Ana Crespo Solana
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Heritage and the Sea

Volume 2: Maritime History and Archaeology of the Global Iberian World (15th-18th centuries)

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Preface

At the core of this book, a collection of chapters from a diverse range of authors, is a desire to draw on a wide array of perspectives and disciplinary approaches to renew our understanding and appreciation of Iberian maritime heritage of the Early Modern Period. Its catalyst is the ForSEAdiscovery Project – a multi-disciplinary endeavour which brought together established and emerging researchers to investigate Iberian shipbuilding and particularly its relationship to forests and timber supply through the lenses of archaeology, history and earth sciences. Many of the chapters draw directly on the project's research results. Other chapters come from collaborations and research associations beyond and encouraged by ForSEAdiscovery.

Our hope is that this collection will be of interest to scientists, academics and students of history and archaeology in the broadest sense, but also accessible to a broad audience seeking a current overview of research into the phenomenon of Iberian seafaring during a period of technological and social transformation. A period in which European horizons expanded to encompass global dimensions through maritime enterprise. Our ambition has been to seek and present new insights and research directions particularly through multi-disciplinary collaboration.

We owe a debt of gratitude to a wider research community than solely the contributors to this collection. To our ForSEAdiscovery family: Aoife Daly, Ute Sass-Klaassen, Jan Willem Veluwenkamp, Ignacio García González, Tomasz Wazny, Garry Momber, Christin Heamagi, Brandon Mason, and so many other members of the ForSEAdiscovery consortium, colleagues and friends who accompanied us in this incessant search for answers in the forest and in the sea of the history of the Iberian empires.

We dedicate this book to our beloved Fadi, lost to us too young, always in our hearts.

Madrid, Spain — Ana Crespo Solana
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Chapter 1
Dendroarchaeology of Shipwrecks in the Iberian Peninsula: 10 Years of Research and Advances

Marta Domínguez-Delmás, Sara A. Rich, and Nigel Nayling

Abstract In the Iberian Peninsula, tree-ring research on shipwrecks started in the 2000s by the authors with the aims of identifying shipwrecks as Atlantic–Iberian-built vessels, studying the organization of timber supply, and refining our understanding of the development of shipbuilding along the Iberian–Atlantic coast during the Early Modern Period. This article compiles the results and observations gathered in the period 2009–2019 through dendrochronological analysis of 23 shipwreck assemblages found in the Iberian Peninsula and elsewhere. Only three of these shipwrecks (*Triunfante*, *Magdalena*, and *Bayonnaise*) had been previously identified and had a known ship history, including date and location of construction. The rest (Barceloneta I, Newport, Ribadeo, San Sebastián, Matagrana, Punta Restelos, Arade 1, Ria de Aveiro F and G, Barreiros, Belinho 1, Delta I, II, and III, Cee 1 and 2, Yarmouth Roads, Emmanuel Point II and III, and Highbourne Cay) had less precise dating based on historical information, construction features, archaeological context/artifacts, and/or radiocarbon dates. Our results demonstrate an almost-exclusive use of deciduous oak (*Quercus* subg. *Quercus*) in structural hull elements until the mid-eighteenth century and suggest a transition from differentiated selection of trees based on growth rates in the fifteenth century toward an indifferent selection in subsequent centuries due to technological advances. Our findings are discussed in the context of shipbuilding and seafaring in the Early Modern Period.

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1 Introduction

Dendrochronology is widely used in the North of Europe to establish the date and provenance of timbers from ship finds subjected to archaeological study. The development of extensive reference tree-ring datasets of different species in most of Europe often allows the successful dating of timber structures, including ship assemblages from Roman times (Čufar et al. 2014; Jansma et al. 2014), the Viking era (Bonde and Crumlin-Pedersen 1990; Crumlin-Pedersen and Olsen 2002; Nordeide et al. 2020), as well as from the Late Medieval, Early Modern, and Modern Period (Daly 2007; Daly and Nymoen 2008; Dobbs and Bridge 2009; Domínguez-Delmás et al. 2013; Haneca and Daly 2014; Nayling and Susperregi 2014; Läänelaid et al. 2019; Lorentzen et al. 2020). Dendrochronological research on shipwrecks and maritime sites in the Americas has also taken off in recent years (Martin-Benito et al. 2014; Creasman et al. 2015). Once the date is established, further inferences can be made about the construction period of the ship and the timber supply area, and woodworking techniques and forest management practices can be placed in an exact chronological period (Rich et al. 2018a; Domínguez-Delmás et al. 2019). In the Iberian Peninsula, tree-ring research on shipwrecks has taken great strides in the past 10 years. This chapter presents the observations and results obtained through dendrochronological research of timbers from shipwrecks found in the Iberian Peninsula, as well as Iberian shipwrecks found elsewhere (the Mediterranean and the Caribbean), predominantly in the period of 2009–2019. These shipwrecks were researched to find out whether they were built in the Iberian Peninsula and, if so, to refine our understanding of the development of shipbuilding along the Iberian–Atlantic coast during the Early Modern Period. Specific objectives were gaining knowledge about (i) their chronology, (ii) the provenance of the wood, and (iii) the procurement of timber for shipbuilding (selection of species and growth rates for particular elements in the ship). In the following, we compile the results of this research, presenting the results of each individual shipwreck, and make inferences, when possible, about the organization of the wood supply.[1] We then reflect on the lessons learned in these 10 years and discuss the results in the context of shipbuilding and seafaring in the Early Modern Period.

[1] Given the length of this chapter, we decided to present a synthesis of dendrochronological results of each shipwreck, and refer the interested reader for detailed results (e.g., graphs and statistics of internal cross-matches between samples of the same shipwreck) to the reports that have been uploaded into Zenodo or other repositories, where they are openly available.

2 Background to Dendroarchaeology of Shipwrecks in the Iberian Peninsula

In the Iberian Peninsula, dendroarchaeological studies started in the 1980s with the research of timbers from historic buildings (Richter and Eckstein 1986). Until the first decade of the twenty-first century, investigations were mostly restricted to the study of historic buildings in the northeast, center, and south of Spain (Domínguez-Delmás et al. 2015 and references therein). To initiate tree-ring studies on cultural heritage outside these regions, the project *Filling in the blanks in European dendrochronology: building a multidisciplinary research network to assess Iberian wooden cultural heritage worldwide* (also known as Iberian Heritage Project, henceforth IHP) was launched in 2009. A network of foresters, historians, nautical archaeologists, and dendrochronologists was assembled to identify old-growth forests, historic buildings with timber-framed roofs, art pieces, and shipwreck assemblages in Spain and Portugal that could be subjected to dendrochronological research (Domínguez-Delmás 2015). Through this network, the opportunity arose to examine and sample diverse groups of timbers from archaeological structures and shipwrecks at the Catalonian Centre for Underwater Archaeology (CASC) in Girona (Spain), at the Centre of Underwater Archaeology (CAS) in Cadiz (Spain), and at the former *Divisão de Arqueologia Náutica e Subaquática, Instituto de Gestão do PatrimónioArquitectónico e Arqueológico* (DANS/IGESPAR) in Lisbon (Portugal). The assemblages studied at those underwater archaeology centres between 2009 and 2011 became, together with the Newport Medieval Ship (excavated in Wales between 2002 and 2003 and identified as a Basque Country-built merchant vessel; (Nayling and Jones 2014), the first Iberian ships/wrecks being subjected to dendrochronological inquiry.

