Tree ring dating of timbers retrieved from the Thames during the London Gateway development

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Abstract

Dendrochronological analysis was carried out on samples from fifteen oak timbers recovered during dredging operations as part of the London Gateway project. None of the ring-width series from these samples could be absolutely dated against British or European chronologies. However, three tangentially sawn timbers (LG5021, LG5023 and LG5024) cross dated against each other allowing construction of a 67-year sequence and analysis suggests they were part of the same structure and may have been sourced from the same tree. Examination of two further timbers (LG2003 and LG1147) indicates that they are sourced from tropical hardwood species and would require further specialist microscopic examination to identify them to species level.

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Introduction

In June 2015 a dendrochronological assessment was undertaken on 47 timbers recovered during dredging works on the Thames London Gateway project. Sixteen contained sufficient rings (<50) to warrant dendrochronological analysis.

Methods

Methods employed at the Lampeter Dendrochronology Laboratory in general follow those described in English Heritage guidance (English Heritage 1998). Dry samples were surfaced using an orbital sander using increasingly fine grit (from 60 to 400 grit) to clearly reveal the growth rings. A clean surface on wet samples was achieved by hand using razor blades. The complete sequence of growth rings in each sample was 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) are employed to search for positions where the ring sequences are highly correlated against each other.

Dating is dependent on trees over large geographical areas showing a similar relative pattern of wide and narrow annual rings as a result of climate during the growing season. Of course, tree growth is not only affected by climate, and individual tree growth, or of trees in one cohort or area can be affected by a whole host of other environmental variables. For example a tree growing on a flat area close to a stream with abundant water is less likely to exhibit a narrow ring in a dry year than a tree on a steep slope with thin soils and the ring width series would be termed complacent. Competition, age trends, injury and human/animal interference (such as pollarding or foliage defoliation by insects) can result in a ring width pattern unrelated to climate. Even in regions with harsh climate up to a quarter of trees within a woodland will contain ring width patterns that do not correspond to the wider climate and therefore do not date. In order to eliminate some of the background, non-climate driven 'noise' in individual tree/timber data, multiple radii are measured from a single tree or timber, followed by the creation of a multiple sample mean ring-width series that contains less of the 'noise' associated with individual samples, which is more likely to cross-date against external reference chronologies. The likelihood of a sample dating is further increased by the availability of well-replicated tree-ring series from the time period and geographical source that a given timber sample comes from, with some time periods and geographical areas less well represented in terms of tree-ring data.

The ring sequences in this instance were tested against a range of oak reference chronologies from Britain, North America and Europe. The *t*-values reported 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, and that satisfactory visual matching supports these positions and that the overlap is at least 50 years. A *t*-value of over 10 between samples is indicative of originating from the same parent tree, though t- values of far less than 10 are often observed from measuring different radii across a single oak tree cross section. Correlated positions are checked visually using computerised ring-width plots.

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 ten and forty six years (English Heritage,1998), an estimate based on observations of many thousands of samples from living trees and archaeological wood. At a microscopic level, sapwood in

Quercus spp 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 an estimate of between ten and forty six rings is used to infer a date range for a British oak sample (English Heritage,1998). 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 at least ten years after the date of that final ring.

Results

Ring width characteristics for each measured sample are provided in table 1 and the raw ring width data is included (appendix 1). Photographs of each surfaced sample (including sub samples) are also included (figures 2-17).

None of the fifteen measured samples cross dated against external reference chronologies so it is not possible to provide absolute dates for any of the timbers. Cross dating between samples is confined to three tangential samples (LG 5021, 5023 and 5024) that cross dated with each other (table 2 and figure 1). While the *t*-values between the samples are less than 10 (an indication of originating from the same tree), the high *t*-values (table 2), similar average ring width (table 1) and visual matching of both the inter-annual and low frequency trends (figure 1) suggest that they are likely to have originated from the same tree.

