Tree-Ring Dating: The Mermaid Theatre, City of London

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TREE-RING ANALYSIS of oak timbers from the Mermaid Theatre site was the means of providing an accurate date for the excavated revetment. At the same time, the study also extended the existing London medieval tree-ring chronology by 42 years, thus enhancing the possibilities of dating future timbers from London and elsewhere.

In 1979, excavations at the site of the Mermaid Theatre (Fig. 1), undertaken by the Museum of London's Department of Urban Archaeology, uncovered the remains of a medieval revetment. Only the oak timbers of the base-plates had been preserved in the waterlogged deposits, but it was possible to make a complete reconstruction of the revetment by the examination of the timber joints (Fig. 2). The base-plates had supported upright timbers to which were attached horizontal planks. The whole structure was braced at the front and back; it was a sophisticated and expensive prefabricated construction. This contrasts with the well-preserved "Waterfront III" revetment at Seal House[1] (Fig. 1), which was front-braced only and a rather crude structure by comparison (Fig. 3).

There were no associated finds to suggest a date for the construction of the Mermaid revetment. An early to mid 13th century date was postulated on stylistic grounds, based on the carpentry chronologies of Hewett[2]. This date was suggested by the use of the chase mortise and secret notched lap joint, which were used for the front and back braces respectively.

The preservation of some of the oak timbers which had formed the base-plates, however, allowed absolute dating to be obtained through the use of dendrochronology[3]. Tree-ring studies have been carried out on timbers from many sites in the City of London and the results have been very encouraging[4]. Of the hundreds of samples that have been examined, a high proportion have been dated: the "Waterfront III" revetment at Seal House mentioned above, for example, was dated to *c.* AD 1220[5]. The primary purpose of this type of analysis in London is obviously to date the timber structures found during excavation. However, there are two other, longer-term, aims of the tree-ring studies: first, to extend existing reference tree-ring chronologies for the London area, which will provide a dating framework for future samples, both from London and elsewhere, and second, to collect information about the timber itself and about the woodlands from which it originated[6].

The timber

Sixteen timbers were examined at the DoE dendrochronology laboratory in Sheffield (Table 1). Apart from 241, a timber of unknown function, all the samples related to the same structure. All were from base-plates as no timbers survived from the upper part. There was no evidence of any timbers having been re-used, so the wood was probably felled specifically for use in the revetment. This agrees with the findings at Trig Lane (Fig. 1) which suggests that base-plates tend to be primary timbers; supports and piles are more likely to have been re-used[7].

The trees used to produce the timber for the Mermaid revetment were young oaks, probably less

1 J. Schofield, "Seal House", *Current Archaeol*, **5** (2) (1975), 54-7.

2 C. A. Hewett, "The Notched Lap joint in England", *Vernac. Archaeol.*, **4**, (1973), 18-21.
C. A. Hewett, *"The Development of Carpentry 1200-1700. An Essex Study"*, David & Charles, (1969), esp 55.

3 Further details of this method can be found in M. G. L. Baillie, "A recently developed Irish tree-ring chronology" *Tree Ring Bulletin*, **33** (1973), 15-28.
J. Hillam, "Tree-rings and Archaeology: some problems explained", *J. Archaeol. Science*, **6**, (1979), 271-8.

4 For further details, see:
J. Hillam & R. A. Morgan, "What value dendrochronology to waterfront archaeology?" In *Waterfront Archaeology in North European Towns* edited by G. Milne & B. Hobley, CBA Research Report (forthcoming).
R. A. Morgan & J. Schofield, "Tree-rings and the Archaeology of the Thames Waterfront in the City of London", in *Dendrochronology in Europe* edited by J. M. Fletcher, *BAR* **S51** (1978), 223-38.