Part of the network built during the IHP subsequently launched the ForSEAdiscovery project (*Forest Resources for Iberian Empires: Ecology and Globalization in the Age of Discovery*; henceforth FSD), which ran from 2014 to 2018. This project recruited 18 fellows as researchers, who were divided into three work packages (History, Nautical archaeology, and Wood provenancing) to examine the timber supply for Iberian Empires during the Early Modern Period (Nayling and Crespo Solana 2016; Crespo Solana et al. 2018; Crespo Solana 2019). Within the FSD, we targeted Iberian shipwrecks along Atlantic–Iberian coasts, the south of England and the Caribbean, aiming to determine their exact chronology and to understand the organization of the timber supply for shipbuilding (including the selection of trees (old/young, fast/slow-grown) and species for different timber elements, forest management practices to increase timber production, timber imports, etc.).

3 Sampling Strategy and Dendrochronological Methods

Between 2009 and 2019, a total of 23 shipwrecks were inspected and sampled for dendrochronological research (Fig. 1.1; Table 1.1). In addition to these wrecks, the Newport Ship has been included in this chapter to contribute to the discussion of fifteenth-century ships. The identifications of the *Triunfante*, *Magdalena*, and *Bayonnaise* were known and well documented. The former two were both built in the Spanish royal shipyard of Esteiro (Ferrol, NW Spain) and launched in 1756 and 1773, respectively. The *Bayonnaise* was a French corvette built in Bayonne (W France) in 1794. The rest of the shipwrecks targeted have been relatively dated to different times of the Early Modern Period (fifteenth to eighteenth centuries) based on historical information, construction features, archaeological context, and/or radiocarbon dating.

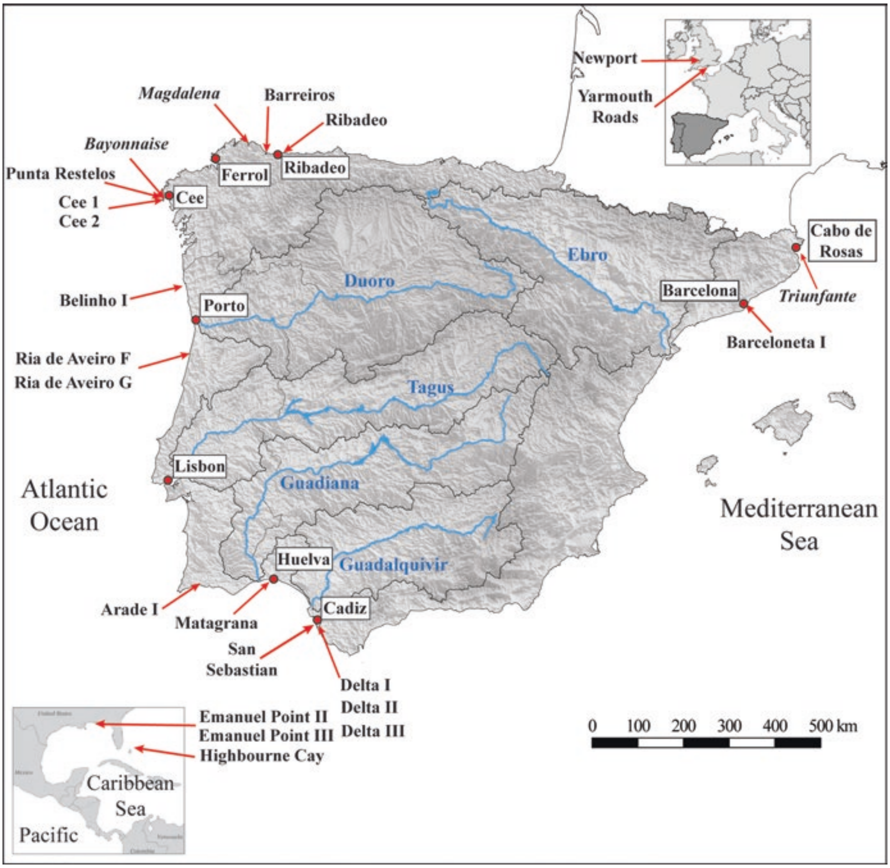

Fig. 1.1 Shipwrecks studied in the period 2009–2019 within the IHP and the FSD projects, plus the Newport Ship, indicating the location where they were found. Some cities and geographical features are indicated for additional geographical reference

Table 1.1 Number of samples collected on each shipwreck, presented with their corresponding identification of wood species when known

Shipwreck	Chronology	*Quercus* subg. *Quercus*	*Pinus sylvestris/ nigra*	*Picea abies/ Larix decidua*	*Abies alba*	Conifer	*Fagus sylvatica*	*Castanea sativa*	Tropical	Others	Total
Barceloneta I	c. 1410?	14									14
Newport	c.1450	110					1				111
Barreiros	Fifteenth century?	4								1	5
Ría de Aveiro G	Fifteenth century?	2									2
Ría de Aveiro F	Fifteenth–eighteenth century	1						1	9		11
Highbourne cay	c. 1520	16									16
Emanuel point II	c. 1550s	31									31
Emanuel point III	c. 1550s	4									4
Yarmouth roads	Mid-sixteenth century	17									17
Belinho 1	16th–eighteenth century?	12				2			1		15
Delta II	Mid-sixteenth century	35				3	2		4	5	49
Arade 1	c. 1583	24						2			26
Punta Restelos	c. 1590s	7									7
Ribadeo	c. 1590s	36	2	3	2	1	1	2		1	48
Delta I	Seventeenth century	22	3				1				26
Delta III	Seventeenth century	6	1				2				9
Matagrana	17th–eighteenth century	2									2
Triunfante	1754/56		6								6
Magdalena	1778	17	4			1					22
San Sebastian	Eighteenth century?	2									2
Bayonnaise	Eighteenth century	10									10
Cee 1	Late nineteenth century	5				1					6
Cee 2	?	3									3
		380	16	3	2	8	7	5	14	7	442

Some of those samples were collected for wood identification only, or to have an idea of the growth rate of the tree furnishing the timber. Therefore, the total number does not represent the number of samples selected for dendrochronological research

Given the objectives of the research, which included the characterization of trees used during the Early Modern Period for shipbuilding, the sampling strategy avoided bias toward timbers suitable for dendrochronological dating (i.e., containing more than 80 tree rings). Therefore, samples with as little as 15–30 rings were also selected for tree-ring analysis in order to acquire growth rates of the trees used for specific elements of the ship. For some shipwrecks (*Triunfante*, Ribadeo, Yarmouth Roads, and *Bayonnaise*) preliminary wood identification and ring counts were carried out under water directly on some of the timbers (Fig. 1.2a, b) to have an estimation of tree species used and tree ages without having to saw off samples from all the timbers.