A further sample (LG1147), initially thought to be a softwood species, has been further examined and would appear to be an as yet unidentified tropical hardwood species and unsuitable for tree-ring dating. In addition, cleaning and examination of sample LG2003 indicates this is also sourced from a tropical hardwood tree and would likewise require specialist identification to reveal the species used.

Conclusions

The relatively low *t*-values between LG5023 and LG5021 and LG5024 may be a reflection of the short duration of the ring width series (48-67 rings). Moreover, the three samples' ring-widths are characteristic of a complacent tree (low variance in the ring widths), and coupled with the short nature of the obtained sequences it in not altogether surprising that none of the three samples or a combined three timber mean series provide convincing matches against external reference chronologies. The visual match (figure1) between the samples is howeververy convincing and the degree of similarity suggests that the three timbers may have originated from the same tree. Apart from the aforementioned group of three samples that date with each other, none of the others could be cross-matched and do not appear to form part of a single structure, perhaps a reflection of the method by which the timbers were retrieved. Individual samples may have been sourced from an area with few if any existing reference chronologies, lack a robust enough climate signal as single samples to cross-date externally or are from a date range where there is little in the way of reference material. The lack of internal dating among the majority of the samples, coupled with the relatively low ring counts evident (six samples containing >80 rings), and the knotty nature of two of the samples (LG1146 and LG1186) also hinders efforts to absolutely date the assemblage.

References

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

English Heritage. 1998 Dendrochronology: guidelines on producing and interpreting dendrochronological dates, London

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

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

Figures and Tables

timber	conversion	cross section (mm)	rings	sapwood/bark info	ARW (mm)	relative date range
1111	Tangential	255 x 60	75	-	1.29	1-75
1146b	Boxed Heart	150 x 125	90	-	1.36	1-90
1148b	Halved	115 x 70	80	-	0.99	1-80
1150	Quartered	160 x 115	53	14+?B	2.43	1-53
1186b	Quartered	175 x 115	81	-	1.2	1-81
1188	Quartered	0 x 0	99	-	1.9	1-99
1191	Radial	150 x 130	123	-	1.09	1-123
1204	Sub Halved	190 x 105	70	-	2.28	1-70
1216C	Sub Halved	150 x 55	91	-	0.82	1-91
5018a	Radial	150 x 110	84	-	1.66	1-84
5021B	Tangential	215 x 60	58	-	1.91	1-58
5023	Tangential	100 x 80	48	-	1.63	17-64
5024	Tangential	200 x 60	67	-	1.73	1-67
5033b	Radial	120 x 110	88	-	1.19	1-88
5054d	Sub Quartered	160 x 150	59	+?HS	2.75	1-59

Table 1. Sample information. ARW = average ring width (mm). HS= heartwood/sapwood boundary. B= bark

Filenames	-	-	LG5021	LG5023	LG5024
-	start	dates	2	17	1
-	dates	end	59	64	67
LG5021	2	59	*	5.42	9.34
LG5023	17	64	*	*	7.3
LG5024	1	67	*	*	*

Table 2. *t* value matrix between relatively dated timbers LG5021, LG5023 and LG5024

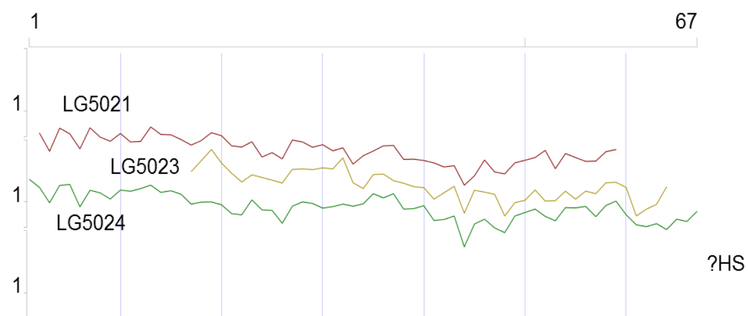

Figure 1 Visual representation of cross dating position between samples LG5021, LG5023 and LG5024

Figure 2 Photograph of LG1186 sample

Figure 3 Photograph of LG1188 (sample 1)

