Roots in the Sand: Human Perspectives and Vegetation Change of Buxton Woods

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Abstract

Buxton Woods, located on North Carolina's Outer Banks, is one of the most extensive remaining maritime forests on the Atlantic Coast. Protected by both the North Carolina Coastal Reserve and the National Park Service, Buxton Woods provides ecosystem services, such as a freshwater source and a refuge for biodiversity, to the surrounding community. Maritime forests are dynamic ecosystems that evolve to withstand disturbances and change, and their vegetation and surrounding community reflect this progression. This study investigates how stakeholders relate to Buxton Woods and documents how the vegetative composition and structure of the Woods has changed since 1988. To better understand community perspectives and attitudes, ten semi-structured interviews were conducted and analyzed using the Conceptual Content Cognitive Mapping (3CM) method. Interviews suggested that local stakeholders possess diverse mental models of Buxton Woods, shaped by place-based uses, occupation, and local ecological knowledge. To catalog vegetation species in Buxton Woods, eight plots were established by the Carolina Vegetation Survey (CVS) in 1988. Bailey et al. (2021) resampled three of these original plots, and in 2022, we resampled two additional plots. Compiling both years' data provided a more complete picture of the vegetative composition and structure of Buxton Woods. Our results suggest that today, the Woods is a more diverse, but less dense forest, with more herbaceous and shrub species. This could be attributed to a variety of disturbances that maritime forests are subject to, including salt spray, diseases, and pests. Natural disturbances and stakeholder perspectives impact the evolving ecosystem of the Woods. Our assessment is a present snapshot of Buxton Woods that can support decision-making by the community and natural resource managers.

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Introduction

Purpose

Buxton Woods, a seemingly idyllic maritime forest on Hatteras Island, was once at the forefront of the battle between development and preservation. In the 1980s, local community members banded together to protect a portion of the forest from a proposed golf course. Their work was successful, and now most of the Woods is managed by the National Parks Service (NPS) and North Carolina Coastal Reserve. While this community, and others, have been successful in preserving maritime forests, countless others have been lost to development, saltwater intrusion, and storms (Jones et al., 2013). Continuing and expanding the protection of these vulnerable ecosystems requires knowledge of how they are changing and how humans value them. This study will explore and document how the vegetative structure and composition of Buxton Woods have changed since 1988. In addition, it will investigate and model how stakeholders think about and relate to the forest. This study serves as an expansion of the capstone research project conducted by the 2021 UNC Institute for the Environment Outer Banks Field Site (OBXFS) on Buxton Woods (Bailey et al., 2021).

Physical Setting

Maritime forests, such as Buxton Woods, often occur on barrier islands. Barrier islands comprise nearly 10% of the world's open ocean coasts (Stutz & Pilkey, 2011) and they continually change in response to wind, wave, tide, and sea-level fluctuations (Masterson et al., 2013). The Outer Banks, a string of barrier islands off of North Carolina and Virginia's coasts, are coastal plain islands. Coastal plain islands are a type of barrier island built across the mouths of flooded river valleys, usually on broad coastal plains (Stutz & Pilkey, 2011). The mainland rivers of the Outer Banks empty their discharge and sediment into a broad bay. The northern Outer Banks are separated from the shoreline by the Pamlico and Albemarle Sounds, which are up to 100 kilometers wide, and in the south, the barrier islands are no more than a few kilometers from the shoreline. Lower Hatteras Island, where Buxton Woods is located, is a deltoid-shaped section of the barrier island system (Fig. 1). At its widest point, it is 12 km long by 5 km wide – this will be our area of study.

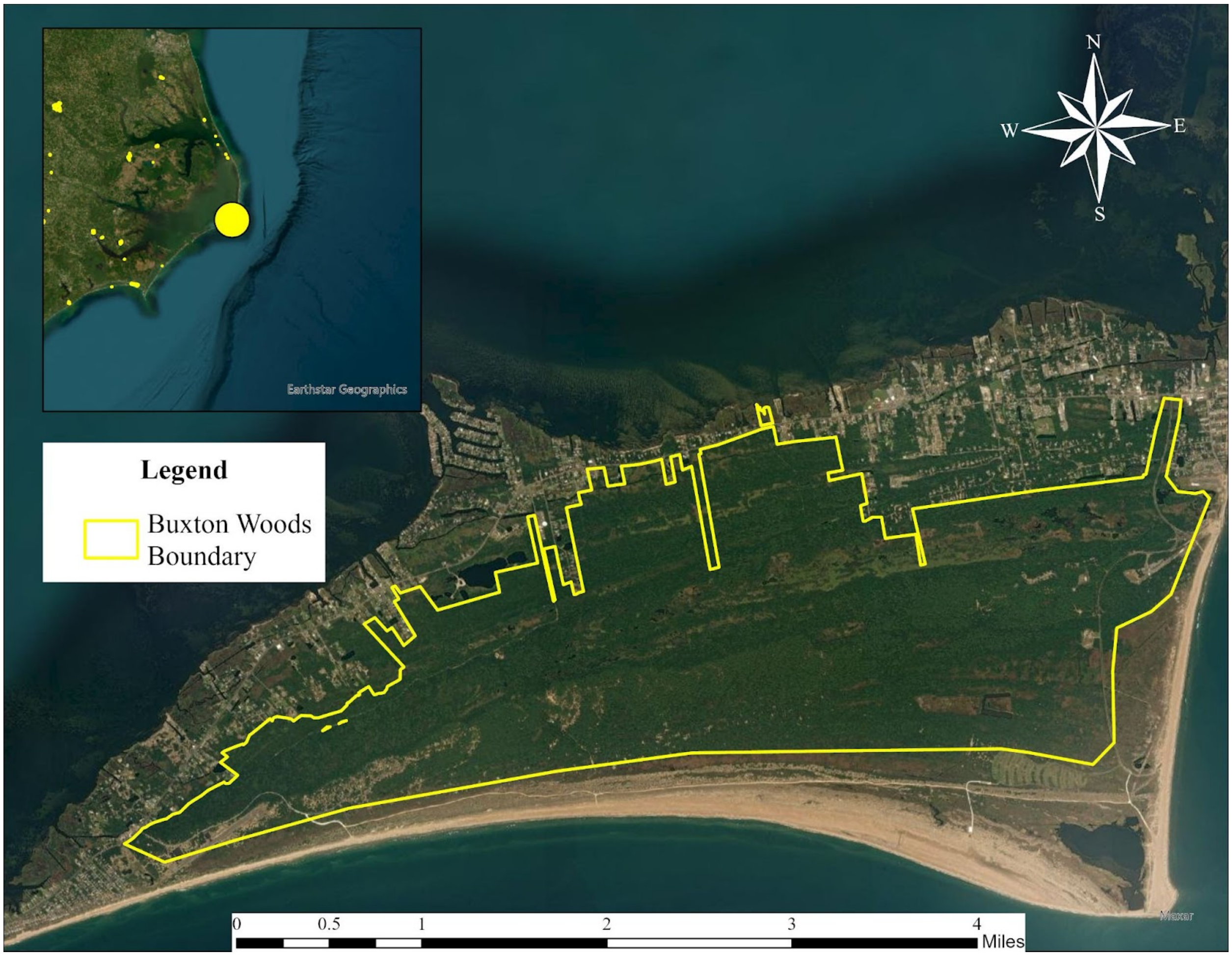

Figure 1. Map depicting the boundary of the entirety of Buxton Woods, located between the towns of Frisco and Buxton on the Outer Banks, Dare County, North Carolina.

As barrier islands experience natural forces, they can shift and change, gradually moving landward. Inlet processes and overwash events caused by storms, such as hurricanes and nor'easters, contribute to the migration of barrier islands (Williams, 2015; Smith et al., 2008). Extreme weather events may overtop low foredune systems, creating large overwash fans that deposit sediment on back-island areas and push barrier systems landward. Inlets allow for sediment to be transported from the ocean to the estuary side of a barrier island. This nourishes back-island areas and eventually forms tidal deltas, which grow and connect to front-island sections. An example can be found on Pea Island, where inlets that naturally closed experienced net landward growth. Meanwhile, in Avon-Buxton, an inlet was artificially closed and has consistently eroded over the past 146 years (Fig. 2).

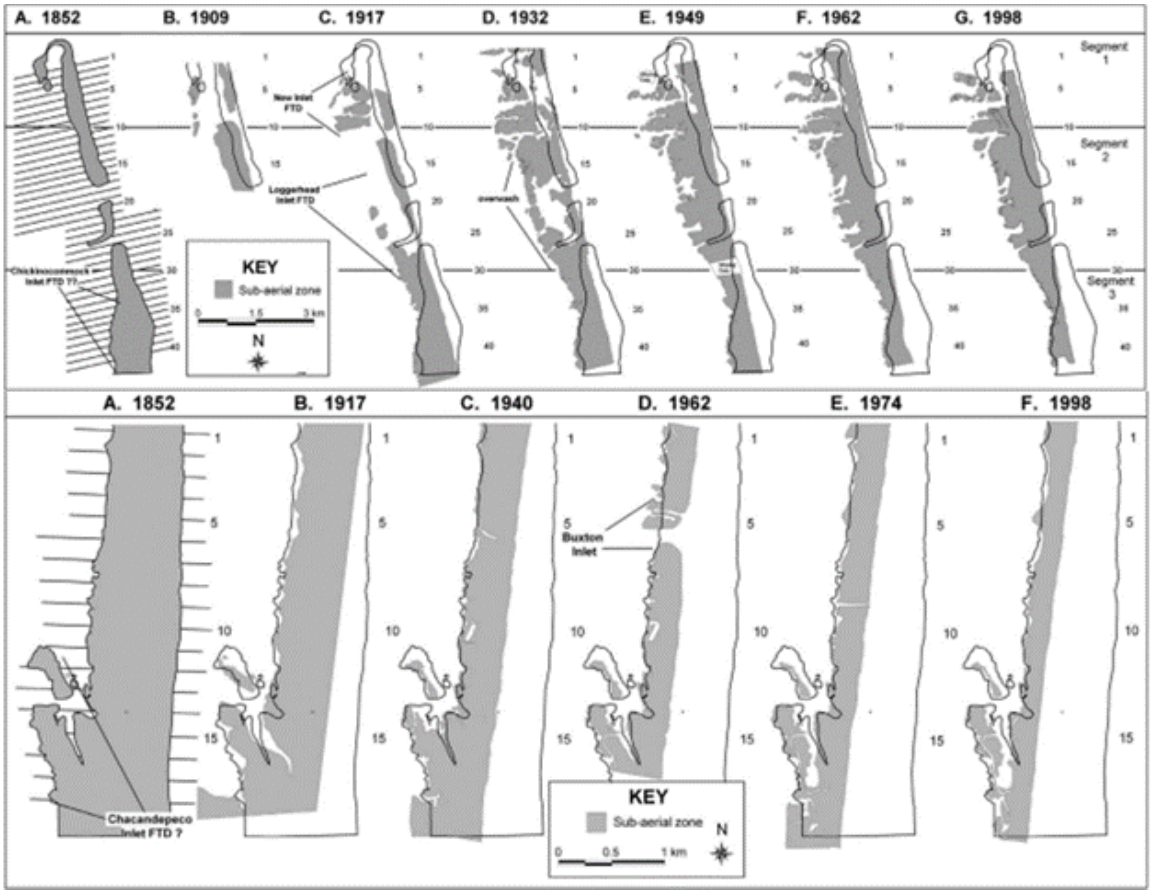

Figure 2. Shoreline change from 1852-1998 for the Avon-Buxton area (bottom) and segments of Pea Island (top). The shoreline from each time step is overlain with the 1852 shoreline (Smith et al., 2008).

Another important element of Buxton Woods is its dune system. On Lower Hatteras Island, accreted sands have formed a series of parallel, high sandy ridges called relic dunes, alternating with low-lying swales (Jones et al., 2013), creating a dune system with high and low elevations. This change in elevation creates bistability (Vinent & Moore, 2014), controlled by dune erosion and formation. Storm erosion, sea-level rise, and other aeolian processes drive dune erosion and formation. In one such stable state, when foredunes are high and eroded, vegetation can recover more quickly to maintain elevation when the next erosive high-water event (HWE; exceeds mean high water level) occurs. However, low dune systems cannot grow in elevation fast enough after HWEs, so they can become "stuck" at a perpetually low elevation. Both cases are stable. Since barrier islands are usually the farthest oceanward terrestrial ecosystem, changes in their stability can affect the states of inland ecosystems.

Maritime Forest Ecology

Maritime forests are dynamic ecosystems, evolved to withstand sea level rise, salt-spray-wind, storms, and surges (Sacatelli et al., 2020). A maritime forest is defined as "woody vegetation growing near any of the world's oceans" (Bellis & Keough, 1995). They can be found in both coastal areas and on barrier islands, transforming sand dunes into mature, vegetated dunes. The vegetation cover retains nutrients, enhances soil moisture and stabilizes dunes (Bellis & Keough, 1995). Unlike many coastal ecosystems, maritime forests grow in upland settings and are co-dominated by evergreens and deciduous hardwoods. The unique hydrology of maritime forests provides a freshwater source for humans, animals, and vegetation alike. Due to their high elevation and abundant vegetation, aquifers are commonly located and recharged beneath maritime forests (Jones et al., 2013). Many of these aquifers are the sole source of freshwater for island communities, making them essential for sustaining human life on barrier islands. The water table on Hatteras Island forms a freshwater lens, which floats atop denser, underlying saline water (Heath, 1988). This freshwater lens controls the wetland swale communities in Buxton Woods, affecting the timing, frequency, and length of soil saturation. Today, the Buxton community receives drinking water from one of the four Dare County Reverse Osmosis Plants, desalinating the water from the groundwater aquifer (Dare County, n.d.).

Due to their locations on coastlines, maritime forests are subject to continuous disturbance, causing fluctuations in the composition of trees, shrubs, and grasses over time. Close proximity to the ocean exposes maritime forests to various influencing conditions, such as salt spray, high winds, extreme tides, saltwater intrusion, sandy, low-nutrient soils, and dynamic sands (Baker, 2014). Natural processes, including flooding, drought, accretion, erosion, diseases, and the introduction of new species, can affect the resiliency of the ecosystem. The impacts of climate change, such as sea level rise, are also causing coastal sediments from the estuarine system to be dumped onto pre-existing geologic frameworks, impacting the shore's morphology, sediment composition, and erosion rates (Riggs et al., 1995). Resilience in such a dynamic environment is tied to vegetative species that are responsible for stabilizing barrier islands through slowing erosion processes (Jones et al., 2013). As strong winds and storms threaten barrier islands, maritime forests act as buffers for the mainland. The frequency of storms, such as hurricanes and nor'easters, is increasing due to climate change (Pörtner et al., 2022), and forests dissipate the effects of these storms, protecting the mainland (Jones et al., 2013).

North Carolina maritime forests support the hunting, recreational, and ecotourism industries (Buxton Woods Trailhead, n.d.), as well as maintain freshwater aquifers that many communities on barrier islands rely upon for drinking water (Jones et al., 2013). Despite their importance to local coastal communities, maritime forests and barrier islands remain understudied (Bellis & Keough, 1995). Understanding the characteristics of a maritime forest is the first step toward understanding its many valuable ecological and anthropogenic resources.

Vegetation Change

Barrier island ecosystems similar to Buxton Woods have been the subject of vegetation change studies over the years. Each island's vegetation responds differently to ecosystem pressures and disturbances. As a result, species composition lends insight into past and current perturbations. For example, live oaks are more resistant to harsh conditions faced in hurricanes, while pines are destroyed more frequently but regenerate their population quickly after disasters (Conner et al., 2005). Back-to-back disturbances affect the growth and composition of species. For example, the shift from salt-sensitive to salt-tolerant species conveys the extent of salt-water inundation, while the shift from wind-sensitive to wind-tolerant species conveys the growing damage via storms (Woods et al., 2021). Overall forest resiliency can be determined by tree death and replacement rates. This is exemplified by maritime forests on Virginia's Eastern Shore; the *Morella cerifera,* or wax myrtle, shrub is rapidly replacing the evergreens in these forests (Woods et al., 2021) which is believed to reveal the disassembly and loss of tree species due to changes in climate.

Human Dimensions

The town of Buxton is set 10 feet above sea level in the sheltered, wooded elbow of Cape Hatteras, making it a desirable living area for coastal residents. Initially occupied by the Cape Hatteras Indians, Buxton became home to European settlers and those seeking refuge from storms in Avon in subsequent migrations throughout the 1900s (Impact Assessment Inc., 2005).

Modernity, along with the completion of the Bonner Bridge in 1963, brought changes to the socio-economic and socio-ecological structure of the community. Tourism provided opportunities for alternative livelihoods, driving locals further away from the original fishing industry. Despite changes in community and economic structure throughout history, Buxton Woods maintained its roles as a refuge, place of play, trade path, and water source (Impact Assessment Inc., 2005).