The collection of samples was carried out under different circumstances and followed, when possible, the methods now detailed in Rich et al. (2018b) and Domínguez-Delmás et al. (2019). Most of the shipwrecks were sampled underwater (*Triunfante*, Ribadeo, San Sebastián, Delta shipwrecks, Yarmouth Roads, *Magdalena*, Cee shipwrecks, *Bayonnaise*, Highbourne Cay, and Emanuel Point), whereas the Matagrana and Barreiros were sampled in an intertidal zone. Waterlogged timbers from the Newport Ship, Arade 1, Ría de Aveiro F and G, and Belinho 1 shipwrecks were sampled on land at different conservation facilities, before undergoing conservation treatment (Fig. 1.2c). In all these cases, samples for dendrochronological research (cross-sections) were removed with a handsaw from the selected structural timbers, as well as from some cargo elements (in the cases of the Ribadeo and the Delta II) (Fig. 1.2d, e). Additionally, fragments of some timbers were also collected for wood identification and to establish whether those timbers may contain enough tree rings for following up dendrochronological research.

In the case of Barceloneta I, sampling was constrained by the fact that the wreck was going to be reassembled and displayed at the Barcelona History Museum after conservation treatment with polyethylene glycol (PEG). Therefore, sampling of timbers by sawing a cross-section was restricted to the fragments of hull planks broken when the backhoe unearthed the wreck. In two of the frames, tree-ring patterns in the notches carved to accommodate the futtocks were photographed (Fig. 1.2f, g). In this way, photographing the surface of several notches after cleaning them with razor blades and applying chalk to enhance visualization of tree rings, it was possible to register the tree-ring patterns from the pith to the outermost rings, which corresponded to the waney edge, representing the cutting year of the tree. Tree rings were also photographed on one hull plank, as the edge was quite smooth and it was possible to clean it with razor blades. Similarly, the barrel staves from the cargo of the Delta II shipwrecks were cleaned with razor blades and analyzed by means of digital photographs.

To analyze the tree rings in the sawn samples, the transverse surface of the wood was cleaned with razor blades from the inner- to the outermost ring. The presence/absence of pith and sapwood was also recorded. This manner of inspection served to identify some species that show distinct anatomical features in the transverse section, which make them distinguishable by the naked eye. Such identification is possible, for instance, for deciduous oaks (*Quercus* subg. *Quercus*), which show large earlywood vessels placed in a ring-porous disposition and large multiseriate

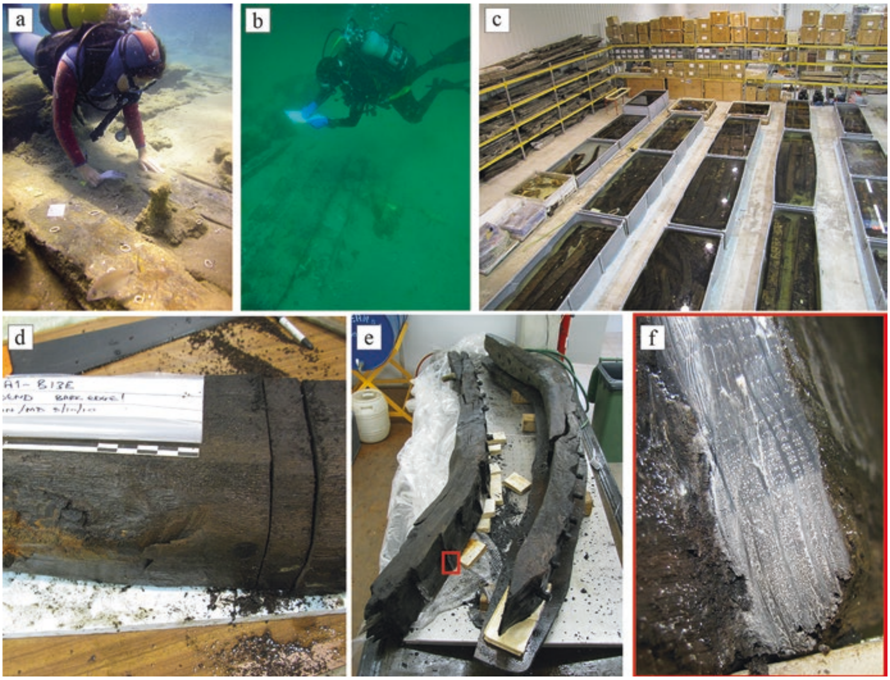

Fig. 1.2 Inspection and sampling of shipwrecks (**a**) examining *Triunfante* timbers to determine the species as oak or conifers. (Source photo: CASC archive), (**b**) underwater registration of Ribadeo timbers prior to sampling. (Photo: R. González Gallero), (**c**) facilities of the IGESPAR in Lisbon where several shipwrecks were inspected and sampled, (**d**) framing timber of the Arade 1 sawn where complete sapwood was present, (**e** and **f**) joggle on framing timbers of Barceloneta shipwreck where tree rings were recorded after cleaning with razor blades and applying chalk powder to enhance the visibility of the tree rings. (Photos **c**–**f**: M. Domínguez-Delmás)

medullary rays; chestnut (*Castanea sativa*), which is very similar to the group of deciduous oaks but lacks the multiseriate medullary rays; beech, ash, etc. (see Schweingruber 1990 for a detailed description of the wood anatomy of those species). The identification of species that cannot be distinguished by the naked eye was done by cutting cube-shaped subsamples of approximately 1 cm^3. Then, thin slices were manually cut with razor blades from the transverse, radial, and tangential sections of the subsamples, in order to observe the micro-characteristics of the wood anatomy of each sample (see http://www.woodanatomy.ch/micro.html Schoch et al. 2004). Transmitted-light microscopes (Zeiss Axioscope40 or Olympus BX40) coupled with a digital camera (Zeiss AxioCam MRc5) were used to visualize and photograph the key anatomical features of each sample. Identifications were made using the keys proposed by Schweingruber (1990), García Esteban et al. (2003), or, in the case of tropical woods, the following online resources: Wood Anatomy of European Species (http://www.woodanatomy.ch/micro.html Schoch et al. 2004) and the Inside Wood database (http://insidewood.lib.ncsu.edu/search Wheeler 2011).