5 R. A. Morgan, "Tree-ring dating of the London Waterfronts" *London Archaeol*, **3**(2) (1977), 40-5.

6 Hillam & Morgan, *op cit.*

7 Morgan & Schofield, *op cit*, fn 4.

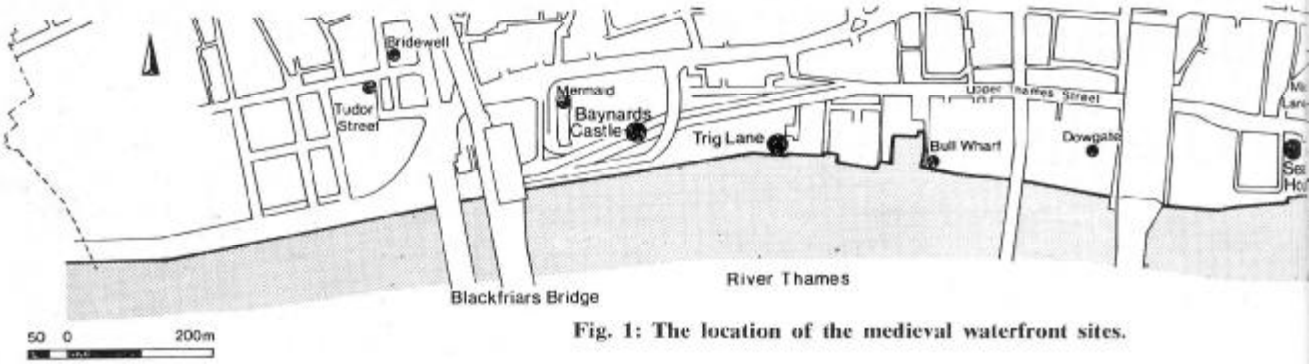


Fig. 1: The location of the medieval waterfront sites.

