WARWICK: A RIGGING RECONSTRUCTION OF AN ENGLISH GALLEON FROM 1619

A Thesis

by

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ABSTRACT

Warwick was an English galleon that sank in 1619 off the coast of Bermuda while transporting colonists and goods. The wreck was excavated in 2010-2012 under the direction of Dr. Piotr Bojakowski and Dr. Katie Custer-Bojakowski, as part of a joint National Museum of Bermuda, Institute of Nautical Archaeology, and Center for Maritime Archaeology and Conservation, project. A total of 24 complete, or nearly complete, rigging elements, 13 rigging fragments, and several rope fragments were identified and recovered from *Warwick,* including deadeyes, blocks, dead blocks, a mast truck, a potential fid, chain plates, and miscellaneous rigging pieces and rope. This thesis reanalyzes outfitting and rigging transitions of ships during the 17th century and creates a rigging reconstruction of *Warwick*. Machine learning applications on archaeological data, iconography, treatises and ship lists, and ship models, were used for analysis.

After an introduction to *Warwick's* history and recovered artifacts, an overview of the previous literature on rigging from the 17th century is covered as comparison for new data presented in this study. Then, a summary of archaeological data is presented via the creation of a rigging database from which nearly all known wrecks containing rigging artifacts were logged, accounting for 58 wrecks and at least 2,512 artifacts. A deadeye typology was made using this database including each deadeye's dimensions, shape, face form, wood grain, strap or strop attachment, score shape, and number of eye holes. Machine learning was applied to this deadeye database, which indicated that *Warwick's* deadeyes, with the exception of #79: 155-344, were within range of *Warwick's* sinking date. Combining the archaeological data and historical and iconographic sources, *Warwick* was then deduced to have a bowsprit, fore mast, fore topmast, main mast, main topmast, mizzen mast, and mizzen topmast, and each masts' corresponding yards, except for the mizzen topmast which may have only been fitted occasionally with a yard. The thesis ends with descriptions of the standing and running rigging which include shrouds, ratlines, catharpins, stays, backstays, ties, halliards, jeers, lifts, braces, parrels, trusses, sails, tacks, sheets, clew lines, martinets, bunt lines, bowlines, and brails.

DEDICATION

Dedicated to Ned Tsai.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Kevin Crisman, and my committee members, Dr. Donny Hamilton and Dr. Karen Kubena, for their guidance and support throughout the course of this research.

I would also like to thank Hannah C. Clark for her patience and willingness to develop the machine learning portion of this study, the National Museum of Bermuda for their help in providing information on *Warwick*, and Dr. Katie Custer-Bojakowski and Dr. Piotr Bojakowski for granting permission to *Warwick's* material and for allowing me to use their excavation and research for this thesis. I would also like to thank the other members of the *Warwick* excavation, Doug Inglis, Karen Martindale, and Michael Gilbart who compiled the data used herein. My deepest gratitude to Dr. Fred Hocker and Dr. Kroum Batchvarov for providing their guidance and knowledge on rigging, Dr. Jose Luis Casaban for his contribution on rigging sources and his translation of documents, and Charles Bendig for information on mast steps and rigging data from wrecks. I also want to mention the various researchers who contributed information on rigging artifacts from their projects and excavations for the database, without whom this thesis would not be complete, and who I am indebted to.

Finally, thanks to my parents (Amy and Tommy), grandparents, and siblings (Faith and Joyce) for their encouragement, Ned and Batman for keeping me company through long nights of writing, and to Jose for his support.

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The data on *Warwick* in Appendix A and Chapter 2 were provided by Piotr Bojakowski, Katie Custer-Bojakowski, Karen Martindale, Michael Gilbart, and Doug Inglis. The machine learning analyses in Chapter IV were conducted in conjunction with Hannah C. Clark. Fred Hocker provided information and consultation throughout the thesis, but contributed primarily in Chapters 3, 5, and 6, and provided data from *Vasa* in Appendix C. Data within Appendix B and C were provided via personal communication from Charles Bendig, Colin Martin, Daniel Brown, Dave Parham, Filipe Castro, Fred Hocker, John Bratten, Jose Luis Casaban, Katie Custer-Bojakowski, Nathaniel Howe, Niklas Eriksson, the National Museum of Bermuda, Piotr Bojakowski, Robert Parthesius, Thomas Bergstrand, and Tom Cousins.

All other work conducted for the thesis was completed by the student independently.

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CHAPTER I

INTRODUCTION

England's first permanent colonization efforts in North America began in 1607 when the Virginia Company landed a group of settlers, under the direction of Captain Christopher Newport, in what would become Jamestown, Virginia.[1] The Virginia Company investors were primarily interested in acquiring New World products such as lumber, gold, and especially tobacco that the colonists would produce and send back to England.[2] In addition to procuring goods, the English were vying for power in the Americas which they aimed to achieve by establishing a permanent presence there to counter the expansion of other European powers.[3] However, as lucrative as the New World seemed, colonization was difficult because the settlers were unprepared for disease, starvation, the harsh climate, and the lack of shelter and clean water. The settlers did not intend to grow the food they needed and instead planned to trade with the local inhabitants for sustenance.[4] Although tentative trade was established with the nearby Native Americans, relations were often strained and led to raids and warfare, some of which nearly wiped out the budding colony.

To support the failing colony in Virginia, annual fleets were sent from England in order to supply the necessary food needed to survive. The first and second supply fleets led by Christopher Newport successfully brought provisions as well as new settlers to Jamestown. On

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[1] This thesis follows *American Journal of Archaeology* style.
[2] Smith et al. 1626, 21-9.
[3] Smith et al. 1626, 29.
[4] Smith et al. 1626, 89-94.

June 2, 1609, the third supply consisting of seven ships and two pinnaces carrying 500 colonists and supplies left Plymouth under the direction of Newport.[5] However, unlike the previous two fleets, the third supply encountered difficulties on the way to Jamestown. On July 23, 1609, when the ships were about a week from Jamestown, a violent storm struck, scattering the fleet. *Sea Venture*, the flagship carrying the majority of the supplies intended for the colony, lodged between two rocks off the shores of Bermuda.[6] Prior to this wrecking, English mariners avoided Bermuda, known as the "Isle of Devils," due to the black hogs that inhabited the Island and its dangerous reefs.[7] To their surprise, the passengers and crew of *Sea Venture* found the island to be well-supplied with natural resources including potable water. For ten months, the castaways stayed on Bermuda and fashioned two smaller vessels, *Deliverance* and *Patience*, which eventually brought the colonists safely to Jamestown. Two of the 150 people on *Sea Venture* remained on Bermuda and were later joined by a group of colonists who officially claimed the island for the English.[8]

The colonization of Bermuda meant that the Virginia Company and its offshoot, the Somers Isles Company, had to send more supply ships to keep both colonies functioning. *Warwick*, an English galleon belonging to Sir Robert Rich, the second Earl of Warwick, was one such vessel commissioned to deliver new colonists and supplies to Bermuda and Virginia in 1619.[9] Estimated to be a 160-ton vessel, *Warwick* carried cordage, coarse textiles, grain, iron tools, and other goods, in addition to more colonists.[10] *Warwick* was to deliver Captain Nathaniel

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[5] Smith et al. 1626, 89.
[6] Wright 2013, 4-16; Lefroy 1882, 11-2.
[7] Smith et al. 1626, 172-73; Wright 2013, 16, 20-2.
[8] Wingood 1982, 333-34; Wright 2013, 53.
[9] Smith et al. 1626, 191; Ives 1984, 140-43.
[10] Bojakowski and Custer-Bojakowski 2017, 296; Ives 1984, 142-43.

Butler, the newly-appointed governor of Bermuda, to the island colony before continuing on to Virginia to unload more settlers and supplies.[11]

Butler's appointment to Bermuda was especially important because in 1618, mounting complaints of negligence and wastefulness of already scarce resources threatened the survival of the nascent colony. Miles Kendall, the temporary acting governor, was incompetent and lacked discipline, resulting in a dysfunctional colony.[12] In an attempt to regain control of the government and instill order, the Virginia Company recalled Kendall and appointed Butler as the fifth (but officially the third) governor of Bermuda.[13] Butler proved to be an excellent choice for governor and his tenure was pivotal in the history of Bermuda, leading to the construction of many of Bermuda's fortresses that still stand today including the State House, the oldest surviving English settlement in the New World, introduction of potatoes to Jamestown, in addition to the successful day-to-day management of the colony.[14] He later went on to write several books including *Six Dialogues about Sea-Services* and *The Historye of the Bermudaes or Summer Islands* that are still commonly cited historical works from the period.[15]

In addition to the safe transportation of Nathanial Butler, *Warwick* was then supposed to continue its journey and transport the year's tobacco crop back to England (otherwise it would spoil) after a short stop in Jamestown.[16]

A few primary sources mention *Warwick.* One of them is *The Rich Papers*, a series of letters and correspondences between Robert Rich and colonists in the New World; another is

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[11] Ives 1984, 347-48; Lefroy 1882, 148.
[12] Smith et al. 1626, 181-91.
[13] Smith et al. 1626, 181-91; Ives 1984, 121-25.
[14] Smith et al. 1626, 191-201; Neill 1886, 28; Lefroy 1882, 277-78; Lefroy 1877, 75.
[15] Carr Laughton 1911, 23-7.
[16] Lefroy 1882, 156-57.

John Smith's *The Generall Historie of Virginia, New England & the Summer Isles,* first published in 1624, to record the early history of English colonization in North America); Nathaniel Butler's *The Historye of the Bermudaes or Summer Islands* (an account Bermuda's history from its beginning to 1622); and John Lefroy's *Memorials of the Bermudas or Somers Islands* (a compendium of official Colonial Records from A.D. 1515-1687).

According to these sources, *Warwick* left England on August 9, 1619 bound for Bermuda and Jamestown.[17] On October 20, 1619, *Warwick* reached Castle Harbor, Bermuda where it unloaded part of its cargo. Governor Butler and a few other passengers also disembarked.[18] *Warwick* was ready to be both re-provisioned for the next leg of its journey to Jamestown and loaded with Bermudian products (mainly tobacco to carry back to England) when a hurricane struck Castle Harbor in late November.[19] For three days and three nights the storm beat down on the island, eventually driving the ship into steep cliffs on the eastern side of Castle Harbor where it sank.[20] Salvage operations led by Butler resulted in the recovery of a few items, but tightly secured hatches thwarted the salvagers.[21] Further work was abandoned and the wreck was left undisturbed.

Warwick was not forgotten, but interest in the ship was not revived until 1966 when Teddy Tucker, a Bermudian salvor, relocated the wreck. Tucker surveyed the site at a depth of between 3-10 m. (9.8-31.8 ft) below the surface and partially excavated it.[22] Field work was

[17] Ives (1984, 140). According to John Dutton, the new bailiff who arrived with Butler, *Warwick* had sailed ten weeks and two days before arriving at Bermuda on October 20, 1619. Based on the 1619 calendar and counting back from their arrival date, the estimated departure date is August 9, 1619.
[18] Smith et al. 1626, 191; Lefroy 1882, 148.
[19] Lefroy 1882, 156-57; Smith 1626, 191; Ives 1984, 144.
[20] Ives 1984, 144.
[21] Hallett 2007, 192; Smith 1626, 193-94.
[22] Bojakowski and Custer-Bojakowski 2017, 286.

revived again between 2010-2012, when *Warwick* was fully excavated under the direction of Dr. Piotr Bojakowski and Dr. Katie Custer-Bojakowski, as part of a joint National Museum of Bermuda, the Institute of Nautical Archaeology, and the Center for Maritime Archaeology and Conservation project.[23]

Warwick is one of a handful of early 17th-century transatlantic ships to be excavated and found to contain rigging artifacts. Analysis of its rigging elements and a conjectural reconstruction of its hull and rig are useful for understanding ships from this period, a time when dramatic technological changes were occurring in shipbuilding and rigging.[24] This thesis presents a hypothetical rigging reconstruction of *Warwick*. Perhaps more importantly, this work serves as a 17th-century rigging artifact compendium, containing a detailed catalogue of rigging artifacts from wrecks dated between A.D. 1545-1700. The data it presents can be used to understand the rigging of ships during this period and to refute, support, or refine future research on this topic.

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[23] Bojakowski and Custer-Bojakowski 2017, 286, 288.
[24] Moore 1912, 267-74; Parker 1996, 271-74.

CHAPTER 2

WARWICK'S EXCAVATIONS, FINDS, AND RIGGING ARTIFACT DESCRIPTIONS

Over the course of three field seasons, Piotr Bojakowsi and Katie Custer-Bojakowski excavated the extant remains of *Warwick's* hull—including the starboard side of its stern (2010 season), amidships (2011), and bow (2012).[25] The hull was estimated to originally be 100.7 ft (30.5 m.) in length, to have a depth of 10.58 ft (3.24 m.), a beam of 23.0 ft (7.0 m.), a keel length of 75.5 ft (23.0 m.), a fairly rounded bow, and an elongated, narrow stern. It was approximately 160 tons.[26] Dendrochronology suggests that the ship's timbers were felled between the winter of AD 1616 up until the summer of AD 1617. The ship therefore could not have been completed before summer AD 1617 and its wood is consistent with timbers felled in southern Britain.[27] The excavation raised hundreds of artifacts from the site including a gunport lid, an iron grenade, ceramic sherds, barrel staves, ship ballast, brick, coal, wood fragments, and leather. The diagnostic items support an early 17th-century date for the wreck.[28] Recovered artifacts are still being analyzed and conserved at the National Museum of Bermuda.

A total of 24 complete or nearly complete rigging elements, 13 rigging fragments, and 15 rope fragments were identified and recovered from *Warwick*, including deadeyes, blocks, dead blocks, a mast truck, a potential topmast fid, chain plates, and miscellaneous rigging pieces (Appendix A). Although the author was unable to personally view the artifacts, information was

[25] Bojakowski and Custer-Bojakowski 2017, 286.
[26] Bojakowski and Custer-Bojakowski 2017, 296-98.
[27] Bojakowski and Custer-Bojakowski 2017, 299.
[28] Bojakowski and Custer-Bojakowski 2017, 284-302.

provided by Piotr Bojakowski and Katie Custer-Bojakowski, members of their team including Doug Inglis, Karen Martindale, and Michael Gilbart, and by staff from the National Museum of Bermuda. The descriptions of these rigging-related finds and their possible uses are described below in two sections: standing rigging and running rigging. While an attempt was made to determine the location and context of these artifacts, *Warwick* was heavily salvaged by Tucker so the provenience of some finds is unknown or questionable. When known, context is mentioned in the sections below.

Standing Rigging

Standing rigging refers to the parts of rigging used to support the masts, some yards, and which are normally fixed in place when sailing.[29] In the case of *Warwick's* artifact assemblage, these consist of the deadeyes, chainplates, a mast truck, and a potential fid.

Deadeyes

A total of nine deadeyes, or partial deadeyes, were recovered from *Warwick* (Figure 1). Seven of the deadeyes have three eyes, while the other two have six eyes. Of the seven with three holes, these can be divided into three categories based on their shape: rounded with tapered base (RTB) (1), pear-shaped (3), and round (1), while two are too degraded to give a definitive shape.

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[29] Goell's (1970, 24) transcription of John Smith's *A Sea Grammar* notes that "The standing ropes are the shrouds and staies, because they are not removed, except it be to be eased or set taughter." Manwaring and Perrin (1922, 233-34) wrote that "Standing ropes are counted all those ropes (as the shrouds, stays, and backstays) which are not used to be removed or to run in any block, but are only set taut or slacker as they have occasion."

Figure 1: All the deadeyes from *Warwick*, except for 80:129B (Image by Doug Inglis).

The RTB deadeye (02: 155.254557-764-u) is drastically smaller than the others, measuring 8.9 cm. x 9.8 cm. x 3.0 cm. and having horizontal wood grain. Pear-shaped three-hole deadeyes are the most common type on *Warwick* (93: 30-008, 93: 30-13-2, 80:129B), measure 18.4 cm. x 13.6 cm. x 4.4 cm. on average and all have vertical wood grain. Deadeye 80:129B is associated with *Warwick's* assemblage according to the National Museum of Bermuda's database, but new images were not taken and it is not mentioned with the reports from *Warwick's* most recent excavations, so it is likely that it was recovered during earlier excavations by Teddy Tucker. The round deadeye (79: 155-344) measures 16.3 cm. x 16.0 cm. x 4.6 cm. and has radial wood grain. According to excavation notes, it is believed that the round deadeye is intrusive. Two deadeyes have six eyes and measure 26.5 cm. x 19.4 cm. x 5.0 cm. and are pear-shaped with vertical grain.

Excavation notes indicate that deadeyes were almost all loose finds. Detailed photos, dimensions, and the state of preservation of deadeyes are listed in Appendix A while Table 1 below provides a summary.

ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Diameter of eye hole (Averaged)	Shape	Flat or Round Face	Grain	# of Holes	Square or Round Score	Notes
02: 155.254557-764-u	8.866	9.796	2.959	1.6	1.5	RTB	Flat	Horizontal	3	Round	
02: 155-034		14.207	4.383	3	3.16		Flat		3		Too degraded and broken to tell many features
93: 30-008	18.21	12.37	4.094	2.7	2.9	Pear-shaped	Flat	Vertical	3	Square	
93: 30-13-2	18.065	13.517	4.211	2.7	3.4	Pear-shaped	Flat	Vertical	3	Round	In 2 pieces
93: 30-13-4	17.057		4.755	2.5			Flat	Vertical	3	Round	Deadeye fragment. 2 holes showing but third is likely on broken side.
79: 155-344	16.304	16.05	4.566		3.8	Round	Flat	Radial	3		No score found due to concretion. Believed to be from a different wreck.
80:129B	19	15	5		3.1	Pear-shaped	Flat		3		Not included in conservation plan. Maybe because in good shape?
93: 030-007	26.674	16.914	4.62		3.22	Pear-shaped	Flat	Vertical	6	Square	
80: 129C	31	21.978	5.356		3.08	Pear-shaped	Flat	Vertical	6	Square	

Table 1: Deadeyes from *Warwick* (1619) and their features.

Deadeyes are rounded pieces of wood with a number of holes cut through them used to connect shrouds, and sometimes stays and other lines, (lines supporting masts) to the ship's hull.[30] They worked in pairs; a shroud's lower end was turned in (stropped) to a groove in the

[30] Mainwaring, transcribed in Manwaring and Perrin (1922, 138), wrote that "Dead-men-eyes are a kind of blocks wherein there are many holes but no shivers, wherein the lanniers go that make fast the shrouds to the chains. The main stays in some ships are set taut by lanniers in dead-men-eyes, but most great ships use double blocks. The crow-ft do reeve through dead-men-eyes."

upper deadeye's circumference.[31] The lower deadeye was strapped to a chainplate (covered in next section), which ran through channels and was bolted into the hull. A thin rope, called a lanyard was rived through the holes in the deadeyes, connecting the two deadeyes and completing the set (Figure 2).[32] The lanyard knot is located in the top deadeye and the inside face of this hole is not rounded, so as to keep the knot from slipping. All other deadeye holes are scored to allow the lanyards to run smoothly.[33] The use of a lanyard to connect two deadeyes provided adjustable tension, providing flexible support for the shrouds, while acting as shock absorbers between the hull and the masts.[34] The stresses generated by the masts and sails aloft were transferred along the shrouds and absorbed by the two-deadeye arrangement, thus significantly reducing the stresses to the chain plates and hull.[35]

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[31] *A Treatise on Rigging*, transcribed by Salisbury and Anderson (1958, 61), notes that "Deadmens eyes serve to fasten ropes to the chainewales with other deadmens eyes and laniers."
[32] Smith, transcribed by Goell (1970, 23), wrote that "Those Lanniers are many small Ropes reeved into the dead men's eyes of all shrouds, either to slaken them or set them taught; also all the staies have their blocks, and dead men's eyes have Lanniers. Dead men's eyes are blocks, some small some great, with many holes but no shivers."
[33] Kochiss 1970, 16.
[34] Kochiss (1970, 7); Manwaring and Perrin (1922, 175) indicated that "Lanniers are the small ropes which are reeved in the dead-men-eyes of all the shrouds and chains, and the use of them is either to slacken or to set taut the shrouds. Also all the stays belonging to any mast (whether they have blocks or dead-men-eyes belonging to them) are set taut by a lannier. Also the small rope which makes fast the stopper of the halliards to the halliard, is called a lannier."
[35] Kochiss 1970, 7.

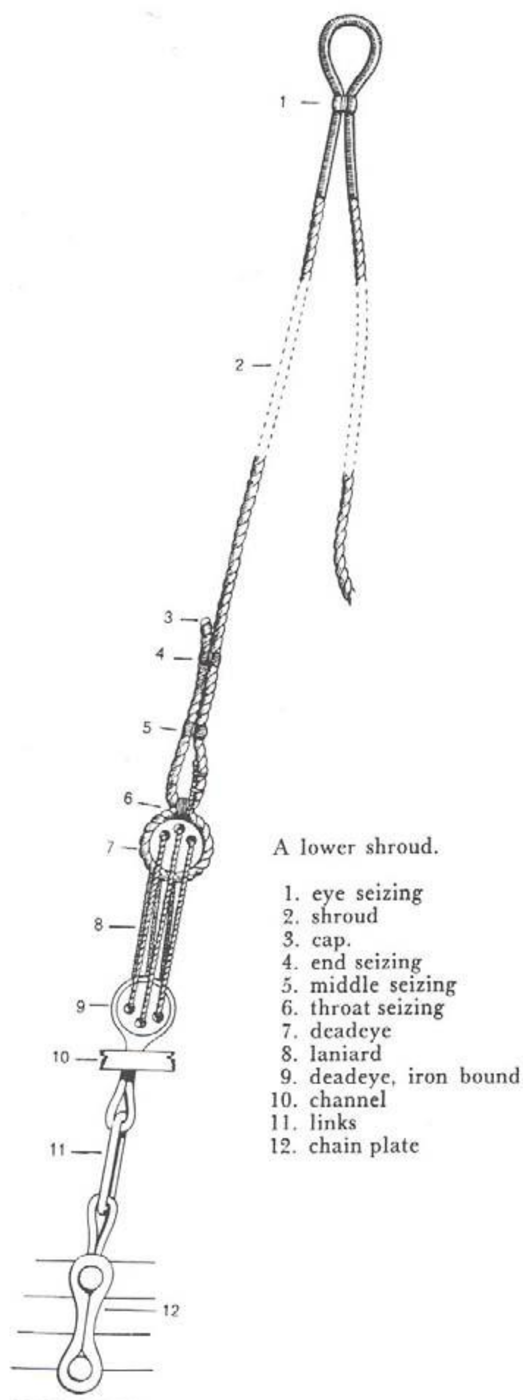

Figure 2: Diagram of a shroud. The fully assembled shroud configuration including an upper and lower deadeye, the latter strapped to a chainplate that is bolted the hull (Petrejus 1970, 183).

It is believed that *Warwick's* three-holed deadeyes were used for shrouds, while the six-hole deadeyes were used for tightening forestays (covered in later chapters). Examples of deadeyes recovered from other wrecks are referenced in Appendix C.

Chainplates (Chains)

Lower deadeyes were encircled within a metal loop whose ends were fastened together (Figure 3). This loop was called a strap, and the deadeye was said to be strapped.[36] The deadeye strap was attached by a hinge to a chainplate, which was either 1) a metal plate, or 2) metal links. The chainplate passed through the chainwales, or a piece of wood that spread the chainplates and shrouds apart. The end of the chainplate was then bolted to the side of the ship (Figure 4).[37]

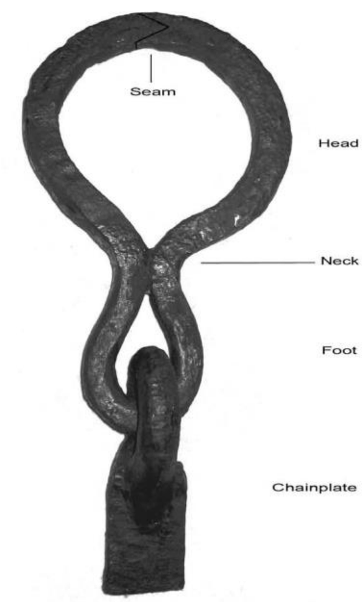

Figure 3: Chain plate # 1586 from *La Belle* (1686) with standard terminology (Corder 2007, 51).

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[36] Mainwaring, seen in Manwaring and Perrin (1922, 122), wrote "Chains. […] is meant those chains to which the shrouds are made fast on the ship-sides; also those which belong to the top-mast shrouds are called chains."
[37] Mainwaring also notes that "Chain-wales is a broader timber (set on the outside of the ship) than the ordinary wales, and is made so of purpose to spread out the shrouds wider, that they may the better succor the mast, [for the more the shrouds are kept out from the lower part of the mast, by so much the more power, force, and aptness they have to keep the mast steady, as is obvious and plain to sense]." Manwaring and Perrin 1922, 122-23. Salisbury and Anderson (1958, 9) write "The chain wales are two broad pieces of timber bolted upon one of the wales to the ship's

Figure 4: A chainplate from *Warwick* and how it would have been attached to the hull (Image by Doug Inglis).

Chainplates came in two forms, they either consisted of actual chain links, as described in Diego Garda de Palacio's work which indicates "chains of four or five links each link about a palm [in width], somewhat elongated according to the thickness of the said chain-wales."[38] Or, the chainplate was an actual flat metal plate as described in *A Sea Grammar* (1627) by John Smith (Figure 5).[39] It is not yet clear if links or plates have advantages over the other.

side, reaching from the loof forward and from the main mast aftward according to the spreading of the shrouds. There are certain scores made in them for the chain plates to rest in, into which the ends of the shrouds are fastened, and they are set off on purpose to keep the shrouds from wearing against the ship's sides and to strengthen the masts."

38 Grenier et al. 2007, IV-3.

39 Smith, in Goell (1970, 23) wrote "And the *Chaines* are strong plates of iron fast bolted into the Ship's side by the Chain waile."

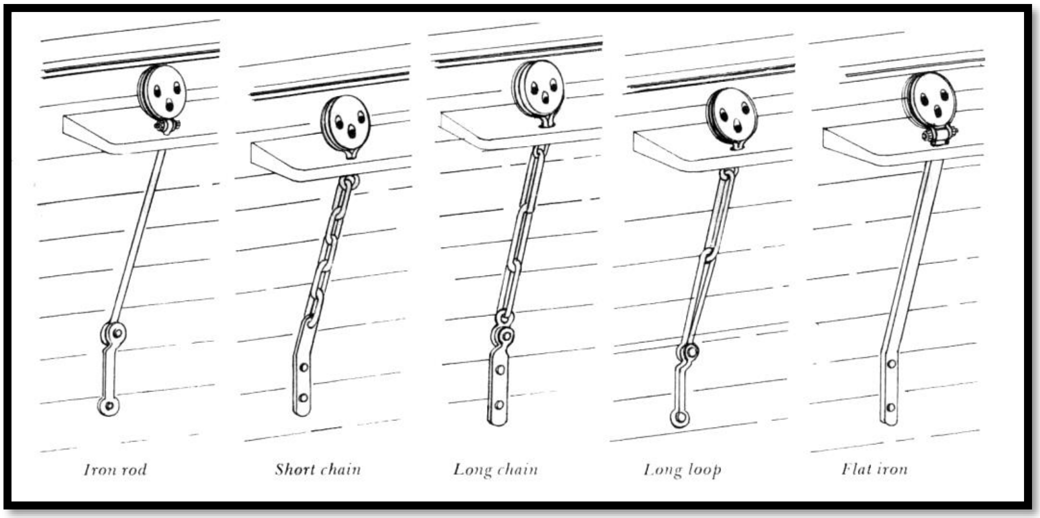

Figure 5: Various types of chainplates including the links and metal plates (Kochiss 1970, 29).

A total of four concreted chainplates were recovered from the wreck, and all have the flat plate rather than links (Figure 6). Unfortunately, these were not cleaned or conserved after recovery, so very few features are known about these artifacts. The concretions measure 66-69 cm. (2.1-2.2 ft.) in length on average and the deadeye straps are slightly different sizes (See Appendix A for details). Two of four chainplates were surface finds, discovered inside the hull of *Warwick*. It is believed they were found by Teddy Tucker and reburied inside the section of the hull that he originally uncovered.[40]

Two chainplates were solidly concreted to the hull, but upside-down, perhaps due to the chainwale breaking during *Warwick's* sinking (Figure 7). Their location, a little aft of master frame, indicates that they belonged to the mainmast shrouds, and were located at the height of the third futtocks. The spacing between them helps reconstruct the shroud intervals.[41] However,

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[40] Piotr Bojakowski, personal communication, November 21, 2013.
[41] Douglas Inglis, personal communication, February 18, 2013.

chainplate spacing could be irregular because tackle rings (the standing portion of tackles) and gun-ports often interrupted consistent spacing.

Appendix A shows the approximate dimensions of the chainplates. Until they are cleaned and conserved, more precise dimensions are unavailable.

Figure 6: The four concreted chainplates from *Warwick* (Image by Doug Inglis).

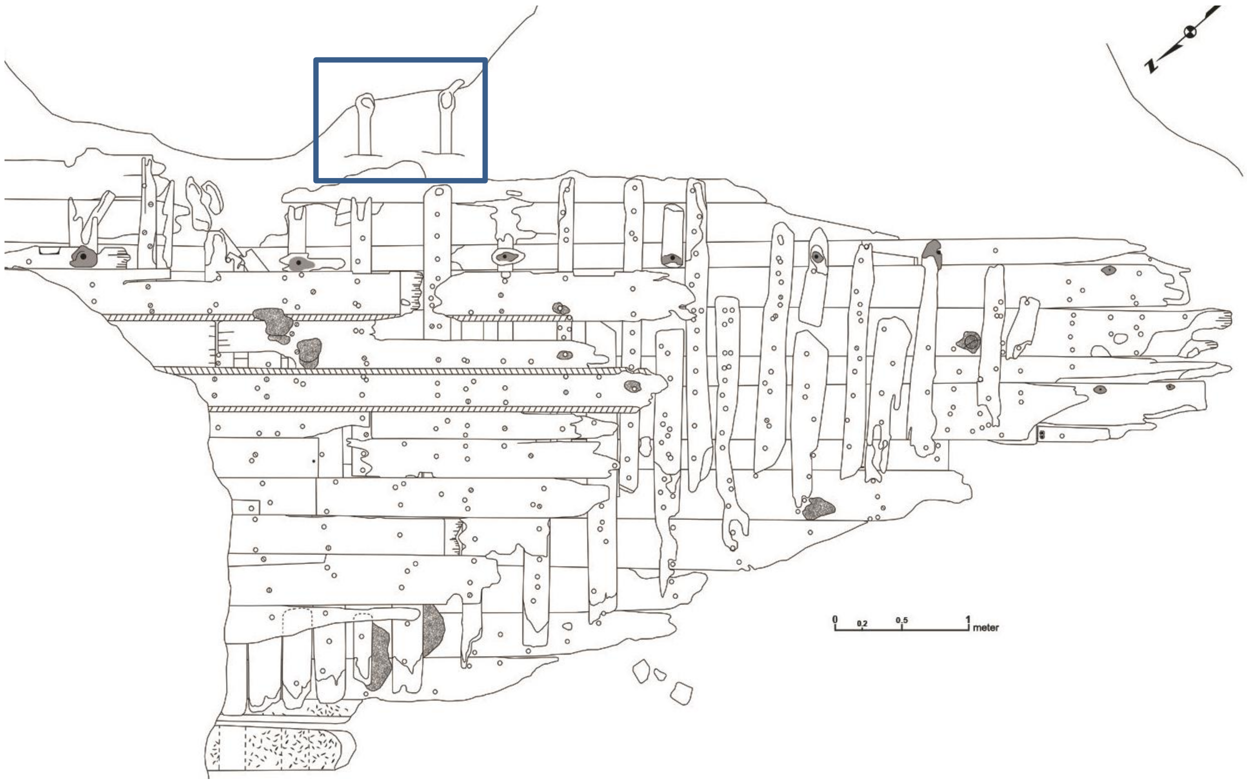

Figure 7: The two chainplates found upside-down, but otherwise apparently near where they are believed to have been placed on the ship (Image by Piotr Bojakowski and Katie Custer-Bojakowski).

Fid

A fid-like wooden piece that measures 28.3 cm. x 5.1 cm. x 5.6 cm. was recovered from *Warwick* (Figure 8). Due to its fragmented nature, it is difficult to determine what this object was used for—it could have been used as a fid that was inserted through the heel of a topgallant mast to secure it between the trestletrees, but its small size makes this less likely because fids need enough length to sit securely on the trestletrees.[42] A possible comparative fid was found on *La*

[42] Mainwaring notes in Manwaring and Perrin (1922, 147) that "The pin in the heel of the topmast which bears it up on the chess-trees is a fid."

Belle (1686), but until further conclusive evidence is discovered, this object's use on *Warwick* is unknown (Figure 9).

Figure 8: Potential fid from *Warwick* (Artifact 02: 155.294003-1165) (Image modified from photos by Karen Martindale).

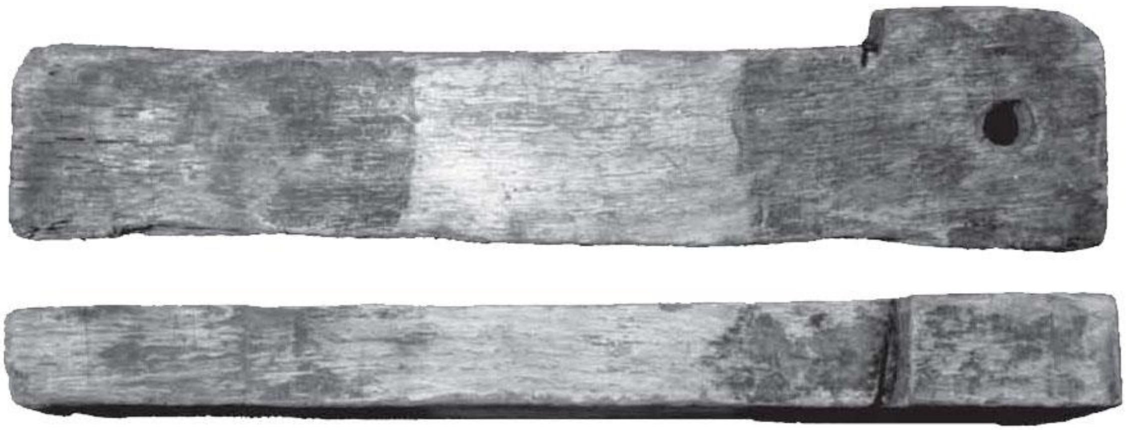

Figure 9: Topmast fid from *La Belle* (1686). (Photo by A. Borgens and C. Corder in Corder, 2007, 49).

Mast Truck

A possible mast truck was discovered on *Warwick* and believed to have been mounted around the mast and, when fitted with pulleys, used to raise signal flags (Figure 10).[43] Similar to deadeye 80:129B, it is associated with *Warwick's* assemblage according to the National Museum of Bermuda's database, but not mentioned with the reports from *Warwick's* 2010-2012 excavations, so likely salvaged during earlier excavations by Teddy Tucker.

[43] National Museum of Bermuda Exhibit, Artifact 02:155.294003-1015.

Figure 10: *Warwick's* Mast Truck (Artifact 02:155.294003-1015 courtesy of National Museum of Bermuda).

The truck is crescent-shaped, and measures 33 cm. x 28 cm. No other archaeological parallel has been located that resembles *Warwick's* mast truck. The term truck also described another rigging element, circular beads with a hole through the center allowing them to be strung on ropes between larger flat wooden pieces (ribs), together making parrels. Parrels were used to slide the yard up and down the mast, and to hold the yard close to the mast.[44] A well-preserved parrel assembly was found on *Mary Rose* (1545) (Figure 11); an additional ten wrecks that contain trucks are listed in Appendix B.[45]

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[44] "Parrels are those things made of trucks and ribs and ropes, which go about the mast and are at both ends made fast to the yards; and are so made with trucks and ribs, that the yard may slide up easily. These also, with the breast rope, do hold the yard close to the mast." Manwaring and Perrin 1922, 195; "Every mast hath his yearde fastened to it by the Parrell and the sayles ar fastened to the yeardes by the Robins, every yeard hath his name from the mast they ar fastened unto." Salisbury and Anderson 1958, 47.

[45] According to Mainwaring "Trucks are […] those little round things of wood which belong to the parrells[…]" Manwaring and Perrin 1922, 249; Mainwaring also notes that "Trusses are ropes which are made fast to the parrell of the yard, and are used to two uses: one to bind fast the yard to the mast when she rolls either a-hull or at an anchor; the other is to haul down the yard in a storm or gust. These belong only to the main-yard and fore-yard, and they are brought-to but upon occasion; and also to the mizen, which hath ever a truss" in Manwaring and Perrin

This artifact was entered as a mast truck in the National Museum of Bermuda database, and also designated as such in the museum exhibit, but no explanation was given as to why, especially because the author was unable to locate an archaeological parallel. It is possible that because the museum exhibit's description for this artifact indicates that it was used for signal flags, this artifact encircled the entire flagstaff and is called a "truck" due to its somewhat wheel-like shape.

Figure 11: Parrels, showing trucks and ribs, from *Mary Rose* (1545) (McKee 1982, 141).

Rope

At least 15 fragments of rope (Artifact 02:155.294003-1051) were recovered from *Warwick* (Figure 12). These measure up to 15 cm. in length and 6.5 cm. at largest width. The rope is also not noted in the 2010-2012 excavation records, and nor could detailed notes be

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(1922, 249-50); the term truck was also applied to the wheels of gun carriages. John Smith (Goell 1970, 84) wrote: "If for Sea. She have Trucks, which are round, intier peeces of wood like wheels."

located regarding them, so it is also believed that they were recovered during Teddy Tucker's earlier salvage efforts.

Figure 12: Rope from *Warwick* (Artifact 02:155.294003-1051 courtesy of National Museum Bermuda).

Unfortunately, little information was recorded on the recovered rope so no further analysis can be done at this time. Upon proper conservation and recording in the manner prescribed by Damien Sanders in "Knowing the Ropes: The Need to Record Ropes and Rigging on Wreck-Sites and Some Techniques for Doing So," it will be possible to better understand how they were constructed and used.[46]

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[46] Sanders 2010, 2-26.

Running Rigging

Running rigging refers to the parts of rigging that are adjusted when maneuvering the ship, such as parts associated with raising, lowering, and trimming the sails.[47] In the case of *Warwick's* artifact assemblage, these consist of blocks.

Blocks

Blocks, or pulleys, are leverage mechanisms used to maneuver ropes, yards, and sails.[48] Standard blocks are made of an oblong outer wooden shell that encases a wood or metal wheel called a sheave that is held in place with a pin.[49] The rope passes through a channel between the sheave and the shell, the former which rotates around the pin. One side of the channel is usually rounded, through which the rope is reeved to enter through the feed, while the opposite end is flat.[50] Blocks were stropped around the middle, with grooves in the cheeks, to hold the rope it served. The crown was not completely scored and the unscored area was where the splice was placed (Figure 13). Sometimes the sheave had metal cubes, called coaks, inserted to add extra support to offset strain around the pin and prevent the shell from cracking.[51] Blocks were often

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[47] "Running Ropes. We call all those ropes in a ship which belong to the yards and sails, for the traversing of the yards or trimming the sails, running ropes; and are taken generally for all ropes that do not stand fast to the masts, without veering or hauling; as shrouds, stays, and the like." Manwaring and Perrin 1922, 217.

[48] "Pulleys are small blocks with one or two shivers in them, and may either be called so, or by the name of small blocks (for great blocks are not usually called by the name of pulleys), as the pulleys of the topsail braces, clewlines, martnets, &c." Manwaring and Perrin 1922, 202-203.

[49] Smith, transcribed by Goell (1970, 23), "Blocks or Pullies are thick peeces of wood having Shivers in them, which is a little Wheele fixed in the midest with a Cocke or Pin; some are Brasse, but the most of Wood, whereon all the running Ropes doe runne. Some are little, some great, with 3, 4, or 5 shivers in them, and are called by the names of the Ropes whereto they serve. There are also double blocks, that where there is use of much strength, will purchase with much ease, but not so fast as the other; and when wee hale any Tackle of Haleyard to which two blocks doe belong, when they meet, we call that blocke and blocke."

[50] Smith, transcribed by Goell (1970, 28) wrote that "Reeving is but drawing a rope thorow a blocke or oylet [eyelet] to runne up and down."; see also Corder 2007, 24.

[51] "Coaks are little square things of brass with a hole in them, put into the middle of some of the greatest wooden shivers to keep them from splitting and galling by the pin of the block whereon they turn." Manwaring and Perrin 1922, 128.

named after the ropes they belonged to and can be categorized by the number of sheaves they contain (Figure 14 depicts a variety of blocks that existed).[52]

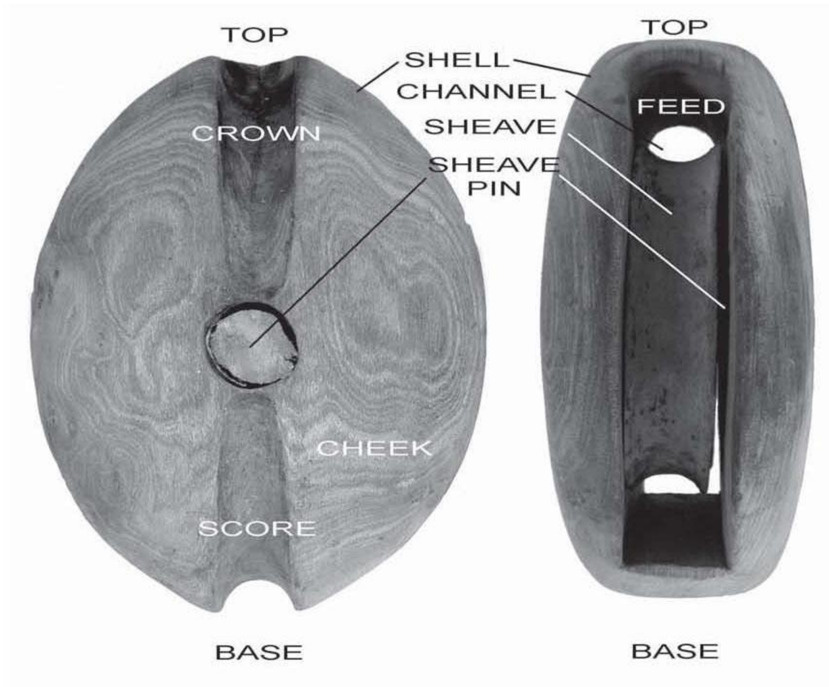

Figure 13: Block diagram (Corder 2007, 23).

Blocks and other rigging elements during this period were made with traditional tools including handsaws, axes, various types of augers, and in some cases a hand-turned wooden lathe.[53] Figure 15 depicts a blockmaker's shop showing various hand tools used to produce rigging. The lack of industrial standardization in the production of 17th-century rigging is critical for pattern analysis as covered in Chapter 4.

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[52] "Blocks are those small wooden things having shivers in them wherein all the running ropes do run. There are divers kinds of blocks; as single blocks, double blocks, and blocks with 3, 4, or 5 shivers in them, and they are called by the names of the ropes whereunto they serve, as the Sheet-block, the Tackle-block, the Fish-block, &c. Note that double blocks do purchase made than single blocks, and therefore in all places where we have occasion to use strength with few hands we have double blocks, as to tackle our ordnance. But you must note also that though double blocks purchase with more ease, yet single blocks do purchase faster." Manwaring and Perrin 1922, 100.
[53] Kochiss 1970, 18-26.

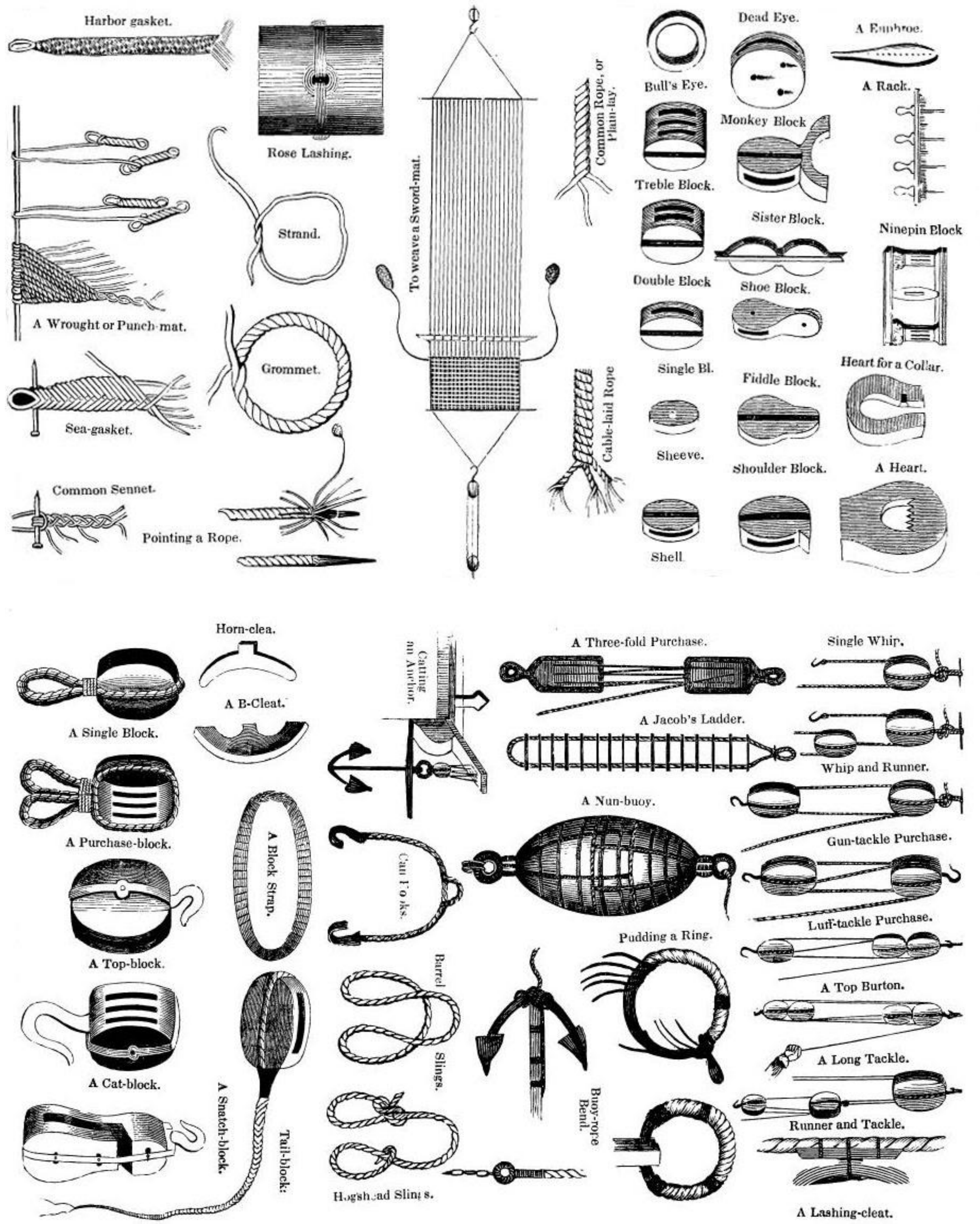

Figure 14: Folios from The Kedge-Anchor or Young Sailor' Assistant (Brady 1852, folios 3 and 4).

Figure 15: A wooden sign dated to 1694 showing a blockmaker's shop in Rotterdam. Two men on the left work an auger while the man on the right fashions a block. (Collectie Historisch Museum Rotterdam, inv.nr. 11320 https://museumrotterdam.nl/collectie/item/11320?itemReturnStart=0&objectrow=0&itemReturnSearch=11320).

A total of six standard blocks, or block fragments, and two dead blocks, were recovered from *Warwick*. The six regular blocks include a complete single block, a nearly complete block, four cheek fragments, and one sheave (Appendix A).

Two complete or near-complete blocks (Artifacts 02:155.294003-1162 and 02:155.294003-1014) are noted in the National Museum of Bermuda's inventory, but were not mentioned in the 2010-2012 excavation reports, so were likely recovered during Teddy Tucker's earlier salvage operations (Figure 16). Certain details are lacking in the National Museum of Bermuda catalogue.[54]

[54] National Museum of Bermuda 2015, Artifact 02:155.294003-1162. Artifact 02:155.294003-1162 appears to be a complete block and measures 20 cm. x 14 cm. x 9 cm. Catalogue notes indicate that it is possibly not associated with *Warwick* but found on site. The block appears to have vertical wood grain and have the generic oblong block shape; National Museum of Bermuda 2015, Artifact 02:155.294003-1014. Artifact 02:155.294003-1014 is a slightly

Figure 16: Complete blocks recovered from *Warwick*. Artifact 02:155.294003-1162 (left) and Artifact 02:155.294003-1014 (right).

Four cheek fragments (Artifacts 10:02.028, 93-30.3, 93: 30.5, 93: 30-4) are all split near the middle, where the holes for the pin created a weak area in the block shell (Figure 17). This split down the middle allows an accurate measurement of length and accurate width by doubling the halved block cheek. Artifact 10:02.028 is slightly larger than the other cheek fragments, measuring 19.1 cm. x 7.0 cm. (original 14 cm. width) x 2.7 cm. with a pinhole diameter of 3.5 cm. It is similar in size to the two complete blocks. The other fragments are from smaller blocks and measure 16.1 cm. x 6.1 cm. (original 12.2 cm.) x 2.2 cm. with an average pin diameter of 1.9 cm. All cheek fragments have vertical wood grain and some portions of the inner blocks show concentric grooves where the sheave left marks from usage. These scores are between 6.2 and 6.5 cm. in diameter, indicating sheaves about the size of one of the loose sheaves found (Artifact 115.294003-1111). Block cheeks 10:02.028 and 93:30-4 are too fragmented to suggest the number of sheaves they contained, but Artifacts 93_30.3, 93: 30.5 show portions of the other

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damaged block that is missing a few fragments on one side. It measures roughly 20 cm. x 14 cm. x 9 cm. and has vertical grain.

cheek of the shell, revealing that they are both single sheave blocks with mortises about 12.1 cm. long and 21.5 cm. wide on average.

The detached wooden sheave (Artifact 02: 115.294003-1111) has chipped edges and measures 6.6 x 7.7 cm., indicating a minimum diameter of 7.7 cm. with a thickness of 1.8 cm. The pinhole measures about 2.3 cm. Mainwaring notes that wooden sheaves made from single pieces of wood are used in small blocks.[55] Several hundred blocks and block parts recovered from other wrecks are referenced in Appendix B.

The provenience of the blocks and block fragments from *Warwick* was unfortunately not recorded, and for lack of context makes their use on the ship difficult to determine. These blocks are fairly standard and could have employed in a variety of different tasks.

Figure 17: Block fragments recovered during 2010-2012 excavations (Image by Doug Inglis).

[55] "Shivers. There are two sorts of shivers used, either of brass or wood. The brass shivers are now little used but in the heels of the topmasts. The wooden shivers are either of one whole piece, and these they use for all small pulleys and small blocks; but in the knights and winding-tackle blocks they use shivers which are made of quarters of wood let in to each other, for these will hold when the whole shivers will split, and are called quarter shivers." Manwaring and Perrin 1922, 224.

Dead blocks

Two dead blocks were recovered from *Warwick* (Figure 18). Unlike standard blocks, dead blocks have a hole, or swallow, across the center instead of a sheave.[56] It is likely that they were also called deadeyes during this period, but should not be confused for the deadeyes that were used to secure shrouds.[57]

Warwick's two dead blocks (Artifacts 80:129E and 93:30-13-1) are slightly different sizes. Artifact 80:129E measures 14.5 cm. x 9.0 cm. x 6.8 cm. and has a swallow depth of 9.0 cm. that would hold a rope approximately 2.8 cm. in diameter. Artifact 93:30-13-1 is 10.0 cm. x 7.7 cm. x 4.7 cm. with a swallow depth of 6.7 cm. and rope diameter of 2.5 cm. in diameter.

Figure 18: *Warwick's* two dead blocks (Artifact and 80:129E (left) 93:30-13-1 (right)) (Image after photos by Karen Martindale).

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[56] Howe, unpublished article.
[57] Smith, as transcribed by Goell (1970, 23), wrote that "Dead men's eyes are blocks, some small, some great, with many holes but no shivers. The Crowe's-ft reeved thorow them are a many of small lines, sometimes 6, 8, or 10, but of small use more than for fashion to make the Ship shew full of small Ropes."

Although dead blocks do not contain sheaves, they were used in a similar fashion for ropes with light loads, or they could be used as a euphroe to balance the pull on a bridle. However, their most common use during the 17th century was on the bowlines, where they were used as bridles to distribute the pull of the bowline over several cringles.[58] From the dead blocks the bowlines ran forward, typically to the bowsprit, through blocks and then back to the forecastle.[59] The size of these dead blocks makes them suitable for the topgallant sails or mizzen topsails, or they could have been used on the brails of the mizzen in a smaller vessel.[60] Similar dead blocks have been found on *Vasa* (1628) and the Angra C Wreck (First half of 17th century) (Figure 19).[61]

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[58] Goell 1970, 23, 28.
[59] Marsden 2009, 263.
[60] Fred Hocker, personal communication, March 23, 2014.
[61] DigitaltMuseum, Vasamuseet; Phaneuf 2003, 147.

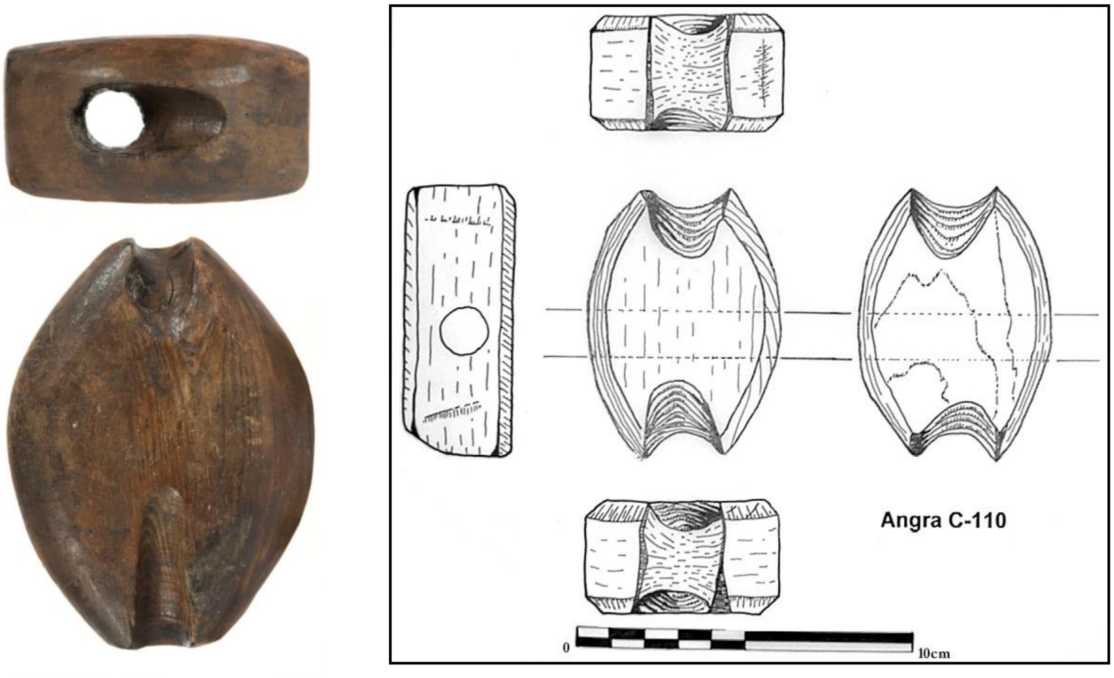

Figure 19: Dead blocks. The example from *Vasa* (1628) (left), was probably part of the tackle for the mainsail bowlines. The second example is from the Angra C Wreck (an excavated early 17th century wreck found off Terceira Island in the Azores) (right) (Digitalt Museet: Vasamuseet and Phaneuf 2003, 158).

Warwick's rigging assemblage is typical of most excavations of 16th-17th-century ships, with several of the smaller wooden rigging elements and a little cordage recovered. Even with an incomplete rig, these artifacts still serve as important clues to the wrecking date and its rig plan.

CHAPTER 3

HULL FORM AND RIGGING TRANSITIONS DURING THE EARLY 17TH CENTURY

This chapter is a review of existing literature on changes in shipbuilding and rigging during the 16th and 17th centuries.

Hull

The 17th century saw significant changes in shipbuilding and is considered by some scholars the most important century in European ship innovation as it was the period many ship design problems were solved.[62]

About AD 1500 the full-rigged ship (known by various regional styles, including hulks, naos, carracks) had become the standard ship type with deep holds, heavier-framed and planked construction that was capable of absorbing more stresses than previous assemblies, and high fore and stern castles which held the majority of the cannons and served as fighting platforms in warfare.[63] Heavier construction allowed for the introduction of the artillery broadside with hinged gunport lids on the lower decks, and great hull displacements allowed ships to carry an even greater number of heavy guns.[64] By the mid-16th century ships had high sterncastles, lower forecastles, a beak that protruded below the bowsprit, a high and flat stern, and full rigs including topsails on the fore and main masts. These ships were faster, more maneuverable, and better able

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[62] Howard 1979, 89.
[63] The debate on which nation was the first to develop new ship designs is extremely biased, fraught with national pride, and differs depending on the historian. Rahn Philips (1986, 35-43) in chapter 2 of *Six Galleons for the King of Spain* gives an excellent break down of ship transitions, pointing out where prejudiced opinions may lie in literature, while making objective conclusions based upon facts; See also Parker 1996, 270-71, 276.
[64] Parker 1996, 270-71.

to sail into the wind […]"[65] By the 17th century, ship designs continued to transition away from vessels with high fore and sterncastles to more frigate-like ships with reduced superstructures to lessen windage.[66] There was also a general increase in the size of ships, particularly warships. After these modifications, English ships had larger gun-carrying decks and were able to hold artillery totaling up to 4.5% of total displacement, but with the added advantage of an absence of the bulky fore and sterncastles.[67] Sometime during the first half of the 17th century the 'round tuck' at the stern was also adopted in place of the flat stern, at least in English ships (it is speculated the square tuck was used up to 1620 and the round tuck after 1640).[68] For explanations of the changes in ship construction please refer to Carla Rahn Philips' *Six Galleons for the King of Spain*, Frank Howard's *Sailing Ships of War 1400-1860*, David Childs' *Tudor Sea Power: The Foundation of Greatness*, and M. S. Robinson's *The Paintings of the Willem Van de Veldes*.

Rigging

The change in hull shape for defensive concepts required the rigging configuration and sails to balance out windage on the upperworks. From the mid-16th century to the early 17th century, ships generally carried a spritsail, fore course, fore topsail, main course, main topsail, and a fore-and-aft lateen sail on the mizzen mast (which would often be sheeted to a boomkin or

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[65] Rahn Philips (1986, 43) notes that many historians agree that the Spanish developed the classic galleon, but also that some claim John Hawkins improved the carrack after 1570 by eliminating the high forecastle laying claim that the English developed the proper galleon. It is possible that Hawkins' improvements were based on the Spanish galleons he saw in the West Indies; see also Parker 1996, 270.
[66] Howard 1979, 95-98.
[67] Parker 1996, 271. Note with caution, however, that Parker's study did not consider different types of ships, as Rahn Philips (1986, 44-5) notes that the term galleon can refer to many types of vessels, and that the comparison of tons appears to confuse displacement with volume; See also Howard 1979, 96.
[68] Howard 1979, 96.

outligger, a fixed spar that attached off of the sterncastle (Figure 20).[69] Mainwaring notes that the reason for this spar, which he calls an 'outlicker,' is if the mizzen mast is placed too far aft (likely if there was a bonaventure) that there is not enough room on the ship to haul down the sheets, so it is done outboard.[70] This implies that ships during the 16th and early 17th century may have had mizzen masts placed further aft. The sail area could be increased by lashing a bonnet or drabbler to the foot of the main and fore course, and on some ships to the mizzen sail and spritsails (Figure 20D).[71] The largest ships, such as *Mary Rose* (Figure 20A), commonly carried a second mizzen, called the bonaventure mizzen, which was fitted with a lateen fore-and-aft sail and even a bonaventure topsail. Topgallant sails were uncommon, but occasionally present on the fore and main masts. The topsails of this period were proportionately smaller than the courses.

[69] Moore 1912, 268-69.
[70] Manwaring and Perrin 1922, 193. "The Outlicker is a small piece of timber (some two or three yards long, as they have occasion to use it) and it is made fast to the top of the poop, and so stands right out astern. At the outward-most end there is a hole, into which the standing part of the sheet is made fast, and so, being reeved through the block of the sheet, is reeved again through another block which is seized to this piece of timber near the end; and so the use of this is to haul down the mizen sheet to it. This is seldom used in great ships, but the cause why in any ship it is used is for that the mizen mast is placed so far aft that there is not room enough within-board to haul down the sheet flat, and so are forced to use this without-board."
[71] Manwaring and Perrin 1922, 105-106, 141, 193.

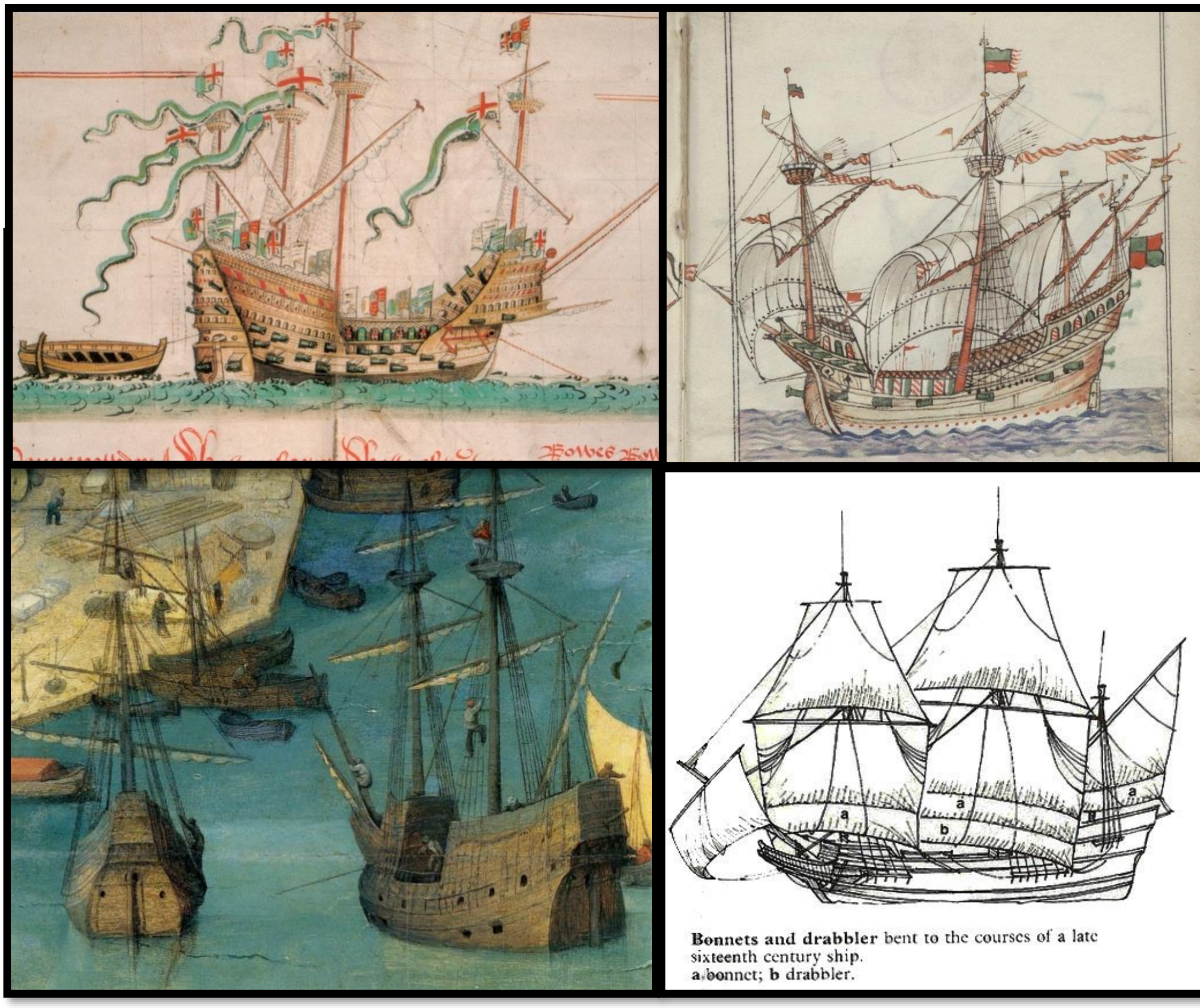

Figure 20: A) *Mary Rose* (1545) (top left), B) *Manuel de pilotage, à l'usage des pilotes bretons* (top right), C) The Tower of Babel, Detail ships in the port (bottom left) by Pieter Bruegel the Elder D) A modern schematic view of the rig of a 16th-century ship (Anthony Roll, Magdalene College, Cambridge; Brouscon c. 1501-1600, Folio 29; Bruegel (the Elder). c. 1563. *The Tower of Babel*. Inventory Number GG 1026. Painting. Kunsthistorisches Museum, Vienna; Harland 1984, 75).

The 17th century saw changes including adding a spritsail topmast with topsail at the forward end of the bowsprit, the increasing use of fore and main masts' topgallant sails, and the introduction of a mizzen topsail, staysails, and crossjack yard.[72] This period also saw the

[72] Moore 1912, 268-69; Anderson 1994, 241; Howard 1979, 125.

elimination of the bonaventure mast and the outligger, and at the end of the century the addition of the jib on large ships.[73]

Masts and Yards

Only a handful of archaeologically-studied shipwrecks from this period have had any masts, yards, tops, or larger rigging elements found on them; these include *Mary Rose* (1545), *Vasa* (1628), and a well-preserved wreck sunk in the Baltic, the Ghost Ship (c. 1650).[74] The Basque Whaler *San Juan* (1565) also has pieces of what is believed to be topmast masthead timbers found.[75] None of these ships can be directly compared to *Warwick*, as they are either a different nationality, size, and/or decade. However, when it is possible to use these wrecks as examples later in this thesis, they will be referenced.

Deadeyes

Hearts, were wooden elements employed in standing rigging with one large hole through the center. They are thought to be the precursor to the more commonly known three-holed deadeye.[76] It is believed that the heart originated from a rigging element called a "bull's eye," which was a wooden ring with a groove on its exterior for a rope (Figures 21 and 22).[77]

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[73] Howard 1979, 125.
[74] Marsden 2009, 248-261. None of *Mary Rose's* masts or yards survived, but its main mast step and a top did, among various smaller rigging elements; Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet; Eriksson and Rönnby 2012, 350.
[75] Grenier et al. 2007, IV-42 to IV-43.
[76] Kopp 2007, 3-4.
[77] Kopp 2007, 4.

Figure 21: A bull's eye from *San Juan* (1565) (Grenier et al. 2007, IV-19).

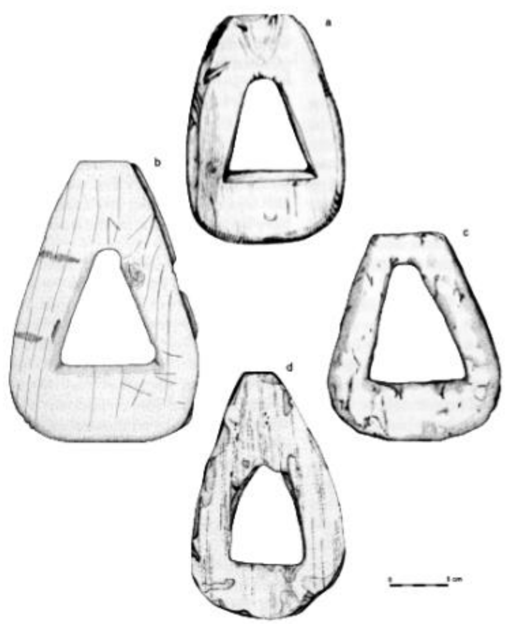

Figure 22: Hearts from the Red Bay Wreck (*San Juan*) (1565) (Grenier et al. 2007, IV-10).

Hearts led way to a pear-shaped three-holed deadeye, but it is uncertain when this change occurred. What is known is that sailing rigs as far back as Roman vessels from the 2nd century AD contained deadeyes with a three-holed configuration, but also that heart blocks have been discovered on several post-Medieval vessels such as the Red Bay Wreck and *Trinidad Valencera* and then increased in popularity from the late 17th century until the early nineteenth century.[78]

Scholars have noted that around the late 16th- and early 17th-century, deadeyes changed from the pear-shape to a more circular form, typical of later centuries (Figure 23).[79] Howard notes that until at least AD 1640, deadeyes were pear-shaped and in cross-section a short, broad ellipse.[80] Early 17th century deadeyes were longer than they were wide (pear-shaped) but increased in width so that by the second half of the century they were round.[81] The transformation of deadeyes styles can be seen by comparing the examples from *Mary Rose* (1545), *Vasa* (1628), *La Belle* (1686), and *Kronan* (1676) (Figure 24). Sometime during the early 17th century, deadeyes also transitioned from having vertical wood grain to horizontal wood grain, presumably because this made them less prone to splitting. This transition in wood grain can be seen from the 16th-century-style deadeyes seen on *Vasa* (1628), with vertical grain, to the newer-style deadeyes that were found from *Kronan* (1676) that have horizontal grain.[82] In addition to wood grain, pear-shape forms tended to have a flat profile, whereas rounded forms had convex profiles.[83] Deadeyes that were strapped in metal also had square scores whereas

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[78] Grenier et al. 2007, IV-1 to IV-23; Martin 1979, 32-3; Mondfeld 1989, 244.
[79] Corder 2007, 37; Parthesius et al. 2003, 67.
[80] Howard 1979, 134.
[81] Howard 1979, 144.
[82] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015
[83] Corder 2007, 34, 37; Parthesius et al. 2003, 67.

those stropped in rope had rounded scores to hold the rope in place (Figure 25)—this seemed to be consistent throughout this period so is not a good indicator of chronology as discussed in Chapter 4.

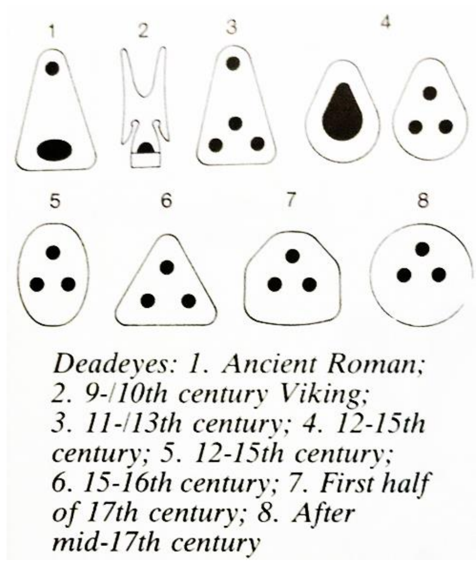

Figure 23: Mondfeld's diagram of deadeyes from different periods and geographical areas. (Mondfeld 1989, 244).

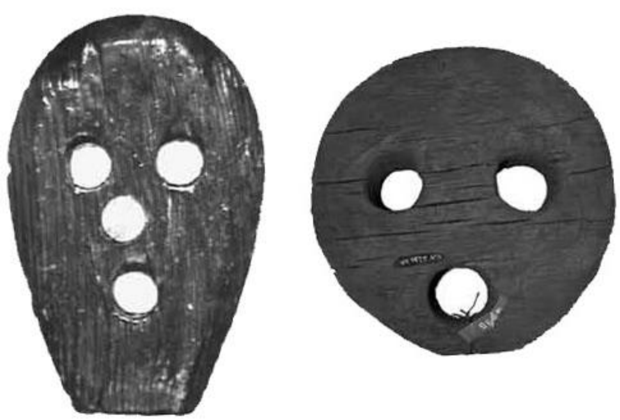

Figure 24: A 16th-century-style deadeye from *Vasa* (1628) (left) and a deadeye from *Kronan* (1676) (right) (After Corder 2007, 38).

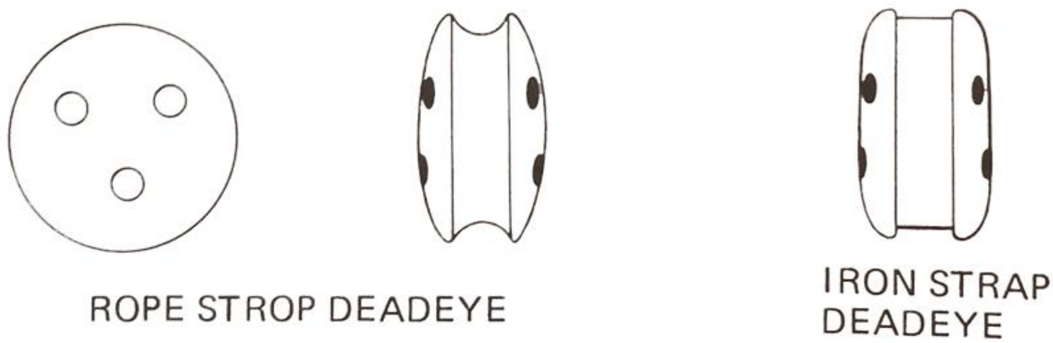

Figure 25: Profile differences between stropped and strapped deadeyes. Note that this example also shows the convex faces of the deadeye as is typical of round deadeyes (Lees 1984, 168).

While many have noted the features and transitions within deadeyes, a definitive typology and chronology of when each form becomes prominent has not been established. Chapter 4 of this thesis covers deadeye transitions using archaeological data and provides a chronology and typology of them from AD 1545 to 1700.

Chainplates

As noted in Chapter 2, chainplates either consisted of links or solid plates, and both appear throughout the 16th and 17th century (Figure 26). Historians of ship rigging vary in their chronology of chainplate types. Anderson notes that all nationalities during the first 40 years of the 17th century used solid plates, then chains were used between AD 1640-1655, after which most ships except for those rigged by the English reverted back to solid plates. [84] Mondfeld includes an image of chainplate evolution, showing a solid plate during the 17th century, links for British ships after 1760, differently-shaped links on early 18th-century British ships, another different form for late 18th-century French ships, and solid plates for late 18th-century Dutch

[84] Anderson 1994, 68.

ships (Figure 26).[85] Howard notes that for at least the first third of the 17th century solid plates were used, between AD 1640-1655 three-link iron chains were used, then afterward the plates gained popularity again. The exception is with Continental ships that used links only. [86]

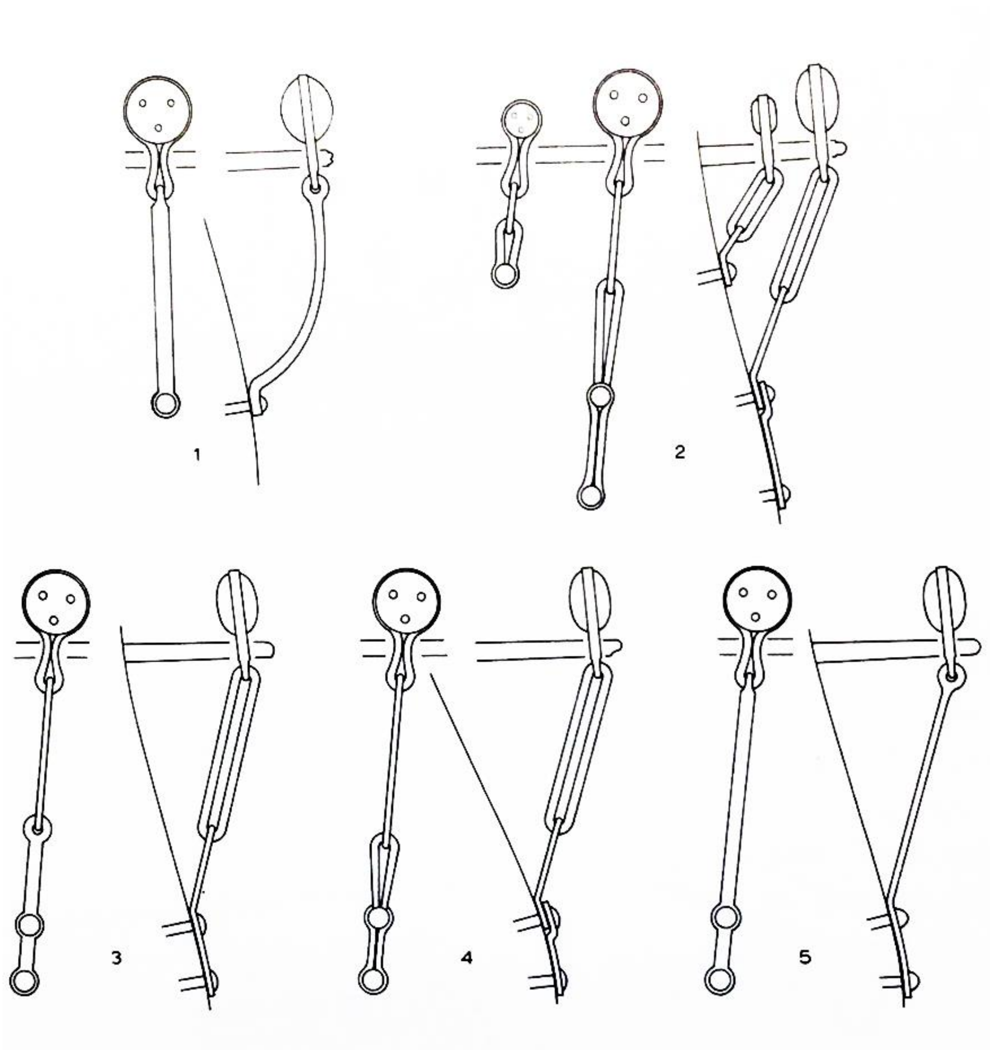

Figure 26: Mondfeld's illustration showing transitions in chainplates. 1. 17th century; 2. British after 1760; 3. British early 18th century; 4. French late 18th century; 5. Dutch late 18th century (Mondfeld 1989, 136).