Tree rings were measured in selected samples with a TimeTable measuring device (University of Vienna) coupled with PAST4 software v.4.3.1025 (SCIEM). When samples could not be taken and the research was done through photography, tree rings were photographed with a macro lens using a Sony compact camera on macro mode, and ring widths were measured on screen with CooRecorder (Cybis). The photographs included a ruler to allow the calibration of the measurements. Therefore, the obtained ring widths represent absolute values.

Crossdating between the samples and with reference chronologies was also done with PAST4. To identify potential dates, Student's *t*-values were considered after modifying the data according to Baillie and Pilcher (1973), in combination with the percentage of parallel variation (%PV) (Eckstein and Bauch 1969) and its associated significance (*p*).

4 The Shipwrecks: History, Archaeology, and Results of Dendrochronological Research

The ship finds are presented in approximately chronological order (date of construction) based on a combination of historical and archaeological information including, where relevant, scientific dating by radiocarbon and/or dendrochronology.

4.1 Barceloneta I

The Barceloneta I shipwreck was found in 2008 during development works in the eponymous coastal district of Barcelona (Spain) (Fig. 1.4a). It represents the first archaeological discovery of a clinker-built ship on the Spanish Mediterranean coast. Considering the radiocarbon dates (calibrated at two sigma) of 1310–1440 obtained for the moss found in the ship's hull, the radiocarbon date of 1395 cal CE (maximum probability) obtained for the sediments underlying the wreck, and the *ante quem* date of 1439, when the construction of a harbour dock favoured the intrusion of sand that covered the shipwreck, a possible construction date around the 1410s seems plausible (Soberón et al. 2012, p. 419).

The dismantled shipwreck was transported to the CASC, where Marta Domínguez-Delmás carried out the inspection and sampling. A total of 14 timbers were inspected and identified as deciduous oak (*Quercus* subg. *Quercus*) (Table 1.2). Cross-sections were sawn from nine plank fragments that had been damaged during the excavation on the development site. Five other elements (one hull plank, three frames, and a beam/wale) were photographed on the transverse surface after cleaning with razor blades and applying chalk.

Results showed that the hull planks had been converted radially from the parent trees' trunks, and the samples contained between 85 and 168 tree rings (Domínguez-Delmás 2009). They all lacked pith and sapwood. In contrast, framing timbers had

Table 1.2 Results of dendrochronological research of the Barceloneta I shipwreck

Sample code	Timber element	Dendro code	N	Pith	SR	Bark edge	MRW (mm)	σ (mm)
BM-T5A	Hull plank	SBS00011 SBS00012	75 69	– –	0 0	–	1.24	0.37
BM-TSN-E	Hull plank	SBS00020	100	–	0	–	1.03	0.42
BM-TSN-H	Hull plank	SBS00030	88	–	0	–	1.12	0.32
BM-TSN-I	Hull plank	SBS00040	112	–	0	–	1.30	0.37
BM-TSN-K	Hull plank	SBS00050	93	–	0	–	1.06	0.23
BM-TSN-L	Hull plank	SBS00060	166	–	0	–	0.68	0.36
BM-TSN-M	Hull plank	SBS00070	124	–	0	–	1.79	0.76
BM-TSN-N	Hull plank	SBS00080	95	–	0	–	1.24	0.36
BM-TSN-O	Hull plank	SBS00090	85	–	0	–	1.18	0.36
BM-T10A	Hull plank	SBS00100	168	–	0	–	1.31	0.37
BM-PL	Beam/Wale?	SBS00110	37	+	7	3 ± 2	4.25	1.51
BM-Q9	Framing	SBS00120	69	+	22	3 ± 2	5.55	3.01
BM-Q10A	Framing	SBS00130	64	+	25	2 ± 1	3.67	2.57
BM-Q11	Framing	–	29	+	12	LW		

All samples were oak (*Quercus* subg. *Quercus*); N: number of rings; Pith: present (+)/absent (−); SR: sapwood rings; Bark edge: absent (−), estimated number of rings till bark edge (n ± n), latewood present in last ring (LW); MRW: mean ring width; σ: standard deviation

pith and sapwood, even bark edge, allowing an estimation of the age of the trees at around 30 years (BM-Q11, which showed a regular growth pattern) and 80 years (BM-Q9 and BM0Q10A, which showed severe growth reductions). Although there is an important difference in the age of the trees used for framing timbers, their dimensions are very similar, which indicates that the trees were selected based on diameter and shape. This implies that there was a differentiated selection of trees for hull planks (slow-grown, straight-grained oaks) and for framing timbers (fast-grown trees with appropriate curvature; Fig. 1.1e).

Internal crossdating revealed that some samples from hull planks corresponded to the same element, allowing us to refit pieces that broke during the excavation (Domínguez-Delmás 2009). Furthermore, good matches were also found between two sets of hull planks and between two frames, suggesting that the wood originates from the same forest. Attempts at cross-matching these series with reference chronologies and other contemporary shipwrecks have yet to be successful.

4.2 Newport Ship

This clinker-built ship was excavated in the midst of development in this Welsh port in 2002–2003 (Nayling and Jones 2014). Tree-ring dating of a timber structure (constructed from local timber), onto which the ship had been maneuvered, provides a *terminus post quem* for the ship's arrival during spring of 1468 CE. Thousands of individual timbers were recovered for detailed documentation. The recovered

Table 1.3 Summary of Newport Ship timbers by major type

Timber type	Number	Ring count	Dendrochronology samples
Keel	1	0	1
Planks	820 (373)	440	50
Framing	524 (211)	123	32
Fillers	56	34	6
Ceiling	181	51	2
Chock/buttress	22	0	1
Bilge boards	72	41	6
Repairs/refits			
Riders	4	1	2
F10 block	1	0	1
Tingles	18	18	10
Total	939	708	111

Number of recovered pieces (number of discrete timbers in brackets), number for which ring counts and/or average ring widths collected, and number of dendrochronology samples analyzed

timbers were, where possible, assessed for species, annual ring counts, and mean ring widths by Nigel Nayling (Table 1.3). These data were collected to inform our understanding of timber selection and usage in the ship's construction and subsequent repair and alteration as well as informing a sampling strategy for full dendrochronological analysis. Tree-ring dating of a well-replicated oak ring-width mean for the clinker planking of the ship against Basque oak ring-width chronologies provided a precise date for the ship's construction (1449++CE) and provenance (Nayling and Susperregi 2014). In addition to the article publication or the dendrochronological dating of the ship's hull planks, further details are provided in a specialist report and datasets are available in the Archaeology Data Service (Nayling 2013; Nayling and Jones 2017).

