Exploring the Maritime Structure of Castle Island: A Historical and Archaeological Study of an Offshore Island Near Washington, North Carolina

By

Olivia Livingston

December 2024

Director of Thesis: Jason T. Raupp, Ph.D.

Department of History, Program in Maritime Studies

ABSTRACT

North Carolina's long history is often overlooked in comparison to that of surrounding states, as the lands were not as fertile, nor were the cities as industrialized during colonial and post-colonial periods. Through the expansion and utilization of waterways, however, the state became a priority to local, regional, and international trade of lumber and naval stores. Harbors and ports served as a link to the economic prosperity of North Carolina's maritime activities. With the formation of waterfronts and usage of wharves, eastern North Carolina became an asset to commercial services, and particularly the city of Washington played a vital role in the development of waterborne commerce. Settled on the Tar-Pamlico River, Washington became one of the largest mercantilist centers in the eastern region, trading not only nationally, but internationally as well. The early expansion of Washington's maritime infrastructure, such as that established around Castle Island, remains an unexplored aspect. Integrating historical and archaeological findings, this thesis considers the role of Castle Island and its development from the eighteenth to mid-nineteenth century through an analysis of its wharf structure.

Exploring the Maritime Structure of Castle Island: A Historical and Archaeological Study of an Offshore Island Near Washington, North Carolina

A Thesis

Presented to the Faculty of the Department of History

East Carolina University

In Partial Fulfillment of the Requirements for the Degree Master

Arts in Maritime Studies

By

Olivia Livingston

December 2024

Director of Thesis: Jason T. Raupp Ph.D.

Thesis Committee Members:

Nathan Richards, Ph.D.

Jennifer F. McKinnon, Ph.D.

R. Stockton Maxwell, Ph.D.

Dedication

This thesis is dedicated to my Papa, whose love for history has led me to the path I am on today.

Acknowledgments

This thesis was possible through the vast network of family, friends, colleagues, and professionals to whom I must express my profound gratitude. First, I would like to thank Dr. Jason Raupp. Your thoughtful guidance, constant encouragement, and remarkable patience has played a valuable role in the development of my graduate journey and thesis. I am very fortunate for your mentorship and the privilege of working alongside you outside of this research. I would also like to acknowledge my committee members, Dr. Nathan Richards, Dr. Jennifer McKinnon, and Dr. Stockton Maxwell, who all have provided kindness and stewardship throughout my time at East Carolina University. Thank you, Dr. Richards, for your help throughout field schools and fruitful discussions about experimental archaeology, along with allowing me to take part in testing the new tools. Thank you, Dr. McKinnon, for giving me the resources needed, as they are so appreciated. Lastly, a big thank you to Dr. Maxwell for inviting me into the field of dendrochronology and having the utmost patience with me as I learn to navigate the discipline. I truly cannot thank everyone enough for their help in this thesis research. I would like to thank the 2021 Fall Field School participants, as their findings have greatly contributed to my research. Lastly, the 2023 and 2024 fieldwork would not have been possible without the help of Allyson Ropp, Jeremy Borrelli, Mark Keusenkothen, Ryan Bradley, and Dayan Weller. I am eternally grateful to have worked alongside these amazing beings in the beautiful waters of the Tar and Pamlico Rivers.

As for family and friends, I would like to thank my mother, Cammie Livingston, for the unconditional love and support throughout this process. I am lucky to have a father like Tim Livingston, who has given complete guidance and compassion these last few years. Both have provided me with substantial support, and I recognize what they have done and sacrificed to ensure my happiness and success. Thank you to my brother, Alex Livingston, who was always willing to listen to what I had to say, even if it made zero sense to him. I also would like to thank my nana, Carol Dean, for being the incredible woman she is. Her enduring love and encouragement are unlike any other, and I am so grateful for her. For my friends in and out of the program, I thank you for actively supporting me throughout this journey. Lastly, a very special thank you to Allyson Ropp, who has always been beside me while I tried to navigate through this thesis. Thank you for giving clarity, aid, and responding to my random questions at any given hour.

Table of Contents

List of Tables

List of Figures

Chapter One. Introduction

The early history of Washington, North Carolina, is understudied as there has been little acknowledgment of the colonial period before the end of the eighteenth century. Since the establishment of North Carolina as a colony under Great Britain, the eastern region of the state was vital in production and trade. Eastern North Carolina became important to trade as several entrepôts developed along its coastline, with smaller ports being crucial to the supply and demand of commercial goods (Perry 1968:509-511). Among the many developing cities along its coast, Washington was one of the most valuable due to its access to resources as export goods, which in turn caused rapid industrialization and expansion of the port in the mid to late eighteenth century. Given its location and connection to major waterways, maritime trade was a cornerstone of North Carolina's economic growth. While some research has considered the economic impact of eastern North Carolina as a whole (Perry 1968; Outland 2001; Combs III 2003), few studies focus on the importance and function of individual ports and associated wharves, such as Washington's maritime infrastructure at Castle Island (Byrd 2018; McGuinn 2000; Minford 2012; Parkin 2019). Structural design and modifications of wharves are important indicators of the amount and types of goods being exchanged, as well as the spatial development of an area of interest. This thesis builds from past studies (Cox 1989; McCabe 2007; Edwards 2015; Nassif 2020; Lowe 2022) to synthesize the archaeological and historical record into a cohesive narrative of Washington and Castle Island's progress and modifications of its wharf infrastructure.

Historical Context for Washington, North Carolina

Washington, North Carolina, has an interesting environmental and historical setting due to its location. Being further inland in comparison to other ports, Washington allows greater access to raw materials through waterborne transport. As such, the port of Washington experienced great economic growth throughout the eighteenth and nineteenth centuries, which led to the expansion of its waterfront and port infrastructure (Mayo 1903:37).

Geography and Environmental Setting

The former colony and now the state of North Carolina faced numerous obstacles throughout its development, as it lacked reliable, deep-water ports, and has a treacherous coastline in comparison to surrounding states, such as Virginia and South Carolina (Edwards 2015:4). Historically speaking, the Outer Banks restricted growth of inner coastal towns, such as those on the Albemarle and Pamlico Sounds. The Pamlico Sound is fed by the Tar and Pamlico Rivers, which start near the Virginia border and extends to the city of Washington, a once bustling colonial port.

Washington, North Carolina, is situated in Beaufort County, a Coastal Plain region that is located on the Pamlico Sound, where waterfronts are dominated by estuarine waters, comprising a total of 1,255 kilometers (km) of shoreline. According to the North Carolina Department of Environment and Natural Resources (DENR) and Division of Coastal Management (DCM), estuarine shorelines can be found along the coast's brackish sounds, marshes, rivers, and creeks and are a transitional area where fresh and saltwater meet. Approximately 61% of Beaufort County's shorelines are characterized as marsh, while the remaining is 10% modified shoreline, 19% sediment bank, and 9% swamp (McVerry 2012:26). As Washington is the biggest town in Beaufort County, the city itself encompasses approximately 14 square km and includes 13 km of an estuary. The estuary has characteristics ranging from a marsh to sedimentary bank, to modified shoreline (DENR 2015:104; Washington Park and Recreation Department 2014:i).

In particular, the Pamlico River Estuary has relatively shallow waters ranging from 3 to 6 meters (m). The climate of Washington is temperate, which includes hot and humid summers, with the average temperature peaking at 30.7° Celsius, a low of 20.9° Celsius, and an annual precipitation of 13.5 centimeters (cm). In contrast to the summer months, winter in Washington tends to be short and cold, as the temperature peaks at 12.7° Celsius, low of 1.7° Celsius, and an annual precipitation rate of 9.3 cm (National Centers for Environmental Information 2024). Being an estuary, the Tar-Pamlico River system can have tidal ranges that do not exceed over half a meter, although hurricane winds can impact this. Due to its location, several environmental factors impact the Tar and Pamlico Rivers; some of these environmental factors include having an unbalanced pH and nutrient run-off from agriculture, thus causing algae (Washington Parks and Recreation Department 2014:i-ii). Along with this, there are river grasses and other flora that can become overgrown, as well as barnacles and bottom dwelling organisms (Rodgers et al. 2006:8). The brackish water of the Tar and Pamlico Rivers is orange to brown with low visibility and easily disturbed sediment. Parallel to the city's waterfront and in the Tar and Pamlico River Basin lies a 2.84-acre piece of land, known as Castle Island. This land is owned by the city of Washington; however, part of the island is privately owned. Castle Island is about 150 m southwest of the North Carolina Estuarium (FIGURE 1).

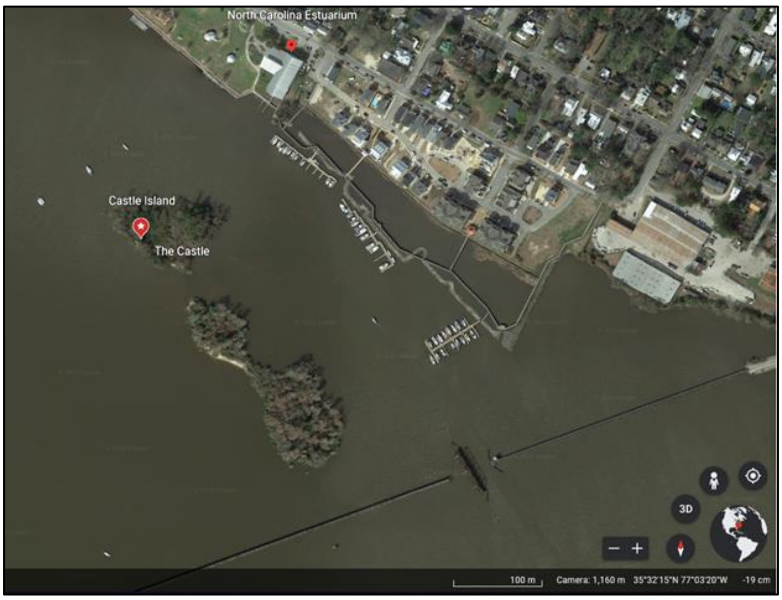


FIGURE 1: Aerial view of Castle Island in relation to Washington's waterfront (Google Earth 2022).

Historical Narrative

Eastern North Carolina saw a period of European migration from the late sixteenth to early seventeenth centuries. In 1663, around 4,000 colonists occupied the eastern part of the state, with many resettling in present day Beaufort County (Mayo 1903:34). An exploration of the Pamlico region was conducted in 1701 by John Lawson, who found it rich with natural resources (Rodgers et al. 2006:11). Though nestled between the Tar and Pamlico Rivers and originally called "Forks of the Tar" the town was not established until the mid-eighteenth century due to its location and services. A land grant in 1726 was passed to a merchant and planter family, the Bonners, who contributed to the town's development through its resources. In 1758, a lot consisting of 32 m of riverfront and 64 m off the river was sold to Aquila Sugg, a merchant from Edgecombe County. Sugg bought more land to construct a wharf, warehouse, and other buildings which ultimately created the steppingstones of the city. The facilities Sugg built were used for shipping naval stores and other local products brought from the hinterland on the Tar River (Hill 1984:1-2).

In 1761, Jacob Blount and Richard Blackledge enhanced their mercantile business in the town by purchasing and erecting several stores on the waterfront (Hill 1984:2). The sons of Jacob Blount, John Gray and Thomas Blount, played a crucial role in the expansion of the waterfront infrastructure, carrying trade to local, coastal, and even foreign regions (Mayo 1903:36). Their business laid the foundation for possibly the largest mercantile business in the early history of North Carolina, having one of the leading shipping interests in the state (Barnwell Keith 1952:XV). Along with this, their names were associated with those who ran larger ports along eastern North Carolina, such as John Wallace from the settlement of Shell

Castle Island at Ocracoke Inlet (Mayo 1903:36-37). According to English transplant Robert Hunter, the chief exports of Forks of the Tar were "tobacco, which they send to Europe, tar, turpentine, naval stores, lumber, and pork, which they send to the West Indies" (Hunter in Hill 1984:4). The central points of exchange in the Caribbean were Pointe-á-Pitre, Guadeloupe, St. Kitts, and Turks Island. In exchange for the exports, the West Indies traded molasses, salt, English dry goods, coffee, rum, and sometimes fruit and porcelain. Due to the location of Forks of the Tar, it was common for smaller vessels to travel to Shell Castle Island to exchange cargoes, hence the relationship between the Blount family and Wallace. Although heavily involved in international trade, the town engaged in colonial commerce, particularly with the ports of Boston and New York (Mayo 1903:36-37).

In the late eighteenth century, naval stores became central to the town's economy and remained so throughout the antebellum period. In 1770, the colony accounted for 60% of the total amount of naval stores produced by all British colonies (Hill 1984:4-5). The Revolutionary War broke out just as the town began to prosper, but unlike other southern ports, the town served as an operational base for the Continental Army. The constant need and use of the supplies from Forks of the Tar allowed the town's waterfront infrastructure to grow, along with the incorporation of Castle Island (Rodgers et al. 2006:13-14). By being such a vital role during the Revolution, the town was renamed "Washington" in honor of General George Washington (Paschal 1976:2). From the years 1782 to 1815, the production and trade of naval stores thrived in eastern North Carolina due to its riverine transportation networks, and because they were the only place of dominant production in contrast to other states (Perry 1968:512).

In comparison to naval stores, lumber was the second biggest industry in North Carolina. Similarly, being on or near water provided easy access to transportation of such heavy items. In the mid-eighteenth century, North Carolina produced and exported three-fifths of all naval stores from the continental colonies (Perry 1968:512). By 1790, Washington was recognized by the federal government as an official port of entry, meaning foreign goods and people could lawfully enter (Rodgers et al. 2006:14). The main consumer of lumber from eastern North Carolina was the West Indies, both before and after the Revolutionary War (Combs III 2003:7). From 1805 to 1830, export records show a shift from tar and pitch to turpentine and rosin due to there being a variety of uses for those goods, such as rubber products and illuminants (Perry 1968:512). At the turn of the twentieth century, however, Washington lumber overtook naval stores as the premier export, extending the town and waterfront.

At the end of the eighteenth century, Castle Island became important to the lumber industry as the sawmill constructed on the island provided scantlings for vessels. By the mid-nineteenth century, the town became the largest shipbuilding center in North Carolina (Rodgers et al. 2006:16). Although the location of Washington eventually became detrimental to the town's economy, it still proved itself to be industrious and productive, making a historical impact on the development of North Carolina. Thus, this research aimed to date the initial construction of the maritime infrastructure at Castle Island throughout the eighteenth and nineteenth centuries.

Research Questions

This thesis considers the construction and development of Castle Island's maritime infrastructure. To address it, various lines of evidence were investigated, including historical and archival sources, archaeological data, and physical properties of the construction materials. To better understand this topic, the following list of ancillary questions were considered:

1. What are the different colonial types of wharf construction? Of what type was Castle Island's wharf built, and does its form assist with dating the structure?

2. What wood species were used for construction of the Castle Island wharf? How did it/they have a role in the historical narrative?

3. How did the artifacts identified at the site connect to the period of construction? Can they assist in determining dates for construction and use?

4. Can dendrochronological analysis be used to determine when the wharf at Castle Island was erected? If so, what are the initial dates of construction? Can dendrochronological sampling provide evidence of modifications in addition to the original structure?

5. Does the implementation of a resistograph produce data comparable to the core samples used for dendrochronological analysis? What does the resistograph reveal about the timber density and the preservation of Castle Island's wharf structure?

Justification

As an exporter of commodities to larger markets in the United States and abroad, Washington had an important role in North Carolina's maritime history and was a contributor to the establishment of eastern part of the state's economy from the eighteenth century onward. Investigation of the construction and modifications of Castle Island's infrastructure provides a foundational date to the employment of the structure. Dating analysis and historical research also demonstrates social and economic demands imposed on it. Being one of the few archaeologically identified colonial wharves in the region, the structure contributes significantly to the knowledge of construction practices for maritime infrastructure. The proposed thesis can also create a pathway for possible site interpretation, public outreach, education, and management.

Previous Research

Most archaeological and historical research related to the Tar and Pamlico Rivers and to Castle Island has largely been conducted by the Program in Maritime Studies in the Department of History at East Carolina University (ECU). Previous archaeological work conducted by the Program in Maritime Studies occurred throughout the 1980s, though the field method courses around Castle Island and the wrecks on Washington's waterfront in the past few decades are the most in depth and relevant to the proposed study.

From 1998 to 2000, ECU field schools primarily focused on surveying the waters and abandoned crafts around Castle Island. Those field seasons resulted in detailed maps, photographic imaging, and archaeological analysis of various abandoned watercraft. Although the sites documented in the 1998 field school were heavily impacted by Hurricane Floyd in 1999, the 2000 field season identified a total of 11 wreck sites (Rodgers et al. 2006:2). A 2004 ECU field school focused on the investigation of the Tranter's Creek wreck located upriver, though other activities included remote sensing and site investigations at previously identified wrecks around Washington (Richards 2005).

Due to the outbreak of the Covid-19 pandemic, an ECU field school returned to the waters surrounding Washington, concentrating on the "Copper Wreck" and "Centerboard Wreck" in 2020 (Raupp et al. 2021). The goal of that field season was to obtain details relating to vessel construction and potential identification. In 2021, the Program in Maritime Studies continued to work locally, surveying the remains of a late nineteenth or early twentieth century ferry boat, as well as industrial remains surrounding Castle Island. Investigations onshore identified the remains of a sawmill and lime kiln, while underwater investigations focused on those of a wharf and an extensive seawall developed around the island (Raupp et al. 2022:2).

The western and northern side of Castle Island include the remnants of cribbing and a wharf structure, while the northeastern seawall consists of stacked timbers, sheeting, and pilings filled with ballast stones (Raupp et al. 2022:13). The southeastern seawall consists of an additional cribbing structure, as well as a few header and stretcher timbers. Further research and examination of the structure suggests that it is an example of the crib-type wharf (Heintzelman 1985:8-12). Along with the structure, students also documented and recorded artifacts that include ceramics, ballast stones, coal, oyster shells, coral, and brick. In relation to the artifacts found and the type of construction used, Castle Island's maritime infrastructure indicates that it was erected earlier than previously considered and played a significant role in the development of Washington (Raupp et al. 2022:23-24).

Other research conducted by ECU students on Washington and the Tar and Pamlico Rivers help to provide historical context for the study of Castle Island. Among the more relevant studies are theses completed by James Cox (1989); Christopher McCabe (2007); Justin Edwards (2015); Will Nassif (2020); and Matt Lowe (2022), each of which pertain to the historical and archaeological record of the Tar and Pamlico Rivers and eastern North Carolina. Some studies, though not focused on the Tar and Pamlico Rivers, are also applicable as they discuss North Carolina's role in trade and evolution of ports; these include Robert Minford's analysis of Eagles Island (2012) and Sara Parkin's thesis on Buffalo City (2019). In terms of port studies, Phillip McGuinn's (2000) investigation of Shell Castle, an island that has a close relationship to Washington and Castle Island, is an excellent study of colonial adaptation. Lastly, ECU Department of Anthropology student Stephanie Byrd's (2018) thesis demonstrates a similar study, through consideration of the construction of

Brunswick Town's (North Carolina) wharf and the artifacts associated with the town's shipping and commercial endeavor.

Research related to wooden wharf construction of the eighteenth and nineteenth centuries also proved valuable to this thesis. The examination of wharf construction and archaeology through Andrea Heintzelman's (1985) and Molly McDonald's (2011) work was essential to the classification of Castle Island's wharves and its reconstruction. Case studies throughout the northeastern region of the United States such as Edwin Small's (1941) research of the Derby Wharf in Massachusetts; the Cultural Resource Group Louis Berger and Associate's investigation of New York City's colonial waterfront (1990); and Joseph Gary Norman's analysis of Baltimore, Maryland's eighteenth century wharf construction (1987), all provided insight into what is considered a wharf, how they were erected, maintained, and preserved. Richard A. Stephenson and William N. Still, Jr.'s Deer Island Wharf investigation (1994) in Swansboro, North Carolina, however, has parallels with Castle Island in terms of environment, economics, and development of the wharf.

Thesis Outline

This thesis consists of six chapters, with this introduction being the first. The second chapter delves more deeply into the historical narrative of the development of eastern North Carolina through a transatlantic synthesis. With the broader history discussed, it is to be tied into Washington, North Carolina, and what is known of Castle Island through archival records. Primary and secondary source documents such as newspaper articles, maps, company papers, government reports, and personal letters added insight into the economic development and infrastructure changes at Castle Island. Other sources, such as prior fieldwork, reports, and journal articles also assisted in that research. Chapter Three establishes a synthesis of the history of wharves and the various typologies often found in the eastern United States. The discourse of wharf typologies leads into the discussion of Castle Island's structure, making a more defined timeline on the erection of the wharf around the island. Chapter Four discusses the artifacts documented during the Fall 2021 ECU Field School and considers them using Stanley South's mean ceramic date formula to produce an occupation date of Castle Island. Chapter Five introduces the methodological component of this thesis's research, being that of dendrochronology and the use of a resistograph. Chapter Five also delves into the basic concepts and function of wood, wood identification, and the field work and discusses the methodology used in the postprocessing of samples. Along with this, a nondestructive tool known as a resistograph is assessed by its purpose, functions, and employment to previous studies and this thesis. Furthermore, Chapter Five provides the results of core sampling and resistograph testing data. Lastly, Chapter Six offers the discussion of various dating methods and considers their applicability to this thesis research. It encompasses preceding chapters by compiling the various lines of data to show the framework and discussion Castle Island's historical narrative. Ultimately, Chapter Six readdresses and summarizes the questions and process of historical research and applied methods to the study of Castle Island's wharf. The chapter includes a discussion of limitations encountered, recommendations for future research, and concluding remarks on Castle Island and its maritime infrastructure.

Chapter Two. Tides of Transformation: Washington, North Carolina (1700s-1850s)

Although it is now a small town nestled at the confluence of the Tar and Pamlico Rivers, Washington, North Carolina, was once a bustling port that traded with local, regional, and international partners. Through the production of raw materials once sought by Great Britain, Washington became a prosperous entrepôt with a waterfront that steadily expanded and modernized throughout the eighteenth and nineteenth centuries. To understand the development of the city and site of interest, Castle Island, it is necessary to understand the geographic and historical context. This chapter outlines the history of Washington's establishment and its industrial tendencies, which will incorporate the production of Castle Island.

English Mercantilism and the Colonies

In the eighteenth century, Great Britain became a dominant colonial power by building up strategic trading centers and authority overseas. The British Empire was comprised mainly of North America and the West Indies, where colonists extracted resources as a source of profit. The eighteenth century, however, was an era of war, which led the Royal Crown to not only build up its navy, but to seek materials and goods outside of Europe. The success of the British navy in both warfare and trade was dependent upon tremendous growth in shipbuilding and an accompanying increase in demand for shipbuilding materials, including naval stores (Driscoll and Kicks 2013:9). Although the term "naval stores" was not in use until 1800, it is often used to refer to products derived from pine trees, including turpentine, rosin, tar, and pitch (Outland 1996:32). Increasing prices and the instability of the supply chains of naval stores from the Baltic region led the monarchy to look outward to supply its needs.

By enforcing mercantilist policies, such as the Navigation Acts, Great Britain capitalized on the production and exportation of goods throughout the colonies. Created by the British Parliament, the Navigation Acts mandated the subsidy of certain colonial commodities, such as naval stores and indigo, while also forbidding the manufacturing of other goods, like fur hats (Sawers 1992: 263). Some historians, such that as David Ramsey (1789); George Bancroft (1879); and Larry Sawers (1992), think that the Navigation Acts and other British mercantilist policies were the cause of the American Revolution. Under the acts established, trade was restricted between the colonies and was only sought to benefit the Empire. In Sawers' (1992), "The Navigation Acts Revisited" the years prior to America's independence are analyzed to demonstrate the various grievances colonists experienced from such laws. Through the Navigation Acts, economic burdens and stressors were imposed on colonists who often competed with British merchants and could not financially support tariffs or re-export costs. England saw the colonies as an investment, and North Carolina eventually became one of the primary economic drivers through its production of naval stores (Outland 2004:6).

In particular, North Carolina caught the interest of the British as the colony consisted of untouched pine trees. North Carolina can be divided into three regions: the Coastal Plain, the Piedmont Plateau, and the Mountains (Powell 1989:1). The Coastal Plain is of great importance in this case, as it connects the inner region to the Atlantic through several important rivers, creating access to various sources for the British and colonists to trade. Particularly, the pine trees grown throughout North Carolina were essential for the British to harvest, as they created naval stores, which ultimately impacted the colony throughout its early development (Williams 1935:169). The British took advantage of the colony's coastline, creating various ports to export the produced goods. The city of Washington, North Carolina, was of great importance as it is nestled on the Tar and Pamlico Rivers and provided easy access to untapped land through intercoastal waterways. As such, the city served not only as an essential colonial port for England but continued to prosper after the establishment of the early American Republic. Since it was largely unimpacted by the Revolutionary War, Washington became a crucial port for naval stores from the late eighteenth and into the nineteenth century due to its physical location and the availability of cheap labor and slavery (Paschal 1976:3).

Through the enactment of several policies, British mercantilism in North Carolina allowed the coastline to prosper with regional, national, and international trade. Historian Edwin Combs' 2003 article, "Trading in Lubberland: Maritime Commerce in North Carolina," explores the value of each of the state's early ports and its commerce. Colonial North Carolina had a delicate balance of mercantilist policies, maritime trade, and economic development. As Combs (2003:27) notes, merchants profited from their goods as the several acts and policies established by the Royal government controlled the sales. In "English Mercantilism and Carolina Naval Stores, 1705-1776," Justin Williams (1935) offered his views of mercantilism in North Carolina by looking specifically at naval stores, which he credits as the main reason for the development of the eastern region of the colony. By understanding the region and the best areas to trade, colonists were able to take advantage of the waterways and exchange of commodities even after their fight for independence. William Powell's 1989 book *North Carolina Through Four Centuries* describes how the colony was at an advantage during the Revolutionary War due to its inlets and treacherous shores, thus allowing locals to engage in coastal trade despite British efforts to blockade the entire coast. Through such inlets lies the city of Washington, North Carolina. Herbert Paschal in *Washington and the Pamlico* (1976) explains how Washington remained opened during the Revolutionary War and became essential to the Continental Army for supplies and labor forces, as the surrounding region provided bountiful forests for timber-based industries.

From Europe to America: The Shift of Naval Stores

The rise of naval power among European nations resulted in a demand for vessel maintenance, trading, and shipping operations as colonies became essential to empires and monarchs. And while all major powers needed tar, pitch, and timbers for ship construction in the eighteenth century, the nation that consumed the most of those materials was Great Britian. Prior to 1700, the major supplier of tar, pitch, and lumber to the English market was Sweden-Finland (Kirby 1974:98). The Baltic region constantly manipulated tar prices, which led England to spend more money as their exports could not compete with the Baltic imports (Harrup 2013:35). As the need for more materials became prominent within Europe, the private monopoly Stockholm Tar Company doubled its prices (Williams 1935:172). Coupled with these developments, the outbreak of war impacted Swedish production of naval stores and created decades of chaos. The Great Northern War between Russia and the Swedish Empire caused difficulties shipping out naval stores as areas became depleted and destroyed. Finally, the War of the Spanish Succession prompted the Stockholm Tar Company to double its prices (Williams 1935:172). Through the pricing increase of naval stores, England realized the need for a new and reliable source as they rose to naval supremacy. As the British Empire's supply became low, their debts rose due to its heavy dependence on Sweden-Finland's imports. With war and shifting loyalties, England's source of naval stores was threatened (Williams 1935:173).

The year 1696 saw the establishment of the Commissioners for Trade and Plantations, otherwise known as the Board of Trade, which transposed British dependence for naval stores from the Baltic to colonial America (Malone 1972:381). The campaign to shift to colonial trade was successful as the Baltic region was constantly in a state of unrest (Malone 1972:382). Although the impetus to seek materials elsewhere occurred at the end of the seventeenth century, it was not considered an important matter or export until 1705, when a bill was passed by the Lords and Commons to encourage manufacturing of colonial ship materials (Williams 1935:173).

Naval Stores in Colonial America: Eastern North Carolina

Although the English first sought naval stores within New England, efforts to establish the industry in the region failed as other crops and industries, such as agriculture, livestock, textiles, and furs, were deemed more profitable. Also contributing to the failure was the loss of the region's native pines due to overharvesting by the colonists (Perry 1968:511). To compensate for the industrial failure in the New England colonies, King Charles II demanded that the colonists in Virginia diversify their produce to include naval stores. The settlers in Virginia saw an abundance of pine forests, making it profitable to the English as it was an easy source to exploit (Harrup 2013:13). Although southern colonies like Virginia and South Carolina had their share of naval store exports, their industries relied heavily on goods such as tobacco and indigo, which ultimately pulled colonists in that direction of production (Outland 2004:11). In contrast to Virginia and South Carolina, North Carolina did not see this competition between goods as its land lacked in fertility and a labor shortage prevented the production of such commodities (Perry 1968:512). North Carolina also held what seemed like a never-ending supply of pines, with majority of its forests being home to the longleaf pine.

The longleaf pine (*Pinus palustris*) can be found in a variety of climates as it is tolerant towards a multitude of environmental conditions and soil types. The longleaf pine can dominate in dry and rocky grounds as well as more fertile areas that consist of clay and silt (Outcalt 2000:309). With the longleaf pine having high resin levels, it was deemed the most suitable for producing naval stores in comparison to other trees throughout the colonies.

Fortunately for the English, the pine in North Carolina was untouched, providing a great economic resource (Outcalt 2000:311).

Although the colonial naval stores produced in greater amounts than their European counterparts, the Swedish pine (*Pinus silvestris*), there were unfortunately drawbacks to relying on them as a primary supply. In comparison to the Baltic or Stockholm naval stores, the colonies used smaller barrels, and freighting from New England to England costing three times more. Transporting naval stores from the Carolinas could be more than four times the cost of what it would be from the Baltic areas (Kirby 1974:99). In the beginning of naval store production in the colonies, English merchants were the primary group utilizing the goods, as the Royal Navy implemented tar for graving, or repairing and maintaining ship bottoms due to the lower quality. The Royal Navy preferred the superior Baltic naval stores and was passive to the colonial production unless the prices and quality were equal to the Baltic's commodities (Kirby 1974:104-106). Unlike the tar made in the Baltic region, Carolina tar was produced from dead wood collected from the forest floor, which burned hotter than the fresh pine used in Sweden (Williams 1935:183, 185). Despite this deficiency in quality, Carolina tar saw an increase in its importance and use.

In 1705, the English Parliament initiated the Naval Stores Act, which encouraged trade of the naval stores within the colonies. The purpose of that law was to "… provide the colonies with staples to exchange for English manufactures, correct England's unfavorable balance of trade with the Baltic, and spur English shipping and navigation" (Williams 1935:174). Through that system, the British government paid bounties to push the production of naval stores in the colonies, in hopes that the colonial naval stores could equal the profitability and production levels of the Baltic suppliers. The results of this act were effective, as England was successful in stimulating naval stores production in the colonies, ensuring adequate supply and availability of the products (Williams 1935:178).

Following the enactment of the Naval Stores Act of 1705, American colonies became England's chief source of tar and pitch. About a decade after the Naval Stores Act was passed, about a fourth of England's annual supply came from the colonies. In 1716, colonial tar and pitch overpowered the market in England as the Baltic supplies declined (Williams 1935:175) and roughly 94% of England's naval stores were produced from the colonies by 1724 (Robinson 1997:58). In 1721, the Board of Trade saw improvements in the quality of colonial tar and pitch, stating:

> We have already had very successful proof of what due encouragements produce in the particulars of pitch and tar, which at present are made in as great perfection in your Majesty's plantations as in any other part of the world, and in such plenty as will enable us to supply foreign parts, since it both reduced the price of those commodities one-third of their former cost within the space of a very few years, whereby the importation of pitch and tar from the Baltic is greatly decreased and much money is saved in the balance of our trade (Board of Trade 1721).

The continuation of the legislation allowed Great Britain to profit further from the supply of naval stores, this time including timber. Throughout this time the mercantilist policies produced by England stimulated trade by continuing to grant bounties for naval stores and providing favorable markets for these types of goods. By 1729, the Naval Stores Act was restored again, causing the colonies to become Great Britain's primary supplier, and they eventually exported the excess of goods to other European powers (Outland 2004:13). During the mid-eighteenth century, about 135,000 barrels of colonial naval stores were being imported by Great Britain (Driscoll and Kick 2013:11).

As reliance on colonial naval stores increased, North Carolina alone exported the same number of barrels in 1775 (Williams 1935:176). Despite North Carolina's reputation for having a treacherous coastline, lack of fertile land, and limited population, the colony saw a steady increase in influence on maritime commerce as the need for naval stores became prominent. As it developed into the primary source of export for naval stores, five major ports were established throughout the eighteenth century. These ports include Brunswick, Roanoke, Bath, Beaufort, and Currituck (FIGURE 2). The exports of these ports were similar, with tar, pitch, turpentine, lumber, livestock, deerskin, and corn dominating (Combs III 2003:13). Regardless of the similarities in their cargo, each port had a distinct pattern of trade, as they were spread out along the coastline of North Carolina.

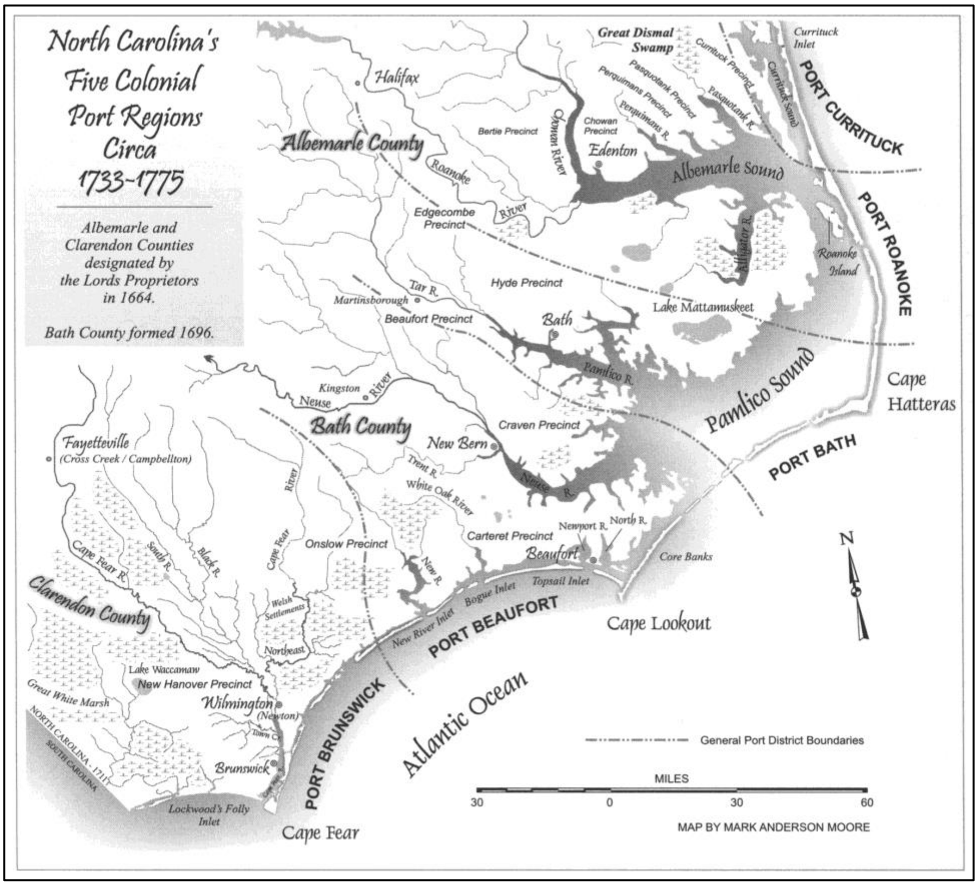


FIGURE 2: Map of North Carolina's regional ports from the mid to late eighteenth century. Each port had a distinct trade of pattern, exports, and imports. (Map by Mark Anderson Moore, taken from Combs III 2003:3).

While the colony was superior in exporting naval stores, mercantilist policies, such as the Navigation Acts, limited North Carolina's development by restricting direct trade with Portugal, Spain, and Ireland (Combs III 2003:21). Under the Navigation Acts in 1763, the colonists had to produce and sell certain products only to England or English colonies, with foreign trade passing through England as well to collect taxes. Along with these elements, the goods being transported, sold, or shipped to and from the colonies were required to be carried onboard vessels built in either England or the colonies (Sawers 1992:271-272). Enforcing the Navigation Acts, Parliament also enacted several other legislations that highly taxed colonists, leading to the outbreak of the War of Independence. In comparison to naval stores, lumber was the second biggest industry in North Carolina. Similarly, being on or near water provided easy access to transportation of such heavy items. In the mid-eighteenth century, North Carolina produced and exported three-fifths of all naval stores from the continental colonies (Perry 1968:512). Towards the end of the century, manufacturing in eastern North Carolina persisted as it was free from the mercantilist policies (Williams 1935:185).

The Role of Washington, North Carolina: Early Development

European migration to eastern North Carolina began in the late 1500s and continued into the early 1600s. By 1663, approximately 4,000 colonists had settled in the eastern part of the state, with many relocating to what is now Beaufort County (Mayo 1903:34). In 1701, John Lawson explored the Pamlico region, noting its abundance of natural resources as settlers arrived, eager to capitalize on the area's untapped potential (Rodgers et al. 2006:11). In the early eighteenth century, the town of Bath became a central focus on the region for business and trade as it was the first to be named a port of entry in the province (Lefler and Newsome 1973:55). This town became an essential link to settlers as it connects parts of the colony that were deemed inaccessible and facilitated waterborne trade.

Further north of Bath nestled between the Tar and Pamlico Rivers and originally named Forks of the Tar as the city of Washington was not established until the mid-eighteenth century due to its location and services. Being further inland, however, allowed Forks of the Tar greater access to raw materials through waterborne transport (FIGURE 3). A land grant in

1726 was passed from the by True and Absolute Lord Proprietors to a merchant and planter family, the Bonners, who contributed to the development of the town through its resources (Paschal 1976:1). In 1758, a lot consisting of 32 m of riverfront and 64 m off the river was sold to Aquila Sugg, a merchant from Edgecombe County. Sugg bought more land to construct a wharf, warehouse, and other buildings which ultimately created the steppingstones of the city. The facilities Sugg built shipped naval stores and other local products brought down on the Tar River to English merchants (Hill 1984:1-2). A few years after Sugg built the waterfront, Jacob Blount and Richard Blackledge bought a store in Forks of the Tar, otherwise known as present day Washington (Edwards 2015:5).

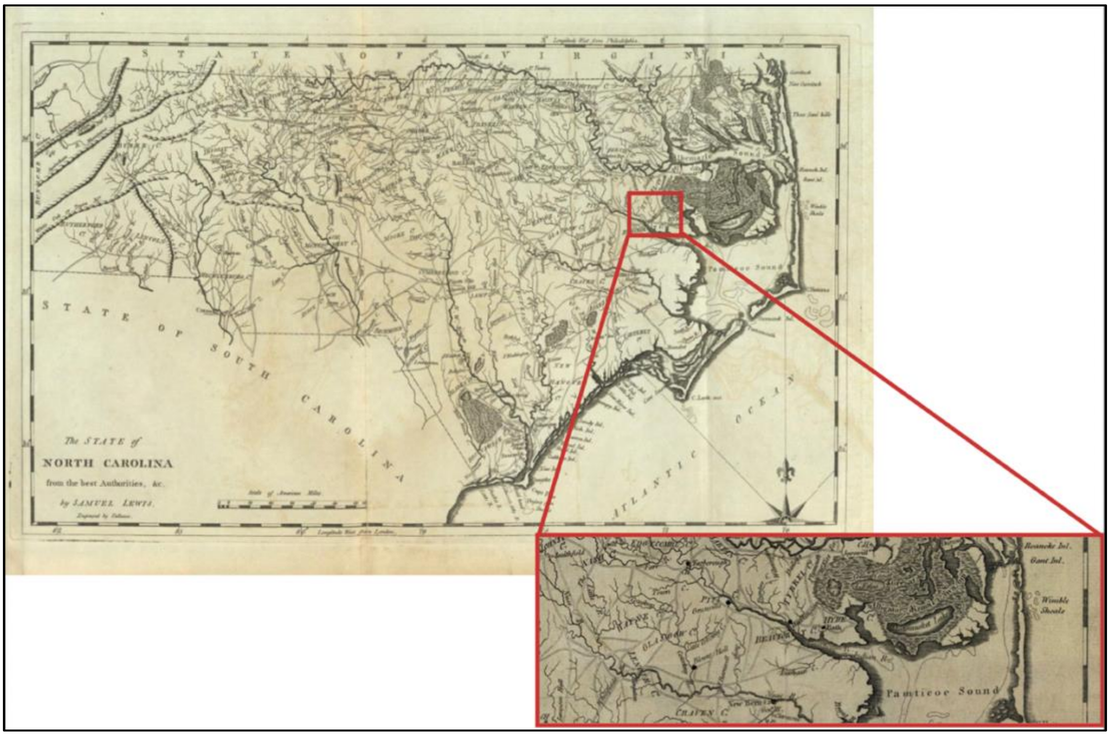


FIGURE 3: Map of North Carolina from the best Authorities, done by Samuel Lewis (State Archives of North Carolina, 1795). Zoomed portion of the map added by the author.

The location of Washington proved itself to be an advantage, as it was more intercoastal and provided access to the longleaf pine forests in North Carolina. In 1770, the colony accounted for 60% of the total amount of naval stores produced by all British colonies. The Revolutionary War broke out just as the town began to prosper, but unlike other southern ports, the town served as an operation base for the Continental Army as it was not impacted by the Trade Acts or Intolerable Acts of 1775. Under these acts, the British Parliament limited colonial trade through restrictions. With these restrictions, the colonies could only import and export any goods with Great Britain and the West Indies. However, North Carolina was unaffected by the acts as Great Britain was punishing the northern colonies for their revolting against the mercantilist policies (Hill 1984:4-5).

