# *Lake-dwelling building techniques in prehistory: driving wooden piles into lacustrine sediments*


■ **Fig. 1** Lake Luokesas' geographical location

**This contribution is an account of an archaeological experiment testing the effort required and the techniques used in order to drive wooden piles into submerged soft lake sediments based on finds from the LBA/IA lake-dwelling settlement on Lake Luokesas (Lithuania).**

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## Introduction and aim

'Why our ancestors chose to build houses and villages in seemingly inhospitable wet environments, such as lake shores, marshlands or river banks' still remains one of the most frequently asked questions within the lake-dwelling research. Although there is no single straightforward answer to this 'enigma', a few theories on this intriguing topic have nevertheless been formulated. Pétrequin and Bailly (*2004*), for instance argue that such locations were ideal defensive habitats. Bryony and John Coles (*1992:* 151) give us an explanation by asking another simple, but straightforward question: 'who had an easier life, the hillfort people, who, after a hard day at work, had still to carry heavy loads (food, wood, water) uphill to their homes, or the lake-dwellers, who had 'everything' around, sometimes even within, the village'? We all know that 'convenient' choices of living were not always very popular in prehistoric times. But, how convenient was living on lakes or similar wetlands in prehistory? And, above all, how difficult (or, easy) was it to construct a settlement in that kind of environment?

A number of archaeological experiments have been carried out throughout Europe in order to shed more light on this fascinating topic. A full size Neolithic pile-dwelling was for instance constructed on Lake Chalain, France in 1988-89 (*Monnier et al. 1991*), and a similar experiment was carried out at the Pfahlbaumuseum Unteruhldingen, Germany, on the northern shore of Lake Constance in 1996 (*Schöbel 1997:* 83). Bloc-construction building techniques in shallow water were tested on Lake Graifen, Switzerland (*Bauer and Leuzinger 2004*), whereas on Lake Neuchâtel, Switzerland, wooden piles were driven into the lake marl near the shore, using the twisting and hammering techniques (*Pillonel 2007a:* 260-262; *2007b*).

Although there are various construction techniques linked to environmental as well as cultural factors, a large number of wetland sites were built on stilts, regardless of if they were in water or humid ground (*Menotti 2004, 2001*). Piles were erected in various ways:

**a)** by digging postholes,
**b)** by leaving them outside the terrain, but stabilising them with perforated base-plates (Pfahlschuhe),
**c)** or simply by driving them into the ground.

The difficulty of the latter technique, and the depth to which the piles were driven, depended on the geological formation of the terrain. Within the Alpine region, this depth was on average between 1 m in semi-wet environments (swamps, lake shore – outside the water) and 2-3 m in lake marl near the shore (*Monnier et al. 1991*: 34; *Schöbel 1997:* 86). In other parts of Europe, for example, in the eastern Baltic countries such as Lithuania, we have examples where piles were driven up to 4.5 m into the soft lacustrine sediments (*Menotti et al. 2005:* 385).

All the above-mentioned experiments had specific questions to answer, such as, how difficult it was to build a pile dwelling, how long it would have taken, how much material would have been needed, how long would such a dwelling last, etc. None of them though, was especially designed to find out how difficult it was to drive wooden piles into permanently flooded lacustrine sediments; and, most importantly, how prehistoric lake-dwellers managed to do it.

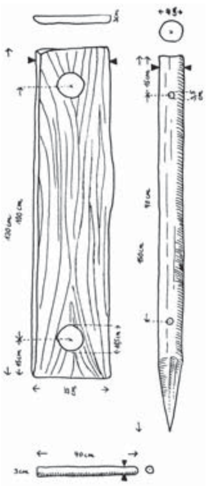
This paper is a detailed account of an archaeological experiment done at the Late Bronze Age/Iron Age lake-dwelling settlement on Lake Luokesas (Lithuania) (**Fig. 1**), to test the effort required and the techniques used to drive wooden piles into soft and submerged lake sediments, e.g. shallow-water morainic shoals near the shore.

