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LYTHAM HALL, LYTHAM, LANCASHIRE
DENDROCHRONOLOGICAL ANALYSIS OF OAK AND PINE TIMBERS, AND LIVING OAK TREES

SCIENTIFIC DATING REPORT

Ian Tyers

INTERVENTION
AND ANALYSIS

ENGLISH HERITAGE

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SUMMARY

A tree-ring dating programme was commissioned on oak and softwood timbers from Lytham Hall. This building is an eighteenth-century manor house on the site of an earlier manor house and Benedictine Priory. The Hall is set in 30 hectares of mature parkland within which a further programme of sampling was undertaken on living oaks. The results identified that oak and pine timbers from the roof of the eighteenth-century building were datable by tree-ring dating techniques, with the earlier ranges to the west containing some oak timbers from the sixteenth century, and further oaks and pines from the mid-eighteenth century. Oaks that were two centuries old were identified from the park. This report archives the dendrochronological results.

CONTRIBUTORS

Ian Tyers

ACKNOWLEDGEMENTS

The sampling and analysis of timbers at Lytham Hall was funded by English Heritage (EH). Practical help and valuable discussions were provided by Cathy Tuck, Heritage at Risk Projects Officer (EH), Adam Menuge, Senior Investigator, Assessment Team North (EH), Lucy Jessop, Investigator, Assessment Team North (EH), Isabelle Parsons and Allison Borden. Cathy Tyers, Scientific Dating Team (EH) discussed the softwood results.

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INTRODUCTION

This document is a technical archive report on the tree-ring analysis of oak and pine timbers from Lytham Hall, Ballam Road, Lytham, and living oaks from the parkland to the north-east of the Hall. It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. Elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the building.

Lytham Hall stands about 1km north of the Ribble estuary coast between Preston and Blackpool (NGR SD 3568 2790). It was formerly the centre of a 6000 hectare estate, with some 30 hectares of mature parkland still extant (Fig 1). The park is low lying, at around 10m OD throughout. At the east of the main range of buildings is the Hall (Fig 2). This was built for Thomas Clifton by John Carr between *c* 1752 and 1764 on the site of both an earlier manor house and a Benedictine Priory. To the west is a courtyard surrounded by buildings with some apparently earlier timber framing in stairways, under the floors, and in loft spaces. To the south-west is a long range (Fig 2), with exposed roof trusses. The building was formerly occupied as a large company head office and has lots of relatively recent modifications; the Long Gallery was formerly a typists pool, and the south-west range was modernised as a meeting room, conference centre, or reception area. The building is Grade I listed and is on the Heritage at Risk register and is subject to on-going Heritage Lottery Project proposals.

METHODOLOGY

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

The building was visited in April and November 2008 in company with Cathy Tuck, Adam Menuge, and Isabelle Parsons. An assessment of the dendrochronological potential of timbers in several areas of the structure had been requested by Cathy Tuck. This assessment aimed to identify whether oak or softwood timbers with sufficient numbers of rings for analysis existed in any part of the complex. This assessment concluded that timbers in the Hall roof (Figs 3–7), along with various timbers of the floor of the south range and the exposed roof of the south-west range, contained suitable oak and softwood material (Fig 8). *In situ* panelling and plasterwork severely restricted access to the structural elements lower down the Hall, whilst most of the exposed timbers, and those timbers accessible by lifting floors or entering roof spaces throughout the kitchen

range, the current offices and cottage, and the basement of the hall were unsuitable for sampling and analysis.

Sampling was subsequently commissioned in order to inform advice and enhance understanding of this important building complex and its environs. The sampling took place during November 2009, and February through March of 2010. The selected timbers were sampled using a 15mm diameter corer attached to an electric drill. A group of large oaks from the park were cored by 5.15mm diameter hand turned increment corers. The cores were taken as closely as possible along the radius of the timbers so that the maximum number of rings could be obtained for subsequent analysis. The ring sequences in the cores were revealed by sanding.

This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved. Dendrochronological samples need to be free of aberrant anatomical features, such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample. The complete sequence of the annual growth rings in suitable samples was measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequence of ring widths was then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position need to have been obtained from a range of independent sequences, and that these positions are supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees cannot be reliably cross-matched, even when enough rings are obtained.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling

date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a minimum of 10 rings and a maximum of 46 rings as a sapwood estimate (eg English Heritage 1998, 10–11).

Where bark-edge or bark survives, the season of felling can be determined by examining the completeness or otherwise of the terminal ring lying directly under the bark. Complete material can be divided into three major categories:

- 'early spring', where only the initial cells of the new growth have begun - this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;
- 'later spring/summer' where the early wood is evidently complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year, and
- 'winter' where the latewood is evidently complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

These categories can overlap as, for example, not all oaks simultaneously initiate leaf-bud formation. It should also be noted that slow growing or compressed material cannot always be safely categorised.

Timber technology studies demonstrate that many of the tool marks recorded on ancient timbers can only have been done on green timber. There is little evidence for long-term storage of timber or of widespread use of seasoned, rather than green, timber in the medieval period (eg English Heritage 1998, 11–12).

Reused timbers can only provide tree-ring dates for the original usage date, not their reuse. Identifying reused timbers requires careful timber recording which notes the presence of features which are not functional in the structure. It is always possible that some timbers exhibit no evidence of earlier usage, and are thus 'hidden reused' timbers. The dendrochronological impact of this problem is particularly acute where only single timbers have been dated from a structure.

The analysis may highlight potential same-tree identifications if two or more tree-ring sequences are obtained that are exceptionally highly correlated. Such pairs, or sometimes more, are then used as a same-tree group and each can be given the interpreted date of the most complete of the samples. They are most useful where several timbers date but only one has any sapwood or where same-tree identifications yield linkages between different areas.

RESULTS

In 2009 and 2010 50 timbers from across the building were cored, these cores were labelled 1–50 inclusive. Figures 5 and 8 show the distribution of the samples through Lytham Hall. In total 21 samples were obtained from nine oak timbers and 12 softwood timbers from the roof of the eighteenth-century Hall. Fifteen samples were obtained from floor joists in the long gallery of the south range, 14 of these were oak and one was a softwood. Fourteen samples were obtained from the roof of the south-west range, nine were softwood purlins, and five were oak elements of the roof trusses. Thirteen oak trees selected from within a *c* 450 x *c* 250m area north-east of the Hall were cored, these cores were labelled 51–63 inclusive.

Each building sample was assessed for the wood type, the number of rings it contained, and whether the sequence of ring widths could be reliably resolved. This assessment confirmed that all the sampled softwood timbers were pine (*Pinus sylvestris* type) and that 18 of the 28 oaks, and 17 of the 22 softwoods were suitable for dendrochronological analysis. The exceptions either had too few rings for analysis or had fragmented badly during sampling. The unsuitable oaks comprised ten samples, two from the Hall roof, six from the long gallery joists, and two from the south-west range roof trusses. There was good survival of oak sapwood in the Hall roof and the south-west range roof, but very poor survival in the long gallery joists. Oak bark-edge survival was good in the Hall roof. The five unsuitable softwoods comprised three from the Hall roof, the only softwood joist sampled in the long gallery, and one of the south-west range purlins. There was poor survival of pine sapwood in all of the targeted areas, with no bark-edges surviving the sampling process. The 13 living-tree cores were recovered successfully, and each was suitable for analysis. All were complete to bark-edge. The sampled park oaks are mostly *Quercus petraea* type. Details of the oak, softwood, and living tree samples are provided in Tables 1–3 respectively.

The 18 suitable oak samples from the building were prepared for analysis, measured, and the resultant ring series were initially compared with other material from the same area of the building. Further comparisons were then made between areas, various interim composite groupings were made of sequences during this process. Finally the interim composites and the individual sample series were individually compared with reference series of medieval and later oak tree-ring data from throughout Britain. These results were reviewed and a single final composite series was constructed from four samples from the Hall roof and two samples from the south-west range roof. This group is formed by cross-matched tree-ring data (Table 4), supported by good external cross-matching. Sequence LythamOak1 constructed from these, a 178-year composite, matches with reference data (Table 5) at AD 1578 to AD1755 inclusive. In addition one individual sample from a long gallery joist timber (sample 28) was found to exhibit good external cross-matching with reference data at an earlier date (Table 6). A summary of the results for the component and individual samples are provided in Table 1 and Figure 9.

The 17 suitable softwood samples from the building were prepared for analysis, measured, and the resultant ring series were initially compared with other material from the same area of the building. Further comparisons were then made between areas; various interim composite groupings were made of sequences during this process. Finally the interim composites and the individual sample series were individually compared with reference to a series of softwood tree-ring data from northern and central Europe, and with other softwood data from buildings from Britain. These results were reviewed and a single final composite series was constructed from five samples from the Hall roof and two samples from the south-west range roof. This group is formed by cross-matched tree-ring data (Table 7), supported by individual external cross-matching (Table 8). Sequence LythamPine constructed from these, a 211-year composite, matches with reference data (Table 9) at AD 1522 to 1732 inclusive. A summary of the results for the component and individual samples are provided in Table 2 and Figure 9.

The 13 living oak samples from the park were taken along 3 separate transect lines (Figure 10). These cores were prepared for analysis, measured, and the resultant ring series were initially compared with each other. This material is characterised by unusually rapid growth, some trees contain some aberrant growth sequences, and the assemblage as a whole exhibits relatively poor internal cross-matching (Table 10). Sequence LythamOak2 constructed from these, a 193-year composite, matches with other modern reference data (Table 11) at AD 1817 to AD 2009 inclusive. A summary of these results is given in Figure 11. This material was cored on 26 March 2010 and no visible signs of the onset of growth for 2010 were observed at the bark edges of the cores. The trees were not in leaf.

The measurement data for all the measured samples are listed in the Appendix.