Unlike the port cities of Wilmington, North Carolina, and Charleston, South Carolina, Washington remained open during the war which allowed the city to expand physically and economically. Washington continued to produce tar, turpentine, rosin, and barrel staves for merchant and naval vessels. Despite Royal Navy raids on port towns during the war, North Carolina's trade with the West Indies and other overseas ports remained unimpacted (Worthy 1976:8-9).

As the town became more prominent in eastern North Carolina through its trading services and location, Washington was the first town to be recognized and named after President George Washington in October of 1776 (Paschal 1976:2). A center of privateering activity with leading merchants, such as John Gray Blount, the armed vessels from the port cruised the Atlantic and preyed on British shipping, collecting numerous prizes (Paschal 1976:2). Remaining open also allowed local merchants, such as the John and Thomas Blount, to supply the Continental Army with arms, vessels, and food from the West Indies and other colonies. Warehouses took over the waterfront, and as numerous vessels relied on the port of Washington during the war, shore facilities became crowded, forcing many ships to anchor in the Pamlico channel (Hill 1984:4).

After playing such a significant role during the Revolutionary War, Washington developed rather quickly at the turn of the century. By the 1780s, numerous wharves constructed along the waterfront regularly traded tar, turpentine, pitch, rosin, boards, shingles, and tobacco, and regularly shipped such goods to the West Indies and other states along the east coast as Great Britain was no longer the chief buyer (Nassif 2020:14). From the years 1782 to 1815, the production and trade of naval stores thrived in eastern North Carolina due to its riverine transportation networks, and because the state dominated production in contrast to its neighbors (Perry 1968:512). At the time, the Blount family became prominent as they helped to build the waterfront through trade and labor. John Gray and Thomas Blount were merchants who settled in Washington and operated several businesses along the Tar River and Pamlico Sound. The Blount's often traded with New Englanders and sought opportunities with new partners in Europe and the West Indies when relationships were strained between other European powers (Keith 1948:201). The main consumer of lumber from eastern North Carolina was the West Indies, both before and after the Revolutionary War (Combs III 2003:7). In 1783, Johann David Schoepf, a German botanist, stopped in Washington and noted the town's size and trade. Morrison (1911:125) cites Schoepf as stating that Washington was twice the size of Bath, a once dominant port of eastern North Carolina, and that its primary focus at the time was shipbuilding, although the vessels were small and "put together entirely of pine timber and sold very cheap." Shoepf further noted that the trade of pelts, pitch, and tar was primarily with New Englanders (Morrison 1911:125). This trade relation continued into the nineteenth century, as evident in a letter to John Gray that a ship would soon sail from Providence to Washington "with a Yankee Cargo (as usual)" (Keith 1959:322).

According to North Carolina historian Percival Perry (1968:512), those generating naval stores in North Carolina were "small farmers living in the pine forest, many of whom worked unassisted". From the 1720s, small and middle-sized farmers manufactured a significant portion of naval stores produced in the state (Outland 2001:312). As the profit from naval stores increased, more individuals and families took up the trade to capitalize on the blossoming industry. The extractive naval stores industry employed slaves, as well as white laborers, as the need for these goods increased (Outland 1996:28). With the industry operating nontraditionally, it provided the English, as well as colonists, a source of cheap labor.

With the rise of naval stores, shipbuilding, and the lumber industry, the Blount family utilized slave labor to produce and export goods. Eventually, John Gray Blount was the second largest slave owner in Beaufort County. The number of enslaved people throughout Washington was relatively equal to the population of free persons, although they were split between working on local plantations, maritime labor, or nontraditional labor (Edwards 2015:76-77). Rather than being part of the triangular trade, many enslaved arrived in North Carolina by overland routes, such as passing from Virginia or South Carolina. Slave traders exchanged captives as a payment for exported goods, like naval stores, timber, and livestock (McCabe 2007:86-87). John Gray Blount often put enslaved people into maritime labor, having them pilot vessels and dig canals throughout the region. It was noted that they were often knee deep or up to their torso as they worked in the water. Along with this, they worked in the tar kilns, sometimes alongside Irish immigrants, and other sources of free labor. As the profit from naval stores increased throughout North Carolina, so did the labor population. From 1790 to 1800, the enslaved population increased by 20%, which could be seen throughout Washington (Edwards 2015:74-75).

In terms of production and transportation of materials, the history of naval stores is fragmented and inadequately documented. This paucity can be attributed to the industry being mainly in the rural countryside and having a “nontraditional” agricultural role. Rather than relying on crops like wheat, tobacco, rice, and cotton, North Carolina’s agriculture dominantly consisted of tar, turpentine, and pitch. Tar kilns and turpentine operations required heavy labor and vast numbers of people to carry the products from inland to the waterfront. The extraction of naval stores was destructive and grueling, and the practice used was referred to as the box system, which created a wide shallow hole in the base of a pine tree and a "v-cut" downwards, then hacking off the bark and few outer rings of the wood on the tree (Olmsted 1856). A pine tree could have from one to four boxes, advancing higher upon the trunk. Through boxing, the pine tree was left weak, and susceptible to wind, drought, disease, fire, and insect infestation (Driscoll and Kick 2013:15). However, the pine species were of great value for Americans as they continued to exploit it for trade and building materials.

By 1790, Washington was recognized by the federal government as an official port of entry, meaning foreign goods and people could lawfully enter (Rodgers et al. 2006:14). The town began to develop towards the turn of the century, with ten wharves established along its waterfront (Hill 1984:5). During this period, Washington continued to progress through industries such as timber, naval stores, shipbuilding, and maritime transportation through modes of labor. Those enslaved continuously worked producing naval stores in the winter when other seasonal crops concluded. In the nineteenth century, the naval stores trade in Washington represented nearly 75% of the exports leaving the city as several distilleries were in operation (Outland 2001:45).

The constant need for naval stores and lumber allowed Washington to prosper. As Great Britain needed resources to expand its naval power, Washington provided commerce and labor. Even after the American Revolution, the town's naval stores reached not only across the Atlantic to Great Britain, but to the Caribbean and northeastern colonies, such as Massachusetts and New York (Edwards 2015:30). With cheap labor and maritime commerce, Washington was able to develop and expand throughout the nineteenth century and saw various industrial trends throughout the century (Nassif 2020:37).

As the lead mercantilist in Washington in the eighteenth century, John Gray Blount capitalized on the industries that utilized natural resources (Edwards 2015:36). And since the town's early economy relied on surrounding raw materials, the Blount family turned from producing naval stores to shingles and boards. With the need for such goods, an industrial revolution took place throughout the city of Washington, which expanded its waterfront and prosperity.

Antebellum Washington

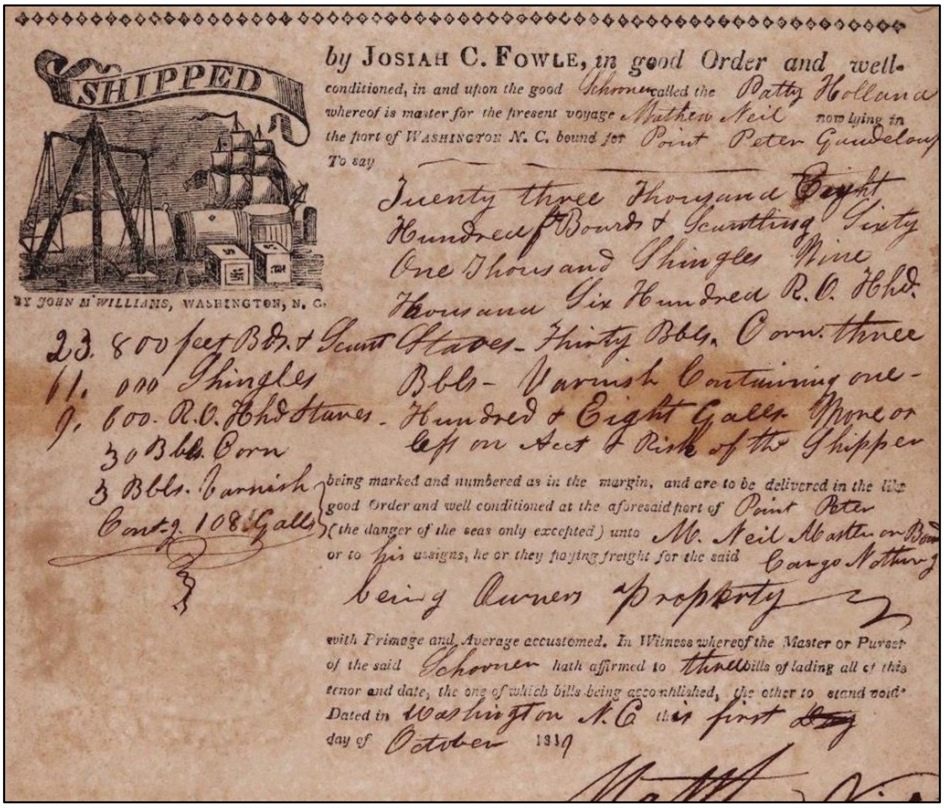
Throughout the nineteenth century locals in North Carolina depended on waterborne transportation of passengers and goods. The fingerlike waterways of the land were the method commonly used to move, putting Washington at an advantage as it is situated along a riverbank.

As the new century dawned, two families dominated Washington's mercantilist businesses. Although the Blount family established Washington, the Fowle brothers arrived shortly thereafter. Relocating to Washington from Concord, Massachusetts, in the early nineteenth century, brothers Josiah and Luke Fowle became a contributing factor in the development of the city (McCabe 2007:97). Shortly after their arrival, their brother Samuel joined them, forming the S.R. Fowle and Son Company. As they became more prominent in importing, exporting, and building, they established a shipbuilding business on an island parallel to Washington's waterfront. Eventually known as Castle Island, the first known reference to the island was not made until the year 1818, when Josiah and Luke Fowle made note of their business and office being located on the island known as "The Castle" (Rodgers et al. 2006:16). Castle Island's name comes from the stack of chimneys that were erected with the limekilns, resembling the turrets of a castle. The kilns on the island were made to burn oyster shells to create lime for cement (Hill 1984:5). Along with the kilns, Castle Island housed a sawmill established by Tannyhill and Lavender in the early nineteenth century, which aided the booming shipbuilding industry (Worthy 1976:11). As the Fowle brothers established their base of operations on the island, their businesses quickly blossomed.

Records of the trading done throughout the era of the Fowles was kept in daybooks showing their business, investments, and partners. Their fast-growing business eventually supplemented their shipbuilding interest through variety of goods. A collection of the Fowle daybooks curated at the George H. and Laura E. Brown Library in Washington demonstrate that the family traded from New York to the West Indies (FIGURE 4: Sample of 1819 Bill of lading to Point Peter Guadeloupe (Fowle Shipping Records, George H. and Laura E. Brown Library).). From 1815 to 1830, shipbuilding in Washington became a dominant industry due to the increasing demand for merchant shipping (Rodgers et al. 2006:16; Lowe 2022:33). After the Revolution, shipwrights who once made vessels for privateering against Britain turned to merchant ship construction (Nassif 2020:19). Along with the resurgence of shipbuilding, the production of lumber increased during that time as naval stores were no longer considered to be the main export. Logs were transported to mills by floating down the river or on-board flat-bottomed boats. Since Castle Island's location provided easy access to this resource, not only did the S.R. Fowle and Sons Company utilize the island for lumber, but shipbuilder Abner Peale also established a business on Castle Island, making the isle home to two enterprises (McCabe 2007:90).

Throughout the nineteenth century, the increasing wealth of the Fowle brothers mirrored broader economic trends of the period, shifting from naval stores production and exportation to that of shingles, lumber, and staves (Nassif 2020:105). Both naval stores and lumber products, however, remained consistent in the Fowle daybooks throughout the period.

Along with shipping agricultural goods for finished products from cities like Boston, Baltimore, New York, and Philadelphia, the Fowle family business also exchanged their goods for molasses and rum from the islands of the West Indies (Fowle Shipping Records 1808-1836).



SHIPPED by JOSIAH C. FOWLE, in good Order and well-conditioned, in and upon the good Schooner called the Patty Holland whereof is master for the present voyage Mathew Neil now lying in the port of WASHINGTON N. C. bound for Point Peter Guadeloupe To say

Twenty three Thousand Eight Hundred feet Boards & Scantling Sixty One Thousand Shingles Nine Thousand Six Hundred R.O. Hhd. Staves - Thirty Bbls. Corn three Bbls - Varnish Containing one - Hundred & Eight Galls More or less on Acct & Risk of the Shipper

23. 800 feet Bds & Scant
61. 000 Shingles
9. 600 R.O. Hhd Staves
30 Bbls Corn
3 Bbls. Varnish
Contg 108 Galls

BY JOHN M'WILLIAMS, WASHINGTON, N. C.

being marked and numbered as in the margin, and are to be delivered in the like good Order and well conditioned at the aforesaid port of Point Peter (the danger of the seas only excepted) unto M. Neil Master or to his assigns, he or they paying freight for the said Cargo Nothing being Owners property with Primage and Average accustomed. In Witness whereof the Master or Purser of the said Schooner hath affirmed to three bills of lading all of this tenor and date, the one of which bills being accomplished, the other to stand void. Dated in Washington N.C. this first day of October 1819

FIGURE 4: Sample of 1819 Bill of lading to Point Peter Guadeloupe (Fowle Shipping Records, George H. and Laura E. Brown Library).

As the S.R. Fowle and Sons Company expanded, its range of commercial goods also grew, establishing and expanding its resources in the process. As noted in the Fowle daybooks, naval stores and the lumber industry became Washington’s primary exports (Fowle 1817). By the mid-nineteenth century, these products accounted for 75% of the value of all products leaving the city’s port, as Washington had seven turpentine distilleries in operation (Outland 2004:44-45). The region’s bountiful pine and cypress trees allowed the Fowles to capitalize on resources and produce vital products. Timber commodities proved to be important within Beaufort County as newspapers emphasized the industry and its impact on the economic growth of eastern North Carolina (*Tarboro Press* 1845).

Commerce on the Tar and Pamlico Rivers prospered throughout the nineteenth century, as Washington utilized the turpentine and lumber industries (FIGURE 5). Castle Island thrived as an industrial link in the first half of the nineteenth century until the economic recession known as the "Panic of 1857" dropped shipping production by 17% (Lowe 2022:34). Along with this, events leading to the Civil War paused the businesses on the island as the Union and Confederacy saw Washington as a strategically important city to occupy. The impact of the Civil War brought negative changes to Washington as it stunted its economic growth and industries during the war and several years after, as there were new modes of transportation for trade (Cox 1989:46).

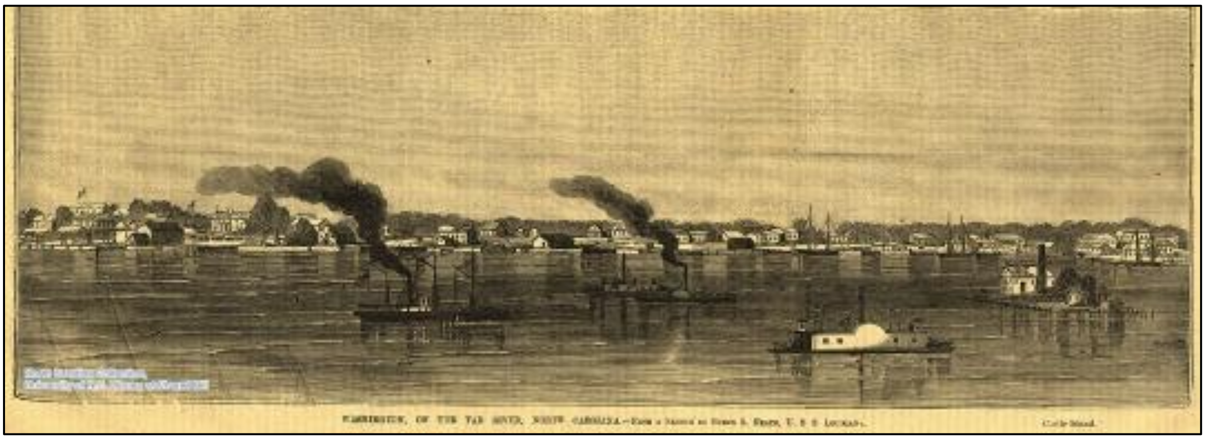


FIGURE 5: Sketch of Castle Island by Byron S. Heath, 1862 (North Carolina Collection, UNC Chapel Hill)

Conclusion

Washington, North Carolina, served itself to be an integral facet to the region of eastern North Carolina throughout the development of the state. With the first known erection of warehouses and wharves being around 1758, the port slowly expanded until the Blount and

Fowle families made their mark. The British once capitalized on the bountiful and untapped resources that once thrived in eastern North Carolina, and American merchants sought to expand their businesses and wealth following the Revolution. The swampy terrain of the port necessitated waterborne trade, which also served as a critical location for providing access to raw materials further inland and to other intercoastal waterways. As Washington prospered in economic growth through the production of goods, the waterfront expanded and adapted to fiscal needs, putting warehouses and wharf extensions into the Tar and Pamlico Rivers.

Chapter Three. Colonial Wharf Construction and Identifying Castle Island's Maritime Infrastructure

Given the historical context of Washington's waterfront development, this chapter delves into colonial wharf typologies and identifies the one found in the waters surrounding Castle Island. The chapter defines term wharf, the characteristics of the structure, and the materials used to build different types of wharves and offers a brief historical context. Through this, a more comprehensive narrative about the history of wharves and their construction is formulated. Lastly, it discusses archaeological investigations of other early wharf structures, particularly those in the eastern region of the United States as they were once dominant throughout the seventeenth to nineteenth centuries. Through the various analyses conducted in this chapter, the context of Castle Island becomes more clearly defined and comprehended.

Defining "Wharf"

The term wharf originates from Old English and Old Dutch, both having the connotation of "yard," or a place of coming and going, a turn-around place (Wright 2024: 73). Although wharves can have numerous definitions and meanings based upon context and location, they are essential to the use of ships and can be seen as one of the numerous physical indications of past maritime activity (Small 1941:1). As historian Edwin Small mentions in "Wharf Building of a Century and More Ago" (1941:3), the first detailed recording of the construction of wharves in the United States was not completed until 1840. Stated in Freeman Hunt's *Merchant's Magazine and Commercial Review,* the wharves erected within New York City's harbor were "formed entirely of timber and earth, in a very rude and simple manner" (1840:313). Within the United States, a wharf is defined as "projection of wood or stone constructed along the banks of an anchorage or in a harbor to provide accommodation for shops to lie alongside for the loading/unloading or cargo, passengers, etc." (Heintzelman 1985:6). In simpler terms, it can be described as an extension of the land for the purpose of loading and unloading vessels. Other terms, such as quay, dock, and jetty, can be synonymous.

As stated, the term wharf is synonymous with terms such as docks, slips, piers, jetties, and quays. And though these classes of maritime infrastructure have some similarities, there are distinguishable differences that must be outlined to gain a better understanding of core characteristics of a wharf. The structure and term perhaps most synonymous with the American concept of a wharf is the British quay. In comparison to a wharf that projects into the water, however, a quay is parallel to the land and more likely to be bounded by mass concrete or pilings, often made of timber (Bird 1971:53). The construction of a quay allows water to act as a cushion between a vessel and structure as vessels load and unload on the platform. It is important to note that a quay can be more closely related to a jetty than a wharf, though a jetty is not necessarily attached to land and can sometimes be a solid blockwork or "large buoyant boxes floated out, sunk, and filled" (Bird 1971:51). Lastly, piers and docks are two structures that can be confused with a wharf. The modern definition of a pier is a wooden structure that projects out from shore above water level, being a transitional structure between water and land. In colonial times, however, a pier was defined as a "strong mound, or fence, projecting into the sea, to break off the violence of the waves from the entrance of the harbor" (Falconer 1780:227). In contrast to a pier, a dock is often built within an enclosed space (Bird 1971:54). As mentioned in Falconer's marine dictionary, a dock can be seen as "a sort of broad and deep trench, formed on the side of a harbor or on the banks of a river; and commodiously fitted either to build ships, or to receive them to be repaired and breamed therein" (Falconer 1780:100). A wharf, on the other hand, can contain all of these as they are intricate constructions that can contain buildings which support businesses or commercial services to visiting vessels. Along with this, the size of the wharf is dependent on economic success, which can be seen through its evolution and construction in earlier times (Welliver Southerly 2006:11).

Wharf Technology

Several different types of wharf construction were used throughout the eighteenth to nineteenth century. The choice of structure was often related to socio-economic conditions, such as availability of raw materials, permanency, water activity, wind direction, soil conditions, and size of vessels serviced. While timber was the dominant construction material in the United States as it was more readily available and cheap to produce, stone was more common in New England than in the south (Heintzelman 1985:15; Norman 1987:7). In areas where maritime commerce dominated, wharf construction can be described as:

> "…wooden piles, driven close to each other into the bed of the river... The piles, of which the face-work of the piers is composed, are driven perpendicularly into the ground, and are secured in their place by horizontal wale-pieces or stretchers, bolted on the face... and running throughout its whole extent. Diagonal braces are also bolted on the inside of the piles and beams of wood are connected to the face-work and extend behind it to the shore... The void between the perpendicular piles... is generally filled up with earth" (Hunt 1840:313).

This description applies to the wharf construction seen throughout New York City in the nineteenth century, and there were three prototypes of colonial wharf construction: timber, timber and stone, and stone (Heintzelman 1985:8).

Timber constructed wharves were frequently built with a crib structure. The crib construction alternates between header and stretcher timbers, overlaying one another. A header is a length running timber, while the stretcher is a width-spanning timber. In a crib wharf, timbers run from the shoreline out to or into a body of water. The joinery within the crib construction is often described as a "Lincoln Log" structure due to it forming a box-shape frame with transverse and longitudinal crossties (McDonald 2011:42). A crib has multiple subdivisions called cells which are created by crossties, or blocks (FIGURE 6,

FIGURE 7). The term crib incorporates both block-and-cell construction or a box-shaped structure that does not have clear cell division (McDonald 2011:42-45). Crib wharves encompass a design that lets the wharf settle and conform to the bottom of the harbor or river. This construction has the flooring raised above the first tiers of timbers as the bottom is merged to the sea or riverbed, preventing the wharf from moving with tidal activity. Depending on the type of flooring, such as sand, mud, or silt, the wharf was further stabilized by having a fender piling placed vertically along the joined cribs (Heintzelman 1985:24). Fastening the timbers that make cribs was critical to stabilizing the interlocking timber pieces, which was done in various ways.

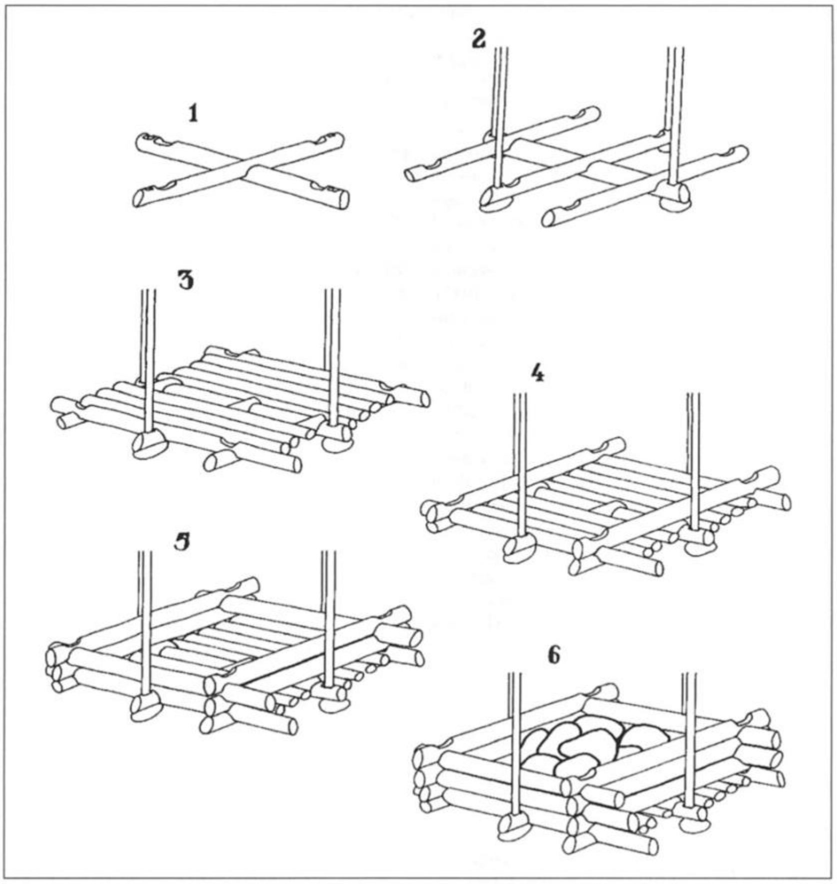


FIGURE 6: The construction sequences of a crib-type wharf. (1) serves as a base for the wharf construction, allowing the "vertical lock bars" (2) to be placed in the slots of the timbers for reinforcement. Step (3) shows the foundation of the crib wharf as (4) and (5)

show the alternating logs used to create the walls. Lastly, (6) represents the final crib structure with ballasts as the fill (McDonald 2011:57).

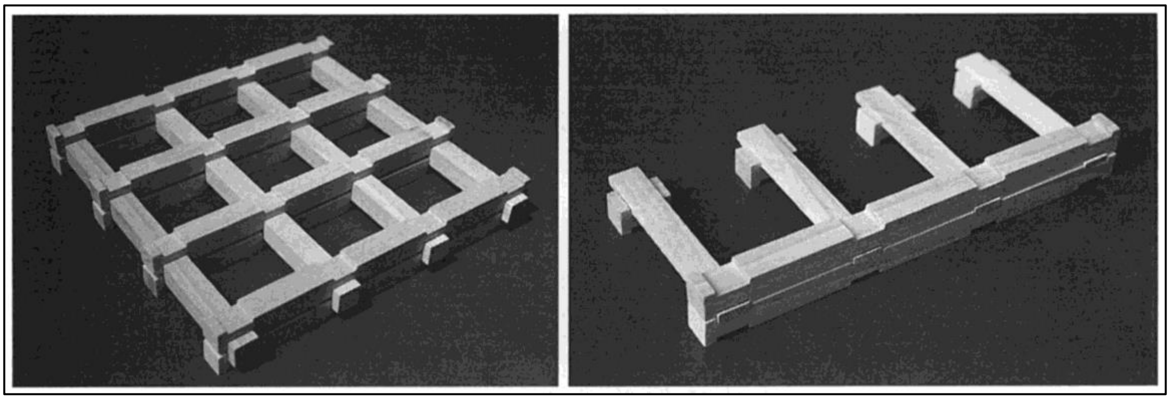


FIGURE 7: Model figures demonstrating a crib-type wharf and its wall form (McDonald 2011:43).

There are four different ways in which cribs are retained and joined: lock-notch, dovetail, dowel locked, and saddle notched. The types of joining timbers determined the style of crib construction, being open or closed. Through the lock-notch, timbers had square cuts placed about 30 cm from the ends, and the timbers into a square cut opening. Dovetail is like the lock-notch as it has joining location at the end of each timber, however the hewn timbers flare out to lock into place by using the force of weight. Next, the dowel lock usually consists of hewn timbers and squared cuts at the end, with a wooden peg being fitted into a hole that is drilled through the timbers to hold them in place (FIGURE 8). This is the only method that uses a wooden trunnel (sometimes referred to as treenail) or other fastener to secure and interlock the timbers. Finally, the saddle notch join incorporates a semicircle cut in the timber to fit to the rounded surface of the other timbers. The saddle notch allows the timber to retain the bark and original shape and is the fastest way to build a wharf (McDonald 2011:44-45; Byrd 2018:14).

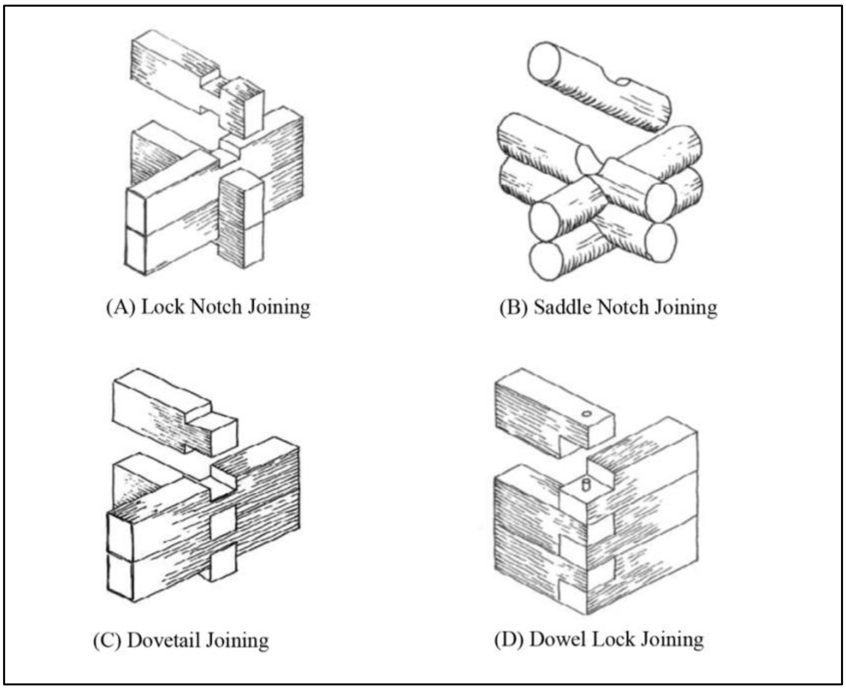


FIGURE 8: Sketches of the four common types of joinery found on wharves (Byrd 2018:16-17).

With the various types of structure being opened or closed, there are some defining characteristics of each. A cobb wharf is of similar construction to the crib, but the timbers are laid next to each other without flooring or fill between them (Heintzelman 1985:10; Smith 2014:85). The building style for the cobb wharf is also referred to as the open construction due to these gaps, as the logs are layered loosely on top of one another. The cobb style tends to utilize unfinished timbers and often uses cobblestones, usually ballast rocks used by trading vessels for stability, and/or tree stumps to fill and sink the structure (FIGURE 9) (Heintzelman 1985:10). As builders sourced various materials to sink the structure, a floor was often built near the bottom of the framework. The name "cobb" refers to the timbers of the wharf being held down or sunken by rocks or cobblestones (Small 1941:3).

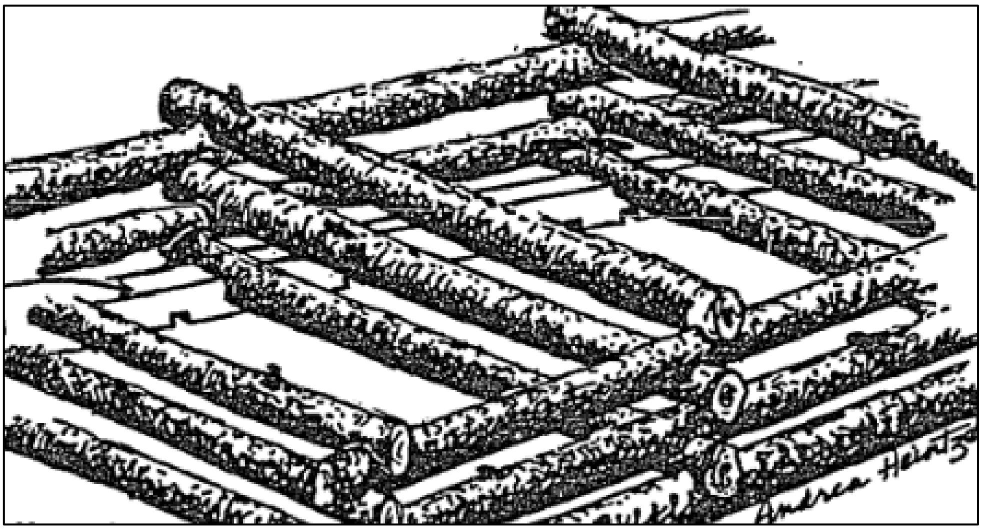


FIGURE 9: Example of cobb-type wharf (Heintzelman 1985:11).

In contrast to the cobb style, closed construction utilizes finished timbers that are fitted in a way that leaves no gaps between them. Finer materials such as mud, earth, and sand are preferred for the closed construction style, though ballast stones were also used historically. Ballast was often discarded by vessels loading cargos, making it a prominent feature within a wharf. Once the foundation of the crib wharf was constructed, it was then floated to the desired location and sunk using fill materials (Heintzelman 1985:9-12).

The last construction style for wharves is the stone wharf. Although most stone wharves tended to be complimented with the crib style, three distinct construction types of a stone wharf are known: dressed, semi-dressed, and undressed, which refer to type of stone used. Dressed indicates that the entire stone was processed, or cut, and ready for installation, whereas semi-dressed employed stones with at least one flat or processed surface and were sometimes reinforced with wood fender piles. Undressed or uncoursed stone was rubble, irregularly shaped, and had rounded edges or was found from a quarry and used transverse fenders and bolted drifts for stability (FIGURE 10) (Heintzelman 1985:13; Bothara and Brzev 2011:8-9). It is noted, however, that stone in the United States was not the dominant wharf construction material until the early to mid-nineteenth century, as they were usually built of wood and sunk using rock (Small 1941:3).

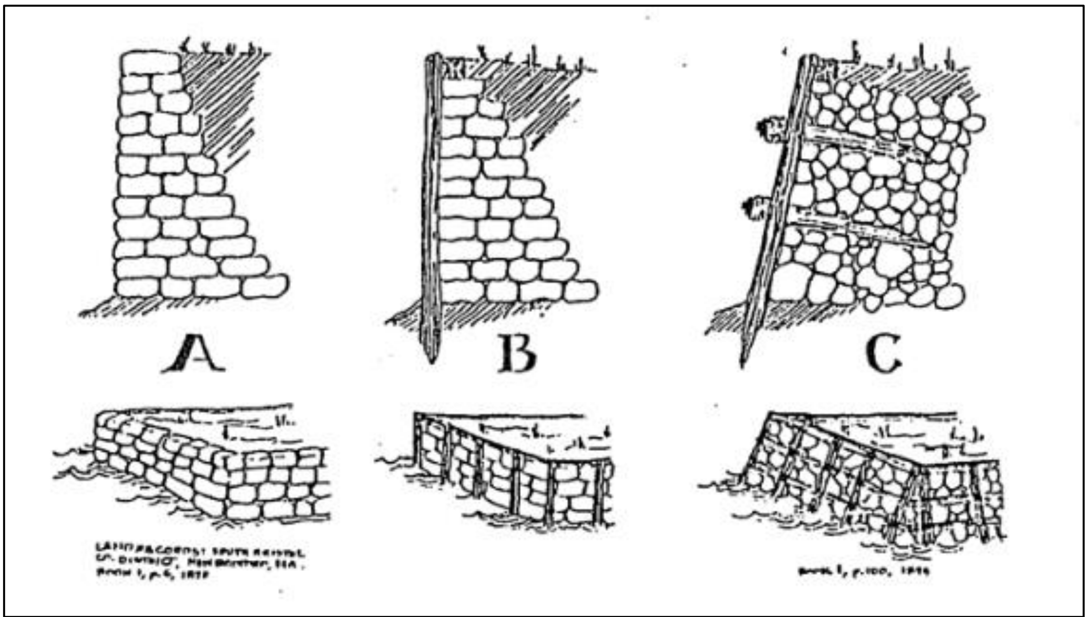


FIGURE 10: Sketches of stone wharves that exhibit (a) dressed stone (b) semi-dressed stone with fender piles and (c) undressed stone with transverse fenders (Heintzelman 1985:13).

In continuation with wharf technology, maritime infrastructure was constructed in two different styles: L-shape and T-shape. These configurations were made by adapting a linear wharf projecting out into the water to a T or L shape, meaning that the wharf transitioned and added modifications as the port saw an increase of activity (Bird 1971:69-70; Heintzelman 1985:46). The L-shape wharf, otherwise known as a "returned wharf," is placed perpendicularly to the shoreline with a finger extending in one direction (Heintzelman 1985:27). A L-shaped wharf is designed to provide protection and shelter for vessels to safely dock. T-shaped wharves were situated in the same way; however, the center of a finger is attached to the linear wharf. A T-shaped wharf offered more space, therefore allowing multiple vessels to dock and to safely maneuver (Cornick 1959:18-19). With this type of construction, a wharf accumulates depositional materials, thus introducing the “open” crib for the materials to flow through the wharf (Heintzelman 1985:27).

History of Wharves

The expansion of power from Europe into the New World meant a concentration on maritime activities, such as trade. Needing to capitalize on material goods for their own benefit, European powers erected ports along not only colonial waterways and coastlines, but in their homeports as well for easy access to trade. Ports allowed for legitimate access to maritime trade and commercial activities, which assisted with colonizing efforts (Heintzelman 1985:30). The rise of ports and wharves was from the increasing populations and demand for materials throughout the sixteenth and into the seventeenth centuries led to a significant rise in ports with established wharf systems (Heintzelman 1985:30). Thus, flourishing trade brought the need for organized and centralized areas of transaction, as well as transportation.

Extant evidence throughout Europe and North America shows the importance of an expanding waterfront and the use of available resources obtained from surrounding area, which were often timber. Although the vernacular and archaeological record of early wharf history is somewhat vague, the following discussion provides examples of landfill retained structures that have been documented in Europe, with some being built more than 800 years ago.

In the United Kingdom, wharf structures dating to the thirteenth century have been recorded and were often built of timber and planking, with some loose fill. This can be seen through archaeological investigations undertaken in the mid-1970s at Trig Lane in London, England. There medieval landfill structures were built in several phases from the thirteenth century to the fifteenth century. Through those structures, the state and style of the wharf and quay remains were seen as indicators of economic health (Milne and Milne 1978:84, 103). However, due to lumber shortage by the end of the medieval period, stone became the new foundational source for maritime infrastructures. From the seventeenth to nineteenth century, however, England used a combination of oak and imported softwood timbers for wharf structures (McDonald 2011:55).

Another thirteenth century wharf structure was identified in the main harbor of Bergen, Norway. The former waterfront of Vågen Bay included two sites exclusively built in crib form, filled with stone, and strengthened by vertical lock bars placed through the timbers (Myrvoll 1991:152). This type of log-construction was a very common theme in Scandinavian wharf construction from the thirteenth century onward, as it utilized a traditional type of construction associated with the region (McDonald 2011:56). With the colonization and immigration of various European states into the New World, some of the same construction characteristics used in Europe were likely transferred to North America.

During European colonization of the Americas, waterborne commerce provided an essential link from the colonies to a given empire. The establishment of ports and wharves allowed colonies to trade raw and manufactured goods with their European counterparts. Areas that became heavily populated and provided access to such materials were often situated on coastal or riverine waters that could accommodate sizeable vessels. With ports developed and extended into the waterways, such towns prospered and became economic drivers (Nassif 2020:42).

The New England colonies saw the earliest and most rapid development along their coastal and riverine environments. As early as 1660, maps indicate that few wharves were constructed into the rivers on each side of New York City. A 1767 map of the Manhattan, New York, however, illustrates a riverfront development with short and straight shaped wharves extending into the water (FIGURE 11). Being situated between two deep rivers, the Hudson and East, provided vital access to the city for sea-going vessels (Heintzelman 1985:45-46). In Boston, Massachusetts, numerous wharves were erected by 1645 to support the shipbuilding, whaling, fishing, and trading occupations of the city (Heintzelman 1985:46). Due to the Boston's immediate proximity to the ocean, many T-shaped and L-shaped wharves were constructed in the early to mid-eighteenth century, which reflects the increase of commercial activities until the enforcement of British trading acts and the American Revolution (Heintzelman 1985:47). Following the war, Boston's prosperity returned, and it was once again recognized as a major maritime trade center. Along the east coast, New Haven, Connecticut, developed a wharf in 1666 that extended from the town's waterfront to the sand flats of the nearest marsh (Heintzelman 1985:50). The early wharves of each of these cities were situated on the coastline and consisted of T- and L-shapes, thus allowing more access to vessels in the waterways.

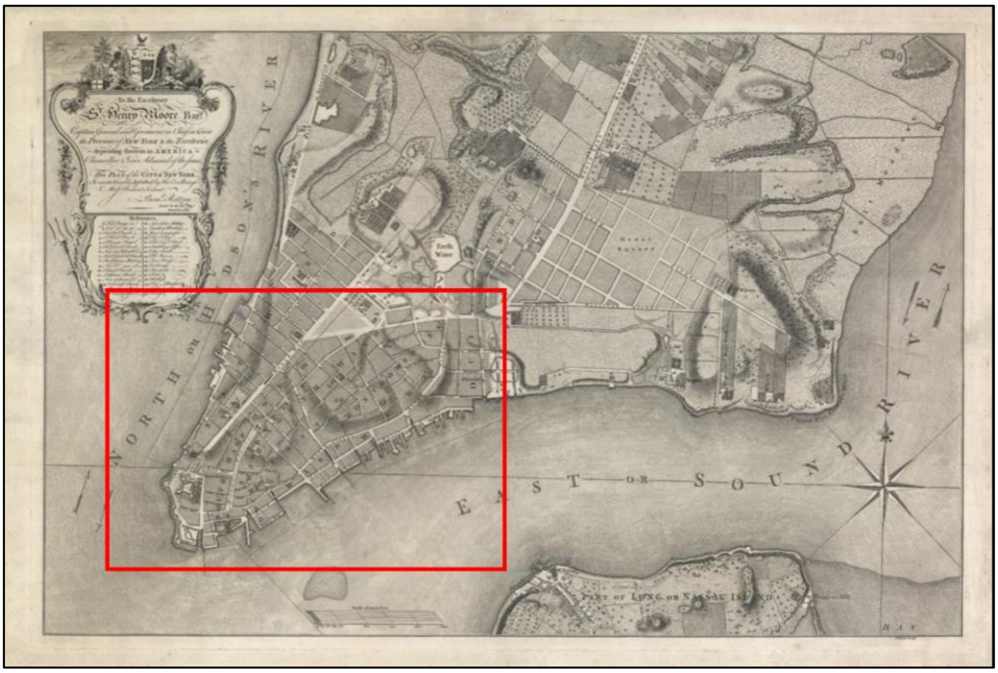


FIGURE 11: Map of New York City in 1767 done by Bernard Ratzer. Otherwise known as the "Ratzen Plan" due the misspellings on the map. This was done because of the Stamp Acts of 1765, made just prior to the American Revolution for British authorities (Ratzer 1767).