In many ways, increasing tourism and conflicts in land use set the stage for a controversy over development in Buxton Woods. In 1986, developers proposed building a golf course on forested land in Buxton Woods. Alarmed by this proposal, locals formed an organization called the Friends of Hatteras and petitioned the state to make Buxton Woods an Area of Environmental Concern (AEC), which would impose controls on development (NC DEHNR Department of Coastal Resources, 1996). The State ultimately tabled discussions on making Buxton Woods an AEC, deciding to leave the management of Buxton Woods to Dare County. The County subsequently deemed Buxton Woods a Special Environmental District, which altered zoning to prevent development and protect the forest. North Carolina later acquired 152 acres of land, making Buxton Woods part of the North Carolina Coastal Reserve and sparking conflicting sentiments within the Buxton community. Despite the initial efforts of the Friends of Hatteras, some residents felt that the state and federal influence on local land management practices was unwarranted (Bailey et al., 2021).

Today, the majority of Buxton Woods is owned and managed by the National Parks Service and North Carolina Coastal Reserve, subjecting it to both federal and state jurisdiction (Fig. 3). The Woods remain open to the public, accessible via highway NC 12 (NC DEQ, n.d.). Now, the North Carolina Coastal Reserve is responsible for approximately 1,007 acres of the Woods, while Cape Hatteras National Seashore lies along the southern edge, connected to state property via various walking and hiking trails (NC DEQ, n.d.).

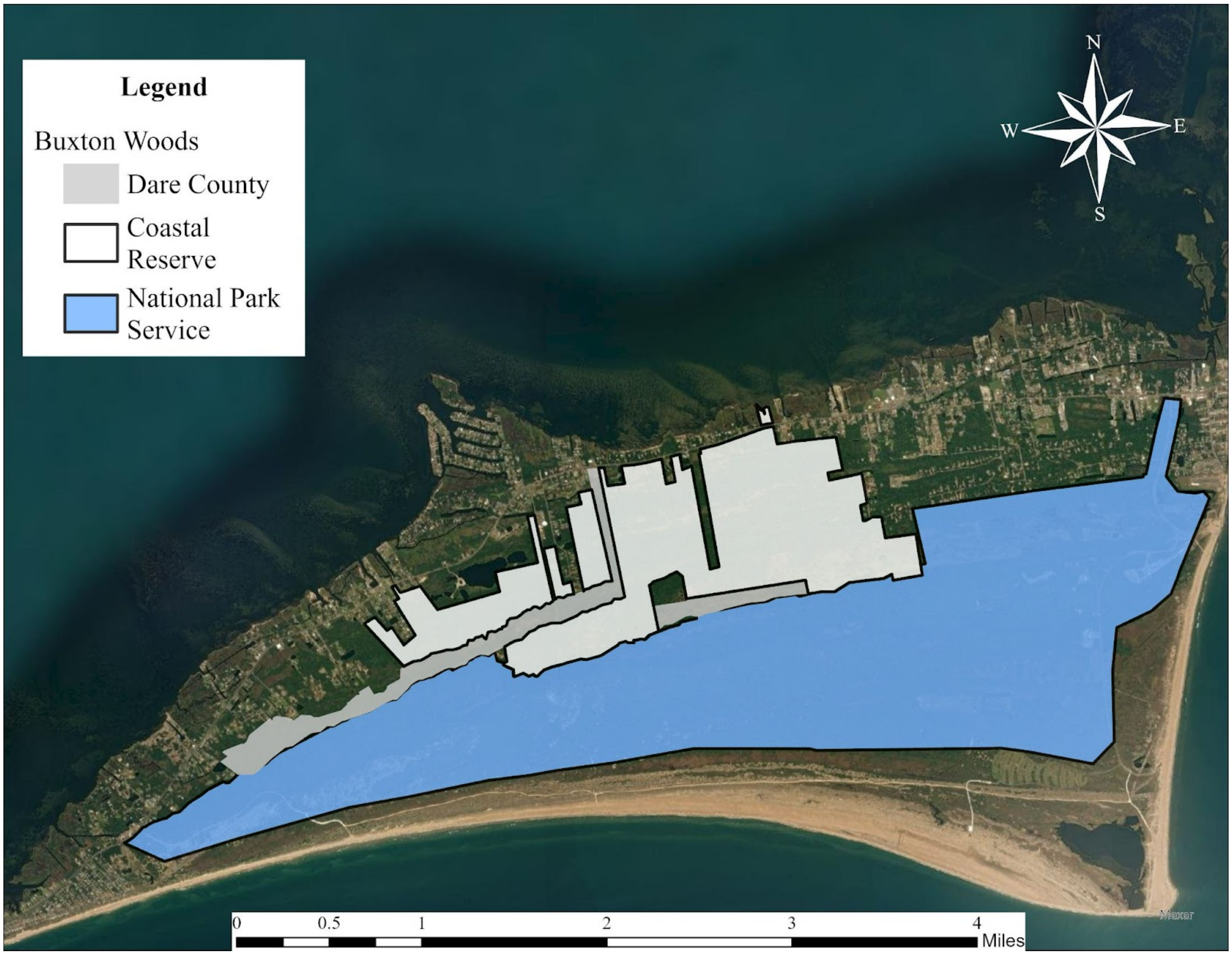

Figure 3. Map depicting the separate jurisdiction entity boundaries of Buxton Woods in 2022. The majority of Buxton Woods is protected by the North Carolina Coastal Reserve (in white) and the National Parks Service (in blue). Dare County also owns small parcels (in grey).

Within the patchwork of state and federal jurisdiction in this setting, residents and other stakeholders may assign varying values and meaning to Buxton Woods. Existing theories, Perceived Restorativeness (PRS) and Attention Restoration Theory (ART) highlight the importance of natural spaces on the well-being of individuals. These state that there are specific characteristics in strategically managed natural environments that bolster people's vitality, positive moods, stress reduction, and more; many of which can be found in the Woods (Simkin et al., 2021). They provide an opportunity to hunt, to connect with the land through recreation-based activities like hiking and birdwatching, to seek out an area of intrigue for running, biking, nature walks, camping, and more (Buxton Woods Trailhead, n.d.).

Positive outdoor experiences grow environmental stewardship (Larson et al., 2018). Place-protecting and pro-environmental behaviors are formed in communities like Buxton where livelihoods revolve around recreation-based activities. It is because of this attachment that the local population is poised to offer input to management choices for the Woods. Understanding the importance of the Woods for the local community is paramount and an open line of communication between stakeholders and management services is critical to the longevity of Buxton Woods. When a land management agency seeks to implement a new proposal or carry out existing ones, stakeholders should be involved early to avoid potential conflicts (Sharp et al. 2012). This study provides a small sample of stakeholder perceptions to further inform management practices in Buxton Woods.

Human Dimensions

Introduction

Natural spaces are heavily impacted and managed by humans. Various stakeholders have had a significant impact on the preservation of Buxton Woods, and their perspectives moving forward must continue to be taken into consideration. To better understand the perspectives of stakeholders, we used a mental modeling approach, which provides insight into the heuristics that individuals use to process and store new information on a subject (Kolkman et al., 2005). We surveyed individuals with pre-existing connections to Buxton Woods to understand the similarities and differences between held perceptions. With multiple managing bodies and a diverse set of uses, considering various perspectives is essential to holistic and publicly acceptable management. Our limited survey presents emergent themes and case studies demonstrating the alignment and divergence across individuals' perceptions of Buxton Woods. To accomplish this purpose, we sought to answer the following question: How does the content and structure of the mental models of the maritime forest of Buxton Woods vary among stakeholders and nearby residents?

Methods

Participant Selection and Sampling

We selected our participants using purposive and snowball sampling by identifying persons who had a pre-existing relationship with Buxton Woods. In the 2021 study, eleven participants were interviewed to gather their personal history with and perception of Hatteras Island and Buxton Woods (Bailey et al., 2021). From that pool of interviewees, four of the 2021 participants, along with six new participants, were interviewed in our study. All ten interviewees reside in the same county as Buxton Woods: Dare County.

Conceptual Content Cognitive Mapping

When we better understand how stakeholders process their thoughts and feelings about a natural space, we can provide information to potentially assist stakeholders as they approach problems, solutions, or opportunities with that space in the future. Mind-mapping activities, including the Conceptual Content Cognitive Mapping (3CM) method developed by Kearny and Kaplan (1997), assess mental models, which are how individuals organize their thoughts about any given topic. Mental models “provide a framework for interpreting new information and determining appropriate responses to new situations” (Kearny & Kaplan, 1997). 3CM prompts participants to visually organize information and ideas about a topic using a card-sorting activity. The 3CM process begins with a focus question, and then instructs participants to choose from a set of 25-30 concepts that best answer the question for them. The participant is subsequently asked to group the concepts and then title and rank the groups (Biedenweg et al., 2013; Kearney & Kaplan, 1997). The concepts on the notecards, used to structure the participants' conceptualization of the question, are generally selected from a separate representative sample population.

Concept Collection

To select concepts for the 3CM card sorting activity, we analyzed the 2021 interviews with Buxton Woods stakeholders. For each interview transcript, we identified a list of concepts, terms, or ideas about the Woods discussed by the interviewee. Across the 11 interviews, we compiled 213 terms that were either significant or frequently mentioned, then narrowed the list down to 176 terms by eliminating concept overlap. Through an iterative process, we continued narrowing our pool of concepts and arrived at 26 final concepts that we agreed comprehensively conceptualized Buxton Woods.

Card-Sorting Activity

During one-on-one recorded interviews, which occurred throughout October and November 2022, ten participants were asked the open-ended question: "Imagine you're talking to someone who knows nothing about Buxton Woods. Which of these items or concepts do you need to be able to explain the Woods and why it matters to you?" Afterwards, we asked them to choose any of the 26 concept cards that they would use to best answer this question. They could also add concepts they felt were necessary to include by writing them on blank cards. As they selected cards, we inquired as to why they chose or left out certain cards. When they were satisfied with their choices, we asked them to group the cards into categories that made the most sense to them and to give each group a title. Finally, participants were instructed to rank the groups on a numerical scale (from one to however many groups they created) by importance in explaining Buxton Woods, with number one being the most important. Once their groups were ranked, we asked a series of debriefing questions to encourage broader reflection. One such question was: "How do you think your thinking about Buxton Woods has changed?" Once the interview ended, we took photographs of their groupings for data analysis.

Results

Content of Mental Models

The 3CM method produces both qualitative and quantitative data to analyze within and across participants. The data we collected for each participant includes the concepts selected, concept groups, group titles, and group rank, as well as the discussion that accompanied the card-sorting activity. The frequency of concept selection across our 10 interviewees ranged from 4 to 9 (Fig. 4). The average selection frequency for the 26 core concepts was 6.15.

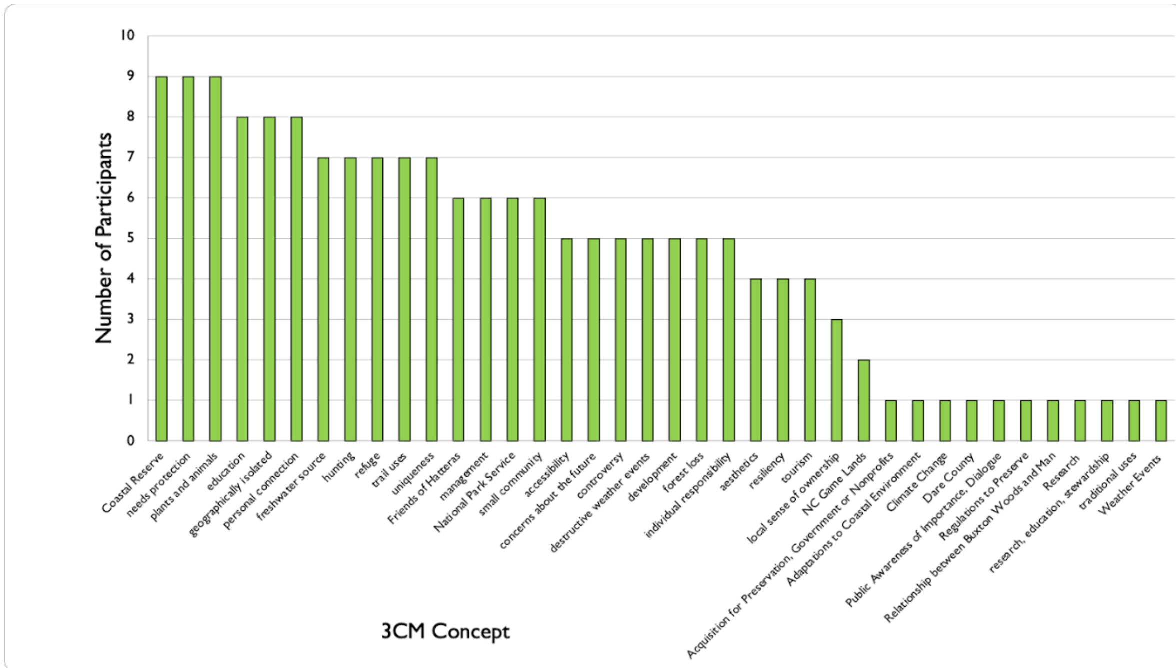

Figure 4. Frequency of concept selection by participants in a mental modeling study about Buxton Woods (n=10), including both the 26 concepts we provided and any additional concept created by participants.

Figure 4 also includes any concept added by the interview participants beyond the original 26 concepts. For example, the concepts *Dare County* and *research* both had a frequency of one. When including these additional concepts, the average frequency decreases to 4.55. It is also worth noting that there were commonalities across the newly formed concepts. The concepts *NC Game Lands* and *Game Lands* were added by two separate interviewees, giving this added concept a frequency of two. The fact that two participants separately felt it was necessary to supplement the core list of concepts with a form of Game Lands could imply that the concept should have been present in the original set presented to all participants.

In addition to providing quantitative data about the frequency of concepts selected by participants, the 3CM method's ranking system conveys the importance of concepts to interviewees. Per the 3CM method, when a concept is selected for their mental map, the participant establishes groups of concepts based on associations. After doing so, the interviewee classifies the importance of groups by giving each a group rank. This ranking only applies to the group established by the participant, not specific concepts themselves. To gain some understanding about the importance of the individual concepts themselves, we standardized group rank across all interviews using equation a below. The mean of these individual rankings was taken across all participants who chose the concept to get an average standardized concept group rank.

a. G=1- (r-1)/n

Where r = concept group rank, n = number of groups individual created, G = standardized concept group rank (Range 0-1, where 1 is most important)

Figure 5 plots standardized concept group rank relative to frequency of concept selection for the 26 core concepts. In Figure 5, *local sense of ownership*, for example, had a low selection frequency of three and a standardized concept group rank of 0.78. In other words, despite being selected by a minority percentage of the participants, *local sense of ownership* was perceived to be very important when chosen, as evidenced by its high ranking. On the other side of the spectrum, the concept of *National Park Service* was chosen by six out of ten participants. However, the concept was placed in lower-ranked groups with a standardized concept group rank of 0.44. This indicates that despite being selected by the majority of interviewees, *National Park Service* was considered less important compared to other concepts when explaining Buxton Woods. For one final example, *needs protection* is a concept with both high frequency and ranking values. More specifically, the majority of participants, nine out of ten, included the concept in their mental map. Of those nine individuals, they all ranked the group containing *needs protection* highly, leading to a calculated standardized concept group rank of 0.74. The high ranking and frequency suggests that among our interviewees, *needs protection* is perceived as necessary and pertinent by the majority of participants for their mental map of Buxton Woods.