DISCUSSION

The dated samples are derived from three different areas of the building. These areas are discussed firstly from the roof of the eighteenth-century Lytham Hall range, then those from the roof of the south-west range, and finally the single datable sample from the Long Gallery, south range. The datable oak material matches with other local and regional reference data and it is likely that all the oak timbers were derived from the general vicinity of Lytham. The datable softwoods appear to represent a reasonably coherent group from a single source, probably from Latvia or the river systems east into Belarus.

Lytham Hall, the main roof

This two and a half storey high double-pile building (Fig 3) is known to have been built for Thomas Clifton between *c* 1752 and 1764, by architect John Carr. The 23 timber trusses of the roof (Fig 4) run as a series around a central masonry block (Fig 5), with east-west aligned trusses along both long sides, and north-south aligned trusses along the short sides. These overlap in a rather complicated arrangement such that the tiebeams of some

trusses then form the crossing beams through other trusses. There are a number of distinct truss forms, 16 being full trusses, and seven being half trusses. The trusses fairly consistently use oak for the vertical elements (king posts and various struts) and softwood, pine where identified, for the main tiebeams, cross-beams, and the principal and common rafters (one exception being oaks used for the raised ties that lie over the central block).

The 21 samples obtained from timbers within the roof yielded nine datable tree-ring sequences. These are of two types, four are oak, and five are pine. The tree-ring analysis dates the rings present in the cores. The correct interpretation of these relies upon the characteristics of the final rings in them. Bark-edge survived on two of the oak timbers, some sapwood survived on another oak, and one of the pines. No sapwood was present on the remaining datable timbers. Making allowances for minimum and maximum likely amounts of missing oak sapwood provides individual felling dates, or felling date ranges, or *terminus post quem* dates for each of the datable oak timbers. Making the assumption that pine sapwood can be difficult to identify with certainty provides the datable pine timbers with *terminus post quem* dates. Figure 9 and Tables 1 and 2 include the felling date or interpreted felling date ranges for each of the datable samples.

The interpretation of two of these dated samples is straightforward. Samples 5 and 7 are complete to bark edge. These both retain a complete ring for AD 1755, and the onset of growth for the following year. These timbers were therefore felled in the spring of AD 1756. The calculated felling date ranges for the other oak samples indicates this group of timbers were either precisely or broadly contemporaneous. The pine samples are less complete, and pine typically has large quantities of sapwood. Significant lengths of these cores disintegrated, probably indicating sapwood was present. These samples have sequences ending in the late-seventeenth century and it is likely that they are broadly contemporaneous with the oaks (Fig 9).

One unique feature of this roof is the presence of a softwood timber bearing both a distinctive hauling or rafting hole and ownership stamps in the form of 'PR' repeated several times (Figs 5 and 7). Rafting holes are relatively widely seen in continental softwood buildings, particularly of log-cabin type and are apparently derived from the habit of forming rafts of timbers for their downstream delivery from the forests to the ports (Thomas Eising *pers comm*). Presumably such features are rare in British buildings as they were typically cut off when constructing roof tiebeams of specific lengths, or perhaps they are common but well hidden along the outside edges of the roofs. Lytham Hall's double pile-plan form and rather anomalous overlapping tiebeams may have made either their removal unnecessary, or simply provides opportunities for seeing them that are rarely presented elsewhere. A further timber that forms both the T3 tiebeam and the T4-T6 centre-beam was also noted bearing 'PR' stamps although these were not photographed. Neither of these timbers proved datable, indeed the former could not even be sampled due to its location and alignment. However there is no reason to suppose that the results obtained from the other softwoods in this roof are not indicative

of the source and origin of these marked timbers. The 'PR' stamp may indicate the exporter, the importer, or some other stage in their travels.

The dated softwood beams match strongly to material used in the AD 1760's Danson House, and to a building in Latvia. Both these potentially utilise material derived from present day Belarus, as discussed by Groves (2000). The strong cross-matching between these three groups suggests that the Lytham Hall main roof, and the south-west roof softwood timbers, are further timbers derived from this area.

South-west range

This long building contains five roof trusses and three rows of purlins. The roof is mixed softwood and oak, but at least three trusses have been extensively modified, possibly after a fire in the twentieth century. The eastern truss is a complete modern metal replacement, the next has a metal tiebeam, and the next has been converted to a rather curious arch-vaulted form by clamping oak beams around the original truss timbers, and then sawing off the kingpost and tiebeam.

The 14 samples obtained from timbers within this roof yielded four datable tree-ring sequences. These are of two types, two are oak, and two are pine. The tree-ring analysis dates the rings present in the cores. The correct interpretation of those dates relies upon the characteristics of the final rings in them. Bark-edge survived on none of the oak timbers, but some sapwood survived on one oak. No sapwood was identifiable on the datable pine timbers. Making allowances for minimum and maximum likely amounts of missing oak sapwood provides a felling date range for one oak, and a *terminus post quem* date for the other datable oak. Making the assumption that pine sapwood can be difficult to identify with certainty provides both the datable pine timbers with *terminus post quem* dates. Figure 9 and Tables 1 and 2 includes the felling date or interpreted felling-date ranges for each of the datable samples.

The interpretation of these dated samples is straightforward. Sample 44 has sapwood out to AD 1749, whilst sample 42 has its heartwood/sapwood edge at AD 1715. These samples combine to provide a calculated felling date range of AD 1749 to AD 1761. The pine samples are less complete, and pine typically has large quantities of sapwood. Significant lengths of these cores disintegrated, probably indicating sapwood was present. These samples have sequences ending in the late-seventeenth century and it is likely they are broadly contemporaneous with the oaks (Fig 9). These results indicate that the south-west range roof is therefore likely to date from the Carr period and that it utilises oaks and softwoods of similar origins to those used in the main roof of the Hall.

Long gallery

The southern side of the floor of the long gallery could be lifted along almost its entire length. This exposed a set of 36 north-south aligned joists of varying size. One of these was a softwood timber, the rest were oak. The western end of the floor was entirely replaced by softwood east-west aligned joists. A small area of the underside of these joists was visible in the ceiling of a lavatory on the ground floor.

The 15 samples obtained from timbers within this set of joists yielded a single datable tree-ring sequence. This was an oak joist. The tree-ring analysis dates the rings present in the cores. The correct interpretation of those dates relies upon the characteristics of the final rings in them. The datable sample was complete to the onset of sapwood. Making allowance for minimum and maximum likely amounts of missing oak sapwood provides an individual felling date range for the datable timber. Figure 9 and Table 1 includes the interpreted felling date range for this datable sample.

The interpretation of this dated sample is straightforward. Sample 28 has heartwood out to AD 1483. This sample has a calculated felling date range of AD 1493 to AD 1529 (Fig 9). This result indicates that the joists in this area include some pre-dissolution period timber, perhaps from the Priory phase of the site.

BIBLIOGRAPHY

Arnold, A J, Howard, R E, and Litton, C D, 2003 *Tree-Ring Analysis of Timbers from Hulme Hall, Allostock, near Northwich, Cheshire*, Centre for Archaeol Rep, **84/2003**

Arnold, A J, Howard, R E, and Litton, C D, 2004 *Tree-Ring Analysis of Timbers from Ordsall Hall, Taylorson Street, Salford, Greater Manchester*, Centre for Archaeol Rep, **49/2004**

Arnold, A J, Howard, R E, and Litton, C D, 2005 *Tree-Ring Analysis of Timbers from the Riding School, Bolsover Castle, Bolsover, Derbyshire*, Centre for Archaeol Rep, **40/2005**

Arnold, A J, Howard, R E, and Litton, C D, 2006 *Middridge Grange, Shildon Road, Heighington, Durham: Scientific Dating Report, Tree-Ring Analysis of Timbers*, English Heritage Res Dept Rep Ser, **9/2006**

Baillie, M G L, and Pilcher, J R, 1973 *A simple cross-dating program for tree-ring research*, Tree Ring Bulletin, **33**, 7–14

Bridge, M C, 1998 Tree-ring dates from University College London: List 86, *Vernacular Architect*, **29**, 104–5

Groves, C, 2000 Belarus to Bexley and beyond: dendrochronology and dendroprovenancing of conifer timbers, *Vernacular Architect*, **31**, 59–66

Groves, C, 2002 *Dendrochronological Analysis of Conifer Timbers from Danson House and Danson Stables, Bexley, Kent*, Centre for Archaeol Rep, **69/2002**

Groves, C, and Hillam, J, 1990 Tree-ring dates from Sheffield University: List 36, *Vernacular Architect*, **21**, 44

Howard, R E, Laxton, R R, and Litton, C D, 2003 *Tree-Ring Analysis of Oak Timbers from Combermere Abbey, Whitchurch, Cheshire*, Centre for Archaeol Rep, **83/2003**

Howard, R E, Litton, C D, Arnold, A J, and Tyers, C, 2006 *Tree-Ring Analysis of Timbers from Warleigh House, Tamerton Foliot, Bickleigh, South Hams, near Plymouth, Devon*, English Heritage Res Dept Rep Ser, **38/2006**

Laxton, R R, and Litton, C D, 1988 *An East Midlands master tree-ring chronology and its use for dating vernacular buildings, University of Nottingham,* Dept of Classical and Archaeological Studies, Monograph Series, **III**

Leggett, P A, 1980 *The use of tree-ring analyses in the absolute dating of historical sites and their use in the interpretation of past climatic trends*, unpubl PhD Thesis CNAA, Liverpool Polytechnic

Pilcher, J R, and Baillie, M G L, 1980 *Eight Modern Oak Chronologies from England and Scotland*, Tree Ring Bulletin, **40**, 45–58

Tyers, I, 1997 *Tree-ring analysis of timbers from Sinai Park, Staffordshire*, Anc Mon Lab Rep, **80/97**

Tyers, I, 1999 *Tree-ring analysis of the bell tower of the Church of St Mary, Pembridge, Herefordshire*, Anc Mon Lab Rep, **1/99**