Figure 4 Photograph of LG1188 (sample 2)

Figure 5 Photograph of LG1146 sample

Figure 6 Photograph of LG1148 sample

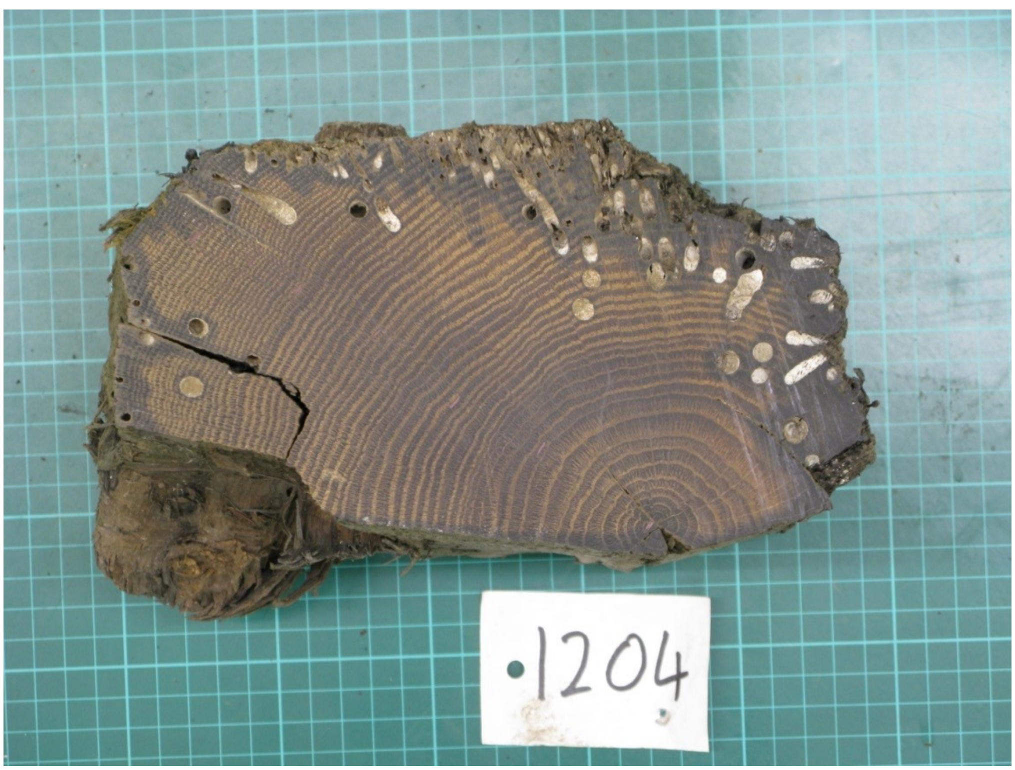

Figure 7 Photograph of LG1204 sample

Figure 8 Photograph of LG1216 sample

Figure 9 Photograph of LG5035 sample

Figure 10 Photograph of LG1111 sample

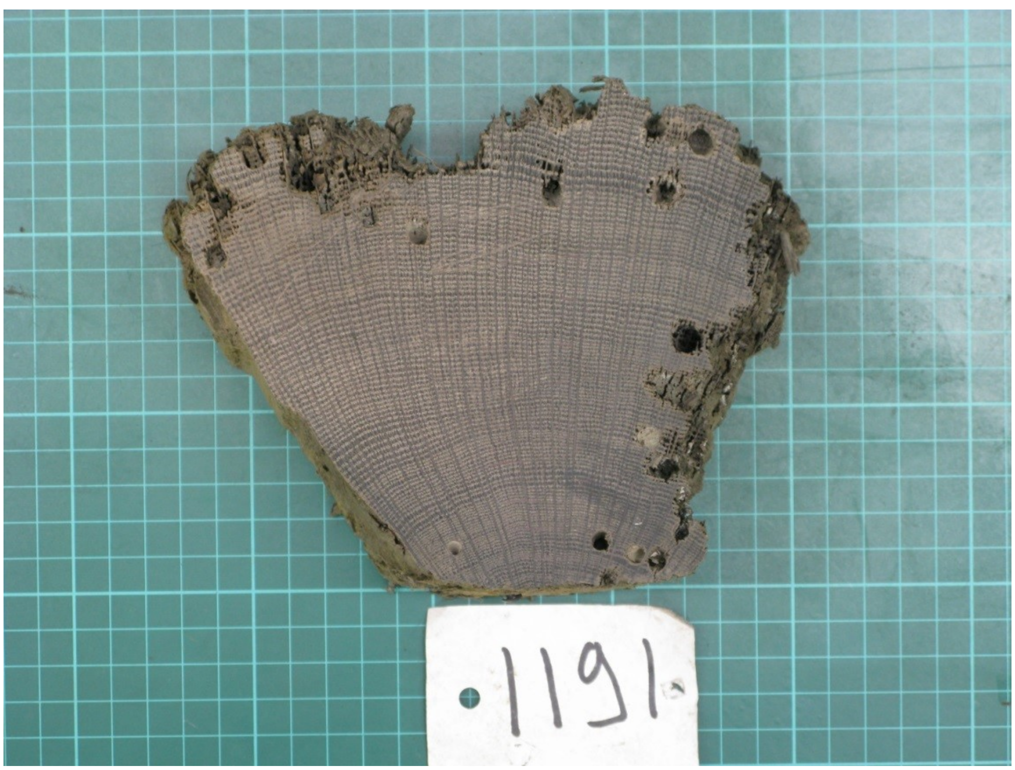

Figure 11 Photograph of LG1191 sample

Figure 12 Photograph of LG5054 sample

Figure 13 Photograph of LG1150 sample. Sapwood is visible in outer right top corner

Figure 14 Photograph of LG5018 sample

Figure 15 Photograph of LG5024 sample

Figure 16 Photograph of LG5021 sample

Figure 17 Photograph of LG5023 sample

Appendix 1

Raw ring width data for all analysed samples and three timber mean (LG5021,5023 and 5024)

Title : LG1111

Raw Ring-width QUSP data of 75 years length

Undated; relative dates - 1 to 75

0 sapwood rings and no bark surface

Average ring width 128.67   Sensitivity 0.15

1	165	164	95	117	104	134	124	148	150	156
-	178	213	179	135	182	148	144	151	111	115
-	106	119	126	129	118	145	114	117	151	153
-	156	157	167	179	132	155	107	97	103	99