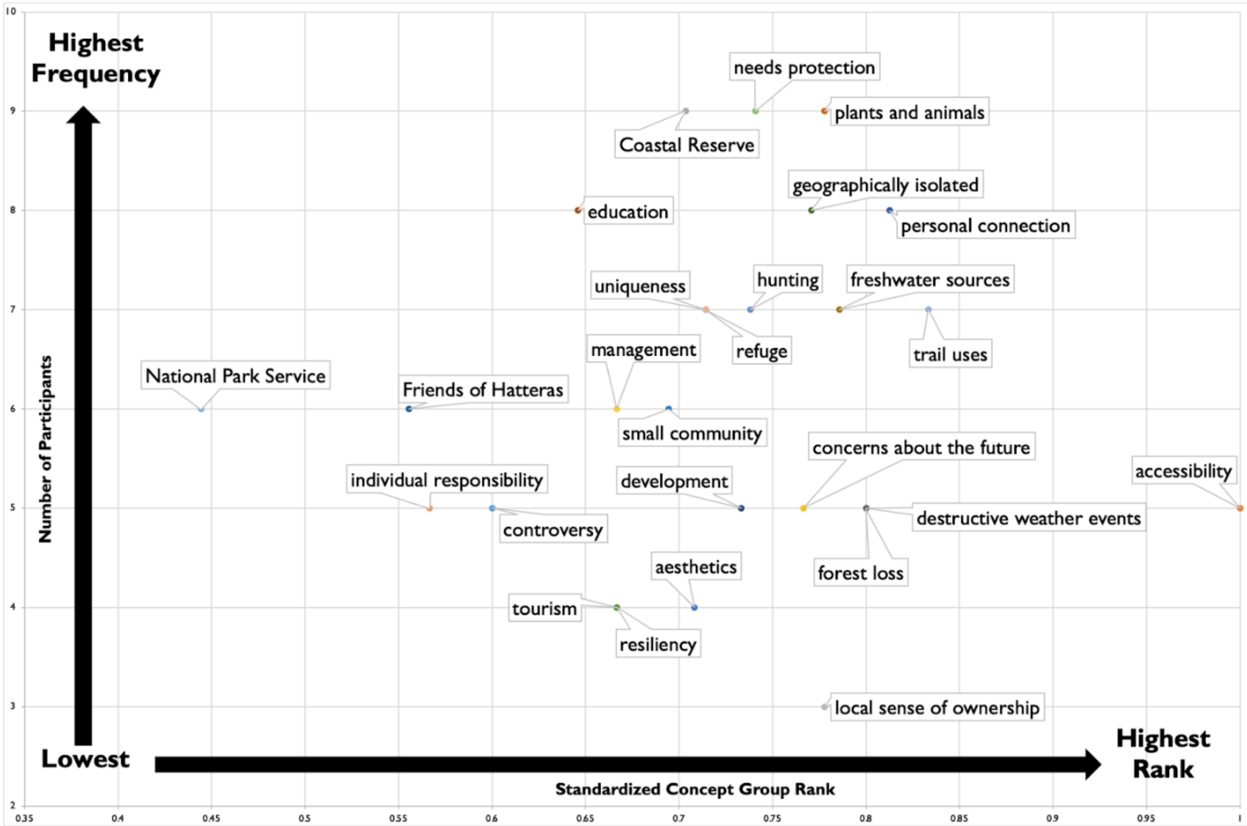

Figure 5. Frequency of concept selection and standardized concept group rank by participants in a mental modeling study about Buxton Woods (n=10) for the 26 concepts we provided.

The number of concepts selected by an interviewee ranged from 8 to 32 with a mean of 15.5, and the number of groups that those concepts were sorted into ranged from 1 to 6. We created a variable called Prominence to understand what combining frequency and group rank told us about the significance of each concept across all of the interviewees' mental maps. The participant-created concepts were excluded from this analysis due to their frequency of one except for *Game Land* and *NC Game Lands*, which were combined and included. This new variable highlights the salience of each concept across all of the interviews and allows for nuanced comparisons to be made. Prominence was calculated by combining the frequency with which a concept was chosen and its standardized group rank across all interviews using equation b:

b. $P = f/(2-MG)$

Where G = standardized concept group rank (Range 0-1, where 1 is most important), f = concept frequency, MG = mean G, P = Prominence

The more often a concept was chosen and the higher ranked group it was in when chosen increased its Prominence. Standardizing and combining these measures of importance allowed us to distill out the most valued concepts across all interviews (Fig. 6). This also allows for meaningful similarities and differences to be identified across demographic groups. Our analysis of this data looked at the content of interviewees' mental models and as a result, the qualitative trends were not assessed.

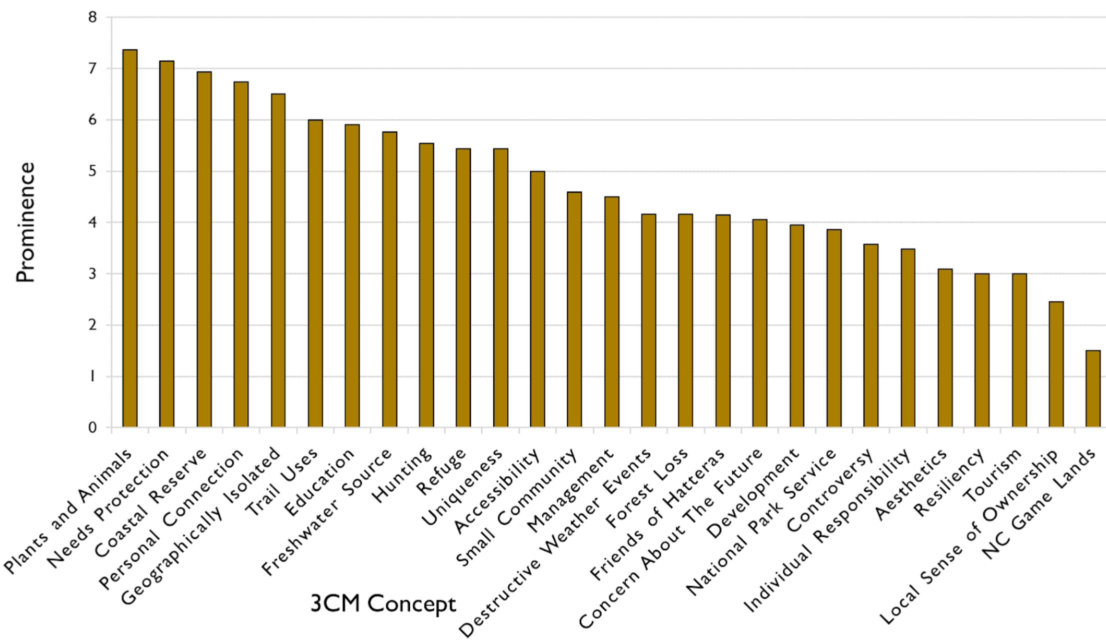

Figure 6. Prominence, the calculated variable combining frequency and standardized concept group rank, for the 26 provided concepts in a mental modeling study about Buxton Woods (n=10).

Structure of Mental Models

Once the interviewees selected concepts to answer the prompt, they were asked to group the concepts in ways that made sense to them. Figure 7 shows an example of two participants' created concept groups and titles. In order to begin qualitatively analyzing this portion of the activity, we identified groups that were given similar titles, and we refer to these as clusters. The first cluster we identified had some form of the word "conservation" in the group titles, while the second cluster had the term "management" in the group titles. Despite these similarities, we found varying perspectives within clusters. For example, conservation was viewed by some in terms of ecology, and by others in terms of usage of the Buxton Woods. We found these varying perspectives about topics within the clusters by identifying concepts that appeared in more than one group (overlapping concepts) and concepts that were related but only used once (non-overlapping concepts). Importantly, our analysis highlights that the Buxton community is composed of many varying perspectives, even on the same topic.

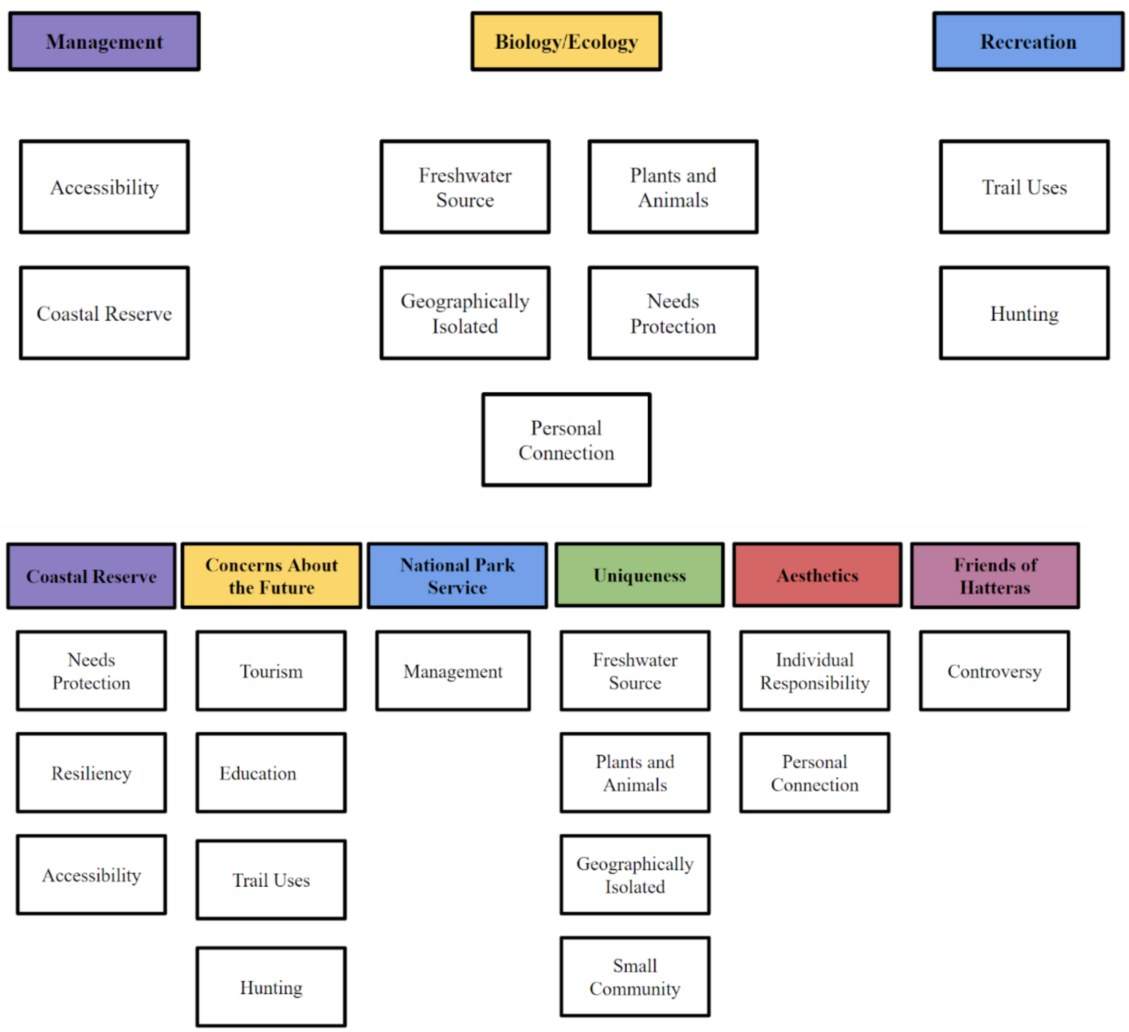

Figure 7: Examples of two interviewees' groupings.

Group Cluster 1: Conservation.

Four interviewees made a group about conservation (Fig. 8). These four group titles were as follows: two named "concerns about the future," one named "conservation" and another, "protective measures." In this sense, 40% of our interviewees decided that conservation and the future of the Woods is a topic worth discussing when describing Buxton Woods. Within these four conservation groups, we identified two themes: ecology and usage.

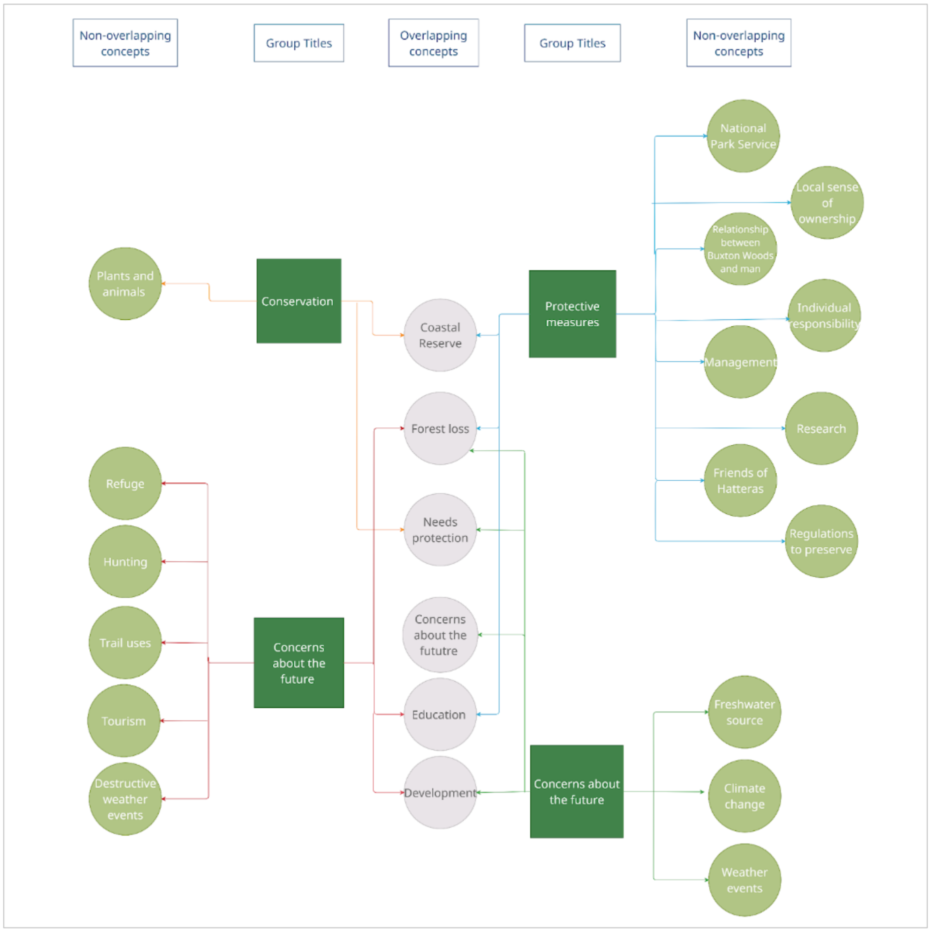

Figure 8. The four concept groups with a "conservation" theme in the title and their concepts.

Different forms of ecology were identified as an important theme within the groups regarding conservation and the future of Buxton Woods. These forms included, but were not limited to, forest loss, the effects of destructive weather events on nature, and plants and animals.

Three interviewees placed *forest loss* into a group relating to conservation. This was the most used concept among the groups, which shows that these interviewees were concerned that forest loss either is or will become an issue for Buxton Woods. According to our analysis of the recorded interviews, forest loss is understood in terms of development and large weather events. For example, a participant questioned what might be driving forest loss in the following quote:

"If you go on the nature trail, [...] all the big oaks are dying. Is it getting more impacted

by northeast winds? Is it [...] because the Park Service moved the lighthouse and created a huge swath of open area through the woods, and is there more infiltration of the salt spray there?"

This participant mentioned the National Park Service clearing land, which was a common topic for multiple people. Two of the participants with conservation-related groups used the concept *development,* and mentioned concerns about the correlation between forest loss and development via land clearing. The following quote also comments on this correlation:

"It breaks my heart to see some of these people come in and clear cut. You know, they'll take a piece of property here and they won't leave anything."

While Buxton Woods itself is protected land, adjacent development remains a concern for Buxton residents. Besides development, another way forest loss was highlighted was through the concept *destructive weather events.* Two interviewees spoke to the effects of hurricanes on the Woods, specifically in relation to trees.

"I remember going down there after [Hurricane Emily] and all these trees were down and then that's when the pine beetles came in [...] they go into dead pine trees and pretty much devour them."

"The hurricanes took a really deep toll when I first came here, particularly Hurricane Emily and it destroyed a huge number of pine trees."

Interestingly, both interviewees mentioned the loss of pine trees in a positive light, hypothesizing that this loss would make space for more "deciduous trees and live oaks." Whether or not forest loss was viewed positively, multiple participants mentioned forest loss throughout their interviews as a concern for conservation to focus on.

Besides forest loss, general ecology showed up in other ways. For example, an interviewee who works for a management agency valued protecting the land for the various wildlife that call it home – through the term *plants and animals*.

"I like to see different animals and wildlife and plants […] I think those things are really a crucial part of the ecosystem down there […] So I think I value protecting that land a lot."

Within the topic of conservation, there were different perspectives about what should be conserved. According to a few interviewees outlined above, value was placed on the general ecology of Buxton Woods as a driver for conservation.

The second theme related to the four "conservation" titled groups was a connection to the usage of Buxton Woods. This means that an important quality to conserving the Woods for these four people was maintaining the current and traditional uses that they know and love. Both groups titled "concerns about the future" included concepts related to usage: *hunting, trail uses, fresh water source, tourism,* and *research.* These concepts were discussed with a focus on the future, considering the groups they were placed in. For example, one interviewee used the concept *hunting* to explain the overhunting of ducks in Buxton Woods and what their future might look like.

> *"There's too many people [waterfowl hunting]. And not that it's wrong. It's just too many people doing it [...] [Ducks] just can't take that kind of constant disturbance. So they're just going to be out of there."*

Another interviewee spoke to the usage of water from Buxton Woods. The concept *freshwater source* sparked many questions for them, as seen in the following quote.

> *"The Dare County Water Department, are they really managing [the freshwater source] well?"*

They question this usage of the Woods in regards to a specific management entity, in this case Dare County. Yet another participant mentioned their own personal usage of the Woods, involving interests in birding and herping. These interests are values this person places on the Woods, and a reason for why conserving Buxton Woods is important to them.