[85] Mondfeld 1989, 136.
[86] Howard 1979, 134.

However, a look at the archaeological finds indicates that *Mary Rose* (1545), the Padre Island Wrecks (1554), *San Juan* (1565), *Sveti Pavao* (1574-1585), *Santo Hieronimo* (1576), *San Pedro* (1596), the Megadim Wreck (last quarter of 16th century), *Sea Venture* (1609), *Princess Maria* (1686), *Santo Antonio de Tanna* (1697) appear to have chains in the form of links, while *Warwick* (1619), *Batavia* (1629), the New Old Spaniard Wreck (1620-1640), *Vasa* (1628), and *La Belle* (1686) have plates (See Appendix B for list of rigging artifacts from each wreck).[87]

Archaeological finds do not support Anderson nor Mondfeld's chronology of chainplate typology. To his credit, Anderson wrote that "this matter of chains or plates is not easy" and notes a few exceptions to his chronology from ship models and iconography.[88] Too few chainplates have been discovered to provide a full picture of any transitions, and whether these changes correlate to anything, but Appendix B in this thesis provides the start of such a typology.

Blocks

Perhaps due to the many different functional forms of blocks, no chronological typology has been established to date. Anderson mentions a few generic changes but notes that much of this is guesswork.[89]

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[87] Marsden 2009, 271; Olds 1976, 43-50; Grenier et al. 2007, IV-3 to IV-4; Beltrame et al. 2014, 50; Jose Luis Casaban, personal communication, July 18, 2015; Watts 2014, 58; Ridella et al. 2016, 187-89; Adams 2013, 122-128; Rijksmuseum 1980, 7; Thompson 1988, 70-9; Douglas Inglis, personal communication, February 18, 2013; National Museum of Bermuda 2015, Artifact 12-03-011 ; Western Australian Museum, Artifact BAT3516; National Museum of Bermuda Exhibit, Artifact 10 in case (no ID given); DigitaltMuseum, Vasamuseet; Corder 2007, 51-52.
[88] Anderson 1994, 68.
[89] Anderson 1994, 144-45.

Other than Anderson, Grenier et al., in their work on the Red Bay Wreck, write that the block sheaves from *San Juan* exhibit a linear grain pattern rather than a radial grain, and that those with radial grain are intrusive, not recovered in a tight provenience, and therefore represent a later deposition (Figure 27).[90] This would imply that around AD 1565, sheaves with a linear grain pattern were common, while at a later time radial grained sheaves replaced them. This is presumably because a radial grain pattern ensures a stronger sheave due to its alignment with the cut, as it is cut parallel to the grain direction through the radius of the growth rings.[91] L.G. Carr Laughton also wrote a note in *Mariner's Mirror,* titled "Shivers of Brasse," which analyzed the cost of brass sheaves from *Henry Grace a Dieu* (sunk in 1553), concluding that wooden sheaves were only used for small blocks carrying ropes with smaller diameters. However, no further commentary on differences in usage between types of sheaves is given.[92]

Although information on hundreds of blocks archaeologically-recovered has been collected for the creation of this thesis, a full typology and chronological analysis of the various types is beyond the scope of this work at this time. Rather, an example of what can be done in the future is demonstrated through deadeye typology in Chapter 4.

[90] Grenier et al. 2007, IV-15 to IV-17.
[91] Grenier et al. 2007, IV-15 to IV-17.
[92] Powell et al. 1933, 117-18.

Figure 27: (Left) a representative of the majority of sheaves recovered from Red Bay. (Right) one of two sheaves that have radial grain from Red Bay believed to be intrusive. (Photo: (Right) R. Chan, Parks Canada; RA13829B and (Left) R. Chan, Parks Canada; RA13798B) (Grenier et al. 2007, IV-17).

Problems in Previous Literature

As Damien Sanders noted in "Knowing the Ropes: The Need to Record Ropes and Rigging on Wreck Sites and Some Techniques for Doing So," much of what was published on rigging in the past was based on the work of modelmakers such as Frank Howard, James Lees, Wolfram zu Mondfeld, and R. C. Anderson. Many works were published before the recent discoveries in nautical archaeology, and nearly all historical rigging analyses rely on non-archaeological evidence such as iconography, ship models, and historical documents including treatises and ship lists.[93] While the primary sources cited by these authors are useful in understanding changes in ship models, these same conclusions cannot always be applied to the real ships investigated by archaeologists. Alan Moore, who wrote some of the earliest

[93] Sanders 2010, 4.

contemporary rigging comparisons in *Mariner's Mirror* starting in 1912, reaches the same conclusion as Sanders: historical documents, iconography, and (in particular) ship models are full of inaccuracies.[94] This is problematic for chronological typologies, but even more so for rigging elements that are often eliminated from iconography and ship models because they obscure other parts of rig plans. Sanders notes that chafing gear, a critical element of rigging that keeps yards from rubbing against the masts, the sail clew from rubbing against the gunwale, and that protects the foresail, is almost never shown on ship models and is rarely seen in iconography.[95] Anderson's chronology of plate versus link in chainplates, is another example of data from ship models and iconography not reflecting the actual transitions seen in the archaeological record. Further, many of these sources contain unsubstantiated dates and claims. For example, Anderson based some of his rigging chronology features on sources he dated himself based on rigging features. A print he frequently cites has an unknown date, but he concludes that it is "probably not later than 1625" and uses this as a reference for rigs from the first quarter of the 17th century.[96] He applies the same circular argument with some ship model dates.[97]

Even with such flaws, Howard, Lees, Mondfeld, and Anderson are some of the most commonly cited works on rigging within nautical archaeology because handy sources of archaeological data are not available. Even today, many rigging components described in

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[94] Moore 1912, 267-68; Sanders 2010, 4.
[95] "Mats are broad clouts weaved of sennit and thrums together [and some are made without thrums], the use whereof is to save things from galling, and are used in these places:--to the main and fore yards at the ties, to keep the yards from galling against the mast; upon the gunwale of the loof, to keep the clew of the sail from galling there; upon the boltsprit and beak-head, to save the clew of the foresail." Manwaring and Perrin 1922, 187; see also Sanders 2010, 10-11.
[96] Anderson 1994, ix.
[97] Anderson 1994, x.

historical documents have never been found on shipwrecks, and the work of early ship modelers are still relied upon to understand these rigs. However, data derived from nautical archaeology studies can now provide meaningful new information to supplement and revise these works. This thesis, in addition to reconstructing *Warwick's* rigging, is an attempt to use archaeological evidence to support, refute, or refine the existing literature.

CHAPTER 4

AN ARCHAEOLOGICAL DATABASE OF RIGGING, STATISTICAL TYPOLOGICAL ANALYSIS, AND APPLICATIONS OF MACHINE LEARNING IN RIGGING DEADEYES: A CASE STUDY OF A NEW TOOL IN ARCHAEOLOGY AND THE CREATION OF DEADEYE TYPOLOGY

The majority of archaeological studies of ships' rigging cite *Mary Rose* (1545), *San Juan* (1565), *Vasa* (1628), and *La Belle* (1686) because of their well-documented and comparatively abundant collections of rigging artifacts. However, using artifacts from a handful of wrecks to understand *Warwick's* rigging is myopic. A more extensive archaeological database is necessary to fully understand rigging transitions in the late 16th and early 17th centuries. Prior to this work, no rigging typology existed, nor was there a comprehensive database of the rigging elements from shipwrecks. This chapter and its corresponding appendices attempt to bridge this gap by producing a database and presenting a case study of the applications of machine learning (ML) for predictive analysis and dating in rigging.

Comparative Archaeological Database

To begin, a typology of rigging artifacts was created by compiling a database of all known rigging artifacts from wrecks that sank between AD 1545 and 1700. Each artifact was documented including its dimensions, form, wood grain, wood type, associated concretions, and various other features, and presented along with images and citations. Sources include published excavation reports, museum archives, personal communications with project directors (for relevant unpublished data), and in a few cases, images and updates from websites and official social media outlets from ongoing excavations such as the London Wreck.[98] Sources were double checked and any questionable items were excluded. If artifact information was included that had a chance of error, this was mentioned within the footnotes. The result can be found in Appendix B, which includes finds from a total of 58 wrecks, listing a minimum of 2,512 artifacts (some publications did not list the exact number of finds in detail). The wrecks are presented in chronological order by their date of sinking; the build (nationality), tonnage, and ship type are also listed. Future analyses can include more features to improve pattern recognition, for example ship function, type of propulsion, and hull shape.

After the database was compiled, each artifact was grouped into one of six categories: deadeyes (including hearts), blocks (coaks, pins, and sheaves listed separately only if disarticulated), cordage, parrels (trucks and ribs), chainplates, and miscellaneous items. The original plan was to create a typology of each group of rigging artifacts but in the interest of keeping of this thesis within a reasonable length the typology was narrowed to one category of artifact. Given that deadeyes account for the largest rigging artifact group in *Warwick*, statistical analysis was conducted only for this category.

Deadeye Database and Typology

Features chosen for inclusion in the database were as comprehensive as possible and included measurements (length, width, thickness, the averaged diameter of eye, and score width), shape (pear-shaped, pear-shaped with flattened base, round with tapered base, and round), face form (convex or flat-faced), wood grain (vertical, horizontal, or radial), strapped or stropped,

[98] The London Shipwreck Trust, 2011.

square or round scored, and number of lanyard holes. Figures 28-34 illustrate the features recorded.

Deadeye terminology has not been fully standardized, and deadeyes are often described differently and categorized unreliably. To ensure consistency in categorization, qualitative data were gathered and recorded using the deadeye images. Measurements proved more difficult. In many cases, only some dimensions were recorded by the excavators, normally length and width, and sometimes thickness. In instances where only a diameter is given in a publication, the length and width are assumed to be equal, and entered as such unless its image clearly showed an artifact with unequal length and width. Measurements that were omitted by excavators or conservators were measured by importing the image into Photoshop and overlaying the photography scale within the same image over the deadeye. The maximum lengths, widths, thicknesses, average eye diameter, and score widths were measured this way, excluding any rope, concretions, or chainplates which are sometimes attached to deadeyes.

The actual dimensions of the artifact may vary given that several of the recorded measurements came from photos. The scales within several photos were not placed at the same height as the deadeye, changing their actual recorded measurement slightly. There is also a possibility of the wood warping, or use of conservation methods that modify size and shape. Further, the deadeyes come from ships of different sizes (tonnage) and even if from the same wreck, from different masts of the ship (e.g. main mast shroud, main topmast puttock, etc). Given these potential issues, the ratios of different deadeye measurements were also included to produce a more reliable way to track changes and standardize the measurements. The ratios of deadeyes' width to thickness, length to width, and width to score width, were also calculated and used for statistical analysis. Appendix C contains the entire deadeye database with its features, measurements, and accompanying notes.

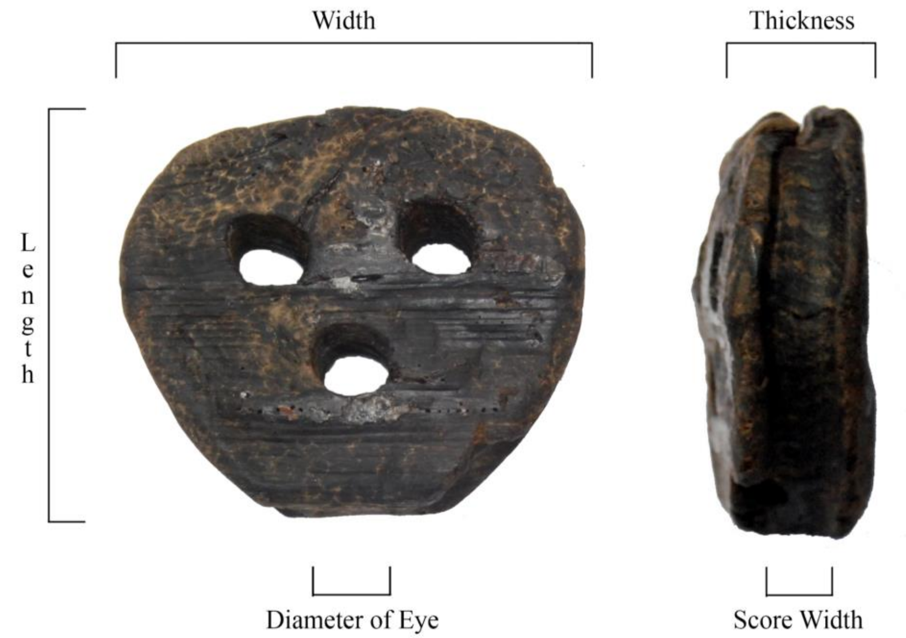

Figure 28: Diagram showing where deadeyes were measured including: length, width, diameter of eye, thickness, and score width. The average mean of all eye diameters is entered in the database. *Warwick* deadeye 02: 155.254557-764-u (Not to Scale) (Photos by Karen Martindale with modifications by author).

Figure 29: The four different shapes of deadeyes: pear-shaped, pear-shaped with flattened base (PFB), rounded with tapered base (RTB), and round deadeyes. From left to right: *Warwick* deadeye 93: 30-13-2, *Warwick* deadeye 02: 155.254557-764-u, *Warwick* deadeye 79:155-34. (Not to Scale). Pear-shaped and PFB have lengths that are greater than their widths whereas rounded and RTB deadeyes have lengths that are shorter or approximately equal (±1 cm.) to that of the width. PFB are pear-shaped deadeyes which have bases that are greater than 1/3 to its greatest width, whereas regular pear-shaped deadeyes have bases equal or lesser than its greatest width. RTB are round deadeyes that have a flattened base, whereas regular round deadeyes are nearly perfectly circular (All deadeyes from photos by Karen Martindale with modifications by author with the exception of the pear-shaped with flattened base example that is from *Vasa* and found in Corder 2007, 38.).

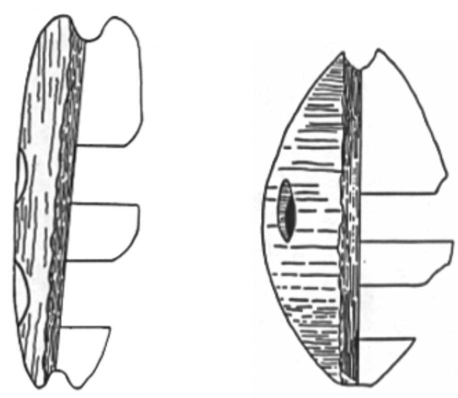

Figure 30: Profile views of two deadeyes showing a flat-faced deadeye (left) and a round-faced deadeye (right). From left to right: *Santo Antonio de Tanna* deadeye MH 5236 and *Santo Antonio de Tanna* deadeye MH 1509 (Not to Scale). (Images modified from Thompson 1988, 65 and 68).

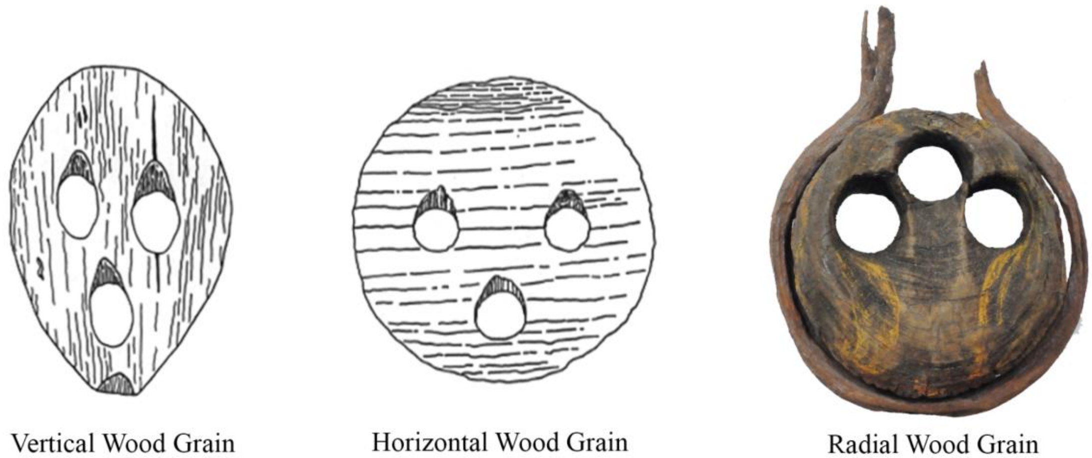

Figure 31: Three deadeyes showing the different types of wood grain present on deadeyes: vertical, horizontal, and radial. From left to right: *Santo Antonio de Tanna* deadeye MH 5236, *Santo Antonio de Tanna* deadeye MH 1509, and a *Corolla* Wreck deadeye recovered by Roger Harris. (Not to Scale) (Images from Thompson 1988, 66 and 68; Daniel Brown, personal communication, June 22, 2015).

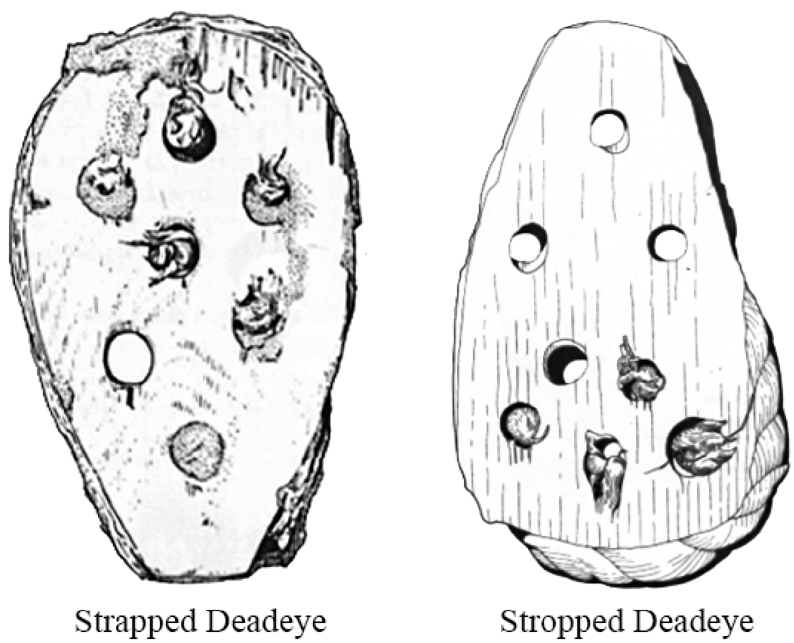

Figure 32: A strapped deadeye showing the metal concretions from the chainplate that was strapped to it (left), and a stropped deadeye showing the remainders of the rope stropped around it (right). Deadeyes are only listed as strapped or stropped if chain or rope is present. From left to right: *Mary Rose* deadeye 82A3746 and *Mary Rose* deadeye 81A2644. (Not to Scale) (Image from Marsden 2009, 271 and 272).

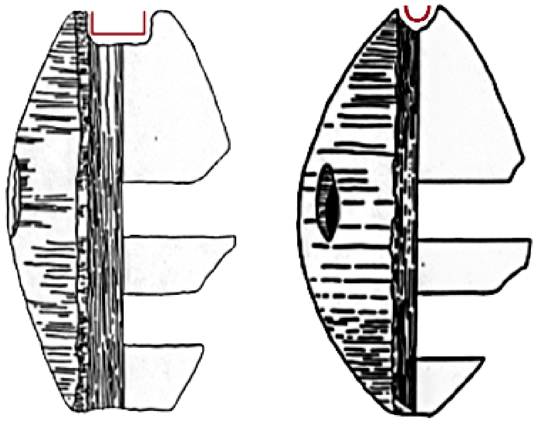

Figure 33: A deadeye showing a square score (left, outlined in red) and a deadeye showing a round score (right, outlined in red). From left to right: *Santo Antonio de Tanna* deadeye MH 1508 and *Santo Antonio de Tanna* deadeye MH 1509 (Not to Scale). (Image from Thompson 1988, 65 and 66).

Figure 34: Three deadeyes illustrating the different number of holes in deadeyes including a 3-hole deadeye, 6-hole deadeye, and 14-hole deadeye. From left to right: *Warwick* deadeye 02: 155.254557-764-u, *Warwick* deadeye 80:129C, *Katthavet 3* deadeye (Not to Scale) (Images from Karen Martindale, personal communication December 7, 2013 and Cederlund 1983, 215).

Statistical Analysis of Deadeye Transitions

To begin understanding deadeye trends, linear regression analyses were run on the quantitative values of all 293 deadeyes including potential outliers and intrusive deadeyes (this was done because they have not yet been proven to be statistical outliers and are thought to be such from archaeological context). Regression analysis describes the relationship between two values via an equation. Generally, a higher R^2 value is preferred, but what is deemed as an acceptable value depends on the data; an arbitrary threshold of a 10% R^2 value minimum was set, given that no previous standards for deadeye statistics has been established. A ‘good’ value for deadeye statistics was anything greater than 30% because a large amount of variation is expected from rigging. All rigging during this period was individually made by hand—machines for mass production had not been developed yet—so no two pieces were exactly the same.[99] The purpose of testing for regression was to understand if relationships between the variables exist at all and for basic visualization for machine learning analysis.

Figure 35 shows that over time deadeyes’ lengths and widths lowered and their ratios seem to remain around 1 during the second half of the 17th century. This corresponds to the prevalence of round deadeyes in the latter half of the century (previously noted in Chapter 3, pgs 37-38).

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[99] Clark 1976, 137-44.

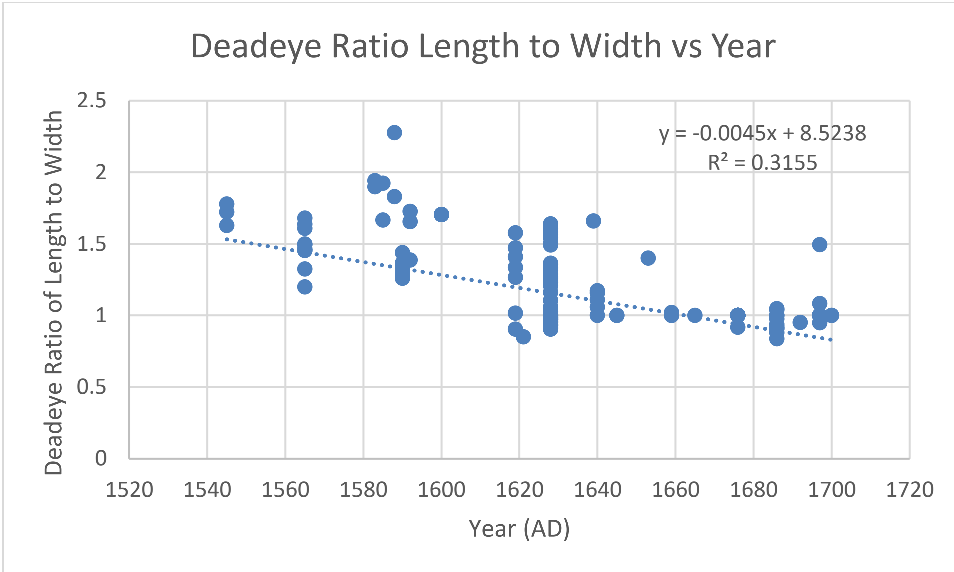

Figure 35: The deadeye length to width ratio plotted against year. A regression equation (y = -0.0045x + 8.5238) was determined with a $R^2 = 0.3155$. A slight negative correlation exists, showing a decrease in the length-to-width ratio through the years (Image by author).

Figure 36 shows that deadeyes became thicker in relation to their eye hole. It is unclear why this may have happened, but it may be a desire to create more robust deadeyes with thicker profiles to prevent breaking as eye holes became larger. However, thickness to year directly (not the ratio) revealed only a very slight positive correlation, but a $R^2 = 0.0498$. Diameter of eye hole to year directly (not the ratio) revealed a slight negative correlation, but a $R^2 = 0.0698$.

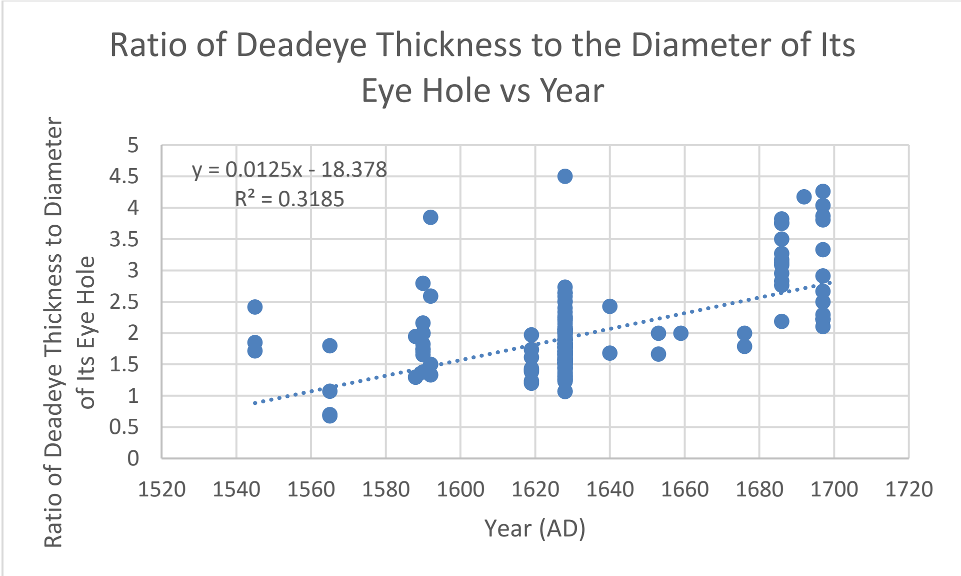

Figure 36: The deadeye thickness to eye hole diameter (averaged eye hole diameter) ratio plotted against year. A regression equation (y = 0.0125x - 18.378) was found showing a R^2 = 0.3185. A slight positive correlation exists, suggesting that over time deadeyes increased more in thickness compared to the diameter of the eye (Image by author).

Figure 37 supports the previous idea that deadeye widths did not increase the same amount as their thickness. Therefore, deadeyes were not getting wider, but were getting thicker.

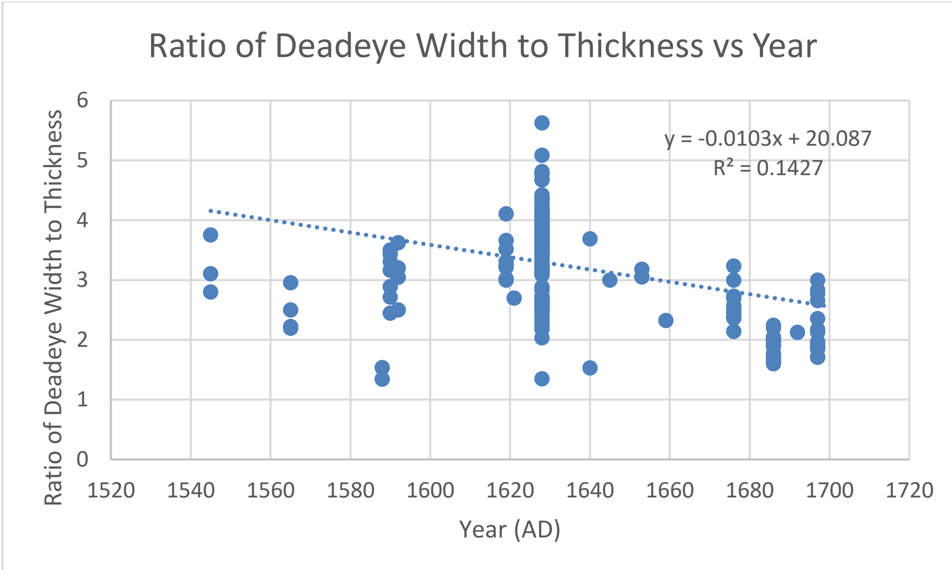

Figure 37: The deadeye width to thickness ratio plotted against year. A regression equation (y = -0.0103x + 20.087) was found showing a R^2 = 0.1427. A slight negative correlation exists, suggesting that over time deadeyes' widths decreased compared to their thickness (Image by author).

Patterns were also found related to ship tonnage. Figure 38 shows that the ratio of the deadeye thickness to its eye diameter plotted against its respective ship's tonnage, had a positive correlation. Deadeyes increased more in thickness compared to its eye diameter as ships got larger. Given that larger holes in deadeyes weaken them, it is hypothesized that the greater thickness is needed to counteract larger holes. The larger holes were needed on deadeyes of greater ships, because bigger masts and yards to support the lower sail area were needed to propel the ship, and therefore the entire rig required larger shrouds and lanyards for support.[100] However, these are tentative hypotheses and more evidence is needed to validate them. Also note that both thickness and diameter of eye hole when plotted individually (not their ratio) against tonnage did not show strong correlations. However, thickness to year directly (not their ratio)

[100] Mondfeld 1989, 272-3.

revealed a very slight positive correlation, but a low R^2 of 0.0498. Diameter of eye hole to year directly revealed a slight negative correlation, but a low R^2 of 0.0698.

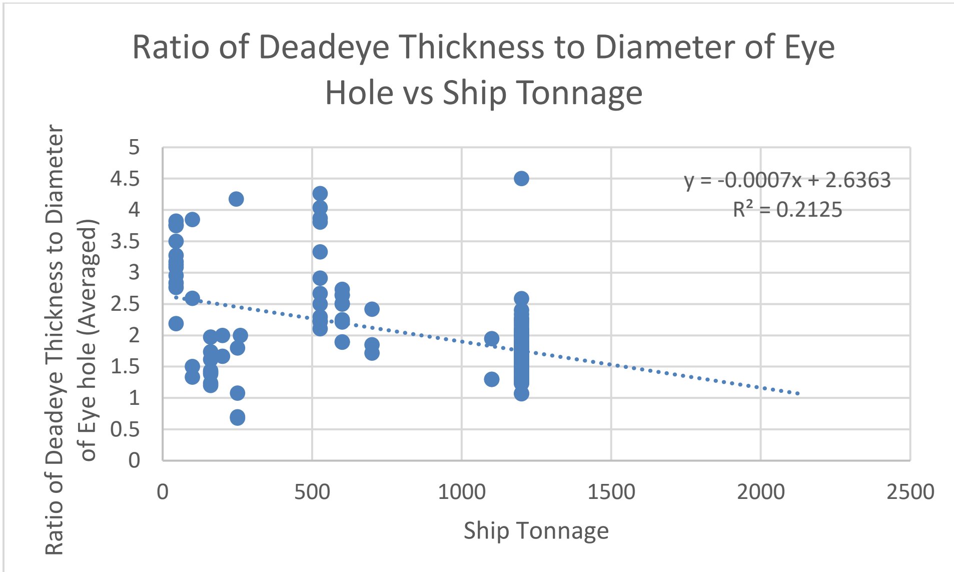

Figure 38: The deadeye thickness to its diameter of eye ratio plotted against ship tonnage. A regression equation (y = -0.0007x + 2.6363) was determined showing a R^2 = 0.2125. A slight negative correlation exists, suggesting that larger ships had smaller thickness compared to the average diameter of the deadeye's hole (Image by author).

When the ratio of deadeye width to thickness was plotted against ship tonnage (Figure 39), a slight positive correlation was present, suggesting that the larger the ship, the larger the width of the deadeye became compared to deadeye thickness. An explanation for this trend has not yet been established but this suggests that deadeye makers had standardized procedures for deadeye thicknesses and probably guild-like structures with a limited number of people producing deadeyes.[101]

[101] Clark (1976, 137-44) covers blockmaking techniques during the 18th and 19th centuries but blockmaking.

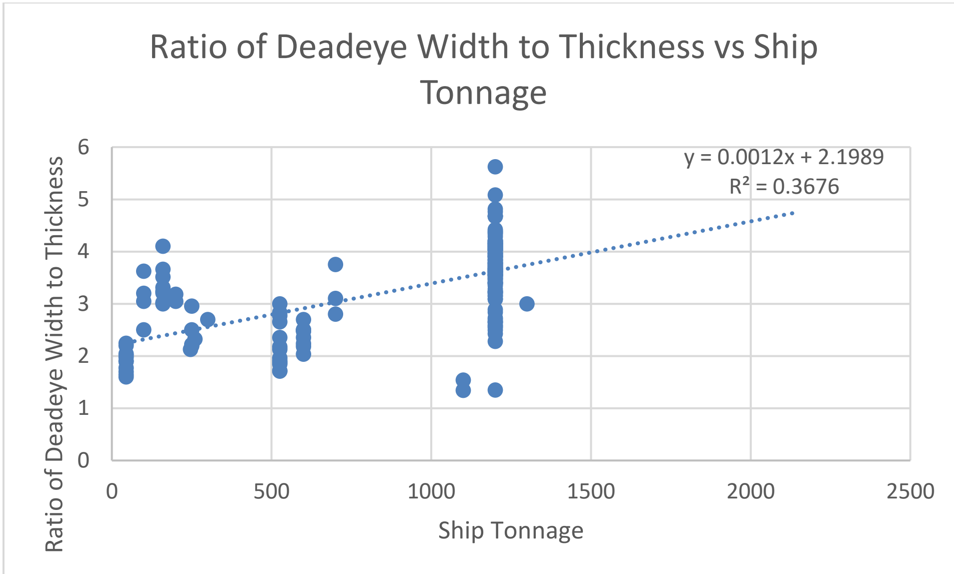

Figure 39: The deadeye width to thickness ratio plotted against ship tonnage. A regression equation (y = 0.0012x + 2.1989) was determined showing a R^2 = 0.3676. A slight positive correlation exists, suggesting that as ships got larger their widths increased at a greater rate than their thicknesses (Image by author).

Note that the ranges of the values and R^2 values are low on several of the charts generated thus far on individual deadeyes. These equations should not be used for predictions, but only for general understanding of trends. More reliable statistics using normalized data by wreck and machine learning will be used later for predictions.

Trends in qualitative data (ship build [nationality], wood grain, shape etc.) were determined using box plots, G scatter plots, and stem-and-leaf plot diagrams in Figures 40-49. Explanations of each figure are in their caption.

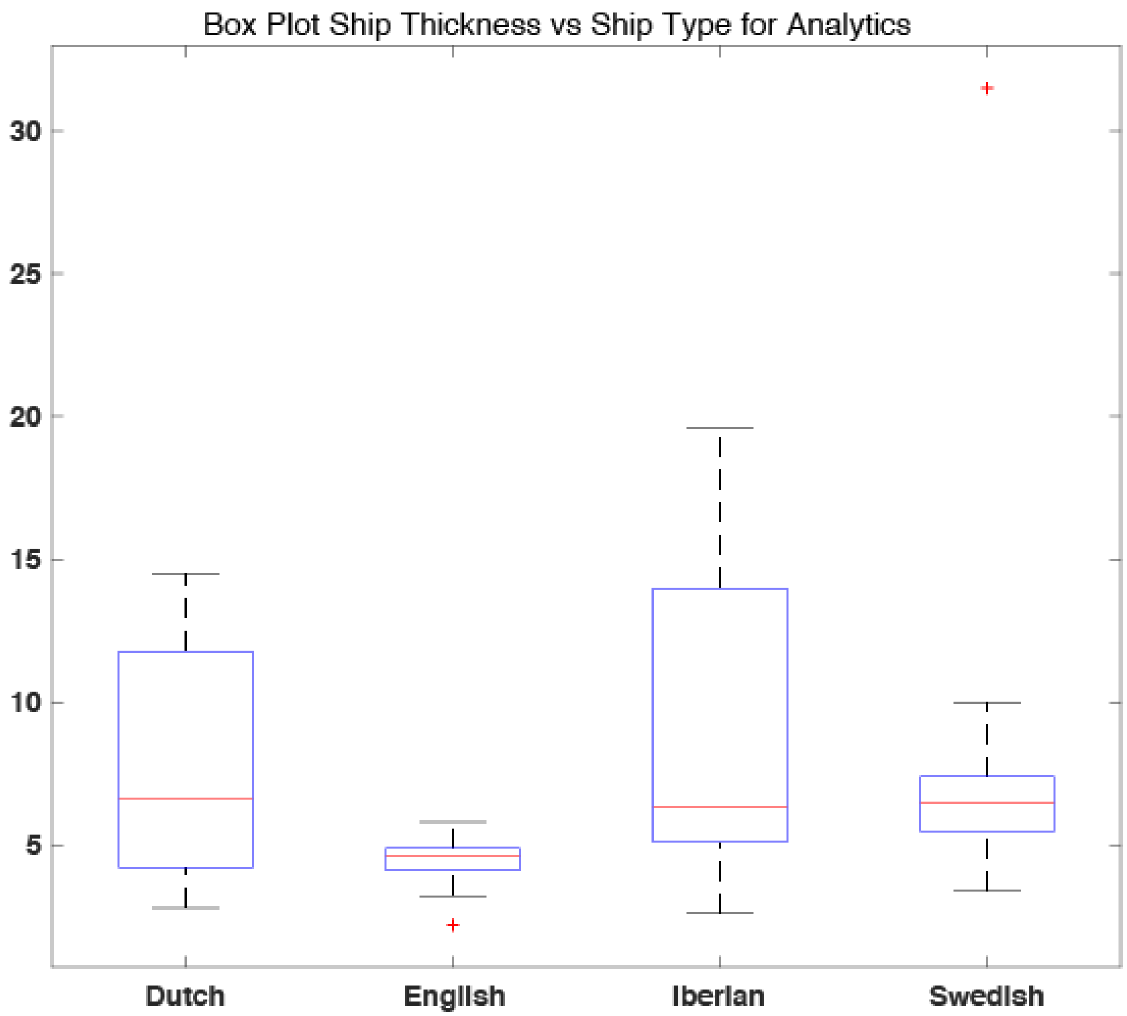

Figure 40: A box plot showing the ship build (nationality) to deadeye thickness between AD 1545-1700. The spread of variability of thicknesses for each nationality of ship build can be seen. Note that Dutch and Iberian ships appear to have greater variability in thicknesses. French ships show low variability, but this is likely due to the fact that only two French wrecks were included accounting for 13 deadeyes, so the sample size is much smaller. The Swedish category contained seven wrecks accounting for 148 deadeyes, the Dutch category had 5 wrecks with a total of 32 deadeyes, the English category had 6 wrecks containing a total of 48 deadeyes, and the Iberian category had 7 wrecks accounting for 41 deadeyes. Two wrecks have unknown nationality and so were omitted (Image by Hannah C. Clark).

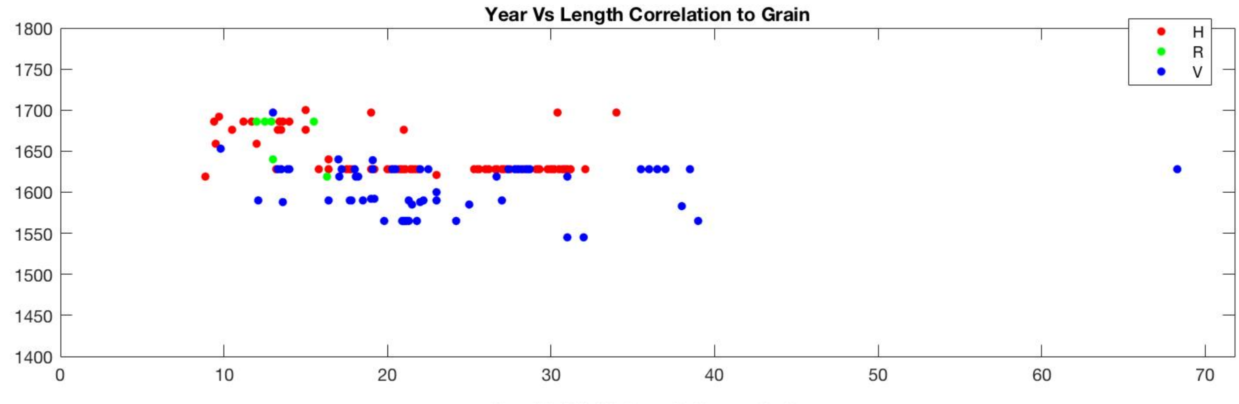

Figure 41: A G scatter plot comparing shipwreck year to deadeye length, and wood grain. Horizontal wood grain is represented by a red dot, radial by a green dot, and vertical grain by a blue dot. It is interesting to note that circa AD 1653, vertical grain deadeyes appear to almost disappear and are replaced by mostly horizontal wood grain deadeyes and a few radial grained deadeyes. Note also that a slight negative correlation exists, indicating that older deadeyes tended to have greater lengths compared to later deadeyes (Image by Hannah C. Clark).

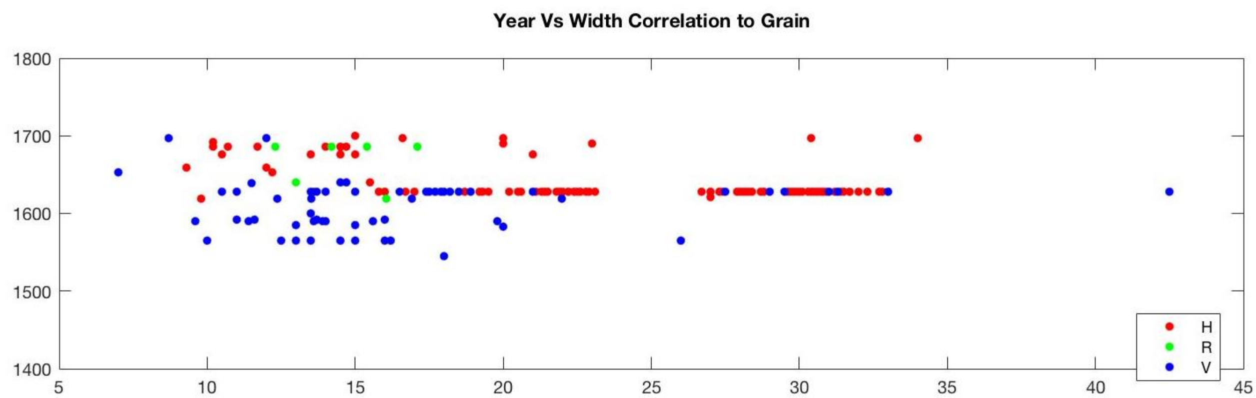

Figure 42: A G scatter plot comparing shipwreck year to deadeye width, and wood grain. Horizontal wood grain is represented by a red dot, radial by a green dot, and vertical grain by a blue dot. Note that around year AD 1628, horizontal wood grain suddenly appears and replaces vertical deadeyes. Horizontal deadeyes also appear to be associated with greater width, clustering between 15.8 to 32.7 cm., whereas the vertical deadeyes cluster between 10-20 cm. width. Radial deadeyes cluster between 12-17 cm. width (Image by Hannah C. Clark).

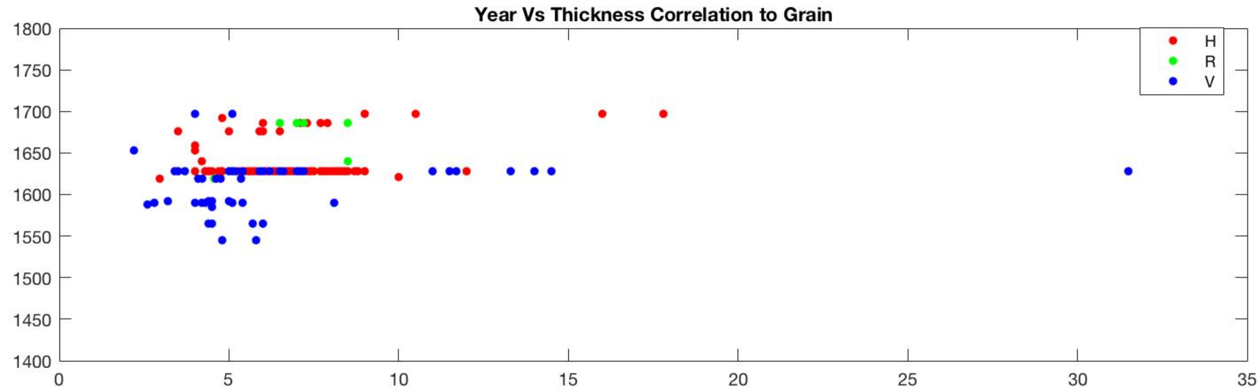

Figure 43: A G scatter plot comparing shipwreck year to deadeye thickness, and wood grain. Horizontal wood grain is represented by a red dot, radial by a green dot, and vertical grain by a blue dot. Vertical deadeyes tended to be thinner (5.2 cm.) whereas radial (7.2 cm.) and horizontal deadeyes (6.7 cm.) are thicker (Image by Hannah C. Clark).

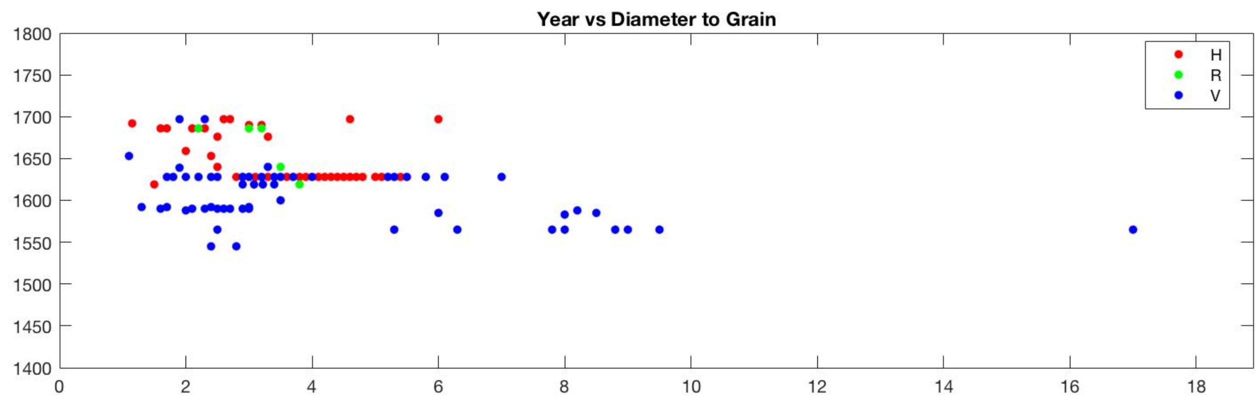

Figure 44: A G scatter plot comparing shipwreck year to deadeye hole diameter, and wood grain. Horizontal wood grain is represented by a red dot, radial by a green dot, and vertical grain by a blue dot. Vertical grain deadeyes, which correlate with earlier deadeyes, appear to have a greater standard deviation and less standardization in hole diameter, ranging between 1.7 to 7 cm. Horizontal and radial deadeyes have hole diameters that cluster between 2-5 cm. and are prevalent after AD 1628 (Image by Hannah C. Clark).

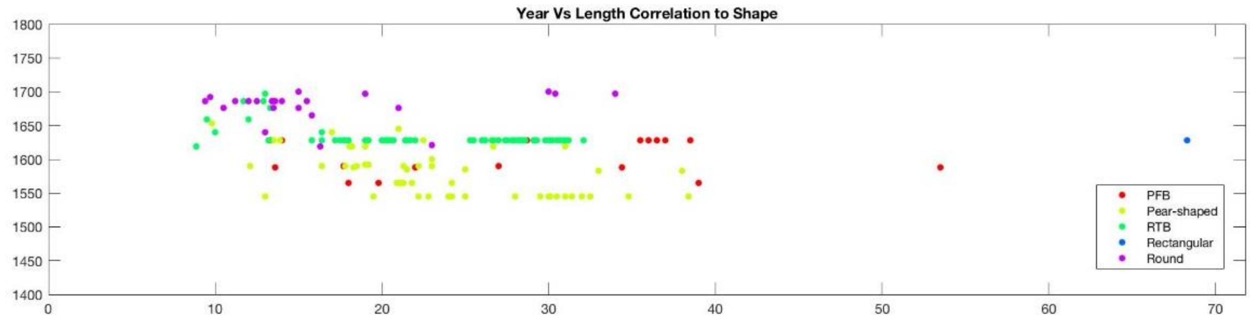

Figure 45: A G scatter plot comparing shipwreck year to deadeye length, and deadeye shape. PFB deadeyes are red, pear-shaped deadeyes are yellow, RTB deadeyes are green, rectangular deadeyes are blue, and round deadeyes are purple. Pear-shaped deadeyes appear to be prevalent from AD 1545 to 1583. PFB deadeyes seem to increase in frequency from AD 1565 to 1628, but similar to pear-shaped deadeyes, disappear after AD 1628 with the exception of *Santo Antonio de Tanna* (1697). RTB deadeyes appear in AD 1628 and begin to decline up to AD 1697. Rounded deadeyes appear to become most common in AD 1686. RTB and round deadeyes appear to have less variation in length, which is expected based on their shape, whereas pear-shaped and PFB deadeyes vary more in length (Image by Hannah C. Clark).

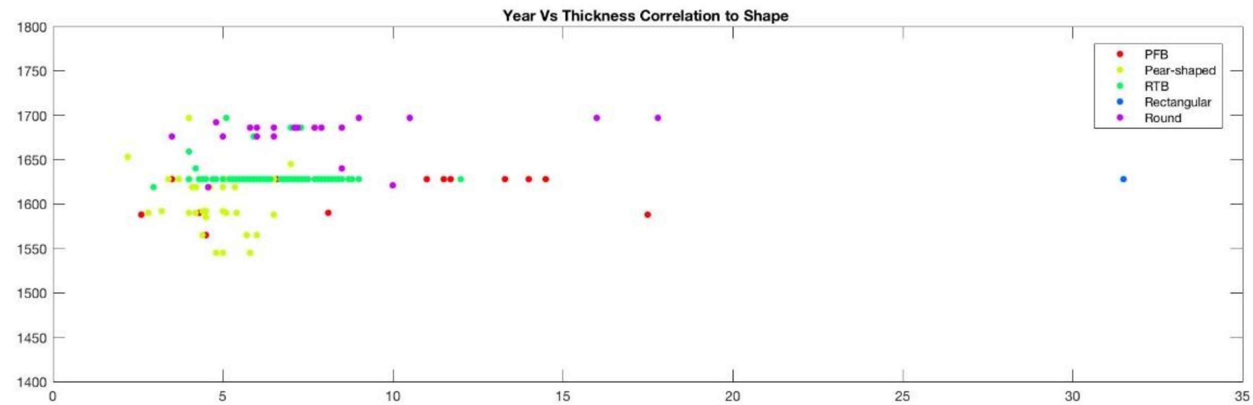

Figure 46: A G scatter plot comparing shipwreck year to deadeye thickness, and deadeye shape. PFB deadeyes are red, pear-shaped deadeyes are yellow, RTB deadeyes are green, rectangular deadeyes are blue, and round deadeyes are purple. PFB deadeye thicknesses ranged from 2.6 to 17.5 cm. with an average of 7.1 cm. Pear-shaped deadeyes appear to be thinner than other deadeyes, with thicknesses falling between 2.8-7 cm. with an average of 5 cm., RTB deadeyes were between 3 to 9 cm. in thickness, with an average of 7 cm., and round deadeyes thicknesses range from 2.5 to 10.5 cm., averaging in at 7.1 cm. (Image by Hannah C. Clark).

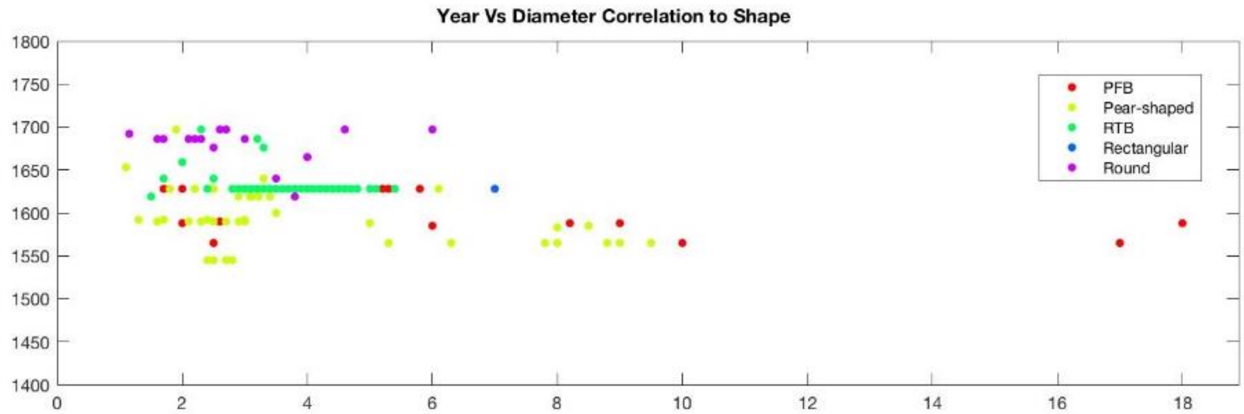

Figure 47: A G scatter plot comparing shipwreck year to deadeye hole diameter, and deadeye shape. PFB deadeyes are red, pear-shaped deadeyes are yellow, RTB deadeyes are green, rectangular deadeyes are blue, and round deadeyes are purple. Note that PFB and pear-shaped deadeyes have more variation in eye hole diameters, but that round and RTB deadeyes appear more standardized, with hole diameters of 4.1 cm. on average and a standard deviation of 2.0 for RTB, 2.4 cm. on average and 1.8 standard deviation for round deadeyes, 3 cm. on average and a standard deviation of 1.8 for pear-shaped, and 3.6 cm. on average and a standard deviation of 3.0 for PFB. Standard deviations were calculated using Q3-Q1, where Q stands for quartile (Image by Hannah C. Clark).

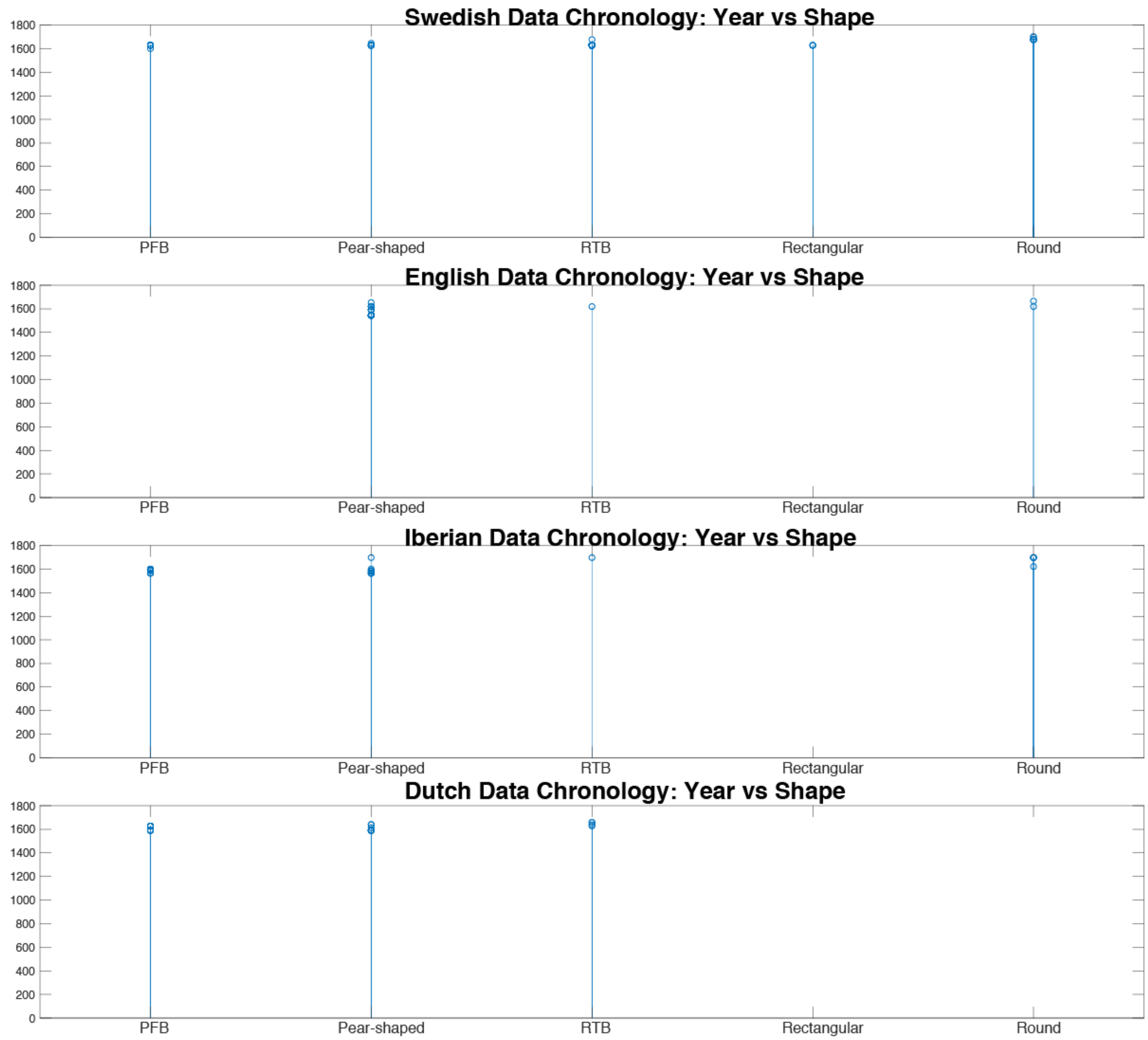

Figure 48: Stem and leaf plot diagram showing when deadeye shape types appear for each nationality. The Swedish ship chronology shows that PFB shapes appear in 1600 and 1628, Pear-shapes appear 1628 and 1645, RTB shapes appear from 1628 to 1676, rectangular shapes appear 1628 (only *Vasa* has rectangular deadeyes, hence this appears only under Swedish), and round shapes appear in 1676 and 1700. English ship deadeye chronology shows pear-shaped deadeyes in years 1545, 1592, 1619, 1653, RTB deadeyes in 1619, and round deadeyes years 1676, 1700. Iberian ship deadeye chronology has PFB deadeyes in 1565, 1588, 1600, pear-shaped deadeyes in 1565, 1583, 1588, 1600, 1697, RTB deadeyes in 1697, and round deadeyes in 1621 and 1697. Dutch deadeyes chronology revealed PFB deadeyes in 1590 and 1628, pear-shaped deadeyes in 1590, 1613, 1640, and RTB deadeyes in 1628, 1640, and 1659 (Image by Hannah C. Clark).

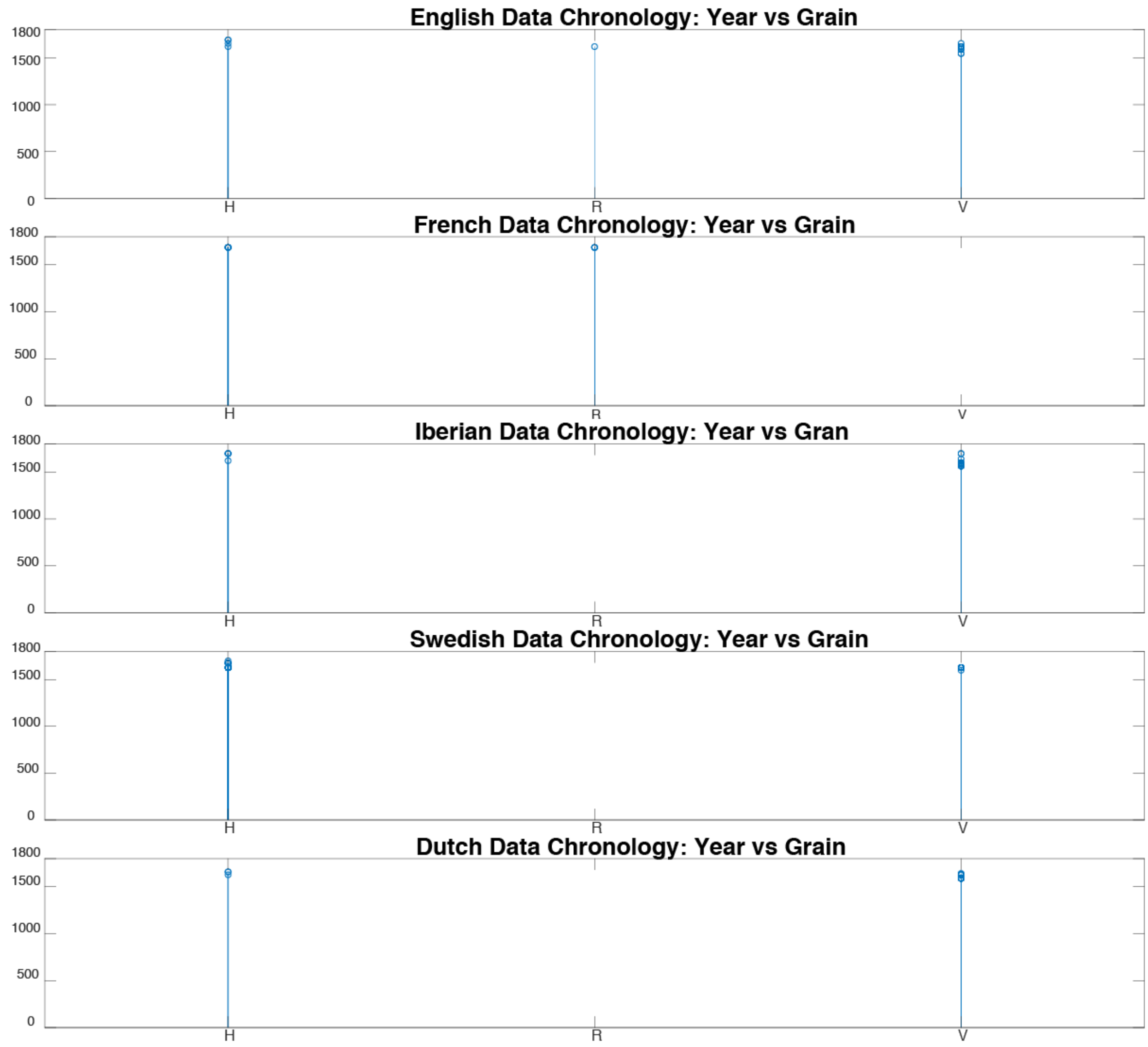

Figure 49: Stem and leaf plot diagram showing when these shapes appear for each type of nationality. For Dutch ships, horizontal grained deadeyes appear in 1628 and 1659, vertical grain appears in 1590, 1628, and 1640. English ships had wrecks containing horizontal grained deadeyes in 1619, 1653, and 1690, radial deadeyes in 1619, and vertical deadeyes in 1545, 1592, 1619, and 1653. French ships had a wreck containing horizontal and radial deadeyes in 1686. Iberian wrecks with horizontal deadeyes appear in 1621 and 1697, and vertical deadeyes appear in 1565, 1583, 1588, 1600, and 1697. Swedish wrecks with horizontal deadeyes show up in 1628, 1676, and 1700, and vertical deadeyes appear in 1600 and 1628 (Image by Hannah C. Clark).

The qualitative data show that around AD 1653, vertical grain deadeyes become uncommon and are replaced by horizontal grained deadeyes. Horizontal grained deadeyes correlate to the round shape and also have a greater width and thickness than vertical grained deadeyes. Vertical grained deadeyes correlate to the pear-shape, and have larger standard deviation and less standardization in hole diameter. Pear-shaped deadeyes are prevalent between AD 1545 to 1583, PFB deadeyes appear from AD 1545 to 1628, RTB deadeyes appear in AD 1628 to 1697, and round deadeyes become common in AD 1621 TO 1700. PFB and pear-shaped deadeyes also have more variation in eye hole diameters compared to round and RTB deadeyes.

Statistical Analysis on Wreck Averages

The data from each wreck was then manually consolidated to represent one data point for each of the features per wreck. This normalizes the data, given that some wrecks such as *Mary Rose* (1545) and *Vasa* (1628) have numerous deadeyes, whereas other wrecks have few, which skews the data. For this reason, a hypothetical deadeye was generated to represent the common deadeye for each wreck either by averaging the data by mean if the data were quantitative, or by mode if qualitative.

This was done by first removing outliers and intrusive deadeyes. These include removing deadeye 79: 155-344 from *Warwick*, the deadeye from *Katthavet 3 (Näckström 1),* the possibly intrusive deadeye from the *Corolla Wreck*, and the rectangular deadeyes from *Vasa*. The columns for “ID,” “Strap/strop”, and “Score shape” were deleted as these are not related to chronological changes, whereas the columns for “Ship,” “Year,” “Tonnage,” and “Ship Type” were kept the same. Columns for “Length,” “Width,” “Thickness,” “Score Width,” and “Diameter of Eye Hole,” were then averaged and the mean recorded. For “Shape,” “Flat or Round Face,” “Grain,” and “Number of Holes” the median feature per wreck was noted, so that the majority feature is what was recorded. In the case where there is no majority (i.e. two qualitative features were tied, such as if a wreck only has two deadeyes and one has a round face but the other has a flat face), it was left blank to not skew the data. Columns for “Wood species” and “If Heart, what shape hole” were removed as there are too few entries for proper analysis. The consolidated data from the averaged deadeye data per wreck can be seen in Figure 50.

Ship	Year (latest date of range)	Tonnage (largest possible)	Ship Type (Build)	Length (cm)	Width (cm)	Thickness (cm)	Score Width (cm)	Diameter of eye hole (Average)	Shape	Flat or Round Face	Grain	Number of Holes
Mary Rose	1545	700	English	27.9	16.7	5.2	3.7	2.5	Pear-shaped	Flat	Vertical	7
Western Ledge Reef Wreck	1600	143.2	Iberian						PFB	Flat	Vertical	1
San Juan	1565	250	Iberian	22.8	15	5.2	2.8	8.4	Pear-shaped	Flat	Vertical	1
Sveti Pavao	1585		Venetian ?	23.8	14	4.5		7.3	Pear-shaped	Flat	Vertical	1
Arade I	1583		Iberian	35.5	18.5			8	Pear-shaped	Flat	Vertical	1
La Trinidad Valencera	1588	1100	Iberian	28.4	16.8	8.9	6.7	8.4	PFB	Flat	Vertical	1
Scherurrak SO1	1590		Dutch	19.6	14	4.8	3	2.5	Pear-shaped	Flat	Vertical	3
Alderney Ship	1592	100	English	19.1	13.1	4.3	2.5	2.1	Pear-shaped	Flat	Vertical	5
Megadim Wreck	1600			23	13.5			3.5	Pear-shaped	Flat	Vertical	3
Witte Leeuw	1613	700	Dutch						Pear-shaped			3
Warwick	1619	160	English	19.8	14.8	4.4	2.5	2.9	Pear-shaped	Flat	Vertical	3
New Old Spaniard	1640		Dutch	14.7	12.7			2.8	Pear-shaped	Flat	Vertical	3
San Antonio	1621	300	Iberian	23	27	10			Round		Horizontal	3
Swash Channel Wreck	1628	600	Dutch	34.3	28.6	12.1	7.3	5.1	PFB	Flat	Vertical	3
Vasa	1628	1200	Swedish	24.4	24	6.5	3.2	3.8	RTB	Flat	Horizontal	3
El Galgo	1639		Iberian	19.1	11.5			1.9		Flat	Vertical	3
Stora Sofia	1645	1300	Swedish	18	18	7			Pear-shaped			
Corolla Wreck	1640			16.4	15.5	4.2		2.5	RTB	Flat	Horizontal	3
Duart Point	1653	200	English	9.8	9.6	3.1	2.2	1.8	Pear-shaped	Flat		3
Avondster	1659	260	Dutch	12.6	10.6	5.3		2	RTB	Flat	Horizontal	3
HMS London	1665	1104	English	15.8	15.8			4	Round	Round		3
Kronan	1676	2140	Swedish						Round	Round	Horizontal	3
Grone Jagaren	1676		Swedish	15.5	15.5	5.3			Round	Round	Horizontal	3
Riksapplet	1676		Swedish	17.4	17.5	6.3		2.9			Horizontal	3
La Belle	1686	45	French	12.7	13.4	7.1	2.1	2.3	Round	Round	Horizontal	3
HMS Dartmouth	1690	266	English		21.5			3.1			Horizontal	3
La Hougue Wrecks	1692		French								Horizontal	3
Port Royal Shipwreck	1692	246	Engish	9.7	10.2	4.8	1.6	1.15	Round	Round	Horizontal	3
Santo Antonio de Tanna	1697	526.1	Iberian	23.8	23	10.2	2.8	3.5	Round	Round	Horizontal	3
Jutholmen	1700		Swedish	22.5	22.5				Round	Round	Horizontal	3

Figure 50: Chart of consolidated deadeye data averaged by wreck (Image by author).

Regression analysis was then run on this new set of data. Figures 51-59 show the results with explanations provided in the captions.

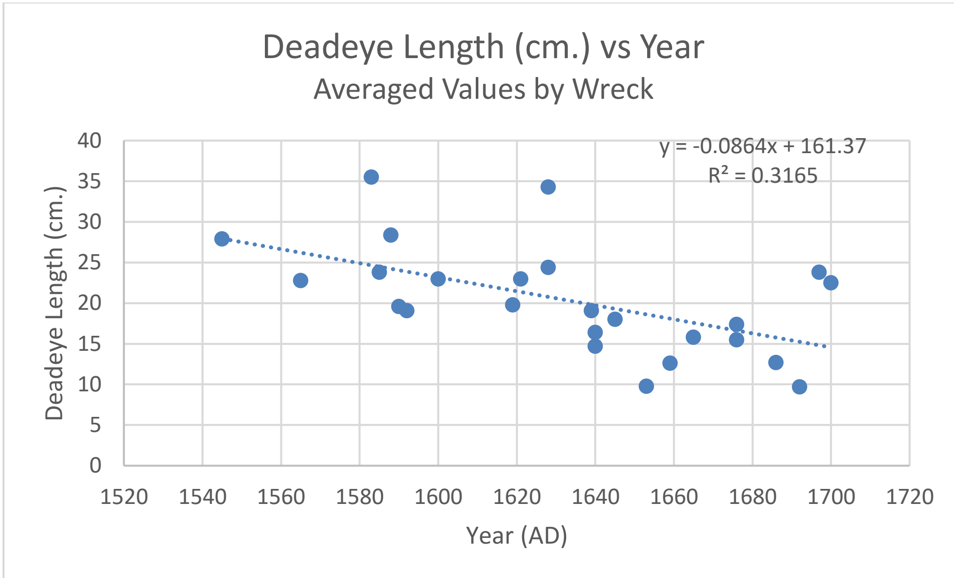

Figure 51: Deadeye length (cm.) plotted against Year showing a negative correlation (y = -0.0864x + 161.37 and R^2 = 0.3165). Data are averaged by wreck (Image by author).

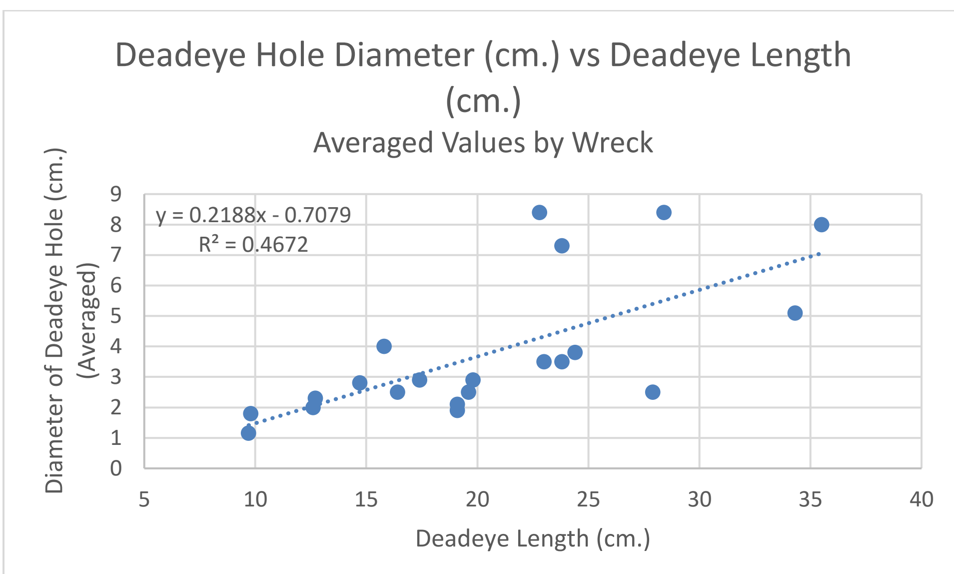

Figure 52: Deadeye hole diameter (cm.) plotted against deadeye length (cm.) showing a positive correlation (y = 0.2188x - 0.7079 and R^2 = 0.4672). Data are averaged by wreck (Image by author).

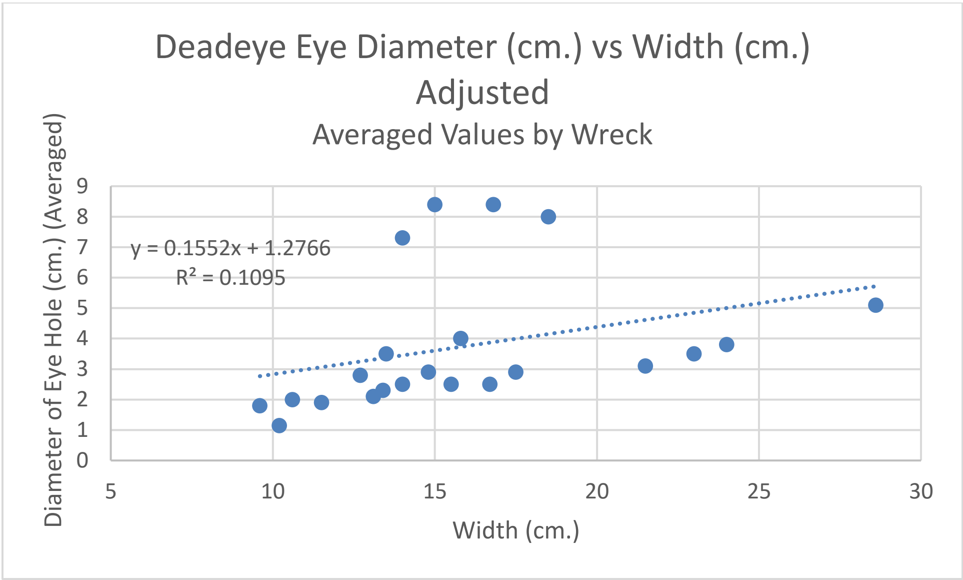

Figure 53: Deadeye eye diameter (cm.) plotted against width (cm.) and adjusted (4 deadeyes were removed). Deadeye hole diameter (cm.) plotted against deadeye width (cm.) showing a positive correlation (y = 0.1495x + 0.4211 and R^2 = 0.6955). Data are averaged by wreck (Image by author).

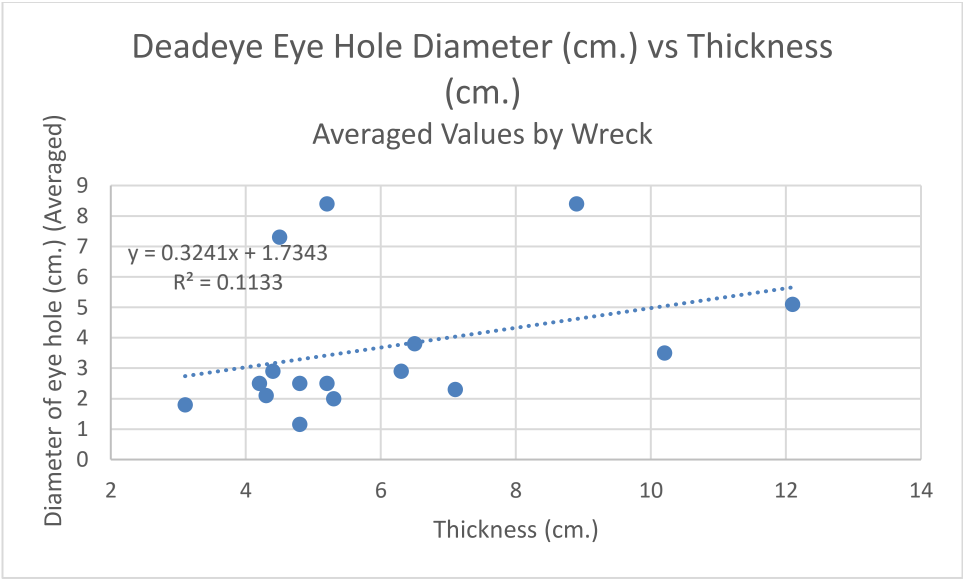

Figure 54: Deadeye eye diameter (cm.) plotted against thickness (cm.) and adjusted (4 deadeyes were removed). A positive correlation exists (y = 0.3173x + 0.7851 and R^2 = 0.6485). Data are averaged by wreck (Image by author).

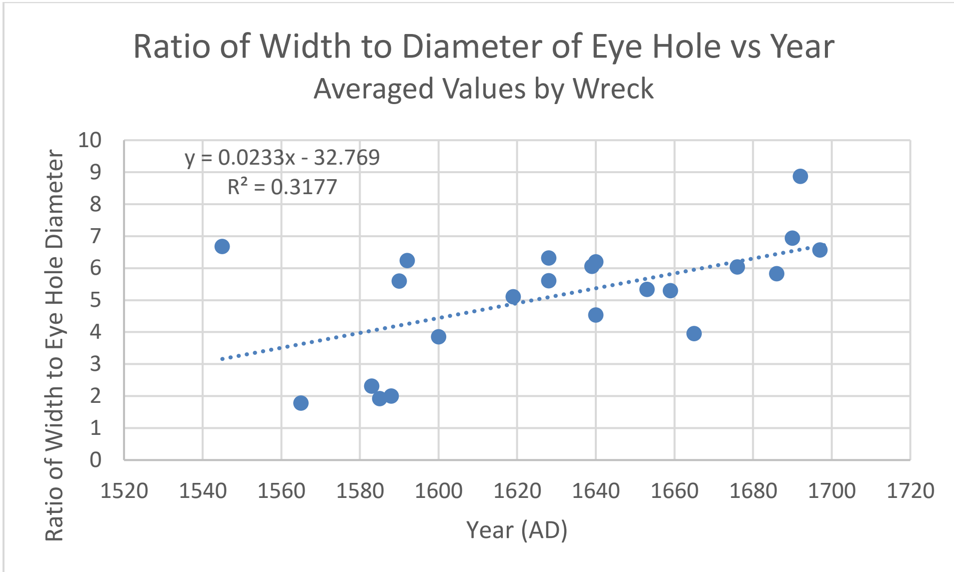

Figure 55: Ratio of deadeye width to hole diameter plotted against year showing a positive correlation ($y = 0.0233x - 32.769$ and $R^2 = 0.3177$). Data are averaged by wreck (Image by author).

