centuries of traditional knowledge gained through practical work have placed the Yurok people in a unique position to act as leaders in climate policy. Their plan is ecosystem-specific, demonstrating a keen understanding of complex ecological interactions as well as how predicted changes to the climate will affect their region. Additionally, the Yurok Tribe Environmental Program includes multiple stakeholders and acts upon the needs of their own historically marginalized community, serving as a case study in environmental justice and collective action. While this thesis' ethnobotanical focus is narrow in comparison to ecosystem rehabilitation, utilizing traditional knowledge is beneficial across all ecosystem levels.

II. Literature Review

Miami Ethnobotanical History

Performing research into Miami ethnobotany is primarily hindered by the little knowledge available regarding Miami culture and ethnobotanical practices prior to European settlement of Indiana. What *is* known has been pieced together through archeological evidence, recorded observations by European explorers and missionaries, and inherited understandings of plant use by Miami elders; however, there remains a significant gap in Miami cultural understanding due to bouts of severe community instability immediately prior to and after initial French contact. The little knowledge available on pre-European Miami life, however, demonstrates a subsistence relationship with the environment that was bolstered by extensive land use management—a characteristic common among many indigenous peoples across North America. Late eighteenth-century military expeditions, for example, found hundreds of acres of croplands surrounding Miami villages (Whitaker & Amlaner, 2012). Where open, natural clearings were not available for cultivation, the Miami would slash-and-burn forested plots to create areas of dense nutrient availability until fertility was depleted, the cropland abandoned, and the area allowed to regenerate (Whitaker & Amlaner, 2012). Further investigations into movement patterns indicate that the Miami were a semi-nomadic people who coupled autumnal/winter hunting activities with spring/summer agriculture. Both seasonal activities were paired with foraging for edible species and medicinal plants (Wheeler-Voegelin et al., 1974). The resulting ethnobotanical system is highly diverse and place-based due to the Miami's seasonal movement through forest, riparian, and prairie ecosystems.

Most interestingly, however, is the Miami's ability to self-stabilize after considerable community upheaval–in the century prior to first contact with French missionaries and explorers in 1654, the Miami suffered drastic population decreases due to smallpox, measles, and bubonic plague outbreaks that would continue well into the second half of the nineteenth century. The ensuing power shifts, disruption of agricultural activities, alteration in hunting territories, and the disintegration of religious and cultural practices altered Miami society and culture significantly (Rafert, 1996). Ethnohistorian Stewart Rafert notes that the Miami culture of 1654 is not the Miami culture of the eighteenth century, nor is it the Miami culture of the modern-day. It is not difficult to imagine that their ethnobotany would have evolved under these situational pressures as well.

By the eighteenth century, the Miami were heavily influenced by interactions with French and British populations, and it is during this period that their material culture began to closely resemble that of European Americans. A list of goods available between 1680 and 1760 demonstrates that the Miami could trade for items such as guns and powder, scissors, ruffled shirts, bed lace, pipes, tea, wheat, barley, and oats (Schoolcraft, 1857). Artist George Winter's paintings and sketches of Miami life during the 1830s display a culture slowly adopting material elements of their white counterparts; his work depicts women in European dress with neckerchiefs, but wearing elaborate silver earrings, native leggings with ribbon, and decorated shawls. The men in Winter's work are often shown pairing frock coats with moccasins, and ruffled shirts with traditional beadwork, feathers, and face paint (Winter, 1810-1876). It is likely during this period that the Miami began to cultivate and integrate foreign plant species into their ethnobotanical tradition. Gonella's 2007 ethnobotanical dissertation lists the cultivation of Old World crops such as plantains, peaches, and cabbage by the Miami (Gonella, 2007) (Crosby, 2001).

It can be argued that the most comprehensive list of ethnobotanical species was recorded after the 1795 Treaty of Greenville. Between 1774 and 1794, indigenous villages throughout the Great Lakes– including Miami, Shawnee, Delaware, Iroquis, Odawa, Wyandot, and Mingo villages–were subject to destruction and massacres by American militias. On paper, the Treaty of Greenville sought to put an end to the violence that was rooted in white hostility and American expansionism. The treaty, to which many tribes had not agreed and which defined native land, forged a shaky peace that would later be broken by the same expansionism the treaty was designed to curb (Hemenway, 2015). It was during this period that the Miami moved from their large village of Kekionga (modern-day Fort Wayne, Indiana) to smaller villages along the Eel, Mississinewa, and Wabash rivers. These villages were relatively isolated compared to Kekionga where the Miami had grown accustomed to engaging in market activities with American frontier settlements. The dissolution of Kekionga allowed the Miami to make use of plant species that grew abundantly in Indiana's riparian ecosystems and marked a cultural return to subsistence-oriented activities over market-oriented ones. Goldenseal, dog fennel, boneset, yarrow, pennyroyal, bloodroot, and sweet flag provided medicinal benefits. Strawberries, plums, grapes, persimmons, papaws, berries, and crabapple supplemented cultivars such as corn, beans, squash, wheat, and European garden vegetables. Mulberry, common milkweed, skunk cabbage shoots, sour dock, and wild onion were used as greens, while spikenard, spicebush, and sassafras were used in teas. These species continue to characterize Miami ethnobotany to the present day (Rafert, 1996).

