FLOODPLAIN RESTORATION AT THE STATE BOTANICAL GARDEN OF GEORGIA:

AN ADAPTIVE MANAGEMENT APPROACH INTEGRATING CANEBRAKE ECOSYSTEM SERVICES

by

THOMAS RADDFORD PETERS

(Under the Direction of Alfie Vick)

ABSTRACT

Conservation staff at the State Botanical Garden of Georgia are in the process of removing large stands of invasive species and restoring native plant communities along the Oconee River floodplain. The species selected for restoration plantings must be quick to establish, provide habitat for a variety of wildlife, and be able to compete with invasive exotic plants. They must also be able to withstand floodwaters and stabilize soils preventing further erosion along the river corridor. Rivercane (*Arundinaria gigantea*) is a regionally appropriate plant that can improve ecosystem function and cultural value while creating a distinctive aesthetic. This thesis includes a comprehensive overview of canebrake restoration, an inventory of *in situ* populations of cane at the State Botanical Garden and management guidelines for encouraging canebrake establishment and expansion.

INDEX WORDS: Rivercane, Switchcane, Arundinaria gigantea, Arundinaria tecta, Floodplain Restoration, Invasive Exotic, Propagation, Ethnoecology, State Botanical Garden

FLOODPLAIN RESTORATION AT THE STATE BOTANICAL GARDEN OF GEORGIA:

AN ADAPTIVE MANAGEMENT APPROACH INTEGRATING CANEBRAKE ECOSYSTEM SERVICES

by

THOMAS PETERS

BS, University of Tennessee, 2009

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF LANDSCAPE ARCHITECTURE

ATHENS, GEORGIA

2013

FLOODPLAIN RESTORATION AT THE STATE BOTANICAL GARDEN OF GEORGIA:

AN ADAPTIVE MANAGEMENT APPROACH INTEGRATING CANEBRAKE ECOSYSTEM SERVICES

by

THOMAS RADDFORD PETERS

Major Professor:	Alfie Vick
Committee:	Brad Davis Jace Weaver Melissa Tufts

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2013

DEDICATION

To rivercane

ACKNOWLEDGEMENTS

If it were not for my family and a dedicated community of friends, instructors, and professionals in the fields of ethnobiology, landscape architecture, horticulture, and Native American studies, I would have never achieved my dream of attaining the degree of Master of Landscape Architecture, nor would I be as good of a person. Those close to me know that canebrake restoration ecology has become an obsession only rivaled by my affinity for gardening and ornamental horticulture.

The Institute of Native American Studies, Dr. Jace Weaver and professor Laura Weaver have been very generous and accommodating to me throughout my time at the University. Their dedication to education and cultural preservation has been inspiring. The Native American Studies Graduate Certificate Program enriched my capabilities as a designer by exposing me to new cultural and environmental perspectives, alternative histories, and multiple worldviews beyond what I have learned from a typical public education founded solely on Western idealism and science; a predominately colonial and capitalistic perspective. The Native American community has been welcoming to me and always quick to share knowledge that might further the movement of canebrake restoration.

While on a Maymester (summer course) taught by Professor Alfie Vick, I was exposed for the first time to rivercane and the implications it has for cultural and environmental restoration. Professor Vick has been an essential resource and pivotal influence on me for the entirety of my graduate education.

Professor Brad Davis has always encouraged me to pursue my interest in horticulture and plant sciences despite the distraction that it often caused me from his studio class. Our conversations on plants, propagation, and the psychology of horticulture kept me sane during times of extreme academic exertion that was associated with attaining this degree.

Professor Jon Calabria has always been available for practical and cutting edge advice on environmental restoration especially pertaining to alluvial ecology.

Professor David Berle made the GIS inventory of cane at the State Botanical Garden of Georgia possible by generosity sharing his equipment with me.

Melissa Tufts was very kind to lend her expertise.

I would like to also thank Dr. Affolter and the State Botanical Garden staff for having been accommodating and encouraging to me in my research. I only hope that this document will be of value to conservationists working for the SBG. I am confident that one day I will revisit the Orange and White trails to witness the unrivalled beauty of a healthy canebrake and a resident population of Hooded Warblers where once stood a dark and dreary jungle of Chinese Privet concealing a host of mangy squirrels.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

Fig 1: Philip Juras: *Canebrake on the Mississippi*, Montgomery Island, AR. Oil on Canvas, 2010

CHAPTER 1

INTRODUCTION

Canebrake ecosystems were once an integral element of the environmental and cultural context of alluvial landscapes across the Southeast. This includes the Oconee River watershed and the land that is today the State Botanical Garden of Georgia (SBG). William Bartram, a naturalist and explorer who lead an expedition of the southern frontier during the late 18th century described vast expanses *Arundinaria gigantea* and *A. tecta* he commonly referred to as "cane meadows". Excerpts from his accounts include:

"An endless wilderness of canes," as he travelled "twenty miles through...cane meadows" in Alabama; "about eight miles in a cane forest," in Louisiana.[1]

An "immense plain" of a "cane swamp" as he approached the headwaters of the Ogeechee. His animals "Grazed themselves fat on the nutritious leaves of the cane.[2]"

An "enormous canebrake rolling to the horizon like the ocean which was alive with cattle, deer, and turkeys." It "could not be penetrated without previously cutting a road.[3]"

[1] S. G. Platt and C. G. Brantley, "Canebrakes: An Ecological and Historical Perspective," *Castanea* 62, no. 1 (1997).
[2] Mart A Stewart, "From King Cane to King Cotton: Razing Cane in the Old South," *Environmental History* 12, no. 1 (2007).
[3] Ibid.

Fig 2: Louisiana Canebrake in 1905 or 1906: USDA Bureau of Plant Introduction negative #3208

The canebrakes Bartram observed while travelling through the region were largely the result of an anthropogenic disturbance regime that included prescribed burns and selective harvest and rotational agriculture by Southeastern Indigenous Nations who had long valued rivercane as a material and cultural resource.

To European settlers and early Americans who displaced Native communities by disease, litigation and military force, canebrakes were often viewed as obstacles to progress or as refuge for undesirable characters and beasts. Many were destroyed by grazing cattle who value the evergreen shoots as winter forage. After canebrakes had been grazed down, swine would complete the total destruction of the brake by rooting up the rhizosphere (root network). The livestock that came part-in-parcel with settlers was almost as detrimental as the development patterns and land management decisions made by the young nation following in their footsteps.[4]

Channelization and damming of waterways to create artificial reservoirs has taken a toll on canebrake habitat in the south. Cane commonly persists in a stunted state in many bottomlands and wet sites across the region, but only a fraction form the dense monotypic stands traditionally known as a canebrake. In *An evaluation of threatened North American Ecosystems* by Reed Noss (1995), the author estimated a 98% decline in total acreage of canebrake since the European colonization of North America and suggested that it be regarded as a critically endangered ecosystem.[5]

The canebrakes that once resided along the Middle Oconee floodplain were most likely destroyed by several factors including agricultural practices related to Georgia's cotton farming past and alterations in hydrology. This damage was done long before the land was acquired by the SBG in 1968. The natural ecology of the floodplain has been negatively altered as a result of past land uses.

Currently, invasive exotic plant species and erosion continue to jeopardize the health of natural ecosystems such as canebrake.

---

[4] Ibid.

[5] Reed F. Noss, Edward T. LaRoe, and J. Michael Scott, *Endangered Ecosystems of the United States [Microform] : A Preliminary Assessment of Loss and Degradation / by Reed F. Noss, Edward T. Laroe Iii, and J. Michael Scott*, Biological Report: 28 (Washington, D.C. : U.S. Dept. of the Interior, National Biological Service, 1995., 1995).

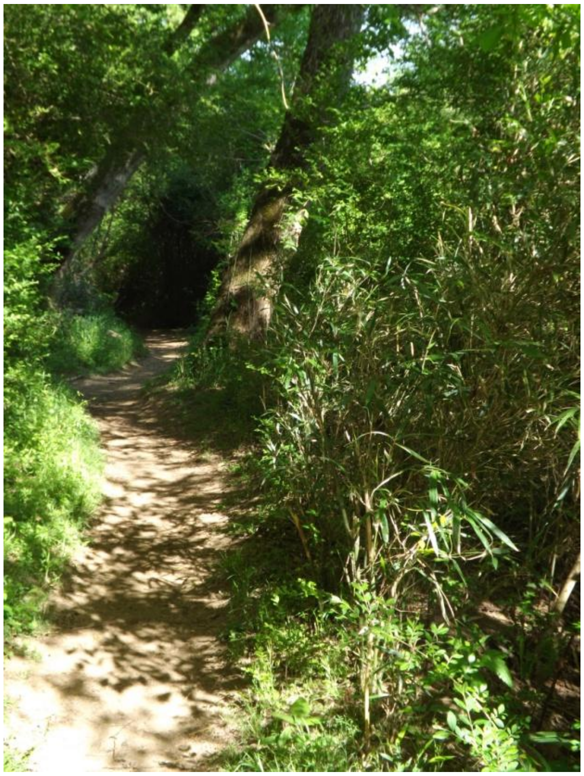
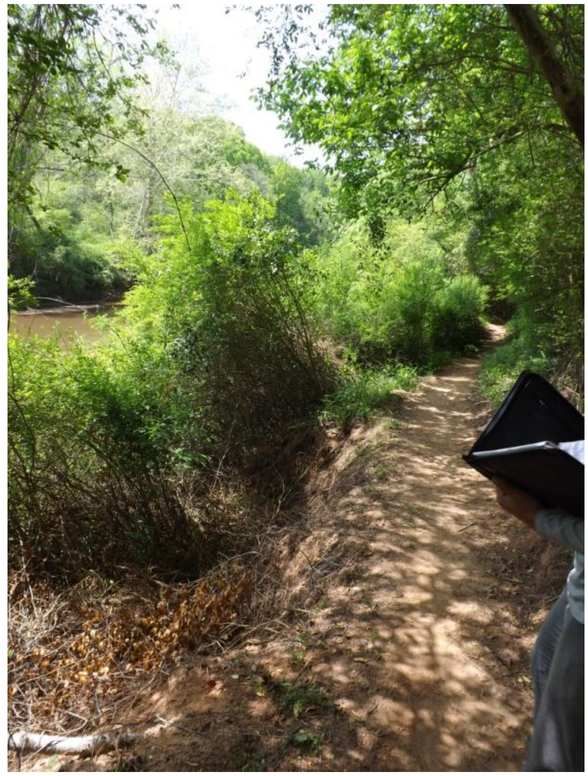



Fig. 3 (left): Cane (P8) at SBG impeded by physical isolation (river, trail, and hedge of invasive privet)

Fig. 4: Erosion along White Trail

The SBG has been diligently removing invasive exotic species with the intention of restoring native vegetation to areas that have been sufficiently cleared. The native vegetation intended to replace the invasive populations must be vigorous and spread quickly if it stands a chance at outcompeting invasive intrusions.[6] The plant community must also be functional for stabilizing sandy floodplain soils, reducing erosion, and also be aesthetically pleasing for guests visiting the SBG daily for various reasons including bird watching, exercise, reflection and research.

This thesis seeks to reveal if canebrake establishment and expansion following invasive plant removal is an appropriate methodology for floodplain restoration at the State Botanical Garden of Georgia. And if it is, what are the challenges and recommended strategies for success?

[6] John Klepac and others, "Mechanical Removal of Chinese Privet," *Research Paper-Southern Research Station, USDA Forest Service*, no. SRS-43 (2007).

Canebrakes create an aesthetic that is distinctly endemic to southeastern United States. Rivercane ecosystems can be highly functional at stabilizing soils, building fertility[7], and phytoremediation[8] (the uptake of harmful inorganic pollutants in soils.) Canebrakes offer refuge and forage for a broad range of wildlife including several endangered species[9] and obligate Lepidoptera associates.[10]

There are already several native populations of cane existing in the SBG floodplain. A Geographic Information Systems (GIS) inventory is the first step in planning for expansion of canebrake habitat. Suitability modeling with GIS technology allows for various layers (soil type, elevation, existing vegetation, floodplain, etc.) to be weighted as to their significance and overlaid in order to expose and prioritize ideal sites for canebrake establishment and expansion. Canebrake restoration at the State Botanical Garden of Georgia is a sustainable and progressive approach to establishing ecosystem integrity and cultural significance in the floodplain. There is evidence that planting cane has great potential for quick establishment and competitive ability against other common non-native plant species.[11]

This thesis will be a comprehensive overview of existing literature on canebrake ecology and restoration. After reviewing the latest publications and research concerning canebrake restoration, the text will transition into a more site specific population survey assessing rivercane populations at the State Botanical Garden of Georgia. The literature overview and site inventory will provide insight into the formation of specific management guidelines. Guidelines shall be designed to facilitate the expansion of existing canebrakes and target locations ideal for the establishment of new populations.

In Chapter Two, "Canebrake Ecosystems: a Context," the plant biology, character, and habit are described in detail providing the reader with a context of canebrake ecology as well as the history of *Arundinaria* in the Southeast. This chapter also includes a chronology of the expansion and demise of canebrakes in response to anthropogenic

---

7 J. E. Schoonover and others, "The Utility of Giant Cane as a Riparian Buffer Species in Southern Illinois Agricultural Landscapes," *Agroforestry Systems* 80, no. 1 (2010).
8 C. R. Blattel and others, "Ground Water Nitrogen Dynamics in Giant Cane and Forest Riparian Buffers," *Castanea* 74, no. 3 (2009).
9 Noss, LaRoe, and Scott.
10 Platt and Brantley.
11 M. J. Osland, J. W. Pahl, and C. J. Richardson, "Native Bamboo [Arundinaria Gigantea (Walter) Muhl, Poaceae] Establishment and Growth after the Removal of an Invasive Non-Native Shrub (Ligustrum Sinense Lour., Oleaceae): Implications for Restoration," *Castanea* 74, no. 3 (2009).

activity over the past three hundred years. Chapter 2 is concluded by an academic review of scholarly publications and research on canebrake ecology and restoration efforts to date.

Chapter Three, "Ecosystem Services," is an overview of the environmental value inherent in canebrake restoration. This section is important to convey how canebrakes provide critical habitat to many species including several that are threatened or facing extinction. The value of canebrake habitat for floodplain restoration and streambank stabilization is illustrated in its capability to mitigate pollution in soils, compete with invasive exotics, infiltrate runoff and thwart erosion.

Chapter Four delves into the ethno-ecology of *Arundinaria*. One could argue that there was never a plant so monumentally significant to pre-Columbian civilization in the southeastern United States. Indigenous Nations in the region still consider cane to be of utmost cultural significance. Native artists are struggling with locating enough cane to continue their cultural traditions and sustain their livelihoods. This chapter is an overview of Indigenous uses of cane in implements, architecture, and even ceremony across the ages. Also highlighted is the ongoing cultural significance of cane to contemporary Native Americans. Valuable insight on canebrake ecology and management can be gleaned from consulting with Indigenous experts who have interacted with canebrakes for generations.

Chapter Five introduces the State Botanical Garden of Georgia and details the present day integrity of the Middle Oconee River floodplain. The abundance of invasive exotic plant species along the banks of the Oconee warrants an invasive removal campaign. Invasive removal must be followed by the establishment of an aggressively spreading native plant community so that erosion will be minimized. Species used in the restoration planting must be effective at quickly securing alluvial soils. An inventory on SBG lands revealed at least 14 distinct populations of rivercane. A description of each population including site-specific management guidelines is provided in this section.

Chapter Six concludes the thesis with a discussion of the findings and summary of general guidelines beneficial to informing long-term management and phasing of restoration plantings. Several options for an in-house propagation initiative are addressed under the assumption that the SBG will have interest in generating propagates for sustaining future restoration plantings. A GIS suitability analysis incorporating variables such as soil type, hydrology and elevation is provided to reveal areas suitable for canebrake establishment. The chapter concludes with a list of suggested research topics and experimental designs that could be implemented at the SBG in the future. Restoration ecologists are moving ever closer to unlocking the secrets of canebrake ecology and restoration. The SBG is poised to be a living resource on floodplain restoration via canebrake establishment and could be instrumental in rebuilding the integrity of many degraded alluvial ecosystems in Clarke County, Georgia, and beyond.

CHAPTER 2

CANEBRAKE ECOSYSTEMS: A CONTEXT

Fig. 5: Botanical Sketch of *A. tecta*. USDA-NRCS PLANTS Database / Hitchcock, A.S. (rev. A. Chase). 195

Habit

Canebrake ecosystems were once a defining feature of the southeastern alluvial floodplains. Canebrakes consist of large stands of *Arundinaria gigante and A. tecta,* two North American bamboo species known by the common names of maiden cane, switch cane, swamp cane, mutton grass, pole cane, rivercane, and, most commonly, just "cane." Plants currently classified in the genus *Arundinaria* were first described by Thomas Walter in his *Flora Caroliniana* (1788). However, Walter did not recognize cane as a bamboo species. Instead, he placed them in the distantly related grass genus *Arundo*. In 1803, the French botanist André Michaux, unfamiliar with Walter's floristic survey, also published a description of the rivercane. Michaux recognized only one species, but created a new monotypic genus for it: *Arundinaria macrosperma* Michx.

A decade later in 1813, G.H.E. Muhlenberg took note of common grounds between the two previous authors' work and transferred Walter's two species to Michaux's new genus, yielding the taxonomy *Arundinaria gigantea* (Walt.) Muhl. and *Arundinaria tecta* (Walt.) Muhl.. Muhlenberg considered the genus to consist of these two species in addition to *Arundinaria macrosperma* Michx.. One hundred years later, A. S. Hitchcock reviewed the taxonomic state of the North American bamboos (1951). He interpreted Michaux's *Arundinaria macrosperma* Michx. as synonymous to Walter's *Arundinaria gigantea* (Walt.) Muhl., reducing the genus once again to two species.

One other species, *Arundinaria appalachiana,* commonly known as "hill cane" or "arrow cane", was identified in 2006 and seems to prefer higher and drier growing conditions.[12] No propagation trials with *A. appalachiana* or research as to its restoration potential have been done thus far. Further research is needed in this area.

Woody, cool season grass members of the family Poaceae, *Arundinaria* species are the only native North American members of the subfamily Bambusoideae.

[12] JK Triplett, AS Weakley, and LG Clark, "Hill Cane (Arundinaria Appalachiana), a New Species of Bamboo (Poaceae: Bambusoideae) from the Southern Appalachian Mountains," *Sida, Contrib. Bot* 22, no. 1 (2006).

Characteristic	A. appalachiana	A. tecta
Rhizome air canals	present or absent	present
Sulcus	usually absent	usually absent
Culm leaf duration	persistant	persistant
Culm leaf auricles	absent	present, deciduous
Top knot leaves	6-12	9-12
Top knot blade length (cm)	9-22.5	20-30
Compressed basal internodes on primary branch	2-5	2-4
1° branch basal nodes:2° branches	absent	present; subequal
Primary branch length (cm)	7-33	usually >50
Foliage leaf blade length (cm)	5-20	7-23
Foliage leaf blade width (cm)	0.8-2	1-2
Foliage leaf vestiture	pilose or glabrous	densely pubescent or glabrous
Foliage leaf duration	deciduous	evergreen
Foliage leaf texture	chartaceous	coriaceous
Foliage leaf abaxial tessellation	weakly tessellate	strongly tessellate

Table 1: Table comparing features of Arundinaria anatomy. Adapted from Triplett et al (2006) p.85

A. tecta and *A. gigantea* are nearly indistinguishable by surface inspection even from the people most adept at native plant taxonomy. *Gigantea* typically attains maximum heights of 20-30' whereas tecta, only a 12-15'.[13] Phenotypic variation within *Arundinaria* species, and the fact that *gigantea* often persists in a stunted state when located out of ideal growing conditions, make it hard to discern between populations of *tecta* and smaller specimens of *gigantea*. Tecta culms generally reach full height before beginning to unfurl their first set of branches (8'-12') while *gigantea* branching begins to unfurl as low as one foot from the base of the culm before it attains full height (20'-30').[14] The characteristic of tecta to remain unbranched while attaining full length facilitated the development of the common name "switch cane."[15]

[13] Emmet J Judziewicz and others, *American Bamboos* (Smithsonian Institution Press, 1999).
[14] Ralph H. Hughes, "Observations of Cane (Arundinaria) Flowers, Seed, and Seedlings in the North Carolina Coastal Plain," *Bulletin of the Torrey Botanical Club* 78, no. 2 (1951).
[15]J. K. Triplett and L. G. Clark, "Towards a Stable Nomenclature for the North American Temperate Bamboos: Epitypification of Arundo Gigantea Walt, and Arundinaria Macrosperma Michx. (Poaceae)," *Castanea* 74, no. 3 (2009).

By examining rhizome anatomy in cross-section, one can more easily distinguish *A.tecta* from *gigantea* by observing the presence of well developed peripheral air canals.[16] It has been suggested that this feature allows for increased aeration of rhizome tissues and also *tecta's* increased ability to withstand extended periods of inundation[17]. The increased affinity of *tecta* for wet sites should be taken into consideration in restoration planning where soils are subject to longer periods of saturation. *A. gigantea* can also take periods of several weeks in saturated soils but does not grow as well as *A. tecta* in such conditions.[18]

Gigantea and *tecta* have the capability of forming dense monotypic stands of individual canes, or "culms." Culms can grow over an inch in diameter.[19] Vast monotypic stands of cane are commonly referred to as a "canebrake." Healthy canebrakes grow vigorously and densely, at about 20,000 to 65,000 culms per acre.[20] *Arundinaria* is a woody, semelparous (or monocarpic) grass species meaning that it flowers on intervals of 50-100 years and then dies completely.[21] The grass occurs from Florida to eastern Texas in the south, in parts of the Midwest, and north to New York. Cane has been found in at least 22 States.[22]

[16] F. A. McClure, "A New Feature in Bamboo Rhizome Anatomy," *Rhodora* 65, no. 762 (1963).
[17] M. C. Mills, B. S. Baldwin, and G. N. Ervin, "Evaluating Physiological and Growth Responses of Arundinaria Species to Inundation," *Castanea* 76, no. 4 (2011).
[18] Ibid.
[19] Platt and Brantley.
[20] DL Marsh, "The Taxonomy and Ecology of Cane, Arundinaria Gigantea (Walter) Muhlenberg. Fayetteville, Ar: University of Arkansas, 303 P" (MS thesis, 1977).
[21] P. R. Gagnon and W. J. Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)," *Journal of the Torrey Botanical Society* 135, no. 3 (2008).
[22] Marsh.

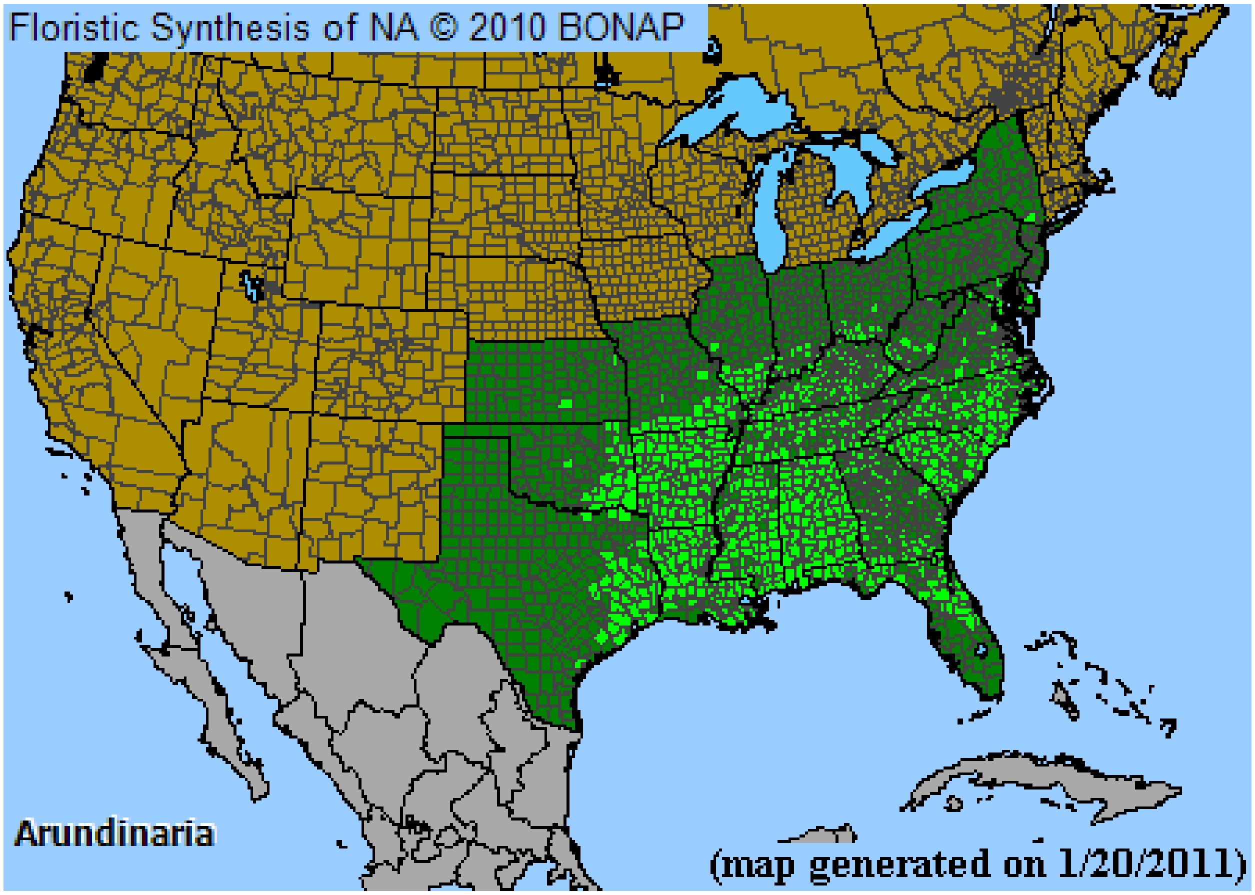


Fig. 6: Cane distribution. Dark green symbolizes range and the bright green, counties with verified populations. (www.bonap.org)

A cool-season member of the grass family (Poaceae), *Arundinaria* is the only bamboo genus native to the United States. It has erect, perennial woody stems or culms that can reach one and a half inches in diameter. Another diagnostic character for this genus is the presence of culm sheaths at each node of the culm. These sheaths are deciduous in nature and remain attached to nodes for several growing seasons. Culms can live for five to seven years and often add a new set of branches each spring. The foliar leaves are evergreen and strongly cross-veined.[23]

Canebrakes are often composed of a single monoclonal organism, or "genet" (genetic individual). A genet is an interwoven network of culms (shoots) attached to a rhizosphere, or network of rhizomes that share and allocate nutrients within the organism according to certain environmental factors.

[23] Triplett and Clark, "Towards a Stable Nomenclature for the North American Temperate Bamboos: Epitypification of Arundo Gigantea Walt, and Arundinaria Macrosperma Michx. (Poaceae)."