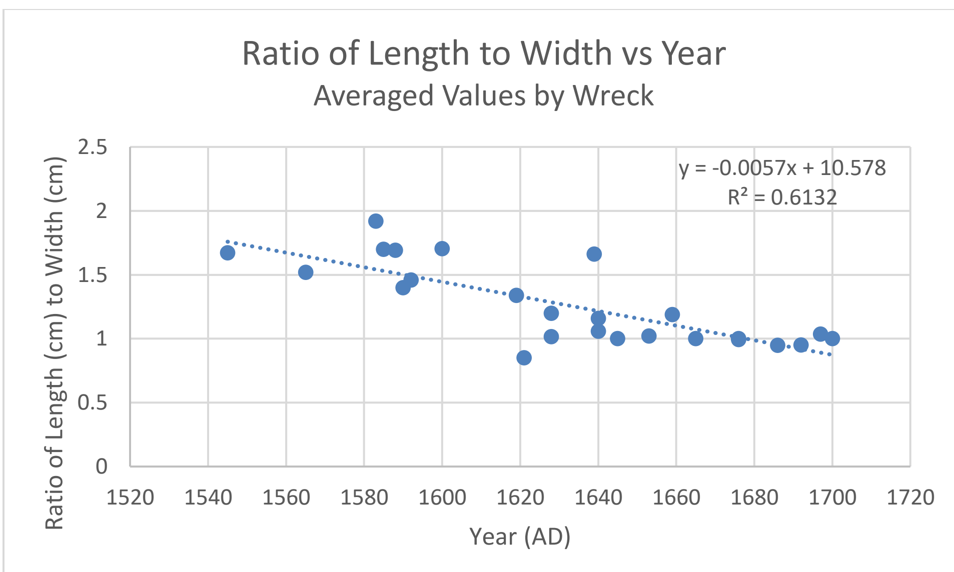

Figure 56: Ratio of deadeye length to width plotted against year showing a negative correlation ($y = -0.0057x + 10.578$ and $R^2 = 0.6132$). Data are averaged by wreck (Image by author).

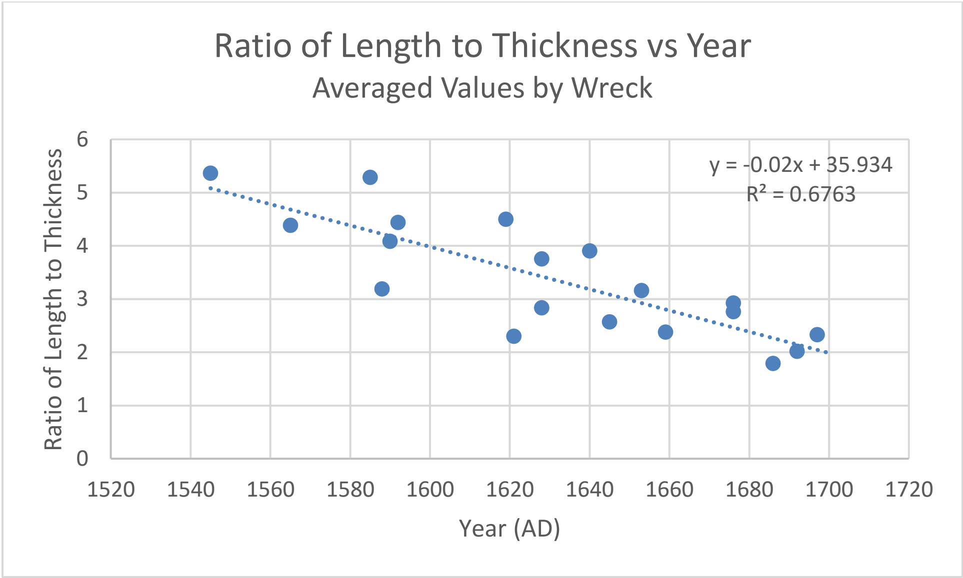

Figure 57: Ratio of deadeye length to thickness plotted against year showing a negative correlation ($y = -0.02x + 35.934$ and $R^2 = 0.6763$). Data are averaged by wreck (Image by author).

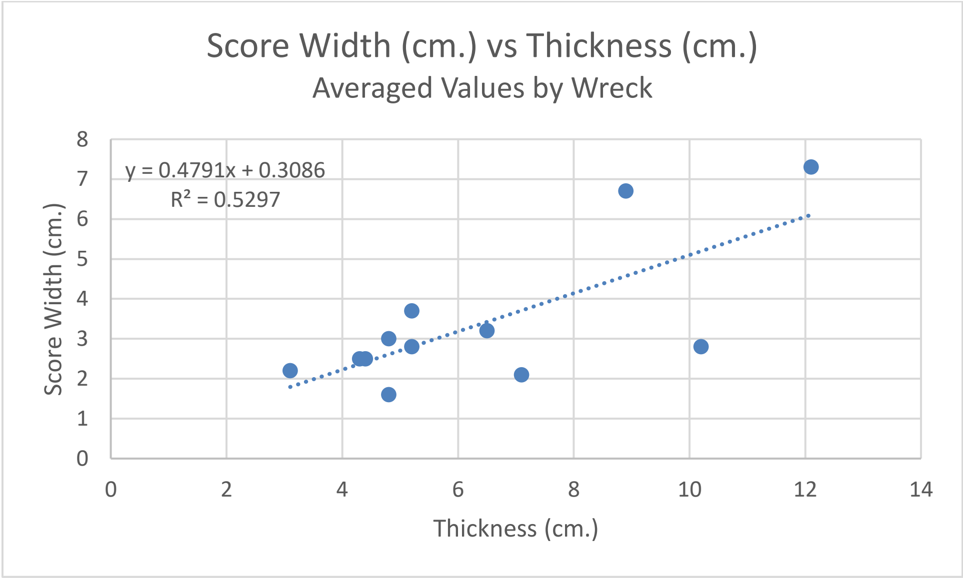

Figure 58: Deadeye score width (cm.) plotted against thickness (cm.) showing a positive correlation ($y = 0.4791x + 0.3086$ and $R^2 = 0.5297$). Data are averaged by wreck (Image by author).

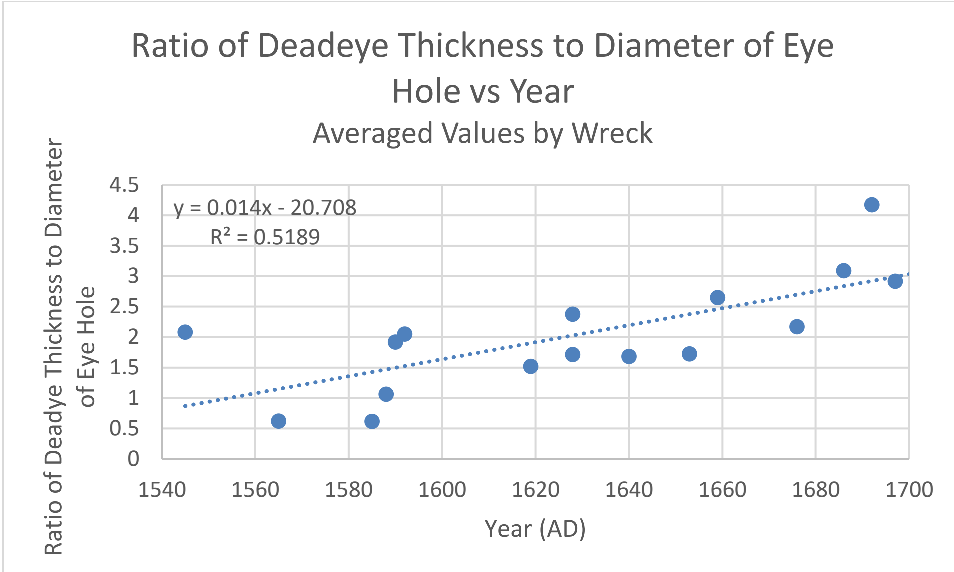

Figure 59: Ratio of deadeye thickness to diameter of eye hole plotted against year showing a positive correlation (y = 0.014x - 20.708 and R^2 = 0.5189). Data are averaged by wreck (Image by author).

These data appear to support the hypotheses from the previous section, but by removing the background noise and consolidating the data, clearer patterns and much stronger R^2 values are seen. This information is better for predictions of deadeyes (note: predictions can only be drawn for deadeyes believed to be from wrecks that sank between AD 1545-1700, it cannot be applied to other periods). For example, if a deadeye is found showing the diameter of its eyehole and overall thickness, then its suggested dimensions, date of sinking, ship tonnage, and other features can be predicted within a range, which can be refined if additional deadeyes are found from the same wreck. This section was also the basis for the different features selected for classification for machine learning.

Machine Learning and Statistical Analyses of Deadeyes

Machine learning (ML) is a subfield in computer science that deals with developing system models that are trained on a set of data to make predictions using statistics and probability-based algorithms.[102] ML algorithms are able to build a mathematical model to predict an outcome given a matrix that consists of observations correlated to each variable. ML is primarily used today for self-driving cars, email filtering, and computer vision, but has crossed into many other disciplines including archaeology. Archaeologists and anthropologists have applied ML approaches to predict human skeletal stature, the archaeological potential of soil profiles, flint tool classification and use-wear analysis, automated identification of anthropomorphic landforms in conjunction with LiDAR, and typology of Bronze Age pottery, among many other topics.[103] To date, the author has not been able to find applications of ML on ships' rigging.

In this thesis, a Supervised Learning Algorithm (SLA) is applied for computational statistics in deadeye feature prediction (applied to the non-averaged-by-wreck data), which was done in collaboration with Hannah C. Clark, an independent researcher, NASA computer scientist, and contributor to this chapter.

The ML was applied to the deadeye database in four steps:

1) Data Preprocessing
2) Feature Selection
3) Supervised Learning Algorithm and Hyper-Parameter Optimization
4) Testing Results and Algorithm Performance Assessment

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[102] Mitchell 1997, 1-19.
[103] Czibula et al. 2016, 85-99; Oonk and Spijker 2015, 80-88; Van Den Dries 1998, 1-227; Guyot et al. 2018, 1-19; Hörr et al. 2014, Article no. 2.

Data Preprocessing

First, the data were normalized by removing outliers or intrusive artifacts that may skew the data. Outliers that were removed include the deadeye from *Katthavet 3 (Näckström 1)* and the rectangular deadeyes from *Vasa* (which were only found on *Vasa*). Further, given that the purpose of this thesis is to understand where *Warwick's* deadeyes fall among standard deadeyes of the period, *Warwick's* deadeyes were also removed from the training set (so that they can be processed by the algorithm after its completion to see how the applications categorize them). Unknowns, or information-limited deadeyes which are missing too many categories, were also removed from the dataset. The possibly-intrusive deadeye found on the *Corolla Wreck*, similar to *Warwick's* deadeyes, was kept for testing the algorithm, but not to build the algorithm—this was done to see if the algorithm could prove if it is anachronistic as suggested by Daniel Mark Brown and Dr. Fred Hocker.[104]

The final pre-processed training set consisted of 280 deadeyes. As a caveat, note that 280 data points is considered too small for traditional ML—this technique is generally used for large-scale computational statistics. However, even with a small sample size, the ML algorithms accurately predicted the majority of the training and testing dataset, and show promise in improving further as the database grows.

To adjust to the size of the small dataset, the training data were randomly sorted to account for variation, and fractioned off into the following: 40%, 60%, and 80%. The remaining portion (20% and *Warwick's* deadeyes) were reserved as data for testing. This was done as an additional measure to verify that the algorithm is making realistic predictions, and not being

[104] Brown 2013, 164-65. Daniel Brown, personal communication, June 22, 2015.

influenced by shipwrecks that contained many deadeyes versus those that only had a few. The final training dataset used to build the algorithm consisted of approximately 57.9% of the original data, and the dataset for testing consisted of 42.1% of the original data. After both sets were created, a 15-fold cross-validation was applied while developing each algorithm on the training dataset. Additional parameter optimization values were also adjusted to avoid overfitting (the occurrence of an algorithm that customizes itself too much to produce positive results, therefore not truly identifying the trend correctly—i.e. false positive) and making faulty predictions.

Feature Selection

Bagged tree algorithms, or bagging (covered in depth in the following section), were used to assess which recorded features (e.g. shape, size, build etc.) had the greatest influence on other deadeye features. The decision to use bagged tree algorithms was based on the statistical analyses done earlier in this chapter, combined with the occurrence of relatively few data points, which bagging helps counteract. This step determines which features are important to include in algorithms and which can be ignored because they have no effect and would slow or confuse the algorithm. For example, whether the deadeye was strapped or stropped did not have an influence on the desired output variables, so this feature was eliminated within the analysis to not impede the algorithm's accuracy and performance. In this way, features that skew outcomes were selected or omitted.

Supervised Learning Algorithm

After data preprocessing and feature selection, a Supervised Learning Classification Model was created in MATLAB®, a computing analytical environment and language. Supervised learning is a type of ML algorithm that learns by training on pre-labeled data to use as an example of input and output. A classification model (in this case, AdaBoost or Bagged Tree) takes input (e.g. year range) and makes predictions on output variables (e.g. shape of deadeye, deadeye wood grain etc.). Every row in the dataset consists of an input variable and its corresponding output value. The supervised learning algorithm takes the rows of training data that are given to it and correlates the influence of each feature value to the desired output variable, therefore "training" the algorithm to produce correct predictions. Once the algorithm is trained on the initial data set, it then processes a second dataset that does not include the output variable to see if the algorithm correctly predicts the desired output. The second dataset is known as the testing dataset and is used to assess algorithm performance and prediction accuracy. Three models were generated in MATLAB®, to make predictions on Year, Shape, and Wood Grain using either AdaBoost Classification Ensembles or Bagged Tree Ensembles.

Models which predicted the year and grain type in this study used an AdaBoost Ensemble Tree algorithm, whereas shape predictions used a Bagged Tree algorithm (i.e. Bootstrap Aggregation Tree Ensemble).

The AdaBoost (Adaptive Boosting) Ensemble method was chosen for year and grain type because it helps mitigate the problem of the high dimensionality (the so-called curse of dimensionality), and adapts the algorithm to properly classify difficult observations within the dataset. The curse of dimensionality refers to the fact that each sample (i.e. deadeye) consists of a large number of features (e.g. shape, grain, year), and each feature has a large number of potential outcomes (e.g. horizontal grain, vertical grain, radial grain, under the feature of deadeye grain type). Evaluation of each feature reduces the speed of training and execution, in addition to the predictive power of the algorithms. With such high dimensionality, using a single algorithm to properly factor in the weight of each feature without substantial bias is difficult and results in incorrect predictions. To combat this, the AdaBoost Ensemble uses many “weak learners” (i.e. weak classifiers) or algorithm models with lower prediction accuracy (any algorithm that has accuracy above that of random chance can be used). The weak learners are combined into a single strong classifier model by combining the weighted sum of each individual weak learner. The “weight” referred to above is the influence that AdaBoost assigns to each algorithm, determining the probability that each weak learner appears in the training set. Those with higher weights have a greater probability of being included. Weak learners that misclassify observations within the set are adjusted to by increasing the weights of each learner which incorrectly predicts the most observations, forcing the learners to become more accurate at predicting the dataset as a whole through a complex algorithm balancing the loss (e.g. faulty predictions) with weight. This procedure is repeated, and at the end of each training round, the weights of misclassified weak learners are boosted, until the loss reaches zero, or the loss no longer changes, indicating that it has reached the apex of its capabilities and no further modifications can improve it.

For instance, if predicting the year of the shipwreck is the desired output, and two other features are given such as thickness (for example, 5 cm.), and length (19 cm.), the weak learners for these features are generated, and the individual results weighted by importance of influence, together producing a final output of a predicted year. For the sake of example, if Figure 51’s equation was used with the length information provided, resulting in a shipwreck year of AD 1647 ($R^2 = 0.3165$). If the above data (ratio of length to thickness) were entered into Figure 57’s equation, AD 1606 is the resulting shipwreck year ($R^2 = 0.6763$). The first equation only has a R^2 of 0.3165, whereas the second equation has nearly double the $R^2 = 0.6763$ (these are the weights used for this example). If the dates from the equations are multiplied by the R^2 values and added, (i.e. 521 + 1086), the final result date of AD 1607 is predicted, which falls within ± 10 years of the wreck's true date of sinking, as this deadeye is 80:129B from *Warwick* dating to AD 1619. The equations used in this example are in place of more complex algorithms, while the R^2 values are used as weights. The example overall is an oversimplification of AdaBoost, but demonstrates the concept with weak learners and weights.

The model used for classifying shape type used a Bagged Tree algorithm, otherwise known as a Bootstrap Aggregation (Bagging) Tree ensemble. Similar to AdaBoost, Bagged Tree algorithms work by combining multiple smaller algorithms together for the purpose of reducing the variance found within typical classification tree models by applying the bootstrap statistical method to each learner. Bagged Tree ensembles create sub-samples of the dataset and train each model using each individual subset of samples. Then, the final predictions are made by averaging all the predictions made by all of the models. For example, if five models had the following predictions from a subset of data: PFB, PFB, PFB, Pear-Shaped, and RTB, then the average prediction is PFB. Thus, PFB is the final prediction from the model as a whole in this example.

Hyper-Parameter Optimization

Hyper-parameter optimization was adjusted for each model for additional overfitting measures to optimize algorithm performance. In ML, hyper-parameter optimization refers to the preset design of the model including number of models, features used, etc. that are predetermined according to observations made from the feature selection in the first portion of statistics within this chapter. The following parameters were adjusted: learning rate, number of learners, and maximum number of splits.

Learning rate is a hyper-parameter that determines how much the weights within the algorithm are adjusted with respect to loss gradient. The loss is the penalty given to a learner when it makes wrong predictions. For example, if the learner (i.e. algorithm/model) has a perfect prediction, then the loss is zero, but if it has error then the loss will be assigned a numerical value. The goal of adjusting the learning rate is to create weights that have low loss (i.e. fewer mistakes) across all examples. In mathematical terms, the optimal learner rate is found by implementing the fewest steps (a step is the forward and backward evaluation of the set used in each update of a model's weights during training) required to reach the minimum of the loss versus weight curve. This is known as gradient descent. In short, learning rate is gradually adjusted to find the best combination of weights to minimize loss. For example, a learner rate of 0.01 might take 100 steps to reach the minimum within a curve, whereas a learner rate of 1 may only take 1 or 2 steps to reach the minimum. The learning rate for each model differed, but suffice it to say that the optimal learning rate chosen required the fewest steps to reach the minimum. This hyperparameter was only optimized within the AdaBoost algorithms because Bagged Trees do not use weights for prediction.

The number of learners is the number of (smaller) models used within the single (larger) model. For example, a model consisting of 30 learners will have 30 smaller models used to make predictions on a given dataset. Each trained model will be assigned a weight, and typically these weights are adjusted for each model to find the optimal prediction accuracy of the algorithm as a whole (e.g. the learner that influenced the final model the most). Often times the number of learners with little, or redundant trees are removed. The goal is to find the algorithm that consists of learners with optimal weights that influence the prediction accuracy of the algorithm as a whole, without overfitting the data.

The maximum number of splits refers to how many splits (branches) each node within a classification tree will have. The node in a decision tree refers to the artifact feature condition (i.e. artifact feature) being input into the algorithm (e.g. shape, year range, or grain) which breaks off into multiple conditions depending on the algorithm, leading to a final classification (i.e. prediction). Typically, the number of splits start high, and those that are redundant or irrelevant are removed or "pruned" for each learner. The purpose of the initial high number of splits is to test which features within a learner truly influence the ML model as a whole. For example, given a tree that consists of four conditions and each condition node consists of two splits, if two of the four splits are removed but accurate predictions are still achieved, then the four removed splits have little influence on predictions and are permanently eliminated from the model.

Testing Results and Algorithm Performance Assessment

Once the testing dataset was run through the models, algorithm performance was assessed by analyzing the generated confusion matrices, table layouts that allow visualization of an algorithm's performance, and classification trees of each learner within a model.

Evaluations were made of the algorithm's ability to correctly predict each output class, as well as the reasonability of connection between features and output listed within the classification tree with its corresponding weight. The final models developed for "Year," "Shape," and "Grain" prediction were chosen based on:

1) The prediction accuracy on the testing data. This means that testing data were accurately predicted by the algorithm. The prediction accuracy was obtained by calculating the number of points the model got wrong, and subtracting that number from the overall number of observations in a dataset. For example, if 3 points were predicted incorrectly out of 118 observations then the accuracy is (118-3)/118 * 100 (97.5% accurate). This is the overall accuracy of the entire large classifier, but often times the model varies in accuracy for predicting individual classes, which is the

reason confusion matrices are used and low variance between classes (discussed in the next paragraph) is desirable.

2) Low variance across classes in the confusion matrix. For example, having a 70% prediction accuracy across all classes is desirable, whereas a 90% accuracy for one class, 93% for the other, and 20% for the third class is not because this creates a biased algorithm. Low variance across classes is necessary because the goal is to produce an algorithm that predicts all classes correctly. Therefore, the hyper-parameters of the algorithm are tweaked until a confusion matrix with a more uniform percent accuracy is achieved across all classes. In some cases, this means modifying the algorithm to give up a class that has a 98% prediction accuracy, but only a 15% accuracy at predicting the other class, and changing it to something like 80% prediction accuracy for the first class, and a 75% class for the second, which prevents prediction bias of any one class.

3) Ability to predict difficult or unusual samples correctly. Some deadeyes are harder to predict because they belong to a rarer category, such as the radial-grained deadeyes. Often in these cases, the algorithm predicts radial-grained deadeyes as having horizontal grain because radial-grained deadeyes do not account for many samples in the training and testing dataset. Due to this reason, the algorithm must make predictions using classes it does not normally predict, and then improve upon the hyper-parameters to accurately make predictions evenly across all classes. The ability to predict harder samples is done using AdaBoost and Bagged Tree ensembles. The algorithms that were chosen also performed best at these difficult predictions.

Predictions were made on behalf of the following output variables: year (range), deadeye shape, and grain type.

Year

An AdaBoost algorithm classification scheme was created to predict the range of years individual wrecks sank using features from each wreck's deadeyes. To do this, the period of study, AD 1545-1700, was broken down into 9-year increments with the exception of the earliest range that covered AD 1545-1560. Ranges were created because exact year predictions were not satisfactorily accurate, whereas ranges allow more variability while still giving useful information from an archaeological standpoint (e.g. if a ship sank in AD 1592, it was categorized into the class of AD 1591-1600).

A total of 13 classes ranging from 1545-1700 AD was used within the training data set. Note that the category "AD 1601-1610" was not included in any of the learners, because no deadeyes within this range exist in the database; however, it is still factored into the ML model for future predictions, as more data will be collected in forthcoming years and it is likely that some will fall within this class.

Once the model was trained and optimized on the training dataset, the testing dataset was processed through the algorithm to assess its overall prediction accuracy. The highest performing algorithm for predicting the year range was Model 17, which had an 87.1% prediction accuracy on the training data and a 97.5% accuracy on the testing data. Model 17 consisted of 33 learners, a starting value of 156 maximum number of splits, and a learning rate of 1. Figure 60 below illustrates the confusion matrix of Model 17.

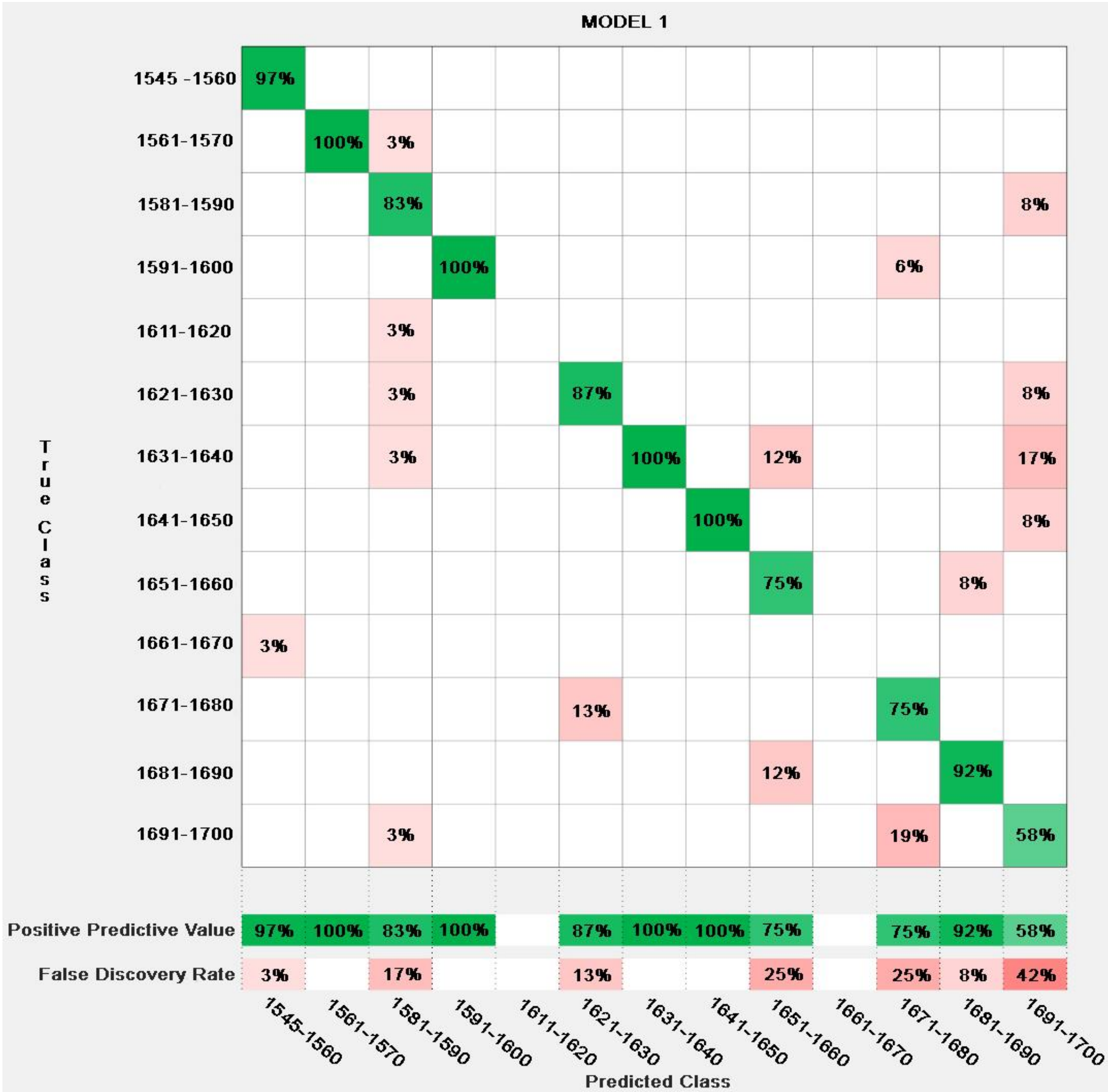

Figure 60: Model 17 Confusion Matrix. Correct predictions are shown in green, whereas incorrect predictions are in red (Image by Hannah C. Clark).

The confusion matrix for Model 17 demonstrates the algorithm's ability to classify observations within the training dataset. The positive predictive values (green) indicate correct predictions, whereas false discovery rates (red) correlate to false predictions. Model 17 was unable to correctly classify the ranges AD 1611-1620 and AD 1661-1670 due to an insufficient number of deadeyes for each range within the dataset, which consisted of only one observation each. However, Model 17 predicted the following ranges from the training set with 100% accuracy: AD 1561-1570, AD 1631-1640, AD 1641-1650, and AD 1681-1690. The ranges with the lowest prediction accuracy are the following: AD 1691-1700 with a 58% correct classification, AD 1671-1680 with a 75% correct classification, and AD 1651-1660 with a 75% correct classification.

The weight of each learner in Model 17 was assessed to determine how each feature condition within a given classification tree influenced the output variable. Table 2 shows the two most accurate learners in Model 17 and includes each learner's assigned weight and loss value.

Learner	Weight	Loss
1	0.95	0.12
11	0.46	0.30

Table 2: Learner 1 in Model 17.

Learner 1 (Figure 61) had the least amount of loss, and highest weight within Model 17, whereas Learner 11 (Figure 62) had the second lowest loss, and second highest weight. Note that Learner 1 and 11 classification conditions do not account for all predictions within the Model 17 and are only mentioned because these had the highest accuracy and the least loss at predicting year ranges compared to other learners within the Model. There is a total of 33 learners within this model.

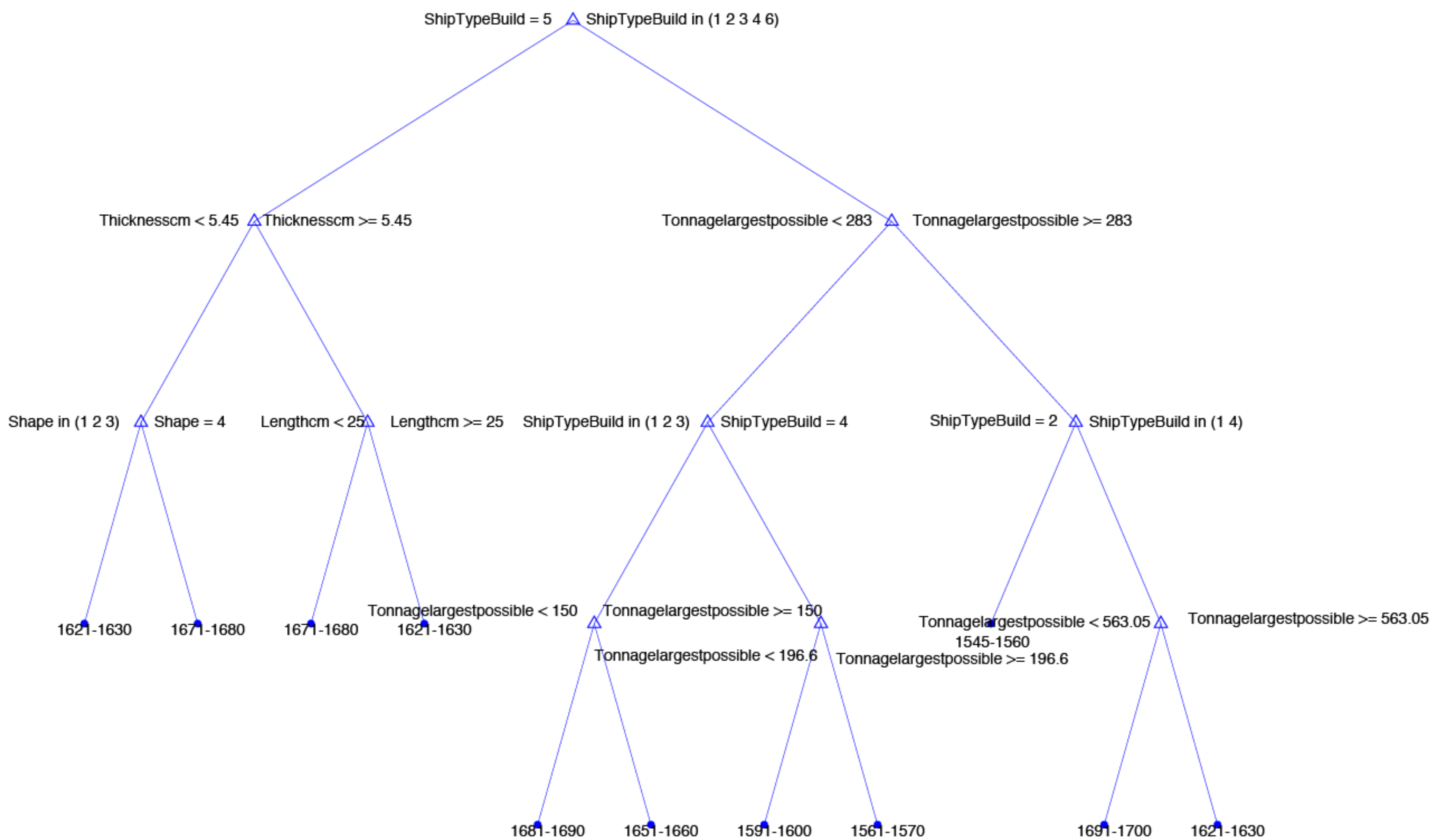

Figure 61: Model 17, Learner 1 Classification Tree. Tonnage, face shape, diameter of eye hole, ship build (nationality), and deadeye thickness, are the feature conditions included. The tonnage of the ship from which the deadeye belongs appears to be an extremely important feature condition in year predictions. The conditions are shown as triangles whereas the final output variables, in this case year ranges, are shown as a blue circle. Also note that qualitative feature conditions (e.g. nationality, shape, face shape, etc.) had numerical values assigned for use in classification, and the key can be found in Table 3 (Image by Hannah C. Clark).

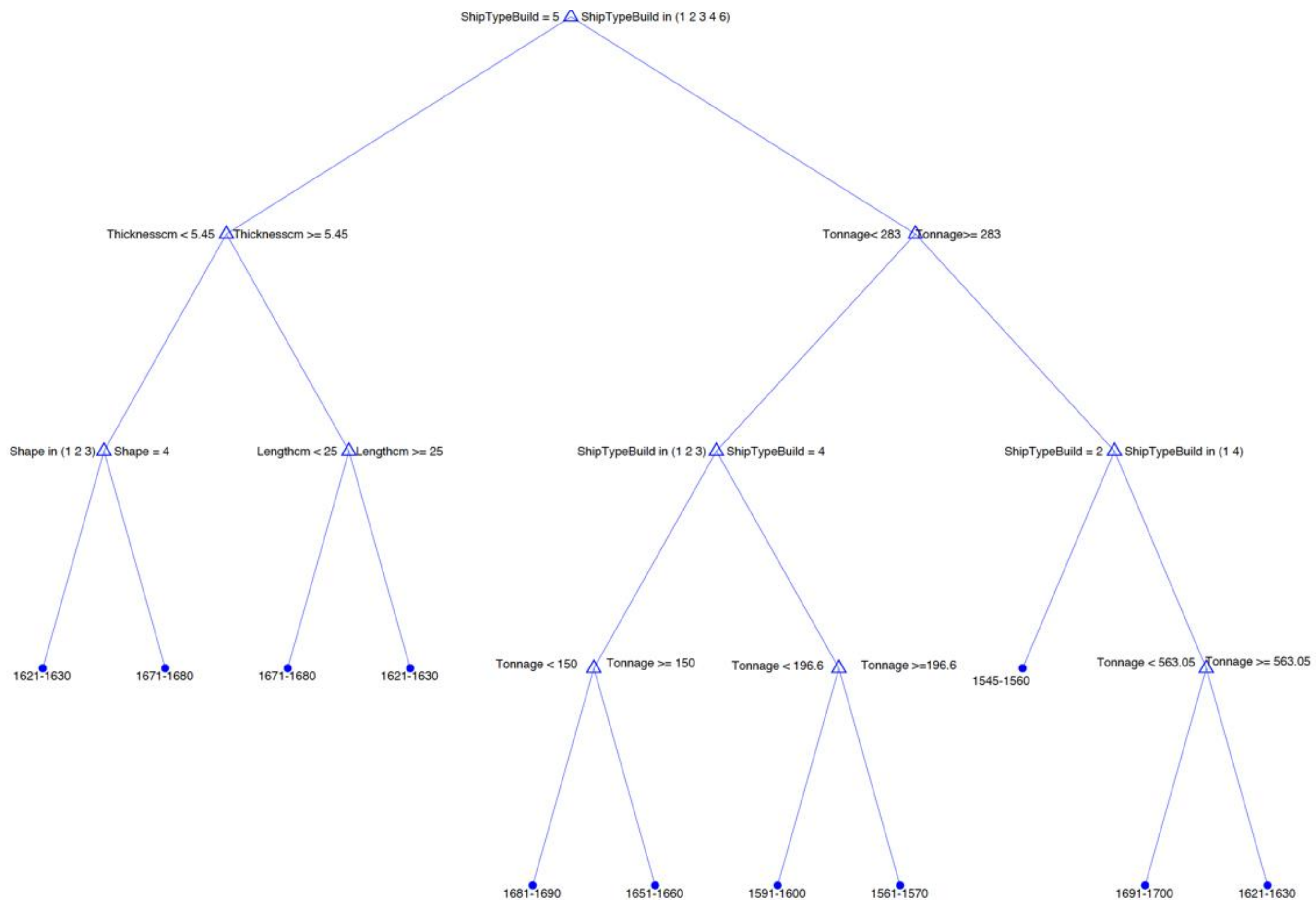

Figure 62: Model 17, Learner 11 Classification Tree. Ship build (nationality), where each nationality is assigned a numerical value that can be seen in Table 3, deadeye thickness, ship tonnage, deadeye shape, and deadeye length, are the feature conditions included in this learner. Note that ship build is the most important feature condition in this learner. The conditions are shown as triangles whereas the final output variables, in this case year ranges, are shown as a blue circle. Also note that qualitative feature conditions (e.g. nationality, shape, face shape, etc.) had numerical values assigned for use in classification, and the key can be found in Table 3 (Image by Hannah C. Clark).

The classification tree consists of decision nodes (triangles) representing conditions that break off into branches, leading to the final output variable (shown as blue circles) which in Model 17 is the year range. In Figure 61, tonnage was the most predominant feature in classifying the year range, along with diameter of eye hole, thickness, ship type build, and flat or round face of deadeye. In Figure 62 the classification tree used the Ship Type Build, Length, Shape, Thickness and Tonnage as the conditions that correlated to each year range output. A reference table to summarize all categorical predictors in Model 17, or the numerical values assigned to each qualitative condition, is listed below in Table 3. A summary of conditions that correlate to each year classification can be found in Table 4 for Learner 1, and Table 5 for Learner 11.

Category	**ShipTypeBuild**	**Shape**	**FlatRoundFace**
1	Dutch	PFB	Flat
2	English	Pear- Shaped	Round
3	French	RTB	
4	Iberian	Round	
5	Swedish		
6	Venetian		

Table 3: Model 17 Learner 1 Categorial Predictors.

1591-1600	1681-1690	1561-1570	1691-1700	1621-1630
Tonnage < 283	Tonnage < 283	Tonnage < 283	283 ≤ Tonnage < 563.05	563.05 ≤Tonnage <1152
Diameter of Eye Hole < 4.25 cm.	Diameter of Eye Hole < 4.25 cm.	Diameter of Eye Hole ≥ 4.25 cm.		or
Thickness < 5.4 cm.	Thickness >= 5.4 cm.			Tonnage ≥1152
				Flat face
1611-1620	**1545-1560**	**1581-1590**	**1661-1670**	**1671-1680**
650 ≤ Tonnage < 900	650 ≤ Tonnage < 900	900 ≤ Tonnage < 1102	1102 ≤ Tonnage < 1152	Tonnage ≥ 1152
Dutch Ship	English			Round face

Table 4: Model 17 Learner 1 Classification Conditions. Note that for each year range the feature conditions that have greater influence are listed from greatest to lowest from top down.

1621-1630	1671-1680	1681-1690	1651-1660
Ship Type Build: Swedish	Ship Type Build: Swedish	Tonnage < 283	150 ≤ Tonnage < 283
Thickness < 5.45 cm.	Thickness < 5.45 cm.	Ship Type Build: Dutch or English or French	Ship Type Build: Dutch or English or French
Shape: PFB or Pear-Shaped or RTB	Shape: Round		
or	or		
Ship Type Build: Swedish	Ship Type Build: Swedish		
Thickness ≥ 5.45 cm.	Thickness ≥ 5.45 cm.		
Length ≥ 25 cm.	Length < 25 cm.		
or			
Tonnage ≥ 563.05			
Ship Type Build: Dutch or Iberian			
1591-1600	**1561-1570**	**1545-1560**	**1691-1700**
Tonnage < 196.5	Tonnage ≥ 196.5	Tonnage ≥ 283	283 ≤ Tonnage < 563.05
Ship Type Build: Iberian	Ship Type Build: Iberian	Ship Type Build: English	Ship Type Build: Dutch or Iberian

Table 5: Model 17 Learner 11 Classification Conditions. Note that for each year range the feature conditions that have greater influence are listed from greatest to lowest from top down.

Shape

A Bagged Tree ensemble algorithm classification scheme was used to predict deadeye shape and categorize deadeyes into one of four classes: Pear-Shaped, PFB, RTB, and Round. The highest performing algorithm was Model 19, which had a 79.0% prediction accuracy on the training data and a 95.6% accuracy on the testing data. Model 19 consisted of 30 learners, and 20 maximum number of splits. Figure 63 below displays the confusion matrix of Model 19.

Figure 63: Model 19 Confusion Matrix. Correct predictions are shown in green, whereas incorrect predictions are in red (Image by Hannah C. Clark).

Model 19 had the most difficulty predicting the Pear-Shaped class, with a 74% positive prediction value. The classes with the highest prediction accuracy consisted of class RTB and Round, with an 86% and 95% prediction accuracy, respectively. However, due to the insufficient amount of data points for the Round class, this predictive value does not accurately reflect the algorithm's ability to classify the Round class as a whole until more data points are collected.

A curvature test was also examined using MATLAB® Out-of-Bag Permuted Predictor Importance which uses permutation to assess the features with the greatest influence in predicting the deadeye shape for Model 19 (Figure 64).

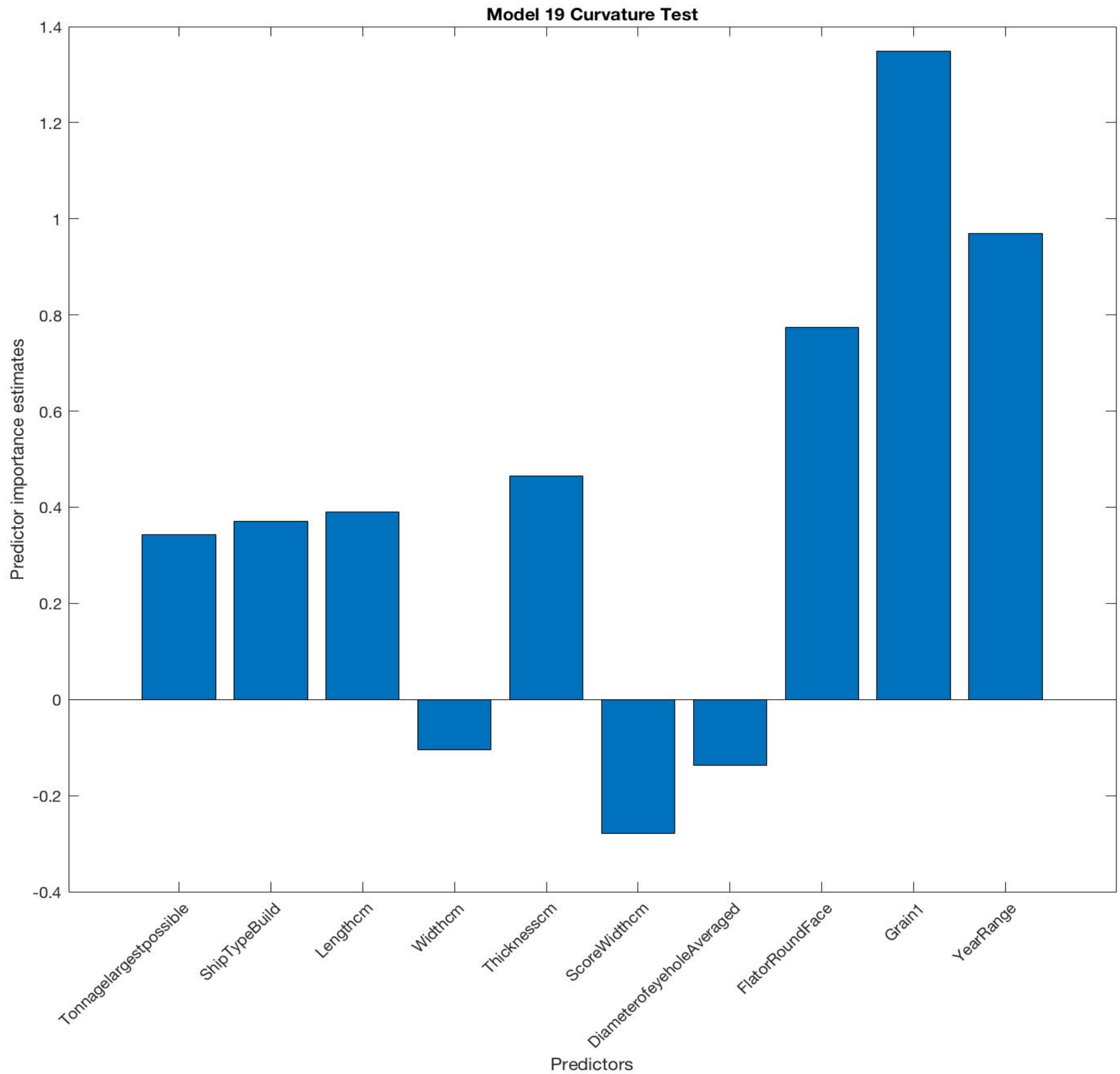

Figure 64: Model 19's Curvature Test showing the Predictor Importance Estimates (Image by Hannah C. Clark).

The curvature test of Model 19 (Figure 64) shows that the feature with the greatest importance on predicting the shape of the deadeye was the grain type, the second was the year range of the ship, and the third was the flat or convex profile of the deadeye. An example of this can be seen in one of the classification trees from Learner 2, below in Figure 65. After pruning and eliminating learners with little influence on the overall performance of Model 19, Learner 2 had the greatest influence on predicting the correct shape values (Figure 65).

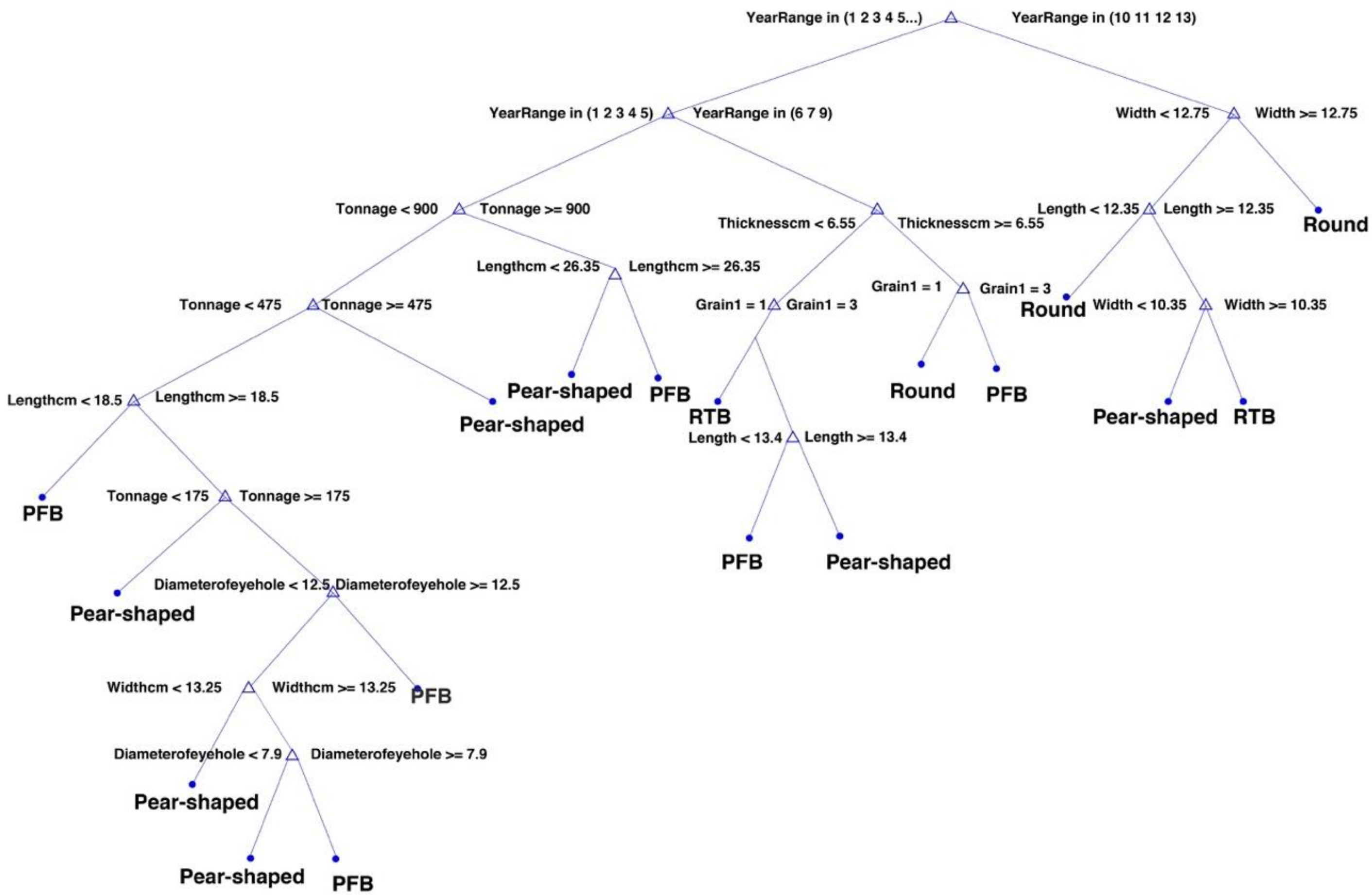

Figure 65: Model 19 Learner 2 Classification Tree. Year range, deadeye width, length, grain, ship tonnage, and diameter of eye hole, are the feature conditions used in this learner. Also note that qualitative feature conditions (e.g. nationality, shape, face shape, etc) had numerical values assigned for use in classification, and the key can be found in Table 6 (Image by Hannah C. Clark).

Learner 2 used the following features to determine shape: year range, tonnage, width, thickness, length, grain type, and diameter of eye hole. Table 6 summarizes all categorical predictors, and Table 7 summarizes the conditions within Learner 2 that correspond to each shape.

Category	**Year Range**	**Grain**
1	1545-1560	H=Horizontal
2	1561-1570	R=Radial
3	1581-1590	V=Vertical
4	1591-1600	
5	1611-1620	
6	1621-1630	
7	1631-1640	
8	1641-1650	
9	1651-1660	
10	1661-1670	
11	1671-1680	
12	1681-1690	
13	1691-1700	

Table 6: Model 19 Learner 2 Categorical Predictors.

PFB	**Pear-Shaped**	**RTB**	**Round**
Year Range: 1545-1620	Year Range: 1545-1620	Year Range: 1621-1640 or 1651-1660	Year Range: 1621-1640 or 1651-1660
175 < Tonnage < 475	Tonnage < 175	Thickness < 6.55 cm.	Thickness ≥ 6.55 cm.
Length < 18.5 cm.	Length ≥ 18.5 cm.	Grain Type: Horizontal	Grain Type: Horizontal
or	or	or	or
Year Range: 1545-1620	Year Range: 1545-1620	Year Range: 1661-1700	Year Range: 1661-1700
Tonnage ≥ 175	Tonnage ≥ 175	10.35 ≤ Width < 12.75 cm.	Width < 12.75 cm.
Length ≥ 18.5 cm.	Length ≥ 18.5 cm.	Length ≥ 12.35 cm.	Length < 12.35 cm.
7.9 ≤ Diameter of eye hole < 12.5 cm.	Diameter of eye hole < 12.5 cm.		
Width ≥ 13.25	Width < 13.25		
Diameter of eye hole ≥ 7.9 cm.			
or	or		or
Year Range: 1545-1620	Year Range: 1545-1620		Year Range: 1661-1700
Tonnage ≥ 175	Tonnage ≥ 175		Width ≥ 12.75 cm.
Length ≥ 18.5 cm.	Length ≥ 18.5 cm.		
Diameter of eye hole ≥ 12.5 cm.	Diameter of eye hole < 7.9 cm.		
	Width ≥ 13.25		
or	or		
Year Range: 1545-1620	Year Range: 1545-1620		
Tonnage ≥ 900	475 ≤ Tonnage < 900		
Length ≥ 26.35 cm.			
or	or		
Year Range: 1621-1640 and 1651-1660	Year Range: 1545-1620		
Thickness < 6.55 cm.	Tonnage ≥ 900		
Grain Type: Vertical	Length < 26.35 cm.		
Length < 13.4 cm.			
or	or		
Year Range: 1621-1640 and 1651-1660	Year Range: 1621-1640 and 1651-1660		
Thickness ≥ 6.55 cm.	Thickness < 6.55 cm.		
Grain Type: Vertical	Grain Type: Vertical		
	Length ≥ 13.4 cm.		
	or		
	Year Range: 1661-1700		
	Width < 10.35 cm.		
	Length ≥ 12.35 cm.		

Table 7: Model 19 Learner 2 Shape Classification Conditions.

Grain

The model used to predict the grain type of the deadeye used an AdaBoost algorithm classification scheme that categorized the grain types into three categories: H, R, and V (i.e. horizontal, radial, and vertical). Note that the radial deadeyes only consisted of five data points within the entire dataset (this includes training and testing data), thus making predictions on behalf of the radial grain type uncertain until more data are collected. The highest performing algorithm was Model 35, which had a 92.1% prediction accuracy on the training data and a 90.0% accuracy on the testing data. Model 35 consisted of 30 learners, a starting maximum number of splits of 162, and a learning rate of 0.1.

The confusion matrix for Model 35 in Figure 66 shows that the model had a 95% correct prediction at classifying vertical grain types, and an 88% accuracy at classifying horizontal grain types. Model 35 was unable to classify radial grain types, as it was only exposed to one radial grain type within the training data. In addition to the confusion matrix, each learner was assessed to understand which variables had the greatest influence in predicting the grain type. Similar to Model 19 under shape predictions, the learners with the highest weights were assessed to understand the variable values that correlated to each prediction. Table 8 displays the weight and loss of the most accurate learner within the model, Learner 1. The classification trees of Learner 1 and 14 are listed below in Figures 67-68.

Figure 66: Model 35 Confusion Matrix. Correct predictions are shown in green, whereas incorrect predictions are in pink (Image by Hannah C. Clark).

Learner	Weight	Loss
1	0.2	0.05
14	0.1	0.1

Table 8: Learner Weight and Loss in Model 35.

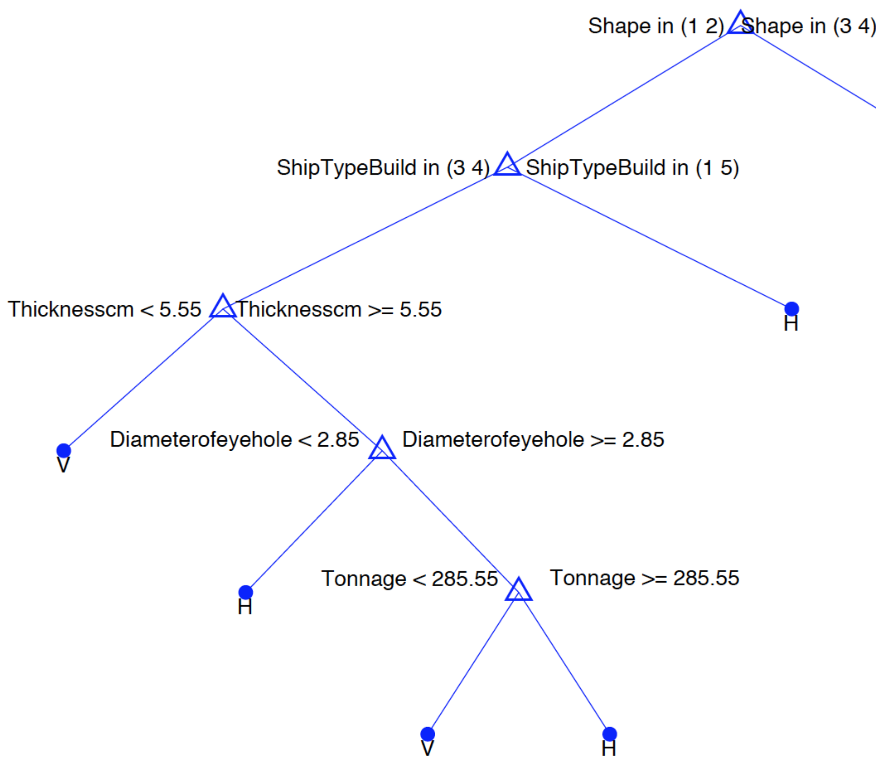

Figure 67: Model 35 Learner 1 Classification Tree. Shape, Ship type (nationality), deadeye thickness, diameter of eyehole, and ship tonnage, are used to determine deadeye grain (Image by Hannah C. Clark).

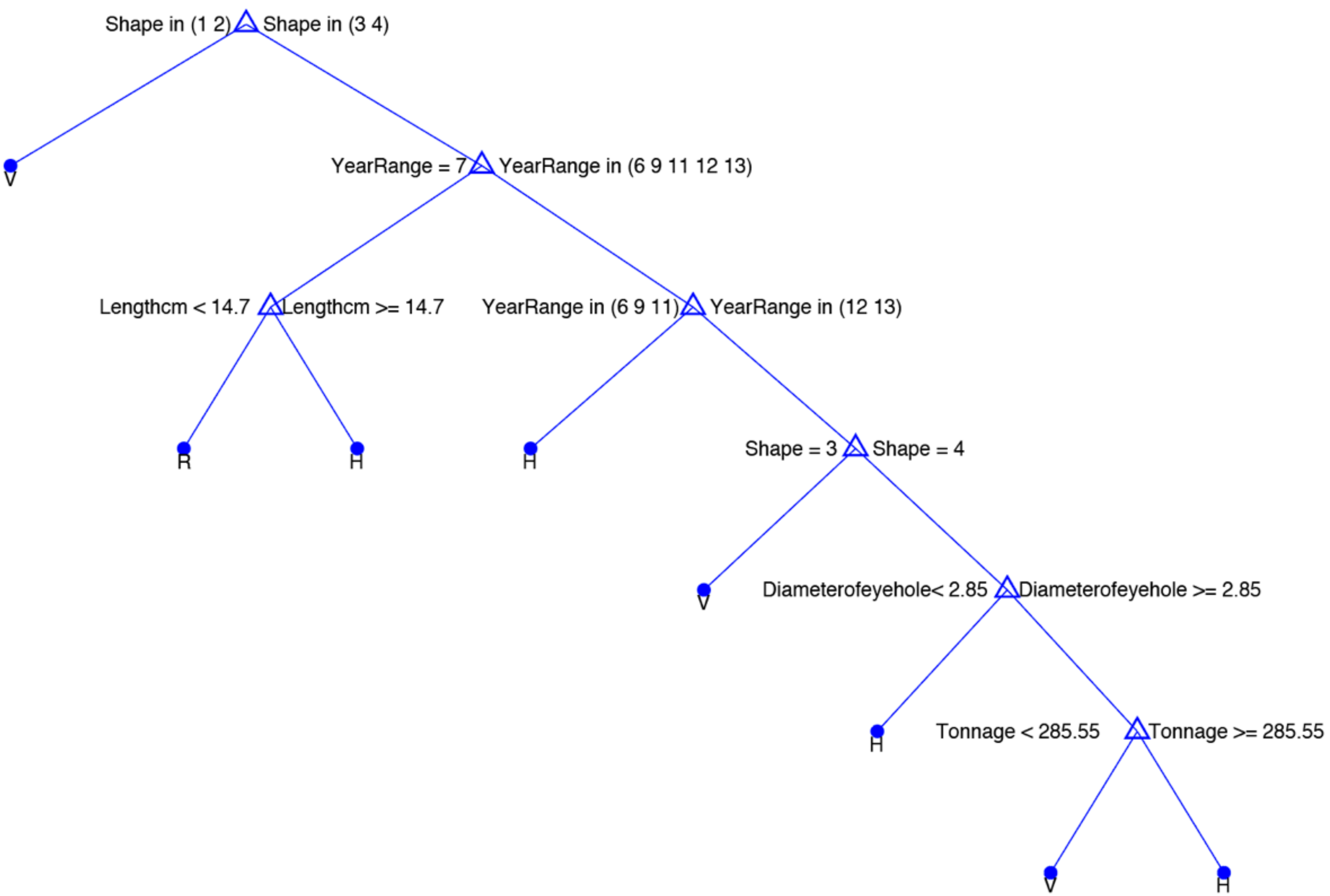

Figure 68: Model 35 Learner 14 Classification Tree. Shape, year range, length, diameter of eyehole, and tonnage are the feature conditions within this learner (Image by Hannah C. Clark).

The features used in Model 35's Learner 1 to predict the grain type class are as follows: shape, ship type build, tonnage, thickness, and diameter of eye hole. Learner 14 used the following features to predict the grain type: shape, year range, length, tonnage, and diameter of deadeye eye hole. Table 9 summarizes all categorical predictors listed in Figures 67-68, and Tables 10-11 summarize the conditions within Learners 1 and 14 that correlate to each grain class.

Shape	Year Range	ShipTypeBuild	Category
PFB	1545-1560	Dutch	1
Pear Shaped	1561-1570	English	2
RTB	1581-1590	French	3
Round	1591-1600	Iberian	4
	1611-1620	Swedish	5
	1621-1630	Venetian	6
	1631-1640		7
	1641-1650		8
	1651-1660		9
	1661-1670		10
	1671-1680		11
	1681-1690		12
	1691-1700		13

Table 9: Model 35 Learner 1 and Learner 14 Categorical Predictors.

Vertical	Horizontal
Shape: PFB or Pear-Shaped	Shape: PFB or Pear-Shaped
Ship Type Build: French or Iberian	Ship Type Build: French or Iberian
Thickness < 5.55 cm.	Thickness ≥ 5.55 cm.
	Diameter of eye hole < 2.85 cm.
or	or
Shape: PFB or Pear-Shaped	Shape: PFB or Pear-Shaped
Ship Type Build: French or Iberian	Ship Type Build: French or Iberian
Thickness ≥ 5.55 cm.	Thickness ≥ 5.55 cm.
Diameter of eye hole ≥ 2.85 cm.	Diameter of eye hole ≥ 2.85 cm.
Tonnage < 285.55	Tonnage ≥ 285.55
	or
or	Shape: PFB or Pear-Shaped
Shape: RTB or Round	Ship Type Build: Dutch or Swedish

Table 10: Model 35 Learner 1 Grain Classification Conditions.

Vertical	Horizontal	Radial
Shape: PFB or Pear-Shaped	Shape: RTB or Round	Shape in RTB or Round
or	Year Range: 1631-1640	Year Range: 1631-1640
Shape: RTB	Length ≥ 14.7 cm.	Length < 14.7 cm.
Year Range: 1681-1700	or	
or	Shape RTB or Round	
Shape: Round	Year Range: 1621-1630 or 1651-1660 or 1671-1680	
Year Range: 1681-1700	or	
Diameter of eye hole ≥ 2.85 cm.	Year Range: 1681-1700	
Tonnage < 285.55	Shape: Round	
	Diameter of eye hole < 2.85 cm.	
	or	
	Year Range: 1681-1700	
	Shape: Round	
	Diameter of eye hole ≥ 2.85 cm.	
	Tonnage ≥ 285.55	

Table 11: Model 35 Learner 14 Grain Classification Conditions.

Final Results

Using Models 17, 19, and 35, *Warwick's* deadeyes were individually run through the algorithm to determine if *Warwick's* deadeyes matched standard deadeyes from c. AD 1619. The predictions created by the ML program can be seen in Table 12 below.

ID #	Actual Year	Actual Shape	Actual Grain	Predicted Year	Predicted Shape	Predicted Grain
02: 155.254557-764-u	1619	RTB	Horizontal	1651-1660	RTB	Horizontal
02: 155-034	1619	Unknown	Unknown	1651-1660	Pear-Shaped	Vertical
93: 30-008	1619	Pear-shaped	Vertical	1651-1660	Pear-Shaped	Vertical
93: 30-13-2	1619	Pear-shaped	Vertical	1591-1600	Pear-Shaped	Vertical
93: 30-13-4	1619	Unknown	Vertical	1591-1600	Pear-Shaped	Vertical
79: 155-344	1619	Round	Radial	1651-1660	RTB	Horizontal
93: 030-007	1619	Pear-shaped	Vertical	1591-1600	Pear-Shaped	Vertical
80: 129C	1619	Pear-shaped	Vertical	1591-1600	Pear-Shaped	Vertical
80:129B	1619	Pear-shaped	Unknown	1591-1600	Pear-Shaped	Vertical

Table 12: *Warwick's* actual deadeye features versus *Warwick's* deadeye predictions according to the ML algorithm. Correct predictions for predicted shape and grain are highlighted in green if correct, yellow if neither correct or incorrect (for example, if the actual values are unknown), and red if incorrect. With regard to year range predictions, no single deadeye was dated to the AD 1619 range, but the combined averages of the deadeye years resulted in a date of AD 1622 as explained below.

Year-Range Predictions

The ML algorithm with the least accuracy predicting the correct feature of the *Warwick* data was Model 17 that predicted the year range. This model predominantly classified each observation in the ranges AD 1651-1660 and AD 1591-1600. The algorithm predicted AD 1591-1600 for five observations and AD 1651-1660 for four observations.

To examine the reason these classifications occurred, the confusion matrix and learner conditions of Model 17 were studied. The confusion matrix demonstrated that the year range 1611-1620 AD was incorrectly predicted as there were too few observations of ships within the testing and training data set that included this year range. Learner 1 and Learner 11 feature conditions corresponding to AD 1591-1600 and AD 1651-1660 were observed, and cross-examined with the same features within the *Warwick* data to understand the reason the algorithm misclassified these observations. Table 13 shows the feature values of each observation within the *Warwick* data.

Ship	Tonnage (largest possible)	Ship Type (Build)	ID#	Thickness (cm.)	Diameter of eye hole (Averaged)	Year Range	Predictions
Warwick	160	English	02: 155.254557-764-u	2.959	1.5	1611-1620	1651-1660
Warwick	160	English	02: 155-034	4.383	3.16	1611-1620	1651-1660
Warwick	160	English	93: 30-008	4.094	2.9	1611-1620	1651-1660
Warwick	160	English	93: 30-13-2	4.211	3.4	1611-1620	1591-1600
Warwick	160	English	93: 30-13-4	4.755		1611-1620	1591-1600
Warwick	160	English	79: 155-344	4.566	3.8	1611-1620	1651-1660
Warwick	160	English	93: 030-007	4.62	3.22	1611-1620	1591-1600
Warwick	160	English	80: 129C	5.356	3.08	1611-1620	1591-1600
Warwick	160	English	80:129B	5	3.1	1611-1620	1591-1600

Table 13: *Warwick* data feature condition values for year range predictions.

Model 17's Learner 1 placed all observations in category AD 1591-1600 if three conditions were met: a tonnage below 283 tons, diameter of eye hole < 4.25 cm., and a thickness of 5.4 cm. Learner 1 in this Model did not specify conditions for AD 1591-1600. Learner 11 placed observations into the class AD 1591-1600 if the following two conditions were met: a tonnage < 196.5 tons, and a ship type build of Iberian. Learner 11 placed observations into the class AD 1651-1660 if two conditions were met: 150 ≤ tonnage < 283 tons, and a ship type build of

Dutch, English, or French. Due to the fact that the *Warwick* data matched these conditions, they were incorrectly classified. More data from ship wrecks dating between AD 1611-1620 must be collected to correctly identify the year range of *Warwick's* data.

Even with such error from the raw results of the algorithm, when averaging the slightly incorrect years, a final date of AD 1622, which is very close to *Warwick's* actual sinking date of AD 1619, can be manually calculated. This was done by assigning a midpoint year for each range—1595.5 and 1655.5—per deadeye, and averaging the assigned date for *Warwick's* entire deadeye assemblage.

Shape Predictions

The prediction accuracy of Model 19, the model for shape prediction, on the *Warwick* data was calculated by including only deadeyes with known shape values within the data. Model 19 had an 83.3% prediction accuracy for correctly classifying the shape of *Warwick's* deadeyes. The class that was incorrectly predicted was the Round class which was predicted as RTB. Model 19's Learner 2 classified observations into the class RTB or Round shape when the following conditions in Table 14 were met.

RTB	**Round**
Year Range: 1621-1640 or 1651-1660	Year Range: 1621-1640 or 1651-1660
Thickness < 6.55 cm.	Thickness ≥ 6.55 cm.
Grain Type: Horizontal	Grain Type: Horizontal
or	or
Year Range: 1661-1700	Year Range: 1661-1700
10.35 ≤ Width < 12.75 cm.	Width < 12.75 cm.
Length ≥ 12.35 cm.	Length < 12.35 cm.
	or
	Year Range: 1661-1700
	Width ≥ 12.75 cm.

Table 14: Model 19 Learner 2 RTB and Round Shape Conditions.

RTB and Round shape categories have very similar conditions, which can cause the algorithm to misclassify data points. Curiously, while the *Warwick* data were listed in the year range AD 1611-1620 the deadeye with ID #: 02: 155.254557-764-u and shape of RTB was still classified correctly as was the data for all of the pear-shaped observations. This correct classification demonstrates that Model 19 was able to learn and correlate these predictions into a year range not far off from the actual year of the *Warwick* data, with the exception of the same misclassified year range found in Model 17, AD 1651-1660.

Upon analysis of the same features of the misclassified data point ID #:79: 155-344 to the feature conditions of Table 14, it was deduced that this data point was misclassified into the RTB category because it had an earlier year range, a thickness of approximately 4.6 cm. (which is less than the 6.55 cm. threshold), and a radial grain type which appears only once within the dataset to the deadeye associated with the *Corolla* Wreck which is also believed to be intrusive. In this model, thicknesses ≥ 6.55 cm. and widths ≥ 12.75 cm. correlated to the round shape. For example, a deadeye with a width of ≥ 12.75 cm. and a year of AD 1661-1700 would be classified as Round, but because *Warwick's* deadeyes were incorrectly predicted into the categories AD 1621-1640 or AD 1651-1660 (despite it not being a part of either group) it was misclassified into the RTB shape.

Grain Predictions

The prediction accuracy of Model 35, calculated on only the known values of *Warwick's* deadeye data was approximately 86% accurate (compared to 95.6% correct on the testing data). Model 35 was unable to correctly classify Radial grain types due to the fact that this feature only appeared five times within the dataset, thus deadeye ID# 79: 155-344 was incorrectly classified. Despite the Radial grain type error, Model 35 was still able to accurately predict the single deadeye with horizontal grain type and all the vertical grain deadeyes within the *Warwick* data, and evenly distributed importance between the two highest weighted learners given a single observation. Table 15 demonstrates the *Warwick* data features that correlated to both Learner 1 and Learner 14 feature classification conditions, and the algorithm's ability to correctly predict the grain.

The following features were assessed within Model 35's Learner 1 and 14: shape, ship type build, tonnage, thickness, diameter of eye hole, and length. Learner 1 tended to predict horizontal grain types to PFB or Pear-Shaped deadeyes, whereas Learner 14 tended to predict horizontal grain types for RTB and Round deadeyes. While Learner 1 still had the highest weight, the horizontal grain type, seen in deadeye ID# 02: 155.254557-764-u, must have been classified into the correct grain class by Learner 14. One of the conditions Learner 14 used to predict horizontal grain types was a shape (RTB or Round), and a year range between AD 1621-1630, AD 1651-1660, or AD 1671-1680, as well as a diameter of deadeye hole that is < 2.85 cm. Furthermore, vertical grain correlated to Pear-shaped deadeyes that had thicknesses less than 5.55 cm., or greater than 5.55 cm., with diameters greater than 2.85 cm. Thus, by working together both learners were optimally able to classify the majority of observations within the *Warwick* data, except for the single radial deadeye.

Year Range	Tonnage (largest possible)	Ship Type (Build)	ID#	Length (cm.)	Thickness (cm.)	Score Width (cm.)	Diameter of eye hole (Averaged)	Shape	Prediction
1611-1620	160	English	02: 155.254557-764-u	8.866	2.959	1.6	1.5	RTB	Horizontal
1611-1620	160	English	02: 155-034		4.383	3	3.16	Pear-shaped or PFB	Vertical
1611-1620	160	English	93: 30-008	18.21	4.094	2.7	2.9	Pear-shaped	Vertical
1611-1620	160	English	93: 30-13-2	18.065	4.211	2.7	3.4	Pear-shaped	Vertical
1611-1620	160	English	93: 30-13-4	17.057	4.755	2.5			Vertical
1611-1620	160	English	79: 155-344	16.304	4.566		3.8	Round	Horizontal
1611-1620	160	English	93: 030-007	26.674	4.62		3.22	Pear-shaped	Vertical
1611-1620	160	English	80: 129C	31	5.356		3.08	Pear-shaped	Vertical
1611-1620	160	English	80:129B	19	5		3.1	Pear-shaped	Vertical

Table 15: *Warwick* Data Feature Condition Values for grain type.

Results & Conclusion

Given the predictions regarding year, shape, and grain, deadeye #79: 155-344 from *Warwick*, which was already believed to be intrusive but which was unable to be statistically proven as such previously, has been mathematically categorized as anachronistic via ML.

Excluding this outlier, *Warwick's* deadeye assemblage appears to be standard for the period it falls in, exhibiting a mixture of pear-shaped (vertical grain) and RTB (horizontal grain) deadeyes. *Warwick* is the earliest wreck within the database with an RTB deadeye, and the first to have a mixed assemblage of pear-form (pear-shaped/PFB) deadeyes mixed with round-form (RTB/round) deadeyes.

These data indicate that as early as AD 1619, deadeye shapes had begun transitioning from a pear form to a round form. It is also noteworthy that deadeye shapes often varied within the same vessel, and that multiple "older" and "newer" types of deadeyes are often found on the same wreck, suggesting that shipwrights and ship equipment buyers did not purchase all deadeyes new and that older deadeyes may have been recycled on newer ships, or that there were manufacturers of deadeyes who produced the old deadeye forms.

These algorithms allow reinterpretation of shipbuilding and rigging transitions, particularly pertaining to the feature conditions which have the most influence on year range, deadeye shape, and deadeye grain, and therefore which factors may have advanced rigging innovation (but the caveat that correlation does not imply causation still applies). A combination of historical research with these proposed feature condition correlations can add significant value to nautical archaeology.

Applications & Future Plan

Even with good results, ML is intended for use with large data sets. More data points are needed to further refine the algorithm for a proper ML approach, especially given that at least two date ranges are still missing sufficient data for accurate predictions. To expand the data set and continue refining the algorithm presented with these new data, an online application is currently being created in what is known as the Digital Humanities Database for Comparative Ships' Rigging.

Hannah C. Clark, the codirector and programmer of this project, is in the process of creating an online open-source tool, currently named "Shiprek," that implements the deadeye data presented in this thesis, and simultaneously allows other researchers to access and add to the database. An example of the data entry website can be seen below in Figure 69.

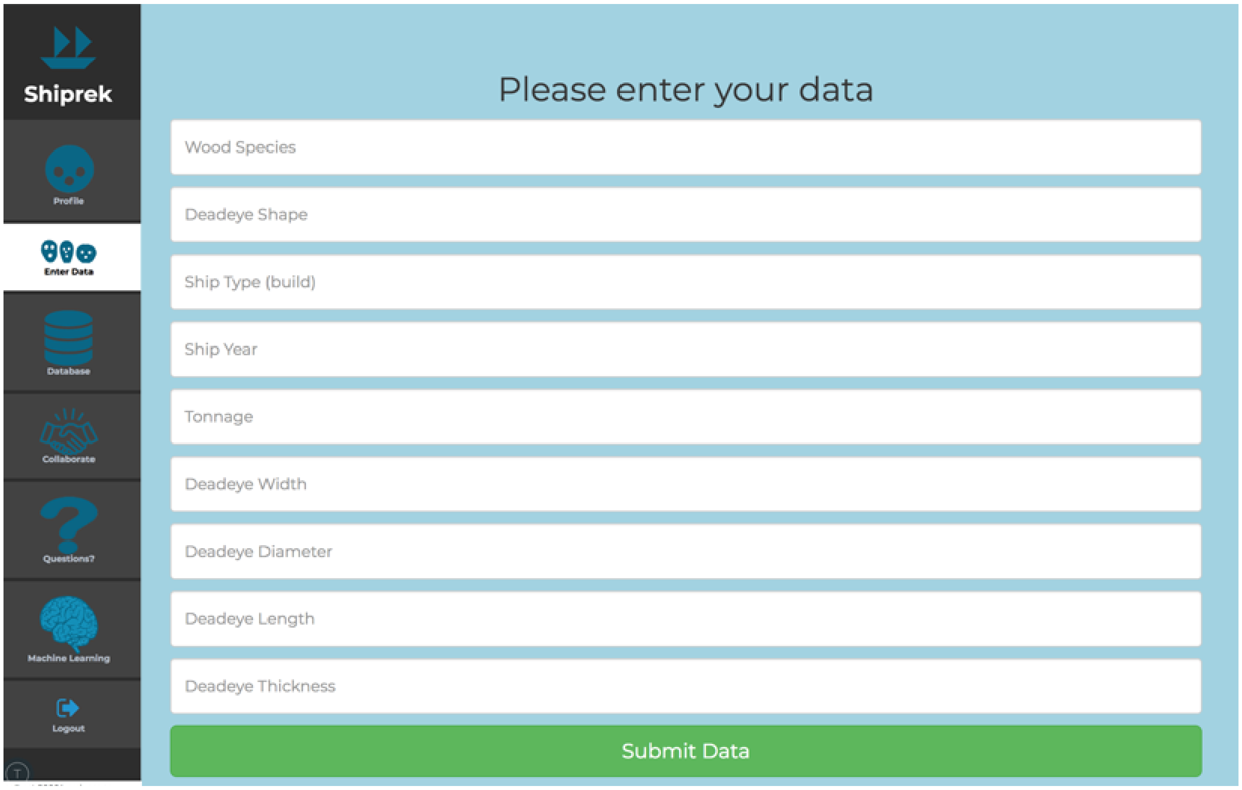

Figure 69: The data entry user interface for Shiprek, showing the entry form collaborators will be presented with to submit information for the database, which will also generate predictions for the new data entered. Note: measurements should be entered in cm. into the form (Image by Hannah C. Clark).