> *"I really go there to just explore the wildlife. I also have a dog so I take her there to walk."*

Overall, the usage of Buxton Woods was provided as a reason why the Woods warrant protection. Certain concepts were used to explain why, including *hunting, freshwater source, trail uses,* and *plants and animals.*

To review, our analysis reveals a trend amongst nearly half of the interviewees to include conservation-minded ideas in the title of one of their groups. These groups reflected both a concern for the future and a need for protection. We found two main themes among these conservation-focused groups. First, the groups were highly connected to the specific ecology of Buxton Woods, such as forest loss, impacts of destructive weather events, as well as plants and animals. Secondly, the four conservation-minded focus groups also highlighted a connection to the usages of the Woods. Usage was mentioned in multiple ways, such as hunting, trail use, and water acquisition.

Group Cluster 2: Management.

Five out of our 10 interviewees created a group with "management" in the title, as seen in Figure 9. Management was a recurring and important idea to many of our participants. Similar to the group cluster about conservation, we analyzed this trend to find two different perspectives among these five participants regarding management of Buxton Woods: management entities and personal connection.

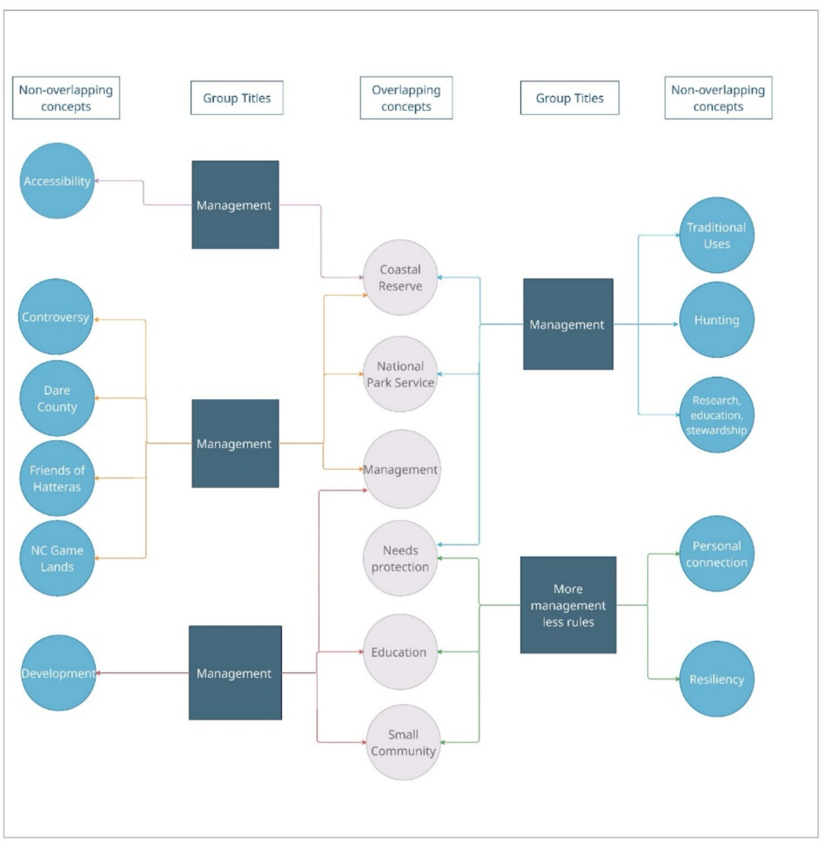

Figure 9. The five concept groups with "management" in the title and their concepts.

The first trend we identified between these five groups related to management entities. Three of the management-titled groups included concepts with specific agencies, such as *Coastal Reserve* and *National Park Service.* One participant even created two of their own entity-specific concept cards: *Dare County* and *NC Game Lands.* All of these participants reflected on the management strategies these agencies have implemented during their interviews, as well as the participants' own opinions on that work and how it should be done in the future. The following interviewee explained why they grouped the concepts *Coastal Reserve* together with a*ccessibility*:

> *"I put Coastal Reserve and accessibility together because the Coastal Reserve manages [Buxton Woods]... so accessibility is, in a sense, up to them."*

For this participant, management was viewed in terms of specific practices. Similarly, a participant that works for a management agency, spoke about Buxton Woods in terms of management practices at their own agency.

> *"Management incorporates the rules that protect the property, the different uses that occur on the property, working with different agencies to instill different programs on the property and then continuing that protection through good management decisions."*

Evidenced by both the selection and grouping of concepts, as well as particular statements by participants, one lens through which management is conceptualized focused on management entities. These entities ranged from Coastal Reserve to the National Park Service to Dare County.

Rather than focusing on specific agencies, some participants framed their discussion of management around their personal connection and usage of the Woods. This was done through the selection of concepts such as *education* and *small community.* One participant said:

> "*Education ties into management because it's how you're educating the public about how to use the land."*

This participant suggested that educating people about the Woods would inherently provide a form of management, as people will then understand how to make better use of the land on an individual level. If people know how to use and respect the land, much of it will remain intact and protected, according to them. Another participant noted that simply connecting people to the Woods was a way to increase awareness about the necessity of management.

> *"I would hope that I could instill the need for management through connecting people with it."*

Connecting people to the land, similar to educating the public, was viewed as a way to manage the land.

Overall, the participants who created a group with management in the title primarily viewed the concept in one of two ways. For some, management was approached in terms of specific management entities, such as the National Park Service. Others viewed management through their own personal connection to the Woods.

Our data show that there were two main concept group clusters across interviews: conservation and management. On the topic of conservation, participants perceived its importance through an emphasis on the current and future states of ecological factors and/or important uses of the Woods. The groups titled management also had two different perceptions of the topic: one related to the work of specific management agencies, and another about participants' own connection to Buxton Woods. Overall, we found that there were varying perspectives on these topics despite similarities in grouping and titling of the concept groups.

Trends Among Stakeholder Groups

Among the ten interviewees included in the study, four worked in natural resource management, and six were Buxton residents unaffiliated with management. Historically, residents and users of Buxton Woods have contended with governmental natural resource management entities over space use and regulations. Given these historical conflicts, a modern analysis of stakeholder perceptions of natural spaces must differentiate between resident and management professional responses.

Figure 10 depicts the concepts most important to management-affiliated and resident interviewees, based on the frequency of concept selection and its corresponding rank when chosen. Concepts that appear in the central green circles were chosen by both management and residents who ranked them highly. It is critical to note that concepts appearing on one side of the figure, such as *forest loss*, were not exclusively chosen by management or residents but were more frequently selected or ranked higher in one group. For example, *geographically isolated* was selected by both residents and management. Residents simply selected it more frequently and ranked it higher relative to other groups, whereas management selected it less frequently and ranked it relatively less important. Therefore, *geographically isolated* is connected to "Residents."

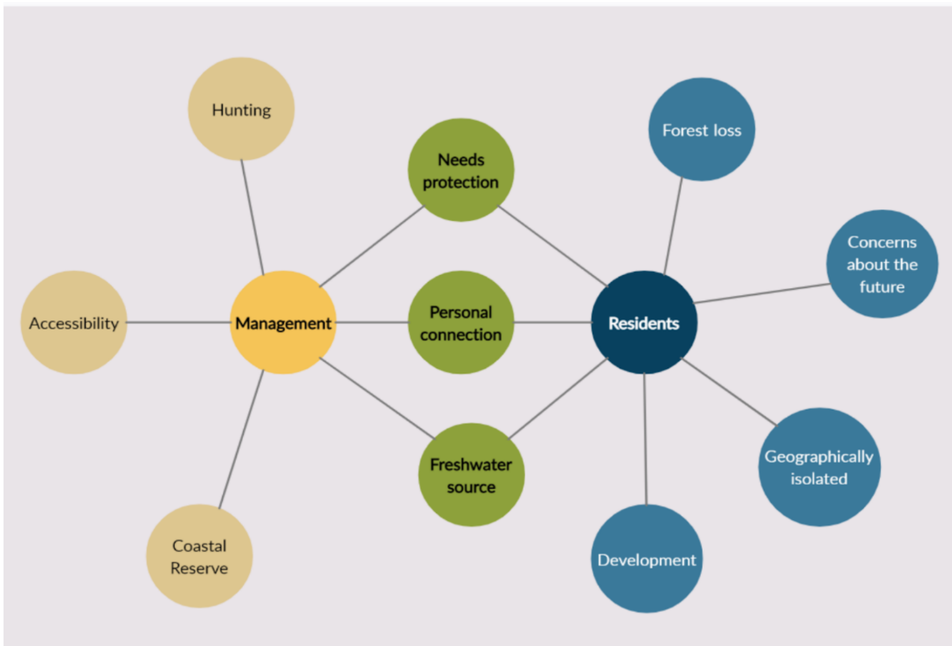

Figure 10. Concepts that were important to management professionals and residents in a mental modeling study about Buxton Woods (n=10). The concept *plants and animals* was important to both stakeholder groups, but is not pictured.

Overall, management-affiliated interviewees found *accessibility*, *hunting*, and the *Coastal Reserve* to be the most important elements in describing Buxton Woods and why it matters to them. Residents unaffiliated with management found *forest loss*, *concerns about the future, geographically isolated*, and *development* to be the most important concepts.

Participants' use of Buxton Woods shapes their attachment to the natural space. For residents, *geographically isolated* was often grouped with *plants and animals* and *uniqueness.* These natural characteristic concepts were frequently grouped with other concepts describing the use value for recreational activities. One participant, for example, cited that the natural spaces afforded by the Woods made it a "very special place for [horseback] riding." These types of groups attempted to describe a sense of natural space and its relation to human use. Several interviewees titled these groups "uses" or "public use/involvement" and included the concepts *hunting* or *trail uses.* Residents' groupings demonstrate use-specific valuations associated with Buxton Woods.

In contrast, management professionals created place-based groups in ways that implicated their roles in natural resource management. One manager created a group called "Location," which included the concepts *refuge*, *geographically isolated*, and *uniqueness*. This participant stated:

> *"I think the reserve is […] just a different environment than anything else. And it's obviously a refuge for a lot of animals."*

The role of Buxton Woods as a wildlife refuge was significant to this participant's occupation and place-based personal activities, such as wildlife watching. Another management professional created a group titled "Game Lands," which included the concepts *hunting*, *personal connection*, and *controversy*. When asked to explain their choice, this participant stated:

> *"[...] you got the Coastal Reserve, and the game lands fall under the Coastal Reserve […] That is so people can hunt."*

Though this management professional was not involved in hunting directly, their descriptions of Buxton Woods relied on an understanding of the hunting regulations within the Coastal Reserve. For this management professional, traditional uses and needs shape management and regulation in Buxton Woods.

Another manager asserted that Buxton Woods is a place characterized by how it is managed "predominantly for research, education, and stewardship, while allowing for traditional uses." Through this perspective, the landscape of federal and state regulations in Buxton Woods delegates the parameters of its uses. Managers' concept groupings suggest a different, managerial layer to place-based perceptions of the Woods – in which research, education, and regulation of traditional uses play key roles.

One of the most notable differences between these stakeholder groups was that while *forest loss*, *concerns about the future*, and *development* were selected often by residents, these concepts were rarely or never selected by management-affiliated individuals. Resident interviewees often grouped these concepts together, suggesting a dominant connection specific to the residents we interviewed. One resident interviewee placed *forest loss*, *needs protection*, and *development* in a group named "concerns about the future." The reasoning for this grouping stemmed from two central beliefs: that Buxton Woods is a special place for its natural features and freshwater aquifer, and that it is threatened by development and climate change.

> *"Why [Buxton Woods] needs protection? There's climate change […] and a freshwater source which […] people and the ecosystem rely on."*

This interviewee further explained their selection of *needs protection* by stating that "development is out of control" on Hatteras Island.

Interviewees in natural resource management positions did not group together *concerns about the future, forest loss, development*, and *needs protection*. However, *geographically isolated* was often grouped with *plants and animals* and other biogeochemical features of the space, such as *freshwater source*. *Needs protection* was sometimes grouped with *plants and animals*. More often, *needs protection* was placed in groups related to management or containing management-related cards. One interviewee commented:

> *"I value protecting that land a lot. And then I guess that rolls into how you manage the land […] Just seeing how much land is being developed down there is pretty crazy and there really is not a lot of refuge lands."*

When asked why they selected *needs protection*, another interviewee noted:

> *"It has habitats that need to be protected because they're unique globally. And it just, you know, it keeps some area natural and a huge area in the context of the Outer Banks natural with surging homebuilding… And so, being in this position you know, you realize the history that makes the place and the management that's guiding decisions forward."*

Management professionals reasoned that development in the Outer Banks made protecting the plants and animals of Buxton Woods critical, yet did not explicitly choose to include *development*, *forest loss*, or *concerns for the future* as concept cards. Instead, many management-affiliated participants emphasized management entities, like the Coastal Reserve or National Park Service, and their importance in protecting Buxton Woods from threats like development. Managers tended to emphasize communication and education about Buxton Woods as a way to protect the natural resources in an area developing so rapidly. As a result, we found diverse ways of thinking about the future of the Woods in the context of the dynamic Hatteras Island.

Both management professionals and residents deemed the concepts *needs protection*, *personal connection*, *freshwater source,* and *plants and animals* very important by their high frequency of selection and high rankings relative to other concepts. Regardless of occupation, interviewees each expressed a meaningful, personal connection to Buxton Woods and a desire to protect the natural resources and recreational opportunities offered by the place. General interviewee sentiments were summarized well in a statement offered by one resident:

"It's [Buxton Woods] holding the island together."

Limitations and Insights

Three main limitations impacted our results and analyses: overall study limitations, method limitations, and application limitations. Overall study limitations included our small sample size; only ten people were interviewed. We cannot generalize from our results to the broader Hatteras Island population. Within this small interviewee pool were six residents and four management-affiliated professionals. We found overlap between residents and management professionals in our interviews as some of the management professionals live near Buxton Woods. This limits the application of these results to other areas of study.

The 3CM method itself has inherent limitations. The process entailed choosing concepts from last year's interviews that we thought were important, meaning we had a direct influence on participants' responses. A different group of researchers might have selected a different set of concepts. While this cannot be controlled, it is important to consider as we cannot identify what influence our concept selection had on the responses of our interviewees. Additionally, the concepts themselves had innate positive, negative, or neutral connotations and could have been either too specific or not specific enough. For example, the generality of *plants and animals* on its own did little to reveal the thought process behind participants' mental maps. This inconsistency throughout the concepts could have effects we are unaware of.

Continuing with 3CM limitations, participants had trouble when answering the prompt during interviews. To reiterate, the question asked was: "Imagine you are talking to someone who knows nothing about Buxton Woods. Which of these items or concepts do you need to be able to explain the Woods to them and why it matters to you?" This is two questions in one, and often caused confusion. Some interviewees became concerned as to whether their answers truly fulfilled the prompt, which might have influenced how concepts were grouped. If this study were to be repeated, we would suggest that this question be reworded or broken into two parts. Two rounds of the grouping activity might help eliminate this uncertainty. Overall, the question should have been more developed and clarified.

Finally, we did not establish a fully standardized interview process. While the interviewers followed a guide, each interview was conducted by a different student. This resulted in oddly posed prompts, uncertainties surrounding how many groups were to be chosen, whether concepts could be chosen as group names, what part of the question should be answered first, and more. In addition, some interviews were conducted in semi-shared spaces. A more standardized interview script and time spent testing the guide more thoroughly before implementation would have improved the process and confidence in our results.

Additional background considerations could have improved our insights. For example, stakeholders' perspectives of other maritime forests in North Carolina are unexplored. Other local stakeholders could provide a worthwhile comparison and a further area of study. Additionally, an exploration of existing historical records at the Outer Banks History Center (Manteo, NC) could contain older aerial photos of the Woods and transcripts of past interviews for further comparison and discussion (Bratton & Davison, 1987). Lastly, considerations of major historical events in the area could reveal other overlooked patterns and how social norms affected who interacted with the Woods and how.

Conclusions

Natural spaces, like forests, are often valued for their restorative effects on individuals (Simkin et al., 2021). Communities create attachments to these natural, communal spaces and stakeholders often seek to protect these areas. For example, Jekyll Island, a barrier island community in Georgia, has their own maritime forest to protect. Local management professionals have started the process of “evaluating stakeholder attitudes toward management options” (King & Nibbelick, 2018). They hope to follow a “semi-structured” interview process to determine the acceptability and support of current and future plans. The 3CM method used in our study could be a tool to facilitate those considerations.

Pro-environmental behaviors by resource users are important to park managers because they reflect '...actions that generate positive environmental impacts, promote environmental quality, and result in sustainable use of natural resources'" (Larson et al., 2018). For the entities involved in managing Buxton Woods, future efforts could include repeating or emulating Snider et al. (2010), who focused on the importance of education, leading nature-based activities to encourage interest, reaching out to stakeholder organizations and persons, and discovering what news media and platforms share updates. As a participant summarized:

"I think [Buxton Woods] is probably the most influenced by people's feelings."