Inside the red box depicts the development of wharves extending into Hudson and East Rivers (adapted by author, 2024).

Heintzelman's (1985) research, however, considered the riverine ports of Philadelphia, Pennsylvania, Annapolis, Maryland, and Norfolk, Virginia. By 1684, Philadelphia, Pennsylvania, had a 91 m "key" that accommodated vessels and shipyard. By 1750, numerous other wharves were constructed as Philadelphia became a bustling maritime trade center (Heintzelman 1985). Lastly, Norfolk, Virginia, has a rich history as a maritime community as it was founded in 1680 and was recognized as an official port and town in 1691. As Norfolk began to grow, so too did the waterfront. Dating to 1728, a comment made by William Byrd compares the cribbing wharf to that of a log cabin:

> The Method of building Wharffs [sic] here is after the following Manner: They lay down long Pine Logs, that reach from the Shore to the Edge of the Channel. These are bound fast together by Cross-Pieces notch into them, according to the Architecture of the Log-Houses in North Carolina. A wharff built thus will stand Several Years in spight [sic] of the Worm, which bites here very much, but may be soon repaired in a Place where so many Pines grow in the Neighborhood (Byrd 1929:36).

Similar statements regarding wharf construction can be found in the eighteenth century from other port cities, such as those of Baltimore, Maryland, and the District of Columbia (Norman 1987:11). In the late eighteenth century, a condition report for Baltimore Harbor lists 26 wharves consisting of filled timber cribbing, as it was the simplest form to build (Norman 1987:28, 32).

Archaeological Case Studies of Wharves Throughout Eastern North America

Case studies throughout the northeastern region of the United States include Edwin Small's (1941) research of the Derby Wharf in Massachusetts; Louis Berger and Associate's investigation of New York City's colonial waterfront (1990); Andrea J. Heintzelman's study of coastal and riverine port developments (1985); Joseph Gary Norman's analysis of Baltimore's eighteenth century wharf construction (1987); and Molly McDonald's (2011) analysis and comparison of European and North American wharf and waterfront structures. Each of these provides insight into what have been identified as wharf structures and how they were erected, maintained, and preserved. Furthermore, several theses prepared by ECU students explore colonial wharves found in North Carolina and Virginia as case studies for construction, preservation, and economics (Stephenson and Still 1994; Hicks 2012; Smith 2014).

Edwin Small's 1941 study of the Derby Wharf and Central Wharf in Salem, Massachusetts, provides an early example of research into eighteenth century maritime infrastructure, as both wharves are made entirely of wood. Although the wharves were built in the cobb style, there are also indications of stone being used on both sides. According to historical records, the Derby Wharf was a total of 231.6 m in length and 15.8 m in width by the year 1800, as the wharf was consistently extended since its construction in 1762 (Small 1941:6). Rather than fixing the structure, the owners of the wharf created a seawall using granite stone. The Central Wharf was built in 1791 of cobb structure, and like the Derby Wharf it was constantly under repair and improvement. A seawall of granite stone was also implemented to protect the structure from mooring vessels (Small 1941:9).

Another archaeological study of a colonial waterfront is the Cultural Resource Group Louis Berger and Associate's 1990 research in New York City. The site is located on city Block 35, formerly known as the United States Assay Office Building. Along with other structures, three wharves (Roosevelt, Bache, and Gouverneur) once extended into the East River. The lot on which the wharves were found, Lot 8, had a "water lot grant" dated as early as 1775, and historic records detail shops being established on the wharves since 1795. Excavations of the lot had three major stages: deep testing, backyard testing, and mitigation.

The deep testing was oriented towards landfilling processes and technology, while the backyard testing was geared towards identifying and evaluating archaeological remains associated with landfill. Through excavation, the waterfront structures of the wharf were found. Based on analysis of the construction techniques, the wharves were determined to be constructed in cobb style (Cultural Resource Group Louis Berger and Associates, Inc., 1990:I-4, IV-25-39).

As mentioned previously, Andrea Heintzelman's (1985) research explored the colonial trade and ports of New York City, New York, Boston, Massachusetts, New Haven, Connecticut, Philadelphia, Pennsylvania, and Norfolk, Virginia. Through historical and archaeological research complied by Heintzelman, historic wharves were documented to better understand the technological design of wharves and the economic and environmental influence on the style. Taking place in the mid-twentieth century, three privately owned wharves were studied: Follett's wharf in Portsmouth, New Hampshire; Forrester's wharf in Salem, Massachusetts; and Carlyle's wharf in Alexandria, Virginia (Heintzelman 1985:1). By archaeologically analyzing each wharf's structure, Heintzelman concluded that environment factors, such as topography, current, and sourced materials, determined the type of build and the structure (Heintzelman 1985:194). Of particular interest, Forrest and Carlyle had solid crib construction that were better able to withstand the pressure and weight of ships and warehouses, whereas Follett's had open cobb with no evidence of a warehouse (Heintzelman 1985:144,188,201).

In July of 1983, archaeological research at the Baltimore Center for Urban Archaeology in Maryland determined that wharf remains were present at a construction site. Through the investigation it became clear that several wharves remained at the site and that several structural timbers of one with an exposed bulkhead and a series of stone foundations were present. Excavation of the Cheapside Wharf in 1984 unearthed crib construction, which corresponds with eighteenth century documents referring to the early wharves built in Baltimore. This project exposed approximately 32 m of the structure thought to have been constructed in 1780 and originally recorded as being 13.7 m in width and 30.5 m in length (Norman 1987:70). The wharf was continually under repair and extended in the following years.

Molly McDonald's 2011 analysis of wharves and their construction types included these studies to compare with others recorded in Europe. With the Baltimore wharf excavations, most of the wharves exhibited crib styled construction, containing timbers partially squared off and partially rounded, or untouched (McDonald 2011:58). The Cheapside Wharf was erected with local lumber of yellow pine, and was filled with local sands, silts, and clay. When looking at various excavations undertaken in New York, she described a plethora of eighteenth-century waterfront features, especially a set of bulkheads ranging from 1730 to 1780 (McDonald 2011:59). Those bulkheads dated from the earliest period and consisted of grillage formation, while others from the following decades consisted more of a crib structure. Archaeologists distinguished grillage from crib by determining how the timbers were stacked on one another without joinery, bulkhead, or room for filling (McDonald 2011:59). Along with this, McDonald considered the investigation of Keith's Wharf in Virginia and the Thomas Penrose Wharf in Pennsylvania to understand eighteenth century wharf construction, though some difficulty was experienced in identifying the structure type. Although both exhibited crib style, Keith's wharf had linear features that resembled a projecting wharf and consisted of stacked timbers with a dovetail notch. The Thomas Penrose Wharf, on the other hand, was likely a crib structure, as evidence by the remaining timbers resembling round logs notched together in a Lincoln log fashion and filled with sand and cobble stones (McDonald 2011:58).

In North Carolina, several studies have considered colonial wharf structures. Hannah Smith, a former master's student at ECU, investigated maritime infrastructure at colonial Brunswick Town (Smith 2014). This research recorded the remains of two early eighteenth-century wharves situated along the channel of the Cape Fear River. Tentatively identified as Dry's and Moore's Wharves, the construction of both follows the crib or cobb-crib construction type seen throughout eastern North America during this period. The remains of the longer of the two, Dry's Wharf, extends 33.5 m into the river and integrates 7 m long by 6 m wide cribs that are held together by saddle notches and trunnels, and refilled with ballast (Smith 2014:85-86). In contrast to Dry's Wharf, Moore's Wharf had little remaining, that being of sharp timbers lying on top of a ballast stone shelf. However, Smith concluded that it exhibits similar construction features as Dry's wharf, being that of crib or crib-cobb (Smith 2014:87). Smith also gave insight into the environment in which the wharves were built and how their establishment helped to counter the fast currents of the Cape Fear River. Lastly, Smith noted the preservation of not just the wharves mentioned, but also the artifacts found at the site of Brunswick Town (Smith 2014).

ECU student Theresa Hicks (2012) compared wharf construction at six different coastal plantations in Maryland, Virginia, North Carolina, and South Carolina, to understand their link to a plantation's prosperity throughout the eighteenth century. This MA thesis project noted that two of the six wharves used piling construction, two were cobb type, and two were solid cribbing. Furthermore, each of the wharves were constructed from timber and filled with whatever the plantation owners had readily available, such as organic material or ballast (Hicks 2012:180). Dendrochronological samples were taken at two of the wharves, Mulberry Landing in Maryland, and the Bowling Farm Site in North Carolina. The Mulberry Landing example was a solid-crib wharf that had bark remaining on the faces of interior and exterior timbers. Conducted by the Maryland Historical Trust, 14 dendrochronology samples were extracted from various points on the Mulberry Landing Wharf and its timbers were successfully dated to 1747. Although the research at the Bowling Farm Site conducted by ECU's Program in Maritime Studies determined it to be a cobb styled wharf built of southern yellow pine, attempts at dating were unsuccessful as no dendrochronological record was available for comparison (Hicks 2012: 24, 65-66).

Perhaps the most comprehensive study of early maritime infrastructure in North Carolina is the investigation of a wharf at Deer Island near Swansboro. According to archival research, Deer Island is recognized as early as 1730, though it is believed that the wharf remains were not constructed until approximately one hundred years later (Stephenson and Still 1994:32). Fieldwork included both terrestrial and maritime archaeological survey and excavation. A contour map created using a visual transit set upon a baseline helped determine the point on the island from which the wharf extended, and its visible remains included two timbers and an extensive pile of cobbles and ballast rocks (Stephenson and Still 1994:33). The wharf was built in the cobb style with the intersecting timbers held in place by trunnels, or wooden pegs (FIGURE 12) (Stephenson and Still 1994:42). An excavation unit of 9 m long by 1 m wide was established outside of the two timbers to determine the presence of other timbers, to understand the joinery method, and to obtain artifact material from the wharf structure. The excavation indicated that the fill material consisted of anaerobic clay mixed with wood shavings and chips, suggesting that a sawmill was situated on the island as early as the Revolutionary War period (Stephenson and Still 1994:33-36). Artifacts documented at the site included sherds of creamware and other ceramics, as well as bottle glass fragments dating to the early nineteenth century.

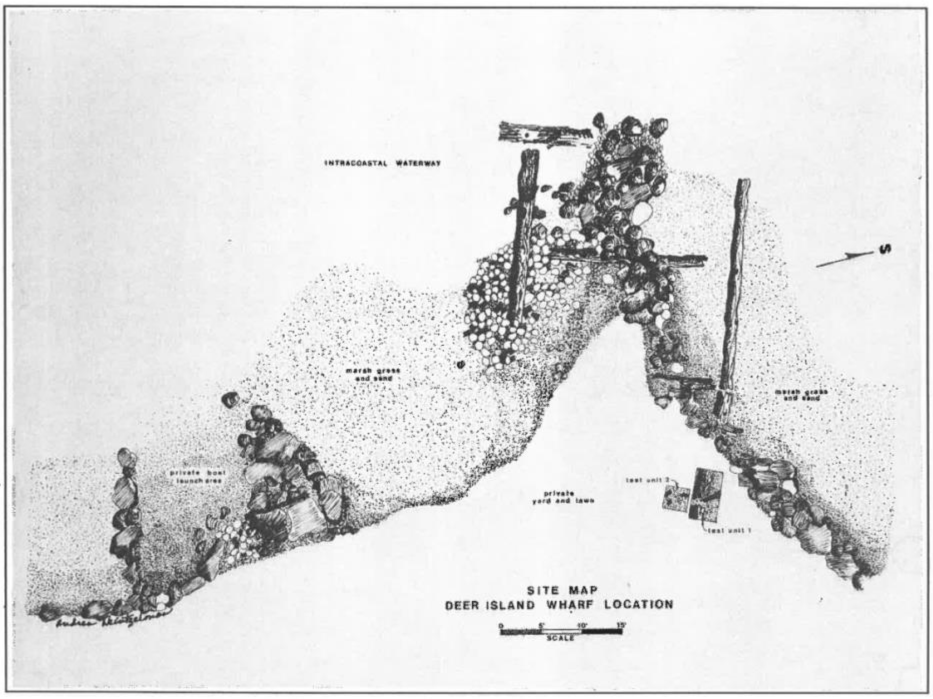


FIGURE 12: Site map of Deer Island in Swansboro, North Carolina. It was drawn from the point of land where the wharf extends, showing what remains during low tide. The extending headers are about 9 m while the stretchers are unknown (Heintzelman 1984: 94-95).

Determining Castle Island's Wharf Structure

Situated in the Tar-Pamlico River system across from the Washington waterfront lies Castle Island. This naturally formed landmass was modified in times past and incorporates an extensive submerged structure which encompasses nearly its entire perimeter, portions of which can be seen at low tide. Information pertaining to the wharf structure on Castle Island was largely gathered through the ECU Program in Maritime Studies 2021 Fall Field School. Faculty and students focused their efforts on recording and understanding the remains of several industries that once operated on the island, and the maritime infrastructure that provided access (Raupp et al. 2022:2).

The wharf structure is located on the western end of Castle Island, however submerged infrastructure is extant around the entire island and portions of them can be seen during extreme weather events or low tidal periods (FIGURE 13). The wharf provided an extension of natural outgrowth into deeper water, allowing maritime trade and traffic to increase in volume. Through this extension, the city of Washington grew and prospered as the wharf served as an asset to economic and maritime expansion.

FIGURE 13: The north side of Castle Island during a blowout of the Pamlico River. Pilings used to help support the structure are visible, along with several cribbing timbers (Photo courtesy of Ray Midgett, 2021).

Wharf Features

As the western part of Castle Island turns to the north, the structures shift to submerged pilings, where a log pen was used by the sawmill and timber industry that were once located there. At the site of the log pen, fourteen submerged pilings were identified. These pilings extended from the northeastern tip of Castle Island into the Pamlico River. While investigating the pilings, no evidence of fasteners or fastener holes were noted, suggesting that the pilings were driven into the riverbed for structural security (Raupp et al. 2022:17). A mostly submerged seawall created by crib structures was documented along the extent of the northern shore of the island (FIGURE 14). Similar structures were also documented along the eastern and southern shore, though much of it is buried due to erosion (Raupp et al. 2022:23).

Castle Island’s wharf provides an interesting combination of construction styles. While it is clearly a closed timber crib structure, there is evidence of a cobb construction, and it is filled with ballast stones. The timbers used in its construction were milled or hewn to remove their tops and bottoms to allow them to sit flush atop one another, but the sides were left unfinished. Several fender piles were also documented along the wharf; these are small posts that are driven into the sea or riverbed on the outside of a wharf to protect the wall from the impact of vessels (Schilling and Allen 2013:910). Given this combination of both finished and unfinished timbers, Castle Island presents an intriguing situation as it encompasses a structure that mirrors eighteenth and nineteenth century construction of a L-shape wharf.

FIGURE 14: A closer examination of the wharf structure on the northern end of Castle Island. The cribbing timbers are exposed, as are ballast stones that were used to sink the cribs (Photo courtesy of Ray Midgett, 2021).

As mentioned previously, the wharf structure extends approximately 25 m into the Pamlico River and incorporates crib cells approximately 3.5 m wide. The timbers were sawn off to be placed on top of one another, so only two sides of the timbers are modified, while the rest remain rounded with bark still present in some places. The head of the wharf extends the cribbing another 3 m as the headers jut out from the island, thus making the head 6.5 m wide in total. The head of the wharf serves as an intriguing piece to the wharf's construction due to the extent of piling and ballasts used to secure it. From the south side of the head, at least six pilings are in place to secure a header timber, along with ballast stones as the fill. This is likely to keep the wharf from moving or sliding on the riverbed. Erosion noted on the southern side of the island leads to a relatively deep drop off, making the wharf become more susceptible to damage with the constantly changing river currents. On the northern part of the wharf's head, there are four visible tiers of timbers, with the six pilings to secure them (Raupp et al. 2022:23).

Throughout the wharf, the headers vary in size, having a height range of 21 to 40 cm, width of 15 to 50 cm, and a length variation of 70 cm to 5.5 m. Several distorted timbers are deteriorated or missing due to erosion, which impacts the lengths of the northern and southern headers; however, the headers are ultimately consistent throughout the site with an average length and width of 32.5 m (Raupp et al. 2022:21). In contrast to the headers, the stretchers are more fragmented and have more variation in size. The remaining stretchers have a height of 10 cm, varying widths that range from 26 to 40 cm, and lengths of 2 to 6 m long. As previously stated, the measurements have fluctuation due to erosion and/or deterioration. It should be noted that the short stretcher lengths were found in the middle of the crib amongst the ballast piles (Raupp et al. 2022:23).

The maritime infrastructure surrounding Castle Island includes a total of 18 headers recorded, 6 stretchers, and 10 pieces of timber that could not be identified as a header or stretcher (see Appendix A). With erosion taking place on the island, evidence of an iron fastener with a diameter of 3 cm can be found on the south side of the wharf, exhibiting a dowel-locked joinery (Raupp et al. 2022:24).

The wharf is filled with ballast stones of varying size that are not local to the region. Although the origin of the ballast fill is unknown, it was common for visiting vessels to discard such material while engaging in trade at Castle Island and the Washington waterfront. Instead of simply dumping the stones overboard when needed to make space for cargos, it was used to anchor the crib structures and reinforce the wharf in its riverine environment (Raupp et al. 2022:24). Using ballasts for Castle Island's wharf construction allows the wharf to fill more easily. This is evident for Castle Island as the middle of the wharf is where there is a large cluster of ballast stones averaging 35 cm in diameter (Raupp et al. 2022:23). Ballast stones could have been used to reinforce the strength of the wharf and were more accessible rather than other fill material since numerous vessels and businesses once occupied the waterfront.

Aside from artifacts recorded (addressed in Chapter 4), the last characteristic of Castle Island is metal sheeting surrounding a cask-like feature that is situated within the cribbing on the north side of the wharf. A cask is a cylindrical container made of wooden staves and hoops that is enclosed on both ends and is typically used for storing and transporting liquids (Smith 2009:2). The metal sheeting that encompasses the cask at Castle Island is less than 1 cm thick and varies in height from 1 to 20 cm, with its base buried in the sediment. The head of the cask has a diameter of 90 cm, with widest measurements for the cask reach 1 m. The cask is made of wood and includes four metal nails on its rim and a concrete bung hole (Raupp et al. 2022:25). The measurements of the cask on Castle Island are comparable to tun cask or a double-puncheon cask (Smith 2009:12).

Overall, the construction of the wharf presents an interesting opportunity to investigate a combination of colonial wharf types in one structure. It is evident that the Castle Island wharf typifies a cobb structure on the north and eastern seawall, as it is more open with unfinished timbers and filled with ballast stones. The wharf also resonates with a closed crib construction, as it has finished timbers, stacked on top of one another and joined with a dowel-lock fastening. This type of construction was found on the southern and western side of the wharf.

The combination of the two types creates an interesting case study and raises some questions. As the tops and bottoms of the timbers were milled flat, the sides were left untouched. This could be evidence of attempts to save time, or because it was deemed unnecessary to finish them. In addition, cobb construction might have been used to discard and reuse some materials that were no longer in use, or because of the flow of the riverine environment impacted the structure and docking situation. Lastly, differentiation could result from quick additions and modifications, which can only be understood through timber dating analyses.

Conclusion

Castle Island's wharf, with its variations in construction and reinforcement, was likely established as the town of Washington experienced economic growth driven by the naval stores industry. The wharf demonstrates a combination of cobb and closed-crib construction, with cribs filled with ballast that were likely discarded by trading vessels. Some silt was also present, either trapped within the closed-crib structure or moving more freely through the cobb design. Artifacts found within the cribbing provide more valuable evidence for dating the wharf are further examined in the following chapter.

Chapter Four. Artifact Analysis and Ceramic Dating of Castle Island's Wharf

The 2021 ECU Program in Maritime Studies Fall Field School focused on documenting the maritime infrastructure of Castle Island. Previously collected side scan sonar surveys of areas around Castle Island produced the targets for investigation. Over the course of the field season teams identified and mapped the remains of structures both in the water and on shore, including seawalls, building and vessel remnants, and pilings. These archaeological investigations were conducted under a permit granted by the North Carolina Office of State Archaeology's Underwater Archaeology Branch (UAB).

2021 ECU Program in Maritime Studies Fall Field School Artifact Assemblage

Among the goals of the 2021 ECU Program in Maritime Studies Fall Field School was the survey and mapping of the remains of the Castle Island wharf and cataloging of any diagnostic artifacts that could potentially aid in dating it. According to the permit, when artifacts were identified, their positions were mapped in relation to the site plan and recorded using a Global Positioning System (GPS) unit. If deemed to be diagnostic, the position was marked with a bright pin flag before the artifact was raised from shallow river bottom (less than 1 m depth) to be photographed, sketched, and described. Once recorded, recovered artifacts were placed back in their original locations and pin flags were removed. In total, 34 artifacts were recorded and photographed (Raupp et al. 2022). Artifacts were identified among the ballast stones situated inside the remains of the wooden structure, as well on the seabed in adjacent areas. The assemblage consisted of pieces of ceramic, metal, glass, clay, wood, bone, and lithics.

Ballast

Ballast consisted of stone, iron, gravel, or other materials that are deposited into a ship's hold when there is no cargo onboard, or too little to sufficiently keep the vessel low in the water (Falconer 1780:29). The quantity of ballast was determined by the vessel's sharpness and flatness of the bottom, referred to as the floor (Falconer 1780:29). Ballast was often used to counterbalance the wind upon the masts of a vessel, placing center gravity at the bottom of the vessel to keep it from being too crank, too light, or stiff, overweight (McGrail 1989:352). The use of ballast stone was commonly seen in merchant vessels, where it, along with casks, cases, boxes, and other heavy cargos, was carefully placed at the keelson (Falconer 1780:29). Merchantmen often loaded and unloaded ballast at ports and harbors depending on the tonnage of the cargo, recycling the stones for other voyages or infrastructure.

Ballast stones were recycled for filling the cribbing built at Castle Island's wharf. The stone ballast was scattered in piles with individual pieces ranging from 10 to 60 cm in diameter (Raupp et al. 2022:27). The wharf exhibits a complex structure of cobb and closed crib construction, with both using ballast stone as fill. As previously mentioned, ballast stone was often reused material from trading vessels to fill, sink, and place the timber-made structure. It should be considered, however, that no petrographic analyses were conducted on the ballast found around Castle Island.

Wood

One wooden artifact was documented at the Castle Island wharf site. Retrieved from the site for documentation, it was identified as the disintegrated tip of a trunnel measuring approximately 3 cm in width and 3.5 cm in length. Due to its small size and fragmented condition, evidence of wedging the trunnel was not visible. As previously mentioned, a trunnel, or tree nail, is a long cylindrical wooden peg that is used to fasten timber pieces together (Falconer 1780:579). Trunnels are commonly found as a method of joinery at wharf sites instead of iron nails due to the latter's tendency to deteriorate quicker and inability to respond to environmental shifts. In contrast to iron nails, wood can be wedged tightly into the timbers without causing major damage (Sloane 1965:37).

Cask

Within the wharf site, a single cask was found. As mentioned previously, the cask is imbedded on the northern side of the interior of the wharf and situated within its cribbing, with a metal sheeting encompassing it. Chime, or the rim of the cask, and body hoops could be felt on the outside of the cask. The head diameter is estimated at 90 cm, which was determined by measuring across the void from below the chime on the inner stave rather than the groove cut inside the cask, otherwise referred to as the croze (Raupp et al. 2022:25). The outer measurement is about 1 m. With the dimensions of what remains, it likely falls under the size of a double-puncheon cask or tun cask (Smith 2009:12). Casks were commonly used for transporting and storing goods on vessels, but there is also a possibility of them being used as fill for the wharf. Evidence of this was noted at the Deer Island Wharf excavation in Swansboro, North Carolina (Heintzelman 1984:101). Given that the cask at Castle Island wharf is intact, it is possible that it was used in the same way.

Faunal

Two pieces of possible bovine leg remains were found next to each other at the Castle Island wharf. Both bones exhibit evidence of butchering. The length of the first bone is 18 cm and width being 4 cm; the second bone is 12 cm long and 4 cm wide (Raupp et al. 2022:27, 64). By 1728, cattle were plentiful in North Carolina and continued to be in the following years (Bowling 1942:148). The remains of bovine livestock are commonly found on vessels throughout the seventeenth to the nineteenth centuries. This is due to salt beef being a large part of a sailor's diet since it did not spoil while onboard, unlike fresh-cut meat. The salt preserved the meats as they were packed in casks, ensuring it to be safe to eat on long voyages (Spalding 2014:59). Along with this, cows were also transported as cargo on merchant vessels to trade with farmers (Bowling 1942:148; Spalding 2014:59). Being further inland, Washington was situated between farmers and merchants, thus making it undoubtable that livestock was used as a source of food and trade.

Lithics

There was only one lithic artifact found on the Castle Island wharf, which was a gunflint measuring 3 cm in length and 2 cm in width. Gunflints have been used for hundreds of years, but they were not introduced to the English Royal Navy until the mid-1700s (Bingeman 2004). There are four distinct types of English gunflint, however each type is relatively flat (FIGURE 15). The flint found on Castle Island is a square blade-based with a heel, firing (leading) edge, and one dorsal arris (sharp ridge), which was more commonly produced and used in the latter half of the eighteenth century (de Lotbiniere 1984:206; Woodall 2004:3). The introduction of the percussion cap at the start of the nineteenth century marked a significant shift, leading to the near-total replacement of gun flints by the mid-1800s.

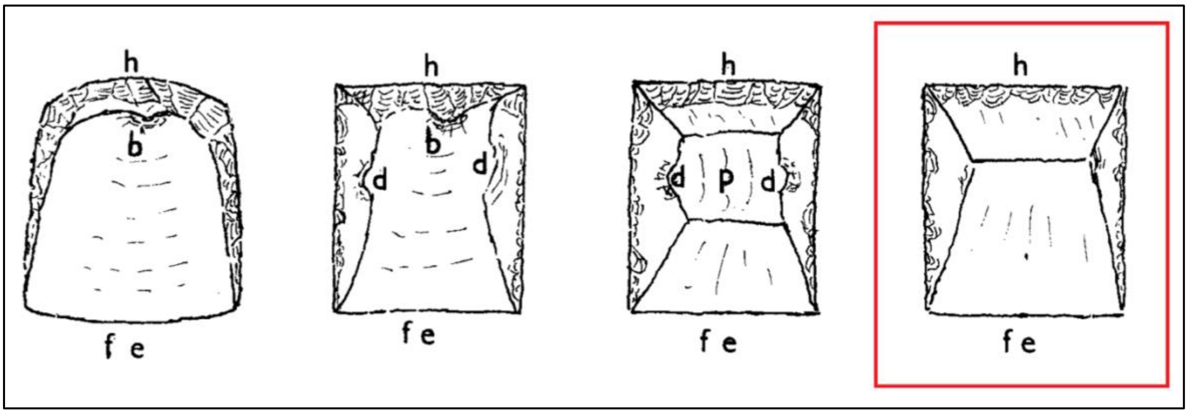


FIGURE 15: The four distinct types of English gunflints: (h) represents the heel, (b) bulb of percussion, (d) demicone, (p) platform, and (fe) the firing edge. The gunflint found on Castle Island closely resembles the figure on the far right (de Lotbinier 1984:206, adapted by author 2024).

Metal

A square-cut iron nail measuring 15 by 15 millimeters (mm) (FIGURE 16) was found at the Castle Island wharf. Square-cut iron nails were a product of blacksmiths hammering forged iron rods on all sides, making the rod rectangular or square with a thickness ranging from approximately 6 mm to 13 mm (Wells 1998:82). Forged nail technology was still in use until the nineteenth century in America when technological innovations led to a move to machine cut nails. Cut nails are made from strips of iron and are cleaved at the end, leaving it rounded or flat (Wells 1998:83). Generally, the heads of machine cut nails tended to be more regular in size and thicker. Based upon the general appearance of the corroded iron nail found at Castle Island, the square-cut thicker top, flat end, and consistent width aligns with the cut nails of the nineteenth century. This type of nail could have been used in the joinery of the wharf, as there was evidence of dowel-lock joinery with a fastener on its south side.

FIGURE 16: Corroded nineteenth century square cut nail (Photo courtesy of the Program in Maritime Studies at ECU, adapted by author).

Glass

Three glass artifacts were documented at the Castle Island wharf. The first of the three was the base and body of a mold-made brown bottle with decorative motifs with a diameter of 21.3 cm and length of 15 cm (Raupp et al. 2022:60). The decorative motif embossed on the bottle says “*Phila. Registered Consumers. B. CO, ~ Era 4*” with a leaf or feather design underneath at the bottom of the bottle (FIGURE 17). Embossing in the United States occurred from the years 1800 to 1950 but became more common from the late nineteenth to twentieth centuries. The coloring of the bottle comes from natural impurities in the glass, such as iron and manganese, but also from color additives like nickel, sulfur, carbon, and lead (Lindsey 2024). The color of the bottle can be characterized as “dark amber,” which became dominant in machine-made bottles in the beginning of the twentieth century.

FIGURE 17: Embossed brown bottle that is mold-made with decorative motif stating *Phila. Registered Consumers. B. CO, ~ Era 4.* The exact date of the bottle is unknown (Photo courtesy of the Program in Maritime Studies at ECU, adapted by author).

A second embossed brown bottle was found at the site. With a decorative motif reading "*No Deposit + No Return, Not to be Refilled, 52, 4, L.*", it is a base measuring 6 cm, length of 20.5 cm, and a diameter of 10.75 cm (Raupp et al. 2022:68). As previously mentioned, the dark amber color embodies the typical American spirits bottle and amber color was often used for beer bottles as it protected light wavelengths, preventing photochemical reactions of beer. The bottle is again machine made, and with the embossing stating "*Not to be Refilled.*" It likely dates to the twentieth century, as the statement "*Federal Law Forbids Sale or Re-use of this Bottle*" was commonly found on bottles from the period 1935 to late 1960s (Lindsey 2024).

Lastly, a screw-top glass jar with the possible date of 1905 was recorded at the site. It measured with a diameter of 2 cm, width of 3 cm, and a length of 11 cm (Raupp et al. 2022:27). The jar has external threads and is embossed with "*NEW Y; ATUYLERS.*" Although the inscription failed to produce diagnostic information, screw top jars were created in 1858 by John L. Mason but were not commonly used until the twentieth century, when glass was machine made (Lindsey 2024).

Ceramics

Several ceramic types documented through the field activities proved to be the most diagnostic of the artifact assemblage. The types identified include creamware, earthenware, stoneware, clay, porcelain, and a prehistoric sherd. Of the ceramic sherds found at the wharf, banded annular ware, debased stoneware, and a Jackfield-type sherd were particularly useful for dating. Using the mean ceramic dating formula, which is discussed later in the chapter, the field school team produced an initial mean date of 1757 (Raupp et al. 2022:26). As these ceramic sherds were able to be identified in the field, they provide an opportunity to better understand the materials in use on Castle Island in the eighteenth and nineteenth centuries, furthering the historical narrative of the island. The following section will be a further analysis of the different types of ceramics, and where the remaining unidentified pieces can be categorized with their potential manufacture date, leading to an updated mean ceramic date of Castle Island.

Defining Ceramics

Ceramics are artifacts that can be used to help archaeologists understand everyday life, give a date, and provide context to the site in which they are found, and are often most prevalent in terms of surviving diagnostic material. In terms of an archaeological definition of a ceramic, it can be stated as easily as an object that is made from clay that has in some way been processed (Degryse and Shortland 2017:335). Since the diversity of clay and the various properties that influence its composition can be a complex topic in chemistry, this section provides a simplified summary for a basic understanding.

Clay has a high plasticity from phyllo-silicates and high-water content which allows it to morph easily. When fired at high temperatures, shapes of vessels made from clay can be permanently set as ceramics. Through the firing process, irreversible chemical modifications play a role in making the ceramic difficult to deteriorate as they create petrified remains (Boch 2007:30). The process often includes adding glaze, the thin glossy layers that appear on the surface of a fired ceramic. For this study, lead and salt were the most prevalent glazes applied to the documented ceramics. A discussion of each of the types identified includes following data: analysis of the different ceramic types, common properties, types of vessels commonly found, and context.

Earthenware

Earthenware is a ceramic product made up of a porous compound, such as clay combined with quartz, chalk, or ground glass, and covered with a glaze. Earthenware is split into two categories, coarse and refined, which can be defined by compactness and porosity. It is often shaped by slip casting and fired at high heat. This process of firing in high heat is referred to as biscuiting, which is followed by two other stages of firing at lower temperatures. The final firing helps the glaze, or the glossy coating, to settle and to fix and contain any included decorations. Although this ware is one of the oldest ceramic materials known due to its vast availability and adaptability, earthenware is less commonly used and produced today (Boch 2007:108).

Earthenware was the cheapest to make regarding pottery and the most used during the seventeenth to mid-eighteenth century (Hume 1969:102). Coarse earthenware is porous and soft, being fired at temperatures of 900 to 1200° Celsius. It is the least compact in terms of the paste or clay used, with colors that range from cream to dark red (Patterson 2009:124). The coloration of coarse earthenware is representative of the chemical composition of the clay and the way in which a vessel was fired (Bloch 2011:11). The various types of earthenware recovered from the Castle Island wharf site, as identified during the 2021 field school, were analyzed in detail to determine how their ceramic dates were established. This analysis offers insights into the different uses of the ware and its significance in dating the site.

One coarse earthenware type identified at the Castle Island wharf site is from a Jackfield-type ware (FIGURE 18). The piece found on southwestern end of the wharf is 8.5 cm in length and 5 cm in width and is likely to be part of a pitcher. The body sherd has a brown base with brown lead glaze (Raupp et al. 2022:62). This thinly turned ceramic was dominantly produced in the village of Jackfield in the county of Shropshire, England, in 1740, but also later produced in Staffordshire, England, from 1745 to 1790. This type has a hard and dense body that is high fired and often produces a purple or grey color (Hume 1969:123). The glaze used for Jackfield wares was often dark in color, usually brown or black, and vessels often featured a floral or banded design. Generally, the type of glaze used for this earthenware was lead, making the ceramic appear shiny and almost metallic looking

(Patterson 2011:128). Vessel shapes classified as Jackfield are teapots, pitchers, saucers, and cups (Maryland Archaeological Conservation Lab 2015). This type of ceramic is commonly found at American colonial sites dating to around the 1760s (Hume 1969:123). This could be due to the continuous trade with England and its other colonies, as well as the fact that Staffordshire potter, John Bartlam moved to South Carolina in 1763, ultimately making Jackfield wares more readily available for the colonies (Hudgins 2009:69).

FIGURE 18: Part of a Jackfield-type pitcher (ceramic date range 1740-1790) found at the Castle Island wharf site. It has a brown lead glaze with a brown base (Photo courtesy of the Program in Maritime Studies at ECU, adapted by author).

In comparison to coarse earthenware, refined earthenware is fired at a temperature of 1100 to 1200° Celsius and is only slightly porous. Refined earthenware is hard and compact, are usually cream and white in color, and much thinner in thickness (Patterson 2009:124). Creamware and pearlware are examples of refined earthenware types, as they are commonly used for tableware and are press molded or slip-cast rather than wheel thrown. It should also be noted that refined earthenware, despite a few exceptions, were not produced in North America prior to the nineteenth century (Bloch 2011:11). In terms of Castle Island's earthenware sherds, those identified were dominantly refined.

Among the refined earthenware sherds documented in the Castle Island wharf assemblage is banded annular ware (FIGURE 19). A banded annular ware sherd found on the southern side of the wharf, has a diameter of 4 cm. The coloring of this sherd was cream and blue on the exterior with dark brown bands and a cream paste (Raupp et al. 2022:61). This type of factory-made ceramic was originally produced in Staffordshire, England, from the years 1785 to 1840 and often consisted of a white to cream colored base (Hume 1969:131). Banded annular ware was popular throughout the late eighteenth and early nineteenth centuries, being exported in large quantities to the United States from England. Sometimes the glaze on banded annular ware is dependent on the color scheme used, such as whiteware having a white glaze, pearlware having a light blue glaze, and creamware having a creamy or pale-yellow glaze. The colors of the bands were often earth tones, such as black, tan, olive green, terracotta, grey, brown, and pale blue. The shift from earth tones to greens, oranges, greys, and blues, however, occurred in the later decades of production (Hume 1969:131-132). Bowls were the dominant vessel produced using this type of earthenware, though jugs and mugs were also common.

FIGURE 19: The base portion of a banded annular ware vessel (ceramic date range of 1780-1820) found at the Castle Island wharf site, with light blue and dark brown bands and a white base (Photo courtesy of the Program in Maritime Studies at ECU, adapted by author).

Creamware

Creamware, also referred to as “Queen’s ware”, is another type of refined earthenware. Although similar in production to other refined earthenware, creamware is distinguished by its cream color and often a lead glaze. It is hard and compact with slightly porous paste, and can have a creamy, yellow glaze due to adding copper to the transparent lead glaze (Patterson 2009:127). Creamware was developed in the mid-eighteenth century in Staffordshire, England. During that time, the thin cream or yellow colored earthenware was perfected and dominantly fired with a lead glaze. Designs on the ware became more popular in the latter half of the eighteenth century (Hume 1969:126). Low fired earthenware was perfected by the 1740s, however in 1760, the paler and more refined creamware became a new interest (Hudgins 2009:70). Creamware was imported from England until it was produced in the American colonies during the nineteenth century, though was soon replaced by the newest type of ware, pearlware (South 2004:231). There are several types of creamware with a date range, such as “plain” creamware (1762-1820), hand painted creamware, overglaze (1765-1815), underglaze (1795-1820), and the last variation being a transfer print design (1783-1820) (Hume 1969:128). As previously described, refined earthenware was ideal for tea and tableware. Two sherds of creamware were found on Castle Island’s wharf, one having a blue design while the other was lead glazed. The analysis of these two sherds will be discussed further in this chapter, as they were not dated during the field school.

Stoneware

Stoneware is an interesting type of ceramic due to its characteristics that makeup the compound. The clay used to make stoneware often contained silica, potassium, and aluminum and was fired at temperatures higher than earthenware (e.g. above 1200° Celsius), making it nonporous. Often brown in color or even opaque, a salt glaze was frequently applied to a stoneware vessel prior to the firing process. Stoneware was known to be unchangeable and strong in terms of its various usage and resistance to erosion and chemical agents (Bloch 2007:110). This ceramic type, particularly the white salt glazed version, was a major advancement in eighteenth century English ceramics as it brought new designs to the scene. In colonial America, production of earthenware, although cheap to make, transitioned to stoneware for mugs, pitchers, bowls, and bottles (Atterbury 1978:18). Colonial American pottery remained inferior to imported goods, however, so its use did not expand much further than where they were crafted (Hume 1969:99-100).

A debased scratch stoneware sherd (FIGURE 20) found on Castle Island was likely in use from 1795 to 1820. Although this type of ceramic hailed from England, a specific city is not in association with its origin like previously discussed earthenware. This type of ceramic was particularly common in the years 1685 to 1785, with its peak production being 1720 to 1770 (Edwards and Hampson 2005:30, 34). While researching the artifact found on Castle Island, the scratch blue made it easy to date as it was commonly used to decorate cups, pitchers, pots, and saucers from the year 1744 to 1775 (Hume 1969:117). The thin blue lines present on the body result from a process of creating deep lines in the ceramic and filling them with cobalt blue oxide before firing. The sherd found at the northwestern side of Castle Island's wharf, was likely a cup and had a salmon-colored paste with a blue glaze design. The sherd is 9.5 cm in length and 5 cm in width (Raupp et al. 2022:61).

FIGURE 20: Debased of scratched stoneware body sherd with a blue design. It was a wheel thrown piece of ceramic that has a blue-glaze design with a salmon-colored base. The date range for this piece of ceramic are 1795-1820 (Photo courtesy of the Program in Maritime Studies at ECU, adapted by author).

Two other stoneware sherds are included in the Castle Island wharf assemblage. Of these, one is a portion of a rim from a jugware (FIGURE 21). Based upon the characteristics exhibited, it is believed that the grey and blue salt glazed ceramic was produced in Germany's Rhine Valley (Patterson 2009:126). The surface of Rhenish stoneware, otherwise described as blue and grey stoneware, is shiny, grey, and pebbly, like an orange peel. They were often decorated with a cobalt blue underglaze with molded reliefs (Patterson 2009:126). Germany is renowned for its salt glazed jugware, with the glaze having a particular grey (Rhenish) paste. Based upon these characteristics, the manufacturing range for sherd from Castle Island is between the years 1575 to 1775 (Greer 1996:17). The Rhenish jugware rim measures 15 mm with a thickness of 6 mm, and a diameter of 11 cm (Raupp et al. 2022:63).

FIGURE 21: The rim portion of Rhenish stoneware (ceramic date range 1575-1775) found at the wharf site on Castle Island. This sherd exhibits grey paste with a blue decor line and a salt glaze (Photo courtesy of the Program in Maritime Studies at ECU, adapted by author).