Ethnobotanical Theory

The ethnobotanical theory upon which the research question rests is the cultural keystone species theory, suggesting that there are certain animal and plant species that play such an outsized role in defining socio-cultural systems that the extinction or removal of these species from the landscape would negatively affect the identity and stability of a culture (Garibaldi & Turner, 2004). Derived from the keystone species theory in ecology, the cultural keystone species theory highlights the emerging intersections between ethnobotany and ecology, and it has been argued that the former subject's methodology may benefit from the latter's scientific rigor and unifying theories (Gaoue et al., 2017). Existing literature surrounding the ethnobotany of the

Miami people may act as proof of this argument--much of current Miami ethnobotany involves conducting interviews with Miami elders regarding current and historical plant usage, or with the synthesis and correction of interviews and observations conducted by mid-seventeenth century ethnobotanists (Gonella, 2007). However, while appearing to lack the rigorous methodologies characteristic of other scientific fields, a look at primary ethnographic sources proves that there is still much work to be done in the proper documentation of any native nation's ethnobotany whose documentation may have been improperly recorded due to the agendas and biases of their documenters. One of the earliest available works documenting Miami plant use, for example, is a memoir recounting Nicolas Perrot's interactions with several North American nations (Perrot, 1680); it is entitled *Memoir on the manners, customs, and religion of the savages of North America.*

The work involved in correcting such biases and misobservations not only involves cross-referencing with seemingly unrelated sources (Gonella, 2007), it may also involve the integration of techniques from subjects such as chemistry, molecular biology, ecology, and medical anthropology, among others (Balick & Cox, 2020). There have been several ethnobotanical studies conducted across the world that reflect this newer, integrative method of ethnobotany. For example, Salick et al.'s 2009 study on climate change's effects on Eastern Himalayan plant ecology is notable in that it integrates an analysis of how changing vegetative patterns may influence native Tibetan plants used for medicinal and food purposes, as well as grazing, wood sources, and commercial sales of alpine plants (Salick et al. 2009). In a similar vein, Rodriguez et al.'s 2018 ethnobotanical inventory among farming communities in the Colombian Andes was conducted using semi-structured interviews and pre-existing botanical collections to inform land conservation strategies (Rodriguez et al., 2018). This emerging use of ethnobotany firmly roots the field in critical issues such as climate change, natural resource management, and conservation, ultimately making the field a critical tool in the revitalization of indigenous culture and environmental ethic.

There are large gaps in the existing Miami ethnobotany literature as it pertains to modern applications and it is largely limited to the syntheses of seventeenth, eighteenth, and nineteenth-century interviews and observations (Gonella, 2007; Toupal, 2006). This thesis builds upon these necessary syntheses by integrating predicted climatic conditions in southern Indiana to determine which native plants may thrive in Indiana's changing climate.

III. Data & Methodology

This thesis was a qualitative study of how various human and climate-related risk factors may affect the habitat suitability of Miami ethnobotanical plant species native to southern Indiana. Using Gonella's 2007 *Myaamia Ethnobotany* dissertation, an initial list of native Indiana plant species was compiled using NatureServe Explorer. This initial step was critical to establishing a narrow focus due to the large geographic range of Miami movement since European contact in 1654–of the 160 ethnobotanical species Gonella identified, 139 were used in this study. *Myaamia Ethnobotany* was invaluable to the development of this thesis because Gonella compiled and verified existing ethnobotanical observations by French explorers against the traditional knowledge systems held by living Miami elders.

Of the 139 native Indiana species compiled, 18 were chosen for the study on the basis of conversation status. Using NatureServe's state-level conservation status ranking, plant species with S1 (critically imperiled), S2 (imperiled), and S3 (vulnerable) rankings were chosen. When rankings were not available for Indiana (designated by SNR), Indiana native plants with status rankings of S1-S3 in surrounding Midwestern states were chosen–habitat/ plant vulnerabilities and climate projections tend to be sufficiently similar across the Midwest due to similar climates.

