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Agency and Structure in Shipbuilding: Practice and Social Learning Perspectives

Charles D. Bendig [1,*,†] and Marijo Gauthier-Bérubé [2,*,†]

1 Centre for Functional Ecology, Department of Life Sciences, Universidade de Coimbra, 3000-456 Coimbra, Portugal
2 Institut de Recherche en Histoire Maritime et Archéologie Subaquatiqu, Montréal, QC H2K 3V2, Canada
* Correspondence: cdbendig@otrms.com (C.D.B.); marijogberube@irhmas.com (M.G.-B.)
† These authors contributed equally to this work.

Abstract: Shipbuilding is inherently a social process involving numerous craftsmen utilizing their knowledge and skills while working together to produce a complex machine. The construction of a ship traditionally relies on a stratified apprenticeship system that entails a master teaching apprentices their trade. In this type of setting, the shipyard becomes the classroom where the younger generations learn and mimic mannerisms from their instructors. The development of this technique is considered an individual practice, which, with other construction methodologies and shared interactions, becomes social structures within a specific society. Repetition of this type of practice may reaffirm the existing structure, which in this article relates to various communities of shipbuilders. This paper addresses shipbuilding's social perspective through an operational process based on surviving shipwreck timbers. Two case studies are addressed: Mediterranean shipbuilding between the Medieval and Modern periods and a case study of late 17th-century French shipbuilding social organization.

Keywords: shipwreck archaeology; anthropology; shipwrights; operational sequence; operational process; practice theory; communities of practice; social learning; Mediterranean; France

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1. Introduction

Nautical archaeology studies the remains of boats and ships to interpret the cultures that created and relied on these technologies. Ships and their parts are located in various depositional environments, but the prime examples of historical construction are mainly interpreted from shipwrecks. These vessels represent transient architectural features studied as complex cultural technologies frequently assessed based on their sailing abilities or diffusionist perspectives on shared influences that led to further maritime development. Over the past half-century, this focus has dominated the subfield, incorporating cultural historical perspectives derived from surviving documentary records and estimation to locate identities for static objects. Technical discussions sometimes remove themselves from the complex interactions between humans and their social and natural environment. This subfield's initial development necessitated this historical particularist approach to create a catalog of relevant examples, while its subsequent growth and the addition of professionally excavated shipwrecks generated substantial datasets for comprehensive studies. Cumulative comparative analyses represent the next developmental stage for nautical archaeology to understand contemporary variation and discuss human behavior.

The authors propose an anthropological approach based on practice and social learning theories, navigating the societal landscape of shipbuilders by describing their communities of practice. By breaking down ship remains through an operational process, individual practices are identified that provide evidence for both unique and shared behavior between shipwrights of medieval and early modern Europe. While comparative analyses of ships are becoming more widespread, the current proposal is part of a greater trend in underwater archaeology to review the subdiscipline and provide a solid theoretical background. Incorporating social learning and the communities involved allows the authors to reinstate the capacity for agency and embodied knowledge in shipwreck analyses.

The first half of this article introduces the basic tenets of practice and social learning theories, including a discussion on the development of the operational process and its inclusion by archaeologists in shipbuilding analyses. Subsequently, several examples of how practice and social learning theories were applied to material culture studies support its widespread use regardless of the object or geographic location. The remainder of this discussion introduces the reader to two nautical archaeological case studies. Beginning in the Mediterranean, the first case study examines the major transition between edge-joined hulls to frame-based construction. Significant research has already been accomplished regarding the building transition itself, but there is less focus on the continued practices of frame-based construction as it became the norm throughout the region between the late medieval and early modern periods. Examining the hull remains from 41 archaeological sites suggests an exchange between regionally and geographically influential practices, possibly due to the migration of particular shipbuilding communities.

Following this model, the second case study addresses French shipbuilding in the late 17th century by comparing contemporary shipwrecks and construction treatises. This analysis relies on a typical excavated component often found on shipwreck sites, the frames, which are deconstructed through an operational process. Archeological evidence suggests that regional construction traditions prevailed despite the French Navy's best effort to standardize shipbuilding.

2. A Summary of Practice Theory

French sociologist Pierre Bourdieu introduced practice theory as a dualism between social structures that shaped the individual and provided a framework of thoughts and unconscious behaviors that led to participation in the edification and modification of this dynamic relationship [1]. Habitus is described as a system of schemes, perceptions, and unconscious thoughts created through social conditions set forth by a specific society [2]. New experiences will continually change the individual outlook, but earlier memories remain influential as the foundation for their purported agency later in life. Here, we defined agency as the capacity of an individual to consciously or unconsciously act and make their choices, more or less independently from social and environmental pressures [3,4].

In this case, the individual unconsciously avoids disturbing the structural equilibrium concerning their habitus as an overall social class self-defense mechanism evading questioning previously acquired information.

Adding to Bourdieu's work are the concepts the English sociologist Anthony Giddens provided with his structuration theory [5]. Giddens argued that while individuals and structure are engaged in a dynamic relation of influencing and creating each other, intentionality does not matter. By adopting, reinforcing, refusing, or modifying their behaviors, agents can cause the social structures to react thanks to the ongoing relationship between individuals and these structures. When it is a question of change and impact, intentional and unintentional behaviors or consequences do not matter. What counts is the capacity to act. This observation means that individuals might not directly seek change, but their actions might have that result.

For example, individuals in a protest use their agency to participate, usually in reaction to an aspect of their social structures. Their participation might have unintentional consequences, either in the short term or the long term, and bring change to the social structure, such as new rulings or law enforcement. In this vision, Giddens suggests that individuals can be defined by how much power they hold, where power is described as the ability to make a difference [5].

3. Social Learning Theory and Communities of Practice

Psychological paradigms in the first half of the previous century centered on behavioristic principles that outlined a linear input-output model where the individual performed without exerting a personal influence on the outcome. The introduction of computers only exacerbated this supposed behavior by describing the human mind as an organized intellect that calculated multiple operations simultaneously without feedback. When Albert Bandura established social cognitive theory as bidirectionality between agency, intentionality, and sociostructure, it rejected the previous singular determinist strategy and insisted that human behavior was a reciprocal exchange [6]. Bandura argued that direct learning involves witnessing others' behaviors and avoids the trial and error that leads to costly mistakes. This observational learning is a symbolic process that exposes the witness to modeled activities before any response is performed.

Exposure to the action observed may not necessarily result in any cognitive retention. The same applies to innovations in new technologies, ideologies, or social practices. Some persuasion or stimulant provides a greater likelihood that a learned innovation is tried, and its intrinsic functional value may develop into common practice until something more appropriate develops [7]. Observational learning produces a cognitive model of how new behaviors should be performed, becoming a codified informational guide to action. In this sense, modeling transmits new behaviors by allowing access through partial control by those with influence. Not everything modeled is adopted, as social and economic factors regulate what is feasible. Compared to similar theoretical paradigms, social cognitive theory rejects the earlier philosophy of straight dualisms by arguing about the interdependent relationship that relies on the personal agency to operate effectively in a broad network of sociostructural influences. Thus, people are the producers and products of their social systems [8,9].

Jean Lave and Etienne Wenger share a similar viewpoint as Bandura in describing a theory of social practice as the interdependency between agency and sociostructures. Lave and Wenger are interested in situated learning, defined as understanding the whole agent, their activity, and interaction within the world rather than being provided only direct factual knowledge about the said environment [10]. Situated learning involves learners participating in communities of practitioners. This involvement is defined as legitimate peripheral participation, where the actor changes locations within the social world as part of their trajectory of developing identity and membership forms. The terminology suggests a dualism between legitimate versus illegitimate, peripheral versus central and participation versus non-participation; these are considered inseparable aspects that combined create a complex social landscape. Lave and Wenger rely on the input from several ethnographic case studies of apprenticeships to outline their concepts of situational learning within various communities of practice.

From a peripheral perspective, apprentices learn what constitutes a practice of the community through legitimate access by observation and interaction. The learning curriculum is improvisational development to mimic how masters conduct their lives, observe what other apprentices are doing, and perform the necessities to become full practitioners. In this system, conferring legitimacy becomes more important than the direct teaching provided by a master. Mastery does not reside in the individual but is based on the organization of the community of practice. As a result, the focus is not on direct instruction but on structuring the learning curriculum. Apprentices learn their craft often in different sequences than how the overall production usually unfolds. Becoming familiar with the technologies of everyday practice is an essential component for apprentices to become full participants, as artifacts can carry a substantial portion of that practice's heritage [11]. Only through their legitimacy in peripheral participation will older generations provide transparency on how to use these artifacts and their significance as part of their learning process. Collective social practice is also contradictory. As new participants enter the community, the result is either the transition, addition, or reduction of older members. The learning process becomes part of social reproduction, providing resolutions for this conflict through reproductive cycles [12]. Historical artifacts become physical, linguistic, and symbolic, along with social structures that constitute or reconstitute the practice over time.

4. The *Chaîne Opératoire* or Operational Process

Introduced by the French anthropologists Marcel Mauss and André-George Haudricourt, the chaîne opératoire, or operational process, is a methodological and analytical tool to understand the order of an artifact's morphological changes [13,14]. Beyond the step-by-step processes, the operational process embraces mental representations such as knowledge, the learning process, and symbolic or ritualistic aspects [15,16]. For archaeologists, the absence of living informants hinders access to myths or direct social explanations for the steps in the technical process, and this observation does not mean these social factors are absent or inaccessible. The operational process provides a framework wherein technical variations are understood and interpreted in terms of intentionality, choices, learning processes, and errors.

Since the operational process is socially and culturally defined, it provides an analytical environment where archaeologists can identify and define communities of practice [17,18]. By breaking down the process of artifact production, the operational process can highlight the practices and map the geographical and chronological distributions of these methods and the communities involved. Archaeologists have often used this approach primarily for lithics, ceramics, beads, and other artisan products [17,19,20].

The operational process could be considered ill-suited to study larger structures encompassing hundreds of phases and tasks, but archaeologists and ethnologists have already used it successfully [21,22]. Nautical archaeology is no exception, as Patrice Pomey and Eric Rieth present a general sequence for analyzing ships [23]. Pomey and Rieth introduced the operational process as a methodological and analytical tool where the manufacture and usage of a ship could be broken down into smaller steps, each to be described and evaluated.

True to the French tradition, Pomey and Rieth deconstruct ships into four successive sequences: level, phase, operations, and acts. Each of these sequences is heavily influenced by different socio-political factors such as financial investment, the marine environment, the potential use of the ship, and the means of propulsion. Pomey and Rieth mentioned two levels of analysis and description: ship usage and its construction process. Since the original discussion was on shipbuilding, only the latter is described. The construction process is divided into two phases: the design and the assembly. Pomey and Rieth then separate the phases into multiple operations that they define as larger multi-composite tasks. Finally, each operation is allocated into acts (or actions) [24,25]. Fred Hocker and Matthew Harpster complemented this interpretation using alternative terminology [26,27].