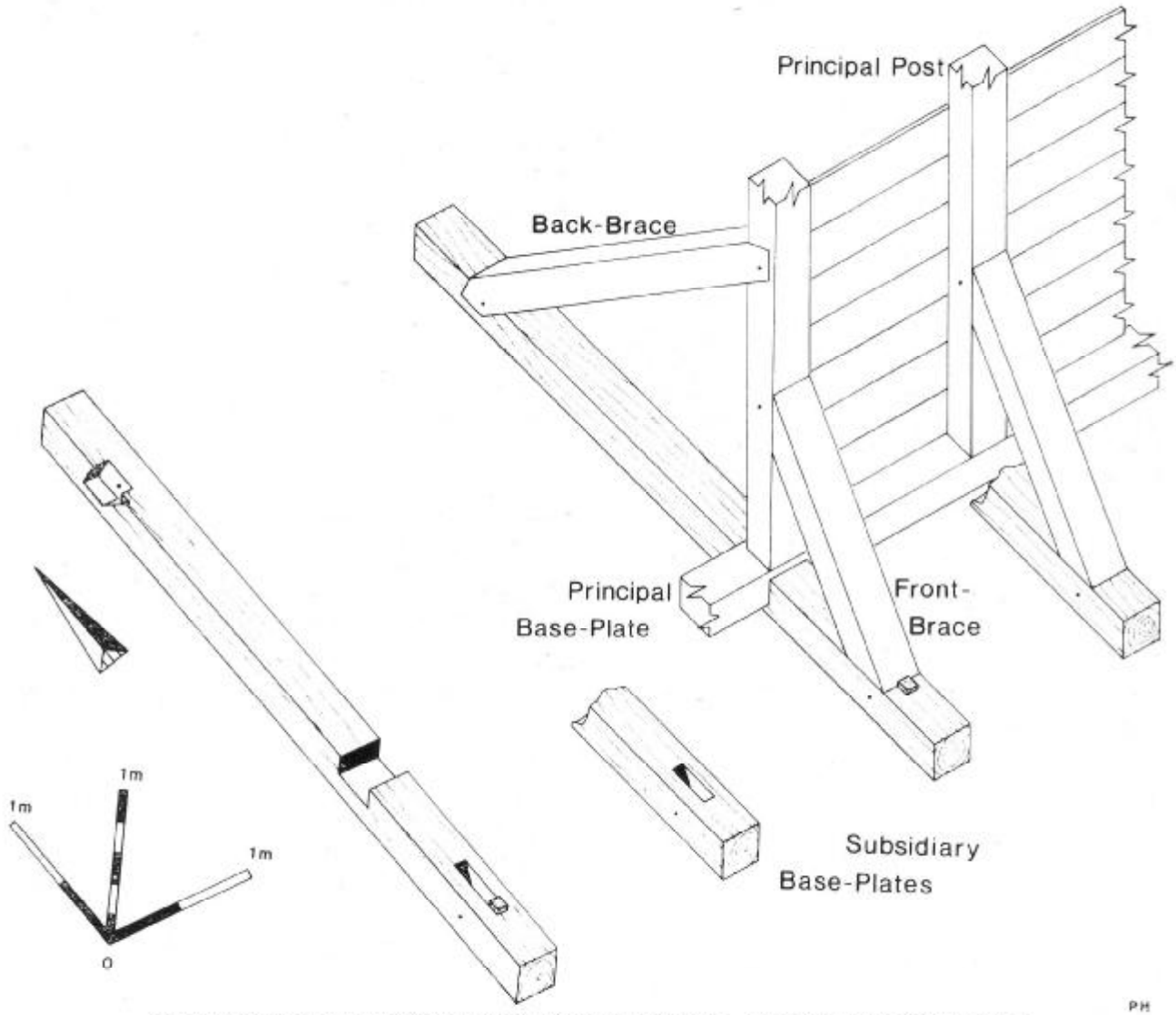
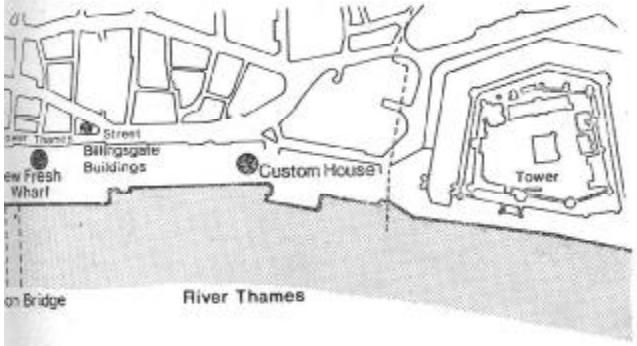


Fig. 2: Isometric reconstruction of the Mermaid revetment. Only the toned timbers were excavated; the remainder are reconstructed.



than 100 years of age when felled. They had been roughly hewn into squared or rectangular shapes. Usually the whole trunk was used, but sometimes it was first halved or quartered before being shaped. This seems to depend upon the size of the tree and has no relation to function, eg whether the timber was intended for a principal or subsidiary base-plate (Fig. 2). Such deductions, however, are limited by the absence of upper timbers for study. The sapwood, which was often removed due to its susceptibility to insect or fungal attack, was present on some of the timbers. These are indicated in Table 1 together with the sizes and sketches of the samples.

The average width of the rings, mostly 2-3mm (about .10in), indicates that the trees were fairly fast-grown (wide-ringed) and thus had grown under favourable conditions without too much shading from other trees. That mature oak timber from slow-

