Forestry practices and hull design, ca. 1400-1700

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Wherever ships have been built, the acquisition of shipbuilding materials has left an archival trail and the eyes of historians have thus turned naturally to the relation between forests and shipbuilding. Their studies reveal the state's growing interest in forestry from the 15th to the 17th centuries, mostly in support of national shipbuilding programmes. The precocious Mediterranean, as the examples of Venice and Genoa demonstrate, intensified the exploitation of oak forests at the end of the middle ages.[1] In 16th-century England, monastic lands were seized and the timber on these lands was aggressively harvested, disrupting traditional forest economies and creating the exhorbitant wealth of "timber merchants". When the new timber economy ran into shortages at the time of the Dutch wars and the London fire in the 17th century, large areas of the Forest of Dean were reserved for naval timber, while John Evelyn and Samuel Pepys formulated their ideas on forests and national policy.[2] Also in the 17th century, the growing naval ambitions of the French state prompted Jean-Baptiste Colbert to plant the forests of Nevers and Alliers, experimenting with red oak species from America.[3] The articulation, on a local level, of state shipbuilding and forestry programmes has been explored in the case of 16th-century Biscay, where subsidies for growing oaks were linked to shipbuilding bounties since the union of the coastal Basque provinces with Castille in the 13th century.[4] The Lusitanian timber problem was slightly different. Here, at the southern limit of its natural range, the European oak could not sustain the maritime ambitions of the state and, in the 16th century, timber suppliers turned to stands of cork oak in the middle Tagus for frames and the pines of Leire for planking.[5]

This generalized movement toward reserving forests for state shipbuilding coincided with the appearance of the first texts on hull design in 1570-1620 which were, without exception, produced in the context of the same shipbuilding programmes. These "architectural treatises" not so much heralded a new theory of hull design as they described daily

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[1] F.C. Lane, *Venetian Ships and Shipbuilders of the Renaissance* (Westport, Conn.: Greenwood, 1957), F. Ciciliot, *Nautica Genovese. Tipologia delle imbarcazioni di Varazze alla fine de Medioevo* (Savona: 1993); F. Ciciliot and G. Paola, "I boschi ed il legname per uso navale", *Proceedings of the Ecology Society of England, Nottingham, 1996.*

[2] S. Pepys, *Diary*, 1660-1668 (J. Warrington, ed.; London: Dent, 1953); J. Evelyn, *Sylva. A discourse on forest trees and the propogation of timber...* (London: 1679); R.G. Albion, *Forests and Sea Power: the Timber Problem of the Royal Navy*, 1652-1862 (Cambridge: Harvard University Press, 1926).

[3] P. Bamford, *Forests and French sea power*, 1660-1789 (Toronto: University of Toronto Press, 1956); H.-L. Duhamel du Monceau, *Du transport, de la conservation et de la force des bois...* (Paris: Leroi, 1835); M. Leroy, *Mémoire sur les travaux qui ont rapport à l'exploitation de la mâture dans les Pyrénées* (Paris, London: 1776).

[4] G. de Artiñano y Galacano, *Arquitectura Naval Española en Madera* (Madrid, 1920); J.L. Casado Soto, *Los Barcos Españoles de Siglo XVI y la Gran Armada de 1588* (Madrid: San Martín, 1988); M. Barkham, "La construcción naval en Zumaia, 1560-1600. Estructura y organización de una industria capitalista mercantil", in S. Barkham, ed., *Itsasoa 3. Los vascos en el marco Atlántico Norte. Siglos XVI y XVII* (San Sebastian: ETOR, 1988), pp. 211-274.