Tyers, I, 2003a *Tree-Ring Analysis of Oak Timbers from a Building on the Lea Road Foundry Site, Church Street, Dronfield, Derbyshire*, Centre for Archaeol Rep, **75/2003**

Tyers, I, 2003b *The tree-ring analysis of the Saracens Head, 81 The Green, Kings Norton, Birmingham*, ARCUS Rep, **717f**

Tyers, I, 2004a *The tree-ring analysis of timbers from Oxburgh Hall, Oxborough, Norfolk*, ARCUS Rep, **717L**

Tyers, I, 2004b *The tree-ring analysis of timbers from two buildings at Ash House Farm, Myrtle Road*, Sheffield, ARCUS Rep, **853a**

Tyers, I, 2006 *Tree-ring analysis of timbers from a building: Moseley Farm Barn, Cookridge, West Yorkshire*, ARCUS Rep, **853u**

FIGURES

Figure 1: Location of Lytham Hall. © Crown Copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100024900

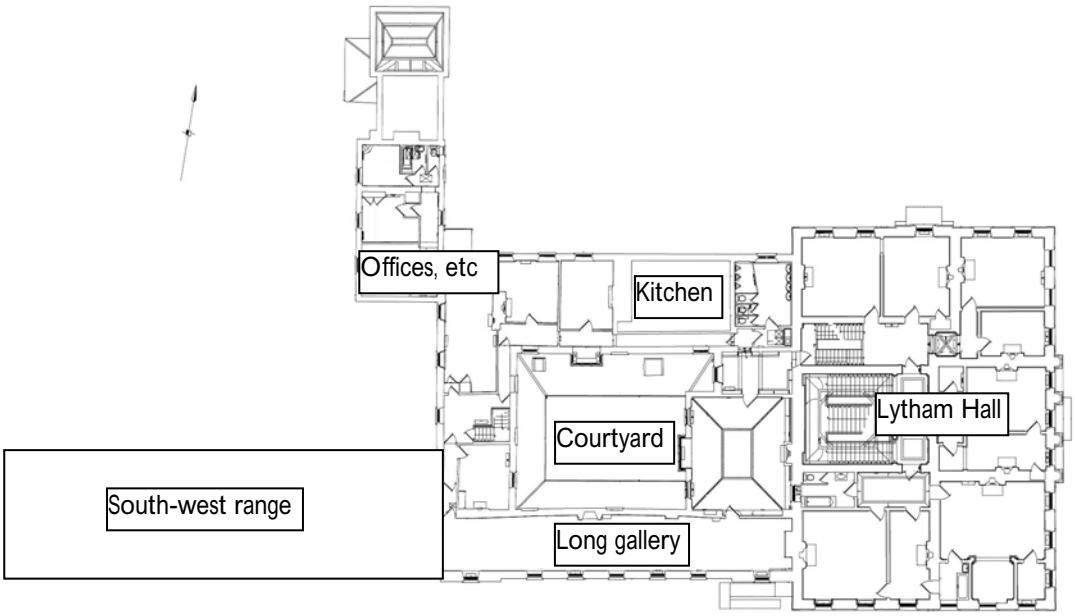


Figure 2: First Floor plan, showing areas mentioned in the text, based on Foster Survey 2007 drawing, with permission Lytham Hall Heritage Trust. NB the South-west range not to scale

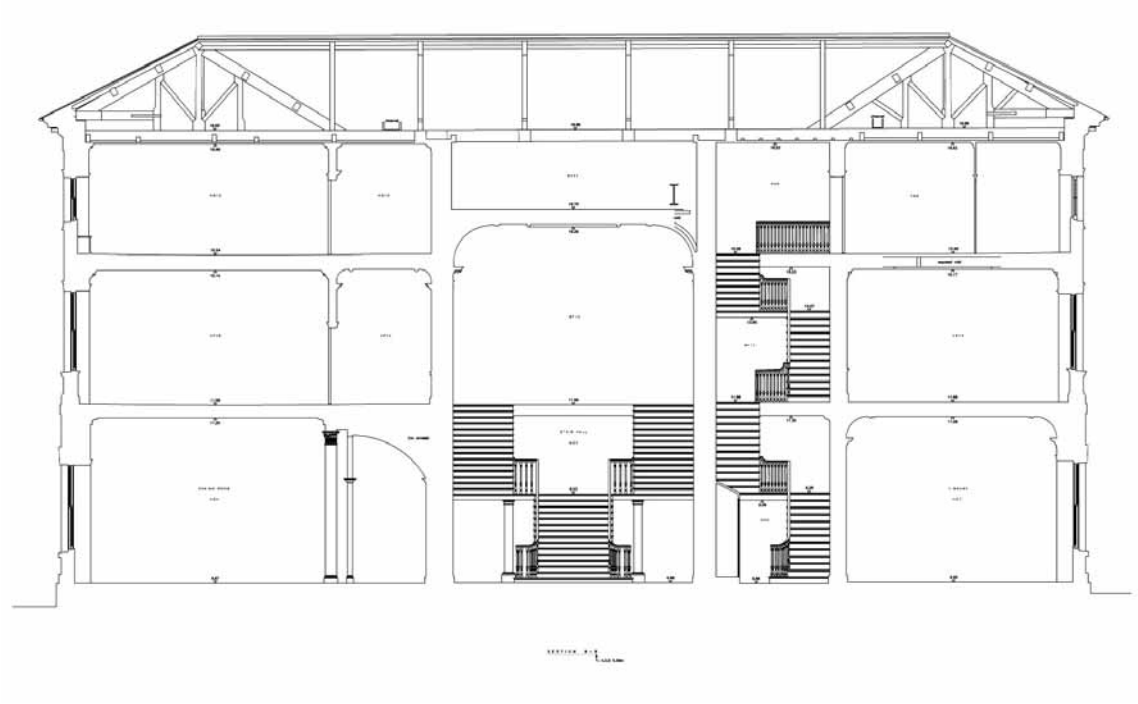


Figure 3: Lytham Hall north–south cross section, Foster survey drawing, with permission Lytham Hall Heritage Trust. The shown roof trusses are probably T2 and T13

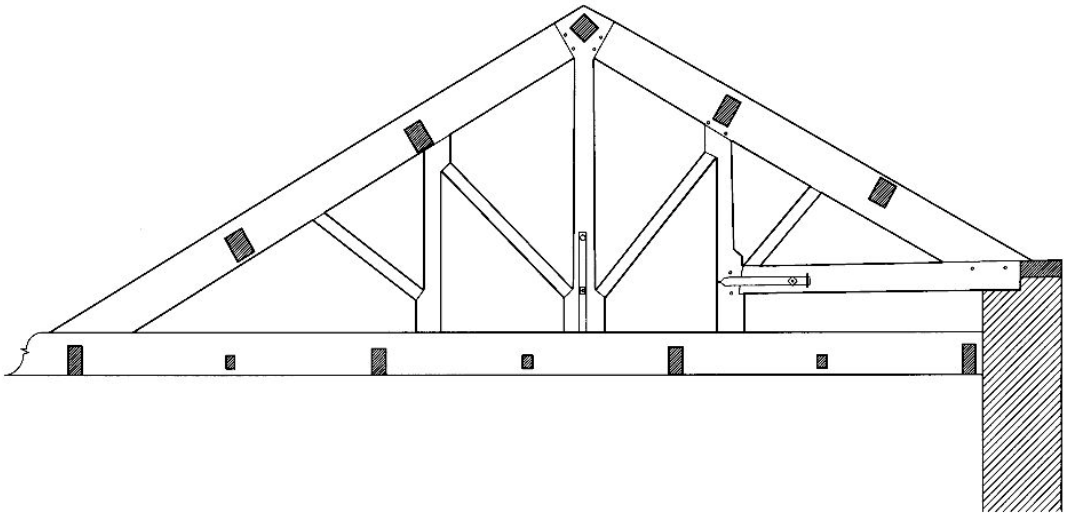


Figure 4: Lytham Hall typical full roof truss, EH survey drawing. This roof truss is typical of T1-T3, T6-T9 and T12-T14, and some of the trusses in T17-T22

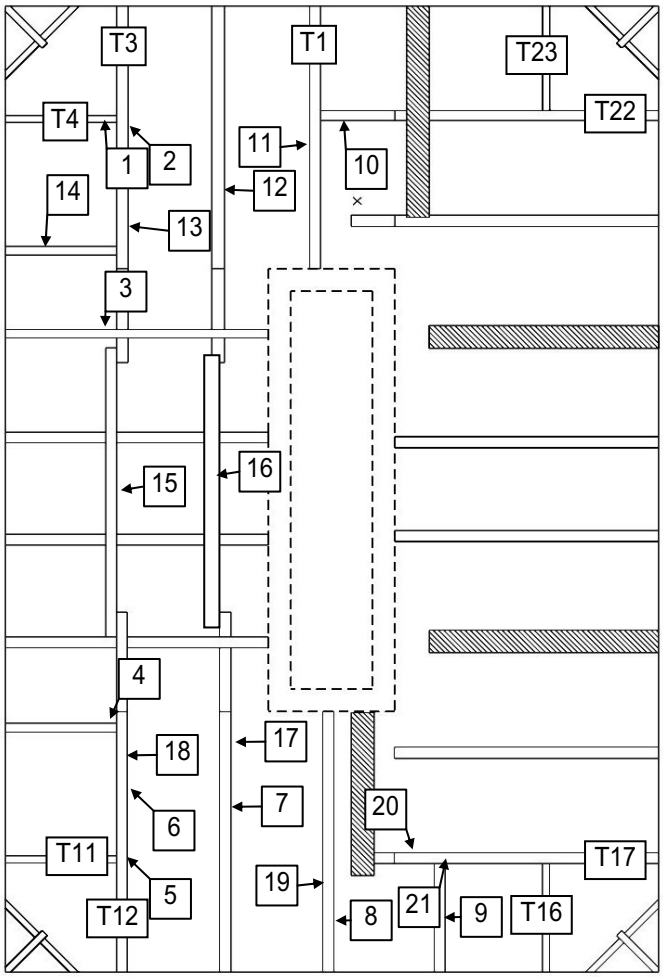


Figure 5: Lytham Hall roof truss numbering scheme T1-T23, with T1 at the centre of the north side and each truss or half-truss numbered in a sequence running anti-clockwise. The approximate locations of the sampled timbers are marked as arrows. Based on an EH survey drawing. Note trusses T17-T23 are relatively inaccessible. The T21 tiebeam end (marked x) is the location of Figures 6 and 7