-	157	203	180	161	163	116	95	100	83	114
51	133	106	112	146	89	87	93	82	82	80
-	76	111	118	142	107	144	153	129	116	121
-	130	105	78	83	112					

Title : LG1146b

Raw Ring-width QUSP data of 90 years length

Undated; relative dates - 1 to 90

0 sapwood rings and no bark surface

Average ring width 135.72   Sensitivity 0.35

1	336	96	38	32	32	44	18	50	49	52
-	61	109	114	122	82	59	87	177	134	117
-	106	129	115	118	96	112	112	85	80	86
-	66	38	28	31	31	23	31	59	80	128
-	85	71	57	42	91	125	150	159	183	143
51	226	157	143	251	356	375	400	178	346	542
-	281	373	525	240	77	40	39	61	54	73
-	132	58	127	160	240	217	188	305	182	76
-	61	54	81	330	272	144	108	84	111	79

Title : LG1148b

Raw Ring-width QUSP data of 80 years length

Undated; relative dates - 1 to 80

0 sapwood rings and no bark surface

Average ring width 99.46   Sensitivity 0.33

1	105	34	26	22	14	27	24	28	17	25
-	28	9	13	29	34	32	32	21	34	19
-	43	26	21	16	13	15	15	21	23	23
-	23	23	32	23	35	55	69	46	34	92
-	81	108	66	113	103	153	240	222	196	113

51	100	94	102	70	124	168	144	164	268	169
-	146	253	202	249	134	102	265	349	203	170
-	235	146	212	212	412	223	125	119	93	88