Table 1: Final Ethnobotanical Species List

Species Name	**Myaamia Name**	**Scientific Name**	**Conservation Status Ranking (IN)**	**Conservation Status Ranking (Midwest)**	**Miami Use**
American Chestnut	maamišimiši*	*Viburnum prunifolium L.*	S1	S1 (MI, KY) S3 (OH)	Food, Medicinal
Butternut Tree	*kiinošiši*	*Juglans cinerea*	S2	S2 (IL, KY, WI) S3 (MI)	Material
Water Chinquapin/American Lotus	*poohkihšiikwalia**	*Nelumbo lutea*	S3	S2 (MI) S3 (IL)	Food
Goldenseal	unknown	*Hydrastis canadensis*	S3	S2 (MI, WI)	Material, Technological
Red Osier Dogwood	*neehpikaahkwi*	*Cornus sericea*	S4	S1 (KY)	Cultural
Wild Ginger	unknown	*Asarum canadense*	S5	S3 (IL)	Food, Medicinal
Red Mulberry Tree	*mihtekwaapimiši*	*Morus rubra*	S5	S2 (MI)	Food, Material, Technological
Missouri Ironweed	*mihtekwaapimiši*	*Vernonia missurica*	SNR	S2 (OH)	Medicinal
Skunk Cabbage	*mihtekwaapimiši*	*Symplocarpus foetidus*	SNR	S3 (IL)	Food
Rock Elm	unknown	*Ulmus thomasii*	SNR	S1 (IL) S3 (OH)	Material
Eastern Wild Rice	*naloomina*	*Zizania aquatica*	SNR	S2 (MI, OH) S3 (IL)	Food
Smooth Blackhaw Tree	*naloomina*	*Viburnum prunifolium*	SNR	S2 (WI) S3 (MI)	Food
Northern Fox Grape	*waawiipinkwahki*	*Vitis labrusca*	SNR	S2 (KY) S3 (OH)	Food, Technological

Common Elderberry	*waawiipinkwahki**	*Sambucus racemosa*	SNR	S1 (IL)	Food, Material, Technological
Kentucky Coffeetree	unknown	*Gymnocladus dioicus*	SNR	S2 (WI) S3 (MI)	Food, Material
Big Shellbark Hickory	*ceecinkilaakia*	*Carya laciniosa*	SNR	S2 (IL) S3 (MI)	Food
Pecan Tree	*kaanseeseemini*	*Carya illinoenensis*	SNR	S3 (IL, KY)	Food
Blackjack Oak	*maamhkatiaahkatwi*	*Quercus marilandica*	SNR	S3 (KY)	Food

* = unconfirmed Myaamia name

Climate risk factors were chosen using Phillips et al.'s 2019 *An integrated assessment of the potential impacts of climate change on Indiana forests* and human risk factors were chosen using Carman et al.'s *The Hardwood Ecosystem Experiment: a framework for studying responses to forest management.* These human and climate risk factors were then compared to the optimal growing conditions and contemporary threats of the 18 ethnobotanical plant species chosen for the study in order to determine the trajectory of habitat suitability by mid to late-century.

Table 2: Human and Climate Risk Factors

A rise in average annual temperature	Temperatures that exceed 95°F	Increase in spring and winter precipitation	Decrease in summer precipitation	Habitat destruction*
Invasity	Increased pathogen incidence	Forest fragmentation*	Decrease in summer precipitation	Over-harvesting*

* = human-related risk factors

IV. Background

It has become startlingly apparent within the past decades the effect humans have had on the climate, and thus the stability of their natural environments, due to the emission of greenhouse gasses. Climatic threats to the current structure of terrestrial ecosystems include:

(1) Terrestrial species range shifts to the poles and to higher elevations across the majority of global ecosystems, including those of North America (with very high confidence);

(2) Increased incidence in drought-related tree mortality (with high confidence);

(3) Widespread deterioration of the function, structure, seasonal timing, and resiliency of ecosystems, effects which are becoming increasingly irreversible (with high confidence).

(IPCC, 2020)

A detailed look at the impacts of climate change on Indiana's ecosystems demonstrates, too, that the state is not exempt from the global deterioration the IPCC describes. Threats to the current structure of Indiana forests include:

(1) A rise in Indiana's average annual temperature by 5 to 6°F by 2050 and 6 to 10°F by 2100;

(2) In southern Indiana, daily high temperatures that exceed 95°F 50 to 89 days of the year by late century, a significant increase from a current average of 7 extremely hot days of the year;

(3) A 17 percent increase in spring precipitation and a 32 percent increase in winter precipitation by late century, with a decrease in the volume of winter precipitation as snow;

(4) A 7 percent decrease in summer precipitation by late century, increasing the threat of water stress already exacerbated by warmer temperatures and increased rates of evaporation;

(5) An increase in heat-tolerant invasive species that were once absent from Indiana's native forests due to cooler temperatures, such as Japanese stiltgrass and Amur honeysuckle;

(6) An increase in the incidence of pathogen-related diseases, such as bur oak blight, due to wetter springs and flooding;

(7) A reduction in habitat suitability for 17 to 29 percent of Indiana tree species including eastern white pine, American beech, and American basswood;

(8) An increase in habitat suitability for 43 to 52 percent of Indiana tree species including sweetgum, sycamore, and silver maple.

(Phillips et al., 2019)

An analysis of global terrestrial ecosystems has demonstrated that southern midwestern forests have a moderate to high sensitivity to variabilities in temperature, water, and cloud cover (Sedon et al., 2016). This means that Indiana's forests are not among the most resilient ecosystems on the planet–the combination of Indiana's climate projections may result in a greatly altered forest landscape with effects that will cascade through trophic levels. However, it must be noted that it does not take whole ecosystem collapse, nor does it take all of Indiana's climate projections coming to complete fruition, to significantly affect the survival of individual and associated species. A significant example of this can be seen in the near-extinction of mature American chestnut trees due to chestnut blight throughout the northeast. While the exact consequences of chestnut extirpation are difficult to measure due to a lack of empirical data prior to chestnut blight’s introduction, it is likely that the reduced presence of the American chestnut has decreased soil carbon and nitrogen availability in certain soils (Rhoades, 2006), significantly altered decomposition, nutrient cycling, and productivity, reduced carbon and nutrient sequestration, and decreased autumn leaf inputs as the predominant energy base in riparian ecosystems (Ellison et al., 2005). With this in mind, the contribution of each individual species to a greater forest landscape cannot be overstated.

