ABSTRACT

Amy M. Mitchell A COMPARISON OF WOOD USE IN EIGHTEENTH-CENTURY VESSELS.(Under the direction of Dr. Lawrence E. Babits) Department of History, 1994.

The purpose of this thesis is to conduct a comparative analysis of wood use in eighteenth-century British and Anglo-American vessels. Research utilizes contemporary and modern historical sources to create a series of hypotheses pertaining to eighteenth-century ship timber trade and wood species selection. The hypotheses evaluate differences in wood species selection due to origin, time, and/or use. The thesis' primary purpose is to determine the reliability of historical documents.

Wood samples from eighteen eighteenth-century vessels were examined to determine actual wood use. The vessels represent a variety of times, uses, sizes and origins to achieve a more holistic view of wood use in ship construction.

The hypotheses are tested against the archaeologically identified wood samples. The analysis compares predicted wood species selection against actual constructional use. The combination of archaeological and historical source material establishes a model for future study and a new perspective on eighteenth-century wood use.

A COMPARISON OF WOOD USE IN EIGHTEENTH-CENTURY VESSELS

A Thesis

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CHAPTER ONE

Introduction

Building a wooden ship required more than fastening one plank to another. Each scantling, barrel, and piece of furniture was designed to varying tolerances and manufactured for distinct purposes from different kinds of wood. Eighteenth-century wood technology, though different from today's plastic, concrete, glass and steel, was very complex, derived from hundreds of years of practical experimentation. Over many previous centuries, shipbuilders developed, tested and passed on a wood technology tradition from master shipwright to journeymen and apprentices. This system enabled craftsmen to know what worked, what was available and what was cost effective.

Choosing wood for a particular task was one of the first and most important steps in building a wooden ship. Timber was chosen according to specific requirements for durable planking, knees, frames, treenails, rudders or keels. If timbers were faulty or of a low quality, the consequences would manifest themselves later when the ship sprang a plank, split a mast or began to leak.

Finding and choosing trees in the eighteenth century was not easy since Britain had depleted most of her usable forests.

Nearly constant warfare during the eighteenth century created larger demands on the British timber supply. The Navy Board and Board of Trade further exacerbated these problems by putting men into power who were ill-prepared for the tasks set before them.

Matters were further complicated in eighteenth-century Britain due to government regulations which gradually grew up around the shipbuilding profession. Administrators oversaw each level of the timber harvesting and manufacturing process. For example, principal forests had a Lord Warden or a Surveyor General to mark and observe trees set aside for the crown.[1] The Royal Navy dockyards had different officials organizing, bargaining for, or inspecting loads of timber. The Navy Board and other high officials also created regulations for shipping, building or repairing wooden vessels. Reportedly, these men rarely communicated or cooperated, operating instead on hidden personal agendas to gain wealth or power.[2]

Geography and trade networks played a large part in selecting which woods could be used economically for ship construction. In the eighteenth century the British disapproved of using "foreign" woods. Only reluctantly, after depleting their forests, did Britain utilized maritime trade routes to help alleviate British timber shortages. Because Great Britain had few forested areas by the end of the eighteenth century, her shipbuilders were forced to broaden the range of acceptable wood species. Trade routes brought in exotic woods, such as lignum vitae, or replenished depleted woods such as white oak.

The crux of the problem was that timber could not be produced but must grow and occur naturally. Once a tree was chopped down, it could take up to 120 years for a replacement to grow to a usable size. This increased the chances that complications such as disease or drought might affect the tree's quality or even kill it. To supply an increasingly large fleet of short-lived hulls (ships lasted perhaps twenty years at best) in this manner proved almost impossible.

These combined factors created a complex situation involving many areas such as the timber trade itself, government, military and private affairs. Numerous individuals were involved in determining which woods were usable or available for eighteenth-century ship construction. Shipwrights, naval architects, government officials and private individuals had opinions and varying power to select wood for ship construction. Timber's importance generated a large number of treatises, letters and other documents. Unfortunately, much of this correspondence, like the woodworking tradition itself, has been lost, forgotten or replaced with new technology.

Research Methodology

The purpose of this thesis is to combine history and archaeology to gain a better insight into eighteenth-century wood use in ships by focusing on species selection. This is accomplished through a comparison of documentary sources to archeological resources. Each class of sources yields a thorough yet incomplete view of wood use. This analysis incorporates historical, archaeological and botanical research to create a holistic view of eighteenth-century wood selection.

Historical documents indicate ideal wood species that shipwrights and naval architects chose for ship construction. Manuscripts, describing what an individual thought or proposed for ship manufacture, fail to identify what woods were finally utilized. Archaeological data then reveals which woods were actually used. Archaeological information does not say why or how a wood was selected but shows what woods were incorporated for ship manufacture. Researchers must consider additional conditions such as patches, repairs, regional adaptations and changes in trends over time that may affect archaeological data. Botanical research combines with archaeological analysis to identify scientifically archaeologically retrieved wood samples.

An examination of archaeological sites shows that no shipwreck is complete, as over time much of the vessel was lost or removed. A comparison of vessels is therefore necessary to obtain reliable results. By combining a variety of vessels, each component will be represented. This wide range provides a more precise examination and therefore a more accurate one. The comparison will not equally reflect each component but will increase the likelihood of discovering true wood use.

Archaeologically recovered wood samples from an eighteenth-century collier, Betsy, will be tested against hypotheses derived from historical documents. The analysis is designed to determine if Betsy accurately reflects British wood use, whether Betsy has evidence of repairs and whether the furniture and casks found on board paralleled eighteenth-century land trends.

Betsy offers a unique opportunity since it was extensively sampled. Thorough sampling created a substantial data base and therefore a statistically more precise analysis. The Betsy is a model baseline to which other eighteenth-century vessels can be compared. The vessel represents only one moment in time and space, however, necessitating additional vessels to examine thoroughly eighteenth-century maritime wood use.

Other vessels represent a variety of sizes, origins, uses and dates. Each additional vessel had a series of identified wood samples that underwent the same examination as the Betsy's. The samples and their results were examined to see if differences in wood choice existed for different sizes, origins or times. Factors such as patching and repairs were taken into account and played an important role in eighteenth-century wood use analysis.

Importance of Wood Use

Wood use comparison in eighteenth-century vessels is important as it provides researchers with a clearer idea of eighteenth-century ship construction preferences. Most site reports and research papers focus on one vessel or vessel type. This gives researchers a limited view as one vessel is not representative of eighteenth-century ship wood use. A wide-ranging comparison, however, expands the informational base allowing a more comprehensive understanding of ships.

Historical research examines the problems and factors affecting wood selection. The documentary evidence reveals why certain selections were made and how that wood came to be utilized in ship construction. Documentary evidence sheds additional light on related aspects such as the timber trade, wood preferences and life in general. Each of these areas affected wood selection and is an integral part of eighteenth-century ship wood use.

This documentary analysis provides archaeological researchers with a model to test, compare and predict future recoveries. The hypotheses include predicting differences in wood use, factors in wood choice, changes over time and whether the archaeological material substantiate historical documents.

Conclusion

A comparison of eighteenth-century vessels should reveal a number of construction trends. The foremost should be a contrast between British and northern colonial Anglo-American versus southern colonial Anglo-American ship wood use. Differences in available woods, trade routes and geography should create differences reflected in woods used for ship construction. Other trends should include a difference between naval and merchant ship wood use, as historical information suggests that military and civilian builders utilized different woods for structural components. A third trend should be a change in wood use over time. According to documentary evidence, as white oak supplies became depleted, shipwrights and architects compensated by utilizing other, less common species. Ideally, historical and archaeological material should be the same. If the two expected wood types are different from the observed on archaeological sites, then further research is necessary to determine why theoretical use differs from actual wood use.

An important aspect brought out by the comparison was a need for accurate and thorough sampling to analyze properly wood use in ship construction. Archaeologists should analyze as many elements as possible. Most excavated ships lack remains of basic structural elements such as deck planking, knees, masts, frames or stem and stern posts, making sampling impossible. Precise and detailed sampling will help future research and analysis by providing archaeologists and historians with an additional tool to help understand and evaluate their largest artifact, the ship itself.

The timber trade and ship wood species selection were not separate entities; they influenced one another and influenced political, economic, and military thought in the eighteenth century. Competition for timber to make houses, furniture or to trade with Spain and France created further difficulties for shipbuilders in Britain and in the American colonies. The Crown tried to set aside certain areas of forest for naval use but met with much resistance. The acts and laws pertaining to shipping and lumber that were enforced during the eighteenth century helped lead many colonists to rebellion.

References

1.Robert Albion, Forests and Sea Power: The Timber Problem of the Royal Navy, 1652-1862 (Camden, Connecticut: Archon Books, 1965), p.111; James Dodds & James Moore, Building the Fighting Ship (New York: Facts On File Publications, 1984), p.17.

2.Albion, Forests and Sea Power, p.49.

CHAPTER TWO

Introduction

This chapter is a brief examination of the eighteenth-century timber trade between Great Britain, the Baltic and her American colonies. It will look at both the home timber shortage and overseas timber trade. Primary focus is placed on Britain's inefficient forest policy. Though other factors, such as non-standardized vessels played an important role, due to time and space limitations they are not pursued in length here. For all its shortcomings, Britain's timber policy did manage to keep her ships afloat and allowed the preservation of British naval superiority.

Britain needed her ships to maintain herself as a dominant sea power. A good supply of growing timber and a well-seasoned reserve were critical factors in sustaining naval power in the eighteenth century. If Britain had accomplished a reserve, it would have avoided many problems that plagued her throughout the remaining years of the wooden ship navy.

The industrial revolution created extreme demands on Great Britain's timber supply. Iron production required hardwood charcoal and firewood to fuel furnaces and smithies. The population explosion resulting from the industrial revolution created a greater demand for houses, fuel, tools and other wooden objects.[1]

Continual warfare prevented Britain from developing a regular systematic timber trade within her own boundaries and with her North American colonies. Maintaining naval superiority quickly consumed any surplus, preventing Britain from developing a strategic reserve.[2] Great Britain did not completely ignore her colonies as a source but lacked the time, money, ships and local power to create an effective long-term colonial forest policy.

Shipbuilding consumed great quantities of timber.[3] Proper construction necessitated wood of exceptional sizes or shapes, creating unusual and difficult supply demands.[4] Keels and masts required extremely large straight trees, while knees, breasthooks and other curved pieces required unique, crooked compass timber. Between 1751 and 1761 the dockyard at Woolwich used almost 40,000 loads or 2,000,000 cubic feet of timber to build 16 vessels.[5] The 74 gun Triumph alone consumed 3,028 loads or 151,400 cubic feet of timber.[6]

Peasants also stripped hedgerows for fuel wood, reducing available compass timber for ship construction.[7] Compass, or curved, timber comes from trees exposed to the wind and elements, such as those found in hedgerows. Trees found in forested or protected areas grew straight trunks and limbs. In many instances the lack of compass timber greatly inhibited the construction of fighting ships.[8]

Without massive, curved pieces Britain could not build her vessels.

Other factors contributing to the timber shortage were Royal Navy prejudice and requirements for only the best timber.[9] These expectations placed heavy demands on a limited number of species such as English oak (Quercus robur). Exclusive use of oak created spiralling price increases as the high demand for white oak quickly reduced supply.

Oak shortages resulted in some experimentation. During the eighteenth century it was found that other species such as larch and ash could replace white oak for many purposes. While using other woods helped, the Royal Navy failed to effectively institute measures to alleviate the shortage. They rejected Baltic and North American white oak because of favoritism and faulty assumptions. In desperation, Great Britain chose to assuage the shortage by using green wood.

Green wood is unseasoned timber. It was neither as durable nor as strong as seasoned wood because bound water remained inside the cell wall. The cells swelled, allowing easier bending and breaking. Swelling and shrinkage associated with green wood created ill fitting joints and leaks. Water more easily penetrated green than seasoned wood, helping propagate the spread of rot and fungus.

While builders and merchants understood the problems associated with using green wood as early as the seventeenth century, they continued using it.[10] Gabrielle Snodgrass, surveyor for the East India Company, recommended covering and storing timber where it would receive ample circulation and protection.[11] In an appendix to the 11th report of the Commissioners of the Land Revenue, Snodgrass again advocated the use of slips and roofs to house timber until it was seasoned.[12] Lord Sandwich, First Lord of the Admiralty, was warned by a Mr. William Wells in 1771, to erect storehouses for seasoning lumber and not to use green materials to build vessels, but to let timber dry for 3-4 years.[13] Nevertheless, shipwrights omitted proper seasoning and continued building with green wood.

Sapwood was also used during times of emergency or scarcity. Sapwood consists of the outermost annual rings of the tree. It was the "living" part of the tree, usually lighter and less dense than heartwood. During normal timber production, sapwood was removed before shaping planks because it was less durable and weaker than heartwood. Although its inclusion promoted faster decay and easier water absorption, using sapwood yielded more wood per tree.

The result of using improper materials can be seen in numerous accounts of vessels rotting and breaking up after a short time at sea. William Richardson, who served on board many vessels during the late eighteenth century, claimed most vessels he sailed in were leaking and rotten.[14] This observation appears almost as an afterthought, implying that decaying and crumbling vessels in the Royal Navy were commonplace.

Robert Albion's book, Forests and Sea Power, relates other instances substantiating Richardson's observations. According to Albion, most British vessels suffered from cracked or sprung masts and bowsprits, leaky hulls and broken knees.[15] Other sources, such as Admiral Augustus Keppel, also complained of broken masts and spars and of having no replacements available. Further examples included a report from HMS Vigilant, whose sailors refused to sail because they were afraid her hull was giving way. A sailor scuttled HMS Bute by punching his fist through the hull and Royal George's bottom fell out while being heeled over for repairs.[16] Given these accounts, it seems decrepit vessels were not a rarity during the eighteenth century.

British timber procurement and management was fraught with problems. The system was easily corrupted from the lowest apprentice to shipwrights, timber magnates and government officials. Timber land owners brought on artificial shortages by cutting off supplies to raise prices.[17] The Admiralty was helpless to stop them as there was no other way to obtain wood. Since the Board and other officials received higher payments from timber suppliers little effort to stop these powerful men was expended.[18]

Eighteenth-Century War

To further understand Great Britain's dilemma, a short review of wars fought in the eighteenth century by Britain is necessary. The outstanding feature of this century was Britain's almost constant military rivalry with France, Spain and the Baltic countries. The century began with the War of the Spanish Succession (1702-1713), known as Queen Anne's War in America.[19] Britain was allied with Holland to prevent Louis XIV from gaining access to the Spanish throne and obtaining Spanish naval supplies and colonies. The War of Jenkins' Ear began in 1739, when British merchants threatened Spanish trading interests in the Caribbean and Central America.[20] By 1744, this economic conflict developed into the War of the Austrian Succession (1744-1748) or King George's War. This time Britain joined Austria to prevent France from claiming the Austrian throne.[21]

In 1754, British colonies became involved in the French and Indian War, known in Europe as the Seven Years' War, (1756-1763). Hostilities actually began in 1754, when English speculators tried pushing the French out of the Ohio River valley.[22] This war was different in that North America became a important theater in Britain's rivalry with France.

By 1765, frequent warfare began to take its toll. British reserves of men, supplies, and money were low. Parliament, resolved that the North American colonists should pay for their defence.[23] This resolution brought about new legislation which eventually precipitated the Revolutionary War (1775-1783).[24] The end of the century found Britain again at war with the French.

Great Britain spent almost one-half of the eighteenth century in warfare. The intervening years were spent preparing for or recovering from hostilities. Britain had enemies in the Baltic, Europe and the New World, each trading and striving for the same markets. No matter where Britain sent her ships, she encountered competitive adversaries.

British Dockyards and Forests

Without an adequate timber acquisition or management policy, Britain's forests became depleted and her dockyards emptied. Dockyard officials were the first to note the effects yet perhaps the last to understand them. Without proper foresight, management, and competent personnel, neither dockyards nor forests could meet Royal Navy requirements.

Ship production was run by the Navy Board, which discussed agreements, framed policies and oversaw construction, repair and care of ships.[25] The Navy Board also prepared estimates for lumber quantities, made contracts and regulated the timber supply in the royal dockyards. The Board lacked ultimate control as all transactions were submitted to the Lords of the Admiralty for final approval.[26]

The Navy Board tried to use a contract system to keep a three to four year timber reserve in the dockyards. Such a system would have allowed adequate time for lumber to season. The contract system failed due to "injudicious management of the timber policy, venality of the civil branch, growth of a contract monopoly, and unstable credit of the navy...."[27] Board members and other officials came to expect certain "presents" in exchange for contracts.[28] The Board rarely allowed proper seasoning, instead keeping a minimal supply of green wood. Demand for timber was so great that it was used as it came into the dockyard.[29] Timber magnates and merchants took advantage of the system by stealing, buying off officials and withholding goods.

Dockyards created further problems by operating as separate entities and changing policies at will to suit their particular needs.[30] All deliveries were made in the presence of two dockyard officers, usually inspectors, who checked the wood for agreed quantity and quality. Like the merchants, inspectors became easy subjects for corruption. Many received larger incomes from contractors in the form of bribes and "presents" than they did from the Royal Navy.[31]

After timber passed inspection, the contractor received a navy "imprest" bill. The treasury usually had insufficient funds to pay the bill, forcing the contractor to wait months or years for payment. Eventually, some contractors refused to provide timber to the navy unless promised ready money.[32]

Royal Dockyards

There were six principal dockyards in eighteenth-century Britain: Portsmouth, Plymouth, Deptford, Woolwich, Chatham and Sheerness.[33] Of the six, Plymouth, Chatham and Portsmouth each had a resident Commissioner who oversaw dockyard operations. He was usually a naval sea captain who was, in essence, part of the Navy Board, though he rarely met with the Board in person.[34] Deptford and Woolwich did not need Commissioners as they were close to London and were overseen by the Navy Board, while Sheerness operated under Chatham.

Under the Commissioners and Navy Board were salaried officers who answered directly to the Board. These officers, such as the Master Shipwright, the Storekeeper or Clerk of Cheque, managed separate areas of each yard.[35] They were in charge of other workers including assistant shipwrights, foremen, caulkers and rope makers.[36]

Dockyards developed into major centers with naval hospitals, ordnance yards, victualling yards, shops, etc.[37] On a logistical level, the vast yards were hard to control because they incorporated large quantities of stores.[38] The dockyards had a major impact on surrounding communities. Local citizens were reluctant to report graft for fear of losing jobs.[39] Yard officials and workers both profited by corruption, leaving few who would come forward to help yard investigations. Blame was usually focused on unknowns or low-ranking apprentices. Dockyard apprentices were easy targets for blame because they had less to lose and were not allowed the privilege of "chips."[40]

Chips were pieces of wood less than three feet long which shipwrights or dock workers took home for firewood. Few stuck to the rule, as women and other outsiders came into the yards and took chips along with nails and pieces of scrap iron.[41] When Samuel Bentham investigated the misappropriation of chips in 1798, he reported purchasing chips which fit together to form a log and claimed he heard workers sawing larger pieces into smaller ones to conform to the chips law.[42] Earlier in the century, Admiral Warren estimated that a sloop-of-war's worth of chips was taken each day.[43]

Merchant Yards

Merchant yards were, on average, equal to or exceeded royal dockyards in quality. They made cheaper, better built, vessels than royal dockyards because their yards were run as businesses dependent upon profit and reputation. Profits depended on efficiency rather than having bills paid by the public.[44] In many instances, private yards outbid navy yards for lumber shipments and ship construction contracts.

In 1710, the Royal Navy ended contracts with private yards and began to depend exclusively upon royal yards.[45] Royal dockyards had better resources and more highly skilled shipwrights.[46] Contracts with merchant yards were reopened in 1739, during the War of Jenkins' Ear, when more ships were needed for the Royal Navy.[47] By 1805, Royal Navy dockyards produced only 15% of ships of the line and only 17.9% of smaller vessels.[48]

British Forests

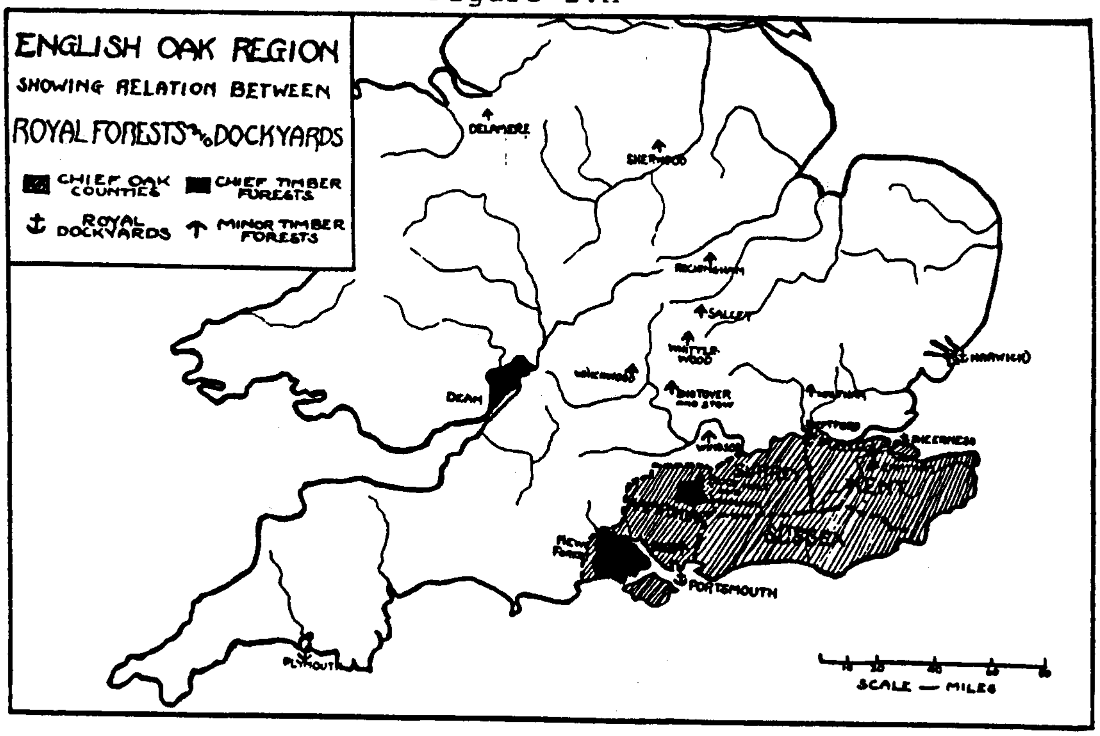
Great Britain had three geographic areas from which to obtain suitable timber: the Baltic, North America and Britain itself. None of these areas, however, were properly exploited to sustain Royal Navy requirements. Each area had unique problems requiring different solutions. The following is a brief summary of forests within Great Britain (Figure 2.A).

A Royal forest usually was an area set aside for the king.[49] Each forest had a Lord Warden and a Royal Purveyor who inspected trees and marked suitable timber with the broad arrow, indicating the tree was reserved for the Royal Navy. Royal Purveyors inspected the forest to prevent cutting down and selling of Royal trees.[50] Royal Forests supplied only one-tenth of the trees obtained from Great Britain in any given year during the eighteenth century, the rest came from parks or woodlands of nobility and landed gentry.[51] By the second half of the century, only New Forest and Forest of Dean could supply substantial amounts[52] (Table 2.A.).

Members of Parliament owned many private forests. Quite naturally, they created legislation to protect their investments and make them more profitable. For example, private forests sold timber to iron foundries, creating competition between the Royal Navy and foundries for trees.[53] Private owners also kept white oak profitable by limiting supply and preserving their timber lands. They refused to cut their oaks, which represented both wealth and a symbol of continuity.[54]

The men in charge of forests were often chosen unwisely and did not fulfill their duties. It was hard to achieve an effective policy when many wanted unreasonable profits and fast returns for little effort. Planting forests did not produce immediate profits as many species

Figure 2.A



(Albion, Forests, p.109)

Table 2.A

Decrease in Number of Oak Trees

	1608	1783
New Forest	123,927	32,611
Alice Holt	13,031	9,136
Whittlewood	51,046	5,211
Salcey	15,274	2,918
East Bere	5,363	256
Sherwood	23,370	(1789) 1,368[1]

Figures for the Forest of Dean were not taken in 1608, but the decrease had been similar.[2] (Albion, Forests, p.136)

[2]H.C.J.; 1792, p.351.

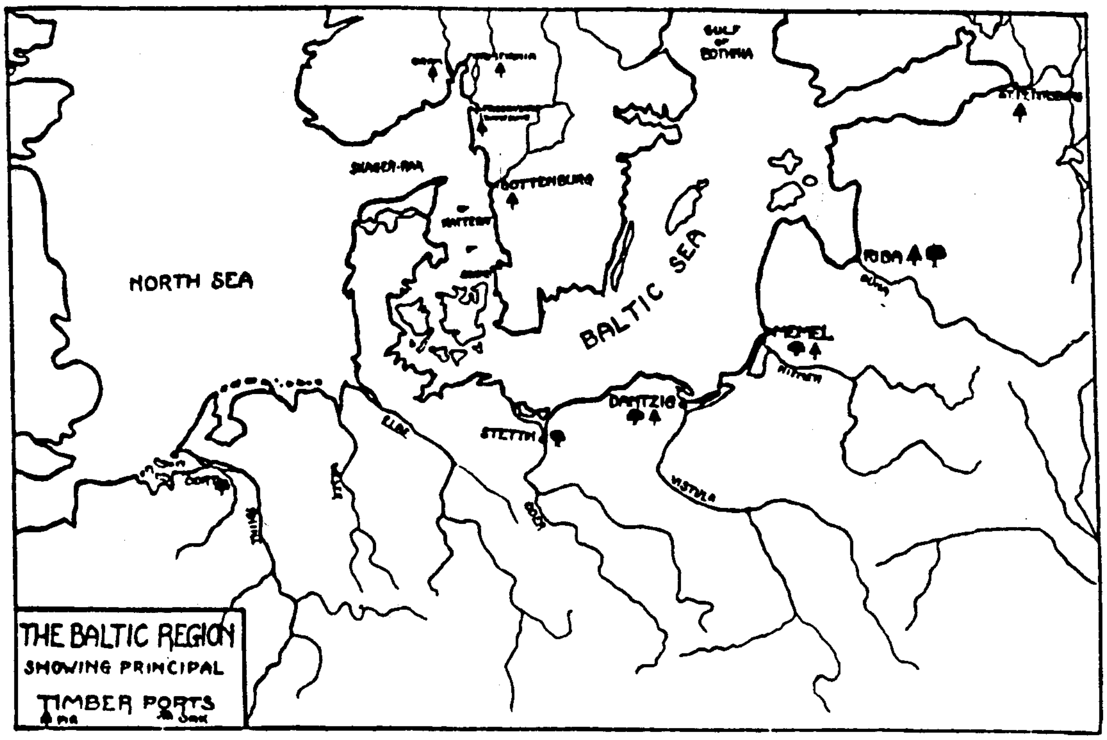
took over 100 years to reach their most valuable size. A tree planted in 1700 would not be ready for use until the Napoleonic wars.[55] This meant the great-grandson of the person who planted the tree would reap the profits. Instead, many forest land owners chose to plant more profitable crops or raise livestock.[56] These alternatives decreased acreage available for tree nurseries. By the time any shortage was felt, it was too late to reforest the land.