In order to successfully understand these paramount feelings, management must seek that in-person feedback from stakeholders.

In conclusion, while our data are suggestive rather than definite, we provide insights into community and management stakeholder perspectives of Buxton Woods. Interview participants created a snapshot of their various knowledge, opinions, and connection to the Woods. Their wants and desires regarding how the space should be used determined the formation of various mental models. These models, generated through the 3CM method, will continue to change and evolve over time. Despite chosen concepts and groupings varying greatly, we identified patterns and nested patterns through both quantitative and qualitative analyses. This reflects the diversity of interviewee backgrounds and engagement with the Woods. In general, there was, and continues to be, great concern for the future of this forest. Our research provides a potential resource to increase collaboration between stakeholders and to allow these different groups to come together through a shared concern and care for Buxton Woods.

Natural System

Introduction

Maritime forests are successional ecosystems with dynamic plant communities. Different areas within the same forest experience various levels of elevation, soil moisture, and disturbances. Therefore, maritime forests are prone to both short-term and long-term shifts in vegetation (Woods et al., 2021). This study divided vegetation in Buxton Woods into two categories: woody stem counts and overall cover of vascular plants. Plants with woody stems make up the understory and overstory canopy of the forest. They are important in regulating environmental factors, such as light and salt spray. Overall cover, the measure of presence and spatial extent of all vascular plants, helps determine plant diversity and biomass (Peet et al., 1998). Using these two categories, we attempted to answer the question: How and why has the vegetative community structure and composition in historical plots in Buxton Woods changed since 1988?

Methods

Carolina Vegetation Survey

This research project used the Carolina Vegetation Survey (CVS) method to measure the structure and composition of vegetation in the plots. Created as a multi-institutional research project, the CVS method provides a snapshot of vegetative communities present at the time of sampling. The method was designed to standardize the documentation of vegetation composition in the Carolinas (Peet et al., 1998). The maritime forest vegetation data from 1988, to which we compare our 2021/22 data, were the first to be collected using the CVS method (Peet et al., 2013).

Plots Sampled

The original 1988 study sampled several plots representing different plant communities throughout Buxton Woods. In this year's study, we resampled two of those plots (Fig. 11). Plot 001-01-0213, originally sampled May 26, 1988, was resampled Sept. 23, 2022 and represents a midslope environment. Plot 001-01-0208, an upland plot, was originally sampled May 25, 1988 and resampled Oct. 5, 2022. This paper also includes data from three plots resampled last year (Bailey et al., 2021; Fig. 10). Plot 001-02-0207, a swale originally sampled May 25, 1988, was resampled in Sept. 2, 2021. Plot 001-01-0209, another swale, was originally sampled May 25, 1988 and resampled August 31, 2021. Finally, plot 001-002-0206, representing an upland dune, was originally sampled May 25, 1988 and resampled October 8, 2021.

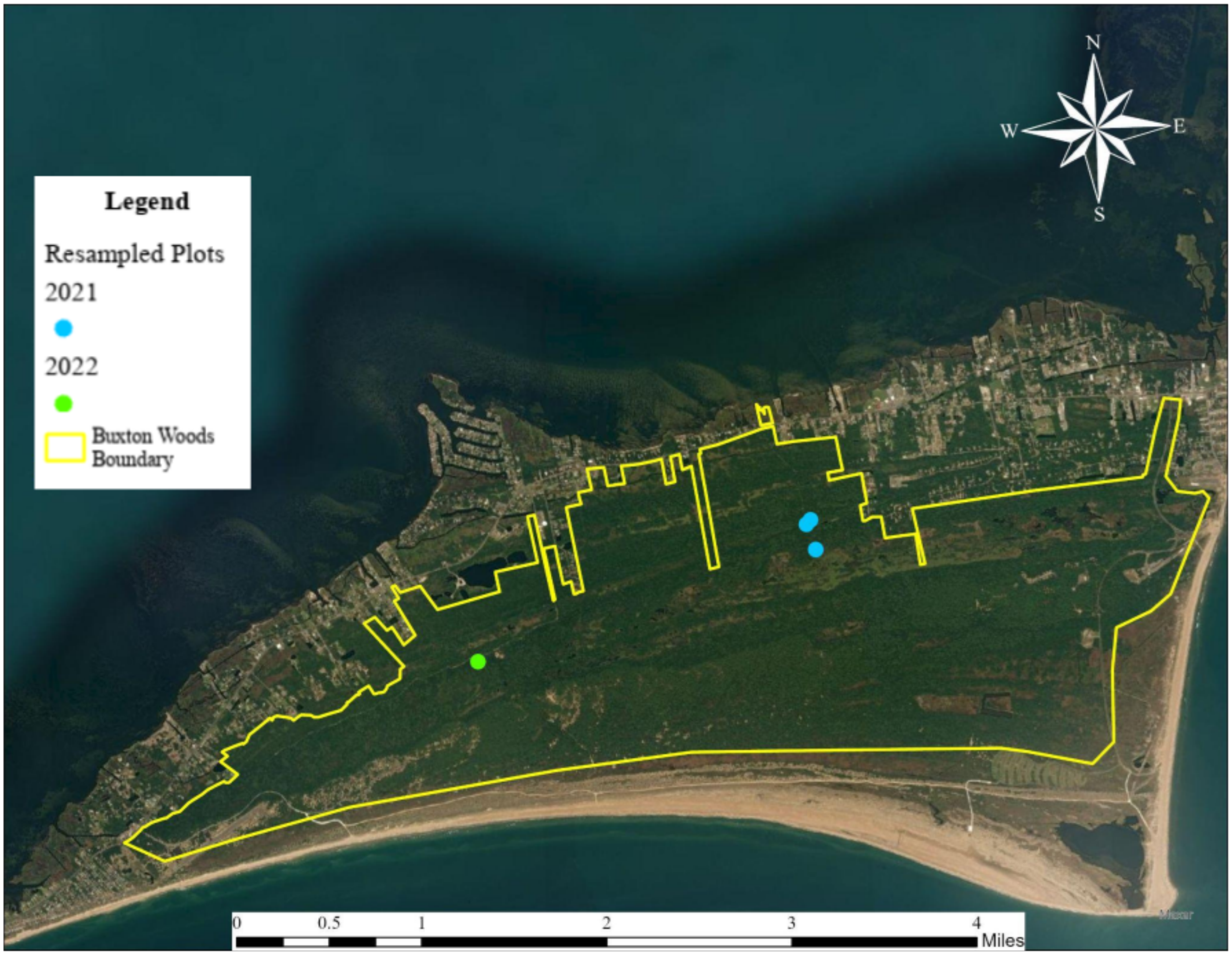

Figure 11. Map depicting five previously sampled plots established in the Buxton Woods by the Carolina Vegetation Survey (Peet et al., 1998) in 1988 that were resampled in 2021 and 2022. Due to the scale of the map, plots 0206 and 0208 appear as one dot.

Plot Structure

Each plot is divided into 10m-by-10m sections, called modules (see Fig. 12). In this year's research, we resampled plot 0208, which consisted of five modules, and plot 0213, which contained ten modules. The same intensive modules established in 1988 were resampled: two for the smaller plot and four for the larger plot. Two of the four corners of each intensive module were marked with flags as intensive corners and resampled.

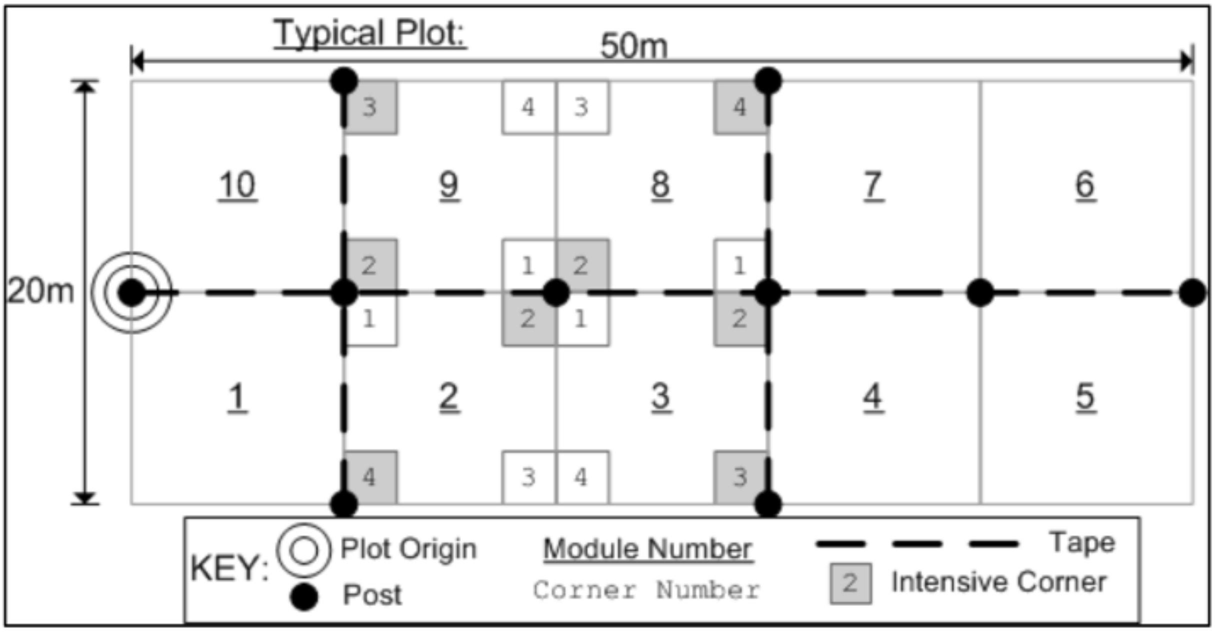

Figure 12. Diagram of a 10-module plot, like plot 0213 in this study of the change in the vegetation of the Buxton Woods. This diagram highlights four 10m-by-10m intensive modules within the plot, with two intensive corners each (Peet. et al., 1998).

Cover Methods

As detailed in the CVS method, we recorded the plant cover and species presence at five layers of depths in intensive corners, from largest to smallest: 0.01 m^2, 0.10 m^2, 1.00 m^2, 10.0 m^2, and 100 m^2. We recorded the cover and presence of each new vascular species subsequently encountered throughout the intensive modules and then the whole plot; those encountered outside of the intensive modules but within the plot were recorded as “residual.”

The cover team also recorded percent cover of each species at the herbaceous, shrub, and tree strata. Herbaceous species ranged from 0-0.5 m tall, shrubs ranged from 0.5-5 m tall, and trees were all vascular species above 5 m in height. The cover of individuals spanning multiple strata was broken up into cover of the plant for each stratum level. To mitigate error from inferring percent cover of plants, the CVS method uses ten cover class levels representing ranges of percent cover (Table 1).

Cover Class	Range of Percent Cover
1	trace
2	0-1
3	1-2
4	2-5
5	5-10
6	10-25
7	25-50
8	50-75
9	75-95
10	> 95

Table 1. Cover classes used to capture the range of percent cover for each species in a Carolina Vegetation Survey plot. Cover classes range from a trace amount to >95% (Peet et al. 1998).

Reported overall percent cover reflects the stratum with the highest percent cover for each individual species. Data is reported as the mean of the range of percent cover for respective species. While we recorded percent cover of individual species at every stratum, the researchers in 1988 only recorded overall percent cover of each species in the intensive modules.

Woody Stem Methods

According to the CVS method, we recorded the species, number, and diameter of all vegetative species (woody stems) in each plot at breast height, 137.5 cm. The diameter at breast height, or DBH, was split into ten classes by centimeter ranges: 0-1, 1-2.5, 2.5-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, and 35-40 cm. Any stems above 40 cm were measured individually to the nearest 0.5 cm. DBH measurements are reported as the mean of the class's diameter. We did not count any woody stems that did not reach breast height or were dead. Unlike woody stems sampling in 1988, we did not measure vines that reached breast height.

Unknown plant identification

Unidentified plants (n=3) were collected, including the roots, and pressed in the lab. We then identified them using print and web-based plant guides (Schultz, 2022; Faucette et al., 2020).

Results

The following results are divided into two themes: *composition* and *structure*. Composition refers to the species richness of the vegetative community. Species richness is the number of unique species found in a defined area. Structure expands on composition, indicating the location and spread of each species, which is measured by cover, strata, and stem size.

Theme 1: Forest Composition

Species Richness

Species richness can be used to measure forest composition change by revealing plant biodiversity and fluctuations over time. Across all plots, species richness increased from 1988 to 2021/2022 by 4 species (Table 2). The five plots resampled in 2021 and 2022 lost 12 species but gained 16 since 1988 (Table 2). Last year, two non-native grasses were identified (Bailey et al., 2021), however no other non-native species were present. Buxton Woods lost and gained plants at every strata level. At the individual plot level, species richness remained relatively constant. However, in Plot 0209, species richness increased from 20 to 28 unique species. Overall, four out of five plots reported increased species richness, indicating the forest is more diverse than in 1988.

Species Abundance

Canopy-forming species, or woody stems, make up the overstory and understory of Buxton Woods. The majority of the woody stems sampled in 1988 remain in the five resampled plots. However, the species abundance, or number of individuals of each species, has changed (Fig. 13). Most notably, the total stem count of *Benthamida florida* (Flowering Dogwood) decreased by 238 stems since 1988 (Fig. 13). In addition, *Carpinus caroliniana* (Ironwood) lost 99 stems and *Quercus hemisphaerica/laurifolia* (Red Oak) lost 94 stems. Stem counts of several species remained stable, including *Quercus virginiana* (Live Oak), *Swida foemina* (Swamp Dogwood), and *Morella cerifera* (Southern Wax Myrtle). However, several other species experienced a large increase in stem count. *Pinus taeda* (Loblolly Pine) saw an increase of 219 stems in the five sampled plots. Also, *Persea borbonia/palustris* (Red/Swamp Bay), *Ilex vomitoria* (Yaupon Holly), and *Ilex opaca* (American Holly) increased by 179, 72, and 70 stems, respectively.

Table 2. Plants Gained and Lost from 1988 to 2021 and 2022 in plots 0206, 0207,0 208, 0209, and 0213 in Buxton Woods. Overall, sampled plots lost gained species.

2020s Species Change	
Plants Lost	**Plants Gained**
Berchemia scandens	Arundinaria tecta
Boehmeria cylindrica	Aralia spinosa
Decumaria barbara	Chamaecrista nictitans
Elephantopus sp.	Dicanthelium sp.
Galium hispidulum	Digitaria sp.
Gaylussacia frondosa	Eleocharis falvescens
Lonicera sempervirens	Hypericum hypericoides
Poaceae sp.	Juncus effusus
Rhus copallinum	Leersia virginica
Rubus L. sp.	Mikanius scandens
Spiranthes odorata	Rhynchospora miliacea
Woodwardia virginica	Rubacia sp.
	Salix sp.
	Sceptridium biternatum
	Thelypteris palustris
	Vitis aestivalis
net total:	**4**

Focusing on the woody stem species at a plot level further clarifies changes in species abundance. “Midslope” plot 0213 (Table 3A), had an average elevation, a medium soil moisture, and was set on the side of a dune. In 1988, this plot (Table 3A) was dominated in stem count by *Quercus hemisphaerica/laurifolia* and *Carpinius Caroliniana.* In 2022, it was dominated by *Persea borbonia/palustris* and *Pinus taeda*. This plot also saw a drastic increase of 177 individuals. Two “Upland Dune" plots, 0206 (Table 3B) and 0208 (Table 3C), were characterized as having a high relative elevation and a low soil moisture. In 1988, plot 0206 (Table 3B) was dominated by *Benthamidia florida* and *Q. hemispherica/laurifolia.* In 2021, it was dominated by *Ilex opaca* and *Pinus taeda.* Plot 0208 (Table 3C) was dominated by *B. florida* and *Carpinus caroliniana* in 1988. In 2022, plot 0208 followed the same trend as plot 0206: domination by *Pinus taeda* and *Persea borbonia/palustris.* Both “Upland Dune” plots slightly decreased in overall stem count. Two “Swale” plots, 0207 (Table 3D) and 0209 (Table 3E), had relatively low elevation and high soil moisture. In 1988, plot 0207 (Table 3D) was dominated by *Swida foemina,* and in 2021, was still dominated by *S. foemina* but with the addition of *Persea borbonia/palustris.* Plot 0209 (Table 3E) was dominated by *B. florida* and *Q.*

hemispherica/laurifolia in 1988, and then by *C. caroliniana* and *Pinus taeda* in 2021. The two "Swale" plots not only differed in dominating species, but also had drastically different total stem counts, with less than 30 stems in plot 0207 compared to over 150 in plot 0209.