A second stoneware sherd found at Castle Island was determined to be a body sherd manufactured in Fulham, England, between 1690 to 1775. This type of stoneware has a thick, grey stoneware paste, dipped in a brown glaze, and then salt glazed. The salt glaze then produces a pebbly and mottled brown surface and is usually undecorated. Furthermore, the interior of the vessel is unglazed. This artifact has a brown salt glaze exterior, a white interior, and an overall grey and brown color. Brown salt glaze stoneware largely replaced Rhenish stoneware in England after 1700 and was reproduced in colonial America by the 1730s (Patterson 2009:127). It was also commonly used for drinking vessels, such as jugs and mugs. The body of the sherd found at Castle Island measures 6 mm in thickness (Raupp et al. 2022:64).

Porcelain

Porcelain is different from stoneware and earthenware, as it is made from a more refined type of clay. The clay that compromises the material is of kaolin and finely ground feldspathic rock. Although kaolin is a dense and durable clay base, it is less porous than stoneware and earthenware. As porcelain is fired at higher temperatures (e.g. 1300-1450° Celsius), its defining properties include being resistant to corrosive agents (Boch 2007:112). Another difference between porcelain from other ceramics is that it has a high gloss glaze that is infused in the body of the object, which prevents it from flaking. The colors used in porcelain also range from pale greys to off-whites and were commonly accompanied with blue designs, though in the seventeenth and eighteenth centuries the designs had hints of red highlights (Hume 1969:258). Given its high-cost value it was a luxury to have in the household; as it was mainly used in teaware, it therefore does not appear in great quantities until the end of the eighteenth century, when most of Europe was able to replicate and produce the Chinese ceramic (Bloch 2011:5, 46).

Prior to the twentieth century, however, ceramics in North America were commonly imported from European countries, with a few replications and innovations within the colonies (Bloch 2011:5). With trade being a dominant economic factor of eighteenth to nineteenth century Washington and Castle Island, it is suggested that the ceramics found were discarded from vessels while undergoing trade. This is most likely the reason that only one porcelain artifact was identified at the Castle Island wharf. It was a sherd with the width being 3.4 cm and length of 4.2 cm, entailing a blue design (Raupp et al. 2022:67). Because of its high status, and at the time of the island being a bustling entrepôt, merchants and sailors would not carry such a ceramic onboard.

Determining a Mean Ceramic Date

There are a few definitions that archaeologists use when analyzing ceramics: attributes, type, shape, and form. Attributes refer to the observable criteria by which a ceramic type is defined, and include shape, paste, hardness, color, design, glaze, decoration, etc. Type refers to a particular kind of pottery, and shape refers to the physical form of the object. Form is a generalized term that includes the shape and other attributes, which exemplifies the evolutionary processes and changes to an object (South 1971:1). In using the mean ceramic date (MCD) formula developed by Stanley South (1978), these definitions help to understand and provide context to the ceramics found on a site. The formula was developed as a way of using ceramics to determine an occupational date range by assigning the development date to the ceramics found (Bonath 1978:82). The point between the beginning and end of the manufacturing dates is known as the median manufacture date, which is essential in dating artifacts. However, through this formula the connection between the manufacture date of ceramics and the occupation date of a site can be found. The median date for historic sites is determined through the start of the manufacture date, which provides a *terminus post quem*, or a date after an object found its way into the ground (South 1971:3). It is important to consider that the type of ceramic cannot appear on a site prior to the beginning of the manufacture date, therefore, a temporal relationship between the manufacture date and occupation date of the site is created (South 1971:8). Regarding this, another consideration that must be considered is longevity of the site in question. Thus, South proposed the MCD formula as:

$$MCD = \frac{\sum_{i=1}^{n} x_i f_i}{\sum_{i=1}^{n} f_i}$$

In this formula, the x_i represents the median manufacture date for an artifact, f_i is the frequency of the ceramic type, meaning how much of the type is present at the site, and n is the total number of ceramic types in the sample (South 1971:19). While looking at the artifacts, South noted a pattern and relationship at the intra- and intersite levels. These binary levels show function, structure, status, chronology, settlements patterns, and environmental variables (South 1978:223). This pattern recognition, which can be replicated, helps to determine the mean manufacture date of artifacts, however, the success of the formula is dependent upon the trade and distribution of goods from the mother country to its colony.

From there, dispersal mechanisms, such as the procurement, preparation, cleaning, displaying, and storing, are taken into consideration (South 1978:225).

MCD: Previous Studies

With the mean ceramic date, archaeologists have been able to get a range of when sites of interest were occupied using ceramics and historical documents. The formula has been employed in numerous studies determining a site's occupation, some of which are mentioned to show its importance. As the originator, Stanley South certainly made the most out of the formula, but it was also utilized by archaeologists throughout the United States, with its biggest impact on seventeenth to eighteenth century sites. South proved his formula by looking at four sites that had little occupation since their peak in the eighteenth century: Brunswick Town (North Carolina), Fort Prince George (South Carolina), Goudy's Trading Post (South Carolina), Fort Moore (South Carolina), and Charles Towne (South Carolina). By considering these former towns that were once fortifications and ports under the English colonial system, South was able to determine interpretative dates and provide a median occupation date for each. While using this formula, South noted that an average deviation of plus or minus four years should be considered on sites from the eighteenth century (South 1971:17, 35). Other factors such as subjectivity of what to include and exclude when using the formula, as well as skewing of the date based on this information, should be taken into consideration.

Another example of the use of the mean ceramic date formula is at sites where the Spanish ceramic majolica is found. Shawn Bonath's (1978) work in northern Florida, particularly at sites in St. Augustine and Pensacola, demonstrated its use at sites with known occupation dates and others without. Majolica became a big interest in the twentieth century as it was consistently identified at archaeological sites in Florida, sometimes compromising entire ceramic assemblages. Out of all Spanish ceramics, majolica is the most useful historical tool as it is the most sensitive to cultural shifts and was universally distributed (Bonath 1978:81). Through the various sites studied, Bonath concluded that the formula for majolica was more accurate for dating than any other tool on well documented sites. As the formula was used across five Florida sites, the mean ceramic date for majolica was only an average of 2.69 years off from the mean historic occupation date (Bonath 1978:91). Although there were only so many artifacts found per site, the dates provided in the study were reasonably accurate in comparison to other dating methods.

MCD of Castle Island

The artifacts documented at Castle Island provided an initial mean ceramic date of 1757 for the assemblage, based on only 5 out of 23 ceramics (Raupp et al. 2022:27). To get a more accurate date for the occupation of Castle Island's wharf, for which the first historical documentation is 1818, the rest of the ceramic sherds were appropriately dated. The process of dating the rest of the assemblage was complicated by having to rely solely on images and notes, since the artifacts were returned to their respectful locations after documentation. Despite this, South's (1978) mean ceramic date formula was applied to detect the approximate time of occupation for the island.

The first type analyzed was stoneware, which was the most abundant type of ceramic identified on Castle Island and its surrounding waters during the 2021 field season. Each of the nine sherds identified had a salt glazed exterior (TABLE 1). Salt glaze stoneware became dominant in colonial America between the seventeenth to the nineteenth centuries, although it was prosperous in England during those times as well. As manufacturing in America increased, significant amounts were still imported through the mid-nineteenth century (Hume 1969:99). The colors of the Castle Island specimens varied; two were brown, one was grey, one was cream, two were grey and tan, one was grey and pink, one was brown and cream, and one was green and cream (Raupp et al. 2022).

TABLE 1: List of stoneware artifacts found during the 2021 ECU Fall Field School that were undated. Through their description and decoration, seven of the nine stoneware sherds were dated. The undated pieces were due to items being difficult to compare and identify with other ceramics based upon the information given. This table excludes the previously dated pieces (Table by author, 2024).

Field Specimen #	**Object**	**Description**	**Décor.**	**Production Dates**	**Mean Date**	**Measurements (l x w)**
0007	Stoneware base sherd	Jar/bottle	Salt glaze	-	-	Diameter: 3cm
0008	Stoneware base sherd	Jar	Salt glaze	1840-1850	1845	4.5cm x 5.3cm Diameter: 7cm Thickness: 1.9cm
0010	Stoneware body sherd	-	Salt glaze	1810-1900	1855	8cm x 6.5cm
0011	Stoneware base sherd	-	Salt glaze exterior	1810-1900	1855	Diameter: 6cm
0013	Stoneware body sherd	Pink paste interior	Grey salt glaze exterior	1830-1860	1845	Body: 7mm
0014	Stoneware body sherd	Grey exterior and tan interior	Brownish salt glaze	1725-1800	1762.5	Body: 5mm
0017	Stoneware body sherd	Grey paste, tan interior	Salt glaze exterior	1830-1860	1845	Body: 6mm
0028	Stoneware body sherd	Cream colored	Salt glaze exterior	-	-	6cm x 3.4cm
0034	Stoneware body sherd	-	Salt glaze exterior	1720-11775	1747.5	1.8cm x 1.5cm

* Centimeter is abbreviated as cm.

Six other earthenware sherds from the assemblage were included in the dataset. Three were described as coarse earthenware, which results from clay being fired at lower temperatures, being more porous, and less compact than the previously described types (TABLE 2) (Raupp et al. 2022:64-65). Two of the three coarse earthenware found were redware, one having a lead glaze and the other exhibiting no glaze but a red paste. Redware is an unglazed coarse earthenware, with an orange to red brick paste, and is the most found ceramic on sixteenth and seventeenth century colonial sites in the United States (Patterson 2009:126). It was often used in utilitarian vessel forms. The remaining coarse earthenware exhibits characteristics of a mortar, as it does not have any glaze or paste. The following three were classified as refined earthenware as their exterior was salt glaze and less porous. Overall, the colors of the unidentified earthenware were sporadic, ranging from brown, grey, green, blue, and red, and those in the assemblage exhibited the earth tones of brown and red. Lastly, two pieces of creamware were analyzed, one being a rim sherd with a blue transfer print design and the other being a cream colored, lead glazed vessel (TABLE 3) (Raupp et al. 2022:69).

TABLE 2: List of earthenware artifacts found and undated during the 2021 ECU Fall Field School. Through their description and decoration, three out of the six earthenware sherds were dated, as redware was excluded and others were difficult to do comparative studies with the information given. This excludes the previously dated pieces (Table by author, 2024).

Field Specimen Number	**Object**	**Description**	**Decoration**	**Production Dates**	**Mean Date**	**Measurements (l x w)**
0016	Coarse earthen-ware /mortar body sherd	-	-	-	-	-
0018	Coarse earthen-ware base sherd	Redware	Red or clear lead glaze	1500-1750	1625	Diameter: 9mm Thickness: 8mm
0019	Coarse earthen-ware body sherd	Redware	No glaze	1500-1750	1625	Body: 8mm

0026	Earthen - ware body sherd	Grey paste, green discoloration	Salt glaze exterior	-	-	5.2cm x 4.3cm
0029	Earthen -ware body sherd	Blue/grey paste	Salt glaze exterior, blue design, engraved	1784-1859	1821.5	3.8cm x 2.9cm
0030	Earthen -ware body sherd	Grey paste	Salt glaze	-	-	2.4cm x 2.4cm

TABLE 3: List of creamware artifacts undated during the 2021 ECU Fall Field School. Through their depiction and descriptions, both creamware sherds were dated (Table by author, 2024).

Field Specimen Number	**Object**	**Description**	**Decoration**	**Production Dates**	**Mean Date**	**Measurements (l x w)**
0031	Creamware rim sherd	-	Blue design, transfer print	1765-1815	1790	3.5cm x 3cm
0032	Creamware body sherd	-	Lead glaze	1770-1825	1797.5	3.5cm x 2.1cm

The interpretive dates for the ceramic pieces are based upon the analysis of paste color, type of glaze used, and the texture of the ceramic piece. The characteristics described in the 2021 field report were compared to stoneware and earthenware catalogs (Maryland Archaeological Conservation Lab 2012; NYC Archaeological Repository 2016), a lab manual (UWF Archaeology Lab Manual 2016), and work undertaken by Ivor Noel Hume (1969); Paul Atterbury (1978); and Georgeanna Greer (1996). Although one prehistoric, corded and sand- or quartz-tempered rim sherd was identified on Castle Island’s wharf, it was excluded from the ceramic dating analysis (Raupp et al. 2022:27). A rim sherd made of a sand/quartz, it could have almost a thousand-year production and use range (Herbert 2009:108). This finding could suggest that Native Americans used the island prior to European settlers, though more prehistoric findings and research are needed to support that supposition. Combining the characteristics of the first five identified sherds produced an adjusted an occupation date of 1776.38 (see Appendix C). It should be considered that there is potential for skewing of dates due to certain wares, such as the redware, having a long production sequence (250 years). The longevity of the site is relatively unknown, however, thus making the occupation date 41.62 years earlier than the first historical reference to Castle Island. While the sampling size is something that cannot be controlled, it should be noted that a lower sample amount, such as this one, can be less reliable when using the mean ceramic date formula in comparison to a bigger sample group (South 1971:21).

Pipe Stem Dating

Numerous formulas have been developed and modified by historical archaeologists to provide an equivalent of a mean ceramic date to a site through tobacco pipe assemblages by analyzing both stems and bowls. This type of dating is popular in North American archaeology, especially on sixteenth to eighteenth century sites, as seen through the work of Adrian Oswald (1951); J.C. Harrington (1954); Lewis Binford (1962); Georgia Fox (1998); Seth Mallios (2005); and Lauren McMillan (2016).

Pipestem analysis is conducted by assessing the basic shape, material, decoration, and surface treatment of the stem. It also looks at bore diameter, otherwise known as the "Harrington Theory" (McMillian 2010:15). The Harrington Theory was developed by J.C. Harrington, as he looked at the bore diameter of English clay pipestems and their relation to time. Doing so he defined five different time periods: 1620-1650 with bore diameters measuring 3.175 mm, 1650-1680 at 2.78 mm, 1680-1710 at 2.38 mm, 1710-1750 at 1.98 mm, and 1750-1800 at 1.59 mm (Harrington 1954:64). The scrutinization and modernization of this theory caused Lewis Binford to create a statistical dating formula, though it had an uncertainty of ±10 to 15 years (McMillian 2010:21).

There are also four conditions that must be met to attempt Binford's formula, including: the sample must be before 1780, the sample must be random, the sample must be representative of the site, and there must be a constant rate of deposition at the site (Binford 1962:66-67). Despite criticism and inaccuracies, these methods are universally used to date pipestems at British colonial sites. It must be emphasized that to get an accurate date using the pipestem date formula, at least 250 samples from the site of interest are required (Teed 2008:48).

A single pipe stem found on the Castle Island wharf is made of kaolin or white ball clay, which is important in terms of dating tobacco pipes, as they were prominently used from 1500 to the 1800s (Bradley 2000:108). The basic shape of the white clay pipe remained the same throughout the seventeenth and eighteenth centuries, having a slight variation in the size and surface treatment (McMillian 2010:6). In particular, the English often used kaolin clay for pipes shipped to their colonies as the demand for tobacco products increased. Pipe stems are often found on seventeenth- and eighteenth-century sites as they were often manufactured, smoked, and discarded within a year due to the stems becoming clogged with resin from tobacco. Detailed analysis of the evolution of the tobacco pipe noted that the holes, or bores, in the pipe stem became smaller and narrower from the seventeenth through the second half of the eighteenth century (Hume 1969:297).

Regarding the stem found at the Castle Island wharf, it was recorded at 5.5 cm in length and 0.7 cm in width. The coloring of the stem was noted as grey with blue tints or stains and no design or curve (Raupp et al. 2022:61). Unfortunately, the small sample size did not allow for a site occupation date to be determined. Attempts were made, however, to establish an estimated data range for the artifact. To achieve this the stem-bore diameter of the sample was measured in increments of 0.40 mm, decreasing in size. Although this estimate cannot be unequivocally accepted as a mean date due to limitation to the sample size, the stem-bore diameter measurements suggest manufacture of the pipe stem between 1750 to 1800 (FIGURE 22) (Harrington 1954:64).

FIGURE 22: Clay pipe stem found on Castle Island's wharf (estimate date of 1750 to 1800) (Photo courtesy of the Program in Maritime Studies at ECU, edited by author).

Conclusion

While there is little historical documentation regarding Castle Island and its occupation during the colonial period, evidence provided through artifact analysis suggests that commercial operations occurred there during that period. Although Castle Island became known as a place of business and trade in the early nineteenth century, the mean ceramic date suggests otherwise. The identified ceramics and pipe stem were of utilitarian use, meaning that they were the types of pottery used in an everyday manner. This makes sense, especially as there were more stoneware fragments found throughout the site and that type of ceramic has more durability than earthenware. Common household items throughout the eighteenth and nineteenth centuries were often made of this ceramic type, and shipping vessels carried them as well due to their cheap production costs, popular styles, and longevity. The following chapter further aids the historical narrative of Castle Island through a form of absolute dating, dendrochronology.

Chapter Five. Methodology: Wood Analysis of the Castle Island Wharf

Investigations in archaeology cannot be undertaken without an understanding of the historical past and sequence of events. The field of archaeology employs numerous methods for dating sites and structures. These methods can be broken into two categories: relative and absolute dating. Relative dating, otherwise known as "historical chronology," relies on non-scientific methods, creating an analysis of comparative data or the context in which an object is found. This produces a date range rather than an accurate year. Examples of relative dating in archaeology can be stratigraphy, cross-dating, and *terminus post quem*. In contrast, absolute dating assigns a numeric age or a specific calendar year (Emaefor and Ugwu 2023:27-28). Examples of absolute dating methods used in archaeology include mean ceramic dating, radiocarbon dating, and dendrochronology.

Throughout history, dendrochronology has been an important method scientists use to determine absolute dates for timber features. In recent years, however, dendrochronology has become a particularly powerful tool in the subdiscipline of maritime archaeology. Tree-ring samples for dendrochronological analysis in maritime archaeology have been recovered from shipwreck sites to help determine the date of the fallen trees used for ship construction and to estimate the regional origin (Farrell and Baillie 1976: 45). Outside of examining shipwrecks, dendrochronology in the maritime field has also been employed to date wharf structures and period of construction and usage. Dendrochronology has proven itself to be useful to archaeologists as it provides contextual information with absolute dates.

Given the state of preservation at Castle Island's wharf, data collection for this thesis project involved not only standard archaeological site survey and assessment, but also timber analysis through dendrochronological sampling. To better understand the timbers used in the construction of the wharf, core samples were collected, and tree species were identified to build a tree-ring chronology. Along with this, a resistograph was employed to gather information regarding the structural integrity of the wharf. The resulting dendrological, dendrochronological, and timber density data offer insight into the past environmental conditions, site preservation, and possible dating for the maritime infrastructure. This chapter provides contextual information on dendrochronology, the resistograph system for measuring wood density, and wood species that have been identified. By providing background information into these matters, the methods employed for this thesis project are better understood.

Dating Wood: Dendrochronology and Dendroarchaeology

The word dendrochronology comes from the Greek words "dendro," or tree, "chrono" relating to time, and "-logy" being the study of. Dendrochronology can examine the past serving as a long-term environmental proxy for temperature, rainfall, fire, ice storms, and insect infestations (Speer 2010:1). The study of tree rings can provide environmental and cultural context through the selection of wood species, technological use, and modifications made to sourced wood (Newsom 2022:32). Dendrochronology serves as one of the main absolute dating methods in archaeology since the physical properties needed to calculate an object's age can be measured. Absolute dating and its application are important methods as dating archaeological wood from certain periods to their calendar year, can provide a complete chronology, and a set of dates (Farrell and Baillie 1976:45). Dendroarchaeology is the fastest-growing subfield, as it correlates wood anatomy to regional chronologies (Speer 2010:153). As such, archaeologists can use wood to understand, create, and add to the historical narrative by looking at it for environmental, temporal, and cultural information.

The Structure and Function of Wood

To understand the environmental responses and impacts of wood, its genetic makeup and structural components must be considered. There are two main elements that make up the tree: the shoots and the roots. The shoot comprises of the trunk, branches, and leaves while the roots are responsible for water and nutrient intake, mechanical anchoring, and storage of biochemicals. When looking from the outer to the inner composition of a tree, one can notice the rough exterior, or bark, and smooth, soft interior. The pith is the center of the tree, which is the oldest part. At the same time, the vascular cambium is the main growth tissue that provides a layer between the inner and outer bark. Along with this, the vascular cambium's function is to increase the circumference of the plant (Ross 2021:66). The division of cells through cambial activity creates xylem cells, which are the primary conductive tissue that transports water and absorbs minerals through the plant body (Rathgeber et al. 2016:2; Newsom 2022:94). There is a secondary xylem that develops beyond the primary growth, which is the interior of the bark, or the wood. As the secondary xylem develops throughout the tree's lifetime, the girth increases despite there being interruptions, such as dormant season and natural disturbances, throughout periods of time (Newsom 2022:12). Wood is a complex system of tissues that helps to maintain the structure and growth of the tree. Through products of the vascular cambium, wood forms towards the center of the tree, resulting in annual rings.

Within woody plants there is a well-known phenomenon called the incremental growth, which can be seen at microscopic and macroscopic levels. In this, wood forms growth rings, which ultimately mark the starting and ending points of structural changes within a growing season. Throughout the growth cycle, there is a distinction and contrast between the color of bands, which demonstrates the individual growth signs in tree species growing in mid-latitude climate regions. In conifers, these bands are labeled earlywood, or "springwood", and latewood, otherwise known as "summerwood" (Newsom 2022:77). In conifers, the wood that is considerably lighter in color is formed in the beginning of the growing season, is labeled as earlywood. In contrast, the darker and denser portion of the wood forms in the latter part of the growing season, hence the name latewood.

In general, wood is comprised of two zones: heartwood and sapwood. Sapwood is the lighter or more pale color that is near the outer edge of a tree and can be more susceptible to decay. Heartwood, on the other hand, is the wood that is extending from the pith to the edge of the sapwood. Paradoxically, heartwood is dead tissue, no longer participating in the processes of a tree. However, heartwood does contain gum, resins, and other materials that help protect it from decay and make its color richer than that of the darker sapwood (Ross 2021:508, 513).

There are two types of trees that have different structural components: hardwood and softwood. In summary, hardwoods come from a flowering plant or angiosperm and have a greater structural complexity due to their cells being greater in variety (Ross 2021:66). Hardwoods have vessel elements called pores, causing the wood to be porous. There is a type of hardwood that is diffuse-porous, which means that vessels are evenly distributed throughout the annual ring and do not vary in size. Hardwoods are also ring-porous, which can be described as the vessels established in the beginning of the growing season that vary greatly in size in comparison to the vessels from the end of the season (Speer 2010:43; Newsom 2022:9). While hardwoods have these variations in pores, softwoods do not, as they are gymnosperms, otherwise characterized as needle-leaved trees (Ross 2021:30).

Due to the prominence of pine in this research, the genetic structure of softwood trees will be considered more in depth for a better understanding of growth. Their genetic structure is simpler than that of hardwoods as it consists of two cell types, along with their lack of vessel elements and pores. The cellular component and chemistry of softwood is a complex topic that is generalized here for fundamental comprehension. There are several features that make a softwood species distinctive.

Unlike most hardwoods, softwoods are made of tracheids and parenchyma. Tracheids are long cells that are major components of softwoods, making up about 90% of their volume (Ross 2021:74). Axial tracheids found in the secondary xylem of softwoods form the bulk of the tissue, appearing tube-like with the cell walls and lumens (e.g., the open part of the cell). They occur in regular rows and are first formed during the initial activity of the vascular cambium. Parenchyma is divided into two cell distinctions: axial (vertical) parenchyma and ray (horizontal) parenchyma. In general, parenchyma are short cells that have pits, functioning primarily in the metabolism and storage of plant food (Ross 2021:511). Ray composition, primarily parenchyma, is a diagnostic trait for softwoods as they are exclusively composed of parenchyma (Newsom 2022:99-100). In axial parenchyma, the cells are short and rectangular and stacked vertically on one another, which often trains their cellular contents. It is even common for the stored contents of axial parenchyma to be preserved in waterlogged archaeological wood. In most softwoods, rays are classified uniseriate, meaning they are one cell wide. The areas of contact between ray parenchyma and adjacent axial tracheids are where cross-field pitting occurs. Along with this, circular bordered pits grow in the cell walls of the axial and ray tracheids. The pits are essential to water transport. Another diagnostic trait found in softwoods are axial and radial resin canals. Resin canals are open, tube-like spaces that transmit and contain resinous material, usually delivering such material to wounded sites (Newsom 2022:103-104). Through these distinguishing features, softwoods can be identified (FIGURE 23).

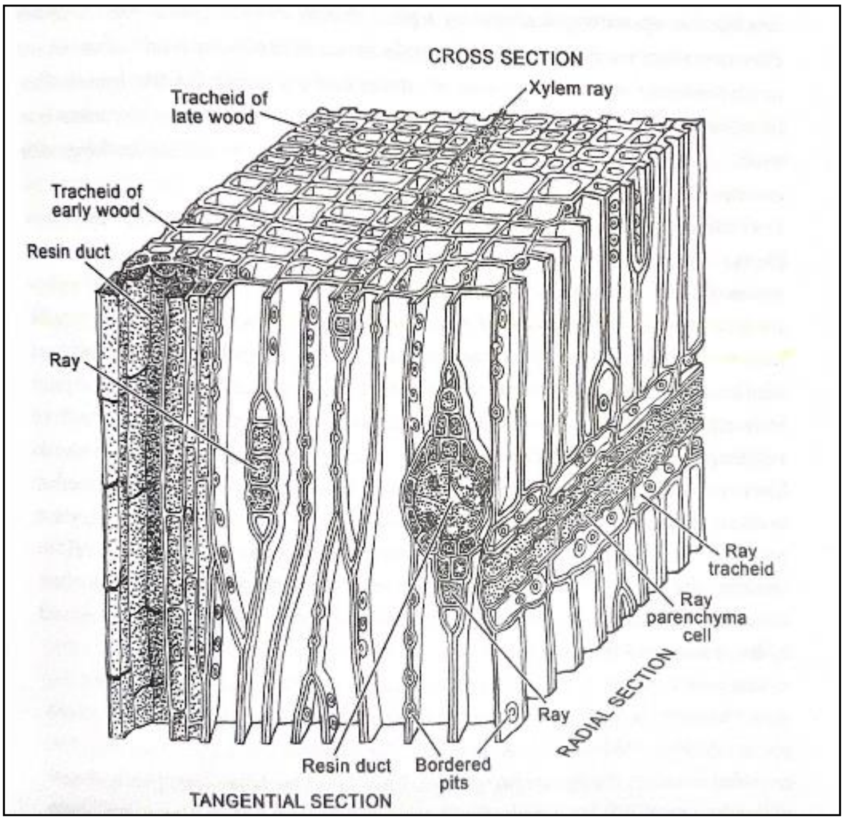


FIGURE 23: Diagram of secondary xylem and its composition in softwood (Newsom 2022:99).

By exploring the cells of wood, the growth of the tree ring and its variations can be better understood. In the wood, the plant cell consists of protoplasts and a cell wall. The protoplast is the number of living contents that are enclosed by the cell membrane. As wood matures, however, the protoplast is no longer needed, thus they no longer exist in wood. Lumen is a vacuous space or void in the interior of the cell and replaces protoplasts, becoming the new critical component in the cell by protecting the tree from sunlight damage and producing oxygen from water (Ross 2021:71). The cell wall provides mechanical support for the plant, giving wood its properties. Cell wells often undergo modifications, known as pits. Pits allow communication and transport between cells and consist of three domains: pit membrane, pit aperture, and pit chamber (Newsom 2022:14, 94). The pit membrane is semi porous, while the pit aperture is an opening or hole, and the pit chamber is the open area of the pit. The pit can vary in size, proportion, and number, which can directly affect how wood behaves and responds to the environment (Ross 2021:72-73).

Along with this, there are vertically and horizontally orientated cellular elements in the wood that are interconnecting and help define the characteristics of wood. Two rudimentary systems are responsible for the cell's orientation, the axial and the radial system. In the axial system, the cells form vertically, up, and down the trunk. The vertically oriented cells provide mechanical support and movement of water whereas the horizontally oriented cells, otherwise known as the radial or ray system, provide storage and transportation of biochemicals (Ross 2021:67; Newsom 2022:95). Wood can be identified in any type of cut, however, by understanding the axial and radial system there are three perspectives that help scientists to examine the wood's anatomy.

The three perspectives or planes that allow thorough comprehension and identification are the transverse plane, the radial plane, and the tangential plane (FIGURE 24) (Ross 2021:68). The transverse plane is the face of the tree, which is the exposed part of a tree when it is cut down. It is also referred to as the cross section, and provides information about the radial direction, or from the pith to the bark. The radial plane runs from the pith to bark and is the face that is exposed when a log splits through the middle. This plane gives information about the longitudinal variations in the wood. Lastly, is the tangential plane, which is the right angle cut to the radial plane. The tangential plane exposes the waves of the annual rings as if the bark was peeled away (Ross 2021:68). These three planes often assist scientists in wood identification and growth ring analysis.

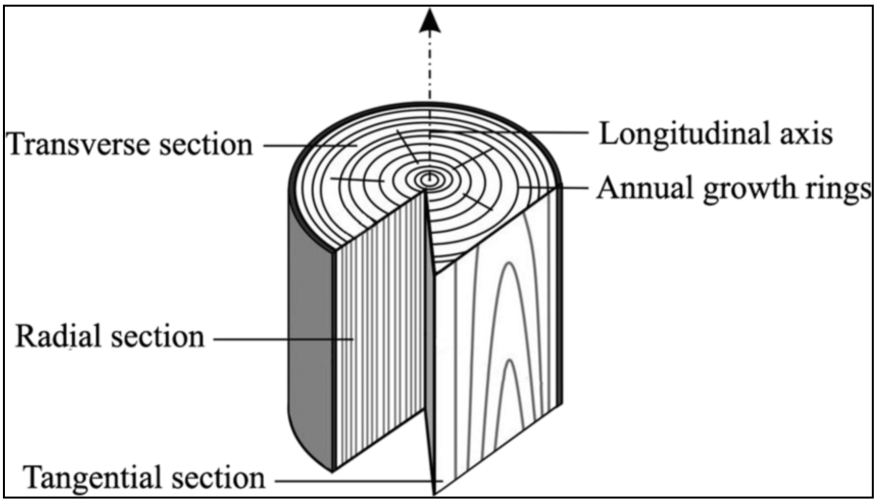


FIGURE 24: The three principal planes of wood (Geus et al. 2020).

Principles and Methods of Dendroarchaeology

Several methods and lab procedures are necessary for extracting and examining a wood sample. The primary tools used to extract a sample of wood for analysis are the increment borer and the saw. The saw cuts out larger transverse or cross sections, which can be destructive and detrimental to an object. An increment borer or drill is less destructive leaving a hole approximately 5 mm wide (Speer 2010:81). Generally, in the case of dendroarchaeology, a specially designed hollow drill bit that is attached to a speed hand drill is used, extracting 12 mm diameter cores (Rochner et al. 2019:402). These cores are taken from timbers that typically have some remnants of bark or a waney edge to obtain the outermost ring for analysis. The cores are then stored in tubes and labeled with their respective provenience information.

In the lab, preparation of the core sample is dependent upon the preservation of the wood. Archaeological wood can be degraded through biodeterioration, decayed, frozen, or waterlogged. When preparing a moist wood sample for examination, wood should be placed in an oven to dry. If it was waterlogged and may deteriorate with drying, the sample can be kept damp using a solution to prevent dehydration (Newsom 2022:154-155). Through the various cutting planes of wood, archaeologists can expose sections of the degraded wood or artifact for microscopic analysis.

As for waterlogged wood, the post processing of the core samples follow the same process. The samples collected need to be dried prior to mounting. Once collected from the field, and depending on the instrument used to extract the core samples, the samples are placed into a tubular container, such as a drinking straw or PVC pipe to keep them damp. Samples should be dried out using a fume hood or being placed in an oven at a low temperature to remove moisture before any continuation with the mounting process. Prior to mounting, the information pertaining to the sample (e.g., species and sample identification provenience) is transcribed onto the mount. The samples are then glued using a water-soluble white glue, secured with painter's tape, and left to dry completely. Once dry and in place, the cores are sanded with sandpaper ranging from 50 grit to 400 grit, depending on the wood species. The sanding is conducted in a progressive sequence as it is used to flatten the core sample to create a clean, polished sample that shows each individual cell within the cross-sectional view (Speer 2010:88-96). Once complete, samples are ready for measurement and analysis. The core samples are marked using standard decadal dot notation where the pith is marked as zero and every tenth ring a pencil dot designates the decade year. Two dots represent 50 years, three represents a century (Speer 2010:96).

Dendrochronology is facilitated by the distinct visibility of annual rings in the cross section of trees, which tend to exhibit characteristic patterns. To effectively analyze patterns, four essential conditions must be met: (1) the presence of an annual ring; (2) even though there will be numerous interacting factors, a single environmental factor must predominantly limit growth of the tree; (3) the growth-limiting climatic factor must exhibit annual variability in intensity, meaning that such variations are reflected in the width of the annual rings; and

(4) the variable environmental growth-limiting factor must exert its influence over a large geographical area (Stokes and Smiley 1968:3-5).

Through understanding the above concepts and various cuts of wood, the basic principle of dendrochronology, known as "crossdating," are explored. Crossdating is the matching of wood's annual ring patterns to assign a year to each ring (Leavitt and Bannister 2009:374). This principle has three requirements: annual rings, variability, and enough replications. Crossdating is important in dendroarchaeology, as it is done with the core samples taken from the site of interest. This creates a "floating chronology," which is then used against a master or reference chronology for the identified tree species to compare, analyze, and accurately crossdate tree-ring samples from a new site (Farrell and Baillie 1976:48). Master chronologies, however, are dependent to a given region, as temperate zones show more clearly the annual rings because of the seasonal changes (Grynaeus 2000:213). Further analysis of the collected wood samples allows archaeologists to report and compare the assemblages and the sites at which they were found or from which they were derived.

Circuit uniformity means that the rings are concentric, sharing the center. In terms of variability, scientists look for whether rings are complacent or sensitive. When a tree is complacent, there is a low degree of interannual variability in tree growth and roughly the same width of rings, whereas sensitive tree growth includes a mixture of wide and narrow annual rings (Speer 2010:22). The variability in rings shows how the tree reacted to its environment (FIGURE 25); however, ring anomalies like false rings, locally absent rings, and injuries can impede accurate dating.

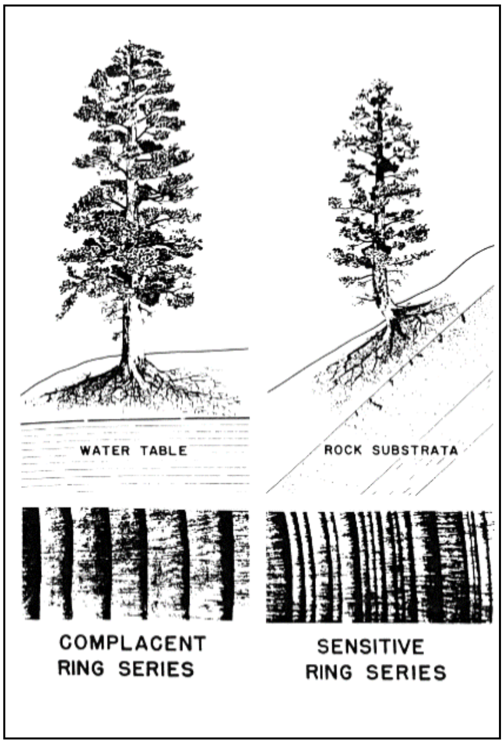


FIGURE 25: Complacent vs. sensitive ring series. The images show how climate and other factors can cause variations within tree rings (Courtesy of Laboratory of Tree Ring Research, University of Arizona).

Once the processing is complete, samples are scanned and uploaded into various software programs to measure the tree rings in a precise manner, while being able to save the data for future use. The core samples from an archaeological site undergo the same methods as those used in the science of dendrochronology, which are explored in greater depth later in the chapter.

Previous Studies: Dendrochronology in Maritime Archaeology

By its nature, wood encompasses the material record, giving insight into an artifact's origin and date. Through wood, human agency and cultural traces or practices can be surveyed. Culturally modified material can be broken down into five categories: wooden artifacts, roundwood, timber, wood debitage, and charcoal. In these categories, wooden artifacts are tools or smaller movable objects, while roundwood can be a little more in-depth with cultural or natural variations and usage. Roundwood is the state in which wood is encountered, being that of cylindrical segments (Newsom 2022:36). It can show tool markings, which may be human influenced or natural alterations. In comparison to roundwood is timber, which is a systematic reduction of logs. Timber or lumber is the vertical cut of the trunk, showing the tangential plane. Through wood debitage, classifications such as size, form, dimensions, and tool marks can aid in analyzing cultural or behavioral motives. Lastly, charcoal, or carbonized wood, can provide the condition of the wood and growth rings, even when it is found in various forms (Newsom 2022:41, 51-55). When looking at these elements, archaeologists must try to take a sample of the outer surface of the wooden object, as it reveals the cutting date of the tree (Speer 2009:245). Through these various types of archaeological wood, scientists record and assess growth rings, which may lead to the age and identification of the species.

Dendrochronological methods as applied to maritime archaeological research have developed over time and offer interesting insights into dating and origins for timbers of wrecks, wharves, or even barrels that once held cargo. One example of such comprehensive analysis is the investigation of a medieval cargo vessel referred to as the Bøle Ship in Skien, Norway. Identified in 1959, parts of the ship were removed from the brackish river in which it was deposited and are currently stored at the Norwegian Maritime Museum (Daly and Nymoen 2008:154). Among the site's artifact assemblage are whetstones, which led researchers to believe that the vessel played a vital role in the growth of a neighboring town through trade. Although Carbon-14 dating of the timbers was attempted, the results were not precise enough to offer information about the construction methods employed in building the vessel. In 2008, dendroarchaeologists Aoife Daly and Pal Nymoen conducted dendrochronological analysis of some timbers recovered during the 1959 dredging operations. Dendrochronological samples taken from four being planks and six frames all revealed consistent narrow ring patterns but showed regular growth (Daly and Nymoen 2008:158-160, 162). Upon completion of analysis, it was concluded that the felling date for the tree used for the plank was calculated to be between 1376 and 1396. Using dendrochronology not only provided the date more precise than the Carbon-14 dating, but it also showed that the tree ring pattern had the highest correlation with the chronologies from coastal Poland (Daly and Nymoen 2008:168). Through this application of dendrochronological research of the Bøle Ship, more questions and studies can be conducted in relation to ship construction, trading routes, and goods during the Middle Ages.

Another recent study that is relevant to this thesis was undertaken by Aoife Daly (2013) and involved analysis of timbers and cargo from *Vasa*, a Swedish warship sunk in 1628 and recovered from the seabed in 1961. The case study considered barrel staves and ship timbers to determine the geographic origins for the wood used to build the ship, as well as potential sources of cargo material that were once in the barrels (Daly 2013:1). Saws were used to collect 5 samples from ship timbers and 17 from barrels staves. The samples were split into five groups for analysis; groups one and two consisted of planking from *Vasa*, while groups three to five were made up of the staves. By examining tree-ring curves on the planks in the first group, researchers noted a correlation between three of the planks. The limited correlation in the second group suggests that the timbers are from the two distinct geographic regions. The stave samples revealed that one was made from pine, while the rest were oak (Daly 2013:2-3). The main group of the study was group three, which consisted of seven-barrel staves that matched a chronology in northern Germany, showing that the woods used for *Vasa* were acquired from a range of provenances (Daly 2013:8). Along with this, the staves produced an average tree-ring time series of 195 years in length, with the date being between 1420 to 1614. The next group did not have high correlation with each other, making it difficult to date the group or determine an area of geographical origin, in turn leading researchers to believe that it could be from eastern Sweden, where chronologies for oak are not available. Lastly, group five included two oak staves that indicated a diverse origin, not correlating to one another but could be from the southern Baltic and northern Poland based upon *Vasa*'s historical inventory (Daly 2013:3-5). With the possibility of the cargo being from diverse sources of wood, some regions of Northern Europe may be underrepresented in the dendrochronological dataset. Thus, extensive analysis of *Vasa* and its cargo are needed to help determine the date and provenance of the material (Daly 2013:6). Through this study of *Vasa*, dendrochronology not only proves its utility, but also the trickiness that comes with relying on archaeological wood.

Turning away from the implementation of dendrochronology on wrecks or related features, it was used to document Grand-Pré aboiteaux and the Horton Landing Wharf in Nova Scotia, Canada. In 2009, two remains of an aboiteaux, French-Acadian method of draining a marsh was discovered, which uncovered a buried cultural landscape in Gran-Pré. The aboiteaux underwent dendroarchaeological methods, taking collectively 18 samples from the remains. After analysis of the core samples, it was concluded that the felling date of the timbers used for the aboiteaux was in 1688 and 1689, ultimately suggesting that the construction date was in the late 1680s, which aligns with the first arrival of the Acadians (Robichaud et al. 2009:14). As for the Horton Landing Wharf, 17 core samples were taken for dating analysis. The timbers used to build the wharf were very large, all being over 40 cm in diameter, and proved to hold high dendrochronological potential. The results indicated that the wharf was a younger structure in comparison to the aboiteaux, having the construction date being in the 1880s (Robichaud et al. 2009:14). This research further exemplifies the importance of dendrochronology in archaeology, as it provides an absolute date for unknown structures.

The use of dendrochronology in the twenty-first century has posed new challenges and techniques. Different techniques for identifying wood species and origins are being tested in new areas, on new species, and on various projects to try to mitigate limitations. Through multidisciplinary studies and collaborations, the exchange of data with tree ring labs throughout the world benefits research in all the subfields of dendrochronology, particularly dendroarchaeology (Domínguez-Delmás 2020:11). Through dendrochronology, new layers of information are being presented where the historical and archaeological record lack. With the new technologies found today, there is a possibility of getting dendrochronological data through nondestructive means.