For example, if part of a canebrake is in ideal growing conditions (i.e., full sun, rich soils, low competition), the genet can allocate nutrients and the products of photosynthesis to different parts of the individual in order to push growth far into the understory of the forest edge.[24] This allows the genet to capitalize on future canopy gaps, fires, or forest blow-downs.[25]

Research by Dr. Paul Gagnon for his dissertation at Louisiana State University proved that cane has a unique ecology dependent on a cyclical disturbance regime that can be natural or anthropogenic in origin.[26] Dr. Gagnon and others[27] have concluded that periodic burning (of every 7-10 years) is a process that not only rejuvenates stands by encouraging vigor of young shoots, but also discourages woody plant competition.[28] Burning decadent cane stands that have grown vegetatively stagnant or are suffering from intrusions of invasive exotics can be a way to jump start re-growth and expansion.[29] Over time, exclusion from fire will cause canebrakes to decline in vigor.[30] Fire ecology and the potential of prescribed burns should be considered by any landscape manager wanting to maximize the health and vigor of canebrake populations.

Arundinaria species are obligately-outcrossed, wind pollinated.[31] This means that to produce viable seed, a genet must be pollinated by another genetic individual.[32] For this reason, canebrakes that are a cohort of different genets have higher fertility rates in the occurrence of a synchronous flowering event than rogue culms or isolated genets that flower out of sync with the greater surrounding population.

---

[24] Keith Michael Hoffman, "Patterns of Recruitment and Young Culm Morphology in Arundinaria Gigantea ([Walt.] Muhl. Canebrakes in Western North Carolina" (Western North Carolina, 2010).
[25] Mary Arquette and others, "Holistic Risk-Based Environmental Decision Making: A Native Perspective," *Environmental Health Perspectives* 110, no. ArticleType: research-article / Issue Title: Supplement 2: Community, Research, and Environmental Justice / Full publication date: Apr., 2002 / Copyright © 2002 The National Institute of Environmental Health Sciences (NIEHS) (2002).
[26] Paul R. Gagnon and William J. Platt, "Multiple Disturbances Accelerate Clonal Growth in a Potentially Monodominant Bamboo," *Ecology* 89, no. 3 (2008).
[27] Hughes.
[28] PR Gagnon, HA Passmore, and WJ Platt, "Multi-Year Salutary Effects of Windstorm and Fire on River Cane," *Fire Ecology* 9, no. 1 (2013).
[29] Paul R. Gagnon, "Fire in Floodplain Forests in the Southeastern USA: Insights from Disturbance Ecology of Native Bamboo," *Wetlands* 29, no. 2 (2009).
[30] A. J. Dattilo and C. C. Rhoades, "Establishment of the Woody Grass Arundinaria Gigantea for Riparian Restoration," *Restoration Ecology* 13, no. 4 (2005).
[31] Brian S. Baldwin and others, "Propagation Methods for Rivercane [Arundinaria Gigantea L. (Walter) Muhl.]," *Castanea* 74, no. 3 (2009).
[32] Ibid.

Two types of flowering have been recorded in semelparous bamboos; gregarious (mast), and sporadic. Sporadic flowering occurs on single culms, or individual genets within a canebrake. This type of flowering happens every year somewhere within the range of the species, and usually yields minimal fertile seed.


Fig 7: Images of cane synflorescence on wild specimen (left) in Atlanta, GA and on nursery grown stock from Dr. Brian Baldwin's "Octoc" germplasm in Athens, GA. By: Victor Vasquez and Thomas Peters

Gregarious flowering occurs much more infrequently (typically every few decades) and is characterized by the synchronous flowering of entire canebrakes followed by total senescence. Even young cane explants that have been divided and transplanted far from, and in entirely different environments as their source population, will mysteriously flower at the same as the source population.[33] Synchronous flowering of explants and parent material has been recorded in several instances but there are exceptions to almost every rule about the flowering habits of the bamboos.[34] One rule that seems to be without exception thus far is that in any flowering event seed fertility increases with pollination between two genetic individuals.[35] Gagnon hypothesizes that the evolutionary significance of synchronized flowering is to encourage cross pollination of genetic individuals. As woody bamboo species, *Arundinaria* have

[33] Hughes.
[34] Daniel H. Janzen, "Why Bamboos Wait So Long to Flower," *Annual Review of Ecology & Systematics* 7, (1976).
[35] Gagnon and Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)."

mechanisms within their physiology that facilitate outcrossing in sexual reproduction. For example on the flowers, stamens emerge initially producing pollen grains (deliverer of male gametophyte) which get carried by the wind before the stigmas (female anatomy receptive to pollen grains) open on rivercane flowers.[36]

Janzen (1976) prefers the term "mast seeding" to the term gregarious flowering. Mast seeding is the synchronized production of seed at long intervals by a population of plants. The term derives from oak mast, beech mast, etc., which are often used to describe multitudes of acorns or seeds on the ground on the forest floor in the year of a heavy mast.[37] Mast seeding is a common adaptation among wind pollinated plants to maximize pollination. Janzen argues that the term "gregarious" implies collective deliberate actions that are in response to a chemical or bio-physiological signal between seeding individuals and their cohorts, a form of plant behavior has that has yet to be explained by modern science.

Canebrakes are often filled with multiple genets that form a cohort.[38] Janzen sees mast seeding in bamboo species as most likely being related to selective mortality, or the natural culling over time of individuals that have flowered out of harmony with their cohorts. It could also be an adaptation for predator sedation. Cane seed is highly nutritive and known to be consumed in great abundance by insects and herbivores. Cane seed begins to germinate immediately after fracturing from the parent culm and landing on the ground. Seeds quickly succumb to desiccation or decay if they do not establish quickly. By shedding such a large quantity of seed, it is more likely that a percentage will successfully develop into young plants.

Most masting species (e.g. oaks, hickories, pecans) are "iteroparous," meaning that they flower and fruit several times throughout their lifecycle.[39] Bamboos are an exception to this rule, as mast flowering is largely restricted to semelparous species that have extended periods of juvenility before they flower and die[40]. Mast synchronization may

[36] Judziewicz and others.
[37] Dave Kelly, "The Evolutionary Ecology of Mast Seeding," *Trends in Ecology & Evolution* 9, no. 12 (1994).
[38] Gagnon and Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)."
[39] J. W. Silvertown, "The Evolutionary Ecology of Mast Seeding in Trees," *Biological Journal of the Linnean Society* 14, no. 2 (1980).
[40] Janzen.

also be triggered by certain environmental or climactic cues as is the case with oaks (*Quercus sp*.) and beeches (*Fagus sp*.).[41]

Keeley and Bond (1999) hypothesize that mast flowering and semelparity in bamboos are intimately related to cyclical wildfires in what they have termed the "Bamboo Fire Cycle Hypothesis." They propose that massive die-off after flowering (semelparity) is an evolutionary adaptation of bamboo species where conditions for maximizing seedling recruitment and success are created at the same time as the seed mast.[42] Based on observations that mast flowering, monocarpy, extended juvenility, and gregarious distribution are all adaptations correlating to bamboo's efficacy at creating canopy gaps and clearings for the spread of clones and seedling recruitment, The Bamboo Fire Cycle Hypothesis suggests that annual wildfires in the evolutionary history of bamboos are what ultimately resulted in the adaptation of monocarpy following mast flowering.

Throughout history, wildfire has commonly been the cause of canopy gaps in many temperate forests. Patterns of burning in these ecosystems are most often combined factors of fuel loads and climate.[43] Plant species well adapted to affect fuel loads increase the probability of disturbance in their habitat and thus directly influence the patterns of canopy gap formation.[44]

Rundel (1981) suggests the possibility that plant species reliant on fire ecology may have evolved characteristics across time that facilitate their potential for ignition.[45] Mass mortality in post fruiting bamboos generates a widespread and synchronous fuel load that significantly increases potential for wildfire disturbance. The dense monospecific nature of canebrake stands also serves to increase probability of ignition as density and lateral growth increase exponentially in relation to canopy gaps so that in the event of a fire, the gap will be expanded at the fringes.

Arundinaria, and other monoclonal bamboos have the capacity to spread far into the forest understory by

---

[41] Ibid.
[42] Jon E. Keeley and William J. Bond, "Mast Flowering and Semelparity in Bamboos: The Bamboo Fire Cycle Hypothesis," *American Naturalist* 154, no. 3 (1999).
[43] James S Clark, "Fire and Climate Change During the Last 750 Yr in Northwestern Minnesota," *Ecological Monographs* 60, no. 2 (1990).
[44] Robert W Mutch, "Wildland Fires and Ecosystems--a Hypothesis," *Ecology*, (1970).
[45] PW Rundel, "Fire as an Ecological Factor," in *Physiological Plant Ecology I*(Springer, 1981).

allotting nutrients from an area of the genet growing in more favorable conditions.[46] This pattern of expansion may be an adaptation of the species for quickly capitalizing on even the smallest canopy gaps created by a fallen tree.

Keeley and Bond (2001) propose that this pattern of effect has been of sufficient advantage to select for the semelparous life history.[47] Saha and Howe (2001), critique the hypothesis of monocarpy being a direct evolutionary response to wildfires[48] on the grounds that multiple causation is the rule in ecological and life-history explanation.[49]

Janzen (1974) proposes that mast flowering arose as an evolutionary adaptation for predator satiation as cane seeds are commonly devoured in large quantities by birds, insects, and mammals.[50] By placing all vested energy into the production of abundant quantities of seed, the species has the greatest chance of a fraction of the mast to germinate and persist *in-situ.*

Regardless of what evolutionary process lead to the development of monocarpy in rivercane, it is a variable that must be taken into consideration for canebrake restorationists who intend to establish cane in a permanent location. Eventually, every canebrake will come to a point in its lifetime where it will flower and senesce. Restorationists must plan for this accordingly, taking measures to increase the potential for seed viability and possibly manage post-fruiting stands with a prescribed burn.

After a massive die off, the dead parent culms will, metaphorically speaking, "stand guard" over young seedlings while creating the partial shade conditions and leaf litter that have been proven to facilitate germination by Gagnon[51] (2006) and Gagnon et al. in 2008.[52] Simultaneously, dead culms left standing after a flowering event serve to create a fuel load that will eventually host a wildfire.

Cane benefits from fire because it impedes woody and herbaceous competition, increasing density and vigor within an expanding canebrake. Dr. Paul Gagnon's research has revealed that fire ecology is not only essential to

---

[46] Hoffman.
[47] Keeley and Bond.
[48] Somali Saha and Henry F. Howe, "The Bamboo Fire Cycle Hypothesis: A Comment," *American Naturalist* 158, no. 6 (2001).
[49] J. F. Quinn, and A. E. Dunham, "On Hypothesis Testing in Ecology and Evolution," *American Naturalist*, no. 122 (1983).
[50] Janzen.
[51] Paul R Gagnon, "Population Biology and Disturbance Ecology of a Native North American Bamboo (Arundinaria Gigantea)" (Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Biological Sciences by Paul R. Gagnon BA, Baylor University, 2006).
[52] Gagnon and Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)."

canebrake survival, vigor, and expansion, but that canebrakes have persisted through the ages by creating the very conditions that they thrive in.

The Reign and Decline of Canebrakes in the Southeast: A Dynamic History

Accounts made by early European visitors to the Southeast are full of references to the expansive cane meadows that dominated the floodplain. Mart Stewart, a professor in the Department of History and affiliate professor in the Huxley College of the Environment at Western Washington University authored *From King Cane to King Cotton: Razing Cane in the Old South* (2007), a chronicle of the history of cane including its rise and demise, and how it had everything to do with anthropogenic activities.

Stewart, and other authors[53], have mentioned the inclusion of canebrake in the rotation of agricultural fields by most Indigenous nations in the Southeast before European invasion.

Native American communities traditionally planted crops in the floodplain for several reasons. Proximity to the water table helped crops like corn, squash, tobacco, pumpkins and beans resist drought. The floodplain was also selected because of the rich, fertile soils that were largely a result of canebrakes seining floodwaters of sediment, debris, and organic matter. Native Americans would often manually clear canebrake by burning and then exhuming rhizomes with a hoe or similar tool.[54] After several years, Native agriculturalists would relocate fields and rhizome segments left behind would quickly regenerate and overtake fallow fields.

Europeans brought with them strains of flu and smallpox that wreaked havoc on the Native population of North America. Many Native communities, and even entire townships were completely eradicated by smallpox and other introduced diseases. Many individuals contracted viruses through trade routes without even having direct contact with Europeans.[55] As the Native population collapsed in many areas of the Southeast, cane expanded with new vigor where it

[53] Platt and Brantley.
[54] Stewart.
[55] Colin Gordon Calloway, *First Peoples: A Documentary Survey of American Indian History* (Bedford/St. Martin's, 2004).

had once been maintained at the margins of Indigenous communities for its utility as a renewable resource and rapidly expanded, overtaking the abandoned sites.[56]

Historical accounts supporting this model are recounted in Nuttall[57] (1821), Hawkins[58] (1848) and Iberville[59] (1689-1702). William Dunbar (1749-1810), an explorer commissioned by President Thomas Jefferson, encountered "thick canebrakes" covering an abandoned mound complex on the Catahoula River, Louisiana.[60] William Bartram gave reports of abandoned Indian fields "extending for 25 to 33 km (15 to 20 mi) along either bank" being reclaimed by cane.[61] This area, the first levy of the floodplain, is an area where some of the largest intact canebrakes can be found today.[62] Froeschauer (1988) attributed the patterns of native vegetation, including canebrakes, along the Ocmulgee River, Georgia to past agricultural practices of Indians.[63]

As soon as permanent European settlement was established on the North American continent, canebrakes began a steady and consistent decline. European agricultural practices included grazing livestock and swine that were a disasterous combination pertaining to rivercane; especially in the winter when forage is scarce. Swine would then complete the annihilation of a canebrake by uprooting and devouring rhizomes. European practice would be to burn undergrowth in the spring to encourage lush herbaceous growth for grazing. This was of particular detriment to new cane shoots emerging in the spring. Native Americans burned cane in the fall, when it was partially dormant to encourage vigorous springtime growth.

Europeans also intentionally destroyed canebrakes as they were often viewed as an obstacle to progress and development. Canebrake habitat was also commonly viewed as undesirable by Europeans because it was often the refuge for wild then beasts like the black bear, the Florida panther, and venomous reptiles like the canebrake rattler.[64]

---

[56] Stewart.
[57] Thomas Nuttall, *A Journal of Travels into the Arkansa Territory, During the Year 1819: With Occasional Observations on the Manners of the Aborigines* (Palmer, 1821).
[58] Benjamin Hawkins, *Sketch of the Creek Country in 1798 and 1799* (1848).
[59] P.L.M. Iberville, *Iberville's Gulf Journals* (Tuscaloosa, AL: University of Alabama Press, 1689-1702; reprint, 1981).
[60] W Dunbar, "1749-1810. Life, Letters, and Papers of William Dunbar," *Press of the Mississippi Historical Society, Jackson*.
[61] M VanDoren, "Travels of William Bartram. Macy," *Masius Publishers. Dover ed., New York: Dover Publications Inc* 414, (1928).
[62] B. Meanley, *Swamps, River Bottoms and Canebrakes* (Barre: Barre Publ., 1972).
[63] P. Froeschauer, *A Vegetation History of Ocmulgee National Monument Macon, Georgia* (School of Environ. Design, 1988).
[64] Stewart.

Furthermore, canebrakes could be used by the Indigenous population, which was well familiar with the range and extent of local canebrake habitat and utilized them for concealment of war parties and orchestrating guerrilla warfare. Canebrakes were also commonly utilized by outlaws, enslaved Africans who were on the run, illegal bootleggers and a variety of other social denizens seeking refuge from society or law. In the civil war, canebrake was often refuge for Confederate troops, and destroyed by cannon fire and arson.[65]

Kelby Ouchley, naturalist and director of the Nature Conservancy in Louisiana, compiled accounts of canebrake by Union and Confederate soldiers who used cane for numerous purposes in his book, *Flora and Fauna of the Civil War*. Soldiers valued cane for its utility in constructing temporary shelters and beds, and for its security in warfare. Fortifications and fencing could be made quickly of cane, and their capability to resist or deflect musket fire was comparable to hardwoods. Lightweight gurneys could be fashioned of cane. Sap rollers were dense cylindrical baskets rolled ahead of men working on a trench to provide cover from small arms fire. Sap rollers made of cane were particularly effective in siege operations. In some cases, cane was a supplement to meager rations. Major Samuel H. Lockett, CSA Chief Engineer at Vicksburg, Mississippi had his troops run low on rations and resort to devouring cane shoots and rhizomes.[66]

Canebrake ecosystems had defining impacts on the outcome of many Civil War battles occurring in the southeast. There would be great value in canebrake restoration to support historic interpretation at battlefield sites such as the Cowpens and 96 Historic Battlefield Sites in North Carolina where canebrake played such a pivotal role in the outcome of battle. Two compelling quotes from soldiers from Ouchley (2010) demonstrate the significance of canebrakes to military activities in the South at the time of the Civil War:. :

Brigadier General N. B. Buford, U.S. 7th Corps, Helena, Arkansas, May 20, 1864

"The flat county, the narrow roads, the impenetrable thickets of brush and can afford concealment for guerrillas at every step."

[65] Kelby Ouchley, *Flora and Fauna of the Civil War: An Environmental Reference Guide* (LSU Press, 2010).
[66] Ibid.

Maj. John W. Rabb, 2nd Missouri Artillery, New Madrid, Missouri, April 10, 1864

"I send you copies of several papers captured by Captain Preuitt, on the dead body of the guerrilla Captain Williams. You will notice that one of the enclosed orders is dated at the Blue Cane. This is a dense canebrake, in the center of which is one of the rebel camps. They here have a store supplied with stolen goods, a distillery, several houses, and a large amount of stock."

A Review of Canebrake Restoration and Propagation

Given the history associated with canebrake destruction in the southeastern United States, the threatened status of canebrake ecosystems and the infrequency of sexual reproduction of cane, restorationists in the past decade have started from scratch to develop a successful and replicable restoration and long-term management protocol. Although the establishment of a successful propagation methodology capable of fueling large scale restorations is surely in the near future, cultivating rivercane explants in a nursery environment is still often highly problematic and horticulturalists continue to work towards unlocking the secrets of raising cane. Presently there is very little cane being produced in the commercial nursery industry. A list of specialty bamboo nurseries presently offering cane for sale can be found on the American Bamboo Society website (www.bamboo.org). Several growers offer cane in one to five gallon pots; prices average twenty dollars for a one gallon plant and up to four times that price for an established three to five gallon plant. These prices are reasonably affordable to gardeners and bamboo enthusiasts who want cane added to their collections; however, they are not conducive to the economics of sustainable floodplain restoration ecology. Most often cane being sold by private nurseries has been cultivated by division from an on-site patch or nearby source by a method commonly known amongst circles of rivercane enthusiasts as "clump division."

Clumps of three to five culms (ortets) can be dug from a source population and successfully transplanted into a pot or directly in another location if adequate moisture and protection from exposure is available during the transition.[67] This method of division is a time-tested and reliable approach for successful and quick establishment of a new canebrake. Dattilo and Roads had 98% success in relocating ortets to their research site in central Kentucky.[68] They manually irrigated the cane for a week after transplanting, and after two growing seasons, the authors noted a 400% increase in ramet population. Transplanted clumps had expanded laterally by 26 fold. The authors, through experimental design, determined that applications of hardwood mulch and organic compost significantly improve growth rates and vigor among cane transplants. Creating new canebrakes in this manner (clump division) is an ideal option for restoration when multiple healthy source populations are located within short travelling distance to the transplant site. Culms can be left intact or trimmed back to only a few nodal sections. When a culm is cut, a seal is created at the septum of the next lowest node. Sometimes the node will be initiated in this process and begin meristematic growth although, more often, the plant's energy is put into growing new shoots from rhizome tissue below ground.

Dr. Brian Baldwin of Mississippi State University has done more propagation experiments with North American Bamboos than anyone in the field. He believes that by trimming the culms transpiration rates in the explants are slowed. This has value in the prevention of embolism, perhaps the most nefarious obstacle in propagating cane by vegetative division.[69] Embolisms occur because cane is a monocot with linear vascular bundles (tracheids) that channeling water upward through the plant by convection and transpiration.[70] Cavitation can occur in vascular tissue and an air bubble may form within a vessel. The bubble abruptly breaks the bonds between chains of water molecules eliminating cohesive tension in the vesicles causing great detriment or even death to young explants suffering embolism. A tracheid, once cavitated, cannot heal and return to service. If a propagate suffers from too many embolisms, it will likely die. Only through the development of new adventitious roots and fibrous root hairs do explants have the potential to become established and begin lateral growth.[71]

---

[67] A. D. Griffith, K McDowell, and R. S. Young, "Rivercane Restoration Project: Recovering an Ecologically and Culturally Significant Species (North Carolina)," *Ecological Restoration* 25, no. 2 (2007).
[68] Dattilo and Rhoades.
[69] Baldwin and others.
[70] Ibid.
[71] Ibid.

Propagation by rhizome segments offers an alternative and more economically viable mode of producing large amounts of explants from a relatively small amount of germplasm.[72] Baldwin and others[73] have discovered that by dividing rhizomes into segments that have at least two or three active nodes and planting them in plug trays of commercial nursery mix with the distal end slightly exposed yields great potential for producing large amounts of small explants from a relatively small amount of field collected rhizomes. Even single node culm segments have been used similarly, but with less success than rhizome cuttings. Root development is problematic in rhizome cuttings, and even more so in the culm segments.[74] Propagates often suffer from embolisms. Because cane grows telescopically from nodal sections which contain stored starch and nutrients, it is not unusual for rhizome sections to vigorously sprout shoots in the initial phase of transplant, but never develop root tissue. When the rhizomes have been severed by a shovel or shears, an opportunity is created for an air bubble to enter the vascular tissue of the explant and cause embolism. There are several preventative measures for reducing embolism among cane explants.

First and foremost, it is important to always provide rivercane divisions and rhizome cuttings with adequate moisture throughout the transition to their new environment. Keeping rhizome cuttings in sealed plastic bags works for a period of several days to prevent desiccation, and in hot weather, an insulated cooler can also aid in keeping plant material fresh through a transit. Rhizomes can be kept in cold storage for up to a month without drastically affecting viability.[75]

Baldwin has discovered an unconventional and ingenious method for preventing embolisms in plants grown from rhizome sections. Manually dug clumps of three to five culms each were placed in a length of Polypipe® tubing with a liter of purified water and sealed at both ends. Polypipe® tubing, primarily used in agriculture for irrigation purposes, is a flexible, thick walled, white plastic tube. By trial and error, Baldwin et al. discovered that by digging a

[72]James J. Zaczek and others, "Propagation of Giant Cane (Arundinaria Gigantea) Using Rhizome Cuttings," *Combined Proceedings - International Plant Propagators Society* 54, (2004).
[73] Ibid.
[74] Baldwin and others.
[75] J. L. Hartleb and J. J. Zaczek, "Culm Production and Morphology of Fresh and Stored Rhizomes from Field-Planted and Wild Giant Cane," in *General Technical Report - Southern Research Station, USDA Forest Service*, ed. D. S. Buckley and W. K. Clatterbuck (Asheville; USA: Southern Research Station, USDA Forest Service, 2007).

clump of three to five culms approximately one to two years old a 96.3% success rate was achieved by rhizome divided from for culms of all ages, and 100% success rate for groupings of one to two year old culms.

The clumps of rivercane in Polypipe® tubes were placed in deep shade (50% light reduction) and suspended from the distal end, where they remained sealed for six weeks. After six weeks, the clumps were removed and planted into a pot-in-pot setup where they were watered well and utilized for future rhizome harvests.[76] Perhaps Dr. Baldwin's method of using sealed Polypipe® could be adapted for collecting and relocating cane ortets for longer distances, increasing the feasible travel distance for relocating germplasm to a restoration site. Cane is best transplanted in the winter when water demands are low and the plant, although evergreen, is in a state of dormancy. Rhizomes that have been gathered in winter can be planted into plug trays or pots and raised in either a temperature controlled greenhouse or even an unheated rowhouse as long as proper ventilation and moisture are available. If root development occurs, nursery grown plants can be transitioned to the wild the following spring or into pots where they are easily accessible for rhizome tissue harvest or transplant in the future.

[76] Baldwin and others.

Fig. 8: Dr. Baldwin's method of rhizome production. Images from: *Optimizing rhizomal propagation of rivercane (Arundinaria gigantea)* a presentation given by Rachel Jolley, Diana Neal,Brian Baldwin, and Gary Ervin Department of Biological Sciences and Department of Plant & Soil Sciences Mississippi State University

In my own propagation trials, by recommendation of my colleague Victor Vasquez, I have used Mycogrow®. Mycogrow® a commercially available mycorrhizal inoculant. When transplanting rhizome cuttings. Many species of flowering plants have evolved adaptations for symbiotic relationships with fungi known as mycorrhizae. The fungi benefit from the products of photosynthesis and the plant may benefit from the production of enzymes that aid in nutrient availability, moisture retention, and even germination. Some plants will dwindle or even perish without their mycorrhizal associate. Victor Vasquez has photographed Endo-mycorrhizal arbuscules and penetrating hyphae in *Arundinaria* root tissue that we gathered from a local canebrake.

