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## Looking for the perfect tree? Selecting and felling a Neolithic logboat tree

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### Summary

The Koruc association's 2022 project aims to reconstitute and test a monoxyle oak dugout canoe over 8 m long under different navigation conditions (river and sea, loaded and unloaded). The model chosen was inspired by European boats discovered in estuarine contexts. The approach adopted since 2021 implies that the entire *chaîne opératoire* is compatible with Neolithic technologies (excluding log transport, for obvious reasons of excessively long timber supply distances) and is recorded according to various variables in order to feed our database. Particular attention was paid to the production of polished stone tools facsimiles (dolerite axes and adzes), wood and antler implements (pointed sticks, picks, pickaxes, chisels). Similarly, so as to be able to compare our working times and come close - perhaps - to Neolithic conditions, the same team, experienced and well-versed in the handling of the various tools, follows the different stages from felling the tree to finishing the dugout canoe.

This article deals with the first stage of this project, namely the felling of an oak tree 33 m high and 2.75 m in circumference. This will involve to:

1. determine what a “logboat tree” could be according to Neolithic criteria,
2. select the ideal tree in the field, produced in existing forest stands, and determine its axis of fall,
3. determine the most appropriate felling technique for the project,
4. present the main work phases, the time and number of people required to complete them, and the types of waste produced,
5. ask the question of tool effectiveness,
6. and finally, to provide feedback of this full-scale felling.

## **Introduction**

Many hypotheses about the human diaspora are based on an understanding of the capabilities of prehistoric sailors and the conditions they may have encountered (Birdsell 1977; Surovell 2003; Westley and Dix 2008; Kirch 2010; O'Connell and Allen 2012). However, archaeological traces of maritime technology are few and far between, and most of the events that led people to take to the sea are beyond the reach of written accounts or oral traditions. So how were islands like Australia populated in ancient times (50,000 years ago)? How were the British Isles neolithized and domesticated animals transported? These questions have already been tackled from a variety of angles, from chemical analyses of archaeological materials to ancient DNA analyses. Despite the scarcity of prehistoric nautical evidence, the hypothesis of coastal navigation remains strong, based on a convergence of clues (Anderson *et al.* 2010; Philippe 2018; Gaffney 2021).

At present, monoxyle canoes are the only known remains of prehistoric boats, although it is certain that other models/types existed (Philippe 2023). These logboats are technologically classified as boats. Their distinctive feature is that they are made from a single timber, by subtraction of raw material. Because of their narrow beam, their stability seems at first sight insufficient or, at best, marginal for sea navigation. In any case, while this type of watercraft was undoubtedly common on inland waters and estuaries from the 8<sup>th</sup> millennium B.C. onwards, its use at sea for short coastal journeys remains an open question.

Their census is complex and has only been the subject of a few syntheses on an European scale (Cordier 1963 and 1972; Arnold 1995; 1996; Fry 2000). The work of Lanting (1997/1998), covering the whole of Europe since prehistoric times, listed over 3,500 logboat wrecks, of which only 600 have been dated by radiocarbon or dendrochronology, showing a clear predominance of mediaeval elements.

In order to test different prehistoric sailing solutions, the Koruc project is resolutely committed to an experimental archaeology approach, in which different types of craft will be reconstituted (dugout canoes, skin and reed boats, rafts), then tested to compare their performance in a variety of conditions, their ability to transport people, domestic animals, granite blocks weighing several tons... In this human adventure, multiple academic, technical and artisanal skills are required for the smooth running of the operations.

### **1. Selection: characteristics of the logboat tree**

Just because we are talking about ancient forests, do we necessarily have to assume that these areas were rich in large trees, and that most of them were suitable for making a logboat? In other words, does the absence of forest management for forests that have reached their climax lead to the growth of 'perfect trees' in quantities greater than today? If we judge by the characteristics of the trees preserved in the rare forests considered as primary in Europe today, if we look at the time spent by traditional communities in South America, Africa or Oceania on locating logboat trees in equatorial forest zones, if we look at the defects observed on Mesolithic and Neolithic logboats, we can affirm that the answer is no!