The application is being developed using a Meteor framework, with a Mongo database that consolidates data and links it to a Python Flask API that contains the ML component for data analysis. The ML component (once connected to the client side of the application) will include algorithm optimization, access to users input data, data import and export, and use the Seaborn Python visualization library to graph ML algorithm results (RMSE, Parallel-Coordinates Plot, Confusion Matrices etc.). AWS EC2 will be used as the virtual server and linked to the Meteor Amazon Machine Image (AMI), in conjunction with the Mongo DB being deployed on the EC2. Dependent on funding and interest from the nautical archaeology community, future work may include the AWS Rekognition feature which will be used as a deep learning component. This extra feature allows automated 3D analysis from artifact images (unlike photogrammetry that requires extensive labor), assessing this data from an archived database to "learn" features from the 3D models, and incorporating them into its algorithm (i.e. computer vision). If time and funding suffice, Shiprek will incorporate not only deadeyes exclusively, but all rigging components.

The goal is to create an easy-to-use open-source database with capabilities to analyze new data on demand, so that algorithms for new data entered by scholars can instantly recalibrate the existing typology to further refine it, allowing scholars to freely access useful rigging data in one place for global collaboration.

CHAPTER 5

COMPARATIVE RIGGING EVIDENCE INCLUDING SHIP TREATISES, DICTIONARIES, MASTS & YARDS LISTS, ICONOGRAPHY, AND SHIP MODELS

While rigging elements such as deadeyes and blocks are commonly recovered from wrecks, the principal components, the masts, yards, and lines, are almost never found on archaeological sites. Non-archaeological sources must be relied upon to attempt a rigging reconstruction of *Warwick*. The types of information referred to for this type of reconstruction include: 1) Ship treatises and dictionaries, 2) Masts and yards lists and inventories of specific ships, 3) Iconography and, 4) Contemporary ship models. This chapter will explain how each type of source is used in this thesis, explain the reasons specific examples under each type were chosen, and provide a short description and analysis of them.

Ship Treatises and Dictionaries

Nautical treatises and dictionaries of the 17th century were intended as practical guides for both professional sailors and laymen. They often included details on ship construction, rigging assembly, ship management, and sailing. As such, they provide direct insight into contemporary sailing rigs.

Only primary documents dating between AD 1600-1640 written by English authors were analyzed for *Warwick's* rig reconstruction. Earlier works, such as Matthew Baker's "The Fragments of Ancient English Shipwrightry" (1586), were not selected for detailed analysis because of the technological changes which occurred during the first decades of the 17th century (as evidenced by the trends seen in the previous chapter). *Warwick* was likely built by the summer of 1617 (based on dendrochronological analysis), and so it is likely that parts of treatises written before 1600 were already becoming obsolete. While a few non-English treatises fall within these years, such as Joseph von Furtenbach's *Architectura navalis* (1629), Bartolomeu Crescencio Romano's *Nautica Mediteranea* (1607), and King Leopold of Denmark's 1613 ship contract (not a treatise, but similar due to the data it provides), it was decided to only use English sources given that *Warwick* was an English vessel.[105] Four documents were analyzed for this section.[106]

The earliest document is the Newton Manuscript, believed to have been written c. AD 1600.[107] The Newton Manuscript is named as such because it was transcribed and signed by Sir Isaac Newton circa 1700, and later discovered in the Cambridge University Library.[108] Although the copy is listed under Newton's name, parts of it can be traced to two earlier works that date to c. 1600. The rigging sections were evidently copied almost verbatim from the Scott Manuscript (RINA No. 798), a manuscript that John Coates tentatively dated to 1590-1605, and that Richard Barker determined fell between 1598 to 1603.[109] Barker, in his analysis, concludes that it is likely that the original work dates to c. 1600.[110] This manuscript contains 66 rules (or so-called

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[105] Orlogskaptajn and Anderson 1932, 81-6.
[106] Near the completion of this thesis, the author discovered a fifth treatise dated to c. 1608-1610 by John Harriot. Please refer to Pepper 1978, 275-403, Howse 1981, 204-16, and Stedall 2013, 325-27 for more information. Curiously, the most commonly cited secondary sources published after Pepper's initial 1978 PhD thesis on Harriot's work do not reference this treatise. Regardless, Pepper (1978, 293) compares the values from Harriot to the treatises noted in this thesis and concluded that they are quite similar: "Anderson says it "was just less than [sic] 21 times the beam in large English ships and might be as much as 3 times in small ships", which is rather close. Mainwaring is quoted at 2.4 times the beam, which fits the larger size for which it is most probably intended, and this is the proportion "most used", as John Smith wrote." Only four treatises will be used in the interim and Harriot's work will be studied in future work.
[107] Barker 1994, 16.
[108] Barker 1994, 16.
[109] Marzari et al. 1981, 285-86; Barker 1994, 16.
[110] Barker 1994, 16.

“propositions”), several charts and tables for hull design, and most importantly for the purpose of this thesis, proportions for the masts and yards.

Sir Henry Mainwaring’s *The Seamen’s Dictionary: or, an exposition and demonstration of all the parts and things belonging to a shippe: together with an explanation of all the termes and phrases used in the practique of navigation* (1623), is a valuable source for early 17th-century rigging and contains definitions of rigging hardware, masts, yards, as well as sailing and navigational terms. Mainwaring (1587-1653) was a lawyer, politician, and an experienced seaman and pirate and was therefore knowledgeable in the workings of ships and how to rig and sail a ship.[111] In addition to definitions of ship terms, Mainwaring includes proportions or dimensions of parts of ships and rigging in addition to descriptions of how they are used.

Third, *A Treatise on Rigging c. 1625*, written by an anonymous author and discovered in Lord Leconfield’s ‘Petworth House,’ describes rigging and its details.[112] This document is probably the closest in date to *Warwick’s* construction compared to the other treatises analyzed in this thesis. The c. 1625 date of the manuscript was estimated by R.C. Anderson based on the rigging elements it describes.[113] These include the spritsail topsail, topsails, and mizzen topsail which Anderson believes date after 1618, when such sails were first adopted officially by the Royal Navy; while the inclusion of the bonaventure mizzen dates it before *Sovereign* in 1637.[114] As the later parts of this chapter will show, the appearance date of a sail or mast can rarely be

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[111]Manwaring and Perrin 1922, 9-49.
[112] Salisbury and Anderson 1958, 46.
[113] Salisbury and Anderson 1958, 46.
[114] Note that in Salisbury and Anderson (1958, 46) and as will be covered in the next section, the 1618 date mentioned here likely refers to the *Commission into the State of the Navy* that looks into the recommended renovations to Royal Naval vessels that year. However, it is the author’s opinion that these features existed on other ships prior to being officially adopted as part of the reform.

sharply defined, and rig innovations often existed well before being "adopted officially" by the navy. Although Anderson's date is approximate, in this thesis the circa 1625 will be accepted as reasonably close to the true date. No new evidence is available to refine the dating. The manuscript is 64 pages including a list of standard standing and running rigging and associated elements per mast with their descriptions and functions.

A Sea Grammar with the plaine exposition of Smiths accidence for young sea-men, enlarged (1627) is a nautical dictionary written by Captain John Smith who is most famous for his role in the colonization of Virginia.[115] It is believed that Smith copied, or at least was strongly influenced by Mainwaring's 1623 work, although the information Smith presents is updated to reflect his experiences and slightly later ships are referenced.[116] *A Sea Grammar* consists of 76 folios and was reprinted with further explanations and additions several times (1653, 1691, 1692, 1699) but for the purposes of having the closest date to *Warwick*, the first version published in 1627 is used.[117] Like Mainwaring's dictionary, this work covers ship terms and their definitions, including details on rigging, ship management, and sailing.

Although treatises are one of the most useful types of primary sources in nautical archaeology, these documents described how ships should be rigged and sailed, but perhaps not how it was done in practice. In fact, according to *A Treatise on Shipbuilding,* many ships were "spoilt" because the actual ship did not resemble what was plotted arithmetically and geometrically within the treatise once it is scaled up to its actual dimensions.[118] Although good

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[115] Goell 1970, xi.
[116] Barbour 1972, 93-101; Goell 1970, xii.
[117] Goell 1970, xiv.
[118] Salisbury and Anderson 1958, 32.

sources, they describe the ideal rigging arrangements on hypothetical ships, and not all ship riggers followed these instructions precisely.

Appendix D contains a table comparing the four treatises. Hypothetical dimensions were calculated using *Warwick's* estimated hull dimensions (total length of 100.7 ft [30.5 m.], a depth of 10.58 ft [3.24 m.], a beam of 23.0 ft [7.0 m.], a keel length of 75.5 ft [23.0 m.], and tonnage of 160).[119] The range of possible dimensions and features are included in the left "Analysis" column in Appendix D.

Masts and Yards Lists and Inventories of Specific Ships

Lists of mast and yard dimensions and ship inventories have the advantage of revealing what was truly fitted on ships, unlike the ship dictionaries and treatises which reveal how ships should have been built and rigged. Two ship lists are used in *Warwick's* rigging reconstruction.

The ship list closest in time to *Warwick's* is the *Commission into the State of the Navy* compiled by Sir Nicholas Fortescue, which describes the renovations intended for naval ships in June 1618.[120] In 1971, several related copies and supplemental documents were compiled by A.P. McGowan for the Navy Records Society in a book titled *The Jacobean Commissions of Enquiry 1608 and 1618* which gives background on the cause of the Commissions and a historical overview.[121] The manuscript was written by a commission appointed to rectify abuses in the Royal Navy and includes a complete list of rigging on the navy's vessels, followed by rigging modifications recommended for each ship. The list shows the transition between what was considered outdated and inadequate for ships in 1618 and reveals new trends in ship

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[119] Bojakowski and Custer-Bojakowski 2017, 296-98.
[120] National Museum of the Royal Navy Library, personal communication, May 1, 2014; Admiralty Library 7/826.
[121] McGowan 1971, vii-xiii.

outfitting. These updates were not described as “recommendations” but rather “abuses” of the navy, implying that the vessels were severely out-of-date.[122] Newly-built ships around this date, and likely a few years prior, such as *Warwick*, were probably built in accord with the newer trends.

The author was unable to locate a complete facsimile of the original 1618 document noting changes in the masts and yards, but a copy of folio 29 that shows the rigging changes in *Bear* was included in Alan Moore’s 1912 article series titled “Seventeenth Century Rigging” in *Mariner’s Mirror*. This folio will serve as the primary reference and case study used from the Commissions (Figure 70).[123]

[122] McGowan 1971, vii-xiii.
[123] Moore 1912, 267-74.

H.M.S. "Bear":	Lengths in Yards, Feet and Inches.	
	Old.	New.
Main mast	30 0 0	30 0 0
Main yard	31 2 8	28 2 8
Main topmast	16 1 0	15 0 0
Main topsail yard	13 0 1	12 1 1
Main topgallant mast	———	6 1 6
Main topgallant yard	———	5 1 0
Fore mast	28 0 6	28 0 0
Fore yard	24 2 8	23 0 2
Fore topmast	14 0 0	14 0 0
Fore topsail yard	10 1 1	9 0 3
Fore topgallant mast	———	7 0 0
Fore topgallant yard	———	4 0 10
Bowsprit	28 0 0	28 0 0
Spritsail yard	17 0 3	17 0 9
Spritsail topmast	———	7 0 0
Spritsail topsail yard	———	7 1 5
Main mizzen mast	22 1 0	22 0 0
Main mizzen topmast	not recorded	10 0 0
Main mizzen yard	33 1 0	23 0 2
Crossjack yard	———	17 0 9
Mizzen topsail yard	———	7 1 5
Bonaventure mizzen mast	19 1 0	19 0 0
Bonaventure mizzen topmast	not recorded	8 0 0
Bonaventure mizzen yard	not recorded	17 0 9
Crossjack yard	———	13 0 0
Bonaventure mizzen topsail yard ..	———	5 1 8

Figure 70: Folio 29 of the manuscript listing inventory for the old masts and yards of Bear, and the recommended alterations (Royal Naval Museum Archives, Admiralty Library Manuscript Collection).

Bear, sometimes listed as *White Bear* or *Beare* in some manuscripts, was built in AD 1563-1564 at the beginning of Queen Elizabeth I's reign by Master Shipwright Matthew Baker, and is one of the ships mentioned within this document (Figure 71).[124] *Bear* was rebuilt and refitted once at the end of Baker's career around AD 1598-1599 and again in AD 1618 according to the Royal Commission's proposals. By AD 1627, the ship was unserviceable and broken up at Rochester in June 1629. *Bear's* original dimensions, prior to the AD 1598-1599 rebuilding, showed it was a large ship of 732.6 tons, with a keel length of 110 ft (33.5 m), a breadth of 27 ft (8.2 m), and depth of 18 ft (5.5 m).[125]

Bear is also mentioned in the previously-mentioned c. 1600 Newton Manuscript where it is used as an example for calculating mast length.[126] As already noted, the exact date of the Newton Manuscript is unclear, but in it the main mast length of *Bear* is 2 yards and 2/5 ft (2 m) longer than the "old" outdated rigging list (which states the main mast is 30 yards [90 m]) in the Commissions.[127]

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[124] Winfield 2010, 8.
[125] Winfield 2010, 8.
[126] Barker 1994, 28. "The ship of ye Queens named the Beare was 38 foot broad & 16 foot deep: add 38 & 16 together & it maketh 54 foot take out of 54 foot 3/5 & it will be 32 2/5 & so many yards was the length of the mast."
[127] Moore 1912, 270.

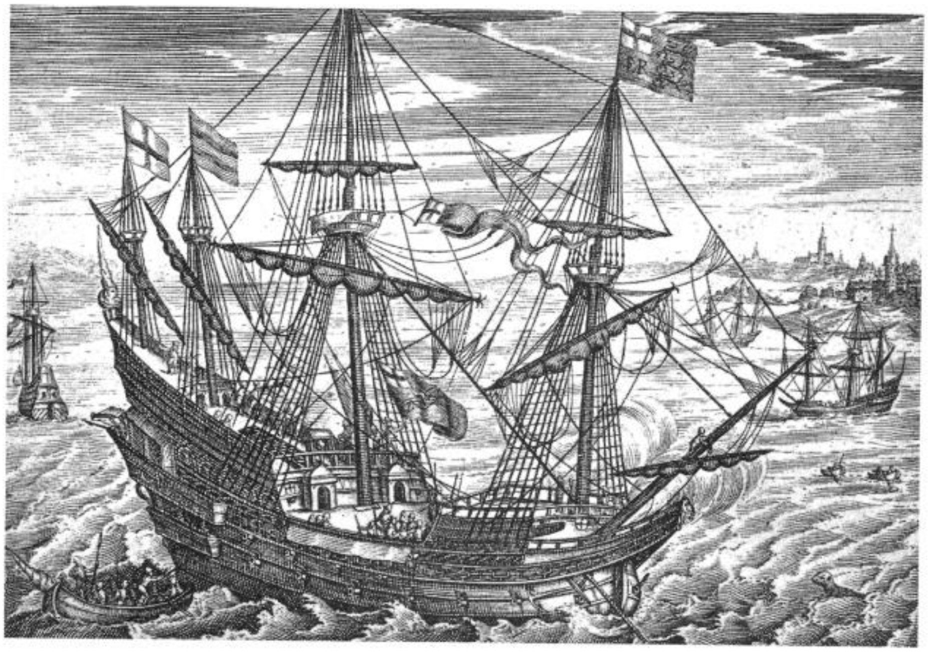

Figure 71: An engraving in a series by Claes Visscher illustrating ships that fought in the Armada, including what is believed to be *Bear*. The image's rigging and hull details should not be relied upon given that it was produced after the event, and because *Bear* was rebuilt several times (Winfield 2010, 9).

Another document consulted for this thesis is *The Lengths of Masts and Yards* (1640) which includes various Royal Navy vessels, their hull dimensions, the lengths of their masts and yards, proportion of cables and anchors, the number of shrouds and stays, their crew and ordnance, and dimensions of their sails.[128] Given that *Warwick* is estimated to be around 160 tons, the comparable ship in this list is the *8th Whelpe* (at 169 tons). *Rainbow* at 731 tons is also included from this list as a 1640 vessel comparison for *Bear*, to understand chronological rigging changes for large vessels.

Appendix E includes a table with dimensions from *Bear* (about 732.6 tons) in the Newton Manuscript (c.1600), and the "Old" and "New" changes in the Commissions, and *Rainbow* from

[128] Clowes 1931, 8-35.

The Lengths of Masts and Yards, to understand rigging changes from AD 1600-1640 in ships approximately 730 tons. The two columns on the right of the table include the dimensions of the *8th Whelpe* (162 tons) in the 1640 ship list, and *Warwick's* hypothesized based on the chronological changes from *Bear* and *Rainbow*, and the smaller size of *8th Whelpe*.

Iconography

Contemporary iconography is useful for visually understanding how rigging from the early 17th century appeared especially when used in tandem with primary documents. However, artwork must be used with caution because:

1) It normally lags behind the actual date of the introduction of a particular technology.[129]
2) During the first part of the 17th century, it was common for ships to be drawn using characteristics of other nationalities. Dutch-style ships, for example, often masqueraded in paintings as English because Dutch artists such as the Willem Van de Veldes, father and son, were paid to paint ships of other nationalities.[130]
3) Artists may draw ships based on imagination.[131] Further, illustrations often depict fictional, metaphorical, or anachronistic ships and events based on their themes and titles. Hendrick Cornelisz Vroom painted two works depicting *Prince Royal* in 1613 and 1623 that show approximately the same ship, but Adam Willaerts' painting of the same vessel in 1613 shows a very different ship.[132]

Even so, the sketches, prints, and paintings by artists of the Dutch School, which make up a majority of the nautical artwork from this period, are renowned for their precision and accuracy

[129] Mott 1994, 40.
[130] Howard 1979, 91.
[131] Howard 1979, 91; Moore 1912, 267.
[132] Howard 1979, 91.

and useful in understanding ships' appearances, keeping the above caveats in mind. Given that *Warwick* was likely built by the summer of 1617, iconography produced between AD 1608-1621 was used.[133] In a few cases, artists who did not include the exact year their paintings were completed were still used if their date of birth and death fall approximately within this period. For example, Aert Anthonisz was born AD 1579 and died AD 1620. The second painting included in this section is attributed to him and depicts the 1588 Armada, but if he painted this c. 1590 as was originally proposed, he would have been 11 years old. Art historians now believe that most of Anthonisz's paintings were done c. 1610, closer to his death, putting his work within the range of years for use in understanding *Warwick*. [134] The following painters were used as iconographical sources: Hendrick Cornelisz Vroom (AD 1566-1640), Hendrik Hondius (AD 1573-1649), Adam Willaerts (AD 1577-1664), Cornelis Claesz van Wieringen (AD 1577-1633), Aert Anthonisz (AD 1579-1620), Abraham de Verwer (AD 1585-1650), Nicolaus Johannis Visscher (AD 1587 – June 19, 1652), Cornelis Verbeeck (AD 1590/91-1637), and Hendrick Cornelisz Vroom (AD 1590/92-1661) (son and pupil of Hendrick Cornelisz Vroom Sr. mentioned above) among others. The paintings discussed here depict Dutch, English, and Spanish-built vessels. A total of 31 ships from 12 images were analyzed, and therefore present a limited sample set, but one that shows patterns from the period nonetheless (Figures 72-87).

The works are listed in chronological order of the date of the painting and not the date of the event or ship it depicts because events and ships can be painted any time after their existence, but not prior, therefore indicating the earliest date this ship existed. As a general rule of thumb,

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[133] Bojakowski and Custer-Bojakowski 2017, 300.
[134] RKD—Netherlands Institute for Art History, 2019.

the date of a work of art is a better indication of the date of a ship's features than the date of the event depicted.[135] Each ship within the image was analyzed for the presence or absence of mast and yard elements and for the number of shrouds shown for each mast (See Appendix F). When a rigging element is obscured, or if the image quality is not sufficient to indicate the presence or absence of a mast or yard or exact number of shrouds, an asterisk (*) is used. Absence does not mean the element did not exist, for it may be obstructed by sail, or was temporarily taken down due to sailing conditions or other reasons. Running rigging elements were not noted in Appendix F because they are more variable depending on how the ship is being sailed, thus presenting greater room for error. They are also often small, blurry, or difficult to see, making their analysis via iconography unreliable.

[135] Rahn Phillips 1986, 34.

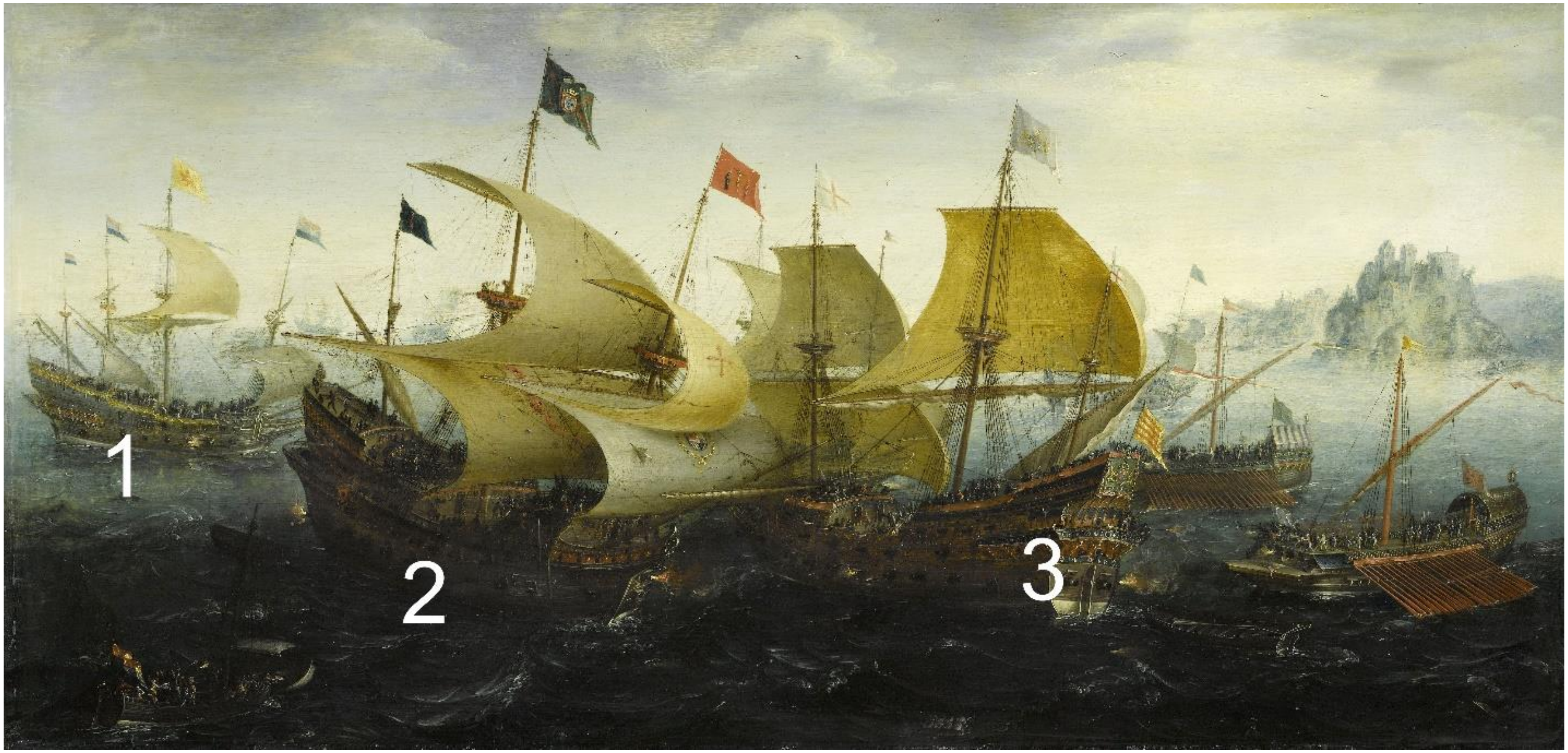


Figure 72: ***Battle of Cadiz*** **by Aert Anthonisz (1579-1620). Dated 1608. In the Battle of Cadiz (1596), the Dutch and English forces joined to fight against the Spanish in the Anglo-Spanish War. On the left (1), the four-masted** ***Neptunes*** **is commanded by the Admiral John de Duyvenvoorde (Johan van Duivenvoorde), Lord of Warmond, while in the foreground the Spanish** ***San Felipe*** **(2) is engaged with the English 42-gun 800-ton** ***Ark Royal*** **(3). In reality,** ***Ark Royal*** **was not a participant in the battle but was added as symbolism of the English Navy. Object Number SK-A-1367. Painting. Retrieved from https://www.rijksmuseum.nl/nl/collectie/SK-A-1367: Rijksmuseum; See also Lavery 2003, 158.**

Figure 73: ***Launch of Fire Ships Against the Spanish Armada, 7 August 1588*** **by an unknown artist. Painted c. 1590. A Flemish interpretation of the launch of the English fireships against the Spanish Armada in 1588 depicting an imagined scene showing the fireships running down the Spanish fleet with the English fleet following, which in reality did not happen. The left foreground shows a Spanish ship (4) engaged with an English vessel (5), and another English ship (6) running down from the right. In some sources attributed to Aert Anthonisz, although if the date indeed is c. 1590, the painter would have painted it around age 11. This work most likely can be dated to the early years of the 17th century when the majority of Anthonisz' work was done. Object ID BHC0263. Painting. Retrieved from http://collections.rmg.co.uk/collections/objects/11755.html?_ga=1.105248643.1452250482.1486680207#v2eubrX8kybWHtOo.99: Royal Museums Greenwich Caird Collection.**

Figure 74: ***A Dutch Ship Close-Hauled*** **by Aert Anthonisz (1579-1620). Painted c. 1610. Two Dutch three-masters are seen off of a rocky coast, painted in the 16th-century tradition of the Southern Netherlands. The ship's rigging (7) displays great detail. (Object ID BHC0713. Painting. Greenwich. Retrieved from http://collections.rmg.co.uk/collections/objects/12205.html?_ga=1.64370863.1452250482.1486680207#ThJdPMxMSDS7rQgS.99: National Maritime Museum, Greenwich, London, Macpherson Collection.**

Figure 75: ***An English and a Dutch Ship Attacking a Spaniard*** **by Aert Anthonisz (1579-1620). Painted c. 1610. In the foreground a Spanish ship (8) and English ship (9) are closely engaged. A Dutch ship is seen in the background center. Object ID BHC0714. Painting. Retrieved from:**
http://collections.rmg.co.uk/collections/objects/12206.html?_ga=1.105184131.1452250482.1486680207#xOzwKlvU3waajqVc.99
National Maritime Museum, Greenwich, London, Macpherson Collection.

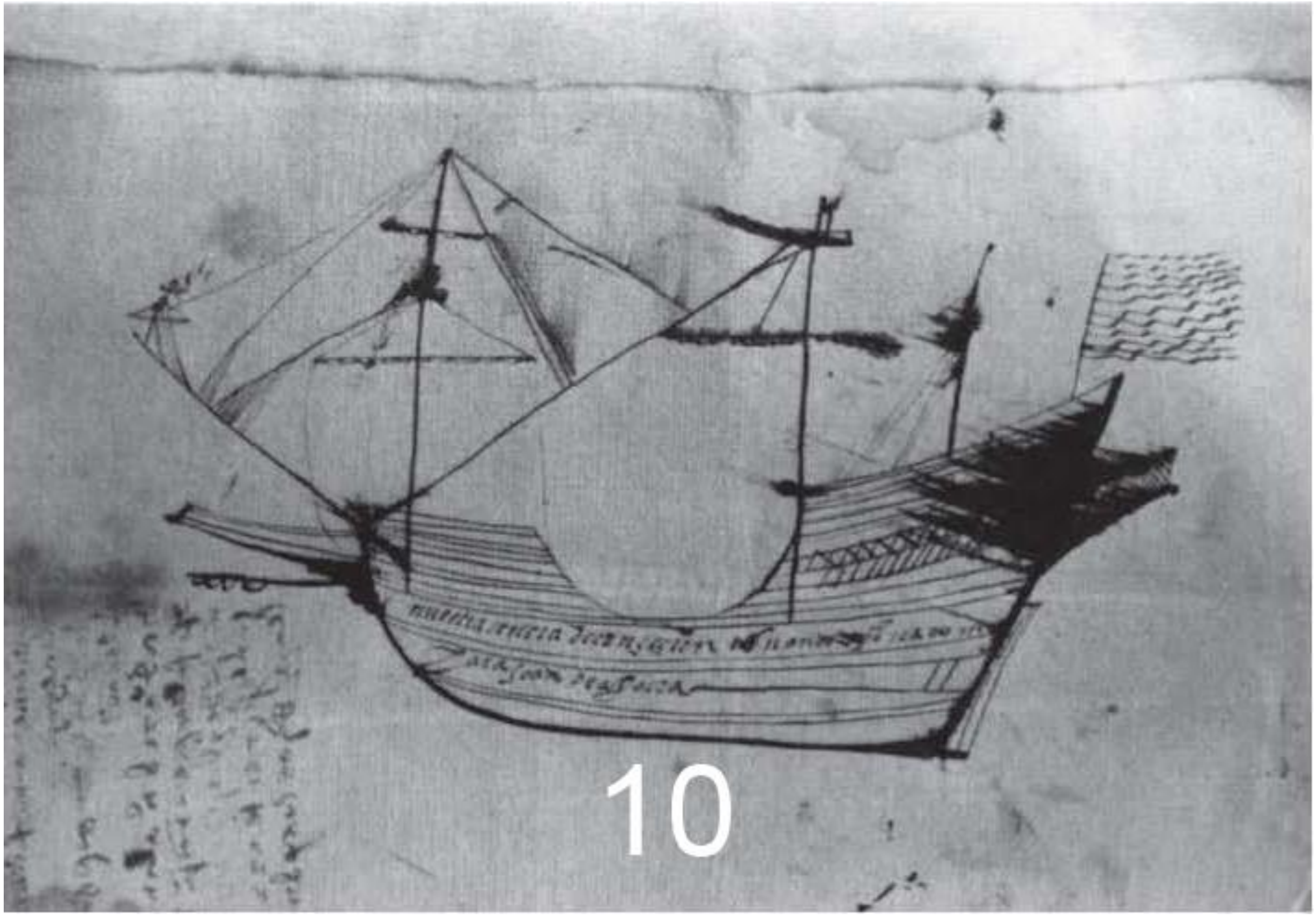
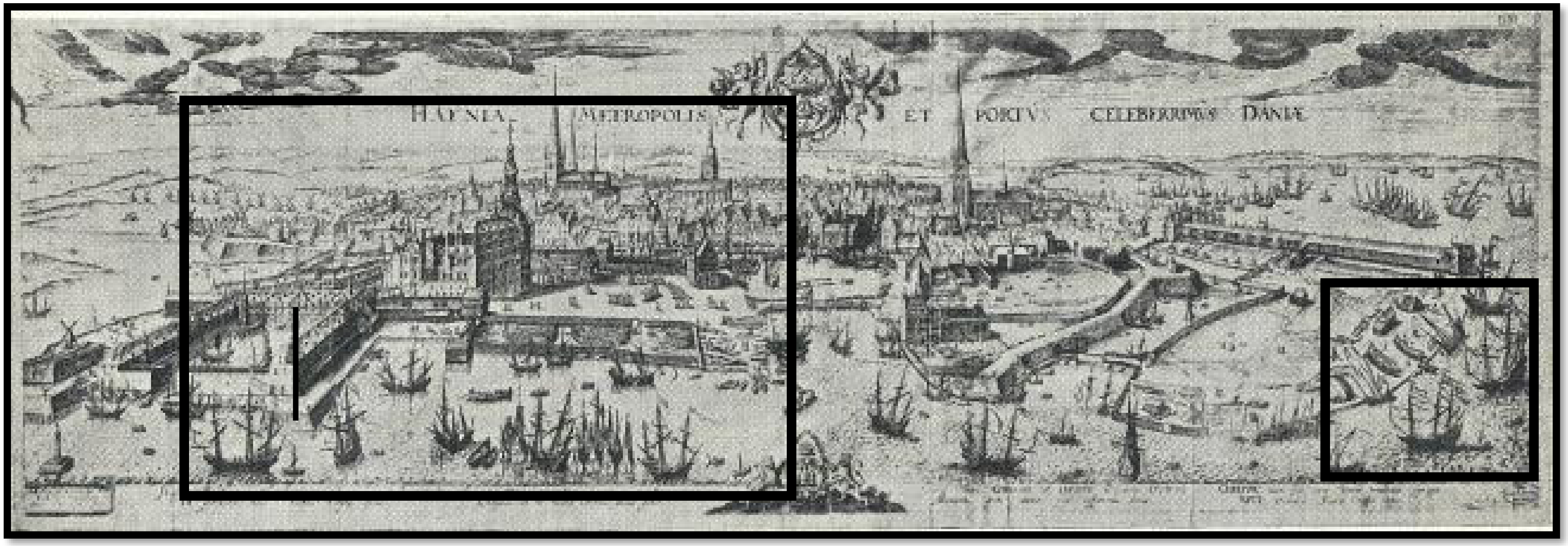


Figure 76: ***A Sketch of Nuestra Señora de la Conçepçion*** **by an unknown author. Dated 1611. Note the presence of the spritsail topmast and yard on this Guipúzcoan galleon. Object ID 2.567. Archivo Histórico Provincial de Guipúzcoa, Oñati, partido de Vergara.**[136]



Detail A   Detail B

Figure 77: Detail of the etching *Hafnia Metropolis et portus celeberrimus daniae* by Jan Diricks van Campen (1596-1657). Dated 1611. This etch is created after an oil painting (now lost) by Jan van Wijk. In the centre is the royal castle on *Slotsholmen*, now home of the Danish Parliament, and to the left is the arsenal harbour –*Tøjhuset*—built by Christian IV at the beginning of his reign. Photo number 172764. Engraving. Retrieved from: https://rkd.nl/en/explore/images/242571: Royal Library, Copenhagen, Denmark.

[136] Rahn Philips 1986, 71.

Figure 75, Detail A of the etching *Hafnia Metropolis et portus celeberrimus daniae* by Jan Diricks van Campen (1596-1657). Dated 1611. In the center foreground are depicted the different maritime activities that took place in the Gronnegaard harbour: several ships are moored to pilings driven in the harbour waters, a larger ship is being careened, heeled over another vessel, as men work on the hull from a barge. Photo number 172764. Engraving. Retrieved from: https://rkd.nl/en/explore/images/242571: Royal Library, Copenhagen, Denmark.

Figure 75, Detail B of the etching *Hafnia Metropolis et portus celeberrimus daniae* by Jan Diricks van Campen (1596-1657). Dated 1611. The scene shows shipbuilding activities on Bremerholm. Photo number 172764. Engraving. Retrieved from: https://rkd.nl/en/explore/images/242571: Royal Library, Copenhagen, Denmark.

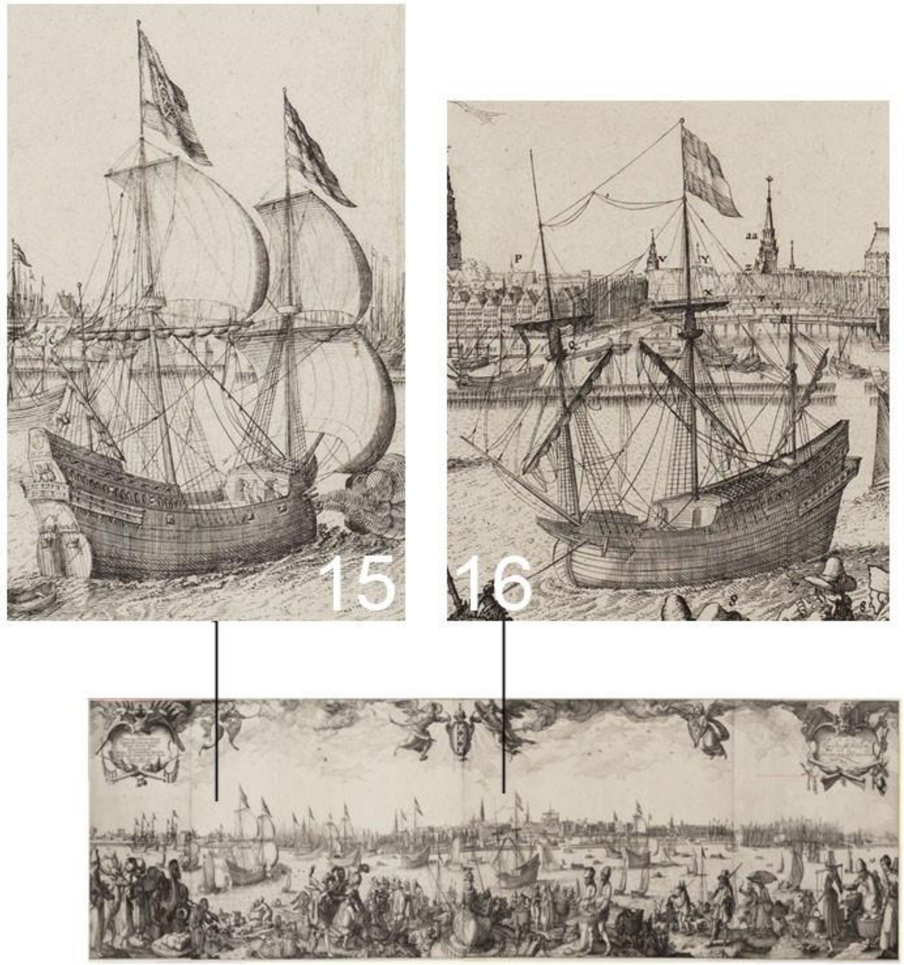


Figure 78: ***Profile of Amsterdam, 1611*** **by Claes Jansz Visscher (II) (1587-1652). Dated 1611. A panorama of Amsterdam showing various vessels in background. Object Number RP-P-1884-A-7654. Painting. Retrieved from https://www.rijksmuseum.nl/en/collection/RP-P-1884-A-7654: Rijksmuseum, Amsterdam.**

Figure 79: ***Skirmish between Amsterdam and English warships, 20 April 1605*** **by Hendrick Cornelisz Vroom (c. 1562-1640). Painted 1614. An English ship (17) engages a Dutch ship (18), while two other ships fire at each other in the background. Accession Number A.0002. Painting. Retrieved from https://www.wikidata.org/wiki/Q21064847: Het Scheepvaartuseum, Amsterdam.**

Figure 80: ***A Dutch Merchantman Attacked by an English Privateer, off La Rochelle*** **by Cornelis Claesz van Wieringen (c. 1575-1633). Painted 1616. In the center a Dutch fluyt (19) flying Dutch flags is attacked by an English privateer (20). A French warship and the French port of La Rochelle are in view behind them. Object Number BHC0723. Painting. Retrieved from http://collections.rmg.co.uk/collections/objects/12215.html?_ga=1.127769997.1452250482.1486680207: National Maritime Museum, Greenwich, London, Caird Collection.**

Figure 81: ***Ships off Ijselmonde*** **by Aert Anthonisz (1579-1620). Painted 1617. Object number: SK-A-1446. Painting. Retrieved from: https://www.rijksmuseum.nl/en/collection/SK-A-1446: Rijksmuseum, Amsterdam.**

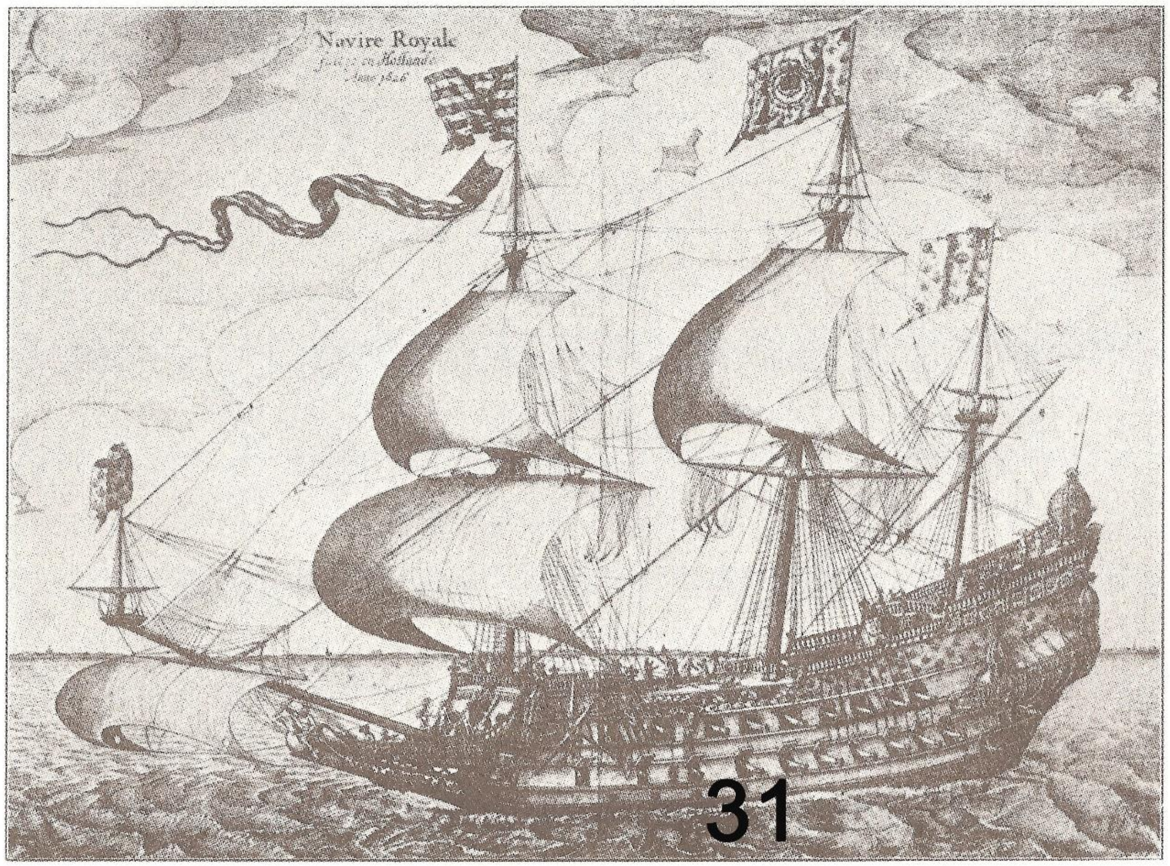
Figure 82: ***A Naval Encounter between Dutch and Spanish Warships*** **by Cornelis Verbeeck (c. 1590-1637). Painted c. 1618/1620. A Spanish galleon (22) fires upon a Dutch warship (23). Catalogue Numbers 1995.21.1-2. Painting. Retrieved from: https://www.nga.gov/collection/art-object-page.156252.html: National Gallery of Art, Washington, Gift of Dorothea V. Hammond.**

Figure 83: ***The Explosion of the Spanish Flagship during the Battle of Gibraltar, 25 April 1607*** **by Cornelis Claesz van Wieringen (originally mistakenly attributed to Hendrik Cornelisz Vroom). Painted c. 1621. This painting depicts a Dutch ship (24) attacking a Spanish ship during a decisive moment in the Battle of Gibraltar. Another Dutch ship (25) runs down upon the Spanish. Object ID SK-A-2163. Painting. Retrieved from: https://www.rijksmuseum.nl/en/search/objects?q=SK-A-2163&p=1&ps=12&st=Objects&ii=0#/SK-A-2163,0: Rijksmuseum, Amsterdam.**

Figure 84: ***A Dutch Squadron Attacking a Spanish Fortress*** **by Adam Willaerts (1577-1664). Dated 1622. This painting depicts a Dutch attack on a fortress defended by the Spanish. The Dutch men-of-war are sailing in from the right. The foreground shows a Spanish galley flying the Burgundian flag. Behind it is a Spanish man-of-war (26) being fired upon by a Dutch ship (27). Object ID BHC0801. Painting. Retrieved from: http://collections.rmg.co.uk/collections/objects/12293.html?_ga=1.4734771.1452250482.1486680207: National Maritime Museum, Greenwich, London, Caird Collection.**

Figure 85: ***Embarkation of the Elector Palatine in the 'Prince Royal' at Margate, 25 April 1613*** **by Adam Willaerts. Dated 1622. This painting shows the departure of *Prince Royal* (28) from Margate to the Continent after the marriage of Frederick, Elector Palatine, to Princess Elizabeth, daughter of James I, in 1613. The smaller ship to the right is believed to be *Phoenix*, laid down in June 1612 as a pinnace for the flagship. Object ID BHC0266. Painting. Retrieved from: http://collections.rmg.co.uk/collections/objects/11758.html: National Maritime Museum, Greenwich, London, Caird Collection.**

Figure 86: ***A Dutch and an English Ship off a Harbour*** **by Abraham de Verwer (1585-1650). Painted c. 1625. A Dutch ship moves across the harbor on the left (29) while an English ship is shown on the right (30) flying St George's flag at the stern and a red and white ensign on the main mast. Object ID BHC0732. Painting. Retrieved from: http://collections.rmg.co.uk/collections/objects/12224.html?_ga=1.160971581.1452250482.1486680207: National Maritime Museum, Greenwich, London, Palmer Collection. Acquired with the assistance of H.M. Treasury, the Caird Fund, the Art Fund, the Pilgrim Trust and the Society for Nautical Research Macpherson Fund.**



6. French Man-of-War built in Holland in 1626
From a print published at Amsterdam by H. Hondius

Figure 87: *A Dutch-Built French Ship* (31) by Hendrik Hondius (1573-1649). Dated 1626. Maritime Museum Rotterdam, Rotterdam, Netherlands.[137]

[137] Anderson 1994, plate 6.

Appendix G contains the consolidated data from Appendix F. Based on consistent iconographical features of ship masts, yards, and standing rigging dating from the first quarter of the 17th century, *Warwick's* rigging configuration most likely consisted of a bowsprit, spritsail yard, fore mast, fore yard, fore topmast, fore topsail yard, main mast, main yard, main topmast, main topsail yard, mizzen mast, mizzen yard, mizzen topmast, a mizzen topsail yard (often not deployed perhaps due to weather or other sailing issues). There were probably seven foremast shrouds, three fore topmast shrouds, eight mainmast shrouds, four main topmast shrouds, four mizzen mast shrouds, and three mizzen topmast shrouds per side.

Contemporary Ship Models

Contemporary ship models provide examples of how ships were rigged, as these were miniature models of ships to be built or that were already built. Ship models, especially if they can be proven to have been unmodified, are useful sources as there is little guesswork to how parts fitted together and viewing perspective is not a problem as it often is in two-dimensional iconography. However, models were often altered after the real ships they were modeled after, re-rigged to resemble newer styles, or ineptly repaired decades or even centuries after they were originally built.

Anderson, Lees, Howard, and Mondfeld provide ample information from rigged ship models in their publications.[138] These researchers also concede that many of the models they cite cannot be dated to a precise period, and that several are rigged inaccurately. As such, only one model will be cited in this study as an example of the benefits and pitfalls of using models for

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[138] Anderson 1994; Lees 1984; Howard 1979; Mondfeld 1989.

rigging reconstructions. Although only a single model will be covered in detail, the other relevant models the author is aware of are thoroughly researched by the scholars mentioned above, whose works will be cited when necessary in later chapters. The model included here is an AD 1593 model of a Flemish ship found in the Museo Naval in Madrid.

This model has been known to researchers for a long time, but its history and rigging accuracy are debated. It is mentioned in Björn Landström's book *The Ship*, where a sketch of the model by Landström is shown, depicting only its lower masts and shrouds in place.[139] According to Landström, the model was given to Philip II in 1593 by the Flemish, and therefore most likely represents the most technologically advanced ship known at the time. Landström's commentary on the model includes noting that the model is not to scale, damaged, and that anachronistic rigging details were added by a later repairer. He adjusted the proportions of the ship according to Matthew Baker's treatise in his sketch and notes that the foremast is forward of the forecastle, which was typical of most sixteenth century galleons, and that the shrouds have "heart-shaped" (equivalent of pear-shaped) deadeyes.[140] Landström does not explain which features of the rigging are anachronistic and how he determined which elements do not belong on the model.

The ship's entry on the Museo Naval's online archives gives a general description and history of the ship.[141] The model is believed to be an *ex voto* offering to commemorate a miraculous survival. *Ex voto* models were typically not built to scale. The entry claims that this model is considered the only sixteenth-century representation of a vessel in three dimensions

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[139] Landström 1961, 125.
[140] Landström 1961, 124-25.
[141] Biblioteca Virtual del Ministerio de Defensa. *Modelo de galeón flamenco (1593).*

which is preserved in the world. Thanks to Dr. Jose Luis Casaban, the entry was translated from Spanish and its content summarized below.

The forecastle is short, with a bulkhead directly abaft the foremast, as is typical of galleons.[142] It has a bowsprit with a spritsail topmast, a foremast with three yards, mainmast with three yards, a mizzen mast with three yards, and a bonaventure mast with a lateen sail only.[143] The spritsail topmast is noted to be anachronistic, but its crows nest is said to be correct. The upperworks are polychrome with several motifs including the necklace from the Order of the Golden Fleece. Along the gundeck is written "ICK VARRE MET NEPTVNVS IN BOREAS ULP IN GHE TOT DIE HAVEN DAER MY ANKER VALT ANNO 1593" which translates to "With the help of Neptune and Boreas I anchored in the harbor in 1593." This text is believed to be an allusion to a fortuitous voyage or a fortunate victory. The lower hull has an exaggeratedly shallow draft, which suggests that the model was built to be hung from a roof and seen from below, as was customary in northern European *ex voto* models.[144]

Landström's book and internet sources state that this model has traditionally been ascribed as a gift to Philip II, but in reality, no historical evidence has been found to support this. In documents from AD 1594 to 1652 within the General Archive of the Royal Palace of Madrid, there is no mention of the model, nor is this ship model included in the Accounts of Charge for Hernando Eespejo and others who attended the auction of property formerly belonging to Philip II and Reyna Doña Ana in AD 1617. Rather, the oldest known description of the ship model

[142] Biblioteca Virtual del Ministerio de Defensa. *Modelo de galeón flamenco (1593).*
[143] Note the Biblioteca Virtual del Ministerio de Defensa entry states that the model "[…] is rigged with a bowsprit with a yard spritsail; foremast with two yards; mainmast also with two yards, and mizzenmast with yard for a lateen sail only." However, the model clearly shows that the foremast, mainmast, and mizzen mast all have three square sail yards, and that there is a fourth mast, the bonaventure, with a lateen yard.
[144] Biblioteca Virtual del Ministerio de Defensa. *Modelo de galeón flamenco (1593).*

appears in the inventory of the Royal Armory that was formed in 1793 from the Marquis of Villena who catalogued this piece as "No. 64 a Ship model with its Rigging, Pulleys, Sails and cannons […]"[145]

It is unclear how the ship came to be in the museum's possession and there is no reference in the museum archives as to when it was received. The model is mentioned in the 1862 catalogue, 1871 catalogue, and 1879 catalogue, and is described as a Tunisian caravel in these earlier documents. In 1894, the ship was described as a bulky ship of an armed naval vessel at the end of the 16th century, that up until that date, was improperly called a Tunisian caravel. It is also noted that the inscription in old Dutch suggests that this design was built in Flanders perhaps as an *ex voto*. In 1934, its entry notes it is a 16th-century 'flamenco,' or Flemish, galleon belonging to the Royal Armory, and it was presented to Philip III as a gift from a Flemish embassy. This entry also states that the model is a votive boat, similar to those that were hung in fish markets and municipalities in Northern Europe. In the mid-19th century, the ship's rigging was restored under Julio Guillén, an officer of the Spanish Navy and the museum's director at the time, and it is believed that during this time the mizzen mast was incorrectly rigged with square courses instead of a lateen sail, similar to the bonaventure. In the middle of the 20th century, it underwent another restoration that did not modify its sail plan.[146]

Personal communications with the current restoration supervisor in the Museo Naval in 2014 indicated that the restoration was primarily a cleaning job that was done in between 2011 and 2012. Included in this cleaning was a complete analysis of its rigging elements, details,

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[145] Biblioteca Virtual del Ministerio de Defensa. *Modelo de galeón flamenco (1593).*
[146] Biblioteca Virtual del Ministerio de Defensa. *Modelo de galeón flamenco (1593).*

measurements, and construction materials. They also noted that the majority of the elements are original as the model was hung in the Real Alcázar, but its black dye was not due to the fire there as was previously written, but actually due to successive layers of painting, which is believed to be what preserved the wood. At the time of communication, the rigging elements had not yet been analyzed for dating. The restoration specialist noted that the rigging is composed of part vegetable fiber and metallic thread and the original layout appears to be true to the original. Some ropes were replaced probably during the 19th century, but the block types and their placement appear to be reliable and to scale. He also noted they are historically accurate and the mast caps match those of Dutch ships c. 1600. The painting on the vessel is original and well preserved. The curator's opinion is that the model represents a real ship from 1593 in both the hull and rigging, with the main inaccuracy being an undersized lower hull that allows the ship to serve its decorative purpose. The model's full analysis including its restoration, images and plans, and measurements will be published by the Naval Museum.[147]

Figures 88-91 are images of the model. Note that this ship carries four masts. Its bowsprit includes the spritsail topsail, and the fore, main, and mizzen mast also have the topsail and topgallant sails. The bonaventure mast has the fore and aft lateen sail, but no crossjack and no square topsail.

This model, representing a ship much larger than *Warwick*, shows a mixture of rigging styles. It likely depicts part of the transition from an older rig plan to the newer rig plan seen

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[147] Biblioteca Virtual del Ministerio de Defensa. *Modelo de galeón flamenco (1593).*

during the early 17th century. For more detailed views of the model's details, please refer to Ángela Jiménez Estrada's study on the 3D modeling of the ship model using photogrammetry.[148]

As can be noted in the history of the model, not all parts of this model can be deemed fully reliable, and only the chemical dating analysis planned by the curator can determine which parts are original.

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[148] Estrada 2014, 1-82.

Figure 88: Portside profile of the 1593 votive model. Image from Museo Naval de Madrid, Nº inventario: MNM-80.

Figure 89: Portside bowsprit, yard, and rigging details of the 1593 votive model. Image from Museo Naval de Madrid, Nº inventario: MNM-80.

Figure 90: Starboard view of the fore and main masts, yards, and rigging details of the 1593 votive model. Image from Museo Naval de Madrid, Nº inventario: MNM-80.

Figure 91: The view from the bow of the 1593 votive model showing rigging details. Image from Museo Naval de Madrid, Nº inventario: MNM-80.

Other ship models that researchers often cite, and from which previous literature on rigging originated, include the models of the French ship, *Couronne* (1638), the English Royal Naval ship, *Sovereign* (1637), the Dutch ship, *Prins Willem* (1651), and the Danish ship, *Norske Löve* (1654). These models will be referenced in chapters 6 and 7 as needed.

The following two chapters compare and evaluate the collective archaeological, iconographical, and historical evidence covered in chapters 4 and 5 and consolidate the data in a rigging reconstruction.

CHAPTER 6

MASTS & YARD RECONSTRUCTION

Even with archaeological evidence, treatises, ship lists, and iconography, *Warwick's* reconstruction is only an approximation of how its rigging may have appeared, but perhaps not how it was truly rigged on its final voyage. In the past, no two ships were exactly the same because of human error during the building process even if they were drafted identically. John Smith wrote that the "Rules [of masts and yards] are divers[e], because no Artist can build a Ship so truly to proportion, neither set her Masts, but by the trial of her condition they may bee impayred or amended."[149] Not only did ships often differ from what was specified in treatises and contracts, but good shipwrights were also careful to customize their ships for their intended function (e.g. merchantman, men-of-war etc.), length of journey, and anticipated sailing conditions.[150] As a ship intended to carry cargo and people for colonization on at least one roundtrip transatlantic voyage, *Warwick* likely had masts that were shorter and thicker compared to other ships. Called "taunt" masts, the more robust spars decreased chances of the masts breaking, since they were especially difficult to fix on such voyages (repaired masts were called "Jury-masts").[151] The same rule applied to yards: "The proportion of [the yards] is not absolute,

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[149] Goell 1970, 18.

[150] "There is much difference in staying of masts, in respect of a ship's sailing or working." Manwaring and Perrin 1922, 235.

[151] "There are some differences in the proportioning of masts according to the use of the ship (for those which are to go long voyages are not to be masted according to true proportion, but to be made shorter and bigger than ordinary for fear of spending them in a long journey where they cannot be repaired)." Manwaring and Perrin 1922, 186; "When a ship is built she should be masted, wherein is a great deale of experience to be used, so well as art; for if you overmast her either in length or bignesse, she will lie too much downe by a wind, and labour too much a-hull, and that is called a Taunt-mast; but if either too small or too short, she is under masted or low masted, and cannot beare so great a saile as should give her true way. For a man of warre, a well ordered Taunt-mast is best, but for a

for he that will have a taunt mast may have the narrower yards (and so contrary)."[152] The dimensions of the spars also depend on whether the mast was made using one timber, or if it was made from multiple pieces of wood, called a "made" mast. Smith notes that masts have a thickness of 1 inch (2.54 cm.) per yard in length, unless it is a made mast, in which case it must be thicker.[153] Mainwaring gave general proportions for topmasts, but then wrote the caveat that "there is no one absolute proportion in these and the like things, for if a man will have his mast short, he may the bolder make his topmast long."[154] At the same time, shipwrights needed to ensure that ships were not overly rigged because this caused them to be top-heavy and to sail poorly.[155] In summary, while the evidence in the previous chapters gives approximations of standard rigging sizes and configurations, *Warwick's* masts and yards were likely customized to be shorter and more robust compared to the measurements given in the written documents. This chapter discusses *Warwick's* masts and yards based on the consolidated information presented in the previous chapters, which can be found in Appendix H, and analyzes it to produce a hypothetical rigging reconstruction.

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long voyage, a short Mast will beare more Canvasse, and is lesse subject to beare by the boord [break and fall overboard]." Goell 1970, 18; "A Jury Mast: that is when a Mast is borne by the boord [sic], with Yards, Roofes, Trees [sic; roof-trees] or what they can, spliced or fished together, they make a Jury-mast, woulding or binding them with ropes fast triced together with handspikes, as they use to would or binde any Mast or Yard." Goell 1970, 21.

152 Manwaring and Perrin 1922, 259.

153 Goell 1970, 19.

154 Manwaring and Perrin 1922, 246.

155 "The rigging of a ship are all ropes which belong either to masts or yards […] We say a ship is well rigged when the ropes belonging to her are of a fit size, not too big nor too little; also when there are no unnecessary ropes put up, as too many shrouds, tackles for the mast, crow-ft, or the like. When that we say a ship is over rigged it is meant the ropes are too big for her, which is a great wronging to the ship's sailing; for a little weight aloft doth hinder more than a great deal alow, by making the ship apter to heel, and holding wind-taut; for note that the more upright any ship goes, the better she doth sail, for a crank-sided ship can never sail well by the wind." Manwaring and Perrin 1922, 210-11; "The Mast is well rigged, or, The Yard is well rigged; that is, when all the Ropes are well sised to a true proportion of her burthen. We say also, when they are too many or too great, Shee is over-rigged, and doth much wrong a Ship in her Sailing; for a small waight aloft is much more in that nature than a much greater below, and the more upright any Ship goeth, the better she saileth." Goell 1970, 22.

Mast and Yard Dimensions

Bowsprit and Foremast

According to ship lists, in particular the dimensions of *8th Whelpe* from *The Lengths of Masts and Yards* (1640), the estimated length of the bowsprit is 50.17 ft (15.30 m) which fits within the ship treatise estimate of between 44.10 ft to 57.6 ft (13.44 m to 17.56 m). *Newton's Manuscript* and the *Seaman's Dictionary* both state that the bowsprit is the same as the foremast in length and thickness.[156] However, in the ship list containing information on *8th Whelpe*, the dimensions of the bowsprit (50.17 ft [15.30 m]) and foremast (59.83 ft [18.24 m]) vary contrary to what the two treatises call for. In this reconstruction of *Warwick*, the ship list dimensions are preferred over measurements gathered from other documents because the dimensions from the ship list are from masts and yards that were truly fitted on a ship of similar size, *8th Whelpe*, rather than measurements from a hypothetical ship. For this reason, in all instances, where there are slight discrepancies in dimensions between sources, data from *8th Whelpe* are used.

The averaged mean of the bowsprit and foremast length within the treatises was 50.85 ft (15.50 m), which makes the closest matching *8th Whelpe* dimension that of the bowsprit at 50.17 ft (15.30 m). This dimension was also used for *Warwick's* reconstructed foremast. The value was rounded down to the closest whole number because masts were shorter for ships destined for long voyages.[157] The diameter was calculated by dividing the length by 3, and rounding up to the nearest whole number, as masts were thicker for ships on long voyages, then taking this number

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[156] Barker 1994, 28; Manwaring and Perrin 1922, 186.
[157] All masts and yards were rounded to a whole number because 1) as noted earlier in this chapter, ship construction was not very precise and often varied from what was specified in its plan, therefore making the calculated number an approximation, and 2) the ship lists and treatises also rounded to whole numbers for their masts and yards in many instances, most likely for simplicity. For example, see Smith's proportions of masts and yards in Goell 1970, 18-9.

as the diameter of the mast in inches. The bowsprit and foremast are 50 ft (15.24 m) in length and 17 in (43.18 cm) in diameter. The lower fore and main masts were sometimes woolded (woulded), or bound with ropes, to strengthen them. [158]

Spritsail Yard

8th Whelpe from the ship list had a spritsail yard length of 27 ft (8.23 m) which is a little lower than the dimensions estimated from the treatises (34.14 to 50 ft [10.41 to 15.24 m], and a diameter of 5.7 to 8 in [14.50 cm to 20.32 cm]). Again, the slightly shorter length matches what is called for in ships being rigged for long voyages. According to treatises, the diameter is 0.5 in. for every 3 ft. of length, yielding 4.5 in. (11.43 cm.), that when rounded up, yields 5 in. (12.7 cm.). The spritsail yard is thus 27 ft (8.23 m.) in length and 5 in. (12.7 cm.) in diameter.

Spritsail Topsail Mast and Yard

The spritsail topsail was a distinctive rigging feature in the 17th century, but the date it first appeared is unclear. Anderson wrote that it was officially adopted in England in AD 1618, that it was in Dutch ships as early as AD 1600, and that small merchantmen probably did not have it in the early 17th century whereas on larger warships during the same time it was considered essential.[159] The sprit topmast is noted as prevalent from the late sixteenth century to about AD 1720 by Mondfeld, but a few pages earlier he includes a table listing dimensions for proportions of masts and yards, and the sprit topmast is not listed until AD 1630 on a French ship according to his chart.[160] Lees writes that the sprit topmast was introduced in AD 1611/1618.[161] Rahn Philips wrote that for Spanish ships, neither the 1618 shipbuilding ordinances held in the

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[158] Manwaring and Perrin 1922, 258.
[159] Anderson 1994, 210.
[160] Mondfeld 1989, 216, 226.
[161] Lees 1984, 158.

Naval Museum in Madrid, nor Martin Araña's (AD 1625) contract for the newest galleons being constructed at the time in Spain, mention the spritsail topsail. However, Rahn Philips states that by the time these new vessels were built and outfitted in AD 1628, the ships carried the spritsail topsail.[162] She provides evidence for the presence of this mast on slightly earlier Iberian ships by citing a sketch of a Guipuzcoan galleon dated to AD 1611 that has a spritsail topmast (see Figure 76).[163] Moore notes in his series on 17th-century rigging that it can be safely assumed that spritsail topsails were occasionally seen up to a decade earlier.[164]

Iconographical evidence presented in this thesis (Appendices F and G) indicates that English ships had the lowest incidence of spritsail topmast use (anywhere from 25%-50%, but probably on the lower end), whereas the Dutch (47% - 59%) and especially Spanish ships (50%-83%) had a greater likelihood of carrying it. The earliest appearance of the mast in the iconography included here dated to c. 1590 (see Figure 73, ship 6). However, the artwork surveyed is only a small sample and the number of wrecks from each nationality was not normalized, so the conclusion can only be applied generally, hinting that there was a lesser likelihood that English ships between AD 1608 and AD 1626 carried it (See Appendix G). Despite its comparatively early date, the 1593 Flemish votive model carries a spritsail topsail but represents a ship much larger than *Warwick*. The Newton Manuscript (c. 1600) does not mention the spritsail topmast, whereas it is listed in Mainwaring (1623) and *A Treatise on Shipbuilding* (1625), but surprisingly not in Smith (1627) (See Appendix D for details). However, in the two treatises that do mention the spritsail topmast, their detailed dimensions or ways to calculate

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[162] Rahn Philips 1986, 70-1.
[163] Rahn Philips 1986, 71.
[164] Moore 1912, 268-69.

them are not given, whereas most other masts and yards have ratios with which to calculate them, hinting that this element was not yet standardized. The ship list comparison indicates that prior to AD 1618 the spritsail topsail was not common on ships, (See Appendix E).

It is uncertain if *Warwick* had a spritsail topmast as its construction date coincides with the transition to the new head rig. However, the iconography, treatises, ship model, and ship list evidence presented in this thesis suggest that there is a lower likelihood *Warwick* carried it because the ship was built in 1617, a year before ship lists note the sail was officially adopted. The one English treatise prior to 1623 does not list it and iconographic evidence suggests an approximately 25% chance that *Warwick* had the sail. It was decided not to fit *Warwick's* reconstruction with a spritsail topmast and its corresponding spar and sail.

Fore Yard

8th Whelpe had a foreyard about 39 ft (11.89 m) in length, whereas the ship treatises indicate a length for ships of this size of between 45.53 to 57 ft (13.88 to 17.37 m.) with a diameter between 11.4 to 17 in. (29 to 43.18 cm). The thicker and shorter dimensions for yards on ships destined for long journeys applies here and as such, a 39 ft (11.89 m) long fore yard, although a little shorter than what is indicated in the treatises, is reasonable. Based on the ratio of a ¾ inch of diameter per every 3 ft. of length, the spar's diameter is 9.75 in., or 10 in. when rounded up (25.40 cm). *Warwick's* reconstructed fore yard is therefore 39 ft (11.89 m) in length and 10 in. (25.40 cm) in diameter.

Fore Topmast

The treatises all indicate that the fore topmast is half the length of the foremast, giving a range of between 22.05 to 28.8 ft (6.72 to 8.78 m) in length and a diameter of 7.35 to 9.6 in. (18.67 to 24.38 cm) in diameter. *8th Whelpe* had a fore topmast length of 28.5 ft (8.69 m) which falls within this range. Given that the foremast was determined to be 50 ft (15.24 m) in length and 17 in. (43.18 cm.) in diameter, these numbers halved yield a fore topmast of 25 ft (7.62 m) in length and 8.5 in., which rounds up to 9 in. (22.86 cm), in diameter.

Fore Topsail Yard

The fore topsail yard, similar to the topsail mast, is half the length of the yard below it. The halved length of the fore yard according to treatises yields a length of between 21.56 to 28.5 ft (6.57 to 8.69 m) and diameter between 5.39 to 7.5 in. (13.69 to 19.05 cm). *8th Whelpe* has a length of 19.5 ft (5.94 m) which is a little shorter than what is given in the treatises, assuming that shorter, thicker yards were also preferred. Given that the foreyard was determined to be 39 ft in length and 10 in. in diameter, these values halved yield a fore topsail yard length of 19.5 ft (rounded down to 19 ft [5.79 m]) and a diameter of 5 in. (12.70 cm).

Fore Topgallant Mast and Yard

The comparison of *Bear* in the ship lists (see Appendix E) shows that the fore topgallant mast and yard were not fitted until the 1618 reformation. Within the treatises, the topgallant is not mentioned in the Newton Manuscript, although it is listed in all other treatises. Interestingly, in Mainwaring's work most masts and yards have both a generic definition (i.e. mast, yard, topsail) and a specific listing for the specific mast, yard, or sail referred to (i.e. "The Mizen-mast. *Vide* Mast"). While the specific term is listed for many masts and yards, "Topgallant" is only listed as a generic dictionary term. When searching for Fore topgallant as an individual specific term, one can find "Fore-Mast. *Vide* Mast […] Fore-Sail. *Vide* Sail. Fore-Top-Mast. *Vide* Top-Mast. Fore-Yard. *Vide* Yard" but fore topgallant is omitted. Further, in several instances, details are given for the main masts and topmasts, but not for the topgallants—topgallant shrouds or puttocks are not mentioned, whereas the lower mast shrouds and topmast shrouds and chainplates are. Topgallant ties are not mentioned while the ties belonging to other masts are described in detail or specifically stated to have not existed (i.e. "The spritsail-yard hath none, for it is made fast with a pair of slings to the boltsprit").[165] When describing puttocks, Mainwaring states specifically that topmast shrouds only had puttocks if the topmast had a topgallant top, implying that ships only sometimes had this top. This hints that while topgallants were known at the time, there was no standardization or consistency for these components because they were just appearing.[166] Clowes notes that it is not until 1640 that topgallant sails were used on fore and main masts.[167] In addition to primary documents, even more striking is the fact that none of the English ships portrayed in the iconography carried topgallants. Although, the 1593 Flemish votive model does carry topgallants, the vessel depicted is larger than *Warwick*, so that even if this element is original from 1593 it may not have been applied to ships of smaller size. Evidence suggests that at least prior to 1618, fore topgallant sails were rarely seen and not standard on English ships. *Warwick*, an English ship built in 1617 and of 160 tons, most likely did not carry a fore topgallant mast and yard and therefore it was not included in the reconstruction.

Main Mast

The length of *8th Whelpe's* main mast is 71.67 ft (21.85 m), longer than what is found in the treatises—in all the other masts and yards *8th Whelpe's* dimensions were shorter than the proportions provided in the treatises. Ship treatises estimate a main mast between 55.2 to 67.16 ft (16.82 to 20.47 m) and a diameter of 18.4 to 22.4 in. (46.74 to 56.90 cm). Although in most

[165] Manwaring and Perrin 1922, 245.
[166] Manwaring and Perrin 1922, 204.
[167] Clowes 1931, 3-4.

cases the dimensions of the ship list of *8th Whelpe* within the ship list is used, in this case the length falls outside of the range in treatises. As noted earlier, vessels on long voyages often had thicker and shorter masts, therefore choosing to follow the dimension given in the ship list is unintuitive, even if it was what was truly fitted on *8th Whelpe*. Instead, the middle value of the range calculated from the treatises (61.18 ft, rounded down to 61 ft in length [18.59 m], and 20.4 in. in diameter, rounded up to 21 in. [53.34 cm]) will be used. The main mast is 61 ft (18.59 m) long and 21 in. (53.34 cm) in diameter.

Main Yard

The main yard on *8th Whelpe* in the ship list is 48 ft (14.63 m), whereas the length of this yard in the treatises is longer—between 60.71 to 63 ft (18.50 to 19.20 m.) with a diameter between 15.2 to 17 in. (38.61 to 43.18 cm). In this case as most others, the dimensions from the ship list will be used given the slightly smaller size which is more appropriate for *Warwick*. The main yard was 48 ft (14.63 m) long and 12 in. (30.48 cm) in diameter given 0.75 in. diameter/yard length.

Main Topmast

The main topmast on *8th Whelpe* is 35 ft (10.67 m), larger than the estimated length of 27.6 to 33.6 ft (8.41 to 10.24 m) and diameter of 9.2 to 11.2 in. (23.37 to 28.45 cm) within the treatises. Similar to the case of the main mast, the dimensions from the treatises were chosen instead of the ship list measurement; the middle of the range within treatises of 30.6 ft (rounded down to 30 ft [9.14 m.]) and diameter of 10 in. (25.4 cm) will be used. The main topmast is 30 ft (9.14 m) long and 10 in. (25.4 cm) in diameter.

Main Topsail Yard

The ship treatises indicate a length of 26.95 ft (8.21 m) and diameter of 6.74 in. (17.12 cm) whereas the ship list give a main topsail yard of 24 ft (7.32 m.). The ship list measurement is used, making this yard 24 ft (7.32 m) in length and 6 in. (15.24 cm) in diameter.

Main Topgallant Mast and Yard

Similar to the fore topgallant mast and yard, most evidence points to a lack of these spars and sails. Curiously, in *A Sea Grammar* (1627) a main topgallant yard is listed and a dimension given, but the main topgallant mast is omitted. The main topgallant mast must have existed if the yard belonging to it did. Main topgallant masts are included in the 1618 reformation ship list, but treatises do not mention this mast or yard until after 1623, and while the iconography pattern is a little different (instead of a 0% appearance of the fore topgallant, the percentage of the main topgallant mast and yard is 25% in English ships). *Warwick*, built in 1617, probably did not carry a main topgallant mast and yard and so it was not included in the reconstruction.

Mizzen Mast

The *8th Whelpe* mizzen mast in the ship lists is 46.5 ft long, approximately twice the length noted in the ship treatises (27.6 ft and 9.2 in. [8.41 m and 23.37 cm] in diameter). According to Howard, the length and placement of the mizzen mast during this period was uncertain because it was sometimes stepped in the hold and sometimes on the lower deck, but in general it needed to be level at about half way up the fore masthead.[168] The main mast was already established as 61 ft (18.59 m.) long and 21 in. (53.34 cm) in diameter, which when halved, according to treatises, yields 30.5 ft (9.30 m) in length and 10.5 in. (26.67 cm) in

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[168] Howard 1979, 126.

diameter (rounded to 30 ft [9.14 m] in length and 11 in. [27.94 cm] in diameter). Given its small size, and Howard's recommendation that the mizzen mast needs to be approximately level to the halfway points of the fore mast head, it was likely stepped on the lower deck rather than on the keelson to raise it to this level.

Mizzen Yard

Treatises indicate a mizzen yard between 30 and 45.53 ft (9.14 to 13.88 m) in length with a diameter of 5 to 7.6 in. (12.7 to 19.30 cm). *8th Whelpe* had a mizzen yard 37.5 ft (11.43 m) long. Although a yard of 37.5 ft falls within the range in the treatises, treatise instructions note that the mizzen yard is the same length as the fore yard (39 ft [11.89 m.]) in the Newton Manuscript, but the same length as the mizzen mast in *A Sea Grammar* (30 ft [9.14 m]). In this case, the shorter length will be used, yielding a mizzen yard length of 30 ft (9.14 m) and a diameter of 5 in (12.7 cm).

Mizzen Topmast

Treatises indicate that mizzen topmasts existed during the early 17th century, but inconsistently so. While the latter three treatises dated from 1623 and onward mention the mast, only Mainwaring gives dimensions, hinting that mizzen topmasts were not standard on ships. The Newton Manuscript (c. 1600) does not list the mast, although it is specific in describing all others. Iconographic analysis indicates that about 75% to 100% of the ships (most likely closer to the lower percentage) carried the mast. The ship lists indicate that in 1618, ships had this mast added. In short, while the treatises and ship lists are unclear if ships just prior to 1618 carried the mast, the iconography indicates that ships likely carried this mast. The mizzen topmast is said to be half the length of the mizzen mast making it 15 ft (4.57 m) long and 6 in. (15.24 cm.) thick (rounded up from 5.5 in.).

Mizzen Topsail Yard

Evidence suggests that while the mizzen topsail yard was known at the time and occasionally used, it was often removed even if the mizzen topmast was fitted. In iconography at least 75% of the English ships carried this mast, but of these same ships, only 13% to 50% (most likely the latter percentage) carried the mizzen topsail yard. Analysis of iconography from all nationalities, shows that 80% (to 90% at highest) of ships carried a mizzen topmast, while only 32% (to 48% at highest) of these displayed a mizzen topsail yard. The Newton Manuscript (c.1600) does not mention the mizzen topsail yard at all, and the two later treatises (of 1625 and D 1627) list them, but without giving dimensions. Mention of the mizzen topsail yard is also omitted from Mainwaring's dictionary, but the mizzen topmast is listed. Ship lists further confirm that prior to 1618 naval ships were not yet required to carry this yard. Although it is counterintuitive to have a mast without a corresponding yard, this seems to have been common during the first quarter of the century. *Warwick's* reconstruction was therefore not fitted with a mizzen topsail yard.

Crossjack Yard

All the treatises except for the Newton Manuscript mention the crossjack yard. This yard was used to spread the bottom of the mizzen topsail and has the same dimensions as the spritsail yard (although the diameter is smaller).[169] However, ship lists indicate that crossjack yards were

[169] Manwaring and Perrin 1922, 259; "Cross-jack is a yard at the upper end of the mizen mast under the top and there is slung, having no halliards nor ties belonging to it; the use whereof is to spread and haul on the mizen-topsail sheets." Manwaring and Perrin 1922, 135; "The Crosse Jacke hath no saile it serves only to spreade the Misson Topsaile and is slonge fast to the misson mast with a rope and hath Braces 2 they ar single ropes fastened to ether arme of the Crosse Jacke and so goe from ether side to the aftermost Timber on the Poupe and are belayed ther." Salisbury and Anderson 1958, 60; "Crossejacke Yard and Spretsaile Yard to be of a [equal] length. [Spretsaile Yard 1/2 inch of thicknesse to a yard in length]." Goell 1970, 20.

uncommon prior to AD 1618 and rarely appear in the iconography (Appendix H). Given that *Warwick* was built in AD 1617, it is more likely that *Warwick* did not have a crossjack yard as implied by the Newton Manuscript, ship lists (masts and yards prior to 1618), and iconography. Howard notes that the crossjack yard was fitted permanently aloft by 1620.[170] As *Warwick* was built just prior to when this yard became common, a crossjack yard is not included in *Warwick's* rigging reconstruction.