Great Britain's forests were handled much like the dockyards. Inefficient methods, unqualified, corrupt personnel, and a lack of understanding permeated both dockyard and forest administration. British officials lacked the foresight and effective management to meet Royal Navy timber requirements.

<u>Baltic Timber Trade</u>

Foreign timber sources became essential as British forests depleted. Timber shortages forced importation from the Baltic. The Baltic Sea drained surrounding rivers and adjacent bays creating a centralized trade area (Figure 2.B). Logs were floated down rivers to processing and export centers. On the southern Baltic coast, timber came down the Oder and Vistuala to Stettin and Danzig. On the east coast, the Nieman and Duna rivers flowed to Memel and Riga.[57] The northern coast was relatively unimportant to

Figure 2.B



(Albion, Forests, p.141.)

the timber trade.

Naval stores were prominent Baltic commodities. Swedish, Russian and other Baltic countries' tar, pitch and turpentine had excellent reputations and comprised a large percentage of their exports.[58] The Baltic was best known for its "small" sticks; masts and spars less than 24 inches in diameter. Tree species remained constant throughout the Baltic although the southern forests had more hardwoods while the northern forests had more conifers. Two types of lumber came from the Baltic, deals and square timber. Deals were lumber 3 inches thick while square timber was shaped lumber such as masts.

In the Baltic basin, workers felled trees during the winter months and used sleds to drag trees to nearby rivers. In the spring, trees were tied into rafts of a thousand or more logs.[59] Upon reaching port, rafts were broken up and the timber floated into mast ponds or storage areas. The pond and mill owners originally purchased the lumber from the forest's owners.[60]

The next step would be to shape the logs before shipment to Britain.[61] Most Baltic ports had inspectors called "brackers". After shaping, these men stamped the processed wood to indicate its quality. "K" represented the best quality, "B" or "W" for second rate, and "BB" or "WW" for third rate.[62]

The Navy Board contracted with British merchants who bought timber from Baltic pond and mill owners. The merchant had to secure shipping, in accordance with the navigation acts, and pay a duty to pass the Sound. Once the merchant arrived safely at a British dockyard, he paid more duties, unloaded his timber and had it inspected by dockyard officials.[63]

Throughout the eighteenth century, the Royal Navy drew ever increasing amounts of timber from the Baltic, but did so in highly competitive, often unstable, circumstances. Other countries also depended upon the Baltic for their timber and naval supplies. Sweden, France and Russia all had interests in or traded with the Baltic. When one or more of these countries became involved in warfare, trade became hazardous.[64]

Sweden proved to be one of Britain's chief adversaries in the Baltic. Sweden restricted exportation by controlling the only entrance into the Baltic, a waterway called the Sound or Skaw. Sweden and Russia had been frequent enemies since the thirteenth century, fighting over Baltic commercial territory. At the beginning of the eighteenth century, these two countries went to war, temporarily stopping most trade with countries further west such as France and Great Britain.[65]

Sweden asked for British assistance after her defeat in 1709. Great Britain incensed Sweden by refusing to help as Britain was preoccupied fighting France. After Queen Anne's War, Sweden continued harassing British commerce, complicating British trade in the Baltic.[66] British merchants had to pay a duty to pass through the Swedish controlled Sound, while other countries did not.[67] This led to further enmity between Great Britain and Sweden.

The Baltic continued to be unstable throughout the eighteenth century. Between 1715-1727, Britain sent 10 fleets to the Baltic to assist trade allies and to control Swedish naval and privateering threats.[68] On almost twenty occasions between 1658 and 1814, there was fighting in the Sound alone.[69]

Britain's mercantile tax hampered the Baltic situation. Measures such as the Trade and Navigation Acts incensed European countries. Britain made few concessions to other nations trading in the Baltic because she wanted to deny competitors any Baltic goods. The Trade and Navigation Acts made it impossible for other countries to export items directly to Great Britain or her colonies and kept profits within British coffers. While Britain did not completely forgo the Baltic, its reliance on North American timber and naval stores increased. Table 2.B demonstrates Britain's mast importation from the Baltic before the

TABLE 2.B

Masts	Great	Middling	Small
1706/07			
Northern Colonies	48	------	------
Virginia/Maryland	------	------	------
Sweden	420	237	379
Denmark-Norway	1216	1369	200
East Country	32	------	------
1744/45			
Northern Colonies	244	------	------
Virginia/Maryland	195	------	------
Sweden	------	------	------
Denmark-Norway	297	995	957
East Country	1298	4	167
1759/60			
Northern Colonies	603	124	58
Virginia/Maryland	------	3	------
Denmark/Norway	60	1566	2007
East Country	352	170	55
Russia	895	107	583

Joseph Malone, Pine Trees and Politics (Seattle: University of Washington Press, 1964), p.56.

Revolutionary War.[70] The Revolutionary War brought back English dependence on Baltic goods. The return was short-lived as Napoleon and the French cut off access to the Baltic.

The Baltic played an important role in Britain's timber trade. The Baltic was much closer than America, allowing for more frequent and quicker shipments of lumber and other naval stores. Ships could make several trips a year from the Baltic while the colonial vessels could only make one or two.[71] Despite its precarious environment, the Baltic remained an important and viable source for timber and naval stores because of its proximity (Table 2.C).[72]

TABLE 2.C

Baltic	**Pounds**
Riga	292,775
Norway	181,299
Russia	17,340
Sweden	16,631
Total	509,586
New England	425,769

Malone, Pine Trees, p.55.

North American Colonial Policy

By the eighteenth century, Great Britain realized the importance of trade with her Anglo-American colonies to maintain timber supplies. When Britain closely examined her New World colonies she realized their potential but eventually came to fear the economic power they possessed.

The colonies became increasingly self-sufficient during Britain's pre-occupation with the French Wars. Although Britain passed laws throughout the century to control colonial trade, she failed to enforce them effectively.

Operating under the principles of mercantilism, Parliament believed keeping the colonies subordinate was the best policy for Britain.[73] Many British merchants believed that since the colonies belonged to Great Britain, Great Britain should share in their profits.[74] Economic interest was strong in Parliament as many merchants were involved in the political arena. Parliament and the crown hoped to utilize the colonies by passing and implementing protectionist legislation, such as the Navigation Acts, which supported British merchants and markets.

The well-known seventeenth-century Trade and Navigation Acts included timber products. These acts had four major components: certain goods were only to be shipped in British ships; enumerated goods could only be shipped through Britain; the colonies were forbidden to compete with British manufactures; and preferential treatment was given to some goods in Britain.[75]

These acts became the basis for trade between the Anglo-American colonies and Britain. During the seventeenth and eighteenth centuries, the acts were modified and expanded with naval stores always a major concern. British attempts at enforcement and American avoidance of the acts led to tension between the colonies and mother country. The colonists felt the Navigation Acts were oppressive while Parliament and British merchants felt the acts were necessary for proper enterprise.

The first law controlling colonial trade was the Trade and Navigation Act of 1660, which stimulated Britain's trade by restricting colonial commerce to British shipping.[76] British merchants feared unrestricted trade would benefit the France, Spain and the Baltic states.[77] The act was irritating but did little to hamper trade because it was irregularly enforced.[78] Later modifications included the Act of 1663, which prohibited European goods from being shipped directly to America. The final act, passed in 1673, required colonists to take out bonds guaranteeing compliance with the Navigation Acts, or pay a duty equivalent to the re-export duty.[79]

The Trade and Navigation Acts affected continental European countries more than the Anglo-American colonies. In 1702, Sweden refused to sell England any tar or pitch unless Sweden could bring it in her own ships at Sweden's price and quantity.[80] This helped create the impetus to find another source for naval stores.

British merchants were aware that naval stores were extremely profitable. They also knew that Russia had a lucrative naval stores export trade and wanted to begin their own.[81] If the American colonies copied Russia by producing and exporting naval stores, British merchants would profit through the Trade and Navigation Acts, making Great Britain self-sufficient.[82]

Timber was one commodity with great economic and political importance. Merchants, timber magnates and royal officials wanted colonial and British timber protected for their personal interests and created legislation to do so. To regulate the cutting, felling and selling of timber required strict adherence to laws and careful watch over their majesties' woods in Britain and the North American colonies. To these ends, numerous acts concerning timber were passed in the seventeenth and eighteenth centuries. Some were designed to preserve woodlands, others encouraged importation, while others forbade exportation to other countries.

Colonial Timber Exports

Britain strove for self-sufficiency in naval stores by shifting from Baltic to North American sources.[83] The Navigation Acts ensured that British ports became essential and necessary transit points as all commodities from both the northern and southern colonies, West Indies and Caribbean had to pass through British ports. As long as trade existed, British merchants profited through the Navigation Acts.[84]

The northern British colonies began a timber trade almost immediately after settlement as the climate was not as conducive to raising crops as the other colonies. The southern colonies had many usable trees, but timber exportation was slow to start because they concentrated on the production of other commodities. The northern colonies imported foodstuffs from the middle and southern colonies and imported manufactured items from Great Britain.[85] Without a profitable cash crop the northern colonies used timber to pay for imported British goods.[86]

The northern colonies' main exports were timber, livestock and fish (Tables 2.D,2.E). The natural topography of America's eastern seaboard contributed to the timber trade, with many good ports having rivers running into the wood producing interior.[87] During the eighteenth century most of the northern colonies became increasingly involved in shipbuilding, both for local and deep water or seagoing craft.[88]

Boston became a commercial metropolis which influenced much of the eastern seaboard, as well as a prime area for shipbuilding.[89] By the mid-eighteenth century, it cost less to build a ship in Boston than in most other areas. In Boston a ship cost 8 pounds per ton, in the Carolinas 10.10 pounds, and in England 15.5-16.6 pounds.[90] New Hampshire and Maine became primary areas for mast production. Although the mast trade comprised only a small part of the overall timber trade it was of extreme importance to the Royal Navy.

As with other colonial commodities, colonial ships acquired a bad reputation. British builders and merchants believed colonial vessels decayed faster than British-built ships.[91] The Navy Board maintained that North American vessels lasted less than four years.[92] They placed the blame on green wood, cheap materials and methods. Perhaps this perception was based on national pride and a fear of colonial ships dominating trade, but some colonial vessels were not designed for longevity, some were built for service in tropical waters where marine organisms destroyed ships, well built or not.[93]

TABLE 2.D

Major Commodity Exports by Region, Pounds Sterling

Commodity	New England	Middle Colonies	Upper South	Lower South	Total
Tobacco			723,286	900	724,186
Bread/flour	20,800	346,101	96,019	4,246	467,166
Rice	1,697	4,427		260,584	266,708
Dried Fish	145,099	1,697	557	13	147,342
Wheat	218	35,435	101,657	1,364	138,674
Pine/Oak/Cedar Boards/Staves	61,014	28,607	20,201	25,310	135,132
Indigo			495	103,430	103,925
Whale Oil/ Candles	73,282	5,670	17	320	79,289
Indian Corn	2,895	16,933	40,632	10,027	70,487
Iron, Pig/Bar	1,552	38,249	26,209	124	66,134
Beef/Pork	16,934	17,942	14,863	7,296	57,039
Flaxseed	1,700	43,398	5,065	15	50,178
Deerskins		2,927	14,282	31,731	48,940
Pitch/Tar Turpentine	2,160	2,050	5,428	28,860	38,498
Potash	21,294	10,228	165		31,687
Rum, American	19,088	2,658			21,745
Bees Wax	434	3,850	63	745	5,668

Table 2.E
Average Annual Value and Destinations of Commodity Exports from New England, 1768-1772, Pounds Sterling

Commodity	Britain	Ireland	S.Europe	West Indies	Total
Fish	206		57,195	94,754	152,155
Livestock	374		461	89,118	89,953
Wood Product	5,983	167	1,352	57,769	65,271
Whale Products	40,443		804	20,416	61,663
Potash	22,390	9			22,399
Grain Products	117	23	3,998	15,764	19,902
Rum	471	44	1,497	*	2,012
Other	6,991	1,018	296	247	8,522
Total	76,975	1,261	65,603	278,068	439,101

Source:James Shepard and Gary M. Walton, Shipping, Maritime Trade, and the Economic Development of Colonial North America (Cambridge, 1972),211-212,217,220,223-224,227. Southern Europe includes all of the continent south of Cape Finisterre and the Wine islands. Cited in McCusker and Menard, The Economy of Britain, p.108; Jones, Wealth of a Nation, p.48. * 16,754 Pounds Sterling was exported to Africa.

Southern Colonies

The southern colonies' most important cash crops throughout the eighteenth century were indigo, cotton, tobacco, rice, hemp and flax (Tables 2.D,2.F,2.G). Britain encouraged this trade to keep the southern colonies focused on agrarian products and dependent on British manufactured goods.[94] To perpetuate this system, Britain offered premiums on agricultural goods, but discouraged refining and manufacturing of items such as woolens since Great Britain already had a cheap and available source. More importantly Britain wanted to retain the North American colonies as a market for British goods.[95]

Naval stores became more important to the southern colonies as time progressed (Table 2.D). In 1717 Carolina merchants petitioned the Commissioners of Trade and Plantations to be allowed to ship more naval stores to Britain.[96] The Carolinas' favorable climate allowed naval stores production from April to September, whereas the Baltic had a much shorter season.[97] The Carolinas already shipped naval stores to the West Indies and northern colonies believed there was enough surplus for Britain. They argued that colonial tar and pitch was better than Swedish products and would reduce the amount Britain had to import from the Baltic.[98] The Royal Navy Commissioners received numerous reports from merchants that colonial naval stores were inferior to those of the Baltic.[99] In spite of complaints, the Carolinas led the colonies in naval stores production, exporting 548,705 barrels of pitch and tar between 1768 and 1772 while the northern colonies exported only 54,909 barrels.[100]

TABLE 2.F

Average Annual Value and Destinations of Commodity Exports from the Upper South, 1768-1772, Pounds Sterling

Commodity	Britain	Ireland	S.Europe	West Indies	Total
Tobacco	756,128				756,128
Grains Products	10,206	22,962	97,523	68,794	199,485
Iron	28,314	416		461	29,191
Wood Products	9,060	2,115	1,114	10,195	22,484
Other	23,344	3,357	526	12,368	39,595
Total	827,052	28,850	99,163	91,818	1,046,883

Table 2.G

Average Annual Value and Destination of Commodity Exports from the Lower South, 1768-1772, Pounds Sterling

Commodity	Britain	Ireland	S.Europe	West Indies	Total
Rice	198,590		50,982	55,961	305,533
Indigo	111,864				111,864
Deerskins	37,093				37,093
Naval Stores	31,709				31,709
Wood Products	2,520	228	1,396	21,620	25,764
Grain Products	302	169	1,323	11,358	13,152
Livestock	75	366	103	12,386	12,930
Other	11,877	515	365	785	13,904
Total	394,030	1,278	54,169	102,110	551,949

Source: James F. Shepard and Gary M. Walton, Shipping, Maritime Trade, and the Economic Development of Colonial North America. (Cambridge,1972),215,218-219,222,225,227. Southern Europe includes all of the continent south of Cape Finisterre and the Wine Islands. Cited in McCusker and Menard, Economy of British America, pp.130, 174.

The southern colonies did have a viable timber supply in live oak. More profitable commodities such as indigo, tobacco and cotton kept colonists from pursuing a less profitable timber trade. Live oak's properties made it hard to work and impossible to season, although after the Revolutionary War, the United States Navy utilized live oak for warships.[101]

Colonial Timber and Surveyor Generals

British timber management problems quickly manifested themselves in the American colonies. In 1705 Jonathan Bridger, a political appointee, became "Surveyor General of

Pines and Trees in North America" with orders to instruct the colonists on how to make tar and pitch. Bridger was a shipwright whose ideas about trade and naval stores agreed with those of the Board of Trade, but he had no experience producing naval stores. The result was an expensive commodity of poor quality.[102]

Bridger's other duty, overseeing the Royal Forests, created even more controversy. Before Bridger's appointment, trees in New England were being "laid to waste" at an alarming rate since there was no control over felling and shipping. Bridger hired two men to assist him but they proved of little help as the survey area was enormous. Bridger's aides also had a conflict of interest as they worked for mast contractors. The Surveyor's job was to place broad arrows on trees to reserve them for the Royal Navy.[103] Far from saving the trees, the broad arrow sometimes acted as a detriment. Colonists and woodsmen acting in the absence of the surveyors simply used the broad arrow as an indicator of the best trees to cut down.[104]

In 1711, Parliament passed the "White Pine Act" to reserve trees: "...there be likewise a particular reservation of all trees of a diameter of 24 inches upwards at 12 inches from the ground for masts for our Royal Navy and also of such other trees as may be fit to make planks, knees, and etc...."[105] This law stated that no person north of Virginia could cut, fell or destroy specific trees, not on private property or without a license. If caught, the transgressor incurred a fine of 100 pounds for each tree. At this time any colonist, other than Bridger and his staff, found marking trees with a broad arrow received a 5 pound penalty.[106]

As Surveyor General, Bridger observed blatant illicit cutting and selling of Royal trees but received little help from either the governors or the royal government. Royal governors were more often than not political appointees who came to North America to get rich.[107] Most governors were paid by a provincial government made up of prominent colonists.[108] Influential New England colonists owned the sawmills. If a governor or other official opposed these politically powerful colonists he risked losing his position. Bridger made arrests, but quickly found it impossible to obtain convictions.[109]

In 1715 the Governor of Massachusetts/New Hampshire, Colonel Elias Burgess, and the Governor of New York, Brigadier Robert Hunter, brought charges against Bridger. They claimed Bridger had sold licenses for 8 shillings and permitted people without licenses to load and sail with masts.[110] Bridger defended his position, explaining how he hired deputies and security guards to protect the trees.[111]

In July 1715, Bridger suggested the crown reserve trees smaller than 24 inches in diameter. Colonists were cutting the smaller trees leaving few to grow large enough for masts. He also suggested that any new land grants should reserve areas where no trees could be cut.[112] He continually sent letters to the Commissioners of Trade and Plantations, reiterating how the forests were being destroyed. The letters continued after his tenure and stated that if he became Surveyor General again, he would know how to protect the trees.[113]

A new Surveyor General was appointed July 1719, but Andrew Burniston stayed in England and appointed Thomas Armstrong as his deputy.[114] At the time, Armstrong was also the customs searcher for Portsmouth, New Hampshire. giving many a ready argument against his new appointment. Colonists contended he was lax in his duties as Deputy Surveyor General and that he allowed timber to leave New England illicitly.[115] Not surprisingly, many of these arguments came from men associated with saw mills.[116]

Armstrong's problems as Deputy Surveyor General paralleled Bridger's. Armstrong reported numerous infractions and he angered local mill owners and colonial legislators. He tried seizing illegally cut trees and arresting local workers but met with the same difficulties of conviction. Not surprisingly, both Armstrong and Bridger had the same results: sawyers and owners continued to fell and ship timber.[117]

In November 1722, a significant complaint was filed against Armstrong by Messrs. Husk, Sharp, and Bolam. (Husk was the deputy customs searcher and a Belcher appointee.) They stated that Armstrong made them pay too much for vessel clearance, then seized the ship and would not allow passage until a share was allotted to him. They also claimed Armstrong allowed trees between 17-23 inches in diameter to be shipped to France and Spain. Finally, Sharp testified that he and "others" overheard Armstrong say "Is it not a shame we should be governed by Germans and Dutch and have such a fine English Prince of our own, but I hope I shall yet live to see the right heir upon the throne."[118] Armstrong was dismissed as Customs Searcher in 1723.

After defending himself in England, Armstrong returned to North America in 1724. For the remainder of his tenure, Armstrong stayed in Boston. It appears that after losing his job as Customs Searcher, Armstrong realized he should keep quiet if he wanted to continue as Deputy Surveyor General. In essence, he gave free rein to the mills.[119]

The crown continued to try preserving forests by passing a new act in 1722. This act reserved all white pines outside townships.[120] It included a clause forbidding cutting of any white pines suitable for masts.[121] These revisions were necessary because colonists continued finding loopholes in existing laws while cutting down forest.

The Board of Trade and Plantations wanted to keep shipbuilding in Britain. They hoped to divert attention from lumber exportation by encouraging the production of naval stores.[122] British merchants saw Russia exporting large quantities of naval stores at opportune prices. Some pointed out that the staves, hogsheads and naval stores imported from Hamburg and Russia could be purchased from American plantations.[123] In 1728, the Commissioners put a premium of two pounds per ton on tar and pitch and one pound on timber.[124] If the colonies started exporting, then the merchants would benefit through the Trade and Navigation Acts.[125]

A new act for preserving the woods and encouraging importation was passed in 1728. No one in the British American colonies could cut trees 24 inches in diameter 12 inches from the ground, unless on private property.[126] Parliament went further and claimed that, although the pines were on private land, the pines themselves belonged to the Crown.[127] In 1729, the Broad Arrow Act reserved any tree which had a broad arrow on it for the navy.[128]

Colonists rarely followed the Broad Arrow Act. It was easier to cut, move and sell lumber for other purposes than mast making. Sawmills got better prices for cut wood than selling it as a mast or spar.[129] The refusal to obey timber laws from the seventeenth century to the

Revolutionary War represents the earliest continuous hostile act by the colonists against dominion.[130]

In January 1728, Colonel David Dunbar was appointed Surveyor General.[131] Dunbar encountered great opposition as colonists consistently threatened him and his agents. Sawyers went to great lengths to avoid the law and make Dunbar's job impossible. They continued to use marked trees for personal purposes and illegally shipped masts to France or Spain.[132]

Dunbar was promoted to Lieutenant Governor of New Hampshire in 1729.[133] This put him in direct confrontation with Jonathan Belcher, Governor of New Hampshire and Massachusetts. Belcher had angered almost everyone in New England with his corrupt policies. When Dunbar took office most colonists wanted Belcher removed from the Governorship.[134]

Belcher made Dunbar a scapegoat for his public opposition. He went so far as to blame Dunbar for inciting the colonists into "making indecent answers" at Belcher's speeches.[135] He also blamed Dunbar for stealing letters and diverting bills before Belcher could see or vote on them.[136] In turn, Dunbar claimed Belcher ignored Dunbar's position as Lieutenant Governor by calling meetings without him and ignoring his letters.[137]

The confrontation between Belcher and Dunbar directly influenced land deforestation. Those who wanted New

Hampshire as a separate colony, those who disliked the royal government and those who wanted Belcher and Dunbar pre-occupied joined forces with Dunbar to spearhead a movement against Belcher.[138] With Dunbar and Belcher busy, the sawmill workers could freely cut and ship trees and conduct business without royal intervention.

The massive anti-Belcher correspondence succeeded in forcing Belcher to leave the colonies by 1737.[139] Unfortunately, both he and Dunbar had to explain their actions before the courts in London. Their absence left New England's forests open to the sawmills. Each faction had accomplished their goals; sawmill owners had free run of the trees; New Hampshire became a separate colony, and New England had two fewer government officials.

Dunbar never returned. In 1743 Benning Wentworth became Surveyor General. Wentworth is an interesting choice since he was already the Governor of New Hampshire and owned numerous lumber mills. He and his family were some of the largest land and mill owners in New Hampshire. Not surprisingly, the Wentworths made a lot of money during his tenure as Surveyor General.[140]

Wentworth at least appeared to try to preserve the forests. He requested permission to make a reserve or nursery for white pines but it never came to fruition. As Surveyor General, Wentworth kept watch on his own trees, but did little to preserve the Crown's. He made many "arrests" but had no convictions because logs always disappeared or were ruined so they could not become evidence or Crown property.[141]

In 1763, Benning Wentworth was ousted and replaced by his nephew John Wentworth.[142] Surprisingly, John Wentworth was one of the better Surveyors General but time prevented his being an effective one. This late in the century, colonists greatly disapproved of royal officials, including the Surveyor General, making his job more difficult.

John Wentworth did more than any other Surveyor General in his relations with mill owners and in attempting to preserve forests. Wentworth traveled over much of the countryside looking for violators. He journeyed farther and stayed out longer than any previous Surveyor General. Instead of making confiscated logs crown property, he put them up for public auction at low prices, avoiding the mill owners' power.[143] This created a decline in the demand for illicitly cut logs. Wentworth did not prosecute the sawmill workers as long as they did not cut the royal pines. This sounds much like previous Surveyors General but Wentworth allowed mills to cut large pines legally. In 1776, after holding the job for 13 years, Wentworth, a loyalist, left America.[144]

During John Wentworth's tenure, Britain continued encouraging colonial manufacture of naval stores. The crown added large bounties on imported deals, planks and grown timber. Colonies could also ship lumber to Ireland, Madeira, the Azores and Europe south of Cape Finesterre.[145] In 1771 unmanufactured wood products were imported duty free while additional bounties were placed on staves and heads.[146] These measures did little as the colonists were well on their way to independence.