Figure 6: The T21 tiebeam end with a rafting or hauling hole. Photo Ian Tyers

Figure 7: The T21 tiebeam end with multiple PR stamps. Photo Ian Tyers

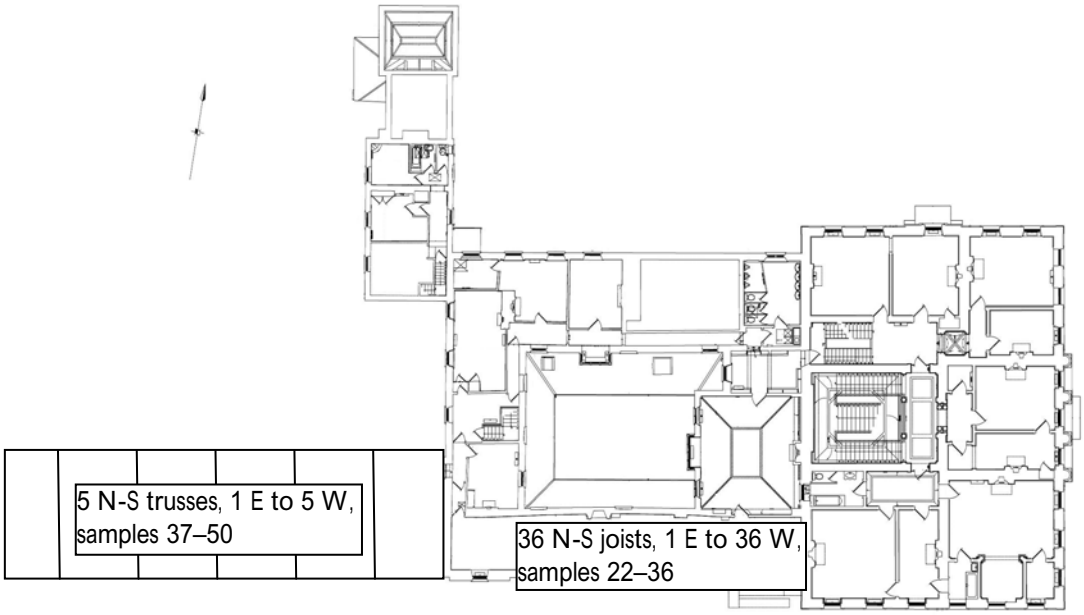
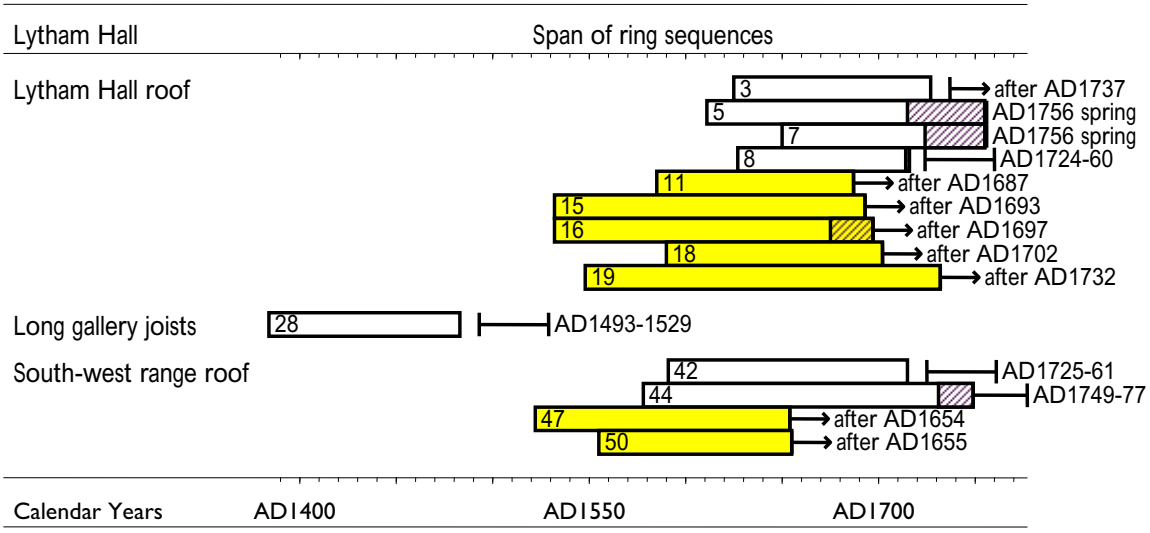


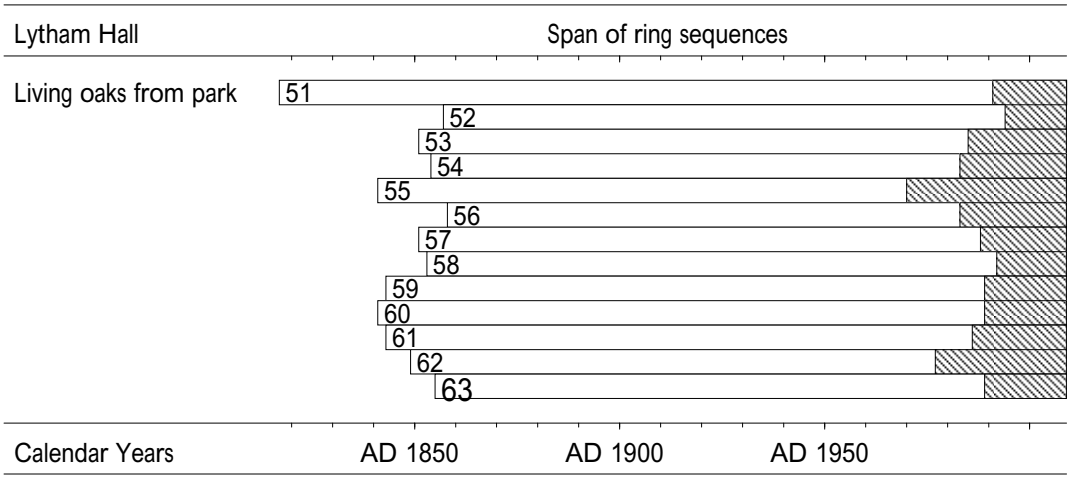
Figure 8: Joist and Truss numbering schemes for Long Gallery first floor and south-west range roof, sample locations given in Tables 1 and 2. South-west range not to scale



KEY. White bars are oak heartwood, black and white hatched bars are oak sapwood. Yellow bars are pine heartwood, black and yellow hatched bars are pine sapwood.

Figure 9: Bar diagram showing the absolute dating positions of the 14 dated tree-ring sequences for samples from Lytham Hall. The interpreted felling dates are also shown for each sample

Figure 10: Transect lines used to select oak trees for coring, samples 51-63



KEY. White bars are oak heartwood, black and white hatched bars are oak sapwood.

Figure 11: Bar diagram showing the sequences from the 13 living oaks sampled from Lytham Hall park. This trees were sampled on 26 March 2010

TABLES

Table 1: Details of the 28 oak samples from timbers from Lytham Hall

Sample	Location	Rings	Sap	Date of measured sequence	Interpreted result
1	Hall roof T4 raised tie	139	20	not dated	-
2	Hall roof T2 king post	62	15	not dated	-
3	Hall roof T6 raised tie	103	-	AD 1625–AD 1727	after AD 1737
4	Hall roof T10 king post	-	-	not measured	-
5	Hall roof T12 king post	145	40+Bs	AD 1611–AD 1755	AD 1756 spring
6	Hall roof T12 queen strut	-	-	not measured	-
7	Hall roof T13 raised tie	106	31+Bs	AD 1650–AD 1755	AD 1756 spring
8	Hall roof T14 raised tie	90	2	AD 1627–AD 1716	AD 1724–60
9	Hall roof T15 raised tie	74	-	not dated	-
22	Long gallery joist 6	90	H/S	not dated	-
23	Long gallery joist 7	97	H/S	not dated	-
24	Long gallery joist 11	77	H/S	not dated	-
25	Long gallery joist 12	-	-	not measured	-
27	Long gallery joist 14	-	-	not measured	-
28	Long gallery joist 17	100	H/S	AD 1384–AD 1483	AD 1493–1529
29	Long gallery joist 23	-	-	not measured	-
30	Long gallery joist 25	76	-	not dated	-
31	Long gallery joist 26	93	-	not dated	-
32	Long gallery joist 28	-	-	not measured	-
33	Long gallery joist 29	-	-	not measured	-
34	Long gallery joist 30	76	-	not dated	-
35	Long gallery joist 31	63	H/S	not dated	-
36	Long gallery joist 32	-	-	not measured	-
42	SW T5 N principal	125	H/S	AD 1591–AD 1715	AD 1725–61
43	SW T5 king post	-	-	not measured	-
44	SW T5 tiebeam	172	18	AD 1578–AD 1749	AD 1749–77
45	SW T3 S principal	-	-	not measured	-
46	SW T3 vaulted tiebeam	71	18	not dated	-

KEY
For locations see Figures 5 and 8
Hall Truss numbers T1-T17 see Figure 5
Long gallery joist numbers see Figure 8
SW roof Truss numbers T1-T5 see Figure 8
N north, S south, E east, W west, C central
H/S is heartwood/sapwood edge, Bs bark after incomplete additional annual ring
Interpretations based on 10–46 sapwood rings.