This operation process allows archaeologists to consider the general sequence of shipbuilding with enough flexibility to address the wide range of floatable devices used by humankind to navigate waterways. It does not allow the precise reconstruction of gestures and tools generally discussed when applied to ceramics, lithics, or other much smaller artifacts. Pomey and Rieth offer the possibility to go further with a fifth layer they call the implementation sequence [23]. This layer can be seen as a specific architectural assemblage such as the frames, the keel, or other architectural features. That is not to say that only the implementation sequence of precise actions matters when dealing with the operational process. A hindsight perspective of more extensive processes can provide information on practices from an upper-level point of view.

5. Applying Practice and Social Learning Theory in Archaeology

Archaeologists apply practice and social learning theories through various interpretations. While most proponents agree with the foundational arguments laid out by Bourdieu and clarified by Giddens, each subsequent practitioner addresses differently the relative degree of freedom the individual wields within a collective social structure. Surviving archaeological material can be interpreted as the physical remains of past behavior and a source for a partial translation of mental cognition. Craft products represent a source for negotiating the multiple loci of practice communities, and the breakdown of their manufacture represents a preferred assembly sequence. Culture historians relied on this analysis to develop typological cultural phases delineating pre-historic cultures and subsequently associated groups from the documentary record. The following presents examples of applying this theoretical basis toward established archaeological collections.

When John Worth revisited ceramic collections by Native American groups from the Southeastern United States before and after the arrival of Spanish colonialism, he noticed the recurrent theme that the archaeological phases were applied as a direct cultural identity [28]. Subsequent analysis revealed that many of the potters in this region practiced similar techniques that crosscut ethnic, political, and linguistic divides. Only the distance between communities factored into preferred construction techniques, while the decision-making for decorative motifs was local. Most ceramic manufacturing in this period was conducted by female potters, which Worth viewed as ceramic communities of practice that shared a geographic area and interacted enough to recognize shared manufacturing stages. The existence of these communities and their possible overlaps are viewed in a three-dimensional contour map described as a horizon of practice. These horizons exist within the confines of a geographical landscape of practice in which the practice communities exist. Unique motifs associated with cultural identities and historically documented polities and ethnicities were ascribed as communities of identity. Suzanne Eckert originally applied the concept of communities of identity while conducting similar research on ceramic manufacture throughout the Southwestern United States [29–32]. Due to drought and other environmental factors, migration led to various groups coalescing with shared ceramic manufacturing practices. Potters chose decorative motifs highlighting their own group's original individuality to reinforce their separate cultural identities from these new polyglots.

In a follow-up to Worth's analysis, Rachel Hensler agreed with shared communities of practice during the Spanish colonial period, while she provided her argument for how female potters exchanged knowledge. By examining the ceramic vessels produced by interior groups living in the Big Bend region of southern Georgia, Hensler could connect them to natives directly involved with the coastal mission system, creating a constellation of practice across the landscape [18]. Surviving evidence indicated that rim production in the interior was initially performed with hand techniques that gave way to tools due to interaction with the coastal groups. Similarly, exchanging stamped paddles with pre-made forms to apply on the outside surface of ceramics and shifting marriage exchange patterns led to developing analogous manufacturing techniques with coastal communities. While this process appeared to be ongoing before the arrival of Europeans, the changing social landscape during the early historical period sped up this exchange, creating communities of practice with a broader range across this region.

Gwendolyn Kelly's research into stone bead-making communities in South India sought to address practice theory through Bourdieu's application of doxa, orthodoxy, and heterodoxy [19]. Bourdieu argues that doxa is the objective principle between the natural and social worlds that appear self-evident. In hierarchical societies, those in dominated classes expose doxa as arbitrary against those above who attempt to keep the status quo or argue for orthodoxy as an imperfect substitute [1,2]. Kelly reinterprets these terms to include any power, authority, or vested interest structure. He also argues that applying orthodoxy does not necessarily mean a holistic, communal social order but can be the adherence to a particular set of practices. In contrast, heterodoxy represents the presence of different practices and social customs that coexist and are accepted. These areas presumably have reduced vested interests that allow new ideas to thrive if they do not directly challenge the status quo, allotting increasingly diverse and heterogenous practices out of disinterest [19].

Within the early historic community of lapidary bead makers from South India, Kelly identified differences in the individual stages of production. Raw materials were procured, then roughly shaped, ground, pecked, drilled, and polished in different orders. While most of the finds from Kodumanal, Pattanam, and Arikamedu suggest heterodox communities of practice, there is also evidence for a much smaller orthodox bead-making practice restricted to grinding, using non-local microcrystalline materials, polishing before drilling, and drilling the central hole from both ends. Kelly argues that this orthodox group possibly traveled carrying their raw materials and sharing technical knowledge with locals as they traded their products between communities. This unidentified group may be one of several factors that brought diversity to the bead-making community in South India.

6. The Medieval and Early Modern Mediterranean: A First Case Study

Examination of artisan wares requires archaeologists to develop categorizations as a multiscalar analysis between individual finds and identifying shared commonalities between communities. Often when a newly discovered object is in situ with no known equivalents, it becomes the initial standard until more examples are discovered. Once a large enough sample size is acquired, whether from the same archaeological context or across a geographical region, comparative analyses begin to identify the similarities and differences between each artifact. Studies involving shipbuilding are no different, except that the object in question is much larger in scale and remains the cradle of an extensive material culture that can sometimes take precedence due to various factors (excavation cost, conservation budget, in situ philosophies, modern politics, etc.) [33]. As a result, compared to colleagues who study ceramics, lithics, bead making, or other related products, the study of the hull remains is somewhat more gradual and piecemeal. Each new find that provides the opportunity to survey the ship itself becomes habitually representative of construction in an approximate geographic location that can extend a century or more. Furthermore, the surviving availability of documentary sources as they became more prevalent in the 15th century leads to culture historians searching for individual identities and the "lives" of these vessels more so than examining the technological development and communities that actively created some of the most complex machines before the modern era [34].

The Mediterranean is one of several locations for some of the earliest human civilizations worldwide. Accordingly, this body of water has become an extensive repository of ship remains that extends for several millennia. Some may also consider it a cradle and original location for the initial development of underwater excavation techniques and first-hand investigations by diving archaeologists [35]. While the Mediterranean repository is extensive, it is not limitless, and the preservation of sites depends on the material culture present, the underwater environment, research interests, and modern development. Many of the reported sites are known to date before the medieval period, mainly due to the preservation of the organic remains from the collection of ceramic amphora containers behaving as sediment traps and barriers against dislodging surviving materials. After this period, more commodities were carried in wooden containers and barrels, leading to less surviving material on the sea floor [36,37].

Since the early development of nautical archaeology in the Mediterranean, the focus remained on the better-surviving ship materials connected to antiquity and the early medieval periods. As more shipwrecks were located and the surviving hull remains published, comparative analyses between this collection recognized that a significant transition occurred during the first millennium AD [38–40]. Ships that for centuries relied on a shell-based principle of thick hull planking edged joined with the use of closely spaced mortise and tenon joints were giving way to a new technique that led to the more modern equivalent of frames erected before the direct installation of thinner planks against the outer faces. Between this observation and the additional reporting of ancient hull remains over the last several decades, Pomey, Yaacov Kahanov, and Rieth decided to review a select corpus of examples to investigate how this change took place [41]. The trio studied a collection of 25 shipwrecks that spanned most of the eastern and northern coastlines of the Mediterranean, two other wrecks located along the Atlantic were included due to similar construction techniques, and the initial findings from 25 sites discovered together in downtown Istanbul, Turkey's Yenikapı district. The latter group appears to be vessels that sank in the former Byzantine Theodosian harbor that were exposed due to a significant underground transit system project [42].

In summary, the team found that shipbuilding across the Mediterranean was non-linear and that shipbuilders incorporated different construction techniques and cross-section designs. Shell-based ships relied on the edge-joined mortise and tenon techniques while relying on copper nails and treenails elsewhere in the hull. The framing was added afterward to support the hull rather than providing overall strength and rigidity. As time passed, these closely spaced mortises and tenons began to be set further apart and the tenons themselves became smaller and/or loose-fitting within the mortises. Eventually, mortise and tenons were used as a guide for installing strakes instead of the main structural component. Framing became more prominent, although only a few key positions included fastening the floor-timbers to first futtocks as guides. The copper nails gave way to iron, and edges between planks were caulked for sealing purposes. Regardless of the varying construction techniques, many of the ships shared amidship cross sections as either a flat bottom with a round bilge, a wineglass cross-section, or a riverine approach called bottom-based that entailed a flat bottom and hard chine. This last design is considered an origin for frame-based construction dating back to the 6th century in the Eastern Mediterranean [41].

Rieth has previously argued about organizing vessels based on hull geometry, and this was later translated alongside Pomey and Kahanov to become suggested "Roots" [43,44]. The ships under study were organized into four roots, two each representing western and eastern origins, with three more eastern sub-additions associated only with the Yenikapı finds [41]. While this analysis included relying on the operational process outlined by Pomey and Rieth to define the concept and construction of each vessel, the underlying tendency to connect these sites with socio-historical associations led to the roots being labeled based on the most prominent or likely cultural affiliation (Hellenistic vs. Roman Imperial vs. Byzantine). Only the bottom-based root is considered by its geographical location to the Nile River than cultural affiliation. Rieth has continued to argue that a few examples of this root found along the French Riviera were only present due to the Islamic conquest of the southern Mediterranean coastline and Iberia instead of local riverine developments [43]. This cultural history is a dangerous precedent already adopted by subsequent studies that tie findings more to a predominant cultural affinity than long-term shipbuilding communities. These roots also become more problematic for the addition of new finds or their expansion into later periods where the socio-economic factors change the political landscape.

Pomey, Kahanov, and Rieth conclude their ship list with the 11th-century Serçe Limanı Bay, Turkey, shipwreck because it is well regarded as a marked point where subsequent Mediterranean vessels are almost exclusively frame-based [41,45]. Serçe Limanı is also an agreed upon wreck in the archaeological community for this transition due to some scholars not entirely convinced of the earlier initial conversion taking place [46]. Until recently, there were few comparative studies of Mediterranean shipbuilding on a similar scale for shipwrecks dating between the Late Medieval and Early Modern periods. Following a similar course as Pomey, Kahanov, and Rieth, a survey of wrecks was comprised to determine whether changes and practices continued well after the first millennium. The remainder of this case study discusses the development of Mediterranean shipbuilding communities of practice between the 11th and 17th centuries based on the findings from 41 archaeological sites. This analysis begins by briefly covering the development of medieval shipbuilding guilds, apprenticeships, and the appearance of documents directly related to ship construction.

6.1. Conception of the Medieval Shipbuilding Communities and Their Ships

In some regards, as with many traditional crafts, knowledge transfer is an oral history to teach a new generation of experts. Although ancient historians and scholars sometimes dabbled in discussions on ship construction, there is a limit to written dialogue by the practitioners themselves [47]. There is an assumption by archaeologists that state-controlled shipyards in antiquity relied upon some standardization due to the need for ships to fit in similar ship sheds and required comparable dimensions for naval maneuvers [48]. Beyond these few instances, it is presumed that ships were built to order at temporary shore locations. Shell-based construction required a larger skilled craftsmen population with shared knowledge that eventually gave way to a single intellectual overseer who relied on a more mundane workforce. These craftsman-managers relied on developing master whole molds that provided the necessary information to build the amidship cross-section where most subsequent data originated for a frame-based ship [49].