Conclusion

Throughout the eighteenth century Great Britain had few alternatives in procuring timber. Britain's three options were the North American colonies, the Baltic basin and forests within Britain itself. To maintain a steady seasoned supply, Parliament and British officials needed to realize the importance of proper management and regulation. Most failed to understand or consider the consequences: deterioration of the timber supply and navy ships.

British forests provided the advantage of a local supply of English oak, Quercus robur. British shipwrights believed English oak surpassed most other woods in durability, strength and water resistance. Unfortunately, centuries of unregulated harvesting had reduced the forests to a level at which they were unable to meet sustained Royal Navy requirements (Table 2.A). Private lands might have alleviated the shortage but owners reserved their trees to increase demand and raise prices.

Most attempts at preserving or procuring a supply were frustrated by corrupt and uninformed officials. Administrators chose personal gain over British needs. This prevented correcting an imperfect system and Great Britain was forced to look elsewhere for a timber supply.

Great Britain had a centuries-old trade with the Baltic region. The Baltic offered large reserves of pine and oak suitable for masts and shipbuilding. Although the oak was not British, it was still suitable for ship construction. The Baltic was close by, allowing cheaper and more frequent timber shipments.

The Baltic had a number of disadvantages. It had been harvested for centuries and larger trees no longer existed. The Royal Navy needed a lot of large masts. Unlike other timber, masts had to be specific sizes. Deviation of a few centimeters created an ill-fitting mast, causing the vessel to sail incorrectly.[147] The Baltic, though dominating the mast trade, was unable to supply masts over 31 inches in diameter.

The Baltic could readily outfit smaller ships but the largest fighting vessels needed masts from the New World.[148] To show this William Sutherland supplied a price list for masts shipped from New England and the Baltic. There are three trends in this information. The first is the Baltic did not supply the largest masts. Secondly, masts from the Baltic were more expensive than

North America and third is a rapid decrease in price as masts become shorter. The shorter masts were more common and therefore cheaper to produce and to ship. Britain could import more smaller, less expensive masts for the same price as fewer, larger more expensive ones.

Table 2.H

Masts From New England

Length	Diameter	Price	Price per yard
36 yards	36"	148 Pounds, 1s	4.11
32 yards	32"	92 Pounds, 8s	2.88
29 yards	29"	52 Pounds, 10s	1.79

Masts From Baltic

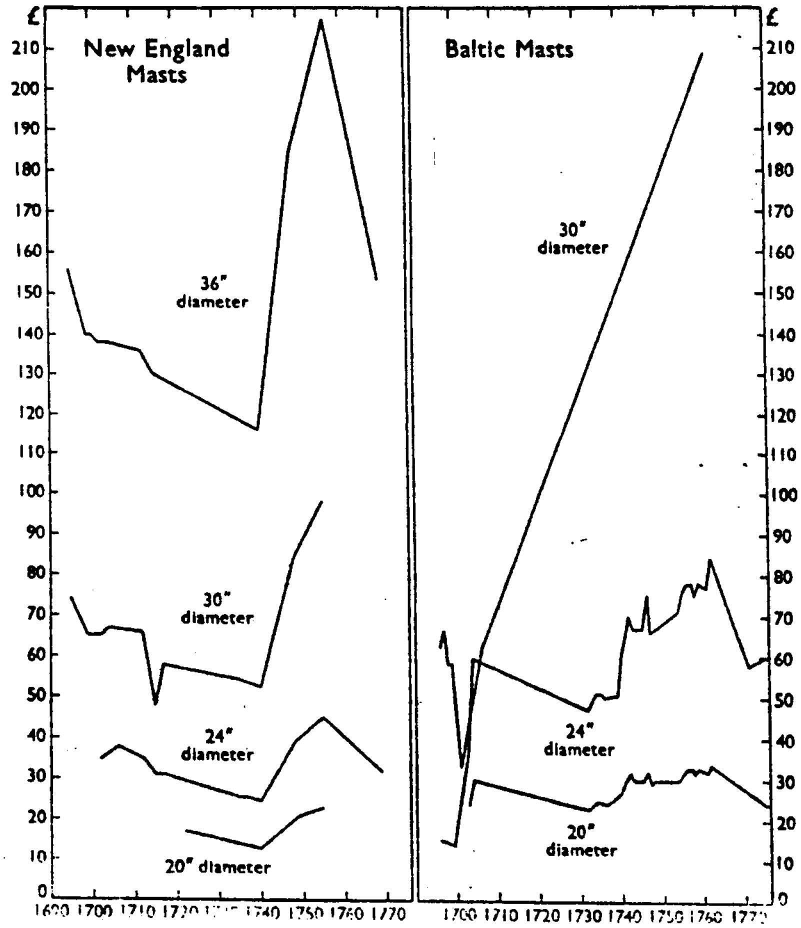
Length	Diameter	Price	Price per yard
29 yards	29 1/4"	64 Pounds	2.11
24 yards	23"	16 Pounds, 3s	.67
20 yards	17 7/8"	7 Pounds	.35
16 yards	12 1/4"	2 Pounds	.13
12 yards	7 1/4"	0 Pounds, 10s	.09

Because other European countries traded in the Baltic for timber and naval stores, competition often developed into hostilities. Consequently, the Baltic was not always a reliable or safe area to conduct trade. Although Britain wanted self-sufficiency and a dependable timber supply, she never entirely stopped trading with the Baltic throughout the eighteenth century (Tables 2.C,2.I).

Britain's desire to end her reliance on foreign supplies led to American timber. By using American supplies, Great Britain remained self-sufficient. The

Table 2.I

Prices of Masts Imported to Britain



(Malone, <u>Pine Trees</u>, P.147.)

American colonies, like the Baltic, offered a large supply of timber. The American forests produced mast timber of all sizes, especially trees larger than 30 inches in diameter.

The American colonies, however, were three thousand miles away while the Baltic was a few hundred. The distance prevented Britain from exercising proper control or communicating with colonial agents and administrators. The lack of controls perpetuated timber shortages by allowing corrupt and inefficient men to run timber trade policies. Despite the problems, colonists continued supplying Great Britain with timber throughout much of the century. Except for the Revolutionary War, American colonies exported timber and naval stores to Britain.

The beginning of the nineteenth century was a pivotal point for Britain. At war with Napoleon and in desperate need of timber and other naval supplies, Britain's annual consumption of oak increased from 22,000 loads to 47,000 loads.[149] This time Great Britain did not have the American colonies, except Canada, and periodically did not have access to the Baltic to obtain timber. At this time Great Britain's necessity for timber forced Britain to accept North American timber, thereafter British North America became a recognized valuable source.[150]

The French continental system cut off most Royal Navy attempts to procure European timber. The Adriatic and Black Seas were denied to British trade. Britain had to rely upon new trade areas such as Asia, Africa, the South Seas and Canada or expand the range of timber species used.[151] With American and Baltic oak inaccessible, British oak alone could not sustain the shipbuilding industry. Britain reacted by using woods such as white pine and fir, and lesser known woods such as pitch pine and larch. Although these woods were not as strong or durable as white oak, they were used to keep the Royal Navy afloat.

The eighteenth century taught Britain the importance of constant timber reserves. If Great Britain had a consistent forest policy in Britain and America and instituted a proper replanting system, she would not have relied upon foreign countries for a supply, or sailed substandard vessels. Her dockyards would have maintained reserves meeting Royal Navy requirements.

Eighteenth-century Great Britain, however, did achieve a functional timber trade. Timber, no matter what size or shape, arrived at British dockyards and Britain remained a viable sea power. Perhaps it is more a testimony to the captain's and seamen's abilities that they managed to keep their vessels afloat and win victories in battle.

References

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2.In 1608 England had 234,229 trees available for the Navy. By 1783 they had only 50,455 trees. John Fincham, History of Naval Architecture (London: Scholar Press, 1851), p.214.

3.Throughout the eighteenth century the total Navy tonnage increased creating additional needs and stresses on the forest supply. The Navy office estimated tonnage at:

Death of Queen Anne (1714)	167,219
Death of King George I (1727)	170,862
Death of King George II (1760)	321,104
By 1806	776,057

Fincham, Naval Architecture, p.214.

4.Albion, Forests, p.5.

5.James Dodds & James Moore, Building the Wooden Fighting Ship (New York: Facts on File, 1984), p.13.

6.Brian Lavery, Building the Wooden Wall (Annapolis: Naval Institute Press, 1991), pp.56-7.

7. Darby, Historical Geography, p.490. He refers to trees being stripped like maypoles. This not only reduced the amount available but reduced the amount available for future growth.

8.Fincham, Naval Architecture, p.110; Albion, Forests, p.6.

9.Albion, Forests, p.10.

10.Ibid., p.13.

11.Gabrielle Snodgrass, "A Letter From Gabrielle Snodgrass to the Right Honorable henry Dundas." (London: 1711), p.30. He also advocates proper care of the forests.

12.Ibid., p.23.

13.G.R. Barnes and J.H. Owen, eds., Sandwich Papers, 1770-1782 (Navy Records Society, 1976), pp.14-15. Mr. William Wells to Lord Sandwich Feb 20th 1771.

14.Colonel Spencer Childers, ed., A Mariner of England: An Account of the Career of William Richardson from Cabin Boy in the Merchant Service to Warrant Officer in the Royal Navy, 1780-1819, as Told by Himself. (London: John Murray, 1908), p.108.

15.Albion, Forests, pp.306-7.

16.Parliament History, XIX p.885, cited in Albion, Forests, pp.314-315.

17.Albion, Forests, pp.58-9.

18.Ibid., p.39.

19.Paul Lucas, American Odyssey (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1984), p.269.

20.Ibid., p.138.

21.Ibid., p.139.

22.Ibid.

23.George Rude', The Eighteenth Century: 1715-1815 (New York: The Free Press, 1965), p.18.

24.Lucas, Odyssey, p.272; William Cumming & Hugh Rankin, The Fate of a Nation (New York: Phaidon Press LTD., 1975), p.8.

25.Albion, Forests, p.42.

26.Ibid., p.43.

27.Ibid., p.41. They did have a three year supply in 1775 when the American supply was terminated but had not found a suitable replacement by 1778.

28.Ibid., p.49.

29.Lavery, Wooden Wall, p.62.

30.Albion, Forests, p.68.

31.Ibid., p.72.

32.Ibid., p.64.

33.Lesser dockyards existed, such as Harwich, but were not as relevant to the timber trade.

34.Baugh, Naval Administration, p.262.

35.Ibid., p.263.

36.Lavery, Wooden Wall, p.52.

37.Jonathan Coad, Historic Architecture of the Royal Navy (London: Victore Gullancz, LTD., 1983), p.19.

38.R.J.B. Knight, "Pilfering and Theft from the Dockyards at the Time of the American War for Independence." Mariner's Mirror, Vol. 61, 1975, p.218.

39.The business involved large contracts. The navy dockyards used up to 30,000 loads of oak a year, or 1,500,000 cubic feet of lumber.

40.Knight, "Pilfering and Theft", p.218.

41.Ibid., p.216.

42.Albion, Forests, p.87.

43.Ibid. This sounds like an exaggeration, but if corruption levels in all 6 yards are correct it might possibly add up to Admiral Warren's statement.

44.Ibid., p.89.

45.Joseph Goldenberg, Shipbuilding in Colonial America (Charlottesville: University of Virginia, 1976), p.53.

46.Ibid., p.55.

47.Stewart R. Brown, Liverpool Ships in the Eighteenth Century (London: Hodder and Stoughton, 1932), p.70.

48.Ibid., p.72.

49.Lavery, Wooden Wall, p.57.

50.Baugh, Naval Administration, p.239; Dodds and Moore, Wooden Fighting Ship, p.17.

51.Albion, Forests, p.106.

52.Baugh, Naval Administration, p.239, By 1771 the New Forest supplied only 870 loads out of 6,000 to Portsmouth and the Forest of Dean supplied comparable amounts to Plymouth.

53.Lavery, Wooden Wall, p.57.

54.Ibid., p.113.

55.Baugh, Naval Administration, p.239.

56.Gipson, The British Empire, p.210.

57.Arthur M. Lower, Great Britain's Woodyard: British America and the Timber Trade, 1763-1876 (Montreal: McGill-Queen University Press, 1973), p.14. Baltic timber was named after the exporting port, for example: Memel oak, Riga fir.

58.Joseph Malone, "England and Baltic Naval Stores Trade in the Seventeenth and Eighteenth Centuries.", Mariner's Mirror, Vol.58 p.375.

59.Albion, Forests, p.145.

60.Albion, Forests, p.148; Lower, Great Britain's Woodyard, p.22.

61.Albion, Forests, pp.145-6.

62.Albion, Forests, p.148; Dodds and Moore, Wooden Fighting Ship, p.19.

63.Albion, Forests, p.153.

64.Mary Miller, "Naval Stores and Anglo-Russian Encounters in the Baltic: The English Expedition of 1715.", in Ships, Seafaring, and Society, Tim Runyan, ed. (Detroit: Wayne State University Press, 1987), p.168.

65.Ibid., p.172.

66.Ibid., p.176.

67.Journal of the Commissioners For Trade and Plantations, Colonial Series (Public Record Office, 1969), Vol.2 (1708-1715), p.174.

68.Ibid., p.176; Miller, "Naval Stores and Anglo-Russian Encounters," pp.176-7.

69.Albion, Forests, p.165. The Sound was important because if it closed no maritime trade could occur between the Baltic and the outside world.

70.Small refers to masts 8-12 inches in diameter, middling refers to masts 12-18 inches in diameter and great refers to masts above 18 inches in diameter. This table is somewhat misleading, although the Baltic area had masts over 18 inches in diameter, the Northern colonies were still the primary source for masts over 31 inches in diameter. Masts from the northern colonies most likely represented masts over 31 inches in diameter.

71.Malone, "England and Baltic Trade", p.375; Joshua Gee, Trade and Navigation and Navigation of Great Britain Considered (London: Sam Buckley, 1739), pp.16-17; Lower, Great Britain's Woodyard, p.13.

72.Baltic mast importation was monetarily higher than New England. The following is a breakdown of the amount of Navy Board contracts for masts imported from 1694 to 1775. The chart shows neither area dominated overall timber trade. Malone, Pine Trees, p.55.

73.Lucas, Odyssey, p.129.

74.Albion, Forests, p.238. Gee, Trade and Navigation, p.85.

75.Jensen, English Historical Documents Volume IX: American Colonial Documents to 1776. (New York: Oxford University Press, 1955), p.353.

76.Arthur Meier Schlesinger, Colonial Merchants and the American Revolution (Columbia: University of South Carolina, 1987), p.35; Malone, Pine Trees, p.IX; Sir Josiah Child, A Discourse About Trade (London: A. Swole, 1690), pp.4,5; Samuel Eliot Morison and Henry Steele Commager, The Growth of the American Republic Vol.1 (New York: Oxford University Press, 1962), p.75.

77.Child, Discourse, pp.94-5.

78.Schlesinger, Colonial Merchants, p.16; Malone, "England and the Baltic Naval Stores." p.384.

79.Lucas, Odyssey, pp.68,268.

80.Macpherson, Annals of Commerce (London: Johnson Reprint Corporation, 1972), p.724.

81.Gee, Trade and Navigation, p.65.

82.MacPherson, Annals of Commerce, p.724.

83.Gipson, British Empire, p.289.

84.James F. Shepard and Gary M. Walton, Shipping, Maritime Trade and the Economic Development of Colonial North America (London: Cambridge University Press, 1972), p.51.

85.Gipson, British Empire, p.15.

86.Albion, Forests, p.233.

87.Lower, Great Britain's Woodyard, p.28.

88.Some English merchants worried that colonial-built ships would eventually dominate trade.

89.Gipson, The British Empire, p.11; By 1720, Boston was producing 200 ships annually. By 1740 Boston was declining as a ship building empire, though still remained prominent. Smaller towns such as Newbury were able to produce cheaper vessels yet larger cities such as Boston and Philadelphia retained most of the ship construction. Carl Bridenbaugh, Cities in the Wilderness (New York: Alfred A. Knopf, 1955), pp.184,337; Carl Bridenbaugh, Cities in Revolt (New York: Alfred A. Knopf, 1955), p.269.

90.Gipson, The British Empire., p.7.

91.Virginia Steele-Wood, Live Oaking (Boston: Northeastern University Press, 1981), pp. 14,19.

92.Julian Gwyn, "Shipbuilding for the Royal Navy in Colonial New England." American Neptune, Vol.48 #1, p.23.

93.Malone, Pine Trees and Politics, p.3.

94.Gee, Trade and Navigation, p.23.

95.Albion, Forests, p.75; Jensen, Historic Documents, p.413; Journal of the Commissioners, Vol.1, pp.30,303; Frederick Hocker, Personal Communication; Evarts Boutell Greene, The American History: A Nation (New York: Harper & Brothers Publishers, 1905), p.37.

96.Journal of the Commissioners, Volume 3, (1714-1718) pp.212-213.

97.Malone, Pine Trees, p.38.

98.Ibid.

99.Ibid., pp.29,46.

100.Ibid., pp.36-7.

101.Steele-Wood, Live Oaking, pp.12,25.

102.Poor quality and expense attributed to a dislike of colonial products. This inclination continued even after Parliament placed premiums on American naval stores to encourage importation. Though quality slowly improved, English merchants still reacted negatively towards American products. Malone, Pine Trees, pp.21,58; Journal of the Commissioners, Vol. 1 (1704-1709), p.184. The Board of Trade considered naval stores as an essential export for the colonies and wanted to encourage naval stores production while discouraging the production of other manufactures.

103.Malone, Pine Trees, p.61.

104.Ibid., p.62.

105.Leonard Woods Labaree, ed., Royal Instructions to the British Colonial Governors, 1670-1776 (N.Y.: Appleton-Century Co., 1935), p.598.

106.Macpherson, Annals, pp.13-14; Malone, Pine Trees, p.70; Labaree, Royal Instructions, has it as early as 1708, p.598.

107.Gee, Trade and Navigation, p.105.

108.Malone, Pine Trees, p.59.

109.Ibid, pp.51-88, 89.

110.Journal of the Commissioners, Vol.3 (1714-1718), pp.42-43.

111.Ibid., p.52.

112.Ibid., p.173.

113.The Journal of Commissioners and Journal of Trade and Plantations in the PRO contain letters to and from Bridger about his ability to protect the trees.

114.Journal of the Commissioners, Vol.4 (1718-1722) p.319, this does not take effect until 1721.

115.Malone, Pine Trees, p.82; Journal of the Commissioners, Vol.4. p.390.

116.Journal of the Commissioners of Trade and Plantations and the Calendar of State Papers are filled with accusations from various men in both England and North America. Further research finds these men with interests in a number of sawmills or in the profiting of sawmills.

117.Malone, Pine Trees, p.83.

118.Journal of the Commissioners, Vol.4 (1718-1722), pp.390-391.

119.Malone, Pine Trees, p.88.

120.Malone, Pine Trees, p.76; Baugh, Naval Administration, p.249.

121.Charles Andrews, The Colonial Period of American History (New Haven: Yale University Press, 1938), p.247.

122.Journal of Commissioners, Vol.4 pp.332-333.

123.Journal of the Commissioners, Vol.4 (1718-1722), p.333.

124.Journal of the Commissioners, Vol.5, (1723-28), p.390.

125.Gee, Trade and Navigation, p.85.

126.Macpherson, Annals, V.3, pp.144-5 Previously the act stated any tree outside of townships. The colonists, however, began forming townships comprising only two or three families covering hundreds of acres. To alleviate this problem, Parliament revised the act to include townships.

127.Albion, Forests, p.255; Malone, Pine Trees, p.98.

128.Albion, Forests, p.241.

129.Ibid., p.260.

130.Ibid., p.254.

131.Journal of the Commissioners, Vol.5, 1723-28, p.373.

132.Ibid., pp.262-4.

133.Malone, Pine Trees, p.102.

134.Ibid., p.119.

135.Calendar of State Papers: Colonial Series, America and West Indies, Vol.XLII (1735-1736) (London: Public Records Office.), p.388.

136.Ibid.

137. <u>Ibid</u>., Vol XLIII (1737), p.202.

138. Malone, <u>Pine Trees</u>, pp.120-121.

139. <u>Ibid.</u>, p.120.

140. <u>Ibid</u>., pp.122,127.

141. <u>Ibid</u>., pp.128,131-132, May 11, 1759, CO s/927 Nov 9 1758, CO 5/94. At this time confiscated logs became crown possession and subject to governmental restrictions.

142. <u>Ibid</u>., p.135.

143. <u>Ibid</u>., pp.135,136.

144. <u>Ibid</u>., p.138.

145. Macpherson, <u>Annals</u>, p.418. (5 George III C.45)

146. <u>Ibid</u>., p.512.

147. Albion, <u>Forests</u>, p.28.

147. Sutherland, <u>Prices of Labour</u>, p.204.

149. Albion, <u>Forests</u>, p.392.

150. Gwyn, "Shipbuilding for the Royal Navy," p.30.

151. <u>Ibid</u>., pp.329-46.

CHAPTER THREE

Introduction

"...The successful applications of wood since prehistoric times have depended upon understanding, exploiting and exploring the subtle differences encompassed by wood."[1] Centuries of experimentation and observation generated a body of information that enabled shipwrights to select and utilize proper species for ship construction. The inherent qualities of a species led to either disastrous or favorable results, regardless of quality or how well seasoned. Shipwrights and naval architects who inherited this knowledge applied it when building ships in the eighteenth century.

This chapter will examine different woods used in ship construction. The first section outlines different structural elements and their requirements (Figure 3.A). It was imperative that shipwrights and naval architects understood the stresses and conditions each ship element underwent. This knowledge enabled them to select the best wood to meet those requirements.

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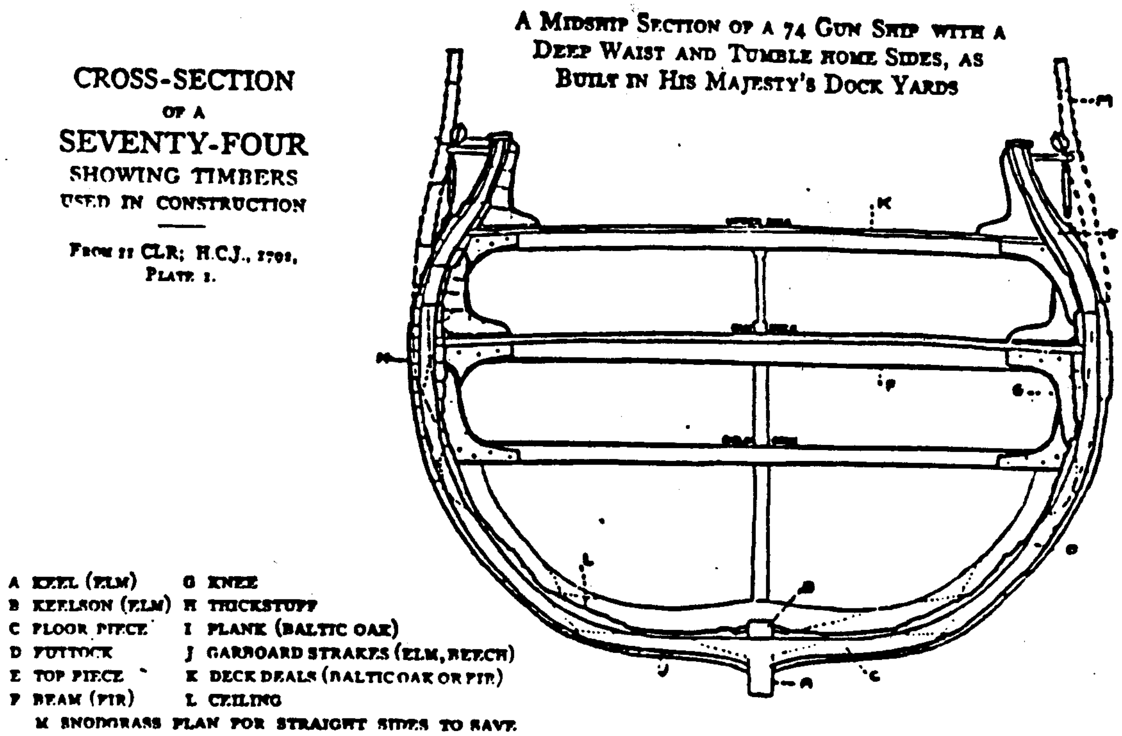
FIGURE 3.A



(Albion, Forests, p.8.)

however, "ideal" woods have those qualities in appropriate quantities. These three factors are among many qualities essential for building long-lasting ships. Obviously, the best woods were not always selected as extenuating conditions precluded the use of some woods. The second section describes various woods used in eighteenth-century ship construction. Only the more commonly used species are examined as it is impossible to account for every possible wood.

Requirements for Construction

When building a long-lasting structure such as a house, the workers and designers know that different areas required specific materials. The same principles apply to ship construction. Different structural elements undergo varying stresses and environments and therefore have unique requirements (Tables 3.A). The following are some major structural elements found in ships, their requirements and conditions. Local variations and extenuating circumstances are not considered when discussing ideal woods. Following chapters will explore local traditions and adaptations not discussed at this time.

Before discussing a vessel's requirements, the following is a brief outline of terms used in this chapter.[2]

Density
: Mass per unit volume.

Durability
: Resistance to decay or deterioration.

Elasticity
: Ability to recover original dimensions after being distorted.

Hardness
: Ability to resist denting, related to ease of working.

Permeability
: Rate of flow of gas or fluid in wood.

Strength
: The ability to resist a load or stress.

Stress
: Force per unit volume.
: Compression is a force reducing volume or dimensions.
: Shear is a force moving one part parallel to another.
: Tensile or tension is a force increasing volume or dimensions.

Toughness
: Amount of energy absorbed before breaking.