Bonaventure Mast

Bonaventure masts were uncommon by the early 17th century. *8th Whelpe* in the ship lists does not mention a bonaventure, nor does the Newton Manuscript, and the other three treatises specifically note that only large ships have this fourth mast.[171] By AD 1640, it appears that even large ships no longer carried a bonaventure as *The Lengths of Masts and Yards* does not mention these masts being fitted on even the largest ships within the fleet. The ship models of *Sovereign* (1637) and *Couronne* (1638) have a single mizzen and were substantial ships, further confirming that by second quarter of the 17th century this mast had disappeared.[172] Anderson noted that bonaventure mizzens were fitted up to AD 1620 (generally on larger ships) but not after AD

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[170] Howard 1979, 139.

[171] "Some great long ships require two mizens, then they call that next the mainmast, the main-mizen; that next the poop, the bonaventure mizen." Manwaring and Perrin 1922, 188; "Somme ships have 2 missons ether in regard of their length or qualeties, when in regard of length it is for handsomnes because to such distance betewene masts is unseemly. In regard of ther qualety is when a ship will not keepe the winde and that her head falles of, which is incident to all ships hie built or which have those sails which flatts of the head of the ship (which ar those of her ffore masts and spritsayles) stronger then those of her Mayne mast and Misson, which ar the sayles which keepes the heade of a ship to the winde. sometymes we geve a ship 2 Missons to keepe her head to the winde when she hulles to the ende that she may ride easely on the waves, and not lie tumbling in the trough of the sea betweene 2 billowes. When a ship hath 2 missons the former is called the Mayne, the other the Bonaventure Misson." Salisbury and Anderson 1958, 47; "In great ships they have two Misens, the latter is called the Bonaventure Misen." Goell 1970, 21.

[172] Anderson 1994, 8.

1630.[173] Howard wrote that bonaventure masts disappeared after AD 1625 but show up in rigging lists until AD 1640.[174] Lees wrote that by AD 1640 no ships had more than three masts.[175] Overall the evidence suggests that an average to small ship built in 1617 did not have a bonaventure, therefore, *Warwick's* reconstruction was not provided with this mast.

Mast and Yard Tapering

Except for a brief example of the proportions for mast and yard tapering in the Newton Manuscript, the primary sources cited do not mention rules or proportions for the tapering of masts and yards.[176] Only secondary sources—Lees, Howard, Anderson, and Mondfeld—provide proportions for the tapering of masts and yards during the early 17th century, along with the dimensions for other details mentioned, which are included in Table 16.[177]

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[173] Anderson 1994, 8.
[174] Howard 1979, 126.
[175] Lees 1984, 158.
[176] Barker 1994, 28.
[177] Anderson (1994, 20-21) primarily used later treatises from the late 17th century and early 18th century to determine rough estimates of tapering for the early 17th century. These later sources include treatises by William Keltridge (1675), Edward Battine (1689), and Cornelis van Yk (1697). Howard (1979, 125-31) and Lees (1984, 2-18) do not list the sources used to determine their tapering proportions, but some of the dates they indicate tapering modifications suggests that they used similar sources as Anderson to determine tapering proportions for the early 17th century. Mondfeld (1989, 218) does not provide the source of his tapering proportions. Of all secondary sources provided, Lees (1984, 2-18) gives the clearest description of tapering dimensions, which is the reason it was chosen as the main source used to calculate *Warwick's* spar tapering.

	Length (ft)	Head (in)	Hounds Length (in)	Diameter at Partners	Diameter at Heel (in)	Diameter at 1st Quarter	Diameter at 2nd Quarter	Diameter at 3rd Quarter	Diameter at Hounds (in)	Diameter at Head (in)	Cap Length (ft)	Cap Width (ft)	Cap Breadth (ft)	
Bowsprit	50			17	12.8	16.5				8.5				
Fore mast	50	62.5	41.7	17	14.2	16.6	15.9	14.2	11.8	9.7	3.2	1.6	0.8	
Main mast	61	76.25	50.8	21	17.5	20.5	19.6	17.5	14.5	12	4	2	1	
Mizzen mast	30	37.5	25.0	11	9.2	10.7	10.3	9.2	7.6	6.3	2.1	1	0.5	
	Length (ft)	**Head (ft)**	**Heel (ft)**	**Hounds (ft)**	**Diameter at lower cap to Heel (in)**	**Diameter of Lower Part of Head (in)**	**Diameter of Upper part of Head (in)**	**Diameter of Top (ft)**						
Fore Topmast	25	2.5	4	1.25	9	6.3	4.95	7						
Main topmast	30	3	4	1.5	10	7	5.5	8.7						
Mizzen topmast	15	1.5	44	0.75	6	4.2	3.3	4.05						
	Length (ft)	**Yard Arm Length (ft)**	**Yard Arm Cleats Length (in)**	**Yard Arm Cleats Breadth (in)**	**Yard Arm Cleats Thickness (in)**	**Taper at Yard Arm (in)**	**Diameter at Slings (in)**	**Sling Cleat Length (ft)**	**Sling Cleat Shoulder (ft)**	**Sling Cleat Breadth (ft)**	**Sling Cleat Depth (ft)**	**Gap Between Sling Cleats (ft)**		
Spritsail yard	27	1.125	3.75	0.9375	0.703125	2.5	5	1.35	0.45	0.3375	0.225	1.25		
Fore yard	39	1.6	5	1.25	0.8	3.3	10	2.0	0.7	0.5	0.3	2.5		
Fore topsail yard	19	0.8	3.8	0.9	0.7	2.5	5	1.0	0.3	0.2	0.2	1.25		
Main yard	48	2	6	1.5	1	4	12	2.4	0.8	0.6	0.4	3		
Main topsail yard	24	1	4.5	1.1	0.8	3	6	1.2	0.4	0.3	0.2	1.5		
	Length (ft)	**Lower Yard Arm Length (ft)**	**Diameter of Lower Arm (in)**	**Upper Yard Arm Length (ft)**	**Diameter of Upper Arm (in)**	**Yard Arm Cleats Length (in)**	**Yard Arm Cleats Breadth (in)**	**Yard Arm Cleats Thickness (in)**	**Diameter at Slings (in)**	**Sling Cleat Length (ft)**	**Sling Cleat Shoulder (ft)**	**Sling Cleat Breadth (ft)**	**Sling Cleat Depth (ft)**	**Gap Between Sling Cleats (ft)**
Mizzen yard	30	0.5	2.5	0.4	3.3	3.75	0.9	0.7	5	1.5	0.5	0.4	0.3	1.25

Table 16: Tapering dimensions of masts and yards and associated parts (Table by author, created using ratios from Lees 1984, 2-18).

Mast and Yard Configuration

Equally important to which masts and yards were on *Warwick* is understanding how they connected to the ship's hull and to each other. What follows is a summary of mast and yard configurations.

Masts

Mast configuration

The heels of the lower masts are secured to the bottom of the hull by a mast step.[178] According to *A Sea Grammar*: "These Masts have each their steps in the Ship, and their Partners at every Decke, where thorow they passe to the Keele; [these] being strong timbers bolted to the Beams, incircling the Masts to keep them steady in their steps, fast wedged for rowling [rolling].[…] Their Cotes are peeces of tarred canvas, or a Tar-pawling, put about them and the Rudder to keepe the water out."[179] In addition to the partners, wedges of wood were used "[…]to make fast the mast in the partners [the framework that held the mast at each deck] with wedges."[180] The bottom of each lower mast was slanted so that the mast can be steadied or stayed aftward.[181] Although masts rarely survive on shipwrecks, archaeological examples of mast steps have been discovered on *Mary Rose* (1545), the Emanuel Point Wrecks I and II (1559), *San Juan de Pasajes* (1565), the Fuxa Wreck (1590), *Vasa* (1628), *Swan* (1653), *La Belle*

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[178] "They call that piece of timber which is made fast to the keelson, wherein the main-mast doth stand, a step. Also those places and timber wherein the mizzen-mast, foremast, and the capstans do stand, are called steps." Manwaring and Perrin 1922, 236.
[179] Goell 1970, 19; Manwaring and Perrin 1922, 128.
[180] Manwaring and Perrin 1922, 255.
[181] "The heel of the mainmast, foremast, or mizzen is nothing but that part which is pared away a little, slanting on the aftward side of the foot of the mast, like a heel, to give the mast leave to be stayed aftward on; as the Flemings do especially. But the heels of the topmasts are square, and in that they put the fid of the topmast." Manwaring and Perrin 1922, 163.

(1686), and *Santo Antonio de Tanna* (1697).[182] *Warwick's* mast step likely looked something like that of the Duarte Castle Wreck, *Swan* (1653) given similarity in nationality and closeness in tonnage (Figure 92).[183]

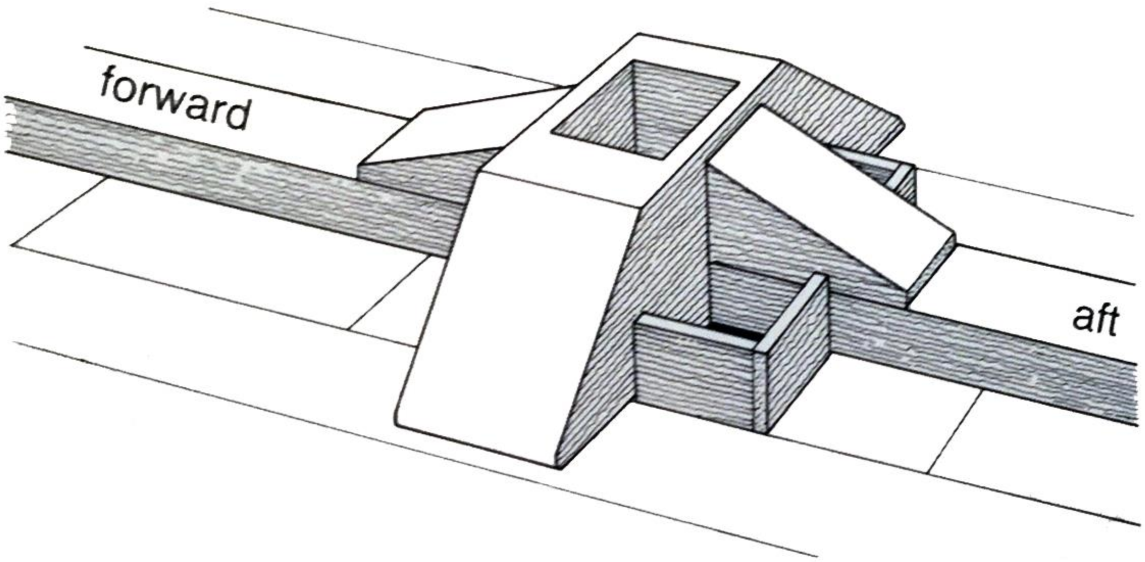

Figure 92: Reconstruction of *Swan's* (1653) saddle-type mast step. Chocks can be seen on top of the keelson reinforcing it longitudinally, while the box features aft the pump wells. Removable limber-boards are fitted on either side of the keelson (Martin 2017, 103).

As for mast wedges and partners, one example of mast wedges, in iconography can be found in Figure 93, but its details are unclear given its quality. Mast partners have been found on *Mary Rose* (1545), *Mars* (1564), and *Vasa* (1628).[184] Figure 94 gives a detailed view of how mast partners and coats appeared and Figure 95 shows the cross section of the deck where the

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[182] Marsden 2009, 244-45; Charles Bendig and John Bratten, personal communication, December 3, 2015; Smith et al. 1995, 26-7; Grenier et al. 2007, IV-32 to IV-33; Pérez and Sansón 1992, Fig 2a. Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; Martin 2017, 102-3; Corder 2007, 71; Thompson 1988, 4.
[183] Martin 2017, 102-3.
[184] Marsden 2009, 243-44; Eriksson and Rönnby 2017, 100.

mast passed through. These are not shown in *Warwick's* reconstruction as they are below deck or obscured by the rail in the rig profile.

Figure 93: A magnified view of *Ships off Ijselmonde* by Aert Anthonisz (1579-1620) showing the mast coat. Painted 1617. Object number: SK-A-1446. Painting. Retrieved from: https://www.rijksmuseum.nl/en/collection/SK-A-1446: Rijksmuseum, Amsterdam.

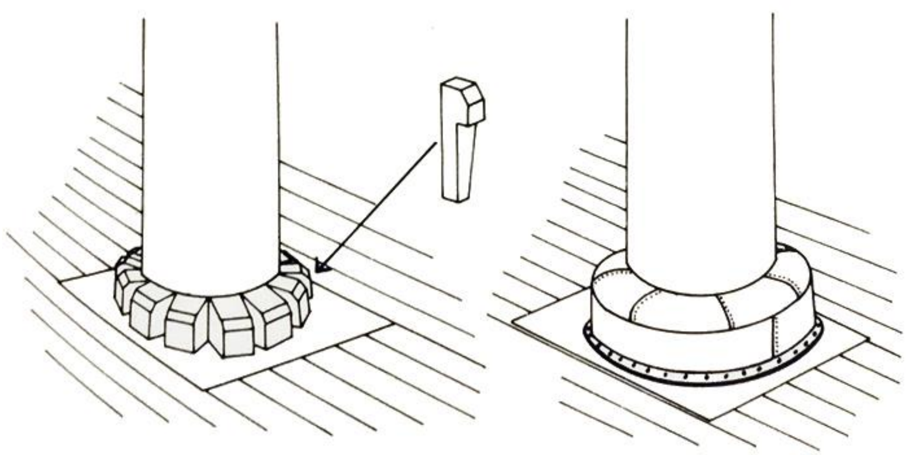

Figure 94: Mast partners at deck: Left, ring of partners, right, mast coat (Mondfeld 1989, 219).

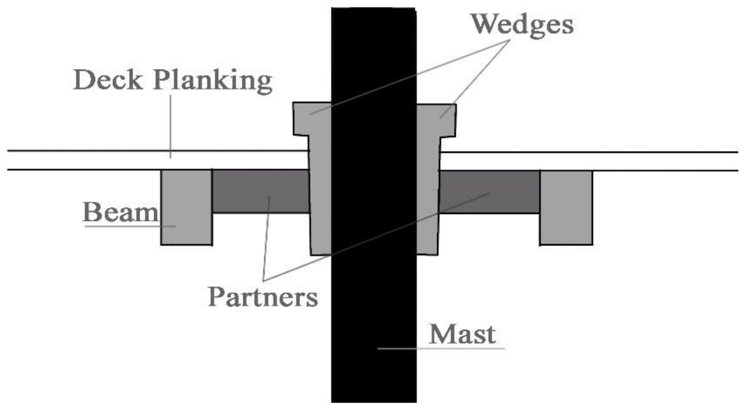

Figure 95: A cross section of the deck at the mast showing where the partners and wedges were placed to hold the mast in place. (Image by author)

The bowsprit is not stepped like a mast as it lies horizontal with its heel with its heel (the after end) fitted to a step-like vertical post, its lower central portion rakes upward from the timber called the pillow (close by the stem) and fixed to the ship's beakhead through multiple turns of a rope called gammoning (also called wouldings of the bowsprit).[185]

Fore, main, and mizzen masts can be assembled with anywhere from one to three separate masts (lower masts, top masts, and topgallant masts if they were present). Each individual section of mast supported its own yard. Each mast section was joined to the next at its head [the upper portion of the mast], overlapping with the next mast's heel [bottom portion of the mast] at what was called the doublings.

At the top of every mast doubling was a mast cap, a rectangular timber that had a round hole in it for the topmast attachment (or flag staff), placed forward of the lower mast's head.[186] The head had to be long enough so that the cap was not too close to the heel of the upper mast,

[185] Goell 1970, 20; Manwaring and Perrin 1922, 258.
[186] Manwaring and Perrin 1922, 115-16; Goell 1970, 19.

because otherwise the upper mast would be unstable.[187] Just below the mast heads were cheeks, or wooden clamps, that contain hounds with wheels, or sheaves, for the ropes (called ties) to list the yard (Figure 96). The main and fore mast had two hounds, but the topmasts had only one (Figure 97).[188] The topmasts heels are square so that a fid can be put in, on top of which sat trestletrees.[189] Lees notes that the fid hole had to be cut through the heel athwartships about halfway up the heeling, and that the height of the hole was approximately one third of the diameter of the topmast, and about one quarter of the diameter in width.[190] Fitted above the hounds at the top of each lower mast was a framework of bolted-together crosstrees and trestletrees, forming a simple grid pattern to fit around the lower mast head and upper mast heel. Their purpose is to hold up the topmast, given that the heel of the topmast placed between the trestletrees and secured in place by a transverse key called a fid.[191] Mainwaring wrote that a general term for the entire configuration of trestletrees (sometimes spelled chesstrees) and crosstrees, was simply called crosstrees, but that to be precise the crosstrees are perpendicular to the axis of the ship, whereas trestletrees are placed along the longitudinal axis.[192] Trestletrees and crosstrees were also used for the attachments of the shrouds.[193] Above the trestletrees and

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[187] Manwaring and Perrin 1922, 116; Goell 1970, 19.
[188] Goell 1970, 19; Manwaring and Perrin 1922, 125.
[189] "The heel of the mainmast, foremast, or mizen is nothing but that part which is pared away a little, slanting on the aftward side of the foot of the mast, like a heel, to give the mast leave to be stayed aftward on […] But the heels of the topmasts are square, and in that they put the fid of the topmast." Manwaring and Perrin 1922, 163; The author believes the wedge mentioned in the following also refers to the fid: "[…]and also to put a wedge into the heels of the topmasts, to bear up the topmast upon the trestle-trees." Manwaring and Perrin 1922, 255.
[190] Lees 1984, 5.
[191] Manwaring and Perrin 1922, 135.
[192] Manwaring and Perrin 1922, 135, 248; Goell 1970, 19-20.
[193] Salisbury and Anderson 1958, 48; Note also Grenier et al. 2007, IV-42 to IV-44 that reported the Basque Whaler ship *San Juan* (1565) was found with two possible trestletrees within its assemblage.

crosstrees was the top, which was fitted only for masts that had another mast or flag staff above it.[194]

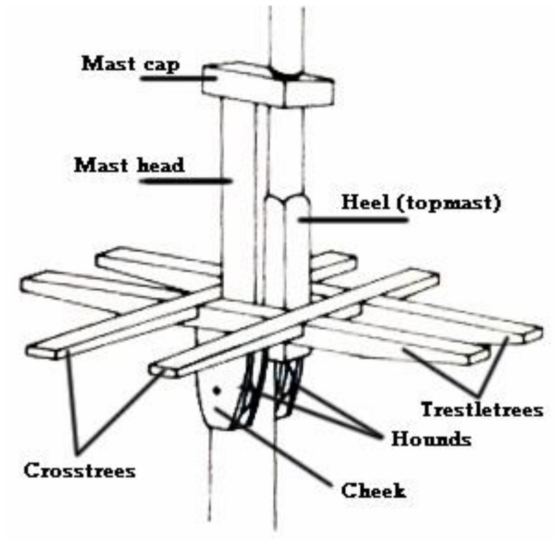

Figure 96: A labeled diagram of a 17th century lower and top mast doubling. The fid in the topmast and sheave for top ropes is not shown here but in Figure 97. (After Mondfeld 1989, 219).

[194] Manwaring and Perrin 1922, 135; Goell 1970, 19-20.

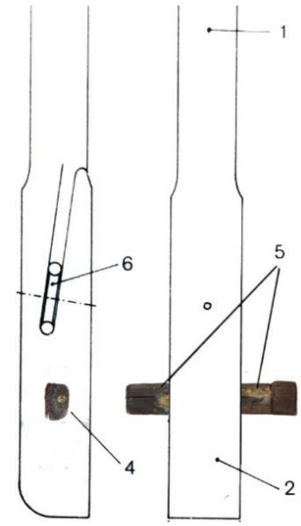

Figure 97: The configuration of a topmast heel from the 16th and 17th centuries. 1. Topmast; 2. Topmast heel;3. Iron hoop; 4. Fid hole; 5. Fid (fid shown is the one from *Warwick*); 6. Sheaves for top ropes. (After Mondfeld 1989, 225)

Rake of the Masts

The rake, or angle off of the vertical, of the fore, main, and mizzen masts appears to have varied greatly; sources only give vague instructions regarding mast placement. Smith noted that all masts except for the bowsprit are upright.[195] Mainwaring wrote that short deep ships (such as *Warwick*) sail better with upright masts, whereas long shallow ships needed their masts to be raked further aft. [196] *A Treatise on Rigging* indicates that the main mast leans aft because it

[195] Goell 1970, 20.
[196] "There is much difference in staying of masts, in respect of a ship's sailing or working. Generally, the more aft the masts hang, the more a ship will keep in the wind; and the forwarder, the less. The Flemings stay their masts much aft, because else their ships, being long floaty ships, would never keep a wind; but short and deep ships rather covet upright masts." Manwaring and Perrin 1922, 235; Also note that the Flemish specialized in large, flat-bottomed ships during this time according to Rahn Philips (1986, 40). Bojakowski and Custer-Bojakowski 2017, 296-99.

prevents the forward area of the ship from being too heavy and plunging into the sea, and allows the ship to sail closer to the wind.[197]

Among more recent secondary sources on rigging, Anderson states that the rakes of masts are uncertain, but that the foremast is generally vertical (or sometimes raked forward), the mainmast is slightly raked aft, and the mizzen raked even more, but he does not provide any set rules or angle degrees.[198] Howard wrote that the foremast leaned a little forward but sometimes it was vertical, that the mainmast leaned aft as much as 1/25 of its length, but was sometimes vertical, and that the mizzen was always sloped backwards but slightly greater than the mainmast.[199]

The bowsprit, given that it is a horizontally-oriented spar, was always at an angle, known as the steeve, but like the other masts, no set angle was specified. Anderson wrote that the angle is normally defined by the height of the figurehead and as examples states that the English warship *Sovereign's* bowsprit was 24º, the English ship designer Deane's plans had a 30º angle, a Dutch-built French ship dated to AD 1626 had an angle of 20º, the *Prins Willem* model (1651) had a rake of 28º, the Swedish ship model *Amarant* (1653) was raked at 33º, and several Dutch models dated to 1665 have bowsprits raked at 40º.[200] During this time it appears that English ships had their bowsprits to one side of the stem (normally starboard), rather than atop the stem and sternpost.[201] This feature was not noted in treatises and was a trend noticed primarily in ship

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[197] Salisbury and Anderson 1958, 62.
[198] Anderson 1994, 13.
[199] Howard 1979, 127.
[200] Anderson 1994, 14.
[201] Howard 1979, 128; Anderson 1994, 10.

models. *Warwick* likely had an angle of steeve between 20 to 40º, and when observed from a plan view, the bowsprit may have been placed slightly starboard.

Matthew Baker’s *Fragments of Ancient English Shipwrightry,* written c. 1570, shows outlines of the masts. When the lines for the bowsprit and foremast are extended into the hull, the angle where the lines intersect indicates the bowsprit had a 40º angle from the keel, and the foremast had a 46º angle from the bowsprit. The mizzen mast is 90º from the keel (Figure 98).

Figure 98: Matthew Baker’s *Fragments of Ancient English Shipwrightry*, written c. 1570.

In this thesis, the rakes of the masts are taken from Baker given that his manuscript is one of the few English treatises that shows the rake of masts which are believed to have been added around c. 1610, about four decades after and coinciding approximately with *Warwick*[202]—the other treatises included did not have an image that provided this information. *Warwick’s* reconstruction has a bowsprit with a 40º angle of steeve, a slightly raked forward foremast (39º from keel), and a slightly raked backwards main mast, and even further raked mizzen mast.

[202] Hocker, personal communication, December 17, 2013.

Mast Placement

The placement of the masts themselves is unclear during this period and appears to have differed greatly from ship to ship. Mondfeld wrote that the main mast was located at the mid length of the keel, or mid length of the main deck, that the fore mast was located 1/3 of the length between the forward end of the keel and the fore side of the stem prior to 1630, and that the foremast was in front of the beakhead bulkhead.[203] Howard states that the mainmast was just in forward of amidships at the beginning of the century, the foremast was 1/3 of the length between the end of the keel and the stem, whereas the mizzen mast moved forward to about half way between the taffrail and the mainmast.[204]

Warwick's main mast step placement is thought to be indicated by a construction mark located 2.5 m. abaft of the midship frame (Figure 99), going against what was previously thought (main mast step placed directly in the center or slightly forward of amidships).[205] *Warwick's* proposed main mast step placement puts it only 9 m. forward of the sternpost, which when given yields a ratio of 0.39 (length from sternpost to mast step (9 m.): length of keel (23 m.). For comparison, although slightly smaller than *Warwick*, the Duart Castle wreck (*Swan*) is close in size (keel 18.25 m. [59.88 ft.] in length, beam 7.6 m. [24.93 ft.], depth in hold 2.4 m. [7.87 ft.], and between 120-133.5 tons depending on how tonnage is calculated), it was a three-masted ship like *Warwick*. Its main mast step was 9.5 m forward of the keel's after end, placing it 0.75 m. (2.5 ft.) forward of amidships. The ratio of *Swan's* mainmast placement (from the back of the keel to the main mast step: keel length) is 0.52, agreeing with what previous researchers suggest.

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[203] Mondfeld 1989, 218.
[204] Howard 1979, 127.
[205] Bojakowski and Custer-Bojakowski 2017, 290-91.

The author's personal opinion is that *Warwick's* proposed mast placement according to the construction mark is too far aft (ratio of .39 as opposed to Duart Point wreck's ratio of .52) and that it was actually placed forward at amidships. As noted in the previous paragraph, the majority of sources indicate the amidships (or slightly forward) main mast placement was more common. Further, when a draft of the rig plan was created using the construction mark as *Warwick's* mainmast position, the fore and main masts were separated by too great a distance, while the mizzen mast and main mast were too close to each other and too far abaft. This placement of the masts would result in an unbalanced vessel that was stern-heavy and steered badly; in addition to poor sailing ability, this could increase hogging. Rather, if the main mast was placed amidships, and the mizzen mast is placed at the halfway point between the main mast and taffrail, the construction mark indicates where the mizzen mast would have been placed. Based on this line of evidence, the mast step in this reconstruction was not placed as far aft as previously suggested and was placed amidships, while the mizzen mast was placed near the construction mark.

The fore mast was one third of the length between the forward end of the keel and the stem as noted by previous researchers, the main mast placed approximately amidships, and the mizzen mast was stepped at the halfway point between the taffrail and the mainmast.[206]

[206] Mondfeld 1989, 218; See also Anderson 1958, 9-10. Anderson primarily uses ship models, for example, the Danish *Norske Löve* ship model (that had a mizzen just under the halfway point between mainmast and taffrail) to speculate where masts were positioned.

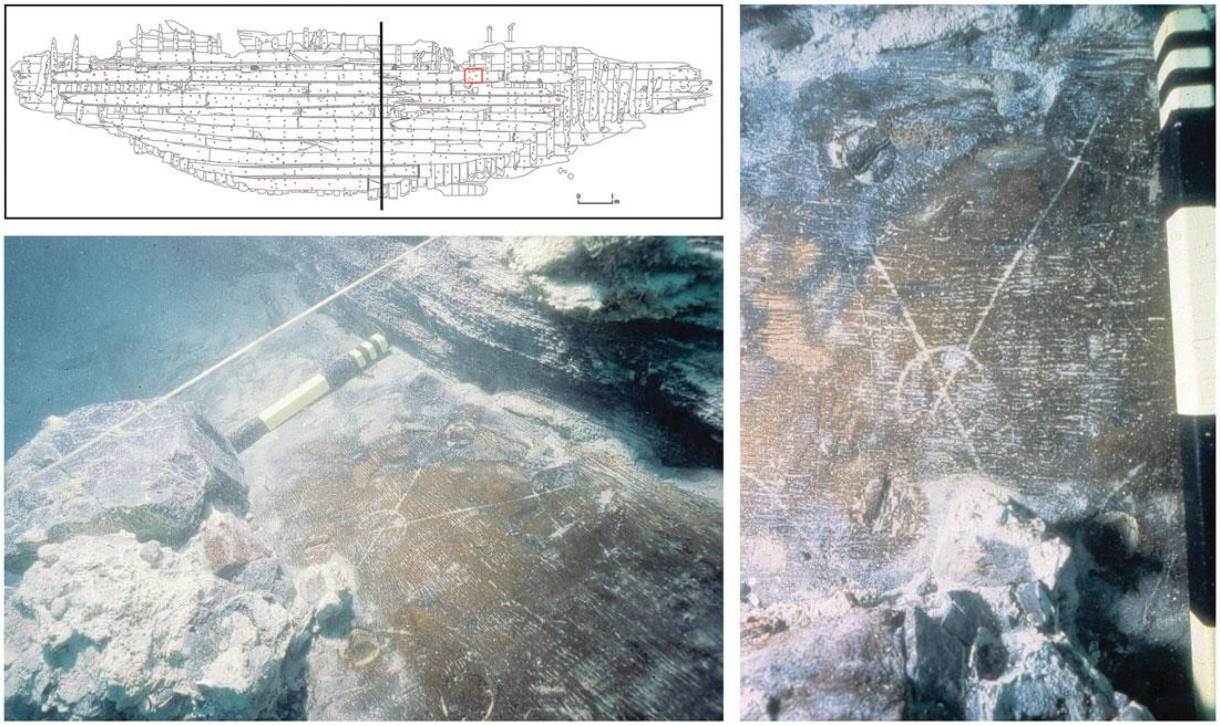

Figure 99: Construction mark carved on a shelf clamp; inset showing a site plan with the location of the mark in relation to the midship (indicated with a black line) (Illustration: P. Bojakowski; Photo: J. Adams; from Bojakowski and Custer-Bojakowski 2017, 291).

Yards

Yard configuration

Lower and top mast yards were fastened to their masts using parrels which were attached to the mast through a breast rope or truss.[207] Parrels are made of two components: trucks (small round wooden balls) and ribs (thin pieces of wood with holes through them) (Figure 100). A rope

[207] "Breast-ropes are the ropes which make fast the parrel to the yard." Manwaring and Perrin 1922, 110; "Trusses are ropes which are made fast to the parrell of the yard, and are used to two purposes: one to bind fast the yard to the mast when she rolls either a-hull or at an anchor the other is to haul down the yard in a storm or gust. These belong only to the main-yard and fore-yard, and they are brought-to but upon occasion; and also to the mizzen, which hath ever a truss." Manwaring and Perrin 1922, 249-250; "The Truss is fastened to the middle of the mayne yearde betwene the Parell with a tymber hitch and from thence goes through a blocke fastened to the mayne mast close to the middle decke and so to the [capstan] when you will use him […] The Trusse serves to heave downe the yeard." Salisbury and Anderson 1958, 51-2.

was run through the holes in the trucks and ribs to make a parrel assembly.[208] While an artifact labeled a "mast truck" was found on *Warwick*, it is not the same kind of mast truck described here, and probably had a different purpose. Parrels, or parts of parrels (ribs or trucks separately), have been found on *Mary Rose* (1545), Scheurrak SO1 (1593), *San Pedro* (1596), New Old Spaniard (1620-1640), *Vasa* (1628), *Stora Sofia* (1645), *Swan* (1653), *Avondster* (1659), *La Belle* (1686), and *Dartmouth* (1690).[209] All appear similar in form but had slight differences in size. Parrels normally had four to two rows depending on the size of the yard. Lees wrote that lower yards had three rows of trucks, whereas upper yards had two.[210] All yards had parrels except for the crossjack yard that attached to the mizzen mast using a sling rather than parrels according to *The Seamen's Dictionary* and *A Treatise on Rigging*.[211]

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[208] "Parrels are those things made of trucks and ribs and ropes, which go about the mast and are at both ends made fast to the yards; and are so made with trucks and ribs, that the yard may slide up easily. These also, with the breast rope, do hold the yard close to the mast." Manwaring and Perrin 1922, 195; "The Parrell, is framed of a Rope, Truckes and Ribs or sisters the rope goeth 3 tymes losely about the mast, and hath the Trucks and ribbs laced on the Truckes through on hole, the Ribbs through 3 holes, the Parrell rope is fastened to the yeard in ether side the mast in 3 partes or boules at ether fasteninge which make in both fastenings 6 partes and from thence is fastened on the Ribbes of the parrell in 2 notches called brookes in 6 parts more." Salisbury and Anderson 1958, 49; "The Parrell fastens the yeard to the mast." Salisbury and Anderson 1958, 52; "Truckes Ribbes or sisters: they serve to put on all parrell ropes of mastes and Truckes ar placed in divers pts to carrie som ropes to a knowen place to ende men may reddely finde them." Salisbury and Anderson 1958, 61; "Parrels are litttle round Balls called Trucks, and little peeces of wood called ribs, and ropes which doe incircle the Masts; and so made fast to the Yards that the Yards may slip up and downe easily upon the Masts, and with the helpe of the Brest-rope, doth keepe the Yard close to the Mast." Goell 1970, 24.

[209] Marsden 2009, 258-260; Data Archiving and Networked Services, Scheurrak SO1 Project; National Museum of Bermuda 2015; Watts 2014, 110; Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet; Bohusläns museum/Studio Västsvensk konservering and Bergstrand and Arbin 2003, appendix; Martin 2017, 132-37; Canmore, National Record of the Historic Environment. Swan: Duart Point, Sound of Mull; Parthesius et al. 2003, 26 and 69; Corder 2007, 42-3; Martin 1978, 35; Canmore, National Record of the Historic Environment. Dartmouth: Eilean Rubha An Ridire, Sound of Mull.

[210] Lees 1984, 168.

[211] Manwaring and Perrin 1922, 135; Salisbury and Anderson 1958, 60.

Figure 100: Parrel truck and rib from *Swan* (Martin 2017, DP00-140).

In addition to parrels, yards had various cleats (small wooden wedges), or other similar parts that helped secure rigging to it and keep ropes from slipping. [212] Mondfeld wrote that between 1530 to 1660, sling cleats were introduced.[213] Howard wrote that ships of this period had two pairs of yard arm cleats, a pair of sling cleats, and two roband strips per yard.[214] Howard states that chocks were at the ends of the yardarms as early as 1623, and that in the middle of the yards were cleats to hold the tie, jeer blocks and parrel-rope in place.[215] Sling cleats were used to keep the yard in place and prevent it from falling in case the ties came loose.[216] Further, ties, jeer blocks, and various other rigging also attached to the sling cleats. Yard arms also had cleats which were used for the lifts, braces, and other ropes used to maneuver the yard. *Warwick's*

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[212] "A Cleat is a small wedge of wood fastened on the yards to keep any ropes from slipping by where that is fastened. There are also divers other uses of it, as to keep the earing of the sail from slipping off the yard." Manwaring and Perrin. 1922, 126.
[213] Mondfeld 1989, 230.
[214] Lees 1984, 13-4.
[215] Howard 1979, 131.
[216] "[…] any rope or chain wherewith we bind fast the yards aloft to the cross-trees and the head of the mast, to the end that if the ties should break the yard may not come down. These are called slings, which are chiefly used when we come to fight, for fear of cutting the ties." Manwaring and Perrin 1922, 228.

reconstructed yards have sling cleats and yard arm cleats. The rigging attached to yards' various cleats is covered in Chapter 7.

In addition to cleats, other rigging on yards include grommets, staples, and chaffing gear.[217] Grommets are little rings which are attached to the upper side of the yard, with staples which are driven into the yard, for gaskets to attach.[218] Grommets have gaskets, or small ropes, attached to them that help bind furled sails.[219] Chafing gear was also added to prevent the masts, yards, and various other rigging elements from rubbing and damaging each other, such as mats that were added to prevent masts and yards from galling.[220] Three examples of what are believed to be mats can be found in *San Juan* (1565).[221] Grommets, staples, and chaffing gear, although present on *Warwick*, were not added to the reconstruction as they obstruct important parts of the rigging from view. *Warwick's* mast and yard reconstruction is seen in Figure 101.

[217] Goell 1970, 21.
[218] Manwaring and Perrin 1922, 157.
[219] Goell 1970, 31.
[220] "Mats are broad clouts weaved of sennit and thrums together [and some are made without thrums], the use whereof is to save things from galling, and are used in these places:--to the main and fore yards at the ties, to keep the yards from galling against the mast; upon the gunwale of the look, to keep the clew of the sail from galling there; upon the boltsprit and beak-head, to save the clew of the foresail." Manwaring and Perrin 1922, 187; "A Paunch. Those mats made of sennit which are made fast to the main and fore-yards, to save them from galling against the masts, are called paunches, by a proper name." Manwaring and Perrin 1922, 196; "Puddings are ropes nailed round to the yard-arms of the main and fore-yards close to the end, and so are three or four or more a distance one from another upon each yard-arm. The use of them is to save the robbins from galling asunder upon the yards when we haul home the topsail sheets." Manwaring and Perrin 1922, 202.
[221] Grenier et al. 2007, IV-23 to IV-24.

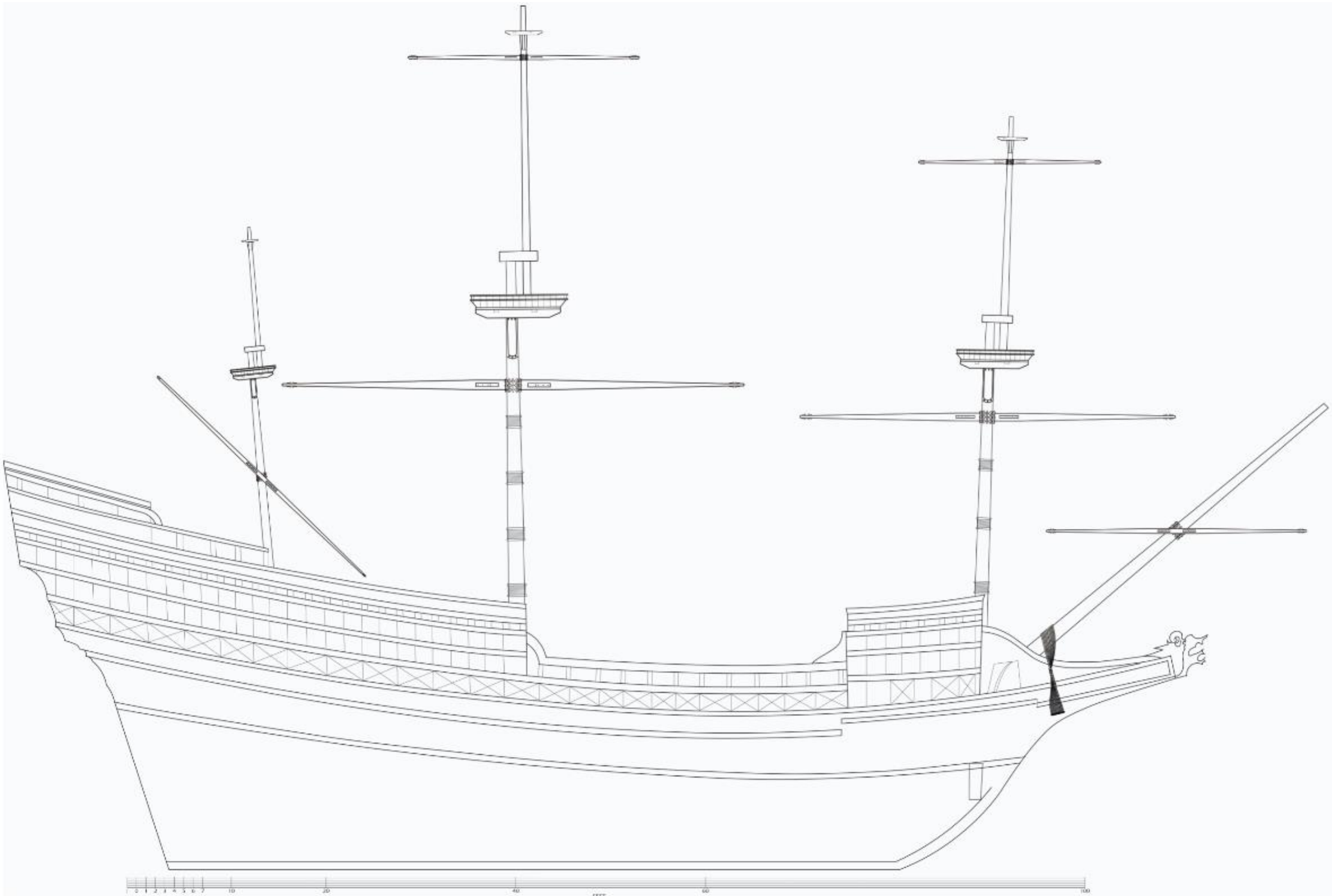

Figure 101: *Warwick* masts and yards. Reconstruction and image by author.

CHAPTER 7

STANDING & RUNNING RIGGING RECONSTRUCTION

In the previous chapter, elements of standing rigging that attach the masts and yards together were covered; this chapter gives an overview of the remaining standing rigging and summarizes the running rigging.

Standing Rigging

Shrouds

The lower shrouds were used to support the sides of the masts. Each was comprised of two deadeyes that were seized together with a lanyard; the lower deadeye was stropped into a chainplate that passed through a chainwale before being bolted into the side of the hull (see chapter 2 for the history and description of parts on a standard ship rig).[222] The main and fore mast shrouds are three-strand rope hawsers.[223] At their upper ends, the shrouds are put over the head of the mast by the trestletrees (pendants, tackles, and swifters are under this rope), and the rope is served, or wound with smaller rope around it for protection.[224] Iconography shows that only 3-holed deadeyes were used for shrouds. All masts had their corresponding shrouds except for the bowsprit.[225]

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[222] "and the Chaines are strong plates of iron fast bolted into the Ship's side by the Chaine waile." Goell 1970, 23; "[…] the chaine waile is a broad timber set out amongst them, a little above where the chaines and shrouds are fastened together, to spread the shrouds (the wider the better) to succour the masts." Goell 1970, 7.
[223] Manwaring and Perrin 1922, 161.
[224] Manwaring and Perrin 1922, 220, 225-26; Salisbury and Anderson 1958, 48.
[225] Manwaring and Perrin 1922, 225-26; Goell 1970, 23.

Four chainplates that were approximately the same size, and three 3-holed pear-shaped deadeyes (93: 30-008, 93: 30-13-2, 80:129B), along with one partial deadeye that may have been in this category (02:155-034), are believed to be part of the same assemblies (Figure 102).

Figure 102: Image comparing deadeyes (93: 30-008, 93: 30-13-2, 80:129B, 02:155-034) with one of the chainplates found in situ (Image by Doug Inglis).

Two of the chainplates were found *in situ* near the construction mark originally thought to mark the location of the main mast, but that is now believed to be for the mizzen mast (Figure 103). These chainplates are thought to be for the mizzen mast shrouds. The similarity in size of the two *in situ* chainplates and the other chainplates found, infer that they may also belong to the mizzen mast shrouds but were removed from their original positions as they were loose finds. The site plan shows that the chainplates were approximately 2 ft. (61 cm.) apart and located 1.1 ft. (1/3 m.) abaft the possible mizzen step location. This evidence was used in the reconstruction to determine the standard distance between mizzen shrouds.

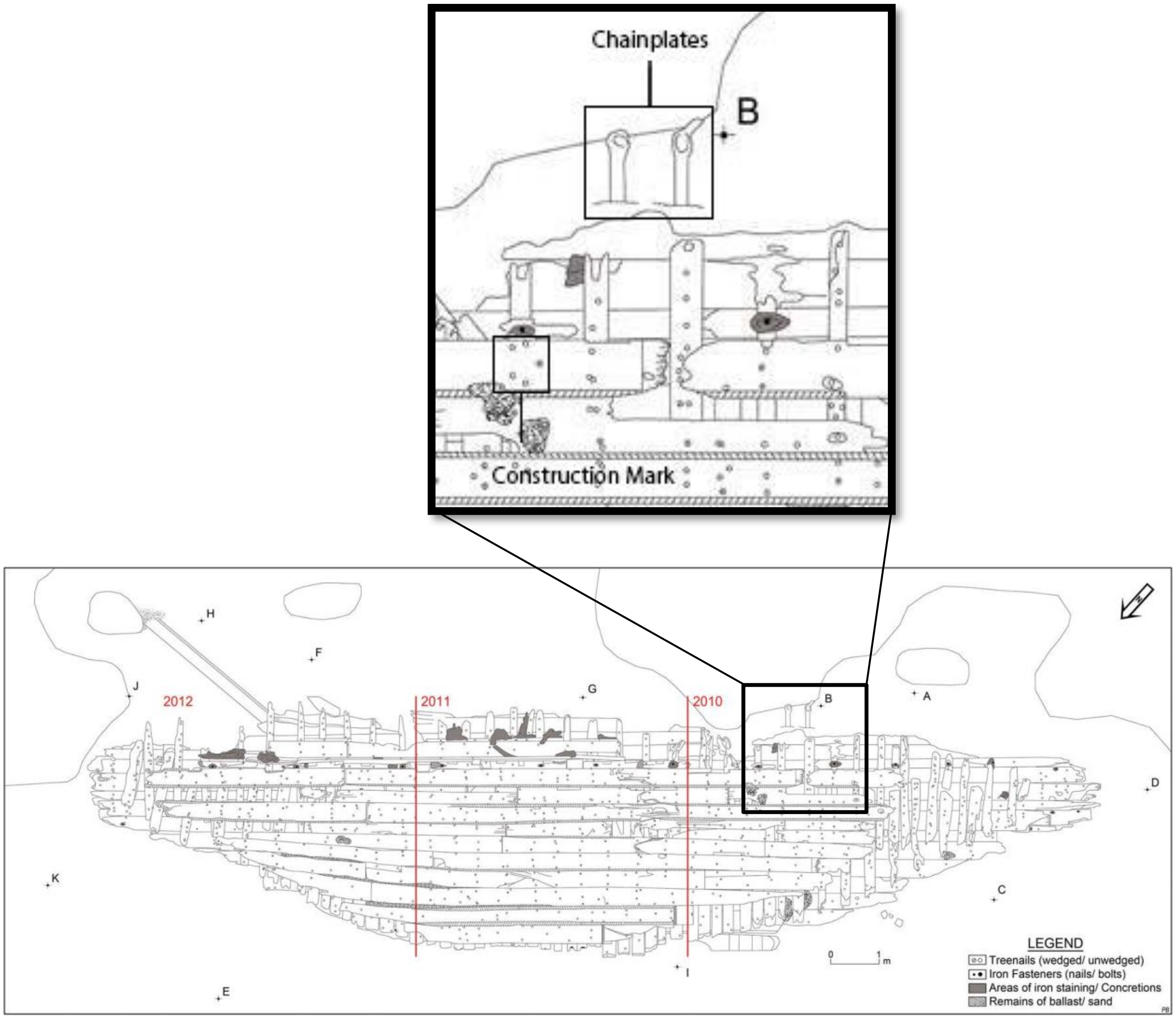

Figure 103: *Warwick's* site plan showing the location of the construction mark (possibly for the mizzen mast step), and also the two *in situ* chainplates (After Bojakowski and Custer-Bojakowski 2017, 287).

Several researchers state that deadeyes were approximately half the diameter of their mast.[226] It is unclear where this ratio originated, how the diameter can be determined from non-round deadeyes that have different lengths and widths, and whether this only applied to shroud

226 Howard 1979, 134; Mondfeld 1989, 244; Anderson 1994, 71.

deadeyes (because deadeyes can be used for other purposes as will be described later), but it provides potential insight into the size of the mizzen mast and a way to see if the previous mizzen mast diameter was correct.

The hypothetical mast diameters from Chapter 6 are halved in Table 17.

	Mast Diameter (in.)	**Mast Length Halved (in.) (e.g. deadeye diameter)**
Bowsprit	17	8.5
Foremast	17	8.5
Main mast	21	10.5
Mizzen mast	11	5.5
Fore topmast	9	4.5
Main topmast	10	5
Mizzen topmast	6	3

Table 17: *Warwick's* hypothetical mast diameters halved, which according to researchers is the approximate diameter of the corresponding masts' deadeyes.

Given that it is unclear if this applied to the length or width of non-round deadeyes, both the length and width of *Warwick's* deadeyes are listed in Table 18 for comparison.

ID#	**Greatest Width (in.)**	**Greatest Length (in.)**
02: 155.254557-764-u	3.9	3.5
02: 155-034	*5.6*	
93: 30-008	*4.9*	*7.2*
93: 30-13-2	*5.3*	*7.1*
93: 30-13-4		6.7
79: 155-344	6.3	6.4
80:129B	*5.9*	*7.5*

Table 18: *Warwick's* deadeye lengths and widths. The deadeyes believed to belong to the mizzen mast are italicized.

The widths of the deadeyes that correspond to the mizzen mast are between 4.9 and 5.9 in. with an average of 5.4 in. The lengths of these deadeyes are between 7.1 and 7.5 in. with an average of 7.3 in. Meanwhile, *Warwick's* halved hypothetical mizzen mast diameter is 5.5 in., matching the widths of the speculated mizzen mast deadeyes, further giving support to the hypothesis that the chainplates and their corresponding deadeyes belong to the mizzen mast. This also suggests that deadeye widths, rather than lengths, were being referred to by researchers when writing that their diameters are half the diameter of the mast.

Using this same rule, Artifact 02: 155.254557-764-u, which is much smaller than the previous deadeyes and a different form (RTB), is matched to the mizzen topmast; the deadeye has a width of 3.9 in. while the mizzen topmast diameter halved yields 3 in. Similar to shrouds of the lower masts, the upper masts also had shrouds, but instead of chainplates, they had puttocks (iron plates), which served the same function as chainplates but instead attached to lower mast shrouds rather than being bolted into the hull.[227] The remaining 3-holed deadeye (79: 155-344) which was already shown in Chapter 4's analysis to be anachronous and most likely intrusive to the site will be omitted from the reconstruction.

Ships had a varying number of shrouds depending on their size, but few documents specify the standard number. The only primary document that provides information on the approximate number of shrouds is *A Treatise on Rigging*, which states that the mizzen topmast had three shrouds per side, and that the main mast had anywhere from four to eight shrouds.[228] Archaeological evidence on the number of shrouds per mast include the wrecks of *Mary Rose*,

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[227] "Puttocks […] go from the shrouds of the main, fore, and mizen masts, and also to the topmast shrouds, if the topmast have a topgallant top. The use whereof is to go off the shrouds into the top, for when the shrouds come near up to the mast they fall in so much that otherwise they would not get into the top from them. The puttocks are at the bottom seized to a staff which is made fast there to the shrouds, or some rope which is seized there, and above to a plate of iron or to a dead-man-eye to which the lanniers of the topmast-shrouds do come." Manwaring and Perrin 1922, 204; "The top-mast shrouds are in the same manner fastened with dead-men-eyes and lanniers to the puttocks, or the plates of iron which belong to them, and aloft over the head of the mast at the other" Manwaring and Perrin 1922, 226.

[228] Salisbury and Anderson 1958, 48, 59.

Vasa, and *San Juan*, but they are larger than *Warwick* and therefore poor comparisons.[229] The most useful evidence for the appropriate number of shrouds per mast comes from iconography that can be seen in Appendix G.

The iconographic information on shrouds in Appendix G agree with the numbers from *A Treatise on Rigging*, so the shrouds in the reconstruction will follow what is indicated in Appendix G.

Other ropes related to the shrouds include ratlines (ratling or rattlin) and catharpins. Ratlines are ropes that are secured perpendicular to the shrouds that sailors used to climb to upper masts (Figure 104).[230] In this reconstruction, the distances between ratlines were set at 1.5 ft. (0.46 m.). Catharpins (catharpings) are ropes reeved through blocks that run across the ship (starboard to port) to secure the shrouds to their corresponding shroud on the opposite side (Figure 105).[231] Ratlines are shown in the reconstruction, but catharpins are not due to difficulty seeing them from the ship's profile.

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[229] Grenier et al. 2007, 5; Marsden 2009, 256-57.
[230] "Ratling is a line wherewith they make the steps by which we go up the shrouds and the puttocks, and so the topmast shrouds in great ships; and these steps, which make the shrouds look like ladders, are called the ratlings of the shrouds." Manwaring and Perrin 1922, 208; "And all those small ropes [that] doe crosse the Shrouds like steps are called Ratlings." Goell 1970, 24.
[231] "Cattharpings they ar 6 of every side and every on fastened to a shroud they passe through a deadmans eye with 3 holes in it on every side and so going in 2pts make six to the ende of every deadmans eye is fastened a blocke, to the one of which the standing part of the ffalle is made fast, the other ende of it passeth through the other blocke and thence goeth through the blocke it is fastened unto and so is belayed to the necke of the blocke." Salisbury and Anderson 1958, 51; Goell 1970, 25.

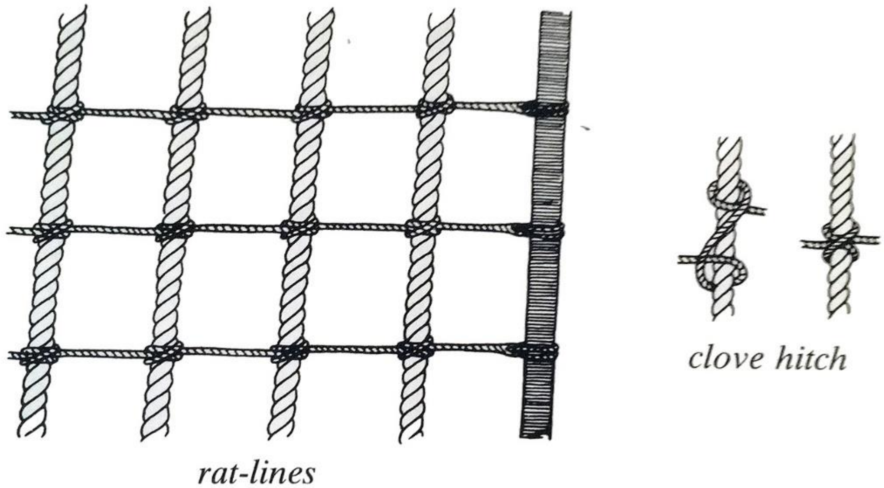

Figure 104: Ratlines (Mondfeld 1989, 285).

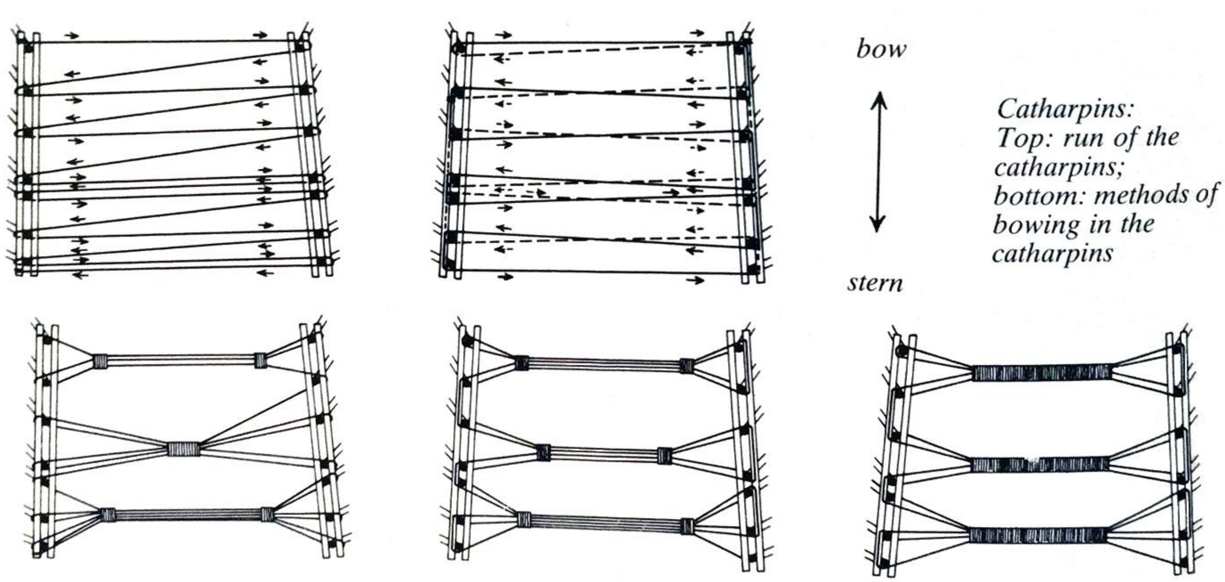

Figure 105: Catharpins (Mondfeld 1989, 284).

Stays

While shrouds prevented masts from toppling to the sides, the stays and backstays supported the masts from falling forwards or backwards. All masts and flag staffs had a stay except for the spritsail topmast and bowsprit.[232] In general, the stays were attached to the mast head to which it belonged by a collar that was wormed, parceled, and served.[233] The lower end of the stay was attached to the mast immediately forward of it, or the ship's beak if it belonged to the fore mast. The main mast stay was attached to a collar around the head of the mast at the upper part of the crosstrees (sometimes called a garland), while the other (lower) end of the stay connected to a collar around the beakhead.[234] The main collar at the beakhead had a deadeye seized to it where the main stay was fastened.[235] The main topmast stay attached to a collar at the head of its mast and at its lower end was attached to the foremast through two deadeyes that were fastened together with lanyards, or with just a deadeye and a strop according to some treatises, which was then fastened to the foremast with a strap. [236] The main topgallant mast stay attached in the same way to the head of the fore topmast where it passed through a block before going to the fore mast top where it was fastened.[237] The foremast stayed much like the main mast, but gammoned to the bowsprit, which also stabilized the bowsprit (if a ship's foremast or bowsprit

[232] Manwaring and Perrin 1922, 234-35.

[233] "To sarve any rope with plats or Sinnet is but to lay Sinnet, Spun yarne, Rope yarne, or a peece of Canvas upon the rope, and then rowle it fast to keepe the rope from galling about the shrowds at the head of the masts, the Cable in the Hawse, the flooke of the Anchor, the Boat rope, or any thing." Goell 1970, 31.

[234] Manwaring and Perrin 1922, 234, 93-4; Salisbury and Anderson 1958, 48; Goell 1970, 22-3, 12; there are variations in backstay configuration depending on masts, for example: "[Mizzen topmast] Stay. it hath a Pennant that fastens it to the Topmast head at the end of which is a block spliced, through which blocke is rived a double pennant which hath at ether end an other blocke, through ether of which blockes is rived other double pennants to ether ende of which pennants ar spliced a blocke. The falles of the stay ar at ther standing endes fastened to the aftermost shroude of the mayne mast on ether side one, from thence they goe through the pennant last blocke, and thence through other blockes fastened to the mayne shroudes, thence through the last pennant blockes again and thence through blockes fastened to the after shrouds againe and ar belayed to the shroudes, so that this stay hath his fastenings to the mayne shroudes on ether side of the ship." Salisbury and Anderson 1958, 59-60.

[235] "The Collar is that rope which is made fast about the beak-head, whereunto the dead man's eye is seized unto which the main stay is fastened. There is also a rope about the mainmast-head which is called a collar or a garland, and is there placed to save the shrouds from galling." Manwaring and Perrin 1922, 129.

[236] Manwaring and Perrin 1922, 234-35; Goell 1970, 22-3; Salisbury and Anderson 1958, 52.

[237] Manwaring and Perrin 1922, 234-35; Goell 1970, 22-3; Salisbury and Anderson 1958, 54.

fouled, the other mast would likely fall as well) (Figure 106 and 107).[238] The mizzen stay attached to the bottom of the mainmast, and its topmast stays extended down to the mainmast shrouds via crowsfeet (Figure 108).[239]

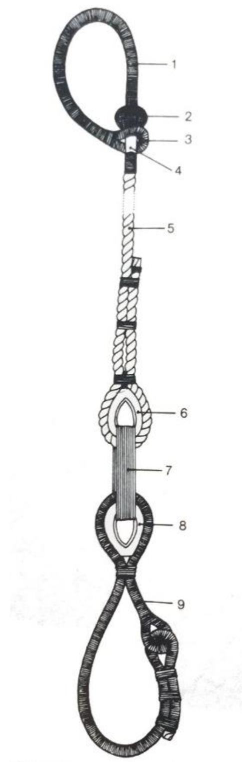

Figure 106: Diagram of a main stay. 1) Stay eye at main masthead; 2) Mouse; 3. Spliced eye; 4) Leather parcelling; 5) Stay; 6) Upper heart; 7) Lanyard; 8) Lower heart; 9) Stay collar from 18th century fully served (Mondfeld 1989, 294).

[238] Manwaring and Perrin 1922, 234-35, 105; Salisbury and Anderson 1958, 56; Goell 1970, 22-3.
[239] "The mizen stay comes to the mainmast by the half deck, and the topmast stays come to the shrouds with crow feet. The use of these stays is to keep the masts from falling aftward towards the poop." Manwaring and Perrin 1922, 234-35; see also Goell 1970, 22-3.

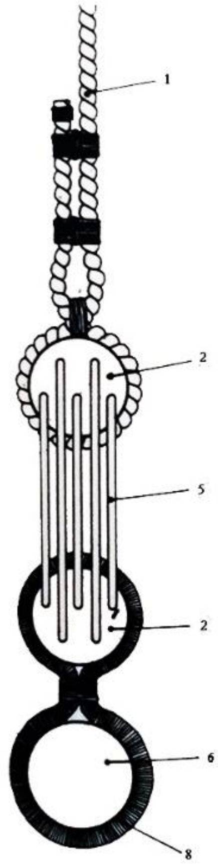

Figure 107: Continental 17th-century fore stay according to Mondfeld 1) Stay; 2) Deadeyes; 5) Lanyards; 6) Bowsprit; 8) Bowsprit strop (Mondfeld 1989, 295).

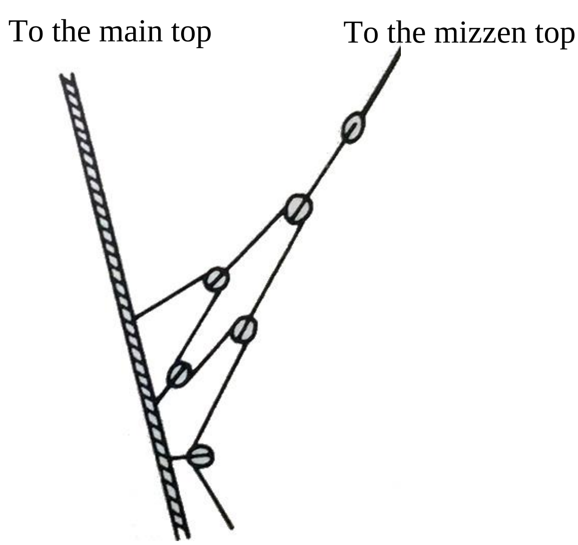

Figure 108: Mizzen stay on English ships in 1620 (Mondfeld 1989, 299).

Warwick likely had six stays, one belonging to each of the following masts: fore mast, fore topmast, main mast, main topmast, mizzen mast, mizzen topmast. The two 6-hole deadeyes (93:030-007 and 80:129C) found on *Warwick* may belong to the stays, as treatises and iconography (Figures 109-111) suggest that the foremast and mainmast, and their topmasts, secured their stays with deadeyes. Howard states that stay deadeyes had 5 holes.[240] Each pair of deadeyes was attached via lanyards, and the lower deadeye was stropped to the collar. [241] The two 6-hole deadeyes from *Warwick* differ significantly in size and are likely from different stays, rather than the deadeye pair from the same stay (Table 19). It is likely that the smaller deadeye (93:030-007) belonged to the lower fore stay, or main topmast stay, and the larger deadeye (80:129C) was from the lower main stay based on their sizes.

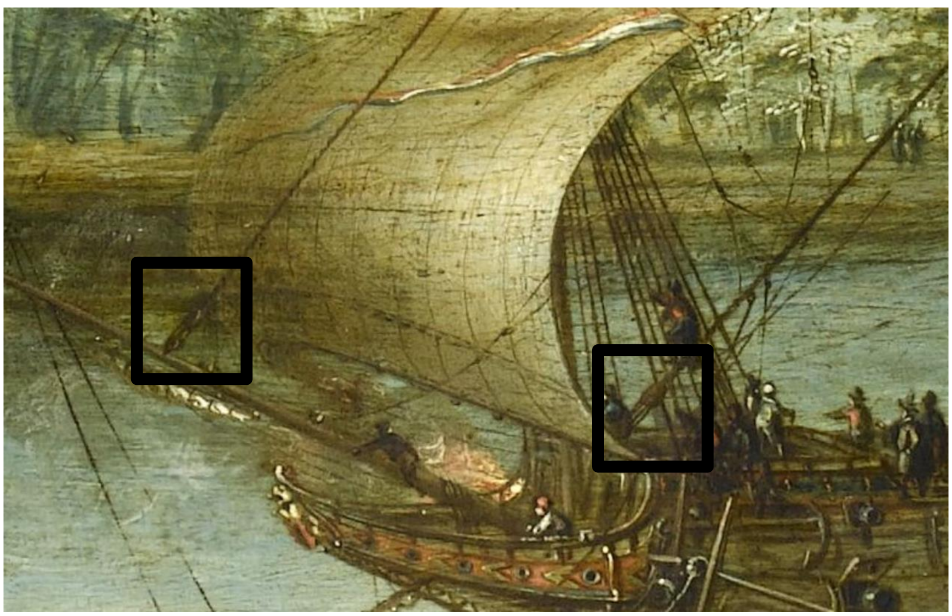

Figure 109: Detail from *Ships off Ijselmonde* by Aert Anthonisz (1579-1620). Painted 1617. Showing the lower foremast stay (left), and lower mainmast stay (right) with secured deadeyes. Object number: SK-A-1446. Painting. Retrieved from: https://www.rijksmuseum.nl/en/collection/SK-A-1446: Rijksmuseum, Amsterdam.

[240] Howard 1979, 135.
[241] Goell 1970, 23.

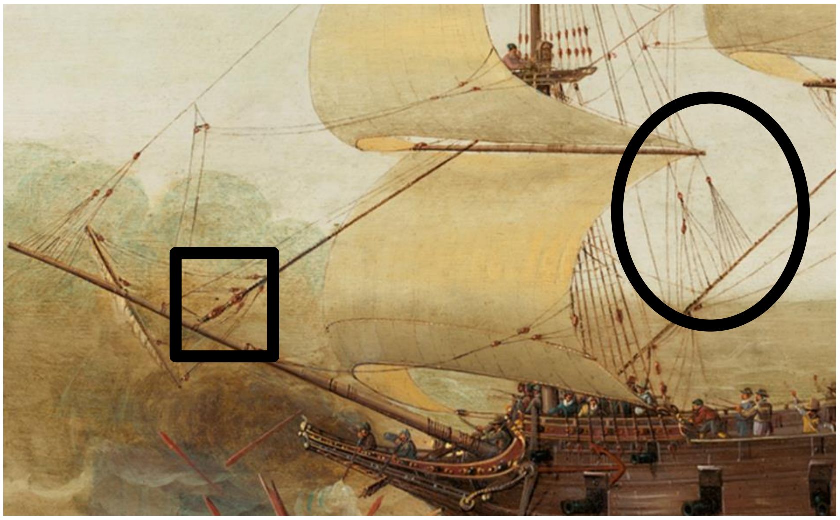

Figure 110: Detail from *A Naval Encounter between Dutch and Spanish Warships* by Cornelis Verbeeck (c. 1590-1637). Painted c. 1618/1620. The lower foremast deadeye stay assembly is in the square. The ends of the fore topmast backstays are in the oval. Catalogue Numbers 1995.21.1-2. Painting. Retrieved from: https://www.nga.gov/collection/art-object-page.156252.html: National Gallery of Art, Washington, Gift of Dorothea V. Hammond.

Figure 111: Detail from *A Naval Encounter between Dutch and Spanish Warships* by Cornelis Verbeeck (c. 1590-1637). Painted c. 1618/1620. The lower foremast deadeye stay (left) and lower main mast stay (right) assemblies are noted in squares. Catalogue Numbers 1995.21.1-2. Painting. Retrieved from: https://www.nga.gov/collection/art-object-page.156252.html: National Gallery of Art, Washington, Gift of Dorothea V. Hammond.

ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Diame ter of eye hole (Aver aged)	Shape	Flat or Round Face	Grain	# of Holes	Square or Round Score	Notes
93: 030-007	26.674	16.914	4.62	3.22	Pear-shaped	Flat	Vertical	6	Square	
80: 129C	31	21.978	5.356	3.08	Pear-shaped	Flat	Vertical	6	Square	

Table 19: Dimensions from *Warwick's* two 6-hole deadeyes.

Backstays

Although backstays are traditionally considered standing rigging, it is likely that during the early 17th-century backstays resembled a form of running rigging. Anderson wrote that standing backstays are mentioned in 1618, but most primary documents only describe running backstays which consisted of pendants and whips.[242] These pendants came down to the level of the main top or fore top and had blocks spliced to them, which were attached to a fall that ran to the deck (Figure 112).[243] Lees doubted that standing backstays were ever fitted, and wrote that the after-shroud or swifter, served as the standing backstay.[244] Howard also stated that if a ship at the beginning of the century had backstays, they were swifters, and that the swifters' pendants went over the shrouds.[245] Mondfeld wrote similarly that prior to the middle of the 17th century, running backstays were used which were set up with tackles. The running part was belayed inboard to a belaying pin or cleat while the lower part was fitted with a hook.[246] In short, secondary sources have the same consensus that true backstays did not exist at this time.

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[242] Anderson 1994, 72.
[243] Anderson 1994, 118.
[244] Lees 1984, 45.
[245] Howard 1979, 135.
[246] Mondfeld 1989, 290.

Treatises support what Anderson, Lees, Howard, and Mondfeld wrote about backstays. Within Mainwaring's Dictionary, only the main and fore masts and topmasts have backstays.[247] These backstays are pendants which have a standing part at the head of the mast with a block at the other end, which hangs down inside of the shrouds. *A Treatise on Rigging* describes backstays being as large as shrouds and fastened to the mast head above the shrouds. At the lower end, they carry a deadeye attached to another via lanyards, which are set into the chainwale in a manner similar to shrouds, and that there are two backstays per mast, one on each side.[248] The lower ends of the fore topmast and mizzen topmast backstays are fitted with crowsfeet, or small ropes that are divided by deadeyes in 6, 8, 10 or more parts (in this case, the reference is likely to a heart or dead block rather than a deadeye) and attach to the fore stay of the mast behind it, or in the case of the mizzen topmast backstay, to the shroud (Figure 110 and 113).[249] According to *A Treatise on Rigging*, the main topmast backstay consists of pendants that are fastened to the head of the topmast. These pendants come down to the main top that has a block spliced through where a fall is reeved, which has its standing part fastened to the railing behind the main shrouds.[250] The mizzen topmast backstays go to the shrouds with crowsfeet (the primary source does not use the term backstay, but describes these as ropes that help prevent the masts from falling forwards and backwards, implying backstays were probably used (Figure 113).[251] Mainwaring wrote that backstays only belong to the fore and main masts, and also stated that swifters only belong to the main and foremast; he also notes that swifters have the purpose of "succor[ing] the shrouds and keep[ing] the mast stiff" which implies they had the same purpose as backstays[252] The swifters have pendants that are fixed to the shrouds at the mast head with a double block, through which the swifter is reeved, with one end attached to a hook that is hitched to a ring set in the chainwales, while the other end was belayed at the timber heads at the lower rails.[253] Overall, running backstays appear to have been fitted on ships during the early part of the 17th century and are included in *Warwick's* reconstruction.

Figure 112: Backstay (Mondfeld 1989, 291).

[253] Manwaring and Perrin 1922, 240.

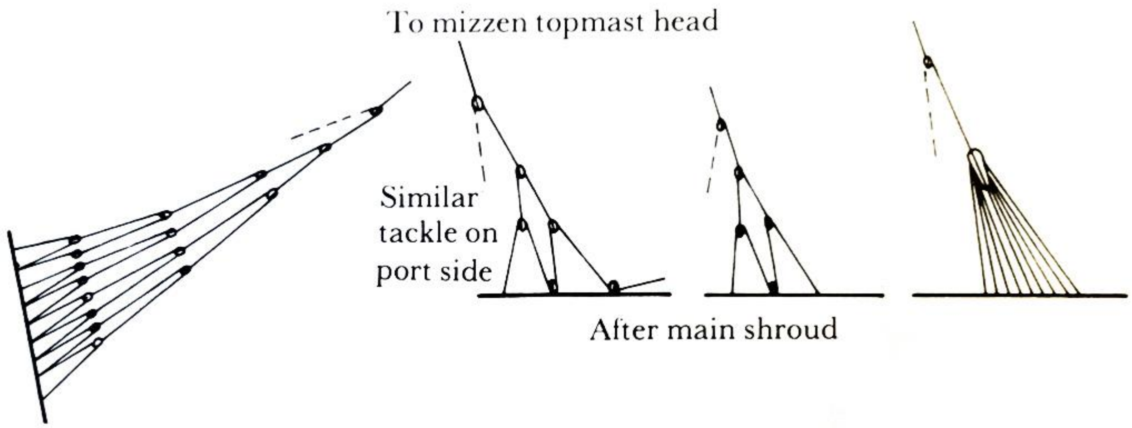

Figure 113: Mizzen topmast backstay. Note: the caption on this image shows the crowsfeet attaching to main shroud, making it a mizzen topmast stay, not backstay. The same crowsfeet would be used for the backstay, but most likely go to the sides of the ship (Howard 1979, 138).

Warwick was reconstructed with two backstays (one per side per mast, but due to profile view, only one is shown) on the foremast, fore topmast, mainmast, and main topmast. While the mizzen topmast backstays are mentioned in *A Sea Grammar*, the others do not mention this mast having them, meanwhile, they are also uncommon in iconography and were seen clearly only in *A Dutch Merchantman Attacked by an English Privateer, off La Rochelle* by Cornelis Claesz van Wieringen (c. 1575-1633) (Figure 80). As such, the mizzen topmast was not fitted with backstays.

Due to slightly differing variations in backstay configurations, this reconstruction had the backstays that consisted of pendants, or a short rope fastened around the mast's head below the shrouds, that had a double block stropped to it.[254] The swifter went through the double block; one end of this rope is fixed (standing) to a hook, which is attached to a ring in the chainwales. The

[254] Goell 1970, 24.

other end (running) is called the fall and was belayed to the railing.[255] The fore topmast backstay shown ends in crowsfeet (split into 6 parts), rather than in the pendant and tackle assembly, and is attached to the main fore stay.

Running Rigging

Running rigging describes rigging that is adjusted when sailing. Few running rigging artifacts are normally recovered from wrecks with the exception of blocks. However, although several blocks and block parts have been recovered, from *Warwick*, almost all blocks recovered from wrecks are not found *in situ*. Given the complexity of running rigging, the lack of artifact provenience, and blocks' multiple purposes, most cannot be assigned to specific parts of rigging. Due to the lack of meaningful archaeological data, the majority of *Warwick's* running rigging was reconstructed through primary and secondary documents.

Ropes Belonging to the Yards

To support the yards, ties (tyes) were fitted to the masts via the sheave that was inserted within the hound.[256] The tie rope, made of 4-strands, is slung from the middle of the yard and the two ends went through the hounds, before going down and attaching to a ramshead at its other end (ramsheads were only used for fore and main halliards) (Figure 114).[257] The halliard runs through the ramshead and connects to a knightshead at the deck and is used to raise the yards (Figure 115).[258] Lower masts have two hounds and two ties, the topmasts and mizzen yard only

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[255] Manwaring and Perrin 1922, 240; Salisbury and Anderson 1958, 49; Goell 1970, 23.
[256] Salisbury and Anderson 1958, 52-3.
[257] Goell 1970, 25; "The ties are always made of four-strand ropes because they are smoother to run in the hound than three-strand ropes." Manwaring and Perrin 1922, 136.
[258] Mondfeld 1989, 310; Manwaring and Perrin 1922, 125, 175. "Ram-head. The ram-head is a great block with three shivers in it, into which are reeved the halliards, and at the head of it into a hole are reeved the ties. This block doth only belong to the main and fore halliards." Manwaring and Perrin 1922, 207; see also Salisbury and Anderson 1958, 50, 61.

have one hound and one tie, and the spritsail yard does not have ties and is slung to the bowsprit.[259] The topmast ties and halliards attached to a block instead of a ramshead, which on one end had another block with the halliard that ran through it, while the other end was fastened to the side of the ship. Mats were used to reduce chafing where the main and fore yards lay against their masts.[260]

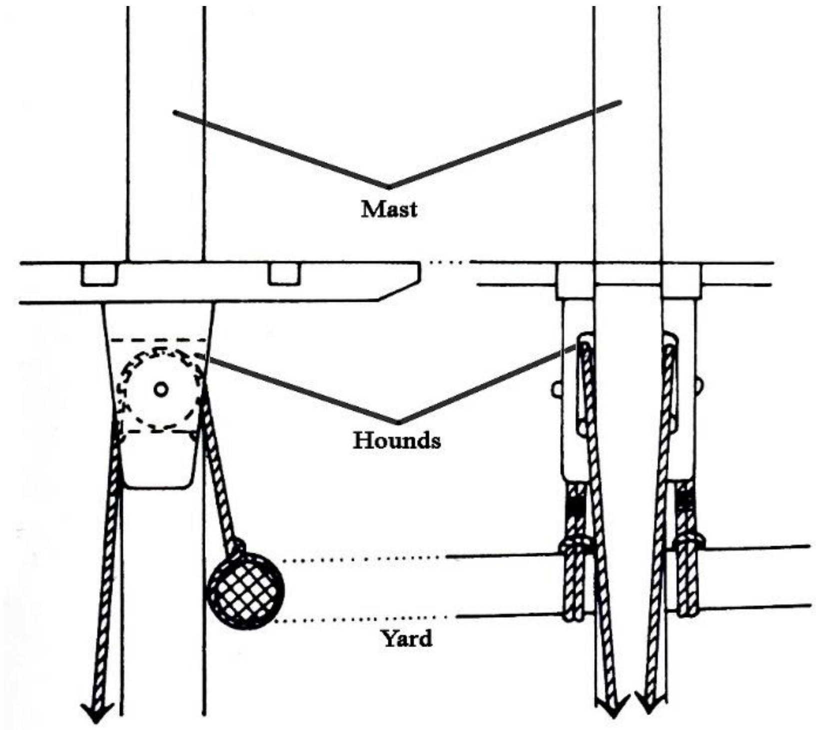

Figure 114: Ties (After Mondfeld 1989, 311).