Most of our understanding of traditional shipbuilding communities from the late medieval and early modern periods originates from surviving documents related to state-sanctioned shipbuilding enterprises. The most coherent and preserved examples are the state documents that survive from the Venetian arsenal. Families pursued shipbuilding as a generational business, with children learning from their parents while being indoctrinated into the community through participation in the local guild and other social activities. Guilds represented social cohesion by shared occupation that relied on dues to cover religious expenses to support a local church or patron saint's altar, covering burial finances and dowries, codifying terms for quality control, and enacting social insurance for the elderly and disabled [50,51]. The shipbuilder's guild provided part of the developed habitus in the form of a social structure reaffirmed daily and through annual meetings by the participation of its members. Another aspect of habitus is in the shipyards, as the legitimate participant observation in the construction and assembly of the ship provided a routine sequence specific to a tradition. Preferences for fasteners, scarves, or other specifics showcased the agency of the craftsmen in his overall continued reaffirmation of the general habitus.

Traditional medieval apprenticeships often relied on early teens to become trainees of a specific craft by familial obligation or choice. The length of the apprenticeship varied by choice of the master craftsmen or completion of a board exam. After graduation, the individual was described as a journeyman who continued to work or travel while operating their trade. Journeymen eventually reached the rank of master after a prolonged period of completing high-quality products while becoming well respected in their communities [52,53]. Venetian shipbuilding apprentices followed a similar course, with generational families continuing the tradition of either working for the state-owned arsenal and/or private local shipyards. Apprentices learned to construct a ship with many opportunities to engage, learn, and adopt the appropriate practices within the community. Masters initially decided when an apprenticeship was completed, but certain abuses eventually required an examination board led by the guild master and later overseen by arsenal officials. There does not appear to be a journeyman rank within Venetian shipbuilding. Apprentices directly became master shipbuilders, and their pay in the arsenal and assumed respect within the guild was based on general seniority. Only the shipbuilders who became arsenal foremen or owned private shipyards appeared to be considered part of a higher tier [50].

Many early documents related to shipbuilding are expense lists for creating fleets or notarial documents listing each element for generating ships based on a preferred type [54–57]. The pivotal knowledge necessary for creating these vessels remained in the hands of the shipbuilders, who often kept it as a regarded secret from others. Beginning in the 15th century, interest in ship construction as an academic subject led to manuscripts and notebooks that included the topic. Most of these examples retrieved their information from Venetian arsenal records or plagiarized each other with varying errors [58]. Due to the arsenal's focus on maintaining the Venetian war fleet of galleys, these ships were the focus of most written works, with a few descriptions of the round ships often constructed by private industry. These documents mainly represent "recipes" based on the overall measurements of the ship, the measurements on central frames, and the necessary number of frames installed for the ship type.

In the 16th century, Venetian shipbuilders associated with the arsenal also provided their "recipe" lists. These lists were improved with discussions of the proportional relationships between overall dimensions and description for installing temporary battens but still withheld the shape of the central hull profile [59–61]. In a letter written at the end of the century, the shipbuilder Baldissera Quinto Drachio reveals that much of the galley construction relies on the overall dimensions based on proportions, the use of a master mold and tablet and that certain shapes necessary for construction are empirically conceived with cord and bendable wooden slats [62]. Written descriptions in the subsequent century were composed of naval officers or merchants relying on direct source material to suggest idealized forms [61,63,64]. The difference from previous work is a greater reliance on the drawing compass as an intellectual exercise for predesigning the molds employed in the shipyard and attempts to determine the forms of all frames, rather than only the central examples.

6.2. Mediterranean Ship Construction

While the Venetian sources provide a robust catalog regarding the lives of the shipbuilder's community and their relationships with the government in the northern Adriatic, it does not account for the remainder of the Mediterranean. Few similarities are explored by researchers referring to shipyards in other places such as Catalonia, Genoa, or Istanbul, but these references are much more dispersed. For instance, we know that celebrations were held after completing major milestones during the construction stages of Catalonian ships [65]. Genoese vessels were completed on makeshift beaches near waterway outlets into the Mediterranean scattered along the Ligurian coast [66]. Furthermore, Ottoman sultans regularly relied on their Greek subjects to provide expert shipbuilders to oversee the work of supplying their war fleets [67]. Between these locations, some master builders were traveling craftsmen or focused on constructing the larger swath of smaller vessels that were coastal traders or riverine-bound. By organizing an assortment of 41 shipwrecks from across the Mediterranean, a comparative analysis of the practices of these communities provides an interesting perspective into the transfer of knowledge and development of regional behaviors.

Table 1 presents the archaeological sites chronologically, while Figures 1–4 provide their geographical locations. Three wrecks are not included in these figures, as the Church Rocks shipwreck found along the southwestern coast of Britain, Kinnagoe Bay vessel lost on the north coast of Ireland, and the West Turtle Shoals hull located in the Florida Keys are also assumed to be Mediterranean in origin. In addition to the crosswise issue of detailed reporting on finds, another glaring concern is the missing data for earlier ships in the western basin, early modern ships from the Eastern Mediterranean, and the lack of finds known along the North African coast. Apart from a handful of smaller wrecks near Venice and one example in Lake Garda, the appropriate archaeological publications on surviving Venetian ship structures, especially round ships, are limited. A similar statement should be said about the availability of information from 17th-century shipwrecks. Dendrochronology applications to identify timber sources, and probable associated construction sites are still strongly lacking throughout the Mediterranean compared to studies conducted in Northern Europe. The largest swath of this sample dates to the 16th century, where the plethora of surviving documents and the material culture from these sites provide highly feasible identities.

While shipboard use and the operational life of these vessels remain essential, it also imparts certain biases connecting the construction and historical typology to nationalities. An archaeological taxonomy was devised that divided the remains between either being identified as a longship or round ship based on their overall length-to-breadth ratios. Any remains or reconstructions that suggested a ratio of 1 to 5 or greater were considered longships for this discussion. Most of these sites are round ships with differences between the smaller to medium coastal traders and the larger offshore operators. Since the preservation of propulsion systems and surviving superstructure remain limited, the majority of the following discussion is based on surviving remains from below the waterline.

Table 1. List of Late Medieval and Early Modern Mediterranean Shipwrecks with Available Recorded Scantlings and Profiles.

(#) [1] Shipwreck [#] [2]	Date	LOA (m)	Beam (m)	Depth (m)	Ratio [3]	Cross-Section Amidship
(1) Serçe Limanı [45]	1025	15.66	5.2	2.4	3.01	FFT [4], hard chine 72° flair outward
(2) Marsala A [68,69]	1050s	18	5.8	2.9	3.1	Slight deadrise, round bilge
(3) Marsala B [68]	1100s	8.4	2.8	1.4	3	FFT, hard chine 72° flair outward
(4) Rhodes 4 [70]	1175–1200s	30–35				FFT, hard chine 71–72° flair outward
(5) Precenicco [71]	1180–1300	8	1.6		5	FFT, soft chine flair outward
(6) Çamaltı Burnu I [72]	1200–1225	25	8		3.1	FFT, unknown bilge

Table 1. *Cont.*

(#) [1] Shipwreck [#] [2]	Date	LOA (m)	Beam (m)	Depth (m)	Ratio [3]	Cross-Section Amidship
(7) Rhodes 1 [73]	1240 ± 60	20+				FFT, round bilge
(8) Culip VI [74]	1290–1300	18.8	4.8	2.2	3.92	FFT, round bilge
(9) Camarina [75]	13th ca. (1301?)	30	4		7.5	FFT, round bilge
(10) Olbia Wreck 4 [76]	1323 (?)	9.5+	3+		3.1+	FFT, round bilge?
(11) Boccalama A [77]	1300–1325	23.6	6	0.74	3.9	FFT, hard chine
(12) Boccalama B [77]	1300–1325	38	5		7.6	FFT, round bilge
(13) Les Sorres X [78]	1390s	9.5	1.9	0.9	5	FFT, slight round bilge
(14) Olbia Wreck 10 [76]	1405–1440					FFT, round bilge (?)
(15) Bacàn 2 [79]	1420s	15–16				FFT, round bilge
(16) Marinières [80]	1420–1430	25	8.45	2.07	3	FFT, round bilge
(17) Cavoli [81]	1440s					Limited Hull Remains
(18) Bacàn 1 [82]	1450s	15–16				FFT, round bilge
(19) Contarina I [83]	1460s	20.98	5.2	2.46	4.05	FFT, round bilge
(20) Contarina II [83]	1475s	20.5	6.3	1.67	3.25	FFT, round bilge
(21) Mariposa A [84]	1475–1525	16.8 (25)	4.5 (9)		14.15	FFT, round bilge (?)
(22) Rhodes 2 [73]	1480 or 1522					Unknown
(23) Mariposa B [85]	1500–1525	16				Slight deadrise, round bilge
(24) Lazise [86]	1509	39.6	4.9		8.08	FFT, round bilge
(25) Villafranche [87]	1516	46.45	14	4.4	3.32	Half-Circle - deadrise 35 cm
(26) Mortella III [88]	1527	36.8	10.5	6.15	3.5	Half-Circle - deadrise 33 cm
(27) Sardinaux [89]	1500–1550 (1540s?)	10–12	~1.8		5	FFT, round bilge

Table 1. *Cont.*

(#) [1] Shipwreck [#] [2]	Date	LOA (m)	Beam (m)	Depth (m)	Ratio [3]	Cross-Section Amidship
(28) Chrétienne K [90]	1500–1550 (1540s?)	20–30				FFT, round bilge
(29) West Turtle Shoals [91]	1550–1600					FFT, round bilge (?)
(30) Yassi Ada 3 [92]	1572+	21.2	6	1.2	3.53	FFT, round bilge
(31) Cadiz-Delta II [93]	1573 (1587)	30				(Half-Circle?)
(32) Calvi I [94–96]	1575	23.4	7.8	2.2	3	Half-Circle - deadrise 39 cm
(33) *Kadırga* [97]	1575–1625	39.57	5.72	1.34	6.92	FFT (slight deadrise), round bilge
(34) Cap Lardier 1 [98]	1575–1600	20 ± 2				FFT, round bilge
(35) Agropoli [99]	1575–1625	23	5.75		~4	FFT, round bilge
(36) Sveti Pavao [100]	1580	24	6+		4+	FFT, round bilge
(37) Church Rocks [101]	1582+					Unknown
(38) Kinnagoe Bay [102]	1588					Flat floor-timbers, round bilge (?)
(39) Ribadeo [103]	1590 (1597)	34.48	11.78	7.76	4.49	(Half-Circle?)
(40) Rodinara [104]	1590–1620	14	4.5	2	3.11	FFT, round bilge (?)
(41) Saint-Honorat 1 [105]	1637	25–30				Shallow wineglass (?)