## Methods and materials

Before we start describing the methodology and the materials used, it is important to point out that the whole experiment is based on archaeological evidence found in the past five years of excavation in both sites (the village, on the northern shore of the lake, and the large platform, southern shore of the lake) (*Menotti et al. 2005*).

### Archaeological evidence

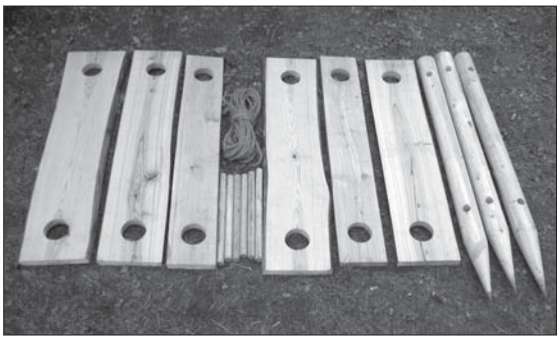
Initial archaeobotanical and micromorphological analyses have shown that both, the village and the platform were probably built in the water, on the morainic shoals near the shore (*Lewis 2007:* 49). The precise depth of the water at the time of the first occupation is still unknown, but it is presumed that it might have varied between 20 and 100 cm. The lacustrine sediments, at the bottom of the lake (on the morainic shoals), consist of very soft lake marl, on which it is almost impossible to stand without sinking several centimetres. It is indeed these soft lacus-



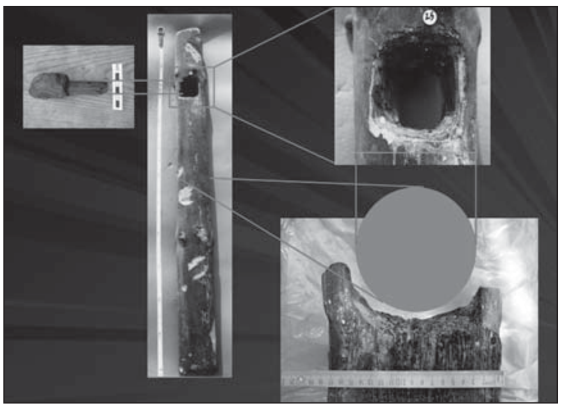
■ **Fig. 3a** Drawing of the wooden material used to reconstruct the movable structure (Drawing: B. Pollmann)

trine sediments that raise another important question: 'how did prehistoric lake-dwellers manage to drive long and heavy piles, while standing in that soft lake-bottom?' Of course, once the frame of a platform was erected, the work would have been much easier, but the problem did exist at the very beginning, especially to build the settlement double-fence, around which no permanent wooden structure was ever constructed.

During the past five seasons of excavation on Lake Luokesas, a large number of wooden structures (planks, frames, piles, cross-beams, etc.) have come to light on both sites (1 and 2). Most of them belonged to the remains of platforms, houses and walkways. Some of them are nevertheless different, and they resemble the remains of a movable structure (see **Fig. 2**), possibly used as a small standing platform, or rack to drive piles into the lake marl, where there was no other stable contractions. In order to prove this possibility, following the above-mentioned archaeological evidence, we have reconstructed a similar full-size structure, and used it to drive wooden piles into the lake marl *in situ*.



■ **Fig. 3b** Wooden material used to reconstruct the movable structure (Photo F. Menotti)



■ **Fig. 2** Archaeological evidence of the movable wooden structure used to drive the piles into the lake marl

## The reconstructed structure: materials

The structure consists of two levels of six wooden (ash) planks (20-25 cm wide, 130 cm long and 3 cm thick), three wooden (fir) piles (150 cm long and 10 cm in diameter), and finally six wooden (oak) pegs (40 cm long and 3 cm in diameter).