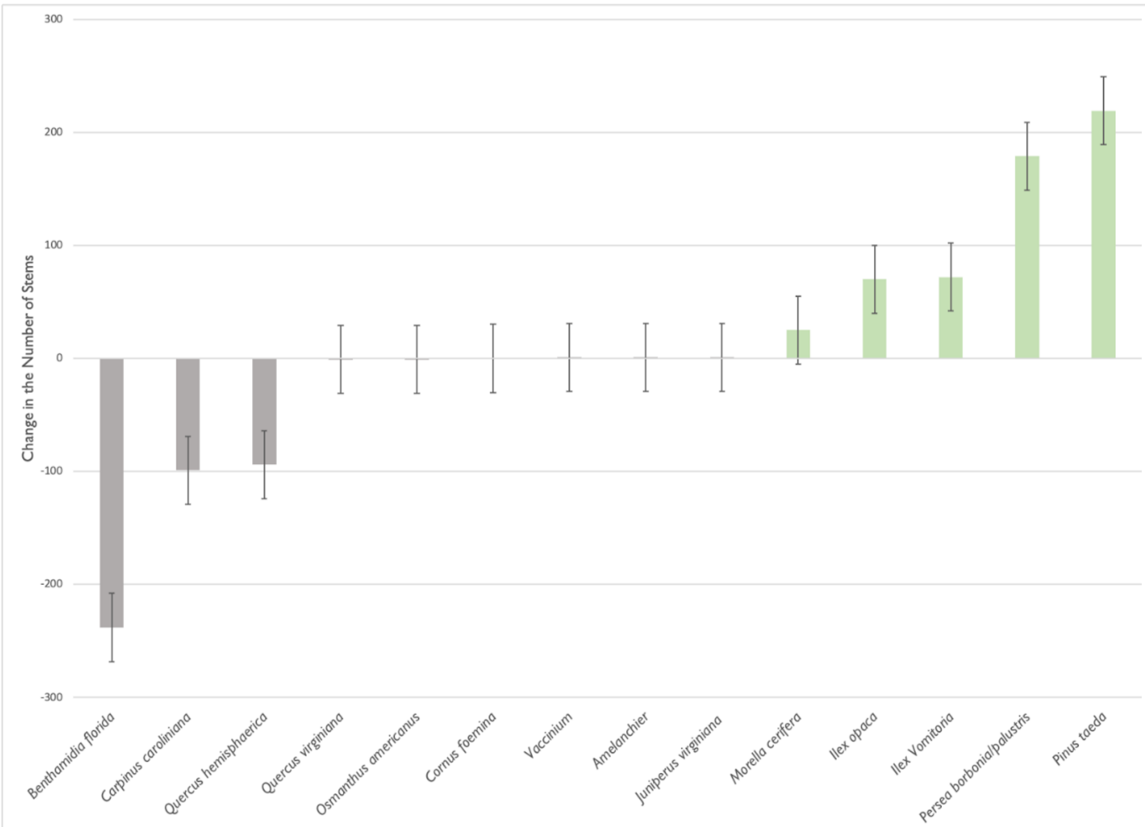

Figure 13. Change in stem count, or number of individuals at breast height, organized by species, from 1988 to 2021 and 2022 in plots 0206, 0207, 0208, 0209, and 0213 in Buxton Woods. Grey represents a decrease in the number of stems present, green represents an increase in the number of stems present, little to no change is seen in several species. *B. florida, C. caroliniana, and Q. hemisphaerica* saw the greatest decrease in stem count, and *P. borbonia/palustris* and *P. taeda* saw the greatest increase in stem count.

Considering all five sampled plots, there were many *Quercus hemispherica/laurifolia* and *Benthamidia florida* stems in 1988, while in 2021 and 2022, there were more *Pinus taeda* and *Persea borbonia/palustris* stems. In addition, there was a slight decrease in total stem count in most plots, with the exception of plot 0213 (Table 3A).

Table 3. Woody stem species abundance from 1988 to 2021 and 2022, represented as percent of total number of stems sampled at the plot level in Carolina Vegetation Survey plots in Buxton Woods. (A) "Midslope" Plot 0213, (B) "Upland Dune" Plot 0206, (C) "Upland Dune" Plot 0208, (D) "Swale" Plot 0207, and (E) "Swale" Plot 0209.

A.

Stem Species	**1988**	**2022**
Benthamidia florida	5%	0%
Carpinus caroliniana	21%	1%
Ilex opaca	0%	4%
Ilex vomitoria	3%	13%
Morella cerifera	0%	0%
Persea borbonia/palustris	16%	41%
Pinus taeda	0%	25%
Quercus hemisphaerica/laurifolia	53%	16%
Vaccinium	1%	0%
Total Stems	327	504

B.

Stem Species	**1988**	**2021**
Benthamidia florida	25%	0%
Carpinus caroliniana	7%	2%
Cartrema americanum	1%	0%
Ilex opaca	8%	28%
Ilex vomitoria	19%	16%
Morella cerifera	1%	5%
Persea borbonia/palustris	3%	1%
Pinus taeda	7%	26%
Quercus hemispaherica/laurifolia	29%	22%
Quercus virginiana	1%	0%
Total Stems	197	170

C.

Stem Species	**1988**	**2022**
Benthamidia florida	55%	6%
Carpinus caroliniana	31%	12%
Ilex opaca	0%	10%
Ilex vomitoria	3%	5%
Morella cerifera	0%	7%
Persea borbonia/palustris	3%	18%
Pinus taeda	8%	25%
Quercus hemisphaerica/laurifolia	0%	13%
Vaccinium sp.	0%	2%
Total Stems	214	201

D.

Stem Species	**1988**	**2021**
Carpinus caroliniana	0%	9%
Morella cerifera	4%	4%
Persea borbonia/palustris	19%	22%
Pinus taeda	0%	9%
Swida foemina	73%	57%
Vaccinium sp.	4%	0%
Total Stems	26	23

E.

Stem Species	**1988**	**2021**
Benthamidia florida	40%	0%
Carpinus caroliniana	17%	26%
Ilex opaca	0%	1%
Ilex vomitoria	2%	15%
Morella cerifera	1%	1%
Persea borbonia/palustris	12%	12%
Pinus taeda	8%	23%
Quercus hemisphaerica/laurifolia	20%	10%
Vaccinium sp.	0%	1%
Total Stems	169	151

Theme 2: Forest Structure

Cover and stem diameter describe the structure of the forest, including the vertical and horizontal distribution of vegetation. Cover is the amount of visible, above-ground plant biomass. Stem diameter reveals age and growth rates.

Cover Change

Several species across the five plots demonstrated a large change in cover from 1988 to 2021 and 2022. The species with the greatest decline in cover were *Benthamidia florida, Pinus taeda,* and *Persea borbonia/palustris.* Those with the greatest increase in cover were *Ilex opaca*, *Muscadinia rotunifolia (*Muscadine Vine)*,* and *Morella cerifera* (Fig. 14). However, the cover of most species remained stable overall across plots.

Decrease in Cover

Pinus taeda exhibited the greatest overall loss in cover – 34%. In 1988, *P. taeda* cover ranged from 62.5% in upland and swale plots (0208 and 0209), 37.5% in upland and swale (0206 and 0207), and 3.5% in midslope plot (0213). *P. taeda* cover decreased by more than half in all plots, except the midslope. In upland plot 0208 and swale plot 0209, *P. taeda* dropped to about 5% of its original value.

*Benthamidia florid*a experienced the second largest reduction in cover (Table 3). Once a dominant understory tree, covering roughly 29% of sampled area in 1988, as of 2021 and 2022, the percentage plummeted to <1%. *B. florida* loss was concentrated in plot 0208, decreasing from about 59% to 3.5% cover. However, in plots 0206, 0209, and 0213 *B. florida* decreased from 37.5%, 37.5%, 7.5% to zero. No *B. florida* saplings were found in these plots, indicating complete die-off and lack of regrowth.

Figure 14. Greatest changes in percent cover of plants found in five Buxton Woods Carolina Vegetation survey plots from 1988 to 2020s. Increases are represented in green, and decreases in gray. Most species' cover remained stable with minimal changes.

Table 4. Cover change at the individual Carolina Vegetation Survey plots (0206, 0207, 0208, 0209, 0213) in Buxton Woods from 1988 to 2021/2022. In general, all plots decreased in percent cover except for plot 0206.

Plot	1988 Cover (%)	2021/2022 Cover	Point Change (%)
0206	135.4	140.7	5.3
0207	151.9	87.1	-64.8
0208	168.8	109.5	-59.25
0209	226.2	49.1	-177.1
0213	131.6	91.35	-40.3

Table 5. Species as drivers of cover change across all plots. Measured plots include Carolina Vegetation Survey plots (0206, 0207, 0208, 0209, 0213) in Buxton Woods from 1988 to 2021/2022. (0206, 0207,0 208, 0209, and 0213). Cover change percentages calculated based on midpoint cover classes.

Drivers of Plot Cover Change				
	Positive Cover Growth		Negative Cover Growth	
Plot	Species	% cover change	Species	% cover change
0206	*Ilex opaca*	34.0	*Benthamidia florida*	-37.5
	Quercus hemisphaerica/laurifolia	25.0	*Pinus taeda*	-20.0
	Morella cerifera	7.0		
0207			*Pinus taeda*	-34.0
			Benthamidia florida	-30.0
			Berchemia scandens	-17.5
	Muscadinia rotundifolia	7.0	*Persea. borbonia/palustris*	-16.0
0208	*Carpinus caroliniana*	20.0	*Benthamidia florida*	-59.0
	Ilex opaca	17.0	*Pinus taeda*	-59.0
	Quercus hemisphaerica/laurifolia	14.0		
	Muscadinia rotundifolia	7.0		
0209			*Pinus taeda*	-59.0
			Benthamidia florida	-37.5
			Quercus hemisphaerica/laurifolia	-35.5
			Persea. borbonia/palustris	-30.0
			Carpinus caroliniana	-20.0
0213			*Carpinus. caroliniana*	-17.0
			Quercus hemisphaerica/laurifolia	-10.0
			Benthamidia florida	-7.5

Persea borbonia/palustris cover decreased by 10% across all plots. P. *borbonia/palustris* cover shrunk in plots 0209, 0207, decreasing by 30%, 16%, and 4%, respectively. Cover remained constant in the upland plots. Net loss in cover is concentrated within tree species, highlighting a changing understory and overstory canopy from 1988 to 2020s.

Increase in Cover

While the cover of many species declined, *Ilex opaca, Muscadinia rotundifolia,* and *Morella cerifera* had large increases in cover: 11%, 3.31%, and 1.32%, respectively. *I. opaca* cover increased in every plot, expanding more than 10-fold in the upland plots, and it more than tripled in the rest. *M. rotundifolia* increased in four out of 5 plots, most notably by 7% in mid and upland plots (0207 and 0208). However, the *M. rotundifolia* cover decreased in upland plot 0206. *M. cerifera* increased in 3 plots: (0206, 7%, 0207, 1%, and 0213, 0.05%), but decreased in upland plot 0208. *I. vomitoria* increased in three plots, including an upland, midslope and swale plot but dropped in a separate upland plot 0206. These notably increasing species are shrub-tree species more common in earlier successional stages.

Stable Cover

Many plants experienced minimal to no change (-.7% to .7%). The species with the most stable cover was *Quercus hemisphaerica/laurifolia* (28.8%). Although *Q. hemisphaerica/laurifolia* decreased by 14 percentage points in swale plot 0209, it increased in two upland plots (0208 and 0209), and remained stable in the rest. Overall, *Q. hemisphaerica/laurifolia* dominate the overstory canopy in the (62.5%) upland and midslope plots (0206 and 0213), maintain a fraction of tree cover (17.5%) in upland plot 0208, and is not found in the others. Only found in swale plot 0207, *Swida foemina* continues to dominate cover (62.5%) at the tree level.

Stem Distribution

Woody stems are canopy-forming species, and the size of their stems can indicate their maturity and role in forming the canopy of a forest. Larger, hardwood species create the overstory of the five sampled plots, such as *Quercus hemisphaerica/laurifolia* and *Carpinus caroliniana.* Other species, such as *Benthamidia florida* and *Quercus virginiana,* create the understory of the canopy. The woody stem species observed in the five sampled plots showed great variation in stem diameter. Some species were dominated by individuals with small diameters, indicating they are juvenile. Whereas some had much larger average diameters, indicating they are mature, while others had widely dispersed stem diameters (Fig. 16). In 1988, *C. caroliniana*, *I. vomitoria*, *I. opaca*, and *P. borbonia/palustris* had small stem diameters, with median stem diameters measuring 1.75 cm, 1.75 cm, 1.75 cm, and 0.50 cm, respectively. Their mean stem diameters measured 2.85 cm, 1.54 cm, 2.84 cm, and 1.79 cm, respectively. In

1988, *P. taeda* and *Q. hemisphaerica/laurifolia* had relatively wider distributions of stem diameters, and larger median and mean stem diameters. *P. taeda* had a median diameter of 32.5 cm and an average diameter of 33 cm. *Q. hemisphaerica/laurifolia* had a median diameter of 12.5 cm and an average diameter of 9.98 cm.

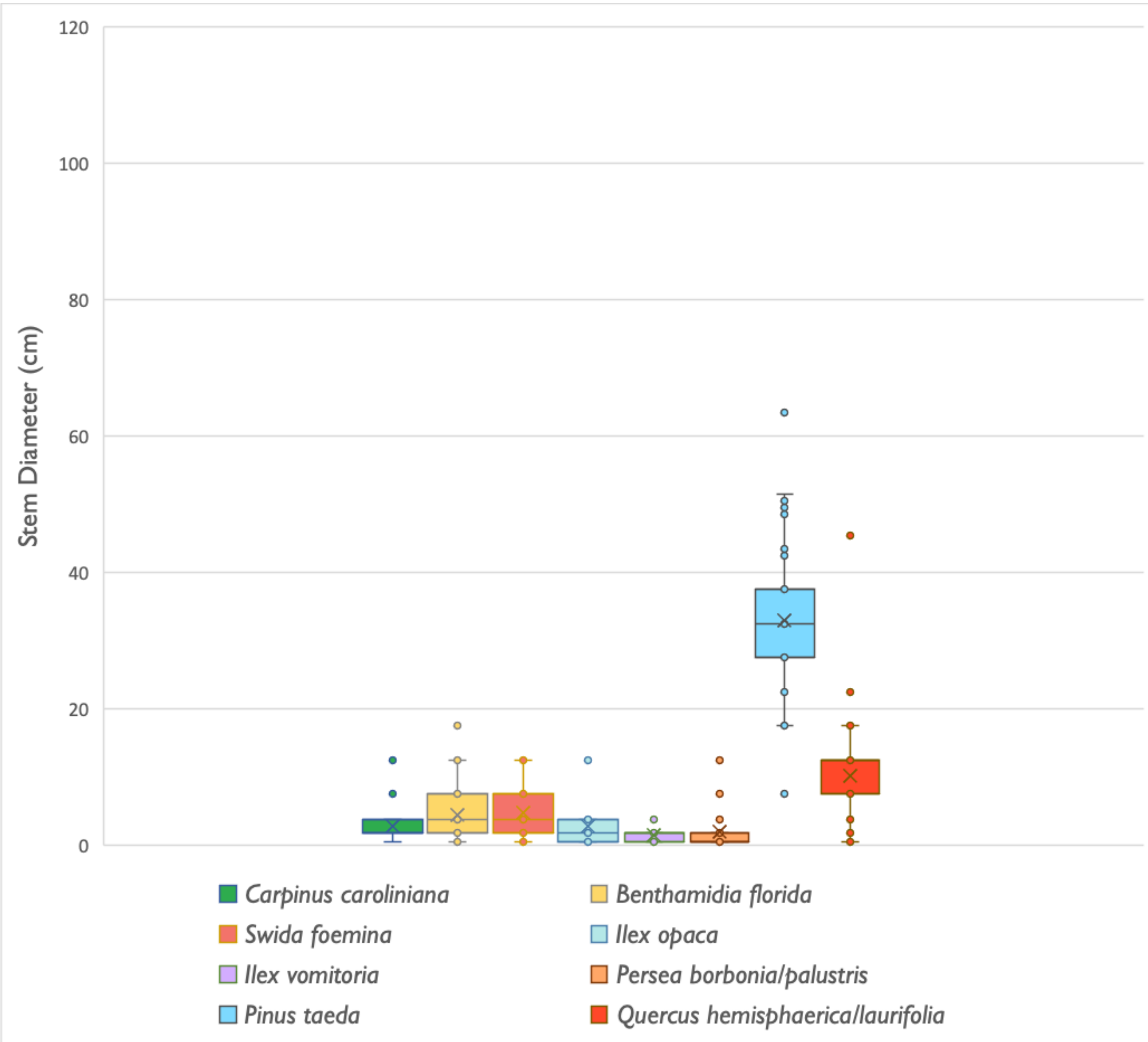

Figure 15. Distribution of stem diameter of select woody stem species (those with highest stem count) found in plots 0206, 0207, 0208, 0209, and 0213 in 1988 in Carolina Vegetation Survey plots with Buxton Woods. Lower quartile, median, upper quartile, minimum, and maximum are represented with box and whisker, with outliers beyond the structure.