So how do we define this 'logboat tree'?

1. The first step is to choose the most suitable tree species. Empirical knowledge of the wood's qualities is essential: the type of wood determines the boat's mechanical strength and durability, its buoyancy, and even more prosaically, how easily it can be worked and hollowed out with stone tools and fire.

Among European Neolithic logboats, here are some of the most commonly used species:

Pine (*Pinus* sp.), the 'Mesolithic' tree, was also used in the Neolithic period in northern and central Europe. It is said to be easy to work with stone or antler tools, making it a practical choice for dugout construction. However, our experiments show that felling and hollowing with stone tools proves difficult for the edges of polished blades, which dull rapidly, partly due to the resin.

Limewood (*Tilia* sp.) was used to build dugout canoes during the Mesolithic and Neolithic periods in Scandinavia and Switzerland. It is relatively light, easy to carve, not very prone to splitting and has good buoyancy properties (Andersen 1987, 90).

Oak wood (*Quercus* sp.) was a commonly used material for dugout canoes from the Middle Neolithic onwards in Europe, which explains why the project presented here was carried out using a large pedunculate oak (*Quercus robur* L.). It is a durable, dense wood, making it ideally suited to the boat's construction. Its strength and resistance to decomposition are, *a priori*, strong arguments for its robustness and durability. However, when a trunk is hollowed out to make a logboat, the periphery of the tree, where the sapwood is more fragile and subject to biological attack, is given priority over the harder heartwood, which is largely removed. This appears to be an obvious technical weakness, if not an aberration. In addition, the natural fissility of oak along its ligneous radii needs to be closely monitored to prevent possible cracks and water ingress.

During the Neolithic period in Europe, various other types of wood such as ash (*Fraxinus* sp.), alder (*Alnus* sp.) and poplar (*Populus* sp.) were also used, influenced by local availability and cultural traditions.

2. It is imperative that the shaft and the fibres be straight (fig. 1). Unfortunately, the defect of straight fibres can appear once the dugout is finished when internal tensions are released. As for straightness of fibres, the latter criterion is particularly important when working with logs, especially when splitting the wood.

3. There must be no main branches along the entire length of the trunk that will form the dugout canoe, as the wood's veins are deformed there and constitute hard points in the structure, areas where the fibres are oriented at an angle or perpendicular to the main axis, and therefore potential fragilities and waterways. Forks should also be avoided to prevent any shearing effect when the tree falls, which can cause the trunk to split and burst over a fairly long length.

4. The length of the shaft will also determine how it is used. The average length of complete European Neolithic canoes is around 7 m.

5. Likewise, its diameter will ensure that it is more or less seaworthy, bearing in mind that the cross-section of Neolithic logboats in most cases retains that of the chosen tree, i.e. a circular

