Application of Dendrochronology to Underwater Archaeology

Nigel Nayling
Lecturer, Department of Archaeology and Anthropology,
University of Wales Lampeter

Abstract

Drawing on a range of recent underwater and intertidal archaeology projects, the role of dendrochronology as an essential tool in the analysis of submerged landscapes and shipwreck sites is examined. The use of appropriate sampling strategies, to ensure that sophisticated questions which go beyond dating alone, is advocated and the potential of such approaches demonstrated.

Introduction

The use of dendrochronology or tree-ring dating has a surprisingly long history. The discipline can be seen as having passed through a 'pioneer' phase in the nineteenth century with the focus on climate, botany, and astronomy before expanding to encompass archaeological applications in the early twentieth century in both northern America and Europe (Schweingruber, 1989). Widespread fascination with the remains of so-called 'lake dwellings' in the shallow waters of alpine lakes in Switzerland, Germany and France began over 150 years ago but it required the vision of a German botanist, Bruno Huber, beginning in the late 1930's to identify the potential of the dendrochronological method for tree-ring dating these sites (Billamboz, 2004). Dendrochronology has become central to the ongoing investigation of these prehistoric alpine lake settlements but has also been harnessed in an ever expanding range of applications to underwater archaeologies. That this has happened even since the advent of radiocarbon dating is testament to the unparalleled accuracy of the method as a dating technique but also indicative of its other applications in an archaeological context including addressing questions of woodland management and exploitation , timber trade and supply, and the provenance of that portable antiquity par excellence, the ship. Establishment of radiocarbon as an accepted dating technique required the creation of European oak (Quercus L.) tree-ring chronologies to provide calibration and provided much of the research impetus for the extension of long chronologies in Ireland and Germany.

This paper aims to provide a review of application of dendrochronology to underwater archaeology, drawing largely on the author's own experience but also with reference to notable sites or studies which have played a part in cementing the role of the technique in this sphere of archaeology. The intention is not only to encourage the usage of dendrochronology in appropriate situations, but also to highlight the potential and limitations of the technique and look to possible future trends and challenges.

Submerged landscapes

In Western Europe, in many parts of the Atlantic and North Sea coasts a pattern of relative sea level rise since the beginning of the Holocene is most evocatively demonstrated by the widespread occurrence of peat horizons exposed in the intertidal zone. In a review of the palaeo-environmental potential of the coastal archaeology of England, Bell highlighted the role of polymaths, geologists and antiquarians in the nineteenth century in describing and discussing these exposures and their potential for providing understanding of past human communities within the context of dynamic processes of coastal change (Bell, 1997). These deposits frequently contain the remains of relict woodlands, often described as ‘submerged forest’. Their examination from a dendrochronological perspective has been intermittent in Britain. Godwin noted innovative work undertaken by Munaut on Dutch exposures, and undertook some of the earliest pollen studies of British sequences but did not publish any tree-ring analysis (Godwin, 1968). Attempts in the 1970s and 1980s at dendrochronological analysis were frustrated by a lack of absolutely dated long chronologies although associated radiocarbon dating of tree-ring sequences helped refine models for sea-level change (Heyworth, 1978; 1985; 1986). The construction of the British and Irish long oak chronologies largely depended on inland bogs for prehistoric material, although intertidally exposed oaks on the southern shore of the Severn Estuary at Stolford proved essential in providing absolute dating of the Neolithic allowing tree-ring dating of the Sweet Track in the Somerset Levels and a succession of forest exposures on the foreshore of the Isle of Wight at Wootton Quarr (Hillam, 1991; Hillam et al., 1990).

Case Study: Submerged Forests of the Severn Estuary and Solent. As part of a multi-disciplinary study of Mesolithic to Neolithic coastal environmental change c. 6500-3500 Cal BC in a lowland coastal study area, an extensive survey of submerged forest exposures on the northern shore of the Severn Estuary was undertaken. The estuary has an extreme tidal range, up to 10m, so that on exceptional low spring tides basal deposits with Mesolithic oak stumps and fallen trunks could be recorded and sampled for dendrochronological analysis under the direction of the author. Other team members undertook parallel studies of pollen, plant macrofossil and beetle remains (Bell et al., 2002). Investigation focussed initially on a submerged, apparently oak-dominated forest exposed for at least 1.7km along the lower foreshore at Redwick (Figure 1).