[5] L. Freire Costa, *Naus e Galeões na Ribeira de Lisboa. A constução naval no século XVI para a Rota do Cabo* (Cascais: Patrimonia Historica, 1997).

practice in a thousand shipyards on the European seaboard.[6] They also helped to address a need for large-scale planning in the state shipbuilding process, from the forest to the launching cradle, whose scale greatly surpassed that of private construction. The 1616 treatise of Manoel Fernandes, for example, contains lists of the timbers required for a ship, while the texts of Fernando Oliveira and João Baptista Lavanha contain lengthy passages on the supply of timber and other materials.[7] The Spanish shipbuilding ordinances of 1613 and 1618 also include sections on the organisation of the trades in the arsenal. The contrasts with private construction are numerous. Stockpiling timber, a rare practice in private shipbuilding, was the rule in state arsenals. Whereas the arsenals acquired entire trees and applied them to any of several ship being built, in private construction trees were harvested with one ship in mind and the timber was readied in the forest to reduce the cost of transport.[8] Supervising and supplying a score of crafts in a state arsenal required intensive planning and a rethinking of professional knowledge at a level of organisational complexity well beyond what was needed in even the most developed networks of artisans and merchants in the contractual world of private shipbuilding.[9] In this sense, the new profession of naval architect at the helm of a complex organisation was decidedly different from the ancient craft of ship carpenter.

Yet, as guides for managing arsenals, the treatises may also have had some basis in existing commercial practice. To explore the link between hull design and forestry, no textual analysis can reveal as much as a study of actual ship's timbers. The archaeology of ships reveals numerous aspects of Renaissance naval forestry, an art that has been all but forgotten. This art, and its practitioners, fixed the parameters of hull design many years in advance of the shipwright who eventually worked out the dimensions, proportions and geometry of a given ship.

The frames of the Red Bay vessel

An exceptional archaeological document for many aspects of 16th-century shipbuilding is the so-called Red Bay vessel, a Basque ship of 200 to 250 tons that was loaded with whale-oil *barricas* when it was lost on the south coast of Labrador. Presumed to be the *San Juan* of Pasajes which foundered at this spot in 1565, the wreck was excavated from 1979 to 1985 by Parks Canada, under the direction of Robert Grenier. Although the hull had opened up like a book on the seabed, it was largely intact up to the water line. While the

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6 R. A. Barker, "Design in the Dockyards, about 1600", in T. Reinders, K. Paul, eds., *Carvel construction techniques* (Oxford: Oxbow, 1991), pp. 61-69; S. Bellabarba, "The ancient methods of designing hulls", *Mariner's Mirror*, 79 (1993), pp. 274-292; C. Apestegui Cardenal, commentary in F. Fernandez Gonzalez, *et al*, eds., *Arte de Fabricar Reales* de Antonio de Gastañeta Yturribalzaga, 1680 (Barcelona: Lunwerg, 1992); B. Loewen, "Codo, carvel, mould and ribband: the archaeology of ships, 1440-1620", *Mémoire-vive*, 6-7 (1994), pp. 6-21; E. Rieth, *Le Maître-gabarit, la tablette et le trébuchet* (Paris: CTHS, 1996).

7 M. Fernandes, *Livro de Traças de Carpinteria,* 1616 (facsimile, Lisbon: Academia de Marinha, 1989); J.B. Lavanha, "O Livro Primeiro da architectura naval", c. 1600-1620 (Madrid, Library of the Royal History Academy, Salazar, Ms 63; facsimile, Lisbon: Academia de Marinha, 1997); F. Oliveira, *Livro da fabrica das naos*, 1570 (tr. Manuel Leitao, Lisboa: Academia de Marinha, 1991).

8 C. Rahn Phillips, *Six galleons for the King of Spain. Imperial defense in the early seventeenth century* (Baltimore: Johns Hopkins University Press, 1986; P. Pomey, "Conception et réalisation des navires dans l'Antiquité", in E. Rieth, ed., *Concevoir et construire les navires, de la trière au picoteux* (Ramonville Saint-Agne: Érès, 1998), pp. 49-72; B. Loewen, *The Red Bay vessel and 16th-century Biscayan shipbuilding* (Ottawa: Parks Canada, forthcoming).