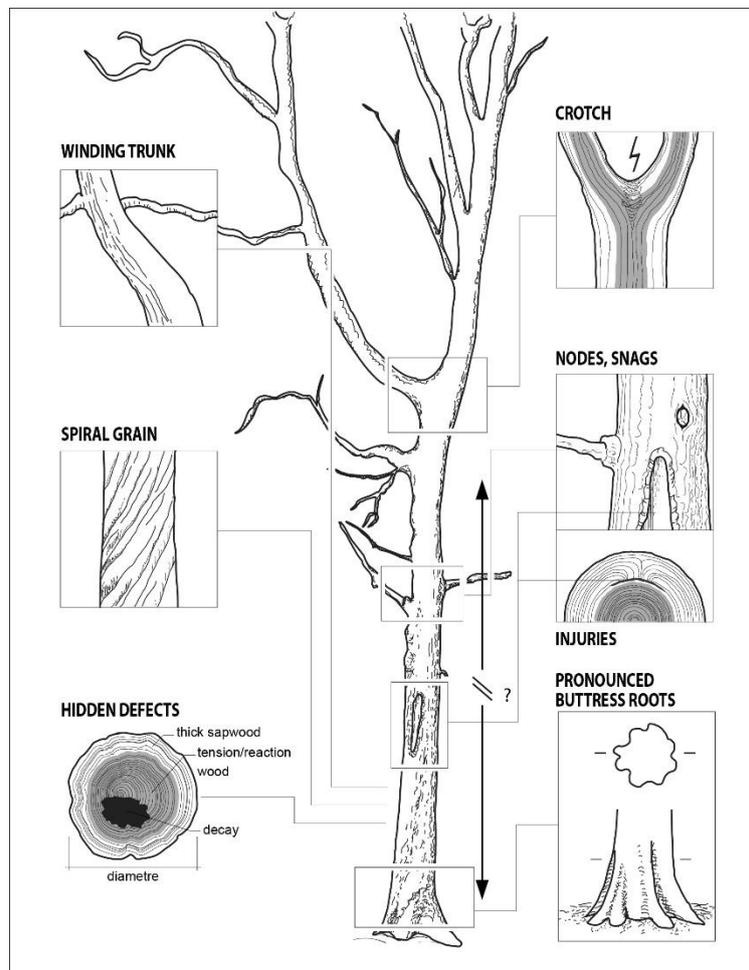
cross-section, which is naturally unstable. The average cross-section length of Neolithic logboats is 0.67 m.

6. We also need to keep an eye on wood defects and health: knots, cankers, wounds, cracks caused by frost or lightning, external and internal fungi... All of them are areas of weakness and sources of wood deformation.

7. The density of the forest stand must also be considered before felling a tree: a low density leads to the production of lateral branches on stocky trunks but make them easier to fell; a too high density risks keeping the subject of all covetousness trapped by others. This means clearing the land around the tree beforehand.

8. And the use of a living tree, which guarantees fresh wood that's easier to work, is preferable for the workers and their tools. Ideally, therefore, the dugout tree should be spotted during the vegetative period, and its qualities confirmed during the dormancy period, before felling, when the foliage no longer masks the tree.

<<fig. 1>>



<caption>Figure 1: Schematic drawing of the main defects to avoid when selecting a logboat tree. © V. Bernard.

As perfection is not of this world, such trees must have constituted remarkable individuals within prehistoric forests, and their preservation over decades, or even generations, seems to

have been observed on several occasions. In Denmark, the lime trees recruited for the Tybrind I and II dugouts had undergone extensive selection in the direction of large, straight, 100–150-year-old trunks with very few knots or branches (Moses 1987). In Switzerland, another lime tree used in the construction of the Hauterive-Champréveyres 1977/CH-77 dugout may have been pruned some 50 years before felling, in order, for example, to remove knots and branches from under the young wood (Arnold 1995, 53). In other contexts, in British Columbia (Queen Charlotte Islands) for example, quadrangular holes about 50 cm on a side, cut deeply with an axe, adze or chisel, known as ‘test holes’, were used to determine the health of the tree's heartwood (Stryd 2001, 38-40) until the 19<sup>th</sup> century.

Considering the imperfections visible on preserved prehistoric logboats, the gap between the theoretical level of requirements and the choice of logboat tree seems to be due to a varied forest potential that only well-controlled silviculture would have been likely to minimise.

## **2. Felling a tree in Neolithic times: when archaeological data enrich experiments, and vice versa**

### **2.1. *Grub felling (GF)***

There are still few archaeological references on felling methods other than the classic ‘felling above the rootstock’ (FAR). A range of archaeological, morphological, anatomical and experimental arguments tends to demonstrate that GF, i.e. stump removal (fig. 2a), was used alongside the ‘good old axe felling’, but set aside for the giants of Neolithic forests.

Was it performance, saving time and energy, and saving tools that were sought here? Certainly, for a part, but alternative systems using fire have been applied in other times and on other continents with just as much efficiency. Similarly, the extra metre of trunk spared by the felling notch could not, on its own, be taken into consideration. Other factors must therefore be taken into account, such as the role of the GF in the organisation of the logging sites, and its link with the formation of agro-pastoral landscapes.