In each plank, two holes (10.5 cm in diameter) were drilled at 15 cm from its extremities. Two 3.5 cm holes were drilled in each pile; the first at 15 cm from its upper part, and the second 90 cm from the first hole down to the point (see **Fig. 3a**, **3b**). The planks were first arranged into two triangular forms (**Fig. 4**) and subsequently, the tree piles were slid through the three holes of each triangle, to form a sort of prism (**Fig. 5**). Three of the six pegs were positioned in the upper part of the structure to hold the plank on which people are standing (**Fig. 6**; also compare it with **Fig. 2**); and the other three pegs to hold the lower triangular structure (**Fig. 7**), which prevents the whole prismatic structure from sinking into the soft lake marl.

The structure was designed to be assembled very quickly, and without the use of glue or nails. The ropes, visible in figure 5, are just holding the whole structure together for transportation. Once the structure is in the water and three people are standing on it, it stabilises automatically, following the principle of gravity. The three vertical piles are purposely left sticking out in the lower part of the structure in order for them to sink into the lake bottom and stabilise the structure even further. It has to be pointed out that both the structure and the pile for the experiment were made using conventional modern tools. The structure was built by a professional carpenter under the supervision of the authors. Finally, the assembling of the structure and the cutting of the pile for the experiment was carried out by archaeologists, e.g. non-professional carpenters.

## Choosing the pile for the experiment

Before proceeding with the selection of a suitable pile to be driven into the lake sediments, we extracted two old ones in the lacustrine settlement to see how they looked, the wood used and, above all, the average depth to which they were driven. The extraction operation lasted several hours and we were astonished to see that both piles had been driven more than four metres into the lake marl (**Fig. 8**) (*Menotti et al. 2005:* 385). Because of the straightness of the tree trunks, the majority of such long piles were obtained from pine trees. We therefore set off in search for a suitable one that resembled the old piles. This was an easy task since the majority of the land surrounding Lake Luokesas is still covered in primary forest (mainly pine, oak, birch, and alder). The pile that we obtained was 7.2 metres long, 13 cm in diameter at one end, and 10 cm at the other. The total weight of the pile was about 40 kg. Only branches were removed from the pile; the bark was left in place (**Fig. 9**). The pile was subsequently made sharp for the first 20 cm at the thinner end (10 cm in diameter) (**Fig. 10**).

## The experiment

As previously stated, the experiment is two-fold:

**a)** To test the efficiency of the above-mentioned structure when used as a help to drive long wooden piles into the lake marl.

**b)** To see how much effort is required to drive an over-7m-long pile, about four metres into a permanently flooded (by about 1m of water) lacustrine sediment surface.

The structure was put in the water and pushed to the chosen place of the experiment. This operation turned out to be extremely simple because the structure floats (three people were needed) (**Fig. 11**). The pile to be driven into the lake marl was also floated to the site (one person needed). Once the predetermined spot for the experiment was reached, the structure was turned in a horizontal position and the pile passed through it (**Fig. 12**); the pile was subsequently put in a vertical position (along with the structure) (**Fig. 13a**, **Fig. 13b** and **Fig. 14**). At this point, the three people jumped onto the upper planks of the structure, making it sink to the bottom of the lake. The three pointed ends of the structure sunk into the lake marl up to the lower planks (see **Fig. 7**), and thus stabilizing it. Because the water was about as high as the structure, the three people standing on it were almost completely out of the water (**Fig. 15a** and **Fig. 15b**).

### The pile

The pile, held simultaneously by the three people in a vertical position, was lifted up about 30-40 cm and then dropped effortlessly following the principle of gravity. Before the whole operation was repeated, the pile was inclined to an angle of about 10° and rotated a few times (4-5) (**Fig. 16**). The whole operation (rotating, lifting up and letting the pile drop) was repeated ten times until the desired depth (4 m) was reached. The last four times the pile was also pushed downwards during the dropping procedure to accelerate the whole process.