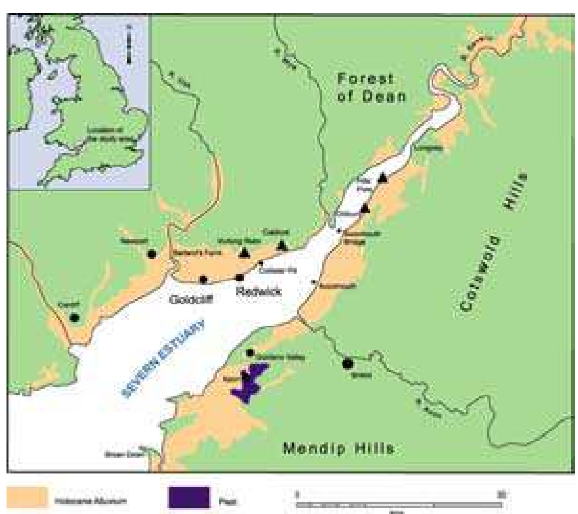

Figure 1 The Severn Estuary indicating the location of intertidally exposed Mesolithic ‘forests’ at Redwick and Goldcliff

The trees appeared to have been rooted in minerogenic sediment comprising a palaeosol developed on head deposits, and were overlain by a thin basal peat and in some instances by silt possibly associated with marine inundation. Over 100 individual trees, comprising almost equal numbers of in situ stumps and fallen trunks were sampled for analysis and details of each tree noted on a record sheet accompanied by digital photographs. Excavation next to a subset of these trees examined their stratigraphic context in detail. Tree-ring analysis successfully cross-matched over 50 of the trees’ ring-width sequences to produce a very well-replicated site chronology (Figure 2).

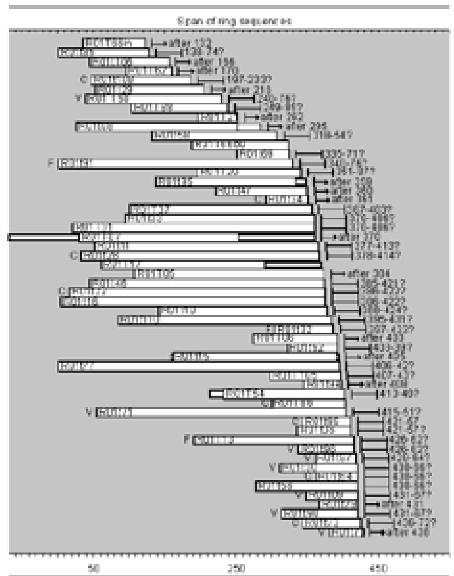

Figure 2 Bar diagrams indicating the date ranges of cross-matched ring-width sequences from individual oak trees at Redwick, Severn Estuary. Estimated death date ranges are also given.

Interpretation of the results is challenging given the absence of bark edge and the outer sapwood rings which would have allowed more accurate relative dating of death dates for these trees, and permitted analysis of growth rates immediately before death which might have informed the processes leading to their demise. If the outermost surviving ring on most samples is interpreted as the heartwood/sapwood boundary this would imply that the trees were unlikely to have all died contemporaneously as a result of a single catastrophic event such as aggressive inundation. It may be that some casualties represent natural disturbance as a result of wind throw, with the trees surviving in an increasingly decayed state as deadwood on the forest floor. Certainly the ages, growth rates and morphology of the trees suggest a relatively closed forest environment. Absolute dating of the site chronology from Redwick has not proved possible with wiggle-match radiocarbon dating of one of the component trees indicating a date range for these trees of 6206–5811±4 cal BC (Nayling et al., 2007). This pre-dates existing absolutely dated oak chronologies in Britain and Ireland by some 600 years. Additional survey some 4km further west along the same shore at Goldcliff led to the cross-dating of 15 oaks from a similar basal context. A ring-width mean of these trees cross-matched against the Redwick chronology and also against a more limited sequence from a relatively small exposure of peat and trees on the opposite, English shore of the estuary at Gravel Banks, a site subjected to palaeo-environmental investigation in the 1990s (Druce, 2000).