The presence of root wood at the base of very large architectural elements, as observed at Houplin-Ancoisne (Nord; Praud *et al.* 2007) or at the ‘Fontaines Salées’ at Saint Père-sous-Vézelay (Yonne; Bernard *et al.* 2008), raises questions. GF involves digging up and severing a tree's main roots before cutting it down, helped by the inertia of its branches. **To date, this hypothesis, tested under ‘neo-compatible’ conditions only on two oak trees with a diameter of 60 and 80 cm (fig. 2a), has come up against difficulties in sourcing forest trees of sufficient calibre (section  $\geq 1$  m).** To carry out this felling technique, in which digging plays an important role, stone axes and adzes have been joined by picks made of wood and deer antlers, shovels made of wood and bovine scapula, as well as wooden levers and spikes. For the time being, no animal traction has been mobilised, apart from a few pairs of human arms.

<<fig. 2>>



<caption>Figure 2: a. Grub felling of an oak tree 80 cm in diameter at Plouezoc'h (Finistère, France). © V. Bernard/Koruc. b. Fire tree felling a maritime pine of 87 cm in diameter at Mézeray (Sarthe, France). © P. Bacoup/APERA.

## 2.2. Fire tree felling (FTF)

The FTF is an activity difficult to understand in prehistoric times, since, in the absence of archaeological evidence, it is based on the presupposition that there were no macro-tools fit to such a task before the Neolithic period. However the use of firewood for digging dugout canoes, for example, is attested at Noyen-sur-Seine (Seine-et-Marne, France) by one of the oldest known examples in the world. As far as felling is concerned, we have to refer to the meagre iconography found in the accounts of the first settlers in North America, or to a few ethno-archaeological references (Stewart 1984, 38; Rostain and Wack 1987, 130). In British Columbia, fire was used to make large cuts in wood before the advent of iron tools. Identification remains difficult, as forest fires can produce identical stigmata. The burnt areas must be relatively small and clearly delineated, and chisel marks are often found in the charred wood. In each of these cases, it is clear that the burning was accompanied by, and preceded, extensive work with chisels, adzes and stone axes, which obviously makes identifying the use of fire a tricky task (Stryd 2001, 13-14).

Experimental reference material for FTF is thin on the ground in archaeology, especially about trees with diameters suitable for logboats manufacture. One of the few experiments carried out in this field is that launched in 2021 by APERA<sup>1</sup> (fig. 2b), in collaboration with Koruc (Bacoup *et al.* 2022). Unfortunately, this operation could not be completed due to a lack of time (cf. 3.1.).

### **2.3. *Felling above the rootstock (FAR)***

Given the context of this study, we will not discuss the felling of small trees with axes or adzes (Jørgensen 1953, 40; Choulot *et al.* 1997, 189-197; Mathieu and Meyer 1997; Bacoup 2022, 310-332), or even, in a more original way, with stone or bone chisels and mallets (Cinq Mars and Le Blanc 2008; Bacoup 2022, 332-337).

The felling of very large trees required for the construction of monoxyle dugout canoes has been the goal of few experiments. However, a remarkable (if too concise) comparative study of felling by stone, bronze or iron axe was carried out in Switzerland (Arnold 2003). A 1.20 m in diameter oak trunk was felled with an axe made of serpentinite, a fairly soft rock (3 to 4 on the Mohs scale), for a cumulative total of 32 man-hours, but the participation of two to four people reduced the effective time to 13.30 hours. According to the author, most of the chips produced were sawdust-like, the result of crushing the wood. The larger splinters had a sliced base, while the upper part, stressed by the edge of the blade, was marked by a crushing of the material.