## Results

### Moveable platform

The dimensions of the prism-shaped structure constructed using archaeological evidence proved to be ideal for three people to stand on for a depth of water between 20 and 100 cm. Without people on it, the structure floats, making the transportation to the desired place extremely easy. Transporting the structure and the pile from the lake shore to the chosen location on the morainic shoal (about 50 m) took less than five minutes. This movable platform is also extremely easy to disassemble (once the pile is driven into the lake marl) and assemble again (in the water) for the next pile (**Fig. 17**). In fact, the structure does not even have to be disassembled completely; it is enough to slide one of the three piles off, open up the triangular structure, and pull it away from the driven-in pile. The entire disassembling and reassembling operation lasts only a few minutes (4-5).

### The pile into the lake marl

Once the pile was transported to the chosen spot for the experiment, it was, first of all, slid into the wooden structure and then erected in a vertical position (see **Figs. 12-14**). This process took about two minutes. Once the pile (and the movable structure) was in a vertical position, three people climbed up on the movable structure (see **Fig. 15a** and **Fig. 15b**) and started to drive the pile into the lake marl following the procedure describe above. Within six lift-and-drops times, and in about 4 and a half minutes, the pile had reached a depth of 3.6 metres. The last 40 cm were the most 'difficult' ones; more than one minute per 10 cm. The desired depth of four metres was eventually reached, after ca. 9 and a half minutes of work. The entire experiment (assembling the movable structure, transporting it (along with the pile) to the designated place, and driving the pile into the lake marl) was carried out by five people, but only three of them (including one of the authors) drove the pile into the lake sediments.

## Discussion and conclusions

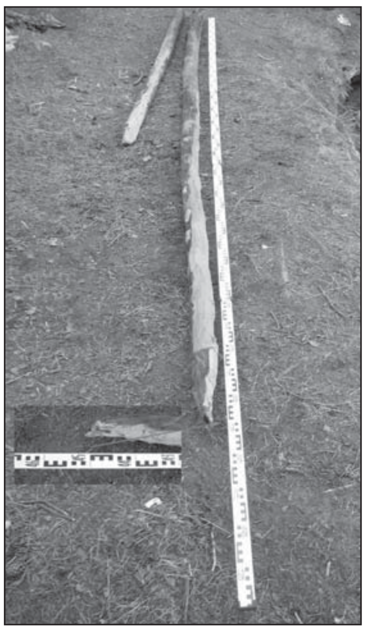
Before starting the experiment, we have to admit that we were all a little daunted by it; the never-tested movable structure, the extremely-soft lake bottom, the water-level reaching our waist, the length of the pile (7.2 m), and above all, the depth (4 m) to which we were supposed to drive the pile into the lake marl. But as the experiment progressed we were pleasantly surprised to see how some parts of it turned out to be actually easier than we thought they would be. For example, lifting the pile in a

■ **Fig. 7** Detail of the lower part of the movable structure

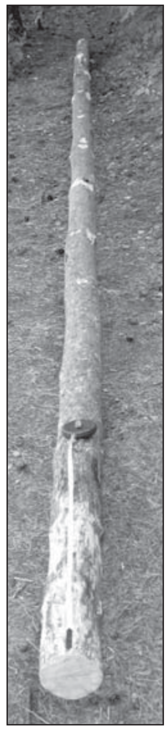
■ **Fig. 4** Planks of the movable structure placed in a triangular form (Photos 4-10: F. Menotti)

■ **Fig. 5** The fully-reconstructed movable structure

■ **Fig. 6** Detail of the upper part of the movable structure



■ **Fig. 8** Original Late Bronze Age wooden pile extracted from site 1



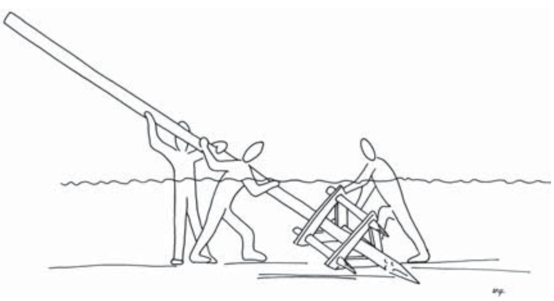
■ **Fig. 9** Wooden pile cut for the experiment