While climate change poses a significant threat to the existence of southern Indiana’s forests as we know them, human destruction of these ecosystems poses a significant, secondary threat. Indiana’s history of land management after European settlement continues to define the modern landscape. The early to mid-nineteenth century was characterized by rapid population growth as Indiana gained statehood. Rates of deforestation similarly increased in order to accommodate lumber and agricultural needs (Carman, 2013). Prior to this period, 90 percent of Indiana was forested. By 1900, that number dropped to 4 percent (Phillips et al., 2019). It would not be inaccurate to assume that Miami ethnobotany would have suffered greatly during this period due to significant habitat destruction.

Modern forest management has shifted greatly since the overharvesting and deforestation of the nineteenth century. Beginning with the 1903 passage of Indiana Code 14-23-4-1 which allowed for the establishment and management of state forests, Indiana increased its forest cover to 23 percent by the century’s end (Phillips et al., 2019). The results of this management change can be seen most clearly in southern Indiana’s Brown County landscape. What may appear to be pristine wilderness to the unfamiliar tourist is actually the work of park builders and the Civilian Conservation Corps who revitalized the area following extensive agricultural deforestation (Greiff, 2019).

Despite the considerable success of conservation and revegetation efforts in southern Indiana, forest management concerns have shifted to a newer threat: forest fragmentation. Forest fragmentation, as a product of development, results in a change in forest composition and species association. Additionally, increased forest edge encourages the growth of shade-intolerant species (Carman, 2013).

V. Results

Missouri Ironweed–kiišiinkwia
(*Vernonia missurica*)

An herbaceous perennial species that prefers moist to wet soils and full or partial sunlight, the Missouri Ironweed was foraged by the Miami for medicinal use. Habitats include forest edge and openings, lake edges, overgrazed plots, swamps, as well as vacant lots (Hilty, 2018). The Missouri Ironweed has been found to be drought-tolerant, meaning the species may survive the decrease in summer precipitation projected to occur in Indiana by late century. However, a look at a related species, the Fascicled Ironweed (*vernonia fasciculata),* demonstrates that the Missouri Ironweed may be vulnerable to increased flooding duration and frequency, and non-native invasivity (Government of Canada, 2021). Human threats to its habitat include herbicide use, development, and landscaping (Hilty, 2018).

Butternut Tree–kiinošiši
(*Juglans cinerea)*

Prior to its decline across the eastern United States, butternut was valued for its sweet nuts that served as a food source for both woodland species and humans (Purdue, 2016). It is likely that the Miami used the butternut as a food source as well as for material. Butternuts thrive in mesophytic forests consisting of hardwoods such as basswood, hemlock, oak, hickory, and sugar maple. While able to grow on dry, limestone soils, the butternut prefers well-drained soils and is often found on stream banks and hillsides (USDA, 2021). Butternut has widely varying climatic conditions and it is found in environments with mean annual temperatures between 40 and 60°F, though its average maximum suitable temperature is 114°F. Its average minimum suitable temperature is -30°F (USDA, 2021).

The sudden decline of the butternut is attributed to the rapid spread of bunch disease. When infected, the tree's branches fail to become dormant in winter and are subsequently killed by frost (Purdue, 2016). Bunch disease is believed to be spread by leafhoppers, a pest that is killed by cold winter temperatures or that migrates to warmer regions (University of California Statewide Integrated Pest Management Program, 2021). Winter temperatures, then, slow the spread of bunch disease as the pathogen's carriers either die or migrate during the season–as average annual temperatures increase across Indiana, what little remains of the butternut tree in southern Indiana's forests are at risk of year-round exposure to the disease.

Butternut is susceptible to a number of other pests including bark beetles, butternut calico, wood borers, and lace bugs (Purdue, 2016). Like with leafhoppers, warmer winter temperatures may provide suitable habitat for pests year-round, furthering the spread of pests and pathogens to butternut and associated species. Additionally, while the butternut may not succumb to heat stress alone due to high maximum suitable temperatures, associated decreases in water availability and a projected 7 percent decrease in annual precipitation puts the butternut in considerable risk of water stress.

Red Mulberry Tree–mihtekwaapimiši
(*Morus rubra)*

Though found sparingly, the red mulberry can be found in moist wooded slopes and forest edges. It is important to note that its current status rank is due to hybridization with white mulberry (Weeks, 2003). Red mulberry is both shade and drought tolerant, though higher summer temperatures and an increase in annual "extremely hot" days may prove too extreme for the species. Red mulberry is relatively susceptible to pests and disease (NRCS, 2008), however, heat and drought stress associated with summer projections, and water stress associated with spring flooding can reduce the tree's capacity to resist pest and disease damage. This may increase red mulberry's vulnerability to armillaria root rot, bacterial blight, white flies, and mealybugs among other diseases and invertebrate pests (UCIPM, 2021).

