Historic England

Scientific Dating

The London Thames Estuary London

Tree-ring Analysis of Ship Timbers

Nigel Nayling

Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 9-2022

Front Cover: Sample 7006 from The London. Photograph Nigel Nayling.

Research Report Series 9-2022

THE LONDON THAMES ESTUARY LONDON

Tree-ring Analysis of Ship Timbers

Nigel Nayling

NGR: TQ 89848 80963

ISSN 2059-4453 (Online)

SUMMARY
This report summarises dendrochronological investigation of *in situ* timbers of a designated wreck identified as the *London*, located underwater at two sites in the Thames Estuary off Southend. Samples were taken from ceiling planks, framing timbers, and outer hull planks during diving operations in 2010. Four samples from Site 1 (including a sample from a previous study) were absolutely dated suggesting that the parent timbers were felled in Britain sometime after AD 1637. The dates produced support interpretation of Site 1 as part of the ship *London* which was launched in AD 1656 and lost following an explosion in AD 1665. Samples recovered from Site 2 generally had fast growth rates and therefore relatively few rings and no samples produced absolute dates.

CONTRIBUTORS
Nigel Nayling

ACKNOWLEDGEMENTS
I am most grateful to Wessex Archaeology for provision of all diving support allowing access to a particularly challenging site for dendrochronological sampling and for supply of copies of designated site assessment reports. This study was commissioned and funded by English Heritage (now Historic England). Peter Marshall and Cathy Tyers, both Historic England Scientific Dating Team, provided useful comments on early drafts of this report.

ARCHIVE LOCATION
Historic England Archive
The Engine House
Fire Fly Drive
Swindon SN2 2EH

HISTORIC ENVIRONMENT RECORD
Greater London Historic Environment Record
4th Floor
Cannon Bridge House
25 Dowgate Hill
London EC4R 2YA

DATE OF INVESTIGATION
2010

CONTACT DETAILS
Lampeter Dendrochronology Laboratory
Institute of Education and Humanities
University of Wales Trinity Saint David
Lampeter
Ceredigion SA48 7PP
n.nayling@uwtsd.ac.uk

CONTENTS

INTRODUCTION

This document is a technical archive report on the tree-ring analysis of samples taken from a wreck designated under the Protection of Wrecks Act (1973) and identified as the *London*. The *London* was built at Chatham, launched in AD 1656, and wrecked following an explosion in the Thames in AD 1665.

Two sites, some 400m apart (Fig 1; and *see* Tables 1 and 2 for the extents of the sites designated under PWA 1973), had previously been investigated during assessment of sites which might be impacted by the London Gateway development. The author had undertaken diving on Site 1 (known as the *London*) in 2005 and produced a dendrochronological date from a single timber indicating felling of the parent tree after AD 1635, and hence consistent with identification of this section of wreck as part of the *London* (Nayling 2005). No timber samples were recovered from Site 2 at that time, although the location of a timber structure and a single cannon did suggest the presence of a historic wreck.

METHODOLOGY

Underwater assessment and sampling of timbers at both sites was undertaken as part of a wider study carried out by Wessex Archaeology, a Designated Site Assessment of the *London*, as part of their Contract for Archaeological Services in Relation to the Protection of Wrecks Act (1973) (Wessex Archaeology 2012). Diving operations took place in June and July 2010 by a surface-supplied diving team. The author employed handsaws and a hydraulic chainsaw to recover selected samples. Poor visibility restricted sampling to dives undertaken on high water slacks. Six samples were recovered from each site, all timbers being of oak (*Quercus* spp).

Methods employed at the Lampeter Dendrochronology Laboratory in general follow those described in Historic England guidance (English Heritage 2004). Prior to measurement, the dendrochronology samples were cleaned with razor blades to expose the fullest ring sequence. Those samples which retained sufficient rings for analysis (ie a minimum of 50 rings) were then measured. The complete sequences of growth rings in the samples that were selected for dating purposes were measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 2004). Cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated against each other. The ring sequences were also tested against a range of reference chronologies from Britain and Northern Europe. The *t*-values reported below are 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 must be obtained from a range of independent sequences. The ring sequences were plotted electronically and exported to a computer graphics software package (Inkscape V0.91) to enable visual comparisons to be made between sequences.