[1] Ships are listed numerically to match their locations in Figures 1–3. [2] Citations for the hull structure of each corresponding shipwreck. [3] Overall Length: Beam Ratio. [4] Flat floor-timbers.

Earlier shell-based practices relied on edge-joined planking that formed the hull. Insertion of alternating floor timbers and half frames was installed afterward in a supportive role. By the beginning of the 11th century, Eastern Mediterranean shipbuilding showcased an exclusive favor of erecting the central transversal frames before the planking installation. Compared to earlier examples, these frames were designed as long-armed floor-timbers that overlapped or butted a short-armed futtock. The appearance of central floor timbers overlapping longer futtocks on either side was not paramount until the 13th century. Planking thickness was reduced and attached to the framing almost exclusively with iron nails. Previous practices focused on the connection between the keel and the garboard, and the keel was either rabbeted or chamfered to provide the edge-joined connection.

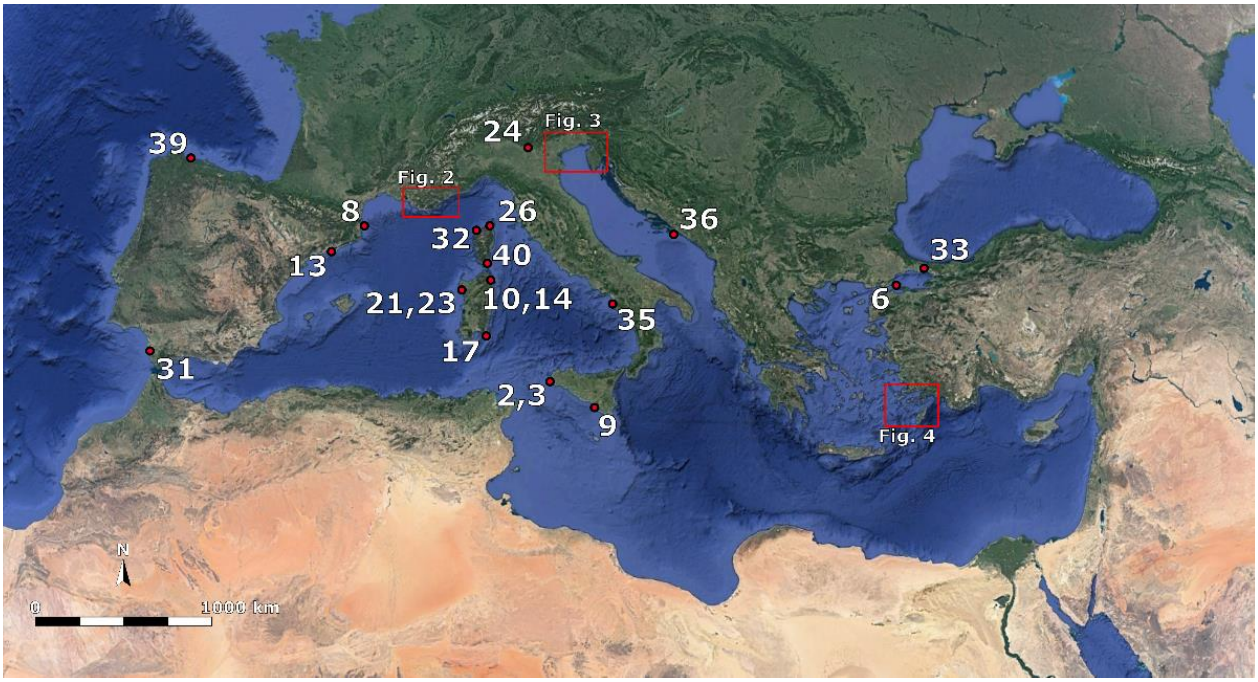

Figure 1. Location of shipwrecks in the Mediterranean. (2) Marsala A; (3) Marsala B; (6) Çamaltı Burnu I; (8) Culip VI; (9) Camarina; (10) Olbia Wreck 4; (13) Les Sorres X; (14) Olbia Wreck 10; (17) Cavoli; (21) Mariposa A; (23) Mariposa B; (24) Lake Garda; (26) Mortella III; (31) Cadiz-Delta II; (32) Calvi 1; (33) Kadirga; (35) Agropoli; (36) Sveti Pavao; (39) Ribadeo; (40) Rodinara. After Google Earth, 2020.

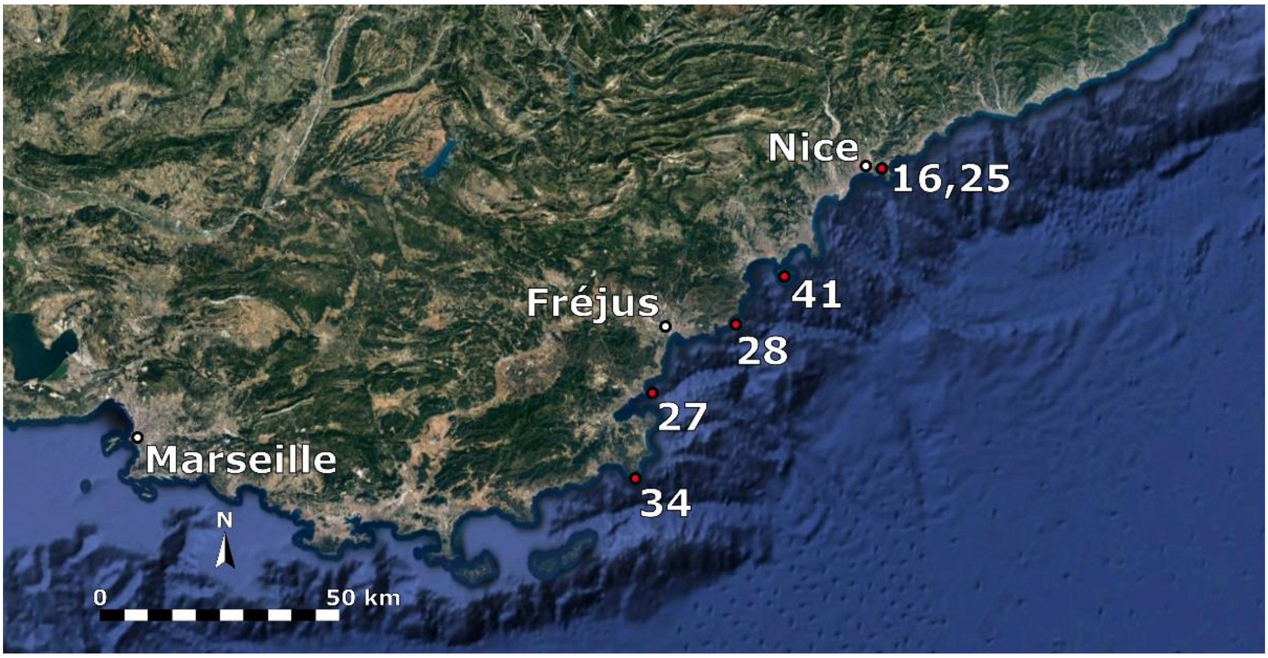

Figure 2. French Riviera map of shipwreck sites. (16) Marinières; (25) Villefranche; (27) Sardinaux; (28) Chrétienne K; (34) Cap Lardier 1; (41) Saint-Honorat 1. After Google Earth, 2020.

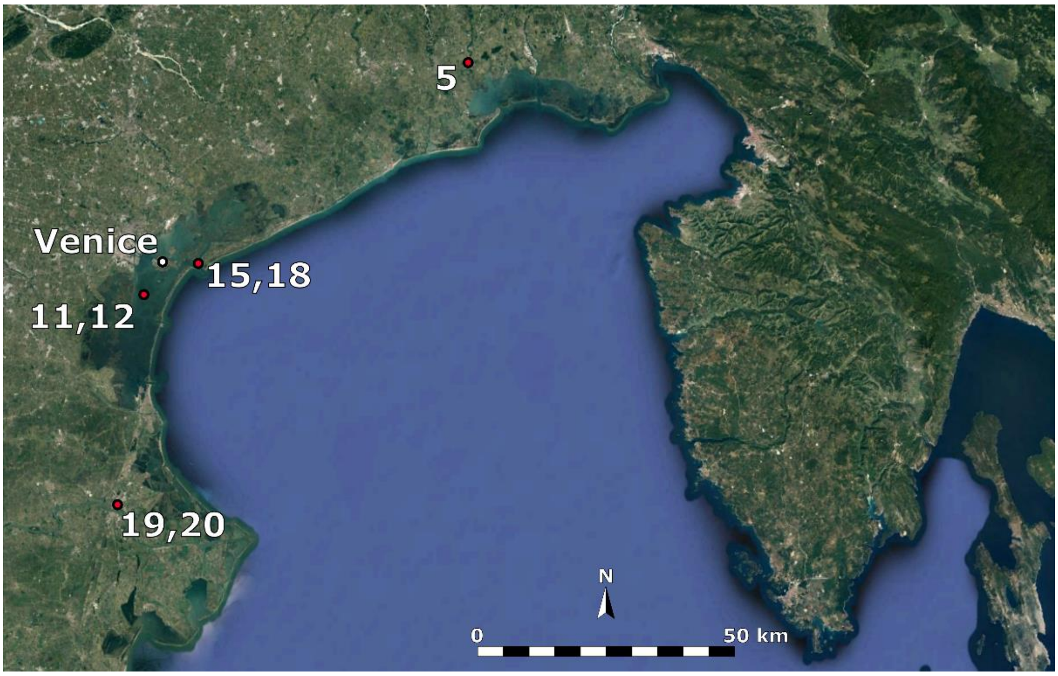

Figure 3. Northern Adriatic location map of shipwreck sites. (5) Precenicco; (11) Boccalama A; (12) Boccalama B; (15) Bacàn 2; (18) Bacàn 1; (19) Contarina I; (20) Contarina II. After Google Earth, 2020.

