DENDROCHRONOLOGY AND ROMAN LONDON

J. HILLAM, R. MORGAN and I. TYERS

We have been prompted to write this note in response to a paper by Dr John Fletcher in this journal[1]. We feel the general reader and the professional archaeologist might be confused by certain aspects of tree-ring dating presented there, and we want to comment on two points in particular—the accuracy of estimating felling dates in the presence of sapwood, and the possibilities and pitfalls of dating timbers with short series of growth rings. The dating of the Roman Custom House quays presented by Fletcher is based on material which can be included in both categories. We also present a summary of other tree-ring work which has been carried out on the Roman waterfront structures in London.

SHORT SEQUENCES

The crossmatching of short oak tree-ring sequences and their absolute dating is a difficult and controversial process. The number of rings found to be acceptable varies according to laboratory, but it is not usually less than 50. Below this, the uniqueness of the ring pattern may be questionable. However, a high proportion of archaeological wood samples submitted for analysis have fewer than 50 rings for example 61% of the oak timbers from the Iron Age causeway at Fiskerton, Lincolnshire were short sequences. If we were to ignore these samples, we would be losing a great deal of information and dating potential.

Experience has shown that the actual number of rings is less crucial to successful dating than the number of related samples. For example, one sample with 30 rings is probably undatable, whereas several samples, all from the same context, might be datable. The single 30-year pattern might not be unique, but several ring patterns can be crossmatched with each other, and with a reference or master chronology. This latter process, where pattern A matches B, B with C, A with C, and so on, is called replication, and is a fundamental principle of dendrochronology. Without it, tree-ring dating would not be a reliable dating method.

The basic requirement for the analysis of short ring sequences therefore is that several samples must be examined from the same context. The Somerset Levels short sequences, mentioned by Fletcher[2], for example, are used for relative dating on single period structures with very large numbers of samples[3]. Short sequence samples should contain sapwood, and preferably retain the bark surface, since initial assumptions have to be made about their contemporaneity.

The short sequences from Custom House do not meet these requirements. The dating of Quay B to AD137–42 relies on one timber, III 1, which has 39 rings. The *t*-values given for it, and the other Custom House short sequences, are low and require greater replication to be accepted by most dendrochronologists. Since neither the ring widths nor the tree-ring graphs of the short sequences are presented, the match between III 1 and I D (39 years overlap), and between III 1 and I C (26 years overlap) cannot be examined, but the possibility of these being chance high value correlations cannot be ruled out[4]. On these grounds therefore, the dating of Custom House Quay B, based on the short ring sequences, can only be accepted with caution. There is no question about the dates of the longer sequences without sapwood, which give a felling date of post-AD122 (based on 10 years minimum sapwood allowance—see below).

SAPWOOD ESTIMATION

When we consider the sapwood, the outer growth of an oak-tree which is both softer and more vulnerable to decay than the heartwood[5], it is clear that the variation in sapwood number is large and cannot easily be related to other measurable variables. The only rigorous method for estimating sapwood numbers is to study a large number of samples with full sapwood and statistically describe the variation in a way which can be subsequently applied to samples that lack some or all of their

sapwood. In the British Isles this method has been applied to data from several different areas and the results show a range of around 10–55 years[6]. For most archaeological purposes this is quite adequate. However numerous attempts have been made to relate sapwood number to a further variable in order to reduce this range[7]. These experiments have shown that, for trees of 100 years or more total age, the use of average ring widths or tree-age for sapwood estimations is of little value.

Fletcher presents some figures which show the 'likely' number of sapwood rings for trees younger than 100 years and with different average rates of growth[8]. If correct these figures would be gratefully accepted by archaeologists and dendrochronologists since they suggest that the sapwood number varies by as little as five years for fast grown young trees. Since timbers of this sort are so common on archaeological sites it would increase the applicability and accuracy of dendrochronology by a significant extent. However, comparison between Fletcher's published values and values derived from actual data, shows that, although the trends in the data are similar, the variability is considerably underestimated. Figure 1 illustrates the variability in sapwood numbers: five of the observed values lie outside the lines that denote the 95% confidence limits for the data set. By contrast, 46 lie outside the limits set by Fletcher's values.