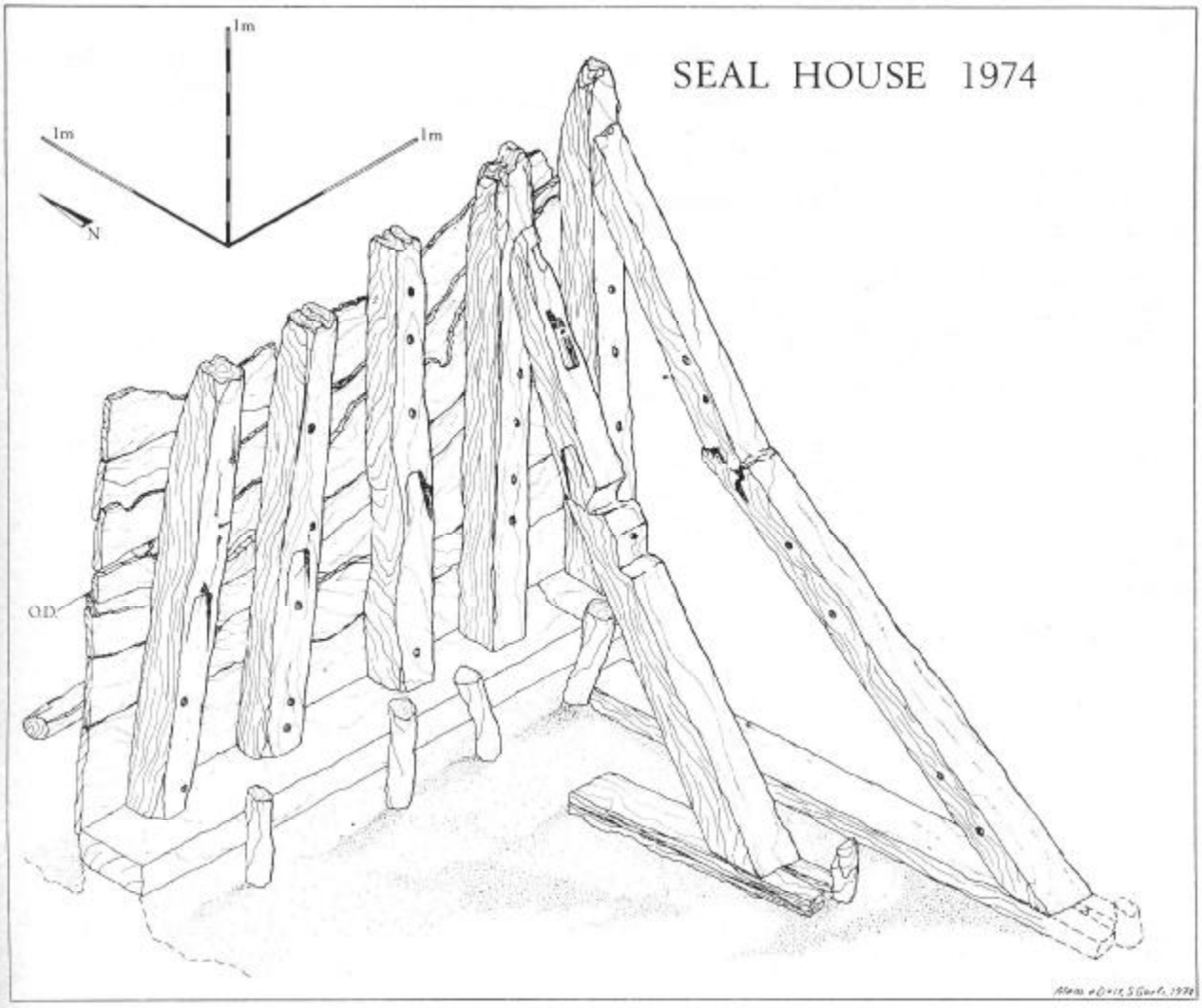


Fig. 3: Isometric drawing of Waterfront III, Seal House.

