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Selective reburial: a potential approach for the *in situ* preservation of waterlogged archaeological wood in wetland excavations

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Excavations at Dispilio, a prehistoric lakeside settlement in northern Greece, have revealed a significant number of vertical wooden piles that need to be protected during and after excavation. Lifting of the piles is not possible and approaches such as reburial, cannot currently be implemented as excavation is still in progress. In 2005, several posts were “selectively buried” on an experimental basis, by encasing them in PVC pipes and backfilling with the surrounding sediment. This approach appeared to be capable of protecting the piles during excavation and be a potential solution for their post-excavation preservation. This preliminary study sets out to asses if this alternative approach to reburial could be an effective *in situ* preservation method.

Fresh beech and pine samples were “selectively buried” similarly to the encased piles, and exposed to open excavation conditions. Retrieval of samples was undertaken every three months over a one year period and their condition was assessed by their physical properties, chemistry and biodeterioration. As no baseline data existed for the site, spot measurements of Eh, T, pH and water table were recorded every three months at three dipwells located inside the excavation trench. Physical properties of both buried and exposed pine and beech samples did not indicate considerable decay as longer exposure periods appear to be necessary to adequately reflect the effects of deterioration. However, assessment of micromorphology and chemistry showed some differences in the deterioration degree of the exposed samples compared to those buried in sediment.

Monitoring results showed high seasonality in all environmental parameters throughout the 12 month monitoring period and indicated a hazardous environment for wood preservation.

Preliminary results obtained showed that the “selective reburial” is directly dependant on overall site conditions. It reconstructs a similar microenvironment to the site burial environment and therefore can be effective for sites that favour wood preservation. In contrast to typical reburial, “selective reburial” can be applied during excavation without impeding its progress. However for environments like the one studied, this method is not recommended after excavation.

1. Introduction

Dispilio is a prehistoric lakeside settlement in northern Greece, (Hourmouziadis, 2002; Whitley, 2004) that has been excavated annually since 1993 (Sofrodidou, 2008). The large amount of waterlogged wooden structural elements revealed every year at Dispilio (Chatzitoulousis, 2006) has created an imperative need for their protection and management.

The most urgent problem, appears to be the management of the vertical elements of the settlement, during and after excavation. These timbers are up to 2.85 m in length and are driven deep into the sediment (Chatzitoulousis, 2008). During the transverse progress of the excavation, their uppermost parts become exposed to drying. Lifting of these partially unearthed piles is extremely difficult and can severely jeopardise their integrity, therefore during excavation their exposed tops are manually sprayed with water. Spraying however, can be problematic for the excavation process and does not guarantee a permanent wetting of the wood.

If these vertical piles survive the excavation process, they are likely to undergo post-excavation damage due to further drying and biodeterioration as they cannot be lifted. Their reburial, or their *in*

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Fig. 1. "Selective reburial" of piles undertaken during the project FAITH (Panter et al., 2007).

situ preservation by raising the water table, could be a solution for their management. However, these approaches are not feasible while excavations are ongoing. Moreover, the efficacy of water spraying the piles (constant or periodical) after excavation is also in question, as it could generate a high risk of biodeterioration (Pournou and Bogomolova, 2009).

In June 2005, an alternative approach has been experimented with, under the European project FAITH (Panter et al., 2007), where in a freshly excavated trench (10 × 10 m), located ≈2 m from the lake's edge, several vertical elements were encased in plastic pipes and backfilled with the surrounding sediment (Fig. 1).

This "selective reburial" was proven to work during excavation, as the piles were kept wet by watering the filling sediment, and the excess water was kept inside the pipe without flooding the trench. Furthermore, it appeared to be a potential solution for the protection and management of the vertical piles post-excavation.

However, baseline monitoring hasn't been undertaken before the implementation of this approach. Spot measurements of pH and Eh acquired during that period, showed groundwater pH to be slightly acidic to neutral (6.74–7.15), whereas redox values ranged between +175 and −51 indicating slightly to moderately reduced conditions. Water table levels appeared to remain stable but these data are not considered reliable due to the shortness of the monitoring period (Panter et al., 2007).