Together, the cross-matched ring width sequences from Redwick, Goldcliff and Gravel Banks point to a widespread marine transgression of the former river valley to form the Severn Estuary at c. 5800 cal BC. Prior to this inundation, the valley floor would appear to have had extensive oak-dominated forest cover perhaps challenging the widely debated ‘Vera hypothesis’ (Vera, 2000) which proposed a ‘park-like landscape consisting of grasslands, scrub, solitary trees and groves bordered by a mantle and fringe vegetation’ for Mesolithic central and western Europe. Much of this debate has hinged on interpretation of pollen data with Mitchell comparing relative proportions of Quercus and Corylus pollen from regions which supported large herbivores with data from Ireland, where large herbivores were excluded (Mitchell, 2005). Mitchell and others have recognised the need to broaden the evidence base to include other indicators of vegetation cover including molluscan and beetle proxies (Birks, 2005; Moore, 2005). What better than the trees themselves? The oaks examined in the basal sediments of the Severn Estuary grew on mineral soils, and can not be dismissed as unrepresentative of lowland vegetation cover – a criticism levelled by Vera at the use of bog oaks as an indicator of past forest cover. With charring evident on many of the oaks examined at Goldcliff and Redwick, both fire and wind throw may be seen as viable disturbance factors, presumably along with grazing wild animals such as aurochs and red deer, in a forest ecology where gap dynamics played its part in allowing oak regeneration.

In parallel with the multi-disciplinary project in the Severn Estuary, fledgling work on fully submerged Mesolithic landscapes in the Solent off the northern shore of the Isle of Wight has also involved sampling of oaks, on a more limited scale, from a 2km stretch of peat shelf lying in some 11m of seawater (Momber, 2000; Momber, 2004; Momber and Campbell, 2005). Larger oaks in the vicinity of stratified, worked lithics at Bouldnor Cliff were sampled during AD 2000 using a large survey vessel, surface-supplied divers and a hydraulic chainsaw. Subsequently drift dives along the peat shelf using SCUBA equipment permitted sampling of selected oaks along the length of the exposed peat shelf. An eleven tree, 285-year oak ring width chronology, again predating existing British absolutely-dated chronologies has been constructed and dated by radiocarbon to c. 6270-5985 cal BC. This has been tentatively cross-matched against the Severn Estuary oak sequences with credible computer correlations and visual matching. Conceptually, if the Severn sites are seen as a single chronology, then the correlations with the Bouldnor Cliff chronology do not provide the level of replication required to consider the cross-matching between them as definitive. The extension of dated British oak chronologies beyond the present limit of approximately 5200BC will require the identification of additional site locations around the coast where Holocene sediments, either intertidally exposed or fully submerged, are being actively eroded leading to the uncovering of further tree assemblages. British submerged Mesolithic coastal sites or landscapes on the scale, number or quality of those encountered particularly near Danish (Fischer, 2004) or German (Lübke, 2002) coasts have yet to be identified. The southern North Sea may offer the challenging opportunity not only to 'bridge the divide' in terms of understanding the drowned landscapes of Mesolithic 'Doggerland' but also to identify contemporary ancient woodlands which through dendrochronological analysis will permit absolute dating of these presently 'floating' British sequences.

Shipwrecks

The dendrochronological analysis of ship finds emphasises the potential of the technique but also the need for extensive and thoughtful sampling strategies if the full potential of this method is to be realised. Early examples of successful application include the dating of the Bremen Cog to AD 1378–1379 (Haneca et al., 2008; Liese and Bauch, 1965). This result allowed linkage of the site to historical records of the loss of a cog prior to its completion in the river Weser. During the early 1990s tree-ring results were presented for the first time for a number of ship finds which had been excavated many years before. One of the iconic ship finds from Roskilde Fjord, Skuldelev 2, was not only dated precisely to AD 1042 but shown to be constructed from oak derived from Ireland, an early instance of dendro-provenancing (Bonde and Crumlin-Pedersen, 1990). Soon afterwards, the Norwegian ship burials of Oseberg and Gokstad (and Tune) were also dated giving dates to the year for construction of their burial chambers and somewhat earlier dates for the ships themselves (Bonde and Christensen, 1993). In addition to permitting improved consideration of ship development, the results also provided much sought after precision in the dating of associated Viking artistic styles. Dates for ships excavated in London from Roman and medieval contexts were published (Tyers, 1991; 1994; 1996) including the intriguing identification of the late Roman County Hall ship as having been constructed from local oak even though it had been built in the Mediterranean, shell-first tradition. Preliminary results from analysis of the Tudor warship, the Mary Rose, focussed on the identification of alterations to the ship shortly before its well-documented sinking (Bridge and Dobbs, 1996). More recent research has led to the comprehensive publication of extensive sampling of all five of the eleventh-century Skuldelev vessels identifying dates and origins of primary construction as well as repair events which often occurred in different locations allowing a broader appreciations of the ships' 'spheres of operation' (Crumlin-Pedersen, 2002). Developments in methods to identify the source of timber employed in ship construction drawing on the increased geographical availability of historic tree-ring data (Daly, 2007b) have been applied successfully in sourcing the timber for the planking of the Karschau Ship from Schleswig-Holstein to the area around Odense, a medieval town on the island of Funen, Denmark in the AD 1140s (Daly, 2007a). The most recent publication by this author emphasises the potential difficulties of locating timber sources during periods of widespread timber trade with the tree-ring sequence from a Norwegian ship find, the Bøle ship, cross-matching against traded Baltic timber now found on archaeological sites throughout the North Sea and Baltic Sea regions (Daly and Pål, 2008). This Baltic timber trade is now widely appreciated by dendrochronologists although historically it has caused difficulties in the interpretation of both art-historical and archaeologically recovered material (Haneca et al., 2005).