Table 3.A
COMPARATIVE PHYSICAL DATA FOR HARDWOODS NATIVE TO THE UNITED STATES

Common name of wood a (1)	Sp gr, average: Green (2)	Sp gr, average: 12% (3)	Weight lb/cu ft: Green (2)	Weight lb/cu ft: 12% (3)	Shrinkage based on green dimension, % b: Volume (6))	T (7)	R (8)	T/R (3)	Index classes to mechanical properties c: Bending strength (10)	Compression as a post (11)	Hardness (12)	Stiffness (13)	Shock resistance (14)	Splitting (15)	Screw holding (16)	Ability to stay in place (17) d	Drying defects (18) e	Machining qualities (19) f	Gluing qualities (20) g	Durability rating (21) h
Elm, American	0.46	0.50	54	35	14.6	7.2	4.2	2.3	3	4	3	3	3	2	2	5	3	P	2	S
Elm, rock	0.57	0.63	53	44	14.9	8.1	4.8	1.7	2	2	2	3	2	2	2	5	3	P	2	S
Elm, slippery	0.48	0.53	56	37	13.8	8.9	4.9	1.8	2	3	3	3	3	2	2	5	3	P	2	S
Maple, red	0.49	0.54	50	38	12.6	8.2	4.0	2.0	3	3	3	1	4	3	2	3	3,4	A	3	S
Maple, sugar	0.56	0.63	56	44	14.7	9.9	4.8	1.9	2	2	2	1	3	1	2	4	3,4	G	4	S
Oak, live	0.80	0.88	76	62	14.7	9.5	6.6	1.4	1	1	1	1	2	1	1	4	3,4,5	P	4	R
Oak, red j	0.57	0.62	64	43	14.7	8.9	4.2	2.1	2	3	2	2	3	2	2	4	3,4,5	G	3	S+
Oak, white k	0.59	0.67	63	45	15.9	9.2	5.3	1.7	2	2	2	3	3	2	1	4	3,4,5	G	3	R
Walnut, black	0.51	0.55	58	38	12.8	7.8	5.5	1.4	2	2	2	2	3	2	2	2	2,5	G	3	R
Willow, black	0.36	0.39	50	26	13.9	8.7	3.3	3.1	5	5	5	5	3	4	4	3	3	P	1	S
Yellow-poplar	0.40	0.42	46	30	12.7	8.2	4.7	1.8	4	4	4	3	4	4	4	2	2	A	1	S
Baldcypress	0.42	0.46	51	32	10.5	6.2	3.8	1.6	4	3	5	3	4	4	3	2	1	A	3	R,M
Larch, western	0.48	0.52	50	36	14.0	9.1	4.5	1.9	3	2	4	2	4	4	2	3	2	A	1	M
Pine, eastern white	0.34	0.35	36	25	8.2	6.1	2.1	2.6	5	4	5	4	5	5	5	1	2,4	G	2	M
Pine, lodgepole	0.38	0.41	39	29	11.1	6.7	4.3	1.5	5	4	5	3	5	4	4	2	2	A	2	S+
Pine, longleaf	0.54	0.59	55	41	12.2	7.5	5.1	1.5	2	2	4	1	3	4	2	3	2	A	2	M
Pine, ponderosa	0.38	0.40	45	28	9.7	6.2	3.9	1.6	5	4	5	3	5	4	4	2	2	A	2	S+
Pine, red	0.14	0.46	49	30	11.3	7.2	3.8	1.6	5	4	5	3	4	4	3	2	2	A	2	S+
Pine, shortleaf	0.47	0.51	52	36	12.3	7.7	4.6	1.8	3	3	4	2	4	4	3	3	2	A	2	S+
Pine, sugar	0.34	0.36	52	25	7.9	5.6	2.9	1.9	5	4	5	3	5	4	5	1	2	G	2	S+
White-cedar, atlantic	0.31	0.32	26	23	8.8	5.4	2.9	1.69	5	4	5	5	5	5	5	2	1	A	2	R

Column no.	Mechanical property	Index classes: 5	4	3	2	1
10	Modulus of rupture in bending, green wood, psi	<6000	6000 to	7000 to	8000 to	11,000+
11	Maximum crushing strength parallel, green wood, psi	<2200	2200 to	3000 to	3600 to	4500+
12	Side hardness, green wood, lb	< 400	400 to	600 to	900 to	1200+
13	Modulus of elasticity in bending, psi x 1000	< 800	800 to	1000 to	1300 to	1500+
14	Height of drop with 50-lb hammer, in	15 to	25 to	35 to	50 to	70+
15	Load, lb/in of width to split green wood	< 150	150 to	250 to	350 to	450+
16	Nail and screw withdrawal as function of sp gr OD	< 0.40	0.40 to	0.45 to	0.55 to	0.70+

d Dimensional changes with moisture in normal use ranges from Class 1 with little change, to Class 5 with greatest dimensional change.
e Drying defects classed as follows: 1. Slight warping and little dimensional change. 2. Distinct warping. 3 Pronounced warping. 4. Tendency to check and split. 5. Subject to collapse and honeycombing.
f Machining qualities: G = good to excellent, smooth surface. A = average, P = poor, requiring care to be acceptable
g Gluing qualities: 1. Glues very easily. 2. Glues well. 3. Requires control. 4. Difficult to glue, requires close control.
h Heartwood durability ratings: R = resistant to decay. M = moderate resistance to decay. S = low decay resistance. + Indicates high rating within the group.

(Panshin, Textbook, pp.499-501,641-643.)

Keel and Keelson

Keels are the "backbone" of vessels. They run longitudinally and support much of the vessel's structure. Keelsons give added support and stability. Together their main tasks are to help brace masts mortised into the keelson, to "anchor" the floor timbers and to provide longitudinal support.

The keel and keelson require woods that are extremely strong, durable, stiff and hard as much of the vessel's stress and weight rests here. The strongest keels and keelson are made of one piece and require trees of exceptional length, size and straightness. Keels do not need seasoning since they are exposed to water, but keelsons are seasoned to increase durability and help prevent dry-rot.

Woods such as white oak and elm are ideal for the keel and keelson. Both species are hard, strong, durable and grow to great heights and sizes. Larger trees allow fewer segments, thus increasing overall strength. Elm is particularly advantageous in the keel because of its height and durability without seasoning.

Stem and Stern Post

Stems are vertical members terminating the forward end of the vessel. Stern posts are vertical members terminating aft. The two pieces are scarfed into, butt against, or are mortised and tenoned into the keel and help contribute to the ship's overall strength. The stern post has the additional stress of bearing the rudder. Both stems and stern posts are exposed to water and therefore require the same properties of strength, permeability and durability as the keel.

White oak is the ideal wood for stems and stern posts. It is strong, durable and impermeable. Elm is not a good wood for stems and stern posts because it decays quickly in the intermittently dry/wet zones above the waterline.

Frames

Frames are transverse pieces which give a ship its shape. They form the "ribs" of a vessel to which planking is attached. Frames are comprised of floor timbers, futtocks and top timbers. Floor timbers rest between the keel and keelson. Futtocks are attached to the floor timbers and create the lower tiers of the side. Top timbers are attached to futtocks and comprise the ship's uppermost tiers (See Figure 3.A).

Frames must tolerate varying forces and conditions while providing overall support. Although frames are not exterior elements, the damp environment between the ceiling and planking necessitates a durable wood able to endure wet and dry conditions. Some frames, especially futtocks, must curve, introducing further stress. Ideally, this curvature is obtained naturally in compass timber, but this is not always possible, necessitating the wood be sawn to shape.

As with most structural timbers, white oak is preferred. Since it is highly durable, strong and hard, white oak is ideal for framing. Live oak grows with extremely crooked limbs, making it ideal for fitting the ship's curvature. Live oak is also extremely strong, dense and durable.[3] Other possible woods for frames are beech and elm.[4] Beech and elm are strong, tough woods. Elm also has an interlocked grain allowing it to take fasteners easily without splitting.[5]

Ceiling and Planking

The primary purpose of ceiling and planking is to provide longitudinal strength and rigidity, and to repel water.[6] Ceiling covers the interior side of frames while planking covers frame exteriors. Impermeability to water depends upon proper installation of planking on both interior and exterior surfaces.[7]

Ceiling and planking have to be strong, durable and water resistant. Ceiling requires woods able to endure damp environments and constant abrasion by stores, ballast and men. Planking requires wood capable of enduring wet environments or wet/dry environments. All planking has to be flexible enough to withstand unnatural bending to fit the ship's curves.

There were two major wood groups used for eighteenth-century planking: oak and southern yellow pine. Each combines strength, durability and a strong ability to hold fasteners. Oak withstands bending but southern yellow pine does not swell or shrink as much as oak. The two woods were easily worked, hard, strong and readily available in the eighteenth century.

Deck Planking

Deck planking supports transverse stresses, adds stiffness and helps prevent hogging or sagging. The planking must withstand constant wear from men and equipment and remain watertight to protect interior sections of the vessel. The wood needs to be tough and hold fasteners well with little shrinkage or swelling.[8] Deck planking, therefore, requires a hard wood with good compressive and bending strength, yet light in weight.

Softwoods, such as red, scots or southern yellow pine are good woods for deck planking.[9] All three woods are resinous. When resin dries it hardens, creating better endurance, wear and resistance.[10] Douglas fir, though resinous, was not utilized in the eighteenth century because the tree grows only in the western United States and Canada and was therefore unavailable.

Sheathing

Sheathing, or sacrificial planking, is fastened to the exterior surface of the outer hull. It helps preserve the vessel's structural integrity. Its chief purpose is to protect the outer hull against ice, damage due to grounding and marine organisms.[11] Sheathing needs to be hard enough to endure constant abrasion by water, sand and rock.

The wood should be strong, and capable of lasting in a wet or wet/dry environment. Resinous woods such as red/scots pine lasted well in this environment because the resin helps repel water.[12] Sailors and shipwrights believed that resin discouraged worms from attacking. They thought the resinous odor and taste were unpleasant to marine organisms and would therefore prevent them from destroying the wood.

Red/scots pine is the ideal wood for sheathing. Southern yellow and other pines are secondary sheathing alternatives. Before the resin hardens, red/scots pine is elastic enough to easily conform to a vessel's curvature. As discussed previously, southern yellow pine and red/scots pine were strong, hard and readily accessible woods.

Treenails

Treenails are wooden fasteners that hold ship's timbers together. They are wooden dowels set into bored holes and often wedged at the ends. Iron fasteners were used in the eighteenth century and although it is outside the study's scope, iron was by no means a minor factor in eighteenth-century ship construction.

Treenails are found in most areas of a vessel. If wood still exists on a site, there is a high probability of archaeologically recovering treenails. Treenails have to be strong and durable to hold two planks together under any conditions. They cannot shrink, warp or crack with changes in humidity or environment. If this occurs the vessel will leak or fall apart.

White oak is good for this task because it fulfills the majority of requirements. White oak is strong, tough, hard and impermeable though it shrinks and swells. Other woods are available but lack the combined properties or availability of white oak. Pine, though often used, is more stable, but is not as durable or tough as white oak.

Knees

Knees help reinforce the vessel's overall strength and durability. They are primarily used to reinforce angular joints between timbers. They are used where additional bracing is needed as in a beam or deck support. Knees are found in all levels of the vessel. The strongest knees are derived from compass, or naturally crooked, timber. Artificially cut or bent knees introduce additional weaknesses into the wood.[13] They have to be durable, strong, and not warp or check with environmental changes to effectively strengthen the vessel.

Knees were traditionally made of the same wood used throughout the vessel. Possible woods include southern yellow pine, live oak, white oak and larch. All are strong, tough, durable woods with minimal warping.[14]

Blocks

Blocks facilitate lifting of equipment and stores, and help adjust the standing and running rigging. Blocks must withstand extreme stress and constant abrasion by lines. Block woods must be strong, wear well and resist shock. The best blocks are made from woods with natural lubricants facilitating the movement of sheaves and ropes.

The favorite block woods are elm, ash or lignum vitae. These tree woods are used for shells while lignum vitae is most common for sheaves.[15] Lignum vitae is extremely strong with natural oils that lubricate the sheaves and lines. Elm, ash and lignum vitae are strong hard woods able to withstand extreme shock and abrasion.

Masts and Spars

Masts and spars require woods that are elastic yet strong and durable. They need to be strong enough to hold sails, rigging and men, and yet not brash, or brittle, lest they snap. Taller trees were needed to eliminate the demand for less efficient composite masts, composed of a number of smaller trees bound around a central spindle.

Red/scots pine, white pine and spruce were the three species most used for masts and spars.[16] These woods are light weight and less apt to split, crack or warp than many hardwoods. They had to resist wind shear and stress from the sails and rigging. Both red/scots and white pines reach heights of over 100 feet. This allowed masts to be made of one tree rather than many smaller ones.

Furniture

Compared to other structural features, ship's furniture comprises a small percentage of wood. Sailors lacked room, money or a need for large amounts of furniture. Eighteenth-century basics included cupboards, tables, benches, beds and sea chests.

Eighteenth-century ship's furniture was generally not a specific category or made from a specific set of woods but represented adaptations from land furniture styles.[17] Adaptations include rounded corners and edges, as well as fittings to fasten the piece down.[18] Further alterations are needed because furniture had to fit between existing structures such as knees or beams. Furniture also had to be collapsible or small enough to be stowed away.[19]

There are no ideal woods for shipboard furniture. Eighteenth-century ship's furniture was made of oak, pine, walnut, mahogany and fruitwoods such as cherry.[20] Walnut and mahogany were favorite eighteenth-century furniture woods. Oak and pine were used for lower-class vernacular items while mahogany was used in elite furnishings.

Casks

Wood containers, especially casks, were an essential aspect of eighteenth century life. Almost every item, both liquid and dry, was shipped, stored and sold in casks. Proper construction and wood selection were therefore imperative for preserving foodstuffs for storage on long voyages.

There are two basic types of barrels: tight and slack. Tight cooperage is for holding liquids such as water, ale, molasses and wine. Tight casks are made from woods that were durable and impervious to liquids. They are harder to make than slack casks because they must hold liquids, withstand internal pressures of fermentation and bear the strain of transportation.[21] Their staves are thicker and fit precisely against one another. White oak was the best wood for tight casks since it is durable, strong, water impermeable and left no taste on its contents.

Slack cooperage holds dry goods such as peas, oatmeal, meat, flour and corn. Less stringent requirements meant slack casks were made of woods such as red oak, ash, chestnut, beech, fir and pine.[22] These woods are neither as durable nor as water-resistant as white oak. They lack inherent qualities for preventing water penetration or seepage and therefore could not be used for tight cooperage.

Wood Species

There are two major types of wood: hard and soft. Hardwoods are broad-leafed porous trees such as elm, oak and maple. Softwoods are non-porous needle-like-leafed trees such as pine. The two groups exhibit a wide variety of properties and characteristics. Some hardwoods are extremely hard while others are softer than many softwoods. An explanation of wood structure is detailed in Appendix A.

The following are those woods most commonly found in eighteenth-century ship construction. These woods are derived from excavated wood samples and reflect those species found in vessels discussed in this thesis. Given the range of vessel types and the sampling size, the wood species listed here should be considered representative of the most common woods actually used in ship construction.

Hardwoods

Ash

Ash is separated into two main groups: white and black. The white ash group includes white ash (Fraxinus americana), green ash (Fraxinus pennsylvanica) and Oregon ash (Fraxinus latifolia).[23] The second group black, or brown, ash is Fraxinus nigra. Less common ashes include Carolina ash (Fraxinus caroliniana), pumpkin or red ash (Fraxinus profunda) and blue ash (Fraxinus quadrangulata).[24] The various species of ash are difficult or impossible to differentiate microscopically.

Most ash varieties grow in the eastern United States though some species are found in the western United States. American white ash (Fraxinus americana) grows throughout eastern North America from Maine to Florida.[25] European ash (Fraxinus excelseor) is found throughout Europe, Norway, Sweden and Great Britain.[26] Microscopically, there is little difference between American and European ash.[27] White ash commonly grows between 80 to 100 feet with a diameter of 2 feet but can reach heights of 125 feet with a diameter of 4 feet.[28]

American ash is tough, strong, elastic and shock resistant.[29] European ash though having the same properties was considered superior to American ash.[30] Ash is easy to work because it is pliable, splits and seasons well. Although it does warp or check and is too elastic for most structural work.[31] Ash is not durable, even after seasoning.[32] Like elm and birch, ash will not last in an intermittent dry/wet zone.[33] Thomas Laslett contended that ash was durable only if felled in winter and seasoned properly; if not, then the wood would be extremely perishable.[34]

Ash is commonly used in furniture, boxes, baskets and toys.[35] Additional uses include oars, handles, bats and other purposes where hardness, strength and a "capacity for wearing smooth" are needed.[36]

Beech

There are two species of beech, American beech (Fagus grandifolia) and European or common beech (Fagus sylvatica). American beech grows in the eastern United States where it reaches heights up to 130 feet.[37] European beech grows throughout central Europe and in central and southern England.[38] It reaches heights of 60-70 feet but can grow up to 110 feet.[39]

American beech has two important disadvantages in ship construction; it is not very durable in an intermittently dry-wet zone and it is difficult to season.[40] Another disadvantage of American beech is that it is highly susceptible to warping and fungus. If the timbers are not seasoned properly or warp from the desired shape, the vessel decay or leak.

European beech has the same general characteristics as American. It is strong, hard and heavy but does not last well in wet-dry zones.[41] European beech is not as brash, i.e. does not break easily during the bending process, as American.

American beech is hard to microscopically separate from the European variety although the American species sometimes has crystals in its longitudinal and ray parenchyma cells.[42] Beech, both American and European, has large rays inhibiting radial shrinkage.[43] This aspect, along with tyloses in the heartwood, makes beech a comparable wood to white oak. Beech and white oak are the only two hardwoods with large enough rays to restrict radial shrinkage.

Birch

The name birch is indiscriminately applied to all birch species. The species are: yellow (Betula alleghaniensis); sweet, black or cherry (Betula lenta); river or red (Betula nigra); paper or white (Betula papyrifera); European (Betula pendula); and gray (Betula populifolia).[44] The different species of Betula cannot be microscopically differentiated.

Birch grows in a variety of areas and environments. Most birch species are found in the eastern United States and northern latitudes of the North American continent.[45] European species such as Betula pendula grow throughout Europe and Asia Minor.[46] A more hardy species, Betula pubescens, exists in the tundra near the Arctic Circle.[47]

Birch grows to heights of 40 to 100 feet but usually averages 60 to 80 feet.[48] It has a maximum diameter of 1-2

1/2 feet.[49] European birch (Betula pendula) is comparable to other species of Betula with a height of 50 feet and an average diameter of one foot.[50]

Birch is a sturdy, tough, hard and compact tree.[51] It is not very strong or durable, however, and like elm, birch must be kept either exclusively wet or exclusively dry.[52] Birch was more common as a secondary furniture wood. In the North American colonies birch and white pine were considered the premier secondary woods for furniture.[53] In the last half of the eighteenth century birch and maple became popular primary woods for making Windsor style chairs.[54] Birch was also used for slack cooperage, toothpicks, cabinets and toys.[55]

Chestnut

There are two major species of chestnut, American (Castanea dentata) and Spanish (Castanea sativa). American chestnut grows east of the Mississippi River from Georgia to Ontario.[56] Spanish chestnut grows throughout Europe including Britain.[57] Chestnut's range is not as great today because a fungus in the early twentieth century nearly wiped out the species.[58]

American chestnut reaches heights of 60-100 feet with a diameter of 2-4 feet.[59] Spanish chestnut is shorter, reaching heights of 60-80 feet.[60] Chestnut is durable in wet or dry conditions. It is light, works well, has moderate shrinkage and does not warp.[61] Sources recommend chestnut for slack cooperage and other uses such as tannin, posts, and mill work. It is also a leading wood for furniture, caskets, doors and panels because it splits cleanly and straight.[62]

Elm

There are three elm groupings; American or white elm (Ulmus americana), slippery or red (Ulmus rubra), and hard. Hard elm includes rock, (Ulmus thomasii) winged (Ulmus alata), and cedar (Ulmus crassifolia).[63] The term elm is indiscriminately applied to all species as they are relatively similar in physical properties. The different species, however can be microscopically and macroscopically differentiated.

American elm is found throughout the eastern United States. Elm flourished all over Britain though it tended to grow singly rather than in clumps or groups. This sparse nature led to its rapid decline when subjected to harvesting in Great Britain.[64] American elm grows to heights of 100-130 feet. It can be felled as early as 50-60 years, though it is most valuable when allowed to grow up to 100 years.[65]

Elm is heavy, tough, strong and hard to split.[66] It takes fasteners well since it has an interlocked grain.[67] The interlocked grain prevents the wood from splitting easily.[68] The grain tends to warp when seasoning, however, making the wood difficult to process properly.[69] In an intermittent dry-wet zone elm is not durable, but is long-lasting if kept exclusively underwater.[70] In underwater situations, as with the keel, the wood does not need seasoning. Since green elm does not decay easily under water or in damp environments and is a straight and strong wood, it is the ideal keel and keelson wood.

Lignum Vitae

Lignum vitae (Guaiacum officinale) is one of the hardest and heaviest known woods. It is found only in Central America and the West Indies, where it grows to between 30-40 feet in height.[71] It is extremely decay resistant and naturally lubricated.[72] It was most commonly used for sheaves where it was unsurpassed in quality.[73]

Live Oak

Live oak (Quercus virginiana) is different from the other oaks because it is an evergreen, meaning it does not lose its leaves. It can be microscopically differentiated from other oaks. Live oak has aggregate rays distinguishing it from the broad, simple oak-like rays. It is also diffuse porous rather than ring porous like the red and white oaks.

Live oak grows in the United States from Virginia to southern Texas.[74] It is relatively short, reaching heights of only 40-60 feet.[75] The main trunk is divided into many branches, though its branches can be larger than trunks of other species.[76] This feature makes live oak one of the best trees for compass timber. The natural curves give its branches more strength than artificially bent or manufactured ones.

Live oak was better for construction than white oak because of its high durability, strength and hardness.[77] It was difficult to cut and process, however, making it less profitable for southern merchants. The very properties which made it good for ship construction may have prevented extensive utilization. An extremely dense and water resistant wood, live oak was difficult to work and took a long time to season.[78] As with white oak, the wood's impermeability made it hard for water to disperse. A restricted growing sphere and difficult processing limited live oak's use until the mid-nineteenth century when high naval demand made harvesting profitable.

Mahogany

There are many varieties of mahogany. The most common species is Spanish mahogany (Swetenia mahogoni). Other varieties include Honduras mahogany (Swetenia macrophylla) and a closely related tree, African mahogany (Khaya _ivorensis_). Though similar, these two species did not attain the status of Spanish mahogany.[79]

Spanish mahogany grows in Cuba, West Indies and Central America.[80] It grows up to 100 feet tall and can measure 40 feet in circumference.[81] It is a slow growing tree, taking up to 200 years to reach maturity.[82] Mahogany also takes a long time to season because it is dense and has gum occluding some of its pores.[83] As with most tropical woods mahogany lacks growth rings; vessel size and wood density remain constant throughout the tree. It is moderately strong, rigid, tough and works well without warping or shrinking.[84]

Mahogany was also well known for shipbuilding. Spanish explorers used mahogany to repair their vessels in the New World.[85] It was better than oak for ship construction because it was as strong as oak but did not react badly to iron. Spanish mahogany provided large durable planks and a valuable commodity in Europe and North America.[86]

Mahogany is one of the more sought after woods for furniture because of its massive size, ease in working and beautiful appearance.[87] Mahogany replaced walnut in popularity for furniture in the late seventeenth century. By the mid-eighteenth century, most finer pieces of English furniture were mahogany.[88] The movement towards mahogany gradually made its way overseas and by the 1730's mahogany was beginning to supplant walnut's popularity in the American colonies.[89] Mahogany's expensive price limited it mostly to upper-class homes though some inventories show its use in middle-class houses.[90]

Maple

Maple consists of two groups: hard and soft. Hard maple includes sugar (Acer saccharum) and black or rock (Acer nigrum). Soft maple includes red (Acer rubrum) and silver (Acer saccharinum).[91] The two groups can be microscopically separated because hard maples have uniseriate and multiseriate rays, while the soft have only uniseriate.[92] Species within the maple groups, however, are hard to identify with any degree of certainty.

Hard maples grow in the north-eastern and Great Lakes region of the United States and Canada as well as Europe.[93] Soft maples are found in essentially the same areas as hard but their range extends southward to Florida and Texas.[94] Hard maples grow up to 100-125 feet in height with a possible diameter of four feet.[95] Soft maples' height is comparable to the hard, growing 80-100 feet.[96] Hard maples are heavy, hard, strong and stiff, with good shock resistance and moderate shrinkage.[97] Soft maples are weaker, softer, lighter and less decay resistant than the hard maples.[98] Its properties, however, make it less desirable where strength is required such as with structural timbers. Maple is more commonly found in furniture, veneer and woodenwares, though it is often used in ship construction.

Oak

Two basic groups of oak species were used in British ship construction: white oak (Quercus alba) and red oak (Quercus rubra). The white oak group includes post, swamp and bur oak. The red oak group consists of black, willow and scarlet oak. The red oaks were less commonly used because they were not suitable for ship construction. Red oak is less durable, strong and water resistant than white oak.

There are two varieties of white oak, European white oak (Quercus robur) and American white oak (Quercus alba). Although the argument began centuries ago, shipwrights, botanists and other researchers continue debating differences between the two woods. Modern equipment, allowing microscopic examination, reveals almost no structural difference. Excluding minor variations within individual trees, the two species have essentially identical characteristics. At this time there is no definitive way of microscopically differentiating between Quercus robur and Quercus alba.[99]

Quercus alba grows in the eastern and central United States while Quercus robur grows throughout Europe.[100]

Oak's primary drawback is its long growing time. An oak takes 80-120 years to reach its most valuable size.[101]

White oak's physical properties make it one of the better woods for ship construction. It is heavy, hard, strong, tough and durable.[102] Oak shrinks moderately, warps little and holds fasteners well.[103] Oak has large rays preventing the wood from shrinking radially during seasoning or with changes in relative humidity.[104] It is known to react with iron, however, making it detrimental in working with iron fittings and can shrink tangentially.