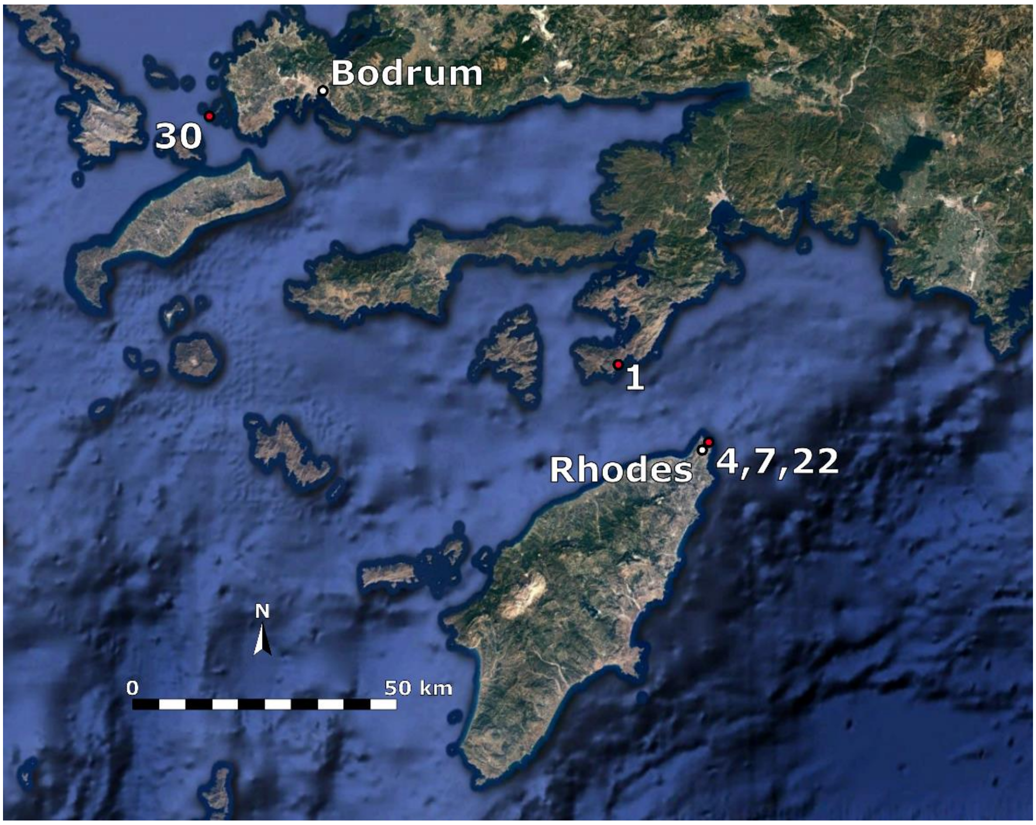

Figure 4. Southwestern Turkey and Rhodes location map of shipwreck sites. (1) Serçe Limanı; (4) Rhodes 4; (7) Rhodes 1; (22) Rhodes 2; (30) Yassi Ada 3. After Google Earth, 2020.

In comparison, the frame-based approach initially showcased less concern for this relationship. The reappearance of the keel rabbet on much later and larger vessels suggests an association with greater strength along the central axis for complex wineglass profiles or to counteract the sagging forces. Thinner planking also required caulking to compress between the seams, while the earlier practice of covering the entire hull inside and out using pitch continued. Lead sheathing known from ships in antiquity became less prevalent thereafter and only reappeared on much larger ships by the 16th century.

Late medieval and early modern ships represent a method of construction still in transition. Ships relied on the erection of central frames that dictated the amidship shape and width of the hull, but difficulty predicting how to form the ends relied on the longitudinal vision from antiquity created with temporary battens connecting the stem or sternpost to the central frames. The limited surviving end posts suggest that many vessels incorporated rounded stems and were double-ended. After the adoption of the stern rudder and straight sternpost by the fourteenth century, subsequent archaeological examples include the aft end of the keel connected at an angle to a straight sternpost with the support of a stern knee and associated deadwood [106]. The angle of the sternpost and the introduction of the flat transom by the beginning of the 16th century affected the overall cargo capacity and deck height [107]. Scarfs connecting sections of the keel and end posts were much more prevalent in shell-based ships. These connections were substituted as the medieval period progressed by simply butting the pieces together.

Aligning central floor timbers to first futtocks with scarf joints is an endowed practice in western basins not seen in earlier eastern vessels. Only in the latest examples of eastern shipbuilding do archaeologists notice the presence of these scarf joints at this juncture. These shallow rebates should be interpreted as part of the assembly process rather than providing transversal strength during the ship's working life. In an earlier study, Rieth pointed out that a signature of Mediterranean construction was the preference for hook scarfs to align this connection [108]. Additional findings from this current study indicate that this scarf type is prevalent, but evidence of dovetail, oblong rebates, and diagonal overlaps also exist. Framing dimensions remained square near amidships throughout this period, and each vessel's overall scantlings continued on par with earlier shell-based examples until size increased in the 16th century. Spacing between frames is also standardized by following a design procedure based on the linear unit used by the shipbuilder. Most applications of a linear unit were idiosyncratic, relying on regionally based interpretations as the development of central government agencies slowly attempted to apply strict uniformity.

There is a practice in earlier eastern ships to avoid installing internal longitudinal components such as the keelson or stringers by utilizing bolts between frames rather than through them. In this manner, the keelson was bolted between frames to the keel, and the lower stringers were similarly connected to bilge stringers. Western shipbuilders only connected the keelson with the frames using smaller nails, but the precise date when shipbuilders installed bolts through frames is unresolved, although it took place in the 14th century [74]. Stringers were intermittently present in shell-built hulls and became much more prevalent in frame-based shipbuilding as internal clamps over frame overlaps and between these connections. A ceiling was installed to protect the framing from shifting cargo and provide raised platforms above the bilge in wineglass profiles. The primary surviving evidence for propulsion systems included the mainmast step, which carried over from earlier shell-built construction that relied on sister keelsons supported by an unfastened keelson or mast step timber. By the late medieval period, this assemblage relied on a composite mast step built over the keelson, creating a makeshift central mortise for the mast heel. In a similar light, the surviving evidence from contemporary ships' pumps relied on composite-built tubes with box-type suction valves [109,110].

Only a handful of bottom-based construction appears together in the late medieval and early modern periods. Most of these examples comprise a plank keel with two or three accompanying strakes to make up the bottom of the hull. The earlier examples of the Marsala B and Precenicco shipwrecks include framing similar to contemporary keel-based examples with long-armed floor-timbers accompanying short-armed futtocks [68,71]. The Rhodes 1, Boccalama A, and Sveti Pavao examples fit with the rest of the transition to central floor-timbers with accompanying futtocks on each arm [73,77,100]. In contrast, the Boccalama A shipwreck is an exception in this dataset as a riverine or lagoon craft unsuitable for the open sea. Sveti Pavao is also unusual as a full-fledged merchantman used for sea voyages that relied on a double-planked hull. The shared profile and construction methodology suggest a riverine practice modified for offshore voyaging, while their sporadic appearances across the Mediterranean suggest further finds necessary to explore its regional development.

As mentioned earlier, the upper assemblies of hulls have much less preservation than below the waterline. Round ship assemblies entail beams and ledges supported by shelf clamps to create the decks. Nevertheless, through-beams, necessary for deck creation and hull rigidity on shell-built vessels, were present on Contarina II remains and could be seen in contemporary 15th-century iconography [83,111]. Similar construction features on longships support this supposed anachronism since the mental concept for these ships is longitudinal. The connection between the beams and wales reinforced the long narrow hull and supported the outriggers' assemblies [97]. Western 16th-century ships with half-circle or wineglass profiles suggest additional lower reinforcements were necessary to support the larger upper castle assemblies [87,88,103].

Smaller craft in the Mediterranean operated by offloading on or near shore and necessitated the presence of bilge keels to protect the hull and keep the ship upright. The position of this strake held equal importance on larger round ships and longships as a short wale was used to girdle the transition between the bilge to the upper deck at the stern. Dimensions of planking and wales depended upon the overall size and dimensions of the vessel. Fastening patterns varied with construction familiarity. Shipbuilders that worked on the Serçe Limanı hull used multiple nails per frame station (with evidence of treenails in repairs), while there was an apparent standardization subsequently across the basin employing only one or two [45]. In the West, the Culip VI shipwreck provided a similar assessment as the Serçe Limanı example with additional nails per frame station [74]. Western Mediterranean shipwrecks provided the predominant mix between iron nails and treenails [76,78,80,81,84,89,91]. Representatives from the Iberian, French Riveria, and Ligurian coasts preferred clenched nails over the typical blind fasteners installed on other vessels [81,84,88,90,94,98]. The Yassıada 3 shipwreck is a rare exception in the Eastern Mediterranean, where the keelson was installed and connected to the keel with treenails and cannot be explained further without additional contemporary examples [39].

6.3. Mediterranean Communities of Practice

Historian Fernand Braudel once referred to the Mediterranean and its coastal communities as separate entities from the rest of Europe and the Atlantic due to the wall of mountain ranges surrounding the basin [112]. Evidence also suggests that historically coastal populations often communicated and shared technological development more frequently than hinterland inhabitants [113,114]. We can temporarily envision the Mediterranean as a bound environment to analyze the summary of findings. The shell-based, frame-based, and bottom-based traditions represent practice horizons. Shipbuilders embody the social landscape where these overlapping horizons influence their practices and each other. Communities of practice throughout the Mediterranean could be identified individually based on orthodox or heterodox groups following similar operational processes in assembling a ship, with differences in how this was accomplished.

Shipwrecks in this current study date to after the horizon of frame-based practice has taken precedence over the Mediterranean. Based on the previous work by Pomey, Kahanov, and Rieth, shell-based and bottom-based horizons already existed, devising this landscape by the 11th century as already a shared heterodox environment. Nevertheless, orthodox communities originating in the Adriatic followed a separate practice regarding installing the master frame. Frame installation initially relied upon dual master frames: two identical floor timbers with a single futtock attached to each outer face of the wrongheads in the direction of the nearest end post. Dual master frames are somewhat ubiquitous across the Mediterranean, but the Adriatic shipbuilders by the 14th century chose instead to follow a practice of a single master frame with two futtocks on either end. Ships built along the Ligurian coast seem to adopt the single master frame practice, and this same initial construction was carried over as frame-based shipbuilding became widespread in the Atlantic. The latter observation ties into the constellation of practice between enclaves that migrated beyond the confines of the Mediterranean. In a similar perspective, the shared frame-based horizon throughout the Eastern Mediterranean allowed Venetian officials to search the Agean for Greek master shipbuilders to take over leadership and instructor roles within state arsenals [115].

The adoption of frame-based practices also included differences in interpretation. Several western ships showcase the futtocks attached in reverse on the sides toward amidships, while the Rhodes 4 hull provides the only eastern example of this practice. Scarfs connecting key floor-timbers and first futtocks were rare in earlier eastern shipbuilding and became widely adopted in the west. This practice found its way into later eastern construction with shallower rebates in comparison. Similarly, the abundance of treenails from ships originating on the northwestern coast is a signature occasionally employed in other Mediterranean regions. This heterodox environment also allowed earlier practices from shell-based construction to continue their existence within the frame-based landscape. For instance, the continual use of scarf joints between strakes was essential for the edge-joined planking connections and became obsolete in frame-based construction. Planking scarfs on eastern vessels, such as Serçe Limanı, Boccalama B, and Rhodes 2, suggest anachronisms from the earlier shell-first horizon fulfilling habitus without providing actual construction benefit [45,73,77]. The decision by several communities of practice to continue sealing the inside of a frame-based hull with pitch is another example of habitus taking priority over pragmatism.