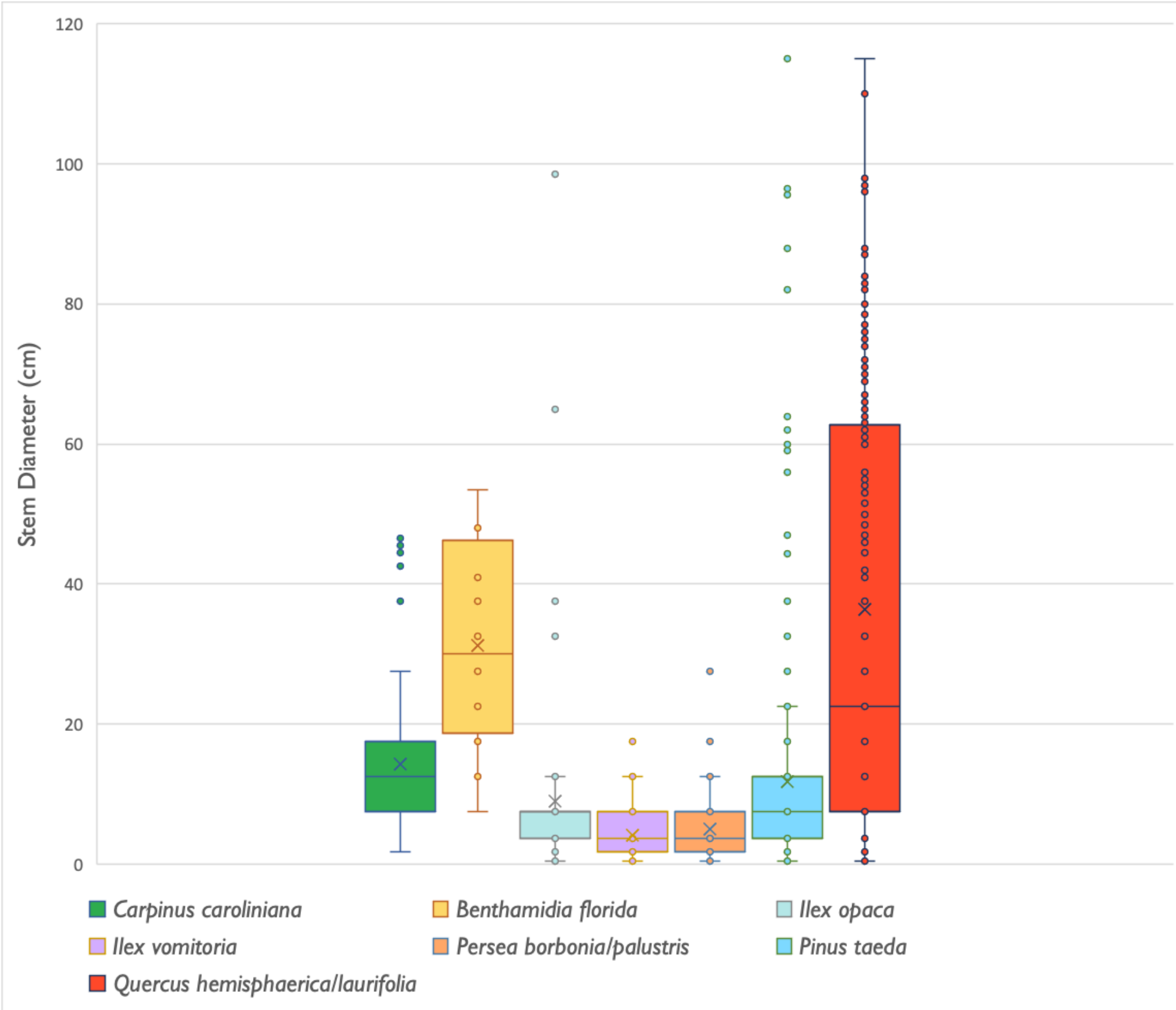

Figure 16. Distribution of stem diameter of select woody stem species found in plots 0206, 0207, 0208, 0209, and 0213 in 2021 and 2022 in Carolina Vegetation Survey plots within Buxton Woods. Lower quartile, median, upper quartile, minimum, and maximum are represented with box and whisker, with outliers beyond the structure.

Looking back at the five plots sampled in 1988 (Fig. 14) and comparing to present day (Fig. 15), the distribution of the size of woody stem species has changed. Species including *Ilex opaca*, *Ilex vomitoria*, and *Persea borbonia/palustris*, continue to have a smaller distribution with smaller stem diameters compared to other species. Their median diameters in (1988) are 7.5 cm, 3.75 cm, and 3.75 cm, respectively. Their average stem diameters were 8.92 cm, 4.12 cm, and 5.03 cm, in (2021/2022). On the other hand, *Benthamida florida* and *Quercus hemisphaerica/laurifolia* had a much wider distribution of stem diameters and a larger mean diameter. The median stem diameters were 30 cm in (1988) and 22.5 cm in 1988, respectively.

Their average stem diameters were 31.29 cm in (2021/2022) and 36.40 cm in (2021/2022). The median stem diameter of *Q. hemisphaerica/laurifolia* increased by 20 cm and the average stem diameter increased by 26.42 cm since 1988, indicating the species is maturing. However, the median stem diameter of *Pinus taeda* decreased by 28.75 cm and its average diameter decreased by 28 cm since 1988, indicating there are less mature *P. taeda* individuals and more juvenile individuals today.

Combined Results: Composition and Structure

Combining the themes of forest composition and forest structure, as seen in Figures 16 and 17, highlights that prominent woody stem species have all changed from 1988 to 2021 and 2022 in the five sampled plots. *Ilex opaca* and *Ilex vomitoria* increased in average stem diameter, number of individuals, and average percent cover. *Benthamida florida* saw a decrease in individuals, average percent cover, but an increase in average stem diameter, suggesting a die off of this species, with an exception for a few that matured. *Quercus hemisphaerica/laurifolia* grew in average stem diameter, average percent cover, and slightly decreased in stem count, suggesting a maturing population. *Persea borbonia/palustris* and *Pinus taeda* increased drastically in stem count, decreased in average stem diameter, and drastically decreased in average percent cover, pointing to a loss of mature individuals and an increase in juveniles. *Quercus virginiana* remained stable in number of individuals, slightly decreased in cover, but grew nearly 3-fold in average stem diameter, suggesting the majority of the same individuals remain in the plots, and they have matured since 1988.

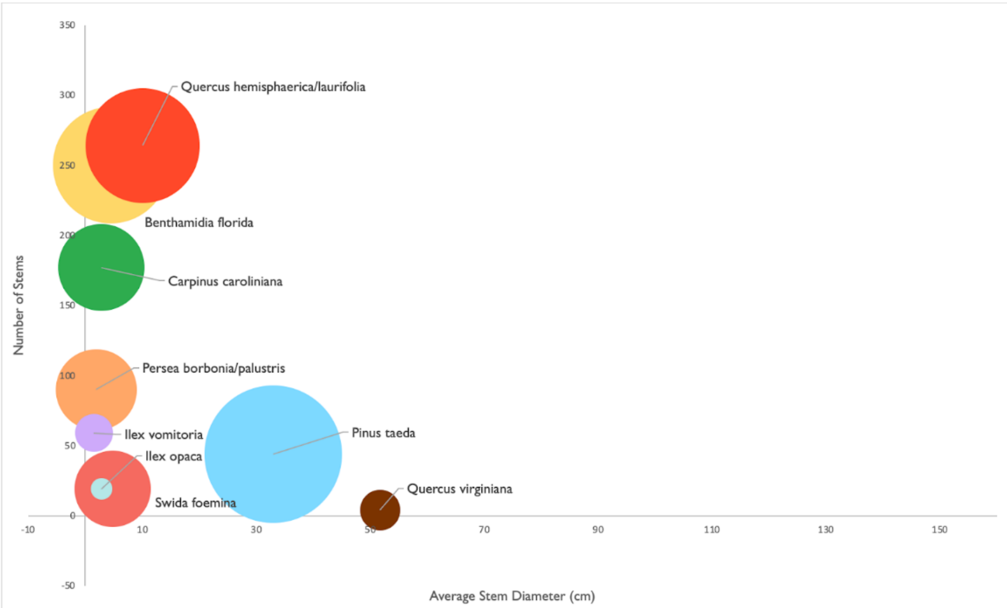

Figure 17. Average stem diameter and number of stems of select woody stem species from Carolina Vegetation Survey plots 0206, 0207, 0208, 0209, and 0213 in Buxton Woods in 1988. Each "bubble" represents a species, the vertical axis represents total stem count of species across five plots, horizontal axis represents average stem diameter of observed individuals, and size of "bubble" represents average percent cover of species across the five plots.

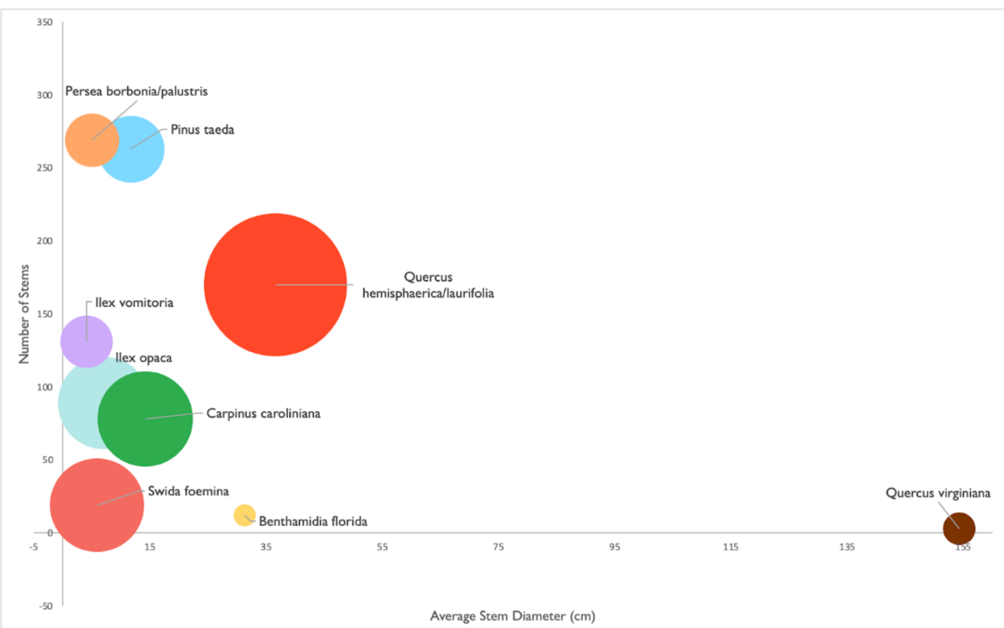

Figure 18. Average stem diameter and number of stems of select woody stem species from Carolina Vegetation Survey plots 0206, 0207, 0208, 0209, and 0213 in Buxton Woods in 2021 and 2022. Data point size represents percent cover of each species. Each "bubble" represents a species, the vertical axis represents total stem count of species across five plots, horizontal axis represents average stem diameter of observed individuals, and size of "bubble" represents average percent cover of species across the five plots.

Summary of Results

Our data suggest similar composition and structure trends across the sampled plots. Today's plots are more diverse, but less dense than in 1988. Species richness increased across all plots despite a decrease in the midslope plot 0213. Cover, or the area plants take up, declined in four out of five plots, indicating less plant overlap and density. A loss of *Benthamidia florida*, *Pinus taeda*, and *Persea borbonia/palustris* are driving the cover decline (Table 5).
Once dominant cover species, *P. taeda* and *P. palustris/borbonia,* suffered major die-offs of mature individuals, but experienced replacement by many juveniles—increased stem count but decreased stem diameter—across plots (Fig. 17, Fig. 18). *B. florida* decreased in cover with minimal replacement trees. The hardwood trees, such as *Quercus sp.*, are maturing with minor increases in juvenile trees and cover. Lack of juveniles indicates these later successional species may struggle to replace dead, old trees, preventing successional transitions.Salt-tolerant shrub tree species like *Morella cerifera*, *Ilex opaca,* and *Ilex vomitoria* are increasing in population, but maintaining the same population age (Fig. 17, Fig. 18).

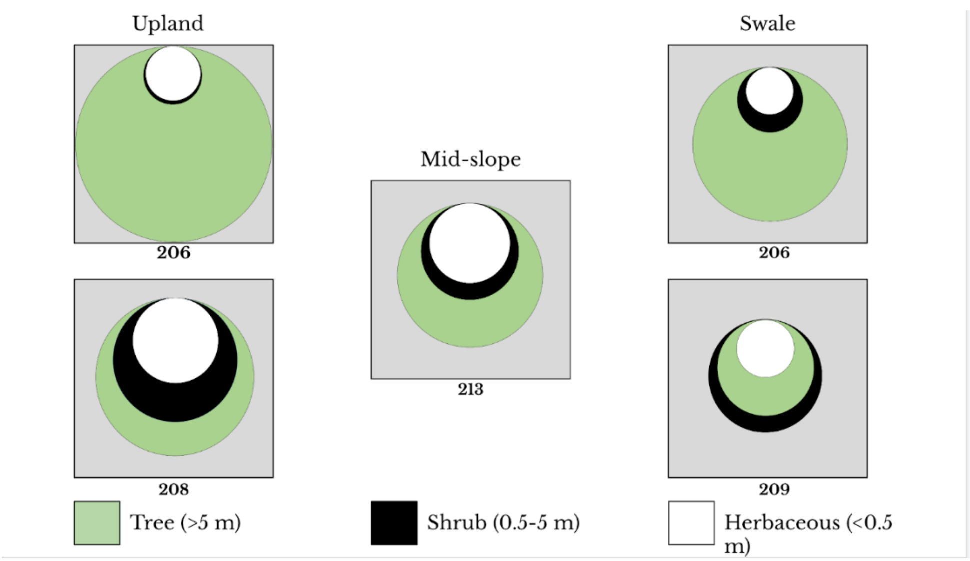

Figure 19. Cover visualization, density, from Carolina Vegetation Survey plots 0206, 0207, 0208, 0209, and 0213 in Buxton Woods in 2021 and 2022. Each plot is standardized to 100% cover. Circle diameter calculated from sum of each species cover class midpoints at three strata levels. In all plots, except for upland plot 0209 where shrubs dominate, trees dominate canopy cover.

Maritime forests are an ever-shifting mosaic of successional stages, evident by the distinctive vegetation composition and structure within each sampled plot. For example, swale plot 0209's cover dropped to one-fifth of its 1988 cover with *Benthamidia florida* and *Pinus taeda* cover decreasing from 30% to 0% and 60% to 3.5%, respectively. Loss of these tree species opens the canopy, allowing more sunlight to shine through and earlier successional plants like herbs and shrubs to grow. In this same plot, we see greater cover of shrubs than trees (Fig. 19).

However, early successional trees like *Pinus taeda* are incredibly fast growers and prolific seed-droppers– more so than hardwood trees like *Carpinus caroliniana* and *Quercus Sp.* (Bellis & Keough, 1995). *P. taeda* cover and diameter dropped in swale plot 0209, but stem count increased indicating replacement of mature, large-cover trees with young, small-cover juveniles. The reduced tree cover, coupled with the increase in number of *P. taeda* juveniles, and larger shrub cover indicates this swale plot may have experienced disturbances, resulting in resetting of the ecosystem to an earlier successional stage.

On the other hand, Figure 19 shows that Upland plot 0206 has the largest tree canopy cover. It was the only plot to increase in cover from 1988, with hardwood *Quercus hemisphaerica/laurifolia* driving the increase in cover. The continued expansion of this species may be evidence of later succession.

Discussion

Maritime forests are in a constant state of change. Located on barrier islands, they impact and are impacted by processes that cause these islands to move (Zinnert et al, 2016). Buxton Woods is no different. From 1988 to today, the vegetative composition and structure of Buxton Woods has changed significantly, likely attributed to continuous disturbances such as diseases, pests, storm events, salt spray, animals, and hydrological changes. In this section, we will be discussing possible explanations for the trends noticed in the sampled plots.