Red Osier Dogwood–neehpikaahkwi
(*Cornus sericea*)

A medium shrub, red osier dogwood is common in a wide range of habitats including floodplains, swamps, forests, shorelines, and sand dunes. It prefers moist soils, though once established, the red osier dogwood has been found to show a high degree of drought tolerance in propagation and restoration studies. While flood-tolerant, red osier is not shade-tolerant. Common garden experiments indicate that it can withstand temperatures from -66 to 3°F (USFS, n.d.)

The primary, contemporary threat to the plant is powdery mildew, a fungus that can stunt and distort young growth in severe cases of infection. Due to its spread in rainy and humid conditions, the red osier dogwood is predicted to experience a greater incidence of powdery mildew infection as a result of higher annual temperatures and increased spring and winter precipitation (Stickland, 2015). Additionally, a decrease in summer precipitation coupled with increased rates of evaporation due to high temperatures may also decrease habitat suitability, particularly for young red osier dogwood growth.

Rock Elm
(*Ulmus thomasii*)

Rock elm can be found in floodplains, swamps, forests, and woodlands with other hardwoods. It prefers moist, well-drained sandy loam, loam, or silt loam soils. While shade-tolerant as a seedling, rock elm grows increasingly shade-intolerant as it matures. Rock elm has a maximum suitable temperature of 100°F and a minimum suitable temperature of -30°F (USDA, 2021). Due to its association with hardwoods in mesophytic forests, rock elm may become increasingly vulnerable to heat and drought stress in the summer months, and vulnerable to water stress as precipitation and flooding increases across the state.

The survival of North American rock elm is also threatened by dutch elm disease, an aggressive pathogen spread by the native elm bark beetle (*Hylurgopinus rufipes*), European elm bark beetle (*Scolytus multistriatus*), and likely the banded elm bark beetle (*S. schevyrewi*) (USFS, 2011). A study of the mountain pine beetle (*Dendroctonus ponderosae*) spread into lodgepole pine trees (*Pinus contorta*) found greater reproductive success for the aggressive pine beetle in previously unaffected stands of lodgepole pine due to increased range as a result of climate change (Cudmore et al., 2010). Southern Indiana may see an increase in dutch elm disease due to increased reproductive success by female vectors. In fact, a study on the distribution of dutch elm disease vectors in Estonia, including *Scolytus multistriatus*, found an increased distribution of dutch elm disease vectors as a result of warmer winters and springs (Jürisoo et al., 2021).

American Chestnut–maamišimiši
(*Castanea dentata*)

The decline of the American chestnut has become one of the most recognizable, contemporary examples of the level of species collapse disease can cause. Once found throughout eastern forests–from Mississippi and northern Florida in its southernmost range and north through Maine–the American chestnut has experienced a catastrophic decline from the "Sequoia of the East" to an early-successional stage shrub (American Chestnut Foundation, 2020). A fatal fungal pathogen, chestnut blight infects the tree through small cracks or wounds in its bark, ultimately producing toxins that cause plant cell death and that stop nutrient flow (Purdue Extension–Forestry and Natural Resources, 2016).

Long-term monitoring of existing sprouts and hybridization with blight-resistant, Asian species have produced marginal success in returning the American chestnut to its former glory (Purdue Extension–Forestry and Natural Resources, 2016). Additionally, efforts are being made to cultivate American chestnuts in ideal conditions with sandy, loamy, well-drained soil, full or partial sunlight, and moderate to dry levels of precipitation (PA-TACF, 2006). However, forest fragmentation and increasing levels of precipitation may weaken young American chestnut trees and make them increasingly susceptible to pests and disease over time.

Eastern Wild Rice–naloomina
(*Zizania aquatica*)

A tall aquatic grass, eastern wild rice was an important food source for the Miami, as well as other Great Lakes indigenous peoples, who harvested the grain via canoe. Beyond its material and cultural importance to indigenous peoples, eastern wild rice also serves as a valuable food source and habitat for waterfowl (Trull, n.d.). Found in lakeshores, slow-moving streams, shallow ponds, and emerging marshes, eastern wild rice is a tall aquatic grass sensitive to hydrologic disturbances (Michigan State University [MSU] Extension, n.d.). Eastern wild rice prefers murky or silty soil, can tolerate annual precipitation of between 13.5 and 45.7 inches, and annual temperatures between 44.4°F and 54.5°F. Growing best in conditions where fresh water is regularly circulating, eastern wild rice is intolerant of stagnant water (Duke, 1983).