Adopting and embracing frame-based construction beginning in late antiquity was a non-linear process. The same could be said about the communities of practice across the Mediterranean in the late medieval and early modern periods. Overlapping construction practices left behind earlier shell-built and bottom-based techniques that sometimes added no apparent benefit to the frame-first architectural project. These horizons also produced a general heterodox community that shared the encompassing operational process of assembling a frame-based hull but included orthodox regional differences on how the result was achieved. Apart from the limitations in the current sample set, it would be difficult to provide a map laying out the practices and presenting borders between communities. Practitioners were widespread, and in social learning environments, any boundaries were permeable, allowing the exchange and development of new techniques between groups. Additional finds may define the continued overlap between the practice horizons present in the Mediterranean, the similarities and differences between communities of practice, and novel hull profiles influenced by the atmospheric and aquatic environment. The connections between several northern Italian enclaves and the transition of frame-based construction in the Atlantic and Northern European ports provide another avenue for exploring how constellations of practice melded in border regions with different horizons not as familiar to Meditteranean shipbuilding communities.

7. Late 17th-Century Shipbuilding in France: A Second Case Study on Social Organization and Framing Pattern

Thanks to the efforts of archaeologists from all over the world over the last three decades, the corpus of known and archeologically excavated French shipwrecks has reached a size where comparative analysis is achievable. This case study seeks to understand variations in late 17th-century French shipbuilding practices based on this collection of associated remains. An operational process approach in the light of communities of practice will focus on the individuals involved in shipbuilding in addition to a social understanding of shipwreck remains.

7.1. Shipwrights Corporations as Communities of Practices

The social structure through which shipwrights learned their practice in late 17th-century France took the form of corporations. These organizations acted as communities of practice where the learning curriculum brought not only the technical knowledge for shipbuilding but also the social legitimacy to the title of shipwright, especially the title of a master shipwright.

Three prominent corporations were present in late 17th-century French naval yards: the shipwrights, the caulkers, and the drillers [116–118]. Other smaller corporations (e.g., sail-making, rope-making, iron forging, rigging, and additional specific trades) were also present. The shipwright's corporations were organized with the masters at the top of their art and a ruling council. Each master shipwright had to take apprentices in addition to other responsibilities such as financial management, quality management, ombudsman, or other tasks. Some masters were more potent than others and were put in charge of supervising ship construction for the entire arsenal. The master shipwrights had a seat at the Construction Councils created in 1671 to discuss and present building projects.

The 1681 Ordinance set apprenticeships for two years [119]. Apprentices had to pay not only the corporations but also their masters in exchange for supervision and a place at their table. Only the sons and sons-in-law were exempt from this payment. This free-of-charge education gave them undeniable advantages. It was likely that master shipwright status was passed from father to son. Once two years transpired, the apprentice had to present a masterpiece: a small boat, a rudder, or a capstan. Again, sons and sons-in-law could provide smaller masterpieces and be exempt [118]. Once the corporation counsel approved the masterpieces, the apprentices became companions (or shipwrights, depending on the nomenclature). They could then work on the hull directly, which the daily workers were not allowed to do. The latter was below the companions. Their daily tasks are not always straightforward, nor is their affiliation with the corporations. Daily workers were involved with a different step of the construction process, which did not involve the hull or any other crucial structures.

There was a growing standardization in the shipbuilding industry. It was accompanied by the monopolization of raw materials, an organization of human labor, and the elaboration of a state-administered bureaucracy and a regulated production schedule [120–123]. Despite an organizational scheme that could lead to the impression that shipwrights were coordinated, it remains a social structure not ruled by formal law. The experience was vital, alongside family affiliation, to pass down knowledge and ensure continuity [124–126]. Dynasties of shipwrights' families are recognized throughout shipyards in the 17th and 18th centuries.

The corporation structure constituted a channel through which practices were passed down. Being a shipwright, therefore, was not only a question of technical skills but also one of social recognition by their peers.

When facing off against naval officers and arsenal administrative power, the master shipwrights' knowledge and social belonging provided a seat at the Construction Councils despite their lower social status. The fact that their knowledge was not shared outside the master-apprentice relations also gave master shipwrights power in a Gidden's sense. Shipwrights were the unique recipient of knowledge that allowed them to impose how a ship would be built and resist the standardization by officials. This situation would change a century later with a significant power shift as the introduction of institutional schooling and formal education disrupted the traditional apprenticeship system.

The corporation system also provided fertile ground for creating solid regional traditions. With the apprenticeship system, the shipbuilding practices went through reproductive cycles, being passed down from generation to generation. Master shipwrights held on tight to their ways of building ships, arguing about the best techniques [127]. In this aspect of their work, the resistance to standardization, and the strength of regional practices are documented archaeologically. An operational process approach can demonstrate the existence of traditions and interactions among this network of shipwright communities.

7.2. Methodology

By deconstructing the different steps and understanding what each entails in terms of technique, resources, and knowledge, ships appear as multifaceted structures through which information can be inferred. When each ship is described individually, it is possible to move to a comparative approach based on their features and how each ship exhibits different technical answers. Multi-site comparative analysis is rare for architectural features due partly to the sample sizes that vary according to the period and geographic area, the variation in site preservation and excavation, and the data availability. These data limitations could, at first sight, prevent the application of the operational process. It is still possible to work on specific aspects where enough data can be compared with one another.

The operational process presented by Pomey and Rieth does not provide the complete sequence of an entire ship [23]. Ships can be divided into smaller sections according to their material, shapes, dimensions, or proportions [35]. This reduction is the fifth layer Pomey and Rieth called the implementation sequences. It is possible to add new categories to their sequences to deal with specific features instead of focusing on the order for the entire ship.

A corpus of known and archaeologically excavated French shipwrecks was used for this comparison (Table 2). These sites were chosen for their cultural affiliation to France and construction dates during the era of Louis XIV (1643–1715) since they share a common socio-cultural and environmental resource background (Figure 5). Since they were all restricted by the same environmental forces, as all were ocean-going vessels, they shared the same navigational environment and had a common conceptional background.

This study includes *La Belle*, built in 1684 at Rochefort, France, and sunk in Matagorda Bay, Texas, USA, in 1686 [128,129]. The five wrecks of La Hougue [130–138]. These five first-rate warships were sunk in 1692 during the battle of La Hougue. The ships were identified as the following: *St-Philippe*, 80 guns built in 1665 in Toulon, the *Magnifique*, an 80-gun ship built in 1680 in Toulon, the *Merveilleux*, a 96-gun ship built in 1691 in Brest, the *Foudroyant* a 94-gun ship also built in 1691 in Brest, and the *Ambitieux*, 96 guns built in 1691 in Rochefort.

French third-rate, *Hasardeux*, built in Lorient, France, in 1701, was also included [139,140] (Grant Ian pers. comm). The British Navy captured *Hasardeux* several months later and renamed it HMS *Hazardous*. This ship continued service in the Royal Navy for three years before it sank in Bracklesham Bay, England, during a storm in 1706. Finally, *La Dauphine* and *Concorde*/*Queen Anne's Revenge* were added to the list. *La Dauphine* was a privateer frigate built in 1703 in the royal arsenal of Le Havre and sank near Saint-Malo in 1704 [138,141,142], *Concorde* was built in Nantes for the slave trade in the early 18th century. The first mention of the ship was in 1710, as it was being outfitted for privateering [143,144]. The infamous pirate, Edward Teach, known as Blackbeard, captured *Concorde* in 1717 and renamed it *Queen Anne's Revenge*. The ship was marooned in 1718.

In addition to the shipwrecks, the construction treatises published in the same period that included details about the framing patterns were added (Table 3). These documents came in two types. The first were the ones written by shipwrights, and the second were the ones written by different officers or observers of shipbuilding. This first category included the two manuscripts by François Coulomb, one of the first French shipwrights who learned technical drawings. He was the son of Laurent Coulomb, master shipwright in the Toulon arsenal. François Coulomb published two documents: *Proportions d'un vaisseau de 5e rang* in 1683 and *Le livre de construction des vaisseaux* in 1686 where he used plans to illustrate his construction procedures [145,146].

The second category included Father George Fournier's *Hydrographie contenant la théorie et la pratique* edition of 1667 and the plates from the *Album de Colbert* published in 1677 [147,148]. Finally, the unknown author of the 1691 *Construction des vaisseaux du Roy* was added since it included drawings depicting frames and Charles Dassié's 1695 *Architecture Navale* [149,150].

Table 2. French shipwrecks that were examined in the cross-comparative analysis.

Ship	Construction Date	Shipyard	Shipwright
La Belle	1684	Rochefort	
Wreck A/B: *Le St-Philippe*	1665	Toulon	Gédéon Rodolphe
Wreck C: *Le Magnifique*	1680	Toulon	François Chapelle
Wreck D or E: *Le Merveilleux*	1691	Brest	Blaise Pangalo
Wreck D or E: *Le Foudroyant*	1691	Brest	Blaise Pangalo
Wreck F: *L'Ambitieux*	1691	Rochefort	Honoré Malet
Hazardous	1701	Lorient	
La Dauphine	1703	Le Havre	
Queen Anne's Revenge	post 1710	Nantes	

Table 3. Construction treatises examined in the cross-comparative analysis.

Table 1667.	Author	Year
Hydrographie contenant la théorie et la pratique de toutes les parties de la navigation	George Fournier	1667
Album de Colbert	Unknown	1677
Proportions d'un vaisseau de 5e rang	François Coulomb	1683
Livre de construction contenant les proportions de châque rang de navire comme aussy les proportions de la masture, manneuvres, canon, les noms de tous les vaisseaux du Roy tant de ponant que de levant	François Coulomb	1686
Construction des vaisseaux du roy et le nom de toutes les pièces qui y entrent	Unknown	1691
L'architecture navale avec le routier des Indes orientales et occidentales	Charles Dassié	1695

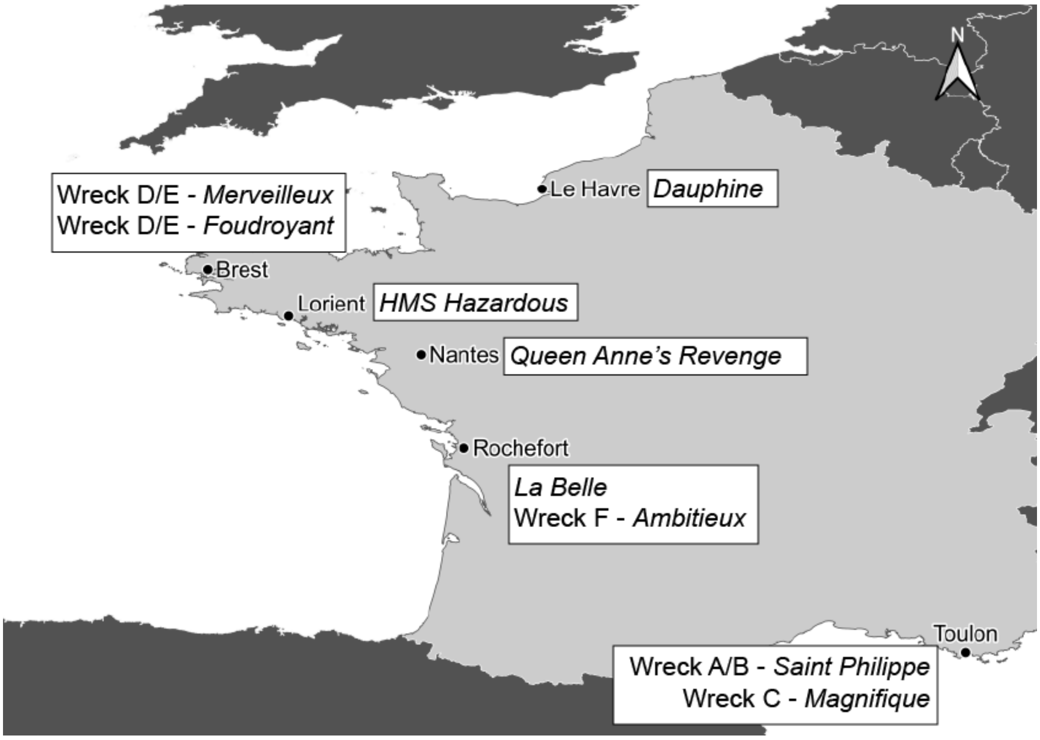

Figure 5. Origins of known late 17th-century and early 18th-century French shipwrecks. Illustration by the author.