9 M. Aroztegui, *El Rey...* (1613, 1618), "Palha manuscripts", Houghton Library, Harvard University, Cambridge, MS 4794, vol. 2, unpaginated; published in Gervasio de Artiñano y Galacano, *op. cit.*, app. 9; *Arte de Fabricar Reales* de Antonio de Gastañeta Yturribalzaga, 1680 (Barcelona: Lunwerg, 1992).

upper works were broken up, the timbers were deposited near the hull and from these, analysts were able to reconstruct the dead works and the castles of the whaling *nao*.[10]

Excavation methods pioneered at Red Bay have since been widely applied in underwater archaeology. The hull was disassembled and its 3,000 pieces were brought to the surface where they were photographed in sufficient detail to reveal tool marks and the grain of the wood, and each piece was then drawn at a 1:10 scale. These drawings, prepared according to architectural standards, include three types of information. First, they record the shape of the timber, typically from three views and including at least two sections. Second, the drawings indicate the position and course of all the fasteners such as treenails, iron nails and bolts. Third, exceptional features in the surface of the wood were noted, including areas of sapwood, degraded wood and unusual tooling. These photographs and scale drawings made up the essential data base for the study of the ship, after the timbers had been reburied on the site.

Four elements of this data base relate to the forestry practices that underlay the design and construction of the Red Bay vessel. First of all, each futtock and floor timber represented the entire section of a trunk or branch. Only two futtocks and four floor timbers represented half a tree's section. Study of the ends of these timbers reveals that the heartwood, situated in the middle of most timbers, was offset at one side in these six timbers. This information was confirmed by the presence of "waney edges" along the timber, that is, areas along the length of the timber where the normally-squared edges retained the natural roundness of the tree. When an entire tree had been used to make up the timber, "waniness" was observed on all four edges of the timber at some point along its length. In the cases of the six half-sections, the waniness occurred only along two edges.

Secondly, the frames of the Red Bay vessel exhibited a close relation between the sculpted arc of the finished timber, and the natural curvature of the parent piece (figure 1). This relationship, which was revealed by following the grain of the wood along the timber's curved shape, was confirmed by noting precisely where the areas of waniness occurred along the four edges. In a curved timber such as a first futtock which formed the turn of the bilge and the flaring section of the hull, the waney edges were concentrated in two areas along the length of the timber. Near the middle, the waniness occurred on the two outboard edges, on each side of the convex face of the timber. This finding reveals that the relatively sharp curve of the futtocks was difficult to find in an oak and the original shape of the tree was slightly less curved than the eventual timber. Accordingly, waney edges were also preserved toward the ends of the timber, but on the inboard edges, that is on the concave face of the timber. This pattern of waniness was consistent, confirming that the trees had been slightly less curved than were the final shapes of the futtocks. Despite this variance, the natural and finished curves were remarkably close, not only for the rounded futtocks in the middle of the ship, but also for the S-shaped first futtocks at the gripe and tuck. Thus we learn that the trees used to make the futtocks had been curved to almost the precise shape that was required for this ship. Was the shape of these trees natural? In fact, their curvature was quite pronounced. If one drew a straight line from one end of a first futtock to the other, the central part of the timber was offset from this line by 50 to 70 cm. Looking at unpruned European oak trees today, one quickly finds that lengths having such a curve, with a diameter of 30 cm and a length of 3 to 4 meters, do not often occur naturally, and cannot be relied upon to do so in commercially viable quantities.

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[10] R. Grenier, "Basque whalers in the New World: the Red Bay wrecks", in *Ships and Shipwrecks of the Americas* (London: Thames and Hudson, 1988), pp. 69-84; articles by J.-P. Proulx, M. Izaguirre Lacoste, E. Rieth, B. Loewen and J.-P. Chrestien in J. Bourgoin, ed., *L'aventure maritime, du golfe de Gascogne à Terre-Neuve* (Paris: CTHS, 1995), pp. 112-169. Special thanks are due to the staff at Parcs Canada and especially Robert Grenier.