■ **Fig. 10** Pointed end of the wooden pile used in the experiment

■ **Fig. 11** Transporting the wooden structure to the chosen spot for the experiment (Photo: E. Pranckenaite)

■ **Fig. 12** Turning the wooden structure horizontally and sliding in the pile to be driven into the lake marl (Photo: E. Pranckenaite)

■ **Fig. 13a** Positioning the wooden structure and the pile in a vertical position (Photo: E. Pranckenaite)



■ **Fig. 13b** Schematic illustration of the positioning of the wooden structure and the pile in a vertical position (Drawing: B. Pollmann)

vertical position; we first tried without the help of any structure, but the water and the soft lake bottom made it extremely difficult. Sliding it into the movable structure and using the latter as sort of lever on the other hand made the operation much easier and faster. Secondly, considering how hard it was to extract one Late Bronze Age original pile, we were all expecting 'the driving of the pile into the lake sediment' to be a much harder task to perform. On the contrary, using the above-mentioned technique, the pile was driven into the lacustrine deposits almost 'effortlessly' and very quickly.

If we take into account this experiment as well as other similar ones done in different environmental and geomorphologic settings (*Pillonel 2007a; Bauer and Leuzinger 2004; Schöbel 1997*: 83; *Monnier et al. 1991*), it is quite easy to fall into the environmentally deterministic 'trap' and think that the wetlands were occupied because dwellings could have been built easily and reasonably quickly within that kind of environment. At the same time though, as previously stressed, opportunistic choices of living were not very popular in prehistoric times. It is also true that sometimes people did not have a choice and they were forced to act against their will. People's strategic approach to occupying and settling the landscape is therefore a combination of both cultural and natural factors, which sometimes result into illogical decisions.

We do not know what made the Late Bronze Age Luokesas lake-dwellers choose that particular spot to build their settlement. What we do know is that in an overwhelmingly forest-covered environment, agricultural land was considered a luxury, and a lake, a sort of oasis or natural outpost which could have offered food and protection. Considering the effort needed to deforest even small areas of primary woodland (especially at the beginning) (*Coles 1973; Billamboz 1987*), and how 'easy' it was to construct on the cleared and spacious morainic shoals of the lake shores, it is not surprising if those late prehistoric groups opted for the lake instead of the 'inland'.

## Acknowledgements

There are quite a few people to whom we are extremely grateful for their invaluable help in the implementation of the experiment. First of all, Mr. Viktoras Pumputis (the carpenter), who built the movable wooden structure impeccably. Secondly the whole Luokesas excavation team, which prepared all the preliminaries for the experiment brilliantly; in particular we want to thank Zenonas Baubonis, Mantas Kvedaravicius, Rokas Kraniauskas and Benjamin Jennings for physically carrying out the experiment. A last but not least thank you goes to Britta Pollmann, who has illustrated the various steps of the experiment brilliantly.

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■ **Fig. 14** The pile just about to reach the vertical position (Photo E. Pranckenaite)

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## Summary

**Les techniques de construction des habitats lacustres pendant la Préhistoire: Planter des pieux de bois dans les sédiments lacustres**

Au cours des fouilles menées sur un établissement de la fin de l'Age du Bronze et du début de l'Age du Fer sur le lac Luokesas, les archéologues ont retrouvé parmi de nombreux vestiges en bois une structure ressemblant à une plate-forme ou à un guide qui aurait pu être utilisé lors de l'installation de pieux dans la marne du lac (roche sédimentaire constituée de calcaire et d'argile).