[259] Goell 1970, 19, 25; Manwaring and Perrin 1922, 160.
[260] Manwaring and Perrin 1922, 187.

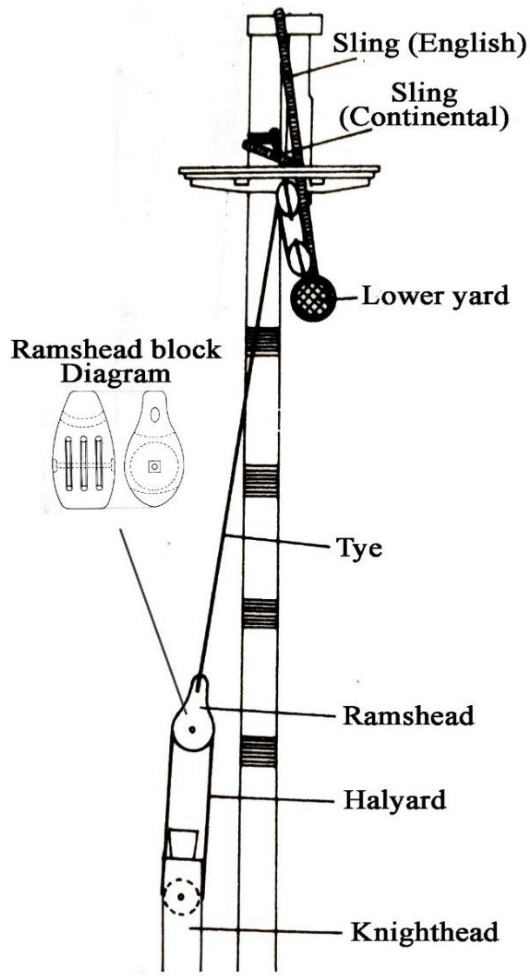

Figure 115: Tie and Halliard diagram (After Mondfeld 1989, 310-11).

Jeers (gere) were used to hoist yards like ties and halliards, but mostly employed to relieve weight on the ties and slings, and to provide secondary support in case the ties failed.[261] The jeer was a hawser near the ties belonging to the main yard and foreyard; its standing end was fastened to the head of the mast above the shrouds and seized to a block, while the running end

[261] Manwaring and Perrin 1922, 169; Salisbury and Anderson 1958, 52.

was reeved through this block (or simply clinched) and then through a block between the two fastenings for the ties. The end of the hawser was then reeved through another block at the base of the mast and/or seized directly to the deck.[262] Large ships had one on each side, but small ships may not have carried many or only one (Figure 116).[263] Although *Warwick* was not a large ship, it is likely jeers were fitted for the long trans-Atlantic voyage.

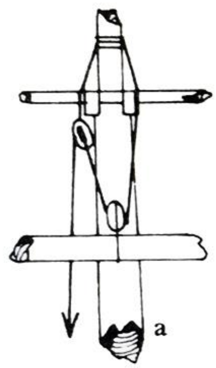

Figure 116: Jeer (Howard 1979, 140).

Lifts were used to top the yardarms (raise or lower the yardarms).[264] Lifts had a standing end at the collar of the main stay, which then passed through two blocks (the first block was seized to the strop of the second block that was a topsail sheet block) fastened to a yard arm, then was rived back to two blocks below the trestletrees, before going down to the deck where it was belayed to the gunwale next to the foremost shroud (Figure 117).[265] Lifts were fitted to the arms

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[262] Manwaring and Perrin 1922, 169; Salisbury and Anderson 1958, 50.
[263] Manwaring and Perrin 1922, 169; Goell 1970, 34.
[264] Manwaring and Perrin 1922, 180.
[265] "Lifts they ar fastened at the standing endes to the coller of the mayne stay thence they goe through 2 blocks fastened to the yeard armes at the inside of the Topsayle sheete blocke, and from thence goe through 2 blocks which ar fastened with a strap to the head of the mast which comes downe below the Tresseltrees, and so goes downe to the deck by the fforemost shroude and is belayed ther to the Gunwale. ther ar 2 lifts on for ether side." Salisbury and Anderson 1958, 50.

of every yard. The topsail lifts also worked as sheets for topgallant yards.[266] Smith provided some details on where the lifts were belayed: main topmast lifts were belayed to the main top and mizzen topmast lifts were belayed to the mizzen mast top (Figure 118).[267] The lifts of the spritsail yard were unusual as they were composed of two pendants fastened to the bowsprit, a running rope went through two blocks at the yard arms and through the two blocks on the either side of the bowsprit, before being belayed to the gammoning on the bowsprit.[268]

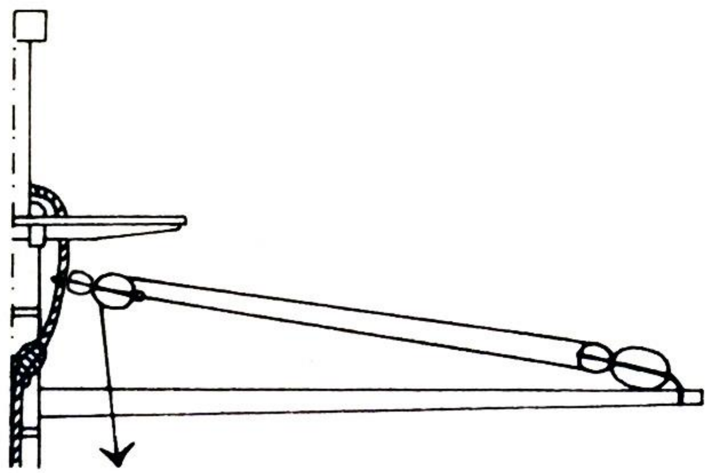

Figure 117: English 17th-century lifts. (Mondfeld 1989, 315)

[266] Manwaring and Perrin 1922, 180; Goell 1970, 29.
[267] "Lifts 2 ther standing parts ar fastened to 2 short Pennants fastened to the utter ended of the bovespright, from thence ther running parts goes through 2 blockes fastened to the yeard armes and thence through 2 other blockes fastened to ether side of the bovespright and so goe to the Gammings of the bovespright where it is belayed. Salisbury and Anderson 1958, 56; see also Lees 1984, 68.
[268] Salisbury and Anderson 1958, 56.

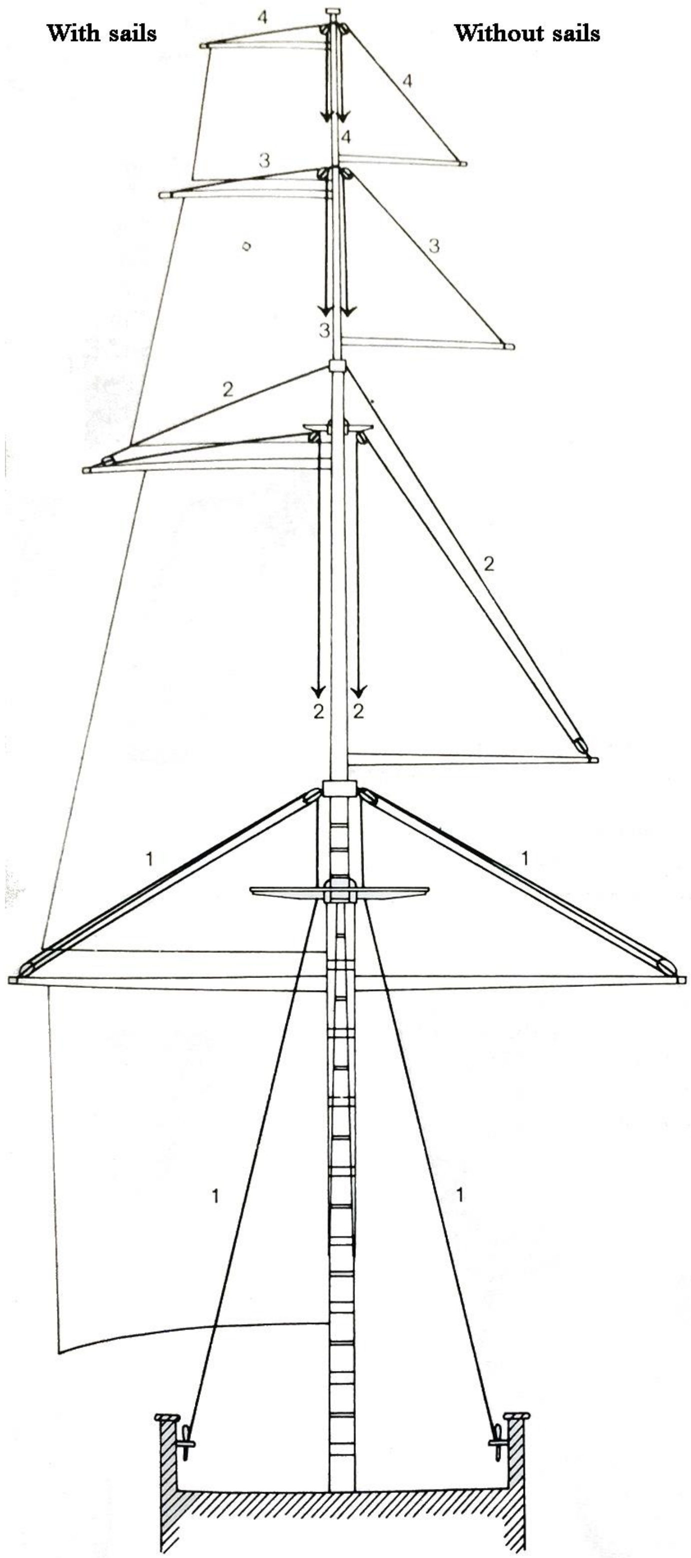

Figure 118: Diagram of the lifts (Mondfeld 1989, 315).

Braces were used to pivot the yards laterally and were fitted to all yards except the mizzen yard.[269] These consisted of a pendant seized to the yard arms, which in turn had a block seized to it, through which the brace (rope) was run (Figure 119).[270] These were secured to a cleat or belaying pin at the deck or to the mast top below and aft of the yard: the main mast brace was secured to the deck, the main topsail brace to the mizzen top, etc. The yards of the mizzen mast did not have braces because their bowlines served as the brace.[271] Figure 120 from Mondfeld shows the lead of the braces.

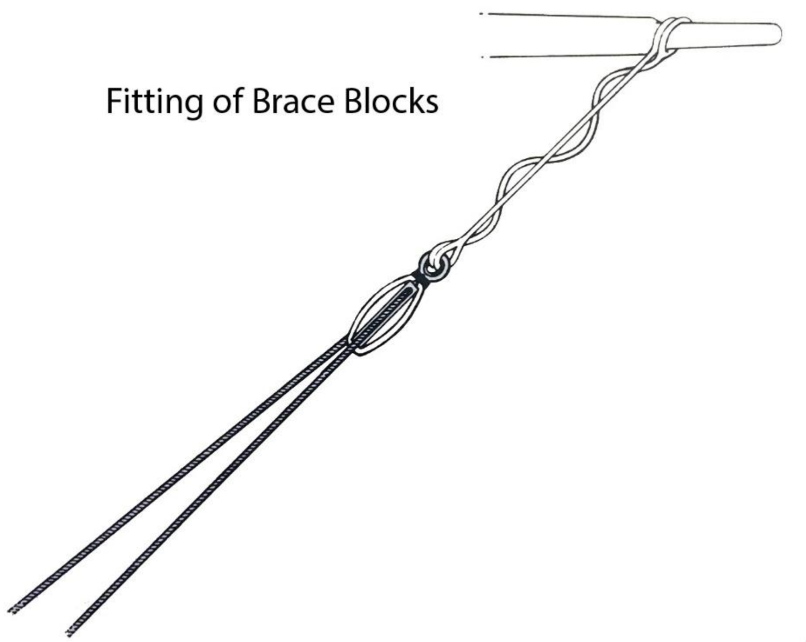

Figure 119: Yard and brace block attachment (Lees 1984, 70).

[269] Manwaring and Perrin 1922, 108; Goell 1970, 28; Salisbury and Anderson 1958, 50, 52.
[270] Manwaring and Perrin 1922, 108.
[271] Manwaring and Perrin 1922, 108.

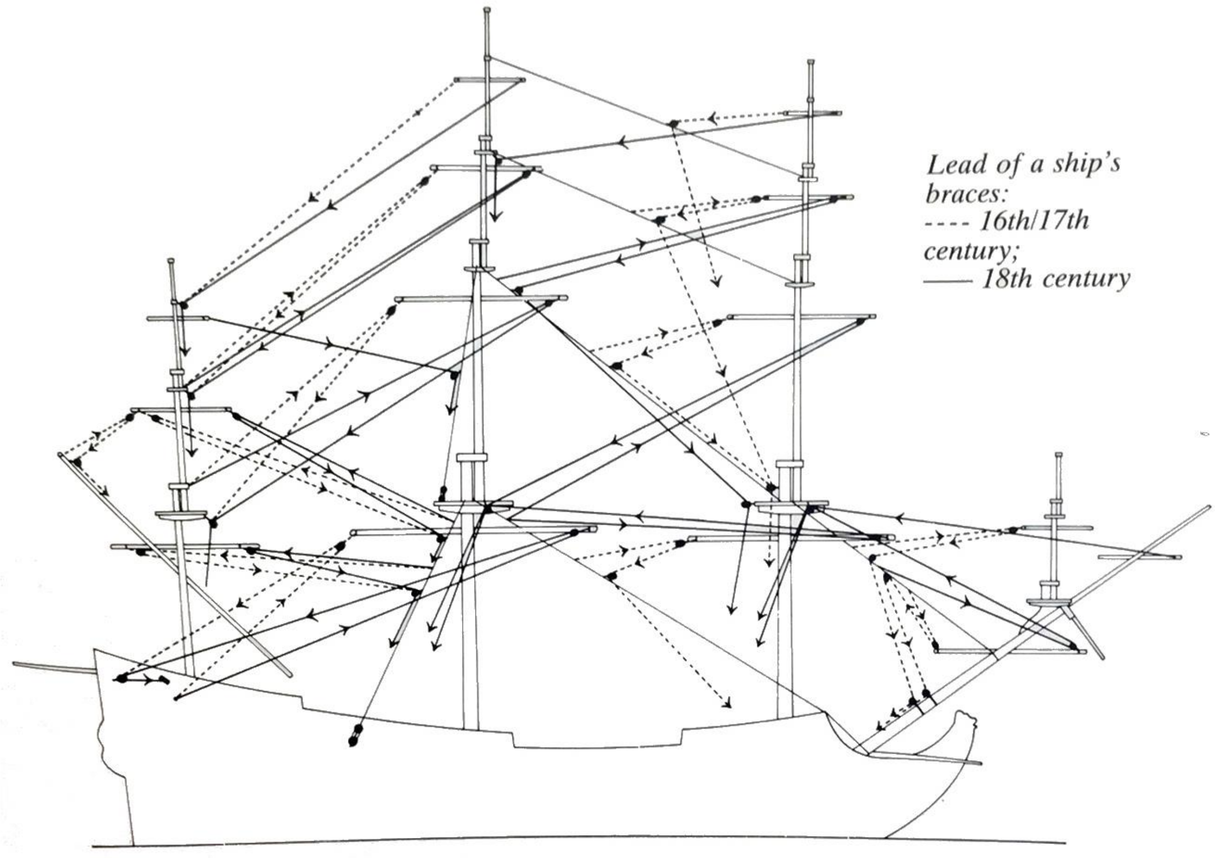

Figure 120: Ship's Braces (Mondfeld 1989, 317).

Lastly, attached to the yards were trusses (also known as breast ropes) that connected to the parrel to hold the yard in place and to haul it down when necessary. These ropes ran from the parrel to the deck. Mainwaring states that trusses only belonged to the fore, main, and mizzen yards, and that they were not always present in the fore and main yards, but always on the mizzen.[272] Trusses attached to the middle of the yard between the parrel with a timber hitch, then went through a block at the mast, before going down to the capstan.[273] When the yard was not being used, this rope was wound around the yard and the parrel several times. When the yard

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[272] Manwaring and Perrin 1922, 249-50.
[273] Salisbury and Anderson 1958, 51-2.

was being lowered, this rope was loosened to allow the yard to roll smoothly down the mast (Figure 121).[274]

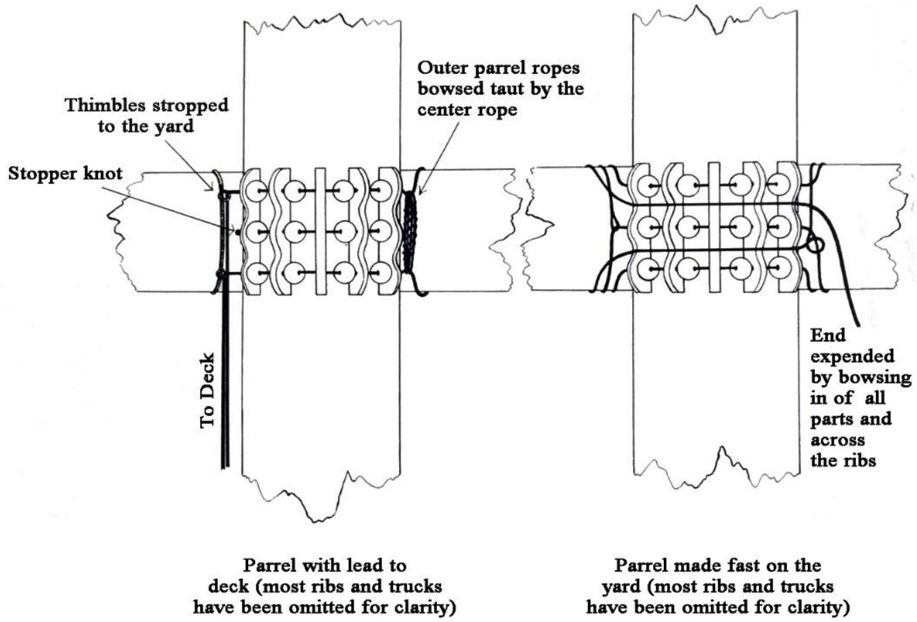

Figure 121: Lower yard parrels and trusses (Lees 1984, 66).

Sails and the Ropes Belonging to Sails

Warwick carried a spritsail, fore course, fore topsail, main course, main topsail, mizzen sail, and possibly a mizzen topsail. Much like to the masts and yards, determining the size of the sails and their construction was not done using a single set of hard rules, and exceptions were often made to customize ships. For example, large ships needed to have double courses if there was good wind.[275] One of the key factors to consider was balancing the sails of the ship so that the ship sailed well in general. Head sails (the spritsail, fore course, and fore topsail) keep the

[274] Lees 1984, 66.
[275] "Note all ships of great burden have double courses to hold more wind and give the ship more way in a fresh gale, but in an easy gale they hinder as do all things that are weighty overhead." Manwaring and Perrin 1922, 133.

ship from the wind, while after sails (the main course, main topsail, mizzen course and mizzen topsail) keep the ship to the wind (wind ward). If a head sail is used, then an after sail should be used to counteract it and balance the forces applied to the ship.[276]

Although preserved pieces of canvas are occasionally found on wrecks, none have been discovered on *Warwick* that are complete enough to be able to reconstruct the actual dimensions of the sails, ruling out archaeological support for sail dimensions. Discussions of sail sizes are also rare in early 17th-century documents. Information on sail dimensions was found on the list of sails and the amount of canvas (also known as the cloth) needed to produce the sails provided in the *The Lengths of Masts and Yards (1640)* which has been summarized and analyzed in Appendix I. Unfortunately, the analysis of the sail dimensions from this document also proved to be problematic as it was unclear what ratios and rules were used to calculate their sizes nor which referred to lengths or to widths.[277]

Other primary documents only mention that square sails are proportioned according to the masts and yards, but that the mizzen is cut by the leech and twice as deep as the mast is long from the deck to the hounds, that the spritsail is ¾ as deep as the fore course, and the mizzen (by

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276 "All head-sails (that is those that belong to the foremast and bolt-sprit) do keep the ship from the wind and are used to flat the ship. All after sails, that is the mainmast and mizzen sails, do keep her to the wind; and therefore few ships are so well conditioned as to steer quarter winds with one sail, but must have one after sail and another head sail, as it were, to countermand one another; yet some ships will steer with their main topsail only. […] The sails are cut in proportion as the masts and yards are in length and breadth one to another, excepting the mizzen and spritsail. The mizzen sail is cut by the leech, twice as deep as the mast is long from the deck to the hounds, and the spritsail is ¾ as deep as the foresail" Manwaring and Perrin 1922, 217; Salisbury and Anderson 1958, 62; Goell 1970, 40.

277 For example, it was assumed that cloths double—double layer of canvas to hold more wind—and cloths square—a single layer of canvas—columns in Appendix I correspond to the widths of the sails, and that cloths double meant that the number given needed to be halved to get the true dimension of the sail. Cloths square columns were not halved. However, in several cases, the clothes square columns when not halved, revealed dimensions of sail that would have been much larger than the yard it hung from. Perhaps a pattern exists that just has not yet been found within this list, but with only detailed analysis of sails from *8th Whelpe*, it is far too small of a sample size to draw firm conclusions.

the leech) is twice as deep as its mast from the deck to its hounds.[278] The main course, all topsails, and topgallants, must be cut with goring (i.e. sloping), so that the foot of the sail is larger than the head.[279]

Given such incomplete or obscure information, secondary sources on 17th-century rigging were extensively consulted for *Warwick's* sail reconstruction. Lees' detailed instructions on sail dimensions were supplemented in conjunction with the little information provided from the treatises:

1. The widths of the heads of each lower sail and the main and fore topsails came to within 18 in. (45.7 cm.) from the yard arm cleats, the mizzen topsail to within 12 in. (30.5 cm.), and the mizzen topsail to within 12 in. (30.5 cm.) [280]
2. The width of the foot of each topsail matched the distance between the cleats of the yard below. The fore course was the same width as the foot as at the head. The main course was wider at the foot by the width of two cloths.[281]
3. Depth of the sail at the leech for topsails depended on length of the mast from the heel to the hounds. The fore course had to clear the main stay, and the main course was cut to clear the boats in the waist. Courses had a hollow foot and the mizzen had a roach, but topsails were straight footed. The fore course at the center was 3 ft (91.4 cm.) higher than the clews (lower outside corners).

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[278] Manwaring and Perrin 1922, 217; Goell 1970, 40.
[279] Goell 1970, 40; "A sail is cut goring when it comes sloping by degrees, and is broader at the clew than at the earing. All topsails and topgallant sails are so." Manwaring and Perrin 1922, 156.
[280]Lees 1984, 134.
[281] "[…] the usual width of a cloth, (and a cloth, by the way, is the sailmaker's term for the canvas he uses) was 24 inches though, in the seventeenth century a 25, 26, and 30 inch width was used." Lees 1984, 136.

Smith addresses bonnets and drabblers by noting that they were 1/3 the depth of the sail they belong to.[282] Bonnets and drabblers were attached to the bottom of sails via eyelets through which small ropes called latchets were laced to attach sails to bonnets and drablers.[283] Drablers simply attach below bonnets, but do not differ in purpose or general shape (Figure 122).[284]

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[282] "Bonnits and Drablers are commonly one third part a peece to the saile they belong unto in depth, but their proportion is uncertaine; for some will make the maine saile so deepe that with a shallow bonet they will cloath all the Mast without a Drabler; but without bonnets we call them but courses." Goell 1970, 39.

[283] "Eylet-holes are those round holes alongst the bottom of those sails unto which do belong the bonnets; and the bonnets have the same for the drablers. The have a little line sewn about them to make them strong, and serve for no other use but to receive into them the latchets of the bonnets, or drablers, with which the bonnet is laced to the course and the drabler to the bonnet." Manwaring and Perrin 1922, 145; "The maine saile and the fore saile is called the fore course and the maine course, or a paire of courses. Bonits and Drablers are commonly one third part a peece to the saile they belong unto in depth, but their proportion is uncertaine; for some will make the maine saile so deepe that with a shallow bonet they will cloath all the Mast without a Drabler; but without bonnets we call them but courses [… Bonet] is made fast with Latchets into the oylet holes of the saile, as the Drabler is to it, and used as the wind permits. Goell 1970, 39; "Latchets are small lines which are sewn into the bonnets and drabler, like loops, wherewith they lace the bonnets and drabler, like loops, wherewith they lace the bonnet to the course, or the drabler to the bonnet, putting them into the eyelet holes and so lacing them one over another." Manwaring and Perrin 1922, 176; "A Bonnet is belonging to another sail, but is commonly used with none but the mizen, main and fore sails, and the spritsail. I have seen (but it is very rare) a topsail bonnet and hold it very useful in an easy gale, quarter winds, or before a wind. This is commonly one-third as deep as the sail it belongs to; there is no certain proportion, for some will make the mainsail so deep that with a shoal bonnet, they will clothe all the mast without a drabler; others will make the mainsail shoaler, that they may with foul weather bear it safer, and then the bonnet will be the deeper […] lacing is here very proper, because it is made fast with latchets into the eyelet holes of the sail." Manwaring and Perrin 1922, 105.

[284] "A Drabler, vide Bonnet, for this is in all respects the same to the bonnet that the bonnet is to the course. This is only used when the course and bonnet are too shoal for to clothe the mast. Some small ships which are coasters (and therefore are for most convenience to have short courses) do use two drablers." Manwaring and Perrin 1922, 141.

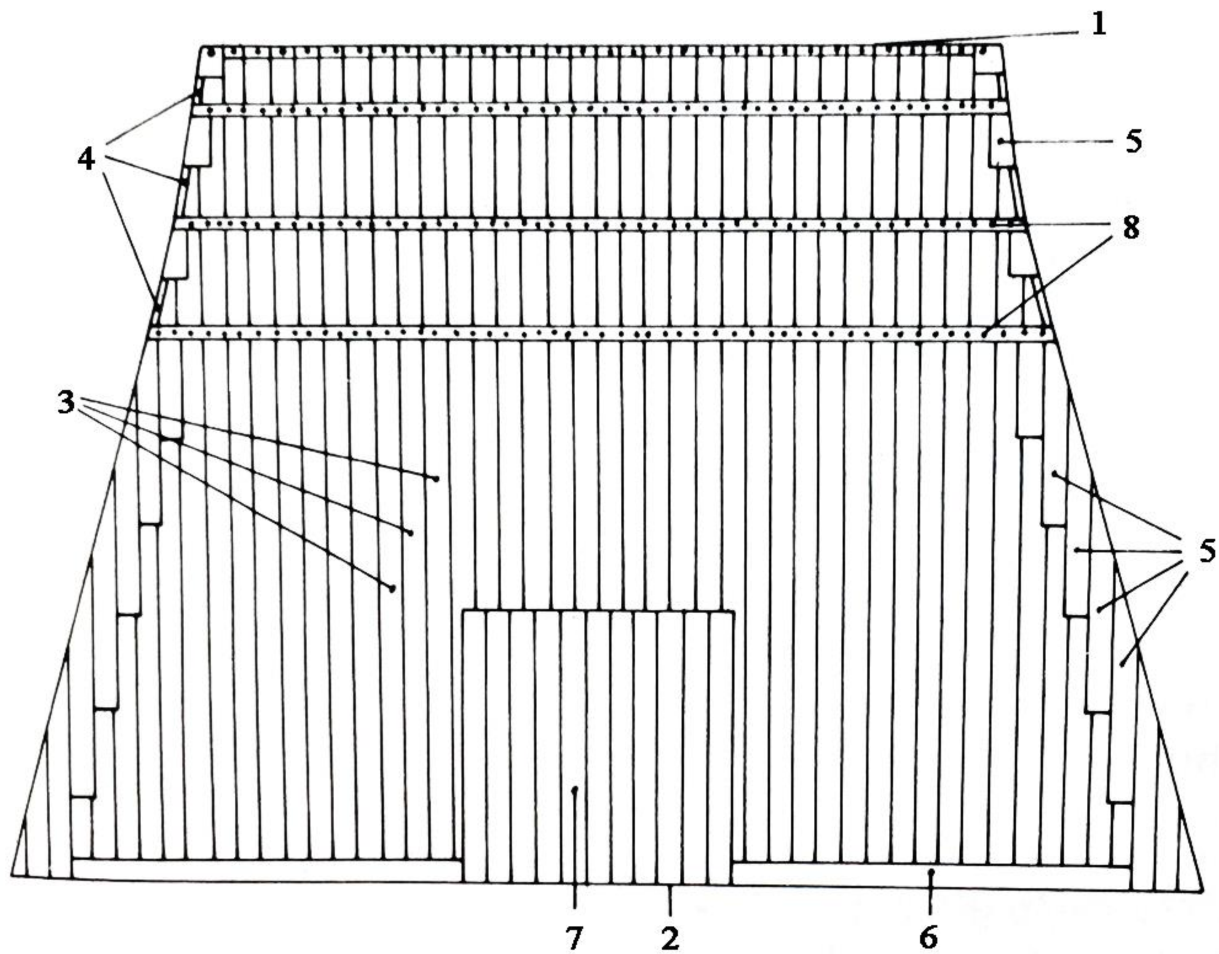

Figure 122: Sail Diagram from Mondfeld. 1) Head; 2) Foot; 3) Cloths; 4) Tabling; 5) Lining; 6) Foot lining; 7) Top lining; 8) Reef bands (Mondfeld 1989, 257)

Given these data, the approximate dimensions of the sails were calculated in Table 20. The dimensions in Table 20 do not consider roaching, the incurving of the bottom of the sail, and so the areas listed below may be slightly less.

	Main Course	Main bonnet	Fore course	Fore bonnet	Main topsail	Fore topsail	Spritsail course	Mizzen Sail
Mast	Main Mast		Fore Mast		Main Topmast	Fore Topsail Mast	Bowsprit	Mizzen Mast
Mast (Feet / Yards)	61 / 20.3		50 / 16.6		30 / 10	25 / 8.33	50 / 16.6	30 / 10
Yard	Main Yard		Fore Yard		Main Topsail Yard	Fore Topsail Yard	Spritsail Yard	Mizzen Yard
Yard (Feet / Yards)	48 / 16		39 / 13		24 / 8	19 / 6.33	27 / 9	30 / 10
Yard Diameter	12 inches		10 inches		6 inches	5 inches	5 inches	5 inches
Yard Cleat (distance from end of yard) (Yards / Feet)	0.33 / 1		0.27 / 0.81		0.17 / 0.50	0.13 / 0.40	0.19 / 0.56	0.21 / 0.63
Sail (in yards)	Main Course (in yards)	Main Bonnet (in yards)	Fore Course (in yards)	Fore Bonnet (in yards)	Main Topsail (in yards)	Fore Topsail (in yards)	Spritsail (in yards)	Mizzen Lateen (in yards)
Depth	13.82	4.15	11.11	3.33	9.00	7.47	~8	~6.77
Foot	16		12.46		15.33	12.46	8.6	~6.77
Head	15.33	16	12.46	12.46	7.67	6.07	8.63	
Mast length	20.3		16.6		10	8.3		10
Mast Head	2.1		1.7		1	0.83		1
Hounds	1.4		1.1		0.5	0.42		0.66
Approximate Total Area	Approximate Main Course Total Area (Including Bonnet): 282.84		Approximate Fore Course Total Area (Including Bonnet): 179.92		Approximate Main Topsail Total Area: 103.5	Approximate Fore Topsail Total Area: 69.21	Approximate Spritsail Total Area: 71.63	Approximate Mizzen Lateen Total Area: 22.92
Approximate sail areas (in square yards)	Approximate Head sail areas (in square yards): 320.76		Approximate After Sail Area (in square yards): 409.26					

Table 20: *Warwick's* reconstructed sail dimensions. The dimensions were calculated according to information provided in *Masting and Rigging of English Ships of War* by James Lees.

Ropes that attached to sails include: robands (robbins), bolt ropes, cringles (creengles), sheets, tacks, clew lines (and clew garnets), leech lines, buntlines, martinets (martnets), bowlines, and brails.

Sails were fastened to their yards with robands, or lines reeved through eyelets under the head rope.[285] The head rope is the top bolt rope on each sail, (the bolt rope is the rope that lines the outside of the entire sail to more easily stow and handle the sails).[286] The bolt rope is three-stranded and not twisted too tightly, but made pliant to give the sails more movement.[287] Spliced into the bolt rope are cringles, or small ropes made into semi-circular loops along the edge of a sail, whose purpose is to attach the bowline bridles.[288] At the top corners of sails are small rope rings called earrings. These are used to attach the sail to the cleats at the end of the yard arms. The two earrings at the lower corners of a sail (called clews or clues) are where the tacks and sheets are seized (Figure 123).[289]

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[285] "Robbins are little lines reeved into the eyelet holes of the sail under the head-line, and are to make fast the sail unto the yard." Manwaring and Perrin 1922, 212; "Robins ar certayne smale ropes fastened to Iletholes under the headrope halfe a foote asunder and ar tied about the yeard to fasten the sayle to it […] The Robins fasten the saile to the yearde." Salisbury and Anderson 1958, 49, 52.

[286] "Boltropes is that roipe [which] is sowed about every saile, soft and gently twisted, for the better stowing and handling the sailes." Goell 1970, 27; "Head lines are the ropes that make all the sailes fast to the yard." Goell 1970, 26.

[287] "A Bolt-rope is the rope into which the sail is sewed, or made fast: that is a three-strand rope made gentle and not twisted so hard as the others, of purpose to be the more pliant to the sail, as also that they may sew the sail into it the better." Manwaring and Perrin 1922, 104-105.

[288] "Creengles are little ropes spliced into the Bolt-ropes of all sailes belonging to the maine and fore mast, to which the boling bridles are made fast and to hold by when we shake off a Bonnet." Goell 1970, 27. "Brailes ther standing partes ar fastened with Cringles to the litches of the sayle[…]" Salisbury and Anderson 1958, 59.

[289] "Earing is that part of the bolt-rope which at all the four corners of the sail is left open, as it were a ring. The two uppermost are put over the ends of the yards or yard arms, and so the sail is at those two ends made fast to the yard. Into the lowermost the tacks and sheets are seized, or (as the more proper term is) they are bent unto the clew." Manwaring and Perrin 1922, 143; "A Cleat is a small wedge of wood fastened on the yards to keep any ropes from slipping by where that is fastened. There are also divers other uses of it, as to keep the earing of the sail from slipping off the yard." Manwaring and Perrin 1922, 126; "The Clew of a saile is the lowest corner next the Sheat and Tackes, and stretcheth somewhat goaring or sloping from the square of the saile, and according to the goaring, she is said to spread a great or a little clew." Goell 1970, 27-8.

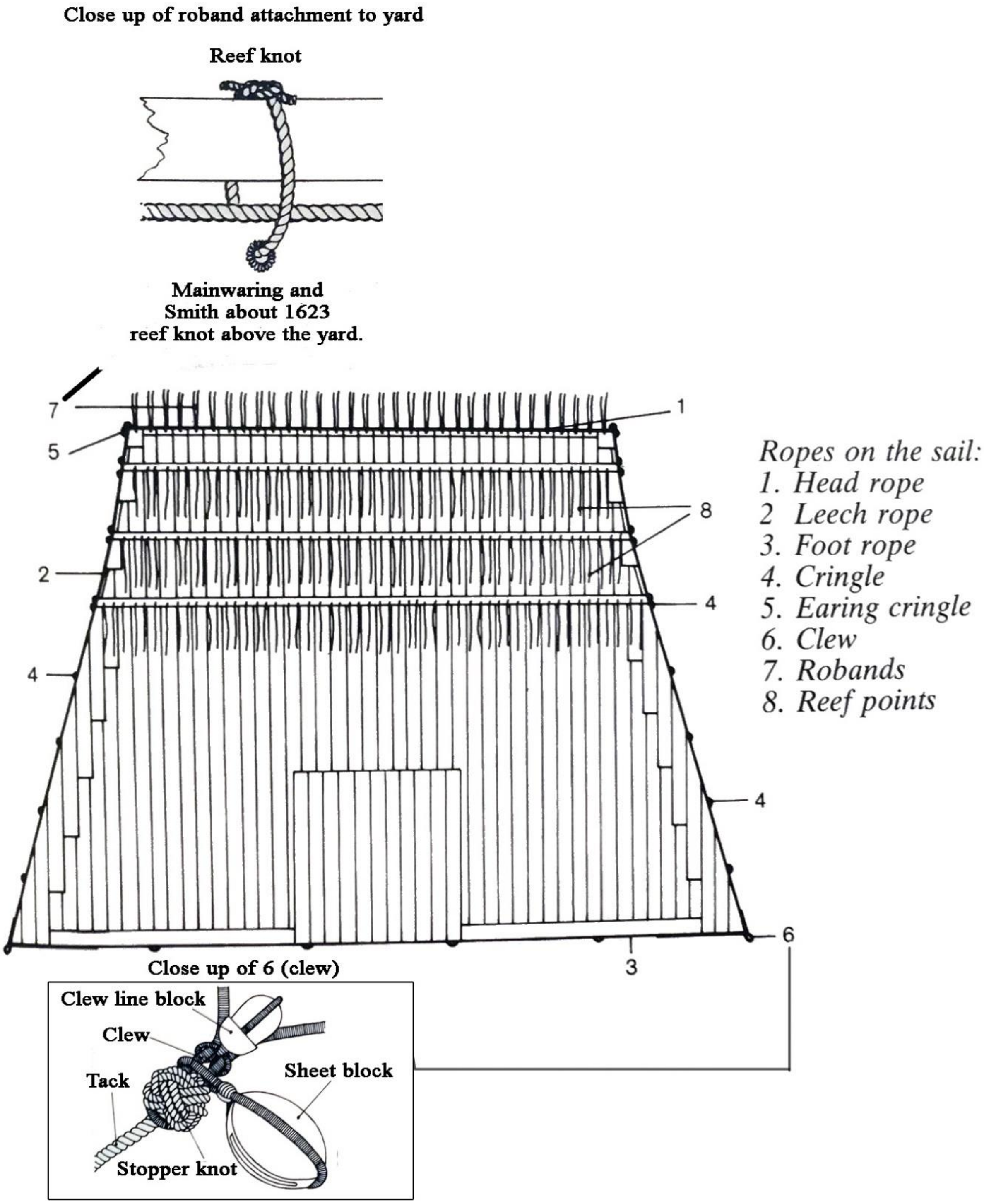

Figure 123: Ropes to a sail (after Mondfeld 1989, 259, 319; Lees 1984, 77).

The clew of the sail served to attach several lines. The tack (which belongs only to main course, fore course, and mizzen sail) and hauls the clew forward, the sheets haul the clew and its sail aft, and the clew line hoists the clew up to the yard when furling the sail (see close up of clew in Figure 123).[290] The tacks have a stopper knot at one end that is seized into the sail clew, the other end is reeved through the chesstrees, and then to the bitts or a kevel.[291] The fore tacks are run through two holes at the comb (Figure 124).[292] Next, the sheets on the lower courses haul aft the clews, but on upper sails they haul them closer to the yard's arm.[293] The standing part of the sheet is attached to a ring on the sides of the ship on the outer side of the bulwarks; the running part runs through a block (sheet block) fastened to the clew, and then through blocks at the bulwarks where the standing part is fastened, before finally being belayed to the gunwale under the shrouds (Figure 125). The clew line (clew garnet in lower courses) is a rope attached to the clew that runs through a block seized to the middle of the yard, with one on each side of the yard arm between the parrel and yard arm, which goes to the sail clews and then to another block

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[290] Manwaring and Perrin 1922, 240-41.

[291] "Tackes are great ropes which, having a wall-knot at one end seased into the clew of the saile, and so reeved first thorow the chestres, and then commeth in at a hole in the ship's sides. This doth carry forward the clew of the saile to make it stand close by a wind." Goell 1970, 28; Manwaring and Perrin 1922, 240-41; "Tackes. Ther standing parts ar fastened to the clew of the sayles with a wale knot and the strap of the mayne sheete keeps it fast, thence they passe throw the Chestrees which ar boulted to the outside of the loffe of the ship and ar belayed to bitpins on the fforecastell." Salisbury and Anderson 1958, 50; "Kevels are small pieces of timber nailed to the inside of the ship, unto which we belay the sheets and tacks." Manwaring and Perrin 1922, 172; see also Goell 1970, 8.

[292] "The Comb is a small piece of timber set under the lower part of the beal-head, near the midst, with two holes in it; and is just in the nature and hath the same use to the fore tacks that the chess-trees hath to the main tacks; which is, to bring the tack aboard." Manwaring and Perrin 1922, 129; Note: Fore tacks and other ropes could have also been fastened to ranges. "Ranges. There are two: the one aloft upon the forecastle a little abaft the foremast, the other in the beakhead before the wooldings of the boltsprit: that in the forecastle is a small piece of timber which goes over from one side to the other, and there is fastened to two timbers, two knees, which are fastened to the deck and this timber, in which run the topsail sheets in a shiver, and hath divers wooden pins through it to belay ropes unto (as the foretacks, fore-topsail sheets and fore bowlines, the fore loof-hook), and that in the beakhead is in the same form, whereunto is belayed the spritsail lifts, the garnet of the spritsail, and other ropes belonging to the spritsail and spritsail-topsail." Manwaring and Perrin 1922, 207-208.

[293] "The Sheats are bent to the clews of all sailes. In the low sailes they hale aft the clew of the sailes, but in top sailes they serve to hale them home, that is, to bring the clew close to the yard's arm." Goell 1970, 28.

on the yard arm, and finally to the deck where it is belayed at the gun wales. They were used to furl the sail to the middle of the yard (Figure 126).[294]

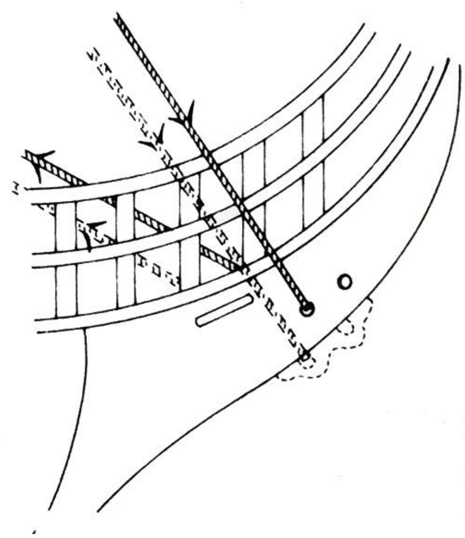

Figure 124: Lead of fore tack (Mondfeld 1989, 318).

[294] "The Clew garnet is a rope made fast to the clew of the saile, and from thence runnes in a blocke seased to the middle of the yard, which in furling doth hale up to the clew of the saile close to the middle of the yard; and the clew line is the same to the top sailes, top gallant and spret sailes, as the Clew garnet is to the maine and fore-sailes." Goell 1970, 27; Manwaring and Perrin 1922, 126-27; "Sheetes, the standing part of ether of them is fastened to rings set on ether side of the outside of the quarter of the ship, from thence their pas through blockes fastened to ether sided of the clewes of the saile and thence goe through pullies placed on the outside of the quarter of the ship before the rings, to which the standing part is fastened, from thence thei goe into the ship and ar belayed to the gunwale under the shroudes." Salisbury and Anderson 1958, 50; "Clewgarnets they ar fastened to the middle of the yeard on ether side of the yeard arme between the parrell and yeard arme from thence thei goe to the clewes of the sayles and art her rived through 2 blockes and from thence pas through 2 other blocks fastened on ether yeard arme within the first fastenings, and so to the decke and ar belayed to the Gun Wales by the foremost shrowds." Salisbury and Anderson 1958, 51.

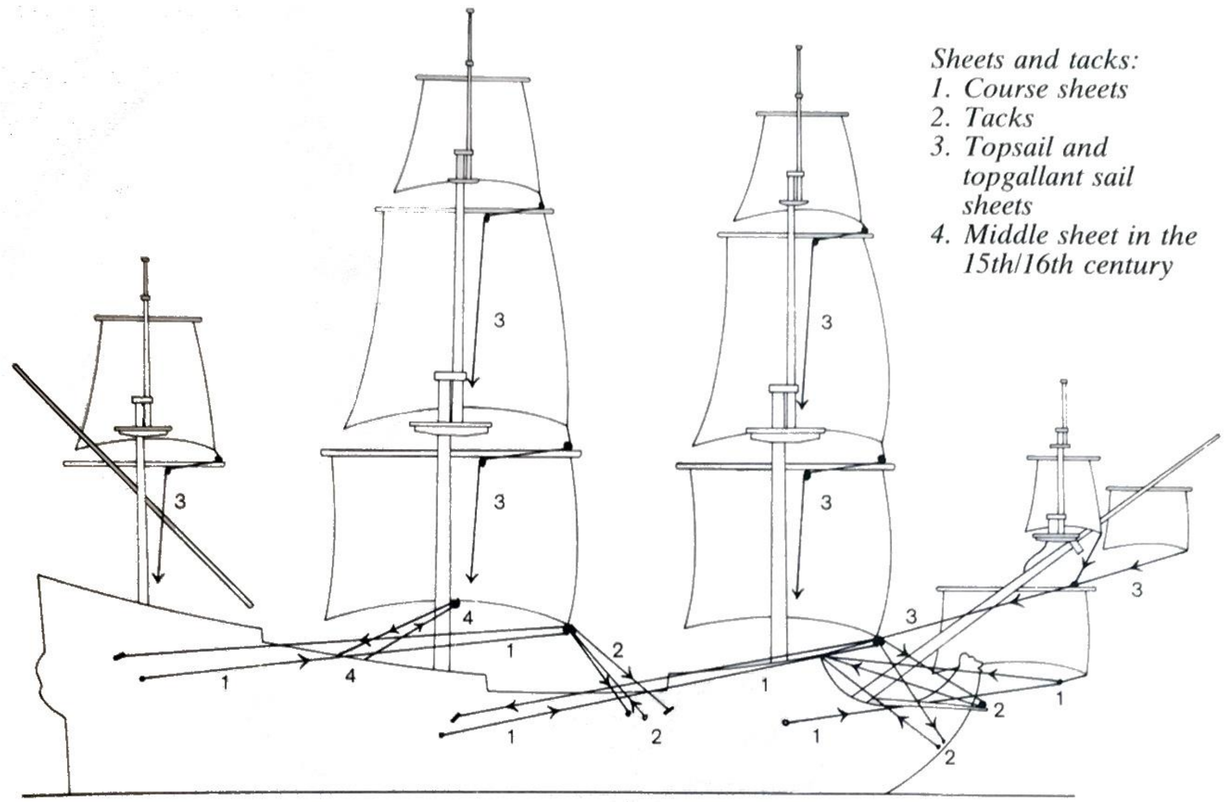

Figure 125: Sheets and tacks (Mondfeld 1989, 319).

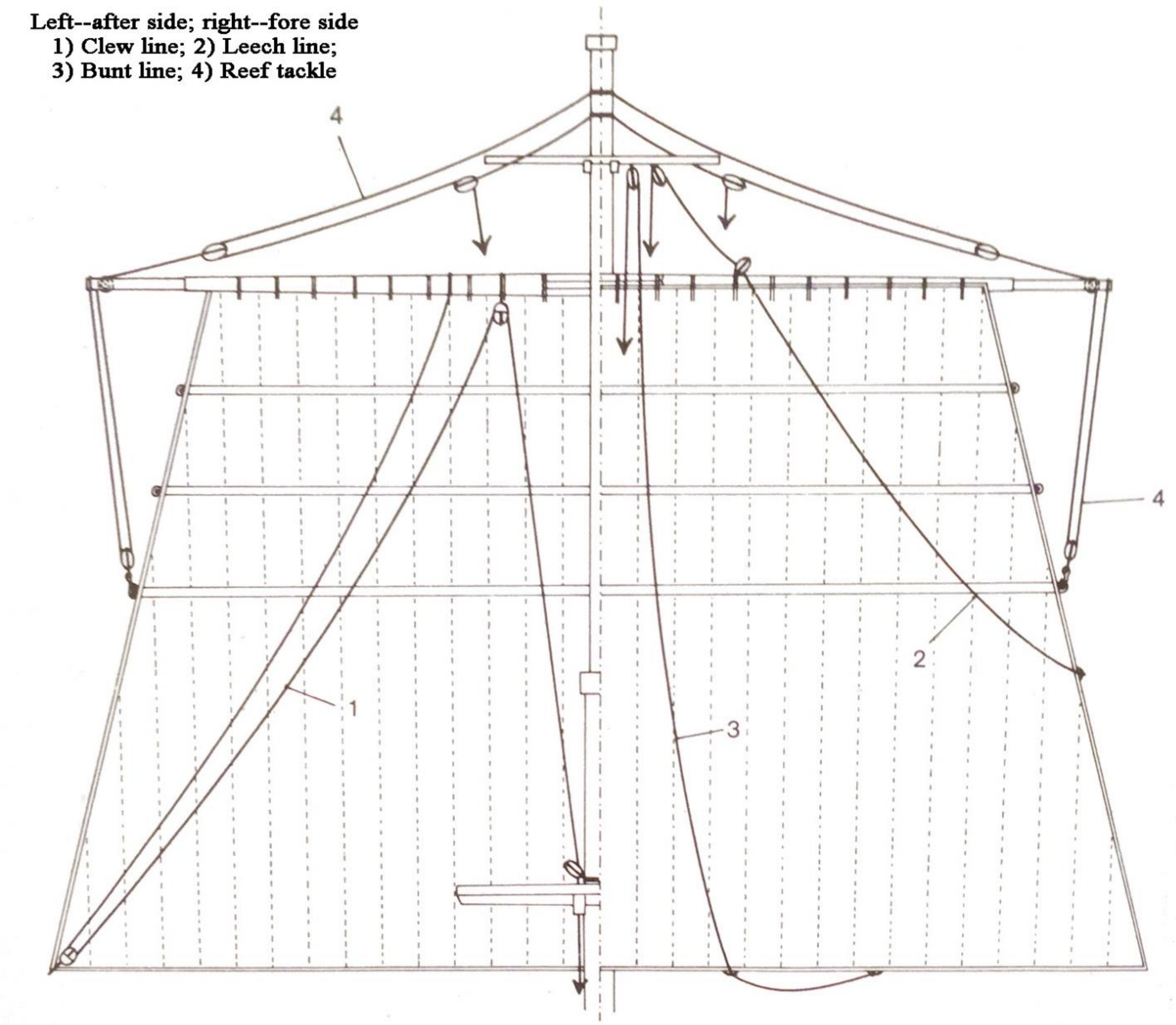

Figure 126: Clew lines, leech lines (note that the upper block can also be seized to the yard, and not only the top as shown here), bunt lines, and reef tackles (Mondfeld 1989, 321).

Martinets (or sometimes leech lines) and bunt lines were used to haul in the sail. Martinets and leech lines served the same purpose—to haul in the leech (sides) of the sail. Lees wrote that leech lines superseded martinets around 1650.[295] But, of the three primary documents that discuss running rigging, all three include martinets, while one (*A Sea Grammar*) also

[295] Lees 1984, 72.

mentions leech lines, indicating that this term was already in use in 1627, even if it was more uncommon than martinets. Leech lines were small ropes attached to the leeches (sides) of topsails only. They were reeved into a block on the yard near the ties, to be used to haul in the leech.[296] Similarly, the martnets (martinets) were ropes fastened to the leech (sides) of the sails.[297] A pendant placed over the topmast head carries a block through which a rope runs; one end of this rope is another block, the other end is fastened at the deck. Through this second block runs another rope that has 3-holed deadeyes fastened at both ends through which the martinet legs (or marlets) in six parts which are fastened to the bolt of the sail leech (Figure 127).[298] Given that more treatises during the early 17th century mention martinets, these are included in the reconstruction rather than leech lines.

Bunt lines were small lines attached to the foot of the sail at the bolt rope to a cringle, the line was then reeved through a block that was seized to the yard (or seized to the underside of the mast top, as seen in Figure 126, see footnotes for variations), before going down to the deck

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[296] "Leech lines are small ropes made fast to the Leech of the top-sailes, for they belong to no other, and are reeved into a blocke at the yard, close by the top-saile ties, to hale in the Leech of the saile when you take them in. The Leech of a saile is the outward side of a skirt of a saile, from the earing to the clew." Goell 1970, 28-9; see also Manwaring and Perrin 1922, 179.

[297] "Martnets are small lines which are fastened to the legs on the leech of the sail and seem like crow ft, the fall being reeved through a block at the topmast-head and so comes down by the mast to the deck: the martnets of the topsails are in the same manner to the head of the topgallant mast, but their fall comes no farther than the top, where it is hauled. […] These most commonly belong to the two courses, yet many great ships have them to the topsails and spritsails." Manwaring and Perrin 1922, 185-86.

[298] "Martnets ar framed of 2 pennants a ffale and the martlets. The first pennant is fastened to the Topmast head over the tresletrees above the shrowdes; and is 2 fadom long, at the lower ende of it is fastened to a blocke to which the fall is fastened and from thence goeth through an other blocke fastened to the lower pennant blocke, and from thence gother through the blocke of the upper pennant, and so to the decke: through the lower pennant blocke goeth the other pennant in 2 partes to the lower ends of ether of which partes is fastened a dedmans eye with three holes in them through which the martlets passe in 6 parts, at every deadmans eye and ar fastened at every end to a smale lope called legs, which ar fast to the boult rope at the Litch of the sayle they goe downe within a yeard of the clew of the mayne cours." Salisbury and Anderson 1958, 51; "Legs. They are called the legs of the martnets, and are small ropes put through the bolt-ropes of the main and foresail in the leech of the sail, near a foot of length, and so at either end, being spliced into themselves, they have a little eye whereinto the martnets are made with two hitches, and the end seized to the standing part of the martnets." Manwaring and Perrin 1922, 179.

where they were belayed to cleats. They were used to furl the sail, and several can belong to one sail depending on its size (Figure 126).[299] The spritsail buntline was belayed to the forecastle.[300]

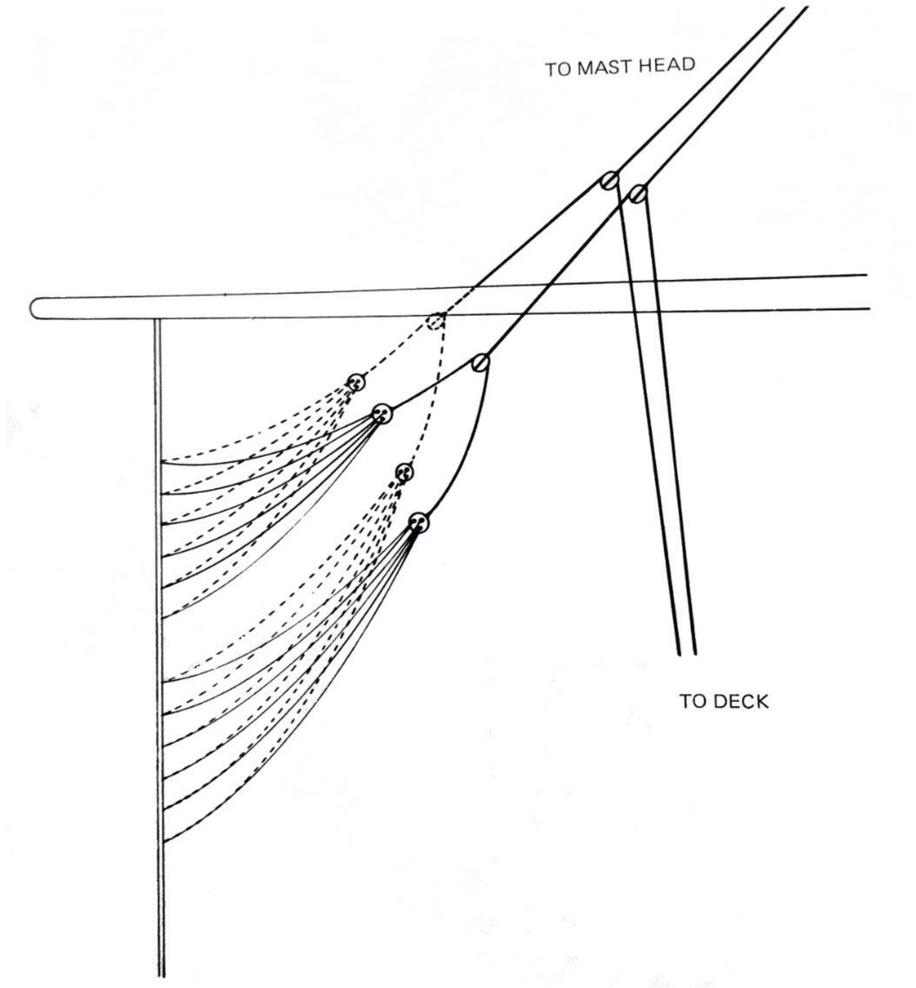

Figure 127: Martinets (Lees 1984, 71).

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[299] "Bunt-lines are small lines which are made fast to the bottom of the sails in the middle part of the bolt rope, to a cringle, and so reeved through a small block, seized to the yard, the use whereof is to trice up the bunt of the sail for the better farthelling and making up of the sail to the yard. [The smaller sails and topgallant sails do not need them.] Manwaring and Perrin 1922, 111-12; "Buntlines they ar 3 one in the middle and one on ether side of the Bunt of the sayle they are fastened to the skertes of the sailes and from thence they goe through a blocke fastened to the collar of the mayne stay and so to the decke and ar belayed to 2 cleates set to ether side of the mayne mast." Salisbury and Anderson 1958, 51; "Bunt lines is but a small rope made fast to the middest of the boltrope, to a creengle reeved thorow a small blocke which is seased to the yard, to trice or draw up the Bunt of the saile when you farthell or make it up." Goell 1970, 27.

[300] "Made fast to the bunt of the sail from which it comes to the bowsprit close by the yard and goes through a block fastened there and goes to the forecastle where it is belayed. Salisbury and Anderson 1958, 57.

The bowline was used to haul the leading edge of a sail forward to allow a ship to sail closer to the wind. Bowlines were found on all sails except for the spritsail and spritsail topsail. The falls of the bowline were forward of the sail and ran through running blocks to the mast before being led aft to the deck where they were belayed. From the dead block run several small ropes that are fastened to the cringles of the sail leech (on the mizzen the bowline is fastened to the foot) using a bowline knot with two, three, or four ropes, via bowline bridles (Figures 128-129).[301] The two dead blocks found at the *Warwick* site, artifacts 80:129E and 93:30-13-1, are possibly one of the types of dead blocks used on the bowline bridles to distribute its lines to the cringles (Figure 130).[302] Similar dead blocks have been found on the Angra C Wreck and *Vasa*, where they were hypothesized to belong to the bowline bridles, or were simply blocks used for light loads in general.[303] The size of the *Warwick* dead blocks makes them suitable for smaller upper sails, or on the brails of the mizzen in a smaller vessel (see next paragraph for brails).[304]

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[301] "The Boling is made fast to the leech of the saile about the middest, to make it stand the sharper or closer by a wind. It is fastened by two, three or foure ropes like a crow's foot, to as many parts of the saile, which is called the Boling bridles, onely the missen Boling is fastened to the lower end of the yard. This rope belongs to all sailes exce[t the Spret-saile and Spret-saile Top-saile, which not having any place to hale it forward by, they cannot use those sailes by a wind." Goell 1970, 28; "Bowlings, they ar fastened by bridles and cringles to the litch of the saile the bridles goe in 3 partes, from the litche of the sayle thei passe ether of them through a blocke fastened to the Bove spright hard by the stemme from thence they com into the ship and ar belayed to bit-pins on the fore castell." Salisbury and Anderson 1958, 50; "Bowline is a rope which is fastened to the leech or middle part of the outside of the sail, the use whereof is to make the sail stand the sharper or closer by a wind […] It is fastened by 2, 3, 4, or more parts to the sail, which they call the bowline bridle; only the mizzen bowline is fastened to the lower ende of the yard. This rope belongs to all sails excepting spritsail and sprit-sail-topsail, which have no place whereby to haul a bowline forward on, and therefore these sails cannot be used close to the wind." Manwaring and Perrin 1922, 107; "The one is a bowline knot, which is so made that it will not slip nor slide. With this knot the bowline bridles are made fast to the cringles, but it is used many other ways. The other is a wale-knot, which is a round knot or knob made with the three strands of a rope so that it cannot slip. The tacks, topsail sheets, and stoppers have these wale-knots, and many other ropes." Manwaring and Perrin 1922, 173.

[302] "Dead men's eyes are blocks, some small, some great, with many holes but no shivers. The Crowe's-ft reeved thorow them are a many of small lines, sometimes 6, 8, or 10, but of small use more than for fashion to make the Ship shew full of small Ropes." Goell 1970, 23.

[303] Phaneuf 2003, 111.

[304] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015.

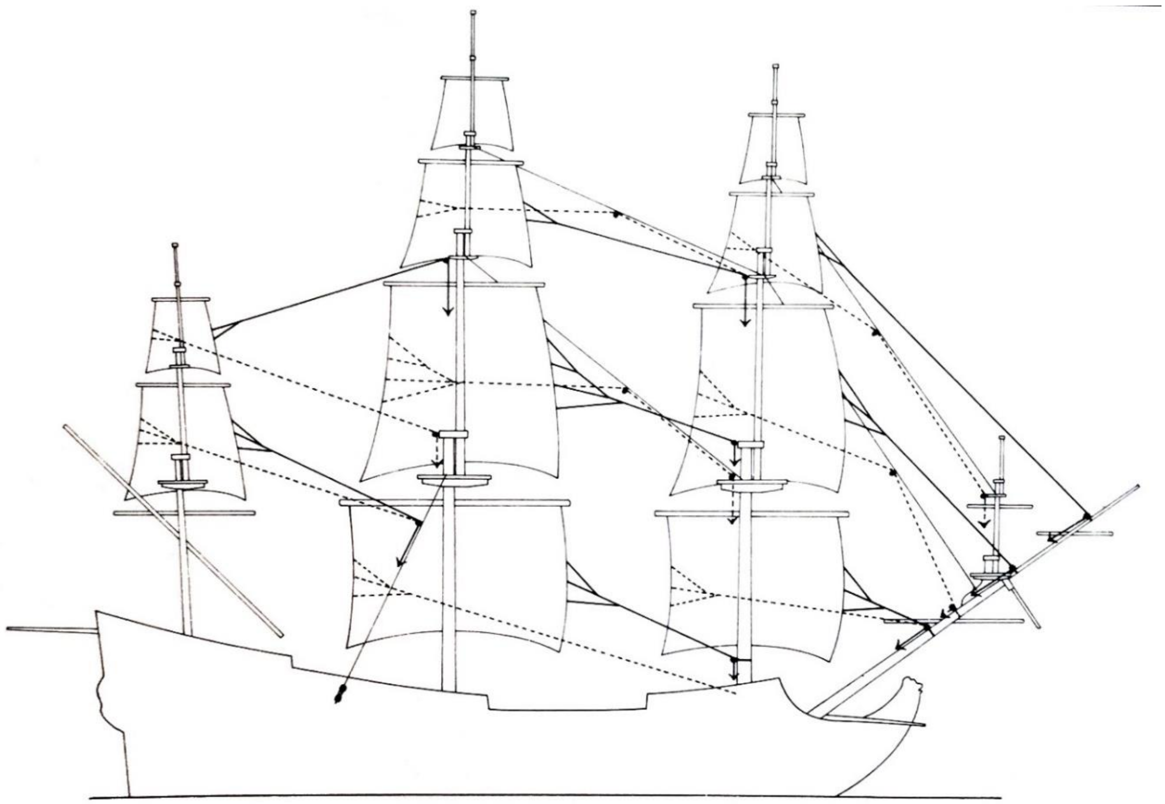

Figure 128: Bowlines (Mondfeld 1989, 323).

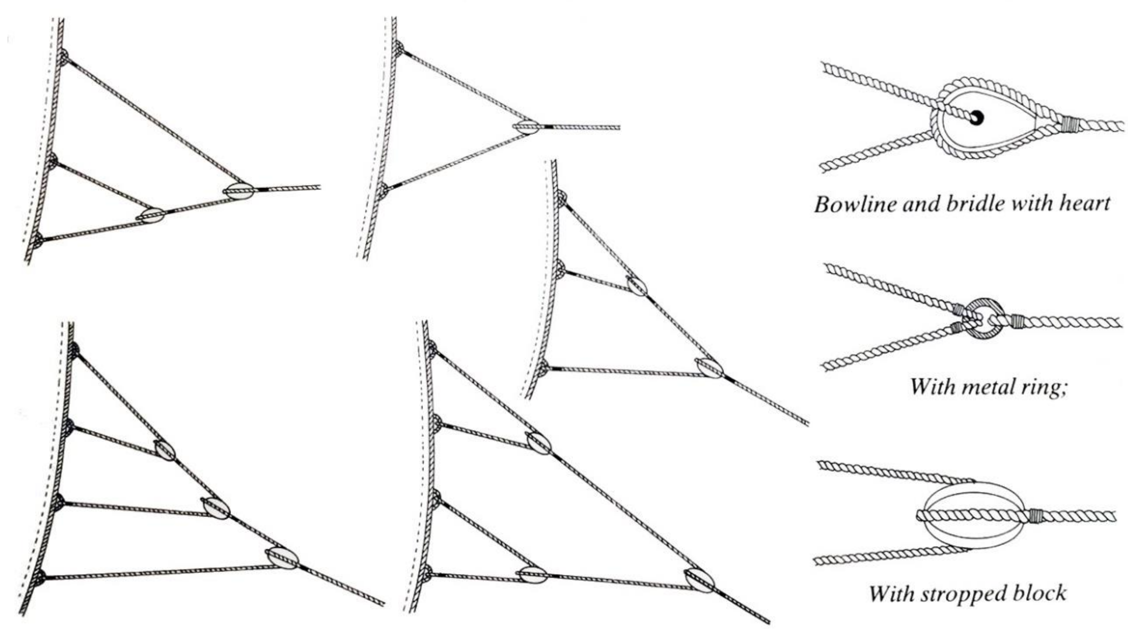

Figure 129: Bowline bridles (Mondfeld 1989, 323).

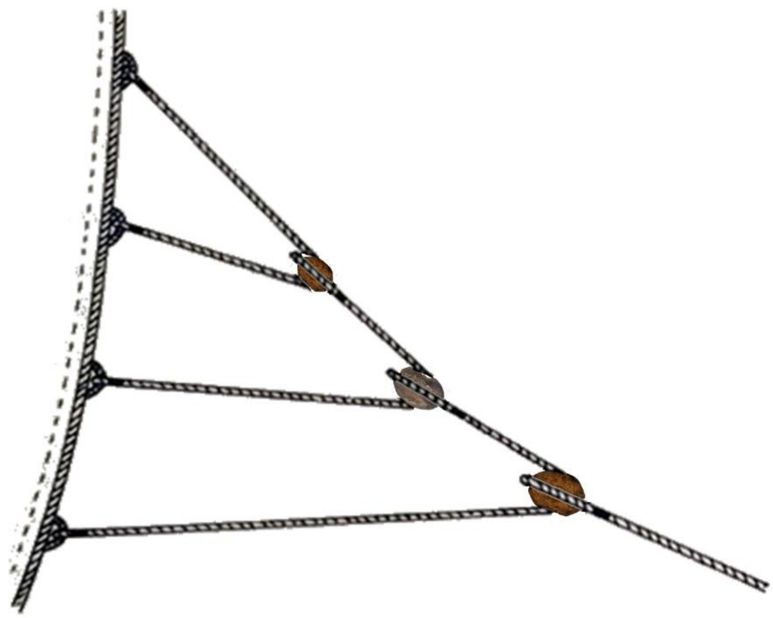

Figure 130: How the bowline bridles may have looked with *Warwick's* artifacts fitted (Artifacts 80:129E and 93:30-13-1, the latter was shown twice in this image as an example) (By author).

Brails belonged to the two lower courses and mizzen sail to haul the bunt of the sail to furl it. Blocks were seized to both sides of the ties on the yard through which the brail was reeved, one end led to the deck, while the other split and attached to the cringles (Figure 131).[305]

[305] "Brails are small ropes reeved through blocks which are seized on either side the ties, some small distance off, upon the yards, and so come down before the sail and are fastened to the cringles at the skirt of the sail: the use whereof is to haul up the bunt of the sail when we do farthell our sails across, which are in this commodious for a man-of-war that he may instantly make up his sails and let them fall […] These brails do only belong to the two courses and to the mizen." Manwaring and Perrin 1922, 108-109; "The Brales are small ropes reeved thorow Blockes seased on each side the ties, and come down before the saile, and at the very skirt are fastened to the Creengles. With them we furle or farthell our sailes acrosse, and they belong onely to the two courses and the missen." Goell 1970, 27.

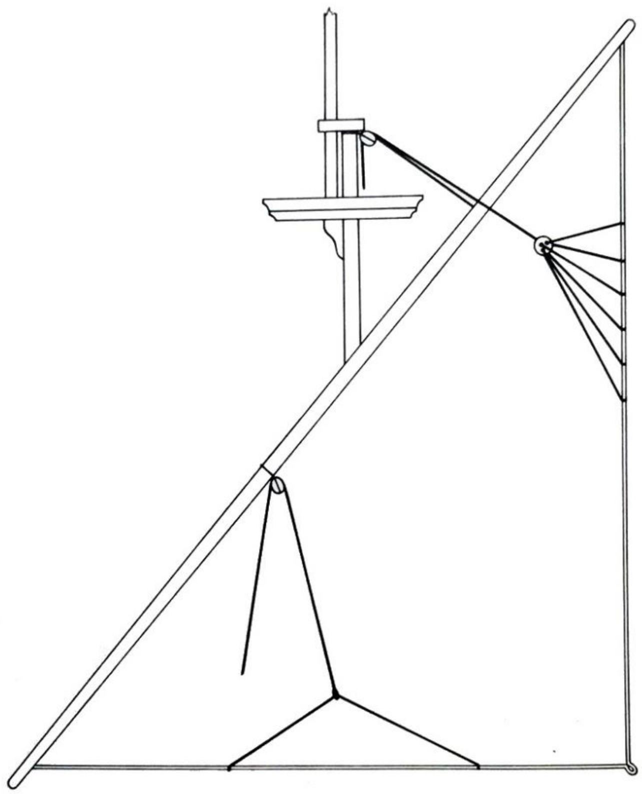

Figure 131: Mizzen brails (Lees 1984, 108).

Miscellaneous

It is possible that when more propulsion was needed studding sails were fitted to *Warwick*. Studding sails were smaller sails that were attached to the sides of main, fore, and spritsail with a boom (long pole) so to increase a vessel's sail area and hence its sailing speed (Figure 132).[306]

[306] "A Boom is a long pole which we use commonly to spread out the clew of the studding sail; yet sometimes also we boom out the clew of the mainsail and foresail to spread them out so much the broader to receive more wind Manwaring and Perrin 1922, 106; "[…] in a faire gaile your studding sailes, which are bolts of Canvasse or any cloth that will hold wind, [which] wee extend alongst the side of the maine saile, and boomes it out with a boome or long pole; which we use also sometimes to the clew of the maine saile, fore saile and spret saile when you goe before the wind, or quartering, else not." Goell 1970, 39.

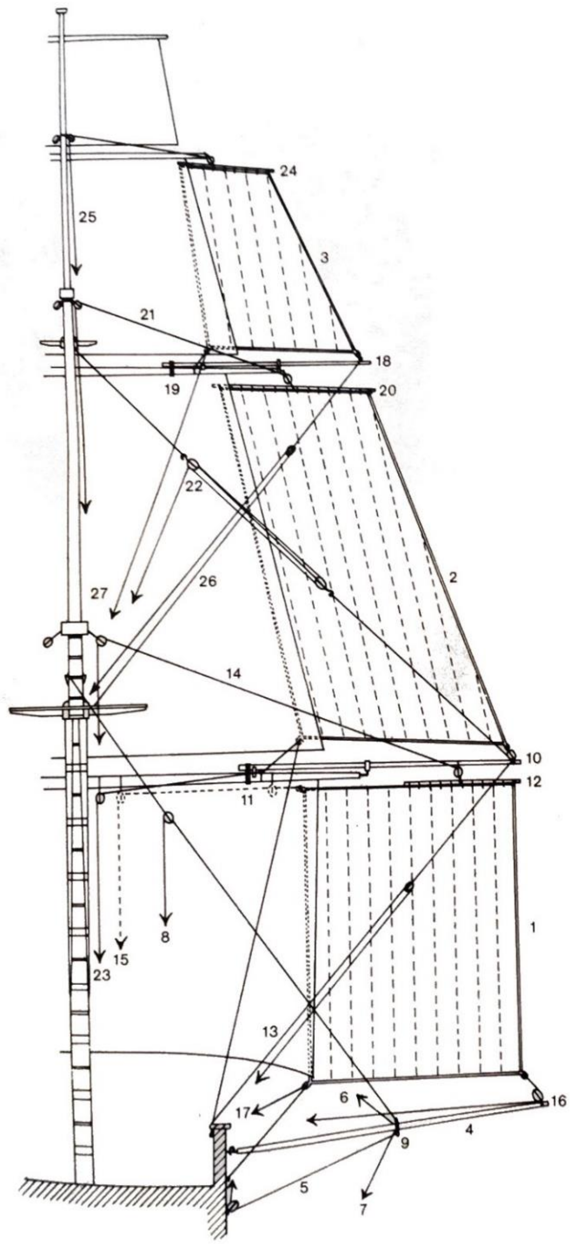

Figure 132: Studding sails. 1) Lower studdying sail; 2) Topmast studding sail; 3) Topgallant studding sail; 4) Studding sail boom, 5) Martingale; 6) Forward guy; 7) After guy; 8) Topping lift; 9) studding sail band or strop; 10) Topmast studding sail boom; 11) Heel lashing; 12) Lower studding sail yard; 13) Topmast studding sail tack; 14) Lower studding sail outer halyard; 15) Lower studding sail inner halyard; 16) Lower studding sail tack; 17) Lower studding sail sheet; 18) Topgallant studding sail boom; 19) Heel lashing; 20) Topmast studding sail yard; 21) Topmast studding sail halyard; 22) Topmast studding sail tack. (Alternative lead—Continental practice); 23) Topmast studding sail sheet; 24) Topgallant studding sail yard; 25) Topgallant studding sail halyard; 26) Topgallant sail tack; 27) Topgallant studding sail sheet. (Mondfeld 1989, 329)

Flagstaffs, on which a flag was displayed, were sometimes fitted to the upper part of topmasts. It is uncertain if *Warwick* carried these, given that it was not meant as a warship and perhaps had less of a need for naval signaling; however, flags were also used simply for decoration or to show one's nationality at sea, and are often but not always shown in iconography.[307] Further, flagstaffs were sometimes used to support a small upper sail.[308]

Warwick's rigging reconstruction with standing and running rigging can be seen in Figure 133.

[307] "Flags. These are not only used at sea for distinctions of Nations, or Officers of Fleets (as that the Admiral should have his in the main-top, the Vice-Admiral in the fore, and the Rear-Admiral in the mizentop), but also for distinctions and signs what ships must do, according as they have directions from the Chief Commander; as to chase, to give over, to come to Council , or the like[…]" Manwaring and Perrin 1922, 148.
[308] "[…] fflagstaves whose number is uncertayne, som ships have them pon every Topgallant mast, and they serve also for Toptopgallant sayles, which ar of good use in a loune gale of winde." Salisbury and Anderson 1958, 47.