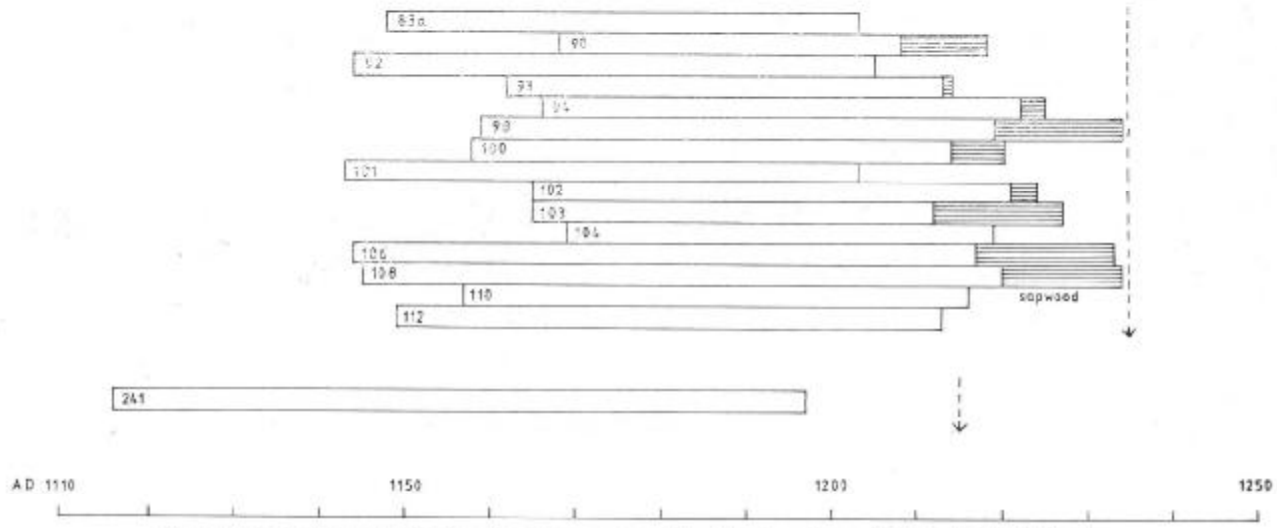


Fig. 4: Block diagram showing the years spanned by the tree-rings of the individual timbers. Arrows indicate the earliest likely felling dates.

grown trees was also available in medieval London is known from sites such as Seal House, where many fine quality boards with 200 or more narrow rings have been found[8].

The Mermaid Theatre tree-ring chronology

The samples had between 50 and 90 annual rings. At one time it was thought that such timbers could not be reliably dated but work at Sheffield has done much to disprove this[9]. All the curves were compared with each other, both visually and by computer. Many were found to coincide and where this occurred, a mean was taken through the individual curves to form a site master curve. The unmatched sequences were tested against this and were all eventually crossdated (Fig. 4) except for 241, the timber known to derive from a different context. To produce a final master curve, which might be dated against other reference chronologies, it was necessary to eliminate the effects of the wide-ringed samples that might otherwise bias the mean curve in their favour. (Rings at the centre of a trunk, that is those that appear early in the life of a tree, tend to be significantly wider than the rings of later growth). This process and the production of the standardised master curve, made up of index values, were carried out with the aid of a computer program[10].

Dating the revetment

The Mermaid Theatre chronology was compared by computer with various dated sequences from Britain, Ireland and Germany, including Morgan's Seal House sequence from London, AD 950-1193. Significant *t*-values[11] were obtained with several of these when the last year of the Mermaid master was equivalent to AD 1234. The overlap between the Mermaid Theatre and Seal House sequences was only 51 years. The match between them was visually acceptable although it gave a *t*-value of only 2.41. It was verified by good agreements with German chronologies from the Munich area[12] ($t = 3.46$) and from the area west of the Rhine[13] ($t = 4.17$). This was not unexpected since other London curves have been dated by these[14]. The highest *t*-value, however, resulted from the comparison with the Dublin chronology[15] ($t = 5.10$); the visual match between the two curves is illustrated in Figure 5. Not only did the

8 Hillam & Morgan, *op. cit.*

9 See, for example:
J. Hillam & R. A. Morgan, "The dating of the Roman Riverside wall at three sites in London", *London Archaeol.* **3** (11) (1979), 283-7.

10 H. C. Fritts, J. E. Mosimann & C. Bottorff, "A revised computer program for standardising tree-ring series", *Tree Ring Bulletin*, **29,** (1969), 15-20.

11 M. G. L. Baillie and J. R. Pilcher. "A simple crossdating program for tree-ring research", *Tree Ring Bulletin*, **33,** (1973), 7-14.