Interpretation of any tree-ring date is limited by whether sapwood or bark edge is present in a sample. Sapwood is distinguishable as lighter coloured band around the outer annual rings of a tree and represents the part of the tree that is alive. For British oaks the number of sapwood rings is estimated to be between 10 and 46 (Bayliss and Tyers 2004), an estimate based on observations of many thousands of samples from living trees and archaeological wood. At a microscopic level, sapwood in oak is recognisable by the open earlywood vessels used for water and mineral transport. Heartwood earlywood vessels appear filled when viewed microscopically as the cell walls have collapsed (tyloses) and no longer form the living part of the tree. Should a sample contain sapwood and bark edge, the year and even season of felling can be inferred from a dated sample. Should partial sapwood be present the estimate of between 10 and 46 rings is used to infer a date range for the sample. In samples where there is no sapwood or microscopic sign of the heartwood/sapwood boundary a date will represent a *terminus post quem* (date after which) the parent timber must have been felled. The date in this case will refer to the date of the last complete annual ring and the felling of the timber will be at least ten years after the date of that final ring.

RESULTS AND INTERPRETATION

Details of the samples recovered and the results of any subsequent analyses are summarised in Table 3. The position of samples taken from the two main sections of the wreck are shown in Figures 2 and 3, derived from sketches produced by the author soon after each dive. Seven of the 12 samples had sufficient rings for measurement and tree-ring width series were obtained (see Appendix). One of these series (Lon7008) cross-matched with the ring-width series from the sample recovered from Site 1 in 2005 (LonGatew) with a *t*-value of 5.11. The individual ring-width series from the LonGatew sample and all measured samples from the 2010 study were compared with British and other Northern European reference chronologies resulting in confirmation of the previous dating of LonGatew, and the dating of three of the newly measured series, Lon7008, Lon7009, and Lon7010 (Table 4) and confirming the match between Lon7008 and LonGatew.

The absolute dating and interpretation of the resultant four dated samples is shown graphically in Figure 4. None of these four samples retained any trace of sapwood and hence it is only possible to derive a *terminus post quem* for felling (Table 4; Fig 4). The four dated samples appear to be broadly coeval and hence it is possible to suggest that all were from parent trees potentially felled sometime after AD 1637.

DISCUSSION

The recovery of dendrochronology samples from a wreck such as the *London* is a challenging undertaking. Diving conditions (generally very poor visibility and very limited tidal windows) and the sites' locations on the edge and within of one of the busiest shipping channels in the world constrain the time available for sampling and requires the use of a dive team with significant previous experience, training, and competence. Nonetheless, as this report demonstrates, samples can be

recovered and dated assisting in the identification and characterisation of historically important shipwreck. Even when samples do not produce dates, the dendro-archaeological information that they provide, especially when *in situ* observation in challenging conditions can be very difficult, can be enlightening. Many of the samples recovered came from substantial timbers which could only have been sampled using a hydraulic chainsaw. Substantial though these were, they had few annual rings being derived from fast-grown oak trees apparently of relatively immature years at the time of felling. It could be argued that this represents effective timber production and selection at a time when the Navy Royal faced difficulties in securing sufficient timber for its purposes (Albion 1926).

The dated timbers from Site 1 are likely to be of English origin (Table 4), though the high level of similarity for one of the timbers with those from the Drogheda boat is of note. The dating evidence produced for the newly-sampled Site 1 timbers is consistent with the single previous date (Nayling 2005) and the identification of this site as part of the *London* launched in AD 1656 and lost in an explosion in AD 1665. Further samples, to confirm that Site 2 could indeed represent part of the *London*, and to produce dates with felling date ranges or bark edge dates, would be desirable if the opportunity presents at some point.