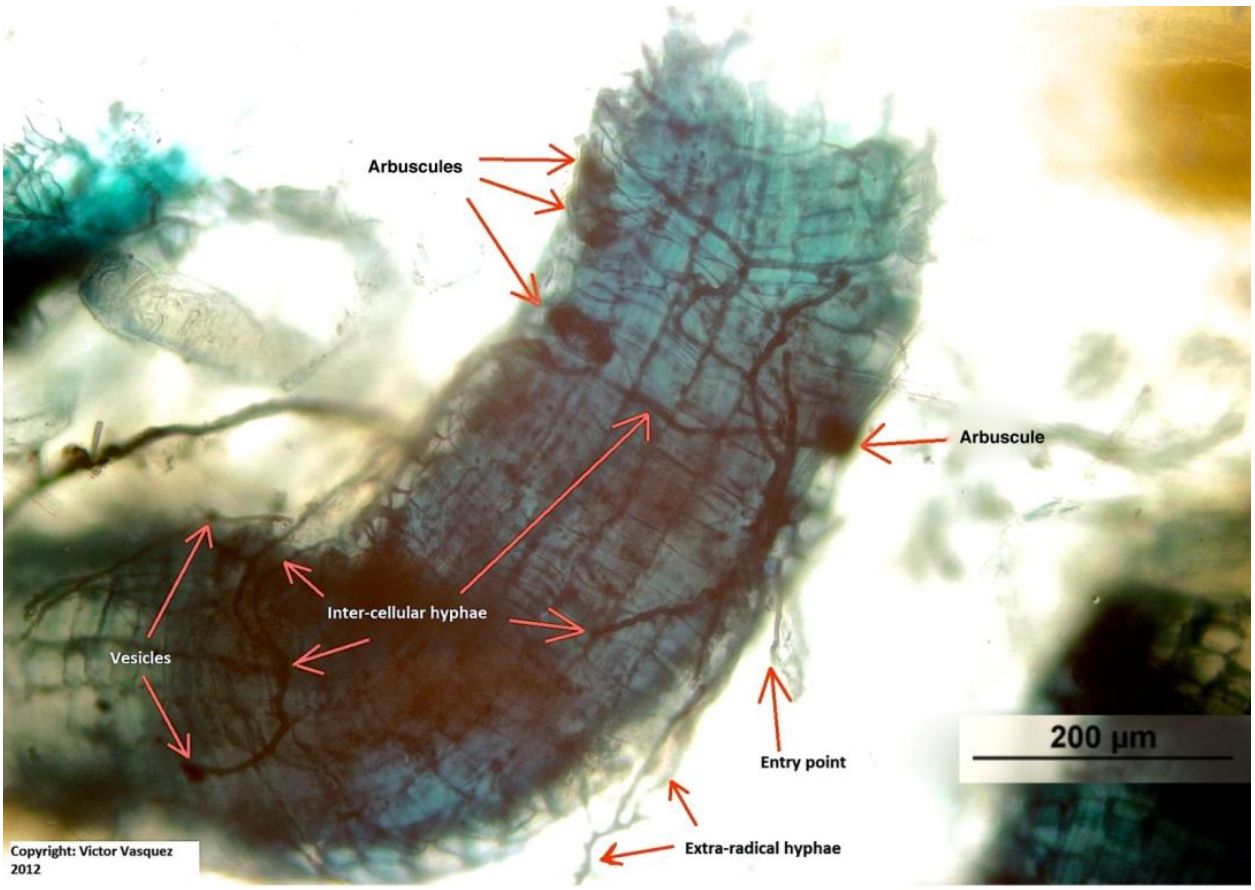


Fig. 9: Arbuscular mycorrhizal associations in an adventitious root of *A. tecta*, by Victor Vasquez

Vasquez believes that there is an element of canebrake ecology that involves an associated mycorrhizal species. This has also been noted as an area of canebrake restoration in need of further study by Gagnon in his dissertation.[77] There are others in the field who have verified mycorrhizal associations in *Arundinaria*[78] and other temperate bamboo species.[79]

In one experiment I transplanted 20 rhizomes cuttings of three to five nodal sections with Mycogrow® and 20 without. I planted each subgroup into a sterile potting medium (Fafard® 3b) mixed with Black Kow® composted manure at a rate of four to one. I have commonly had personal success with this planting medium or a variation with added soil conditioner in propagating rhizome cuttings at my personal research facility (a Tractor Supply Co®. greenhouse and designated area of my driveway). I haven't read of anyone else using this mix, rather more often, researchers use sterile mixes in nursery trials. It is my personal belief as a long-term amateur horticulturalist that either the rhizomes or an associated mycorrhizal symbiont benefit from the added organic matter and nutrients in the manure.

The rhizomes for my experiment were from an Arkansas genotype and were transplanted from plug trays, where they had been initially established with the same soil mix, into one gallon standard nursery containers. Each of the plantings (Mycogrow®, and non-Mycogrow®) were provided water in the morning and evening so that soil was consistently damp but never saturated. In the Mycogrow® treated rhizomes, five percent of shoots experienced embolism. In the untreated subgroup, 40% died by embolism or unknown reasons. Vasquez performed a parallel experiment with germplasm from a local canebrake at the State Botanical Garden Native Plant Center. I helped him gather and prepare the rhizomes for the experiment and plant them into three subgroups: An untreated control group in sterile Fafard® 3b potting mix, A Mycogrow® treated group in the sterile mix, and a group planted in native soil from the collection site. We also performed the same treatments to single node culm segments as per Baldwin (2009). After experiencing initial success, Victor's propagates experienced a massive die-off over the week of (Spring Break).

The variation in success rates between my own experiment and Vasquez's could have been related to different genetic factors. It has been proven that different genotypes can be more vigorous and resistant to transplant shock or

---

[77] Gagnon, "Population Biology and Disturbance Ecology of a Native North American Bamboo (Arundinaria Gigantea)".
[78] A. Elizabeth Arnold, Sarvate, Snehal, and Lutzoni, and Francois, "Diversity and Specificity of Endophytic Fungi Associated with Representatives of Major Plant Lineages," *Inoculum (Suppliment to Mycologia)* 55, no. 4 (2004).
[79] Sudhir Chandra and HK Kehri, *Biotechnology of Va Mycorrhiza: Indian Scenario* (New India Publishing, 2006).

embolism than others.[80] In my opinion, there was a variable of environment (temperature, moisture, light availability), or a variable in husbandry that lead to the sudden collapse of Vasquez's experiment at the SBG.

Rhizome cuttings can also be directly planted in the field without ever spending time in a nursery or a pot. James J. Zaczek of Southern Illinois University has had success with field planted rhizome segments that rivals success of nursery grown propagates. Rhizome segments with seven to ten nodal sections were dug into the ground on-site with the few distal segments exposed to the sunlight. Exposed ends of rhizome segments often turn green after planting, suggesting the initiation of photosynthesis. After five years, with minimal maintenance, the rhizome plantings had become populations averaging 80 ramets, and when exhumed, plantings revealed 500 rhizome segments of at least 30 cm each. The authors noted that the rhizomes that survived field planting were more commonly longer and had more active nodes. Longer rhizome segments yielding higher viability in cane propagates has been noted also by Baldwin (2009), Hartleb (2007), and Schoonover (2011). This has also been my own experience with propagation trials I have conducted at my home.

Zaczek et al. (2004) suggested that rhizome segments could be harvested from a stock population that was maintained solely for the purpose of fueling the production of explants. Harvested rhizome segments could easily be adapted for mechanized planting rather than hand planting, which is the precedent. If a mode of producing rhizome segments and then mechanically installing them directly in the field were developed perhaps large scale restorations could be made more economically feasible and efficient. Most restorations have been done either by transplanting nursery grown stock, which entails more of an initial financial investment, or by clump division from native stands which is laborious and time consuming. Fueling restorations with divisions from native stands also requires access to a broad sampling of source populations so that no native populations are overly depleted by harvest.

Adam Griffith of Western Carolina University has developed an innovative web-based network designed to increase the availability of germplasm available to canebrake restorationists by connecting them with land-owners who

---

[80] J. E. Schoonover and others, "Growing Giant Cane (Arundinaria Gigantea) for Canebrake Restoration: Greenhouse Propagation and Field Trials," *Ecological Restoration* 29, no. 3 (2011).

are willing to share their cane resources. The network also serves to facilitate the availability of cane to Cherokee artists who can contact landowners about harvesting culms for basketry and other art forms.

Initial establishment of canebrake by seed would have several advantages to using clump division or nursery grown stock from rhizome cuttings. Sowing seed is far less labor intensive than either aforementioned methods, A canebrake grown from seed that had been gathered from the same mast would also have inherent genetic diversity (each seed produces a distinct genet), and would be on the same flowering schedule as it's cohorts.

If mast flowering events in canebrakes were reliably predictable, seed collected at a point analogous to the "early dough stage" of development in cereal grains would be ideal for restoring canebrake by direct sowing of seed.[81] Research by Paul Gagnon while at Louisiana State University has shown great success with directly planting cane seeds in a partly shaded forest gaps with a covering of leaf litter. The leaf litter simulates the natural substrate that seeds would fall to as they shatter from inflorescences and land beneath a canebrake, The litter provides cover from voracious rodents, insects, and birds who devour seeds for their high protein content and nutritive value. The mulch also serves to retain moisture and prevent desiccation.[82] Seedlings would have to be monitored over time and managed for expansion. It can take over 10 years for a canebrake to form from seedlings so although restoring cane by broadcasted seed may be more cost effective and less labor intensive than using vegetative transplants, much time will be spent in fostering expansion of a brake developing from seed.

It can take up to three years for a seedling's fibrous root structure to transition into rhizomes. Once rhizomatous growth is initiated the genet begins to expand outward with the potential of creating more ramets and eventually an extensive rhizosphere essential for canebrake establishment. The rhizosphere provides the stability needed for the canebrake to deter erosion and begin functionally performing a variety of ecosystem services that will highlighted in an upcoming chapter.

[81] Hughes.
[82] Gagnon and Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)."

Unfortunately, there are still many mysteries surrounding the sexual reproduction of bamboo species.[83] The one certainty in canebrake reproduction is that in the instance of a flowering event, cross pollination must occur for viable seed to develop and the population to persist in the long term. Cane often flowers and produces no seed, or completely sterile seed.[84] There are several Asian bamboos known to also produce sterile seed due to unsuccessful pollination of sporadically flowering culms.[85]

Brian Baldwin observed an isolated plant that bloomed with over 1000 receptive flowers that produced only eleven seed, three of which were viable, however, by manually outcrossing different genotypes Baldwin was able to get a 71% germination rate.[86] Similar observations were made by Paul Gagnon who noted mass quantities of seeds from a gregarious event of a multi-genotypic canebrake at Tunica Hills, Louisiana.[87] A germination test revealed a 95% success rate. Gagnon also observed sporadic events every year of his study, none of which produced seed.[88] Vasquez observed mast flowering in several sites during the spring of 2013 and collected thousands of viable seed. The seed is currently being germinated as per Gagnon 2008 in two field sites selected for ideal conditions. The planting occurred on Memorial Day weekend, Summer 2013. Along with the field plantings, we prepared eleven trays of sterile Fafard® 3b growing mix and planted 80-100 seeds in each. Germination was observed in several of the seed trays on 6/8/13. Seedling establishment of young cane shoots averaging three inches in height occurred by June 15 in seed trays and both feild plots. Seedlings in feild plots were about a week behind those grown in trays. I hypothesize that the seedlings took longer to develop with the covering of leaf litter.

To maximize fertility in the rare occurrence of a synchronous flowering event, restoration plantings should include a mix of explants from a variety of source populations with a variety of genetic backgrounds. Even if only for the reason that one genet flowers and senesces and the rest of the cohort does not. At least the brake will persist

---

[83] Janzen.
[84] Judziewicz and others.
[85] KC Koshy and G Jee, "Studies on the Absence of Seed Set in Bambusa Vulgaris," *CURRENT SCIENCE-BANGALORE-* 81, no. 4 (2001).
[86] Baldwin and others.
[87] Gagnon and Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)."
[88] Gagnon, "Population Biology and Disturbance Ecology of a Native North American Bamboo (Arundinaria Gigantea)".

vegetatively in-situ and maintain its ecological niche for the time being. Remaining culms would also serve to provide shelter for the developing seedlings that may germinate in the gaps created where the flowering culms have died. .

Another method of propagating rivercane pioneered by Baldwin is by tissue culture also known as micropropagation. This method can be employed to mass produce rivercane explants year round in a laboratory environment. Minimal plant tissue is required to start the process, and once established in culture, explants can continue to be divided without the need for additional source material. Commercial growers involved in plantation establishment and large scale restorations prefer propagation by tissue culture because it yields a continual supply of explants with predictable morphological characteristics and standardized genetics. Dr. Baldwin conducted a series of optimization experiments and determined the best media type, appropriate cytokinin:auxin ratio, and the effect of explant size on micropropagated cane. The experiments determined that maximum shoot growth in propagules was attained using a Murasige and Skoog Medium containing an IBA concentration of 0.1 pM, a TDZ concentration of 0.01 nM, and explants of four to six millimeters in diameter.[89]

Continued research in the area of microshoot multiplication and root development will be needed if micropropagation will be a viable method of mass producing nursery or field ready plants. Most University and Professional horticultural laboratories have capabilities to continually produce rivercane with little additional costs, space, or labor. By continuing to develop micropropagation techniques for rivercane, horticulturalists like Baldwin move ever closer to cracking the code that will establish a propagation methodology capable of sustaining large-scale floodplain restorations. Dr. Hazel Wetzstein of the University of Georgia visited my facility and harvested seedlings and germplasm from my nursery grown stock for use in her own study on micropropagation.

Shared Perspectives in Canebrake Literature

Although there is still uncertainty as to the most successful approach to canebrake restoration, A review of literature on the topic has revealed several areas where authors are in agreement. I have outlined them below:

[89] Baldwin and others.

SITE APPROPRIATELY

When selecting locations for the installation of new canebrakes it is important to remember that although cane is quite capable of adapting to a broad range of environmental variables in its habitat and can grow across a broad variety of ecotones, siting cane restorations on, or near the first levy of the floodplain or edge of a riparian corridor is ideal. Preferred soils are sandy, well drained alluvium containing high rates of organic matter. It is important to remember that experimenting with plantings in a variety of sites can potentially lead to new discoveries in canebrake ecology and habit. A site inventory and GIS analysis to determine soil types, hydrology, and microclimate (slope, aspect, elevation) is an essential part of restoration programming and an invaluable tool for the targeted expansion of canebrake .

WINTER TRANSPLANT

Wintertime transplants are ideal for the following reasons: Although continuing photosynthesis to fuel rhizome development below ground in the wintertime, rivercane maintains a slower metabolic rate throughout the winter and is in a state of vegetative dormancy where little to no new above ground shoots are being generated. Dehydration, transplant shock, embolism, bacterial and fungal infections are all more likely to occur in the hotter months. In Georgia, I have had success establishing rhizome cuttings as late as May. If adequate water is available on a regular basis, summertime transplants are more likely to survive. In my opinion, the time, labor and resources expended are not worth the trouble.

ADEQUATE MOISTURE AVAILABILITY

Transplants benefit from daily watering for the first two weeks of establishment and in times of drought. Desiccation is dangerous to river cane propagates. Embolisms are more likely when water is deficient. Both vertical and lateral expansion of canebrakes and explants are hindered in times of drought. Cane does not stand up well to long periods of inundation but it certainly has an affinity for growing along the margins of wet-seeps and alluvial corridors. Not one of the 14 populations inventoried at the SBG was growing more than 20' away from a form of hydrology be it river, seep or swale.

NEED FOR SUN/CANOPY CLEARANCE

Rivercane prefers full sun![90] Stranded populations living in the dense forest understory are often stunted, persisting in a sporadic pattern and are not capable of providing the multitude of ecosystem services that a thriving canebrake would. Studies done by Cirtain (2009) indicate that cane growing in full sun grows more vigorously than its counterparts growing in filtered sunlight and shade.[91] Furthermore, stagnant populations persisting in the understory can be revitalized by selective canopy clearance.[92]

MULCH/COMPOSTED MANURE ADDITIONS

Dattillo and Rhoades (2005) proved through experimental design that five inches of composted manure and/or hardwood manure applied around the base of transplanted cane ortets facilitated faster establishment of clump divisions planted in southern Illinois. The mulch and organic matter help to retain moisture and also break down into essential nutrients over time.[93]

FIRE MANAGEMENT ON CYCLES OF SEVEN TO TEN YEARS

Fire ecology is an essential facet to healthy canebrake development. Winter burns on intervals of at least every decade have been known to rejuvenate stands of cane that have grown vegitatively stagnant or overcrowded with older or dying culms.[94]

---

[90] Gagnon, "Population Biology and Disturbance Ecology of a Native North American Bamboo (Arundinaria Gigantea)".
[91] Margaret C. Cirtain, Scott B. Franklin, and S. Reza Pezeshki, "Effect of Light Intensity on Arundinaria Gigantea Growth and Physiology," *Castanea* 74, no. 3 (2009).
[92] Ibid.
[93] Dattilo and Rhoades.
[94] Gagnon, Passmore, and Platt, "Multi-Year Salutary Effects of Windstorm and Fire on River Cane."

UTILIZE LONGER RHIZOME SEGMENTS

Greater success in propagation from rhizome cuttings is achieved by using sections with at least five nodes.[95]

VALUE OF SELECTIVE HARVEST

Selective thinning of older culms can rejuvenate canebrakes by stimulating the development of new shoots, similar to the way that a prescribed fire would.[96] Selective harvests would also open the door to collaborations with outside organizations working to generate resources for traditional Native American basket weavers.

INTERPLANTING GENOTYPES TO IMPROVE SEED VIABILITY

Rivercane is an obligately-outcrossed, wind pollinated, semelparous woody grass species (It flowers once and dies). Seed viability and long-term persistence of the population depends on genetic diversity within the canebrake. A well-established canebrake would be more than capable of stabilizing Oconee River floodwaters and inherently restore environmental integrity and cultural appeal to the floodplain landscape. Canebrakes that have been restored from a single source population will eventually flower on schedule as their parent population. Unless an unrelated genet flowers synchronously in close proximity, the entire restoration will be in vain when the population collapses and no seed is left behind to fill the environmental niche. Since many canebrakes in the southeast have been fragmented by human development and reduced to scattered patches spread thinly across the region, these networks of patches are often vestiges of the same genetic stock. Even a harvest of local genotypes gathered across several counties could potentially yield very closely related genets. It is critical that as much genetic variety as possible be incorporated into

[95] J. J. Zaczek and others, "Survival and Genet Growth and Development of Field-Planted Giant Cane (Arundinaria Gigantea) over Time in Southern Illinois," *Castanea* 74, no. 3 (2009).
[96] Amanda Cronin and David M. Ostergren, "Tribal Watershed Management: Culture, Science, Capacity, and Collaboration," *American Indian Quarterly* 31, no. 1 (2007).

restoration plantings in order to maximize the potential for viable seed production.[97] It may be beneficial to plant cane propagates that had been gathered from multiple states or ecotones.

EXPOSURE OF DISTAL END OF RHIZOME CUTTINGS TO SUNLIGHT

This orients the cane to the sunlight and initiates photosynthesis.[98]

These guidelines are formulated by observing general consensus in the academic literature on canebrake restoration to date. Site specific suitability analysis will be required for any restoration, but the aforementioned guidelines can provide insight into selecting the appropriate site for new canebrake and managing decadent stands for rejuvenation.

[97] Baldwin and others.

[98] Zaczek and others, "Propagation of Giant Cane (Arundinaria Gigantea) Using Rhizome Cuttings."

CHAPTER 3

CANEBRAKE ECOSYSTEM SERVICES

Wildlife Value

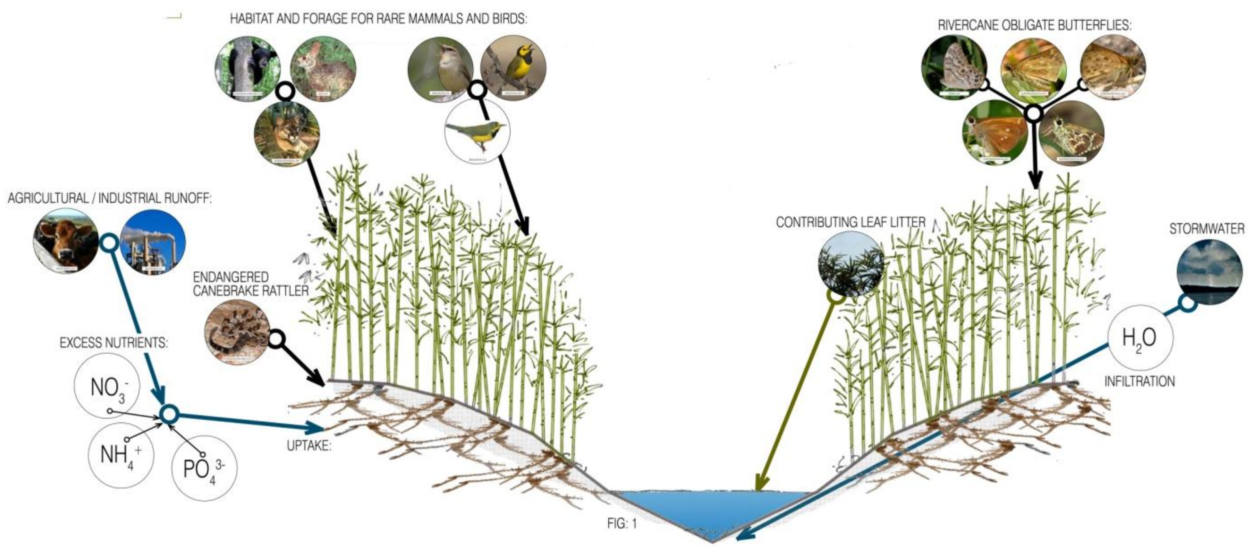


Fig. 10: Diagram of canebrake ecosystem, by: Thomas Peters and Victor Vasquez.

Canebrake provides critical habitat value to over 60 species that have been identified as at least partially dependent on canebrake ecosystems and several that are obligately associated to canebrake habitat.[99] These include the endangered canebrake rattlesnake (*Crotalus horridus*), several cane obligate butterflies including the Creole pearly eye (*Enodia creola*), Southern swamp skipper (*Poanes yehl*), Southern pearly eye (*Enodia portlandia*), Cobweb little skipper (*Amblyscirtes aesculapius*), Cane little skipper (*A. reversa*), and the Yellow little skipper (*A. carolina*) which deposit their eggs on cane so the larvae can feed on the foliage. Several species of birds including the endangered Swainson's Warbler (*Limnothlypis swainsonii*) and the possibly extinct Bachman's Warbler (*Vermivora bachmanii*) nest, forage, and take refuge in canebrakes. The threatened Louisiana black bear (*Ursus americanus luteolus*) and swamp

[99] Platt and Brantley.

rabbit (*Sylvilagus aquaticus*) are both species under threat of disappearing alongside the canebrakes they call home. The elusive Florida panther seeks refuge and prey under cover of canebrakes. As long as they are overgrazed, canebrakes can provide year-round forage for livestock and game that is extremely high in protein, starches, and nutrients.[100]

Riparian Buffer

In the field of floodplain restoration, an increasing amount of professionals are realizing the environmental value of riparian buffer zones. By buffering waterways with appropriate vegetation, storm water runoff is slowed and infiltrated. Pollutants and excess nutrients from agricultural runoff can be mitigated by natural plant metabolism and erosion is halted by stabilizing root structures. Aquatic systems, groundwater reservoirs, natural environments and ultimately entire ecosystems are healthier when riparian buffer zones are intact. Research has lead me to the conclusion that canebrakes may have the potential to provide more ecosystem services in floodplain ecosystems than any other plant community endemic to the southeastern United States.

Historically, the construction of the American built environment including agrarian, urban, and everything in between, has included the practice of razing vegetation to the water's edge and channelizing hydrologic systems. Growing concerns have arisen within environmentalist circles about the leaching of chemical pollutants and sediment from stormwater and agricultural runoff into groundwater.[101] Riparian buffers are increasingly viewed as the solution to pollution and erosion in floodplain ecosystems. Riparian buffers are zones of vegetation strategically placed to slow stormwater runoff and increase infiltration.[102] Plants, like rivercane, with a high capacity for nutrient uptake[103] (phytoremediation) and vigorous root systems are ideal for use in riparian buffers.

---

100 Stewart.
101 Timothy B Spruill, "Statistical Evaluation of Effects of Riparian Buffers on Nitrate and Ground Water Quality," *Journal of Environmental Quality* 29, no. 5 (2000).
102 Ibid.
103 Christopher R Blattel and others, "Abatement of Ground Water Phosphate in Giant Cane and Forest Riparian Buffers1," *JAWRA Journal of the American Water Resources Association* 41, no. 2 (2005).

Fig. 11: Lake Chapman, Athens, GA. By Victor Vasquez and Thomas Peters

The canebrake rhizosphere works to knit soil particles together tightly and support the durable network of culms that can occur at densities of up to 30 per square meter.[104] Canebrake rhizomes spread outward as much as six meters in a growing season and form a thick matting of adventitious roots. The rhizosphere forms a Velcro-like adhesion to sandy alluvial loam characteristic of floodplain soils.[105]

Fig. 12: Rinsed *A. tecta* ortet illustrating rhizosphere density, by Thomas Peters and Victor Vasquez.

[104] Hughes.

[105] Schoonover and others, "The Utility of Giant Cane as a Riparian Buffer Species in Southern Illinois Agricultural Landscapes."

Neisler first described the pattern of canebrake expansion with rhizomes forming buds at the juncture of each nodal section and either producing another rhizome, or an above ground culm.[106] These each in turn can produce additional rhizomes or additional canes, which produce additional rhizomes and canes exponentially until a small population of ramets becomes a massive canebrake.[107] Often all of the growth is clonal expansion of a single genetic organism. A patch of cane will continue to reproduce by this method until no room remains for new canes to grow.[108] The vigor of expanding canebrake is ideal in situations where invasive exotic plant populations like Chinese privet threaten competition.[109]

Canebrakes serve to enrich soil quality by trapping debris seined from floodwaters redepositing it within the brake where it decomposes into rich organic matter.[110]

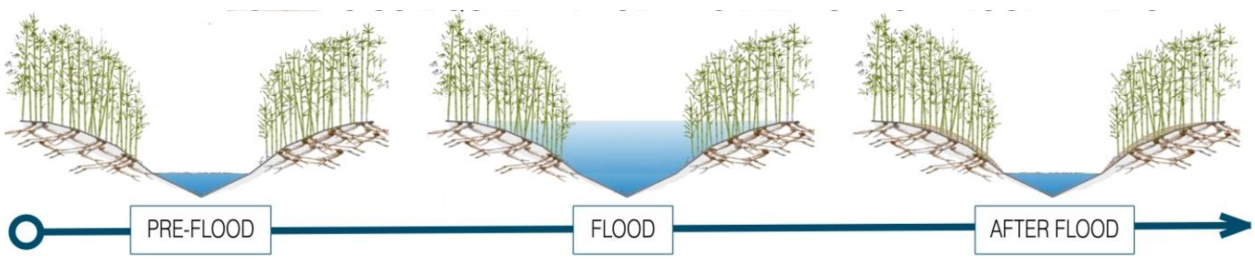


Fig.13: Canebrake soil entrapment, by Thomas Peters

Much of the agricultural success enjoyed by European settlers was due to fertile floodplain soils left behind by the canebrakes that had been cleared for crops or pasture.[111] In fact, canebrakes, were often targeted for agriculture and livestock forage.[112] Swine and livestock could graze on the cane until it was gone, and then crops could be planted in the fertile soils. A study done at Southern Illinois University revealed that a cane buffer outperformed a typical hardwood

106 Hugn M. Neisler, "Art. Ii.—Notes on the Habits of the Common Cane, (Arundinaria Macrosperma, Michx.); by Hughm. Neisler, Corresponding Member of the Essex Institute, Salem, Mass," *American Journal of Science & Arts* 30, no. 88 (1860).
107 Ibid.
108 Ibid.
109 Osland, Pahl, and Richardson.
110 Dattilo and Rhoades.
111 Stewart.
112 Ibid.

forest at slowing the flow of stormwater and mitigating pollutants from agricultural runoff.[113] A canebrake buffer also serves to reduce sediment loads in streams and provide additions of organic matter from decomposing leaf litter.[114] The shaded banks of a well vegetated stream help to regulate water temperature and maintain conditions preferable to aquatic biota.[115]

---

113 Blattel and others, "Ground Water Nitrogen Dynamics in Giant Cane and Forest Riparian Buffers."

114 Schoonover and others, "The Utility of Giant Cane as a Riparian Buffer Species in Southern Illinois Agricultural Landscapes."

115 J David Allan and María M Castillo, *Stream Ecology: Structure and Function of Running Waters* (Springer Science+ Business Media BV, 2007).