New Technology: The Resistograph

Nondestructive evaluation, otherwise known as NDE, is the “process of assessing physical and mechanical properties and developing knowledge of potential intrinsic defects of a material or its structure, without altering the end use of capabilities” (Içel and Güler 2016:900). In this case, a nondestructive tool, such as the resistograph (FIGURE 26), can be of great use in dendroarchaeology as it can show the annual ring structure, ring orientation, placement, and density of a wood sample through the drilling of a needle (Içel and Güler 2016:904). The aim of the resistograph is to provide a practical examination of trees and culturally modified wooden structural materials, such as poles and other timbers.

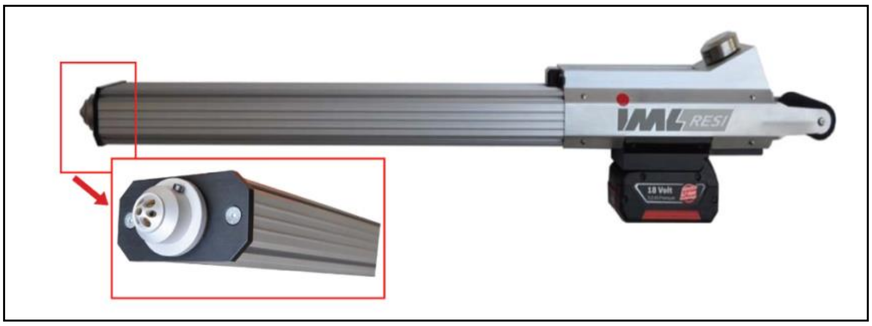


FIGURE 26: Image of the IML-RESI PD-Series 400, showing the profile and the point at which the needle emerges and retracts (IML-RESI PD-Series Manual 2019).

The resistograph has a relatively new history, as it was created in Germany in 1990 to evaluate the conservation of lumber posts. In general, the resistograph uses an extremely fine steel drill bit that turns at a constant speed when penetrating wood. The bit ranges from 1 to 3 mm in diameter and measures up to 50 cm in length. The bit acts as a needle and the resistance from the puncture is registered by a potentiometer connected to the electric engine (Acuña et al. 2011:452-453). The needle turns at five speeds in their respected rotational speed stages: the first speed (1) rotates at 1500 revolutions per minute (rpm); (2) at 2000 rpm; (3) at 2500 rpm; (4) at 3500 rpm; and (5) at 5000 rpm. Along with this, the feed speed of the needle has five different stages, reading the wood's density and rings at (1) 25cm/min, (2) 50cm/min, (3) 100cm/min, (4) 150cm/min, and (5) 200cm/min. The unit consists of the drill bit, a digital chart recorder, and any computer system to which the resistograph is connected. A resistogram is produced on the computer screen, which is the graphic representation of the needle penetrating each layer or section of the wood at the constant rate of 30 cm a minute. The graph that is depicted can vary based on the feed speed as different wood species need different levels to penetrate the wood. For example, hardwoods typically need more energy to penetrate the wood than softwoods (IML-RESI PD-Series Manual 2019). The resistogram is like the standardization and detrending graphs used in dendrochronology, showing peaks and valleys of the wood sample, however, differs as it also shows variations of each area, such as cracks, cavities, and other anomalies (Acuña et al. 2011:455; Içel and Güler 2016:905). Through the resistogram, a series of variables help to determine the amount of energy the resistograph consumes while drilling.

Five variables are considered when using and reading a resistograph. The first is the average value (Vmed), which is the total area penetrated longitudinally and measures the energy consumption per centimeter. The next is variability, consisting of the typical variation (VDES) and the variation coefficient (VCV). These two types can represent homogeneity or heterogeneity of the sampled wood. The last two variables are Average Maximum (Mmax), which shows average energy consumption of denser growth, and Average Minimum (Mmin), which shows the lower density in the wood (TABLE 4) (Acuña et al. 2011:456-457). The total amount of energy used while penetrating the wood is related to the sample's density, making density an important quality trait as it is correlated with the strength of the wood.

TABLE 4: Resistograph variables and their meanings summarized (adapted from Ropp 2023:37)

Variable	**Definition**
Average Value (Vmed)	Total area under each curve. Depicts how much energy is consumed while drilling.
Average Maximum (Mmax)	Average of the high points (latewood).
Average Minimum (Mmin)	Average of the low points (earlywood).
Average Maximum – Average Minimum (Mmax – Mmin)	Variation in the growth density (full ring), important for determining decay.
Maximum Value (Vmax)	Absolute high point.
Minimum Value (Vmin)	Absolute low point.

The values provide a mean to quantify the detection of early decay, cracks, cavities, or anomalies and can be further interpreted through the graphic chart (Acuña et al. 2011:458). By understanding the variables and what they are presenting on the resistogram, the behavior of the resistograph and the state of the wood sample can be interpreted. Unlike dendrochronology, the resistograph's readings and the analysis of the drilling samples are often undertaken in the field to determine the density and structural integrity of the site of interest. However, the resistograph's reading of the annual tree rings is dependent upon the calibration, tree species, preservation, whether the timber is milled, and the angle of the drilling. As for the density, the resistograph has considerable accuracy as the graphs produced can show internal decay and infestation as it depicts drops or low resistance profiles while remaining in situ (Acuña et al. 2011:462).

Previous Applications

Scientists in South Korea recently used a resistograph to determine the tree-ring boundaries and ring-width measurements of trees of cultural and historical value in the Goesan community (Oh et al. 2019:703). The study required crossdating to determine the success of the resistograph in reading the annual rings, using it on two tree species, *Zelkova serrata* (Japanese zelkova) and *Pinus densiflora* (Japanese red pine). The study showed that the resistograph fails to read tree-ring boundaries that are narrower than 1 mm, producing a lower number of tree rings than what is present. This error was found to be more predominant in the sapwood due to its aging effect (Oh et al. 2019:704). However, the study verified that the resistograph can read the ring widths in the heartwood and the tool can be of considerable value when it comes to estimating the date of a wood sample if a comparable master chronology is available (Oh et al. 2019:707).

Following this, the resistograph can also be used for determining the structural integrity of not only trees, but historical architecture as well. Recent research conducted at a Roman villa (*Villa dei Misteri*) located in the main archaeological area of Pompeii involved historical, archaeological, remote sensing, and damage assessment data to aid conservation analysis at the villa. Due to persistent issues resulting from rain, biological attack, and vegetation growth, the villa suffered from degradation to its physical structure. By employing a resistograph, the team was able to capture quantitative and qualitative information on the density of rings, shrinkage, cavities, and decay. The result of the application led to the conclusion that proper intervention was needed as the timbers were of poor quality (Bergamasco et al. 2018:181-183, 189, 196). The approach of combining the resistograph with other methods allowed for a comprehensive and informed understanding of villa's state of preservation.

Most recently, a resistograph was employed by ECU's Program in Maritime Studies during the summer of 2022 in Mallows Bay, Charles County, Maryland. As far as it is known, this was the first time that the resistograph was used specifically for maritime archaeological research. This Ph.D. research project aims to understand the timber preservation and impacts of microbial communities on the wreck throughout several phases (Ropp 2023:31). Resistograph sampling on the project consisted of 24 readings on exterior and interior structural timbers at the remains of the Emergency Fleet Corporation ship *Aowa*. Sampling was also conducted at the at the top and bottom of the vessel's stem and stern posts to analyze timber density in a microbial community (Ropp 2023). With this being an ongoing project, processing of the resistograph data is still in process.

These examples of the application of resistograph data collection show that it has great potential for archaeological research because it is a largely nondestructive method for inspecting wood, and data can be gathered in situ. Furthermore, it can be applied in a maritime environment, as the drill and cables are waterproof. There are some limitations to using the resistograph, however, such the equipment's limited depth capability or its ineffectiveness in wood having significant decay.

Archaeological Fieldwork Methodology

With the thick timbers and the unfinished edges, the suitability of the wood utilized in the construction of Castle Island's wharf was considered viable for dendrochronological analysis. For this study, resistograph data and core samples were collected from various locations around Castle Island's wharf. Building from work conducted during the ECU Program in Maritime Studies field school in the fall of 2021, a sampling plan was developed for specific sections of the wharf. In collaboration with the Tree Ring Laboratory at Radford University in Radford, Virginia, fieldwork aimed at gathering data for timber analysis was untaken at Washington, North Carolina, in May of 2023, and again in April of 2024. Due to time constraints, the project primarily focused on the wharf structure of Castle Island, rather than the entirety of maritime infrastructure around the island. This wharf site was noted in previous ECU studies on the Tar-Pamlico River system, as mentioned earlier in the chapter.

Prior to data collection, the team practiced the planned methods and tested the tools in the controlled environment of a diving well to ensure they functioned properly underwater. Once in the field, dive teams were determined based upon the methods employed, as technology and tools varied throughout the process. A topside crew was also needed since personnel were required to deploy the resistograph and process the information, as well as to handle and store dendrochronology samples. Data collection involved a snorkel team first using a site map created during the 2021 ECU Program in Maritime Studies Fall Field School to determine viable timbers for sample extraction. The timbers selected for sampling were based on visual inspection techniques to determine preservation as well as possible hazards that might be encountered. An example of a potential hazard is barnacle growth on the surface of the timber, which could damage the drill bit used to extract samples. The selected stretchers or headers were then labelled, and their locations recorded using physical measurements and GPS.

The tools used to collect dendroarchaeological and timber data varied, due to difficulties experienced in the field. The original plan called for using a Nemo submersible battery-powered drill equipped with a Pressler coring bit. Measuring 300 mm long and with an external diameter of 19 mm, and an internal diameter of 12 mm, the bit utilizes a round steel bar and cutter-hook for removing samples (Pressler GmbH 2023). For the Nemo drill to work, it must be pressurized in accordance with the ambient operating depth; since the maximum depth of the wharf structure is 3 m, the drill was pressurized to 1 bar/atm. To test the exterior preservation of the wood prior to drilling, a drill guide consisting of four nails and a hollowed-out piece of circular plastic was lightly attached to the sample location to assess wood density. If the drill guide could easily be pushed into the timber, the location was considered too deteriorated for sampling; if it was difficult to penetrate, the timber was determined viable for core sampling. Along with this, the drill guide also provided stability for the insertion and extraction of the Pressler bit.

Teams consisted of two divers, one providing light in the murky and tannic underwater environment and the other to operate the drill. The extracted cores were labeled CAS for Castle Island with the number of the sample following (ex: CAS000). The core samples gathered using the Nemo Waterproof Drill were collected along a stretcher, on the second of the four tiers at the end of the wharf (CAS001). Unfortunately, the Nemo Waterproof Drill did not provide enough battery power to extract a complete sample for tree-ring analysis. The pieces of core extracted during this activity were used, however, for wood identification (addressed in the following section).

Given the issues experienced with the battery-powered drill, the team shifted to a Central Pneumatic Reversible Air Drill rigged with a regulator to a scuba cylinder. With a maximum visibility of approximately 1 m in the Pamlico River and there being more tools in the water, dive teams size increased to three to complete various tasks: one providing light; one stabilizing the scuba cylinder; and one drilling into the wood. A major complication with the Central Pneumatic Reversible Air Drill was insufficient power to penetrate the well-preserved timber. The continuously turning in one spot without movement caused the drill to "chew" at the timber, which resulted in broken core samples. These samples were logged, but not viable for data analysis.

Following this, the increment borer was used as the final method for extracting core samples (FIGURE 27, FIGURE 28). For methodological consistency and to ensure the dense wood exited in the sample location, the drill guide was used prior to using the auger. Once successful in finding a stable timber, a Kobalt pneumatic drill was attached to the auger and aligned using the guide then inserted into the timber's exterior. As the auger punctured the surface and screwed into a stable position, the drill guide and pneumatic drill were removed, and the handle of the increment borer was placed on the auger. The increment borer was then manually turned clockwise until much of the auger is through the wood, which allowed for gathering enough tree ring and heartwood data in the sample. Once the auger was in the timber to the desired depth, the extractor tray was placed into the auger to remove the core. Lastly, the increment borer was turned counterclockwise to remove the auger and extractor tray. The team then ascended with the sample and passed it to researchers on the diving platform, who then created a label and temporarily stored it in a water-filled PVC pipe.

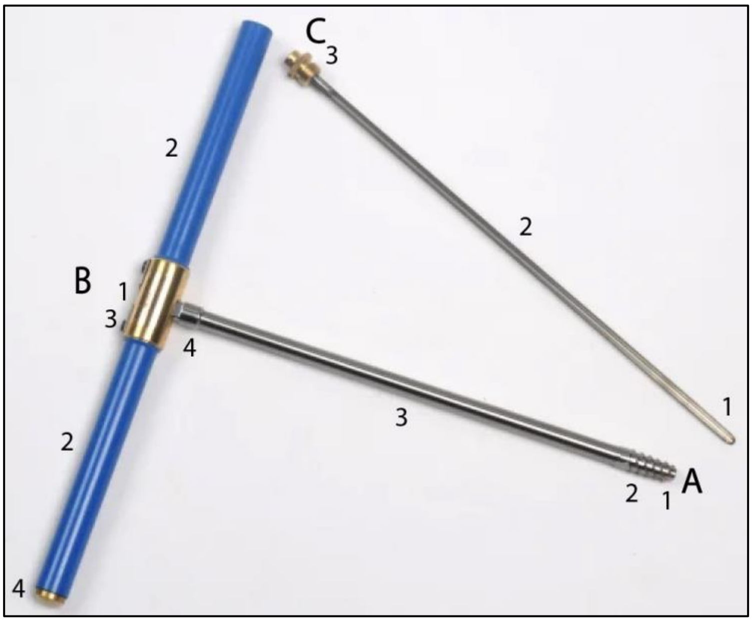


FIGURE 27: Increment borer with labels (A) is the auger, home of the threaded bit (A1) that widens during coring (A2) and the main hallow shaft (A3) that attaches to the handle (A4). (B) is the handle that has the central connector (B1) with handles (B2), a clip to fasten the auger (B3) and an end cap (B4). (C) is the extractor or spoon that has a serrated tip (C1), the main spoon (C2), and the threaded cap (C3) (Grissino Mayer 2003:64). Photo courtesy of Mattson Increment Borers, adapted by author.

FIGURE 28: Use of Kobalt pneumatic drill and placement of increment borer in timber on Castle Island (Photo courtesy of Program in Maritime Studies 2023).

By using the increment borer, the extraction of core samples was less invasive as the auger has a diameter of 4 to 5 mm, rather than the Pressler bit's 12 mm. After each extraction, a pin flag with the sample number was placed in the hole created. Following this, baseline offset measurements to where the core samples were taken on the headers and stretchers were recorded, along with GPS points. Measurements of the timber's diameter was taken, averaging 31 cm. Overall, this last method worked very well in the field season of May 2023 and April 2024, and 24 core samples were recovered in total (FIGURE 29).

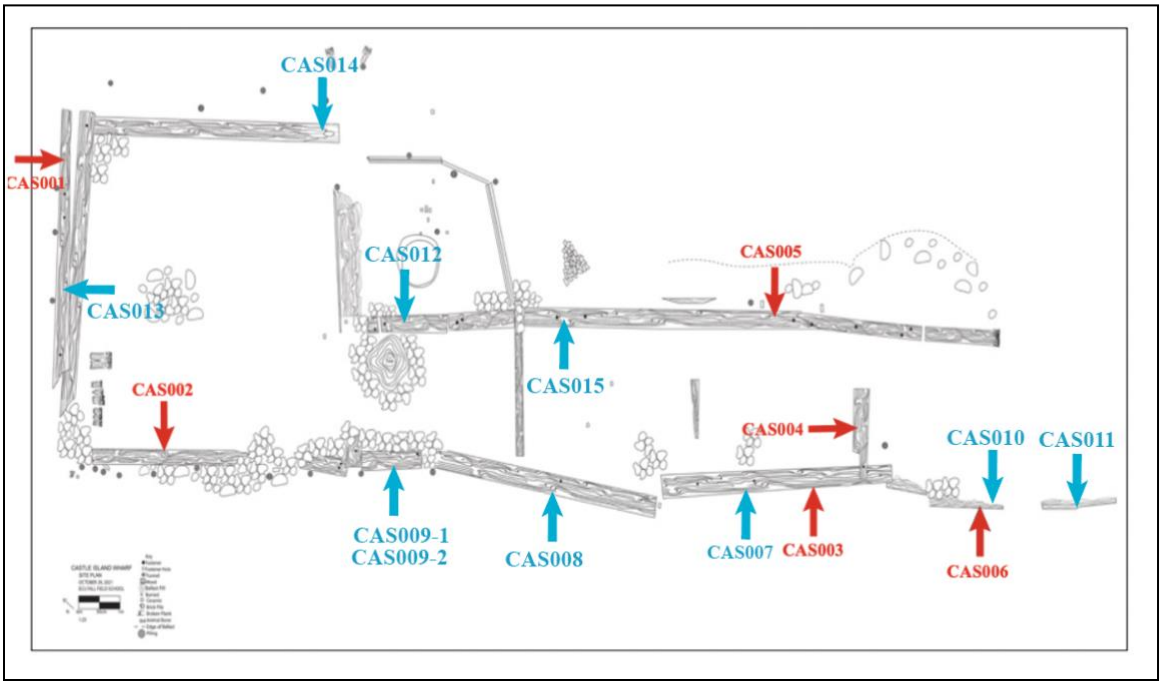


FIGURE 29: Map of where each core sample was extracted from during fieldwork. The placements were due to the accessibility, as the core samples need to be as close to the center as possible for the pith to be present for dating. The red arrows indicate the samples taken from May of 2023; the blue arrows represent where samples were taken from in April of 2024 (Map courtesy of the Program in Maritime Studies at ECU, edited by author).

Following the extraction of each core sample during the May 2023 fieldwork (red numbers in FIGURE 29), the IML-RESI PD-Series (resistograph) was deployed. Prior to data collection, the five stages of the resistograph's feed speed were tested to gauge to appropriate rotational speed for proper data analysis. A proforma developed by ECU Ph.D. student Allyson Ropp for the 2022 Summer Field School in Mallows Bay, Maryland, was adapted for the fieldwork at Castle Island, which kept the process of recording organized (see Appendix E). The resistograph had several components set up on the dive platform that varied from its usual configuration. A scuba cylinder rigged with a regulator attached to the resistograph through a series of cables blew air through the nozzle, where the needle inserts and retracts. The cables attached to the resistograph were 9 m long and connected the tool to the topside operating system.

The feed speed was tested by a dive team consisting of three people (FIGURE 30), where CAS001-4 samples were conducted. Six tests were completed, which indicated an optimal drill speed of 3000 revolutions per minute, which was then used throughout the fieldwork. The topside team consisted of an operator, who was engaged in turning off and on the resistograph when signaled that the tool was engaged.

FIGURE 30: Jeremy Borrelli handing the resistograph to Olivia Livingston (Photo courtesy of Dr. Stockton Maxwell 2023).

As the drill speed remained constant throughout the process, the resistograph unfortunately had some complications towards the end of the project, as the needle did not inject or retract as easily as it did at the beginning of sampling. This led to the resistograph experiencing an internal problem, thus being unusable in the following field season and leaving the dataset with only twelve usable readings to calculate the density.

Laboratory Methodology

Once the fieldwork was completed, the core samples were taken for further analysis, undergoing the dendrochronological lab methods previously mentioned. The following section discusses details of dendrochronological laboratory methods and resistograph readings.

Core Samples

To begin, the samples taken from the May 2023 season were placed near an air conditioning unit to begin drying while fieldwork was continued. Following this, the core samples were placed in the oven at 77° Celsius remaining in their straws until they were completely dried out and mounted on prefabricated wooden mounts. As for the core samples recovered during the April 2024 season, those were kept in their straws and placed under a fume hood for approximately 24 hours to remove the moisture. The samples were then attached to a wooden mount using water-soluble white glue, which allows easy removal if there are any mistakes. When mounting the core samples, the grain of the wood should be perpendicular to the mount, rather than parallel, for the rings to be properly exposed. Some core samples, however, needed to be broken for all the rings to be perpendicular to the mount as they were twisted from either the increment borer, or from being stored for too long.

Once the glue was dry, the cores were sanded, beginning with 80 grit sandpaper to remove the outer layer and continuing to 600 grit for a clean and polished look. With the characteristics of the core sample being exposed, it is easier to see the wood species and the tree's characteristics, such as its rings and cells. Following the sanding process, the samples were reviewed microscopically (FIGURE 31), counting the rings manually using the standard decadal dot notation. The cores then are scanned at 2400 dots per inch (dpi) and uploaded to the computer for software programs, CooRecorder and CDendro.

FIGURE 31: Microscopic image of core sample CAS013. The diagnostic features of high resin context and pronounced latewood banding are visible (Photo courtesy from author, 2024).

CooRecorder measures coordinates and gives the distance between them, producing precise measurements of tree rings. This software is more practical to use, as it measures the tree ring more precisely. The other software program, CDendro, was used for crossdating. Crossdating archaeological wood has some variability in contrast to the method described, as the core samples are relatively dated against one another (termed internal crossdating), thus creating a floating chronology (Rochner et al. 2019:403). Once the samples are relatively dated against one another, a reference chronology is downloaded from the International Tree-Ring Data Bank (ITRDB). This chronology is absolutely dated, meaning it can be used as an anchored reference against the created floating chronology. Statistical crossdating is performed using COFECHA, a software program that assesses the strength and reliability of correlation coefficients between chronologies (Holmes 1983:71) or by using the Shiny application of dplR (Bunn 2010) within the coding software R (R version 4.4.0, 2024). Another software option available for analysis is xDateR, which was developed by Andy Bunn.

In the case of processing Castle Island's wharf samples, the file made from the floating chronology was then uploaded into COFECHA for statistical analysis. The floating chronology was tested against ten master chronologies from the ITRDB that are based in North Carolina. The t-value, which is a statistical test that is used to measure overlap with the tree measurements, was 6.0 with a minimum of a 40-year overlap. This suggests that the timbers came from the same forest. Along with this, the t-value threshold of ≥ 3.5 was used to show statistical crossdating between the trees and chronologies (Rochner et al. 2019:403). However, when using COFECHA for these core pieces, 30-year segments lagged by 10 years were used for optimal number of segments tested to show any potential errors within the series and segments. The standard deviation series intercorrelation is 0.45, with the autocorrelation of 0.56. Autocorrelation is used to show a growth pattern of tree ring widths in successive years, not focusing on year-to-year variability. When the output of COFECHA shows statistically significant correlations and common adjustments for the testing cores against the reference chronology, the floating chronology is absolutely dated (Rochner et al. 2019:403).

For a visual understanding of the comparative evaluation, xDateR was used by uploading the master ring width data file and comparing it to Castle Island's floating chronology. This program displays graphs of both the reference chronology and the floating chronology. Through this, individual core samples are statistically placed in a segment where they best correspond with the reference chronology. A report at the end of the graph displays the years searched within the master reference chronology and the highest overall correlation between the floating series and the reference (Bunn 2010). The minimum segment length for

Castle Island's core samples were 20-years with an overlap 10, as some cores were not long enough to produce data to compare to. Typically, dendrochronologists prefer to calculate correlations with at least 30 years of overlap between a core and the reference chronology, but in this case the number of rings was limiting. Next, the "biweight" and "prewhiten" functions were used to normalize the measurements. The biweight function essentially minimizes irregular datapoints, like irregular growth years, to create a more standardized tree ring series (Riitters 1990:12). As for the prewhiten function, this function identifies autocorrelation or persistence in the time series and removes it to comply with the assumptions of parametric statistics (Riitters 1989:77). These two functions help to refine and improve the quality of core analysis over time by focusing on high frequency or year to year variations. Then, the Spearman correlation method was used to match core samples against the reference chronology (Bunn 2010).

Resistograph Data

Upon completion of field sampling, the tree ring widths and the density of the wood were uploaded and processed in IML Resistograph's *PD-Tools Pro*. The two recorded curves are known as the drill resistance and the feed force curve. When the data is uploaded into the software program, a green curve represents the drilling resistance, or the force that it used to spin the needle, and a blue curve is the feed resistance and interprets decay (IML-RESI PD-Series Manual 2019:6). Through these variables, the wood density and structure can be observed as the resistance drilling is highly correlated with the wood density. While using *PD-Tools Pro*, the "Annual Ring Analysis" function was the primary method for calculating the number of tree rings within a drill sample. This was completed manually by considering high peaks (latewood) and the valleys (earlywood), creating each measurement at the height drilling resistance. The two scales typically have the same behavior, often mirroring one another. It should be noted that the labeling of the annual rings is subjective. The labeling of the pith was based upon the existence of a broad tree-ring trough, making a relatively low profile. If the profile is not below the earlywood, the wood is fully intact (Rinn 2015:16). Another factor in determining the pith was the mirroring of curves (FIGURE 32). However, the pith could be located farther from the center of the timber, or barely present, which is up for interpretation.

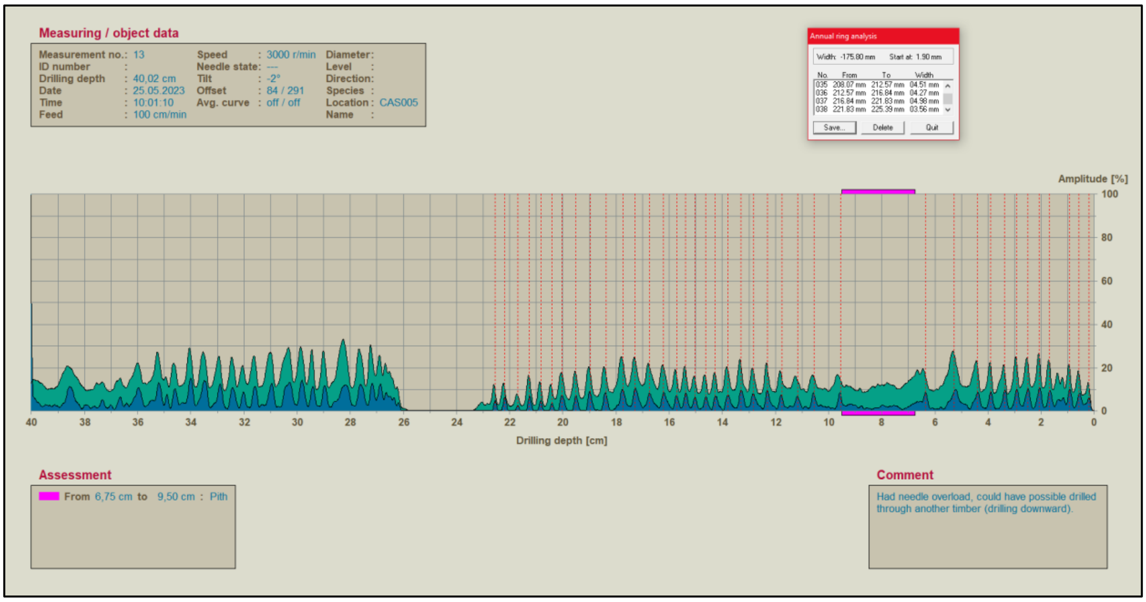


FIGURE 32: Example of resistogram in *PD Tools Pro*. This example (RESI Measurement 13) shows the measurement of each tree ring based upon the curvature, as well as shows the labeling of the pith and the mirroring of curves. Notice the drop around the 24 cm drilling depth. This could be from either decay or penetrating another timber (Graph by author, 2023).

The following steps were undertaken to determine the density of the 12 resistograph readings. The data was extracted from the resistograph to a text file, which was then uploaded into Microsoft Excel. In Excel, the output from the text file was converted into a line graph, replicating the resistogram. In creating this graph, the Average Maximum (Mmax) and Average Minimum (Mmin) were detected by separating the drill resistance curve (green) and the feed curve (blue). Following this, the numbers for the peaks (latewood), and the valleys (earlywood), were shown and recorded to gather the average. The average values of the peaks and valleys in each graph were calculated, and the valley average was subtracted from the peak average (Mmax – Mmin). This result provided the variable required for the density formula. For determining deterioration in the wood, this variable is very important as any change in the Average Minimum indicates early decay (Acuña et al. 2011:456-457).

In continuation with this process, the simple linear regression model adopted by Acuña et al.'s (2011) research was employed to determine the density of the wood as the species used in their research was of the pine family, like the timbers of this research. The formula is as follows:

$$\text{Density} = 394.797 + 0.7598(\text{A Vmed})$$

Through this model, the independent variable is A Vmed (Interval A), which uses the entire curve that was used to calculate the variables. The number 394.797 is the intercept, which predicts the value of density when A Vmed is zero. The regression coefficient is 0.7598, representing how much density is expected to change as A Vmed increases.

Results

The wood species was able to be identified by viewing some of the remnants from pieces that fell apart from the coring process while in the field. The remnants portrayed characteristics such as high resin context and pronounced latewood banding, proving the wharf to be built of longleaf pine (*Pinus palustris*). After the identification of the wood was determined, the regional master chronologies of longleaf pine from North Carolina were downloaded and compared against the floating chronology. The measurements taken from the first field season with the resistograph were then properly calculated and graphed by using a simple linear regression model.

Wood Species Identification: Pinus palustris

As eastern North Carolina has a rich history of producing naval stores, there is no doubt *Pinus palustris*, otherwise known as the longleaf pine, once flourished in the region. The scientific name for the species means “of the marsh,” as the species thrives in moist but well drained and sandy soil and has a very thin band of sapwood that covers resinous heartwood of the tree. The exterior of the tree has scale-like bark that is thick and reddish-brown. The leaves of the tree are needles that can reach to 25 to 45 cm in length and have both seed and pollen cones. Along with this, the species can live up to 500 years, reaching maturity at 100 to 150 years (Coker 1934:18-19). Prior to colonization of North America, the species once covered 37 million hectares. However, during the seventeenth and eighteenth centuries, the longleaf pine ecosystems deteriorated from over exploitation of the trees due to the naval store and timber industries. Longleaf pine once covered the southeastern region of eastern Texas to southern Virginia, being a key component to savanna, woodland, and coastal locations and ecosystems (FIGURE 33).

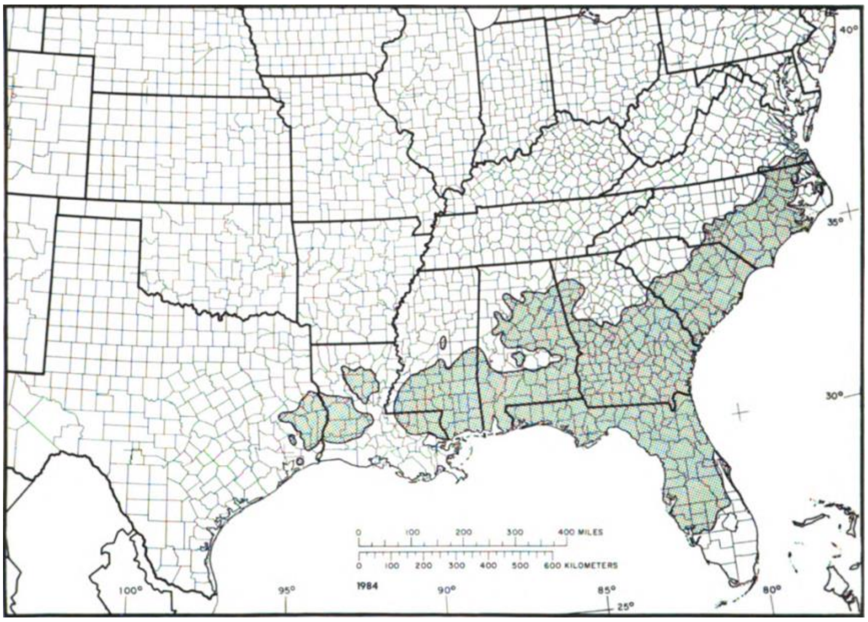


FIGURE 33: The geographic range of longleaf pine in the southeastern United States, ranging from the Atlantic Coastal Plain region to eastern Texas and the northern two-thirds of Florida (Boyer 1990:405).

Thus, the pine can live in multiple ecosystems, with an elevation range of barely above sea level along the coastal plain to about 600 m in the mountainous region of Alabama to the piedmont ridge (Boyer 1990:406). However, about 3% of the pine is found along the Atlantic and Gulf Coastal Plains, where soils are composed of marine sediments, ranging from clay to sand. Eastern North Carolina falls under the Atlantic Coastal Plain Ecoregion, which has different topography and sediment makeup. The Atlantic Coastal Plain Ecoregion has marine sediments with soils of barrier dunes and shorelines exhibiting extremely sandy and dry (FIGURE 34). In this region, the topography tends to be extremely flat with banks and rivers flowing through the inland (Jose et al. 2003:53).

FIGURE 34: Longleaf pine forest in the Atlantic Coastal Plain in Brunswick County, North Carolina (Jose et al. 2003:86).

Longleaf pine is a foundational species and one of the longest-lived trees of the region that actively adapts to its environment. Under these circumstances, the longleaf pine serves as a great component to dendrochronology thanks to its annual ring width growth, which is highly responsive to climatic and environmental fluctuations and a recorder of fire activity.

Generally, pines are more resinous than other species, and the longleaf variety tends to remain well preserved after death due to its high resin content (Gevel et al. 2009:70; Harley et al. 2023:573). The longleaf pine and its vegetation demonstrate the frequency and severity of burning, as the species adapted and became increasingly resistant to surface fires that occurred throughout forests (Harley et al. 2023:578). Throughout the colonial era of the United States, the longleaf pine was widely used in the construction of colonial structures, ranging from homes to wharves. With these factors, the development of tree ring chronologies can be obtained from its living, remnant, and archaeological usage.

Reproduction and Growth

Like all species that correlate to the pine family, the longleaf pine has both male and female counterparts. Pollination of the longleaf occurs during the late winter or early spring, whereas fertilization, when the catkins (male) and conelets (female) merge together before budding, occurs in the following spring. The lifespan of the longleaf pine can be described in several stages. To begin, the pine has seedlings that are dispersed by the wind and begin the germination process usually within less than a week, unlike other southern pines. To properly grow and thrive in the given environment, the longleaf seeds need a mineral soil, which can be achieved by mechanically removing the tall grass, or by fire (Boyer 1990:407-408). In this stage, the seeds are susceptible to disruption by mice, birds, squirrels, and ants.

The germination stage follows, allowing seeds to advance to seedlings. During this stage, the primary needles appear, with secondary needles following a period of two months. Under this phase, the seedlings are vulnerable to fire. A unique growing stage of the longleaf pine is known as the “grass stage”, in which the pine looks more like a cluster of grass rather than a tree. The grass stage can last up to two years, where the young tree develops an extensive root system and is incredibly resistant to fire. Growth within the stage is in correlation to the diameter of the root collar. In other words, the root collar is the area of the tree at ground level that transitions from trunk tissue to root tissue. During the grass stage, the pine is helpless against hogs, livestock grazing, pales weevil, and brown-spot needle blight (Boyer 1990:408-410; Jose et al. 2003:105).

Transitioning into the bottlebrush stage, the structure of the developing tree has rapid growth of pine needles without any branching growing horizontally. The increase of height occurs once the root collar reaches 2.5 cm in diameter. Early rings that develop during the bottlebrush stage can be wide and concentric, depending upon how upright and fast the juvenile tree grows (Newsom 2022:89). When the tree reaches 2 to 3 m in height, the lateral branches begin to emerge, thus shifting to the sapling stage. Progressing into the sapling stage, the bark of the tree becomes thicker as it continues to grow upwards about 1 m a year for the next several years. The longleaf pine does not become fully mature until about 30 years, when the tree develops cones accompanied by seeds (Jose et al. 2003:106). Although the longleaf does not have many damaging agents in comparison to other southern pines, they can be impacted by diseases based upon the local environment. Such diseases that can impact adult longleaf pines are pitch canker, annosus root rot, cone rust, and dry face. In continuation with these, damaged longleaf pines are more prone to being infested by the black turpentine beetle, which can weaken or kill the tree (Boyer 1990:410). If the longleaf pine lives a healthy life, it may live from 300 to 500 years, or possibly even longer (Newsom 2022:91). The stages of the longleaf pine are visualized in FIGURE 35.

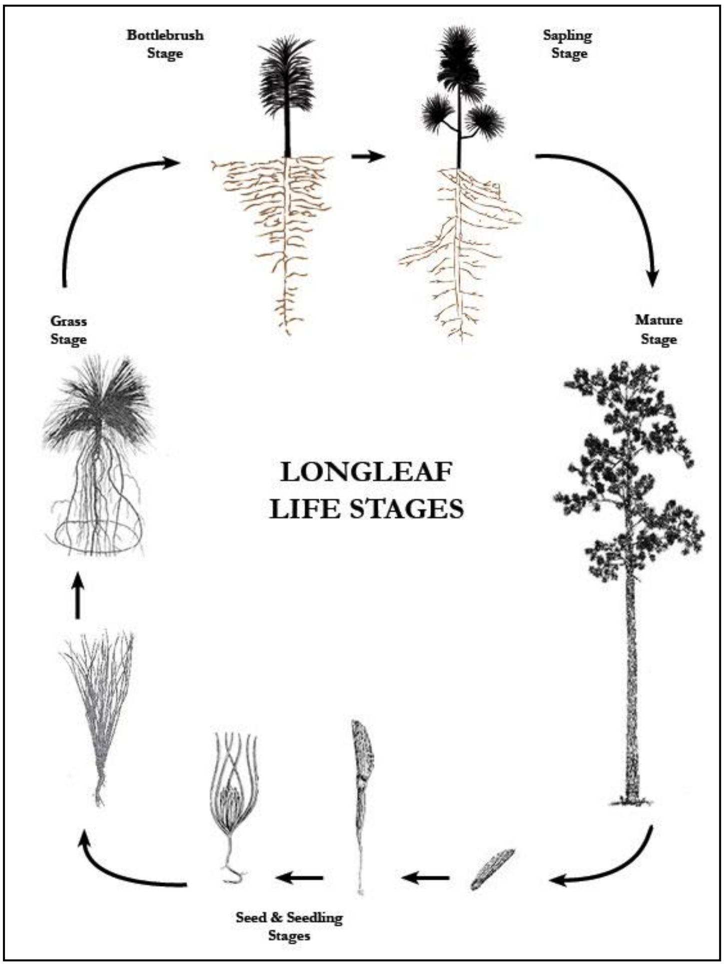


FIGURE 35: The stages of development for the longleaf pine, beginning the cycle at the bottom of the diagram (Longleaf Alliance 2021).

History of the Longleaf Pine

Being a key component to a wide range of ecosystems in the southeastern region of the United States, the longleaf pine was heavily in use throughout the colonial period and well into the late nineteenth century as it was utilized to construct homes, wharves, and naval stores. The naval store industry, particularly in North Carolina, was crucial to the regional economy as it was one of the main exporters to western Europe (Harley et al. 2023:574). The mass production of naval stores over two centuries caused great environmental impacts to the terrain of North Carolina. During this time, eastern North Carolina saw an improvement in transportation that correlated with the expanding production of naval stores. In the 1840s and 1850s, plank roads were implemented, providing access to areas of pine forests not easily accessible before (Driscoll and Kick 2013:15). In a similar way, the railroad system also contributed to the rejuvenation of the naval stores industry. As naval stores were used more throughout mid-nineteenth century, the raw materials became exhausted from overexploitation (Percy 1968:521).

Another contributing factor to this decline was the destructive way in which materials were extracted, known as the box system. In this practice, a wide, shallow hole is chopped into the base of the pine making a "v-cut" downwards and hacking off the bark and few outer rings of the wood on the tree (Olmsted 1856). The pine could have from one to four boxes, advancing higher upon the tree trunk. Through boxing, the longleaf pine was left weak, susceptible to wind, drought, disease, fires, and infestations, slowly eliminating the tree that was needed to produce naval stores (Driscoll and Kick 2013:15). The industry took advantage of the longleaf pine until it was nearly eradicated, ruining the once rich forests.

Not only was the longleaf pine used and exploited in naval store production, but it was also a building material for constructive matters. A dendroarchaeological study done in New York City's Terminal Warehouse took 22 core samples of the original joists of the building to determine the history and provenience of its construction (Leland et al. 2021:2). Of the 22 samples, 16 strongly correlated to the master chronologies of western and central Georgia and eastern Alabama, with the fall date being around 1891. With the increase of population in the United States throughout the nineteenth century, it is no surprise that the tree species was used to construct such a historical building (Leland et al. 2021:5-6). Along with this, the 1994 ECU research at the Deer Island Wharf site in Swansboro, North Carolina, indicated that the wharf was built exclusively of longleaf pine in cobb style (Stephenson and Still 1994:41). Although no absolute dating was undertaken, the construction style and measurements was compared to wharf sites found in New England, interpreting it to be a product of early nineteenth century construction (Stephenson and Still 1994:44). The remaining structures that have longleaf pine show the importance of the species to the development of the eastern United States, as it was used in numerous ways and to the point of near extinction into the twentieth century.

Core Samples

To begin, it should be noted that core samples varied in length as the samples either had broken ends due to the preservation of the wood or from the size of the timber. The segment lengths of the core samples ranged from 15 to 30 cm. As previously discussed in the methods section, the core samples were scanned at 2400 dpi on an Epson 12000XL scanner. The annual increments were measured in the software program of CooRecorder with a resolution of 0.001 mm for the clearest image of the rings to distinguish their boundaries. This program was used to visually and statistically match the patterns of growth using correlation coefficients and t-values, which will be discussed more in depth. As for the ring counts, they exhibit the age of the tree based upon the number of rings present (FIGURE 36) and are measured to the closest 0.01 mm. The ring measurements are separated as both the earlywood and latewood were estimated. The ring count and segment length of each core varied greatly in size and characteristics and gave a relative age for the tree. While measuring the samples, false rings were considered by analyzing the ring within CooRecorder by looking at the integrity of the band structure. If the cells looked like they were “bleeding” or fading into the earlywood, and were not as pronounced in color, they were considered a false ring and were disregarded in the earlywood and latewood measurements.