Title : LG1150

Raw Ring-width QUSP data of 53 years length

Undated; relative dates - 1 to 53

14 sapwood rings and possible bark surface

Average ring width 242.85   Sensitivity 0.28

1	437	380	321	227	255	351	382	353	413	352
-	304	308	247	306	270	448	16	283	223	312
-	241	206	190	265	370	456	331	371	164	285
-	259	210	195	177	250	218	187	110	162	163
-	144	167	181	190	264	266	229	112	71	66
51	47	67	69							

Title : LG1186b

Raw Ring-width QUSP data of 81 years length

Undated; relative dates - 1 to 81

0 sapwood rings and no bark surface

Average ring width 120.17   Sensitivity 0.31

1	121	135	128	77	52	80	68	113	95	38
-	54	97	107	64	135	103	132	201	74	79
-	102	125	145	88	81	108	170	217	348	162
-	130	190	230	163	76	58	75	133	157	174
-	232	207	176	94	80	117	128	144	174	212
51	156	150	111	114	78	65	55	89	112	151
-	168	146	202	109	87	66	120	110	119	132
-	118	39	85	60	81	126	80	64	97	85
-	110									

Title : 1188

Raw Ring-width QUSP data of 99 years length

Undated; relative dates - 1 to 99

0 sapwood rings and no bark surface

Average ring width 189.52   Sensitivity 0.25

1	76	60	149	124	110	113	130	233	224	310
-	284	315	350	229	186	261	209	104	154	177
-	185	191	131	116	79	91	118	130	112	72
-	85	139	155	168	178	273	294	222	152	109
-	128	171	149	143	162	307	252	186	159	318
51	251	191	193	243	299	286	202	244	345	260
-	189	135	125	177	244	225	313	335	178	262
-	288	330	263	268	193	130	204	233	196	228
-	226	214	201	105	102	138	94	209	160	180
-	244	151	136	192	137	97	123	116	134	

Title : LG1191

Raw Ring-width QUSP data of 123 years length

Undated; relative dates - 1 to 123

0 sapwood rings and no bark surface

Average ring width 109.08   Sensitivity 0.20

1	97	69	80	55	43	63	92	99	103	83
-	61	44	48	82	72	77	115	97	81	79
-	42	72	63	65	75	77	92	63	95	73
-	90	67	88	82	90	135	89	144	121	107
-	113	74	97	91	94	106	87	67	99	128
51	100	125	128	123	72	126	109	88	101	101
-	115	91	77	100	111	105	121	96	99	114
-	96	81	107	126	114	149	118	133	96	147
-	141	110	102	111	114	115	122	123	123	96
-	116	121	157	104	130	107	100	122	140	138
101	104	136	156	133	142	211	232	129	196	134
-	181	164	144	167	114	147	149	136	177	151
-	148	127	152							

Title : LG1204

Raw Ring-width QUSP data of 70 years length

Undated; relative dates - 1 to 70

0 sapwood rings and no bark surface

Average ring width 227.99   Sensitivity 0.24

1	318	245	216	187	338	324	401	360	717	499
-	317	299	335	262	180	150	227	334	212	203
-	321	235	282	302	286	234	300	241	331	306
-	209	328	296	267	225	182	240	214	285	192
-	149	180	191	155	165	153	104	158	116	101
51	177	125	113	135	113	149	172	177	215	154
-	214	193	167	96	139	99	135	143	149	222

Title : LG1216C

Raw Ring-width QUSP data of 91 years length

Undated; relative dates - 1 to 91

0 sapwood rings and no bark surface

Average ring width 81.54   Sensitivity 0.22

1	269	142	175	169	158	120	161	99	82	94
-	139	74	78	110	111	116	112	89	85	41
-	70	47	52	90	63	76	86	61	86	73
-	73	52	47	77	64	67	53	39	48	64
-	109	85	101	74	67	31	50	55	79	43
51	52	46	47	42	45	44	29	34	41	39
-	41	40	49	57	53	67	43	50	71	41
-	61	82	79	92	81	109	98	102	98	92
-	95	94	101	108	130	104	110	120	111	76
-	140									