REFERENCES

Albion, R G, 1926 *Forests and sea power. The Timber problem of the Royal Navy 1652–1862*, Harvard University Press (Cambridge)

Arnold, A, and Howard, R, 2007 *St Tetha's Church, St Teath, Cornwall: tree-ring analysis of timbers from roofs and pews*, English Heritage Res Dept Rep, 58/2007

Arnold, J, Howard, R, Litton, R, 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, 38/2006

Arnold, A, Bridge, M, and Howard, R, 2010 *Nyetimber Farm Barns, Gay Street, West Chiltington, Near Pulborough, West Sussex: tree-ring analysis of timbers*, English Heritage Res Dept Rep, 36/2010

Arnold, A, Howard, R, and Tyers, C, 2015a *Sydenham House, Marystow, Devon: tree-ring analysis of oak timbers, panelling, and trees*, English Heritage Res Dept Rep Ser, 45/2015

Arnold, A, Howard, R, and Tyers, C, 2015b *Kirby Hall, Deene, Corby, Northamptonshire: tree-ring analysis of oak and conifer timbers*, Historic England Res Rep Ser, 36/2015

Bailiff, I K, Bayliss, A, Bridge, M C, Bronk Ramsey, C, Cattell, J, Dunbar, E, and Tyers, C, 2017 *St Giles House and the 'Riding House', Wimborne St Giles, Dorset: scientific dating and Bayesian chronological modelling*, Historic England Res Dept Rep, 69/2017

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

Bayliss, A, and Tyers, I, 2004 Interpreting radiocarbon dates using evidence from tree rings, *Radiocarbon*, 46, 957–64

Bridge, M C, 1998 *Tree-ring analysis of timbers from the Home Farm Complex, Newdigate, Surrey*, Anc Mon Lab Rep, 37/98

English Heritage, 2004 *Dendrochronology: guidelines on producing and interpreting dendrochronological dates*, English Heritage (London)

Groves, C, 1998 *Tree-ring analysis of Lightshaw Hall, Golborne, Greater Manchester*, Anc Mon Lab Rep, 77/98

Groves, C, and Hillam, J, 1997 Tree-ring analysis and dating of timbers, in *A multi-period salt production site at Droitwich: excavations at Upwich* (ed J D Hurst), CBA Res Rep, 107, 121–6, Council for British Archaeology (London)

Hibberd, H, and Tyers, I, 1993 Tree-ring dates from the Museum of London Archaeology Service, *Vernacular Architecture*, 24, 50–4

Howard, R E, Laxton, R R, and Litton, C D, 1996 *Tree-ring analysis of timbers from Mercer's Hall, Mercer's Lane, Gloucester*, Anc Mon Lab Rep, 13/96

Howard, R E, Laxton, R R, and Litton, C D, 1998 *Tree-ring analysis of oak timbers from 26 Westgate* Street*, Gloucester*, Anc Mon Lab Rep, 43/98

Howard, R E, Laxton, R R, and Litton, C D, 1999 *Tree-ring analysis of timbers from St Briavel's Castle, Gloucestershire*, Anc Mon Lab Rep, 42/99

Howard, R E, Laxton, R R, and Litton, C D, 2000 *Tree-ring analysis of timbers from Church House, Edenbridge, Kent*, Anc Mon Lab Rep, 34/2000

Howard, R, Litton, C D, and Arnold, A, 2006 *Guildhall, High Street, Worcester: tree-ring analysis of timbers*, English Heritage Res Dept Rep Ser, 42/2006

Lewis, E, 1995 A sixteenth century painted ceiling from Winchester College, *Proc Hampshire Field Club and Archaeol Soc*, 51, 137–65

Miles, D, 2001 *The tree-ring dating of Hergest Court, Kington, Herefordshire*, Centre for Archaeol Rep, 13/2001

Miles, D W H, 2005 *The tree-ring dating of the nave roof at Salisbury Cathedral, Wiltshire*, Centre for Archaeol Rep, 58/2005

Miles, D W H, 2007 *H M Tower of London (TOL99 & TOL100), London Borough of Tower Hamlets: tree-ring dating of the White Tower*, English Heritage Res Dept Rep Ser, 35/2007

Miles, D H, and Worthington, M J, 1998 Tree-ring dates for buildings, *Vernacular Architect*, 29, 111–7

Miles, D H, Worthington, M J, and Roberts, E, 1998 Tree-ring dates for Hampshire 4, *Vernacular Architect*, 29, 117–21

Munro, M A R, 1984 An improved algorithm for crossdating tree-ring series, *Tree-ring Bulleti*n, 44, 17–27

Nayling, N, 1999 *Tree-ring analysis of timbers from the White House, Vowchurch, Herefordshire*, Anc Mon Lab Rep, 73/99