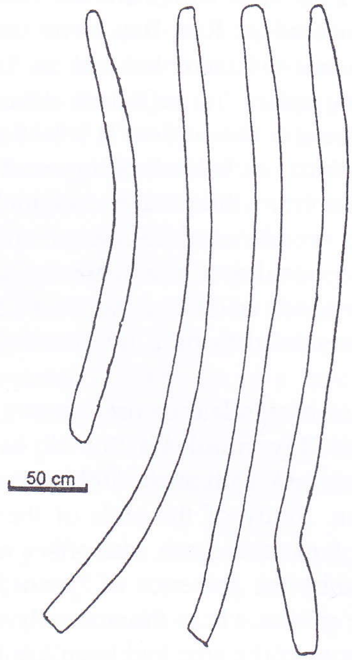

Figure 1. The four essential futtock shapes found in the Red Bay vessel. From left to right, a second futtock; three first futtocks from the central part of the hull, near the quarters and at the stern.

The third observation which concerns the timber supply for the frames was the tree's original diameter (not counting the bark), which was no more than 50% greater than the section of the finished timber. In many cases, it was possible to measure the radius of the tree at each end of the timber, from the heartwood to the waney edge. In all the timbers of the vessel's 48 frames, waniness was observed at some point along their edges. Thus it is clear that, not only was the tree's entire section used and its natural curve chosen to correspond with the finished shape of the timber, but the tree's diameter as well was very close to the eventual scantlings of the frame. This correspondence between the original diameter and the finished section is all the more remarkable for the fact that the Red Bay frame timbers are square and their scantlings are perfectly regular: they measure 19 cm at the bilge, 17 cm at the first deck, and 14 cm at the upper (third) deck. The waste of material had been kept to its strictest minimum, or rather, the needs of the carpenter had been perfectly foreseen by the timber grower.

The fourth observation concerns the correspondance between the length of the tree and that of the frame timbers. No branches or knots of any kind were found on the curved frame timbers, except at the very upper end in several instances. The length of the timbers was between 3 and 4 meters, with the first futtocks being the longest and the floor timbers, second and third futtocks being of about equal length. While it is quite common to find oak timber without branches to such a length, it is significant to observe that in no case did an embranchment blemish the piece's required curvature, diameter and length.

When these four elements are considered together, they suggest that 16th-century Biscayan shipbuilders had access to an ideal supply of frame timbers. First of all, one piece produced one frame timber. Second, it was possible to find pieces that had nearly the precise curve required for each frame timber along the length of the ship, regardless of the hull's shape at this point. Third, these pieces had just the right diameter so that no wood might go to waste. Finally, the piece had no branches along the length where the desired curve and diameter were found. The Red Bay ship is not unusual among 16th-century Basque and Iberian ships to demonstrate such an ideal timber supply, although in some cases such as the Western Ledge Reef wreck in Bermuda, the lower ends of the first futtocks have a gnarled grain indicating that the pieces were cut at their base.[11] These shipwrecks eloquently confirm the statements of 16th- century observers that the Basque province of Guipuzcoa was a land rich in oak forests.[12] However they also reveal that these forests were carefully harvested to meet the specific needs of each shipbuilding project and that cutting ship's timbers was far from being an uncontrolled activity in a virgin forest.

The age of frame pieces

Due to the reburial of the Red Bay timbers, one of the most original observations about Biscayan naval forestry must remain preliminary. During the selection of timbers for dendrochronological study, the tree rings of numerous pieces were counted visually, which brought to light a difference between the hull planks and the frames. The planks were taken from trees that were often over a hundred years old, in one case nearly two hundred years. The typical age was between 80 and 150 years. On the other hand, the frames were taken from trees whose ages clustered within a range of 36 to 40 years.[13] While these data cannot be refined, they bring into focus yet again the regularity of Basque naval forestry practices in the 16th century. These timbers, which may all have been grown and harvested as one crop, also had a perfect morphology for their purpose as ship's frames. Clearly the wood supply for the Red Bay ship was not a natural forest, but an oak plantation carefully maintained so as to regularly produce frame timber as quickly and as efficiently as possible.