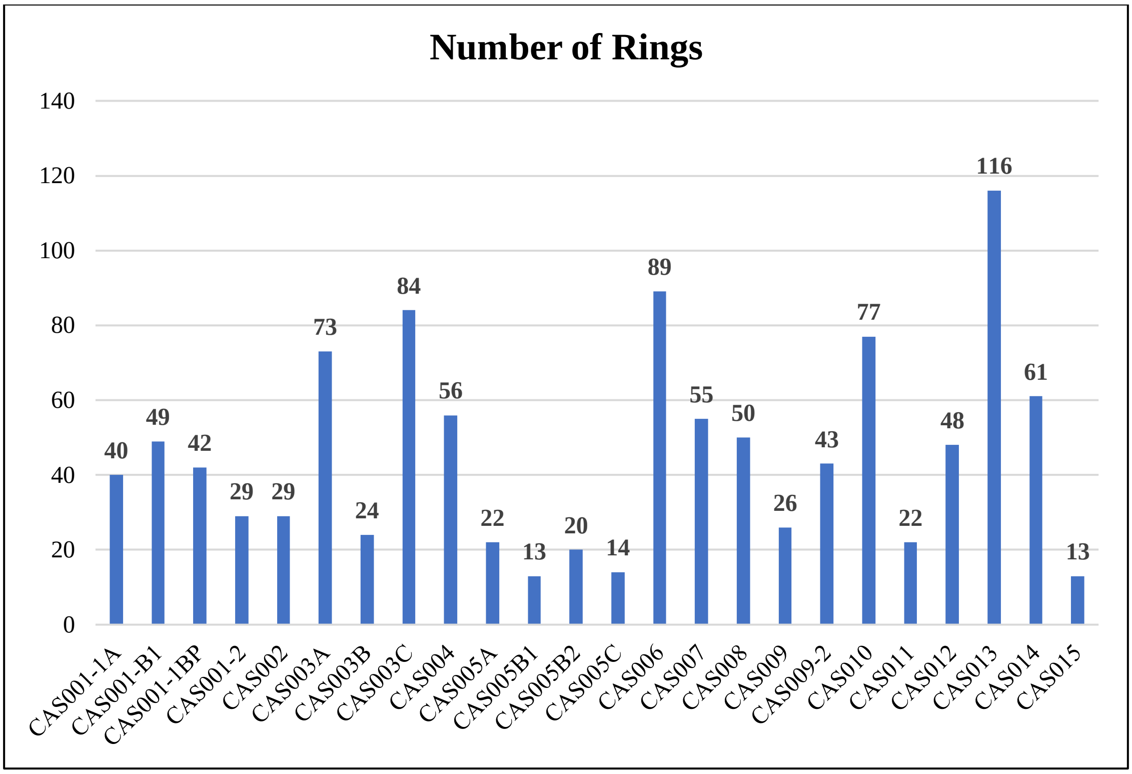


FIGURE 36: The number of rings measured from the core samples taken from the Castle Island wharf (Graph by author, 2024).

As noted above, the core samples lost some of their outer rings due to the timber's degradation from being waterlogged. Each segment had varying characteristics due to the tree's growth patterns; however, 5 out of 24 samples showed complacent ring style while the remaining were sensitive. This could very much be related to the external influences from microclimatic variations, as longleaf pine is climatically sensitive. Complacent ring styles for this case were found on shorter segments where biologically controlled juvenile growth was predominant. The more sensitive the ring growths are, the better it is to compare and create an absolute date as complacent rings are harder to anchor down in time because of the lack of variability. Due to this, complacent rings produce low correlations with reference chronologies.

The previously mentioned software, CDendro, was further utilized to create a temporary reference chronology, or growth average, for the site samples, enabling comparison of each tree core to the site's reference chronology. In CDendro, the correlations were examined between individual cores and a mean chronology calculated from all the samples to identify any cross correlations greater than or equal to 0.4, or with t-values greater than or equal to 3.5, for 20 year overlapping segments. Typically, dendrochronologists tend to use 50 year segments as they are ideal when calculating correlations, but 20 year segments with low correlations might indicate misdating of a tree core or a portion of a tree core, ultimately identifying accurate pattern matches. Any sections with low correlations were examined for errors and corrected if needed.

To further the analysis, growth measurements are converted to a dimensionless index by removing autocorrelation from the time series and calculating a robust biweight mean, which minimizes the impact of outlier growth years. Next, additional correlation functions are calculated to further confirm the statistical crossdating of the floating chronology. Additionally, RBAR was used to determine the overall quality of crossdating among samples. RBAR is the mean series intercorrelation based on normalized time series of tree growth, meaning that it is a statistical measurement of agreement between the core's growth pattern with other cores or a reference chronology. In the case of Castle Island's wharf, the RBAR was measured to be 0.64, indicating accurate dating among samples. However, only nine of the samples were able to be correlated with confidence because they had at least 50 growth rings. One sample out of the nine was statistically a bad pair, having a 0.17 correlation to the floating chronology. This might be due to idiosyncratic growth of that individual tree. The remaining samples had short segment lengths of less than 50 years making it difficult to generate statistically significant results. Nonetheless, the 24 core samples gathered from the Castle Island wharf structure were able to be internally dated to one another, thus creating a floating chronology (FIGURE 37). The visual crossdating of the growth curves with the floating chronology indicates that the samples were placed correctly in time relative to the other samples at the site. A value of 0.4 or higher is considered indicative of accurate dating for the species, although higher values are commonly observed when the sample size is ten or more.

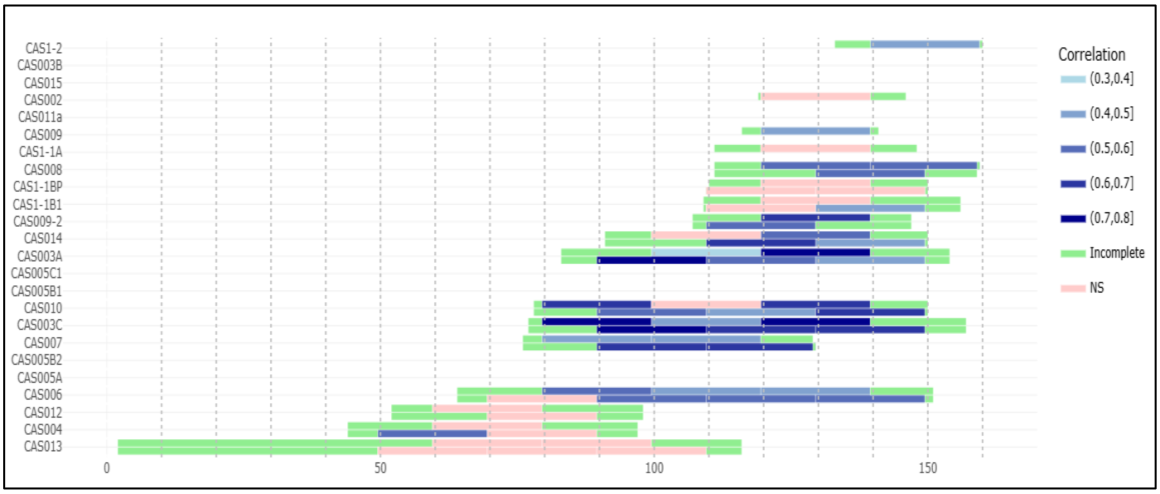


FIGURE 37: The correlation between each tree ring tree ring series segment as it is dated against each other. The correlations are calculated on overlapping segments, this case being 20 years. The pink indicates potential dating problems, while the blue signifies high correlation, and green is incomplete correlations as the dates do not completely overlap. Graph was produced in xDateR (Graph by author, 2024).

With longleaf pine being in little abundance today for chronologies, there are only so many master chronologies in public databases that can be used for comparing the tree ring series. The 12 chronologies gathered from North Carolina range from as early as 1559 and as late as 2018. Some of these chronologies were of more recent decades, making two unusable (FIGURE 38). As mentioned, xDateR was used to show correlation between the floating chronology and the master chronology. This was to further assess the statistical and visual pattern matching in the xDateR program that uses the Shiny application dplR in R. Specifically, dplR creates the process to help determine the temporal placement of individual tree cores relative to other trees at the site. The undated file of the Castle Island wharf had a total of 1,095 measurements to test against the master chronologies, removing autocorrelation to create a more precise dating when comparing chronologies.

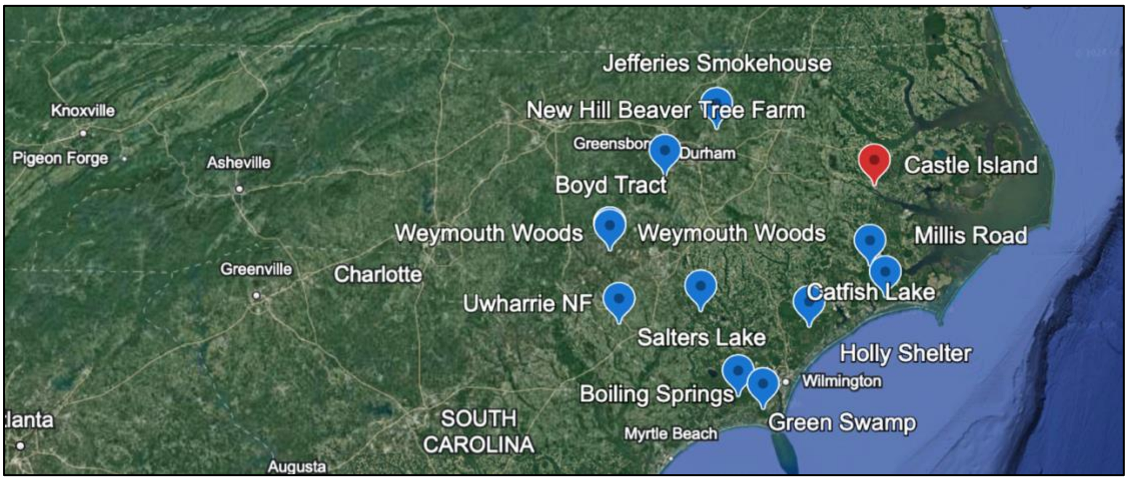


FIGURE 38: Placement of the twelve master chronologies used to potentially place the Castle Island wharf in date. The nearest being in Millis Road and Catfish Lake in White Oak Township, North Carolina (Map courtesy of Google Earth, modified by author, 2024).

In the software program xDateR, the cores with 50 or more years were correlated to the known longleaf pine chronologies. With this program, measurements from the undated core samples are placed against the absolutely dated chronology, finding an optimal placement in time. This program is similar to CDendro, as it standardizes the tree ring series by removing autocorrelation and calculating the robust biweight mean and calculating correlations by 50 year (or less) segments for best alignment. Along with this, it was noticed while looking at the visual graphs, such as the spaghetti plot, that the core samples have minimal correspondence. Typically, when looking at the spaghetti plot, core samples tend to show correspondence and line up with one another, which is not the case for Castle Island's samples (FIGURE 39).

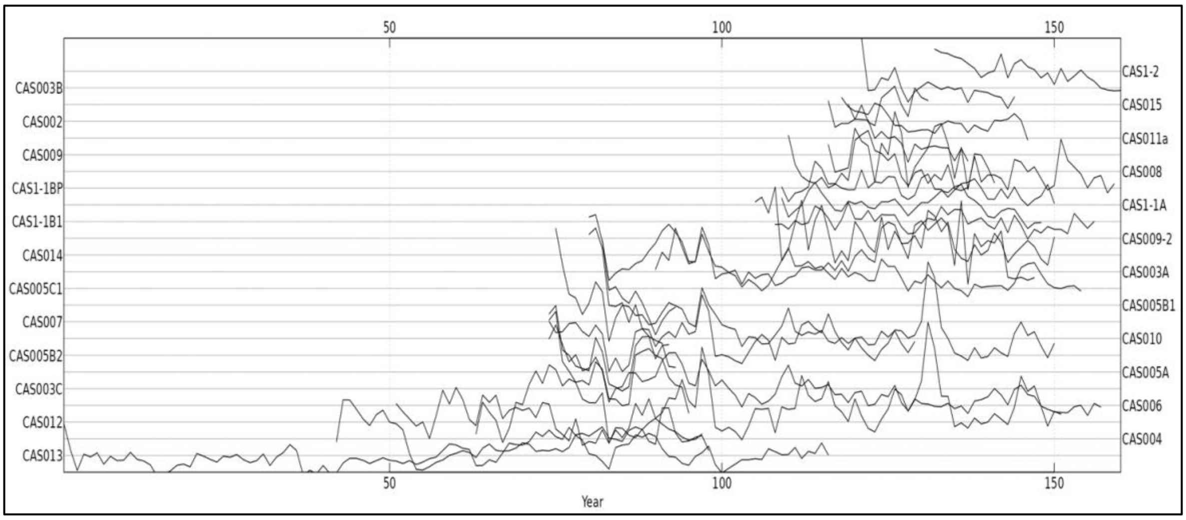


FIGURE 39: Spaghetti plot of Castle Island wharf's core samples. Typically, spaghetti plots are used to show trends and patterns within data. For Castle Island, there is hardly a semblance of a trend or pattern (Graph by author, 2024).

While the samples could be crossdated internally, anchoring them in time proved challenging due to their shorter segment lengths and the complexities associated with this particular tree species. The difficulty in correlating these segments may stem from limited overlap between them, complacent growth patterns, or idiosyncratic growth responses by individual trees to ecological events, such as forest fires or insect outbreaks. These factors make it difficult to find significant correlations, as the ecological noise likely caused year to year variations that does not match regional growth patterns controlled by climate. Although there were some significant matches while crossdating, the correlations were quite low, being around 0.25 to 0.38. Typically, correlations above 0.4 are considered viable.

When comparing reference master chronologies to Castle Island's samples, it was noticed that three taken from the same timber had different years that they correlated against (TABLE 5: Three core samples (CAS003A, CAS003B, and CAS003C) being crossdated using North Carolina longleaf pine chronologies that were gathered from the ITRDB. The number in parenthesis is the highest correlation value of the core sample (Table). With the three core samples (CAS003A, CAS003B, CAS003C) being extracted from the same timber, there should be little, if any, variation within crossdating the samples to another series. In this case, each segment produced a different range of years, some even being in completely different centuries. This was not the only group that was difficult to place a date on, as many other core samples were placed and highly correlated with scattered year spans. Additionally, while comparing cores from the chronologies, the program indicated dates ranging from the 1700s to the 1900s. This lack of consistency while analyzing the data indicates that the samples cannot be accurately placed in time.

TABLE 5: Three core samples (CAS003A, CAS003B, and CAS003C) being crossdated using North Carolina longleaf pine chronologies that were gathered from the ITRDB. The number in parenthesis is the highest correlation value of the core sample (Table by author, 2024).

Sample ID	**CAS003A**
# of Rings	73
Species	*Pinus palustris*
Millis Road (1786-2018)	1750-1822 (.35)
Holly Shelter (1695-2015)	1668-1740 (.4)
Catfish Lake (1690-2018)	1664-1736 (.36)
Boiling Springs (1720-2017)	1933-2005 (.35)
Green Swamp (1649-2017)	1600-1672 (.41)
Weymouth Woods (1690-2006)	1677-1749 (.47)
Boyd Tract (1599-1982)	1526-1598 (.39)
Uwharrie National Forest (1740-	1709-1781 (.44)
Weymouth Woods (1671-1979)	1630-1702 (.4)
Jefferies Smokehouse (1608-1829)	1802-1874 (.46)

CAS003B	**CAS003C**
24	84
Pinus palustris	*Pinus palustris*
1827-1850 (.58)	1726-1809 (.36)
1780-1803 (.71)	1645-1728 (.42)
1918-1941 (.56)	1656-1739 (.32)
1761-1784 (.49)	1700-1783 (.35)
1782-1805 (.51)	1793-1876 (.31)
1700-1723 (.57)	1643-1726 (.53)
1643-1666 (.5)	1518-1601 (.47)
1804-1827 (.48)	1680-1763 (.44)
1760-1783 (.57)	1623-1706 (.3)
1670-1693 (.68)	1547-1630 (.46)

With the years being scattered and hard to pin down, some other measures were considered to help anchor the floating chronology. This includes looking at strictly the latewood measurements due to it being more pronounced and climatically sensitive with longleaf pine. Latewood measurements tend to be a more reliable indicator of year-to-year environmental variability, which is crucial when it comes to crossdating as it is less influenced by non-climatic factors. However, in this case, the latewood measurements did not have a drastic difference in the crossdating of Castle Island’s floating chronology. Another resort was to look at the Palmer Drought Severity Index (PDSI). PDSI is a measure of the moisture available in the soil for plant growth. A tree ring reconstruction of PDSI was conducted by Cook et al. 1999 for North America with reconstructed values of droughts extending centuries into the past. Drought correlates well with tree ring growth in the mid-latitude regions of the world and can be used to aid in tree ring dating. Nonetheless, this method was also inconclusive as the correlation analysis continued to indicate inconsistent dating. Due to this, Castle Island’s wharf cannot be dated with annual accuracy from tree ring samples, but the samples are relatively dated to each other, providing a future opportunity for analysis. Some opportunities for future research will be further discussed in the following chapter.

Resistograph Data

The results obtained from the density formula show that there is a correlation between the feed curve and the density, as the feed curve increases, so does the density. The penetration depth also displays how far the resistograph's needle was injected into the timbers, however, with the timbers being stacked on top of one another, there is a high probability of the needle penetrating a new timber (FIGURE 40). The average penetration depth was 37.345 cm out of the resistograph's maximum length of 40 cm, and the timbers diameter varying in size. In total 17 locations were drilled throughout the wharf structure, with eight measurements correlating to the core samples and 12 being overall suitable for data analysis. The remaining measurements were excluded from the dataset due to malfunctions that occurred at the time of drilling.

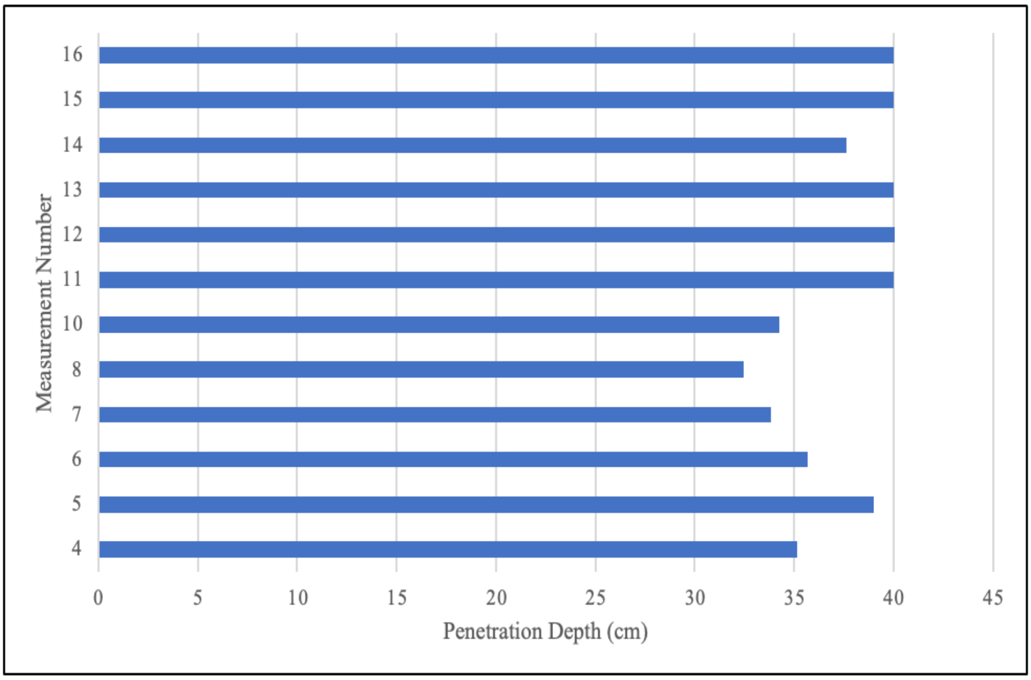


FIGURE 40: The resistograph penetration depth of each timber measurement (Graph by author, 2024).

Wood density is a property that varies significantly depending on the species of the tree. It is typically seen for the pine family (*Pinaceae*) that the density has a considerable variability, ranging from 352 to 849 kg/m³ (The Engineering Toolbox 2004). This great range can be due to numerous factors, such as the pine's ability to adapt to different ecological niches, where environmental factors play a great role in the growth of the tree, as well as the timbers being submerged for over two centuries. As wood sits in water, it tends to break down and replace the cellular structure (Broda and Hill 2021:6). Notably, the longleaf pine, a species that has slow growth and high resin, has an average density of 638 kg/m³ (Sweetman and Goodyear 2020:305). Comparative to the average density of the longleaf pine, the wharf's timbers surrounding Castle Island exhibit a significantly low density (FIGURE 41).

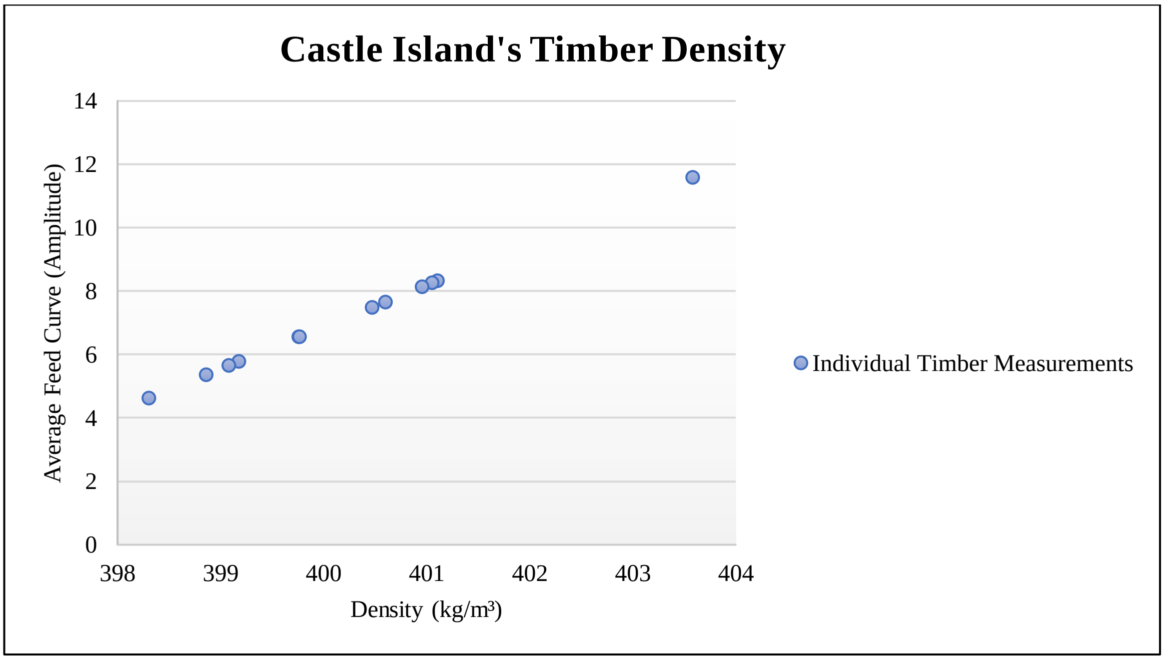


FIGURE 41: The 12 resistograph datasets depicted in a simple linear regression model (Density = 394.797 + 0.7598[A Vmed]) that is adopted from Acuña et al. (2011) (Graph by author, 2024).

Of the 12 selected timbers that the resistograph sampled, the lowest density recorded was 398.3068 kg/m³ to 403.5892 kg/m³, with the average density being 400.2313 kg/m³. Notably, the low amplitude rates show that there was relatively low resistance with drilling and interrelates to the density of the timber. This lower density in correlation to the average density of the longleaf pine can show the degradation of the estuarine environment on the wharf's timbers. Numerous environmental factors can contribute to the preservation and density of the timbers, such as tidal patterns, boats anchoring around the island, salinity levels of the water, and biological determinants. Another possibility, which can be seen through some of the core samples taken, is the use of younger or faster-growing trees for structural members.

Lastly, resistograph readings were compared to the initial core samples taken in the first round of fieldwork. This comparison was conducted by manually identifying latewood peaks and earlywood valleys, recording each point of highest drilling resistance in *PD-Tools Pro* (FIGURE 42). As mentioned, the pith was identified by a wide and low profile section of the data. The mirroring of curve patterns further confirms pith identification in the resistograph chart. If this feature does not dip below the earlywood level, the wood is thus considered fully intact (Rinn 2015:16). The *PD-Tools Pro* measurements were then compared to the tree ring counts to determine if there was a correlation in the number of rings, as drilling took place near the core sample extraction site (FIGURE 43). However, there was insufficient correlation to make a meaningful analysis of the resistograph as a tool to measure tree rings. The resistograph tree ring count and measurements often exceeded the measurements and count of the core samples, with the pith measurement being significantly distant from where it is measured to be with the cores. Although previous studies report success with the resistograph for determining the age of the tree, it was experimented with living trees (Oh et al. 2019). Thus, this fieldwork showed limited effectiveness: possibly due to resistograph malfunctions, wood penetration angles, false rings, and the wood's density.

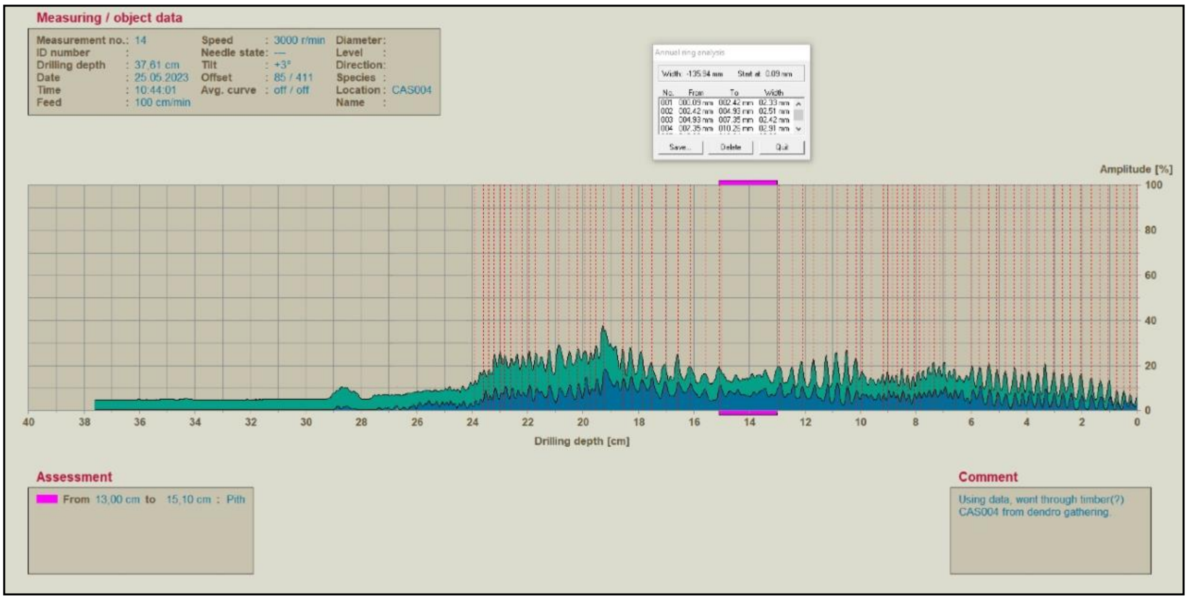


FIGURE 42: An example of the chart in PD-Tools Pro, labeling the pith (hot pink) by looking at the mirroring of peaks and valleys. Careful examination of the peaks and valleys were done to place the ring boundaries. The absent peaks in the green and blue curves towards the end exhibits how decayed the remainder of the timber is (Graph by author, 2023).

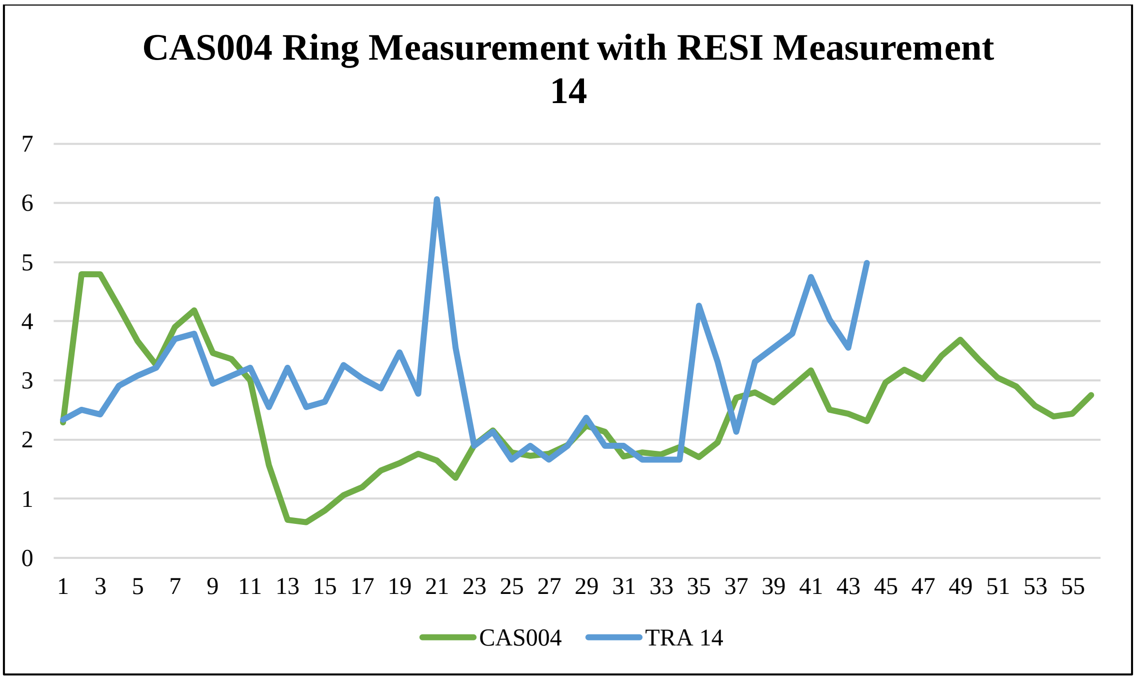


FIGURE 43: Graphic comparison of core sample measurements (green) and resistograph measurements (blue). Resistograph readings extended only to the pith, as they exceeded the

length of the core sample; tree rings are counted from pith to outermost ring. Although there are some overlaps between the two, it is not statistically significant enough to argue that the resistograph can be used as a tool to measure tree rings (Graph by author, 2023).

Conclusion

The results of the wood species, timber core, and resistograph sampling provides interesting details about Castle Island's wharf, the history of Washington, and the preservation of the site. Although it could not be positively dated, the environmental considerations at the site and the methods employed are of value to future studies. With Castle Island's wharf resting in a completely submerged environment, obtaining adequate samples was difficult. The environment caused issues not only for gathering enough samples, but also in terms of preservation. Due to factors such as fluctuating tidal patterns, human and biological agency, and changing salinity levels, timbers can become rotten and less dense. This is shown through the outer members of the Castle Island wharf core samples, but also the resistograph data, as the timbers are less dense. Even though dendrochronology could not set an exact date for the samples, at least the species of the timbers support the narrative of Washington and Castle Island, as longleaf pine was a popular species for construction throughout the eighteenth and nineteenth centuries. Lastly, the limitations of the research will be discussed in detail in the following chapter, as will proposed steps for future research.

Chapter Six. Discussion and Conclusion

Though this thesis uncovered and analyzed numerous datasets related to Castle Island's wharf, certain factors influenced the results and presented limitations. The preceding chapters provided a history of the port of Washington and Castle Island, the historical evolution and defining features of wharf structures, and the archaeological research and methods for data collection related to dating the site of interest. As each of these subjects was evaluated and interpreted individually with research results presented at the end of the relevant chapters, they are considered as lines of evidence that when considered together can provide new insight into the establishment and development of the Castle Island wharf.

Differentiating Dating Methods

Dating methods in archaeology can be categorized into two main types: relative and absolute. As discussed previously, relative dating methods are frequently employed to establish a chronological sequence of past events by linking individual artifacts to a specific artifact or a group of artifacts (Blackham 1998:167). Changes in artifact types are used to delineate the beginning and end of chronological periods, with these transformations referred to as "relative placement dates" (Blackham 1998:167). Unlike absolute dating, which provides specific calendrical dates, relative placement dates represent probabilistic timeframes rather than fixed calendar dates.

In contrast, absolute dating methods provide specific calendrical dates and are based on scientific techniques. These techniques often involve measuring the decay of materials, the accumulation of certain elements over time, or other processes that occur at known rates, including environmental or cultural factors (Emafor and Ugwu 2023:30). While relative dating establishes a general chronological sequence, absolute dating yields precise dates through scientific analysis. Both methods are instrumental in archaeological research and have significantly contributed to the study of Castle Island's wharf, offering a detailed understanding of its historical development. These methods encompass historical context, artifact analysis, dendrochronology, and resistograph analysis.

Historical Context

Through the use archival records, such as diaries, newspapers, journals, and government records, archaeologists build historical context. Knowing exact dates and chronological information pertaining to events, cultures, or artifacts is a valuable form of absolute dating. In the case of Castle Island, the presumed establishment date was 1818, based on records indicating that the Fowle family established offices there (Fowle 1817). However, the historical record also indicates that Washington was first settled in 1726, through a land grant to the Bonner family (Paschal 1976:1). Thus, infrastructure surrounding what was the area then known as Forks of the Tar could have been implemented earlier than what was recorded, as wharves and warehouses were erected there by at least the 1750s through the efforts of Edgecombe County merchant Aquila Sugg (Hill 1984:1-2).

The historical context for Castle Island in the Pamlico River was further complicated by the concurrent existence of another island with a connection to Washington, the Blount brothers' Shell Castle Island (McGuinn 2000). Incidentally, the phrase "the Castle" was often indistinguishable between the two in historic records prior to the nineteenth century, as Shell Castle Island was among the biggest and busiest maritime trade centers in eastern North Carolina during that period. It is also unknown whether Castle Island was referred to by another name prior to S. R. Fowle & Son Company's occupation. Therefore, efforts to determine an absolute date based on archival research for a period of establishment prior to 1818 was inconclusive for this research.

Wharf Typology

Wharf typology undoubtedly plays a role in the historical discourse of Castle Island. The various types of construction used throughout colonial America and their analysis helped to identify the design and methods used in the erection of the wharf at Castle Island and why that type was chosen. As previously mentioned, the structure of the wharf that surrounds the island is an interesting mix of closed timber crib and cobb style, which was commonly used in eighteenth and nineteenth century wharf building. The dating for the type of construction ranges from pre-colonial to as late as the nineteenth century. These construction types are closely related to those in New England, such as the cobb style Derby and Central wharf in Massachusetts (Small 1941), and crib style Cheapside Wharf in New York (Norman 1987). However, in terms of history, environment, and structure, Castle Island's placement is more closely related to the eighteenth-century structures documented at Brunswick Town (Smith 2014) and Swansboro's Deer Island (Stephenson and Still 1994). This is due to the wharves having a cobb-crib construction in an estuarine environment and catering to similar business interests and exports. The use of ballast stones to fill the cribbing is not unusual, as Castle Island was engaged with trading and reused materials that would have otherwise been discarded by visiting vessels.

Artifact Analysis

Along with the synthesis of wharf typology, artifact analysis also allows for more nuanced understanding of Castle Island's period of use. Although the historic period artifacts recorded at the wharf ranged from as early as the sixteenth century to as late as the twentieth century, their analysis undoubtedly illustrates the operational lifespan of the island. The identified artifacts support the historical narrative and evolution of Castle Island, as it transformed throughout the past few centuries based upon the economic needs and trends.

While each documented artifact type offered insight, the use of the mean ceramic dating formula created more contextual information of the ceramics found on site, leading to an occupational date range. With stoneware, and in particular salt glazed stoneware, being popularly made in England and eventually the United States throughout the eighteenth and nineteenth century, it is unsurprising that it made up of 52% of Castle Island's ceramic assemblage (Hume 1969:25). The rest of the relevant assemblage included earthenware, which accounted for 35%, creamware at 9%, and porcelain made up 4%. Most of the pieces recorded were datable, giving the wharf a mean ceramic date of 1776.38. This calculated date puts Castle Island in operation 41.62 years earlier than the first reference date of 1818. It should be emphasized, however, that the number of dated ceramics was limited. Although this cannot be controlled, low sampling size can reduce the reliability of this method as a larger sampling size increases the accuracy of the mean ceramic dating formula.

It should be noted that some limiting factors were encountered while trying to properly date the artifacts documented at the Castle Island wharf. For one, artifact dates were based upon pictures taken in the field and information described in field school data logs. By not having tangible artifacts or photographs taken in a more professional setting, the context provides a limited perspective. Furthermore, image quality was poorer for some than others due to file size, lighting, and handling. As such, images were digitally manipulated to maximize the information pertaining to some artifact characteristics. In addition to issues with specific images, artifacts such as redware and the prehistoric sherd, were excluded due to the large range for their date of manufacture. One other limitation was faced when dating coarse earthenware, as they are not easily attributed to a particular potter or period. Lastly, the artifacts found on or in the wharf have the potential to be out of context. This can be a limitation, as the site is based in a riverine setting, having a constant flow. Along with this, there are environmental upheavals that can disturb artifact placement.

Ultimately, the mean ceramic dating method is an interpretive tool but can provide consistent data when used in conjunction with quantitative and qualitative analysis. And in the case of Castle Island, the use of the mean ceramic date formula suggests that the wharf was constructed in the eighteenth century.

Dendrochronology

Although dendrochronology is a form of absolute dating, it should be noted that recovering samples for analysis does not always guarantee results. It can especially be problematic with longleaf pine, as it is a challenging and complex species. It is difficult to accurately place Castle Island's wharf on a timeline due to the limited number of samples collected. Other challenges for crossdating include samples not having enough years for correlation analysis and missing the critical outer rings and the pith. Short segments often create problems when it comes to crossdating, as they can vary in time and placement. Furthermore, without the pith, calculations are required for the inner growth of the five rings and interpolation of the tree, which can skew the data.

Another principal drawback for dendrochronologists dating longleaf pine timbers is the lack of publicly available chronologies. As of 2023, there are only 27 longleaf pine chronologies from 23 sites in the ITRDB (Harley et al. 2023:585). Along with this, the chronologies found in the ITRDB span several centuries, with only a few being dated prior to 1750. This timeframe is often a crucial component for ensuring sufficient crossdating of structures from the early nineteenth century (Harley et al. 2023:586).

In addition to the limitation to the time periods in the chronologies, some factors may not be recorded in master chronologies, such as variable growth rates caused by local ecological disturbances that are not related to regional climatology (Stockton Maxwell 2024 pers. comm.). The ecological disturbances can thus cause growth releases, suppressions, and false rings, to which is something the species is prone to. These factors caused complications in this study, as it is more than likely that the wharf structure was built using local wood rather than regional.

As mentioned with the dendrology of longleaf pine, fire plays a significant role in the growth dynamics of the species, which is particularly challenging to date with precision due to its adaptability to local ecological disturbances. Ecological disturbances are critical in shaping the growth patterns and development of trees, resulting in variability – or "noise" – in the tree ring width that reflects such factors of localized disruptions (such as fire), or microclimatic conditions (Cook and Pederson 2011:80). Although, this is never truly eliminated. In the context of Washington, North Carolina, the nearest regional chronologies are located 113 km away. With such environmental upheavals affecting the longleaf pine, it is doubtful that chronologies will exhibit the same ecological disturbance if they are some distance apart.

The once-abundant longleaf pine forests surrounding the Tar and Pamlico Rivers have largely been converted to cultivated land. Given the historical exploitation of longleaf pine, it is more plausible that the timbers used for the construction of the wharf on Castle Island were sourced from the nearby or immediate vicinity, rather than being transported from the lower Coastal Plains or the Piedmont region of North Carolina. Based on the recovered samples and statistical analysis, the cores from Castle Island appear to be young trees with much disturbance. When there is great ecological disturbance, the climate signal gets overwhelmed, therefore the results are not definitive (Stockton Maxwell 2024 pers. comm.). Due to some of these factors, the floating chronology could not be accurately and absolutely dated.

Resistograph

As previously mentioned, some complications with the resistograph were experienced in the field, resulting in some of the data being skewed or unusable. In some instances, the motor was overridden, had complications disengaging, and eventually blew a circuit fuse. This could result from the resinous nature of the tree species, as the needle could have been saturated with sap of the longleaf pine (Rinn 2014:46).

Another consideration and probability with the data likely resulted from drilling vertically, as it is unknown whether the needle is drilling into a stacked timber since the structure is fully submerged, and the visibility is limited. Due to sediment build up around the headers and stretchers, drilling was undertaken opportunistically, from either a vertical or horizontal position. The positioning and angles of the resistograph resulted cores missing the pith, skewing the rings, and sampling two separate timbers. If the resistograph needle is not perfectly centered and is drilled at a tangential angle, the ring width becomes wider, skewing with the data interpretation (IML-RESI Power Drill 15). This also is a factor in determining the pith, since it cannot be accurately determined if not centered. These complications can alter the data, making it not as precise as intended.

Processing of the resistograph data had limitations as well. As previously mentioned, the resistograph positioning and drilling angles can skew the rings, miss the pith, and pass between timbers. This can make the readings on IML's *PD Tools Pro* more subjective when annotating the graphs and manually marking the rings. In addition to this, the resistograph failed to measure tree rings that are narrower than 1 mm, and false conclusions about the age range of the tree can add or subtract years to its lifespan (Oh et al. 2019:707). This limitation can also tie into the possibility of false rings within the tree, which cannot be known unless there is a comparative core sample or the age of the tree is known (Oh et al. 2017:94). While the resistograph can provide valuable information about the internal structure of trees, its ability to accurately detect rings may be limited compared to more specialized techniques used in dendrochronology. This data can also become difficult to extract from the resistograph if the tree is less dense since it cannot provide an age if the latewood rings are not intact.