Hillam (1979). *op. cit.*, 274.

12 B. Huber & V. Giertz-Siebenlist, "Unsere tausendjährige Eichenchronologie durchschnitlich 57(10-150)-fach belegt", *Sitz. Ost. Akad. Wiss*, **178** (1969), 37-42.

13 E. Hollstein, "Jahrringchronologische Datierung von Eichenholzern ohne Waldkante", *Bonner Jahrbuch*, **165** (1965), 12-27.

14 Morgan, *op. cit* fn 5.

15 M. G. L. Baillie, "Dublin Medieval Dendrochronology", *Tree Ring Bulletin*, **37** (1977), 13-20.

Mermaid master curve synchronise well with sequences from Germany and Ireland, but the Mermaid individual curves also crossmatched with them, giving *t*-values of up to 4.75. It is an encouraging sign for future tree-ring work that an individual curve from London, with only 65 rings (No. 112), will produce *t*-values of 4.19 and 4.67 with Germany and Ireland respectively. It shows that, for some periods at least, trees growing in the area extending from Ireland across to Germany, were responding to a common climatic signal.

These correlations establish the time-span covered by the Mermaid sequence as AD 1143-1234, but in order to determine the felling dates and hence the construction date of the revetment, it is necessary to take into account: first, the seasoning of the timber and second, the removal of the sapwood from the timbers during construction.

Since seasoning the timber would be unnecessary for a structure of this kind, it is reasonable to assume that the felling date of the timber is very close to the construction date and that the timbers of the revetment were felled during the construction period. It is accepted that the quantity of sapwood in an oak tree remains relatively constant. Younger trees, especially those with wider rings, tend to have fewer years of sapwood. The number of sapwood rings missing from a sample can be estimated with reasonable accuracy provided that the heartwood-sapwood transition is present. Many of the Mermaid timbers do show this boundary (Fig. 4).

Three samples, 98, 106 and 103, give a strong indication of the felling date. They are wide-ringed samples, each having 15-17 years of sapwood, and the dates of their last ring vary by only one year. They therefore, have probably retained almost their full complement of sapwood rings. This amount of sapwood is consistent with that for a young tree and hence we can confidently date the felling of these trees at AD 1235 or just after. This implies that sample 90 originally had 28 years of sapwood, a figure well within the limits of 32 ± 9 years given by

16 M. G. L. Baillie, *op. cit.* fn 3.

No.	No. of rings	Sapwood rings	Average width (mm)	Sketch	Dimensions (mm)
83a	56	—	2.71		270 x 140-150
90	51	11	3.04		260 x 240
92	62	—	1.58		240 x 190
93	53	2	2.01		190 x 160
94	60	4	3.14		250 x 220-250
98	76	16	3.05		250 x 240
100	63	7	2.47		230 x 140-190
101	61	—	2.88		230 x 110-120
102	60	4	3.57		260 x 260
103	63	15	2.41		240 x 190
104	51	—	3.08		250 x 220-260
106	90	17	2.86		250 x 220
108	90	15	2.19		260 x 230
110	60	—	3.15		270 x 190
112	65	—	2.36		245 x 170-190
241	82	—	1.85		240 x 210

Table 1: Details of the Mermaid timbers; the sketches of the cross-sections are not drawn to scale.