Nayling, N, 2005, *London Gateway Project: Diving Inspection Report 1, University of Wales Lampeter*, London Gateway Archaeology Report, 1/2005

Tyers, I, 1996 *Draft Dendrochronology Assessment: Fastolfs sites*, ARCUS Rep, 255

Tyers, I, 1997a *Dendrochronological analysis of timbers from Lower House Farm, Tupsley, near Hereford*, ARCUS Rep, 296

Tyers, I, 1997b *Tree-ring analysis of seven buildings in Essex*, ARCUS Rep, 292

Tyers, I, 2001 *Dendrochronological spot-dates of samples from Abbey Road, Barking, London (AYR99)*, ARCUS Rep, 575d

Tyers, I, 2002 *Dendrochronological analysis of timbers from the Croft Castle, Croft, Herefordshire*, ARCUS Rep, 574

Tyers, I, 2004 *Dendro for Windows programme guide*, 3rd edn

Tyers, I, 2008 *Hoarstone Farm, Bewdley, Worcestershire: dendrochronological analysis of oak timbers*, English Heritage Res Dept Rep Ser, 78/2008

Tyers, I, and Boswijk, G, 1998 *Tree-ring analysis of oak timbers from Dore Abbey, Abbey Dore, Herefordshire*, Anc Mon Lab Rep, 18/98

Tyers, I, and Groves, C, 2000 Tree-ring Dates from the University of Sheffield Dendrochronology Laboratory, *Vernacular Architecture*, 31, 118–28

Tyers, I, and James, D, 2004 *Medieval Pembridge: report on the tree-ring analysis of properties in the village*, ARCUS Rep, 778

Tyers, I, and Wilson, R, 1999 *Tree-ring analysis of oak timbers from the church of St Mary The Virgin, Yatton, North Somerset*, Anc Mon Lab Rep, 61/1999

Tyers, I, Groves, C, Hillam, J, and Boswijk, G, 1997 Tree-ring Dates from Sheffield University, *Vernacular Architecture*, 28, 138–58

Wessex Archaeology, 2012 *The London, Southend, Thames Estuary*, Designated Site Assessment: Archaeological Report

Worthington, M J, and Miles, D W H, 2001 *The tree-ring dating of Upper Lake, Westbury, Shropshire,* Centre for Archaeol Rep, 42/2001

TABLES

Table 1: Latitude and Longitude of protected area for Site 1 of London

Point	Latitude	Longitude
NW	51°29.7477'N	00°44.3802'E
NE	1°29.7435'N	00°44.4159'E
SE	51°29.7240'N	00°44.4091'E
SW	51°29.7287'N	00°44.3734'E

Table 2: Latitude and Longitude of protected area for Site 2 of London

Point	Latitude	Longitude
NW	51°29.7622'N	00°43.9862'E
NE	51°29.7532'N	00°44.0506'E

Table 3: Details of the samples obtained from the two sites identified as the London

Sample Code	Timber location and function	Conversion	Dimensions	Total Rings	Sapwood	ARW	Date of sequence	Felling date
Lon7001	Site 2, ceiling/stringer? 2014, 35mm treenails	Quartered	220 x 205	66	9+?B	3.21	undated	-
Lon7002	Site 2, SW end of ceiling/stringer? 2004, 35mm treenails	Quartered	185 x 150	73	+HS	2.09	undated	-
Lon7003	Site 2, NE end of ceiling/stringer? 2004, 35mm treenails	Halved	245 x 195	51	+?HS	2.86	undated	-
Lon7004	Site 2, framing timber	Whole	360 x 360	40	+HS	6.00	unmeasured	-
Lon7005	Site 2, scarf of framing timber	Tangential	340 x 85	39	-	6.92	unmeasured	-
Lon7006	Site 2, framing timber	Halved	340 x 260	71	22+?B	3.77	undated	-
Lon7007	Site 1, lower (hull?) plank 2016	Tangential	290 x 80	28	+?HS	4.11	unmeasured	-
Lon7008	Site 1, framing timber 2017	Whole	275 x 270	217	-	1.24	AD 1354–1570	after AD 1580
Lon7009	Site 1, framing timber 2018	Quartered	350 x 280	129	-	2.94	AD 1489–1617	after AD 1627
Lon7010	Site 1, upper (ceiling?) plank 2019, 35mm diameter oak treenails	Tangential	350 x 120	72	-	1.85	AD 1556–1627	after AD 1637
Lon7011	Site 1, upper (ceiling?) plank	Quartered	170 x 100	36	14+?B	5.47	unmeasured	-
Lon7012	Site 1, displaced framing timber scarf fragments	Tangential	180 x 30	-		-	unmeasured	-
LonGatew	Site 1, loose framing timber fragment recovered during site assessment in 2005	Quartered	175 x 70	159	-	1.95	AD 1467–1625	after AD 1635