Such an hypothesis was tested on a shipwreck found at Cavalaire-sur-Mer (Provence), dated by dendrochronology to 1470 using a repair plank in the ceiling. This ship, excavated from 1993 to 1995 under the direction of Marion Delhaye, was also dismantled underwater and recorded in laboratory conditions on the surface.[14] The vessel had a single deck, a 14-meter keel and carried an armament of at least four cannon. One flank was preserved up to the height of the stern castle; the hull had sawn carvel planking in the quick works and split clinker planking above the water line. Judging from its oak construction, its iron-and-oak hull fasteners, its dovetail-morticed frames and the recurrence of the Biscayan *codo* of 57.5 cm in its internal measures, this anonymous ship may have been Basque-built.

The frame timbers from Cavalaire-sur-Mer had many of the same characteristics as did the Red Bay timbers. One tree produced one frame timber. Each tree was grown to its required curvature, its diameter corresponded closely with the required section shape, and its length was free of embranchments except at the very top. The scantlings were however lesser than at Red Bay, as the frame timbers measured 12 cm by 17 cm (Å1 cm) both at the

[11] G. P. Watts, "The Western Ledge Reef wreck: a preliminary report on investigation of the remains of a 16th-century shipwreck in Bermuda", *IJNA* 22 (1993), 2, pp. 103-124; *cf.* T. J. Oertling, "The Molasses Reef wreck hull analysis: Final report" and "The Highborn Cay wreck: The 1986 field season", *IJNA* 18 (1989), 3, pp. 229-243 and 244-253.

[12] Pedro de Medina, *Libro de grandezas y cosas memorables de España* (Seville: 1548); Esteban de Garibay, *Compendio Historial* (Antwerp: 1571); Cristóbal López de Zandategui and Luiz Cruzat, *Recopilación de leyes y ordinanzas de la M.N. y M.L. Provincia de Guipúzcoa* (1583; San Sebastian, 1983); Lope Martínez de Isasti, *Compendio Historial de Guipúzcoa* (1625; San Sebastian, 1850).

[13] Peter Waddell, personal communication, Ottawa, 1993.

[14] These data were collected thanks to the gracious invitation of Marion Delhaye, Toulon.

bilge and at the deck. In all cases, waney edges were prominent in certain areas along the timbers' length.

The tree rings present in each frame timber were counted visually. The accuracy of the visual count was found to be within Å5 rings in the eight cases where an exact count was undertaken, and thus the visual counts were rounded off to the nearest multiple of 5 (figure 2). The ages cluster at 65 Å5 years for 39 out of 54 timbers (72%), a proportion which is borne out fairly closely in each of three categories of frame timbers that were studied: floor timbers, first futtocks and second futtocks (figure 3).

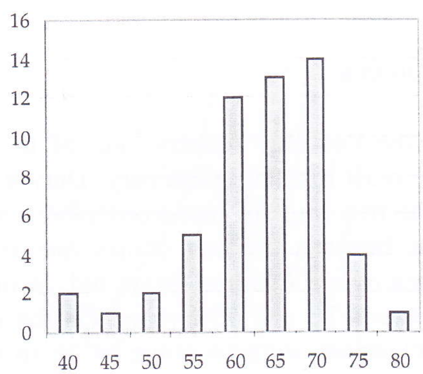

Figure 2. Ages of trees used to make 54 frame timbers. Cavalaire-sur-Mer, ca. 1470.