7.3. Results

The archaeological and historical data of late 17th-century shipwrecks provides a compelling overview of the period's diversity in the construction and design process. The archaeological data indicate the coexistence of two general framing patterns: the single-framing pattern and the double-framing pattern (Figure 6). The latter is subdivided into light double framing and full double framing.

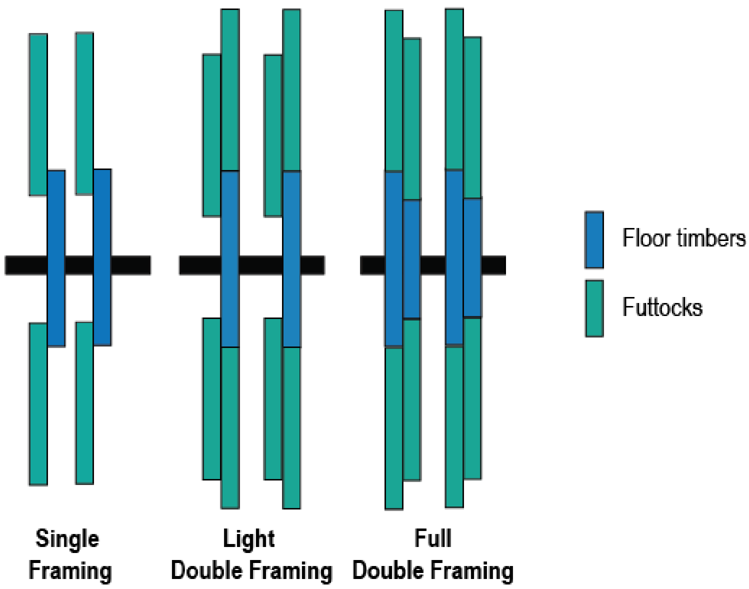

Figure 6. The three general framing patterns observed on the La Hougue wrecks. Illustration by the author based on Elisabeth Veyrat in L'Hour and Veyrat, 2000.

7.3.1. Single Framing Pattern

The single framing pattern can be summarized as a single floor-timber and its futtocks on either side of the keel. There is minimal overlap between the elements of the frame. Both the wrecks A/B and C from La Hougue are archaeo logical examples of this framing pattern (Figure 7). In addition, it is the pattern described by Fournier and the Album de Colbert.

On these wrecks, the single framing pattern is a single floor-timber with a first futtock on either side of the keel, along with the upper futtocks. The floor timbers faced toward the master frame, while the first futtocks faced either the bow or the stern, depending on which side of the master frame they were on.

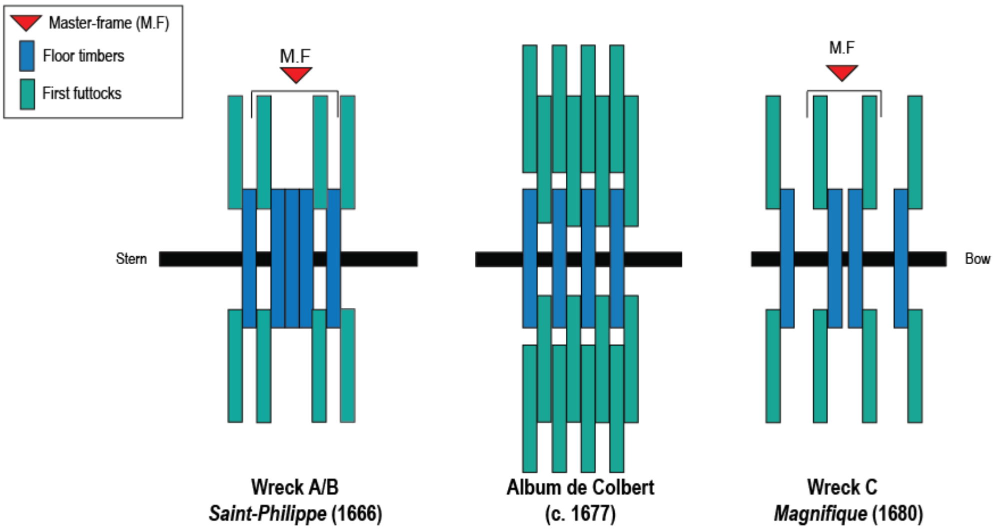

Figure 7. Arrangement of frames for the single-framed pattern on wrecks A/B and C. by Elisabeth Veyrat in L'Hour and Veyrat 2000, adapted by the author.

In Fournier's manuscript, scant information is directly available about framing patterns. A closer look between the lines can provide insight into the ship's frames. First, a frame is mentioned as *côtes* (ribs), a term usually used in opposition to *couple* for double frames [147]. Fournier describes the floor-timbers as having curved extremities joined to the first futtocks. The word *empâter* is used by Fournier to define the scarfs between the floors and the futtocks, but the precise meaning is not known. The use of ribs as a synonym for frames and the fact that floor-timbers and futtocks are joined only at the extremities suggests a single framing pattern. In the *Album de Colbert*, all floor-timbers face the stern, while the first futtocks face the bow on both sides of the master frame.

On Wreck A/B, the master frame is a single floor timber with two floor timbers with their respective futtocks on either side. Wreck C has the master frame as two floor timbers next to one another with their own set of futtocks on opposite sides. In the *Album de Colbert*, the master frame is two floor-timbers and their futtocks.

An interesting feature on both wrecks is the absence of visible scarf, nail, treenail, or bolt between the floor-timber and the first futtocks. As for the upper futtocks, Wreck A/B has evidence of treenails, hook scarfs, and butt-joined pieces. This level of detail is not described in the manuscript. At the same time, some of them can be observed on the *Album de Colbert* plates. There are no scarfs visible between the floor timbers and the futtocks, and no scarfs between the upper futtocks. No type of frame timber fastening is visible on the drawing, but the scale probably did not allow for such small details.

7.3.2. Double Framing Pattern

The double-framed ships present two different types of framing based on the presence or absence of half-floor timbers (Figure 8). Light double framing pattern consists of one floor-timber and its associated futtocks observed on Wreck F (1691), *La Belle* (1684), and *La Dauphine* (1703). It is also the framing described in *Construction des vaisseaux* (1691). The full double framing pattern was identified in Wreck D and Wreck E. It is impossible to state whether *Hazardous* or *Queen Anne's Revenge* was framed with or without a half-floor timber.

Regarding light double frames, the three wrecks have the same pattern: there are no half-floor timbers, and the floor timbers are facing toward the master frame. Wreck F has a significant difference with its seven full double frames, among which the forward-most double frame is the master frame. It can also be noted that *La Dauphine* has a series of chocks between the floor timbers, under the keelson, and unattached to the hull. In the 1691 manuscript, there is a drawing with the different components of a frame where we can see the first futtock having a scarf to fit the floor-timber and the following futtocks (Figure 9). There are no short futtocks.

Illustration by Unknown 1691. Construction des vaisseaux du roy et le nom de toutes les pièces qui y entrent Avec toutes les proportions des rangs, leur explication et l'exercice du cannon. Bibliothèque nationale de France, https://gallica.bnf.fr/ark:/12148/btv1b8626226w?rk=21459;2. accessed on 3 June 2021.

As for the master frame, Wreck F's double master frame also had an additional set of futtocks located forward. *La Belle* was similar, with a master frame made of single floor-timber with three sets of futtocks. As for *La Dauphine*, the description of its master frame is not available.

Regarding assembling the various frame elements, *La Belle* and *La Dauphine* have their floor timbers and futtocks assembled with transversal iron bolts. This information is not available on Wreck F. Additionally, on *La Belle*, the surmarked frames had three fasteners per joint, while the other frames only had two iron bolts. *La Dauphine* has iron bolts between the frame elements, which are also connected with hook scarfs or by butting.

For the full double framing pattern, Wreck D and Wreck E are examples of that pattern (Figure 10). Wreck D was in a poor state of preservation, and very few observations were possible. It was possible to determine that it had the same frame features as Wreck E, which is also confirmed by the fact that they were sister ships. Wreck E's frames were made with a floor-timber, a half floor, and their associated futtocks. On both sides of the master frame, the half-floor timbers face the master frame, while the floor timbers face either the bow or the stern. The master frame was made with half-floor timber, and its futtocks with floor timber and futtocks were also on both sides.

On Wreck E, the floor timbers were assembled with the futtocks using diagonal scarfs and iron bolts. The futtocks were assembled with diagonal and hook scarfs, iron bolts, and treenails. In the forward section, the treenails were obliquely driven facing the stern, while in the aft section, the treenails were obliquely driven facing the bow. These features are related to the assembly sequence of the frames. While the full double framing pattern was not the most common in the late 17th-century shipwrecks and manuscripts, it became the most common in 18th-century France.

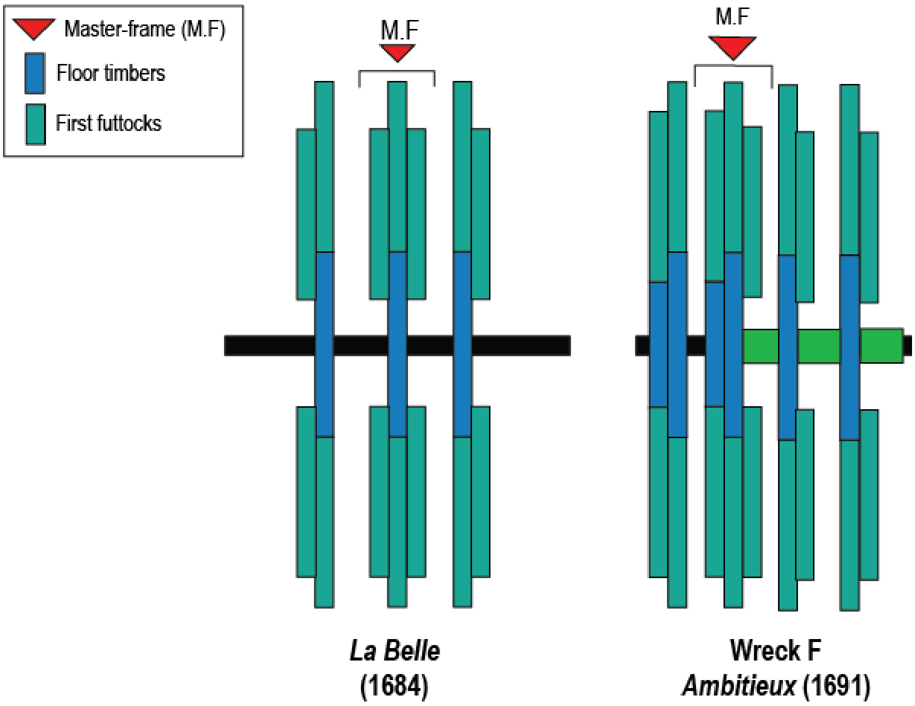

Figure 8. Arrangement of the frames for the light double-framed wrecks *La Belle* and Wreck F (*Ambitieux*). Wreck F by Elisabeth Veyrat in L'Hour and Veyrat 2000, adapted by the author.