Cette structure en bois est composée de deux triangles formés par trois planches de bois et réunis entre eux par trois pieux traversant les angles des triangles au point de contact des planches. La forme obtenue est celle d'un prisme.

L'expérience s'est faite dans deux buts: tester l'efficacité de cette structure pour le transport et l'installation de longs pieux dans la marne, et évaluer les efforts nécessaires pour réaliser l'opération avec un pieu d'un peu plus de 7m de long à planter dans environ 4m de sédiments submergés.

L'installation de la structure fut relativement facile car sans poids à porter elle flotte. Une fois l'emplacement définitif atteint, plusieurs personnes montent dessus pour enfoncer la base des poteaux de soutien. Le pieu ensuite glissé dans la structure peut être redressé par une personne seule se tenant sur la plate-forme supérieure. Il s'enfonce alors par gravité dans le fond sédimentaire.

L'ensemble de l'opération a pris moins de dix minutes.

**Pfahlbau-Techniken in der Urgeschichte: Zum Einbringen von Holzpfählen in See-Sedimenten**

Bei den Ausgrabungen des linearspätbronze-früheisenzeitlichen Siedlungsplatzes am See Luokesas (LB A/I A) wurde unter mehreren, aus Holz bestehenden Fundstücken auch eine bewegliche, hölzerne Struktur entdeckt, die einer Standplattform oder einem Gestell sehr ähnlich ist und von der vermutet wird, dass sie dazu genutzt wurde, Pfähle in den Untergrund des Sees zu treiben. Die Struktur besteht aus zwei Ebenen von je sechs Holzplanken, die zu Dreiecken verbunden waren; drei Pfähle wurden durch die Öffnungen in den Dreiecken geschoben und bildeten dort eine prismenartige Form.

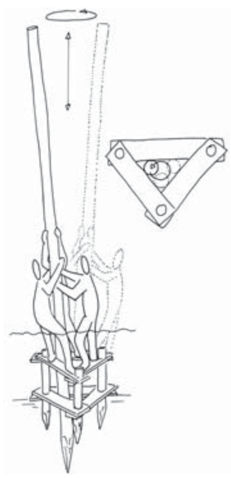
Das Experiment dazu bestand aus zwei Teilbereichen: Einmal ging es darum herauszufinden, wie effizient die erwähnte Holzstruktur als Hilfskonstruktion zum Einbringen von langen Pfählen ist; außerdem sollte herausgefunden werden, wie viel Kraft nötig ist, um über 7 m lange Pfähle in den von Wasser bedeckten Untergrund des Sees bis in eine Bodentiefe von 4 m einzubringen.

Der Transport der hölzernen Struktur war einfach, da sie an der Wasseroberfläche schwamm, wenn keine Personen auf ihr standen. An der Stelle, an der die Pfähle durch die Holzkonstruktion getrieben wurden, sprangen mehrere Personen auf diese herauf und ließen sie dadurch niedersinken. Die drei Pfähle wurden dabei in stabiler Lage in den Boden gerammt. Die drei Personen, die auf der Plattform standen, hoben danach einen der großen Pfähle hoch und ließen ihn anschließend fallen, um ihn in den Boden einzubringen. Der gesamte Arbeitsgang konnte in etwas weniger als 10 Minuten durchgeführt werden.

■ **Fig. 15a** The pile in a vertical position with three people standing on the movable wooden structure, ready to begin driving it into the lake marl (Photo: E. Pranckenaite)

■ **Fig. 15b** Schematic illustration of the beginning of the experiment (three people standing on the movable structure, ready to begin driving the pile in the lake marl – the lake water level is about as high as the structure) (Drawing: B. Pollmann)

■ **Fig. 17** The wooden structure is partially disassembled and extracted from the driven-in pile (Photo: E. Pranckenaite)



■ **Fig. 16** Schematic illustration of the process of driving the pile into the lake marl (conical rotation, uplifting and dropping of the pile) (Drawing: B. Pollmann)

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