A disadvantage of oak is its long seasoning time. White oak contains outgrowths of the cell wall called tyloses. Tyloses block water movement within the wood making it impermeable to water.[105] Tyloses, while preventing water penetration, also keep water from dispersing. A piece of white oak one inch thick takes up to 270 days to reach a 20% moisture content; other hardwoods average 80 to 200 days, while pine averages only 30-70 days.[106]

White oak's elasticity makes it ideal for frames and other curved vessel timbers.[107] Oak is favored for construction because it is a common tree found in most countries and provides an abundance of both compass and straight timber.[108]

Walnut

Walnut has two major species groups in both Britain and North America: white walnut or butternut (Juglans cinerea), and black walnut (Juglans nigra). Black walnut is the more common of the two species though both are regularly used for furniture and cabinetry.

Black walnut grows throughout the eastern and central United States.[109] It averages about 90 feet but can reach heights of 150 feet; most mature trees have a diameter close to four feet.[110] Walnut is strong, and hard, and has good shock resistance qualities. It is stronger than the oaks but not as hard, heavy or stiff.[111] These properties give it good woodworking qualities, which, combined with a pleasant appearance and durability, make walnut a favorite furniture wood.[112]

Walnut also has a straight grain making splitting and processing easy.[113] This feature helps it season without warping or twisting. One of the more beneficial aspects of walnut is that after seasoning, it does not warp with changes in humidity.[114] Walnut's seasoning process is difficult because the wood is dense and takes a long time to dry. If a piece dries too rapidly it will shrink and crack. Walnut is most commonly used for furniture, veneer, molding, gunstocks and cabinetry.[115]

Willow

Salix comprises a number of species and varieties. White (Salix alba), weeping (Salix babylonica), southern (Salix Caroliniana), crack (Salix fragilis) and black (Salix nigra) are just a few of the more common varieties. There are many hybrids and varieties making microscopic separation difficult.[116]

Most Salix varieties are found throughout the United States. A species such as Salix caroliniana is scattered over the south-east, while black willow is found east of the Mississippi river. Other species such as pussy willow grow mainly north of Ohio and Pennsylvania while hybrids grow in the western United States or in Canada and the Northern latitudes.[117]

Black willow is the tallest of the Salix genus. It reaches heights of 60-100 feet. Species such as white willow reach a height of 60-80 feet while a few are only 10-15 feet tall.[118] Willow diameters are in two general sizes. White, weeping, southern, crack, and black willows have diameters ranging 1-2 feet while other species such as bebb, pussy, Florida, balsam and basket have diameters of only 4-6 inches.[119]

Sources advocate willow for hoops and slack cooperage.[120] It is good for hoops because it is soft, light and has good shaping abilities.[121] Willow is highly decay resistant but weak, making it unusable for structural elements in a ship. It is used for items such as table tops, wooden wares, treenails and caskets.[122]

SOFTWOODS

Cypress

Bald cypress (Taxodium distichum) grows in swampy areas from Mississippi to Florida. It reaches a height of about 130 feet.[123] It has a course texture, straight grain, is moderately hard and light and is highly decay resistant. These properties ensure a wood that lasts well in wet or humid conditions.[124] Although found in many underwater structures, bald cypress is not resinous. It was unusual for sheathing and underwater purposes because shipwrights believed resinous woods repelled marine organisms.

Early eighteenth-century shipwrights used cypress to construct local craft such as periaugers and canoes.[125] Reports state vast numbers of cypress trees were available for local construction.[126] Since the tree grows to enormous proportions and is durable it lent itself well to localized ship construction. Cypress is used primarily in rough construction such as fence posts, timbers and pilings. It is most common in railroad tie construction.[127]

Larch

Larch grows in both America and Europe. American larch (Larix laricina) is also known as tamarack, although some ascribe the name to the European species (Larix occidentalis) as well. American larch grows throughout the eastern United States from Virginia to Canada. European larch grows primarily in the central European mountains, although sustaining itself in other areas.[128]

Larch is durable, strong and tough, but it is apt to shrink or warp during seasoning.[129] It is hard, strong and durable.[130] Enough larch did not grow in England to make it a viable substitute for English oak though it was comparable in physical qualities.[131]

Larch is used in rough construction such as poles, posts and crates. The wood is also found in heavy construction such as planking. It is desired for in interior work such as flooring and finishing because of its distinctive color.[132]

Pine

There are two major types of pines, hard and soft. The hard pines are differentiated from soft pines by the ray tracheids. Hard pines have dentate ray tracheids while soft pines have smooth ray tracheids. Hard pines include trees such as red/scots (Pinus resinosa/sylvestris), ponderosa (Pinus ponderosa), jack (Pinus banksiana), southern yellow (Pinus spp.) and jeffery pine (Pinus jeffreyi).[133] Some reach heights of 100-120 feet while others rarely reach 100 feet.[134] The yellow pines such as longleaf (Pinus palustris) and shortleaf (Pinus echinata) are strong, stiff and hard while the red/scots pines are strong, hard, elastic and easily worked.[135]

The soft pines include sugar (Pinus lambertiana), eastern (Pinus strobus) and western white pines (Pinus monticola). Sugar pine, Pinus lambertiana, though easily worked and light weight, was relatively unimportant in ship construction.[136] Western white pine was not available for eighteenth-century ship construction. Eastern white pine, however, was an extensively utilized wood, primarily for masts and spars.

Both hard and soft pines contain resin. Resin creates better endurance and wear resistance.[137] Resin and other gummy substances plug microscopic spaces or cells. This prevents water movement and creates an impermeable wood.[138] When new, the resin helps keep the wood elastic but as the wood ages the resin hardens.[139] Resin adds weight and hardness making the wood more difficult to work. Some eighteenth-century shipwrights believed the smelly, bitter resin kept worms and other marine organisms from attacking the wood.

Pine is a good shipbuilding material because it swells, shrinks and warps less than oak. Pine is also more readily available because it grows rapidly in most environments.[140] Some pines are cut at 60 years though many stand for 80 to 100 years before achieving optimal height.[141]

Pines have other valuable attributes for ship construction. Many pines exhibit the same lack of radial shrinkage as the oaks though lacking large rays. Pines contain large amounts of earlywood. Earlywood shrinks less because the thin-walled cells carry less bound water. During seasoning the wood has less water to lose and cannot shrink as much.[142]

Other beneficial aspects of pine include aspirated bordered pits on cell walls. The aspirated pits block water movement, creating a less permeable wood. Aspiration occurs when the torus, a central thickened membrane, is displaced against one side of the bordered pit.[143] This occurs when one side of the bordered pit is exposed to air while the other is under the reduced pressure of the transpiration stream.[144] The different pressures force the torus to one side, thus blocking water movement through the pit. As the tree ages, the number of aspirated pits increases due to parenchyma breakdown.[145] As the parenchyma breaks down, the bonds holding the torus in place weakens, allowing the torus to fall to one side.

Red/Scots Pine

Red/scots pine (Pinus resinosa/sylvestris) has similar properties to white pine. Red/scots pine was cheap like white pine and easier to work than most woods. It can withstand heavy use, changes in relative humidity and is inexpensive. Some sources claim the best pine for ship construction came from between 53-65 degrees north latitude.[146]

Scots and red pines cannot be differentiated microscopically and are therefore little help in identifying a ship's origin. The argument over using scots instead of red pine was not as common in eighteenth-century literature as the debate between American and English oak, but European species were considered better quality with higher durability. The only substantiated argument against red pine was that it grew crooked, unlike the European Riga and Danzig varieties of scots pine, and therefore made poorer quality planks.[147]

European scots pine is strong, elastic, easy to work, moderately hard and resinous.[148] Red pine is similar to scots pine in that it works well, is strong, elastic and not apt to shrink, split or warp during seasoning.[149] Scots pine is found all over the Baltic, Scandinavia, Scotland and Northern Asia.[150] American red pine grows from Nova Scotia to Pennsylvania and Virginia.[151] The scots and red pines grow to a height of 70-100 feet, though some sources state 125 feet.[152]

Southern Yellow Pine

Southern yellow pine is a general name applied to a group of trees. It includes longleaf (Pinus palustris), shortleaf (Pinus echinata), loblolly (Pinus taeda), slash (Pinus elliottii), pitch (Pinus rigida) and pond (Pinus serotina). Most varieties grow throughout the southeastern and south-central United States, though pitch grows as far north as southern Maine.[153] The different species cannot be microscopically differentiated.

Southern yellow pines are known as some of the strongest, hardest and most dense softwoods.[154] They are used for a variety of purposes reflective of their properties. Southern pines are commonly used in piling, construction, slack cooperage, crates, shipbuilding and woodenwares.[155]

White Pine

White pine (Pinus strobus) is an American species growing throughout southeastern Canada and northeastern United States.[156] It is known to reach heights of 150 feet.[157] It is moderately soft, light, strong and resinous.[158] It is stable despite changes in relative humidity because it contains a large quantity of early wood vessels.[159] It can be microscopically differentiated from the other pines.

White pine became a favorite for furniture construction because it was inexpensive and easy to work. White pine was used for both primary and secondary construction in Britain and the American colonies. Primary construction included chests, tables and chairs.[160] Secondary construction consisted of drawer bottoms and interior of chests.[161]

Conclusion

Eighteenth-century shipwrights understood that each section of a vessel endured varying stresses and environments. Much like a building, a vessel needed different materials for different purposes. In order to build long lasting vessels, shipwrights utilized known wood differences and allocated them according to each structure's specific requirements.

Ideal woods are not always represented in archaeological findings. Although "ideal," they were not always used. Most ideal woods had characteristics of strength, durability and impermeability. Others were selected through availability or extenuating circumstances. Southeastern woods are under represented in eighteenth-century literature. The southeast does offer a variety of suitable woods but were not effectively utilized.

The second section described various woods found in ship construction. An inventory was compiled from historical and contemporary sources. It represents the more prevalent species and not every species found in ship construction. The listing's main purpose is to offer a background for a further understanding of eighteenth-century ship construction wood use.

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125.John Lawson. A New Voyage to Carolina, Lefler, Hugh Talmage, ed. (Chapel Hill: University of North Carolina Press, 1967) p.103. Cypress has been used in dugouts in southeastern America for thousands of years.

126.Lawson, A New Voyage, p.16; Michael B. Alford, "Periauger, Pettiagua, Petty Puzzler: Kunner, Cooner, Colloquial Conundrum." Tributaries, Vol.2, No.1, 1992, p.33.

127.Panshin, Textbook, p.479.

128.Laslett, Timber and Timber Trees, p.344; Brough, Timbers For Woodwork, p.97; Lanzara, Guide To Trees, plate 24.

129.Albion, Forests, p.32; Laslett, Timber and Timber Trees, p.345.

130.Howard, Timbers of the World, p.301; Elliott, Trees of the United States, p.197; Panshin, Textbook, p.453.

131.John Fincham, History of Naval Architecture (London: Scolar Press, 1979), first published 1851, p.218.

132.Panshin, Textbook, pp.455-457.

133.Panshin, Textbook, pp.441-453. Southern pine consists of a number of different species of pine. They include: Longleaf pine (Pinus palustris); shortleaf pine (Pinus echinata); loblolly pine (Pinus taeda), slash pine (Pinus elliotti); pitch pine (Pinus rigida), and pond pine (Pinus serotina), P.445. The jack, ponderosa and jeffery pines are relatively unimportant in ship construction as they are poor woods to work with.

134.Elliott, Trees of the United States, pp.151,162; Peterson, Book Of Wood, p.47.

135.Panshin, Textbook, p.446; Elliott, Trees of the United States, pp.151-168; Peterson, Book of Wood, pp.43-48; Laslett, Timber and Timber Trees, p.351; Stevenson, W. Wood: A Constructive Material, p.135.

136.Panshin, Textbook, p.437.

137.Elliott, Trees of the United States, pp.134,153.

138.Wilson, Anatomy of Wood, p.207.

139.Stevenson, Wood: A Constructive Material, p.135.

140.Elliott, Trees of the United States, p.171; Forest Products Laboratory, Wood: A Manual, p.140. Pines are known to grow an average of 1' per year. Nisbet, British Forest Trees, p.68.

141.Nisbet, British Forest Trees, pp.68,87; Peterson, Book Of Wood, p.47.

142.Ibid., p.174.

143.Panshin, Textbook, p.668.

144.Wilson, Anatomy of Wood, p.36.

145.Ibid., p.207.

146.Albion, Forests, p.30.

147.Laslett, Timber and Timber Trees, p.352.

148.Stevenson, Wood: As a Constructive Material, p.135; Laslett, Timber and Timber Trees, p.314; Elliott, Trees of The United States, p.176.

149.Elliott, Trees of the United States, p.168; Laslett, Timber and Timber Trees, p.351.

150.Peterson, Book of Wood, p.113; Nisbet, British Forest Trees, p.55; Brough, Timbers For Woodwork, p.87.

151.Peterson, Book of Wood, p.52; Elliott, Trees of the United States, p.164; Laslett, Timber and Timber Trees, p.351.

152.Laslett, Timber and Timber Trees, p.351; Elliott, British Forest Trees, pp.176,168.

153.Little, Field Guide, pp.287-298; Hoadley, Identifying Wood, p.148.

154.Hoadley, Identifying Wood, p.148.

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156.Lanzara, Guide To Trees, plate 35; Forest Products Laboratory, Wood: A Manual, p.12.

157.Brough, Timbers For Woodwork, p.90; Forest Products Laboratory, Wood: A Manual, p.12; Lanzara, Guide To Trees, plate 35.

158.Forest Products Laboratory, Wood: A Manual, p.12; Panshin, Textbook, pp.429,572-575.

159.Panshin, Textbook, p.441; Forest Products Laboratory, Wood: Its Use, p.12; Lanzara, Guide To Trees, plate 35.

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161.Ibid.

CHAPTER FOUR

Introduction

The preceding chapters presented a historical and technical foundation derived from contemporary and modern material. Documentary evidence suggests wood species selection in eighteenth-century ship construction is predictable. The hypotheses are derived from historical data and represent basic, general questions pertaining to eighteenth-century wood use. Wood species selection and use should be consistent with both future archaeological data and with historical findings. This chapter organizes the historical information into a series of hypotheses testable against archaeological data. Chapters five and six will test the hypotheses against the scientifically analyzed wood samples.

Hypothesis 1

A difference in wood species use existed between British and northern colonial-built vessels versus southern colonial-built vessels.

Most tree species grow within limited geographical areas, commonly restricting their use in ship construction. Eighteenth-century shipwrights used what was available, incorporating regional localized species. This should create differences in species selection according to the different geographical locations.

Some overlap did occur. Widely used species such as white oak appear in all manner of vessels, so its incorporation should not assign a vessel to either southern colonial, northern colonial or British origin. Southern woods were shipped to Britain and the northern colonies, though comprising only a small part of the overall timber trade.[1] Southern woods such as live oak could appear in limited amounts in northern colonial and British vessels.

This hypothesis infers that since Britain and her northern American colonies had similar trees such as: white oak, red oak, red/scots pine and elm, a wood use similarity occurred. Some differences, such as the availability of white pine, did exist between Great Britain and the northern colonies. White pine grew only in the northern colonies, but it was used extensively for masts in both British and American ships.[2] Excepting minor variations and localized traditions, the two areas historically had similar wood use styles.

The southern colonies had very different tree species which were suitable for ship construction. Live oak, southern yellow pine and cypress grew throughout the south-east providing shipwrights with an abundance of suitable timber. Since southern boat builders incorporated local woods in their ships, southern colonial vessels should exhibit a distinct species selection.

exhibit a distinct species selection.

Since the northern and southern colonies each had independent lumber sources, they rarely traded lumber with one another.[3] The two areas remained essentially separate, inferring little blending of woods in colonial built ships occurred. A wide range of samples and thorough research should be able to reveal a vessel's geographic origin.

Hypothesis 2

There was a wood use difference between naval vessels and merchant vessels.

Contemporary shipwrights and architects described ideal wood preferences for naval vessels. Unfortunately, little information survives for merchant vessel construction. Massive warships required larger lumber pieces for construction while merchant vessels generally did not. The need for specific lumber should create a dichotomy in wood use between warships and merchant vessels. Ideally, merchant wood use should follow suggested naval wood use, utilizing the best available woods such as white oak.

The most apparent difference between merchant and naval vessels should be found in the keel. Historical sources suggest elm rather than white oak for a warship's keel.[4] This hypothesis implies that if one wood use difference existed, then it is possible other elements will demonstrate a similar difference. A question is, was elm used in all warships or in just larger, more massive warships? Shipwrights did not specify whether size, use or navy requirements determined the choice of wood species for keels. Archaeological research can explore whether size, use or other factors created a difference between navy and merchant wood species selection.

Hypothesis 3

Wood use changed over time.

There should be some wood use variation throughout the eighteenth century. Although shipwrights, architects and government officials relied on species such as white oak and red/scots pine, these woods became increasingly difficult to obtain.[5] Ideally, excepting southern colonial ships, archaeological recoveries should be white oak, elm and red/scots pine. Actual wood use, however, will reflect the incorporation of other species along with ideal woods.

Most variation should appear in the extreme latter years of the century due to depletion of preferred woods and the exploitation of new species. As other sources opened in South America and India, new woods such as teak were incorporated into British ships. This occurred during the last years of the century and therefore should not appear in early eighteenth-century vessels.

Historical documents report a change from using British to Baltic white oak. Unfortunately, there is no way of microscopically differentiating Baltic, American or British varieties of white oak and red/scots pine. Changes in sources, therefore, will not appear in the archaeological record but must be gleaned from historical documents.

Another variation was a decrease in wood quality. Unfortunately, degraded, waterlogged wood is difficult to evaluate for quality. Historical documents may offer the only method of determining changes in quality. These possibilities will not be examined in this study.

Hypothesis 4

> Detailed excavation and large sample sizes can reveal if a vessel underwent patching or repairs.

Most historical documents lack details on patching and repairs. Shipwrights, sailors and architects failed to document patching or to detail woods used for repairs. Historically, we know which woods should be used in ship construction within geographical parameters. It would be logical to assume that repairs also came from geographically available woods. Evidence of secondary construction is important because it might provide additional information about a ship's history.

Although some vessels were not in operation long enough to have repairs or patching, most vessels underwent some form of repair within a short period of time. Wood was not a durable material. Table 4.A shows the average length of time for specific species in a given element. Under ideal conditions with properly seasoned wood, most species needed replacement within a few years. Historical documents relate that since ideal conditions rarely existed, many vessels underwent some form of repair within one or two years.

TABLE 4.A

LLOYD'S TABLE OF YEARS ASSIGNED TO EACH KIND OF WOOD

Kind of Timber	Keel	Stem and Stern Post	Apron, Etc.	Deadwoods, Transom	Floors	Timbers				Keelsons	Ceiling				Beams	Knees	Hooks	Plank			Deck		
						1st Foot Hooks	2nd Foot Hooks	3rd Foot Hooks	Top Timbers		In Flat	Bilge	Side	Clamps				Garboards	Bottom	Side	Covering B.	Locks	Upper
East India Teak	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
English, African and Live Oak Greenheart, iron bark	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Sabien, Jarrah, Kurrie, Blue Gum, Red Gum, Pencil Cedar	10	10	10	10	10	10	10	10	10	10	12	12	12	12	12	12	12	12	12	10	10	10	10
Second Hand English, Oak Greenheart	8	7	7	7	8	8	7	7	7	7	7	7	7	7	7	7	7	...	...	...	7	7	7
Red Cedar, Philippine Island Cedar	...	7	7	7	8	8	7	7	7	8	8	8	8	8	7	7	7	12	12	8	7	7	7
Danish Oak, Mahogany (hard)	0	0	9	0	0	9	0	0	0	0	10	10	10	10	0	9	9	12	10	10	10	10	10
North American White Oak	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	7	8	12	12	8	8	8	8
Pitch Pine, Oregon Pine, Kauria Pine, Larch, Hackmatack, Juniper	0	0	0	9	0	9	9	0	0	0	0	9	9	9	9	9	9	12	12	10	10	10	10
Danzie, French, Red Pine	9	9	0	0	0	0	0	9	0	9	0	0	9	0	9	9	9	9	9	9	9	9	9
English Ash	...	4	4	4	8	6	5	5	5	5	...	...	...	...	5	5	5	10	10	5	...	...	...
Rock Maple	10	...	...	...	8	...	...	...	...	...	5	5	...	5	...	...	...	8	8	6	6	6	6
Rock Elm	10	6	6	6	7	6	6	6	6	7	...	...	...	...	7	6	7	12	12	7	...	...	...
Grey Elm		6	6	6	6	6	6	6	6	6	...	...	...	...	6	6	6	12	12	6	...	...	...
Black Birch	10	...	...	...	7	6	...	...	...	...	...	...	...	...	...	...	...	10	10	6	...	...	...
Spruce, Fir	8	8	8	8	8	8	8	8	8	8	...	...	...	...	8	8	8	8	8	8	8	8	8
Beech	...	...	...	...	7	6	...	...	...	...	...	...	...	...	...	...	...	12	12	6	...	...	...
Yellow Pine	8	4	4	4	...	...	...	4	4	4	...	...	...	...	4	4	4	6	6	5	5	5	5

(Desmond, Wooden Ship-Building, p.18.)

Hypothesis 4 posits that evidence of repair or patching should be exposed through an archaeological examination of a vessel's wood use selection. Proper sampling is necessary to accurately understand a vessel's history and construction sequences since it is difficult to determine if a wood sample is geographically unique, or merely represents typical construction material. Combining historical and documentary sources and archaeological research, should reveal differential evidence of patching and repairs.

Hypothesis 5

Archaeological data should support documentary evidence for eighteenth-century wood use.

It is important to be able to trust historical data because the archaeological material is nonexistent in some cases. Historical information is therefore significant in determining eighteenth-century wood use. Through documents, chapter three explained that shipwrights knew "ideal" woods for manufacture. Chapters five and six will demonstrate through archaeologically retrieved wood samples, that ideal woods were utilized in eighteenth-century ships.

Although the timber trade was rife with problems such as inadequate policies, corruption and insufficient supplies, ideal species were used for construction.

Observed archaeological wood species may differ from the expected species predicted from documentary data. It is impossible to account for each ship's wood use as it was necessary at times to use unusual, local or available woods. In a system fraught with corruption, wood choice could not always be ideal. In general, though, wood species selection should follow the documented preferences.

One problem in exploring eighteenth-century wood use is examining the wood's quality. Degraded waterlogged wood is hard to analyze for quality. Historical sources report improper woods were used in construction. Improper here may mean lesser quality planks rather than a lesser quality species. Given the complexity in microscopically determining a wood's quality, it will not be pursued in this chapter.

Hypothesis 6

Furniture and casks should follow documented land-based trends.

Few studies have been conducted on shipboard furniture. It is rarely found archaeologically and few documentary sources exist. Paintings and woodcuts give an idea of furniture found on ships, but do not identify wood species. Some shipboard furniture exists in museums and collections. These represent well-crafted, unique or highly ornate pieces. They give limited information, however, and usually portray only upper-class society. Archaeological retrieval provides the only method of obtaining shipboard furniture wood use information.

Waterlogged wood samples can expand upon the historical information as most existing historical and archaeological examples are based on collections. These sources describe which woods were preferred and utilized on land, rather than aboard ship. Historical texts relate what materials furniture and casks should be made of but research must rely on archaeological evidence to reveal true wood use.

As with furniture, shipboard casks are under-published, though much information exists on terrestrial cooperage. Documentary sources suggest casks were made of white oak, pine, spruce, ash, birch or chestnut. Hoops should be made of ash, hazel, willow, elm, oak or pine.[6]

Tight casks need impermeable woods like white oak to hold in liquid and preserve foodstuffs. Slack cooperage was not as exacting and could therefore be made of thinner, lower-quality staves. Unusual or local woods found in furniture or casks construction might indicate repairs or reflect available woods. Ideally, furniture and casks should follow land-based trends with the incorporation of regional species.[7]

Conclusion

A theme prevalent in this thesis is the need for combining historical and archaeological data to better understand eighteenth-century wood use. In order to test assumptions derived from the documentary sources, formal hypotheses were drawn up. These hypotheses were expected woods, based on the written record. These expectations are tested against observed archaeological examples to determine their accuracy.

References

1.In 1771, a committee report on supplying Royal Navy timber stated that live oak was being shipped from the Carolinas, in small quantities exclusively for knees. "A Report From a Committee on the Problem of Supplying The Navy with Timber, 1771." cited in D. B. Horn & Mary Ransome, English Historical Documents (New York: Oxford University Press, 1957), Vol. X, 1714-1782, p.597.

2.White pine was important because it gave the Royal Navy another species to utilize and helped diminish the timber shortage. The British believed it was thereby inferior to scots pine, though taller and lighter than its rival. White pine's height gave Britain single sticks to use on its largest capital ships rather than rely upon made or composite masts. Robert Albion, Forests and Sea Power: The Timber Problem of the Royal Navy, 1652-1862 (Camden, Connecticut: Archon Books, 1965), pp.29,31.

3.Live oak was rarely utilized in Britain though its properties were known early in the eighteenth century. One theory for its lack of British use was that the south did not actively pursue a live oak timber trade. Bishop, History of Manufactures in the United States, i, p.85, cited in Albion, Forests, p.23; Virginia Steele-Wood, Live Oaking (Boston: Northeastern University Press, 1981), p.13.

4.William Sutherland, Britain's Glory: or Shipbuilding Unvail'd 2nd edition, (London: Printed at the Bible Under the Royal Exchange, 1726), pp.36,37,75,117; Thomas Riley Blankley, Naval Expositor (London: Owen of Warwick Lane, 1750), p.171; Gabrielle Snodgrass, "Letter From Gabrielle Snodgrass to the Right Honorable Henry Dundas." (London: 1797) p.31. Sutherland further specified keel sections according to tonnage: vessels 1,800 tons should have up to five elm segments, 1,000 tons should have four segments, and 400 tons should have no more than three segments.

5.Sutherland, Britain's Glory; Blankley, Naval Expositor; and Snodgrass, "Letter to Dundas". Each of these authors suggested oak and pine for ship construction.

6.Blankley, Naval Expositor, p.5; Phillip Hayward, Wood: Lumber and Timber (New York: Chandler Cyclopedia, 1930), p.176; J. C. S. Brough, Timbers For Woodwork (New York: Drake Publishers, Inc., 1969), p.134; William Sutherland, Prices of Labour of Shipbuilding Adjusted (London: 1736), p.35.