Total rings = all measured rings; ARW = average ring width of the measured rings in millimetres; Sapwood: +?B = possible bark edge, +HS = heartwood/sapwood boundary, +?HS = possible heartwood/sapwood boundary. All samples were oak (*Quercus* spp)

.

Table 4: Correlations between individual ring-width series LonGatew, Lon7008, Lon7009, and Lon7010 and previously dated site masters

a) LonGatew (AD1467–1625)

Reference chronology	Date span	*t*-value
Lower House Farm, Tupsley, Herefordshire (Tyers 1997a)	AD 1425–1613	6.49
Upper Lake, Westbury, Shropshire (Worthington and Miles 2001)	AD 1418–1546	5.61
Abbey Road (AYR99), Barking, London (Tyers *pers comm*)	AD 1314–1599	5.51
Mercers Hall, Gloucester, Gloucestershire (Howard *et al* 1996)	AD 1289–1541	5.56
Broomden Barn, Ticehurst, East Sussex Barrels (Tyers *pers comm*)	AD 1457–1577	5.50
The Guildhall, Worcester, Worcestershire (Howard *et al* 2006)	AD 1361–1609	5.30
Hoarstone Farm, Bewdley, Worcestershire (Tyers 2008)	AD 1350–1617	5.24
Warleigh House, Tamerton Foliot, Devon (Arnold *et al* 2006)	AD 1367–1539	5.20
Church House, Edenbridge, Kent (Howard *et al* 2000)	AD 1377–1538	5.12
Sydenham House, Marystow, Devon Panelling (Arnold *et al* 2015a)	AD 1266–1629	5.08

b) Lon7008 (AD1354–1570)

Reference chronology	Date span	*t*-value
Winchester College panels, Hampshire (Lewis 1995)	AD 1403–1537	7.65
Drogheda boat, Co Louth, Republic of Ireland (Daly *pers comm*)	AD 1390–1530	6.59
26 Westgate Street, Gloucestershire (Howard *et al* 1998)	AD 1399–1622	6.59
St Briavel's Castle, Gloucestershire (Howard *et al* 1999)	AD 1362–1636	6.51
White House, Vowchurch, Herefordshire (Nayling 1999)	AD 1364–1602	6.37
St Tetha's Church, St Teath, Cornwall (Arnold *et al* 2007)	AD 1386–1518	6.27
Mercers Hall, Gloucester, Gloucestershire (Howard *et al* 1996)	AD 1289–1541	6.17
Duppa's Cottages, Pembridge, Herefordshire (Tyers and James 2004)	AD 1319–1478	6.15
Sydenham House, Marystow, Devon (Arnold *et al* 2015)	AD 1266–1629	6.13
Lightshaw Hall, Golborne, Greater Manchester (Groves 1998)	AD 1414–1552	6.10

c) Lon7009 (AD1489–1617)

Reference chronology	Date span	*t*-value
Nyetimber Farm Barns, Gay Street, West Chiltington, West Sussex (Arnold *et al* 2010)	AD 1463–1605	7.94
Queen Elizabeth Hunting Lodge, Chingford, London (Hibberd and Tyers 1993)	AD 1398–1541	7.33
Hays Wharf, Southwark, London (Tyers 1996)	AD 1248–1647	7.11
Abbey Road, Barking (AYR99), London (Tyers 2001)	AD 1314–1599	6.65
Willington Stables, Bedfordshire (Miles and Worthington 1998)	AD 1328–1538	6.21
Croft Castle, Herefordshire (Tyers 2002)	AD 1475–1666	6.08
Droitwich, Worcestershire (Groves and Hillam 1997)	AD 1454–1651	5.71
Hergest Court, Kington, Herefordshire (Miles 2001)	AD 1406–1665	5.59
Titchfield Market Hall, Hampshire at Weald and Downland Museum (Tyers *pers comm*)	AD 1504–1617	5.56
Dore Abbey Church, Herefordshire (Tyers and Boswijk 1998)	AD 1363–1612	5.48

d) London7010 (AD1556–1627)