Our data derive from 106 samples from Iron Age and Roman sites in England. The Roman timbers are from southern England (mostly from the City of London, and Southwark), the Iron Age site is Fiskerton in Lincolnshire. All samples are from trees younger than 100 years. Conclusions drawn from such a data set are readily applicable to sites such as Custom House. Even so, we do not consider the sample size to be adequate for any but the broadest interpretation. Fletcher's values are based on 'fewer than' 67 trees[9], and are used in a way that implies they are not 68% or 95% ranges (one & two standard deviations respectively) but absolute limits. Publication and use of such values attempts to give dendrochronology a greater accuracy than it is capable of under these circumstances.

Dendrochronologists and archaeologists must become reconciled to the fact that where there is no bark surface but some sapwood the felling date of a sample can only be estimated to within as much as 45 years. Where there are two or more samples that have overlapping felling date ranges and are assumed to be contemporary the likely range of felling for the feature can be reduced, see for example Quay 2 at Pudding Lane (Fig. 2). The limitations of the method are clear, when the bark surface is present, a felling date accurate to the year or even the season, can be given. Without it,

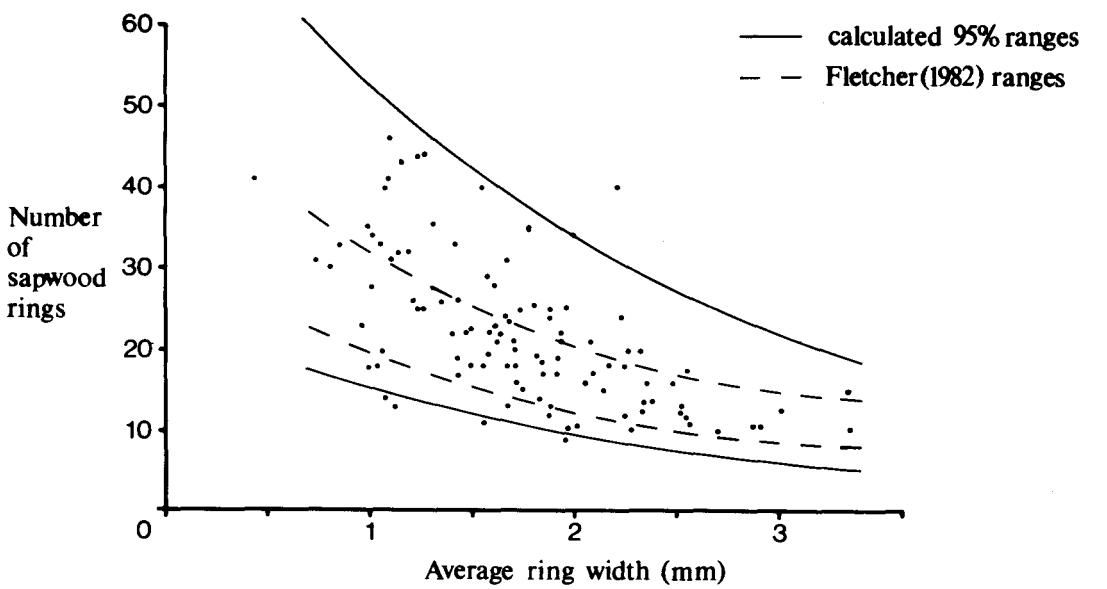

Fig. 1 Relationship between average ring width and number of sapwood rings for trees of less than 100 years of age.