7.Dr. Oscar P. Fitzgerald, Director of the Navy Museum, Washington D.C., Personal communication, March 19, 1993.

CHAPTER FIVE

Introduction

One of the largest collections of eighteenth-century archaeological wood samples comes from the British collier Betsy.[1] The Betsy's samples provide a useful research baseline because extensive surviving structural elements yielded a large sample for examination. The wider range of samples gives a more accurate evaluation. The Betsy's sample created a good focal point for initial comparison with the hypotheses generated from documentary sources.

Since much of the Betsy's structure survived, major structural elements such as the keel, deck planking and fore mast could be examined. Each of these parts were sampled and then identified by a variety of people. The comprehensive sampling allowed for a more accurate and detailed picture of eighteenth-century ship wood use than is available for most sites (See Appendix B).

The Betsy's remains provide a unique insight into eighteenth-century shipboard life. Extant remains include rarely excavated pieces such as table tops, table legs, cupboard pieces and chair rungs or legs. Other wooden artifacts include cask heads, staves and hoops. The cooperage was important because it reveals what goods the Betsy carried: beef, pork and peas as well as grains, nuts, fruits, corn, fowl and fish.[2]

History of the Site

For centuries the York River, in front of Yorktown, Virginia, has been the center of salvage operations. The French had salvage rights in the eighteenth century; contractors recovered material in the nineteenth century. The National Park Service and Mariners' Museum conducted operations early in the twentieth century.[3]

Not until the 1970's did archaeologists survey and study the York River. In 1978, funded by the National Endowment for the Humanities, John Broadwater located the remains of nine wrecks, including 44YO88.[4] (Analysis later identified site 44YO88 as the Betsy.) Site 44YO88 was chosen for further study because it was the best preserved.[5]

In 1981 Broadwater proposed a plan to completely excavate the site within a cofferdam to help visibility. A National Endowment for the Humanities grant in 1982 provided enough money for excavation of the site and completion of the cofferdam. Excavation occurred from 1982 until 1988.[6] Research and analysis of the excavated materials was completed in 1990. That year the site was backfilled and the cofferdam dismantled by the United States Navy's Mobile Diving and Salvaging Unit Two.[7]

History of the Betsy

The excavations revealed that the Betsy measured 73 feet in overall length, 23 feet 7 1/4 inches in breadth, 9 feet 10 inches deep and 176 tons.[8] It is believed that the Betsy was built in about 1772, at Whitehaven, England, as a collier.[9] In 1780 a brig, Betsy, was hired into the service of the crown for transport duty.[10] She was chartered from Peter Butt, for 47.10.0 pounds per month and was paid from the accounts of Lord Cornwallis up to August 31, 1781.[11] At Yorktown she was commanded by John Younghusband, though earlier she had been under James Ballingtine.[12] After the Yorktown campaign of October 1781, she no longer appears in the Register and as all papers concerning ships in that siege were lost, no claim was ever filed on the Betsy.[13]

Identification of the Betsy's Wood

Structural

The Betsy's overall construction relied heavily on white oak. Most of the Betsy's structure (frames, ceiling, planking, rudder and gripe) are white oak (*Quercus alba* or *Quercus robur*) or oak species (*Quercus* spp.).[14] (Degradation made it difficult to differentiate between white oak and red oak groups.) Heavy structural pieces such as the keel, stem, stern post and three of the four keelson timbers are oak.[15] Lesser structural timbers such as stem and stern chocks, treenails and breasthooks are also oak.[16]

Pine constitutes a smaller portion of the Betsy. The sheathing, deck planking, stern bulkhead, fourth keelson piece, mainmast and foremast are from the Pinus genus.[17] (Degradation prevented further identification of many samples.) The mainmast, deck planking and sheathing were further identified as from the hard pine group, which includes red/scots and southern yellow pines.[18] The sheathing and mainmast were identified as a specific species, Pinus sylvestris/resinosa, European scots or American red pine, which cannot be microscopically differentiated.[19]

Furniture

The Betsy has many extant furniture remains. These samples are arranged into groups such as tables and chairs, moulding and veneer, and cupboards. The first group comprises four table tops, a table leg and two chair rungs. One table top was identified as red/scots pine and the other three as walnut (Juglans spp.) or black walnut (Juglans nigra).[20] The table leg is tentatively identified as white pine while the chair rungs are white oak and birch (Betula spp.).

The second group consists of three cupboard samples and a variety of veneer and moulding samples. One cupboard sample is red/scots pine and two are white pine (Pinus strobus). The majority of the moulding and veneer samples are white pine with the exception of one red/scots pine moulding sample.[21] The moulding sections are stylized, raised pieces, possibly representing an officer's area.[22]

Casks

The Betsy excavations yielded numerous cask remains, including heads, staves and hoops. Nine cask heads were sampled. Five are white oak (Quercus alba); two are ash (Fraxinus spp.); one is red/scots pine (Pinus resinosa/sylvestris) and one is beech (Fagus sp.). Five cask staves were sampled and all five staves were identified as white oak.[23] Further identifications include two "cask assemblage" samples: one is Pinus spp., the other Quercus spp.[24] Two hoop or withy samples are also identified, one is willow (Salix sp.) and the other chestnut (Castanea spp.).[25]

Hypotheses Tested Against the Betsy's Samples

Results of Hypothesis 1

Hypothesis 1 suggested there was a wood use difference between British and northern colonial vessels versus southern colonial vessels. The Betsy's wood use suggests a northern colonial or British-built vessel. In particular, the widespread use of white oak is consistent with British shipbuilding traditions. Historical documents indicate the Betsy was built in Whitehaven, England.[26] Additionally, the absence of woods such as live oak or southern yellow pine provides important negative evidence. The primary use of white oak and red/scots pine and the lack of live oak and southern yellow pine support an interpretation of British or northern colonial construction.

Results of Hypothesis 2

Hypothesis 2 predicted that different wood uses existed in navy and merchant vessel construction. Historical sources suggest that only navy-built vessels should have elm keels. As naval shipwrights and architects' documents assign elm to keels, the civilian merchant vessel Betsy should not have an elm keel. Indeed, the Betsy's oak keel is consistent with historical sources. The Betsy's sampling indicates that a difference in navy construction versus merchant construction did exist for keel manufacture. The Betsy's samples fail to confirm any general difference between merchant and navy construction. Naval shipwrights called for white oak and pine for ideal ship manufacture. The Betsy's identified white oak and pine archaeological samples follow historically recommended construction. Overall, the wood samples do not support the historical premise that major differences existed between merchant vessels and navy vessels in terms of wood use, except for the keel.

Results of Hypothesis 3

Hypothesis 3 posited that a change in wood use occurred over time. This hypothesis cannot be tested against the Betsy alone as she represents only one moment in time and space.

Results of Hypothesis 4

Hypothesis 4 predicted that an extensively sampled site could reveal the existence of patching or repairs. The Betsy has only one wood sample that may represent patching or repair. The four-piece keelson has three white oak segments and one pine segment.[27] Pine is not mentioned in contemporary documents as being suitable for primary keelson construction. The presence of a pine keelson section therefore has two possible explanations: original construction and repair.

Replacements, repairs and patching were common occurrences in eighteenth-century vessels. Structural elements, such as a keelson, endured extreme stress and harsh environments. Table 4.A demonstrates that wood, in any capacity rarely lasted more than a few years. Ships that sailed for any length of time, such as the nine year old Betsy, should have repairs or patching. Proper sampling, as with the Betsy's keelson, did reveal possible secondary construction.

Without further historical or archaeological information it is difficult to make a positive conclusion. The Betsy's wood use suggests hypothesis four is viable, but the archaeological wood samples can neither prove or refute the premise.

Results of Hypothesis 5

Hypothesis 5 proposed that historically known ideal woods were actually used in merchant vessel construction. Naval shipwrights' and architects' documents relate that white oak and red/scots pine were preferred for ship manufacture. Even late in the century, the Betsy's builders incorporated white oak and red/scots pine where called for. This showed that, in one instance, ideal woods were in fact utilized for eighteenth-century merchant ships.

In essence the Betsy supports hypothesis five. The Betsy's wood samples correspond with the historically documented species. It was expected that white oak and pine were used for construction; the archaeological samples demonstrated that they were in reality used.

Results of Hypothesis 6

Hypothesis 6 predicted that the Betsy's furniture and cask remains would be consistent with land based trends.

Historically, furniture should be made of walnut, pine, maple, mahogany and fruitwoods such as cherry. Documents suggest tight cooperage should be made of white oak while slack cooperage could be made of a variety of woods such as pine, red oak, ash and beech. Most of these woods were found in the Betsy's excavations.

Furniture

The Betsy's furniture samples were compatible with eighteenth-century furniture wood use. The excavated furniture pieces were mostly walnut or pine.[28] Walnut and pine were cheaper and more readily available than the finer, more popular woods such as mahogany.[29] Pine and walnut were considered middle-lower class furniture woods, consistent with the status of the master of a small merchant vessel.

Other excavated furniture woods include white pine moulding and cupboards. White pine was common for vernacular land furniture in the northern colonies. The white pine pieces were, therefore, most likely manufactured in the northern Anglo-American colonies and incorporated in the Betsy while the ship was stationed in the colonies. Additional historical information on the Betsy's history could further support or discredit this premise.

Casks

Cask wood was also consistent with historical documents and land-based trends. Contemporary documentary sources suggested pine, spruce, douglas-fir, ash, birch and chestnut for cask construction, while hoops should be made of ash, hazel, willow, elm or pine.[30] According to documentary sources, white oak staves were used in tight cooperage to carry liquids and perishable goods. Casks for peas, grain, flour, and other dry provisions were made of woods such as pine, ash, beech and chestnut.[31] Indeed, most of these woods were found in the Betsy's excavations, suggesting she carried an assortment of supplies. The variety of woods correlated with the food stuffs found on board, confirming that the Betsy carried tight and slack cooperage.[32]

Conclusion

The Betsy's wood use was representative of documented eighteenth-century wood use. The Betsy's shipwrights selected specific woods, such as white oak and red/scots pine, for varying purposes in conjunction with recommended practices, and utilized those species in a predictable fashion. The observed Betsy's woods were in agreement with ideal eighteenth-century ship construction woods.

Some hypotheses proved too complex for testing on one vessel. A larger sample size is necessary to properly compare and discuss ship wood selection. The following chapter will compare a variety of vessels against the same hypotheses to determine true eighteenth-century wood use.

References

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2.John Broadwater, "Merchant Ships at War: The Sunken British Fleet at Yorktown, Virginia." Underwater Proceedings from the Society for Historical Archaeology Conference (1989), pp.122-3; Kerry Shackelford, "The Casks From Cork." Historic Trades (1988), Vol.1, p.41; Eri Weinstein, The Recovery and Analysis of Paleoethnobotanical Remains From an Eighteenth Century Shipwreck. (PhD: Texas A&M University, 1992), pp.58,71.

3.John Broadwater, "The Yorktown Shipwreck Archaeological Project: Results from the 1978 Survey." International Journal of Nautical Archaeology (1980), 9:3 pp.227,228.

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5.Morris, Site 44YO88, p.14; Weinstein, The Recovery and Analysis, p.33; Broadwater, "Results from the 1978 Survey", p.231; Broadwater, "an Interim Report", p.301.

6.Broadwater, "An Interim Report", p.301; Broadwater, "Merchant Ships at War," p.122..

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11.John Sands, Yorktown's Captive Fleet (Charlottesville: University Press of Virginia, 1983), p.184.

12. Ibid.

13. David Syrett, Shipping and the American War, 1775-1793 (London: Althone Press, 1970), pp.110-113. cited in Morris, Site 44YO88, p.86.

14. Morris, Site 44YO88, pp.60-70; Marshall White, Associate Professor, Wood Products, Virginia Polytechnic Institute and State University, Letter to John Broadwater, Senior Underwater Archaeologist, Department of Conservation and Historic Resources, January 2, 1986; Broadwater, "Results from the 1986 Season," p.123.

15. Morris, Site 44YO88, p.64. It is often difficult or impossible to differentiate a sample further.

16. Ibid., pp.56,69.

17. Morris, Site 44YO88, pp.66,68-70; White, Letter to John Broadwater, January 2, 1986; Broadwater, "Merchant Ships at War," p.122; Broadwater, "Results from the 1986 Season," p.79. See Appendix B.

18. White, Letter to John Broadwater, January 2, 1986.

19. Morris, Site 44YO88, p.66; See Appendix B.

20. See Appendix B.

21. Ibid.

22. Broadwater, "Merchant Ships at War," p.122.

23. See Appendix B.

24. Marshall White, Associate Professor, Wood Products, Virginia Polytechnic Institute and State University, Letter to Marcie Renner, December 16, 1986. It is unclear what, exactly, is meant by "Cask Assemblage." The term probably means the samples are part of a cask, either head, stave or hoop.

25. White, Letter to John Broadwater, January 2, 1986. Kerry Shackelford in "Casks From Cork" related that casks of white oak, red oak, yellow pine and chestnut have been identified, pp.43,44.

26. Morris, Site 44YO88, p.86.

27. Ibid., p.64.

28. See Appendix B.

29.Victor Chinnery, Oak Furniture: The British Tradition (Woodbridge: Antique Collectors Club LTD., 1979), p.151; Esther Singleton, The Furniture of Our Forefathers (New York: Benjamin Bloom Inc, 1970), pp.139,145; John Gloag, English Furniture (London: Adam & Charles Black, 1973), p.60; Dr. Oscar P. Fitzgerald, Director of the Navy Museum, Washington D.C., Personal Communication, March 19, 1993.

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32.There is insufficient data for wood identification of casks and food remains. Information comes from different sources. Tight staves are thicker and better built

CHAPTER SIX

Introduction

Chapter five tested six historically-based hypotheses derived from documentary sources reflecting ideal woods used in British ship construction against wood species recovered from the Betsy. Although the observed samples support the premises, the Betsy represents only one vessel. This chapter uses nineteen other eighteenth-century vessels subjected to archaeological and historical investigation to further test the hypotheses regarding ship wood use. The vessels represent a variety of construction times, methods, sizes and origins.

Each vessel provides a number of wood samples or documented species used in its construction. The wood species are compared to the hypotheses to examine ship-construction wood use. The larger data base further clarifies eighteenth-century wood use and creates a baseline for future testing. The comparison provides an overview of wood use throughout the century and tests the hypotheses against a wider sample.

Summary of Eighteenth-Century Vessels Used For Comparison

Any current list of eighteenth-century sites will not be complete as new vessels are excavated or analyzed each year. This chapter includes only those eighteenth-century vessels with archaeological wood identification results or documented wood species composition. Some known vessels were excluded because of a lack of time or availability, or because the wood analysis has not yet been completed.

A comprehensively-sampled site is the Ronson ship. The vessel was discovered at a construction site in lower Manhattan in 1982. Preliminary results indicate an American vessel built between 1720-1735.[1] It measured roughly 100 feet long, 26 feet in beam and 150-200 tons.[2]

The Invincible was built in France in 1744, captured by the British off Cape Finisterre in 1747 and lost near Portsmouth, England in 1758.[3] John Bingeman led excavations from 1980 to 1984. The Invincible was a 74-gun 3rd rate, measuring 170 feet long, 49 feet in beam and 1,793 tons.[4]

Deadman's Shipwreck is located at Deadman's Island, in Pensacola Bay, Florida. In 1988 archaeologists from the University of West Florida conducted preliminary investigations.[5] Roger Smith, the State Underwater Archaeologist for Florida, mapped and excavated the vessel's remains in 1989. The ship is interpreted as a British naval vessel sunk between 1760 and 1780, during the British occupation of Pensacola.[6] It was approximately 90 feet long and had a "narrow shallow draft."[7]

The Philadelphia was a gondola built at Skenesborough on the New York shore of Lake Champlain.[8] It was part of Benedict Arnold's American fleet which fought at Valcour Island in 1776. The Philadelphia was a flat-bottomed, oared sailing vessel. The ship was recovered by a commercial salvor, Lorenzo Hagglund in 1935. In 1961, through a provision in Hagglund's will, the Philadelphia was given to the Smithsonian Institution.[9] It measures roughly 53 feet long, 15 feet across and 29 tons.[10]

The Boscawen was built by Joshua Loring in 1759. The use of green wood possibly resulted in her sinking in the Fort Ticonderoga dockyard in the mid-1760's.[11] Excavation was conducted by the Fort Ticonderoga Museum and Champlain Maritime Society. Analysis from the 1984 and 1985 seasons indicated the vessel measured 75 feet long, 26 feet abeam and 115 tons.[12]

The Underwater Archaeology Society of Nova Scotia in 1980, surveyed and excavated the Terrance Bay Site, an eighteenth-century fishing schooner located near Halifax, Nova Scotia.[13] The Society surveyed the main features and excavated the forecastle and midships sections from 1980 to 1983. Architectural and artifactual evidence supports New England construction and use. The numerous cod fish bones found in the vessel's hull suggest it was a fishing vessel rather than a warship. The wreck measured close to 50 feet long, 13 feet abeam and 75-100 tons.[14]

The Brown's Bay vessel was located in Brown's Bay, on the northern shore of the St. Lawrence River.[15] In 1966 and 1967, the vessel was excavated and raised by the National Historic Sites Service, now the National Historic Parks and Sites Branch of Parks Canada.[16] 1985 fieldwork conducted by Parks Canada and Christopher Amer included a re-examination of the hull and material from the 1967 excavation. Hull design and shape suggests a flat-bottomed vessel, typical of British turn-of-the-century construction. It measured 54 feet long, 16 feet abeam and 39 tons.[17]

The North Carolina Underwater Archaeological Unit excavated the Rose Hill Wreck in 1988.[18] The vessel is located in the Northeast Cape Fear River, six miles above Wilmington. It has an estimated length of 67 feet, a beam of 22 feet, and roughly measures 103 tons.[19] The construction methods resemble those used in English merchant vessels built between 1660 and 1750.[20] The wood species imply an American-built vessel, suggesting that a shipwright located in the North American colonies built the vessel in the English tradition.[21]

In 1976, the South Carolina Institute of Archaeology and Anthropology, under the direction of Alan Albright, excavated the hull and cargo of the Brown's Ferry Vessel.[22] The vessel appears to be a mixture of Old World carvel construction and colonial American elements.[23] The mid-eighteenth-century schooner-rigged vessel measured 53 feet in length, 14 feet in extreme beam and 25 tons.[24]

In 1988, Claude Jackson, with North Carolina Underwater Archaeological Unit's assistance, began excavation of the Otter Creek Wreck, near Oriental, North Carolina. The site became a field school under a British-American project called Operation Raleigh.[25] The vessel measured 58 feet long, 16 feet abeam and was approximately 100 tons.[26] The ship is interpreted as a Federal period American-built schooner or brig-rigged vessel with a single deck and raised poop.[27]

The Trent River Flat was discovered in 1989 by the Arnold Seawall Construction Company while adding a new dock at the River Bend Plantation community, west of New Bern, North Carolina. The Underwater Archaeology Unit examined, recovered and transported the remains to the North Carolina Maritime Museum for conservation.[28] The vessel measures 32 feet long and 11 feet wide. It is tentatively dated between mid eighteenth and nineteenth centuries though it construction techniques may have early eighteenth-century Huguenot influences.[29]

Other American-built vessels include the Clydesdale Plantation vessel and Onslow Island wreck. The Clydesdale vessel was excavated in 1992 in the Savannah River, north of Savannah, Georgia. It is a coastal sloop-rigged vessel measuring 46 feet long, dating to the late-eighteenth century.[30] The Onslow Island vessel is in the Savannah

River, near Port Wentworth, Georgia. It was examined in 1993, and is provisionally dated to the last quarter of the eighteenth century. Interpretations suggest a coastal schooner measuring 60-70 feet in length.[31]

The Little Landing Vessel (2) was located at Little Landing on the Cooper River of South Carolina. It was surveyed and excavated in 1988-89 by the South Carolina Institute of Archaeology and Anthropology.[32] It is a flat-bottomed sailing vessel dating to the last half of the eighteenth century. The Institute also surveyed and excavated the Malcom Boat. It is a late eighteenth century sloop estimated at 41.9 feet long, 11.8 feet at midships beam and 22 tons.[33]

Historical sources also provide wood identifications. Details of the Blandford, Bellona, Granado and Diana came from historical documents and not excavations. The Blandford was a 20-gun ship used for convey support, fire support or as a fleet scout. It was built in 1720 and sold out of service in 1742. It was 106 feet long, 26 feet abeam and 376 tons.[34]

The Bellona was a 74-gun ship built in 1757 and broken up in 1814. It was 168 feet long, 46 feet abeam and 1,615 tons.[35] The Granado was a bomb vessel that carried mortars. It was built in 1742 and sold out of service in 1763. It was 91 feet long, 26 feet abeam and 268 tons.[36] The Diana was a 38-gun frigate built in 1794 and burned in

1839. It was 146 feet long, 39 feet abeam and 999 tons.[37]

The preceding references provide background and information about each site. The vessels represent a variety of building techniques, origins, sizes and uses. The wood species used in these vessels can be examined for patterns which may reveal new information about ship building.

Wood Identifications

The Ronson ship is an important vessel because the site had outstanding preservation. Elements such as mast fragments, knees, a block and 61 treenail samples were recovered. The Ronson ship's keelson and ceiling were white oak, and the stem post was identified as possibly white oak.[38] The planking and frames are a mixture of white or possibly live oak.[39]

The 61 treenails are a mixture of woods. 55 are live oak but two white pine, one hard pine, one juniper, one hickory and one ash are also found.[40] Other wood species include white oak or oak knees and a lignum vitae block.[41] Pine was included as red/scots deck planking and a probable white pine mizzen mast.[42]

Historical sources indicate that the Invincible's major components were white oak. Archaeological information supplies further identifications, such as white oak frames and a block comprised of an elm shell and lignum vitae sheave.[43] The Invincible also had a number of casks which were excavated. The powder and spirit barrels had oak staves with hazel hoops and copper bands.[44]

The Deadman's Shipwreck woods are primarily white oak. The vessel has a white oak keelson, stem, stern post, frames and ceiling planking.[45] Deadman's Shipwreck also has a knee, identified as white oak or Quercus spp.[46] Unusual species include a hard pine or southern yellow pine plank and a live oak external plank.[47]

The Boscawen and Philadelphia are primarily made of white oak. The Boscawen has a white oak keel, stem, stern post, frames, keelson, planking, and ceiling. The deck planking is white oak with white pine beams, and the treenails are a combination of white oak and white ash. The Philadelphia had a white oak stem, stern post, frames, ceiling, planking and deck planking.[48]

The Terrance Bay and Otter Creek builders also relied heavily on white oak. The Terrance Bay site has white oak frames, ceiling and planking.[49] Other elements include white oak or oak knees, oak treenails and oak cask staves.[50] Only the deck planking is identified as red/scots pine.[51] The Otter Creek site has white oak keel, frames, ceiling, planking and treenails.[52] This site has red/scots pine sheathing.

The Brown's Bay vessel is also predominantly white oak. Major structural timbers such as stem and stern post, frames and planking are white oak.[53] The ceiling is a mixture of white oak and white pine. Two knees were sampled and found to be oak and larch.[54]

The Rose Hill wreck is something of an anomaly as it incorporated a number of unusual wood species. The wreck has a white oak keelson, a maple keel and red oak stern post.[55] Red oak was also used for the planking. The frames are a mixture of white oak and beech. It also has oak treenails and white oak ceiling. The sheathing is identified as a hard pine, which include red/scots and southern yellow pines.[56]

The Brown's Ferry vessel is a southern-built vessel constructed of southern yellow pine, live oak and cypress. Sampled elements include; cypress treenails and keelson, and a southern yellow pine bottom.[57] The planking is a mixture of southern yellow pine and bald cypress. Live oak appears in the stem, frames and knees.[58]

The Clydesdale Plantation vessel is mostly southern yellow pine and live oak. It has a southern yellow pine keel and keelson. The ceiling and planking were tentatively identified as southern yellow pine.[59] Live oak is incorporated in the stern post, apron and knees with a mixture of live and white oak frames. Cypress is used for treenail construction only.[60]

The Onslow Island and Malcom vessels are primarily of southern yellow pine construction. The Onslow Island vessel has a southern yellow pine keel, keelson and planking.[61] The treenails are a mixture of southern yellow pine and bald cypress. White oak is used in the stern post and frames.[62] The Malcom boat has a southern yellow pine keel, keelson, planking and knee.[63] The ceiling is a mixture of southern yellow pine and cypress.[64] Other identifications include a live oak stem, knee and frames and white oak stern post, frames and knee.[65]

The Trent River Flat has cypress bottom and side planking.[66] The vessels' frames are a mixture of oak and possible southern yellow pine. The knees are identified as possibly live oak.[67]

The Little Landing 2 site has a combination of live oak and southern yellow pine. The vessel has a southern yellow pine keel and keelson with live oak stem and frames.[68] The ceiling, planking and treenails are identified to the southern pines.[69]

Historical warships include Bellona which had an elm keel and white oak structural elements.[70] Diana had an elm keel and white oak stem and stern post.[71] The Blandford had an elm keel, white oak frames and pine masts.[72] Granado had an elm keel, white oak stem and stern post and pine mast.[73] Information for these vessels come from historical sources only.

It is evident that not all structural elements at any one site survived or were sampled. (Appendix C shows the breakdown of wood use by vessel and structural features.) The lack of surviving or sampled elements makes the combining of sites important in order to achieve a wide range of each structure type.

Results of Hypotheses

Results of Hypothesis 1

Hypothesis 1 suggested there was a difference in northern colonial and British construction versus southern colonial construction in terms of wood use. British and northern colonial ships primarily used white oak, elm and red/scots pine for ship manufacture; while southern colonial ships used woods such as southern yellow pine, live oak and cypress. The vessels in this study indicate that a contrast in wood use existed (Table 6.1).