CHAPTER 4

CANEBRAKE ETHNO-ECOLOGY

The significance of canebrake landscapes to pre-Colombian civilization in the southeastern United States cannot be overstated. Indigenous Nations of North America have always valued cane for its utility as a material cultural resource. Cane and materials derived from it were once used in almost every tool, structure, implement, or application imaginable.[116]

Bartram[117] and, other early explorers noted how Native American villages were often proximal to expansive canebrakes. The health and expanse of these historic canebrakes was not mere coincidence or vegetative overgrowth in an untamed wilderness. Very large canebrakes developed partially in response to a management and harvest regime practiced by southeastern Native Americans.[118]

Fig. 14: Pre-Columbian Choctaw town (choctawnationculture.com)

[116] John Reed Swanton, *The Indians of the Southeastern United States* (Smithsonian Institution Press Washington, DC, 1979).
[117] VanDoren.
[118] Christopher G. Brantley and Steven G. Platt, "Canebrake Conservation in the Southeastern United States," *Wildlife Society Bulletin* 29, no. 4 (2001).

Likened to nature's "supermarket," canebrakes can provide raw material for a broad range of purposes.[119] Culms and shoots have always been harvested by Indigenous populations for the making of weaponry, instruments, containers, tools, foods, and even medicines.[120] Hollow cane segments can be used for jewelry, game pieces and hair adornments.[121] By splitting a cane segment into four pieces a set of disposable knives can be made. The sharp edges of the cane's outer cortex are effective at cutting meat or cord for a short time before dulling.[122]

Cane culms of over an inch in diameter can be cut, and straightened over a hot fire before nodal sections are hollowed out by a rod or hot ember for use as blowgun. The most accurate blowgun hunters are capable of shooting small game from impressive distances.[123] The projectile is a dart fashioned of whittled cane or other woods and fletched with thistle down. Cane makes excellent arrow and spear shafts that are lightweight, durable, and need minimal preparation.[124] Rivercane is used to fashion traps and cages used by hunters and fishermen.[125] There are still Cherokee artists today capable of making rivercane fish traps. Historically used for trout, traps were placed facing up stream at the confluence of two stone weirs leading fish into a large terminal cone basket made of woven cane. A "funnel" of sharpened cane splints keeps fish from swimming upstream and out of the trap.[126]

Cane also entered the spiritual and ceremonial lives of many southeastern Tribes.[127] Some, like the Houma[128] and Seminole,[129] make a beverage of the rhizomes that can be taken as a cathartic, detoxicant, and rejuvenating tonic.

---

[119] Swanton.
[120] Steven G. Platt, Christopher G. Brantley, and Thomas R. Rainwater, "Native American Ethnobotany of Cane (Arundinaria Spp.) in the Southeastern United States: A Review," *Castanea* 74, no. 3 (2009).
[121] C. (ed.) Covey, *Cabeza De Vaca's Adventures in the Unknown Interior of America*, ed. C. Covey (Albuquerque, New Mexico: University of New Mexico Press, 1961).
[122] S. Cheatham, M.C. Johnston, and L. Marshall., "The Useful Wild Plants of Texas, the Southeastern and Southwestern United States, the Southern Plains, and Northern Mexico," *Useful and Wild Plants, Inc. Austin, TX*, (1995).
[123] S. Watts, "The Southeastern Indian Rivercane Blowgun: Legacy, Lineage and an Aboriginal Approach to Manufacture," *Bulletin of Primitive Technology*, no. 17 (1999).
[124] S. Watts, *Southeastern Rivercane Arrow Notes*, ed. D. Westcott, Primitive Technology Ii: Ancestral Skills. (Salt Lake City, Utah: Gibbs Smith, 2001).
[125] James Adair and Jr Berkhofer, *The History of the American Indians: Particularly Those Nations Adjoining to the Mississippi, East and West Florida, Georgia, South and North Carolina, and Virginia* (New York: Johnson Reprint Corporation, 1968).
[126] Swanton.
[127] Charles M Hudson, *The Southeastern Indians* (University of Tennessee Press Knoxville, Tennessee, 1976).
[128] Frank G Speck, "A List of Plant Curatives Obtained from the Houma Indians of Louisiana," *Primitive Man* 14, no. 4 (1941).
[129] W.C. Sturtevant, "The Mikasuki Seminole: Medical Beliefs and Practices" (Dissertation, Yale University, 1955).

Young cane shoots are a nutritious potherb, and the seeds, although rare due to infrequent flowering events, can be ground into a culinary flour.[130] Bundles of canes arranged in a circle, or spiral are burned for various ceremonial and utilitarian purposes.[131] Cane burns hot and puts off consistent bright light. In the past, councils of important inter-tribal matters might be timed by burning a spiral of cane splints.[132] One end was lit at the beginning of deliberations, and when the splints burned out, the meeting was adjourned.[133] The long stems of sacred pipes smoked by the Caddo in the Calumet Ceremony, often incorrectly referred to as a "peace-pipe," are traditionally made of cane.[134] Cane torches were used by Native Americans to navigate caves and forests at night.

Cane was used also in funerary practices, the deceased often being displayed on a cane hurdle before being wrapped in cane mats for burial.[135] Ceremony often includes music and dance, which are closely linked with spiritual and individual wellbeing in traditional Indian cultures.[136] Flutes fashioned from a hollowed piece of cane have been used recreationally as well as ceremonially by Native musicians and medicine men. Whistles and duck calls have been similarly fashioned.[137]

Like all members of the bamboo family, rivercane is an excellent construction material with a broad spectrum of architectural applications. Valued for its light weight, load bearing capacity, and high resistance to weathering and decomposition, cane can be used in the framework or thatching of dwellings, corncribs, fencing and fortifications.[138] The weight to tensile strength ratio of bamboo exceeds that of most woods and is more comparable to steel and some

---

[130] André Pénicaut and Richebourg Gaillard McWilliams, *Fleur De Lys and Calumet: Being the Pénicaut Narrative of French Adventure in Louisiana* (Louisiana State University Press, 1953).
[131] J.H. Howard, " The Southeastern Ceremonial Complex and Its Interpretation.," *Missouri Archaeological Society* Mem. No. 6., (1968).
[132] Ibid.
[133] R. Ethridge, "Creek Country: The Creek Indians and Their World," *University of North Carolina Press, Chapel Hill, North Carolina*, (2003).
[134] Fred B Kniffen, Hiram F Gregory, and A George, "Stokes 1987 the Historic Indian Tribes of Louisiana," (Louisiana State University Press, Baton Rouge).
[135] David Ives Bushnell, *Native Cemeteries and Forms of Burial East of the Mississippi*, vol. 71 (Govt. print. off., 1920).
[136] Platt, Brantley, and Rainwater, "Native American Ethnobotany of Cane (Arundinaria Spp.) in the Southeastern United States: A Review."
[137] Kniffen, Gregory, and George.
[138] HH Sineath and others, *Industrial Raw Materials of Plant Origin* (Georgia Institute of Technology, 1953).

modern synthetic fibers.[139] Cherokee "wattle-and-daub" architecture involves weaving dried cane culms into a framework and then plastering the frame with mud to create walls that can stand up surprisingly well against weather and time.[140] This traditional form of architecture, obviously no longer used for a typical Cherokee dwelling, is often used in the construction of interpretative historic villages like Oconoluftee Village in Cherokee, North Carolina or Diligwa in Tahlequah, Oklahoma.

Native Americans from the Mississippian and Woodland time periods also made used cane in architectural applications. Archeological excavations of mounds in east central Louisiana revealed cane laid in crisscrossed patterns to mantle the sloping sides of the bases. Ceremonial mounds in Troyville, Louisiana contained buried layers of the significance of which remains unclear.

Cane matting of woven cane splits has been made for centuries for decorative as well as utilitarian purposes. Historically, cane mats, which can last for over 20 years were used to line and protect the inside, and exterior of dwellings.[141] With the increase of cultural revitalization and immersion programs associated with Native American schooling, there have been an increasing number of Native Americans, including the younger generations that are carrying on this traditional art form.[142]

Perhaps the most important use of cane by contemporary Native artists is in a distinctive form of basketry. Cane baskets start with harvested culms between two and ten years of age that are at least an inch in diameter.[143] It's said that winter harvests yield firmer canes that make better baskets. The harvested culms are cleaned and dried in a covered location before being split into four separate pieces. The inner cortex of the split cane pieces, known as "splints" is then stripped with a knife until only the thin and durable outer shell suitable for basket weaving remains. Freshly prepared cane splits are then tied into bundles, and boiled in water containing natural plant dies for coloring.[144]

---

139 David Farrelly, *The Book of Bamboo: A Comprehensive Guide to This Remarkable Plant, Its Uses, and Its History* (Thames and Hudson Ltd, 1996).
140 Peter Nabokov and Robert Easton, *Native American Architecture* (New York: Oxford University Press, 1989).
141 Hudson.
142 Cozzo, David, Personal Comm. 3/19/2013.
143 Cain, Roger. Personal Comm. 5/31/2013.
144 Sarah H Hill, *Weaving New Worlds: Southeastern Cherokee Women and Their Basketry* (University of North Carolina Press Chapel Hill, North Carolina, 1997).

Bloodroot *(Sanguinaria canadensis)* is used for red and orange hues, black walnut *(Juglans nigra)* for dark browns or black and yellowroot *(Xanthorhiza simplicissima)* for various yellows depending on concentration and time in the boiler. Different designs are produced for different ceremonial, utilitarian, and decorative purposes. Some designs are unique to the artist's tribal affiliation.[145] They can range in size from small storage baskets to large burden baskets for carrying almost like a knapsack. Double weave types are the most durable, consisting of one basket woven inside of another and sharing a common rim. There are accounts of double weave baskets woven so tightly that they are capable of holding water without leaking.[146]

Much time and labor goes into properly preparing cane splits before they can be stored until needed for baskets. Cherokee artists Roger and Shawna Cain use 40-60 culms in an average medium basket. It takes several weeks in preparation before weaving a basket can begin, which takes several more weeks. They only take from brakes what they need for one basket at a time, trying to carefully prune the brake of older and imperfect culms first. With this methodology (pruning for rejuvenation), Roger has seen several canebrakes expand in response to his harvesting regime.[147]

Cane permeated nearly every aspect of Native American culture and daily life prior to European contact. One could say there was a "bamboo culture" (sensu Anderson[148]) in place for as long as mankind had been living in the Southeastern United States.[149] It might seem that with such heavy use, cane would have been gathered to extinction. Why were historical accounts of canebrakes so grandiose when they were constantly being harvested for use in nearly every tool, implement, and dwelling?

Eighteen to 20 culms are required to make small a storage basket[150], and many thousands are required in a traditional wattle and daub house pair, Native American villages undoubtedly consumed millions of culms each year.

---

145 Ibid.
146 Platt, Brantley, and Rainwater, "Native American Ethnobotany of Cane (Arundinaria Spp.) in the Southeastern United States: A Review."
147 Cain, Roger, Personal Comm. 3/19/2013.
148 Edward F Anderson, *Plants and People of the Golden Triangle. Ethnobotany of the Hill Tribes of Northern Thailand* (Dioscorides Press, 1993).
149 Platt and Brantley, "Canebrakes: An Ecological and Historical Perspective."
150 Hill.

Despite the tremendous demand for raw material, It has been suggested that the annual culm harvest was sustainable for the several reasons. Healthy canebrakes grow vigorously and densely, at about 20,000 to 65,000 culms per acre.[151] Culms re-sprout rapidly from harvested brakes as long as sufficient time is given for nutrient reserves to be built in the rhizomes. Considering the regenerative potential of cane[152] and the fact that canebrakes once dominated extensive areas of the pre-settlement landscape,[153] the impact of annual harvesting on the overall resource base was likely minimal.

To better illustrate the land area cover of historic canebrakes, consider kudzu, an Asian invasive commonly referred to as the "vine that ate the South." Kudzu covers about 7,500,000 acres in the Southeast today. It is estimated that at some point between the sixteenth and eighteenth centuries, the land-cover of canebrakes peaked at over ten million acres.[154] Even a relatively small area of canebrake could produce enough culms to meet the annual needs of a village.[155]

Paul Gagnon's research affirmed scientifically that disturbance regimes - either happenstance or manual - are essential for healthy canebrake growth and development. Hurricanes, periodic flooding, and, occasionally, fire increase growth and vigor in canebrakes if occurring within certain parameters. An annual harvesting regime can invigorate growth and outward spread in canebrakes similar to natural disturbances.

Vast cultivated stands of cane persisted for centuries, thriving alongside Native American communities harvesting them as a renewable material resource. These cultures traditionally value balance within natural systems embracing a more cyclical view of time and lifecycles than most western societies. Native agriculturalists employed concepts like crop rotation, intercropping, proto-agriculture (semi-cultivation of forests and wild areas), and fire ecology long before some of the concepts were adopted by western science. In the interest of continuing the availability of resources, Native communities can strive to maximize the health and productivity of their cane resources. The "cane wilderness" experienced by early European explorers was actually a landscape cultivated by annual harvests, occasional

---

[151] Marsh.
[152] Gagnon and Platt, "Multiple Disturbances Accelerate Clonal Growth in a Potentially Monodominant Bamboo."
[153] Platt and Brantley, "Canebrakes: An Ecological and Historical Perspective."
[154] Stewart.
[155] Platt, Brantley, and Rainwater, "Native American Ethnobotany of Cane (Arundinaria Spp.) in the Southeastern United States: A Review."

burning to maintain vigor, and allowing fallow agricultural fields to succeed into canebrake. It would be a great value to the academic community if a hidden wellspring of indigenous knowledge on canebrake ecology and management were unearthed, but the case is to the contrary.[156] A history of cultural abuse, forced removal, discriminatory treatment, and divisive policy exercised by the US government has left many Tribal Nations with voids in traditional knowledge. The many of the nuances of canebrake management were lost over the years and Tribal Nations have not had the opportunity to manage cane on their own lands since removal.

Nonetheless, traditional basket weavers and artists continue to value and use cane as part of their daily lives. Some have learned about cane from a parent or grandparent and remember lessons learned on harvesting parameters and canebrake maintenance. Roger Cain, a Cherokee ethnobiologist, artist, and traditionalist, has dedicated his life to educating Cherokee people about sustainable harvesting and management but also the importance of restoring canebrakes for the long term survival of traditional art forms. Cain is using GIS modeling and survey to research the possibility of a healthy canebrake ecosystems and their proximity to communities retaining higher levels of Cherokee fluency and retention of traditional knowledge. His findings, though preliminary, seem to suggest a positive correlation.[157] Cain and his wife Shawna, both talented basket weavers, were instrumental in getting cane included on the Cherokee Nation's Culturally Protected Species List. For their dedication, the Cherokee Nation awarded Roger and Shawna both the title of "Cherokee National Treasure."

The Cherokee Preservation Foundation, an organization serving the Eastern Band of Cherokee Indians has fostered a resurgence in traditional culture through language immersion programs and traditional art classes in Cherokee schools. Eight years ago, there were only two elders in the Eastern Cherokee Community who knew double weave basketry. Now that the Cherokee Preservation Foundation has reinstituted basketry classes in the public High school, there are thirteen younger basket weavers in the community. The last time rivercane basketry was taught in

[156] Cozzo, David. Personal Communication. 3/19/2013.
[157] Nolan, Justin, Shawna Cain, Roger Cain, and Rick Stepp. "Western Cherokee Ethnoecology and Language Revitalization in the Oklahoma Ozarks." Presentation at the 2012 annual meeting of the Society of Ethnobiology Dept. of Anthropology, University of Arkansas, Cherokee Nation, and Dept. of Anthropology University of Florida.

Cherokee Schools was in the 1960s. Rivercane mat making is also on the rise. The demand for cane resources is higher than it has been in several decdades.[158]

The National Forest Service and the Chattooga Conservancy recently formed an initiative to create nearly thirty acres of canebrake habitat at South Carolina's Sumter National Forest. At its completion, the brake will be the largest actively managed canebrake in the Southeast. The restoration is being funded by The Revitalization of Traditional Cherokee Artisan Resources initiative (RTCAR). The site will be managed as an artisans resource. RTCAR is a multi-year grant making program whose purpose is assisting the Eastern Band of Cherokee Indians (EBCI) in restoring the traditional Cherokee balance in maintenance and utilization of natural resources. Funded by The Cherokee Preservation Foundation and operated through EBCI Cooperative Extension, RTCAR serves to protect existing natural resources and procure new ones for Cherokee traditional art forms.[159] The organization is also active in public outreach and educating future generations about resource management and land care. Since its inception in 2004, RTCAR has already taken action in locating and securing sources of rivercane for Cherokee arts and suitable habitat for cane reintroduction. By forming cooperative agreements with organizations such as the Land Trust for the Little Tennessee, and the Watershed Association of the Tuckaseegee River, RTCAR Director Dr. David Cozzo diligently works to improve Cherokee Artist's access to their much needed resource.

The Cherokee are just one of the Southeastern Tribal Nations that are leading the charge in restoring canebrake ecosystems. The Poarch Band of Creek Indians in Alabama initiated a canebrake restoration on their lands to satisfy the demand for cane that has grown as a result of the traditional arts cultivated by Poarch Creek Cultural Education program. Before the restoration, the closest available source of rivercane for Poarch Creek artists was ninety miles away in central Alabama.[160] Recognizing the need for cane resources closer to home, the Tribe took action and initiated a relationship with the Natural Resource Conservation Service (NRCS) Southeastern American Indian Workgroup, a

---

[158] Cozzo, David. Personal Communication. 3/19/2013.

[159] "Revitalization of Traditional Cherokee Artisan Resources," accessed 7/15/2013. http://www.cpfdn.org/cultural-preservation-connect/major-programs-and-initiatives/rtcar.

[160] Daniel Gibson, "Restoring Sacred Roots," *Native Peoples Magazine* 23, no. 1 (2010).

special division of the NRCS focusing on aiding Tribal Nations in natural resource conservation and management.[161] The Jamie L. Whitten Plant Materials Center in Coffeeville, Mississippi donated one hundred young river cane plants that were planted by the Poarch Creek Tribal Youth Council in the Summer of 2009. If some of those students take up basket weaving, they will have a healthy canebrake to harvest materials from and pass on their skill to the next generation.

A partnership between the NRCS, The Environmental Protection Agency, Mississippi State University and the Mississippi Band of Choctaw Indians has yielded over six years of propagation and restoration efforts in the Pearl River Watershed. In 2006 Baldwin supervised the propagation of several hundred cane plants from rhizome cuttings. The young plants, after established in the nursery, were planted along the Pearl River in plots by experimental design in order to enhance water quality and reduce erosion. Another primary goal of the Pearl River Wetlands Demonstration Project was to develop a protocol for collecting germplasm from native ecotypes and maintain a collection in a nursery environment for dividing rhizome segments that could be combined in future restoration plantings. The Pearl River Project was very effective in making sure that the general community was involved and informed through public outreach, volunteer workdays, field trips and interpretative opportunities for schoolchildren. Mississippi State University hosted a symposium in 2009 to disseminate the knowledge gathered from the Pearl River restoration to the academic community and professionals involved in canebrake restoration. Pearl River was an exemplary project because it involved interdisciplinary cooperation between the Mississippi Choctaw (a sovereign nation), universities, government agencies, private entities and the community at large.

Despite efforts of the diverse community advocating canebrake restoration, there is still scarcity of the resource for Native artists. It is essential for a replicable propagation and canebrake establishment protocol to be developed to fuel the growing demand for this cultural resource. Tensions between landowners and artists still cause problems in Indian country today. Artisans who struggle to gain access to materials for basketry are in direct competition with others in the community who unsustainably harvest cane to mass produce blowguns, pea-shooters

[161] Natural Resources Conservation Service, *Nrcs Southeast American Indian Work Group* 2010.

and flutes that feed the tourism industry on reservation lands. Arguments have also arisen over the mass-harvesting of cane used in the construction of traditional wattle-and-daub house pairs for interpretative villages like Oconoluftee Village in Cherokee, North Carolina or Diligwa in Tahlequah, Oklahoma. It takes between 10,000 and 20,000 culms to construct a single house-pair. Although cane is the traditionally used material in wattle-and-daub construction, it is entirely covered by a veneer of mud mixed with animal hair for stability and insulation in the process. Invasive populations of Asian bamboo run rampant throughout the range of native cane and many canebrake conservationists believe that it could be harvested to serve the same architectural purpose of the cane in the interpretive house-pairs until the day that canebrake scarcity is solved. In the meantime, reserving artisan quality cane for interpretive areas such as Plexiglas® viewing windows revealing the inner structure would be an environmentally responsible alternative.

Until a solid propagation and restoration methodology is developed, there will continue to be incongruence in the opinions of various interest groups including Indigenous Tribal Nations, wildlife conservationists, restorationists, landscape architects, agriculturalists, and horticulturalists. There is a great need for the development of sustainable harvesting and management guidelines that all stakeholders have agreed to by consensus and are willing to abide by.

The ideal approach to canebrake restoration will include a symbiosis of cultural and environmental programming. Canebrake restoration not only has implications of riparian buffering and habitat provision for endangered species but also for cultural preservation and revitalization in Indigenous communties.

CHAPTER 5

FLOODPLAIN RESTORATION AT THE STATE BOTANICAL GARDEN OF GEORGIA

The State Botanical Garden of Georgia (SBG) is a 313-acre preserve set aside by the University of Georgia in 1968 for the study and enjoyment of plants and nature. The mission of the State Botanical Garden of Georgia is to acquire and disseminate Botanical knowledge and to foster appreciation, understanding and stewardship of plants and natural systems.[162] The majority of the lands are covered by a mixed hardwood forest. Several native plant communities can be viewed by a scenic trail network . The southern boundary of the SBG is a meandering stretch of the Middle Oconee River. Since acquiring the lands much effort has been put into the struggle against invasive exotic species that have replaced native plant communities in the floodplain with a monoculture of little environmental or aesthetic value.

Canebrake Ecosystems were historically a major part of the environmental and cultural context of the southeastern landscape including the Oconee River Watershed. The canebrakes that resided along the alluvial floodplain were most likely destroyed as a result of agricultural practices and alterations in hydrology long before the land was fell into the stewardship of the SBG in 1968. Irresponsible and exhaustive land uses related to Georgia's agricultural history have disturbed the natural ecology of the floodplain, and Chinese privet *(Ligustrum sinense),* Amur honeysuckle *(Lonicera maackii)*, English ivy *(Hedra helix,)* along with other foreign plant species have aggressively invaded the river corridor where today lie sections of the lower white, and orange trails used for hiking and recreation.

The continual erosion that occurs along the riverbank of the Oconee and the well established populations of invasive exotic plant species warrant the development of an adaptive ecological management plan with goals of restoring the floodplain at the State Botanical Garden to the grandeur described by Bartram on his Southern explorations. Invasive removal in conjunction with canebrake restoration at the SBG has potential to create an ecosystem more regionally appropriate that includes far more ecosystem services, cultural value, and aesthetic quality.

---

[162] "State Botanical Garden of Georgia." botgarden.uga.edu. (accessed 7/16/2013).

The most pervasive invasive exotic in the floodplain of the SBG by far is Chinese privet. Chinese privet, along with most other invasive exotic shrubs can be removed manually or cut at the base and immediately painted with an 18% glyphosate solution. In the past, a mechanized approach called gyrotracking has been employed to mulch and grind several acres of thick privet undergrowth. This method, although quite successful at ridding the ecosystem of privet in the short term, is ultimately unsuccessful at abating the regeneration of privet from root segments and dormant seed persisting in the soil without diligent follow-up maintenance. Privet seed can also be washed in from upstream in the event of a flood.

Due to the extremely aggressive nature of exotics in the floodplain, the most viable option for preventing the return of invasive populations after removal is to replace the privet with native vegetation that is capable of quickly re-establishment and effective at outcompeting future invasive intrusions.

Several experimental plantings of live-staked cuttings of Black Willow (*Salix nigra*), Elderberry (*Sambucus canadensis*), and Alder (*Alnus serrulata*), were planted on the eroded banks of the Middle Oconee at the SBG. Although a small percentage succeeded in establishment, invasive exotic competition has quickly consumed the majority of the test plots.[163] Several of the test plots have also succumb to erosion from the Middle Oconee River.

Canebrake is an ideal alternative to most plant communities endemic to the southeastern floodplain. It is a rare ecosystem that hosts over 60 species of wildlife including several which are threatened or endangered. Many people value the SBG for the bird watching and wildlife viewing opportunities. Canebrake could provide visitors with a unique experience and a greater chance to see a rare or endangered species. By my own observations, Deer generally do not excessively graze on cane. This could be an asset at the SBG, where an uncontrolled population of white tailed deer could be the early demise of many native species used in restorations.

The mechanical function of cane in the floodplain against the forces of erosion and its ability to rebuild soil quality are rivaled by few. Its ability to mitigate pollutants and sediment loads in groundwater is an added benefit. The presence of a healthy patch of cane directly downstream no less than 50 yards from a hazardous waste material storage

[163] Lindsay Reynolds pers. comm. 7/10/2013.

site (P11) known to leach an array of heavy metals and harmful chemicals into groundwater raises the question as to its potential for phytoremediation. This site has particular value for future graduate research on *Arundinaria* at the SBG. The Georgia Department of Natural Resources issued a report in 1994 on the contaminants leaching from hazardous waste materials site #10269. Through experimental design and research, this population could potentially reveal the phytoremedic value of cane.

GEORGIA ENVIRONMENTAL PROTECTION DIVISION
HAZARDOUS SITE INVENTORY

Site Number: **10269**

SITE NAME: University of Georgia - Milledge Avenue Site
LOCATION: 2450 S Milledge Avenue
Athens, Clarke County, GA 30606

Latitude 33° 54' 21" N   Longitude 83° 23' 7" W

ACREAGE	**PARCEL NUMBER**	**DATE LISTED**
2109.25	183 010	6/29/1994

LAST KNOWN PROPERTY OWNER:
Board of Regents
N Lumpkin Street
Athens, GA 30605

STATUS OF CLEANUP ACTIVITIES:
Cleanup activities are being conducted for source materials and groundwater.

CLEANUP PRIORITY: The Director has designated this site as a Class IV

GA EPD DIRECTOR'S DETERMINATION REGARDING CORRECTIVE ACTION:
The Director has determined that this site requires corrective action.

REGULATED SUBSTANCES RELEASED, AND THREATS TO HUMAN HEALTH AND ENVIRONMENT POSED BY THE RELEASE:
This site has a known release of Lead in groundwater at levels exceeding the reportable quantity. No human exposure via drinking water is suspected from this release. The nearest drinking water well is between 0.5 and 1 miles from the area affected by the release.