Felling techniques, on the other hand, leave more easily legible traces at the base of architectural timbers. The most commonly used technique, because it is the most ergonomic, is the FAR, preferably at man height (1-1.20 m). This position must enable us to work standing up (and not on our knees or stomachs!), but above all to adapt the height of the felling notch ('directional notch') to the diameter of the tree. Indeed, for a large tree in a forest, where the density of the woodland must be taken into account, the preparation of a 'hinge' is essential. Carried out at right angles to the predetermined fall axis, it will remain in place until the fall notch, opposite the felling notch, puts an end to this work carried out in complete safety by the

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<sup>1</sup> Association pour l'Expérimentation et la Recherche archéologique, Univ. Paris 1-Panthéon Sorbonne.

lumberjacks. Pencil point felling, common in the Neolithic period, is generally used for smaller diameters, rarely exceeding 20 cm (Choulot *et al.* 1997). This technique does not use hinges, as no direction can be favoured without a push from the trunk to accompany its fall.

### **3. Discussing experimental results**

#### **3.1 GF and FTF: unlikely candidates?**

In December 2021, APERA undertook the FTF of a maritime pine measuring 2.75 m in circumference, 1 m in height and 28 m in height (fig. 2b) (Bacoup *et al.* 2022). Unfortunately, the three-day operation could not be completed due to time constraints. The experiment lasted almost 46 hours, with the fire burning continuously, including overnight. At the end of the allotted time, the tree was still far from falling, since only a few centimetres of the trunk were burned. Estimating how long it would take for the tree to fall is then difficult. Several days, perhaps as much as ten, are certainly possible. This result in itself is important, suggesting other ways to complete those tested: hooping the tree beforehand to lower the wood's moisture content, using fire as a background task or on several trees simultaneously...

As for the GF, it also requires a significant investment in time, as well as much greater material and human resources than conventional FAR. A large part of the tree's root system has to be completely cleared, and each root cleaned at first to avoid chipping the edge of a polished axe. Once this meticulous clearing work has been carried out, each root must be cut in line with the trunk, which can represent a significant volume of wood to be removed in order to reach the roots hidden in the centre. Finally, the use of human or animal traction must take advantage of the inertia of the tree crown to bring about the fall of a statically well-balanced tree.

These initial trials are rich in lessons and show that the choice of felling method probably depends on the purpose of the operation, beyond the simple supply of timber. The motivations for choosing one of these methods are not obvious, other than to completely clear a site of all stumps for future construction or use (housing, funerary monuments, cultivation, mining, etc.).

#### **3.2. FAR: only advantages? Which tools are best suited?**

The Koruc-22 pedunculate oak had a circumference of 2.75 m at a height of 1 m, and a total height of 33 m (fig. 3). Felling began on January 21<sup>st</sup>, 2022, with the fall notch delineated first at the bottom, then at the top, in the form of a debarked surface, followed fairly quickly by two more or less horizontal cuts made with dolerite adzes and fusiform axes some sixty centimetres apart. For the duration of the felling operation, the low notch corresponds to the cutting plan. For large trees cut down by FAR, this directional notch is always the first to be made, until the tool's dimensions no longer allow it to progress towards the centre of the tree. To spare tool blades and optimise axe performance, this notch is carried out by successive attacks, alternately from above and below. This step aims to reach, then go beyond the heart (in reality, the centre) of the tree in a ratio of about  $\frac{2}{3}$  for the felling notch,  $\frac{1}{3}$  for the falling notch, sometimes  $\frac{1}{2}$ - $\frac{1}{2}$ . This search for an imbalance in the tree's statics means that a relatively thick tool has to sink into an ever-narrower space, with very limited travel. For this reason, the main notch is opened wide from the outset. The ratio of notch height with diameter of the shaft is then practically  $\frac{2}{3}$ -

$\frac{1}{3}$ , sometimes  $\frac{3}{4}$ - $\frac{1}{4}$ . Thus, a diameter of 80 cm will dictate a notch height of around 60 cm, implying that felling times are exponential depending on the diameters selected.

Using the notch-and-split felling system has the advantage of being able to circumscribe material that can be regularly cleared in large debris, saving time, tools and arms. This empirical technique was devised for the Mesolithic site of Star Carr (Bamforth *et al.* 2018, 359) and is sufficiently simple and effective to be developed with less sophisticated tools than in the Neolithic.