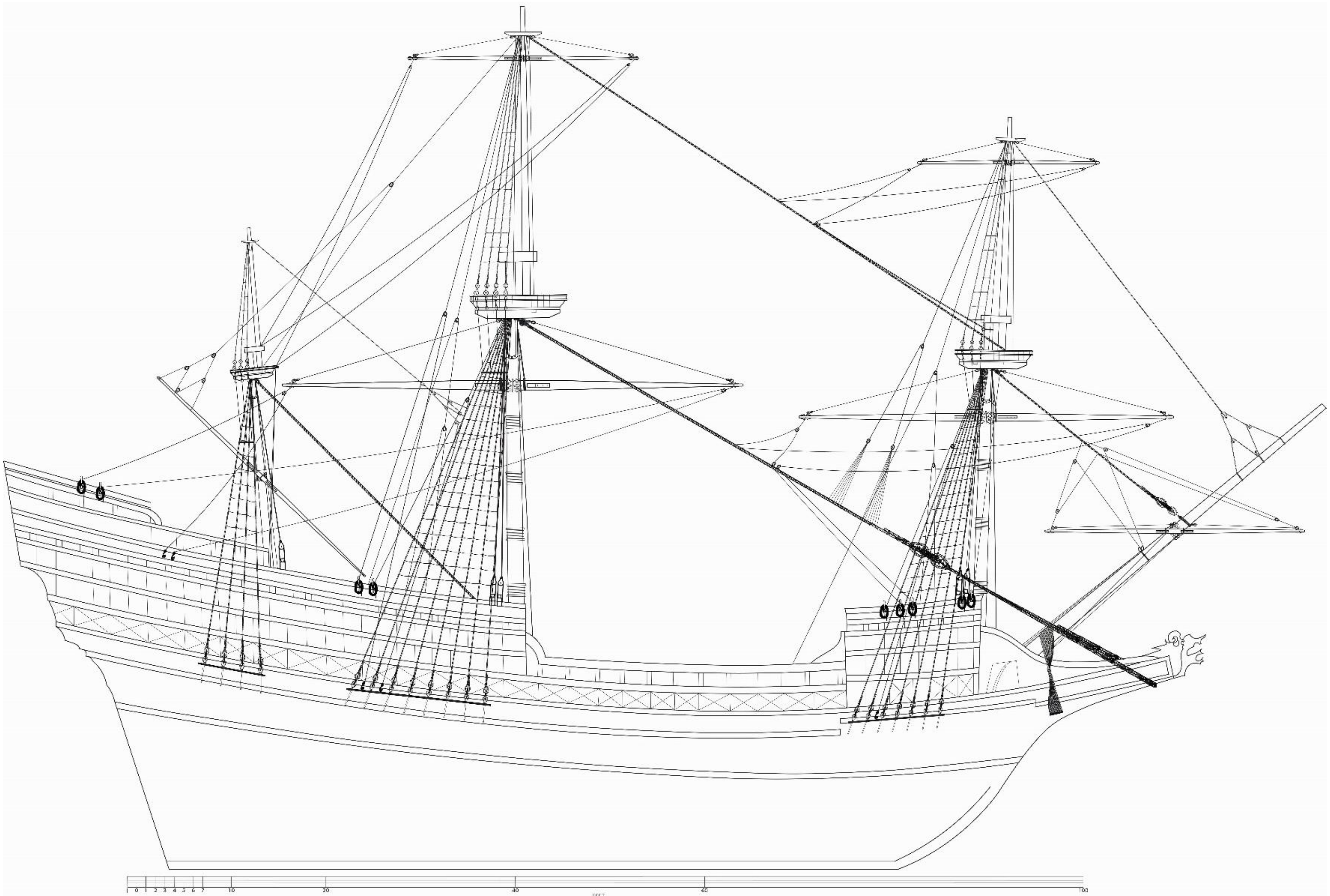

Figure 133: *Warwick's* running rigging with the exception of ropes belonging to the sails (Image by author).

CHAPTER 8

CONCLUSION

Warwick's rigging reconstruction adds to existing knowledge on 17th-century English ship construction and outfitting during a time when significant changes to the rigging of European ships were taking place. This thesis looked not only at *Warwick* as one example, but also placed it within the context of ship rig transitions. In the process, these rig transitions were further refined through the creation of a deadeye typology and analysis of historical sources.

Archaeological study of deadeyes showed that around AD 1653 vertical grain deadeyes became uncommon and were replaced by horizontal-grained deadeyes. Horizontal-grained deadeyes correlated to the round shape whereas vertical-grained deadeyes correlated to pear-shaped deadeyes. The latter form of deadeyes was prevalent between AD 1545 to 1583, pear-shaped-flattened-base (PFB) deadeyes appear from AD 1545 to 1628, round-with-tapered-base (RTB) deadeyes appear in AD 1628 to 1697, and round deadeyes became common between AD 1621 to 1700. Contemporary treatises show that major transitions in rigging took place between AD 1600 to 1623 (Appendix D) and ship lists indicated the defining year in English rigging changes was AD 1618 when official reforms were made to the Royal Navy. Transitions shown in the iconography were not definitive due to the short range of time and limited examples, but pointed to the fact that certain masts and yards, such as the spritsail topmast and spritsail topsail yard, fore topgallant mast and yard, main topgallant mast and yard, mizzen topsail yard, and crossjack yard were not yet consistently fitted at the time, while the bonaventure mast had already been eliminated.

Based on the data obtained, *Warwick's* rig reconstruction included a bowsprit, spritsail yard, fore mast, fore yard, fore topmast, fore topsail yard, main mast, main yard, main topmast, main topsail yard, mizzen mast, mizzen yard, and mizzen topmast. Standing and running rigging include shrouds, ratlines, catharpins, stays, backstays, ties, halliards, jeers, lifts, braces, parrels, trusses, sails, tacks, sheets, clew lines, martinets, bunt lines, bowlines, and brails.

With digital technology and machine learning, collecting and analyzing data will be streamlined and the results can be used to produce an accurate timeline of when each feature was introduced and standardized. New information and trends in rigging can be refined once further archaeological discoveries are made, more iconography analyzed, and new treatises and ship lists found. Hopefully this thesis will serve as the start of research in this direction.

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APPENDIX A

WARWICK RIGGING ARTIFACT DATABASE

Artifact #: 02: 155.254557-764-u
Type: Deadeye, three-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 165.4 g
Dimensions
- **Length**: 88.66 mm
- **Width**: 97.96 mm
- **Thickness/Height**: 29.59 mm
- **Score Width:** 16 mm
- **1: Eyehole Depth**: 29.5 mm
- **1: Eyehole Diameter**: 15 mm
- **2: Eyehole Depth**: 29 mm
- **2: Eyehole Diameter**: 15 mm
- **3: Eyehole Depth**: 28.5 mm
- **3: Eyehole Diameter**: 15 mm

Comments: Dark wood with horizontal grain; waxy with some PEG and "spiderweb" cracking visible on surface; designed to be stropped

Artifact #: 02: 155-034
Type: Deadeye, three-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 519 g
Dimensions

- **Length**: 165.03 mm (broken)
- **Width**: 142.07 mm
- **Thickness/Height**: 43.83 mm
- **Score Width:** 30 mm
- **1: Eyehole Depth (Left)**: 4 mm
- **1: Eyehole Depth (Right)**: 47 mm
- **1: Eyehole Diameter**: 35 mm
- **2: Eyehole Depth (Left)**: 34 mm
- **2: Eyehole Depth (Right)**: 2 mm
- **2: Eyehole Diameter**: 3 mm
- **3: Eyehole Depth (Left)**: 46 mm
- **3: Eyehole Depth (Right)**: 46 mm
- **3: Eyehole Diameter**: 3 mm

Comments: Dark wood covered in loose sugar crystals; bottom is missing (possibly the piece lodged in the top left eye); designed to be stropped.

93: 30-008

Artifact #: 93: 30-008
Type: Deadeye, three-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 253.5 g
Dimensions

- **Length**: 182.10 mm
- **Width**: 123.7 mm
- **Thickness/Height**: 40.94 mm
- **Score Width:** 27 mm
- **1: Eyehole Depth (Left)**: 39 mm
- **1: Eyehole Depth (Right)**: 46 mm
- **1: Eyehole Diameter**: 29 mm
- **2: Eyehole Depth (Left)**: 35 mm
- **2: Eyehole Depth (Right)**: 49 mm
- **2: Eyehole Diameter**: 28 mm
- **3: Eyehole Depth (Left)**: 50 mm
- **3: Eyehole Depth (Right)**: 45 mm
- **3: Eyehole Diameter**: 30 mm

Comments: Dark exterior but light interior with vertical (?) grain; pitting with some crystals on the exterior; designed to be stropped.

93: 30-13-2

Artifact #: 93: 30-13-2
Type: Deadeye, three-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 223 g
Dimensions
- **Length**: 180.65 mm
- **Width**: 135.17 mm
- **Thickness/Height**: 42.11 mm
- **Score Width:** 27 mm
- **1: Eyehole Depth (Left)**: 46 mm
- **1: Eyehole Diameter**: 35 mm
- **2: Eyehole Depth (Left)**: 43 mm
- **2: Eyehole Depth (Right)**: 45 mm
- **2: Eyehole Diameter**: 35 mm
- **3: Eyehole Depth (Left)**: 45 mm
- **3: Eyehole Depth (Right)**: 42 mm
- **3: Eyehole Diameter**: 32 mm

Comments: Deadeye is split into 2 pieces; both show dark exterior and light interior with vertical grain; white spots throughout with a few teredo holes; designed to be stropped.

93: 30-13-4

Artifact #: 93: 30-13-4
Type: Deadeye, stropped (at least 2 eyes, but probably originally had 3)
Material: Wood
Provenience: Unknown/Loose Find
Weight: 123.3 g
Dimensions

- **Length**: 170.57 mm
- **Width**: 46.58 mm
- **Height**: 47.55 mm
- **Score Width**: 25 mm
- **1: Eyehole Depth (Left)**: 49 mm
- **1: Eyehole Diameter**: 30 mm
- **2: Eyehole Depth (Left)**: 49 mm
- **2: Eyehole Diameter**: 30 mm

Comments: Dark exterior but light interior with vertical grain; sugar crystals present on surface with cracks along wood grain; designed to be stropped.

79: 155-344

Artifact #: 79: 155-344
Type: Deadeye, three-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 544.5 g
Dimensions

Length: 163.04 mm
Width: 160.5 mm
Thickness/Height: 30.62 and (raised area) 45.66 mm
1: Eyehole Depth (Left): 38 mm
1: Eyehole Depth (Right): 42 mm
1: Eyehole Diameter: 36 and 26 mm
2: Eyehole Depth (Left): 41 mm
2: Eyehole Depth (Right): 45 mm
2: Eyehole Diameter: 39 and 35 mm
3: Eyehole Depth (Left): 48 mm
3: Eyehole Depth (Right): 42 mm
3: Eyehole Diameter: 40 and 35 mm

Comments: Slightly raised in the center, the edge of deadeye seems to be carved down. Some rust colored oxide on surface with radial grain; some flaking and a few white spots; designed to be stropped. A few fragments that had flaked off were grouped with the deadeye.

Artifact #: 80: 129B
Type: Deadeye, three-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: Unknown
Dimensions
- **Length**: 190 mm
- **Width**: 150 mm
- **Thickness/Height**: 5 mm
- **Average Eyehole diameter:** 31 mm

Comments: Unclear why this deadeye was not photographed and conserved like the others. Measurements were not given for this item, but were estimated from the photo.

Artifact #: 93: 030-007
Type: Deadeye, six-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 548.3 g
Dimensions

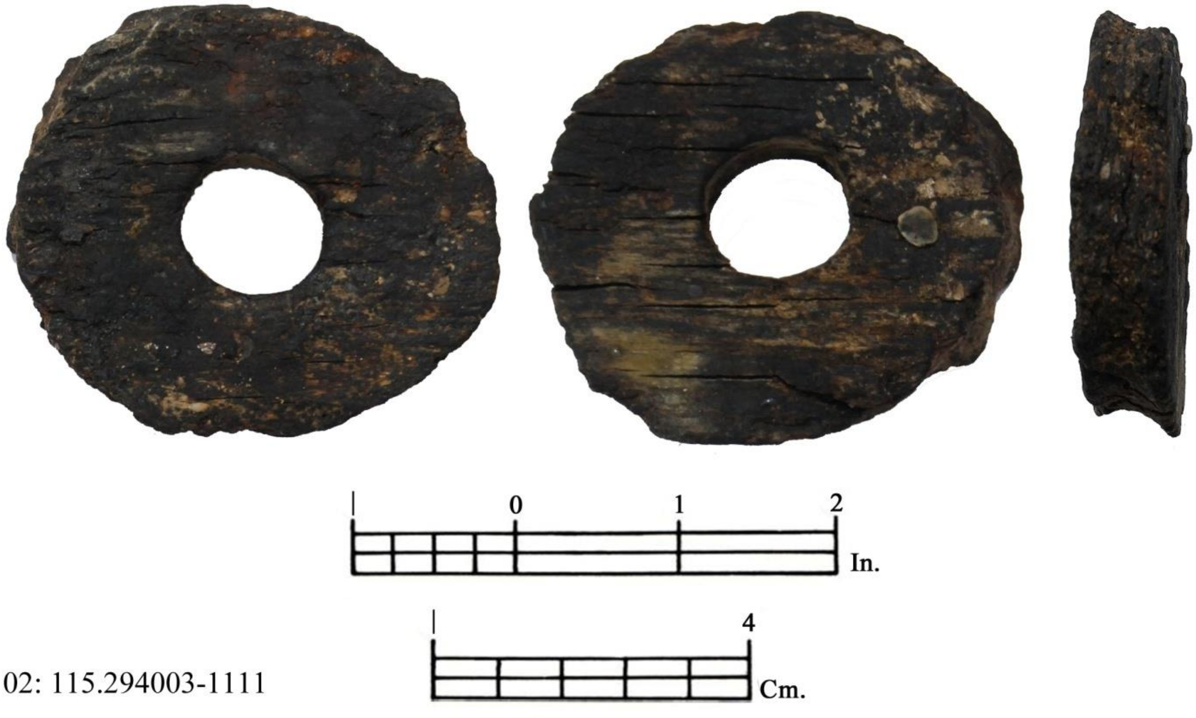
- **Length**: 266.74 mm (fragment: 103.1 mm)
- **Width**: 169.14 mm (fragment: 42.67 mm)
- **Thickness/Height**: 46.2 mm (fragment: 48.06 mm)
- **1: Eyehole Depth (Left)**: 58 mm
- **1: Eyehole Depth (Right)**: 55 mm
- **1: Eyehole Diameter**: 24 mm
- **2: Eyehole Depth (Left)**: 55 mm
- **2: Eyehole Depth (Right)**: 49 mm
- **2: Eyehole Diameter**: 28 mm
- **3: Eyehole Depth (Left)**: 5 mm
- **3: Eyehole Depth (Right)**: 48 mm
- **3: Eyehole Diameter**: 45 mm
- **4: Eyehole Depth (Left)**: 58 mm
- **4: Eyehole Depth (Right)**: 6 mm
- **4: Eyehole Diameter**: 34 mm
- **5: Eyehole Depth (Left)**: 57 mm
- **5: Eyehole Depth (Right)**: 56 mm
- **5: Eyehole Diameter**: 3 mm

Comments: Deadeye is split into 2 pieces; both show dark exterior and light interior with vertical grain; some sugar crystals on surface; designed to be stropped.

Artifact #: 80: 129C
Type: Deadeye, six-holed stropped
Material: Wood
Provenience: Unknown/Loose Find
Weight: 2352.7 g
Dimensions

- **Length**: 310 mm
- **Width**: 219.78 mm
- **Thickness/Height**: 53.56 mm
- **1: Eyehole Depth (Left)**: 56 mm
- **1: Eyehole Depth (Right)**: 61 mm
- **1: Eyehole Diameter**: 3 mm
- **2: Eyehole Depth (Left)**: 64 mm
- **2: Eyehole Depth (Right)**: 57 mm
- **2: Eyehole Diameter**: 3 mm
- **3: Eyehole Depth (Left)**: 6 mm
- **3: Eyehole Depth (Right)**: 71 mm
- **3: Eyehole Diameter**: 25 mm
- **4: Eyehole Depth (Left)**: 58 mm
- **4: Eyehole Depth (Right)**: 55 mm
- **4: Eyehole Diameter**: 35 mm
- **5: Eyehole Depth (Left)**: mm
- **5: Eyehole Depth (Right)**: 56 mm
- **5: Eyehole Diameter**: 3 mm
- **6: Eyehole Depth (Left)**: 5 mm
- **6: Eyehole Depth (Right)**: 48 mm
- **6: Eyehole Diameter**: 45 mm

Comments: Decent condition but covered in sugar crystals from previous conservation. Dark exterior



02: 115.294003-1111

Artifact #: 02: 115.294003-1111
Type: Block sheave
Material: Wood
Provenience: Unknown/Loose Find
Weight: 62.5 g
Dimensions
 Length: 65.86 mm
 Width: 77.15 mm
 Thickness/Height:17.58 mm
 Pinhole Depth (Left): 18 mm
 Pinhole Depth (Right): 17 mm
 Pinhole Diameter: 23 mm

Comments: Dark wood with waxy surface. Some cracking along grain.

10: 02.028

Artifact #: 10: 02. 028
Type: Cheek fragment from block
Provenience: Loose, surface find
Weight: 219.1 g
Dimensions
- **Length**: 191.21 mm
- **Width**: 70.45 mm
- **Thickness/Height**: 26.62 mm

Pinhole Diameter: 35.23 mm

Comments: Light brown with some teredo worm damage visible.

Artifact #: 93:30.3
Type: Cheek fragment from block
Material: Wood
Provenience: Unknown/Loose Find
Weight: 173.4 g
Dimensions

- **Length**: 161.63 mm
- **Width**: 56.71 mm
- **Thickness/Height**: 23.31 mm
- **Sheave Mortise Length**: 126 mm
- **Sheave Mortise Thickness**: 22 mm
- **Pinhole Depth**: 19 mm
- **Pinhole Diameter**: 17.11 mm
- **Diameter of concentric circles**: 86 mm

Comments: Dark wood with a few sugar crystals and small cracks along the grain. Rounded or chamfered edges with concentric lines on the inner surface from the sheave. Single block.

Artifact #: 93: 30.5
Type: Cheek fragment from block
Material: Wood
Provenience: Unknown/Loose Find
Weight: 209.1 g
Dimensions
 Length: 161.86 mm
 Width: 65.98 mm
 Thickness/Height: 21.71 mm
 Sheave Mortise Length: 116 mm
 Sheave Mortise Thickness: 21 mm
 Pinhole Diameter: 17.63 mm
 Diameter of concentric circles: 62 mm

Comments: Dark, rough texture with small cracks. Rounded or chamfered edges with concentric lines on surface from the sheave. Single block.

93: 30-4

Artifact #: 93: 30-4
Type: Cheek fragment from block
Material: Wood
Provenience: Unknown/Loose Find
Weight: 134.7 g
Dimensions
- **Length**: 160 mm
- **Width**: 59.41 mm
- **Thickness/Height**: 21.04 mm
- **Pin Diameter:** 23 mm
- **Diameter of concentric circles**: 65 mm

Comments: Dark color except in a few spots. Slightly sticky with some sugar crystals. Small cracks along grain. Concentric grooves can be found on the inner surface that were caused from the sheave rotations

Artifact #: 02_155.294003-1014
Type: Nearly complete block
Material: Wood
Provenience: Unknown/Loose Find
Dimensions
　　Length: 200 mm
　　Width: 140 mm
　　Thickness/Height: 90 mm
　　Pin Diameter: 35 mm

Comments: Not included in excavation records from 2010-2012, therefore it was most likely recovered by Teddy Tucker during earlier work on the wreck.

Artifact #: 02:155.294003-1162
Type: Complete block
Material: Wood
Provenience: Unknown/Loose Find
Dimensions
Length: 190 mm
Width: 140 mm
Thickness/Height: 90 mm
Pin Diameter: 25 mm

Comments: Not included in excavation records from 2010-2012, therefore it was most likely recovered by Teddy Tucker during earlier work on the wreck. National Museum of Bermuda notes indicate that it is possibly not associated with *Warwick* but found on site.

93: 30-13-1

Artifact #: 93:30-13-1
Type: Dead block
Material: Wood
Provenience: Unknown/Loose Find
Weight: 86.4 g
Dimensions
- **Length**: 99.94 mm
- **Width**: 76.62 mm
- **Thickness/Height**: 46.67 mm
- **Swallow (hole in center) Depth**: 67 mm

Swallow Diameter: 25 mm

Comments: Dark exterior with light interior. Large cracks are on either side along the grain. Sugar crystals are visible but dry to the touch.

Artifact #: 80:129E
Type: Dead block
Material: Wood
Provenience: Unknown/Loose Find
Weight: 409.1 g
Dimensions
Length: 114.65 mm
Width: 89.5 mm
Thickness/Height: 67.97 mm
Swallow (hole in center) Depth: 89 mm (recorded as 8.9 mm, but believed to be a typo and actually cm.)
Swallow Diameter: 27 mm (recorded as 2.7 mm, but believed to be a typo and actually cm.)

Comments: Dark exterior that is covered in soft sugar crystals. Cracks are visible on the ends. It is starting to fragment on the edges.

02: 155.294003-1165

Artifact #: 02: 155.294003-1165
Type: Topgallant fid (possible)
Material: Wood
Provenience: Unknown/Loose Find
Weight: 418.8 g
Dimensions
Length: 282.81 mm
Width: 50.76 mm – 55.91 mm
Thickness/Height:25.33 mm and raised portion is 39.36 mm

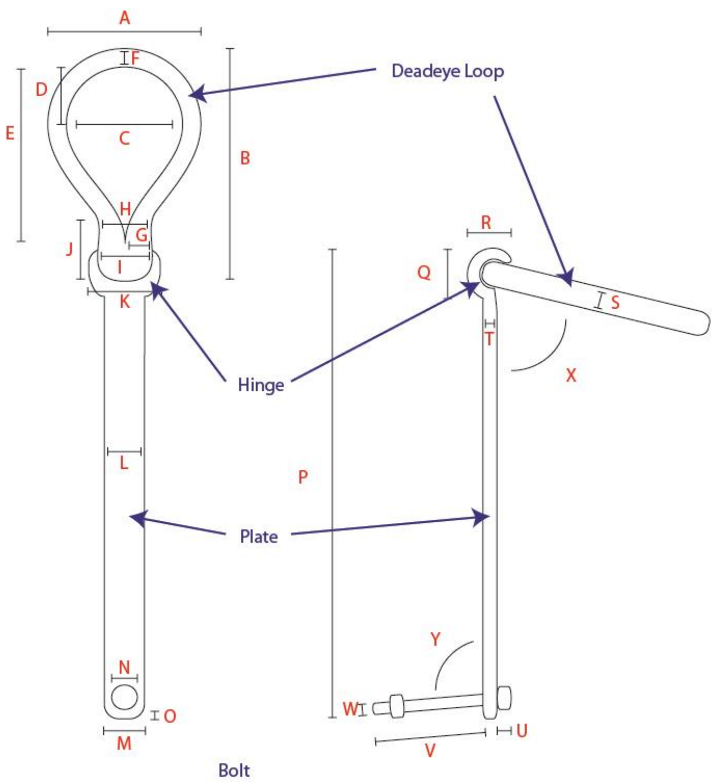
Comments: Dark with some discolored PEG near knots. Conservation notes do not indicate iron concretions, but image show that the "knots" appear similar to concretion from iron fasteners. Waxy surface.

Artifact #: 12-03-011
Type: Chainplate
Provenience: Along top timbers 2nd frame in from bow
Dimensions:[309]

Outer Width of deadeye loop (A)[310]	16.5 cm.
Total Length of deadeye loop (B)	33 cm.
Max Inner Width of deadeye loop (C)	10.5 cm.
Distance from inner edge to point of max width (D)	4.5 cm.
Total Inner Length of deadeye loop (E)	16 cm.
Thickness of deadeye loop (F)	3 cm.
Neck Thickness of deadeye loop (G)	3.5 cm.
Width of deadeye loop neck at narrowest point (H)	9 cm.
Width of deadeye loop neck at base (I)	7 cm.
Distance from deadeye loop base to narrow part of neck (J)	13 cm.
Width of plate at widest point (K)	6 cm.
Width of plate in middle (L)	7 cm.
Width of plate at end (M)	10.5 cm.
Diameter of bolt head (N)	6.5 cm.
Distance from end of plate to bolt head (O)	3 cm.
Total Length of Plate (P)	66 cm.
Total Length of Hinge (Q)	9 cm.
Total Width of Hinge (R)	8 cm.
Thickness of deadeye loop (S)	3 cm.
Thickness of Plate (T)	3 cm.
Thickness of Bolt Head (U)	2.5 cm.
Length of Bolt (V)	28 cm.
Angle of deadeye loop X)	55º
Angle of Bolt (Y)	95º
Average Deadeye Loop Width	13.5 cm.
Average Deadeye Loop Length	24.5 cm.

309 Measurements taken by Michael Gilbart.
310 Please refer to chainplate diagram created by Michael Gilbart below for corresponding measurements (indicated by letter).

Chainplate Diagram:



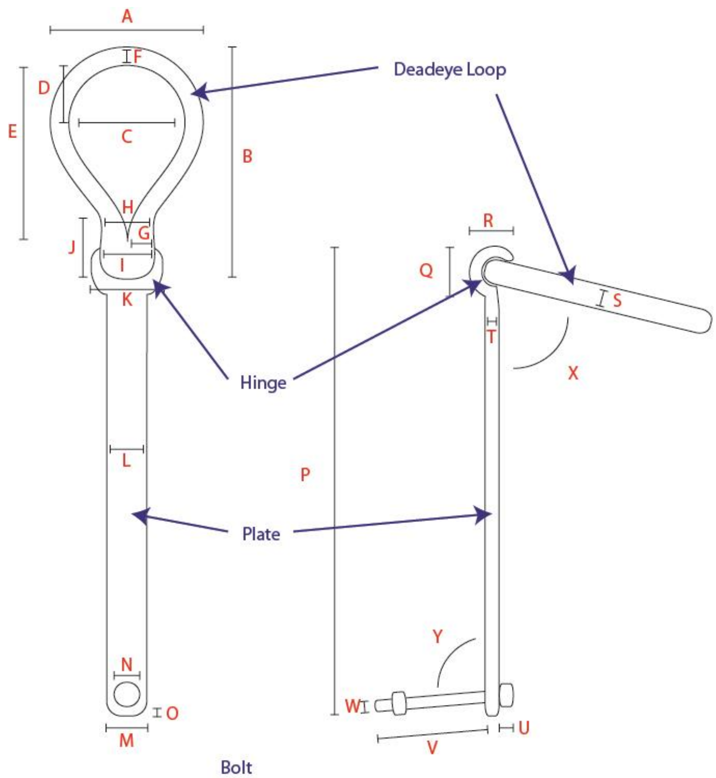
A: Outer Width of deadeye loop
B: Total Length of deadeye loop
C: Max Inner Width of deadeye loop
D: Distance from inner edge to point of max width
E: Total Inner Length of deadeye loop
F: Thickness of deadeye loop
G: Neck Thickness of deadeye loop
H: Width of deadeye loop neck at narrowest point
I: Width of deadeye loop neck at base
J: Distance from deadeye loop base to narrow part of neck
K: Width of plate at widest point
L: Width of plate in middle
M: Width of plate at end
N: Diameter of bolt head
O: Distance from end of plate to bolt head
P: Total Length of Plate
Q: Total Length of Hinge
R: Total Width of Hinge
S: Thickness of deadeye loop
T: Thickness of Plate
U: Thickness of Bolt Head
V: Length of Bolt
W: Diameter of Bolt
X: Angle of deadeye loop
Y: Angle of Bolt

Artifact #: 11-03-094
Type: Chainplate
Provenience: c7/c8—not original position
Dimensions:[311]

Outer Width of deadeye loop (A)[312]	17 cm.
Total Length of deadeye loop (B)	27 cm.
Max Inner Width of deadeye loop (C)	11.5 cm.
Distance from inner edge to point of max width (D)	5 cm.
Total Inner Length of deadeye loop (E)	16 cm.
Thickness of deadeye loop (F)	3.5 cm.
Neck Thickness of deadeye loop (G)	3 cm.
Width of deadeye loop neck at narrowest point (H)	6.5 cm.
Width of deadeye loop neck at base (I)	Unknown
Distance from deadeye loop base to narrow part of neck (J)	8 cm.
Width of plate at widest point (K)	7.5 cm.
Width of plate in middle (L)	7 cm.
Width of plate at end (M)	8 cm.
Diameter of bolt head (N)	6.5 cm.
Distance from end of plate to bolt head (O)	1 cm.
Total Length of Plate (P)	67 cm.
Total Length of Hinge (Q)	9 cm.
Total Width of Hinge (R)	7 cm.
Thickness of deadeye loop (S)	3.5 cm.
Thickness of Plate (T)	2.5 cm.
Thickness of Bolt Head (U)	4 cm.
Length of Bolt (V)	29 cm.
Diameter of Bolt (W)	2.5 cm.
Angle of deadeye loop (X)	150º
Angle of Bolt (Y)	65º
Average Deadeye Loop Width	14.25 cm.
Average Deadeye Loop Length	21.5 cm

[311] Measurements taken by Michael Gilbart.
[312] Please refer to chainplate diagram created by Michael Gilbart below for corresponding measurements (indicated by letter).

Chainplate Diagram:



A: Outer Width of deadeye loop
B: Total Length of deadeye loop
C: Max Inner Width of deadeye loop
D: Distance from inner edge to point of max width
E: Total Inner Length of deadeye loop
F: Thickness of deadeye loop
G: Neck Thickness of deadeye loop
H: Width of deadeye loop neck at narrowest point
I: Width of deadeye loop neck at base
J: Distance from deadeye loop base to narrow part of neck
K: Width of plate at widest point
L: Width of plate in middle
M: Width of plate at end
N: Diameter of bolt head
O: Distance from end of plate to bolt head
P: Total Length of Plate
Q: Total Length of Hinge
R: Total Width of Hinge
S: Thickness of deadeye loop
T: Thickness of Plate
U: Thickness of Bolt Head
V: Length of Bolt
W: Diameter of Bolt
X: Angle of deadeye loop
Y: Angle of Bolt

Artifact #: 2012 #1 (unclear which chainplate in photo corresponds to this ID)
Type: Chainplate
Provenience: In situ under hull
Dimensions:[313]

Outer Width of deadeye loop (A)[314]	25 cm.
Total Length of deadeye loop (B)	20 cm.
Max Inner Width of deadeye loop (C)	15 cm.
Distance from inner edge to point of max width (D)	4 cm.
Total Inner Length of deadeye loop (E)	14 cm.
Thickness of deadeye loop (F)	5.5 cm.
Neck Thickness of deadeye loop (G)	Unknown
Width of deadeye loop neck at narrowest point (H)	Unknown
Width of deadeye loop neck at base (I)	7 cm.
Distance from deadeye loop base to narrow part of neck (J)	Unknown
Width of plate at widest point (K)	10 cm.
Width of plate in middle (L)	8.5 cm.
Width of plate at end (M)	10 cm.
Diameter of bolt head (N)	6 cm.
Distance from end of plate to bolt head (O)	2 cm.
Total Length of Plate (P)	69 cm.
Total Length of Hinge (Q)	5.5 cm.
Total Width of Hinge (R)	Unknown
Thickness of deadeye loop (S)	7.7 cm.
Thickness of Plate (T)	4.5 cm.
Thickness of Bolt Head (U)	3.5 cm.
Length of Bolt (V)	25 cm.
Diameter of Bolt (W)	3.5 cm.
Angle of deadeye loop (X)	165º
Angle of Bolt (Y)	115º
Average Deadeye Loop Width	20 cm.
Average Deadeye Loop Length	17 cm.

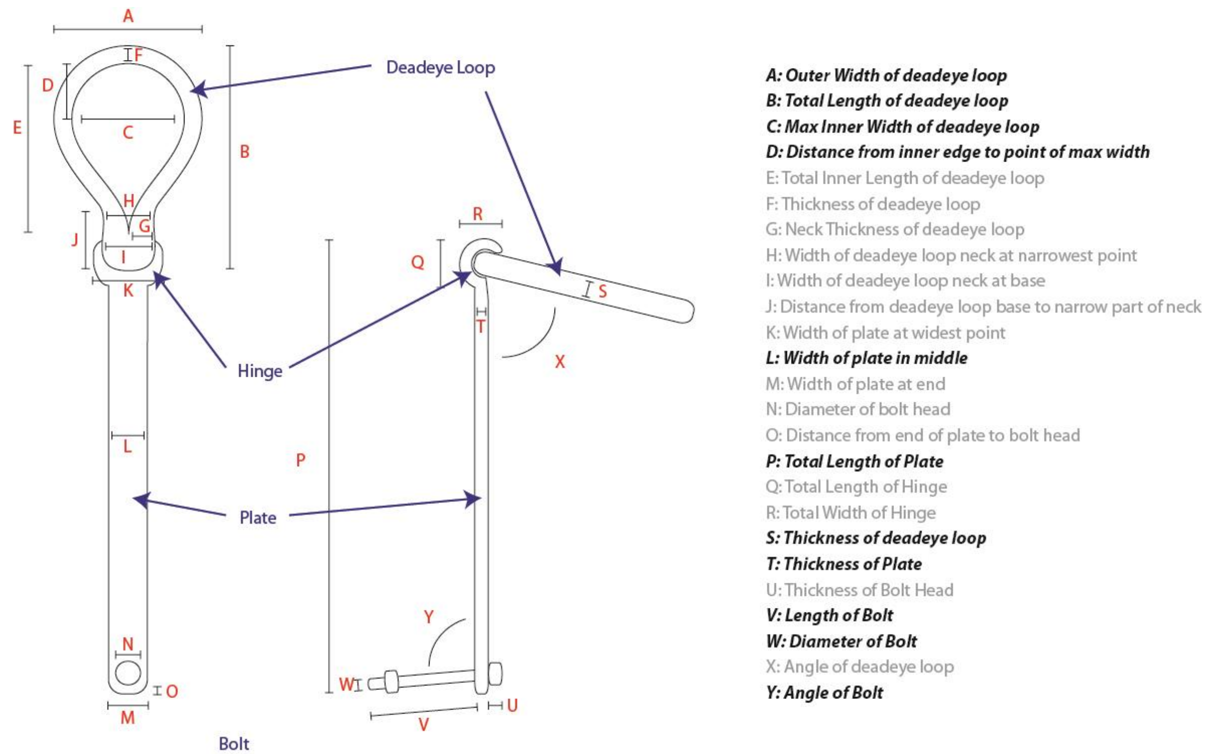
[313] Measurements taken by Michael Gilbart.
[314] Please refer to chainplate diagram created by Michael Gilbart below for corresponding measurements (indicated by letter).

Artifact #: 2012 #2 (unclear which chainplate in photo corresponds to this ID)
Type: Chainplate
Provenience: In situ under hull
Dimensions:[315]

Outer Width of deadeye loop (A)[316]	21.5 cm.
Total Length of deadeye loop (B)	27 cm.
Max Inner Width of deadeye loop (C)	11.5 cm.
Distance from inner edge to point of max width (D)	4.5 cm.
Total Inner Length of deadeye loop (E)	16 cm.
Thickness of deadeye loop (F)	4.5 cm.
Neck Thickness of deadeye loop (G)	3.5 cm.
Width of deadeye loop neck at narrowest point (H)	8 cm.
Width of deadeye loop neck at base (I)	8.5 cm.
Distance from deadeye loop base to narrow part of neck (J)	6 cm.
Width of plate at widest point (K)	9 cm.
Width of plate in middle (L)	7.5 cm.
Width of plate at end (M)	Unknown
Diameter of bolt head (N)	6 cm.
Distance from end of plate to bolt head (O)	Unknown
Total Length of Plate (P)	68 cm.
Total Length of Hinge (Q)	10 cm.
Total Width of Hinge (R)	7 cm.
Thickness of deadeye loop (S)	5 cm.
Thickness of Plate (T)	3 cm.
Thickness of Bolt Head (U)	Unknown
Length of Bolt (V)	24.5 cm.
Diameter of Bolt (W)	3.5 cm.
Angle of deadeye loop (X)	155º
Angle of Bolt (Y)	150º
Average Deadeye Loop Width	16.5 cm.
Average Deadeye Loop Length	21.5 cm.

[315] Measurements taken by Michael Gilbart.
[316] Please refer to chainplate diagram created by Michael Gilbart below for corresponding measurements (indicated by letter).

Chainplate Diagram:



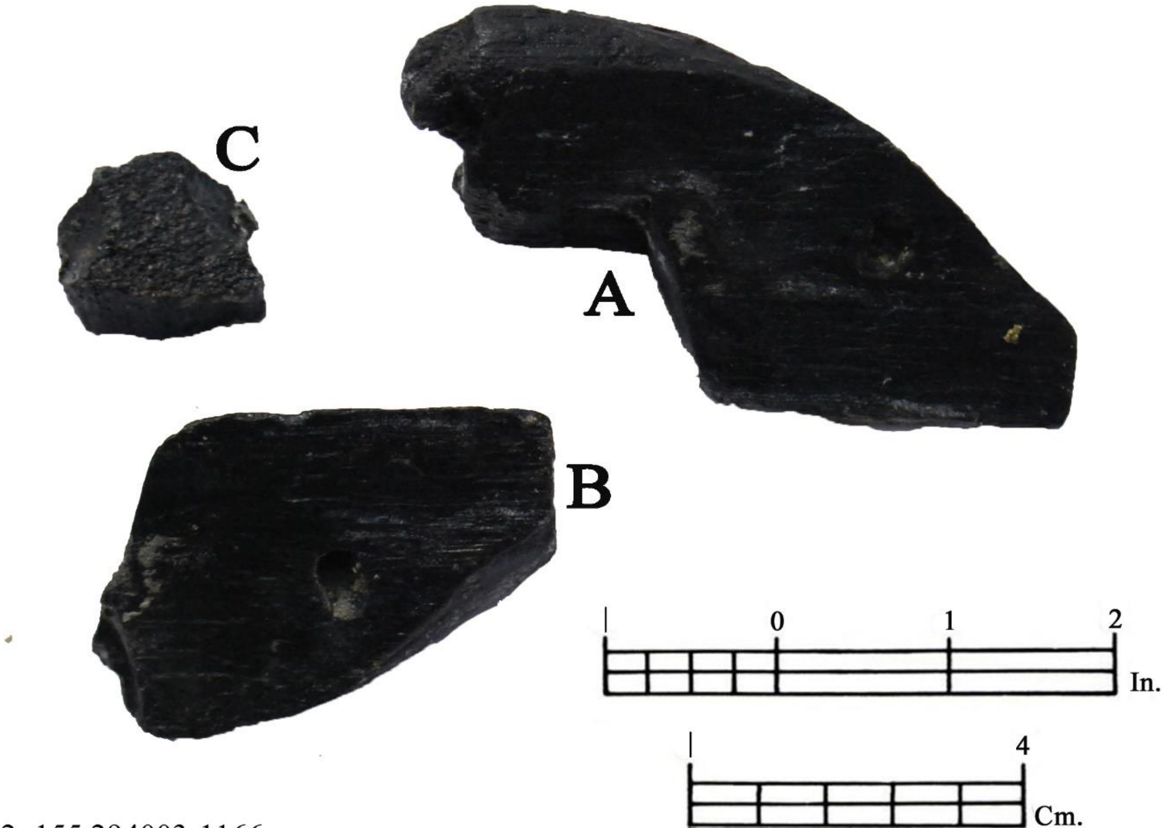
Artifacts 2012 (#1 and #2). Notes and photos are unclear with which corresponds to each ID.

Artifact #: 02:155.294003-1015
Type: Mast Truck (possible)
Material: Wood
Provenience: Unknown/Loose Find
Weight: Unknown
Dimensions
  Length: 330 mm
  Width: 280 mm

Comments: The mask truck is currently on display in the National Museum of Bermuda. Its caption reads "The mast truck was mounted around the mast and fitted with pulleys for raising signal flags." The display did not indicate pulleys associated with this truck.

93: 30-28

Artifact #: 93:30-28
Type: Miscellaneous fragments
Material: Wood
Provenience: Unknown/Loose Find
Weight: 32.6 g and 27.1 g
Dimensions: Unknown
Comments: Grouped under rigging in excavation notes, but unclear which part it belongs to.



02: 155.294003-1166

Artifact #: 02: 155.294003-1166
Type: Miscellaneous fragments
Material: Wood
Provenience: Unknown/Loose Find
Weight: A) 74.7 g, B) 51g, C) 9.7 g
Dimensions: A) 109.6 mm x 50.86 mm B) 67.95 mm x 40.91 mm
Comments: Grouped under rigging in excavation notes, but unclear which part it belongs to.

Artifact #: 80:129F
Type: Two miscellaneous fragments
Material: Wood
Provenience: Unknown/Loose Find
Weight: 3.9 g and 219 g
Dimensions: Large: 185.29 mm x 61.46 mm x 24.57 mm, Small: 15.43 mm x 38. 25 mm
Comments: Grouped under rigging in excavation notes, but unclear which part it belongs to.

Artifact #: 93:30-13-3
Type: Miscellaneous fragments
Material: Wood
Provenience: Unknown/Loose Find
Weight: Small: 20.7 g, Large 63.5 g
Dimensions: Small: 40-50 mm long, Large: 79.8 mm. x 83.12 mm. x 47.37 mm.
Comments: Grouped under rigging in excavation notes, but unclear which part it belongs to. Due to shape and size, it is possible these are deadeye fragments.

Artifact #: 02:155.294003-1051
Type: Fifteen Rope Fragments
Material: Unknown
Provenience: Unknown/Loose Find
Weight: Unknown
Dimensions: 15cm. (length - largest); 6.5cm.
(width largest)
Comments: Found in the National Museum of Bermuda database and likely salvaged by Teddy Tucker.

APPENDIX B

RIGGING DATABASE BY WRECK AD 1545-1700

Appendix B Table of Wrecks and Their Rigging

Wreck	**Date of Sinking**	**Nationality**	**Ship Type and Tonnage**	**Rigging Artifacts**
Mary Rose	1545	English	Carrack, 700 tons	At least 29 deadeyes, 11 chains, many blocks, fighting top, mast step and mast partner, thimble, parrals and trucks. [317]
Padre Island Wrecks	1554	Iberian		5 iron chainplates and 2 coaks [318]
Emanuel Point Wreck II	1559	Iberian	570 tons Galleon	Block and corresponding sheave (note: coak in sheave is unique triangle shape), mast step.[319]
Western Ledge Reef Wreck	1560-1600	Iberian	143.2 tons[320]	A chainplate assembly with a forelock bolt and another chainplate in five fragments.[321] 1 deadeye, 3 hearts, and 3 blocks, rigging shackle, ringbolt.[322]

[317] Marsden 2009, 242-72; Note: Kopp (2007, 19) wrote that there are 46 deadeyes from *Mary Rose* total, but only 29 are included in Marsden.
[318] Arnold and Weddle 1978, 234-39; Olds 1976, 43-50.
[319] Charles Bendig and John Bratten, personal communication, December 3, 2015.
[320] Bojakowski 2012, 335.
[321] Bojakowski 2012 374 -75, 391.
[322] Piotr Bojakowski and Katie Custer-Bojakowski, personal communication, November 21, 2013.

Appendix B Table Continued

Wreck	Date of Sinking	Nationality	Ship Type and Tonnage	Rigging Artifacts
San Juan de Pasajes (Red Bay, Labrador Wreck)	1565	Basque	250 tons	426 ship's fittings and rigging components including: 48 heart blocks, one chain link with a heart still attached, 3 fragments of deadeye, 4 complete parrel trucks and several fragments, 16 single-sheaved blocks, 8 double blocks, 6 long tackle blocks, 8 sheaves and 4 sheave fragments, 1 sheave pin, 5 cheek fragments, 1 spar hoop, 1 toggle, various cordage, 2 possible chesstrees, 3 cleats, a kevel, mast step and several sheaved timbers (such as knightshead). [323]
Santa Clara	1564	Iberian	300 tons	3 bronze coaks[324]
Mars	1564[325]	Swedish		A mainmast partner, several chains concreted to channel, standards to strengthen the chains, and a knightshead with 2 bronze sheaves in place.[326]
The Mukran Wreck	1565			1 bronze coak[327]
Sveti Pavao	1574-1585[328]	Venetian	Merchant man	1 brass coak, 3 wooden hearts (2 complete, 1 broken), with rope remains preserved in one, and 1 chainplate [329]
Angra C	1580s-mid-17th century	Dutch		Dead block [330]

[323] Grenier et al. 2007, 1-23.
[324] Malcom 2017, 97-8.
[325] Eriksson and Rönnby 2017, 92.
[326] Eriksson and Rönnby 2017, 101.
[327] Springmann 1998, 118.
[328] Beltrame et al. 2014, 152.
[329] Beltrame et al. (2014, 49-50) shows the drawing of a chainplate within the map.
[330] Phaneuf 2003, 147.

Appendix B Table Continued

Wreck	Date of Sinking	Nationality	Ship Type and Tonnage	Rigging Artifacts
Arade I	c. 1583[331]	Iberian[332]	Unknown	Several fragments of rope, 3 heart blocks (*sapatas trincadas*) with straps still attached as concretions [333]
Gnalic	1583	Venetian	Venetian galley	6 brass coaks [334]
Santo Hieronimo (Sipan Island, Sudjuraj)	1576[335]	Republic of Ragusa	Ragusan	13 bronze coaks, 1 block, several chainplates with links [336]
La Trinidad Valencera	1588	Spanish	Venetian Merchant man, 1100 tons[337]	4 single blocks, 3 sheaves, 5 hearts, tapered wooden pin (possible belaying pin), a euphroe, one chain, one double block, and at least 8 coaks (but possibly up to 10).[338]
El Gran Grifon	1588	Spanish	650 tons[339]	A sheave, shear hook.[340]
Girona	1588	Spanish	Galleass	2 deadeye chains, one eyebolt, and anywhere from 32 to 41 coaks.[341]

331 Dominguez-Delmas et al. 2012, 1.
332 Castro 2003b, 304.
333 Castro 2003b, 304.
334 Beltrame et al. 2014, 37; Filep et al. 2013, 101.
335 Radić Rossi, 2006, 132.
336 Jose Luis Casaban, personal communication, July 18, 2015; Radić Rossi 2006, 134-35.
337 Martin 1979, 13-4.
338 Martin 1979, 32-3; also, Rodríguez-Salgado (1988, 166) shows 2 coaks, but communication with Ulster Museum reveals there are 8 coaks in their collection belonging to *Girona*. It is possible that the two coaks Rodríguez-Salgado mentions are repeats of those in Ulster Museum, but this cannot be confirmed.
339 Rodríguez-Salgado 1988, 154.
340 Shetland Museum Archives, Artifact SL04306; Martin 1975, 182-83.
341 Rodríguez-Salgado 1988, 166-67; note also Sténuit (1973, 275) writes that there are 32 coaks, and communications with Ulster Museum indicate that there are 32 present there. However, Rodríguez-Salgado (1988, 166) notes that over 40 coaks were recovered from *Girona*. The combination of images and matching of artifact numbers show there is a minimum of 32 verified coaks present, and up to 41 total (unverified number due to potential overlapping of coaks from different sources).

Appendix B Table Continued

Wreck	Date of Sinking	Nationality	Ship Type and Tonnage	Rigging Artifacts
Scheurrak SO1	1593	Dutch[342]	Flute-like	31 loose pins, 13 loose sheaves, 1 possible sheave, and 2 sheave fragments, 12 double shoe blocks (correct name?), 2 double stacked blocks (name?), 1 block fragment, 3 euphroes, 25 single blocks, 12 deadeyes, 2 deadeye fragments, 9 parrel trucks, ringbolts, and hundreds of fragments of rope and canvas.[343]
Alderney Ship	1592	English	Galleon Type, 100 tons[344]	1 blocks, 1 block fragment, 4 deadeyes, 2 sheaves, 14 rope fragments[345]
San Pedro	1596	Spanish	Nao, 350 tons[346]	3 iron ring bolts (one connected to chain, the other two to rings), two deadeye strops (one connected with chain link), two forelocks, one iron fairlead, a fragment of a parrel truck, one bronze sheave, one large iron chain and eye bolt assembly. [347]
Megadim Wreck	Last quarter 16th century [348]	Unknown	Unknown	5 iron chains with 7 to 8 links, attached to 5 deadeyes on one end, and ring bolt on other. [349]
Katthavet 3 *(Näckström 1)*	Early 17th-century [350]	Swedish	Early carvel constructed	Deadeye (large) and 2 blocks[351]

342 Puype 2000, 106.
343 Data Archiving and Networked Services, Scheurrak SO1 Project.
344 Roberts 1998, 108.
345 Bound 1998, 67.
346 Watts 2014, 58.
347 National Museum of Bermuda 2015; Watts 2014, 59.
348 Ridella et al. 2016, 189-90.
349 Ridella et al. 2016, 187-89.
350 Grue 2010, 38.
351 Cederlund 1983, 215.

Appendix B Table Continued

Wreck	**Date of Sinking**	**Nationality**	**Ship Type and Tonnage**	**Rigging Artifacts**
Wittenberg Wreck	1605	German	Dutch-built	Various pieces of rigging.[352]
Nassau	1606	Dutch	Dutch East Indiaman, 320 tons[353]	1 intact pulley wheel, 1 partially melted pulley wheel, large quantities of heavy cordage[354]
Sea Venture	1609	English	300 tons Galleon[355]	Chains and deadeyes.[356]
Witte Leeuw	1613	Dutch	700 tons[357]	7 bronze sheaves and 1 deadeye [358]
Warwick	1619	English	~160 tons	8 deadeyes and 1 deadeye fragment, 1 sheave, 4 cheek block fragments, 1 single block (possibly not from *Warwick* but found on site) and another near complete block, 2 dead blocks, 1 mast truck, possible topgallant fid, 4 chainplates, 12 wood fragments possibly from blocks, rope fragments.
New Old Spaniard	1620-1640	Dutch		9 blocks (including a block with sister hooks, 3 single blocks, a block with unknown number of sheaves, and 4 double blocks), 2 block cheeks, 6 parrel trucks, 3 fairleads, 1 iron bolt, 3 deadeyes[359] and one chainplate[360]
San Antonio	1621	Portuguese nao	300 tons[361]	Two forelock bolts, deadeye, sheave, and one ringbolt[362]

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352 Stanek 2011, 15.
353 Bound 1998, 84.
354 Bound 1998, 99.
355 Adams 2013, 143.
356 Adams 2013, 122.
357 Sténuit 1977, 165.
358 Rijks Studio Archives; Sténuit 1977, 178; Rijksmuseum 1980, 7.
359 Watts 2014, 110; National Museum of Bermuda 2015.
360 National Museum of Bermuda 2015.
361 Macmillan 2010, 45.
362 National Museum of Bermuda 2015.

Appendix B Table Continued

Wreck	Date of Sinking	Nationality	Ship Type and Tonnage	Rigging Artifacts
Trial	1622	English	East Indiaman, Probably over >700 tons [363]	Bronze sheave [364]
Swash Channel Wreck (Fame)	1628	Dutch	300-600 tons[365]	9 deadeyes, 2 cleats, hundreds of sailcloth fragments, 4 cheeks, 2 loose sheaves, at least 86 rope fragments, 9 single blocks, 2 double blocks (1 only has shell), 1 treble block, 1 possible pin, several concretions that were unrecovered that probably belong to chain plates.[366]
Vasa	1628	Swedish	1,200 tons	412 intact blocks and 143 block fragments, including single, double, and treble blocks, dead blocks, Dutch lifts, euphroes, and cube-like blocks, 129 deadeyes, and various other rigging components.[367]
Batavia	1629	Dutch	650 tons[368]	3 blocks, and at least 3 chainplates.[369]
El Galgo	1639	Spanish	Patechuelo[370]	One deadeye and rope fragments[371]
Stora Sofia	1645[372]	Swedish	c. 1,300 tons[373]	20 loose sheaves, 9 blocks, 2 parrel trucks, 2 coaks and 1 possible coak fragment, 1 fiddle block, and 2 deadeyes. [374]

363 Green, 1986, 204.
364 Green, 1977a, 55; Green 1986, 202.
365 Poole Museum Society Blog 2017.
366 Dave Parham and Tom Cousins, personal communication, February 3, 2016.
367 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
368 Green 1989, 213.
369 Green 1989, 5 and 103-4; Western Australian Museum.
370 Watt 2014, 94.
371 National Museum of Bermuda 2015.
372 Bergstrand 2010, 56.
373 Bergstrand 2010, 57.
374 Image by Bohusläns museum/Studio Västsvensk konservering; Bergstrand and Arbin 2003, appendix.

Appendix B Table Continued

Wreck	**Date of Sinking**	**Nationality**	**Ship Type and Tonnage**	**Rigging Artifacts**
Ghost Ship	c. 1650[375]			At least 2 deadeyes and 2 blocks. Several other masting components including masts, knights, and others that are intact.[376]
Corolla Wreck	c. early-mid-17th C. Prob. 1640[377]			2 deadeyes with metal strap still in place.[378]
Swan (Duart Point Wreck)	1653	English	Pinnace or frigate, ~120-133.5 tons[379]	6 loose sheaves, 2 loose pins, a parral truck and rib, a euphroe, 3 blocks or block fragments, 3 deadeyes, at least 4 fragments of cordage[380]
Lastdrager	1653	Dutch	Fluyt, 640 tons[381]	A rope fragment.[382]
Vergulde Draeck	1656	Dutch		1 sheave[383]
Eagle	1659[384]	English	300[385]	3 sheaves.[386]
Avondster	1659	Dutch	250-260 tons[387]	9 single blocks, 1 snatch block, 5 block fragments, 2 blocks with unknown number of sheaves, 5 deadeyes, 5 loose sheaves, 1 pin, 1 ringbolt, and 1 parrel truck.[388]

[375] Eriksson and Rönnby 2012, 350.
[376] Niklas Eriksson, personal communication, September 8, 2015.
[377] Brown 2013, 169-70.
[378] Brown 2013, 164-65; Daniel Brown, personal communication, June 22, 2015.
[379] Martin (2017, 82) notes differences in displacement measurements and possible errors.
[380] Martin 2017, 19; Canmore, National Record of the Historic Environment. Swan: Duart Point, Sound of Mull.
[381] Sténuit 1974, 215.
[382] Sténuit 1974, 216.
[383] Green 1977b, 236.
[384] Watt 2014, 96.
[385] Lefroy 1877, 715,720; Note that Lefroy (1877, 124) wrote that it is also called *Spread Eagle*.
[386] National Museum of Bermuda, 2015.
[387] Parthesius 2005, 220.
[388] Parthesius et al. 2003, 26 and 69.

Appendix B Table Continued

Wreck	Date of Sinking	Nationality	Ship Type and Tonnage	Rigging Artifacts
Resande Mannen	1660[389]			A bronze sheave for a knightshead, deadeyes, and blocks including a fiddleblock[390]
Virginia Merchant	1661[391]	English		3 ringbolts[392]
Kennemerland	1664[393]	Dutch	Dutch East Indiaman	Several rope fragments and rigging thimbles.[394]
London[395]	1665	English	76-gun Second-Rate Ship of the Line, 1,104 tons	At least one deadeye with strap, double block from carriage with some rope still attached, 3 single blocks, 1 sheave fragment, and fragments of rope.[396]
Kronan	1676	Swedish	2,140 tons[397]	Basic single, double, and treble blocks, deadeyes, and cleats.[398]
Gröne Jägaren	1676	Swedish		6 blocks and 3 deadeyes[399]
Riksäpplet	1676	Swedish		12 blocks, 4 block fragments or shells, 6 sheaves, 1 coak, 15 deadeyes/deadeye fragments, 1 cleat.[400]
Constantia	1676[401]			Sheave and pin[402]

389 Eriksson et al. 2013, 7.
390 Niklas Eriksson, personal communication, September 8, 2015.
391 Watt 2014, 96.
392 National Museum of Bermuda, 2015.
393 Price and Muckelroy 1974, 257.
394 Price and Muckelroy 1979, 313; Price and Muckelroy 1974, 263; Price and Muckelroy 1977, 197.
395 The London Shipwreck Trust, 2011.
396 The London Shipwreck Trust, 2011.
397 Einarsson 1990, 279.
398 Corder 2007, 9; DigitaltMuseum, Kalmar Läns Museum.
399 DigitaltMuseum, Sjöhistoriska museet.
400 DigitaltMuseum, Sjöhistoriska museet.
401 DigitaltMuseum, Marinmuseum.
402 DigitaltMuseum, Marinmuseum.

Appendix B Table Continued

Wreck	Date of Sinking	Nationality	Ship Type and Tonnage	Rigging Artifacts
La Belle	1686	French	Frigate or bark 40-45 tons [403]	160 artifacts associated with the rig in addition to hundreds of lengths of rope and cable. Blocks including 3 fiddle blocks, 23 single blocks, 3 double blocks, 2 dutch lifts, and 1 pendant, 12 deadeyes, 3 parrel trucks, a parrel rib, cleats and fairleads, crosstree with deadeye strap and futtock plate, topmast fid, several deadeye chains and straps.[404]
Princess Maria	1686[405]			Chainplate [406]
Dartmouth	1690	English, 5th rate[407]	Frigate, 266 tons [408]	2 blocks, 12 block fragments, 8 loose block pins, 9 loose sheaves (1 with pin attached), and 5 sheave fragments, 2 deadeye fragments, 1 parrel truck, and 1 fairlead truck, at least 1 fragment of rope. [409]
La Hougue Wrecks	1692[410]	French		Nearly a quarter of recovered artifacts are rigging. Images located include at least a treble block, a double block, 2 deadeyes, rope, a block cheek, and a pendant.[411]
Port Royal Shipwreck	1692		~246 tons [412]	A deadeye, ring bolt, and forelock bolt.[413]

[403] Corder 2007, 5-7.
[404] Corder 2007, 18-65.
[405] Rijksmuseum 1980, 5.
[406] Rijksmuseum 1980, 7.
[407] Martin 1978, 29.
[408] Martin 1978, 29.
[409] Martin 1978, 35; Canmore, National Record of the Historic Environment. Dartmouth: Eilean Rubha An Ridire, Sound of Mull.
[410] L'Hour and Veyrat 1998b, 243.
[411] L'Hour and Veyrat 1998a, 400-401. Note: The DRASSM website contained a few images of rigging elements from *La Hougue* that can no longer be found online to the author's knowledge.
[412] Clifford 1993, 107.
[413] Clifford 1993, 121-24, 183-84, 207-10.

Appendix B Table Continued

Wreck	**Date of Sinking**	**Nationality**	**Ship Type and Tonnage**	**Rigging Artifacts**
Santo Antonio De Tanna	1697	Portuguese	Frigate, 526.1 tons[414]	A bitt, 26 ring bolts, 5 rings, 1 ringplate, 2 hookbolts, 2 iron fairleads, one wooden cleat, 16 deadeyes, 12 pieces of chain links, 7 chainplates, 7.08 m shroud-laid rope, 8.34 hawser-laid rope, 1 large single-sheave block (pendant), a shoe block, a double block, 2 fiddle blocks, 17 single-sheave common blocks, 9 block cheeks, 9 sheaves, 2 parrel trucks, 8 hooks (7 with thimbles attached), 4 thimbles, and 5.43 m of cable-laid three-strand rope.[415]
Jutholmen	c. 1700[416]	Swedish		1 fixed block, 1 snatch block, 1 complete block and 7 fragments of a block, 2 complete deadeyes, 1 fragment of a deadeye, and 8 cleats.[417]

414 Thompson 1988, 26.
415 Thompson 1988, 91.
416 Ingelman-Sundberg 1976, 57.
417 Cederlund 1982, 111-13; Ingelman-Sundberg 1976, 60.

APPENDIX C

DEADEYE DATABASE

Appendix C Table of Deadeyes from Wrecks and Their Features

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Mary Rose[418]	1545	82A2338	18								Strop	4		Upper Bonaventure /foremast deadeye with rope	
Mary Rose[419]	1545	82A2572	19.5									3		Bonaventure /foremast deadeye	
Mary Rose[420]	1545	81A0632	16.3									5		Bonaventure /foremast deadeye	
Mary Rose[421]	1545	82A1929	28					Pear-shaped		Oak	Strap	7		Main shroud lower deadeye with chain, lanyards = 20-25 mm	

[418] Marsden 2009, 251.
[419] Marsden 2009, 251.
[420] Marsden 2009, 251.
[421] Marsden 2009, 256.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Mary Rose [422]	1545	82A26 00	32.5					Pear-shaped		Oak	Strap	7		Main shroud lower deadeye with chain, lanyards = 20-25 mm	
Mary Rose [423]	1545	82A37 46	31	18	4.8	2.5	2.8	Pear-shaped	Flat	Oak, Vertic al	Strap	7		Main shroud lower deadeye with chain, 50 mm thick shrouds, lanyards = 20-25 mm	
Mary Rose [424]	1545	82A26 42	30					Pear-shaped		Oak	Strap	7		Main mast lower deadeye with chain, lanyards = 20-25 mm	
Mary Rose [425]	1545	82A26 50	32					Pear-shaped		Oak	Strap	7		Main mast lower deadeye with chain, lanyards = 20-25 mm	

[422] Marsden 2009, 256.
[423] Marsden 2009, 256, 269, 271.
[424] Marsden 2009, 256.
[425] Marsden 2009, 256.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Mary Rose[426]	1545	81A2576	29.5					Pear-shaped		Oak	Strap	7		Main mast lower deadeye with chain, lanyards = 20-25 mm	
Mary Rose[427]	1545	81A3080	30.1					Pear-shaped		Oak	Strap	7		Main mast lower deadeye with chain, lanyards = 20-25 mm	
Mary Rose[428]	1545	82A0008	29.5					Pear-shaped		Oak		7		Main mast lower deadeye, lanyards = 20-25 mm	
Mary Rose[429]	1545	82A3071	31.4					Pear-shaped		Oak		7		Main mast lower deadeye, lanyards = 20-25 mm	
Mary Rose[430]	1545	82A2666	32					Pear-shaped		Oak	Strap	7		Main mast lower deadeye with chain, lanyards = 20-25 mm	

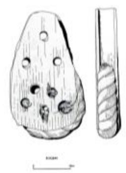
[426] Marsden 2009, 256.
[427] Marsden 2009, 256.
[428] Marsden 2009, 256.
[429] Marsden 2009, 256.
[430] Marsden 2009, 256.

Appendix C Table Continued

Ship	**Year**	**ID#**	**Length (cm.)**	**Width (cm.)**	**Thick ness (cm.)**	**Score Width (cm.)**	**Average Eye Diam. (cm.)**	**Shape**	**Flat or Round Face**	**Wood sp. & Grain**	**Strap/ Strop**	**Hole #**	**Score Shape**	**Other Notes**	**Images**
Mary Rose [431]	1545	?81A2 579	30					Pear-shaped		Oak		7		Main mast upper deadeye, smaller type used on mizzen (?), shroud 50 mm thick shrouds, lanyards = 20-25 mm	
Mary Rose [432]	1545	?81A0 781	25					Pear-shaped		Oak		5		Main mast upper deadeye, smaller type used on mizzen (?), 50 mm thick shrouds, lanyards = 20-25 mm	
Mary Rose [433]	1545	82A00 05	30.5					Pear-shaped		Oak		7		Main mast upper deadeye, 50 mm thick shrouds, lanyards = 20-25 mm	

[431] Marsden 2009, 256.
[432] Marsden 2009, 256.
[433] Marsden 2009, 256.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Mary Rose[434]	1545	81A2236	38.4					Pear-shaped		Oak		7		Main mast upper deadeye, 50 mm thick shrouds, lanyards = 20-25 mm	
Mary Rose[435]	1545	81A2644	37 in publication because measured with rope (32 without rope)	18	5.8	3.9	2.4	Pear-shaped or PFB (bottom is slightly worn)	Flat	Elm, Vertical	Strop	8		Main mast upper deadeye, 50 mm thick shrouds, lanyards = 20-25 mm	
Mary Rose[436]	1545	82Al521	30					Pear-shaped		Oak		7		Upper deadeye, 50 mm thick shrouds, lanyards = 20-25 mm	
Mary Rose[437]	1545	82A2658	24				~2.5	Pear-shaped			Strap	5		Lower deadeye of lower mizzen with chain	

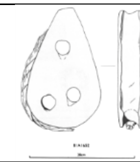
[434] Marsden 2009, 256.
[435] Marsden 2009, 256, 271, 272.
[436] Marsden 2009, 256.
[437] Marsden 2009, 257.

Appendix C Table Continued

Ship	**Year**	**ID#**	**Length (cm.)**	**Width (cm.)**	**Thick ness (cm.)**	**Score Width (cm.)**	**Average Eye Diam. (cm.)**	**Shape**	**Flat or Round Face**	**Wood sp. & Grain**	**Strap/ Strop**	**Hole #**	**Score Shape**	**Other Notes**	**Images**
Mary Rose [438]	1545	82A1655	24.1				~2.5	Pear-shaped			Strap	5		Lower deadeye of lower mizzen with chain	
Mary Rose [439]	1545	82A1636	24.2				~2.5	Pear-shaped			Strap	5		Lower deadeye of lower mizzen with chain	
Mary Rose [440]	1545	?81A0934	34.8				~2.5	Pear-shaped				5		Lower deadeye of lower mizzen, possibly not part of shroud	
Mary Rose [441]	1545	82A2574	24				~2.5	Pear-shaped				5		Lower deadeye of lower mizzen	
Mary Rose [442]	1545	82A1625	22.2			~4	~2.5	Pear-shaped				5		Upper deadeye of lower mizzen	

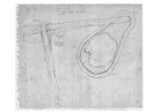
[438] Marsden 2009, 257.
[439] Marsden 2009, 257.
[440] Marsden 2009, 257.
[441] Marsden 2009, 257.
[442] Marsden 2009, 257.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Mary Rose[443]	1545	82A1635	25			~4	~2.5	Pear-shaped				5		Upper deadeye of lower mizzen	
Mary Rose[444]	1545	?82A2338	13			~4	~2.5	Pear-shaped				4		Upper deadeye of lower mizzen, possibly not part of shroud	
Mary Rose[445]	1545	82A2572	19.5			~4	~2.5	Pear-shaped				3		Upper deadeye of lower mizzen	
Mary Rose[446]	1545	81A1652	22.8	14	5	3.8	2.7	Pear-shaped	Flat		Strop	3	Round	Probably used on crowsfeet or martinets	

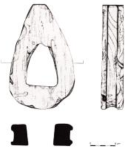
[443] Marsden 2009, 257.
[444] Marsden 2009, 257.
[445] Marsden 2009, 257.
[446] Marsden 2009, 257, 269, 270.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Western Ledge Reef Wreck[447]	1560-1600	89:35-TT-1/13[448]						Pear-shaped or PFB (bottom is broken)	Flat	Vertical	Strap	Probably a heart block		Not drawn to scale	
Western Ledge Reef Wreck[449]	1560-1600	N/A						PFB	Flat			Heart block, trapeoid		Heart block	
Western Ledge Reef Wreck[450]	1560-1600	N/A						Pear-shaped	Flat	Vertical		3, 2 large 1 small		Deadeye	

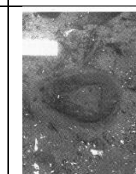
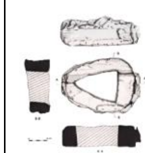
[447] Piotr Bojakowski, personal correspondence, August 7, 2015.
[448] Bojakowski 2012, 376, 391.
[449] Piotr Bojakowski, personal correspondence, August 7, 2015.
[450] Piotr Bojakowski, personal correspondence, August 7, 2015.

Appendix C Table Continued

Ship	**Year**	**ID#**	**Length (cm.)**	**Width (cm.)**	**Thick ness (cm.)**	**Score Width (cm.)**	**Average Eye Diam. (cm.)**	**Shape**	**Flat or Round Face**	**Wood sp. & Grain**	**Strap/ Strop**	**Hole #**	**Score Shape**	**Other Notes**	**Images**
Western Ledge Reef Wreck [451]	1560-1600	N/A						PFB	Flat	Vertical		2, 1 large oval and 1 small round. Heart block		Heart block from a stay with small hole to secure the end of the lanyard (?) or Heart block with circular lanyard eye and a smaller knot hole (fore preventer stay or fore topmast stay)	
San Juan [452]	1565	24M10P11-2	20.9	13	4.4	2	6.3	Pear-shaped	Flat	Vertical		Heart block, trapezoid	Square shallow score	Heart block associated with chains. 18 other similar hearts.	

[451] Piotr Bojakowski, personal correspondence, August 7, 2015.
[452] Grenier et al. 2007, IV-3.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
San Juan[453]	1565	24M8P22-1	21.2	16			7.8	Pear-shaped	Flat	Vertical	Strop	Heart block, triangle		Heart block found starboard associated with starboard main mast shroud. 16 others similar.	
San Juan[454]	1565	24M16K11-1	21.1	14.5			9.5	Pear-shaped	Flat	Vertical	Strop	Heart, triangle/trapezoid		Heart block associated with starboard shrouds for the mainmast.	
San Juan[455]	1565	24M30P1-1	21.8[456]	15	6	3	8.8	Pear-shaped	Flat	Vertical	Strap	Heart block, triangle		Heart block recovered at starboard bow, associated with a large rope-stropped heart for forestay	

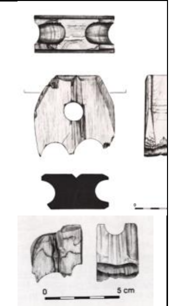
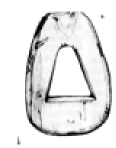
[453] Grenier et al. 2007, IV-4.
[454] Grenier et al. 2007, IV-5.
[455] Grenier et al. 2007, IV-7.
[456] Grenier et al. (2007, IV-7) writes that the heart measures 39.7 cm. in length, but this is inconsistent with the scale. The scale was used for the measurements.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
San Juan [457]	1565	24M28P2-1	39	26			17	PFB	Flat	Vertical	Strop	2, heart block with large trapezoid, and 1 small hole	Round	Heart block from a stay with small hole to secure the end of the lanyard. Small forestay.	
San Juan [458]	1565	24M28P3-1	21	12.5	5.7	3.3	5.3	Pear-shaped	Flat	Vertical	Strap	2, Heart block with large circle, and 1 smaller hole (1.2 cm.)	Round, shallow	Heart block with circular lanyard eye and a smaller knot hole (fore preventer stay or fore topmast stay)	

[457] Grenier et al. 2007, IV-7.
[458] Grenier et al. 2007, IV-7.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
San Juan [459]	1565	24M14M24-2 And 24M14M24-2a		10	4.5	2.7	2.5	PFB	Flat	Vertical		5	Round	Base section of deadeye from aft of the main mast step. Combines with deadeyes fragments (24M14M24-2a) to create 5 hole deadeye	
San Juan [460]	1565	24M16M16-1	19.8	13.5			8	PFB		Vertical		Heart block, triangle		Heart, finely finished with borehole for central cavity smoothed away	
San Juan [461]	1565	24M14K6-2	24.2	16.2			9	Pear-shaped		Vertical		Heart block, triangle		Heart block, more crude	

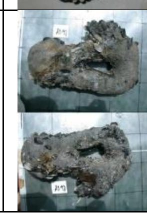
[459] Grenier et al. 2007, IV-8.
[460] Grenier et al. 2007, IV-10.
[461] Grenier et al. 2007, IV-10.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
San Juan [462]	1565	24M14P16-1	18	15			10	PFB				Heart block, trapezoid		Heart block, poorly made	
San Juan [463]	1565	24M-2006-111-2	21.3	13			8	Pear-shaped		Vertical	Strap	Heart block, Rounded triangle		Heart	
Sveti Pavao [464]	1574-1585	180/2009	25	15			8.5	Pear-shaped	Round	Vertical	Strap	Heart block, trapezoid		Heart block	
Sveti Pavao [465]	1574-1585	120/2009	25	13			6	PFB	Flat	Vertical		Heart block, trapezoid		Heart block	

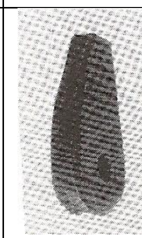
[462] Grenier et al. 2007, IV-10.
[463] Grenier et al. 2007, IV-10.
[464] Beltrame et al. 2014, 50.
[465] Beltrame et al. 2014, 50.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Sveti Pavao[466]	1574-1585	20/2011	21.5		4.5			Pear-shaped	Flat	Elm, Vertical		2, Heart block with 1 large perforation, and 1 small hole (1.2 cm.)		Heart block, from a stay with small hole to secure the end of the lanyard	
Arade I	c. 1583	A1-94[467]	38	20			8	Pear-shaped or PFB	Flat	Vertical	Strap	Heart block, trapezoid		Too concreted to see details	
Arade I	c. 1583	A1-97[468]	33	17				Pear-shaped or PFB	Flat		Strap	Heart block		Too concreted to see details	

[466] Beltrame et al. 2014, 50.
[467] Castro 2003a, 107.
[468] Castro 2003a, 110.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Arade I	c. 1583	A1-110[469]						Pear-shaped or PFB	Flat	Vertical	Strap	Heart block		Too concreted to see details	
La Trinidad Valencera[470]	1588	4.18	34.4			8	18	PFB			Strop	Heart block, trapezoid			
La Trinidad Valencera[471]	1588	4.19	22			3.8	8,2	PFB	Flat	Vertical	Strop	Heart block, trapezoid		Part of the scoring seems to have been made by burning	
La Trinidad Valencera[472]	1588	4.21	13.6		2.6		2	PFB	Flat	Vertical	Strop	Heart block, circle, and smaller circle .6 cm.			

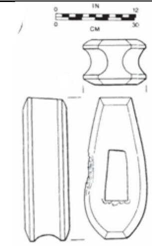
469 Castro 2003a, 123.
470 Flanagan 1988, 48.
471 Flanagan 1988, 49.
472 Flanagan 1988, 49; Rodríguez-Salgado 1988, 166.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
La Trinidad Valencera[473]	1588	57:43	18.3	10	6.5	5.1	5	Pear-shaped	Flat			Heart block, trapezoid. Hole that is 0.7 cm. is pierced in the upper part across the long axis	Round	Heart, with graffito mark on side	

[473] Martin 1979, 33; Flanagan 1988, 49.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
La Trinidad Valencera[474]	1588	56:54	53.5	23.5	17.5	10	9	PFB	Flat		Strop	Heart block, trapezoid	Round	Heart, one of a pair found close to southern anchor. Hearts were stropped with 2 3-strand 2 in cables. (tensioners for main or fore preventer stay)	
Scheurrak SO1[475]	1590	SO1-4600	17.8	14	4	2.3	2.9	Pear-shaped	Flat	Vertical	Strap	3		There is rust and concretion around the score	
Scheurrak SO1[476]	1590	SO1-7042	21.3	15.6	5.4	2.3	2.7	Pear-shaped	Flat	Vertical		3	Square	Some beveling on edges	

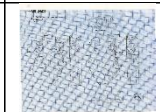
474 Martin 1979, 33.
475 Data Archiving and Networked Services. *Scheurrak SO1 Project.*
476 Data Archiving and Networked Services. *Scheurrak SO1 Project.*

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Scheurrak SO1[477]	1590	SO1-7044	27	19.8	8.1	4.2	2.9	PFB	Flat	Vertical		3	Round	Some beveling on edges	
Scheurrak SO1[478]	1590	SO1-7805-2	17.7	13.6	4.3		2.6	PFB	Flat	Vertical	Strap	3		Strap is still on	
Scheurrak SO1[479]	1590	SO1-7805-3	16.4	11.4	4.2	2.7	2.1	Pear-shaped	Flat	Vertical	Strap	3		Strap is still on	
Scheurrak SO1[480]	1590	SO1-7817	12.1	9.6	2.8	2	1.6	Pear-shaped	Flat	Vertical		3	Round	Interesting groove/split down one face. Some beveling on edges	

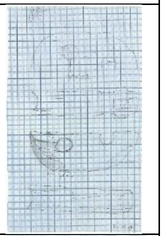
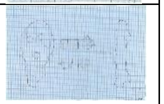
[477] Data Archiving and Networked Services. *Scheurrak SO1 Project.*
[478] Data Archiving and Networked Services. *Scheurrak SO1 Project.*
[479] Data Archiving and Networked Services. *Scheurrak SO1 Project.*
[480] Data Archiving and Networked Services. *Scheurrak SO1 Project.*

Appendix C Table Continued

Ship	**Year**	**ID#**	**Length (cm.)**	**Width (cm.)**	**Thick ness (cm.)**	**Score Width (cm.)**	**Average Eye Diam. (cm.)**	**Shape**	**Flat or Round Face**	**Wood sp. & Grain**	**Strap/ Strop**	**Hole #**	**Score Shape**	**Other Notes**	**Images**
Scheru rrak SO1[481]	1590	SO1-34028	22.2	13 (but broken)	5.4	3.4	2.5	Pear-shaped	Flat	Vertic al		3	Round	Some beveling on edges	
Scheru rrak SO1[482]	1590	SO1-3834						PFB	Flat	Vertic al	Strap	3		Strap is still on it. Some beveling on edges	
Scheru rrak SO1[483]	1590	SO1-04624						Pear-shaped	Flat	Vertic al	Strap	3		Strap is still on	
Scheru rrak SO1[484]	1590	SO1-13002						Pear-shaped or PFB	Flat	Vertic al		3		Large knot is in the center of wood, edges are beveled, significant warping present	

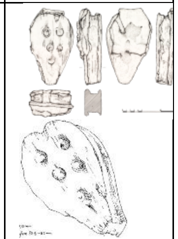
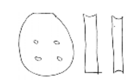
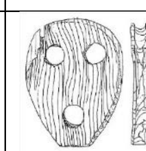
[481] Data Archiving and Networked Services. *Scheurrak SO1 Project.*
[482] Data Archiving and Networked Services. *Scheurrak SO1 Project.*
[483] Data Archiving and Networked Services. *Scheurrak SO1 Project.*
[484] Data Archiving and Networked Services. *Scheurrak SO1 Project.*

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Scheurrak SO1[485]	1590	SO1-4250	28 (do not use because broken)	10 (do not use because broken)	4		2.3		Flat	Vertical				Partial deadeye. Not enough to give accurate measurements	
Scheurrak SO1[486]	1590	SO1-15114						PFB	Flat	Vertical	Strap	3		Cordage is still present in eyeholes. Some concretion is present around edges and bottom	
Scheurrak SO1[487]	1590	SO1-20794	23		5.1	4	3	Pear-shaped or PFB	Flat	Vertical		At least 2 (most likely 3)	Round	Deadeye is broken down center	
Scheurrak SO1[488]	1590	SO1-30255	18.5	13.9	4.2		2.3	Pear-shaped or PFB	Flat	Vertical	Strap	3		There appears to be concretion along edges	

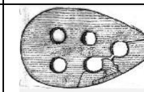
485 Data Archiving and Networked Services. *Scheurrak SO1 Project.*
486 Data Archiving and Networked Services. *Scheurrak SO1 Project.*
487 Data Archiving and Networked Services. *Scheurrak SO1 Project.*
488 Data Archiving and Networked Services. *Scheurrak SO1 Project.*

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Alderney Ship[489]	1592	**303**	19	11	4.4	2	1.7	Pear-shaped	Flat	Vertical	Strap	5	Square	Surrounded by concretion, interesting groove down top center of deadeye	
Alderney Ship[490]	1592	1331	16 (do not use because is longer as seen in x-ray)	16	5		1.3	Pear-shaped	Flat	Vertical	Strap	5		X-ray of deadeye shows 5 holes, bottom 5th hole is concreted. Not originally seen in sketch	 
Alderney Ship[491]	1592	1260	19	13.7	4.5	3	3	Pear-shaped	Flat	Vertical, softwood (possibly pine)		3	Round		

[489] Bound and Monoghan 2001, 41 and 44.
[490] Alderney Wreck 2007; Dave Parham and Tom Cousins, personal communication, February 3, 2016.
[491] Alderney Wreck 2007; Dave Parham and Tom Cousins, personal communication, February 3, 2016.