Table 2: Details of the 22 softwood samples from timbers from Lytham Hall.

Sample	Location	Rings	Sap	Date of measured sequence	Interpreted result
10	Hall roof T1-E wall	-	-	not measured	-
11	Hall roof T1 tiebeam	103	-	AD 1585–AD 1687	after AD 1687
12	Hall roof T2 tiebeam	86	-	not dated	-
13	Hall roof T3 tie/T4-T6	101	-	not dated	-
14	Hall roof T5 ½ tiebeam	-	-	not measured	-
15	Hall roof W T6-T9	162	-	AD 1532–AD 1693	after AD 1693
16	Hall roof E T6-T9	166	22	AD 1532–AD 1697	after AD 1697
17	Hall roof E T9-wall	187	-	not dated	-
18	Hall roof W T9-wall	113	-	AD 1590–AD 1702	after AD 1702
19	Hall roof T14 tiebeam	185	-	AD 1548–AD 1732	after AD 1732
20	Hall roof T17 tiebeam	-	-	not measured	-
21	Hall roof T17 W principal	114	-	not dated	-
26	Long gallery joist 13	-	-	not measured	-
37	SW T5-W low N purlin	107	-	not dated	-
38	SW T5-W mid N purlin	77	-	not dated	-
39	SW T5-wall low S purlin	-	-	not measured	-
40	SW T3-4 low S purlin	85	-	not dated	-
41	SW T3-4 mid S purlin	89	-	not dated	-
47	SW T2-W low S purlin	133	-	AD 1522–AD 1654	after AD 1654
48	SW T2-E low N purlin	100	-	not dated	-
49	SW T2-W low N purlin	122	-	not dated	-
50	SW T2-E low S purlin	101	-	AD 1555–AD 1655	after AD 1655

KEY
For locations see Figures 5 and 8
Hall Truss numbers T1-T17 see Figure 5
Long gallery joist numbers see Figure 8
SW roof Truss numbers T1-T5 see Figure 8
N north, S south, E east, W west
Due to the difficulty in identifying pine sapwood no minimum sapwood estimate has been used in the interpretations

Table 3: Details of the 13 samples from living oaks from Lytham Hall park.

Sample	Description	Rings	Sap	Date of measured sequence
51	3.43m circumference	193	18+Bw	AD 1817–AD 2009
52	2.18m circumference	153	15+Bw	AD 1857–AD 2009
53	2.06m circumference	159	24+Bw	AD 1851–AD 2009
54	2.24m circumference	156	26+Bw	AD 1854–AD 2009
55	2.20m circumference	169	39+Bw	AD 1841–AD 2009
56	3.90m circumference	152	26+Bw	AD 1858–AD 2009
57	2.32m circumference	159	21+Bw	AD 1851–AD 2009
58	2.92m circumference	157	17+Bw	AD 1853–AD 2009
59	2.46m circumference	167	20+Bw	AD 1843–AD 2009
60	3.00m circumference	169	20+Bw	AD 1841–AD 2009
61	2.75m circumference	167	23+Bw	AD 1843–AD 2009
62	4.31m circumference	161	32+Bw	AD 1849–AD 2009
63	3.12m circumference	155	20+Bw	AD 1855–AD 2009

KEY For approximate locations see Figure 10
Bw bark after complete ring.

Table 4: The t-values (Baillie and Pilcher 1973) between 6 sampled oak timbers from Lytham Hall. - t-value less than 3.0. These series were combined to form the composite sequence LythamOak1 used in Table 5

	5	7	8	42	44
3	6.13	8.18	4.29	4.74	3.89
5		7.62	10.42	6.85	6.50
7			4.63	5.85	4.42
8				4.27	4.68
42					6.97

Table 5: Showing example t-values (Baillie and Pilcher 1973) between the composite sequence LythamOak1 constructed from oak timbers in Lytham Hall and oak reference data

Reference chronology	LythamOak1 AD1578–1755
Cheshire, Combermere Abbey (Howard *et al* 2003)	7.41
Cheshire, Hulme Hall Allostock (Arnold *et al* 2003)	6.61
Derbyshire, Riding School Bolsover Castle (Arnold *et al* 2005)	8.82
Herefordshire, Pembridge bell tower C (Tyers 1999)	7.20
Kent, Chatham Dockyard Wheelwrights Shop (Bridge 1998) not from Kent	7.30
Nottinghamshire etc, regional sequence (Laxton and Litton 1988)	7.68
Staffordshire, Sinai Park nr Burton (Tyers 1997)	7.21
Yorkshire, Cookridge Moseley Wood Farm barn (Tyers 2006)	7.47

Table 6: Showing example t-values (Baillie and Pilcher 1973) between the sequence from sample 28 in Lytham Hall and oak reference data

	Lytham #28 AD1384–1483
Derbyshire, Dronfield Church Street Derbyshire (Tyers 2003a)	6.10
Manchester, Manchester Peel Hall I (Leggett 1980)	5.78
Manchester, Salford Ordsall Hall (Arnold *et al* 2004)	6.55
Nottinghamshire etc, regional sequence (Laxton and Litton 1988)	5.74
West-Midlands, Kings Norton Saracens Head (Tyers 2003b)	5.87
Yorkshire, Sheffield Myrtle Road Ash House Farm Barn (Tyers 2004b)	6.07
Yorkshire,-Barnsley Houndhill (Groves and Hillam 1990)	5.63
Yorkshire,-Calderdale Shibden Hall nr Halifax (unpubl. data)	7.31

Table 7: The t-values (Baillie and Pilcher 1973) between 7 sampled pine timbers from Lytham Hall. See also Table 8. - t-value less than 3.0. These series were combined to form the composite sequence LythamPine used in Table 9

	15	16	18	19	47	50
11	4.67	4.21	3.34	-	-	-
15		5.41	-	3.65	-	-
16			3.26	4.51	3.04	-
18				3.05	-	4.19
19					3.56	-
47						7.23

Table 8: Showing example t-values (Baillie and Pilcher 1973) between 7 sampled pine timbers from Lytham Hall and pine reference data. See also Tables 7 and 9. - t-value less than 3.0. These series were combined to form the composite sequence LythamPine used in Table 9

	11	15	16	18	19	47	50
Middridge	-	-	-	-	-	4.37	4.11
Warleigh	-	-	5.01	3.69	7.16	-	-
Danson1	6.20	4.69	6.01	4.36	6.94	6.47	5.43
Dannensterna	4.30	4.20	6.42	5.70	5.46	6.12	4.26
Oxburgh 1	4.81	3.54	3.71	3.96	4.44	-	-
Stockholm	-	-	3.26	4.56	-	3.13	4.00

Chronology references
CoDurham, Middridge Grange Heighington (Arnold *et al* 2006)
Devon, Warleigh House Tamerton Foliot (Howard *et al* 2006)
Kent, Danson House Bexley Kent 1 (Groves 2002)
Latvia, Dannensterna House Riga (Zunde *pers comm*)
Norfolk, Oxburgh Hall 1 (Tyers 2004a)
Sweden, Stockholm/Uppland (Bartolin *pers comm*)

Table 9: Showing example t-values (Baillie and Pilcher 1973) between the composite sequence LythamPine constructed from pine timbers in Lytham Hall and pine reference data

	LythamPine AD 1522–1732
County Durham, Middridge Grange Heighington (Arnold *et al* 2006)	4.82
Devon, Warleigh House Tamerton Foliot (Howard *et al* 2006)	5.65
Kent, Danson House Bexley Kent 1 (Groves 2002)	9.77
Latvia, Dannensterna House Riga (Zunde *pers comm*)	10.26
Norfolk, Oxburgh Hall 1 (Tyers 2004a)	6.67
Sweden, Stockholm/Uppland (Bartolin *pers comm*)	4.93

Table 10: The t-values (Baillie and Pilcher 1973) between 13 sampled oak trees from Lytham Hall park. - t-value less than 3.0. These series were combined to form the composite sequence LythamOak2 used in Table 11

	52	53	54	55	56	57	58	59	60	61	62	63
51	4.08	-	-	6.02	-	5.65	-	4.95	4.22	-	3.39	4.28
52		7.20	4.23	-	-	-	5.14	5.00	-	-	5.85	4.21
53			5.04	-	-	-	6.20	5.37	-	-	4.70	-
54				5.72	-	5.18	7.37	4.27	-	-	3.39	-
55					-	7.31	5.60	5.88	-	5.45	3.05	-
56						-	5.03	4.02	-	-	4.52	3.10
57							6.28	8.41	-	-	-	-
58								7.65	3.74	5.11	3.66	3.26
59									4.64	4.21	4.68	4.65
60										-	3.22	8.19
61											-	-
62												4.04

Table 11: Showing example t-values (Baillie and Pilcher 1973) between the composite sequence LythamOak2 constructed from trees in Lytham Park and oak reference data

	LythamOak2 AD 1817–2009
Cheshire, Combermere Abbey (Howard *et al* 2003)	5.57
Cumbria, Levens Park (Carter *pers comm*)	5.51
Lancashire, Scorton (Pilcher and Baillie 1980)	6.11
Northumberland, Helesyside Hall (Briffa *pers comm*)	5.56
Northumberland, Monk Wood (Briffa *pers comm*)	6.06
Nottinghamshire, Sherwood (Baillie, Pilcher, Brown, Briffa *pers comm*)	5.65
Yorkshire, Castle Howard (Morgan *pers comm*)	7.88
Northern Ireland, Antrim Breen Oak Wood (Pilcher *pers comm*)	6.63