While the ages of the trees used to make the Cavalaire-sur-Mer frame timbers do not provide as neat a picture as is suggested by the preliminary findings from Red Bay, they show a similar tendency. They paint a picture of a controlled oak population where about three quarters of the required pieces were harvested at about 65 years of age, and the remaining pieces were obtained from trees aged from 40 to 80 years. Such a population could only have been found in a plantation environment, for no natural forest could produce a significant number of oaks having the required morphologies for shipbuilding within such a close age range. These two shipwrecks that have been studied from the perspective of understanding Renaissance naval timber supply thus point irrevocably to a practice of controlled forestry in which pieces were produced, within a predictable time span of 40 or 65 years depending on the period or locality, to a specific curvature, diameter and branch-free length.

An important question concerns what part of the tree was used to produce these frame timbers. Two possibilities seem the most likely. Either the timbers were the trunks of planted oaks, or they represent the harvest at long intervals of coppiced stumps or pollarded standards. The gnarled lower ends of the Bermuda futtocks seem consistent with the latter practice, but both the Red Bay and Cavalaire-sur-Mer futtocks manifest a fairly smooth grain exiting at their lower ends. Possibly, both practices existed together.

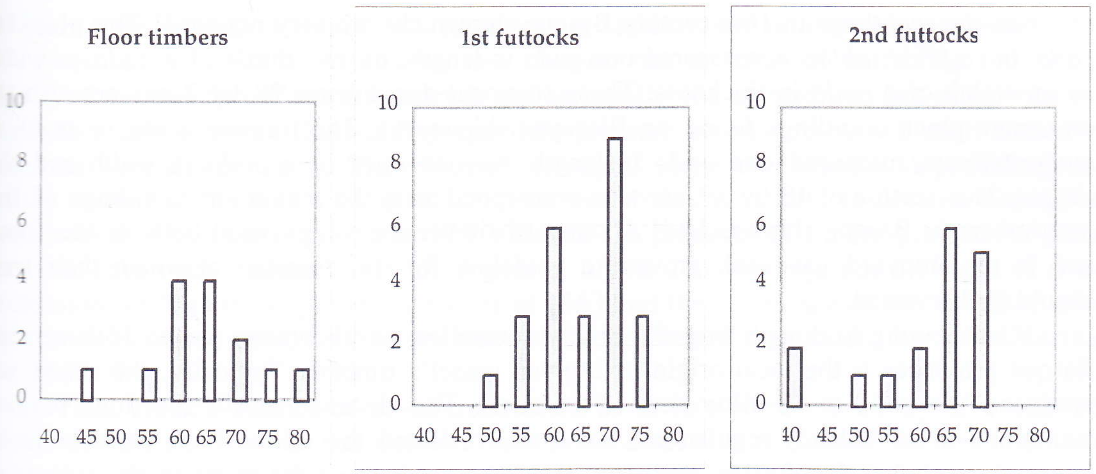

Figure 3. Groups of tree ages used for frame timbers. Cavalaire-sur-Mer, ca. 1470.

Basque forestry practices

Through the prism of these archaeological findings , archival information on the supply of naval timber in Biscay can be read in a new light. The earliest references to on oak management date to the later middle ages, when the Basque coastal provinces of Biscay and Guipuzcoa developed a corpus of laws called the *Fueros* that established the jurisdiction of these provinces in relation to the Kingdom of Castille. The *Fueros* touched upon forestry practices as, for instance, in a law that required anyone cutting down an oak to plant two saplings.[15] The context of this law is clarified at the end of the 15th century, when modern Spain assumed the laws of medieval Castille. Thus from 1498, following the Portuguese example,[16] Spain subsidized shipbuilding and naval forestry in the coastal Basque provinces. These subsidies were available to owners of plantations within three leagues of the sea provided they followed regulations designed to preserve the oak stands.[17] In 1563, the program was expanded and, at this time, other aspects of the naval oak economy become known to us.[18] For instance, not only private individuals but also coastal municipalities could qualify for the plantation subsidies.[19] With the expanded subsidies came a boom in notarial activity as builders and growers substantiated their subsidy requests, and the greater part of existing notarial and judiciary archives relating to Basque shipbuilding dates to the decades immediately following. These ancient timber subsidies explain why the frames found in shipwrecks originate from plantations, rather than from natural forests.