Reference chronology	Date span	*t*-value
The Vyne, Hampshire (Miles *et al* 1998)	AD 1543–1653	6.13
Newdigate, Surrey (Bridge 1998)	AD 1261–1639	5.53
42 High St, Winchester, Hampshire (Tyers and Groves 2000)	AD 1523–1633	5.30
Cressing Temple Granary, Essex (Tyers *et al* 1997)	AD 1487–1622	5.09
St Giles House, Wimborne, Dorset (Bailiff *et al* 2017)	AD 1541–1659	5.06
White Tower, Tower of London, London (Miles 2007)	AD 1463–1616	5.04
Yatton Church, North Somerset (Tyers and Wilson 1999)	AD 1564–1691	4.89
Cressing Temple New House, Essex (Tyers 1997b)	AD 1560–1633	4.80
Kirby Hall, Deene, Corby, Northamptonshire (Arnold *et al* 2015b)	AD 1378–1795	4.73
Salisbury Cathedral, Wiltshire (Miles 2005)	AD 1577–1719	4.71

FIGURES

Figure 1: Maps to show the location of The London *in the Thames Estuary, marked in red. Scale: top right 1:105,000, bottom 1:75,000 © Crown Copyright and database right 2022. All rights reserved. Ordnance Survey Licence number 100024900.*

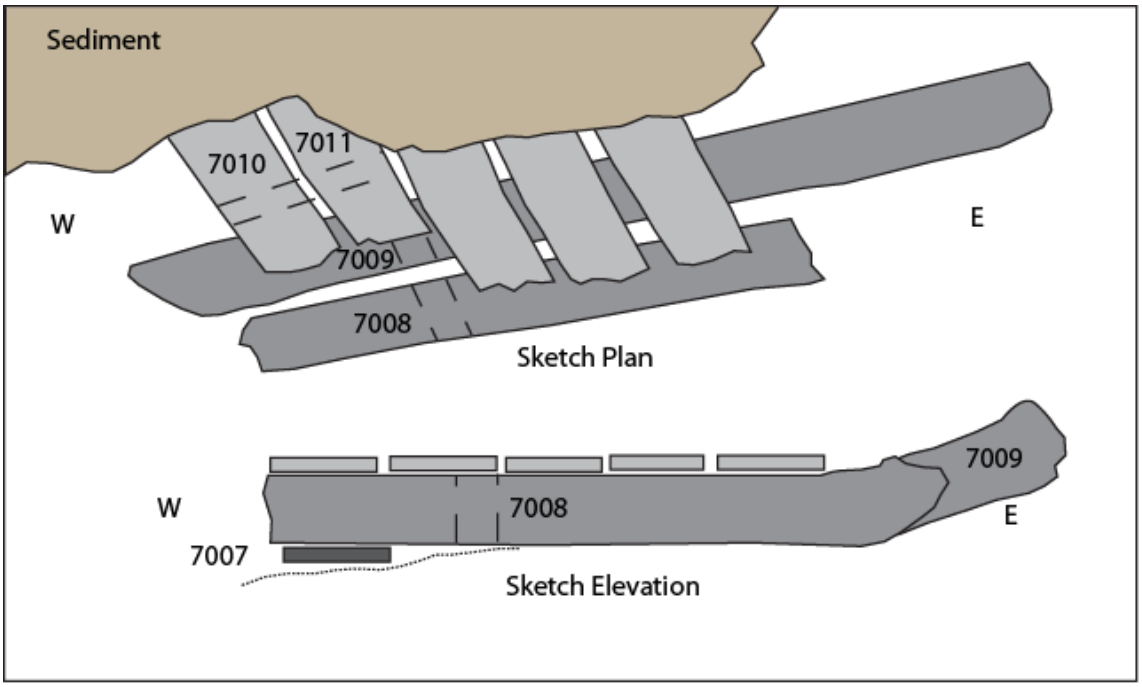

Figure 2: Location of wood samples taken from hull structure at Site 1. Timbers are shaded light grey (ceiling), mid grey (frames) and dark grey (outer planking?)