REGULATED SUBSTANCES:

Substance Name	GW	Soil	Substance Name	GW	Soil
1,1,2,2-Tetrachloroethane	✓		1,2,3-Trichloropropane	✓	
1,2-Dichloroethane	✓		1,2-Dichloropropane	✓	
Barium	✓	✓	Benzene	✓	✓
Carbon tetrachloride	✓		Chloroform	✓	✓
Cis-1,2-Dichloroethene	✓		Dibromochloropropane	✓	
Dichloromethane	✓		Ethylbenzene	✓	
Lead	✓		Mercury	✓	
Methyl ethyl ketone		✓	Methyl isobutyl ketone	✓	
Naphthalene	✓		Tetrachloroethene	✓	✓
Toluene		✓	trans-1,2-Dichloroethene	✓	
Trichloroethene	✓	✓	Vinyl chloride	✓	
Xylenes	✓		Zinc	✓	

Fig. 15: DNR Report for hazardous waste materials site 10269

Fully restored canebrake habitat reflecting the historic character of the Oconee River Floodplain would bring a distinct aesthetic to the SBG that has been all but lost in the region. It would also be a step towards a more accurate interpretation of the Indigenous Cultural Landscape of the Southeastern woodlands (sensu Beacham 2011).[164]

A canebrake restoration initiative at the SBG would demonstrate commitment to the preservation of endangered ecosystems as well as restoring the cultural and aesthetic integrity of the lands under their stewardship. The multiple benefits of canebrake restoration culminate in the potential for interpretive and academic activities that could be a supplement of restoration programming that would ensure the posterity of canebrake in the future by disseminating knowledge to visitors, but also by encouraging future research in the area by the University. With its goals and resources, the SBG is poised to be a hub of knowledge on canebrake ecosystem research, management and restoration that could serve as a living resource to other institutions, organizations, or individuals who are in need of assistance or germplasm for their own restoration efforts.

There are several approaches that can be taken at the SBG in order to restore canebrake. Firstly, it is essential that invasive exotics be removed either manually or by being cut at the base and painted with an 18% glyphosate solution. This could be done in small phases and immediately followed by installing cane transplants. During the cooler season, (December-early May) transplants would suffer less from shock, and require less water to become established. Plantings done in the summer would need to be closely monitored for drying and embolisms.

There are several populations of cane at the SBG that are isolated in areas where it is unlikely that canebrake will ever form in the traditional sense. The sparse upland populations occurring on small tributaries of the Middle Oconee could serve as source populations for clump division plantings in the floodplain. It is my opinion, that after being relocated to the ideal growing conditions and location (first levee of the floodplain and minimal canopy overhead), the transplanted clumps would begin to thrive and expand.

---

[164] Beacham, Deanna. The Indigenous Cultural Landscape of the Eastern Woodlands: A Model for Conservation, Interpretation, and Tourism. In Rethinking Protected Areas in a Changing World: Pro ceedings of the 2011 George Wright Society Biennial Conference on Parks, Protected Areas, and Cul tural Sites. Hancock, Michigan: The George Wright Society. 2012.

It would be benificial to manage in-situ populations for expansion in the floodplain. Canopy reduction inevitably means tree removal. I can almost picture the look of disdain followed by even the mention of tree removal used in the same sentence as "environmental restoration," but canebrake is dependent on full sun exposure. Cane has a multitude of documented evolutionary adaptations that facilitate a lifestyle capitalizing on forest openings and gaps. Cane is a species that when healthy, expands to the maximum potential land coverage of the organism. The brake then sends "fingers" of growth or exploratory rhizomes under the canopy, into the open air, or even plowing through compacted aggregate as I saw one time while visiting Kituwah mound, a sacred site to the Cherokee. If any exploratory rhizomes come into contact with another ideal growing site, the brake will allot nutrients for clonal expansion and capitalize on the new location. Many of the populations at the SBG are most likely isolated clusters that were once exploratory portions connected to a larger canebrake in the floodplain. Many certainly do not qualify as a "brake" in the conventional sense of the term and some are growing far from the typical habitat associated with canebrake formation.

There are several in-situ population currently in the Floodplain along the lower white and orange trails. By clearing the invasive species competition from these populations, expansion would ensue. With organic matter additions, canopy management, mulching, fertilizer applications, and even additional plantings of cane transplants, these populations could be managed for rapid expansion that would aggressively compete with woody invasive species such as Chinese Privet.

Inventory of Rivercane at the State Botanical Garden of Georgia

Despite alterations in hydrology and persistent invasive exotic plant populations in the floodplain of the State Botanical Garden, there are still several populations of *Arundinaria* on SBG Grounds.

A survey of rivercane was conducted in the spring of 2013 with the goal of providing an overview of cane populations accessible on SBG lands and to provide informed guidance on management and expansion. Fourteen presumably distinct populations of cane were discovered by surveying the entirety of SBG grounds. GPS coordinates and data on land area coverage, density, canopy coverage, etc was compiled into an excel spreadsheet. All populations were photo documented and soil samples were taken. Data including land area and culm dimensions are not to be taken as exact but rather the most accurately attainable representation that could be gathered in the field. Often due to hydrology, topography or vegetation, it was difficult to gather exact GPS coordinates or measure populations to the exact degree.

Because no genetic fingerprinting was done, it was impossible to distinguish one genet from another in the field. Often canebrakes are a mixture of genets individuals growing together as a cohort.[165] None of the populations I surveyed would qualify as a canebrake sensu stricto. Most populations consisted of one seemingly continuous patch spread out over no more than a few hundred square feet. Since I could not identify genetic individuals nor could I distinguish them as canebrakes per se. When inquiring amongst other professionals who have done cane surveys about nomenclature applying to the typical cane patches I would discover on trips to the Botanical Garden, it was recommended that I use the terms "ramet population" or "patch" for the sake of my survey. This is the reason for the use of the term "population, " rather than "canebrake" throughout this document.

In a few cases (P11 and P12), there was a contiguous population that had another patch which by visual inspection, seemed to be physically un-connected to the latter, but I can only assume that because they occur merely yards away ,in the same zones of hydrology and soil profiles that they are at the very least, somewhat genetically related. It is not unlikely that at some time in the past, the two were connected to the same canebrake. In these

[165] Gagnon and Platt, "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)."

instances where I assumed shared ancestry, I identified the sub-population with a ".5" (e.g. P11.5 was assumed to be closely related to P11)

For convenience and clarity, data was often rounded to the nearest whole number or easily divisible fraction. Land area coverage was determined by using the formula for the area of an ellipse, and using the longest stretch of cane as the major axis of the ellipse (2a), and the longest width transecting that axis as the minor axis of the ellipse (2b). An estimate of the land area coverage of each population could then be derived by the equation: πab. Average culm height and width was determined by general observation of each population and density/canopy coverage were rated one through five with one being lowest density (a few sporadic culms), and five being extremely dense (nearly impossible to traverse without liberal use of a machete). In the case of canopy coverage, a similar ranking system was employed. A ranking of "one" was given to sites with nearly zero canopy and "five" was assigned to sites with a solid over story canopy. Populations identified with a ".5" in the ID# are presumably related to the preceding individual (for example, 12.5 was presumed related to 12 because general proximity)

Cane is growing at the SBG across a variety of ecotones and environments. Most of the extant cane is where one would expect to find it; on, or near the first levee of the Oconee River floodplain. Several populations were discovered deep in the understory of the mixed hardwood forest along seeps and tributaries of the Middle Oconee. These populations were most often sparse and stunted in appearance compared to the populations growing in canopy gaps along the floodplain. It is possible that these populations are remnant clusters of exploratory rhizomes and ramets that had been isolated after the demise of their "mother brake" residing in the floodplain and have persisted for decades in a state near metastasis. Most often these understory populations (P6, P7, P11.5, P12, P12.5, P13 and P14) have little to zero possibility of developing into a canebrake without drastic intervention in the form of relocating the population, or aggressively thinning the canopy (a topic of much contention amongst environmentalists) in order to provide the stranded cane with some much needed sunlight..

There was also the discovery of a distinct and dense-growing population of *A. tecta* established in the power line easement, just down-grade from hazardous waste materials site 10269. The same population is receiving direct runoff from a University owned agricultural facility detention pond. One can only imagine the potential this population has for future research on nutrient uptake and phytoremedic properties of canebrake ecosystems.

Possibly the greatest asset to a floodplain restoration initiative at the SBG is the patches of cane that are already established and growing along the lower White and Orange trails (P1-5 ,P8, P9, and P10). These populations most often reside in or near an area where a gyrotrac machine was recently used to mulch populations of invasive Privet and Golden bamboo (*Phyllostachys aurea*). Perhaps the cane is doing so well in this area because of the relatively thin canopy and the minimal invasive competition.

If any mast flowering of *Arundinaria* has been observed in Georgia over the past century, I have seen no mention of it in all my research. At the very least, one could assume that mast flowering has not occurred (or has gone unnoticed) in the piedmont foothills since the times of European settlement. For this reason, it is possible that some of the stands persisting in the floodplain at the SBG today are remaining sections or offsets of the exact genetic individuals once subject to the bewilderment of William Bartram on his journeys through the Southern Frontier. There could hardly be a more poetic outcome than to restore the Oconee River and its floodplain ecology to the grandeur Bartram viewed over two centuries ago.

Management techniques and methodology discussed in the following chapter will provide informed guidance on facilitating the spread of these populations so that canebrake formation may be a reality at the SBG in only a few growing seasons if the appropriate actions are taken.

The remainder of this chapter is a survey of every population and patch of rivercane within the SBG boundary. Photo documentation and GIS mapping has been provided and is followed by a brief discussion and specific management guidelines applicable to each site. This section of the thesis is intended to be not only a reference for conservation ecologists wanting to quickly locate canebrake resources on SBG lands, but also to provide a set of best management practices (BMPs) applicable to site-specific management.

The management guidelines and personal commentary included in each site evaluation are backed by extensive research and experience, but it is important to make note that this assessment is only a preliminary survey. It is important to acknowledge that specific variables like microclimate, soils; even values and cultural trends are always changing and will have an effect on the ecology and landscape of the floodplain at the SBG. Floodplain restoration at the SBG is a particularly complex initiative because of the multiple interest groups and stakeholders, overlying lines of jurisdiction on important decisions on the management of the landscape. If a floodplain restoration utilizing canebrake ecosystems services is an approach that staff, stakeholders, and affiliates of the SBG view as worthy of pursuit, then an adaptive management approach must be adopted for canebrake establishment and expansion.. Such an approach must be sensitive also, to the nuances and dynamism characteristic of riparian ecology. A restoration and management plan must also consider anthropogenic influences and variety of activities that the SBG is utilized for such as interpretation, recreational hiking, jogging, and bird watching. These variables may all have influence over land use in the floodplain. There must be an appropriate threshold of canebrake expansion and reestablishment in the floodplain that is a balance of canebrake, other plant communities, and trails or sites intended for recreation or interpretation.

Arundinaria populations at the State Botanical Garden of Georgia

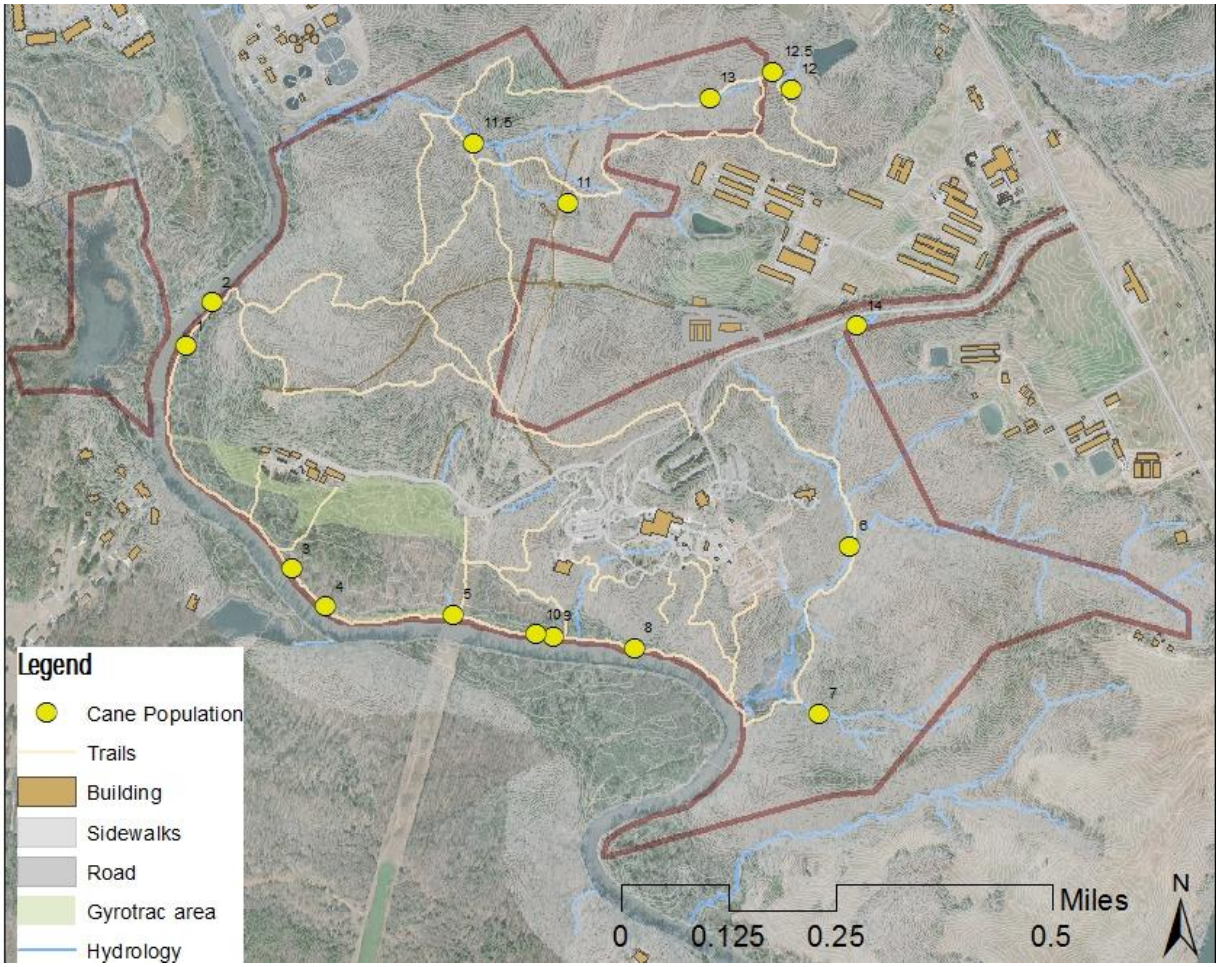


Fig.16: Cane Populations at the SBG. Collected on a Trimble® GeoXM unit with ArcPad® 7.1 Software by T. Peters (5/2013)

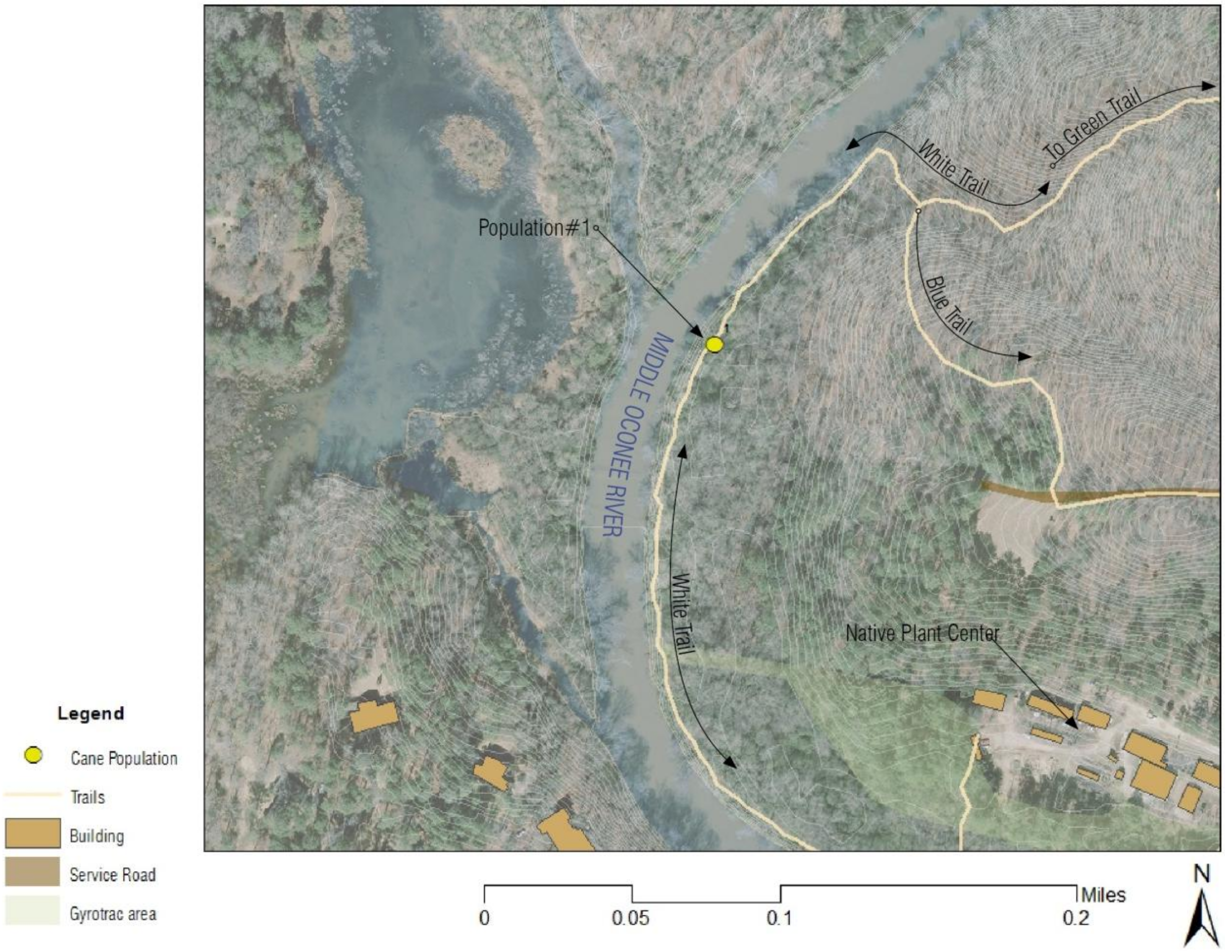
ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
1	302.000	5	7	0.125	0.25	1	1	10
2	4712.000	8	15	0.125	0.75	3	2	250
3	2199.000	10	15	0.25	1	1	2	60
4	14097.000	10	16	0.75	1.125	1	3	150
5	3846.500	NA	NA	NA	NA	1	NA	NA
6	1354.125	4	10	0.125	0.5	4	3	250
7	1130.400	3.5	7	0.125	0.25	4.5	1	550
8	94.200	3	6	0.25	0.25	3.5	2	100
9	37.680	3	9	0.25	0.5	3.5	3	40
10	296.730	10	7	0.25	0.7	3.5	1	60
11	3140.000	5	8	0.125	0.25	1	5	16000
11.5	6280.000	5	6	0.125	0.25	3	1	400
12	17662.200	2.5	4	0.125	0.15	5	1	550
12.5	39.250	2.5	4	0.125	0.16	5	2	40
13	65.940	3	6	0.125	0.25	4.5	3	100
14	35325.000	3	8	0.125	0.5	4	1	250

Table 2: Fourteen populations of cane residing at the State Botanical Garden of Georgia. By: Thomas Peters 2013

Population #1 (P1)

(33.904401,-83.393024)

Fig. 17: Images of Population #1



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
1	302.000	5	7	0.125	0.25	1	1	10

Fig.18: Population #1 at the SBG

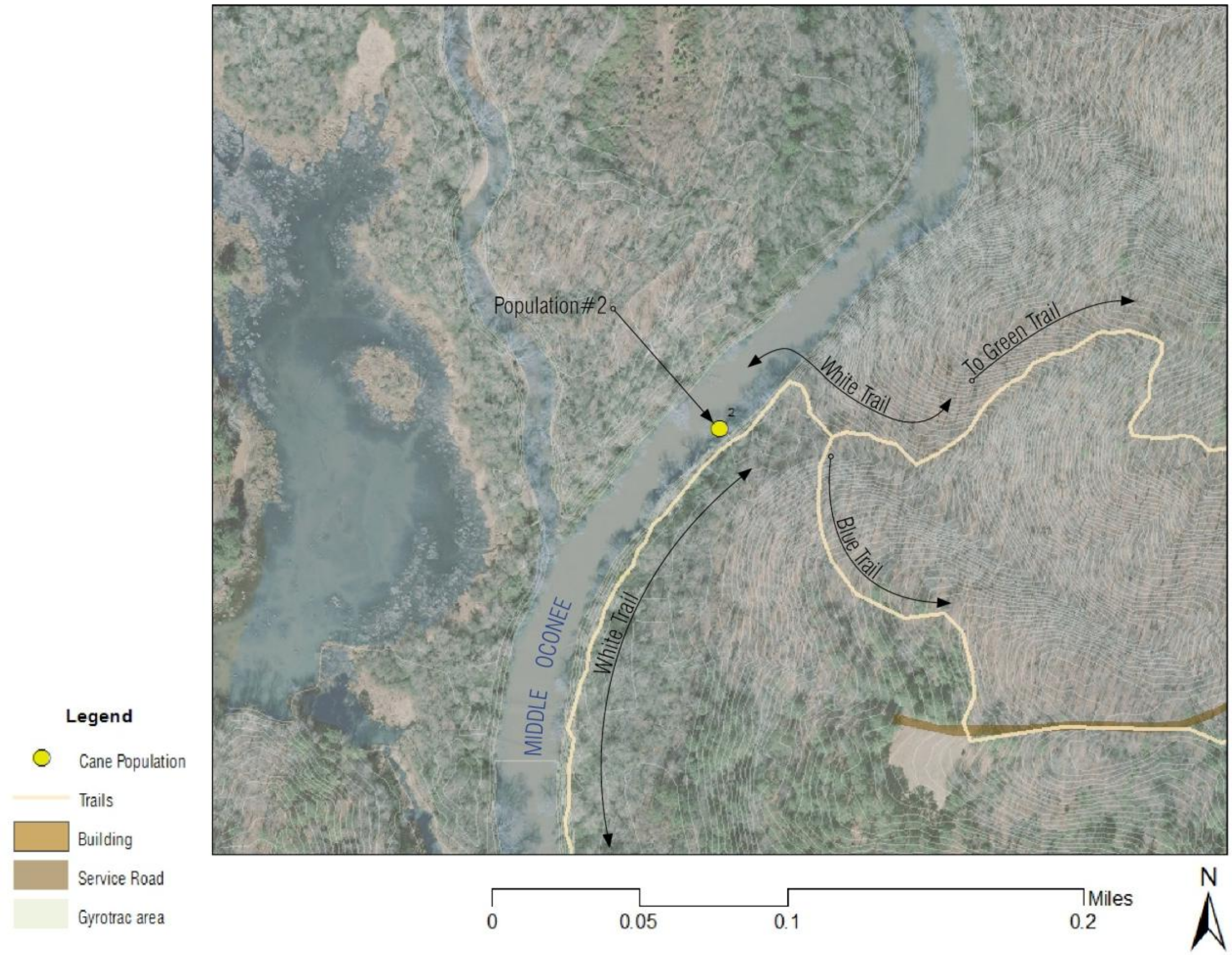
Inventory began in April 2013. I started by parking my truck at the Native Plant Center, walking through the gated double deer fence and down the access trail that intersects with the White Trail after 363'.

At the intersection, I headed North (took a right) on the White trail and traveled roughly .25mi before encountering Population #1 (P1). P1 is a sparse population of only 8-10 ramets growing in a canopy gap created by a fallen tree. This population is physically isolated by an eroded riverbank on the south side, and the compacted trail and thick privet hedge on the north. It would be difficult to facilitate expansion of this patch without rerouting the footpath and removing some of the Privet abutting it. P1 is most likely a relative of the other populations found along the first levee of the floodplain. Since P1 is positioned so closely to the sharply eroded riverbank, and is hindered from expansion by foot compaction, My recommendation for such a small and isolated population would be to monitor it and manage it in situ with the addition of mulch and fertilizer. The more intensive approach would involve relocating the white trail higher up grade. and off the first levee of the floodplain. Eventually, if there is enough sunlight reaching the patch, rhizomatous spread will initiate inland, away from the Oconee.

Population #2 (P2):

(33.905133,-83.392468)

Fig.19: Images of Population #2



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
2	4712.000	8	15	0.125	0.75	3	2	250

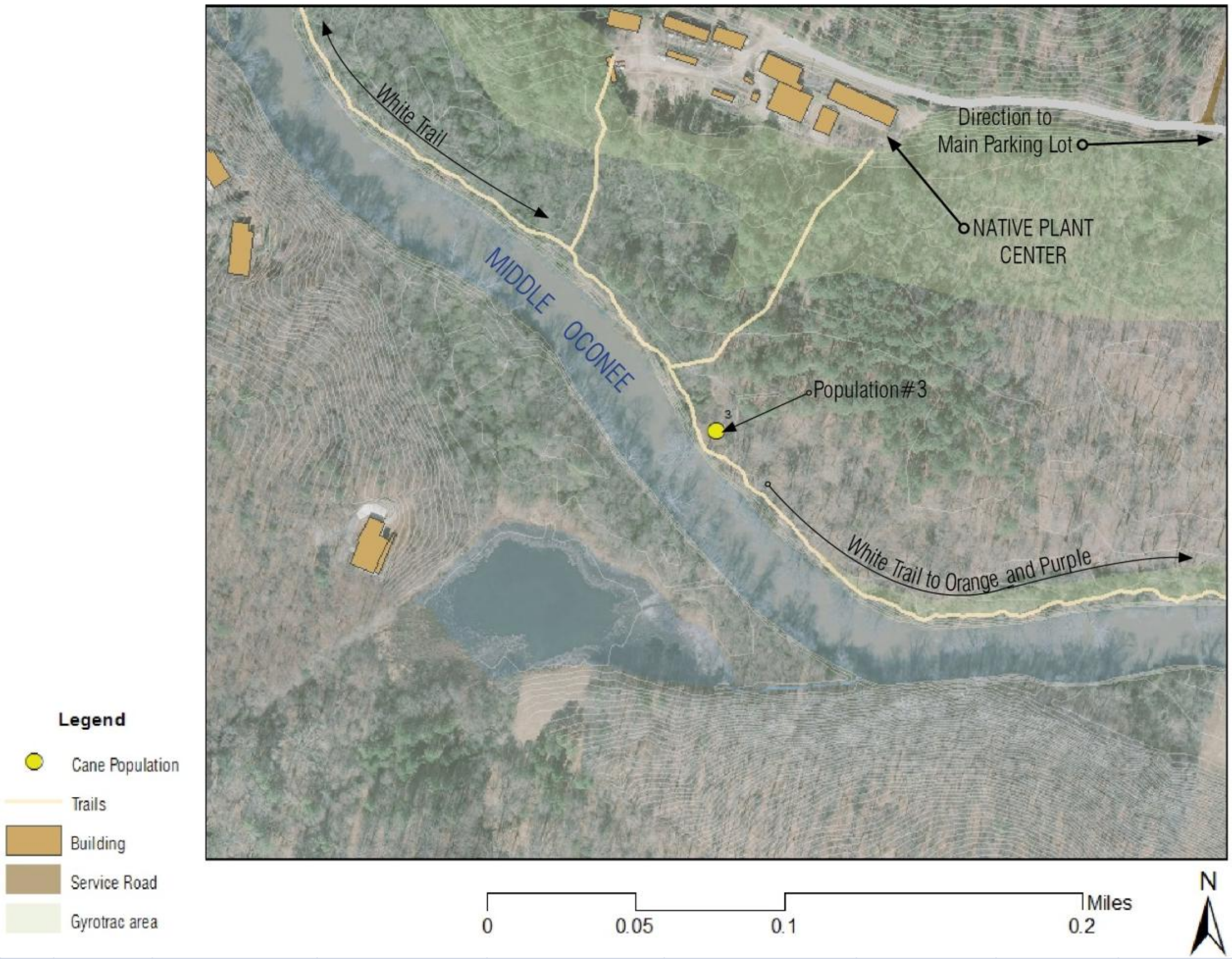
Fig. 20: Population #2 at the SBG

Continuing northward after leaving P1, I headed towards the intersection of the Blue and White Trails. After walking 630’ I came upon a substantial patch of rivercane. The culms are relatively thin and spaced out over a wide area. There is a significant amount of shade from canopy cover, and severe erosion had been undercutting the rhizosphere of the population, exposing it along the streambank. P2 is linear in nature, and stretches for about 300’ upstream along the first levy of the Middle Oconee floodplain before colliding with a dense thicket of Mountain Laurel *(Kalmia latifolia*) and fading out. Canopy management and fertilizer applications could help the patch to increase in density and vigor. Because this population resides in the floodplain, it could be managed for expansion with the intent of mitigating the dramatic erosion and providing increased habitat for bird watchers.