Due to its historic popularity as an edible grain, one of eastern wild rice's most significant threats is over-cultivation. Human-induced habitat changes, such as damming, dredging, boat wakes, lakeshore development, and pollution also threaten favorable hydrologic conditions that once allowed eastern wild rice to grow abundantly (MSU Extension, n.d.). It is predicted that eastern wild rice will also face issues germinating as temperatures increase throughout its native habitat–wild rice requires a hard winter freeze and low spring temperatures to germinate. The decrease in habitat suitability is already apparent across the Midwest. Ojibwe families in Minnesota, for example, have seen a considerable decrease in annual harvests: from 200 lbs of wild rice in the 1920s to just 80 lbs under favorable conditions (Cusick, 2020).

Smooth Blackhaw Tree–papakimišaahkwi
(*Viburnum prunifolium*)

Found in floodplain forests and moist woods, the smooth blackhaw tree prefers full or partial sun and moist, well-drained soils. It can tolerate the occasional drought as well as temperatures up to 90°F, as well as temperatures below freezing (Janoski & Yiesla, 2022). One of the primary, contemporary threats to the smooth blackhaw tree is the destruction of its riparian habitats (Plant Care Today, 2022), however, the smooth blackhaw tree's survival will likely be determined by its ability to withstand heat stress in the coming decades. This will become particularly true by late century when it is predicted that 50-89 days of the year will see high temperatures that exceed 95°F. Its drought tolerance will also likely decrease over time as the frequency and intensity of droughts in the summer, exacerbated by extreme temperatures, are predicted to increase by late century.

Northern Fox Grape–waawiipinkwahki
(*Vitis labrusca*)

The northern fox grape is a perennial woody vine found in low-ground woods and the muddy borders of ditches and streams. It grows best in full or semi-shade, and in soils that are deep, loamy, and well-drained (Plants for a Future, n.d.).

Based upon threats to the frost grape (*vitus vulpina),* a similar woody vine, the greatest threat to the northern fox grape is competition from invasive, non-native, liana species (Consortium of Midwest Herbaria, n.d.). The threat of invasivity to the northern fox grape is likely to grow in the coming decades, particularly as drought, higher temperatures, and flooding diminish native species' ability to withstand and outcompete invasive non-natives (Casey, 2021). Indiana's forests have already experienced unprecedented growth in invasivity from species including Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), and Asian bittersweet (*Celastrus orbiculatus*) (Purdue Entomology, n.d.). Forest fragmentation compounds the threat of invasivity for the northern fox grape–a decrease in shaded habitat will likely weaken the northern fox grape's ability to outcompete encroaching climbing vines.

Water Chinquapin–poohkihšiikwalia
(*Nelumbo lutea*)

One of only two native species of lotus (Sayre, 2004), the water chinquapin is an aquatic perennial found in ponds, lakes, and slow-moving rivers (Indiana Native Plant Society, n.d.). Favoring sunny conditions, water chinquapin can withstand temperatures above 86°F for at least 210 days of the year (Marc Cathey, n.d.). While establishing itself in shallow waters, this plant requires water up to 7 feet deep in order to grow and spread (Sayre, 2004). Under favorable conditions, water chinquapin can quickly dominate its aquatic habitat due to rhizomes which quickly spread and establish colonies (Pennsylvania Sea Grant, 2018).

Despite the water chinquapin's rapid growth in undisturbed environments, it has been classified as endangered in New Jersey and Pennsylvania, and threatened in Michigan, largely due to pollution and habitat destruction (Sayre, 2004). So long as there is insufficient legislation regulating non-point source pollution, particularly from agricultural inputs such as nitrogen and phosphorus, it can be expected that the trend will replicate itself in Indiana. Additionally, predicted changes in the timing, intensity, and volume of precipitation may alter the hydrology of Indiana's lakes, ponds, and rivers (Höök et al., 2018), creating hostile habitat for the water chinquapin.

Skunk Cabbage–šikaakwayinši
(*Symplocarpus foetidus*)

One of the first plants to emerge in the spring, skunk cabbage is a flowering perennial identifiable by a putrid odor similar to that of rotting meat. Though unpleasant to humans, its scent attracts pollinators like carrion-feeding flies and gnats, while the warmth of its petals has been observed to attract beetles, bees, and beneficial wasps (Mahr, n.d.). Skunk cabbage can be found in marshy woodlands, wetlands, or near springs, and prefers partial to light shade. Despite its wet surroundings, skunk cabbage can only tolerate standing water for short periods of time (Baley, 2022).

The primary threat to the skunk cabbage is the destruction of its habitats, particularly lowland habitat (National Wildlife Federation, n.d.). Considering Indiana's increasing issue of forest fragmentation, this threat to the skunk cabbage is likely to remain. Increased levels of light in the forest edge will not be suitable for skunk cabbage's partial shade requirements. Additionally, increasing flooding events as a result of spring and winter precipitation may increase incidences of standing water to which the skunk cabbage is intolerant.

Wild Ginger
(*Asarum canadense*)

The Miami used wild ginger for food and medicinal purposes, the latter of which took the form of a poultice for wounds due to the plant's antibiotic compounds. Found in deciduous forests, wild ginger prefers partial or full shade and mesic, dry-mesic, or dry soil (Strich, n.d.). While wild ginger has several tolerances including heavy shade, erosion, and wet soil, increased spring and winter precipitation might make conditions too wet for wild ginger to tolerate. Additionally, and similar to many aforementioned herbaceous perennials in the understory, increasing rates of forest fragmentation will expose wild ginger to greater amounts of sunlight.