Magor Pill Medieval Wreck

Both the richness and vulnerability of the archaeology exposed in the intertidal zone of the Severn Estuary is again indicated by the case of the Magor Pill wreck – a medieval ship revealed by natural erosion of an infilled palaeochannel off the northern shore of the Estuary (Nayling, 1998a). The initial discovery was made during a cultural exchange visit to the area when visiting archaeologists from the Baden-Württemberg area of Germany were being shown the archaeological potential of the region. Sediment exposures were unusually clear with mobile sediments having been swept away by strong tides and rough sea conditions making observation of the Holocene sedimentary sequence and the palaeochannel relatively straightforward. Whilst a number of features such as remnants of fishing structures which had previously been recorded were noted, a newly exposed feature comprising a central oak timber with overlapping oak planking was seen for the first time. This was tentatively identified as the remains of a clinker built boat and a sample from one of the exposed planks was taken by the author. Dendrochronological analysis indicated a terminus post quem for the felling of the parent tree of AD 1120 with significant computer correlations between the ring-width sequence and a range of British regional chronologies. The implied medieval date for the wreck defined its importance given a relative scarcity of such finds from British contexts. Over subsequent months, the site was evaluated through limited excavation, a potential receiving museum identified and discussions held on the feasibility of recovering the wreck from its threatened location. Following total excavation and in situ recording the wreck was recovered and subsequently dismantled for detailed recording of its constituent timbers. A programme of extensive dendrochronological sampling and analysis was integrated within this post-excavation recording programme with the aim of precisely dating the ship's construction, identifying the origin of the timber employed, and examining the diversity of timber supply. All oak timbers (keel, hull planks, framing timbers, and ceiling plank repairs) were assessed and all with more than 50 annual rings sampled. Beech ceiling planks were also sampled with the hope of correlating ring sequences with floating beech chronologies from south-east England, and possibly through heteroconnections providing absolute dating against oak chronologies.

A total of 47 samples were taken from 42 oak timbers (Nayling, 1998b). The results can be summarised:

The majority of the hull planks were derived from just two oak trees aged 147+ years and 178+ years. At least one of the framing timbers was converted from one of the trees exploited for production of hull planks. This result challenged perceived wisdom that planks framing timbers would normally be derived from different trees, with planks coming from high canopy woodland and framing timbers from trees grown in more open environments such as hedgerows.

Timbers with surviving bark edge (framing) were derived from trees felled in the winter of AD 1239/40. Correlations between the timbers for the ship's original construction and regional chronologies were consistent with construction of the boat in the south-west of Britain, possibly in the Severn Estuary itself.

One of the oak ceiling planks was a reused timber with its ring-width sequence exhibiting strong correlations against data from medieval Dublin. This suggested the reuse of materials from an Irish vessel pointing to cultural contact between boats/ships of Welsh and Irish origins.

Ten samples of radially-split beech ceiling planks were successfully cross-matched, and a mean of these sequences correlated with tentatively dated beech site masters from a range of medieval sites in London (Tyers, 1998). Two samples retained apparently complete outermost rings dated to AD 1240 suggesting that completion of the fitting out of the ship, including the ceiling, occurred some time after the felling of the oak trees employed in construction of the hull. In addition to site-specific insights, this analysis also confirmed the previously uncertain dating of beech sequences in south-east England leading to the construction of a well-replicated and absolutely dated beech chronology in Britain.

Following the successful recovery of the Magor Pill wreck, survey in the intertidal zone in the vicinity of the find spot was undertaken to clarify the context of the ship, examine maritime industry in the area, and reconstruct change in the position of the coast line. The remains of numerous wooden fish weirs were identified and a selection targeted for detailed survey and sampling for tree-ring dating (Nayling, 1999). Seventeen wooden fish traps were surveyed and dated by dendrochronology ranging from relatively small, V-shaped structures dating to the twelfth century to linear weirs came into use after about AD 1170, located progressively closer to the present day sea-bank. This study emphasised the value of combining field survey of such structures with accurate dating to identify changes in fishing technologies and proxy evidence for coastal retreat.