Appendix C Table Continued

Ship	**Year**	**ID#**	**Length (cm.)**	**Width (cm.)**	**Thickness (cm.)**	**Score Width (cm.)**	**Average Eye Diam. (cm.)**	**Shape**	**Flat or Round Face**	**Wood sp. & Grain**	**Strap/ Strop**	**Hole #**	**Score Shape**	**Other Notes**	**Images**
Alderney Ship[492]	1592	1504	19.2	11.6	3.2		2.4	Pear-shaped	Flat	Vertical		5		Fragments pieced back together	 
Megadim Wreck[493]	Last quarter of 16th century	B[494]	23	13.5			3.5	Pear-shaped	Flat	Vertical		3		Iron strap is 34–34.5 cm. long and maximum 16 cm. wide.	
Megadim Wreck[495]	Last quarter of 16th century	A	23	13.5			3.5	Pear-shaped	Flat	Vertical		3			
Megadim Wreck[496]	Last quarter of 16th century	N/A	23	13.5			3.5	Pear-shaped							

[492] Alderney Wreck 2007; Dave Parham and Tom Cousins, personal communication, February 3, 2016.
[493] Ridella et al. 2016, 187-89.
[494] Ridella et al. 2016, 187-89.
[495] Ridella et al. 2016, 187-89.
[496] Ridella et al. 2016, 187-89.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Megadim Wreck[497]	Last quarter of 16th century	N/A	23	13.5			3.5	Pear-shaped							
Megadim Wreck[498]	Last quarter of 16th century	N/A	23	13.5			3.5	Pear-shaped							
Katthavet 3 (Näckström 1)[499]	Early 17th century							PFB	Flat	Vertical		14		Very large deadeye	
Witte Leeuw[500]	1613	NA						Pear-shaped				3		Too small and poor quality to determine features	
Warwick[501]	1619	02: 155.254557-764-u	8.866	9.796	2.959	1.6	1.5	RTB	Flat	Horizontal		3	Round		

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[497] Ridella et al. 2016, 187-89.
[498] Ridella et al. 2016, 187-89.
[499] Cederlund 1983, 215.
[500] Rijksmuseum 1980, 7.
[501] National Museum of Bermuda 2015.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Warwick[502]	1619	02: 155-034	16.503 (Broken so original probably longer)	14.207	4.383	3	3.16	Pear-shaped or PFB	Flat			3		Too degraded and broken to tell many features	
Warwick[503]	1619	93: 30-008	18.210	12.370	4.094	2.7	2.9	Pear-shaped	Flat	Vertical		3	Square		
Warwick[504]	1619	93: 30-13-2	18.065	13.517	4.211	2.7	3.4	Pear-shaped	Flat	Vertical		3	Round	In 2 pieces	
Warwick[505]	1619	93: 30-13-4	17.057		4.755	~2.5			Flat	Vertical		2, maybe 3	Round	Deadeye fragment	
Warwick[506]	1619	79: 155-344	16.304	16.05	4.566		3.8	Round	Flat	Radial		3		No score found, perhaps strap that encased perimeter?	
Warwick[507]	1619	93: 030-007	26.674	16.914	4.62		3.22	Pear-shaped	Flat	Vertical		6	Square		

[502] National Museum of Bermuda 2015.
[503] National Museum of Bermuda 2015.
[504] National Museum of Bermuda 2015.
[505] National Museum of Bermuda 2015.
[506] National Museum of Bermuda 2015.
[507] National Museum of Bermuda 2015.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Warwick[508]	1619	80: 129C	31.0	21.978	5.356		3.08	Pear-shaped	Flat	Vertical		6	Square		
Warwick[509]	1619	80:129B	19	15	5		3.1	Pear-shaped	Flat			3		Not included in conservation plan. Likely retrieved by Teddy Tucker	
New Old Spaniard[510]	*(1620-1640)*	02:155.249166-614-U (First)	17	14.5			3.3	Pear-shaped		Vertical		3			
New Old Spaniard[511]	*(1620-1640)*	02:155.249166-614-U (Second)	17	14.7			3.3	Pear-shaped		Vertical		3			
New Old Spaniard[512]	*(1620-1640)*	02:155.254557-765-U	10	9			1.7	RTB	Flat	Horizonal		3			

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[508] National Museum of Bermuda 2015.
[509] National Museum of Bermuda 2015.
[510] National Museum of Bermuda 2015.
[511] National Museum of Bermuda 2015.
[512] National Museum of Bermuda 2015.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
San Antonio[513]	1621	02:155.244119-486-U	23	27	10			Round		Horizontal		3		Bottom eye seems concreted	
Swash Channel Wreck[514]	1628	324	36.5	33	14	9.5	5.3	PFB	Flat	Vertical		3	Round		
Swash Channel Wreck	1628	436	36	31	11.5	8	5.2	PFB	Flat	Vertical		3	Round		
Swash Channel Wreck	1628	512	29.8	30	12	4.5	4.8	RTB	Flat	Horizontal		3	Square		
Swash Channel Wreck	1628	646	38.5	31.3	14	9.5	5.3	PFB	Flat	Vertical		3	Round		

[513] National Museum of Bermuda 2015.
[514] Dave Parham and Tom Cousins, personal communication, February 3, 2016.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Swash Channel Wreck	1628	648	22	17.4	7	4	3.7	PFB	Flat	Vertical		3	Round		
Swash Channel Wreck	1628	649	35.5	27.5	11	6	5.8	PFB	Flat	Vertical		3	Round	Some fragments	
Swash Channel Wreck	1628	657	37	29	13.3	9	5.3	PFB	Flat	Vertical		3	Round		
Swash Channel Wreck	1628	658	36.5	29	11.7	6.5	5.2	PFB	Flat	Vertical		3	Round		
Swash Channel Wreck	1628	663	37	29.5	14.5	9	5.3	PFB	Flat	Vertical		3	Round		
Vasa	1628	1068 [515]	13.2	13.6	4	2.5	2.4	RTB	Flat	Horizontal		3	Round		

[515] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	17529 [516]	16.4	15.8	4.4	2.8	3.5	RTB	Flat	Horizontal		3	Square		
Vasa	1628	5107 and 5108 [517]	6.5 and 9.3 (Total 15.8)	16 and 14.6 (Width: 16)	5 and 4.3 (Thickness: 5)	3	3.5	RTB	Flat	Horizontal		3	Square	5107 is upper half of 5108	
Vasa	1628	8837 [518]	16.4	16.7	4.7	3.4	3.7	RTB	Flat	Horizontal		3	Round		
Vasa	1628	8164 [519]	17.5	17	4.5	3.2	2.9	RTB	Flat	Horizontal		3	Round		
Vasa	1628	3169 [520]	17.8	17.7	5.6	2.5	3.5	RTB	Flat	Horizontal		3	Square		

[516] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[517] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[518] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[519] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[520] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	7758 [521]	18	17.9	5.3	3.4	2.8	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23500 [522]	17.2	18.5	4.4	3	2.9	RTB	Flat	Horizontal		3	Round		
Vasa	1628	4015 [523]	19	18.7	4.8	4	3.5	RTB	Flat	Horizontal		3	Round		
Vasa	1628	8687 [524]	17.7	18.7	5.5	2.2	3.5	RTB	Flat	Horizontal		3	Square		
Vasa	1628	6001 [525]	17.5	18.7	4.8	2.8	2.8	RTB	Flat	Horizontal		3	Round		
Vasa	1628	7754 [526]	19.2	19.2	5	2.8	2.9	RTB	Flat	Horizontal		3	Round		

[521] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[522] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[523] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[524] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[525] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[526] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	4157 [527]	19	19.3	5.2	3.7	3.4	RTB	Flat	Horizontal		3	Round		
Vasa	1628	18420 [528]	19	19.5	5.5	3	3.3	RTB	Flat	Horizontal		3	Round		
Vasa	1628	8654 [529]	18	19.5	5.3	3	3	RTB	Flat	Horizontal		3	Round	Rope found in one hole	
Vasa	1628	3673 [530]	21.4	20.2	5.5	2.4	3	RTB	Flat	Horizontal	Strap	3	Probably square, but covered by concretion	Remains of strap present	
Vasa	1628	3813 [531]	20.2	20.2	5.9	2.7	3.3	RTB	Flat	Horizontal		3	Square		

[527] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[528] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[529] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[530] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[531] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	2997 [532]	20	20.5	5		3.8			Horizontal		3	Round		
Vasa	1628	20650 [533]	20	20.5	4.3	3.5	3.4	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23328 [534]	20.5	20.5	5.6	2.8	3.4	RTB	Flat	Horizontal		3	Round		
Vasa	1628	3933 [535]	20.3	20.5	5.4	2.2	3.6	RTB	Flat	Horizontal		3	Square		
Vasa	1628	3963 [536]		20.5						Horizontal		3	Round		
Vasa	1628	1814 [537]	20	20.6	5.8	2.9	3.3	RTB	Flat	Horizontal		3	Round		
Vasa	1628	1950 [538]	20.8	21.0	6.5		3.2			Horizontal		3	Round		

[532] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[533] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[534] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[535] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[536] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[537] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[538] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	21737[539]	20.4	21.0	6.4		4.0	RTB	Flat	Horizontal		3	Round		
Vasa	1628	2904[540]		21.1						Horizontal		3	Square		
Vasa	1628	20642[541]	21.4	21.3	6		4.1	RTB	Flat	Horizontal		3	Round		
Vasa	1628	2921[542]		21.3						Horizontal		3	Square		
Vasa	1628	2911[543]	22	21.4	5.3		4.3			Horizontal		3	Round		
Vasa	1628	9973[544]	20.3	21.4	5.3		3.3	RTB	Flat	Horizontal		3	Round		
Vasa	1628	1708[545]	20.5	21.5	5.5		3.8			Horizontal		3	Round		

[539] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[540] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[541] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[542] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[543] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[544] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[545] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	20555 [546]	20.5	21.5	5.7	2.5	3.1	RTB	Flat	Horizontal		3	Round		
Vasa	1628	20641 [547]	20.7	21.5	5.2		3.9	RTB	Flat	Horizontal		3	Round		
Vasa	1628	3672 [548]	20	21.5	5.5	2.8	3.5	RTB	Flat	Horizontal		4, but smaller hole is likely late	Round		
Vasa	1628	9639 [549]	21.5	21.8	6	2.2	3.4	RTB	Flat	Horizontal		3	Square		
Vasa	1628	9436 [550]	20	21.9	6.2	3.2	3	RTB	Flat	Horizontal		3	Round		

[546] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[547] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[548] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet. Database provided by Hocker lists this deadeye as having 3 holes, not 4. 4th hole could have been added later.
[549] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[550] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	1835[551]	22	22	6.3	2.6	3	RTB	Flat	Horizontal		3	Square		
Vasa	1628	1744[552]		22						Horizontal		3	Square		
Vasa	1628	2943[553]	20.9	22.2	5.4		3.3			Horizontal		3	Round		
Vasa	1628	1949[554]	21.7	22.4	5.5		3	RTB	Flat	Horizontal		3	Square		
Vasa	1628	21296[555]	9 (inaccurate because broken)	22.5	4					Horizontal		3	Square	Upper half of broken deadeye	
Vasa	1628	21793[556]	21.9	22.5	5.6					Horizontal		3	Square		
Vasa	1628	23081[557]	22	22.5	6.5					Horizontal		3	Square		

[551] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[552] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[553] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[554] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[555] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[556] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[557] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	5135[558]	20.4	22.5	5.2	2.2	4.2	RTB	Flat	Horizontal		3	Square		
Vasa	1628	10857[559]	20.5	22.6	5.4	2.1	3.5	RTB	Flat	Horizontal		3	Square		
Vasa	1628	2967[560]	15.7 (inaccurate because broken)	22.8	6.1	2.6	4	RTB	Flat	Horizontal		3	Square	Broken through upper holes, incomplete	
Vasa	1628	2869[561]	21	22.9	5.6		3.4			Horizontal		3	Square		
Vasa	1628	23082[562]	21.1	23.1	4.8					Horizontal		3	Square		
Vasa	1628	8462[563]	26.2	26.7	7.5		4.1	RTB	Flat	Horizontal		3	Round		
Vasa	1628	174[564]	25.3	27			3.2	RTB	Flat	Horizontal		3	Round		

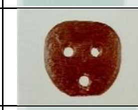
558 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
559 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
560 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
561 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
562 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
563 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
564 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	17219[565]	25.5	27.3	7.3		4.2			Horizontal		3	Round		
Vasa	1628	23456[566]	27.9	27.4	7.1		5	RTB	Flat	Horizontal		3	Round		
Vasa	1628	19959[567]	25.6	27.5	7		4.2			Horizontal		3	Round		
Vasa	1628	4371[568]	27.3	27.9	6.4		4.2			Horizontal		3	Square		
Vasa	1628	20559[569]	27.5	27.9	7.5		4.1	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23522[570]	26	27.9	6.7		4.4	RTB	Flat	Horizontal		3	Round		
Vasa	1628	18785[571]	28	28	7.4	3.8	3.8	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23457[572]	26.7	28.1	8.4		4.4	RTB	Flat	Horizontal		3	Round		

565 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
566 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
567 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
568 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
569 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
570 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
571 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
572 Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	20505 [573]	27.1	28.2	7.1		4.2			Horizo ntal		3	Square		
Vasa	1628	21513 [574]	27	28.2	8.3		4.1	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	21624 [575]	28.4	28.2	7		4.7	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	23493 [576]	25.5	28.2	7.7		4.3	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	23519 [577]	27.9	28.2	8.8		4.2	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	21596 [578]	27.4	28.3	6.8		4.2	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	23089 [579]	28.3	28.4	7		4.2	RTB	Flat	Horizo ntal		3	Round		

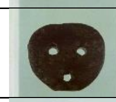
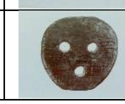
[573] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[574] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[575] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[576] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[577] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[578] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[579] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	21514[580]	27	28.7	7.5		4.7	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23505[581]	27	28.8	7.5		4.2	RTB	Flat	Horizontal		3	Round		
Vasa	1628	19955[582]	26.6	29	7		4.1	RTB	Flat	Horizontal		3	Round		
Vasa	1628	127[583]	28.2	29	8.5		3.9	RTB	Flat	Horizontal		3	Round		
Vasa	1628	21655[584]	28.6	29.6	7.2		4.8	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23090[585]	27.8	29.7	7.5		4.2	RTB	Flat	Horizontal		3	Square		
Vasa	1628	21588[586]	27	29.8	7.4		4.2	RTB	Flat	Horizontal		3	Square		

[580] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[581] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[582] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[583] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[584] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[585] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[586] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	23518[587]	28.4	29.8	7.9		4.2	RTB	Flat	Horizontal		3	Square		
Vasa	1628	21580[588]	29.1	29.9	7.2		5	RTB	Flat	Horizontal		3	Square		
Vasa	1628	21623[589]	29.3	29.9	7.1		4	RTB	Flat	Horizontal		3	Square		
Vasa	1628	23501[590]	27.8	29.9	6.8		4.3	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23088[591]	30	30	8.1		4.4	RTB	Flat	Horizontal		3	Round		
Vasa	1628	20554[592]	30.2	30.1	8.2		4.5	RTB	Flat	Horizontal		3	Round		
Vasa	1628	21425[593]	30	30.3	7.2		4.7	RTB	Flat	Horizontal		3	Square		

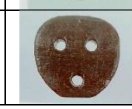
[587] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[588] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[589] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[590] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[591] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[592] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[593] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	3899[594]	30.1	30.4	6.5		4.8			Horizo ntal		3	Round		
Vasa	1628	92[595]	29.2	30.5	7.5	3.5	4.1	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	110[596]	30.7	30.5	8.5	3.5	4.5	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	23087[597]	30.2	30.5	6		4.6	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	23099[598]	28.4	30.5	8.4		4.4	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	21657[599]	30	30.6	8.5		5.4	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	19957[600]	32.1	30.7	8.5	5	4.3	RTB	Flat	Horizo ntal		3	Round		

[594] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[595] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[596] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[597] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[598] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[599] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[600] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	23503[601]	30.1	30.7	7.4		4.7	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	19956[602]	30.2	30.8	8.5		4.5			Horizo ntal		3	Round		
Vasa	1628	21622[603]	30	30.8	7.5		5	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	21668[604]	30.1	30.9	7.8		4.6	RTB	Flat	Horizo ntal		3	Round		
Vasa	1628	19958[605]	30.8	31.2	9		4.5			Horizo ntal		3	Round		
Vasa	1628	696[606]	28.5	31.3	6.7		4.6	RTB	Flat	Horizo ntal		3	Square		
Vasa	1628	21658[607]	30.9	31.3	7.7		4.6	RTB	Flat	Horizo ntal		3	Square		

[601] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[602] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[603] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[604] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[605] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[606] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[607] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	21739[608]	30	31.3	8		4.5	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23446[609]	30	31.3	7.3		4.8	RTB	Flat	Horizontal		3	Square		
Vasa	1628	21989[610]	31	31.4	8.7		4.3	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23077[611]	30	31.4	7.5		5.4	RTB	Flat	Horizontal		3	Round		
Vasa	1628	11177[612]	30.5	31.5	7.2		4.2			Horizontal		3	Square		
Vasa	1628	21656[613]	30	31.7	8		4.4	RTB	Flat	Horizontal		3	Square		
Vasa	1628	118[614]	31	32	8.8	4.8	4.1	RTB	Flat	Horizontal		3	Round		

[608] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[609] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[610] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[611] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[612] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[613] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[614] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	23317 [615]	30	32	9		4.5	RTB	Flat	Horizontal		3	Round		
Vasa	1628	23280 [616]	30.7	32.3	6.9		4.2	RTB	Flat	Horizontal		3	Square		
Vasa	1628	23075 [617]	31.2	32.7	7.4		4.7	RTB	Flat	Horizontal		3	Square		
Vasa	1628	23076 [618]	30.5	32.8	7.9		5.1	RTB	Flat	Horizontal		3	Square		
Vasa	1628	5101 [619]	68.3	42.5	31.5	25	7	Rectangle	Flat	Vertical		6	Square		
Vasa	1628	23114 [620]						Rectangular		Vertical		6	Round		
Vasa	1628	23138 [621]						Rectangular		Vertical		4	Round		

[615] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[616] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[617] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[618] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[619] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[620] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[621] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	18907 [622]	20.3	15	5.9		5.5			Vertical		2	Round	Badly distorted	
Vasa	1628	18912 [623]	22.5	18.2	5.2	3	4	Pear-shaped	Flat	Vertical		2	Round	Badly distorted	
Vasa	1628	12416 and 12689 [624]	28.5 and 23.7	18 and 8.8 (Total breadth 21)	6.5 and 6	4	6.1	Pear-shaped	Flat	Vertical		2	Round	Mizzen parrel? Broken	
Vasa	1628	10120 [625]	13.3	11	3.5	2.2	1.7	PFB	Flat	Vertical		3	Round		
Vasa	1628	10278 [626]	13.5	10.5	3.7	2	1.8	Pear-shaped	Flat	Vertical		3	Square		

[622] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[623] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[624] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[625] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[626] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	10145[627]	13.9	10.5	3.4	2	2.2	Pear-shaped	Flat	Vertical		3	Round		
Vasa	1628	10121[628]	14	10.5	3.4	1.5	2	PFB	Flat	Vertical		3	Square		
Vasa	1628	19711[629]	17.2	13.5	5	3.5	2.5	PFB	Flat	Vertical		3	Round		
Vasa	1628	11613[630]	18	13.7	6	4	2.5	Pear-shaped	Flat	Vertical		3	Round		
Vasa	1628	11306[631]	19.1	14	5.4	4.5	3	Pear-shaped	Flat	Vertical		3	Round		

[627] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[628] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[629] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[630] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[631] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	10074 [632]	20.5	16.5	5.1	3	3	Pear-shaped	Flat	Vertical		3	Round		
Vasa	1628	3671 [633]	22	17.9	6.2	3.3	2.4	PFB	Flat	Vertical		3	Round		
Vasa	1628	17917 [634]	27.4	17.5	7.2	4	3.2	PFB	Flat	Vertical		3	Round	Turned into shroud remnant 19937	
Vasa	1628	19710 [635]	27.8	18	6.6	3.7	3.2	PFB	Flat	Vertical		3	Round		
Vasa	1628	24241 [636]	27.8	18.5	7	4	3.4	PFB	Flat	Vertical		3	Round	Turned into shroud remnants 19937	
Vasa	1628	17916 [637]	28	17.7	7.1	4	3.2	PFB	Flat	Vertical		3	Round	Turned into shroud remnant 19937	

[632] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[633] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[634] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[635] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[636] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[637] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Vasa	1628	18949 [638]	28.2	18.9	7.1	4.5	3.5	PFB	Flat	Vertic al		3	Round		
Vasa	1628	24242 [639]	28.6	18	7	4.2	3	PFB	Flat	Vertic al		3	Round	Turned into shroud remnants 19937	
Vasa	1628	24240 [640]	28.7	17.5	6.6	4.3	2.9	PFB	Flat	Vertic al		3	Round	Turned into shroud remnants 19937	
El Galgo	1639	92:002 .016	19.1	11.5			1.9		Flat	Vertic al		3			
Stora Sofia	1645	52[641]	15	15?										Notes diameter is 15 cm., but unclear if perfect circle	
Stora Sofia	1645	44177 [642]	21	21?	7			Pear-shaped or PFB			Strap				

[638] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[639] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[640] Fred Hocker and Nathaniel Howe, personal communication, October 17, 2015; DigitaltMuseum, Vasamuseet.
[641] Note that Bergstrand and Albin (2003, Appendix) only gives the diameter, so it is unclear if it is a perfect circle, but assumed to be so.
[642] Bergstrand and Albin 2003, Appendix.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Corolla Wreck	1640[643]		16.4	15.5	4.2		2.5	RTB	Flat	Horizontal	Strap	3			
Corolla Wreck	1640[644]		13	13	8.5	3.5	3.5	Round	Round	Lignum vitae, radial	Strap	3		May not belong to wreck	
Duart Point	1653	DP00/104	13.2 but broken	12.2	4	2.8	2.4		Flat	Horizontal		3	Round	Very degraded	
Duart Point	1653	DP99/037	9.8	7	2.2	1.6	1.1	Pear-shaped	Flat	Vertical		3	Round		
Duart Point	1653	DP00018c							Flat		Strap	3		Not recovered, item too concreted to see detail	

[643] Brown 2013, 164-65.
[644] Brown 2013, 164-65.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Avondster	1659	2001GHL007a / L[645]	18.2		6.6							3		Very degraded	
Avondster	1659	2001GHL013a[646]	12	12				RTB	Flat	Horizontal	Strop	3			
Avondster	1659	2004GHL345 / L[647]	10.5	10.5					Flat	Lignum vitae	Strap	3			
Avondster	1659	2001GHL012a / L[648]	9.5	9.3	4		2	RTB	Flat	Horizontal		3			
Avondster	1659	2004GHL242 / L[649]							Round		Strap	3			
London	1665	[650]	15.8	15.8			4	Round	Round		Strap	3			

[645] Bonke et al. 2007, 141.
[646] Bonke et al. 2007, 142.
[647] Bonke et al. 2007, 143.
[648] Bonke et al. 2007, 142.
[649] Bonke et al. 2007, 143.
[650] The London Shipwreck Trust. 2011. *The London Wreck Project*.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Kronan	1676	[651]						Round	Round	Horizontal		3			
Grone Jagaren	1676	O 11937 a[652]	21	~21	6.5			Round or RTB	Round	Horizontal		3		Only diameter listed so width and length likely similar	
Grone Jagaren	1676	O 11937 b[653]	15	~15	6			Round	Round	Horizontal		3		Only diameter listed so width and length likely similar	
Grone Jagaren	1676	O 11937 c[654]	10.5	~10.5	3.5			Round or RTB	Flat	Horizontal		3		Only diameter listed so width and length likely similar	

[651] Corder 2007, 37.
[652] DigitaltMuseum, Sjöhistoriska museet.
[653] DigitaltMuseum, Sjöhistoriska museet.
[654] DigitaltMuseum, Sjöhistoriska museet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Riksapplet	1676	SM 24525[655]	13.5	13.5	5		2.5	Round	Round	Horizontal		3			
Riksapplet	1676	SM 28431[656]	13.3	14.5	5.9		3.3	RTB	Flat	Horizontal		3			
Riksapplet	1676	O 01999[657]	25	~25										Only diameter listed so width and length likely similar	
Riksapplet	1676	O 02000[658]	13	~13										Only diameter listed so width and length likely similar	

[655] DigitaltMuseum, Sjöhistoriska museet.
[656] DigitaltMuseum, Sjöhistoriska museet.
[657] DigitaltMuseum, Sjöhistoriska museet.
[658] DigitaltMuseum, Sjöhistoriska museet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Riksapplet	1676	O 02106[659]	35	~35										Only diameter listed so width and length likely similar	
Riksapplet	1676	O 11907.A[660]	24.5	~24.5	10									Only diameter listed so width and length likely similar	
Riksapplet	1676	O 11907.B[661]	18	~18	7									Only diameter listed so width and length likely similar	
Riksapplet	1676	O 11907.C[662]	15	~15	7									Only diameter listed so width and length likely similar	

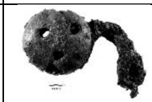
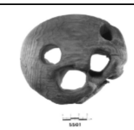
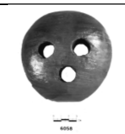
[659] DigitaltMuseum, Sjöhistoriska museet.
[660] DigitaltMuseum, Sjöhistoriska museet.
[661] DigitaltMuseum, Sjöhistoriska museet.
[662] DigitaltMuseum, Sjöhistoriska museet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Riksap plet	1676	O 11907. D[663]	15	~15	6									Only diameter listed so width and length likely similar	
Riksap plet	1676	O 11907. E[664]	13	~13	5.5									Only diameter listed so width and length likely similar	
Riksap plet	1676	O 11907. F[665]	15	~15	5.5									Only diameter listed so width and length likely similar	
Riksap plet	1676	O 11907. G[666]	13	~13	5.5									Only diameter listed so width and length likely similar	

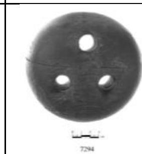
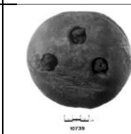
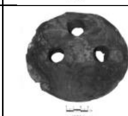
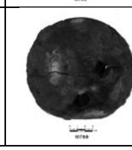
663 DigitaltMuseum, Sjöhistoriska museet.
664 DigitaltMuseum, Sjöhistoriska museet.
665 DigitaltMuseum, Sjöhistoriska museet.
666 DigitaltMuseum, Sjöhistoriska museet.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Riksap plet	1676	O 11907. H[667]	13	~13	5.5									Only diameter listed so width and length likely similar	
La Belle	1686	3419.0 78[668]	9.4	10.2	6	1.6	1.6	Round	Round	Horizo ntal	Strap	3			
La Belle	1686	3419.0 02[669]	13.5	13	5.8	1.8	2.1	Round	Round		Strop	3			
La Belle	1686	5501 [670]	12.9	15.4	7	2.1	3.2	RTB	Round	Radial		3	Round	Very degraded	
La Belle	1686	6058 [671]	11.7	11.7	7.3	2.2	2.3	RTB	Round	Horizo ntal		3	Round		

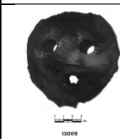
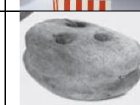
[667] DigitaltMuseum, Sjöhistoriska museet.
[668] Corder 2007, 233-34.
[669] Corder 2007, 231-32.
[670] Corder 2007, 235-36.
[671] Corder 2007, 237-38.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
La Belle	1686	7227 [672]	15.5	17.1	8.5	2.8	3	Round	Round	Radial		3	Round		
La Belle	1686	7294 [673]	14	14	7.9	2.3	2.1	Round	Round	Horizo ntal		3	Round		
La Belle	1686	10739 [674]	13.4	14.7	7.7	1.7	2.2	Round	Round	Horizo ntal		3	Square		
La Belle	1686	10764 [675]	12.5	14.2	7.2	1.8	2.2	Round	Round	Radial		3	Square		
La Belle	1686	10788 [676]	13.6	14.5	7.1	1.7	2.3	Round	Round	Horizo ntal		3	Round	Crosshatch marks from conservation storage crate	

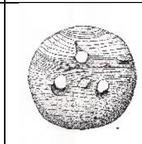
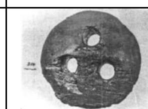
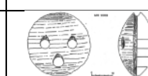
[672] Corder 2007, 239-40.
[673] Corder 2007, 241-42.
[674] Corder 2007, 243-44.
[675] Corder 2007, 245-46.
[676] Corder 2007, 247-48.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
La Belle	1686	11361 [677]	12	12.3	6.5	2.3	2.2	Round	Round	Radial		3	Round		
La Belle	1686	13009 [678]	11.2	10.7	6.5	1.7	1.7	Round	Round	Horizontal		3	Square		
La Belle	1686	13277 [679]			7.5	2.9	2.4				Strop			Very damaged in 3 pieces	
Dartmouth	1690	HXD 281(a) [680]		20			3.2			Horizontal		3		Worn dead-eye, jutting out from possible strap?	
Dartmouth	1690	HXD 504[681]		23			3			Horizontal					
La Hougue Wrecks	1692	[682]								Horizontal		3			

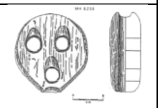
[677] Corder 2007, 249-50.
[678] Corder 2007, 251-52.
[679] Corder 2007, 253.
[680] Canmore, National Record of the Historic Environment. *Dartmouth.*
[681] Canmore, National Record of the Historic Environment. *Dartmouth.*
[682] L'hour and Veyrat 1998a, 402.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Port Royal Shipwreck[683]	1692	PR90 2076-19	9.7	10.2	4.8	1.6	1.15	Round	Round	Horizontal		3	Square	Clifford notes that there is no metal concretion and therefore thinks it is an upper deadeye but score is square. From *Swan*, or similar ship.	
Santo Antonio de Tanna[684]	1697	MH 0338	34	34	16	5.6	6.0	Round		Teak, Horizontal		3			
Santo Antonio de Tanna[685]	1697	MH 1509	30.4	30.4	17.8	2.8	4.6	Round	Round	Horizontal		3	Round		
Santo Antonio de Tanna[686]	1697	MH 1508	19	20	10.5	3.0	2.6	Round	Round	Teak, Horizontal		3	Square	Strap cross section: 1.7 x 1.7	

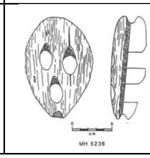
[683] Clifford 1993, 121 and 184.
[684] Thompson 1988, 64.
[685] Thompson 1988, 65.
[686] Thompson 1988, 65-6.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Santo Antonio de Tanna [687]	1697	MH 5235	13	12	5.1	2.1	2.3	RTB	Flat	Vertical		3	Round		
Santo Antonio de Tanna [688]	1697	MH 1507	36.8	36.8	19.6	4.2	4.6								
Santo Antonio de Tanna [689]	1697	MH 0469	33	33			6.8								
Santo Antonio de Tanna [690]	1697	MH 4551	31	31		2.7	4.6								
Santo Antonio de Tanna [691]	1697	MH 4646	30	30	17.5	2.7	4.6								

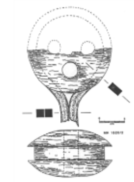
[687] Thompson 1988, 66-7.
[688] Thompson 1988, 66.
[689] Thompson 1988, 66.
[690] Thompson 1988, 66.
[691] Thompson 1988, 66.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Santo Antonio de Tanna[692]	1697	MH 1520/1	27.5	27.5	14	3.4									
Santo Antonio de Tanna[693]	1697	MH 5176	17	17	6.0	2.2	2.4								
Santo Antonio de Tanna[694]	1697	MH 5859	13	13	4.9	2.1	2.2								
Santo Antonio de Tanna[695]	1697	MH 5236	13	8.7	4	1.7	1.9	Pear-shaped	Flat	Teak, Vertical		3	Round		

[692] Thompson 1988, 66.
[693] Thompson 1988, 66.
[694] Thompson 1988, 66.
[695] Thompson 1988, 67-68.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thick ness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Santo Antoni o de Tanna [696]	1697	MH 1520/2	17.2	16.6	9.0	2.7	2.7	Round	Round	Horizo ntal	Strap	3	Square	Half of deadeye and strap missing. Strap is rectangular in cross-section where it fits deadeye but becomes square at lower end. Strap around deadeye: 1.4 x 2.7 Strap below deadeye: 1.6 x 1.6	
Santo Antoni o de Tanna [697]	1697	MH 6502			6.7	2.2	2.3				Strap		Square	Strap: .7 x 2.2	
Santo Antoni o de Tanna [698]	1697	MH 1505	18	18	6.0		2.7				Strap		Square	Similar to MH 1520/2	

[696] Thompson 1988, 67, 69.
[697] Thompson 1988, 68.
[698] Thompson 1988, 70.

Appendix C Table Continued

Ship	Year	ID#	Length (cm.)	Width (cm.)	Thickness (cm.)	Score Width (cm.)	Average Eye Diam. (cm.)	Shape	Flat or Round Face	Wood sp. & Grain	Strap/ Strop	Hole #	Score Shape	Other Notes	Images
Santo Antonio de Tanna[699]	1697	MH 1506	17.2	17.2	6.2	1.6	2.7				Strap				
Jutholmen	c. 1700	25046[700]	30	30				Round	Round			3		Image not labeled (not clear if this is 25046)	
Jutholmen	c. 1700	26007[701]	15	15				Round	Round	Horizontal		3		Image unlabeled (not clear if this is 26007)	

[699] Thompson 1988, 70.
[700] Cederlund 1982, 112.
[701] Cederlund 1982, 111.

APPENDIX D

WARWICK'S RIGGING RECONSTRUCTION: SHIP DICTIONARY & TREATISE COMPARISON

Appendix D Table of Ship Dictionary and Treatise Dimension Comparisons

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Bowsprit	**Length: 57.6 ft (Estimated diameter: 19.2 in.)** "The length of the boysprett must be just the length of the foremast, & of ye same bigness about."[706]	**Length: 44.10 ft. Diameter: 14.7 in..**"[...]the boltsprit ever the same in length and thickness with the foremast."[707]	Listed, but no dimensions given.[708]	Yes, and the same as Mainwaring's instructions.[709] "All the Masts stand upright but the Boulspret, which lyeth along over the Beak-head, and that timber it resteth on is called the *Pillow*."[710]	Length is between 44.10 to 57.6 ft. Diameter is 14.7 to 19.2 in.

[702] Barker 1994. 16-29. Note: for the Newton Manuscript, proportions for the diameter of masts and yards are given, but no value is given to calculate it with, as such, the dimensions from Mainwaring were used to input these ratios in (this was done to compare the final numbers with the ones in Mainwaring to see if they are similar).
[703] Manwaring and Perrin 1922.
[704] Salisbury and Anderson 1958.
[705] Goell 1970.
[706] Barker 1994, 28.
[707] Manwaring and Perrin 1922, 186.
[708] Salisbury and Anderson 1958, 47.
[709] Goell 1970, 18-9.
[710] Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Spritsail yard	**Length: 34.14 ft.** "[…] likewise divide the fore-yard into 4 equal parts & 3 of those 4 parts shall be the length of the spritsail yard"[711] (**Estimated diameter: 5.7 in.**)	"The cross-jack-yard and spritsail-yard is to be all of a length, but allow the mizen-yard and spritsail-yard 1/2 an inch thickness to a yard in length."[712]	Running rigging from it is described, but no dimensions given.[713]	Yes, and exactly the same as Mainwaring's instructions.[714] If using ratios in example on page 20, then spritsail yard is approximately **50 ft in length and 8 in. in diameter**.	Length is between 34.14 to 50 ft. Diameter is 5.7 to 8 in.

[711] Barker 1994, 28.
[712] Manwaring and Perrin 1922, 259.
[713] Salisbury and Anderson 1958, 56-7.
[714] Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Spritsail topmast	None. Mentions main and fore topmast dimensions, then that there are only two topsail yards (implying only fore and main topsails).[715]	Listed.[716] "The topmasts are ever half so long as the masts unto which they belong; but there is no one absolute proportion in these and the like things, for if a man will have his mast short, he may the bolder make his topmast long."[717]	Yes. "The Spritsayle Topmast standeth in a Cap fastened to the Top of a Knee which standes on the utter ende of the bovespright and hath his heele set fast in a step made in the bovespright; under the knee are yron crosse trees and above ar wooden crossetrees which serve only to make the Top stande square for on them the Top standeth."[718]	Listed but no dimensions given. "All the Masts, Top-masts and Flag-staves have staies, excepting the Spretsail-top Mast."[719]	*Warwick* most likely did not have.

[715] Barker 1994, 28.
[716] Manwaring and Perrin 1922, 233.
[717] Manwaring and Perrin 1922, 246.
[718] Salisbury and Anderson 1958, 47, 57.
[719] Goell 1970, 21-2.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Spritsail topsail yard	None. Mentions main and fore topmast dimensions, then that there are only two topsail yards (implying only fore and main topsails).[720]	Listed but with no dimensions given. Possible the proportions for other topmasts can be used "[…] the [main] topsail-yard is to be 3/7 of the main-yard."[721]	Listed but no dimensions given, later page covers running rigging on this yard. "[S]prittsayle Topsayle" mentioned again later.[722]	Listed but no dimensions given. Maybe proportions for other topmasts can be applied: "The top yards beares halfe proportion to the maine and fore yard […][723]	*Warwick* most likely did not have.
Spritsail topgallant sail	None	None	Listed but no dimensions given. Further, Toptopgallant sayles are noted and later page specifically mentions "sprit sayle Topgallant."[724]	None.	*Warwick* most likely did not have.

[720] Barker 1994, 28.
[721] Manwaring and Perrin 1922, 259.
[722] Salisbury and Anderson 1958, 47, 58, 62.
[723] Goell 1970, 20-1.
[724] Salisbury and Anderson 1958, 47, 62.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Fore mast	**Length: 57.6 ft**, "The foremast is to ye main-mast as 6 to 7, working by the rule of 3 for either bigness or length" *Rule of 3 is to hold the same proportions. According to this rule, if four numbers are related like those in his problem, three of the numbers could be used to find the fourth. (Estimated **diameter: 19.2 in.**)[725]	**Length: 44.10 ft. Diameter: 14.7 in.** "The foremast is in length to be 4/5 of the mainmast, which will be 20 yards [from previous example in Main mast] lacking one 4/5 part of a yard and 20 in. through [diameter appears to have been rounded up]." Also, foremast stay is fastened to bowsprit.[726]	Listed, but no dimensions given.[727]	Yes, and exact same as Mainwaring's instructions.[728]	Length is between 44.1 to 57.6 ft. Diameter is 14.7 to 19.2 in.

[725] Barker 1994, 28; Institute and Museum of the History of Science, Museo Galileo 2005, 10a.
[726] Manwaring and Perrin 1922, 105, 186.
[727] Salisbury and Anderson 1958, 47.
[728] Goell 1970, 18-9.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Fore yard	**Length: 45.53 ft** "It is to be noted that by the main yard are all ye rest of any ships yards proportioned: as for example divide ye main yard into four parts then three of those parts must be ye length of the fore-yards […] & the length of ye messen yard must be ye length of ye foreyard & the missen yard must be at 1/3 thickness of the length wch is at ye slinges as much as the foreyard is at 1/3 from ye slinges toward ye small end." (**Estimated diameter: 11.4 in.**)[729]	**Length: 50.32 ft. Diameter: 12.58 in.** "The length of the fore-yard is to be 4/5 of the main-yard." Assumed diameter is 3/4 inch per yard as like the main yard.[730]	Inferred to, but no dimensions given.[731]	Yes, and exactly the same as Mainwaring's instructions. In example on page, fore yard is 57 ft long and 15 in. in diameter.[732]	Length is between 45.53 to 57 ft. Assumed diameter is between 11.4 to 17 in.

[729] Barker 1994, 28.
[730] Manwaring and Perrin 1922, 259.
[731] Salisbury and Anderson 1958, 47.
[732] Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	Mainwaring's *The Seamen's Dictionary* (1623)[703]	*A Treatise on Rigging* (1625)[704]	*A Sea Grammar (1627)* [705]	Analysis
Fore topmast	**Length: 28.8 ft** "The length of the top-mast must be half of the length of ye mast it standeth on, & in thickness the half of ye mast it standeth on." (for both main topmast and fore topmast (estimated **diameter: 9.6 in.**)[733]	**Length: 22.05 ft. Diameter: 7.35 in.** "Topmast. The topmasts are ever half so long as the masts unto which they belong; but there is no one absolute proportion in these and the like things, for if a man will have his mast short, he may the bolder make his topmast long". Fore topmast stay is fastened to bowsprit.[734]	Listed, but no dimensions given.[735]	Listed, but no dimensions given.[736]	Length is between 22.05 to 28.8 ft. Diameter is 7.35 to 9.6 in.

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[733] Barker 1994, 28.
[734] Manwaring and Perrin 1922, 105, 246.
[735] Salisbury and Anderson 1958, 47.
[736] Goell 1970, 21.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Fore topsail yard	Listed but no dimensions are given.[737]	**Length: 21.56 ft. Diameter: 5.39 in.** Assumed to hold same ratios as main yard to main topsail yard (3/7 length of fore mast and 3/4 inch per yard).[738]	Listed, but no dimensions given.[739]	"The top yards beares halfe proportion to the maine and fore yard." If using example, **length: 28.5 ft and diameter: 7.5 in.** [740]	Length between 21.56 to 28.5 ft. Diameter between 5.39 to 7.5 in.
Fore topgallant mast	None.	Not listed in glossary, but topgallant is. Most likely did not have a fore topgallant because not listed in glossary as individual term.[741]	Listed as something some ships have. Details on how it is rigged noted also. [742]	Listed. Probably about half the size of topmast, but this is conjecture based on yard length "[…]and the topgallants the halfe to them [top yards]"[743]	*Warwick* most likely did not have until after first quarter.

737 Barker 1994, 28.
738 Manwaring and Perrin 1922, 259.
739 Salisbury and Anderson 1958, 47.
740 Goell 1970, 20.
741 Manwaring and Perrin 1922, 245
742 Salisbury and Anderson 1958, 47, 54-5.
743 Goell 1970, 20-1.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Fore topgallant yard	None	Not listed in glossary, but topgallant is there. Most likely did not have a fore topgallant because not listed in glossary as individual term.[744]	Listed as something some ships have. Details on how it is rigged also noted. [745]	**Length: 10.78 ft. Diameter: 2.70 in.** "The top yards beares halfe proportion to the maine and fore yard, and the topgallants the halfe to them, but this rule is not absolute." [746] If using example ship dimensions, **length is 14.25 ft and diameter is 3.75 in.**	*Warwick* most likely did not have until after first quarter.
Fore royal	None	None	Listed but no dimensions given. Some ships have "fore […] Toptopgallant."[747]	None	None on *Warwick*.

[744] Manwaring and Perrin 1922, 245
[745] Salisbury and Anderson 1958, 47, 55.
[746] Goell 1970, 20-1.
[747] Salisbury and Anderson 1958, 62.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	Mainwaring's *The Seamen's Dictionary* (1623)[703]	*A Treatise on Rigging* (1625)[704]	*A Sea Grammar (1627)* [705]	Analysis
Main mast	**Length: 67.16 ft.**, For small ships and pinnaces: add breadth and depth x (2/3) = length in yards x 3 = length in ft.[748]	**Length: 55.2 ft. Diameter: 18.4 in.** "[…]the true proportion for the length of any mast is to take 4/5 of the breadth of the ship [in ft], and that multiply by 3 shall give the just number of ft that the mainmast shall be in length; the bigness to be one inch to a yard in length, but more if it be a made mast, for example: Take a ship whose breadth is 30 foot, four-fifths of 30 are 24 foot, so I say that this ship's mainmast must be 24 yards long (for every yard is 3 foot), and 24 in. through, allowing one inch to every yard."[749]	Listed, but no dimensions given.[750]	Yes, and exact same as Mainwaring's instructions.[751]	Length is between 55.2 to 67.16 ft. Diameter is 18.4 to 22.4 in.

[750] Salisbury and Anderson 1958, 47.
[751] Goell 1970, 18-9.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Main yard	**Length: 60.71 ft**, Divide keel length in half, add breadth measurement, divide by 3 = main yard length in yards.[752] (**Estimated diameter: 15.2 in. if using Mainwaring's calculation for the diameter**)	**Length: 62.9 ft. Diameter: 15.73 in.** "[…] the main-yard of the ship is to be 5/6 parts of the length of her keel, [...] and the main-yard for bigness is to be 3/4 of an inch for a yard in length." [753]	Listed, but no dimensions given. "The mayne yeard is fastened to the mayne mast by the Parrell […]"[754]	Yes, and exactly the same as Mainwaring's instructions. In example, main yard is 63 ft long and 17 in. in diameter.[755]	Length is between 60.71 to 63 ft. Diameter is between 15.2 to 17 in.

750 Salisbury and Anderson 1958, 47.
751 Goell 1970, 18-9.
752 Barker 1994, 28.
753 Manwaring and Perrin 1922, 259.
754 Salisbury and Anderson 1958, 49.
755 Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Main topmast	**Length: 33.6 ft** "The length of the top-mast must be half of the length of ye mast it standeth on, & in thickness the half of ye mast it standeth on."[756] (for both main topmast and fore topmast) (estimated **diameter: 11.2 in.**)	**Length: 27.6 ft. Diameter: 9.2 in.** "Topmast. The topmasts are ever half so long as the masts unto which they belong; but there is no one absolute proportion in these and the like things, for if a man will have his mast short, he may the bolder make his topmast long." [757]	Listed, but no dimensions given. "The Topmast is fastened to the head of the mayne mast by the crosse trees and the cap of the mayne mast. and hath standing ropes to steddy it these." [758]	Listed, but no dimensions given. [759]	Length is between 27.6 ft to 33.6 ft. Diameter is 9.2 to 11.2 in.

[756] Barker 1994, 28.
[757] Manwaring and Perrin 1922, 246.
[758] Salisbury and Anderson 1958, 47, 52.
[759] Goell 1970, 21.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Main topsail yard	Listed but no dimensions are given.[760]	**Length: 26.95 ft.** **Diameter: 6.74 in.** "[...] the topsail-yard is to be 3/7 of the main-yard, and the main-yard for bigness is to be 3/4 of an inch for a yard in length." [761]	Listed, but no dimensions given. [762]	Yes, and exactly the same as Mainwaring's instructions. "3/7 of main yard" but this depends on whether or not the yards are "taunt." The general rule appears to be that "The top yards beares halfe proportion to the maine and fore yard, and the topgallants the halfe to them." [763]	Length: 26.95 ft. Diameter: 6.74 in.

[760] Barker 1994, 28.
[761] Manwaring and Perrin 1922, 259.
[762] Salisbury and Anderson 1958, 47.
[763] Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	Mainwaring's *The Seamen's Dictionary* (1623)[703]	*A Treatise on Rigging* (1625)[704]	*A Sea Grammar (1627)* [705]	Analysis
Main topgallant mast	None	Listed but no dimensions given. Perhaps this is because they are not as common. "Topgallants are the masts above the topmasts. These sails do draw very much, quarter winds, in a loom or fresh gale, so it blow not too much."[764]	Listed, but no dimensions given. "It is fastened to the Topmast head by the Tressletrees and the cap of the topmast and hath these standing ropes to steddy it." [765]	Listed, but no dimensions given. [766]	*Warwick* most likely did not have.
Main topgallant yard	None	Not mentioned in "Yard" definition (further evidence that it may not be a common yard to have at this time).[767]	Listed, with no dimensions given, although the part is described.[768]	**Length: 13.48 ft. Diameter: 3.37 in** "The top yards beares halfe proportion to the maine and fore yard, and the topgallants the halfe to them, but this rule is not absolute."[769]	Length: 13.48 ft. Diameter: 3.37 in.

[764] Manwaring and Perrin 1922, 245.
[765] Salisbury and Anderson 1958, 47, 54.
[766] Goell 1970, 21.
[767] Manwaring and Perrin 1922, 259.
[768] Salisbury and Anderson 1958, 47, 54-5.
[769] Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Main royal	None	None.	Main "Toptopgallant" is listed.[770]	None.	Most likely none on *Warwick*.
Mizzen mast	Mizzen mast is not mentioned, but mizzen yard is. [771]	**Length: 27.6 ft. Diameter: 9.2 in.** "The mizen-mast to be half the length of the mainmast [...] [772]	Listed but no dimensions given.[773]	Yes, and exactly the same as Mainwaring's instructions.[774]	Length is about 27.6 ft. Diameter is between 9.2 in.
Mizzen yard	**Length: 45.53 ft** "[…] & the length of ye messen yard must be ye length of ye foreyard & the missen yard must be at 1/3 thickness of the length wch is at ye slinges as much as the foreyard is at 1/3 from ye slinges toward ye small end."[775]	Not given formula for length, but thickness is only 1/2 inch per yard. [776]	Listed but no dimensions given.[777]	"[…]and your Misen-yard so long as the Mast […] but .5 inch of thicknesse to a yard in length." [778]	Length is between 27.6 (if dimensions are same as Mizzen mast above) to 45.53 ft. Diameter is approximately between 4.6 to 7.6 in.

770 Salisbury and Anderson 1958, 47, 62.
771 Barker 1994, 28.
772 Manwaring and Perrin 1922, 186.
773 Salisbury and Anderson 1958, 47.
774 Goell 1970, 18-9.
775 Barker 1994, 28.
776 Manwaring and Perrin 1922, 259.
777 Salisbury and Anderson 1958, 58-9.
778 Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Mizzen topmast	None.	**Length: 13.78 ft. Diameter: 4.60 in.** "Topmast. The topmasts are ever half so long as the masts unto which they belong; but there is no one absolute proportion in these and the like things, for if a man will have his mast short, he may the bolder make his topmast long." [779]	Listed, but no dimensions are given. "The Misson Topmast is fastened to the head of the misson mast as other Topmasts ar and hath these standing ropes." [780]	Listed.[781]	Equally plausible *Warwick* had it, or did not according to treatises. If it did, it would approximately have a length: 13.78 ft. Diameter: 4.60 in.
Mizzen topsail yard	None	Not specifically listed in glossary, although mizzen topmast is.	Listed.[782]	Listed.[783]	If mizzen topmast and crossjack yard existed, it is possible it was often not fitted with the mizzen topsail yard especially in the first quarter of the century.

[779] Manwaring and Perrin 1922, 188, 246.
[780] Salisbury and Anderson 1958, 47, 59.
[781] Goell 1970, 21.
[782] Salisbury and Anderson 1958, 60.
[783] Goell 1970, 21.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	**Mainwaring's *The Seamen's Dictionary* (1623)**[703]	***A Treatise on Rigging* (1625)**[704]	***A Sea Grammar (1627)*** [705]	**Analysis**
Crossjack yard (mizzen)	None	Listed, and has same dimensions as spritsail yard (except spritsail yard only has 1/2 inch to thickness per yard). "Cross-jack is a yard at the upper end of the mizen mast under the top and there is slung, having no halliards nor ties belonging to it; the use whereof is to spread and haul on the mizen-topsail sheets."[784]	"The Crosse Jacke hath no saile it serves only to spreade the Misson Topsaile and is slonge fast to the misson mast with a rope and hath Braces 2 they ar single ropes fastened to ether arme of the Crosse Jacke and so goe from ether side to the aftermost Timber on the Poupe and are belayed ther."[785]	Yes, and exactly the same as Mainwaring's instructions. "Crossejacke Yard and Spretsaile Yard to be of a [equal] length. [Spretsaile Yard 1/2 inch of thicknesse to a yard in length]."[786]	*Warwick* most likely had it, according to treatises. If it did, it approximately had a Length between 34.14 to 50 ft. Diameter is 8.5 to 12.5 in.

784 Manwaring and Perrin 1922, 135, 259.
785 Salisbury and Anderson 1958, 60.
786 Goell 1970, 20.

Appendix D Table Continued

	Newton Manuscript (c. 1600) [702]	Mainwaring's *The Seamen's Dictionary* (1623)[703]	*A Treatise on Rigging* (1625)[704]	*A Sea Grammar (1627)* [705]	Analysis
Bonaventure mizzen mast	None	Used only in large ships at the time. "Some great long ships require two mizens, then they call that next the mainmast, the main-mizen; that next the poop, the bonaventure mizen." [787]	"Somme ships have 2 missons ether in regard of their length or qualeties, when in regard of length it is for handsomnes because to such distance betewene masts is unseemly. In regard of ther qualety is when a ship will not keepe the winde and that her head falles of, which is incident to all ships hie built or which have those sails which flatts of the head of the ship (which ar those of her ffore masts and spritsayles) stronger then those of her Mayne mast and Misson, which ar the sayles which keepes the heade of a ship to the winde. sometymes we geve a ship 2 Missons to keepe her head to the winde when she hulles to the ende that she may ride easely on the waves, and not lie tumbling in the trough of the sea betweene 2 billowes. When a ship hath 2 missons the former is called the Mayne, the other the Bonaventure Misson." [788]	"In great ships they have two Misens, the latter is called the Bonaventure Misen." [789]	Most likely none on *Warwick*.

[787] Manwaring and Perrin 1922, 188.
[788] Salisbury and Anderson 1958, 47.
[789] Goell 1970, 21.

APPENDIX E

MAST AND YARD LIST COMPARISONS

Appendix E Table of Ship List Spar Comparisons

Mast/yard (all lengths in ft.)	***Bear* (c. 1600)** [790]	***Bear* (pre-1618). Tons: 732.6** [791]	***Bear* (post-1618) Tons: 732.6** [792]	***Rainbow* (c. 1640) Tons: 731** [793]	**Changes in Masts and Yards for Ship of 730 tons**	***8th Whelpe* (1640) Tons: 162** [794]	***Warwick* (hypothesized based on Ship Lists) 160 tons**
Main mast	97.2	90	90	85.5	Always present, but gets smaller	71.67	71.67, but maybe slightly larger earlier in century
Main yard	Not recorded	95.67	86.67	82.5	Always present, but gets smaller	48	48, but maybe slightly larger earlier in century
Main topmast	Not recorded	49	45	48	Present	35	35
Main topsail yard	Not recorded	39.08	37.08	41	Present	24	24
Main topgallant mast	Not recorded	None	19.5	24	Did not exist prior 1618, then present after	16.5	None before 1618
Main topgallant yard	Not recorded	None	16	20.63	Did not exist prior 1618, then present after	12	None before 1618

790 Barker 1994, 16, 28.
791 Moore 1912, 270.
792 Moore 1912, 270.
793 Clowes 1931, 11.
794 Clowes 1931, 16, 29, appendix.

Appendix E Table Continued

Mast/yard (all lengths in ft.)	***Bear* (c. 1600)** [790]	***Bear* (pre-1618). Tons: 732.6** [791]	***Bear* (post-1618) Tons: 732.6** [792]	***Rainbow* (c. 1640) Tons: 731** [793]	**Changes in Masts and Yards for Ship of 730 tons**	***8th Whelpe* (1640) Tons: 162** [794]	***Warwick* (hypothesized based on Ship Lists) 160 tons**
Fore mast	Not recorded	84.5	84	74.33	Present, got smaller over time	59.83	59.83, but maybe slightly larger earlier in century
Fore yard	Not recorded	74.66	69.17	66	Present, got smaller over time	39	39, but maybe slightly larger earlier in century
Fore topmast	Not recorded	42	42	40.5	Present	28.5	28.5
Fore topsail yard	Not recorded	31.08	27.25	33	Present	19.5	19.5
Fore topgallant mast	Not recorded	None	21	20.5	Did not exist prior 1618, then present after	13	None before 1618
Fore topgallant yard	Not recorded	None	12.83	16.5	Did not exist prior 1618, then present after	9.75	None before 1618
Bowsprit	Not recorded	84	84	72	Present	50.17	50.17
Spritsail yard	Not recorded	51.25	51.75	48	Present	27	27
Spritsail topmast	Not recorded	None	21	19.5	Did not exist prior 1618, then present after	10.5	None before 1618

Appendix E Table Continued

Mast/yard (all lengths in ft.)	***Bear* (c. 1600)** [790]	***Bear* (pre-1618). Tons: 732.6** [791]	***Bear* (post-1618) Tons: 732.6** [792]	***Rainbow* (c. 1640) Tons: 731** [793]	**Changes in Masts and Yards for Ship of 730 tons**	***8th Whelpe* (1640) Tons: 162** [794]	***Warwick* (hypothesized based on Ship Lists) 160 tons**
Spritsail topsail yard	Not recorded	None	22.42	24	Did not exist prior 1618, then present after	12	None before 1618
Main mizzen mast	Not recorded	67	66	66.33	Present	46.5	46.5
Main mizzen yard	Not recorded	100	69.17	66	Present, got smaller over time	37.5	37.5, but maybe slightly larger earlier in century
Mizzen topmast	Not recorded	Not recorded	30	30	May not have existed prior to 1618	19.5	19.5, but maybe not yet present
Mizzen topsail yard	Not recorded	None	22.42	20.63	Did not exist prior 1618, then present after	12	None before 1618
Crossjack yard (mizzen)	Not recorded	None	51.75	41	Did not exist prior 1618, then present after	24	None before 1618
Bonaventure mizzen mast	Not recorded	58	57	None	Present prior to 1640 list, but disappears in 1640 list	None	Most likely none

Appendix E Table Continued

Mast/yard (all lengths in ft.)	***Bear* (c. 1600)** [790]	***Bear* (pre-1618). Tons: 732.6** [791]	***Bear* (post-1618) Tons: 732.6** [792]	***Rainbow* (c. 1640) Tons: 731** [793]	**Changes in Masts and Yards for Ship of 730 tons**	***8th Whelpe* (1640) Tons: 162** [794]	***Warwick* (hypothesized based on Ship Lists) 160 tons**
Bonaventure mizzen topmast	Not recorded	Not recorded	24	None	Present right after 1618 list, but disappears in 1640 list	None	None
Bonaventure mizzen yard	Not recorded	Not recorded	51.75	None	Present right after 1618 list, but disappears in 1640 list	None	None
Crossjack yard (bonaventure)	Not recorded	None	39	None	Only appears in period between 1618-1640	None	None
Bonaventure mizzen topsail yard	Not recorded	None	16.67	None	Only appears in period between 1618-1640	None	None

APPENDIX F

MASTS, YARDS, & SHROUDS IN ICONOGRAPHY

Appendix F Table of the masts, yards, and shrouds within Chapter 5 iconography as indicated by the number in the top row. An "X" means that the rigging element is present, whereas "*" means it is unclear if the ship had this element. A blank means the element is absent.

	1	2	3	4	5	6	7	8	9	10
Bowsprit	X	X	*	*	*	X	X	X	X	X
Spritsail yard	*	X	*	*		X	X	*	*	
Spritsail topmast	X		*	*	*	X		*		X
Spritsail topsail yard	X		*	*	*	X		*		X[795]
Fore mast	X	X	X	X	X	X	X	X	X	X
Fore yard	X	X	X	X	X	X	X	X	X	X
Fore topmast	X	X	X	X	X	X	X	X	X	X
Fore topsail yard	X	X	X	X	X	X	X	X	X	X
Fore topgallant mast										
Fore topgallant yard										
Main mast	X	X	X	X	X	X	X	X	X	X
Main yard	X	X	X	X	X	X	X	X	X	X
Main topmast	X	X	X	X	X	X	X	X	X	X
Main topsail yard	X	X	X	X	X	X	X	X	X	X
Main topgallant mast					X	X				
Main topgallant yard					X	X				
Mizzen mast	X	X	X	X	X	X	X	X	X	X
Mizzen yard	X	X	X	X	X	X	X	X	X	
Mizzen topmast	X	X	X	X	X	X		X	*	
Mizzen topsail yard	X		X			*			*	
Crossjack yard (mizzen)										
Bonaventure mizzen mast	X			X	X	X				
Bonaventure mizzen yard	X			X	X	X				
Bonaventure mizzen topmast	X									
Bonaventure mizzen topsail yard										
Crossjack yard (bonaventure)										
Shrouds (Fore)	7*	6-9*	5-8*	*	*	8-9*	6-7*	10*	6*	
Shrouds (Fore topmast)	4	3	4	4*	3*	*	1-3*	*	3*	
Shrouds (Main)	7	9-10*	10	7*	6-8*	8-9*	6*	8-10*	7-8*	
Shrouds (Main topmast)	4-5*	4	5	4-5*	*	*	2*	4	*	
Shrouds (Main topgallant)					*	*				
Shrouds (Mizzen)	4	6*	4-5*	5*	*	*	*	5*	3*	
Shrouds (Mizzen topmast)	3	2*	3	4*		*		3		
Shrouds (Bonaventure)	3			2*	*	*				
Shrouds (Bonaventure topmast)	*									
Shrouds (Spritsail topmast)	*					*				
Nationality	Dutch	Spanish	English	Spanish	English	English	Dutch	Spanish	English	Spanish

795 Also has topgallant.

Appendix F Table Continued

	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Bowsprit	X	X	X	X	X	X	X	X	X	X
Spritsail yard	X	X	X	X	*		X	X		X
Spritsail topmast	X		X	X	*			*		
Spritsail topsail yard			X					*		*
Fore mast	X	X	X	X	X	X	X	X	X	X
Fore yard	X	X	X	X	X	X	X	X	X	X
Fore topmast	X	X	X	X	X	X	X	X	X	X
Fore topsail yard	X	X	X	X	X	X	X	X	X	X
Fore topgallant mast										
Fore topgallant yard										
Main mast	X	X	X	X	X	X	X	X	X	X
Main yard	X	X	X	X	X	X	X	X	X	X
Main topmast	X	X	X	X	X	X	X	X	X	X
Main topsail yard	X	X	X	X	X	X	X	X	X	X
Main topgallant mast			X							
Main topgallant yard			X							
Mizzen mast	X	X	X	X	X	X	X	X	X	X
Mizzen yard	X	X	X	X	X	X	X	X	X	X
Mizzen topmast	X	X	X	X	X	X	X	X		*
Mizzen topsail yard	X	X		X	X			X		
Crossjack yard (mizzen)										
Bonaventure mizzen mast			X	X						
Bonaventure mizzen yard			X	X						
Bonaventure mizzen topmast			*	*						
Bonaventure mizzen topsail yard			*	*						
Crossjack yard (bonaventure)										
Shrouds (Fore)	*	*	*	4	6	5	8*	*	6-8*	*
Shrouds (Fore topmast)	*	*	*	2*	2	2*	4*		4*	*
Shrouds (Main)	*	*	*	4*	7	5	8-12*	9-10*	7*	7
Shrouds (Main topmast)	*	*	*	*	3*	3*	6*	3*	5*	*
Shrouds (Main topgallant)			*	*						
Shrouds (Mizzen)	*	*	*	*	3	3	5	*	3*	4
Shrouds (Mizzen topmast)	*	*	*	*			3*	2*		
Shrouds (Bonaventure)			*	*						
Shrouds (Bonaventure topmast)										
Shrouds (Spritsail topmast)	*		*	2*						
Nationality	Dutch	Dutch	Dutch	Dutch	Dutch	Dutch	English	Dutch	Dutch	English

Appendix F Table Continued

	21	22	23	24	25	26	27	28	29	30	31
Bowsprit	X	X	X	X	X	X	X	X	X	X	X
Spritsail yard	X	X	X	X	X	X	X	X	X	X	X
Spritsail topmast	X	X			X	X	X	X			X
Spritsail topsail yard	X	X			X	X	X	X			X
Fore mast	X	X	X	X	X	X	X	X	X	X	X
Fore yard	X	X	X	X	X	X	X	X	X	X	X
Fore topmast	X	X	X	X	X	X	X	X	X	X	X
Fore topsail yard	X	X	X	X	X	X	X	X	X	X	X
Fore topgallant mast											X
Fore topgallant yard											X
Main mast	X	X	X	X	X	X	X	X	X	X	X
Main yard	X	X	X	X	X	X	X	X	X	X	X
Main topmast	X	X	X	X	X	X	X	X	X	X	X
Main topsail yard	X	X	X	X	X	X	X	X	X	X	X
Main topgallant mast		X	X	X							X
Main topgallant yard		X	X	X							X
Mizzen mast	X	X	X	X	X	X	X	X	X	X	X
Mizzen yard	X	X	X	X	X	X	X	X	X	X	X
Mizzen topmast	X	X	X	X	*	X	X	X	X	X	X
Mizzen topsail yard		X			*		*	*	X		X
Crossjack yard (mizzen)											X
Bonaventure mizzen mast								X			
Bonaventure mizzen yard								X			
Bonaventure mizzen topmast								X			
Bonaventure mizzen topsail yard								*			
Crossjack yard (bonaventure)											
Shrouds (Fore)	7	7	8	8	*	*	*	9	5*	*	9
Shrouds (Fore topmast)	3	*	5	5-6*	*	*	*	*	*	*	*
Shrouds (Main)	8	9	8	9	7-8*	*	*	9-10*	5*	4-6*	10
Shrouds (Main topmast)	4	*	6	5	*	*	*	4	*	3*	*
Shrouds (Main topgallant)		5	4	4*	*						3
Shrouds (Mizzen)	4	5	4	6	*	*	*	*	4	3*	6
Shrouds (Mizzen topmast)	3	5	4	4		*	*	*	*	*	3*
Shrouds (Bonaventure)								*			
Shrouds (Bonaventure topmast)								*			
Shrouds (Spritsail topmast)	2*	3			*	*	*	2*			3
Nationality	Dutch	Spanish	Dutch	Dutch	Dutch	Spanish	Dutch	English	Dutch	English	Dutch

APPENDIX G

CONSOLIDATED PRESENCE OF MASTS AND YARDS IN ICONOGRAPHY

Appendix G Table showing the presence of masts and yards based on nationality. *Numbers in parentheses indicate the greatest percentage the element could be present and was done in the case where the presence or absence of the element is obscured in the image and therefore cannot be confirmed. The percentage was calculated by adding the confirmed presence of elements with the asterisked elements in Appendix F, therefore showing the greatest number possible in these unconfirmed cases. It is very possible that not all of these elements exist in the cases where presence is unclear. In most cases the true percentage likely lies somewhere between the percentage without parentheses and those in parentheses.

	Presence on Dutch-rigged (divide by 17)	Presence on English-rigged (divide by 8)	Presence on Spanish-rigged (divide by 6)	Total % Present (regardless of nationality, Divide by 31)	**Presence on *Warwick***
Bowsprit	100%	100%	100%	100%	Yes
Spritsail yard	88%	88%	83%	87%	Yes
Spritsail topmast	47% (*59%)	25% (*50%)	50% (83%)	42% (61%)	Maybe, but slightly lower chance
Spritsail topsail yard	35% (41%)	25% (63%)	50% (83%)	35% (55%)	Maybe, but slightly lower chance
Fore mast	100%	100%	100%	100%	Yes
Fore yard	100%	100%	100%	100%	Yes
Fore topmast	100%	100%	100%	100%	Yes
Fore topsail yard	100%	100%	100%	100%	Yes
Fore topgallant mast	6%	0%	0%	3%	No
Fore topgallant yard	6%	0%	0%	3%	No
Main mast	100%	100%	100%	100%	Yes
Main yard	100%	100%	100%	100%	Yes
Main topmast	100%	100%	100%	100%	Yes
Main topsail yard	100%	100%	100%	100%	Yes
Main topgallant mast	24%	25%	17%	23%	No
Main topgallant yard	24%	25%	17%	23%	No
Mizzen mast	100%	100%	100%	100%	Yes
Mizzen yard	100%	100%	83%	97%	Yes

Appendix G Table Continued

	Presence on Dutch-rigged (divide by 17)	Presence on English-rigged (divide by 8)	Presence on Spanish-rigged (divide by 6)	Total % Present (regardless of nationality, Divide by 31)	**Presence on *Warwick***
Mizzen topmast	82% (88%)	75% (100%)	83%	80% (90%)	Yes
Mizzen topsail yard	47% (59%)	13% (50%)	17%	32% (48%)	Probably yes, but rarely fitted
Crossjack yard (mizzen)	6%	0%	0%	3%	No
Bonaventure mizzen mast	18%	38%	17%	23%	No
Bonaventure mizzen yard	18%	38%	17%	23%	No
Bonaventure mizzen topmast	5% (18%)	13%	0%	6% (13%)	No
Bonaventure mizzen topsail yard	(12%*)	(13%*)	0%	(10%*)	No
Crossjack yard (bonaventure)	0%	0%	0%	0%	No

Number of shrouds based on iconography. Number of shrouds is calculated by first averaging the numbers in Appendix F to find the mean (Ranges where exact number of shrouds were unclear were entered as the mean of the two numbers, i.e. 7-9 shrouds was entered as 8 shrouds per side). The mean, median, maximum number, and minimum number of shrouds for each element were calculated. In all cases the mean and median were very similar, allowing the most likely number of shrouds to be calculated.

	Shrouds per side (Fore Mast)	**Shrouds per side (Fore Topmast)**	**Shrouds per side (Main Mast)**	**Shrouds per side (Main Topmast)**	**Shrouds per side (Main Topgallant)**	**Shrouds per side (Mizzen)**	**Shrouds per side (Mizzen Topmast)**	**Shrouds per side (Spritsail topmast)**
Mean	7.1	3.4	7.6	4.1	4	4.3	3.2	2.4
Median	7	3	7.5	4	4	4	3	2
Maximum	10	5.5	10	6	5	6	5	3
Minimum	4	2	4	2	3	3	2	2
Iconography Suggests	**7**	**3**	**8**	**4**	**4**	**4**	**3**	**2**

APPENDIX H

WARWICK'S MASTS AND YARDS

Appendix H Table of *Warwick's* Final Mast and Yard Dimensions

	Presence on *Warwick* based on Treatises	**Presence on *Warwick* based on Ship Lists**	**Presence on *Warwick* based on Iconography**	**Analysis**	**Verdict**
Bowsprit	Length is between 44.10 to 57.6 ft. Diameter is 14.7 to 19.2 in.	50.17 ft.	Yes	Same as foremast	Length: 50 ft. Diameter: 17 in.
Spritsail yard	Length is between 34.14 to 50 ft. Diameter is 5.7 to 8 in.	27 ft.	Yes		Length: 27 ft. Diameter: 5 in.
Spritsail topmast	*Warwick* most likely did not have.	None before 1618	Maybe, but slightly lower chance (not included here)		None
Spritsail topsail yard	*Warwick* most likely did not have.	None before 1618	Maybe, but slightly lower chance (not included here)		None
Fore mast	Length is between 44.1 to 57.6 ft. Diameter is 14.7 to 19.2 in..	59.83 ft., but maybe slightly larger earlier in century	Yes	4/5 or 6/7 to main mast. Average, then round up nearest whole number	Length: 50 ft. Diameter: 17 in.
Fore yard	Length is between 45.53 to 57 ft. Assumed diameter is between 11.4 to 17 in.	39 ft., but maybe slightly larger earlier in century	Yes	Averaged 3/4 and 4/5 of main yard	Length: 39 ft. Diameter: 10 in.
Fore topmast	Length is between 22.05 to 28.8 ft. Diameter is 7.35 to 9.6 in.	28.5 ft.	Yes	Half of fore mast	Length: 25 ft. Diameter: 9 in.

Appendix H Table Continued

	Presence on *Warwick* based on Treatises	Presence on *Warwick* based on Ship Lists	Presence on *Warwick* based on Iconography	Analysis	Verdict
Fore topsail yard	Length between 21.56 to 28.5 ft. Diameter between 5.39 to 7.5 in.	19.5 ft.	Yes	About half of fore yard	Length: 19 ft. Diameter: 5 in.
Fore topgallant mast	*Warwick* most likely did not have.	None before 1618	No		None
Fore topgallant yard	*Warwick* most likely did not have.	None before 1618	No		None
Main mast	Length is between 55.2 to 67.16 ft. Diameter is 18.4 to 22.4 in.	71.67 ft., but maybe slightly larger earlier in century	Yes	Base on this and treatises. Made it 60 because ship list says earlier might be larger	Length: 61 ft. Diameter: 21 in.
Main yard	Length is between 60.71 to 63 ft. Diameter is between 15.2 to 17 in.	48 ft., but maybe slightly larger earlier in century	Yes	Probably around 60, given that ship lists mention these may be slightly larger, and treatises range is not large	Length: 48 ft. Diameter: 12 in.
Main topmast	Length is between 27.6 ft to 33.6 ft. Diameter is 9.2 to 11.2 in.	35 ft.	Yes	Half of main mast	Length: 30 ft. Diameter: 10 in.
Main topsail yard	Length: 26.95 ft. Diameter: 6.74 in.	24 ft.	Yes	3/7 of main yard	Length: 24 ft. Diameter: 6 in.
Main topgallant mast	*Warwick* most likely did not have during first quarter of 17th century.	None before 1618	No		None
Main topgallant yard	Length: 13.48 ft. Diameter: 3.37 in.	None before 1618	No		None
Mizzen mast	Length is about 27.6 ft. Diameter is between 9.2 in.	46.5 ft.	Yes	Half of main mast	Length: 30 ft. Diameter: 11 in.

Appendix H Table Continued

	Presence on *Warwick* based on Treatises	Presence on *Warwick* based on Ship Lists	Presence on *Warwick* based on Iconography	Analysis	Verdict
Mizzen yard	Length is between 30 (if dimensions are same as Mizzen mast above) to 45.53 ft. Diameter is approximately between 5 to 7.6 in.	37.5 ft., but maybe slightly larger earlier in century	Yes	Length of fore yard	Length: 30 ft. Diameter: 5 in.
Mizzen topmast	Equally plausible *Warwick* had it, or did not according to treatises. If it did, it would approximately have a length: 13.78 ft. Diameter: 4.6 in.	19.5 ft., but maybe not yet present	Yes	Half length of mizzen mast	Length: 15 ft. Diameter: 6 in.
Mizzen topsail yard	If mizzen topmast and crossjack yard existed, it is possible it was often not fitted with the mizzen topsail yard especially in the first quarter of the century.	None before 1618	Maybe, possible it is rarely fitted, hence not seen as often?		None
Crossjack yard (mizzen)	Equally plausible *Warwick* had it, or did not according to treatises. If it did, it would approximately have a length between 34.14 to 50 ft. Diameter is 8.5 to 12.5 in.	None before 1618	No		None

Appendix H Table Continued

	Presence on *Warwick* based on Treatises	**Presence on *Warwick* based on Ship Lists**	**Presence on *Warwick* based on Iconography**	**Analysis**	**Verdict**
Bonaventure mizzen mast	Most likely none on *Warwick*.	None	No		None
Bonaventure mizzen yard	None	None	No		None
Bonaventure mizzen topmast	None	None	No		None
Bonaventure mizzen topsail yard	None	None	No		None
Crossjack yard (bonaventure)	None	None	No		None

APPENDIX I

SAILS FROM SHIP LISTS

The sail dimensions from *8th Whelpe* within *The Lengths of Masts and Yards* and their calculated areas (Clowes 1931, 16, 29).

Main Course		Main bonnet		Fore course		Fore bonnet		Main topsail		Main topgallant sail		Fore topsail		Fore topgallant sail		Spritsail (1) course (2) bonnet (3) topsail		Mizzen (1) course (2) bonnet (3) topsail	
Clothes double	Yards Deep	Clothes double	Yards Deep	Clothes double	Yards Deep	Clothes double	Yards Deep	Clothes square	Yards Deep	Clothes square	Yards Deep	Clothes square	Yards Deep	Clothes square	Yards Deep	Clothes square	Yards Deep	Clothes square	Yards Deep
22	11.5	22	2.75	17	10.25	17	2.25	15.5	11.25	6	5.25	12.5	9.25	5	4.25	12	5.5	6.5	10.5
																0	0	15	1.5
																7	5.5	6	6.25

Main Mast		Fore Mast		Main Topmast		Main Topgallant Mast		Fore Topsail Mast		Fore Topgallant Mast		Bowsprit		Mizzen Mast		Mizzen Topmast	
Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards
71.67	24	59.83	19.943	35	11.667	16.5	5.5	28.5	9.5	13	4.3	50.17	16.723	46.5	15.5	19.5	6.5

Main Yard		Fore Yard		Main Topsail Yard		Main Topgallant Yard		Fore Topsail Yard		Fore Topgallant Yard		Spritsail Yard		Mizzen Yard		Mizzen Topmast Yard	
Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards	Feet	Yards
48	16	39	13	24	8	12	4	19.5	6.5	9.75	3.25	27	9	37.5	12.5	12	4

Main Course		Fore Course		Main Topsail		Main Topgallant Sail		Fore Topsail		Fore Topgallant Sail		Spritsail		Mizzen Course		Mizzen Topmast	
Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
11.5	11	10.25	8.5	11.25	15.5	5.25	6	9.25	12.5	4.25	5	5.5	12	10.5	6.5	6.25	6

Main Bonnet		Fore Bonnet		Spritsail Bonnet		Mizzen Bonnet	
Length	Width	Length	Width	Length	Width	Length	Width
2.75	11	2.3	8.5	0	0	1.5	15

Main Course Total Area (Including Bonnet)	Fore Course Total Area (Including Bonnet)	Main Topsail Total Area	Main Topgallant Total Area	Fore Topsail Total Area	Fore Topgallant Mast Total Area	Spritsail Total Area (Including Bonnet)	Mizzen Course Total Area (Including Bonnet)	Mizzen Topmast Total Area	Spritsail Topsail Total Area
156.75	106.68	174.375	31.5	115.625	21.25	66	90.75	37.5	38.5

Head sail areas	After Sail Area
348.055	490.875