Population #3 (P3):

(33.900643,-83.390911)

Fig. 21: Images of Population #3



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
3	2199.000	10	15	0.25	1	1	2	60

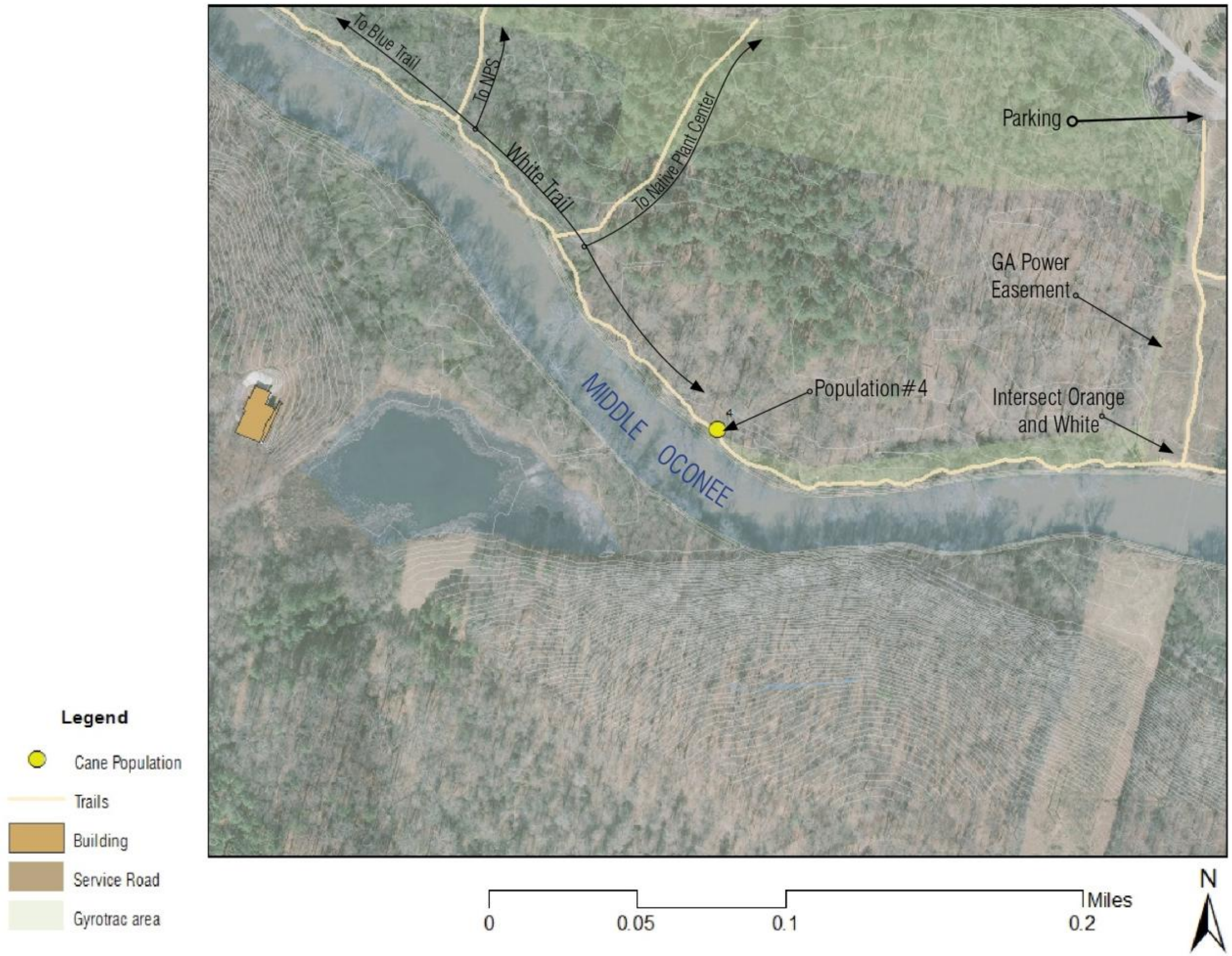
Fig.22: Population #3 at the SBG

P2 is the northernmost patch in the floodplain within the boundary of the SBG. After surveying P2, I backtracked to the point where the Native Plant Center trail intersects the White Trail. Continuing Southeast on the White Trail for about 400', I encountered Population #3 (P3), P3 was a linear cluster of impressive ortets growing in an area that had recently been treated for invasive Privet. Woody species competing with P3 were minimal. Abundant Box Elder (*Acer negundo*) saplings in the area could pose as a threat in the future, as they are fast growing and may begin to shade out the population of cane which, currently, is basking in the glory of a large canopy gap. P3 is an exemplary candidate for expansion management in the form of fertilizer additions, mulch applications and even additional plantings. I would recommend prioritizing expansion in the southerly direction of along the White Trail where another population (P4) is established merely 320' away. By "closing the gap" between extant floodplain populations such as P3 and P4 via expansion management is an approach that can lead to the formation of large continuous canebrakes.

Population #4 (P4)

(33.900006,-83.390220)

Fig. 23: Images of Population #4



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
4	14097.000	10	16	0.75	1.125	1	3	150

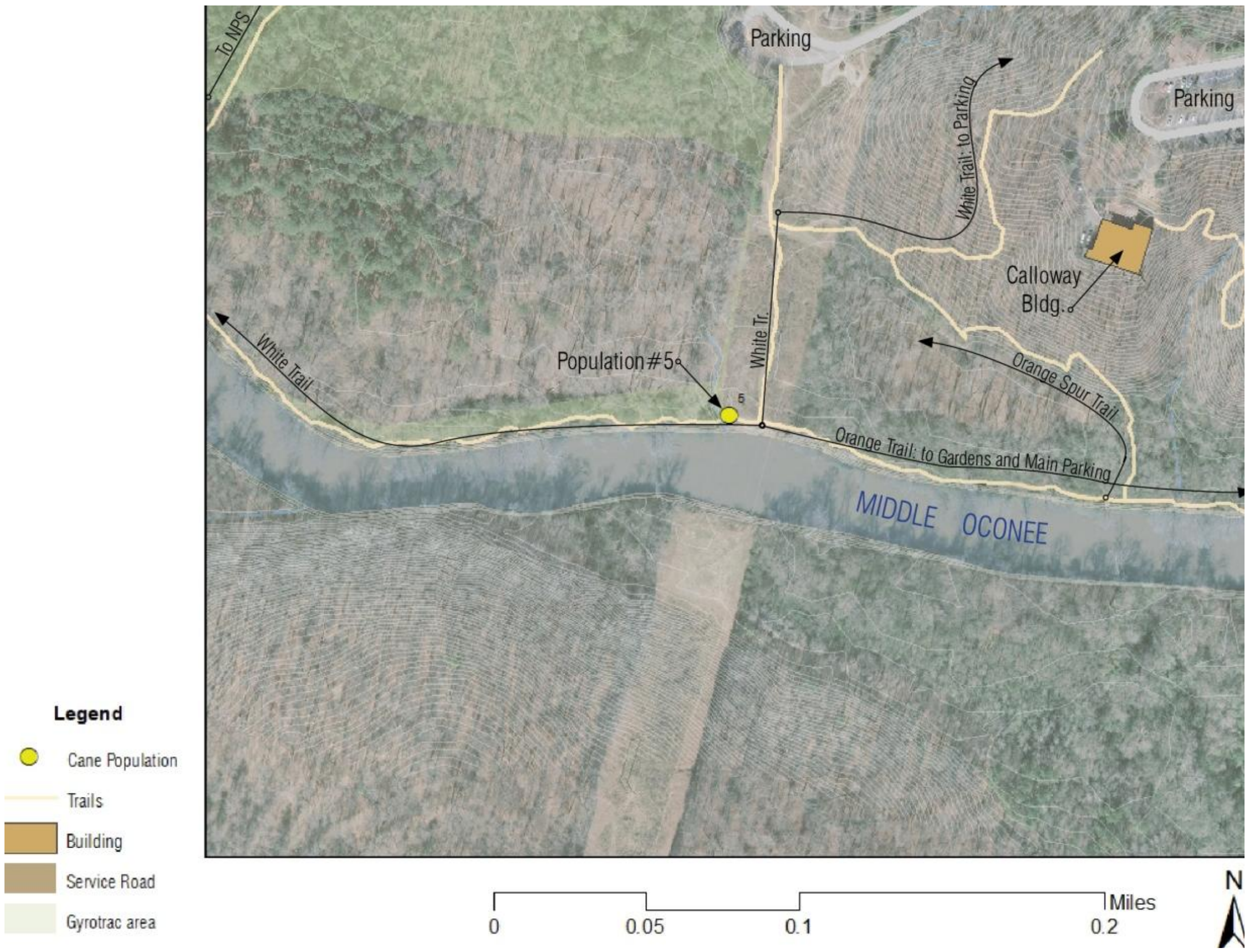
Fig. 24: Population #4 at the SBG

Population #4 is only 320' from P3 down the white trail towards the direction of the power line easement. In my opinion, P4 should be prioritized along with P3 as an epicenter of canebrake restoration in the SBG floodplain. These two populations are experiencing minimal pressure from invasive competition and they are positioned on the first levee of the floodplain. The canopy in the area is inconsistent with a variety of openings suitable for hosting a large canebrake.

Population #5 (P5)

(33.899850,-83.387663)

Fig. 25: Images of Population #5



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
5	3846.500	NA	NA	NA	NA	1	NA	NA

Fig.26: Population #5 at the SBG

Population #5 rests only a few feet directly North of the wooden bridge where the White Trail intersects with the power line easement. At the time I inventoried P5 it had been mowed by maintenance staff and was difficult to survey. I only knew of the population from my daily runs around the perimeter of SBG grounds. I frequently noted birdwatchers taking pictures of the patch, and considered it an ideal population for interpretation or bringing University students to educate them on canebrake ecology. P5 is only 650' down a gentle slope from the parking lot on the road to the Native Plant Center. It could be made ADA accessible with a mere crush gravel pathway. I assume that routine maintenance of the power line is required by Georgia Power however, It seems that an exception could be made for this small population of cane which poses no threat to the power lines above. Considering that P5 is on the very edge of the easement, it could also be managed for expansion in the westerly direction away from the cut.

Another alternative would be sacrificing the population for the sake of generating propagates that could be used in other restoration plantings.

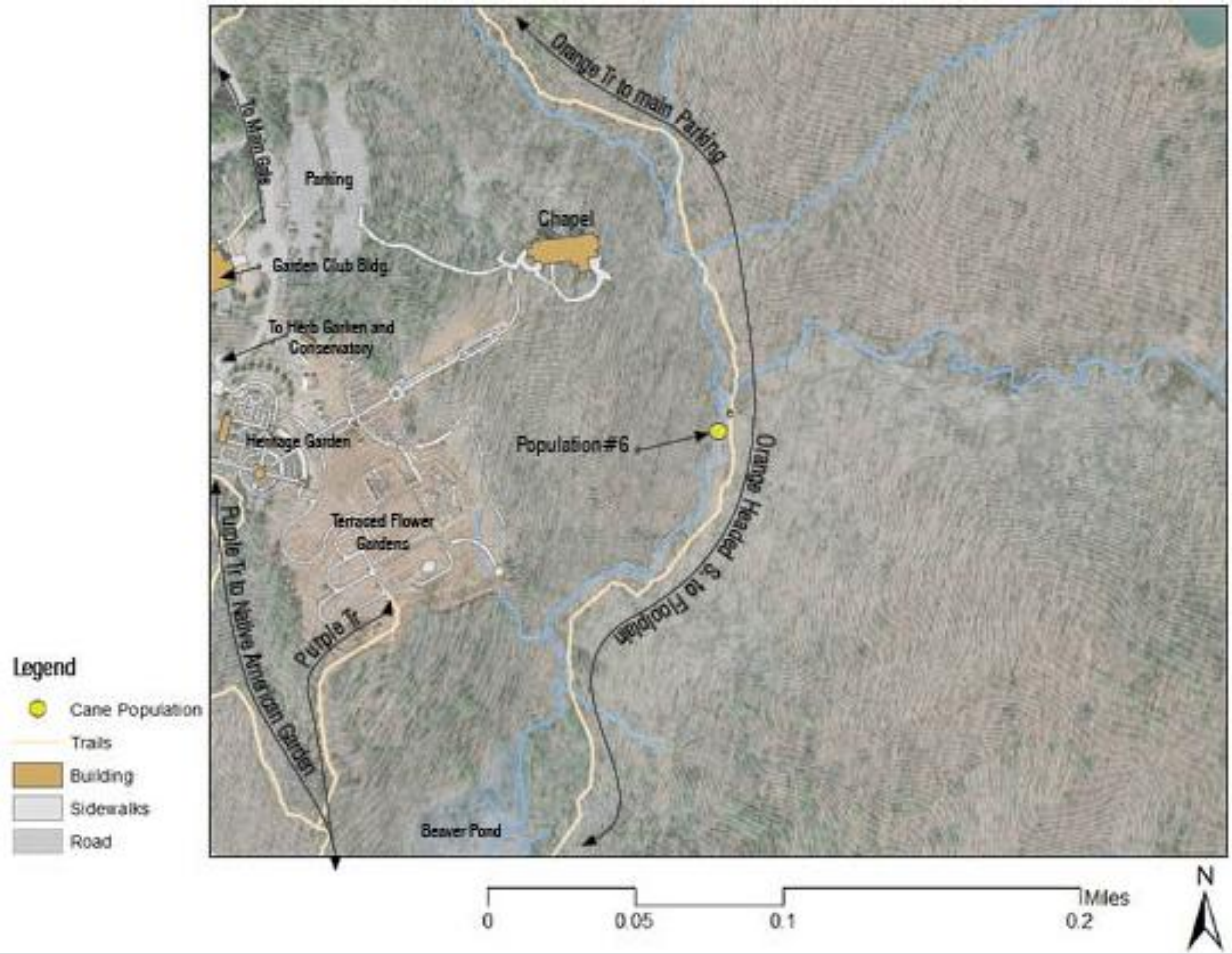
Upon revisiting the population several weeks after conducting my inventory, I discovered that despite a springtime mow, P5 had made a vigorous comeback in the floodplain. Perhaps by simply adjusting the mowing schedule to the winter when the population is in a state of semi-dormancy, the population could make a strong comeback each spring. A prescribed burn in the wintertime could also benefit P5 by clearing some of the herbaceous plants and saplings it is presently competing with. P5 is an ideal population for experimental fire management because it is an easily accessible location with minimal canopy. If executed carefully, risk of wildfire or damage to other plant communities would be minimal.

Fig.27: P5 regrowth several weeks after a spring mow

Population #6: (P6)

(33.900946,-83.379642)

Fig. 28: Images of Population #6



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
6	1354.125	4	10	0.125	0.5	4	3	250

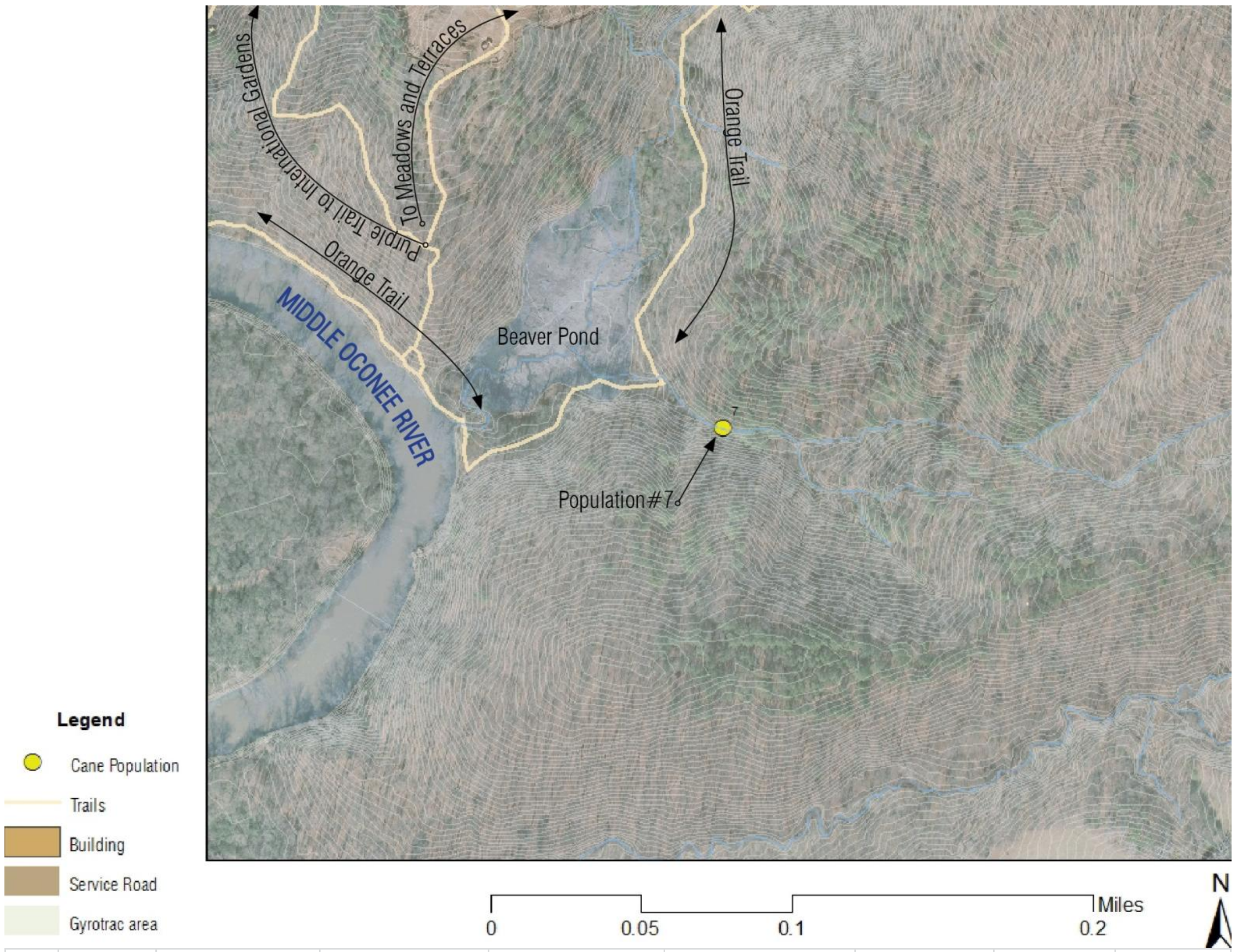
Fig.29: Population #6 at the SBG

If one were to start at the head of the Orange Trail and descend towards the floodplain for about 600yds there is a small population of thin culms between the trail and the small creek that running parallel to the trail. P6 is persisting under the dense canopy of a mixed hardwood forest. Most likely this population was once a tributary population of a canebrake in the floodplain that had spread rhizomatously upstream at a time when the forest was not as dense. By selective thinning of the canopy, P6 could potentially be managed for expansion however, this is a sensitive area of the trail that is heavily traversed by students and visitors. Perhaps it is best to keep the ecology of the mixed hardwood forest in-tact and use P6 as an interpretive stop along nature walks or field trips where visitors may not have time to visit the larger floodplain populations.

Population #7 (P7)

(33.898133,-83.380304)

Fig. 30: Images of Population #7



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
7	1130.400	3.5	7	0.125	0.25	4.5	1	550

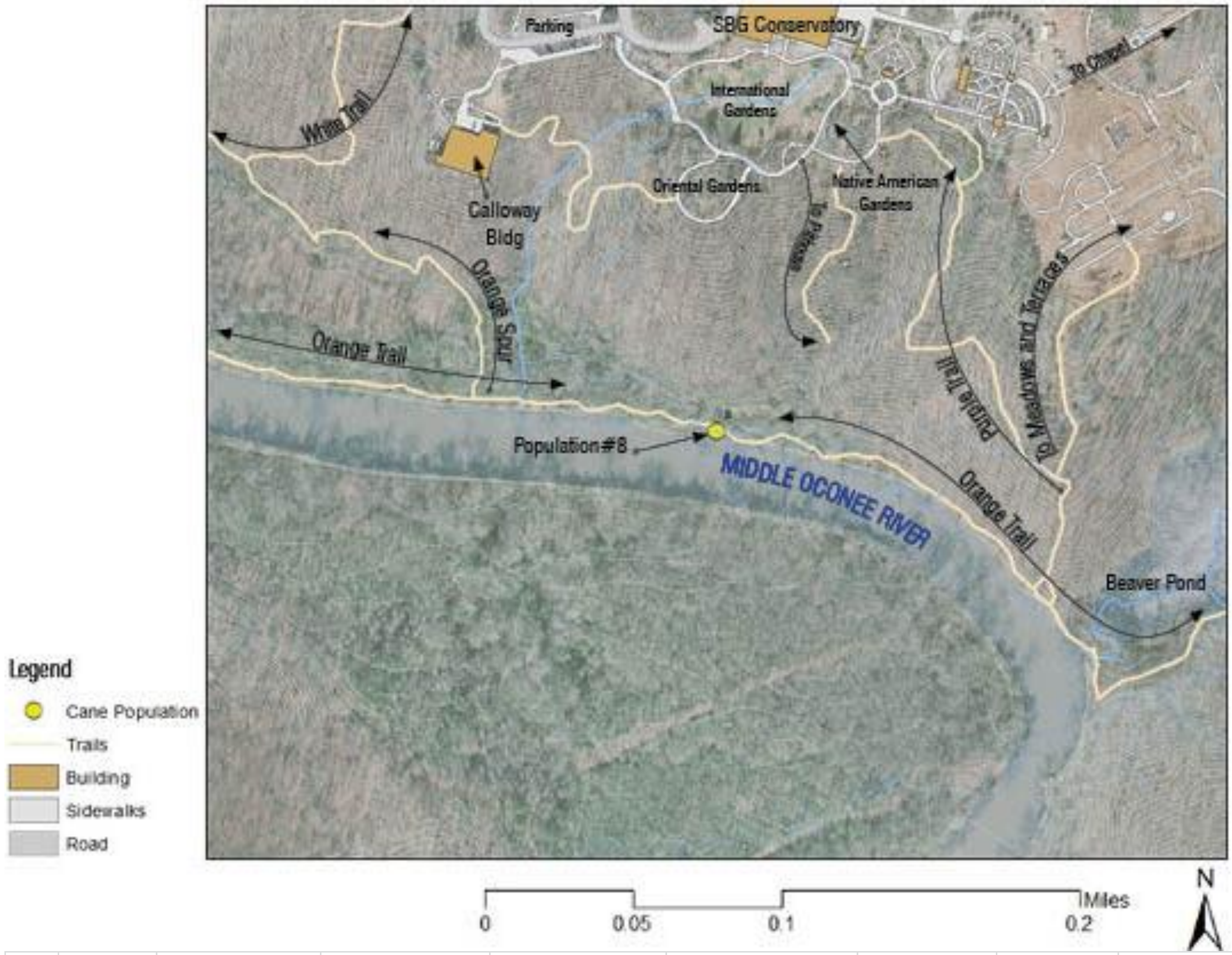
Fig. 31: Population #7 at the SBG

Continuing on the Orange Trail towards the floodplain for another 400yds, there is a wooden footbridge where a series of ephemeral streams converge and flow into a wetland that was created by beaver activity. By walking about 50yds up the dry creek I discovered a stunted but relatively expansive population of cane that enveloped either side of the stream channel (P7). The cane is growing in rocky soil and under a dense mixed hardwood canopy. As I suggested of P6, It is my belief that P7 is a remnant of what once was a larger population. Today, there is little value in trying to manage P7 as a canebrake. The amount of trees that would have to be removed in order to do so would be an atrocity against nature and furthermore, the topography and hydrology in this location are not representative of ideal conditions for canebrake establishment. P7 would best serve as a source population for vegetative cuttings that could be used in propagation initiatives or restoration plantings.