The planks were normally radially split from straight-grained trees with minimal knotting. In some cases, trimmed side branches, encapsulated by later tree growth indicate forestry management (Fig. 1.3). Occasional planks exhibited the normally straight grain curving away from the long axis of the plank at one end, suggesting proximity of the crown or root of the parent tree. The age of the parent trees when felled cannot be determined with total confidence due to secondary working after initial splitting of the timber, removing the feather edge in the vicinity of the pith and the bark and some, if not all, of the sapwood from the outer edge. The majority of planks were converted from parent trees more than 100 years old, with many retaining over 140 annual rings. Marked growth trends, with a distinct transition from relatively fast growth (wide rings) to relatively slow growth (narrow rings), were common, suggesting many parent trees had begun growth in relatively open conditions before coming into competition with neighboring trees in an increasingly closed woodland environment (Nayling and Jones 2014, pp. 249–252). The data on age and growth rates are presented graphically in the Discussion (Fig. 1.5) based on a combination of ring counts and dendrochronological analysis of 339 of the 373

Fig. 1.3 Inboard face of Newport Ship hull plank 766 showing pruned side branch encapsulated in later tree growth. A rare example of direct proof of woodland management. (Photo Newport Museum and Heritage Service)

planks recovered. Care needs to be taken in interpreting scatter plots of this type of data. The samples with relatively fast growth rates and low ring counts usually reflect secondary working where radial splits have been cross-split to provide two or more planks from a single radius. Something of the organization of construction is hinted at by the identification of planks from common parent trees (through use of correlation statistics and close visual matching of growth patterns) in three pairs of planks and a further two groups of three planks. As in the case of the Barreiros wreck (below), cross-matching of tree-ring sequences from disturbed portside planking (fifth and tenth strakes) allowed this detached section to be rejoined to the main, coherent section of hull (Nayling and Susperregi 2014, p. 282).

Analysis of 128 framing timbers (floors and futtocks) indicates exclusive use of oak, carefully converted from trees (often consisting of the main stem and a large side branch in the case of floors) with natural curvature closely matching the hull curvature. Ring counts and growth rates were highly variable ranging from 40 to 157 rings (average 58 years) and 1.1 to 7.6 mm/yr (average 2.9), respectively. Eighty-one percent of these timbers retained at least partial sapwood with 16% having surviving bark (waney) edge. As ever, translating these data into parent tree figures is not straightforward. Even where the pith of the tree is present and there is complete sapwood, many of these samples probably come from branches of lower

Fig. 1.4 Some of the shipwrecks researched between 2009 and 2019 (**a**) Barceloneta. (Photo courtesy of Mikel Soberon, CODEX Arqueologia i Patrimoni), (**b**) Barreiros shipwreck at its most exposed. (Photo courtesy of Luis Ángel García), (**c**) Matagrana shipwreck. (Photo IAPH archive), (**d**) close view of *Triunfante*. (Photo CASC archive)

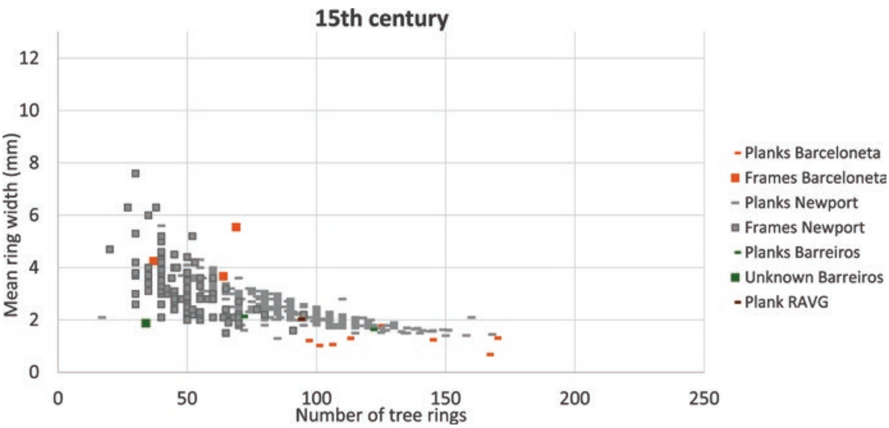

Fig. 1.5 Scatter plot of mean ring width against ring count for studied oak timber assemblages for the medieval (known or suspected fifteenth century) Iberian ships of Barceloneta I, Newport, and Barreiros

age and different growth rates to the stem of the parent tree. Nonetheless, it is evident that the framing timbers were derived from a different group or groups of trees than the planks. None of the ring-width sequences from the framing timbers matched against those of the planks, only a small proportion of them could be cross-matched against each other, and the mean of these series could not be matched against previously dated chronologies or site masters in Spain (or elsewhere). Until we can radically expand the temporal and geographical replication of oak ring width in Cantabric Spain, especially to coastal areas from which compass timber for framing in particular was probably sourced, then ring-width dendrochronology alone is unlikely to provide absolute dating.

Ring-width data (ring counts and average ring widths) were collected from 19 stringers, but none were subjected to full dendrochronological analysis (ring-width measurement). The timber had been sawn from whole or halved, young, fast-grown oaks. Often some sapwood survived on the timbers' corners but never the bark edge. Ring counts averaged 48 (range 29–61) and average ring width 3.6 mm per year (range 1.4–5.4 mm per year).

Lesser numbers of samples were taken from ceiling planks (mostly tangentially sawn from fast-grown oaks), bilge boards (some of which dated against the hull planks and seem to have been derived from the same source), and chocks/buttresses. Samples from repair patches (tingles), and presumed refit timbers including knees and riders dated against British ring-width chronologies, especially from location such as Gloucestershire near the Severn Estuary where the ship was uncovered.

4.3 Barreiros

The Barreiros wreck was uncovered by storms in February or early March 2015 in the intertidal zone of Remior beach near Barreiros, Galicia (NW Spain) (Fig. 1.4b). A substantial section of coherent hull structure was only briefly exposed and, by the time commissioned archaeologists from Zeta Arqueoloxía could visit the site, far less was exposed and available for sampling (Nodar Nodar 2015). The archaeologist of Zeta Arqueoloxía observed that most of the elements were loose boards with negatives of round-section metal nails and a square-head imprint in the wood (some also with a round head, and apparently square section), combined in some cases with round-section treenails of c. 3 cm in diameter. They followed a pattern of two to three metal nails/one treenail (Nodar Nodar 2015). The construction characteristics observed in the preliminary inspection of the wreck pointed to a clinker-built ship, possibly from the fifteenth century or later.