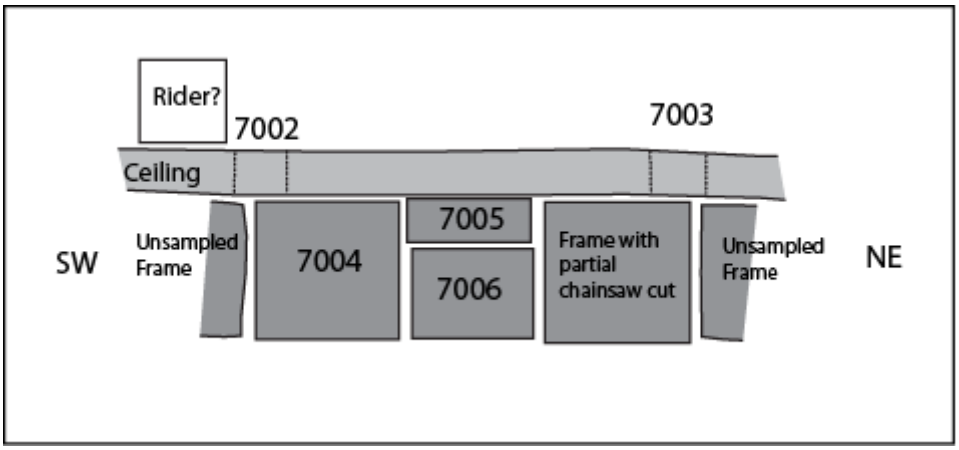

Figure 3: Location of wood samples taken from hull structure at Site 2. Timbers are shaded light grey (ceiling), mid grey (frames)

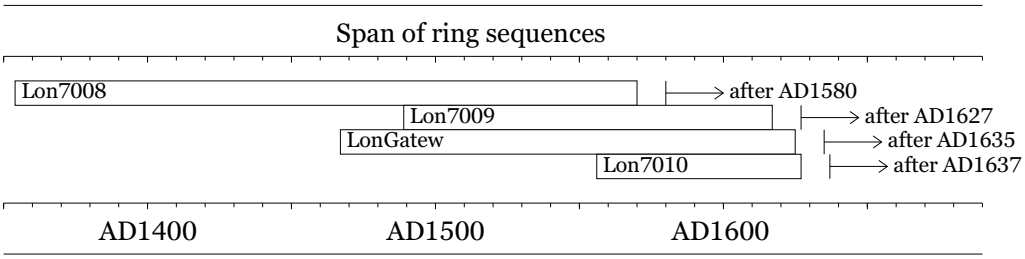

Figure 4: Bar diagram showing relative positions, and individual felling dates, of the four dated samples from site 1 of the designated wreck the London. *White bars = heartwood rings*

APPENDIX

Raw ring-width data in units of 0.01mm

Lon7001

361	299	433	289	280	305	385	252	422	544
462	570	377	433	319	622	469	487	425	369
336	242	262	283	297	234	179	202	238	249
232	181	243	253	278	316	274	327	206	227
226	272	328	248	264	355	284	329	308	352
456	324	381	272	365	398	418	386	284	343
269	221	230	229	266	223				

Lon7002

236	289	238	324	283	260	239	131	251	266
244	374	606	524	352	271	174	129	170	157
245	224	187	225	196	303	250	445	305	309
260	158	210	238	191	274	201	221	231	160
198	178	136	166	261	151	163	277	194	165
134	142	126	158	148	152	123	164	121	143
127	144	146	141	154	168	169	102	96	100
97	91	86							

Lon7003

678	292	312	283	339	322	262	154	247	305
281	139	200	120	266	225	350	330	256	213
201	253	414	430	581	489	389	393	340	387
270	385	335	378	315	210	374	367	335	268
294	296	236	170	119	97	145	86	143	146
148									

Lon7006

357	825	889	830	669	576	574	751	567	387
641	408	559	511	746	432	460	312	348	339
361	465	490	401	555	516	372	514	529	464
452	397	347	232	195	268	286	355	251	377
383	307	305	343	339	442	290	308	313	308
216	258	275	132	237	144	329	260	256	379
170	163	168	174	166	209	221	224	137	192
90									