<<fig. 3>>



<caption>Figure 3: Felling above the rootstock of an oak tree with 87 cm in diameter in ‘Forêt de Bourse’ (Orne, France). © V. Bernard/Koruc.

Recent experimental felling of oak and Scots pine trees with large cross-sections (> 50 cm) conducted by Koruc clearly demonstrates a division between very small millimetric chips at the base of the tree and much larger ones scattered around. These larger chips are sometimes projected several metres away, depending on factors such as the weight of the tool, its power, and the angle of impact. (Arnold 2003, 44). The felling chips exhibit characteristic morphologies that differ from those obtained during the later stages of pirogue manufacture (Poissonnier *et al.*, 2023). Such preserved data is unthinkable in an archaeological context. They can, however, be used to identify logboat-building sites, which are still poorly known but are mentioned on rare occasions (Leroy *et al.* 2023).

On the first day of the experiment, a new axe blade fractured at a defect in the dolerite, after just three hits. On the second day, an ash handle broke at a small knot on an axe that had been used since 2018. Fortunately, the new handle could readily be adjusted on-site to fit the

undamaged blade. To mitigate the wedge effect of the stone blade within its mortise, thereby reducing the risk of handle splitting or splintering (Pétrequin and Pétrequin 1993, 36), the blade should be oriented to press against the wood at the top and bottom, rather than against the sides of the otherwise well-fitting mortise. Leather martyrs can be placed at these two points to ensure this.

Finally, the strength of ash handles for axes, hazel and ash handles for adzes, and holly handles for hammer-axes, proves to be very good, even though they were fashioned from wood cut as required at different seasons. Likewise, dolerite is a tenacious rock that only fractures when faulted. Its sharpening on fine sandstone occurs only after several dozen hours of usage. Hits can therefore be delivered without restraint and without any real fear of breaking the blades, contrary to various earlier warnings (Lepic 1872; Jørgensen 1953, 42; Iversen 1956, 37-38; Steensberg 1957, 67-68; Pétrequin and Pétrequin 1993, 36).

The physical labour of lumbering, carried out in pairs for durations of 10 to 20 minutes, becomes less strenuous with the establishment of a consistent rhythm dictated by the tool strokes. Once the correct cadence is established, each person takes turns striking without interrupting their partner's motion. This characteristic sound ensures perfect coordination of gestures and creates a certain emulation between the two operators. Working in pairs is greatly facilitated when the pair is formed by a left-handed and a right-handed operator, in order to limit the risk of an uneven notch, which could slow down the felling process or even cause the tree to fall off-centre (Bacoup 2022, 311-312).

Every hour, a photogrammetric survey was undertaken to 1) document operations, 2) reconstitute work time curves, 3) produce dynamic plan and cross-section views of felling progress, and 4) calculate volumes of material removed. Photographic and/or video coverage by drone and digital camera was also carried out throughout the exercise, supplemented by note-taking. The Google Fit data capture not only enables us to pinpoint the loggers' break periods with great precision, but also, and above all, to track the intensity of work over the course of a full day by the number of blows delivered. This tool, originally designed to calculate the number of steps and distances covered, works with a smartphone attached to the operator's arm or, more simply, placed against or on the tree or dugout being worked on.

The second day saw the completion of the fall notch. The felling notch, smaller but with a profile similar to that of the directional notch, was not started until 2 hours before the tree fell, i.e. after a total of 6 hours' work. On January 22, 2022 at 4:55 pm, Koruc-22 fell after 8 hours and 22 minutes of cumulative work.

If the motivation behind choosing one technique over another is to save time, both FTF and GF methods will inevitably be more time-consuming (tab. 1). Additionally, with the GF method, meticulous clearing of the root system beforehand is necessary, risking damage to the cutting edges of tools due to stones around the roots. In experiments conducted in this area, two days' work were dedicated to this task alone. This doesn't include the difficulty of guiding the falling tree, especially without a felling hinge. Human and/or animal traction might alleviate some of these challenges. However, if time efficiency is not a primary concern, utilizing the lower part of the tree for crafting a logboat is hardly justifiable and would likely pose more constraints than benefits. Regarding the FTF method, opting for such an operation

during the Neolithic period can only be justified in terms of time if felling is a background task carried out in series on multiple trees or concurrently with other activities. On the other hand, if the choice of a felling technique is justified by a desire to save manpower – which seems contradictory to the cutting of stone blocks and the volumes of earth moved in the course of megalithic construction, for example – the FTF would take pride of place.