Density measurements are critical for understanding wooden archaeological remains, as they show the longevity and resilience of such structures. The relatively low density of the Castle Island wharf's timbers can reflect factors such as environmental influences and the readily available materials at the time. This also correlates with the core samples, as young trees with ecological disturbance can influence the resistograph's readings.

This study originally intended to compare the resistograph's readings with those recovered from dendrochronology core samples to test its viability as a nondestructive way to gather dendrochronological data. At least for this specific dataset, the two were incomparable. This was most likely due to several factors, such as penetration angle, wood density, tree species, and malfunctions of the tool. The resistograph is a relatively new tool for this specific type of research and these complications are not unexpected. Further testing with this tool in maritime environments should be undertaken to gather a more robust understanding of how it works and the proper methods for applying, interpreting, and analyzing the results.

Significance and Justification

Washington, North Carolina, played a pivotal role in the state's maritime history and economic development as an exporter of commodities to markets along the eastern seaboard of the United States and internationally. This thesis sought to provide a more detailed account of Castle Island's historical and maritime significance through a multidisciplinary approach, including a review of archival records at the George H. and Laura E. Brown Library, an analysis of the construction methods used in its wharf, and the dating of archaeological data. As one of the state's few archaeologically documented colonial wharves, Castle Island's maritime infrastructure offers valuable insights through its structural characteristics and associated artifacts, which greatly contribute to understanding its historical context.

Despite the inherent challenges of conducting fieldwork in submerged environments, this research contributes significantly to the study of dendrochronology and highlights the novel application of the resistograph to maritime archaeology. The methodological approach employed in this study diverged from traditional practices, as data collection was conducted entirely underwater on a submerged wharf structure. By detailing both the procedures and the limitations encountered, this research offers critical reflections on the efficacy of the methods used and provides a foundation for improving techniques in future studies.

Conclusion

The primary questions addressed in this thesis research focused on the wharf surrounding Castle Island and determining its initial period of use through absolute dating methods. Previous chapters offered a detailed exploration of Washington's history, wharf construction, artifact chronology, and dendrochronology. These methodologies provided new insights into Castle Island's history, particularly through the identification of longleaf pine as the primary wood used in the wharf's construction. This finding suggests that the wharf was likely built during the later colonial period or in the years of the early republic of the United States. This determination is consistent with the wharf construction style, which was common in eastern North Carolina during the eighteenth and nineteenth centuries. Additionally, the artifact assemblage further supports the timeline of Castle Island's active engagement in trade, offering a clearer indication of its early development.

While dendrochronological analysis has yet to yield definitive construction dates for the wharf, this research has laid essential groundwork for future studies. It also introduced the resistograph, a novel tool in maritime archaeology, used in an exploratory fashion in this study. Although the tool encountered challenges in the field, it still provided valuable information about the structural integrity of the wharf's wood. In conclusion, this thesis not only advances the historical understanding of Castle Island but also paves the way for future research to refine dating methods and deepen knowledge of the site's maritime significance.

Future Research Potential

Future research on Castle Island should be directed toward some key areas. First, a more comprehensive understanding of the island's role in the development of the city of Washington should be pursued. This might be achieved through deeper archival research, particularly in colonial records housed in the State Archives of North Carolina in Raleigh, North Carolina. While this study has focused primarily on the wharf structure, future research could explore how modifications to the wharf relate to changes in the surrounding seawall and land components. The extensive commercial records of the S.R. Fowle & Son Company, found in Joyner Library at ECU in Greenville, North Carolina, alongside the John Gray Blount Papers housed in the State Archives of North Carolina, offer valuable economic data that could help reconstruct Washington's early economic history.

Establishing a precise date for the Castle Island wharf should also be a priority, which might be accomplished by increasing sample size, sample depth, or more years per sample. In continuation with this, building a more localized, absolutely dated reference chronology can strengthen correlations, particularly in relation to ecological disturbances. Lastly, radiocarbon dating can be applied to get a precise date to the erection and modifications of the wharf. Further, collecting more resistograph samples across the wharf structure would enhance understanding of the preservation conditions and the tree species used. Creating a reference dataset for tree density based on resistograph measurements would also contribute to the growing body of dendrochronological knowledge. This would allow for the development of a more accurate historical narrative of Castle Island, facilitating the exploration of additional interpretive frameworks. Three-dimensional modeling could then be employed to reconstruct the island through various historical periods, potentially illustrating the evolution of the wharf over time. With comprehensive data on the structural elements of the wharf, seawall, and other architectural remnants, future conservation efforts for Castle Island can be meaningfully informed, thus allowing for an informed discourse on its preservation.

References

Acuña, L., L.A. Basterra, M.M. Casado, G. López, G. Ramón-Cueto, E. Relea, C. Martínez, A. González

2011 Application of resistograph to obtain the density and to differentiate wood species. *Materiales de Construcción* 61:451-464.

Atterbury, Paul

1978 *English Pottery and Porcelain: An Historical Survey*. Universe Books, New York, NY.

Barnett, James P.

2019 *Naval Stores: A History of an Early Industry Created from the South's Forests*. Southern Forest Research Station. Asheville, NC.

Barnwell Keith, Alice

1948 John Gray and Thomas Blunt, Merchants, 1783-1800. *The North Carolina Historical Review* 25(2):194-205.

Bergamasco, Imma, Anna Marzo, Giuseppe Marghella, Bruno Carpani

2018 In-situ experimental campaign on the covering structures of "Villa dei Misteri" in Pompeii. *Journal of Civil Structural Health Monitoring* 8:181-197.

Binford, Lewis R.

1962 A New Method of Calculating Dates from Kaolin Pipe Stem Samples. *Southeastern Archaeological Conference Newsletter* 9(1):19-21. Reprinted 1978 in *Historical Archaeology: A Guide to Substantive and Theoretical Contributions*, edited by Robert Schuyler, 66-67. Baywood Publishing Company, Farmingdale, New York.

Bingeman, J.M.

2004 Gunlocks: Their Introduction to the Navy. The Web Site of the Royal Navy's First Invincible. <http://www.invincible1756.co.uk/gun_flints.htm>. Accessed 15 May 2024.

Bird, J. H.

1971 *Seaports and Sea Terminals*. Hutchinson, London, UK.

Blackham, Mark

1998 The Unitary Association Method of Relative Dating and Its Applications in Archaeological Data. *Journal of Archaeological Method and Theory* 5(2):165-207.

Bloch, Lindsay

2011 An Archaeological Study of Common Coarse Earthenware in the Eighteenth century Chesapeake. Master's thesis, Department of Anthropology, University of North Carolina, Chapel Hill, NC.

Board of Trade

1721 *Board of Trade Papers: The Trade and Navigation of Great Britain Considered.*

Boch, Philippe and Jean-Claude Niepce
2007 *Ceramic Materials: Processes, Properties, and Applications*. ISTE USA, Newport Beach, CA.

Bonath, Shawn
1978 Evolution of the Mean Ceramic Date Formula as Applied to South's Majolica Model. *Historical Archaeology* 12:82-92.

Bothara, Jitendra and Svetlana Brzev
2011 *A TUTORIAL: Improving the Seismic Performance of Stone Masonry Buildings.* Earthquake Engineering Research Institute, Oakland, CA.

Bowling, G.A.
1942 The Introduction of Cattle into Colonial North America. *Journal of Dairy Science* 25(2):129-154.

Boyer, W. D.
1990 *Pinus palustris* Mill. Longleaf Pine. In *Silvics of North America*, Russell M. Burns and Barbara H. Honkala, editors, pp. 405-411. U.S. Department of Agriculture, Forest Service.

Bradley, Charles E.
2000 Smoking Pipes for the Archaeologist. *Studies in Material Culture Research*, Karlis Karkins, editor. Published by The Society for Historical Archaeology, pg 105-133.

Broda, Magdalena and Callum A. S. Hill
2021 Conservation of Waterlogged Wood—Past, Present and Future Perspectives. *Forests* 12.

Bunn, AG
2010 A dendrochronology program library in R (dplR). *Dendrochronologia* 28(4):251-258.

Byrd, Stephanie M.
2018 The Curious Case of Construction: A Uniquely Built Wharf at Brunswick/Fort Anderson. Master's thesis, Department of Anthropology, East Carolina University, Greenville, NC.

Byrd, William
1929 *William Byrd's Histories of the Dividing Line Between Virginia and North Carolina*. Edited by William K. Boyd, Duke University Press, Raleigh, NC.

Coker, William Chambers
1934 *Trees of the Southeastern States*. The University of North Carolina Press, Chapel Hill, NC.

Cook, Edward R.
1987 The Decomposition of Tree-Ring Series for Environmental Studies. *Tree-Ring Bulletin* 47:37-59.

Cook, Edward R, David Meko, David W. Stahle, Malcolm K. Cleaveland

1999 Drought Reconstructions for the Continental United States. *Journal of Climate* 12(4):1145-1162.

Cook, Edward and Neil Pederson
2011 Uncertainty, Emergence, and Statistics in Dendrochronology. In *Dendroclimatology: Progress and Prospects Volume 11*, edited by Malcolm K. Hughes, Thomas W. Swetnam, and Henry F. Diaz.

Combs III, Edwin L.
2003 Trading in Lubberland: Maritime Commerce in Colonial North Carolina 80(1):1-27. *The North Carolina Historical Review*. Raleigh, NC.

Cornick, Henry F.
1959 *Dock and Harbor Engineering Volume 4*. Charles Griffin & Co. Ltd., London, England.

Cox, James M.
1989 The Tar-Pamlico River and Its Role in the Development of Eastern North Carolina. Master's thesis, Department of History, East Carolina University, Greenville, NC.

Cultural Resource Group Louis Berger & Associates, Inc., The
1990 The Assay Site: Historic and Archaeological Investigations of the New York City Waterfront. HRO International, New York, NY.

Daly, Aoife
2013 Dendrochronological analysis of samples from timbers and cargo from the *Vasa*, Stockholm, Sweden- a case study. *Chronology, Culture, and Archaeology* 13.

Daly, Aoife, Fred Hocker, and Calvin Mires
2022 Dating the timbers from the 'Sparrow-Hawk', a shipwreck from Cape Cod, USA. *Journal of Archaeological Science: Reports.*

Daly, Aoife and Pål Nymoen
2008 The Bøle Ship, Skien, Norway—Research History, Dendrochronology, and Provenance. *International Journal of Nautical Archaeology* 37(1):153-170.

Degryse, P. and A.J. Shortland
2017 Characterization of Ceramics in *Archaeological Science: An Introduction*. Cambridge University Press, Cambridge, UK.

de Lotbiniere, S.
1984 Gunflint recognition. *The International Journal of Nautical Archaeology and Underwater Exploration* 13.3:206-209.

Domínguez-Delmás, Marta
2020 Seeing the forest for the trees: New approaches and challenges for dendroarchaeology in the 21st century. *Dendrochronologia* 62.

Driscoll, Adams, and Edward L. Kick
2013 Naval Stores Extraction in Eastern North Carolina: The Historical Basis of Spatial

Inequity Within a Core Nation. *American Sociological Association*. Washington, D.C.

Edwards, Diana and Rodney Hampson
2005 *White Salt-Glazed Stoneware of the British Isles*. Antique Collectors Club, Suffolk, UK.

Edwards, Justin
2013 Tar River Blounts and a Transitional Maritime Cultural Landscape. Master's thesis, Department of History, East Carolina University, Greenville, NC.

Emaefor, Obinna F. and Israel C. Ugwu
2023 Methods of Dating in Archaeology. *Journal of Archaeology and Tourism* 3(1):26-35.

Engineering Toolbox, The
2004 Wood Species: Densities. <https://www.engineeringtoolbox.com/wood-density-d_40.html>. Accessed 15 June 2024.

Falconer, William
1780 *A Universal Dictionary of the Marine*. Thomas Cadell, London, UK.

Farrell, A.W. and M.G.L. Baillie
1976 The Use of Dendrochronology in Nautical Archaeology. *Irish Archaeological Research Forum* 3(2):45-55.

Fox, Georgia Lynne
1998 The Study and Analysis of the Kaolin Clay Tobacco Pipe Collection from the Seventeenth century Archaeological Site of Port Royal, Jamaica. Ph.D. Dissertation, Texas A&M University.

Geus, André R. de, Sérgio Francisco da Silva, Alexandre Bahia Gontijo, Flávio de Oliveira Silva
2020 An analysis for timber sections and deep learning for wood species classification. *Multimedia Tools and Applications* 79(1).

Gevel, Saskia van de, Justin L. Hart, Henri D. Grissino Mayer, Kenneth W. Robinson
2009 Tree Ring Dating of Old-Growth Longleaf Pine (Pinus palustris Mill.) Logs from an Exposed Timber Crib Dam, Hope Mills, North Carolina, USA. *Tree Ring Society* 65(1):69-80.

Grissino Mayer, Henri D.
2003 A MANUAL AND TUTORIAL FOR THE PROPER USE OF AN INCREMENT BORER. *Tree Ring Research* 59(2):63-79.

Greer, Georgeanna H.
1996 *American Stonewares: The Art and Craft of Utilitarian Potters*. Schiffer Publication, Atglen, PA.

Grynaeus, Andras
2000 Dating Undated Medieval Charters. *Institute of Advanced Study*. Boydell Press, Suffolk, UK.

Harley, Grant L. Matthew D. Therrell, Justin T. Maxwell, Arvind Bhuta, Joshua C. Bregy, Karen J. Heeter, Thomas Patterson, Maegan Rochner, Monica T. Rother, Michael Stambaugh, Nicole E. Zampieri, Jan Altman, Savannah A. Collins-Key, Christopher M. Gentry, Christopher Guiterman, Jean M. Huffman, Daniel J. Johnson, Daniel J. King, Evan R. Larson, Carolina Leland, Hung TT Nguyen, Neil Pederson, Joshua Puhlick, Mukund Palat Rao, Milagros Rodriguez-Caton, John B. Sakulich, Neelratan Singh, Clay S. Tucker, Saskia L. van de Gevel, April L. Kaiser, Sarir Ahmad

2023 The Longleaf Tree-Ring Network: Reviewing and expanding the utility of *Pinus Palustris* Mill. Dendrochronological data. *Progress in Physical Geography: Earth and Environment.* 47(4):570-596.

Harrington, J.C.

1954 Dating Stem Fragments of Seventeenth and Eighteenth Century Clay Tobacco Pipes. *Quarterly Bulletin of the Archeological Society of Virginia* 9(1):10-14. Reprinted 1978 in *Historical Archaeology: A Guide to Substantive and Theoretical Contributions*, edited by Robert Schuyler, 63-65. Baywood Publishing Company, Farmingdale, New York.

Harrup, Matthew

2013 Tar Kilns of Goose Creek State Park: History and Preservation. Master's thesis, Department of History, East Carolina University, Greenville, NC.

Heintzelman, Andrea.

1984 Excavation of an Early Nineteenth Century Wharf Swansboro, North Carolina in *In Search of Our Maritime Past*, Proceedings of the Fifteenth Conference of Underwater Archaeology. Jonathan W. Bream, Rita Folse-Elliott, Claude V. Jackson III, Gordon P. Watts, Jr. (eds), pp. 92-102.

1985 Late Seventeenth and Eighteenth Century Wharf Technology: Historical and Archeological of Three Eastern U.S. Examples. Master's thesis, Department of Anthropology, American University, Washington, DC.

Hicks, Theresa R.

2012 Wharves: The Keystone of Plantation Wealth? Case Studies. Master's thesis, Department of History, East Carolina University, Greeenville, NC.

Hill, Michael

1984 Historical Research Report: The Waterfront Area of Washington, North Carolina. North Carolina Division of Archives and History. Raleigh.

Holmes, R. L.

1983 Computer-assisted quality control in tree-ring dating and measurement. *Tree-Ring Bulletin* 43:69-78.

Hudgins, Lisa

2009 Staffordshire in America: The Wares of John Bartlam at Cain Hoy, 1765-1770 in *Ceramics in America.* Ceramics in America 2009, Robert Hunter and Luke Beckerdite editor, 68-80pp. Chipstone Foundation, Milwaukee, WI.

Hunt, Freeman

1840 The Harbors of North America. *Merchant's Magazine Commercial Review* 2:309-321.

Hume, Ivor Noël
1969 *A Guide to Artifacts of Colonial America*. University of Pennsylvania Press, Philadelphia, PA.

IML-RESI PD Series Manual
2018 IML-RESI PD Series Manual and Warranty Terms & Conditions. Instrumenta Mechanik Labor System GmbH, Weisloch, Germany.

IML-RESI Power Drill
n.d. Users guide for interpretation of resistance drilling profiles from electronically recording. Instrumenta Mechanik Labor System GmbH, Weisloch, Germany.

Jose, Shibu, Eric J. Jokela, and Deborah L. Miller
2006 *The Longleaf Pine Ecosystem: Ecology, Silviculture, and Restoration*. Springer New York, NY.

Kirby, David
1974 The Royal Navy's Quest for Pitch and Tar During the Reign of Queen Anne 22(2):97-116. *The Scandinavian Economic History Review*. London, England, UK.

Içel, Bilgin and Gücarn Güler
2016 Nondestructive determination of spruce lumber wood density using drilling resistance (Resistograph) method. *Turkish Journal of Agriculture and Forestry* 40: 900-907.

Leavitt, Steven W., and Bryant Bannister
2009 Dendrochronology and Radiocarbon Dating: The Laboratory of Tree-Ring Research Connection. *Radiocarbon* 51:373-384.

Lindsey, Bill
2024 Historic Glass Bottle Identification & Information Website. <https://sha.org/bottle/>. Accessed 1 June 2024.

Longleaf Alliance
2021 Life Stages. The Longleaf Alliance, Andalusia, Alabama <https://longleafalliance.org/what-is-longleaf/the-tree/life-stages/>. Accessed 10 November 2023.

Lowe, Matthew
2022 Visualizing Port History: An Historical and Archaeological Reconstruction of Washington, North Carolina's Historic Waterfront. Master's thesis, Department of History, East Carolina University, Greenville, NC.

Mallios, Seth
2005 Back to the Bowl: Using English Tobacco Pipebowls to Calculate Mean Site-Occupation Dates. *Historical Archaeology* 39(2).

Malone, Joseph J.

1972 England and the Baltic Naval Stores Trade in the Seventeenth and Eighteenth Centuries 58(4). *The Mariner's Mirror*. London, England, UK.

Maryland Archaeological Conservation Lab
2015 Diagnostic Artifacts in Maryland. <https://apps.jefpat.maryland.gov/diagnostic/ColonialCeramics/index-colonial.html>. Accessed 29 January 2024.

Mayo, Mellie Gaskill
1903 *Trade and Commerce of Washington from its Infancy*. Washington-Beaufort County Bicentennial Commission, Washington, NC

McDonald, Molly R.
2011 Wharves and Waterfront Retaining Structures as Vernacular Architecture. *Historical Archaeology* 45(2):42-67.

McGrail, Sean
1989 The Shipment of Traded Goods and Ballasts in Antiquity. *Oxford Journal of Archaeology* 8(3):353-358.

McMillan, Lauren K.
2016 An Evolution of Tobacco Pipe Stem Dating Formulas. *Northeast Historical Archaeology* 45:67-88.

Milne, Gustav and Chrissie Milne
1978 Excavations on the Thames Waterfront at Trig Lane, London, 1974-76. *Medieval Archaeology* 22(1):84-104.

Myrvoll, S.
1991 Vagen and Bergen: The Changing Waterfront and the Structure of the Medieval Town. In Waterfront Archaeology: Proceedings of the Third International Conference on Waterfront Archaeology, Bristol, 1988, G. L. Good, R. H. Jones, and M. W. Ponsford, editors, pp. 150-161. Council for British Archaeology, CBA Research Report No. 74. London, UK.

National Centers for Environmental Information
2024 U. S. Climate Normals Quick Access. <https://www.ncei.noaa.gov/access/us-climate-normals/#dataset=normal-monthly&timeframe=30&location=NC&station=USC00319100>. Accessed 12 November 2024.

Nassif, William
2020 Reconstructing the Waterfront: An Historical and Archaeological Reconstruction of the Nineteenth Century Port of Washington, North Carolina. Master's thesis, Department of History, East Carolina University, Greenville, NC.

Newsom, Lee
2022 *Wood in Archaeology*. Cambridge University Press, Cambridge, UK.

Norman, Joseph Gary
1987 Eighteenth century Wharf Construction in Baltimore, Maryland. Master’s thesis, Department of Anthropology, College of William and Mary, Williamsburg, VA.

Oh, Jung-Ae, Seo Jeong-Wook, and Kim Byung-Ro
2017 Establishing Local Master Ring-Width Chronologies and Their Utilization for Estimating the Age of Big Old Trees. *Journal of the Korean Wood Science and Technology* 45(1):85-95.
2019 Determinate the Number of Growth Rings Using Resistograph with Tree-ring Chronology to Investigate Ages of Big Old Trees. *Journal of the Korean Wood Science and Technology* 47(6):700-708.

Online Etymology Dictionary
2024 *Online Etymology Dictionary*. Douglas Harper, Lancaster, PA. Also available at < https://www.etymonline.com>.

Oswald, Adrian
1951 English Clay Tobacco Pipes. *The Archaeological Newsletter*, 3*:*153-159, London, UK.

Outcalt, Kenneth W.
2000 The Longleaf Pine: Ecosystem of the South 1(1):43-52. *Native Plants Journal*. University of Wisconsin Press, Madison, WI.

Outland III, Robert B.
1996 Slavery, Work, and the Geography of the North Carolina Naval Stores Industry, 1835-1860 62(1):27-56. *Southern Historical Association.* Houston, TX.
2001 Suicidal Harvest: The Self-Destruction of North Carolina’s Naval Stores Industry 78(3): 309-344. *The North Carolina Historical Review*. Raleigh, NC.

Paschal, Herbert
1976 In the Beginning. In *Washington and the Pamlico*, Ursula Loy and Pauline Worthy, editors, pp. 1-5. Washington-Beaufort County Bicentennial Commission, Washington, NC.

Patterson, Robert Mitchell
2009 An Archaeological Investigation of Barber Landing, Pitt County, North Carolina. Master’s thesis, Department of Anthropology, East Carolina University, Greenville, NC.

Perry, Percival
1968 The Naval-Stores Industry in the Old South, 1790-1860 34(4):509-526. *The Journal of Southern History*. Houston, TX.

Pilt, Kalle, Vello Pallav, Matis Miljan, Jaan Miljan
2022 *Diagnosis of Timber Structures and Archaeological Wood of Cultural Heritage*. Department of Rural Building, Estonian University of Life Sciences, Estonia.

Powell, William S.

1989 *North Carolina Through Four Centuries.* The University of North Carolina Press, Chapel Hill, NC.

Pressler GmBH
Drills for dendrochronology: Technical notes. Pressler GmBH, Planning and Building Research, Gersten, Germany <https://pressler-gmbh.com/rund-um-das-bohren/bohrerhandling>. Accessed 26 July 2023.

Rathgeber, Cyrille B.K., Henri E. Cuny, and Patrick Fonti
2016 Biological Basis of Tree-Ring Formation: A Crash Course. *Frontiers in Plant Science* 7(734):1-7.

Ratzer, Bernard
1767 *Plan of the city of New York in North America*. Brooklyn Historical Society, New York, New York.

Raupp, Jason T., Jennifer McKinnon, Jeremy Borrelli, Mark Keusenkothen, Dominic Bush, Patrick Boyle, Amber Cabading, Lily Kelley, Matt Lowe, Taylor Picard, Darby Robbins, Andrea Yoxsimer, Trenton Zylstra
2021 HIST6850 Fall Field School 2020 Washington, North Carolina Report of Investigations. Report Submitted to NCDNR Office of State Archaeology, Underwater Archaeology Branch, Kure Beach, NC.

Raupp, Jason T., Jennifer McKinnon, Jeremy Borrelli, Jill Schuler John Detlie, Lydia Downs, Michaela Hoots, Caleb O'Brien, Matt Pawelski, Dante Petersen Stanley, Winston Sandahl, Stephanie Sterling, and Lindsay Wentzel
2022 HIST6850 Fall Field School 2021 Report of Investigations: Castle Island, Washington, North Carolina. Report Submitted to NCDNR Office of State Archaeology, Underwater Archaeology Branch, Kure Beach, NC.

Rinn, Frank
2014 Typical Trends in Resistance Drilling Profiles of Trees. *Arborist News*.

Rinn, F., F.H. Shweingruber, and E. Schär
1996 Resistograph and X-Ray Density Charts of Wood. Comparative Evaluation of Drill Resistance Profiles and X-Ray Density Charts of Different Wood Species. *Holzforschung* 50(4).

Riitters, Kurt H.
1989 A comparison of chronologies from tree rings. Can. J. For. Res., Vol. 20:76-83.
1990 Analysis of Biwight Site Chronologies: Relative Weights of Individual Trees Over Time. *Tree Ring Bulletin* Vol. 50:11-19.

Robichaud, André, Amanda Young, and Colin P. Laroque
2009 The Grand-Pré – UNESCO World Heritage Site proposal: dendroarchaeological survey of aboiteaux and a wharf. MAD Lab Report 2009-16.

Robinson, Kenneth
1997 Port Brunswick and the Colonial Naval Stores Industry: Historical and Archaeological Observations 46:51-65. *North Carolina Archaeology*. Raleigh, NC.

Rochner, Maegen, Zachary A. Merrill, and Laura G. Smith
2019 Dendrochronological investigation of the Knob Creek Cabin at President Abraham Lincoln's Boyhood Home, Hodgenville, Kentucky, USA. *Journal of Archaeological Sciences* 25:400-408.

Rodgers, Bradley A. Nathan Richards, Franklin H. Price, Brian Clayton, Andrew Pietruszka, Heather White, and Steven Williams
2006 The Castle Island Ships' Graveyard: The History and Archaeology of Eleven Wrecked and Abandoned Watercraft. East Carolina University, Greenville, NC.

Ropp, Allyson
2023 An Interdisciplinary Assessment of a Wooden Shipwreck Stability in a Shallow-Water Tidal-Fresh Ecosystem. Dissertation proposal, Department of Coastal Studies, East Carolina University, Greenville, NC.

Ross, Robert
2021 *Wood Handbook: Wood as an Engineering Material.* General Technical Report, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI.

Sawers, Larry
1992 The Navigation Acts Revisited 45(2):262-284. *The Economic History Review*. Hoboken, NJ.

Shortland, A.J. and P. Degryse
2019 Chapter 14: Ceramics. In *Archaeological Science: An Introduction*. Cambridge University Press, Cambridge, UK.

Shweingruber, F.H.
1989 *Tree rings – basics and applications of dendrochronology.* Kluwer Academic Publishers, Norwell, MA.

Sloane, Eric
1965 *A Reverence for Wood*. Wilfred Funk Inc., New York, NY.

Stephenson, Richard A., William Still
1994 Submerged Cultural Resources of Swansboro, North Carolina. Program in Maritime Studies, East Carolina University, Greenville, NC.

Small, Edwin
1941 Wharf Building of a Century and More Ago. National Parks Service Popular Study Series.

Smith, Hannah P.
2014 Revisiting the Port of Brunswick: A Research Design for the Waterfront of Brunswick Town/Fort Anderson State Historic Site, Winnabow, North Carolina. Master's thesis, Department of Anthropology, East Carolina University, Greenville, NC.

Smith, Kimberly M.
2009 Comparative Analysis of Cask Material from Late Sixteenth Through Early

Nineteenth Century Shipwrecks. Master's thesis, Department of Anthropology, East Carolina University, Greenville, NC.

South, Stanley
1971 Evolution and Horizon as Revealed in Ceramic Analysis in Historical Archaeology. *Research Manuscript Series* 15.
1978 Pattern Recognition in Historical Archaeology. *American Antiquity* 43(2): 223-230.

Spalding, Simon
2014 *Food at Sea: Shipboard Cuisine from Ancient to Modern Times.* Rohman & Littlefield, Lanham, MD.

Speer, James H.
2010 *Fundamentals of Tree-Ring Research*. University of Arizona Press, Tucson, AZ.

Stokes, Marvin A. and Terah L. Smiley
1968 *An Introduction to Tree-Ring Dating*. The University of Arizona Press, Tucson, AZ.

Sweetman, Steven C. and Matthew Goodyear
2019 A remarkable dropstone from the Essex Formation (Lower Cretaceous, Barremian), of the Isle of Wight, southern England. *The Geologists' Association* 131:301-308.

Teed, Michael
2008 Mean Ceramic Dates and Chronology. *Lambda Alpha Journal* 38:47-54.

Tootle, Glenn and Matt Therrell
n.d. Dendrohydrology: The Use of Tree Ring Data in Paleo Reconstructions. University of Alabama, Tuscaloosa, AL.

Vollmers, Gloria
2003 Industrial Slavery in the United States: the North Carolina Turpentine Industry 1849-61. *Accounting, Business, & Financial History* 13(3):369-392. Lancashire, England, UK.

Williams, Justin
1935 English Mercantilism and Carolina Naval Stores. *The Journal of Southern History* 1(2):169-185. Houston, TX.

Webb, George
1986 Solar Physics and the Origins of Dendrochronology. *University of Chicago Press: History of Science Society* 77(2):291-301.

Welliver Southerly, Kathy Ann
2006 Landscapes in Transition: Redbanks Landing on the Tar River, Greenville, North Carolina.Master's thesis, Department of History, East Carolina University, Greenville, NC

Wells, Tom
1998 Nail Chronology: The Use of Technology Derived Features. *Historical Archaeology* 32(2):78-99.

Woodall, Ned J.
2004 Gunflints and Other Lithic Artifacts from 31CR314 *Queen Anne's Revenge* Site. RESEARCH REPORT AND BULLETIN SERIES QAR-B-04-01.

Worthy, Pauline
1976 The Town Develops. In *Washington and the Pamlico*, Ursula Loy and Pauline Worthy, editors, pp. 8-14. Washington-Beaufort County Bicentennial Commission, Washington, NC.

Wright, Laura
2024 On Words for London Wharves. *The London Journal* 49(1):67-101.

Appendix A. 2021 ECU Field School Wharf Scantling List

The following tables are taken from the 2021 Fall Field School report. Each table goes over the type of timber found and used within the respective units created for mapping the wharf. Along with this, it goes into the measurements and notes that were found on the timber used for the construction of the wharf.

West Side of Wharf

Section	**Feature Type**	**Height**	**Width**	**Length**	**Notes**
Entire West End	Header Timber	35cm	15cm	5.12m (north end disappears into ground)	Top timber
Entire West End	Header Timber	35cm	Unknown	5.36m (north end disappears into ground)	Under top timber
Entire West End	Header Timber	30cm	Unknown	4.25m (north end disappears into ground)	Under second timber
Entire West End	Header Timber	30cm	Unknown	2.6m (north end disappears into ground)	Bottom Timber
Section	Feature Type	Height	Width	Length	Notes
Entire West End	Header Timber	35cm	15cm	5.12m (north end disappears into ground)	Top timber
Entire West End	Header Timber	35cm	Unknown	5.36m (north end disappears into ground)	Under top timber
Entire West End	Header Timber	30cm	Unknown	4.25m (north end disappears into ground)	Under second timber
Entire West End	Header Timber	30cm	Unknown	2.6m (north end	Bottom Timber

				disappears into ground)	
Entire West End	Piling	0cm (pointed)	7cm	76cm	
Entire West End	Piling	9cm	21cm	72cm	
Entire West End	Piling	5cm	8cm	81cm	
Entire West End	Piling	15cm	18cm	44cm	
Entire West End	Sheeting	30cm	30cm	50cm	

North Side of Wharf

Section	Feature Type	Height	Width	Length	Notes
5m-10m	Stretcher Timber	10cm	26cm	2.2m	Rests atop another timber, breaks and tapers to a point
5m-10m	Stretcher Timber	10cm	40cm	3.9m	East end is buried in mud beneath cribbing timber, timber is also partly buried in ballast
10m-15m	Header Timber	unknown	45cm	1.5m	goes into sand
10m-15m	Header Timber	unknown	50cm	7m	
10m-15m	Header Timber	unknown	30cm	2.9m	continues into 10-5 section
10m-15m	Footer Timber	unknown	20cm	3.1m	
10m-15m	Sheeting	>5cm	>5cm	15cm	Length is 60cm goes into section 15-20

10m-15m	Sheeting	>5cm	>5cm	45cm	Length is 2.4m
10m-15m	Piling	unknown	unknown	60cm	Located at the corner of the two sheeting
10m-15m	Sheeting	>5cm	>5cm	15cm	Length is 60cm goes into section 15-20
10m-15m	Sheeting	>5cm	>5cm	45cm	Length is 2.4m
15m-20m	Timber	30cm	34cm	25cm	
15m-20m	Timber	Unknown – top flush with surface	47cm	2.5m disappears into sediment	
15m-20m	Timber	25cm	43cm	2.44m; continues unbroken into last quadrant	Half-lap joint at east end with fastener hole 20cm long, 12.5cm wide, edge 13cm from end of timber
15m-20m	Timber	15cm	20cm @ widest, 11cm at east tip	2.16m; continues unbroken into last quadrant	Sits directly on top of other timber; extends unbroken into last quadrant
15m-20m	Piling		12cm		Outside of quadrant
15m-20m	Timber	30cm	34cm	1.58m; continues unbroken into previous quadrant	
15m-20m	Piling		7cm		
15m-20m	Piling		9cm		
15m-20m	Piling		9cm	14cm	Comes to a point from a

					rectangular base
15m-20m	Piling		9cm	16cm	Comes to a point from a rectangular base
15m-20m	Piling		9cm		
15m-20m	Piling		9cm	20cm tip to sand	resting at an angle
15m-20m	Piling		10cm	25cm tip to sand	resting at an angle
15m-20m	Piling		8cm		
15m-20m	Sheeting	0.5-1cm		2.67m	Thin sheathing running the length of west edge of T8 from baseline; sticks up .5-2cm intermittently and breaks off at north end
15m-20m	Sheeting	1-2cm		1.9 m	Continues unbroken into the previous quadrant
20m-End	Stretcher Timber	unknown	35cm	5.8m (west end hidden under other timbers)	

South Side of Wharf

Section	Feature Type	Height	Width	Length	Notes
0m-5m	Header Timber	21cm	20cm	178cm	
0m-5m	Header Timber	40cm	20cm	172cm	Notched
0m-5m	Header Timber	22cm	22cm	100cm	Notched

0m-5m	Header Timber	23cm	32cm	70cm	Notched, stretched into next section, not full length
0m-5m	Header Timber	25cm	30cm	160cm	Ran along baseline
0m-5m	Stretcher Timber	Unknown	27cm	103cm	Had hole running through it
5m-10m	Stretcher Timber	15cm	1.5m	5m	
10m-15m	Header Timber	unknown	40cm	5.3m	End of timber has fastener
10m-15m	Header Timber	unknown	45cm	5.5m	fragment in the middle of crib
10m-15m	Footer Timber	unknown	20cm	1.2m	Half lap joint visible from profile, not plan; timber continues into previous quadrant
15m-20m	Timber	40cm	30cm	50cm	Half lap joints on both ends with 15cm thickness
15m-20m	Timber	40cm	40cm	2.8m	Half lap 10cm thick
15m-20m	Timber	30cm	40cm	60cm, disappears into sediment/under ballast	Half lap joints on both ends with 10-15cm thickness
15m-20m	Timber	28cm	37cm	1.4m, disappears under ballast	Possibly a fallen piling as it is not as thick and is more deteriorated than other timbers. No

					bark present and more rounded than rectangular.
15m-20m	Timber		5cm at tip, 20 until end of quadrant	50-53cm, continues unbroken into last quadrant	
15m-20m	Piling	9cm	15cm	73cm	Upright, rectangular base, rounded point
15m-20m	Piling	9cm	19cm	75cm	Upright, rectangular base, rounded point
15m-20m	Piling		8cm diameter	32cm	Upright
15m-20m	Piling	9cm	5cm at tip, 15cm at base	43cm	Upright, rectangular base, rounded point
15m-20m	Piling	N/A	N/A	N/A	Located in last quadrant, but noted on plan drawing
20m- End	Piling	7cm	16cm	1.01m	
20m- End	Piling	6cm	6cm	2.62m	Angled
20m- End	Sheeting	48cm	48cm	47cm	
20m- End	Piling	7cm	16cm	1.75m	
20m- End	Sheeting	35cm	35cm	1.63m	
20m- End	Sheeting	27cm	44cm	1.59m	
20m- End	Sheeting	25cm	25cm	1.54m	
20m- End	Piling	11cm	15cm	1.61m	
20m- End	Piling	6cm	15cm	1.8m	

East Side of Island

Sections	Feature Type	Width	Height Overall
5m-10m	Piling	30cm	35cm
5m-10m	Piling	32cm	32cm
5m-10m	Piling	10cm	43cm

5m-10m	Piling	32cm	38cm
5m-10m	Piling	12cm	31cm
5m-10m	Piling	30cm	53cm
5m-10m	Piling	15cm	42cm
5m-10m	Piling	25cm	40cm
5m-10m	Piling	10cm	45cm
5m-10m	Piling	34cm	33cm
5m-10m	Piling	10cm	55cm
5m-10m	Piling	25cm	80cm
5m-10m	Piling	15cm	62cm
5m-10m	Piling	30cm	70cm
5m-10m	Piling	12cm	57cm
5m-10m	Piling	25cm	70cm
5m-10m	Piling	10cm	66cm
5m-10m	Piling	23cm	110cm
5m-10m	Piling	10cm	72cm
5m-10m	Piling	30cm	95cm
5m-10m	Piling	10cm	65cm
5m-10m	Piling	32cm	108cm
5m-10m	Piling	24cm	75cm
5m-10m	Piling	10cm	67cm
5m-10m	Piling	30cm	132cm

Appendix B. 2021 Field School Artifact Catalog

Table 1: The artifact inventory of the 2021 ECU Fall Field School, excluding some ceramic details that will be mentioned in the following table that determines the mean ceramic date. The measurements and dimensions are read by (length x width) unless labeled otherwise. Aside from the faunal, only 1 sherd or object was found per field specimen (Table by author, 2024).

Field Specimen Number	Material	Object	Description	Measurements/Dimensions
0001	Glass	Bottle	Mold-made brown bottle	Diameter: 21.3cm
0002	Clay	Pipe stem	Kaolin clay	5.5cm x 0.7cm Diameter: 1.4cm
0003	Clay	Brick	-	-
0004	Ceramic	Earthenware base sherd	Banded annularware, dark brown bands	Diameter: 4cm
0005	Ceramic	Stoneware body sherd	Debased or scratched, blue glaze design	9.5cm x 5cm
0006	Ceramic	Coarse earthenware body sherd	Brown lead glaze, Jackfield-type ware	8.5cm x 5.5cm
0007	Ceramic	Stoneware base sherd	Bottle/jar base	Diameter: 3cm
0008	Ceramic	Stoneware base sherd	Jar base	5.3cm x 4.5cm Diameter: 7cm Thickness: 1.9cm
0009	Faunal	-	(2) Possible leg bones	Bone 1: 18cm x 4cm Bone 2: 12cm x 4cm
0010	Ceramic	Stoneware body sherd	-	8cm x 6.5cm
0011	Ceramic	Stoneware base sherd	-	Diameter: 6cm
0012	Ceramic	Stoneware rim sherd	Rhenish/grey past, salt glaze, jug rim	Width: 15mm Thickness: 6mm Diameter: 11cm
0013	Ceramic	Stoneware body sherd	-	Body: 7mm
0014	Ceramic	Stoneware body sherd	-	Body: 5mm
0015	Ceramic	Stoneware body sherd	Brown salt glaze with	Body: 6mm

			grey exterior, tan interior	
0016	Ceramic	Coarse earthenware/mortar body sherd	-	-
0017	Ceramic	Stoneware body sherd	-	Body: 6mm
0018	Ceramic	Earthenware base sherd	-	Diameter: 9cm Thickness: 8mm
0019	Ceramic	Coarse earthenware body sherd	-	Body: 8mm
0020	Iron	Nail	Square cut, broken, rusted	Head width: 15mm x 15mm
0021	Porcelain	Whiteware porcelain body sherd	Blue design	4.2cm x 3.4cm
0022	Iron	Sailing thimble	Rusted	Diameter: 5.4cm Circ: 17.5cm
0023	Glass	Jar	Screw top	11cm x 3.5cm Diameter: 2cm
0024	Wood	Trunnel	Disintegrated	Width: 2.9cm
0025	Clay	Rim sherd	Sand-tempered prehistoric	3.7cm x 5.5cm
0026	Ceramic	Earthenware body sherd	-	5.2cm x 4.3cm
0027	Glass	Bottle	Brown bottle	20.5cm x 6cm Circ: 21.5cm
0028	Ceramic	Stoneware body sherd	-	6cm x 3.4cm
0029	Ceramic	Earthenware body sherd	-	3.8cm x 2.9cm
0030	Ceramic	Earthenware body sherd	-	2.4cm x 2.4cm
0031	Ceramic	Creamware rim sherd	-	3.5cm x 3cm
0032	Ceramic	Creamware body sherd	-	3.5cm x 2.1cm
0033	Lithic	-	Possible gun flint, cut stone	3cm x 2cm
0034	Ceramic	Stoneware body sherd	-	1.8cm x 1.5cm

Appendix C. Mean Ceramic Date

Table 1: List of artifacts found during the 2021 fall field school that were analyzed to determine the mean ceramic date. The undated artifacts were due to the items being hard to identify and compare to other ceramics based upon the images given (Table by author, 2024).