APPENDIX

lh01

134	122	273	199	122	99	92	125	74	72
121	140	191	134	134	126	143	170	103	72
63	73	91	121	90	122	178	173	162	149
169	279	266	347	287	233	211	141	187	314
308	318	288	395	331	332	301	416	219	255
227	168	195	268	250	218	302	203	240	193
167	249	166	193	167	169	131	240	175	122
166	171	167	164	147	100	155	75	85	122
97	132	106	78	95	50	53	59	82	98
64	85	100	105	86	85	79	152	119	69
115	104	154	199	148	132	143	114	115	156
132	98	166	141	140	145	137	148	136	189
116	141	174	197	154	130	177	148	160	176
139	101	112	118	112	118	156	168	108	

lh02

230	295	247	285	290	265	240	227	327	220
276	237	172	246	233	284	290	204	253	210
267	182	333	263	272	268	271	230	249	285
192	264	252	253	252	168	171	184	172	300
160	229	188	179	160	255	209	141	146	149
189	169	200	177	143	123	142	116	101	112
82	114								

lh03

319	491	606	581	569	511	318	347	291	231
205	130	132	102	81	110	142	101	138	156
181	214	211	199	194	163	150	122	124	114
131	170	174	294	219	185	150	209	307	370
335	200	220	274	428	341	304	310	305	261
231	302	291	251	199	191	139	288	170	218
164	168	226	188	182	128	134	98	134	96
107	66	82	93	75	68	96	113	80	116
79	64	113	178	148	106	97	119	136	116
105	154	174	141	159	111	162	139	119	127
129	132	137							

lh05

180	159	201	195	200	114	132	158	180	244
234	255	258	217	141	158	218	166	213	167
142	178	134	108	119	80	97	125	122	132
180	93	87	96	113	217	157	130	158	110
71	73	89	100	166	147	118	135	119	107
98	84	106	126	118	97	100	77	122	122
123	126	97	79	68	112	109	98	92	91
75	95	86	94	52	115	124	80	98	64

100	66	66	71	66	61	63	64	55	44
69	82	88	90	72	54	87	82	88	58
54	37	57	48	44	52	40	35	32	27
35	31	33	34	45	50	55	56	53	47
76	97	112	111	112	93	78	101	84	83
68	53	99	69	80	90	85	80	93	75
118	122	89	114	126					

lh07

197	209	161	173	188	337	437	329	336	298
357	254	292	330	370	293	236	186	192	275
255	294	245	273	252	212	308	286	223	159
160	115	215	170	171	121	170	194	171	150
102	88	77	118	87	100	69	89	85	56
64	74	84	80	89	70	59	90	112	114
83	59	71	86	84	74	73	75	61	97
63	80	63	61	68	66	95	80	80	85
62	82	94	100	71	55	64	70	69	69
61	63	66	110	91	68	110	91	103	99
78	104	98	96	102	141				

lh08

219	190	283	188	176	174	183	138	152	133
173	196	173	147	216	118	119	127	153	220
179	168	165	158	113	125	137	190	193	186
195	190	160	147	180	135	176	181	164	167
134	129	149	142	167	158	165	124	145	188
217	179	137	195	115	142	126	106	77	153
139	116	124	115	126	81	99	97	122	102
110	109	86	66	91	75	86	96	71	70
81	88	107	73	69	70	80	77	80	97

lh09

216	277	143	191	111	165	135	105	132	115
98	74	219	205	175	213	108	120	119	126
128	89	119	76	84	97	115	123	185	117
149	94	111	92	143	143	154	104	88	73
69	88	109	78	70	133	81	80	94	60
84	103	92	73	64	77	65	75	58	65
58	58	67	68	66	83	56	73	46	51
65	69	67	65						

lhs11

163	210	279	328	304	308	301	274	248	258
204	190	157	167	171	187	141	201	142	177
117	123	83	99	156	167	204	159	135	184
153	151	190	142	119	183	148	124	121	140
96	114	118	140	95	147	125	133	118	90
140	123	129	127	156	156	107	74	62	88

77 74 70 91 89 99 111 93 86 103
98 115 94 76 74 104 144 114 107 126
110 81 85 83 88 82 82 84 80 80
96 119 83 90 85 90 144 114 118 158
91 131 99

lhs12

381 383 339 361 237 313 394 423 343 291
263 229 278 348 358 339 325 320 304 289
338 333 296 307 273 342 345 263 263 263
246 212 218 213 284 257 196 164 118 155
156 152 184 240 205 166 124 123 168 129
137 156 132 145 110 112 130 123 151 158
143 123 117 66 47 63 82 99 97 137
99 72 112 118 123 85 71 67 85 76
81 81 69 93 112 95

lhs13

569 558 523 648 499 585 664 652 383 459
325 388 364 463 406 347 236 205 322 229
159 88 158 218 290 253 213 234 237 129
143 200 183 171 172 130 106 68 58 68
73 83 82 93 109 124 109 95 109 123
140 205 110 111 93 111 120 99 66 65
45 71 78 64 29 59 117 130 91 44
43 24 32 31 36 33 46 53 84 86
70 63 72 80 102 96 85 88 93 74
70 64 76 71 60 57 53 68 71 44
54

lhs15

229 271 331 315 248 282 282 296 279 341
245 163 336 264 314 308 274 287 255 195
203 170 120 174 146 118 85 98 74 79
93 90 104 74 119 152 152 120 140 162
143 132 144 117 150 149 175 195 174 119
91 118 73 37 43 51 45 67 50 45
41 42 61 71 53 45 56 52 63 58
58 57 53 51 62 59 60 67 59 56
62 46 53 72 92 120 118 102 103 84
82 114 125 87 60 77 99 59 79 67
70 93 75 71 68 87 82 123 138 72
45 45 79 61 63 46 49 49 46 59
49 65 60 58 63 66 51 66 59 54
46 54 60 49 61 48 61 64 64 60
55 47 56 71 71 65 47 55 54 57
45 47 64 51 79 77 48 55 60 53
43 42

lhs16

185	171	203	203	207	226	228	228	206	236
207	196	212	190	182	182	182	144	207	120
190	155	136	172	187	138	135	181	161	103
137	115	109	86	125	122	135	123	157	130
142	138	134	130	147	173	141	195	183	94
120	138	136	93	109	87	107	109	110	97
135	102	109	114	128	101	93	99	106	104
119	100	104	81	85	95	99	93	88	123
93	86	80	86	95	79	109	83	94	66
66	62	53	45	49	56	50	44	55	46
58	69	55	70	62	69	72	86	90	92
76	61	80	88	77	67	89	88	96	98
67	80	73	84	96	76	54	40	48	57
51	45	64	61	74	62	64	61	65	52
63	37	56	70	80	62	41	29	35	44
44	47	37	43	63	55	58	64	55	67
59	76	63	63	46	60				

lhs17

118	99	116	148	131	133	126	121	119	108
82	77	79	80	92	120	147	115	124	128
140	109	117	114	155	160	156	172	166	142
158	147	125	116	116	81	116	124	123	83
93	85	76	80	80	73	131	126	105	83
90	88	80	95	100	122	89	104	75	101
98	91	103	90	84	77	79	67	48	70
54	79	59	74	65	65	62	61	45	41
69	89	95	60	42	25	34	58	73	63
58	58	57	81	60	51	47	52	42	53
69	59	70	66	54	73	80	70	62	54
58	39	35	37	42	48	46	37	38	30
36	45	36	27	46	53	49	50	37	52
51	50	52	48	38	55	38	58	57	70
49	57	44	69	71	68	53	62	68	92
59	64	72	80	83	71	78	62	68	59
52	73	88	76	56	50	48	55	38	41
33	44	44	34	31	38	37	45	40	28
23	39	32	31	37	40	26			

lhs18

105	107	139	115	143	115	129	102	143	151
138	99	126	113	115	88	100	136	109	81
73	92	100	98	107	115	143	150	128	90
97	103	70	61	59	93	82	69	70	66
73	78	76	89	77	94	96	103	118	107
138	89	95	74	117	113	93	81	79	107
113	103	97	67	74	82	125	95	53	49
51	77	80	92	91	76	75	26	69	66
63	60	47	49	40	76	83	51	65	78
77	73	92	72	93	57	98	90	75	82

76 95 95 92 89 76 86 65 74 58
36 42 53

lhs19

107 91 92 80 112 106 102 102 88 77
57 74 97 136 140 117 96 76 96 124
102 69 76 95 65 71 74 68 87 71
93 86 66 62 53 61 76 74 65 48
45 41 49 46 54 66 64 57 61 51
68 61 72 51 65 78 77 49 63 68
53 52 60 81 66 45 48 66 82 83
71 62 64 46 54 52 35 33 42 52
41 34 51 26 31 44 37 41 33 52
50 43 60 60 53 31 54 47 48 34
34 44 42 39 37 34 36 27 33 25
29 26 30 35 27 32 25 31 30 26
22 23 26 21 25 18 27 28 30 25
29 33 42 67 49 48 45 44 57 50
27 20 19 45 45 32 31 29 23 22
25 30 23 24 40 36 36 37 27 44
36 33 38 38 29 35 45 34 40 27
36 32 41 37 35 45 38 30 22 21
17 15 14 19 19

lhs21

305 254 239 184 182 242 221 290 279 199
158 202 203 185 158 133 124 136 82 51
70 80 108 130 152 190 103 110 103 100
110 81 74 81 72 93 88 129 114 146
153 118 125 165 214 319 178 131 157 156
130 139 119 140 91 82 75 113 161 179
125 98 96 75 108 123 132 99 101 73
93 104 52 65 82 122 163 143 138 106
111 81 55 78 77 59 50 58 46 55
81 84 101 79 74 56 55 86 126 121
118 100 76 64 73 60 69 80 84 93
91 87 78 87

lh22

360 206 178 101 88 76 67 65 39 46
50 79 81 85 64 98 97 107 132 183
187 267 225 219 290 241 262 251 179 153
187 169 136 144 179 146 144 167 129 116
117 108 110 95 66 59 92 79 104 107
115 107 88 107 86 111 124 69 104 102
93 96 102 117 152 128 168 106 130 91
95 96 108 108 109 104 153 87 97 99
92 84 66 69 63 102 86 104 92 102