The 'Gresham' ship

During dredging operations in a busy shipping route, the Princes Channel in the outer Thames Estuary, parts of a substantial, carvel-built wooden vessel were disturbed and sections recovered by the Port of London Authority with the assistance of archaeologists from the marine section of Wessex Archaeology (Auer and Firth, 2007). The author recovered a total of twelve samples from the lifted sections of hull, from oak framing timbers which, on inspection, appeared to have sufficient rings for analysis. Tree-ring width sequences from ten of these samples cross-matched to form a 306-year mean which was dated against regional tree-ring chronologies and site masters for sites in the east of England. The results are consistent with the vessel having been constructed from oak from eastern England, soon after AD 1574. Poor sapwood survival on the recovered sections of the vessel meant that only three samples retained possible bark edge, and possible felling dates of AD 1573 and 1574 were recorded (Nayling, 2004). These results confirmed the relatively early nature of the find but challenged suggestions that some of the construction details might suggest an Iberian origin. The dating assisted informed decision making regarding the fate of the remainder of the vessel which still lay disturbed on the seabed where its was threatened by renewed dredging operations. A major archaeological diving programme was funded to allow recovery of the remainder of the ship, and its detailed recording. This led to renewed questions regarding its construction with structural evidence pointing to alteration of the vessel to increase its breadth, a practice known as furring. A second phase of dendrochronological sampling and analysis was undertaken which confirmed the construction date from timbers with well preserved bark edge dated to AD 1574 including timbers employed in the alterations. This suggested that modifications were made soon after the ships primary construction rather than after some years of service.

This project emphasises the value of tree-ring dating as a method for characterising the nature and importance of unexpected ship finds discovered during development. The importance of close dialogue between dendrochronologist and archaeologist in targeting research questions is also evident.

The Norman's Bay Wreck

This wreck located off the south coast of England was discovered by sport divers and recently designated as an historic wreck under the Preservation of Wreck Act 1973 (Wessex Archaeology, 2006; 2007)

Figure 3 The Norman's Bay Wreck indicating area of exposed timber sampled for tree-ring analysis. After Wessex 2007

The extensive remains are characterised by the presence of numerous large guns indicating its military character. Attempts to identify the wreck through comparison of a detailed survey of the guns with documentary evidence for the artillery carried by Resolution, a British 70-gun third rate that sank in the area during the Great Storm of 1703, proved inconclusive. The author in collaboration with the Wessex Archaeology dive team recovered samples from exposed framing timbers. In contrast with medieval vessels, which normally comprise radially-cleft oak hull planks eminently suitable for tree-ring dating, post-medieval ships were usually built from tangentially sawn hull planks containing relatively few rings. As a result, framing timbers are potentially more useful for dating purpose, are perceived to be less likely to have been traded, and will often retain sapwood allowing accurate felling dates to be determined. The samples taken from this wreck were heavily degraded by the action of marine borers and no sapwood survived. Such material undoubtedly exists on the site but would require excavation below the level of borer damage to enable year specific felling dates to be determined. Tree-ring series from five of the samples were correlated with mean sequences from the Eastern Netherlands and Westfalia. The dating suggests that the parent timbers were felled some time after AD 1659. This raises the possibility that the vessel could be one of a number of Dutch ships lost in the area in the battle of Beachy Head in AD 1690. The results raise a number of issues including questions regarding the source of timber employed both by British and Dutch naval yards at this time, the nature of the mean sequences which may, in part at least, comprise material imported from Germany (Jansma, 1995), and logistical questions about the best approach to sampling protected wreck sites reaching an appropriate balance between information retrieval and maintenance of the integrity of the site.

Conclusions

Dendrochronology when thoughtfully applied to carefully constructed research questions can be a powerful tool in the intertidal and underwater environments. The discipline depends on the construction of regional chronologies to act as reference curves allowing unparalleled accuracy in dating, and potentially sourcing of the timber employed. Application to the characterisation of ship finds is most productive when a dialogue between the dendrochronologist and ship archaeologist is informed by awareness of contemporary practices of timber exploitation and trade, and woodworking techniques. Detailed structural analysis will often be required to ensure that results are meaningful, and sampling strategies may require numerous samples if the questions being asked extend beyond just dating to broader issues of timber supply, woodland management and repair.

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