Timber subsidies were calculated according to the volume of timber that was sold which, in turn, created a need for standard metrological practices. As in shipbuilding, the standard unit of measure in naval forestry was the *codo de ribera*, a unit of 57.5 cm.[20] The ways in which this unit was used to measure the volume of naval timber explain why, for

15 C. L. de Zandategui and L. Cruzat, *op. cit.*

16 L. Freire Costa, *op. cit.*

17 G. de Artiñano y Galacano, *op. cit.*

18 J. L. Casado Soto, *op. cit.*

19 M. Barkham, *op. cit.*

20 J.-P. Proulx, "Essai sur la jauge des navires basques au XVI^{e} siècle", in *L'aventure maritime, du golfe de Gascogne à Terre-Neuve*, Actes du 118^{e} congrès national annuel des sociétés historiques et scientifiques, Pau, octobre 1993 (Paris: Éditions du CTHS, 1995), pp. 115-124.

instance, the scantlings in 16th-century Basque shipwrecks are very regular.[21] The planking *codo*, or *codo de tablazon*, measured one *codo* in length, by two thirds of a *codo* in width, by an eighth of a *codo* in thickness. These sectional dimensions, 38 by 7 cm, are also the maximum plank scantlings found on Biscayan shipwrecks. The framing *codo*, or *codo de maderamiento*, measured one *codo* in length, by one third of a *codo* in width and thickness. This section of 19 by 19 cm also correspond with the maximum scantlings of frame timbers in Basque shipwrecks.[22] A standard timber metrology used both in the forest and in the shipyard gave oak growers a guideline for the diameter at which their trees should be harvested.

Contributing to this picture of a highly-controlled naval forestry in the 16th-century Basque provinces is the local origin of a given vessel's timbers. Typically, the wood was produced within 10 to 12 kilometers of the coast. This distance recalls the three leagues mentioned in the subsidy regulations, but it also reflected the inland limit for the fluvial transport of timber for, further upstream, the steep gradient of the rivers made navigation impossible and here as well, the rivers were harnessed for iron-working, an industry that required large amounts of oak charcoal and was thus competed with shipbuilding for timber resources. Not only was the inland limit of timber production quite close to the sea, but the mountainous terrain dictated that the timber for a ship originated from within the river valley where the ship was built. Along this coast, watersheds are less than 10 kilometers wide. Thus all the timber used in one port came from an area of only 50 to 80 square kilometers, thus creating over the centuries an intense naval timber economy and leading, no doubt, to the forestry practices revealed by Basque shipwrecks. And within these limited watersheds, the timber for a shipbuilding project was typically furnished by two or three growers.[23] Some of their contracts go so far as to specify from which lot the timber was to be taken. The lots were identified as the lot of pollarded oaks (also used for pasture), the lot of standard oaks that produced planking or the lot of frame timbers.[24] These references indicate that timber growers left little to nature, and relate to archaeological evidence that ship's timbers were grown to a specific diameter and curvature, and were grown and harvested as a common crop. While the case of Basque naval forestry contains much that is particular to this region, it reveals the existence of forestry practices that may have been shared by oak growers in other shipbuilding areas of Europe.

Conclusion

It is not clear how much of the intensive naval forestry practices inherited from the Middle Ages survived the sweeping changes that overtook Atlantic shipbuilding in the 16th and 17th centuries. Under the traditional regime, the relationship between ship carpenters and timber wardens (*bosqueros*) was one of immediate collaboration and sometimes their roles alternated.[25] Young trees were given a shape that influenced hull design as much as

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[21] P. B. Villareal de Berriz, *Maquinas hidraulicas de molinos y govierna de los arboles y montes de Vizcaya* (Madrid: Antonio Marin, 1736); A. Gaztanieta, *op. cit.*

[22] T. J. Oertling, "The few remaining clues", in J.B. Arnold III, ed., *Underwater archaeology proceedings from the Society for Historical Archaeology Conference*, Baltimore, 1989, pp. 100-103.