<<tab. 1>>

Felling technique	Plant species	Diameter (cm)	Felling time (min)	Cumulative time 1 pers.	Volume of wood removed (cm3)	Reference
FAR	<i>Quercus</i> sp.	33		63		Mathieu and Meyer 1997
	<i>Quercus robur/petraea</i> L.	34		65		Jorgensen 1985 quote in Mathieu and Meyer 1997, 345
	<i>Quercus</i> sp.	35	30	60		Steensberg 1957, 68
	<i>Quercus</i> sp.	120	810	1920	400 000	Arnold 2003
	<i>Quercus</i> sp.	35		67,2		Olausson 1982, 73
	<i>Quercus robur</i> L.	40	30	60	18 840	Koruc 2019 - Comblessac
	<i>Quercus</i> sp.	55	300			Elburg <i>et al.</i> 2015
	<i>Quercus robur</i> L.	87	493	986.4	241 215	Koruc 2022 - Forêt de Bourse
	<i>Pinus sylvestris</i> L.	87	378	756	140 114	Koruc 2021 - Orches
GF	<i>Quercus robur</i> L.	75	1023	3069	109 956	Koruc 2019 - Plussulien
	<i>Quercus robur</i> L.	80	1525	6100	340 842	Koruc 2019 - Plouezoc'h
FTF	<i>Pinus pinaster</i> A.	87	2760			APERA 2021 - Mézeray (Bacoup <i>et al.</i> 2022

<caption>Table 1: Data relating to felling above the rootstock (FAR), grub felling (GF) and fire tree felling (FTF) of trees over 30 cm in diameter. Data in italics correspond to FTF for which felling could not be completed.

#### 4. Conclusion and outlook: Sea sailing, raw materials transport and other types of watercrafts

Weighing in at around 500 kg, the logboat has still seen little navigation today (fig. 4). In August 2022, Koruc-22 made its first trip to the Aber Wrac'h estuary (Finistère), then out to sea towards Guennioc Island. Seven experienced rowers were on board, and it didn't take long to find the right paddling rhythm to master the navigation. In the end, the boat lived up to expectations, but facing waves and even paddling up a strong current remains a challenge.

Unlike a kayak, this logboat has no skirt to limit water ingress. Its bow is a carbon copy of Neolithic models whose design is more fluvial or estuarine than maritime. And when the swell gets too high, it's urgent to get closer to land and calm spots to bail out. In these conditions, logboat navigation can only be imagined by coastal navigation or on sight, to link point A to point B. In Aber Wrac'h, the coasts are never far away, all the islands are visible, and the sailors have a perfect command of the environment, the landmarks, but also the reefs and currents. So, in the future, we will need to increase the number of sailings to test these single-masted boats in different sea and load conditions.

In addition to transporting people and live animals, Koruc's next experiments will focus on transporting raw materials and stone blocks by boat. There are proven examples of megaliths being transported by water during the Neolithic period in the Gulf of Morbihan region. Moving blocks weighing several dozen or even hundreds of tonnes, as in the Belle-Ile-en-Mer example, remains a challenge that logboats alone are unlikely to meet, given the resistance and limits reached by this type of boat. We will have to come up with other types of craft that are compatible both with the resources available and with a presumed Neolithic level of technology before we can envisage such deep-sea journeys. Nonetheless, logboats remain a magnificent communication tool for a wide audience.

<<fig. 4>>



<caption>Figure 4: Sailing in Landéda (29) aboard the 9-meter-long oak pirogue. The crew size can be decreased to five paddlers. © J. Meslin/Koruc.

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