Common Elderberry–wiikooloomphsa
(*Sambucus racemosa*)

The common elderberry is a shrub or small tree found in swamps and moist woods. Preferring partial or full shade and moist, well-drained soil, the common elderberry is flood tolerant but is less tolerant of warm climates (Consortium of Midwest Herbaria, n.d.). While the plant may not see a decrease in habitat suitability due to increased precipitation and flooding, higher average temperatures will likely decrease habitat suitability, particularly in fragmented areas where sunlight is greater.

Kentucky Coffeetree
(*Gymnocladus dioicus*)

The Kentucky coffeetree can be found in a variety of habitats, with the most abundant populations appearing in Missouri, eastern Kansas, and Oklahoma–the hottest and driest areas of its native range. In Indiana, the Kentucky coffeetree can be found growing on bedrock and loose soils on upland bluffs and steep slopes. The tree can also be found in the bottomland forests of the major watersheds if the soil is sufficiently loamy and well-drained. The Kentucky coffeetree is extremely well-adapted to harsh soil conditions and is drought tolerant (Shmitz & Carstens, 2018).

Habitat loss poses an increasing threat to the Kentucky coffeetree across its native range (Shmitz & Carstens, 2018), particularly if it is associated with hydrology changes that impede soil's ability to drain sufficiently for the plant's growth. The Kentucky coffeetree is also vulnerable to competition from invasive species, specifically Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), and Japanese hops (*Humulus japonicus*), all of which are experiencing an explosion in growth across Indiana's forests (Purdue Entomology, n.d.). A decrease in habitat suitability for the Kentucky coffeetree may ultimately weaken its ability to outcompete these invasive non-natives, furthering the decline of the Kentucky coffeetree.

Goldenseal
(*Hydrastis canadensis*)

Goldenseal is a herbaceous perennial found in riparian and hardwood forests and moist ravines. It prefers moist, loamy soils with plentiful leaf mold, and full or partial shade (MSU Extension, n.d.). Goldenseal is one of the few identified plant species whose primary vulnerability is overharvesting–its slow-growing rhizomes are often destructively harvested for their medicinal benefits. The plant also faces threats from habitat loss due to forest fragmentation and invasivity from species such as Japanese honeysuckle (*Lonicera japonica*), multiflora rose (Rosa multiflora), Japanese barberry (*Berberis thunbergii*), and garlic mustard (*Alliaria petiolata*) (USFS, 2003).

Stable climate and habitat conditions are critical for the revitalization of goldenseal. Its slow growth and seed production mean the goldenseal is much slower to adapt to changing conditions compared to relatively faster seed-bearing plants (MSU Extension, n.d.). While goldenseal may not experience a decline due to increased spring and winter precipitation, lower volumes of precipitation in the summer months and more days of extreme heat may make moist soils unsuitably dry for goldenseal growth. This will be particularly detrimental for goldenseal growth in fragmented habitat; rates of evaporation are higher in forest edges due to wind exposure and higher temperatures, ultimately resulting in lower soil moisture (Nunes et al., 2022).

Big Shellbark Hickory–ceecinkilaakia
(*Carya laciniosa*)

Found growing in floodplains, the big shellbark hickory is valued for its nuts–the largest of any walnut species–by the Miami and animal species such as turkeys, quails, and ducks (New

York Natural Heritage Program, n.d.). This tree thrives in full or partial sun and in medium to wet soils rich with decomposing organic matter. The big shellbark hickory can tolerate occasional flooding and wet sites (Janoski & Yiesla, n.d.), which may make it resilient in the face of increased spring and winter precipitation volumes.

The decline in the big shellbark hickory can be attributed to logging and the draining of floodplain habitat for agriculture. It also faces an emerging threat due to invasivity from shrubs such as privet (*Ligustrum obtusifolium*), which outcompete the hickory's seedlings (Georgia Department of Natural Resources, n.d.). Its preference for moist soils makes the big shellbark hickory vulnerable to a decrease in summer precipitation, an increase in average annual temperatures, and higher annual numbers of extreme heat days. Despite its tolerance for occasional flooding, the predicted increase in spring and winter precipitation events may impede the soil's ability to drain sufficiently, ultimately increasing the probability of water stress for the big shellbark hickory.

Pecan Tree–kaanseeseemini
(*Carya illinoenensis*)

The pecan tree is a mast-producing species valued by the Miami and other Great Lakes indigenous peoples for its large, thin-shelled nuts (Lady Bird Johnson Wildflower Center, 2015). This tree prefers full sun and moist, well-drained soils (Janoski & Yiesla, n.d.). Adequate precipitation is critical to pecan production as the pecan tree extracts the majority of its water from the top 3 feet of the soil profile (Wells, 2016). Though growing abundantly in parts of the United States due to its commercial cultivation, pecan trees in their native habitat face threats from pecan weevil, pecan nut casebearer, and hickory shuck worm. It is also vulnerable to pecan scab disease, a fungal pathogen that stunts and deforms young leaves and nuts (Clemson Cooperative Extension, 2014).