Population #8 (P8):

(33.899260,-83.383998)

Fig. 32: Images of Population #8



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
8	94.200	3	6	0.25	0.25	3.5	2	100

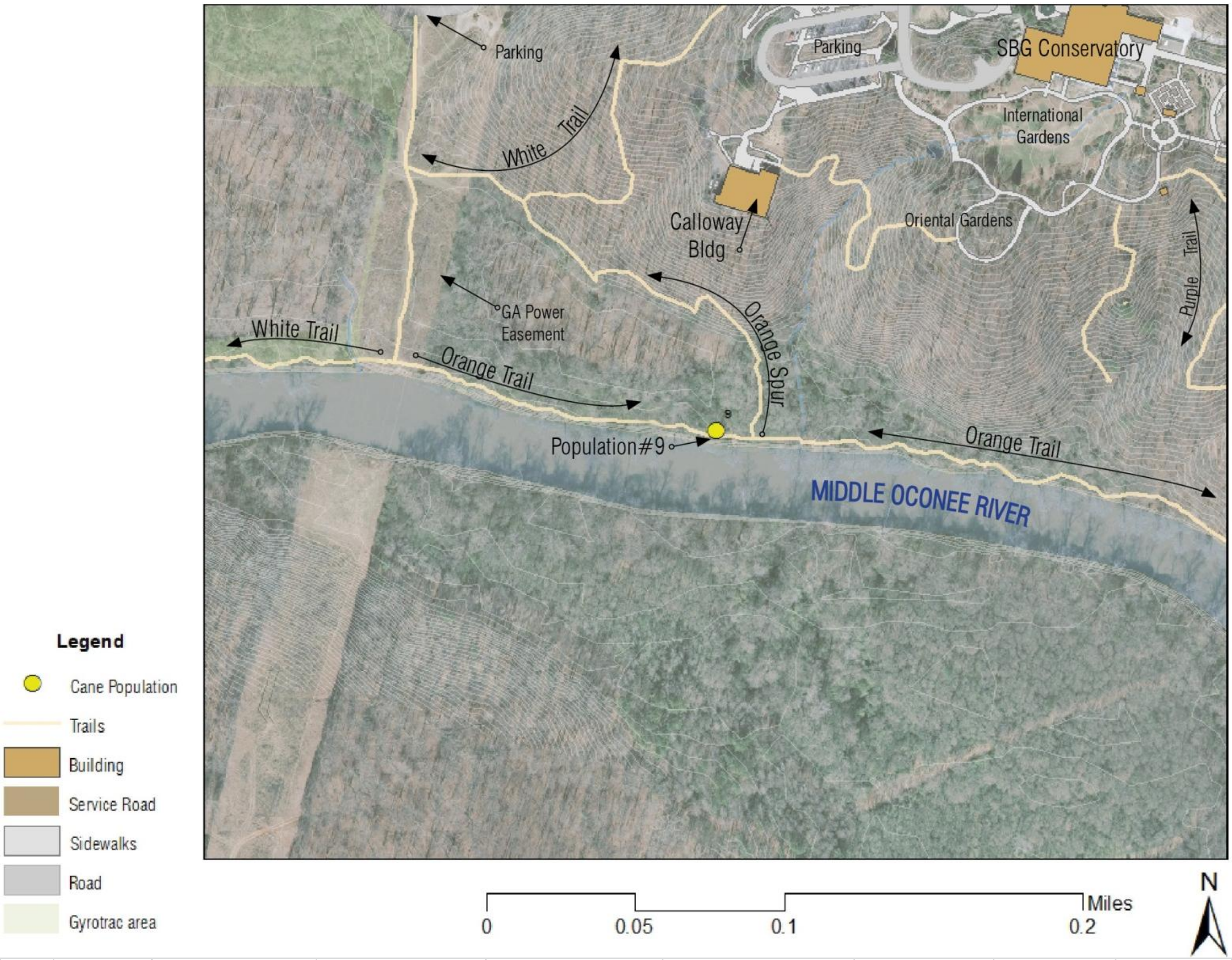
Fig.33: Population #8 at the SBG

One population of cane exists on the Orange Trail in the section between the Purple Trail and the Orange Spur Trail. About 250yds northwest on the Orange Trail from the intersection of the Purple Trail exists Population #8. P8 is a small but dense population of cane thriving in a small canopy gap along the trail. P8 is one of the several populations surveyed in the floodplain that were isolated between the compacted footpath and the Oconee River. The only hope for expanding P8 and other physically isolated populations, is to reroute the trail further back from edge of the riverbank. The compaction occurring along the footpath, and the impenetrable thicket of Privet on the opposing side is enough to impede rhizomatous spread and canebrake establishment.

Population #9 (P9)

(33.899454,-83.385629)

Fig. 34: Images of Population #9



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
9	37.680	3	9	0.25	0.5	3.5	3	40

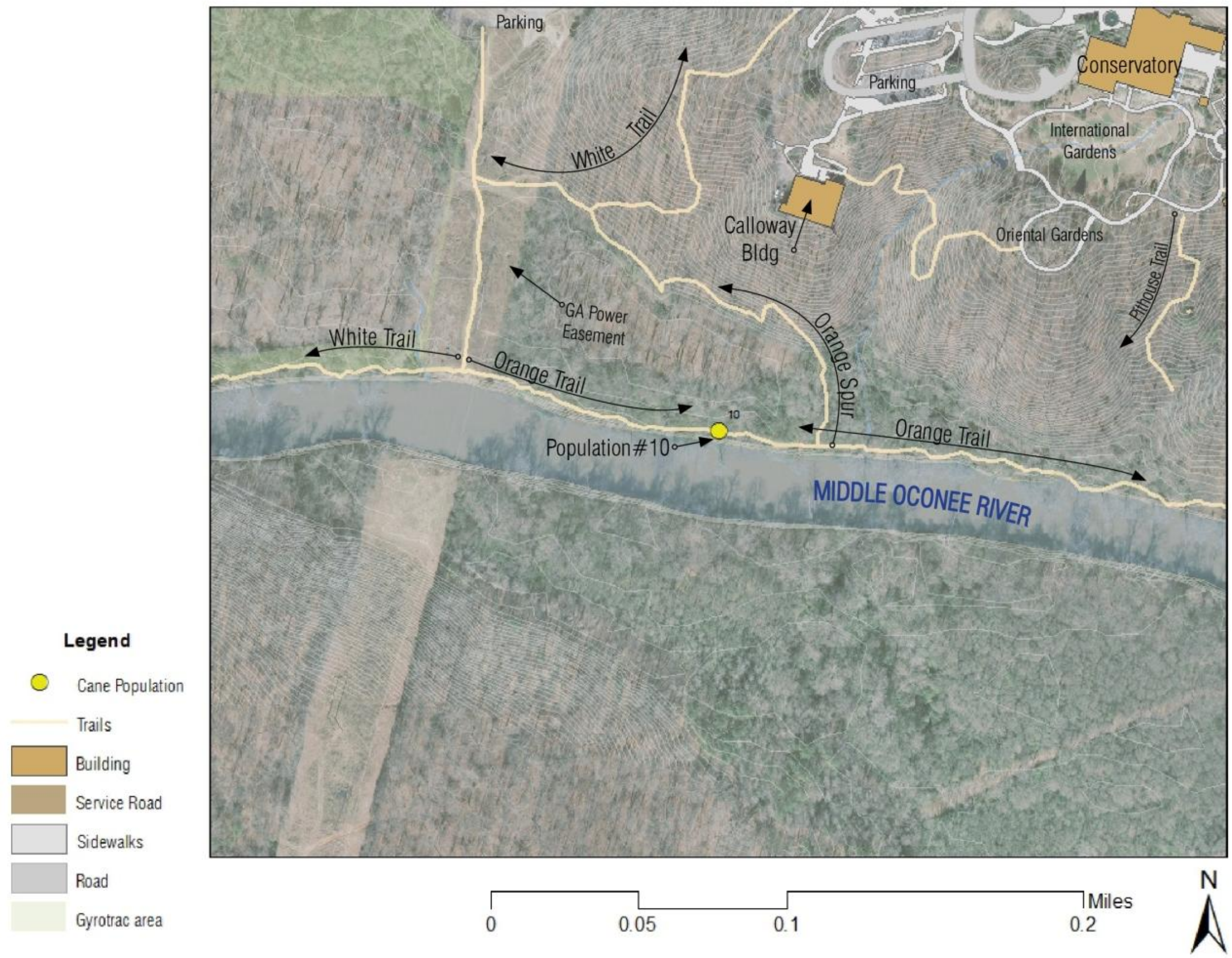
Fig.35: Population #9 at the SBG

Population #9 is 20yds west of where the Orange Spur Trail intersects the Orange Trail. P9 is almost identical in character and context as the aforementioned population P8. P9 is also isolated by the compacted footpath, privet hedge, and Oconee River. The only option for expansion in-situ would be to relocate the path farther back from the edge of the river, remove the invasive Privet and manage the population for expansion by the addition of fertilizers and selective thinning of the canopy. Less than 40yds further west on the Orange Trail lies Population 10 (P10). These two populations could potentially be amalgamated into one continuous canebrake but the implications would include displacing the orange trail away from the edge of the water and then encouraging the expansion of each population towards each other. Methods that would be applicable to such an approach could include additional plantings, canopy management, fertilizer and mulch applications.

Population #10 (P10)

(33.899523,-83.385999)

Fig. 36: Images of Population #10



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
10	296.730	10	7	0.25	0.7	3.5	1	60

Fig. 37: Population #7 at the SBG

Population #10 is only 55yds West of where the Orange Spur Trail intersects the Orange Trail. P10 is one of the several populations in the floodplain that is severely isolated by the Oconee, trail compaction, and invasive intrusion. There is hope in establishing a canebrake between P10 and P9 if a significant amount of effort is bestowed on rerouting the footpath, removing invasives, and selectively thinning the canopy.

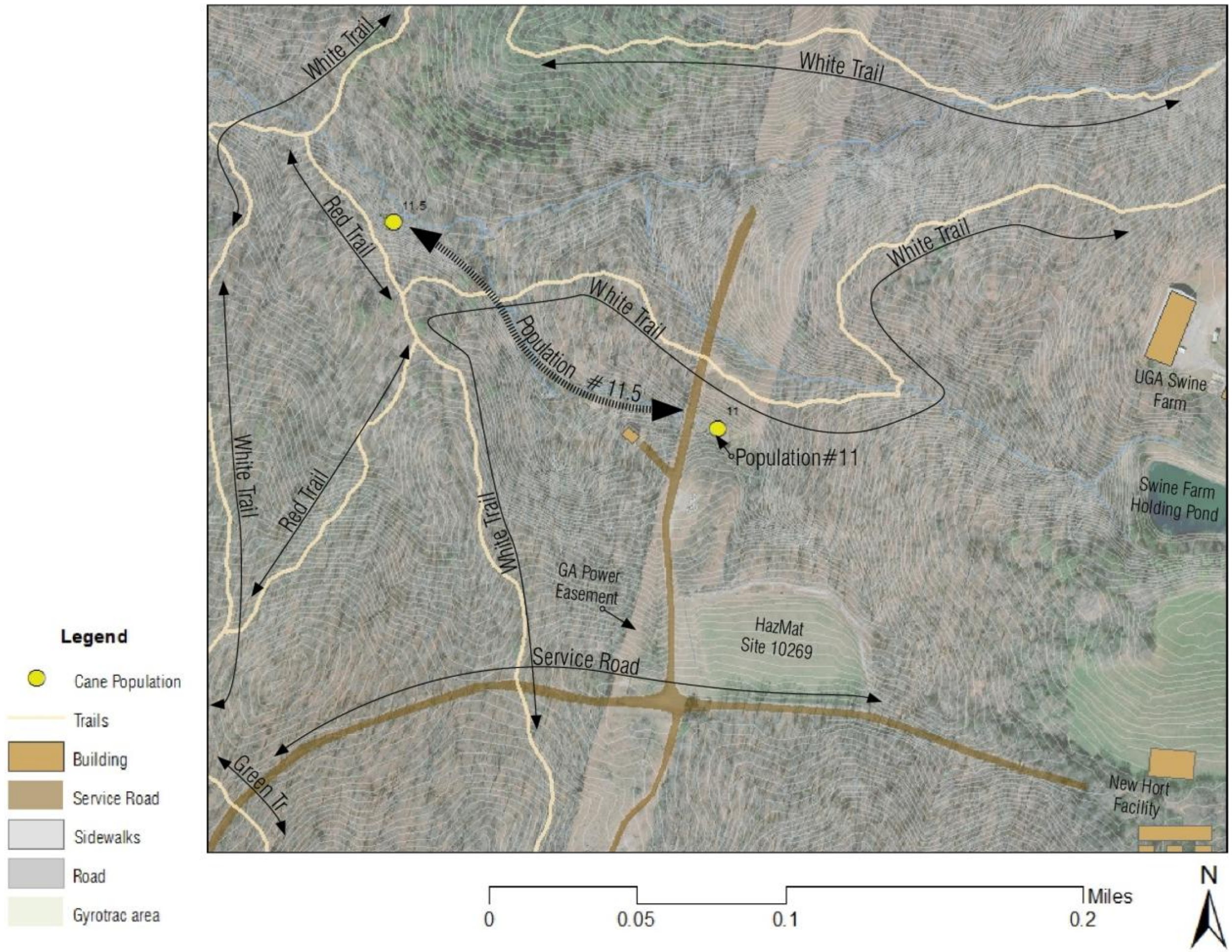
Population #11 (P11)

(33.906743,-83.385298)

Population #11.5 (P11.5)

(33.907755,-83.387168)

Fig. 38: Images of Population #11 and #11.5



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
11	3140.000	5	8	0.125	0.25	1	5	16000
11.5	6280.000	5	6	0.125	0.25	3	1	400

Fig.39: Populations #11 and 11.5 at the SBG

Undeniably, the most unique population of rivercane at the SBG is Population #11. P11 is an extremely dense population of *Arundinaria tecta* that is well established on the Eastern side of the service road that runs through the power line easement. P11 is receiving direct runoff from the University owned agricultural facility on South Milledge Rd. It is also a mere 100yds down grade from a hazardous waste materials site that is known to leach harmful amounts of several chemicals including lead, mercury, and cyanide into soils and groundwater. Judging by appearances only, P11 is by far the most densely growing population of cane at the SBG. This is interesting because it is located far from the floodplain, and thriving amongst an inestimable amount of contaminants associated with the agricultural facility and hazardous waste site #10269 upstream. By recommendation of the Georgia Environmental Protection Department, precautions should be taken when dealing with P11 including, but not limited to, protective clothing and gloves. P11 could potentially serve as a source population for an exponential quantity of clonal divisions for use in floodplain restoration. It could also be used for future experimental research in the determination of phytoremedic properties of cane.

Just across the service road from P11, growing along the same stream channel under the canopy of a mixed hardwood forest begins P11.5. P11.5 persists very sporadically as thin collections of culms from the service road all the way to the point indicated on Fig.. It is also likely receiving toxic contaminants from the pollution upstream. The canopy coverage is obviously stifling the development of P11.5 when a comparison is drawn between P11 and the latter. P11, unimpeded by competition for sunlight has grown to be nearly impenetrable whereas 11.5 is almost unnoticeable in passing as it is so thinly dispersed along the hydrology. Due to the sensitive nature of these populations it would be pertinent to seek guidance from the Georgia EPD and perform additional soil and water testing to determine any dangers associated with disturbing them. If a safe method of gathering divisions from P11 could be determined, it could serve as the ultimate source population for propagation at the SBG.

Fig.40: Rhizome segments easily harvested from the periphery of P11

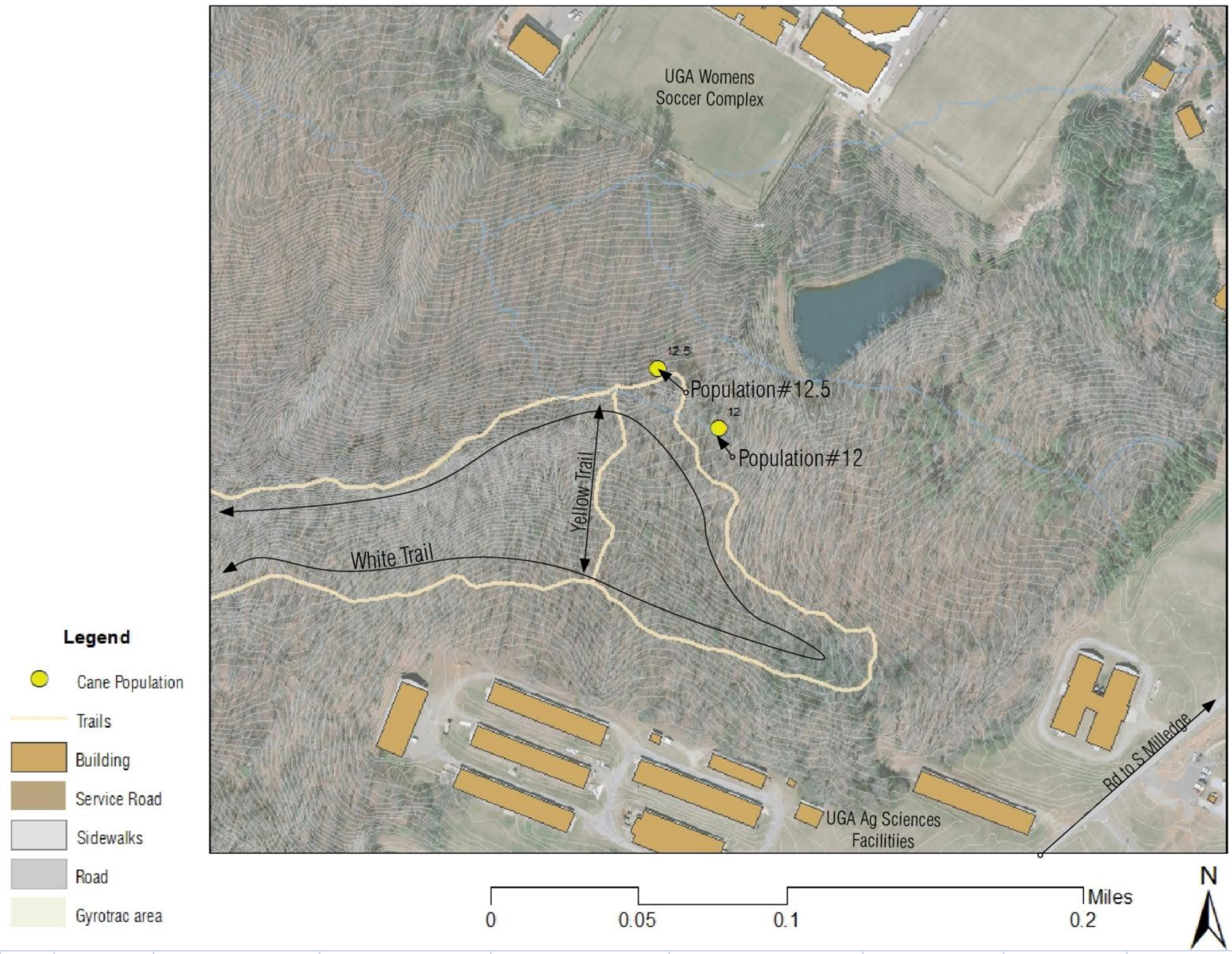
Population #12 (P12)

(33.908626, -83.380754)

Population #12.5 (P12.5)

(33.908923,-83.381122)

Fig. 41: Images of Population #12 and #12.5.



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
12	17662.200	2.5	4	0.125	0.15	5	1	550
12.5	39.250	2.5	4	0.125	0.16	5	2	40

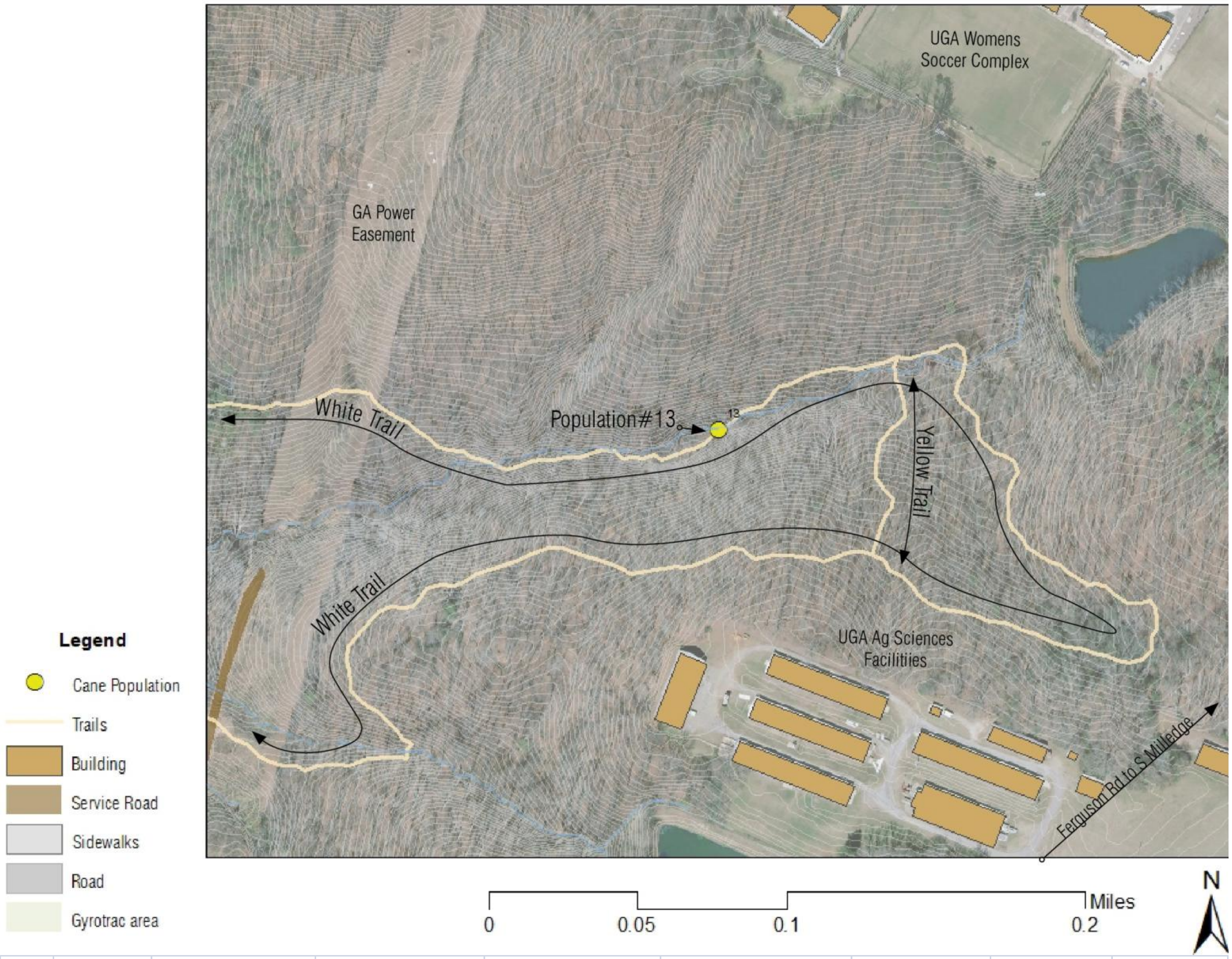
Fig.42: Populations #12 and 12.5 at the SBG

Populations 12 and 12.5 lie on the upper reaches of the White Trail within 100yds West of the Northern end of the Yellow Trail. Both populations are thinly dispersed patches of culms attaining heights of only a few feet. Being located so deeply within hardwood forest greatly diminishes the potential these populations have for canebrake restoration. P12 is spread out over large enough of an area to warrant the thinning of a few trees near the epicenter of growth in an experiment designed to determine the effects of canopy thinning on such a dilapidated population. P12.5 about 60yds down grade from P12 along the same hydrology growing surprisingly close to the eroded bank of an ephemeral stream. Managing the expansion of P12-12.5 could be an approach for mitigating some of the erosion along the aforementioned hydrology.

Population #13 (P13)

(33.908482, -83.382397)

Fig. 43: Images of Population #13



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
13	65.940	3	6	0.125	0.25	4.5	3	100

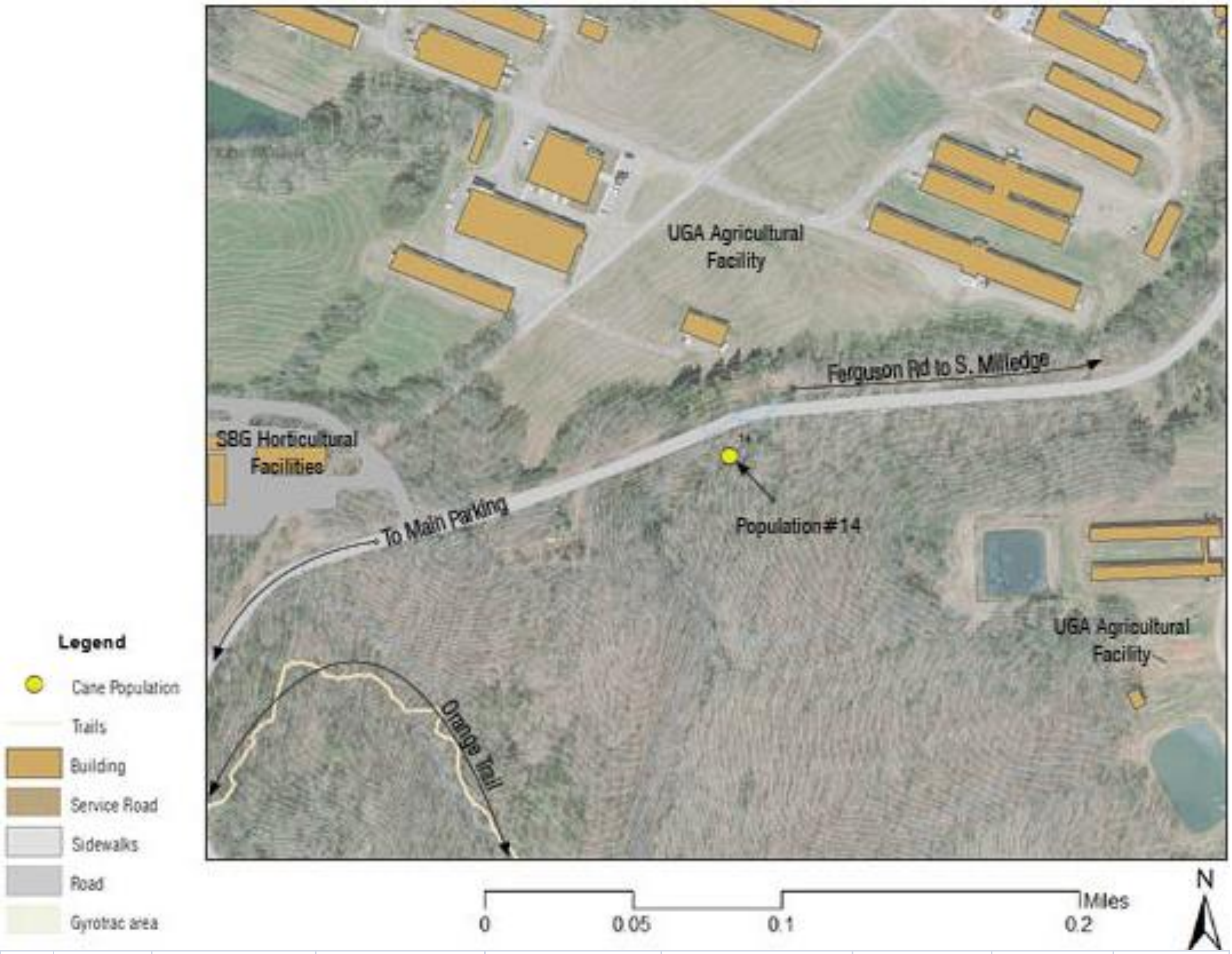
Fig.44: Population #13 at the SBG

On the White Trail 125 yds East of where the Northern end of the Yellow Trail intersection sits Population #13. P13 is on the same ephemeral stream channel as P12 and P12.5. Thriving on the bank of a stream eddy in an accumulation of silty loam, P13 is a handsome collection of healthy but thin ortets.

Population #14 (P14)

(33.904653,-83.379467)

Fig. 45: Images of Population #14



ID #	AREA (SF)	AV. CULM HT (FT)	MAX CULM HT (FT)	AV. CULM DIA. (IN)	MAX CULM DIA. (IN)	CANOPY (1-5)	DENSITY (1-5)	CULM # EST.
14	35325.000	3	8	0.125	0.5	4	1	250

Fig. 46: Population #14 at the SBG

Population #14 begins at a storm water outlet that hits daylight on the South side of Ferguson Rd within 100yds of the secondary entrance gate with the cattle guard. P14 is a thin population facing aggressive competition from other native and non-native plant species. The dense canopy cover overhead makes the formation of canebrake near to impossible. Although a canebrake restoration in this location would be highly viewable by visitors to the SBG and valuable for interpretation, the transition period where trees and vegetation would have to be removed would mar the pastoral scenery enjoyed by many on their approach to the main parking area. Perhaps if canebrake restoration is a success elsewhere on SBG grounds and the public is made aware of the benefit, P14 could be targeted for restoration management and expansion.