lh23

213	213	270	312	235	142	113	79	62	69
67	222	319	305	232	347	199	205	302	174
101	115	95	231	274	180	162	172	98	87
56	69	63	59	110	69	169	135	115	207
149	141	160	144	166	85	69	72	61	141
206	114	63	48	41	85	68	92	92	179
126	80	78	153	196	218	106	128	94	72
67	84	149	185	146	108	82	91	122	104
61	63	65	76	80	69	63	65	62	117
74	127	104	67	61	50	72			

lh24

85	92	150	151	135	168	171	180	192	158
156	221	205	260	259	234	183	196	225	168
205	181	170	175	224	170	144	174	146	138
110	114	105	116	112	140	107	111	98	115
107	110	118	142	121	142	143	129	180	152
161	177	163	237	143	257	129	136	133	122
135	126	147	160	132	135	125	101	86	72
70	60	96	78	87	96	101			

lh28

230	262	256	247	206	189	164	225	179	194
182	156	141	88	113	97	138	118	136	179
180	184	169	151	158	173	181	162	181	172
136	179	143	140	153	108	153	150	137	139
181	144	125	121	101	111	121	109	146	114
134	103	119	137	146	106	126	162	102	109
135	104	94	95	121	107	91	108	143	97
83	94	107	123	101	132	153	145	120	145
135	123	188	154	141	118	109	103	90	130
132	159	144	135	129	131	110	99	79	127

lh30

100	157	110	100	133	125	119	138	214	129
173	155	150	131	60	94	148	182	188	133
160	143	161	151	225	244	127	142	116	102
122	172	298	348	223	274	178	246	258	305
225	417	429	243	283	250	208	120	63	132
142	98	81	68	89	128	97	91	120	81
82	63	112	100	96	95	176	261	206	201
180	236	227	220	145	197				

lh31

180	142	157	221	153	109	108	108	103	107
60	97	115	82	85	64	81	93	87	62
105	109	114	107	115	73	62	83	153	88

92 125 104 156 158 100 89 106 169 173
134 106 182 117 109 106 142 147 155 184
182 154 212 189 184 181 132 110 110 107
129 141 119 130 149 163 135 139 148 119
136 170 128 138 162 133 124 94 77 74
71 84 89 126 75 77 78 77 58 85
69 68 81

lh34

122 191 97 196 142 130 161 182 205 198
133 141 264 191 213 183 178 144 126 89
96 78 69 54 76 79 55 61 59 66
49 67 61 54 81 54 36 38 47 75
89 86 88 101 78 95 89 134 150 132
133 112 95 151 151 291 263 225 190 248
244 274 162 243 306 283 244 298 205 221
209 158 158 148 181 156

lh35

177 217 209 191 198 164 188 148 147 128
104 149 161 123 145 182 193 200 160 191
180 186 165 197 134 209 271 210 223 167
156 138 151 169 191 186 185 199 164 191
194 215 166 157 146 157 132 169 182 242
166 137 164 178 206 185 136 214 175 178
200 173 138

lhs37

253 224 194 243 305 235 250 182 178 180
158 170 112 152 137 130 142 149 161 125
129 129 133 135 103 93 136 141 99 106
94 133 99 96 85 109 118 125 137 181
146 137 176 125 163 124 104 92 88 85
96 105 87 87 84 87 76 91 97 92
103 104 84 56 68 62 72 59 90 86
112 67 106 85 77 65 64 65 71 65
79 94 89 79 79 84 72 65 69 49
63 61 55 68 70 56 66 69 67 45
37 55 54 49 44 52 53

lhs38

175 286 234 178 142 195 193 213 196 179
237 196 204 167 142 156 153 190 179 134
158 142 145 149 178 161 194 143 121 154
139 143 163 218 166 134 138 124 104 182
141 105 124 112 129 140 131 112 113 111
92 102 143 127 104 94 95 122 100 108
134 144 158 89 71 59 68 85 72 59
85 85 71 89 70 56 56

lhs40

277	251	187	178	150	161	156	154	133	164
201	176	153	123	109	135	163	159	171	160
140	129	152	101	111	114	102	109	98	108
89	121	109	112	130	145	120	181	135	119
84	127	152	120	88	102	73	52	55	62
79	76	78	100	111	124	115	113	84	101
85	95	98	104	106	100	110	75	57	86
103	86	122	96	72	84	78	65	79	116
93	70	68	89	90					

lhs41

178	207	256	209	199	194	248	197	207	252
248	279	206	182	115	142	165	121	178	177
120	132	124	146	152	112	98	95	82	75
85	75	72	110	115	140	111	124	154	123
120	139	134	127	125	164	149	134	161	128
123	135	130	126	150	131	117	134	104	89
80	82	74	102	41	82	68	75	71	56
63	58	79	65	79	66	65	66	68	55
34	49	45	65	63	64	67	55	55	

lh42

304	305	367	409	438	326	246	184	162	191
229	135	287	281	227	161	220	163	160	143
251	187	191	154	193	142	158	194	210	195
183	274	166	145	89	92	113	122	125	137
141	159	161	105	87	68	88	87	117	102
167	76	84	100	142	169	141	125	118	85
86	59	63	83	129	158	92	106	111	94
50	83	100	90	89	67	66	48	98	144
111	115	61	72	78	132	116	100	87	94
84	110	43	86	38	81	105	95	89	80
91	58	131	90	85	79	88	67	42	47
57	65	83	103	62	75	89	77	100	73
72	68	82	52	55					

lh44

342	399	498	333	420	370	346	418	466	314
318	328	233	176	200	186	275	263	198	189
204	199	168	152	91	232	248	207	159	240
127	164	146	218	120	150	108	159	75	155
115	146	166	131	175	183	165	98	145	152
174	257	150	127	136	155	96	128	69	100
97	84	92	80	41	58	60	79	82	58
70	97	36	83	49	69	117	142	99	71
74	106	132	130	170	152	153	136	140	148
202	216	190	192	126	87	126	172	183	123
112	87	108	85	165	136	131	55	148	144

116 102 59 104 42 135 98 114 133 114
119 90 50 122 113 97 137 75 85 122
128 99 108 132 80 83 65 58 87 84
91 91 65 74 61 63 53 52 67 67
83 86 86 71 112 108 126 93 78 84
54 67 62 49 46 65 66 52 64 53
46 68

lh46

222 194 317 290 263 175 147 161 269 265
230 221 115 166 102 256 209 185 183 167
126 98 125 167 198 220 106 114 160 180
149 180 107 142 195 191 111 78 187 188
149 146 104 118 172 150 87 78 143 196
167 139 108 155 133 136 119 157 153 103
110 126 79 68 59 82 93 91 134 138
121

lhs47

139 142 130 125 177 158 136 162 105 104
143 108 167 138 167 125 92 76 73 138
145 134 98 108 117 116 100 107 119 97
103 69 65 95 130 94 87 116 113 110
149 106 108 93 99 105 103 86 98 119
106 113 123 99 103 103 86 101 88 101
83 106 127 78 97 63 75 79 53 51
53 69 80 54 73 55 68 51 46 51
75 62 51 38 37 37 43 49 41 57
51 52 64 69 78 74 59 39 63 48
38 52 59 62 52 51 44 61 58 61
46 68 106 72 45 46 57 49 88 89
91 34 29 47 62 36 41 50 44 46
42 41 52

lhs48

147 169 134 144 159 176 160 172 152 175
187 133 173 130 135 145 153 115 109 138
159 105 78 70 92 102 87 88 93 107
94 88 66 89 92 75 88 81 106 114
115 118 110 86 88 89 74 114 141 115
102 126 77 65 82 102 100 92 78 75
80 93 89 77 78 80 68 75 83 101
100 128 108 94 62 63 55 61 56 57
64 72 61 30 32 42 47 53 50 47
45 41 56 47 36 45 58 81 79 83

lhs49

165 193 172 163 141 119 120 138 154 114
153 144 120 130 130 110 120 166 162 139

146	146	171	67	62	120	162	110	131	137
143	96	101	94	118	133	152	152	124	113
80	96	53	33	53	66	105	98	81	90
128	81	91	101	91	67	86	75	44	54
76	72	68	70	59	83	160	106	84	82
63	62	59	68	95	88	58	63	71	76
48	55	36	37	55	54	46	39	43	43
46	46	48	54	52	60	63	57	75	62
51	40	46	32	40	49	61	46	50	56
48	52	50	57	80	68	56	59	46	41
42	47								

lhs50

127	157	135	113	162	197	219	190	190	300
182	159	188	152	137	136	179	151	120	113
95	139	132	154	131	107	167	83	110	127
91	134	92	124	119	93	85	120	78	101
113	130	72	182	79	82	70	121	93	80
53	46	79	84	88	74	73	88	100	87
119	111	122	79	75	113	80	51	70	73
128	92	70	91	106	111	104	64	89	125
79	123	78	93	94	162	105	116	46	55
70	91	57	63	70	68	60	54	46	56
79									

lpo51

302	366	404	287	225	214	197	152	99	82
72	118	237	214	273	122	165	315	364	350
346	290	182	148	145	286	320	263	265	348
363	417	419	399	393	409	330	308	286	347
395	343	417	301	194	170	86	209	281	228
237	206	284	275	153	106	193	157	179	247
182	169	168	94	132	160	145	153	215	240
193	239	220	317	222	163	180	183	229	310
249	262	213	174	224	140	166	261	192	165
166	158	145	224	205	173	195	201	211	158
144	193	175	99	234	232	258	247	226	206
266	232	171	133	157	152	202	230	250	246
336	307	378	170	257	294	244	399	322	353
304	138	195	275	279	216	286	240	236	191
312	267	279	283	218	212	207	191	197	296
231	219	221	222	240	227	192	242	314	292
194	262	265	316	316	276	368	307	210	213
208	253	393	330	294	335	327	220	246	259
339	341	373	305	314	250	268	300	213	200
280	291	198							