[23] M. Barkham, *op. cit.*

[24] Archivo historico de protocolos de Guipúzcoa (Oñati), II, 3335, fos. 171r-173v, 177r-177v and 176r-176v (1602); for the *terreno de maderamiento*, or compass-timber lot of the Casa de Lili, see *ibid*, II, 3318, fo. 29 (1590).

[25] The *bosquero*'s essential tasks were defined as *cortar y desbastar* (fell and square): Archivo historico de protocolos de Guipúzcoa (Oñati), II, 3301 (2), fo. 16 (1576); *ibid.*, 3311, fos. 129, 130 (1583); *ibid.*, 3314, fo. 149 (1586). One *bosquero*, Sebastian de Sorarte of Zumaia, undertook the supply of ship's timbers under his own name in 1584. *Cf.* M. Barkham, *op. cit.*, pp. 255, 259.

60 years later. In such a context of technological stability, the skill of ship carpenters was not measured in terms of innovating new designs, but in terms of perfecting old ones. However, the question of naval forestry is not essentially one of tradition but rather one of scale. In a region where shipbuilding put little pressure on oak resources, such intensive practices were less common. The Biscayan example, where an intensive shipbuilding industry existed within severe geographic limits, was obviously unable to develop beyond a certain level of saturation, no matter how efficient the practices of timber growers. A peak seems to have been attained in the third quarter of the 16th century, but the signs of overextension, such as the expanded subsidies of 1563 and the young age of the Red Bay timbers from the same time, were forerunners of the prolonged depression that set in during the 1580s.[26]

Thus, the new science of naval architecture arose in a climate not only of expanded state shipbuilding interests, but also one in which the scale of traditional forestry methods seemed unable to fulfill the ambitions of the modern state. The naval architect of the period 1570-1620 needed to break free of the limits of traditional commercial practice, perhaps more so in terms of managing a changing timber supply than in terms of hull design. As for the latter, the naval architect needed only to conceive frames in which the clear distinction of floor timbers and first, second and third futtocks - whose shape and position in the hull had been heretofore determined years in advance - was broken down into "double-sawn frames" where pieces of various length and shape could be assembled to make a frame. Thus, forests that were not specifically cultivated to produce ship's timbers could be exploited. The solution adopted on the Atlantic coast seems, at first, to have been inspired by Mediterranean models, where timber resources had long before come under pressure. Thus we find Genoese carpenters in Lisbon and Venetian masters in England in the early 16th century, and we find Italian methods of hull design in the architecture treatises from Lisbon and Seville in the 1610s. In 17th-century France, Toulonese architects brought their methods to the Atlantic arsenals of Rochefort and Brest.[27] This sea-change in naval forestry and architecture, a legacy of the early modern state, was eventually to encounter new limits and refine its methods. Always however, the new science was based on the model of large-scale exploitation of forests requiring little maintenance and the ancient art of naval forestry was increasingly forgotten.

Québec, 1999

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[26] L. A. Clayton, "Ships and empire: the case of Spain", *Mariner's Mirror* 62 (1976), 3: 235-248.; Tomé Cano, *Arte para Fabricar y Aparajar Naos* (1611), ed. E. Marco Dorta (La Laguna, Tenerife: 1964).

[27] E. Rieth, "Les débuts de l'enseignement à l'école de construction de Toulon. Le Livre de Construction des Vaisseaux (1683) de François Coulomb (1654-1717)", in M. Marzari, ed., *Navi di Legno* (Mariano del Friuli: Lint, 1998), pp. 111-118. The 1680 treatise of A. Gaztanieta, *op. cit.*, signals the implantation of Mediterranean methods on the Basque coast.