Two hull planks, a floor timber, a treenail, and another timber of unknown function were sampled on site by the archaeologists and sent to the dendrochronology laboratory of the University of Santiago de Compostela, Lugo (Spain).

The four structural timbers sampled were made of deciduous oak (*Quercus* subg. *Quercus*) and lacked pith and sapwood (Table 1.4). However, the treenail was identified as willow (*Salix* spp.). The two hull planks were radially converted and

Table 1.4 Results of dendrochronological research of the Barreiros shipwreck

Sample code	Timber element	Dendro code	Species	N	Pith	SR	Bark edge	MRW (mm)	σ (mm)
MU01	Hull plank	S0020010	1	71	–	0	–	2.14	0.65
MU02	Treenail	Invalid	2	Ca. 5	+	n.a.	–	–	–
MU03	Hull plank	Invalid	1	25	–	0	–	–	–
MU04	Hull plank	S0020020	1	121	–	0	–	1.65	0.48
MU05a	Floor timber?	S0030031	1	34	–	0	–	1.88	0.41
MU05b		Fragmented; invalid		32	–	0	–	–	–

Adapted from Dominguez-Delmás and García-González (2015f)
Species: *1*, *Quercus* subg. *Quercus*; *2*, *Salix* spp.; N: number of rings; Pith: present (+)/absent (−); SR: sapwood rings; n.a.: not applicable; Bark edge: absent (−); MRW: mean ring width; σ: standard deviation

contain 71 and 121 rings, respectively. MU03 was discarded for dendrochronological investigation because it had only 25 rings. MU05 consists of two different wooden elements, and while they all contained insufficient rings for dendrochronological dating, only one piece (a) (with 34 rings) was included in the research to evaluate its synchronization with the hull planks.

The series obtained from the hull planks do not show a clear synchronization between them. However, the short series obtained from sample MU05a shows an outstanding match with hull plank MU04 (Domínguez-Delmás and García-González 2015f). Crossdating with reference chronologies and with data from potentially contemporary shipwrecks (Barceloneta I and Newport) did not result in a conclusive match.

4.4 Ria de Aveiro G

This shipwreck was located in 2003 following dredging works carried out in connection with the construction of the solid bulk terminal at the Port of Aveiro, Portugal. The disturbed remains comprised a clinker-built ship dated by radiocarbon to 1290–1440 calibrated to two sigma (Bettencourt 2009).

In 2010, timbers held in store were examined at the former *Divisão de Arqueologia Náutica e Subaquática, Instituto de Gestão do Património Arquitectónico e Arqueológico* (DANS/IGESPAR) in Lisbon. Of the dozens of fragments of oak framing and radially converted planks examined, only two plank fragments had more than 50 rings and were sampled. The ring-width series of the two samples exhibited an outstanding visual and statistical match between them indicating that the timbers derived from the same parent tree, or that the fragments sampled originated from the same timber (Table 1.5). Crossdating with reference chronologies did not provide a match. Therefore, these samples remain undated.

Table 1.5 Results of dendrochronological research of the Ria de Aveiro G shipwreck

Sample code	Timber element	Dendro code	N	Pith	SR	Bark edge	MRW (mm)	σ (mm)
GR1–006	Plank	PRAG0010	81	–	0	–	2.14	0.97
GR1–008	Plank	PRAG0021	93	–	0	–	1.93	0.91
GR1-6_8	Plank	PRAG_1-2T	93	–	0	–	2.03	0.92

Adapted from Domínguez-Delmás (2010a)
All samples were oak (*Quercus* subg. *Quercus*); N: number of rings; Pith: absent (−); SR: sapwood rings; Bark edge: absent (−); MRW: mean ring width; σ: standard deviation

4.5 Ria de Aveiro F

The Ria de Aveiro F site was identified in 2002 during dredging of the port of Aveiro in Portugal (Lopes et al. 2020). Radiocarbon analyses of wood samples from the scattered remains of at least two vessels (an oak carvel-built vessel with parallels with Ibero-Atlantic ships and a clinker-built boat) gave date ranges of 1280–1420 CE and 1320–1350; 1390–1460 CE, respectively (95% probability at two sigma, see Lopes et al. 2020 Table 2). Recent reanalysis of these assemblages by Lopes et al. (2020) has questioned the usefulness of these radiocarbon dates. Investigations of the construction methods and materials suggest that the carvel-built ship, with some Mediterranean and some Atlantic features, was engaged in the transatlantic trade in the early sixteenth century. The smaller clinker-built boat, which was perhaps a skiff used to support the main carvel-built ship, was made from tropical wood which strengthens the conclusion that the carvel-built Aveiro F shipwreck had been engaged in the transatlantic trade.

In 2010, timbers from the Ria de Aveiro F shipwreck stored at the facilities of the *Divisão de Arqueologia Náutica e Subaquática, Instituto de Gestão do Património Arquitectónico e Arqueológico* (DANS/IGESPAR) in Lisbon, were inspected by Nigel Nayling and Marta Domínguez-Delmás. Through visual observation of several planks from this wreck, it was immediately concluded that they were of some diffuse porous species, i.e., with pores or small vessels distributed across the entire ring width (Schweingruber 1990). We decided to sample some of those planks, together with smaller fragments from other elements, to identify their species and assess their suitability for dendrochronological research. To this end, cross-sections were manually sawn from one end on nine planks. Smaller fragments of approximately 2 cm^3 were taken from two other elements, and a cross-section was cut from a barrel stave that had been found associated with the shipwreck remains.

The barrel stave was found to be made out of chestnut (*Castanea sativa*), whereas the sample from an element that seemed to be made out of branch wood was identified as deciduous oak (*Quercus* subg. *Quercus*) (Table 1.6). Chestnut is commonly spread in Europe, whereas different species of deciduous oaks can be found in Europe and North America.