lpo52

345	449	460	312	360	449	311	357	356	352
434	353	231	222	180	117	206	195	157	339

281 232 213 229 169 240 160 173 224 416
247 155 213 356 286 267 255 152 216 238
183 204 210 201 249 244 233 218 213 208
209 230 167 206 179 131 191 193 156 140
141 120 94 95 179 153 115 148 147 177
181 165 158 138 166 161 179 123 149 159
164 126 237 138 158 145 163 222 180 168
253 140 194 257 220 189 209 205 237 160
179 174 294 230 135 185 227 308 262 302
263 321 273 207 246 237 298 266 258 214
227 244 250 341 331 386 234 205 132 169
198 94 112 128 106 96 103 140 128 95
123 127 131 112 118 128 119 117 99 92
80 102 98

lpo53

132 219 322 217 290 294 295 283 391 324
339 293 241 246 299 254 294 204 248 293
276 224 247 242 372 254 191 163 161 169
104 88 97 42 83 116 95 66 126 151
142 164 120 57 114 98 118 95 154 125
111 133 115 127 130 157 91 155 110 118
109 72 88 151 144 112 163 60 37 54
85 137 37 168 89 173 86 95 97 86
102 92 97 59 94 134 114 52 170 113
104 153 145 181 159 151 199 95 85 100
178 231 159 158 204 103 102 144 142 176
62 105 60 101 101 87 75 160 153 91
91 90 146 145 135 102 81 161 220 246
321 273 116 115 152 184 161 156 137 140
119 189 127 172 144 144 288 259 251 219
244 165 146 144 94 106 115 173 137

lpo54

351 466 605 525 395 421 384 361 397 229
195 236 212 252 257 209 195 132 117 126
169 236 248 209 104 183 139 134 115 139
208 240 249 209 192 179 264 272 236 182
160 191 246 224 165 188 262 297 230 206
190 173 174 192 147 147 161 149 173 184
183 172 197 228 168 144 170 209 202 150
208 201 155 179 188 133 174 192 164 186
172 198 178 179 148 195 159 217 260 236
222 197 225 229 92 123 148 178 228 244
162 233 238 136 189 214 227 124 144 124
103 119 110 100 101 158 112 106 91 112
100 107 120 159 132 211 181 247 231 154
97 108 118 107 133 128 113 112 111 112
104 71 119 118 129 140 88 143 96 125
94 90 86 100 136 127

lpo55

88	323	511	366	390	254	224	487	516	353
287	309	239	289	208	146	208	165	207	72
140	87	39	114	123	163	112	123	93	101
70	48	60	56	172	173	122	90	186	99
83	115	170	158	165	120	94	130	109	219
132	132	101	84	81	112	90	57	45	62
66	23	21	27	30	27	28	39	32	58
67	78	92	103	66	92	214	176	137	86
166	91	84	76	94	63	123	114	90	166
162	162	152	176	280	151	68	93	136	64
90	153	136	137	177	229	135	66	109	167
152	147	157	108	108	73	112	52	58	187
112	145	127	189	117	89	47	27	36	30
60	50	57	43	42	44	57	73	63	73
104	94	58	68	79	121	90	87	190	98
99	80	103	70	85	77	118	117	131	102
176	140	133	114	83	90	148	244	123	

lpo56

399	775	425	420	425	545	527	460	404	502
362	424	360	419	526	333	329	414	356	227
316	262	357	239	452	215	291	186	536	224
334	443	460	303	405	307	289	396	246	339
303	367	364	432	321	396	276	302	350	351
277	281	309	324	273	308	368	273	334	453
504	353	304	379	190	240	245	316	399	262
467	209	212	228	161	232	220	253	478	431
572	476	425	462	564	408	345	427	375	309
244	264	325	324	276	250	203	196	191	218
197	234	197	255	241	214	186	99	142	195
149	145	130	158	123	138	155	200	161	174
177	309	260	312	441	428	418	592	402	583
662	600	499	411	373	338	247	235	181	284
330	301	233	223	264	281	253	313	187	441
336	422								

lpo57

314	298	357	345	353	402	444	372	477	261
206	265	122	262	256	231	172	153	179	226
267	159	188	145	185	250	217	153	166	99
96	112	129	233	168	174	148	136	137	232
161	177	130	135	163	180	187	124	137	183
185	100	152	141	126	107	93	114	101	130
134	125	111	112	82	131	179	164	140	81
126	129	102	145	72	83	93	105	70	81
70	57	78	95	176	154	86	79	102	115
124	180	158	157	191	151	112	66	84	104
113	92	110	104	118	152	105	85	183	226
139	214	190	207	135	164	151	87	95	116

119	128	95	135	242	181	179	163	198	221
174	221	171	140	197	173	139	135	160	147
148	166	114	64	95	229	209	151	160	148
166	101	99	154	104	125	148	154	117	

lpo58

315	266	320	339	436	287	418	338	374	381
329	365	358	301	340	270	286	322	375	260
287	249	325	298	218	151	248	193	156	219
207	208	201	355	249	172	229	307	274	381
275	199	242	265	261	195	211	281	252	258
329	263	176	191	215	236	234	287	250	218
251	264	192	217	311	226	210	255	270	248
187	237	164	151	182	183	125	96	133	140
135	106	146	142	123	86	100	101	135	202
219	202	205	209	189	89	105	124	153	177
165	180	216	178	179	154	259	329	304	314
250	295	284	336	375	368	365	278	401	288
284	248	369	213	351	380	369	429	408	452
331	228	257	188	199	185	187	127	156	165
215	145	133	173	243	235	217	169	230	216
237	215	220	211	261	329	233			

lpo59

350	220	236	286	334	537	435	444	491	506
471	441	507	394	469	338	566	314	350	263
170	208	327	246	254	172	190	261	271	173
223	165	222	307	221	224	247	269	189	240
182	188	141	218	157	120	197	277	256	255
277	152	249	255	231	166	155	211	169	131
141	148	218	134	127	183	108	203	221	145
139	139	151	144	226	175	119	88	158	147
102	117	103	128	133	214	210	119	139	119
238	130	148	173	150	118	188	181	290	271
195	123	208	226	268	157	117	165	151	238
233	242	286	244	174	128	218	325	163	254
259	295	159	205	136	93	97	110	182	150
101	84	107	83	72	132	140	119	106	149
134	131	179	206	249	256	265	183	185	200
138	84	104	106	144	152	178	181	343	276
281	303	277	232	368	349	215			

lpo60

279	385	311	204	206	318	342	502	401	441
387	281	420	441	361	293	373	211	288	172
109	97	71	113	126	92	137	141	128	150
131	136	106	89	146	224	135	180	217	133
119	113	145	300	252	283	256	245	296	375
251	198	188	161	265	380	351	262	356	293
285	265	356	366	411	292	234	193	189	234

223 169 236 196 208 310 474 564 407 242
329 225 255 274 346 251 221 279 258 205
332 407 508 286 215 190 375 144 181 213
234 197 197 201 208 182 268 175 140 190
221 205 254 232 262 143 168 172 206 247
278 285 265 315 338 417 318 230 288 150
214 177 176 180 220 133 174 132 162 184
187 224 206 184 128 170 162 218 250 170
144 153 138 150 170 129 145 141 288 225
210 177 266 153 116 191 159 203 143

lpo61

406 152 142 153 190 584 611 474 405 458
384 227 254 316 464 432 606 266 229 145
182 204 176 198 269 267 279 288 352 380
350 255 330 257 166 176 280 246 176 217
167 163 127 242 260 348 288 390 356 362
382 207 302 348 362 178 252 321 254 203
249 215 234 182 211 256 210 313 301 245
267 235 124 230 308 310 260 247 278 217
198 251 244 247 272 258 252 198 258 339
352 265 184 102 94 195 257 190 250 267
306 233 242 271 280 292 332 238 191 246
239 220 214 181 213 178 267 236 207 218
106 159 74 96 85 118 146 117 128 114
141 79 90 74 118 136 172 238 250 249
102 118 156 124 161 126 99 84 59 68
65 59 81 86 98 89 79 85 139 98
89 79 78 90 94 126 58

lpo62

558 594 443 671 623 495 714 609 591 669
753 332 420 337 428 320 456 523 472 392
446 449 377 351 286 364 444 460 317 408
343 326 404 369 349 455 373 495 413 287
394 551 387 259 252 199 271 398 294 316
383 400 346 359 376 238 250 305 212 236
229 217 177 191 195 221 208 194 233 234
171 147 260 242 171 223 265 293 235 341
234 238 243 202 372 303 282 312 351 216
275 172 140 193 172 171 197 189 307 154
248 427 243 160 165 175 160 140 192 248
283 273 264 331 288 357 199 292 172 129
147 141 175 204 342 298 303 266 306 332
344 363 423 684 426 416 358 361 439 385
380 291 262 368 282 251 174 119 224 301
207 243 264 260 245 320 261 226 193 211
153

lpo63

509	516	606	392	492	312	213	317	307	376
289	267	251	263	186	280	313	377	384	359
432	480	378	394	391	286	194	160	137	210
271	297	280	297	295	350	258	330	336	286
422	391	329	246	270	253	412	343	360	380
442	313	257	255	159	210	260	241	268	319
257	328	329	419	271	181	230	231	335	371
435	289	312	325	268	202	297	248	335	293
251	292	297	269	332	352	339	275	223	213
206	186	293	196	191	272	214	197	227	180
193	158	165	206	212	211	201	181	150	150
158	200	169	153	220	137	167	148	178	142
233	145	144	157	189	206	208	230	273	168
149	245	351	245	289	175	175	181	224	194
221	179	311	260	296	292	292	264	265	288
263	268	297	276	209					

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