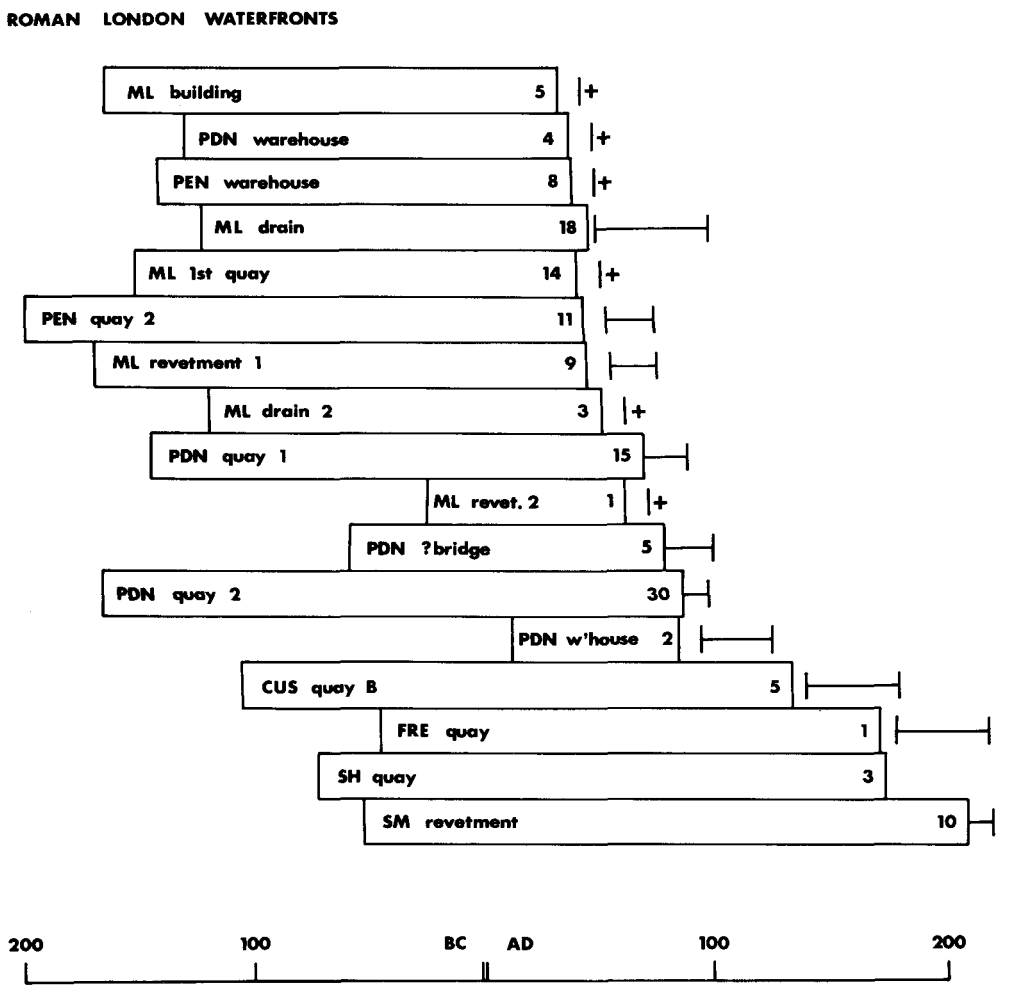

Fig. 2 Relative positions of the ring sequences from waterfront structures in London. Sapwood estimate is 10–55 (95% confidence limits), based on Roman sapwood data from southern England. Key: ML—Miles Lane; PDN—Pudding Lane; PEN—Peninsular House; CUS—Custom House (as dated by Fletcher but our sapwood estimate); SH—Seal House; FRE—New Fresh Wharf. Horizontal bar—estimated felling dates; + – *terminus post quem*. Minimum number of timbers dated is given at right hand side of each bar.

an accuracy of less than 15 or 20 years is only possible if the structure to be dated is represented by many timbers, such as the 30 samples from Quay 2 at Pudding Lane.

DATING LONDON WATERFRONT STRUCTURES

Tree-ring results for the other Roman waterfront structures are illustrated in order to demonstrate how sapwood affects dating accuracy (Fig. 2). Several structures associated with the 1st century quays have been dated. These were excavated at

Miles Lane[10], Peninsular House and Pudding Lane[11]. The 2nd century quay is thought to run under Lower Thames Street[12], but the 3rd century waterfront structures have been dated from Seal House and New Fresh Wharf[13].