Table 1.6 List of sampled timbers

Sample code	Description	Wood type	Observations
RAVF 31	Branchwood framing timber Carvel-built vessel	Deciduous oak	Ring porous (tr) Multiseriate medullary rays (tr, tg) Flame-like pore groupings in latewood (tr) 15 rings, no sapwood, no pith
RAVF stave	Barrel stave	Chestnut	Ring porous (tr) Uniseriate rays (tr, tg) Flame-like pore groupings in latewood (tr) Ca. 5 rings
RAVF 258	Hull plank (clinker), tangential	–	Not possible to identify; the subsample was too small and hard to prepare proper micro-slices
RAVF S/R 01	Hull plank (clinker), tangential	Tropical	Diffuse porous Marginal parenchyma bands not convincing One raw of upright cells in the rays (rd)
RAVF 115	Hull plank (clinker), tangential	Tropical	Diffuse porous One raw of upright cells in the rays (rd)
RAVF 353	Hull plank (clinker), tangential	Tropical	Diffuse porous One raw of upright cells in the rays (rd)
RAVF 354_10 RAVF 354_14 RAVF 354_16	Hull plank (clinker), tangential	Tropical	Abundant radially clustered vessels (x2) (tr) Oil cells apparent (rd) Vessel ray pits big and simple Plenty of septate fibers Oil cells present
RAVF 416	Hull plank (clinker), tangential	Tropical	Simple vessel parenchyma cells Oil cells in axial parenchyma?
RAVF 420	Hull plank (clinker), tangential	Tropical	Inter-vessel pits ca. 15 μm Oil cells present (tr) One raw of upright cells in the rays (rd) Parenchyma in bands (rd) Septate fibers present (tg) Vessel ray pits simple (rd) Vessel size ca. 100–200 μm (tr) 2/4 parenchyma strands (tr)
RAVF 3027	Tangential plank (clinker); timber from rear	Tropical	Diffuse porous One raw of upright cells in the rays (rd)

Adapted from Domínguez-Delmás, 2013 and Lopes et al. 2020, Table 1

The nine planks analyzed were determined to be from the same tropical species (see Domínguez-Delmás 2013 for details). Anatomical features found in all these samples were run in the InsideWood database, including other features that were clearly visible in some of the samples. As a result, InsideWood returned between 5 and 27 species from the taxonomic families Anacardiaceae, Lauraceae, and Myristicaceae (Table 1.7). Species of these families are present in Central and South

America, Africa, and Asia, making it extremely difficult to infer the potential construction area or the route sailed.

The most interesting information obtained from this research was the identification of planks made of tropical wood. While the difficulty of narrowing down the species when dealing with tropical wood was explained above, if most of the hull was made with tropical wood, we could infer that the ship was built in a colonial harbor in the tropics. It is vital to remember that oceangoing Iberian ships from this time had access to timbers on a global scale.

The stave made of chestnut probably originated from a barrel that served as a container for food or liquid and that was transported on the ship. The oak sample belongs to an unidentified element, which hampers the possibility of extracting much information from this piece of wood, but which also illustrates the need to compile a thorough register of all individual timbers found at underwater archaeological sites.

Table 1.7 List of species found for each search performed including different anatomical features observed in the tropical-wood samples

IAWA codes	FAMILY and species
1p, 5p, 9a, 10a, 11a, 13p, 22p, 27p, 31p, 32p, 42p, 56p, 61p, 65p, 79p, 89p, 92p, 97p, 106p, 130e, with 0 allowable mismatch	LAURACEAE Alseodaphne spp. Aniba canelilla, A. ferrea, Aniba spp. Beilschmiedia sp. MYRISTICACEAE Staudtia stipitata Warb.
1p, 5p, 9a, 10a, 11a, 13p, 22p, 27p, 31p, 32p, 42p, 56p, 61p, 65p, 79p, 92p, 97p, 106p, 130e, with 0 allowable mismatch	LAURACEAE Alseodaphne spp. Aniba canelilla, A. ferrea, A. rosaeodora Ducke, Aniba spp. Beilschmiedia sp. Endiandra spp. Phoebe posora Phoebe spp. MYRISTICACEAE Staudtia stipitata Warb.
1p, 5p, 9a, 10a, 11a, 13p, 22p, 27p, 31p, 42p, 56p, 61p, 65p, 79p, 89p, 92p, 93p, 97p, 106p, 124e, 125e, 126e, 130e, with 1 allowable mismatch	ANACARDIACEAE Comocladia spp. Mauria heterophylla Pleiogynium spp. Cryptocarya mannii MORACEAE Morus spp. MYRISTICACEAE Endocomia macrocoma Endocomia rufirachis Myristica irya Staudtia stipitata Warb.

(continued)

Table 1.7 (continued)

IAWA codes	FAMILY and species
1p, 5p, 9a, 10a, 11a, 13p, 22p, 27p, 31p, 42p, 56p, 61p, 65p, 79p, 89p, 92p, 97p, 106p, 124e, 130e, with 1 allowable mismatch	ANACARDIACEAE Comocladia spp. LAURACEAE Aiouea impressa Alseodaphne spp. Aniba affinis, A. canelilla, A. férrea, A. rosaeodora Ducke, Aniba spp. Beilschmiedia sp. Cryptocarya mannii Dehaasia spp. Endiandra spp. Licaria subgrp. Canella Licaria subgr. Guianensis Licaria subbullata Mezilaurus itauba Nectandra saligna Nothaphoebe spp. Ocotea globifera Ocotea glomerata Ocotea nigra Ocotea guianensis Ocotea schomburgkiana Persea raimondii Phoebe posora Phoebe spp. Pleurothyrium spp. Ravensara aromatica Ravensara crassifolia Ravensara ovalifolia MYRISTICACEAE Staudtia stipitata Warb.

Descriptions provided following the IAWA code (1989); p = present; a = absent; e = absent required

4.6 Highbourne Cay

The early-modern shipwreck of Highbourne Cay located next to the island of the same name in the Exumas, Bahamas has a long history of investigation (see Chap. 7, Vol. 2 for details). It was recognized as a significant early-sixteenth-century vessel in the Ibero-Atlantic tradition by Oertling (2001). As a part of the most recent campaign of excavation, examination and selective sampling of the *in situ* hull remains from a dendro-archaeological perspective was undertaken by Nigel Nayling and Miguel Adolfo Martins as part of the ForSEAdiscovery project in 2017.