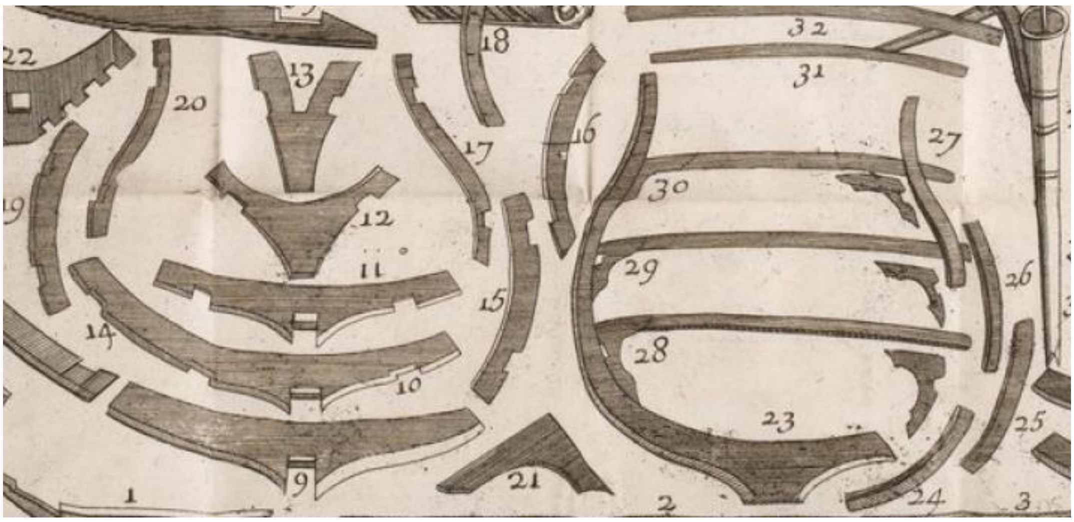

Figure 9. Illustration of the components of a frame by an unknown author (1691).

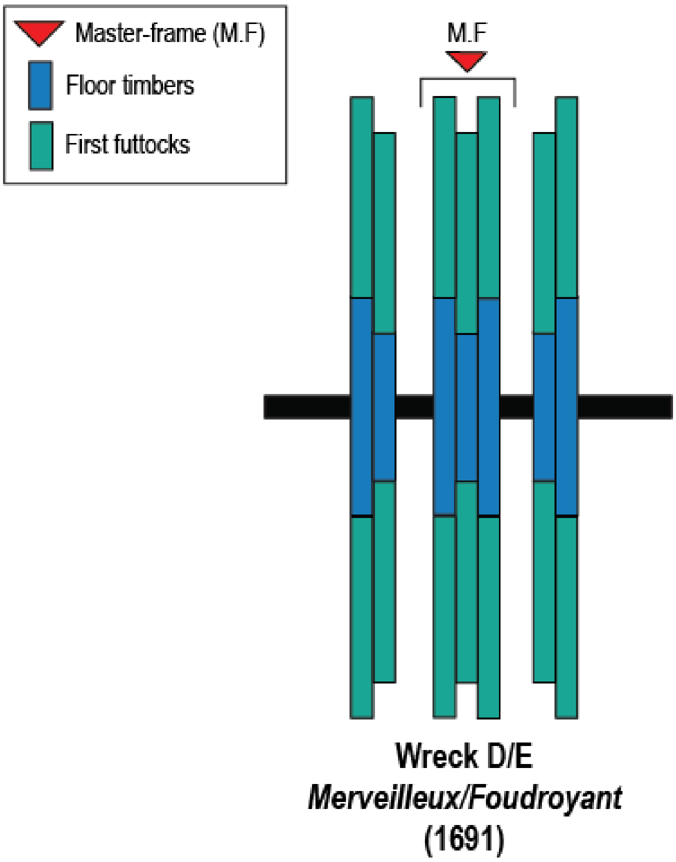

Figure 10. Arrangement of the frames for the double-framed wrecks D and E (*Merveilleux*/*Foudroyant*). Illustration from Elisabeth Veyrat in L'Hour and Veyrat 2000, adapted by the author.

7.3.3. The Case of Coulomb's Manuscript

François Coulomb was one of the first shipwrights to learn technical drawing before the maturity of ship lines [126]. His manuscript, *Proportions d'un vaisseau de 5e rang*, is the oldest French text written by a shipwright. Jean-Claude Lemineur transcribed and analyzed the document to reconstruct a fifth-rate warship [146].

According to Lemineur, Coulomb describes two framing patterns (Figure 11). The first is the same in the *Album de Colbert*: a single frame of one floor-timber and its futtocks with limited overlap. There is room between the head of one piece and the foot of the next, while there is no space between each frame. Coulomb indicates that this is the "old way". According to Coulomb, the second and "new" way is a significant overlap between the floor-timber and futtocks and space between the frames (as seen on *La Belle*). This pattern is closer to the full double frame that became common in the 18th century.

In the 1686 manuscript, Coulomb does not provide a direct description of a frame, but it can be deduced. Coulomb lists the floor timbers and the futtocks but not half-floor timbers. He also provides the dimensions of the floor timbers, first futtocks, and second futtocks for the five rates. The dimensions of the frame pieces, connected with the evidence of the 1683 manuscript mentioned earlier, point toward either a single frame pattern or a light double framing. Moreover, Coulomb's 1683 manuscript indicates the coexistence of different framing patterns within one shipyard. The 1683 manuscripts support the idea of evolution between a single framing pattern with limited overlap to a pattern with significant overlap. This change points toward adopting full double frames and changes in ship design.

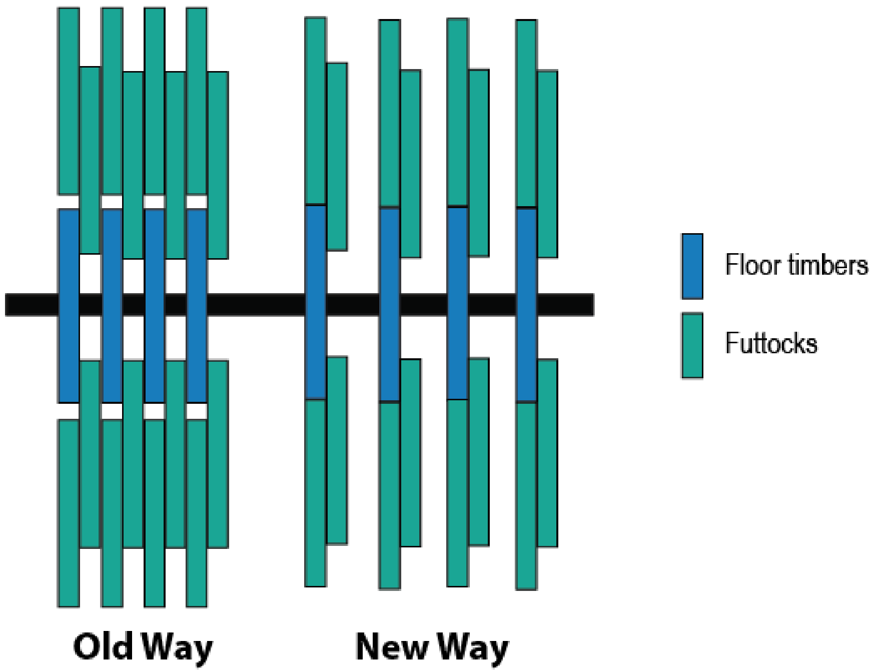

Figure 11. Illustration of the old and the new way of frames described by F. Coulomb. Illustration by the author based on Elisabeth Veyrat in L'Hour and Veyrat, 2000.

The analysis of the late 17th-century and early 18th-century French shipwrecks and their contemporary manuscripts highlighted variations in architectural features. While regional similarities exist, the diversity of approaches within a shared pattern suggests a common technical background and distinctive knowledge.

Shipwrights constituted communities of practice through a body of knowledge, identity, enculturation, and social interactions. Their communities provided the social context for cultural transmission through a more or less formal relationship between the master and the apprentice. This apprenticeship was not neutral but rather a process of enculturation influenced by multiple factors, in part by the habitus of the community. Additionally, shipwrights become shipwrights (or master shipwrights) through their practice. Their craftsmanship is the evidence of their professional personhood. Therefore, shipwrights produced and reproduced their social and material conditions through their corporations and practices.

8. Conclusions

In each nautical case study, social learning and communities of practice provide an opportunity to grasp the societal process of shipbuilding. Shipwright communities replicated knowledge through legitimate peripheral participation within a specific social structure thanks to communal organizations and the apprenticeship system.

Shipwrights are rarely described as active agents in archeological reports, and the focus is usually on larger technological trends that exclude human agency to explain variation and similarities. While it would be wrong to assume that shipwrights were entirely influenced by their sociostructure dictating their actions and decision-making capacity, it is also mistaken to see them as passive individuals. Craftsmen were not mere replicators; they were engaged in a social learning process of enculturation influenced in part by the habitus of their community. This community of practice existed through a body of knowledge, techniques, and social interactions.

When a master shipwright took an apprentice, he engaged in social interactions, creating a channel for transmitting important information. Moreover, the nature of this information was not purely technical knowledge; it was dispersed with personal behavior and experience. This participation sometimes included defiance, whether in competition with other master shipwrights for prestige or rallying against the development of standardization by naval officials. It was neither a neutral act nor a simple action of replicating a technical operation. Shipwrights were part of a more comprehensive social network, and these relationships also played a role in how they behaved. Social networks can also explain variations, as habitus is not a homogenous characteristic. Not everyone agrees on different technical aspects, and these disagreements can be expressed through variations in archeological remains.

Just as modern human technologies can be the nexus through which social and material conditions are produced and reproduced, ancient technologies behaved the same. With the help of shipwreck remains thoroughly recorded and published, the ancient ways shipwrights navigated their social and material conditions can be equally represented. This perspective calls for a greater emphasis on the social aspect of shipwreck remains to go above and beyond the usual technology-grounded narratives of ship design, construction, and navigation.

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