Field Specimen Number	Object	Description	Decoration	Production Dates	Mean Date
0004	Earthenware base sherd	Banded annular ware	Dark brown annular band	1790-1920	1805
0005	Stoneware body sherd	Debased/scratched	Blue glaze design	1795-1820	1807.5
0006	Coarse earthenware body sherd	Jackfield-type	Brown lead glaze	1740-1790	1765
0007	Stoneware base sherd	Jar/bottle	Salt glaze	-	-
0008	Stoneware base sherd	Jar	Salt glaze	1840-1850	1845
0010	Stoneware body sherd	-	Salt glaze	1810-1900	1855
0011	Stoneware base sherd	-	Salt glaze exterior	1810-1900	1855
0012	Stoneware rim sherd	Jug rim, Rhenish/grey paste	Salt glaze	1575-1775	1675
0013	Stoneware body sherd	Pink paste interior	Grey salt glaze exterior	1830-1860	1845
0014	Stoneware body sherd	Grey exterior and tan interior	Brownish salt glaze	1725-1800	1762.5
0015	Stoneware body sherd	Grey paste	Brown salt glaze exterior and interior	1690-1775	1732.5
0016	Coarse earthenware/mortar body sherd	-	-	-	-
0017	Stoneware body sherd	Grey paste, tan interior	Salt glaze exterior	1830-1860	1845
0018	Coarse earthenware base sherd	Redware	Red or clear lead glaze	1500-1750	1625
0019	Coarse earthenware body sherd	Redware	No glaze	1500-1750	1625
0021	Porcelain body sherd	Whiteware	Blue design	-	-

0026	Earthenware body sherd	Grey paste, green discoloration	Salt glaze exterior	-	-
0028	Stoneware body sherd	Cream colored	Salt glaze exterior	-	-
0029	Earthenware body sherd	Blue/grey paste	Salt glaze exterior, blue design, engraved	1784-1859	1821.5
0030	Earthenware body sherd	Grey paste	Salt glaze	-	-
0031	Creamware rim sherd	-	Blue design, transfer print	1765-1815	1790
0032	Creamware body sherd	-	Lead glaze	1770-1825	1797.5
0034	Stoneware body sherd	-	Salt glaze exterior	1720-1775	1747.5

Appendix D. Castle Island Dendrochronology Data

The table below showcases the outputs of Castle Island's floating chronology in xDateR. This report shows the first and last years that the core sample aligns with (based on the year span of 1 to 160). These are more specific statistics for dendrochronology. The year is the number of rings measured, gini is the growth of the tree, ar1is the autocorrelation.

Table 1. Ring Width Length (RWL) report created in xDateR (Table by author, 2024).

series	first	last	year	mean	median	stdev	skew	gini	ar1
CAS002	118.00	146.00	29.00	2.68	2.57	0.61	0.46	0.12	0.61
CAS003A	82.00	154.00	73.00	1.95	1.81	0.97	0.98	0.27	0.77
CAS003B	121.00	144.00	24.00	1.97	1.86	0.81	1.94	0.19	0.17
CAS003C	74.00	157.00	84.00	2.11	1.80	1.13	1.00	0.29	0.81
CAS004	42.00	97.00	56.00	2.47	2.42	0.97	0.33	0.22	0.86
CAS005A	74.00	95.00	22.00	5.42	5.27	1.57	0.52	0.16	0.57
CAS005B1	80.00	92.00	13.00	4.75	4.67	2.57	0.65	0.28	0.72
CAS005B2	74.00	93.00	20.00	5.55	5.64	1.41	0.28	0.14	0.59
CAS005C1	80.00	93.00	14.00	4.61	3.89	2.24	0.93	0.24	0.73
CAS006	63.00	151.00	89.00	2.60	2.47	1.32	0.91	0.28	0.60
CAS007	75.00	129.00	55.00	2.42	2.08	1.36	1.58	0.29	0.64
CAS008	110.00	159.00	50.00	2.63	2.40	0.96	0.94	0.20	0.47
CAS009	116.00	141.00	26.00	4.24	4.27	1.25	0.09	0.17	0.14
CAS009-2	105.00	147.00	43.00	4.25	4.53	1.51	-0.05	0.20	0.25
CAS010	74.00	150.00	77.00	2.26	2.32	1.11	1.24	0.26	0.62
CAS011a	116.00	137.00	22.00	2.38	2.20	0.95	0.39	0.22	0.59
CAS012	51.00	98.00	48.00	2.52	2.42	1.01	0.23	0.23	0.60
CAS013	1.00	116.00	116.00	1.31	1.21	0.65	0.58	0.28	0.71
CAS014	90.00	150.00	61.00	1.99	1.78	1.10	0.45	0.31	0.67
CAS015	119.00	131.00	13.00	5.00	5.02	0.77	-0.22	0.08	0.25
CAS1-1A	109.00	148.00	40.00	1.63	1.64	0.64	0.01	0.22	0.72
CAS1-1B1	108.00	156.00	49.00	1.68	1.69	0.49	0.21	0.16	0.37
CAS1-1BP	109.00	150.00	42.00	1.75	1.73	0.59	0.50	0.19	0.42
CAS1-2	132.00	160.00	29.00	2.35	2.38	0.72	0.07	0.17	0.63

Appendix E. Resistograph Charts and Measurements

The table and figures below consist of the usable data from the resistograph's readings. The first table is the proforma table of the resistograph's sampling, the second table indicates the numbers calculated from the resistograph's feed curve being plugged into the density formula adopted from Acuña et al. (2011). The Y-axis is the ring measurement while the X-axis is the number of rings counted for while drilling in the figures. The graphs are the ring measurements that were interpreted from the *PD Tools Pro* Tree Ring Analysis function.

Table 1. The proforma adapted from Allyson Ropp's 2022 research conducted at Mallows Bay, Maryland. This sampling log kept the information of who was the topside operator, resistograph operator, drilling depth, and the measurement number. The drill speed was also recorded (Table by author, 2024).

Diver/UW Operator	OL/AR/JR*	OL/AR/JR	OL/AR/JR	OL/AR/JR
Topside Operator	NR*	NR	NR	NR
Date	23/5/23	23/5/24	23/5/25	23/5/26
Drill Speed	1	2	3	3
RESI Measurement	1	2	3	4
Drilling Depth (cm)	32	Misfire	33	33
Location	CAS001-4	CAS001-4	CAS001-4	CAS001-4
Depth (ft)	7	7	7	7
Notes	**Too low**	**Too low**	**Too low**	

OL/AR/JR	OL/AR/JR	OL/AR/JR	OL/AR/JR	OL/AR/JR	OL/AR/JR	OL/JR/DW*	OL/JR/DW	OL/JR/DW	OL/JR/DW
NR	NR	NR	NR	NR	NR	AR	AR	AR	AR
23/5/27	23/5/28	23/5/29	23/5/30	23/5/31	23/5/32	25/5/23	25/5/24	25/5/25	25/5/26
3	3	4	3	3	3	3	3	3	3
5	6	7	8	9	10	11	12	13	14
35	40	33	32	Overload	32	40	40	40	35
CAS001-4	CAS001-4	CAS001-1	CAS001-1	CAS001-2	CAS002	CAS005	CAS005	CAS005	CAS004
7	7	7	7	7	7	3	3	3	3
				Too fast				**Needle overload**	

OL/JR/DW	AR	25/5/27	3	15	40	CAS006	3	**Needle overload**
OL/JR/DW	AR	25/5/28	2	16	40	CAS006	3	**Needle overloa**
OL/JR/DW	AR	25/5/29	3	17	13	CAS003	3	**Needle did not extract**

* NR stands for Nathan Richards, AR is Allyson Ropp, OL is Olivia Livingston, JR is Jason Raupp, and DW is Dayan Weller.

Table 2. The numbers calculated per feed curve graph to get the density measurements (Table by author, 2024).

Measurement Number	Average Maximum (Mmax)	Average Minimum (Mmin)	A Vmed (Mmax - Mmin)	Density
4	7.2428947	2.6235065	4.6193882	398.306811
5	9.88838	3.35225	6.53612	399.763
6	12.6607	5.18345	7.47724	400.478
7	9.03061	2.48327	6.54735	399.772
8	11.8358696	3.52978261	8.30608696	401.107965
10	17.24667	5.675	11.57167	403.5892
11	7.93425	2.581951	5.352299	398.8637
12	9.456727	1.819893	7.64583	400.606
13	9.486	1.24691	8.23909	401.057
14	9.72393	3.95441	5.76953	399.181
15	14.01566	5.901807	8.11386	400.9619
16	10.8913	5.2425	5.64879	399.089

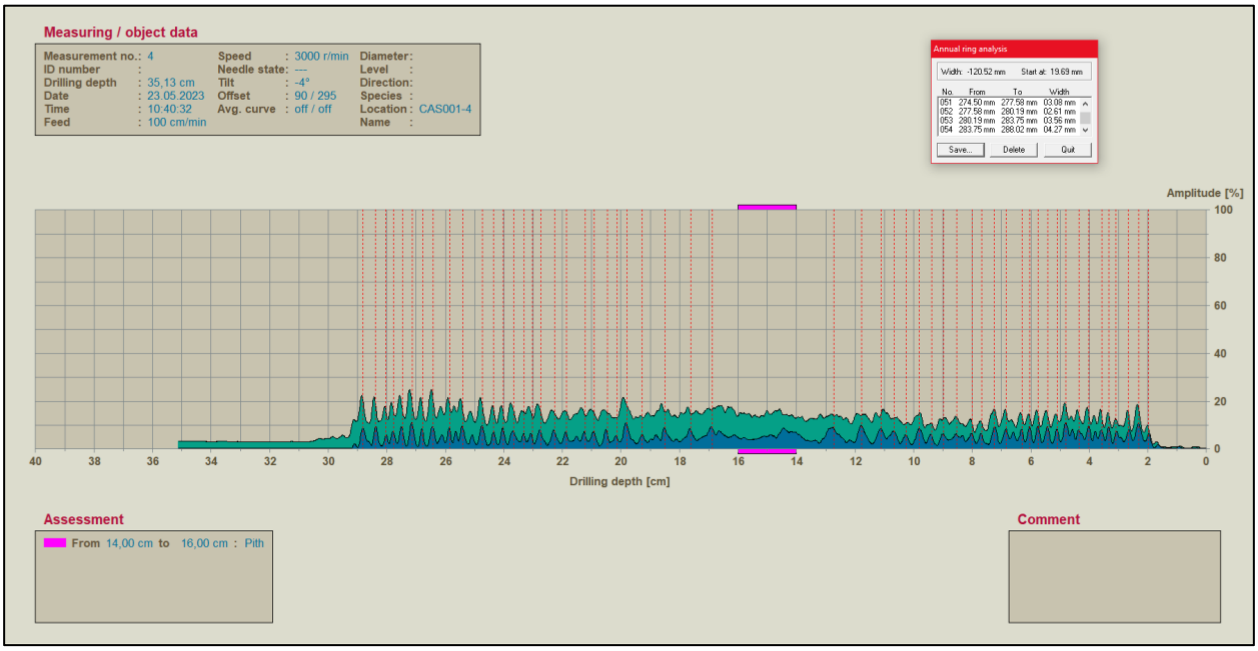


FIGURE 1: Resistograph (RESI) Measurement 4 out of the 17 drillings done in *PD Tools Pro*. This timber is not associated with a core sample. The first three measurements were not counted as they were used to calibrate the tool. The pink represents where the pith is believed to be. The red dotted lines indicate where the tree rings are believed to be based on the peaks and valleys of the green and blue curves (Graph by author, 2023).

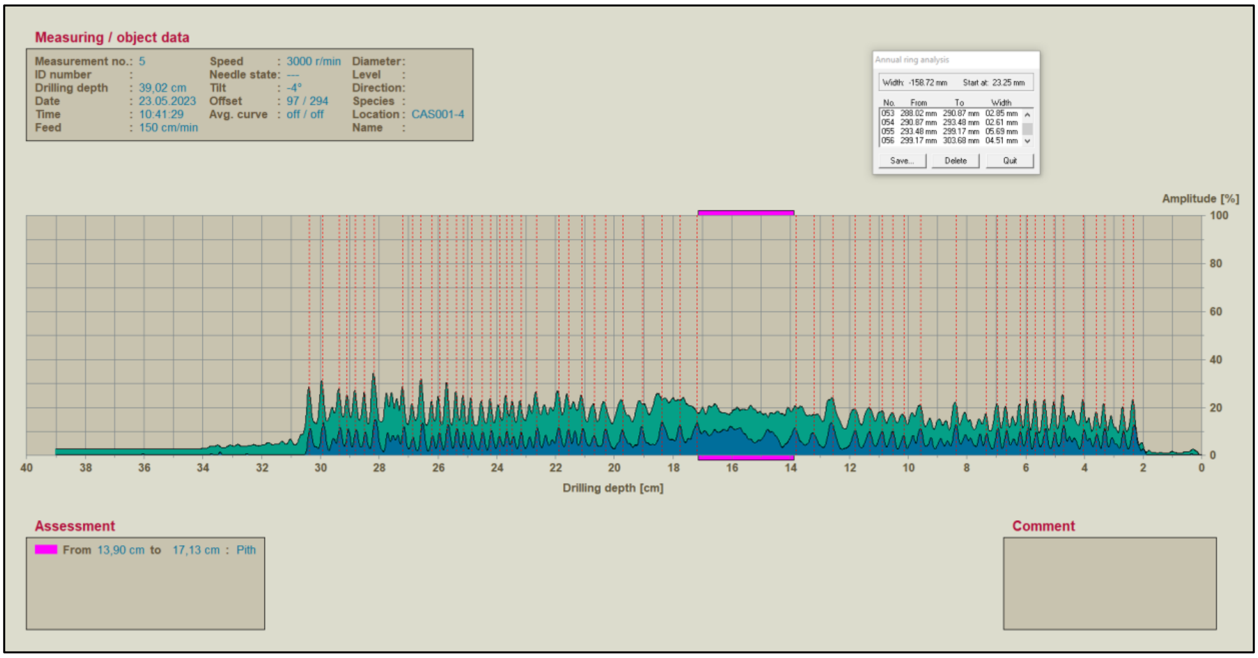


FIGURE 2: RESI Measurement 5 out of the 17 drillings done. This timber is not associated with a core sample (Graph by author, 2023).

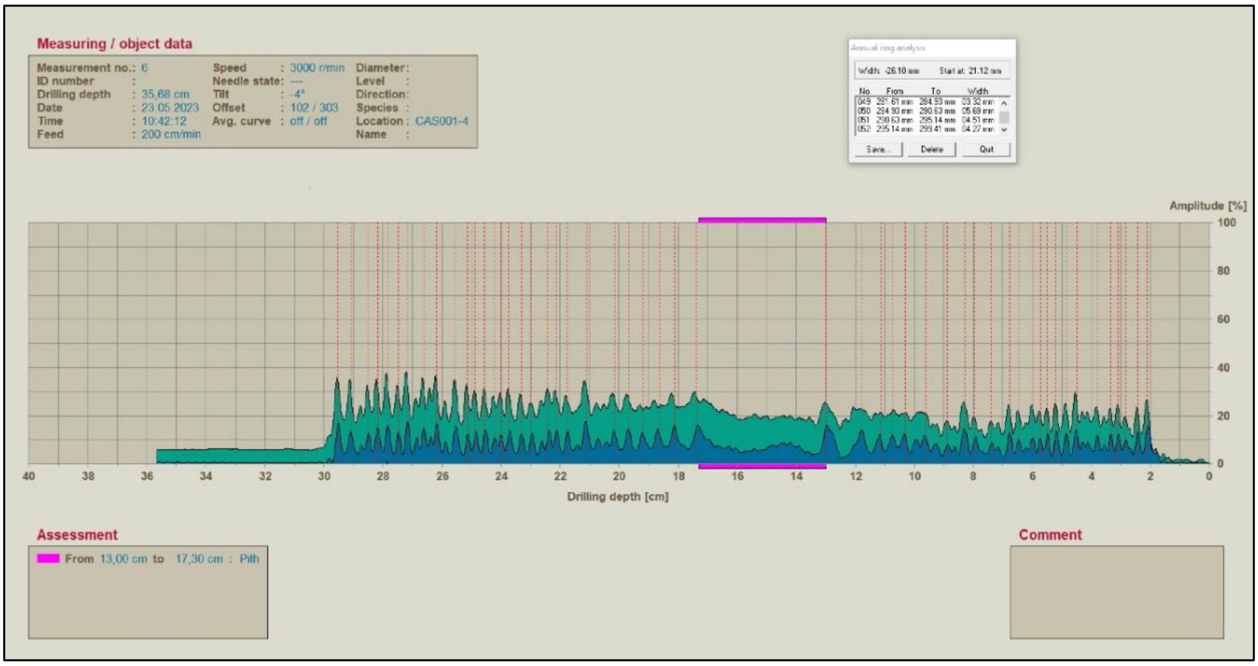


FIGURE 3: RESI Measurement 6 out of the 17 drillings done. This timber is not associated with a core sample (Graph by author, 2023).

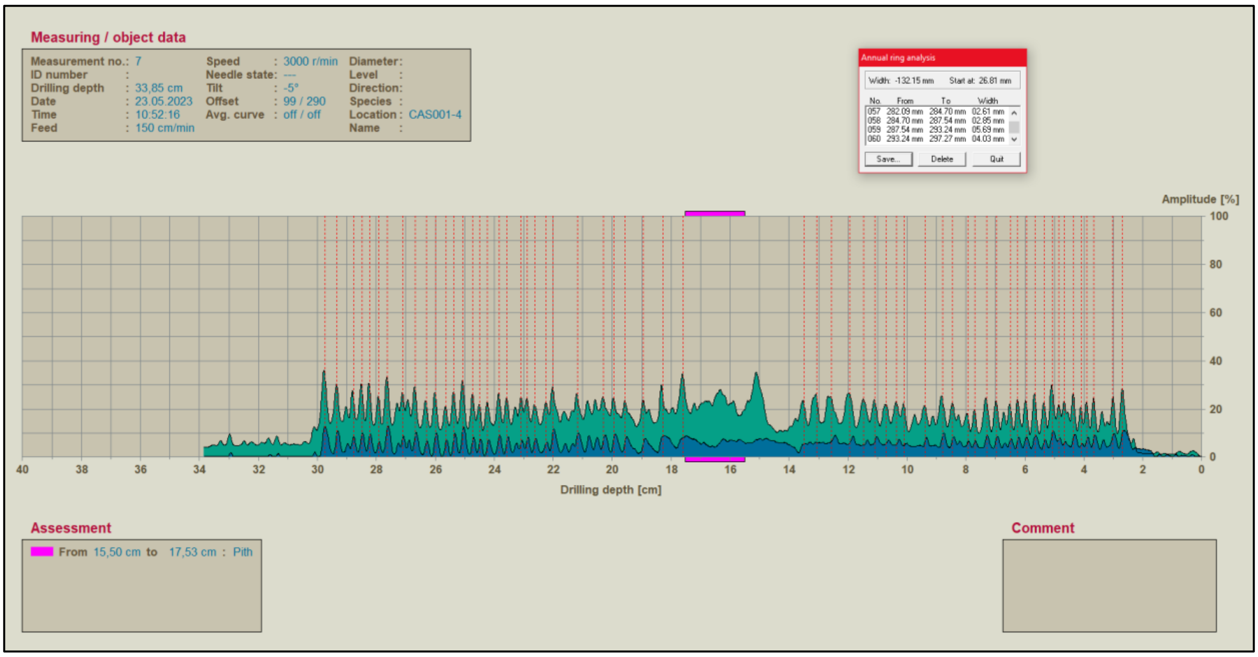


FIGURE 4: RESI Measuremnt 7 out of the 17 drillings done. This timber is associated with CAS001-1 (Graph by author, 2023).

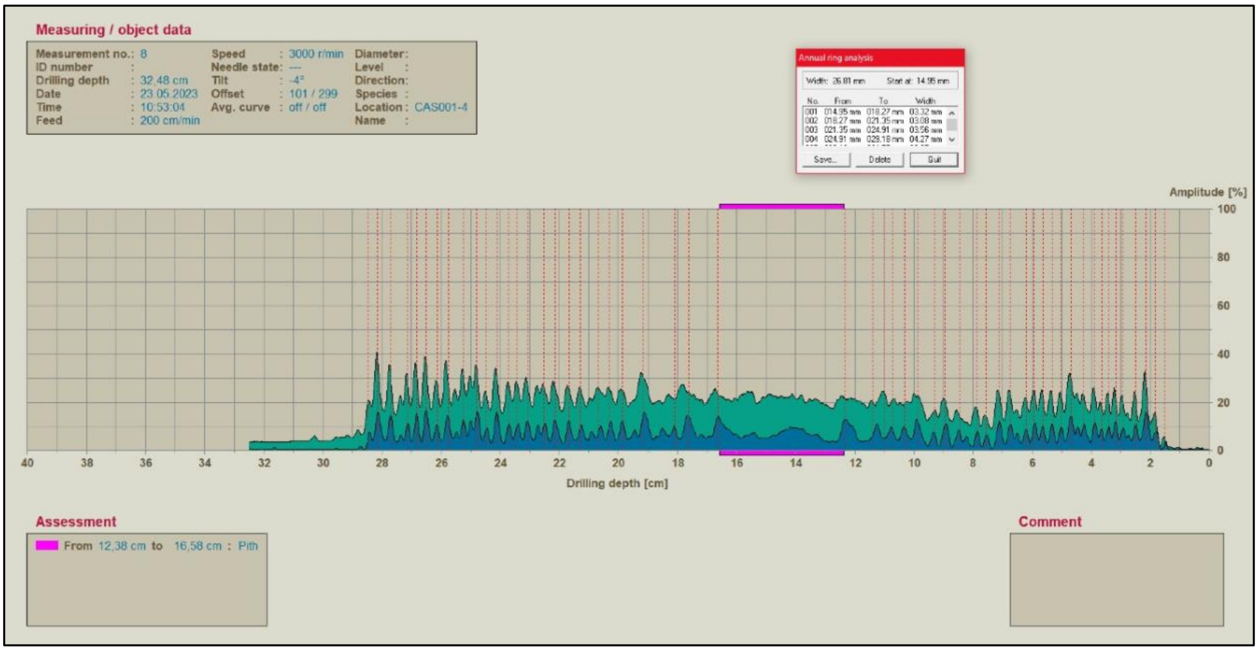


FIGURE 5: RESI Measurement 8 out of the 17 drillings done. This timber is associated with CAS001-1 (Graph by author, 2023).

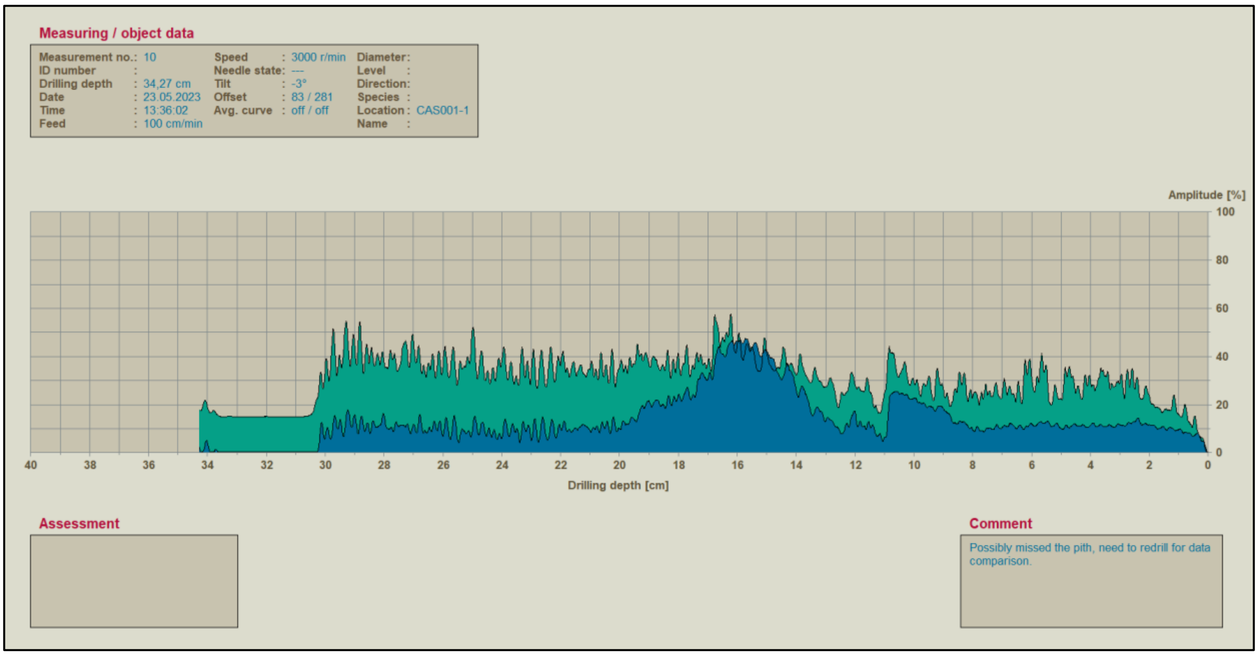


FIGURE 6: RESI Measurement 10 out of the 17 drillings done. This timber is associated with CAS002, though the tree rings are not measured here. It should be noted that this graph was after an overload from drilling too fast. This graph indicates a result from shaft friction, as the feed curve (blue) overlays the resistance curve (Graph by author, 2023).

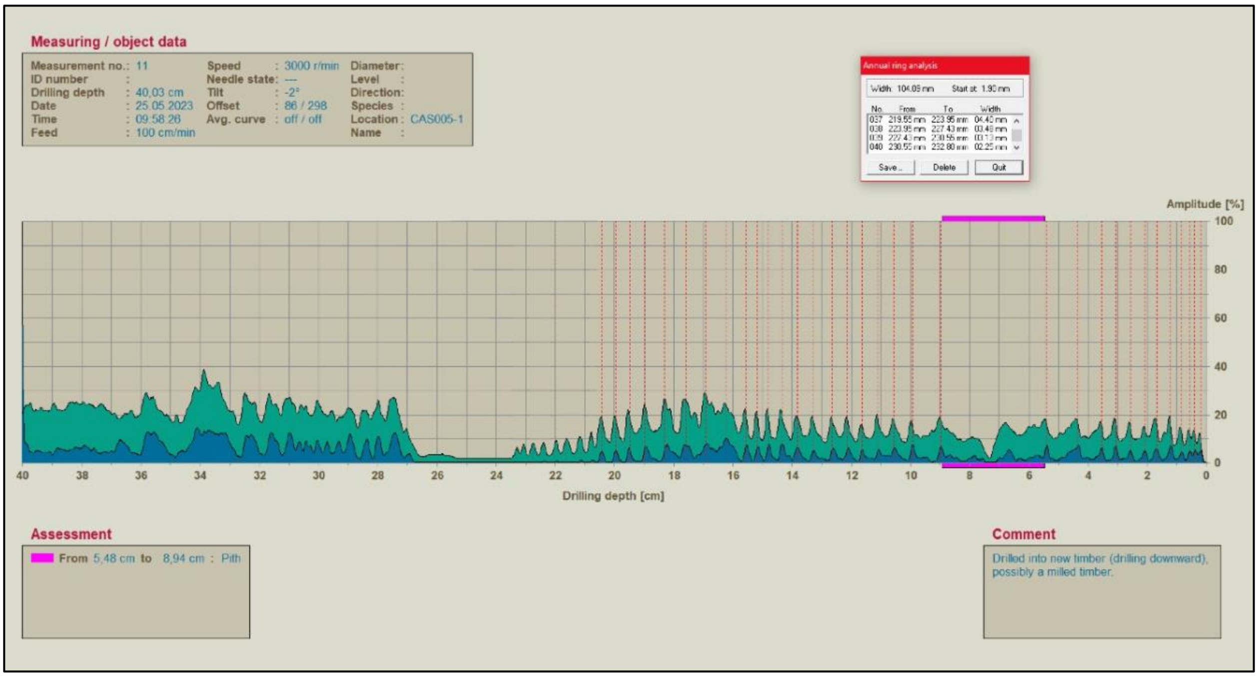


FIGURE 7: RESI Measurement 11 out of 17. This timber is associated with CAS005A. Notice the drop around the 24 cm drilling depth. This could be from either decay or penetrating another timber (Graph by author, 2023).

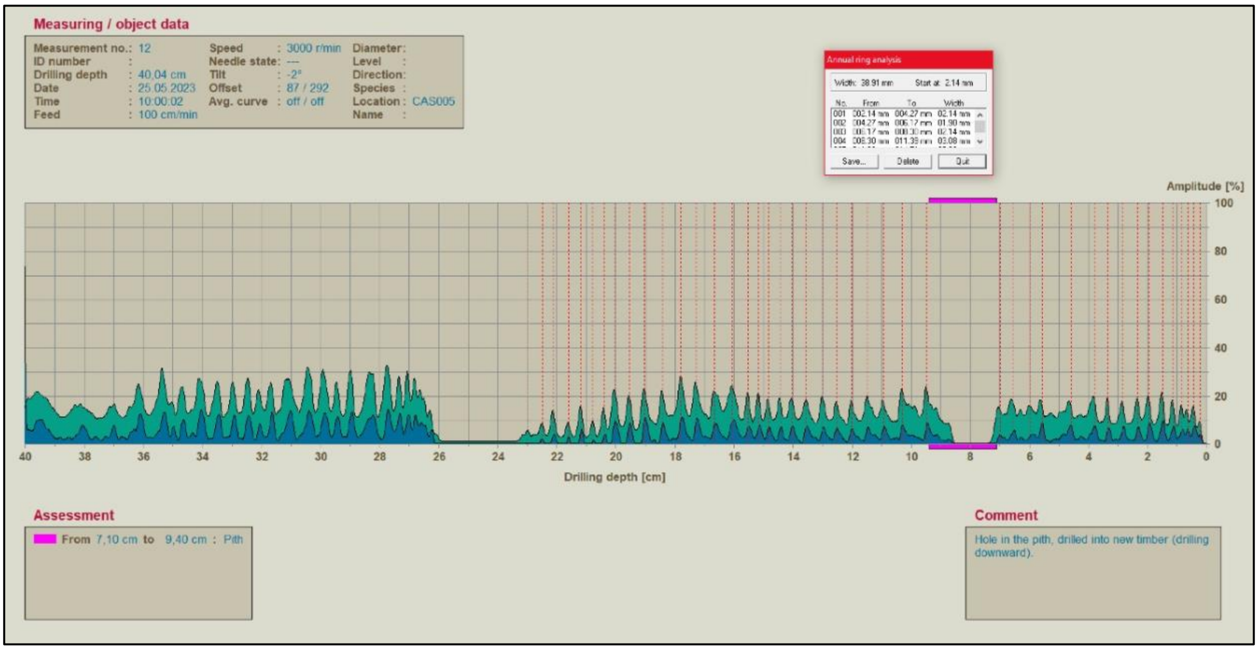


FIGURE 8: RESI Measurement 12 out of 17. This timber is associated with CAS005B. Notice the drop around the 24 cm drilling depth. This could be from either decay or penetrating another timber (Graph by author, 2023).

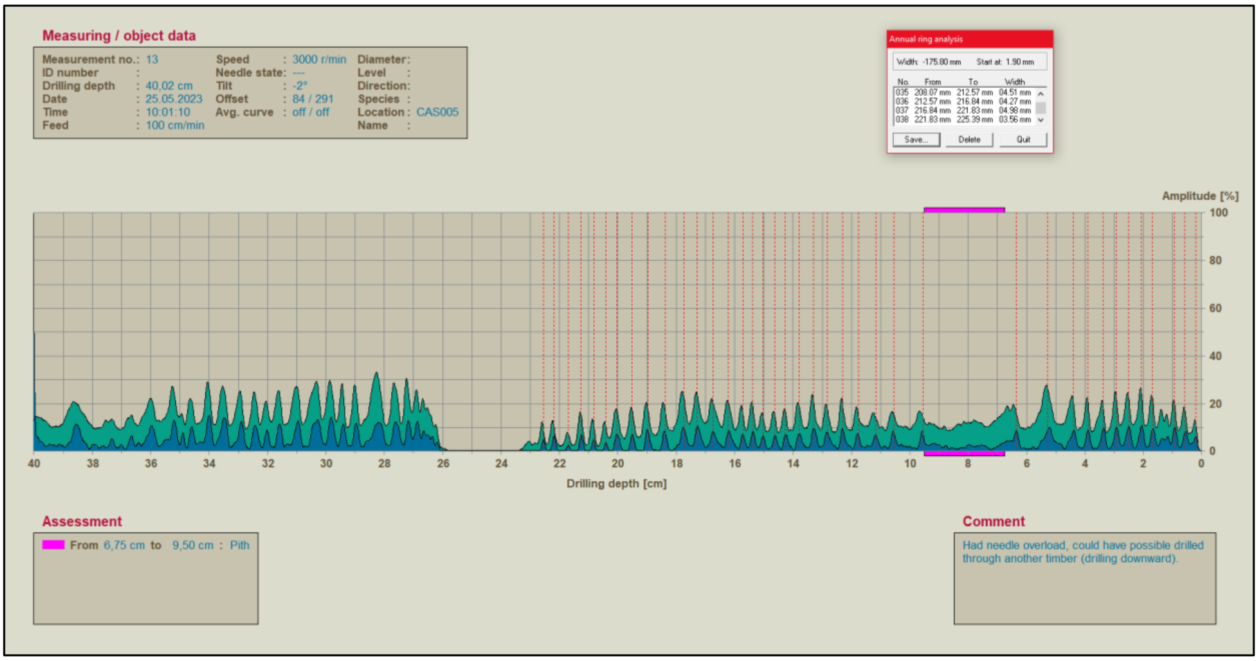


FIGURE 9: RESI Measurement 13 out of 17. This timber is associated with CAS005B. Notice the drop around the 24 cm drilling depth. This could be from either decay or penetrating another timber (Graph by author, 2023).

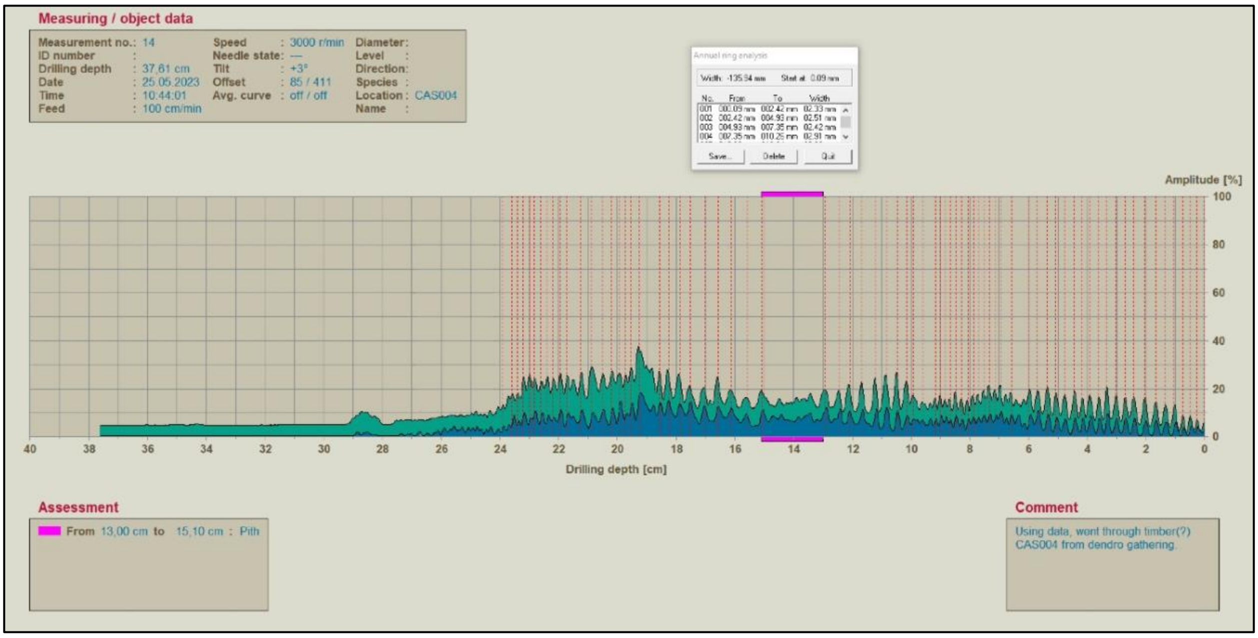


FIGURE 10: RESI Measurement 14 out of 17. This timber is associated with CAS004 (Graph by author, 2023).

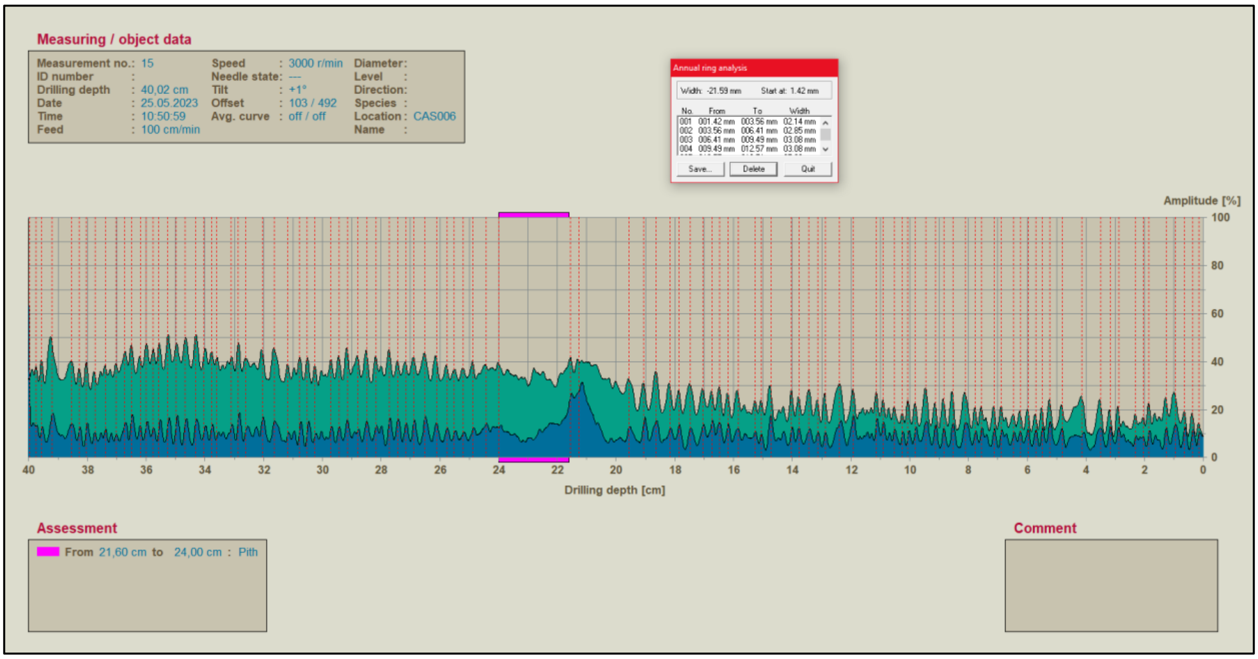


FIGURE 11: RESI Measurement 15 out of 17. This timber is associated with CAS006. There was a needle overload in this sampling (Graph by author, 2023).

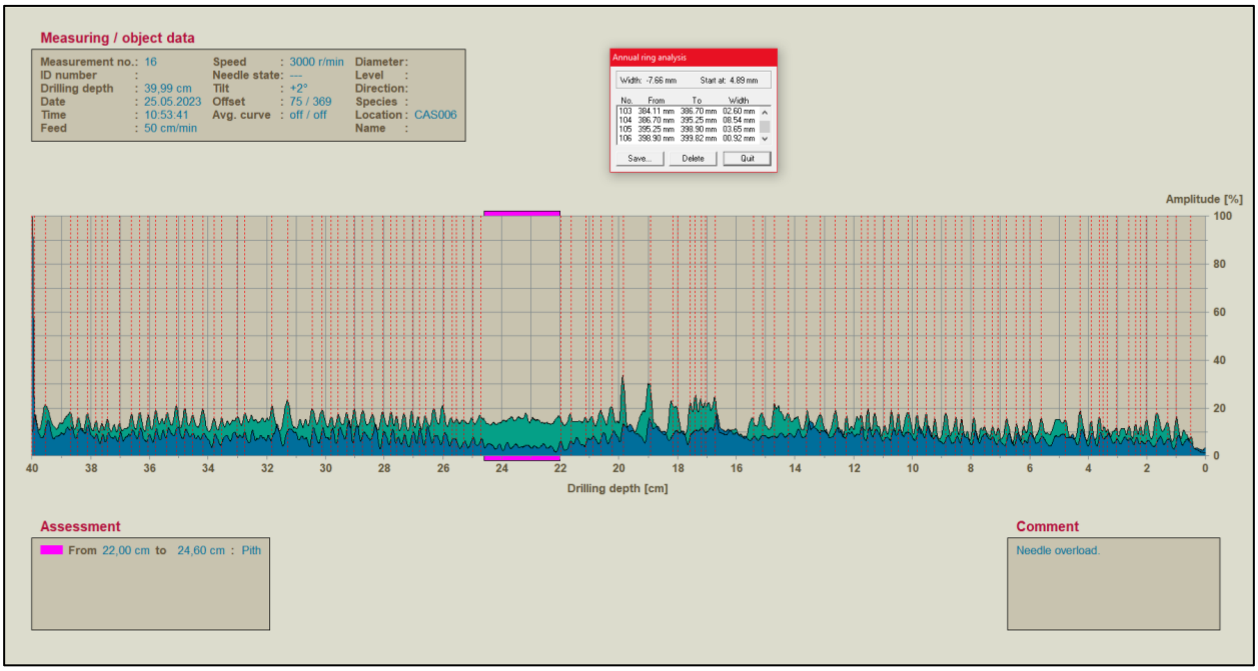


FIGURE 12: RESI Measurement 16 out of 17. This timber is associated with CAS006. There was a needle overload in this sampling. In comparison to the figure above, the calibration and persistence of the Resistograph is crucial when looking at timber density. These are from the same timber but show different results (Graph by author, 2023).