Theme 1: Forest Composition

Forest composition is an explanation as to what species are present/absent in Buxton Woods. Disturbances related to composition, like diseases and pests, target individual species. Across all five plots, *Benthamidia florida* stem count and average cover decreased dramatically while average stem diameter increased (Fig. 17, Fig. 18) As an understory tree, *B. florida* may experience shady, wet conditions. While protected from salt spray and storm damage by canopy species, the lack of sunlight and abundance of moisture makes them susceptible to the disease dogwood anthracnose (Guldin & Moltzan, 2012). This disease is caused by the fungus *Discula destructiva*, which was introduced to the northeastern region of the US in the 1970s from Asia. The fungus spread rapidly, killing up to 89% of *B. florida* in some areas (Anderson et al., n.d.). It made its way into Western North Carolina by 1988, and it has been officially observed in Dare County (USDA Forest Service, Northern Research Station, 2019). Infection seems to be most severe in young seedlings, more shaded individuals, and on north-facing slopes (Guldin & Moltzan, 2012). This could explain why average stem diameter increased across all five plots (4.53 cm to 31.29 cm) if older individuals survived. In addition, greater infection rates on north-facing slopes could explain why there was a complete loss of *B. florida* in plot 0206 (37.5% cover to 0%), a north-facing slope, while plot 0208, a south-facing slope, had major die offs but still had individuals present (59% cover to 3.5%). Dogwood anthracnose could explain why 238 *B. florida* stems were lost and overall cover dropped by 28.3 (±10.83) percentage points.

Another disease potentially found in Buxton Woods is laurel wilt. In 2011, this disease was first observed in North Carolina (North Carolina Forest Service, n.d.). Laurel wilt is caused by a fungus that *Xyleborus glabratus* (redbay ambrosia beetle) transports from tree to tree. The fungus infects species in the Lauraceae family, which includes *Persea borbonia/palustris*. *X. glabratus* is originally from southeastern Asia and was brought over to the southern region of the US. If a tree is infected, the leaves change from green to reddish-brown and typically stay attached to the tree for more than a year. The disease impacts more mature individuals, rather than juvenile species. It has been found to kill >90% of *P. borbonia/palustris* that are larger than 2.5 cm in diameter (North Carolina Forest Service, n.d.). This allows for juvenile populations to grow, but few reach maturity.

Laurel wilt is commonly found in the southeastern region of the US, but has not been recorded in Dare County, even though it has been identified in neighboring counties (North Carolina Forest Service, n.d.). The patterns of change in *Persea palustris/borbonia* populations indicate that this disease may be present, even though it has not been officially observed. The population of *P. palustris/borbonia* increased from 90 to 269 individuals. About 8% of the individuals found today had a stem diameter that was greater than 10 cm, indicating that the populations in the samples are mostly juvenile. During the sampling process, *P. palustris/borbonia* stems in the plots were observed to have reddish-brown leaves in the plots, which look similar to those infected with laurel wilt (North Carolina Forest Service, n.d.). The number of trees with only these leaves were not recorded in our sampling, so it is undetermined how many trees laurel wilt could potentially be infecting.

Pinus taeda is also susceptible to diseases and pests. One of these pests is *Dendroctonus frontalis* (southern pine beetle). After Hurricane Emily in 1993, there was an outbreak of *D. frontalis* in the Buxton area (Nadeau, 2021). Outbreaks can cause weakened or damaged trees to die. Infestations are less common on barrier islands, but they have happened before. In the sampled plots, the average stem diameter decreased from 33 cm to 11.75 cm. However, there was an increase in the total number of stems from 44 to 263. This indicates an increase in juveniles and loss of mature individuals. The native pine beetle could be affecting the species, causing a decrease in the population. The increase in juveniles could be due to other factors discussed later.

Theme 2: Forest Structure

Forest structure builds on forest composition as it describes where species are found and their cover, strata, and stem size. In this section, we will be discussing possible explanations for the trends noticed in the sampled plots. One of these species is *Quercus virginiana,* which is known to be one of the most resistant species in maritime forests (Bellis & Keough, 1995). *Q. virginiana* has strong and resilient bark, and it is a salt tolerant species, making them an ideal species to reside in maritime forests. A study done after Hurricane Camille hit the Gulf of Mexico in 1969, stated that with their root systems and their ability to withstand strong winds, *Q. virginiana* is resistant (Bellis & Keough, 1995). Fewer trees were impacted by this storm than other species, such as *Pinus taeda* and *Benthamidia florida*. Buxton Woods has experienced several major hurricanes since the 1988 study was completed, including Hurricane Emily in 1993. Only one *Q. virginiana* has been lost since 1988 while the rest of the individuals matured, further suggesting demonstrating the resiliency of the species. Even though *Q. virginiana* is adapted to survive in a maritime forest ecosystem, their stem count did not increase. *Q. virginiana* is a slow growing species, which makes it uncommon for juvenile species to grow and survive with other faster growing species (Bellis & Keough, 1995). No juvenile *Q. virginiana* individuals were found in the plots sampled here. The potential juvenile individuals were likely outcompeted for sunlight and space by faster-growing species.

Another major canopy species in maritime evergreen forests is *Quercus hemisphaerica/laurifolia* (Bellis & Keough, 1995). This species is moderately salt spray tolerant

(Glen, n.d.), and it can withstand hurricane-force winds with low rates of limb breakage (Braswell, 2019), making it well-adapted to survive two major facts of life on a barrier island. Across all five plots, a decrease of 94 *Q. hemisphaerica/laurifolia* stems was observed, while average stem diameter increased from 10.11 cm to 36.6 cm. Cover increased or was stable in most plots (Fig. 14). This is evidence of a maturing of the individuals seen in 1988. The species' ability to resist strong winds and salt spray could explain their persistence. Another reason could be that *Q. hemisphaerica/laurifolia* is a relatively fast grower. This allows for juveniles to compete with other species (Carey, 1992), and plenty of seedlings were observed in the sampled plots.

Pinus taeda is found in maritime forests because they are salt tolerant species and germinate at higher salinities (Woods et al., 2021). They are a faster growing species that seeds profusely, so juveniles are plentiful (Bellis & Keough, 1995). Unlike *Quercus virginiana*, *P. taeda* is less resistant to storms. Two studies completed after Hurricanes Camille and Hugo hit the Gulf of Mexico and Charleston, SC respectively, found that *P. taeda* mostly stayed rooted in the soil, but their trunks snapped (Bellis & Keough, 1995). In the plots that were sampled, the number of individuals increased, but the average stem diameter and cover decreased. With the multiple major hurricanes that Buxton Woods experienced from 1988 to present-day, this could explain why there were fewer mature *P. taeda* and more juveniles. The individuals that are present in Buxton Woods today might not have experienced any major storm events, prevailing winds, or other disturbances that would cause the trees to break. *P. taeda* can be considered a resilient species as they can reproduce and grow rapidly, even if they cannot resist storm damage as well as other species.

Along with storms, salt spray is a constant controlling force in maritime forests. Canopy trees, such as *Quercus hemisphaerica/laurifolia, Quercus virginiana*, and *Pinus taeda* can reduce salt spray in understories, allowing for less tolerant species, such as *Benthamidia florida,* to thrive (Bellis & Keough, 1995). Major storms like Emily (1993), Isabel (2003), and Dorian (2019) can destroy canopy trees, ripping holes into the protection they provide, and exposing the understory to salt spray. Across all of the plots we sampled, stem counts of *Ilex opaca, Ilex vomitoria,* and *Morella cerifera* increased by 70, 72, and 25, respectively. As did their average stem diameters and cover (Fig. 17, Fig. 18). In fact, *I. opaca* had the greatest increase in overall cover (11% ±6.52). These three species were primarily observed at the shrub and herbaceous height levels. Also, overall cover in most of the plots decreased from their 1988 levels (Fig. 21). This suggests a less dense forest that might experience increased salt spray in its understory as *I. opaca, I. vomitoria*, and *M. cerifera* were primarily observed there and all three increased across all our variables. As these younger trees grow, holes in the canopy might be filled and salt spray may become less of an influence on understory species.

Other Considerations

While we parsed out possible major reasons for the observed trends, there are many others, such as animal foraging and browsing. Seeds and acorns are a common and important food source in the diets of many species. Of the three major overstory species we observed (*Quercus virginiana, Quercus hemisphaerica/laurifolia,* and *Pinus taeda*), all are food sources for a variety of birds and mammals, including white-tailed deer (Carey, 1992). Although deer will browse on all three species, they appear to generally prefer *Quercus sp*. as their acorns are high in fat and carbohydrates (Self, 2021). Browsing on *Quercus sp.* has been shown to stunt their growth and reduce aboveground plant biomass (Cory & Russell, 2022; Blossey et al., 2019). This could influence the abundance of juvenile *Q. virginiana, Q. hemisphaerica/laurifolia,* and *P. taeda*. However, Dare County has low densities of white-tailed deer (NC Wildlife Resources Commission, 2020), so browsing might not be a large contributing factor to the absence of *Q. viriginiana* juveniles.

Changes in the depth of the freshwater lens (i.e., water table) beneath maritime forests can influence the presence of species, especially in swales where wet conditions are common (Bellis & Keough, 1995). An increase in the water table could encourage the growth of water tolerant species and push out those with lower tolerances. This could explain the recruitment of many new water tolerant species in swale plots 0207 and 0209, such as *Thelypteris palustris*, *Mikanius scandens*, and *Juncus effusus*. It could also be why *Quercus hemisphaerica/laurifolia* was not observed at all in plot 0207 and decreased in cover in plot 0209 (37% to 1.5%). Most of the well data available in Buxton Woods is far from the plots we sampled (Bailey et al., 2021), so localized water level data would be helpful in determining if this is a major factor in the changes observed.

Other diseases could also explain data trends. *Pinus taeda* is a tree species that is susceptible to many different diseases. These include, but are not limited to fusiform rust and littleleaf disease. Fusiform rust is a commonly studied disease that attacks *P. taeda*, so it has been managed since major outbreaks in the 1960s (Schmidt, 2003). There is no evidence this disease is present in Buxton Woods. Secondly, littleleaf disease mostly impacts shortleaf pines, and *P. taeda* less often (Eckhardt, 2009). This disease is less likely causing the changes noticed in Buxton Woods as there were no shortleaf pines observed. There are a wide variety of diseases and pests that could be attributed to the loss of mature *P. taeda* individuals and the increase in juveniles.

The presence of the non-native *Lymantria dispar* (gypsy moth) in Buxton Woods could also be a reason for the changes noticed in *Pinus taeda* and *Persea palustris/borbonia*. *L. dispar* feeds on these tree species, making them more susceptible to disease, so this could have allowed for the possible diseases discussed earlier to spread (Bailey et al., 2021). While *L. dispar* was not present during the 2021 and 2022 samplings, there has been activity in Buxton Woods before, so this could have impacted the observed changes. Further research can be completed to study the state of trees and analyze the conditions of them to determine what or if there are specific diseases or pests impacting them.

Droughts and flooding are also disturbances that can affect forest species. At the end of 2001 and throughout 2002 most of North Carolina, including Dare County, experienced at least a moderate drought (North Carolina Drought Management Advisory Council, n.d.). Dare County experienced a short-term severe drought for a few months of that year. Extremes in precipitation can lead to the decline of less drought tolerant species, such as *Persea borbonia* (Shearman et al., 2018), and younger individuals that become more tolerant with age, such as *Quercus hemisphaerica/laurifolia* (Braswell, 2019). There seems to be a lack of information about droughts in Eastern North Carolina, so better reporting on droughts and flooding in Buxton Woods would help determine their influence on the species present.

Limitations

There are a few limitations that need to be acknowledged when considering our findings. The first is that we had a small sample size (n=5). We are not able to generalize about the entire Buxton Woods because the five plots are not a representative sample. Secondly, we are unable to make casual relationships about specific storm events or other disturbances that may have impacted the forest composition and structure. Buxton Woods has experienced many disturbances since 1988 including, but not limited to hurricanes, droughts, and nor'easters, so it is difficult to pinpoint the exact reasons for change. Lastly, sampling of Buxton Woods was completed during different seasons from 1988 to today– the 1988 team sampled in the spring, while the 2021 and 2022 groups both sampled in the fall. This could have had an impact on presence and percent cover measurements as some plants change and grow differently throughout the year.

Despite these limitations, we have suggested potential reasons as to why we see the changes in Buxton Woods' vegetative species. This paper could be used as a tool to continue further research into these and other possible drivers of change in Buxton Woods.

Conclusion

As a diverse maritime forest located on the geographically isolated Hatteras Island, Buxton Woods presents a unique case study of change in stakeholder perceptions and vegetation. This capstone project by the 2022 UNC Institute for the Environment Outer Banks Field Site (OBXFS) is an extension to the previously conducted research by the 2021 OBXFS (Bailey et al., 2021).

The Human Dimensions evaluation outlines a set of perspectives held by community members for insight into the concerns and trends amongst stakeholders. This evaluation serves to answer the question: How does the content and structure of the mental models of the maritime forest of Buxton Woods vary among stakeholders and nearby residents? The Natural System vegetation assessment is an installment in a series of sampling (Peet et al., 1998; Bailey et al., 2021) seeking to record long term change and provide insight to contemporary managers. The investigated vegetation change serves to answer the question: How has the vegetative community composition and structure in historical plots in Buxton Woods changed since 1988? Together, these aspects demonstrate the ongoing changes in the vegetation and community of Buxton Woods.

More specifically, these two separate yet overlapping systems, Human Dimensions and Natural System, are connected by an overarching theme of succession. From the Human Dimensions perspective, succession can be defined as "a number of persons or things that follow each other in sequence" (Merriam-Webster Dictionary, n.d.). In this instance, the "things" are the interviewee perceptions of the 26 concepts. The shared "specified characteristics" are how the 26 concepts originated in the 2021 OBXFS interviews and how the 2022 interview participants perceive these concepts. From the Natural System point of view, succession refers to the process of ecological succession in which the vegetative community evolves, resulting in a changed composition and structure in the forest (Thompson, 2022). With both of these definitions in mind, our research is one snapshot in the on-going succession of the Buxton Woods community and vegetation.

A stakeholder we interviewed recognized this ever-evolving nature of Buxton Woods by stating:

"I mean, in a sense, I'm a tourist. I've just been here a long time."

In other words, they are simply a temporary visitor to the Woods. They are here for a snapshot in the progression of Buxton Woods. As time goes on, the perceptions, composition, and structure will continue to change. Understanding this change is crucial to providing resources for decision makers and the public.

The 3CM interviews highlighted important concepts related to the Woods and demonstrated diversity in concept assessment. In the 26 provided concepts, the concepts with the highest frequency, standardized concept group rank, and prominence were *needs protection, plants and animals, Coastal Reserve,* and *personal connection.* The high valuation of the previously mentioned top concepts suggests their significance across the participants. Beyond the quantitative analysis, transcripts of the conducted interviews revealed that some of the provided 26 concepts were equally as valued even if not explicitly selected in the mental modeling. For example, the majority of interviewees mentioned *concern for the future* of Buxton Woods despite only half using the concept in their model. In addition to concept specific analysis, the 3CM method provides information about group trends within the sampled population. In the ten interviews, multiple participants created groups centered around the themes of management and conservation. However, even with these common group titles, the interviewees described the grouping through different lenses. For example, those with groups labeled management perceived the associations through their own personal connection or through the management agencies themselves. Furthermore, divergences were visible in the pool of participants as some were Buxton residents whereas others were management professionals.

Documentation of these similarities and differences for individual concepts, concept groups, and their appraised importance within and among interviewees can inform management action and public awareness. Variation and trends in individuals' mental maps highlighted important themes, such as conservation and management. Differences within and among stakeholders demonstrates the need to analyze stakeholder perspectives with nuance.

Stakeholder perceptions are guided by their personal experience with the Woods but are also informed by the natural environment. This study observed changes in the vegetative community composition and structure in five plots since 1988. The plots were found to be less dense due to the total cover decrease which is driven by three major species: *Benthamidia florida, Pinus taeda,* and *Persea borbonia/palustris*. Multiple interviewees noticed these major changes in the Wood's composition and structure such as noting the loss of *B. florida* and hurricanes destroying a significant amount of *P. taeda*. Additionally, new species are dominating the plots today including *P. taeda* and *P. borbonia/palustris* instead of *B. florida* and *Quercus hemisphaerica/laurifolia*. Lastly, there was an increase in species richness across all plots. Maritime forests undergo a wide array of disturbances (Baker, 2014); they are able to adapt to such as salt spray and intense, frequent storms (Sacatelli et al. 2020). Several other factors can be attributed to the change in vegetation, such as diseases, pests, droughts, and floods. Even though no causal relationships can be established between these factors and the discovered vegetation changes, these potential influences can provide suggestive insight. This constantly evolving ecosystem can have ramifications for the future of the forest and the surrounding community.

Recording and understanding the change in Buxton Woods and community equips stakeholders with resources to inform adaptive action. One interviewee described this functionality saying,

> *"The woods will maintain itself as long as man is respectful… the more you can learn about it the better you can protect it. But I think it's important to keep a finger on the pulse."*

Maintaining a prosperous ecosystem requires taking snapshots of both the human and vegetation aspects of Buxton Woods as these systems are constantly interacting and influencing one another. Community understanding of the Woods guides its current state and serves as a driving force for its continued protection. Even with the overall goal of protection, research is an essential part of evaluating and maintaining the health of the ecosystem. Insights from this study present themselves as a potential tool for stakeholders to adjust to inevitable changes in the succession of Buxton Woods.

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