This study sets out to assess whether conditions prevailing at the trench are suitable for the long-term preservation of piles and investigate if "selective reburial" could be an alternative approach to reburial for their *in situ* protection.

Therefore, sound wood was "selectively buried" for one year in the same manner as the encased piles and its condition assessed every three months by examining physical properties, chemistry and biodeterioration. For comparison, control material was left exposed to open excavation conditions. In parallel, an annual preliminary monitoring program of the trench was attempted by spot measurements of Eh, pH, water table and temperature.

2. Materials and methods

2.1. Preparation of samples

Pine (*Pinus sylvestris* Linn.) and beech (*Fagus sylvatica* L.), being the main species recovered during the excavation (Chatzitoulousis, 2008), were used to prepare 140 samples of 2 × 2 × 4 cm (64 for the exposure trials and 6 controls, for each species). For calculating the decomposition rate constant k[1] (Zhou et al., 2007; Sampaio et al., 2008), samples were weighed, labelled with aluminium tags and oven-dried (2 days at 103 ± 2 °C) to constant weight (Müller-Using and Bartsch, 2009). Their oven-dry weight was then measured using a digital balance accurate to 0.001 g. Samples were then waterlogged under vacuum for facilitating their submersion in the trench water, and sterilised by autoclaving (20 min at 120 °C). Samples were then sealed immediately in sterilized polyethylene bags to prevent contamination and stored in a fridge (≈4 °C) until transportation to the field.

2.2. Field trials

Samples were placed in a cool box for transportation. On arrival in the field, they were put inside 16 sterilised litterbags (Wieder and Lang, 1982) (20 × 40 cm), with a 1 mm mesh for allowing access to microorganisms, microphauna and a large part of the mesofauna. Each litterbag contained 8 samples (4 of each species).

Four PVC pipes (70 cm length, 14 cm diameter), were randomly positioned inside the waterlogged trench, (Fig. 2 a, b) and driven 7 cm deep into the sediment. After purging water from the pipes with a manual pump, two litterbags were placed inside each pipe at 5 cm and 35 cm from the site ground level datum after which they were backfilled with the surrounding sediment.

Similarly, four bamboo frames, were positioned next to the four PVC pipes and secured inside the trench in open excavation conditions (Fig. 2 a, b). Two bags were tied to each frame with a fishing line, at two depths similar to the pipes (5 cm and 35 cm from the site ground level datum). Thus, four groups of samples were created, A, B, C and D (Fig. 3). Every three months, one group of samples was retrieved from the field trial, providing data on the condition of beech and pine samples that were exposed to open excavation conditions (air/water environment), or buried in sediment inside the PVC pipes, at two different depths. Immediately upon retrieval, samples were put in labelled sterilized plastic bags and placed in a cool box for transportation.

2.3. Physical properties

For determining moisture content, density and shrinkage values after every exposure period, the retrieved samples were cleaned of sediment, vacuum impregnated with water to expel any trapped air and then weighed. Stainless steel pins were then placed in the transverse surface of the specimens in order to mark the tangential and radial dimensions. Then, the distance between the pins was recorded with a digital calliper. The specimens were air dried and when their moisture content reached equilibrium (three successive constant measurements) they were weighed and measured dimensionally. Finally the specimens were oven dried at 102 ± 3 °C for 48 h and their dry constant weight was recorded. Percentage moisture content, density and cross sectional shrinkage were estimated based on Equations (1.1), (1.2) and (1.3) respectively.

Equation (1.1) Percentage moisture content ($U\%$), (Kollmann and Côté, 1968)

$$U\% = (W_w - W_d)/W_d \times 100 \quad (1.1)$$

where W_w = the waterlogged weight and W_d = the constant dry weight after oven drying for 48 h at 102 ± 3 °C

[1] Constant k was calculated based on a single exponential decay model, $M_0 = M_t e^{-kt}$, or $k = (\ln M_0 - \ln M_t)/t$, where M_0 is the dry mass of wood samples at time zero and M_t is the dry mass at time t (Chapin et al., 2011).