CHAPTER 6

CONCLUDING DISCUSSION

In my interactions with the various interest groups and individuals associated with the SBG I have come to the realization that nothing is simple about managing natural resources or accommodating the changes at are an inevitable part of a dynamic landscape. Staff and stakeholders must come together and reach consensus on many of the nuances of floodplain restoration. It is obvious that no one wants the entire floodplain to be engulfed in canebrake but rather, a variety of native plant communities such as mixed hardwood forest, meadows and wetlands intermixed with stands of canebrake which will form the structural backbone capable of stabilizing and rebuilding floodplain soils.

Canebrake management and restoration should be targeted for places that will most likely be conducive to success. P3 and P4 are an ideal starting place for expansion management and experimental restoration plantings because of their vigor and ideal location on the first levee of the floodplain. Populations that are persisting on SBG grounds outside of the floodplain should be monitored and considered as a valuable source of stock material to fuel future restoration plantings.

A propagation program should be incorporated into restoration planning and could be housed at a number of locations at the SBG including the Native Plant Center. Without a propagation initiative, it is unlikely that the SBG will be able to fight the wave of invasive plant species that continue to regenerate despite manual removal and continued herbicide applications. Establishing Canebrake from seed at the State Botanical Garden of Georgia is not an economically viable or logistically feasible approach for restoring the floodplain at this time. Aside from issues surrounding seed availability, the erosive powers of the Middle Oconee after a heavy rain could wash away seedlings in the early stages of development before rhizomes expand enough to secure the silty loam soils in the floodplain.

The vigor of invasive exotic intrusions and the urgency for erosion abatement along the riverbank demand an establishment protocol designed for establishment and rhizomatous spread in the first season after being planted.

It is my suggestion to target stands of invasive species that are abutting cane patches in the floodplain initially, and then begin to remove other thickets and plant cane in their place. By encouraging directional expansion, staff and conservationists working with the SBG could influence the spread and establishment of canebrake ecosystems to suit their intentions.

The first four chapters of this thesis are intended to provide an overview and context to the history and modern plight of canebrake ecosystems as well as establish the inherent value of canebrake establishment in the floodplain. They are a starting place for understanding and appreciating the unique character of this plant and the culture behind its history. The inventory and management guidelines in Chapters Five and Six are meant to be a tool for monitoring and potentially applying some techniques for expanding in-situ populations of cane. These expansion techniques include:

- Fertilizer applications
- Selective canopy thinning
- Additional plantings
- Removing invasive competition
- Rerouting footpaths to allow room for rhizomatous spread in isolated populations.

It is essential for an in-house propagation initiative to be established at the SBG if restoration plantings are to follow invasive removal. This would be relatively simple and inexpensive if methods of vegetative division and clonal propagation are executed from various source populations in the wintertime. Cane needs only minimal care and access to adequate moisture for establishment in a greenhouse environment before it can be reintroduced to the wild in restoration plantings.

Experimental research is needed that is designed to determine certain variables yet to be discovered in the field of canebrake restoration. The following questions regarding restoration have yet to be answered. What is the time it takes for cane transplants to initiate rhizomatous expansion? How long does it take an homogenous canebrake to form from new plantings? What is the ideal spacing for restoration plantings that would minimize the period of establishment and expansion into an ecosystem capable of supporting cane obligate species and providing culms of harvestable quality for Native American artisans? These questions and more can be answered through experimental design at the SBG. There is also potential for research on P11 to unveil the dynamics of the population in its interaction with the hazardous chemicals and inorganic compounds from the point-source pollution upstream.

With its combined resources and expertise, the SBG is more than capable of ridding the floodplain of invasives and following up removal by planting cane divisions or propagates. Floodplain restoration will be a long and adaptive process that will best be undertaken in phases. By refining methods as experienced is gained, land managers at the SBG will be able to hone their skill and ultimately develop a protocol that could be replicated in other places around the locale and region. There are very few professionals adept in canebrake ecology, propagation, and restoration across the Southeast (and none that I know of in the State of Georgia). It is time that the SBG take initiative and seize the opportunity to make the most of their resources. It is only a matter of time before canebrake restoration receives the recognition it deserves for providing ecosystem services and creating a unique aesthetic distinct to the Southeast. When this happens, there will be a need for an organization like the SBG to serve as a torchbearer and provide guidance and perhaps even plant material for other floodplain restorations.

There is opportunity in canebrake management to form partnerships with organizations like RTCAR that work towards solving resource scarcity among Native American artists. Inevitably, if canebrake restoration is successful, the brakes will need manual thinning of older or damaged culms. The individuals with the most experience in selective harvest of culms are Native Artists who practice traditional forms of basketry or the organizations like RTCAR who assist them in locating and gathering materials. Native Artists like Roger Cain in Tahlequah, Oklahoma have seen canebrakes expand in their lifetimes as a response of selective thinning. It's a win-win situation if the SBG were to become involved with a Tribal organization or affiliate. The artists receive materials to perpetuate their livelihoods and unique cultural practice, the SBG would get valuable guidance and advice on canebrake management and the canebrake would be reinvigorated by the selective thinning.

Finally, it is important to consider long-term management of canebrake habitat in the floodplain. Canopy management and prescribed burns are two management approaches that will certainly be greeted with immediate rejection by many, however if canebrake habitat is intended to be a prominent feature of the floodplain landscape, these methods will need to be considered and their value to the management of canebrake ecosystems will need to be explained to skeptical individuals. Interpretation of restoration plantings through signage and workshops may also be effective in informing the general public about canebrake ecology.

The data gathered in the inventory can be used in conjunction with other geospatial data like elevation, land use, land cover, hydrology and soils into geographic information systems (GIS) software. A technician experienced in GIS can use spatial analysis extensions to create digital models for planning invasive removal, canebrake restoration or reestablishment. Variables can be weighted to their significance in order to target or exclude areas for certain management guidelines. The following figure is an example of a GIS suitability model for targeting areas for canebrake establishment. The dark green areas indicate land that is ideal for supporting canebrake habitat. Red is used to delineate areas unsuitable for canebrake restoration activities. This model is not to be taken literally, but rather as a representation of the kind of mapping that can be generated with data available to the SBG.

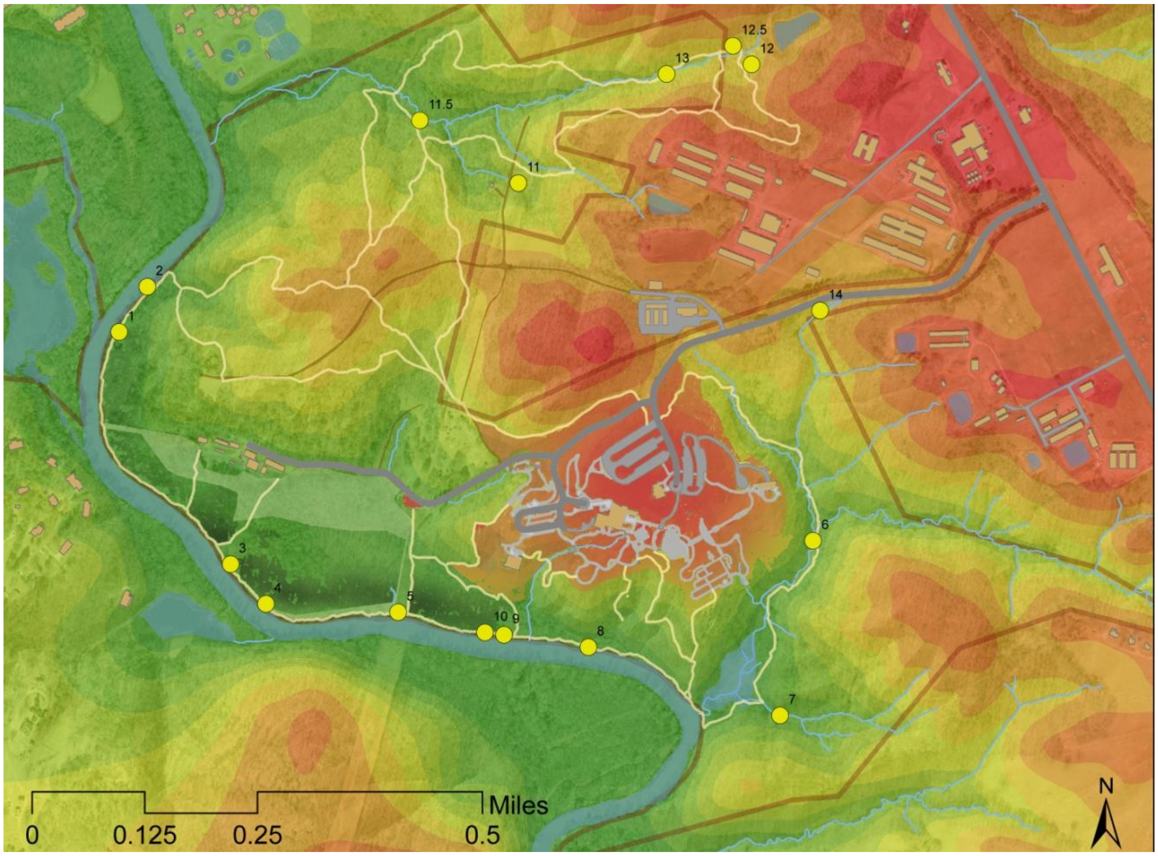


Fig. 47: Suitability Analysis. Created by Thomas Peters with Esri® Software

In conclusion, floodplain restoration at the State Botanical Garden of Georgia will always be a work-in-progress. Alluvial landscapes are especially dynamic and an adaptive approach will be necessary for the long term sustainability of restoration planning in the floodplain.

This thesis has shown that canebrake restoration following the removal of invasive species is an appropriate and desirable restoration strategy at the SBG. The benefits include enhanced biodiversity, floodplain stabilization, cultural preservation, educational opportunities, and a number of additional ecosystem services. Many challenges have been identified and addressed through this thesis, including propagation strategies, site suitability, and the identification of existing site resources. Recommended strategies have been identified from the literature and substantiated through experiments conducted by the author and others at UGA.

BIBLIOGRAPHY

Adair, James, and Jr Berkhofer. *The History of the American Indians: Particularly Those Nations Adjoining to the Mississippi, East and West Florida, Georgia, South and North Carolina, and Virginia*. New York: Johnson Reprint Corporation, 1968.

Allan, J David, and María M Castillo. *Stream Ecology: Structure and Function of Running Waters*: Springer Science+ Business Media BV, 2007.

Anderson, Edward F. *Plants and People of the Golden Triangle. Ethnobotany of the Hill Tribes of Northern Thailand*: Dioscorides Press, 1993.

Arnold, A. Elizabeth, Sarvate, Snehal, and Lutzoni,, and Francois. "Diversity and Specificity of Endophytic Fungi Associated with Representatives of Major Plant Lineages." *Inoculum (Suppliment to Mycologia)* 55, no. 4 (2004): 7.

Arquette, Mary, Maxine Cole, Katsi Cook, Brenda LaFrance, Margaret Peters, James Ransom, Elvera Sargent, Vivian Smoke, and Arlene Stairs. "Holistic Risk-Based Environmental Decision Making: A Native Perspective." *Environmental Health Perspectives* 110, no. ArticleType: research-article / Issue Title: Supplement 2: Community, Research, and Environmental Justice / Full publication date: Apr., 2002 / Copyright © 2002 The National Institute of Environmental Health Sciences (NIEHS) (2002): 259-264.

Baldwin, Brian S., Margaret Cirtain, D. Scott Horton, John Ouellette, Scott B. Franklin, and John E. Preece. "Propagation Methods for Rivercane [Arundinaria Gigantea L. (Walter) Muhl.]." *Castanea* 74, no. 3 (2009): 300-316.

Beacham, Deanna. The Indigenous Cultural Landscape of the Eastern Woodlands: A Model for Conservation, Interpretation, and Tourism. In Rethinking Protected Areas in a Changing World: Pro ceedings of the 2011 George Wright Society Biennial Conference on Parks, Protected Areas, and Cul tural Sites. Hancock, Michigan: The George Wright Society. 2012.

Blackburn, Thomas C., and Kat Anderson. *Before the Wilderness : Environmental Management by Native Californians / Compiled and Edited by Thomas C. Blackburn and Kat Anderson* Bpap: No. 40: Menlo Park, CA : Ballena Press, c1993., 1993.

Blattel, C. R., K. W. J. Williard, S. G. Baer, J. E. Schoonover, and J. J. Zaczek. "Ground Water Nitrogen Dynamics in Giant Cane and Forest Riparian Buffers." *Castanea* 74, no. 3 (2009): 259-270.

Blattel, Christopher R, Karl WJ Williard, Sara G Baer, and James J Zaczek. "Abatement of Ground Water Phosphate in Giant Cane and Forest Riparian Buffers1." *JAWRA Journal of the American Water Resources Association* 41, no. 2 (2005): 301-307.

Brantley, Christopher G., and Steven G. Platt. "Canebrake Conservation in the Southeastern United States." *Wildlife Society Bulletin* 29, no. 4 (2001): 1175-1181.

Bushnell, David Ives. *Native Cemeteries and Forms of Burial East of the Mississippi*. Vol. 71: Govt. print. off., 1920.

Cain, Roger. Personal Communication. 3/19/2013.

Calloway, Colin Gordon. *First Peoples: A Documentary Survey of American Indian History*: Bedford/St. Martin's, 2004.

Chandra, Sudhir, and HK Kehri. *Biotechnology of Va Mycorrhiza: Indian Scenario*: New India Publishing, 2006.

Cheatham, S., M.C. Johnston, and L. Marshall. "The Useful Wild Plants of Texas, the Southeastern and Southwestern United States, the Southern Plains, and Northern Mexico." *Useful and Wild Plants, Inc. Austin, TX*, (1995).

Cirtain, Margaret C., Scott B. Franklin, and S. Reza Pezeshki. "Effect of Light Intensity on Arundinaria Gigantea Growth and Physiology." *Castanea* 74, no. 3 (2009): 236-246.

Clark, James S. "Fire and Climate Change During the Last 750 Yr in Northwestern Minnesota." *Ecological Monographs* 60, no. 2 (1990): 135-159.

Covey, C. (ed.). *Cabeza De Vaca's Adventures in the Unknown Interior of America*, Edited by C. Covey. Albuquerque, New Mexico: University of New Mexico Press, 1961.

Cozzo, David. Personal Communication. 3/19/3013.

Cronin, Amanda, and David M. Ostergren. "Tribal Watershed Management: Culture, Science, Capacity, and Collaboration." *American Indian Quarterly* 31, no. 1 (2007): 87-109.

Dattilo, A. J., and C. C. Rhoades. "Establishment of the Woody Grass Arundinaria Gigantea for Riparian Restoration." *Restoration Ecology* 13, no. 4 (2005): 616-622.

Dunbar, W. "1749-1810. Life, Letters, and Papers of William Dunbar." *Press of the Mississippi Historical Society, Jackson*.

Ethridge, R. . "Creek Country: The Creek Indians and Their World." *University of North Carolina Press, Chapel Hill, North Carolina*, (2003).

Farrelly, David. *The Book of Bamboo: A Comprehensive Guide to This Remarkable Plant, Its Uses, and Its History*: Thames and Hudson Ltd, 1996.

Froeschauer, P. *A Vegetation History of Ocmulgee National Monument Macon, Georgia*. School of Environ. Design, 1988.

Gagnon, P. R., and W. J. Platt. "Reproductive and Seedling Ecology of a Semelparous Native Bamboo (Arundinaria Gigantea, Poaceae)." *Journal of the Torrey Botanical Society* 135, no. 3 (2008): 309-316.

Gagnon, Paul R. "Population Biology and Disturbance Ecology of a Native North American Bamboo (Arundinaria Gigantea)." Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Biological Sciences by Paul R. Gagnon BA, Baylor University, 2006.

Gagnon, Paul R. "Fire in Floodplain Forests in the Southeastern USA: Insights from Disturbance Ecology of Native Bamboo." *Wetlands* 29, no. 2 (2009): 520-526.

Gagnon, Paul R., and William J. Platt. "Multiple Disturbances Accelerate Clonal Growth in a Potentially Monodominant Bamboo." *Ecology* 89, no. 3 (2008): 612-618.

Gagnon, PR, HA Passmore, and WJ Platt. "Multi-Year Salutary Effects of Windstorm and Fire on River Cane." *Fire Ecology* 9, no. 1 (2013): 55-65.

Gibson, Daniel. "Restoring Sacred Roots." *Native Peoples Magazine* 23, no. 1 (2010): 17-17.

Griffith, A. D., K McDowell, and R. S. Young. "Rivercane Restoration Project: Recovering an Ecologically and Culturally Significant Species (North Carolina)." *Ecological Restoration* 25, no. 2 (2007): 144-145.

Hartleb, J. L., and J. J. Zaczek. "Culm Production and Morphology of Fresh and Stored Rhizomes from Field-Planted and Wild Giant Cane." In *General Technical Report - Southern Research Station, USDA Forest Service*, edited by D. S. Buckley and W. K. Clatterbuck. Asheville; USA: Southern Research Station, USDA Forest Service, 2007.

Hawkins, Benjamin. *Sketch of the Creek Country in 1798 and 1799*, 1848.

Hill, Sarah H. *Weaving New Worlds: Southeastern Cherokee Women and Their Basketry*: University of North Carolina Press Chapel Hill, North Carolina, 1997.

Hoffman, Keith Michael. "Patterns of Recruitment and Young Culm Morphology in Arundinaria Gigantea ([Walt.] Muhl. Canebrakes in Western North Carolina." Western North Carolina, 2010.

Howard, J.H. . " The Southeastern Ceremonial Complex and Its Interpretation." *Missouri Archaeological Society* Mem. No. 6., (1968).

Hudson, Charles M. *The Southeastern Indians*: University of Tennessee Press Knoxville, Tennessee, 1976.

Hughes, Ralph H. "Observations of Cane (Arundinaria) Flowers, Seed, and Seedlings in the North Carolina Coastal Plain." *Bulletin of the Torrey Botanical Club* 78, no. 2 (1951): 113-121.

Iberville, P.L.M. *Iberville's Gulf Journals*. Tuscaloosa, AL: University of Alabama Press, 1689-1702. Reprint, 1981.

Janzen, Daniel H. "Why Bamboos Wait So Long to Flower." *Annual Review of Ecology & Systematics* 7, (1976): 347-391.

Judziewicz, Emmet J, Lynn G Clark, Ximena Londono, and Margaret J Stern. *American Bamboos*: Smithsonian Institution Press, 1999.

Keeley, Jon E., and William J. Bond. "Mast Flowering and Semelparity in Bamboos: The Bamboo Fire Cycle Hypothesis." *American Naturalist* 154, no. 3 (1999): 383.

Kelly, Dave. "The Evolutionary Ecology of Mast Seeding." *Trends in Ecology & Evolution* 9, no. 12 (1994): 465-470.

Klepac, John, Robert B Rummer, James L Hanula, and Scott Horn. "Mechanical Removal of Chinese Privet." *Research Paper-Southern Research Station, USDA Forest Service*, no. SRS-43 (2007).

Kniffen, Fred B, Hiram F Gregory, and A George. "Stokes 1987 the Historic Indian Tribes of Louisiana." Louisiana State University Press, Baton Rouge.

Koshy, KC, and G Jee. "Studies on the Absence of Seed Set in Bambusa Vulgaris." *CURRENT SCIENCE-BANGALORE-* 81, no. 4 (2001): 375-377.

Marsh, DL. "The Taxonomy and Ecology of Cane, Arundinaria Gigantea (Walter) Muhlenberg. Fayetteville, Ar: University of Arkansas, 303 P." MS thesis, 1977.

McClure, F. A. "A New Feature in Bamboo Rhizome Anatomy." *Rhodora* 65, no. 762 (1963): 134-6.

Meanley, B. *Swamps, River Bottoms and Canebrakes*. Barre: Barre Publ., 1972.

Mills, M. C., B. S. Baldwin, and G. N. Ervin. "Evaluating Physiological and Growth Responses of Arundinaria Species to Inundation." *Castanea* 76, no. 4 (2011): 395-409.

Mutch, Robert W. "Wildland Fires and Ecosystems--a Hypothesis." *Ecology*, (1970): 1046-1051.

Nabokov, Peter, and Robert Easton. *Native American Architecture*: New York: Oxford University Press, 1989.

Neisler, Hugn M. "Art. Ii.—Notes on the Habits of the Common Cane, (Arundinaria Macrosperma, Michx.); by Hughm. Neisler, Corresponding Member of the Essex Institute, Salem, Mass." *American Journal of Science & Arts* 30, no. 88 (1860): 14.

Nolan, Justin, Shawna Cain, Roger Cain, and Rick Stepp. "Western Cherokee Ethnoecology and Language Revitalization in the Oklahoma Ozarks." Presentation at the 2012 annual meeting of the Society of Ethnobiology Dept. of Anthropology, University of Arkansas, Cherokee Nation, and Dept. of Anthropology University of Florida.

Noss, Reed F., Edward T. LaRoe, and J. Michael Scott. *Endangered Ecosystems of the United States [Microform] : A Preliminary Assessment of Loss and Degradation / by Reed F. Noss, Edward T. Laroe Iii, and J. Michael Scott* Biological Report: 28: Washington, D.C. : U.S. Dept. of the Interior, National Biological Service, 1995., 1995.

Nuttall, Thomas. *A Journal of Travels into the Arkansa Territory, During the Year 1819: With Occasional Observations on the Manners of the Aborigines*: Palmer, 1821.

Osland, M. J., J. W. Pahl, and C. J. Richardson. "Native Bamboo [Arundinaria Gigantea (Walter) Muhl, Poaceae] Establishment and Growth after the Removal of an Invasive Non-Native Shrub (Ligustrum Sinense Lour., Oleaceae): Implications for Restoration." *Castanea* 74, no. 3 (2009): 247-258.

Ouchley, Kelby. *Flora and Fauna of the Civil War: An Environmental Reference Guide*: LSU Press, 2010.

Pénicaut, André, and Richebourg Gaillard McWilliams. *Fleur De Lys and Calumet: Being the Pénicaut Narrative of French Adventure in Louisiana*: Louisiana State University Press, 1953.

Platt, S. G., and C. G. Brantley. "Canebrakes: An Ecological and Historical Perspective." *Castanea* 62, no. 1 (1997): 8-21.

Platt, Steven G., Christopher G. Brantley, and Thomas R. Rainwater. "Native American Ethnobotany of Cane (Arundinaria Spp.) in the Southeastern United States: A Review." *Castanea* 74, no. 3 (2009): 271-285.

Quinn, J. F., and A. E. Dunham. "On Hypothesis Testing in Ecology and Evolution." *American Naturalist*, no. 122 (1983): 602-617.

Reynolds, Lindsay. Personal Communication 6/10/13.

Rundel, PW. "Fire as an Ecological Factor." In *Physiological Plant Ecology I*, 501-538: Springer, 1981.

Saha, Somali, and Henry F. Howe. "The Bamboo Fire Cycle Hypothesis: A Comment." *American Naturalist* 158, no. 6 (2001): 659.

Schoonover, J. E., J. L. Hartleb, J. J. Zaczek, and J. W. Groninger. "Growing Giant Cane (Arundinaria Gigantea) for Canebrake Restoration: Greenhouse Propagation and Field Trials." *Ecological Restoration* 29, no. 3 (2011): 234-242.

Schoonover, J. E., K. W. J. Williard, C. Blattel, and C. Yocum. "The Utility of Giant Cane as a Riparian Buffer Species in Southern Illinois Agricultural Landscapes." *Agroforestry Systems* 80, no. 1 (2010): 97-107.

Service, Natural Resources Conservation. *Nrcs Southeast American Indian Work Group*, 2010.

Silvertown, J. W. "The Evolutionary Ecology of Mast Seeding in Trees." *Biological Journal of the Linnean Society* 14, no. 2 (1980): 235-250.

Sineath, HH, PM Daugherty, RN Hutton, and TA Wastler. *Industrial Raw Materials of Plant Origin*: Georgia Institute of Technology, 1953.

Soderstrom, Thomas R, and Cleofe E Calderon. "A Commentary on the Bamboos (Poaceae: Bambusoideae)." *Biotropica*, (1979): 161-172.

Speck, Frank G. "A List of Plant Curatives Obtained from the Houma Indians of Louisiana." *Primitive Man* 14, no. 4 (1941): 49-73.

Spruill, Timothy B. "Statistical Evaluation of Effects of Riparian Buffers on Nitrate and Ground Water Quality." *Journal of Environmental Quality* 29, no. 5 (2000): 1523-1538.

Stewart, Mart A. "From King Cane to King Cotton: Razing Cane in the Old South." *Environmental History* 12, no. 1 (2007): 59-79.

Sturtevant, W.C. . "The Mikasuki Seminole: Medical Beliefs and Practices." Dissertation, Yale University, 1955.

Swanton, John Reed. *The Indians of the Southeastern United States*: Smithsonian Institution Press Washington, DC, 1979.

Triplett, J. K., and L. G. Clark. "Towards a Stable Nomenclature for the North American Temperate Bamboos: Epitypification of Arundo Gigantea Walt, and Arundinaria Macrosperma Michx. (Poaceae)." *Castanea* 74, no. 3 (2009): 207-212.

Triplett, JK, AS Weakley, and LG Clark. "Hill Cane (Arundinaria Appalachiana), a New Species of Bamboo (Poaceae: Bambusoideae) from the Southern Appalachian Mountains." *Sida, Contrib. Bot* 22, no. 1 (2006): 79-95.

VanDoren, M. "Travels of William Bartram. Macy." *Masius Publishers. Dover ed., New York: Dover Publications Inc* 414, (1928): 1-15.

Watts, S. "The Southeastern Indian Rivercane Blowgun: Legacy, Lineage and an Aboriginal Approach to Manufacture." *Bulletin of Primitive Technology*, no. 17 (1999): 55-61.

Watts, S. . *Southeastern Rivercane Arrow Notes* Primitive Technology Ii: Ancestral Skills., Edited by D. Westcott. Salt Lake City, Utah: Gibbs Smith, 2001.

Zaczek, J. J., S. G. Baer, J. L. Hartleb, W. W. Brendecke, J. E. Schoonover, K. W. J. Williard, and J. W. Groninger. "Survival and Genet Growth and Development of Field-Planted Giant Cane (Arundinaria Gigantea) over Time in Southern Illinois." *Castanea* 74, no. 3 (2009): 286-299.

Zaczek, James J., Karl W. J. Williard, Sara G. Baer, John W. Groninger, and Rebecca L. Sexton. "Propagation of Giant Cane (Arundinaria Gigantea) Using Rhizome Cuttings." *Combined Proceedings - International Plant Propagators Society* 54, (2004): 408-411.