Whilst several hundred ring sequences have been dated altogether from these structures, the problems of interpreting the results has been great, since most of the timbers had no sapwood. None of the fourteen timbers which were dated from the 1st century quay at Miles Lane, for example, had sapwood. Their felling date can therefore only be expressed as a *terminus post quem*. Other structures had one or two timbers with sapwood, and hence estimated felling dates cover a wide range of calendar dates. This is illustrated by the first phase of a drain at Miles Lane. With information from the excavators about the archaeological interpretation of the sites, it may be possible to make suggestions about the dating of these structures, but that dating will not be precise. Precise dates depend on complete samples; for instance we know the foundation piles for a building immediately to the north of the riverside wall at St. Peter's Hill were felled in the years AD293, 294 and 295, because most of the samples were complete and retained their bark surface[14]. We also know that the dating is reliable because although some of the ring sequences were short, the crossdating is well replicated.

CONCLUSIONS

We feel that the use of short ring sequences without adequate replication, and the use of sapwood estimates based on statistically small groups of samples can only damage an otherwise reliable and independant dating technique.

Dendrochronologists should publish their results in detail. The basis for calculating sapwood estimates should be explained, and if short sequences are used for dating, such dating should be backed up by *t*-values, matching graphs, and most importantly replication. A close liason between the dendrochronologist and archaeologist is always helpful, and the dendrochronologist should always be prepared to justify his or her results. Tree-ring dating has a valuable role to play in archaeology, but its application will not be assisted by the publication of unsupported and unrealistic results.

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J. Hillam and R. Morgan,
Department of Archaeology and Prehistory,
The University,
Sheffield S10 2TN.

I. Tyers,
Department of Greater London Archaeology,
Museum of London,
London Wall, London EC2Y 5HN.

NOTES

1. J. Fletcher, 'The waterfront of *Londinium:* the date of the quays at the Custom House site reassessed' *Trans. London Middlesex Archaeol. Soc.* 33 (1982) 79–84.
2. *ibid.* 83.
3. R. A. Morgan, 'Tree-ring studies in the Somerset Levels: the Sweet Track 1979–1982' *Somerset Levels Papers* 10 (1984) 46–64.
4. With short overlaps there is a greater chance of a spurious matches being found by the computer programs used. Further details are given in J. Hillam, R. Morgan and I. Tyers, 'Sapwood estimates and the dating of short ring sequences' in *Brit. Archaeol. Rep.* (forthcoming).
5. See H. Sheldon and I. Tyers, 'Recent dendrochronological work in Southwark and its implications' *London Archaeol.* 4 (1983) 355–61. fig.1.
6. See Hillam, Morgan & Tyers *op. cit.* in note 4.
7. For example, M. G. L. Baillie, *Tree-ring Dating and Archaeology* (London 1982); M. K. Hughes, S. J. Milson & P. A. Leggett, 'Sapwood estimates in the interpretation of tree-ring dates' *J. Archaeol. Science* 8 (1981) 381–90.
8. Fletcher *op. cit.* in note 1, fig. 3.
9. Fletcher *op. cit.* in note 1, 82.
10. L. Miller, 'Miles Lane: the early Roman waterfront' *London Archaeol.* 4 (1982) 143–47.
11. G. Milne, 'Further evidence for Roman London Bridge?' *Britannia* 13 (1982) 271–76; N. Bateman & G. Milne, 'A Roman Harbour in London; Excavations and observations near Pudding Lane, City of London 1979-82' *Britannia* 14 (1983) 207–26.
12. Bateman & Milne (1983) *op. cit.* in note 11 fig. 1.
13. J. Hillam & R. Morgan, 'New Fresh Wharf: Tree-Ring Analysis of the Roman Timbers' in *Excavations at New Fresh Wharf, City of London 1974-8; 1—Roman* Trans. London Middlesex Archaeol. Soc. Special paper (forthcoming).
14. J. Hillam, 'Recent tree-ring work in Sheffield' *Current Archaeol.* 96 (1985) 21–6.