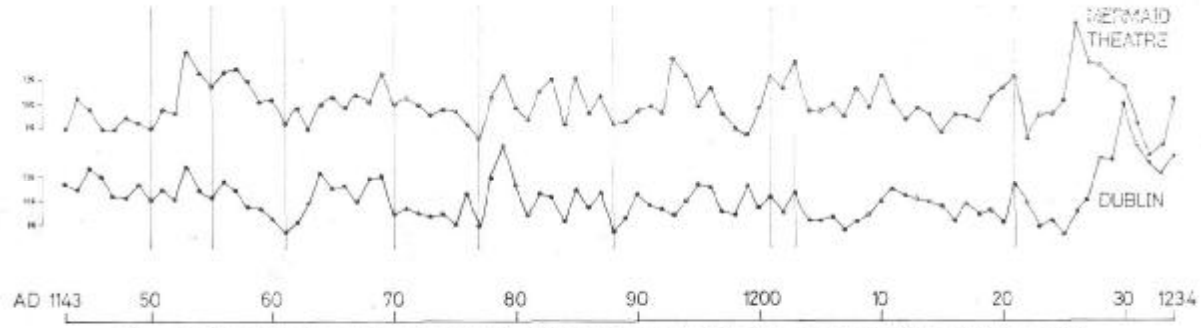


Fig. 5: Matching tree-ring curves: the Mermaid curve with the corresponding section of the Dublin chronology. The ring widths are represented by indices on the vertical scale. Vertical lines are included as an aid to visual comparison.

Baillie[16]. It can therefore be postulated that the revetment was constructed within the period AD 1235-1240.

Timber 241, of unknown function, was dated to AD 1116-1197 (Fig. 4). In the absence of sapwood rings, an estimate of the *terminus post quem* for the felling date is AD 1215.

Conclusions

The above study once again illustrates the importance of dendrochronology to archaeology. Prior to the tree-ring result, only a vague date was available for this unique revetment, derived from Hewett's studies of ancient carpentry[17]. The secret notched lap joint had only previously been recorded in standing buildings dating from the beginning of the 13th century to *c.* 1260, a margin of error equal to that of a radiocarbon date. But this did not however necessarily place the revetment within that period, due to the indefinable human element involved in the use of carpentry joints, and the fact that previous work on the London Waterfront seems to indicate that medieval riverfront revetments were unaffected by these advances, and only incorporated joints which had been tried and tested elsewhere[18]. The date of AD 1235-40, produced by tree-ring analysis, is however incontrovertable because it is independent of such considerations, relying instead upon matching tree-ring patterns.

This date makes the Mermaid structure the earliest back-braced revetment in the country and, as such, is of national importance as well as being extremely interesting from the point of view of London archaeology. Built only a few years after "Waterfront III" at Seal House, the Mermaid is obviously a far superior structure. With accurate dates for the two revetments, it should be possible to deduce something about the status of their respective owners; whoever built, or commissioned the building of, the Mermaid revetment was of some standing in the society. This aspect will be disdussed more fully in the excavation report[19].

In more general terms, the dating of timbers with short ring patterns is encouraging; only a few years ago such samples would have immediately have been rejected by dendrochronologists, thereby ensuring the loss of much valuable information. Of equal importance is the quality of the crossmatching between the Mermaid tree-ring curves and those from Germany and Ireland. It indicates that during the 12th and 13th centuries, trees were showing similar ring patterns throughout a large area of northern Europe; this argues well for the dating of English timbers in the future.

Finally, the Mermaid chronology is a further building block in the production of a long London chronology. It extends Morgan's Seal House sequence (AD 950-1193)[20] by 42 years and forms part of a continuous medieval tree-ring chronology covering the period AD 682-1234[21]. The latter is based on timbers from several sites in the City of London, such as New Fresh Wharf, and will be published in due course.

Acknowledgements

The work at Sheffield was financed by the DoE. The Department of Urban Archaeology are grateful to Bernard Miles and the contractors, Trollope & Colls Ltd, for their full cooperation throughout the excavation[22].

17 Hewett, *op. cit.*

18 G. Milne & C. Milne, "Excavation on the Thames Waterfront at Trig Lane, London, 1974-76", *Medieval Archaeol.* **22** (1978), 102-3.

19 P. Herbert, forthcoming.

20 R. A. Morgan, "Tree-ring dating of the medieval waterfronts at the Seal House site", in J. Schofield "Excavations at Seal House, City of London, 1974-6", Trans. *LAMAS* special paper (forthcoming).

21 J. Hillam, unpublished.

22 All material associated with the site is stored in the archive of the Department under the site code "THE 79".