The often-degraded nature of the surface of the timbers of the exposed ship's hull made in situ assessment challenging. It was clear that most of the timbers derived from relatively young and fast-grown oaks (*Quercus* subg. *Quercus*). Samples were recovered from only a limited number of timbers which might have sufficient rings

Table 1.8 Results of dendrochronological research of the Highbourne Cay shipwreck

Timber code	Timber element	Dendro code	N	Pith	SR	Bark edge	MRW (mm)
T0831	Framing	HCW26	14	+	0	–	3
T0829	Framing	HCW27	20	+	0	hs?	4.2
T0835	Framing	HCW29	41	>10	0	–	1.7
T0835	Framing	HCW30	25	>10	0	–	4.5
T0814	Framing	HCW31	31	+	14	?	4.1
T0843 (fifth floor)	Framing	HCW32	21	<5	3	–	5.0
T0824	Framing	HCW33	15	<5	8	–	6.7
Unnumbered	Framing	HCW34	30	+	3	–	3.7
T0834	Framing	HCW35	23	<5	0	–	7.6
T0832	Planks	HCW28	10	+	0	–	6.9
T0841	Plank	HCW28	16	<5	9	–	5.3
NA	Tangentially converted fast-grown oak fragment of (bilge?) board	NA	5	>10	0	–	5.8
NA	Highly eroded plank fragment. Possible TN hole slightly knotty oak	NA	18	>10	0	–	1.9
NA	Oak straight grained bilge board fragment?	NA	3	>10	0	–	7.0
NA	Oak straight grained bilge board fragment	NA	3	>10	0	–	5.0
NA	Conifer straight grained fragment	NA	14	>10	0	–	2.5

All samples were oak (*Quercus* subg. *Quercus*)
N: number of rings; Pith: present (+) absent (−) less than 5 years from pith (<5) more than 10 years from pith (>10); SR: sapwood rings; Bark edge: possible (?) absent (−) possible heartwood/sapwood boundary (hs?); MRW: mean ring width

for dendrochronological ring-width analysis or other forms of high-precision dating such as radiocarbon wiggle match or isotopic dating. Most of these samples were derived from oak framing timbers with relatively fast growth rates (Table 1.8). A group of wood fragments was located forward of the first buttress on the starboard side found within a bag with prelabeled tag from the 1986 excavations. Details of these are provided in Table 1.8 with Timber code NA. These appear to predominantly derive from oak bilge boards.

4.7 Emanuel Point II

In 1991, the first shipwreck associated with the Tristán de Luna y Arellano 1559 expedition was discovered in shallow waters off the Florida Coast near Pensacola (Smith 2018). The second vessel, the Emanuel Point II (EP II) shipwreck was discovered by University of West Florida (UWF) archaeologists in 2006. The excavation of this ship, and also terrestrial sites associated with the Luna expedition have been undertaken over many years as research and field training by the Department of Anthropology at UWF (Bendig 2018; Worth et al. 2020). Initially, a selection of samples excavated up to 2017 was sent to Nigel Nayling for analysis. Subsequently, he joined the field team on excavations in 2018 and undertook sampling of the EPII wreck with the assistance of experienced members of the UWF team. The site lies in very shallow water, but visibility is generally very limited/zero meaning that timber selection/location required considerable assistance from the site archaeologists with an expert knowledge of the wreck and the recording frames placed over it, and that selection could be based only on feel. Samples were hand sawn from accessible timbers with a preference for timbers with at least a partially curving cross-section profile which could indicate the presence of surviving bark edge or at least partial sapwood or the heartwood/sapwood boundary.

A total of 33 samples were analyzed comprising framing timbers (futtocks and fillers), planking (hull planks and ceiling), and two chocks (buttresses to the keelson at the point of the expanded mast step (Bendig 2018). All samples were oak (*Quercus* subg. *Quercus*) (Table 1.9). It would appear that most major timbers sampled were derived from relatively young and fast-grown oaks. Even where the growth rates are slower (<2 mm per year), the parent trees do not appear to have been very old when felled. Sample 2 from futtock 7534 had the most rings (86) with partial sapwood, no pith, and an average growth rate of 1.2 mm. The only other timbers with growth rates below 2 mm per year (chock 5336 with pith, possible bark edge, and 51 rings; sample 10 futtock 7542 with pith, bark edge, and 57 rings), even if they were converted from branches, clearly derive from relatively young oak trees. Framing timbers were converted from the whole or half of the tree's stem or branch, while the planking was tangentially sawn.

4.8 Emanuel Point III

The third shipwreck associated with the Luna expedition had only recently been discovered when Nigel Nayling joined the excavations in 2018 and only a very limited area was excavated and available for inspection and sampling. Located in even shallower water than EPII, there was sufficient visibility to allow visual inspection. Only four samples were recovered, all of which were oak (*Quercus* subg. *Quercus*). The single-hull plank sample, tangentially sawn, was from a very fast-grown oak. The three framing timber samples all derived from relatively young oaks, certainly less than 100 years old when felled, with ring sequences running from near the pith to possible or certain bark edge. Their growth rates were slow-medium (Table 1.10).

Table 1.9 Results of dendrochronological research of the Emanuel Point II shipwreck

Artifact / catalogue number	Timber element	Dendro code	N	Pith	SR	Bark edge	MRW
5336	Chock	5336	51	+	18	?	1.48
6698	Chock	6698	53	+	12	–	2.46
7422	Futtock	7422	21	–	0	–	9.12
7423	Futtock	7423	18	–	0	–	2
7424	Filler	7424	31	–	11	–	2.06
7425	Ceiling	7425	4	–	0	–	10
7426	Ceiling	7426	36	–	7	–	2.86
7427	Ceiling	7427	12	–	0	–	3.33
7428	Ceiling	7428	50	–	0	–	3.33
7430	Ceiling	7430	31	–	8	–	3.57
7431	Ceiling	7431	14	–	2	–	5
7432	Plank	7432	16	–	–	–	5.35
7433	Plank	7433	5	–	–	–	9
7533	Futtock	1	37	–	–	–	5.3
7534	Futtock	2	86	–	6	–	1.2
7535	Futtock	3	23	–	–	–	3
7536	Futtock	4	24	–	–	–	4.4
7537	Plank	5	20	–	–	–	3
7538	Futtock	6		+		+	
7539	Futtock	7	41	–	–	hs?	4.1
7540	Futtock	8	54	–	23	+	2.5
7541	Futtock	9	34	+	–	hs	4.1
7542	Futtock	10	57	+	21	+	1.4
7543	Plank	11	12	–	–	–	7.5
7544	Plank	12	27	–	8	–	4.9
7545	Plank	13	9	+	–	–	11.1
7546	Plank	14	32	+	–	–	5.3
7547	Plank	15	21	+	–	–	6.1
7548	Plank	16	45	–	–	–	4.5
7549	Filler	17		–			
7551	Plank	19	40	–	–	–	6.9
7552	Plank	20	24	–	–	–	5.4
7553	Plank	21	43	–	–	–	3.8

All samples were oak (*Quercus* subg. *Quercus*)
N: number of rings; Pith: present (+) absent (–); SR: sapwood rings; Bark edge: present (+) absent (–) possible (?) heartwood/sapwood boundary (h/s) possible heartwood/sapwood boundary (h/s?); MRW: mean ring width