Lon7008

92	39	47	59	74	64	83	97	245	94
68	164	203	169	236	413	372	264	243	147
218	159	106	109	104	110	122	148	174	168
227	484	309	149	116	86	70	130	87	105
88	96	109	122	250	242	345	428	276	220
206	160	147	159	216	173	154	92	118	144
103	110	141	180	256	117	182	130	75	178
117	97	103	112	209	234	175	177	237	259
206	197	166	213	162	162	108	95	60	82
160	109	113	129	176	216	142	181	98	130
163	142	174	158	226	142	216	121	114	92
65	80	93	106	141	134	208	143	123	86
83	165	132	95	111	118	63	68	62	75
133	154	189	146	122	102	104	117	77	101
124	90	139	75	66	94	121	119	119	124

90 135 118 105 91 99 71 68 65 57
73 54 44 62 56 63 68 96 149 73
75 63 73 96 115 78 59 70 68 84
93 93 62 55 60 113 81 84 68 58
54 46 64 55 61 54 60 60 38 41
48 64 52 79 78 78 64 42 34 36
50 42 43 39 41 43 43

Lon7009

397 470 418 277 455 473 332 407 392 241
352 311 400 362 432 424 412 417 518 437
354 477 418 493 398 547 463 287 275 420
464 241 299 449 413 391 309 379 384 338
432 462 639 451 496 490 590 609 409 354
299 313 293 219 323 253 431 364 322 405
318 346 543 417 255 344 393 236 323 352
425 227 226 181 219 309 345 151 138 223
221 197 256 183 155 228 166 167 175 142
115 234 194 162 216 189 148 213 217 152
193 188 155 177 199 254 172 163 152 99
116 184 144 164 135 146 111 141 130 156
115 88 136 115 190 118 127 146 151

Lon7010

259 187 184 330 459 412 526 334 257 103
100 201 232 230 222 349 189 131 95 93
54 112 82 176 288 207 120 174 204 351
161 150 101 206 117 112 155 156 226 197
219 209 179 103 155 174 236 199 214 133
199 148 201 129 143 160 171 158 157 153
149 145 121 114 146 161 166 127 133 150
133 99

LonGatew

196 181 195 302 152 144 137 210 291 290
189 193 229 201 358 166 120 150 192 272
227 169 124 120 202 155 211 294 212 419
211 258 206 137 164 209 182 189 229 265
217 181 235 161 186 203 223 230 216 179
328 324 330 133 196 227 167 114 147 110
110 151 119 81 118 114 237 265 210 254
258 227 241 233 499 236 301 242 170 254
204 176 258 176 252 123 124 170 186 118
123 114 143 194 187 224 143 233 409 151
188 188 186 191 201 248 236 179 139 116
218 167 343 171 133 337 218 180 179 201
167 164 160 147 237 135 116 274 216 128
93 94 81 117 183 208 229 162 199 310
150 271 178 149 147 108 210 240 149 126
112 131 156 207 242 167 78 121 142

Historic England Research and the Historic Environment

We are the public body that looks after England's historic environment. We champion historic places, helping people understand, value and care for them.

A good understanding of the historic environment is fundamental to ensuring people appreciate and enjoy their heritage and provides the essential first step towards its effective protection.

Historic England works to improve care, understanding and public enjoyment of the historic environment. We undertake and sponsor authoritative research. We develop new approaches to interpreting and protecting heritage and provide high quality expert advice and training.

We make the results of our work available through the Historic England Research Report Series, and through journal publications and monographs. Our online magazine Historic England Research which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on www.HistoricEngland.org.uk/researchreports

Some of these reports are interim reports, making the results of specialist investigations available in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation.

Where no final project report is available, you should consult the author before citing these reports in any publication. Opinions expressed in these reports are those of the author(s) and are not necessarily those of Historic England.

The Research Reports' database replaces the former:

Ancient Monuments Laboratory (AML) Reports Series
The Centre for Archaeology (CfA) Reports Series
The Archaeological Investigation Report Series and
The Architectural Investigation Reports Series.

ISSN 2059-4453 (Online)