The Brown's Bay, *Philadelphia*, *Boscawen*, Otter Creek, and Terrance Bay vessels can be identified as northern colonial or British construction according to historical and geographical evidence. Their wood identifications of white oak and red/scots pine follow the predicted patterns for such vessels. The absence of southern woods in construction further substantiates northern colonial or British wood use. White pine, white oak, elm and red/scots pine are only indicators, however, and cannot definitively prove if a vessel represents northern colonial or British

Table 6.1
COMPARISON OF WOOD USE

	Elm	White Oak	White Pine	Red Scots Pine	Southern Yellow Pine	Cypress	Live Oak	Pine	Red Oak
Brown's Bay		X	X						
Deadman's		X			X				
Otter Creek		X		X					
Terrance Bay		X		X					
Philadelphia		X						X	
Boscawen		X	X						
Rose Hill		X						X	X
Invincible	X	X							
Bellona	X	X							
Diana	X	X							
Blanford	X	X							
Granado	X	X							
Ronson		X	X	X			X	X	
Brown's Ferry					X	X	X		
Clydesdale		X			X	X	X		
Onslow Island		X			X	X			
Malcom		X			X	X	X		
Trent River					X	X	X		
Little Landing					X		X		

construction styles.

A vessel's origin is more clearly determined through the incorporation of southern woods. Although almost every vessel in this study has white oak in its construction, not every vessel is northern colonial or British built. What separates the two areas is the use of southern woods in specific vessels.

Local shipbuilding traditions are identified in the Clydesdale, Onslow Island, Malcom Boat, Brown's Ferry, Trent River and Little Landing vessels. These vessels were made of locally available woods such as live oak, cypress and southern yellow pine. Their origin stands out because of the inclusion of these regional wood types.

Frederick Hocker attributes construction methods on many southern-built vessels to shipwrights trained in Britain who integrated their traditional knowledge with locally available woods.[74] This explains the continued use of white oak on southern built vessels. Although other, equally serviceable woods were available, shipwrights continued using trusted woods such as white oak.

Vessels such as the Ronson ship appear to be a mixture of the two areas. The Ronson ship had northern woods, such as white pine, but southern woods such as live oak may also have been used. The incorporation of live oak alone should not assign a ship to southern colonial origin as live oak was used for repair, patching and construction on many vessels, especially those stationed or repaired in the southern colonies. The Ronson ship had other woods found in both the northern and southern colonies, such as white oak, juniper, hickory and ash.[75]

The Rose Hill wreck included woods such as red oak, beech and maple.[76] It was probably a northern colonial vessel as European vessels did not use red oak, maple, or beech.[77] Red oak and maple are also not common to southern coastal areas. These factors, along with the absence of southern regional woods, suggest the vessel was built in the northern colonies.

The archaeological data revealed a possible difference between northern colonial, British and southern colonial wood use. Most of the vessels' origins are unknown and therefore cannot assist in validating or refuting this premise. Available information does suggest hypothesis 1 is plausible and warrants further examination.

<u>Results of Hypothesis 2</u>

Hypothesis 2 suggested there was a contrast between wood species used in naval ships from species used in merchant vessels. Archaeological samples show that little wood use difference existed between the two construction styles. The most apparent difference was the use of elm keels in naval vessels. Naval architects advised using elm keels. Indeed, plans for ships such as the Invincible, 1,793 tons; Bellona, 1,614 tons; Blandford, 375 tons; and Diana, 999 tons, denote elm keels.[78] These ships on average were quite large and were navy built.

The Granado, 278 tons, also had an elm keel.[79] Though larger than most ships in this study the Granado is still considered a small vessel. The Granado's elm keel suggests that elm was preferred for naval keel construction, regardless of size, and elm keels should therefore be on British naval vessels.

To substantiate this, further documentary evidence came from William Sutherland's Britain's Glory. Sutherland specified elm keel sections according to tonnage: vessels of 1,800 tons should have no more than five elm segments, those of 1,000 tons should have no more than four segments and those below 400 tons should have no more than three segments.[80] This indicates that size was not a factor in selecting species for keels. Unfortunately, this study lacked any excavated small British navy vessels. The Deadman's Shipwreck is a British naval vessel, but the keel was not identified and therefore could not help prove or disprove this premise.

The other vessels are a mixture of British, northern colonial and southern colonial construction. Although the diversity provides a wide range of ship types and sizes, none of the excavated keels were elm. This suggests that a difference existed but, until there is an identified elm keel from a naval vessel, this hypothesis cannot be confirmed.

Surprisingly, except for regional variations, there were no overall wood selection differences between naval and merchant vessels. British navy, merchant, and colonial built vessels had white oak for most structural elements such as framing, planking, stem and stern posts. Southern colonial vessels incorporated white oak along with southern yellow pine, live oak and cypress. Archaeology failed to show a contrast existed between naval and merchant vessels.

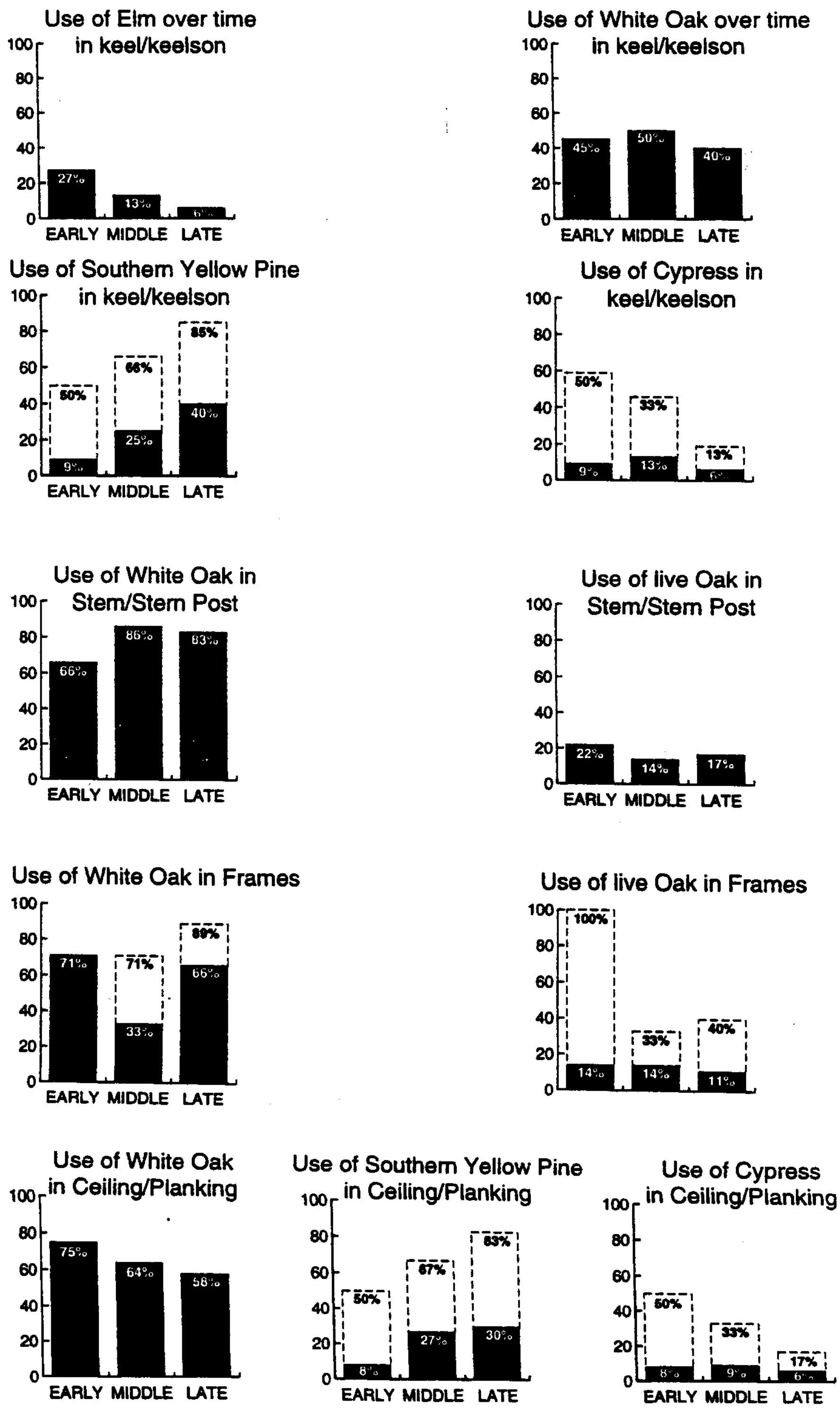
Results of Hypothesis 3

Hypothesis 3 projected that a change in wood use occurred in the eighteenth-century. Page 146 shows a graphic comparison of wood species selection over time.[81] Each graph represents an individual species of wood and its use over time within a specific element. The solid lines represent the sampled percentages of a wood species as determined from a comparison of British, northern and southern colonial vessels. The dotted lines show the sampled percentages of a wood species as determined from only southern colonial vessels. A breakdown of each vessel's wood use by element is found in Appendix C.

The graphs demonstrate that keels and keelsons were primarily made of four woods: elm, white oak, southern

Figure 6.A.

Percentage of wood use over time as determined by species and element



yellow pine and cypress. White oak was the most prevalently used with an average of 45%. White oak remained popular throughout the century suggesting that shipwrights were loyal to white oak and consistently chose to incorporate it in their ships. Other woods, such as maple and red oak, were identified but comprised only 5% of the overall species selection and were therefore not included.

The percentage of elm keels and keelsons declined in number as the century progressed. One possibility is that, historically, it is known that elm's population diminished in the eighteenth-century. The graphs, however, show no other wood increasing to take elm's place. This leaves a void in interpreting wood selection for northern and British vessels.

Southern yellow pine does show a proportional negative correlation to elm's decrease. Southern yellow pine's increase is probably not representative of overall wood use, but demonstrates an increase of use in southern vessels as southern yellow pine was not used extensively on northern or British vessels. A larger sample may show that white oak or another wood such as larch, increased to take elm's place in keel and keelson wood use.

Southern yellow pine increased in keel and keelson construction from 7% to 40%, while cypress remained relatively stable around 10%. When considering only southern vessels, southern yellow pine's percentage increased from 50% to 85% and cypress decreased from 50% to 15%. This suggests, that over time southern colonial shipwrights moved away from using cypress and began incorporating southern yellow pine. This trend may be due to a decrease in cypress trees, economic or other unknown outside influences.

Only two woods were significant in stem and stern post construction, white oak and live oak. White oak averaged 78% of the identified stem and stern posts while live oak averaged only 18%. The graphs show that white oak remained prevalent in stem and stern post manufacture throughout the eighteenth century. Live oak, though comprising only a small overall percent, did remain significant in southern colonial ship construction.[82]

The graphs for frames are almost identical to stems and stern posts. White oak is again prevalent, averaging 77% while live oak averaged only 13%. A difference between stem and stern posts and framing, was that white oak played a significant role in southern colonial framing species selection. By mid century white oak comprised 33% of identified frames and by late century, 60%. This shows that white oak was an integral part of the southern colonial shipbuilding tradition. Shipwrights retained their value of white oak and incorporated it into floors, futtocks and top timbers.

Ceiling and planking utilized three woods: white oak, southern yellow pine and cypress. An overall comparison reveals that white oak was the premier ceiling and planking wood. It averaged 66%, while southern yellow pine and cypress average 22% and 8% respectively. When looking at only southern colonial vessels, southern yellow pine and cypress increased to 67% and 33% respectively. As with keels and keelsons southern yellow pine appears to supplant cypress in ship wood use.

The graphs reveal other trends, such as white oak's continued use in each area. This shows that white oak was a favorite ship construction wood for most elements and was utilized throughout the century. Although historical documents related that white oak was depleted and being replaced, archaeological data suggests that white oak remained a viable ship construction wood throughout the eighteenth century.

Another aspect brought out in the graphs was that live oak, cypress and southern yellow pine were used for certain purposes. Live oak was utilized in stem, stern post and framing construction while cypress and southern yellow pine were found in keel, keelson, ceiling and planking. This difference is probably due to the different physical attributes of each species. Live oak is an extremely crooked timber. Southern colonial shipwrights needed live oak's compass timber to build effective stems, stern posts and frames. Conversely, southern yellow pine and cypress are found where sturdy, large, straight trees were needed. Southern yellow pine and cypress adequately meet these requirements.

Overall, the graphs show that major changes did not occur. White oak was utilized in British, northern and southern colonial vessels while southern yellow pine, cypress and live oak were incorporated in southern colonial vessels. Trends in wood species did occur in specific elements. Southern yellow pine displaced cypress for ship wood use in certain elements, while elm's percentage decreased in keel and keelson construction. The comparison is a guideline, revealing historically undocumented information. Further analysis and a larger data base would help clarify these trends and possibly discover new ones.

Results of Hypothesis 4

Hypothesis 4 proposed that excavated and analyzed sites would reveal patching or repairs. Some wood sample identifications provided evidence of secondary construction. The clearest evidence is found on the Ronson ship. The Ronson ship has 61 identified treenails; 55 are live oak, two are white pine, one is ash, one is hickory, one is juniper and one is identified to the *Pinus* spp.[83] Warren Riess and those associated with the Ronson excavations are probably correct in assuming the odd species are due to patching or replacements.[84] The wide variety is inconsistent with original ship building species as hickory and juniper are not found in other structural elements. This suggests that the odd species were later incorporated in the ship. Unfortunately, none of the species gives conclusive geographical information and can therefore not help in determining origin or ship history.

The Deadman's Shipwreck has two unusual wood species. One external plank is live oak while another plank is identified as a hard pine, possibly southern yellow pine.[85] Deadman's Shipwreck, tentatively identified as a British naval vessel, is primarily white oak.[86] The two odd samples may represent repairs during its station in Pensacola.

A third vessel, at Brown's Bay, also "revealed extensive modifications to the hull."[87] Structural wood identifications substantiate the idea that repairs and changes occurred. Of six frame samples, five are white oak and one is ash. The ash sample comes from archaeologically identified secondary construction.[88] The unusual species and its archaeological context combine to reveal that the vessel underwent repairs at least once. Examples such as this show that extensive sampling reveals undocumented information such as patching or repairs.

Results of Hypothesis 5

Hypothesis 5 stated that if ideal woods were used for ship construction they would be found on archaeological sites. Historical documents relate what woods shipwrights and architects preferred for ship manufacture while archaeological materials indicate actual use.

The archaeological wood sample results show that the majority of historical information, relating to eighteenth-century wood use, is accurate. Although documents relate widespread fraudulent behavior, these actions did not manifest themselves in the archaeological samples.

Shipwrights and architects such as Thomas Riley Blankley, William Sutherland and Gabrielle Snodgrass advocated white oak for ship construction. The excavated vessels show that white oak was heavily used in most eighteenth-century vessels. Despite the timber trade, warfare, government and human intervention, shipwrights were able to construct ships in accordance with ideal species preferences.

Surprisingly, little or no documentation exists for southern colonial-built vessels. Evidence for the use of southern yellow pine, cypress and live oak for ship construction comes primarily from archaeological data. These vessels are not anomalies in wood use but reveal previously undocumented information and further historical research.

Results of Hypothesis 6

Hypothesis 6 predicted that furniture and cask samples would parallel documented trends in land wood use. Since furniture remains rarely survive in archaeological sites, information must be gleaned from historical documents and in private or museum collections. Indeed, no furniture remains were excavated from the vessels discussed in this chapter.

Casks

Three vessels have cask remains: Terrance Bay, Otter Creek and Invincible. The Invincible carried oak barrel staves used for powder and spirits.[89] The Otter Creek site has red oak staves while the Terrance Bay site has staves identified only as oak.[90]

These findings are consistent with historical documentation. White and red oak was used for eighteenth-century cask construction. White oak was preferred for tight cooperage though used for slack cooperage as well. The powder and spirit casks needed an impermeable wood to prevent the contents' leakage or spoilage. The Invincible's staves then were most likely white oak, to keep moisture from the powder or the wine from seeping. The red oak staves on the other hand were probably used for slack cooperage.

No southern colonial built vessels had identified cask remains. This is unfortunate because it would be interesting to see if southern-colonial coopers utilized regional woods for cask construction. Unfortunately, little historical information exists. References imply pine cask construction but do not elaborate further as to species or suggest if other southern woods were utilized for cask construction. Without documentary evidence historians then must rely on archaeological recoveries to provide the best source for determining shipboard cask wood use.

Conclusion

The preceding hypotheses present a guideline for future historical and archaeological research. They demonstrate that a comparison of wood species from eighteenth-century vessels is necessary to reveal important details about ship construction, the timber trade and economic and social thought that is unavailable when examining one vessel or vessel type. The comparison is important because it provides an overview of eighteenth-century ship species selection rather than relating one conclusion.

The hypotheses also reveal that historical and archaeo-botanical research must combine in order to reach a more accurate view of eighteenth-century wood use. Some of the hypotheses rely heavily on historical information because the archaeological material or botanical evidence is scarce or non-existent. Other hypotheses rely heavily on archaeological material and botanical evidence because the historical record is absent. Together the three areas create a stronger and more precise view of eighteenth-century ship construction methods.

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81.The graphs are divided into three groups: early, middle and late. Most of the vessels have unknown construction dates, therefore they were grouped into relative areas to facilitate analysis.

82.More data is necessary to generate percentages to any conclusive amount. The only early southern colonial vessel used in this study is the Brown's Ferry vessel. There is no indication whether the vessel is indicative of true southern colonial wood use or not. Further investigations are needed to propose a hypothesis.

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CHAPTER SEVEN

Introduction

Wood use was an important aspect of eighteenth-century life. It was the primary construction material for ships, houses, furniture, tools and casks. Wood's procurement and proper utilization therefore was essential for effective production. This thesis explored wood use in ship construction, shipboard furniture and casks.

The thesis' primary purpose was to determine what wood species ships were made of and why. The answers evolved from a variety of influences. Shipwrights, naval architects, government officials and private individuals influenced wooden ship construction through a series of regulations, restrictions and beliefs. They determined what woods were usable or available for eighteenth-century ship construction and created an abundance of treatises, letters and documents revealing timber's importance. The timber trade, government, military and private affairs combined to create a complex system of wood procurement.

Research methodology

This thesis combined historical documentation and archaeological samples to better understand eighteenth-century wood use. Historical information from contemporary and modern documents relate which woods were preferred for ship construction. Archaeological wood samples reveal which woods were actually used. Each source alone creates an incomplete perception of eighteenth-century wood use, so the two sources were combined to establish a more holistic understanding of eighteenth-century wood species selection.

The first step in exploring eighteenth-century wood use was to create the historical foundation. This required collecting different historical sources relating to the eighteenth-century timber trade and wooden ship manufacture. The documents show which species shipwrights and architects recommended for ships.

Historical information is limited, however, as documents only suggest what species were preferred. The manuscripts describe which species an individual thought or proposed for ship construction rather than detailing actual wood use. Researchers should also be wary of a document's reliability as it may reflect author bias and misunderstanding rather than reality.

The second area of documentary research focused on wood. Each structural element of a ship exists in a unique set of environmental conditions and has specific requirements necessary to successfully meet projected stresses. This means each structure needed a specific wood species incorporating those properties conducive to the particular conditions. For example, the keel required a strong, durable and straight wood while deck planking needed a hard, light weight wood that held fasteners well.

This section also examined each structural element's ideal wood. Certain species were better suited for particular uses. Pines such as red/scots and white were ideal for masts, deck planking and sheathing, while elm was well suited for keels. The documentary information is important because it implies that shipwrights understood a wood's inherent properties and applied them to specific purposes.

The documentary evidence laid the foundation for a series of testable hypotheses. The hypotheses discussed differences in wood use due to time, origin and use. The hypotheses also proposed that patching or repairs would be evident in accurately examined archaeological material. In general, each hypothesis was tested to see if archaeological evidence supported historical expectations.

The next step tested expected against observed wood use. The vessels represent a number of time periods, sizes, ship types, uses and origins, thus allowing a comprehensive examination of eighteenth-century ship wood use. The archaeological samples indicate which woods were actually utilized for wooden ship construction (See Appendix C). The identified samples were then compared against one another and the historical hypotheses to determine eighteenth-century wood use.

Discussion and Analysis

Hypothesis 1

Hypothesis 1 predicted a wood use difference between northern-colonial and British vessels versus southern-colonial vessels. Archaeological evidence demonstrated that geographically a difference in wood use existed. Southern colonial builders incorporated local woods such as live oak, cypress and southern yellow pine in their vessels while British and northern colonial builders did not make use of these southern woods. Indeed, these woods' inclusion set the wood use trends apart, resulting in a validation of hypothesis 1.

Further examination suggests differences existed between northern colonial and British wood use. Northern colonial vessels such as Brown's Bay and Boscawen included white pine in their construction.[1] White pine grew only in the northern colonies and, except for masts, was not shipped in large amounts to either Britain or the southern colonies. Its inclusion is most likely the result of construction or repair in the northern colonies.

The Rose Hill wreck included a number of northern colonial woods such as maple, red oak and beech.[2] These woods were not utilized in the European or southern colonial boat building traditions.[3] Although white pine was not found on the Rose Hill site, other woods such as maple and beech support northern-colonial origin.[4] This site may represent another variation in northern-colonial ship wood use.

The Ronson ship possibly represents middle-colonial wood use. The vessel had large amounts of white oak, pine and live oak incorporated in its construction.[5] These woods represent both northern and southern-colonial wood use. Middle-colonial origin is a valid conclusion as both southern and northern woods were more accessible to the middle colonies.

Hypothesis 1 would be refuted if archaeological evidence showed a blending of construction materials. A British or northern-colonial vessel would have to incorporate widespread use of southern regional woods to disprove this premise. Southern colonial vessels, constructed of white oak, would not invalidate this premise as white oak grew throughout the world and was found in all Anglo-construction traditions. Differences came from incorporating southern woods in southern colonial vessels. This study showed that the areas had distinct wood use and strengthened hypothesis 1.

Hypothesis 2

Hypothesis 2 posited that a difference between naval and merchant wood use existed. The archaeological data only partially substantiates this hypothesis. The archaeological data shows little difference between navy and merchant construction. Appendix C clearly demonstrates that, excluding southern colonial vessels, white oak was used for most construction elements in every vessel, regardless of size, function or origin.

The only possible difference appeared historically in keel construction. Naval vessels such as the French-built Invincible, Bellona, Diana, Blandford and Granado had elm for keels.[6] This information came from historical sources exclusively. No excavated vessel had an elm keel. This data suggests that a difference existed but an identified elm keel from a naval vessel is necessary to definitively advance this hypothesis.[7]

Hypothesis 2 would be refuted if excavated merchant vessels had elm keel construction or navy built vessels had an oak keels. Vessels examined for this study did not support hypothesis 2 as no large scale wood use differences were revealed. A larger sample, including excavated naval vessels is needed to prove differences existed.

Hypothesis 3

Hypothesis 3 tested wood use change over time. The excavated vessels showed little to no overall change in wood use, but revealed that during the eighteenth century some species were replaced. Minor variations and geographical limitations created some changes in wood use, but were not representative of changes over time. Theses samples were therefore excluded from this discussion.

On one level neither southern colonial, northern colonial nor British built vessels exhibited a wood use change over time. Although no vessel was built identically, each retained an overall wood use continuity. White oak remained prevalent throughout the century and southern colonial builders continued incorporating live oak, southern yellow pine and cypress.

Changes appeared in examining specific elements. The most apparent variation was a shift from using cypress to using southern yellow pine for keels, keelsons, ceiling and planking. The two woods were equally represented at the century's beginning but by the end, southern yellow pine was found in 85% of keels, keelsons, planking and ceiling while only 15% of these elements were cypress.

Documents suggested that many woods were used to replace depleted white oak timber. The incorporation of woods such as larch, teak and pine in the latter part of the century would indicate changes occurred. None of these woods appeared in substantial amounts, suggesting that large scale changes did not occur. As white oak remained prevalent in ship construction for most structural elements, this implies that shipwrights remained constant with white oak construction despite implications of depletion or corruption.

Hypothesis 4

Hypothesis 4 predicted that accurately excavated and sufficiently sampled vessels would reveal evidence of patching or repairs. Archaeological evidence supported this premise by showing anomalies in woods used for individual vessels. The Ronson ship included historically and archaeologically unusual woods such as juniper and hickory for treenails.[8] Possible evidence of patching and repairs was found in specific elements such as the Betsy's pine keelson segment or the Brown's Bay ash frame.[9] These examples indicate that repairs are discernable through archeological investigations.

This hypothesis is difficult to refute. Miscellaneous species could have been included in the original construction due to a lack of available ideal lumber or included to serve in a temporary specialized function. Repairs could be overlooked in the sampling procedure or have disappeared in the site formation process. The vessel may also not have been in use long enough to warrant repairs. This hypothesis can only suggest the possibility of revealing patching but cannot prove that evidence of repairs will always survive or be sampled.

This hypothesis also relies on accurate and proper sampling techniques. Archaeologists take representative samples rather than thoroughly and consistently sampling an entire site. This oversight is usually due to financial and time constraints and available structural remains. If proper analysis is to occur comprehensive sampling of an element is imperative. The greater percentage of elements sampled or percentage of an element sampled, the more accurate the analysis.

Hypothesis 5

Hypothesis 5 suggested archaeological material would substantiate historical documentation. Indeed, the archaeological data generally confirmed documentary information. The wood samples reveal that actual wood use reflected theoretical wood use in most instances. Despite documented fraudulence within the timber trade and ship building industry ideal woods were incorporated in ship construction.

Southern colonial vessels have little existing documentation, therefore much of the information must be derived from archaeological excavations. The lack of documentation suggests that woods such as southern yellow pine or cypress were not utilized in Britain or considered as quality ship building material. The excavated sites corroborated this interpretation since none of the northern- colonial or British ships had widespread use of southern woods.

Indeed, much of the archeological data for northern colonial, British or southern colonial vessels supports historical predictions. Historical documents relating to the timber trade and wooden ship construction have proven reliable and are essential in understanding eighteenth-century ship wood species selection.

A substantial difference between documentary and archaeological data would refute this hypothesis. All hypotheses in this thesis are derived from historical documents. If the other hypotheses were refuted then hypothesis 5 would be contradicted. Hypotheses 2 and 3 did show some differentiation between theoretical and actual wood use, but each needed more information to accurately determine actual wood use trends. In general, the archaeological data corresponded with historical documentation, strengthening research and interpretation.