Current threats to the pecan tree will likely be exacerbated by predicted climate conditions in Indiana's forests. The decrease in summer precipitation and increase in annual temperatures will reduce water availability to the tree. The increase in annual temperatures and spring precipitation will also facilitate the spread of pests and pathogens. Pecan scab disease, for instance, requires temperatures between 65°F and 85°F to fully germinate and spreads quickly in humid conditions (Clemson Cooperative Extension, 2014).

Blackjack Oak–maamhkatiaahkatwi
(*Quercus marilandica*)

Often found growing in the poorest soils of dry upland forests, the blackjack oak prefers acidic soils over sandstone, igneous bedrock, or chert (Missouri Department of Conservation, n.d.). The blackjack oak is also able to withstand forest fires to a greater degree than most other oaks. Despite its ability to thrive in relatively inhospitable conditions compared to other the other plants identified in this study, the blackjack oak is shade and flood intolerant (Brown & Peña, n.d.). Contemporary threats include competition from non-native invasives (Larson, n.d.) and diseases including oak leaf blister, oak tatters, and oak wilt (Brown & Peña, n.d.).

It is predicted that the increase in spring and winter precipitation will negatively impact the habitat suitability of blackjack oak, particularly because it prefers to grow in the excessively drained soils of barrens (Larson, n.d.). The blackjack oak's vulnerabilities will likely be compounded by the spread of oak tree pathogens. Sap beetles, a vector of oak wilt, lay dormant in the winter and become active during warmer, springtime temperatures (Iowa State University Extension and Outreach, n.d.). Warmer annual temperatures may create suitable conditions for sap beetles to become active during the winter, increasing reproductive success and pest movement over a longer period of time.

VI. Discussion

Of the 139 species initially identified as both Indiana natives and Miami ethnobotanical species, only about 13 percent of species (18 species) were identified as critically impaired, imperiled, or vulnerable on NatureServe's state-level conservation status ranking. This indicates that 87 percent of Miami ethnobotanical plants currently exist within a stable ethnobotanical system–widespread loss of this knowledge as a result of species' decline is unlikely to occur in the coming decades.

However, the predicted habitat suitability decline for the 13 percent of plant species used in this study demonstrates an unsettling trend towards species vulnerability that will only be exacerbated by human and climate factors:

(1) all 18 species are predicted to experience a decline in habitat suitability;

(2) all 18 species had at least two human or climate risk factors that are predicted to decrease habitat suitability;

(3) the most prevalent human or climate risk factors among all 18 species are water stress and invasivity by non-native species.

Table 3: Risk Factors & Total Percentage of Affected Plants

Human/Climate Risk Factors	**Total Percentage of Affected Species**
Water-stress	61%
Invasivity	39%
Habitat Destruction	33%
Pest/Pathogen Incidence	33%
Drought-stress	28%
Forest Fragmentation	28%
Heat-stress	22%
Overharvesting	17%

If sufficient climate action is not taken, it can be expected that the highly vulnerable species in this study will slip towards extinction or a "critically imperiled" position.

It is important to note that this study did not take into account the compounding effects of multiple risk factors in the decline of habitat suitability. Due to the qualitative nature of this study and the limited sample size, the effects two risk factors may have on a species compared to the effects of three or four risk factors were not analyzed. Additionally, it is now understood that climate science tends towards more conservative predictions due to a fear of exaggerated conclusions and a general gap in understanding of how the planet's biogeochemical cycles influence one another (Scherer, 2012). It is entirely possible that the species predictions made in this study do not capture the total impact of climate change that could be seen by mid to late-century in Indiana. It is recommended that this study be reevaluated as more precise projection models are developed.

VII. Conclusion

This study has demonstrated that of the 18 vulnerable Miami ethnobotanical species, 100 percent are predicted to experience a decline in habitat suitability by at least two human or climate-related risk factors by mid to late-century. Though this may appear to be an inconsequential number compared to the biodiversity found in the Miami ethnobotanical system, they are indicative of a greater dissolution of indigenous knowledge that will occur if climate change proceeds unmitigated. Indigenous land ethic is born from a practical understanding of the natural world that grows more profound as generations of native peoples interact with their environment. Though this ethic is multifaceted, ethnobotany draws a direct connection between community health and environmental health–when the community's physical, cultural, and spiritual needs are directly dependent upon ecosystem abundance, the two become inextricably linked.

Moreover, if the species on which the ethnobotanical system was created no longer exists, the knowledge generated by that system no longer exists. While the potential extinction of 18 species may appear inconsequential, the cultural and ecological functions of those species also may no longer exist. The story of Mondamin demonstrates more than the human-ecosystem link–the story notes that the maltreatment of the corn harvest was not attributed to the community as a whole, but rather the actions of a small group of irresponsible individuals. The burden of the consequences, however, was shouldered by the community as a whole. It is the responsibility, then, of both indigenous and non-indigenous individuals to protect a vital part of Indiana's cultural and ecological heritage.

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