Hypothesis 6

Hypothesis 6 suggested that shipboard furniture would parallel land trends. Eighteenth-century upper-class homes had fine, ornate furniture pieces made of popular woods such as mahogany. Lower and middle class homes had less ornate, walnut or pine furniture items. Furniture found on smaller vessels should therefore reflect middle to lower class walnut and pine construction. The Betsy's excavated walnut and pine furniture remains supports this premise.[10]

Cabinetry pieces came from the Betsy's stern where the officers and captain were quartered. The cabinet was pine indicating that the furniture item was not an upper-class piece, but was representative of the middle to lower classes. In the bow, where ordinary sailors bunked, excavations found no evidence of furniture.[11]

Excavators recovered cask remains from some vessels. Each site's cooperage paralleled documented cask construction. White oak tight casks carried liquids such as water, wine and ale. White oak was impermeable, durable, withstood internal pressures and did not alter the content's taste. The excavated casks such as the Invincible's white oak powder and spirit barrels corresponded with historical documentation.[12]

Other woods such as red oak, pine and ash carried dry goods such as peas, corn and tools. These woods are permeable, less durable and affected taste. Archaeologically retrieved red oak, ash, pine and beech casks were probably used for slack cooperage.

Contradiction of hypothesis 6 requires archaeological remains of highly ornate, large, expensive furniture pieces to be recovered from small vessels. Larger vessel would reflect higher class officer and therefore would have more elitist furniture. Unusual woods such as teak would also differ from the traditional land based wood use. Cask construction is difficult to refute as most woods are found in slack cooperage. An unusual wood such as red oak, pine or ash, used as tight cooperage would diverge from historical documentation. The excavated furniture and cask samples in this thesis corresponded with historical and previous archaeological evidence. They supported the premise that land-based trends are applicable to ship board trends.

Conclusion

In some hypotheses historical data alone existed, while other hypotheses relied upon archaeological data for interpretation. The two areas are not independent but dependent upon one another to accurately analyze wood use. Together they provided a holistic interpretation of eighteenth-century wood species selection.

An aspect derived from the testing was the need for proper sampling techniques. Extensive and accurate sampling was essential for archaeologists to fully understand a site's wood use. Sampling one or two elements was a hit-or-miss method that revealed basic construction and examined little of the site's overall wood use. Every persisting element should be sampled or an inaccurate picture of eighteenth-century wood use could result.

Complex elements such as framing should be extensively sampled to determine if patching or repairs occurred. Going by "the wood looked different" proves unsatisfactory as degraded wood loses its original appearance. A large percentage of the multiple structures such as planking should be sampled to see what is the representative wood. The higher the percentage of sampled elements, the more accurate the analysis.

This thesis is a guideline for future research. It shows the importance of interdisciplinary analysis. History, botany and archaeology combined to present a better view of eighteenth-century wood use. History provided background; archaeology provided samples; and botany identified the samples and revealed wood species. Together they created a detailed understanding of eighteenth-century wood species selection and use.

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3.Ibid., p.56.

4.Amer, Brown's Bay, pp.123,129,130.

5.The live oak is tentatively identified. The sample showed characteristics of live oak but could not be positively identified. Richard Jagels, "The Anatomical, Mechanical and Chemical Analysis of the Ronson Ship Timbers.", Underwater Proceedings from the Society for Historical Archaeology Conference (1986), p.141; Warren Riess, Personal Communication; Riess, Study of an Eighteenth-Century Merchantman, p.48; Richard Jagels, Betty Seifert, James Shottafer, James Wolfhagen and Jonathan Carlisle, "Analysis of Wet-Site Archaeological Wood Samples." Forests Products Journal (1988) pp.33-34.

6.Peter Goodwin, Blandford (Annapolis: Navy Institute Press, 1988), p.10; Peter Goodwin, The Bomb Vessel, Granado (Annapolis: Navy Institute Press, 1989), pp.8,11,18; Brian Lavery, The 74-Gun Bellona (Annapolis: Naval Institute Press, 1985), p.10; Brian Lavery, The Royal Navy's First Invincible (Portsmouth: Invincible Conservations, 1744-1758, 1988), p.X; David White, The Frigate Diana (Annapolis: Naval Institute Press, 1987), p.8.

7.An elm keel was identified from the Spanish vessel, El Lerri, 1733. Newsom to Stephen James, Research Associate, Office of Underwater Science, Indiana University, Bloomington, Indiana, September 24, 1992.

8.Jagels, "Anatomical, Mechanical and Chemical Analysis", p.141; Riess, Personal Communication; Riess, Study of an Eighteenth-Century Merchantman, p.48; Jagels, et al., "Analysis of Wet-Site", pp.33-34.

9.Amer, Brown's Bay Vessel, p.IV; John William Morris, Site 44YO88: The Sunken British Fleet at Yorktown, Virginia (MA Thesis: East Carolina University, 1990), p.122.

10.See Appendix B,

11.Broadwater, "Merchant Ships of War: The Sunken British Fleet at Yorktown, Virginia." Underwater Proceedings from the Society for Historical Archaeology Conference (1989), p.122.

12.John Bingeman, "Interim Report on Artefacts Recovered From the Invincible (1758) Between 1979-1984." International Journal of Nautical Archaeology 14.3 (1985), pp.195,197.

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APPENDIX A

Wood Identification

To help the reader understand eighteenth-century wood use a section on wood identification is included. Before being able to perceive and appreciate wood use information, a researcher must know what wood identification entails. This requires a microscopic examination of archaeological wood samples.

Each year a tree undergoes a period of growth, creating an annual ring(Figure 3). Annual rings consist of earlywood and latewood. Earlywood develops in the springtime and is fast forming with large pores, making it less dense. Latewood, formed during the summertime, develops slowly with smaller pores. It is more compact giving it a darker appearance.

Samples are sectioned along three planes to ensure all anatomical features are represented. The three planes are transverse (cross-section), radial and tangential (Figures 1,2). The samples must be exactly on these planes or important details become obscured.

The transverse or cross-sectional view shows the arrangement of annual rings, pores, rays and parenchyma. The first feature noticeable from this section is whether the sample is a hardwood or softwood. A basic distinction between hardwoods and softwoods is that hardwoods contain vessels or large pores whereas softwoods do not (Figure 3). (Some softwoods have resin canals which may be mistaken for pores, however, under a hand lens or low magnification microscope the difference is apparent.)

The cross-section also details ray and parenchyma abundance and thickness. Rays conduct food and water laterally along the tree (Figures 2,3).[1] In cross-section they appear much like a wheel's spokes. Parenchyma are thin-walled wood cells involved in food storage and distribution (Figure 4).[2] In cross-section, at a low magnification, they usually appear as lighter colored areas, although after conservation or if occluded, they may appear as dark spots. In some wood species, parenchyma are associated with pores, peritracheal, while in others they are not, apotracheal. These divisions become more specific in terms of species identification (Figure 4).

A radial section needs a higher magnification to discern details. Most information from a radial section comes from the walls of vessels, pores and rays. A major diagnostic feature is pitting on the vessel and ray walls (Figure 2). To see these details requires a high magnification microscope.

Rays are composed of ray parenchyma and ray tracheids. Normally ray parenchyma are located in the middle of the ray while the ray tracheids tend to occur on the upper and lower margins of the ray. The area where ray parenchyma and a longitudinal tracheid meet is a cross field. Pitting within the cross field falls into five distinct categories; pinoid, cupressoid, fenestriform, taxodioid and piceoid. Ray tracheids are either smooth or dentate, having tooth-like projections. Combinations of ray tracheids and ray parenchyma and their pitting are a major aid in softwood identification.

The tangential section is perpendicular to the rays and parallel to the growth rings.[3] This section shows ray ends and exposes another angle of the tracheids and vessels (Figure 2). The section reveals ray width, height, location and quantity in a much clearer and easier to distinguish form. Other features such as intervessel pitting, nodules and spiral thickenings appear more distinct in this section. The view is necessary because degradation may eliminate features from the other less visible sections.

Once all three views are taken and prepared, the slides are checked against a series of keys to determine species. The keys, following diagnostic features, continually branch off until the correct wood is found. Used in conjunction with comparative slides, the keys provide the surest method of wood identification.

Comparative samples are required for wood identification. When compared to modern wood, degraded wood appears distorted, making identification with keys or photographs difficult. Degraded wood samples allow more accurate determination of wood species.

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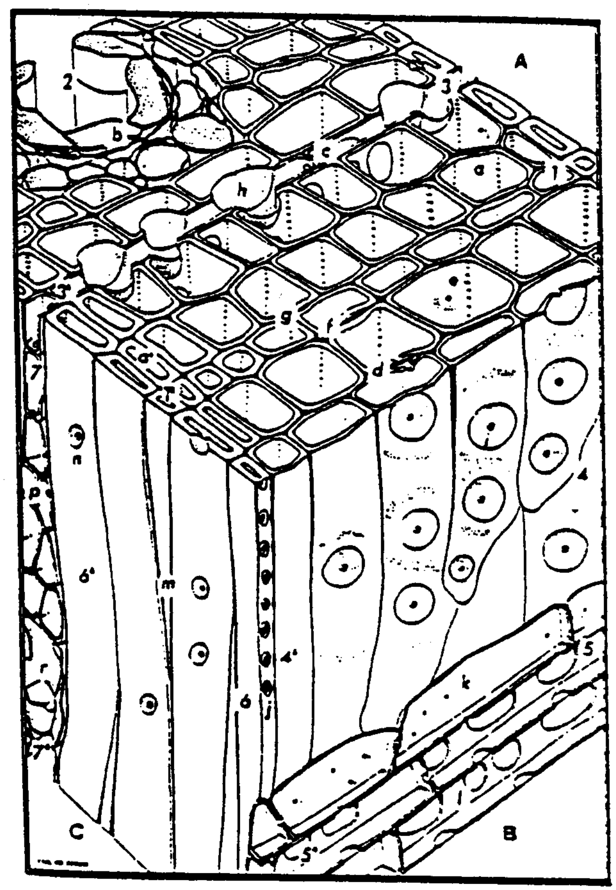
1. Hoadley, Bruce. Identifying Wood. (Newtown, CT: Taunton Press, 1990), p.208.

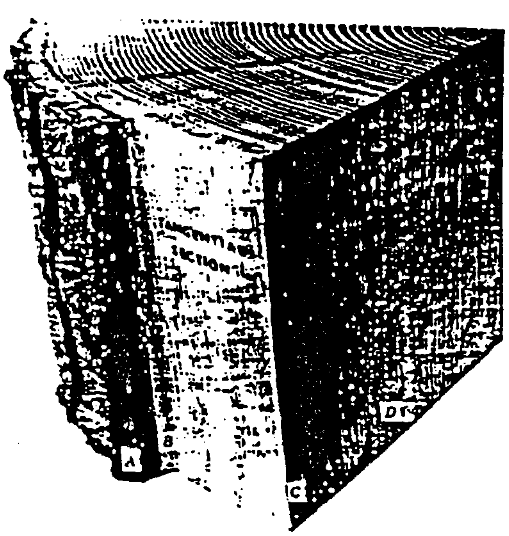
2. Ibid., p.206.

3. Ibid., p.210.



(Panshin, Textbook p.129)

Figure App.1 The Tree Stem



(Panshin, Textbook p.23)

Figure App.2

Schematic Drawing of Eastern White Pine

Surface A. 1-1a, portion of an annual ring; 2, resin canal; 3-3a, wood ray; a-a , longitudinal tracheids; b, epithelial cells; d, pit pair in median sectional view; f, pit pair in sectional view, showing torus; g, pit pair with no torus; h, window-like pairs between longitudinal tracheids and ray parenchyma.

Surface B. 4-4a, longitudinal tracheids; 5-5a, upper part of uniseriate ray; i, bordered pits on radial walls of earlywood tracheids; j, bordered pits on radial walls of late-wood tracheids; l, ray parenchyma.

Surface C. 6-6a, longitudinal tracheids; 7-7a, xylary ray; m, longitudinal tracheids; n, bordered pit; p, ray parenchyma, r, resin canal.

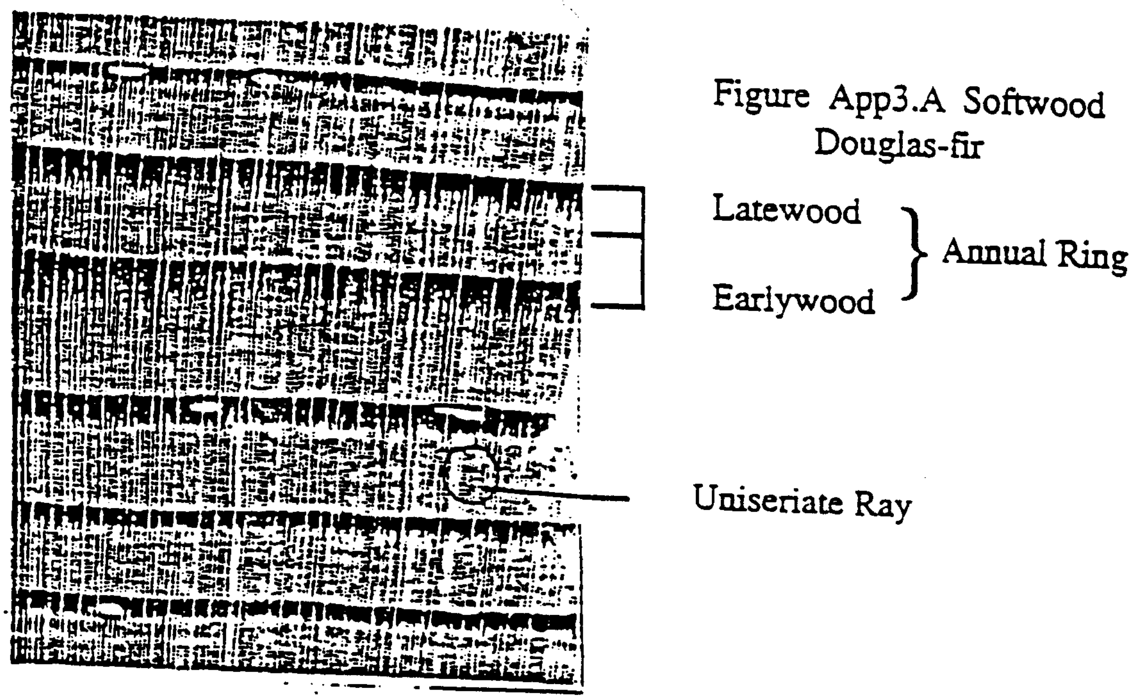


Figure App3.A Softwood
Douglas-fir

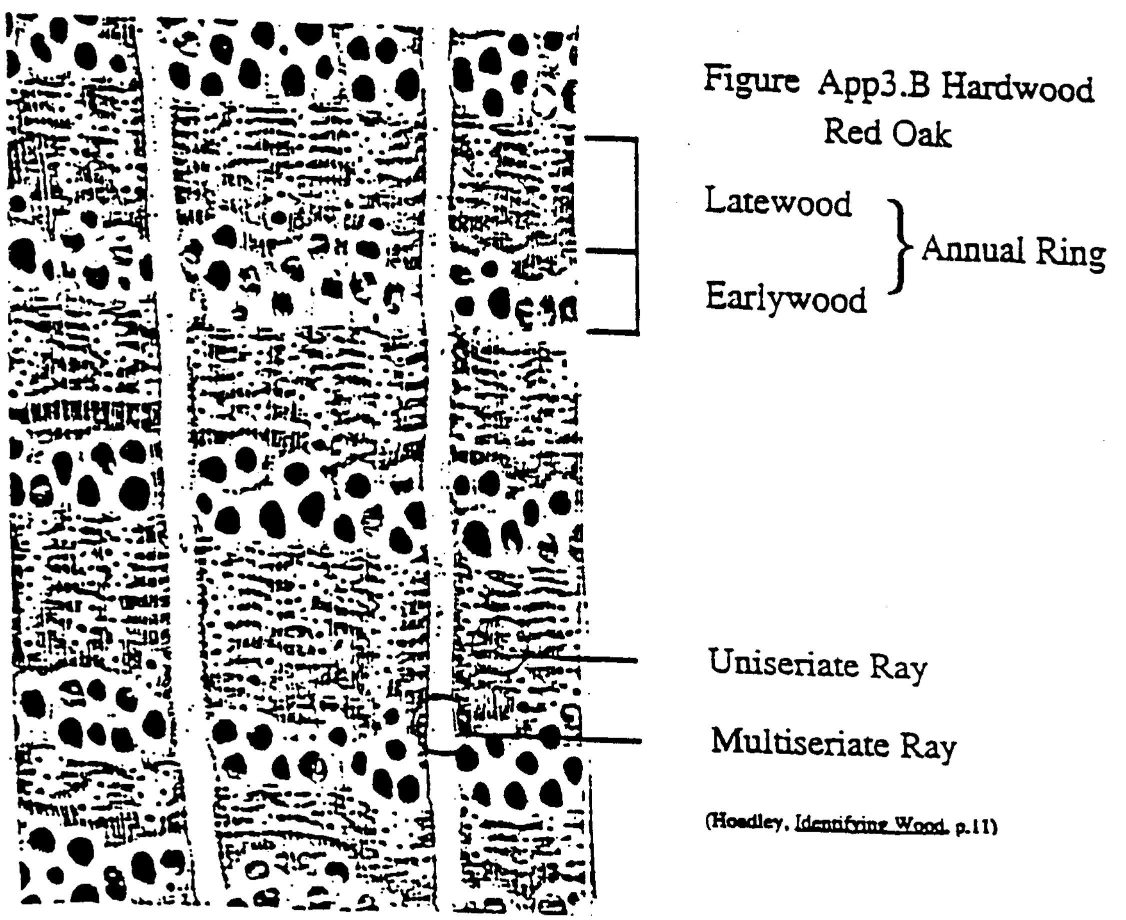
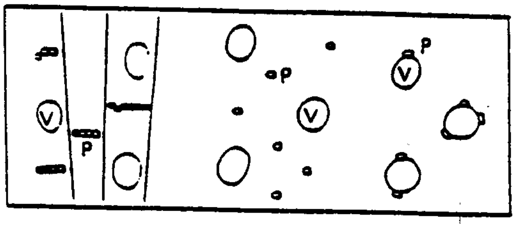


Figure App3.B Hardwood
Red Oak

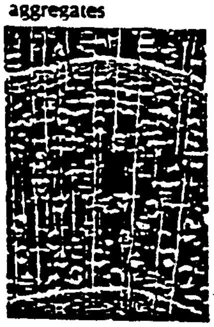
(Hoadley, Identifying Wood, p.11)

Figure App.4

PARENCHYMA TYPES



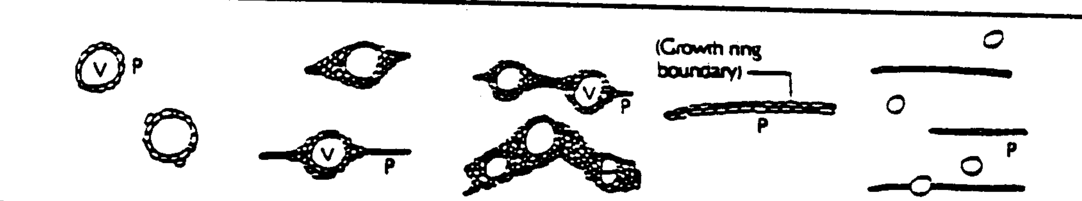
Apotracheal diffuse-in-aggregates | Apotracheal diffuse | Paratracheal scanty



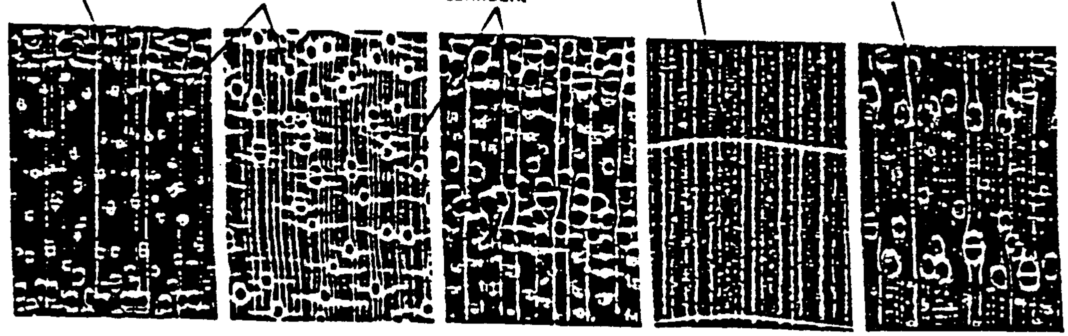
(Apotracheal diffuse and paratracheal scanty parenchyma are not visible with hand-lens magnification.)

Butternut (50x)

Longitudinal parenchyma (P) is classified on the basis of relationship to pores (V) and arrangement as seen in cross section.



Paratracheal vasicentric | Paratracheal aliform | Paratracheal confluent | Marginal | Banded



White ash (50x) | Ramin (50x) | Honeylocust (50x) | Yellow-poplar (50x) | Hickory (50x)

(Hoadley, Identifying Wood, pp.38-39)

APPENDIX B

Betsy Wood Samples by Use and Source

	Morris	Mitchell	White	Broadwater
Structural				
Stern Post	Oak			Structural Timbers Oak
Stem	Oak			
Gripe	Oak			
Chocks	Oak			
Breasthook	Oak			
Framing	Oak			Oak
Rudder	Oak			
Keelson	Oak & Pine			
Foremast	Pine	Red/Scots Pine		
Mainmast	Pine			
Deck Planking	Pine		Pine	
Ceiling	Oak		Oak	
Treenails	Oak			
Planking	Oak		Oak	
Sheathing	Pine	Red/Scots Pine		
Bulkhead				S. Yellow Pine
Cheekpiece				Red Oak
Tiller		White Oak		
Misc. Planks		Red/Scots Pine White Pine		
Casks				
Heads				
CA549		White Oak		
CA828		White Oak		
CA548		White Oak		
ECU#2		White Oak		
CS799		White Oak		
CS712		Possibly Ash		
CA527		Ash		
CS824		Beech		
CS819		Red/Scots Pine		

APPENDIX B (continued)

Staves		
CA515 #3	White Oak	
CA515 #5	White Oak	
CA515 #2	White Oak	
CA515 #2	White Oak	
CA520 #1	White Oak	
Hoops		
AS126		Willow
AS127		Chestnut
AS191		Oak
Blocks	Red Oak	
Furniture		
Board	White Pine	
Table	Red/Scots Pine	
	Walnut	
Table	White Pine	
Chair rung	Birch/Oak	
Cupboard	Red/Scots Pine	
	White Pine	
Moulding	Red/Scots Pine	
	White Pine	
Veneer	White Pine	

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------- Letter to Marcie Renner, Research Center for Archaeology, Yorktown, Virginia, December 16, 1986.

APPENDIX C Wood Use by Element & Vessel

KEEL	KEELSON	STEM	STERN POST	FRAMES	CEILING	PLANKING	DECK	SHEATHING	TREENAILS	KNEES	
OAK	3 OAK 1 PINE	OAK	OAK	OAK	WHITE OAK	WHITE OAK	HARD PINE	RED/SCOTS PINE	OAK		BETSY
	WHITE OAK	POSSIBLY LIVE OAK		WHITE OAK & LIVE OAK	WHITE OAK / POSSIBLY LIVE OAK	WHITE OAK / POSSIBLY LIVE OAK	RED/SCOTS PINE		LIVE OAK, WHITE PINE, HARD PINE, JUNIPER/HICKORY ASH	OAK	RONSON
WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK 1. ASH	WHITE OAK & WHITE PINE	WHITE OAK				LARCH & WHITE OAK	BROWN'S BAY
	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	HARD OR S. YELLOW PINE				WHITE OAK	DEADMAN'S
WHITE OAK				WHITE OAK	WHITE OAK	WHITE OAK	RED/SCOTS PINE	RED/SCOTS PINE	WHITE OAK		OTTER CREEK
				POSSIBLY WHITE OAK	POSSIBLY WHITE OAK	POSSIBLY WHITE OAK	WHITE OAK		OAK	OAK	TERRANCE BAY
		WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK					PHILADELPHIA
WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK	WHITE OAK WHITE PINE BEAMS		WHITE OAK & WHITE ASH		BOSCAWEN
MAPLE	WHITE OAK		RED OAK	BEECH & WHITE OAK	WHITE OAK	RED OAK		HARD PINE	WHITE OAK		ROSE HILL
Bottom Planking S. YELLOW PINE	BALD CYPRESS	LIVE OAK		LIVE OAK		S. YELLOW OR BALD CYPRESS			BALD CYPRESS	LIVE OAK	BROWN'S FERRY
S. YELLOW PINE	S. YELLOW PINE		LIVE OAK	LIVE OAK & WHITE OAK	S. YELLOW PINE	S. YELLOW PINE			BALD CYPRESS OR HEMLOCK	LIVE OAK	CLYDESDALE
S. YELLOW PINE	S. YELLOW OR BALD CYRESS	WHITE OAK		WHITE OAK		S.YELLOW PINE			S. YELLOW PINE/ BALD CYPRESS		ONSLOW ISLAND
S. YELLOW PINE	S. YELLOW PINE	LIVE OAK	WHITE OAK	LIVE OAK & WHITE OAK	CYPRESS & S.Y. PINE	S. YELLOW PINE				S. YELLOW PINE, WHITE OAK, LIVE OAK	MALCOM
				OAK/POSSIBLY S.Y. PINE		CYPRESS				POSSIBLY LIVE OAK	TRENT RIVER
S. YELLOW PINE	S. YELLOW PINE	LIVE OAK		LIVE OAK	S. YELLOW PINE	S.YELLOW PINE			S. YELLOW PINE		LITTLE LANDING #2
ELM	(MAJOR	PIECES OAK)									INVINCIBLE
ELM	(MAJOR	PIECES OAK)									BELLONA
ELM		OAK	OAK								DIANA
ELM											BLANFORD
ELM		OAK	OAK	OAK							GRANADO