Title : LG5018a

Raw Ring-width UNKN data of 84 years length

Undated; relative dates - 1 to 84

0 sapwood rings and no bark surface

Average ring width 165.79   Sensitivity 0.25

1	81	92	90	94	92	190	153	119	107	72
-	53	106	129	106	231	182	138	104	68	98
-	157	189	157	127	117	88	59	32	39	27
-	35	65	36	37	47	35	38	26	49	49
-	42	86	156	161	199	176	204	190	116	134
51	143	114	187	212	208	232	225	205	262	250
-	245	150	233	317	254	322	179	316	342	258
-	332	310	321	269	265	343	284	319	239	242
-	366	264	251	289						

Title : LG5021B

Raw Ring-width QUSP data of 58 years length

Undated; relative dates - 2 to 59

0 sapwood rings and no bark surface

Average ring width 190.50   Sensitivity 0.19

2		280	177	317	275	188	320	253	228	277
-	224	227	327	271	268	238	207	232	283	262
-	203	197	225	153	171	146	235	224	196	209
-	179	193	128	158	178	203	205	144	145	140
-	132	119	123	75	95	142	105	100	132	141
51	151	181	114	167	151	137	138	175	185	

Title : LG5023

Raw Ring-width QUSP data of 48 years length

Undated; relative dates - 17 to 64

0 sapwood rings and no bark surface

Average ring width 162.71   Sensitivity 0.21

17							215	283	375	266
-	206	165	198	185	173	161	227	230	226	236
-	230	304	162	140	199	202	171	160	147	143
-	107	126	148	75	134	128	121	70	98	104
51	135	102	103	131	107	131	123	162	164	144
-	70	83	94	146						

Title : LG5024_2

Anatomical features

Ring 16 type T

Raw Ring-width QUSP data of 67 years length

Undated; relative dates - 1 to 67

0 sapwood rings but possible h/s boundary

Average ring width 172.09   Sensitivity 0.18

1	330	270	183	284	291	165	251	235	201	252
-	245	262	286	238	248	227	177	186	187	174
-	139	135	197	153	151	109	168	187	180	160
-	166	177	168	178	230	207	230	156	158	170
-	117	120	131	60	107	121	97	86	131	143
51	156	130	116	162	161	167	129	171	191	135
-	105	100	108	93	121	114	147			

Title : LG5033b

Raw Ring-width QUSP data of 88 years length

Undated; relative dates - 12 to 99

0 sapwood rings and no bark surface

Average ring width 118.93   Sensitivity 0.26

12		161	105	126	102	152	166	89	160	227
-	210	277	173	181	116	88	137	106	96	98
-	162	170	142	163	139	114	136	136	99	106
-	115	101	68	68	101	147	150	113	88	79
51	125	107	188	170	165	169	121	136	163	93
-	120	118	65	96	83	76	121	123	79	111
-	118	127	150	151	121	68	71	74	140	94
-	111	123	95	73	119	75	55	121	66	72
-	68	92	84	142	56	78	92	105	129	

Title : LG5054d

Raw Ring-width QUSP data of 59 years length

Undated; relative dates - 1 to 59

0 sapwood rings but possible h/s boundary

Average ring width 275.00 Sensitivity 0.29

1	238	218	296	263	288	324	297	399	453	152
-	327	343	347	456	514	576	661	305	369	280
-	372	580	679	432	314	426	352	473	351	464
-	341	340	406	408	431	184	117	113	164	182
-	111	109	75	73	79	81	78	153	91	55
51	66	106	90	48	74	112	177	289	123	

Title : LG5021_5023_5024 3 timber mean

Timber mean with signatures Ring-width QUSP data of 67 years length

Undated; relative dates - 1 to 67

3 timbers raw data mean

Average ring width 179.97   Sensitivity 0.18

1	330	296	189	307	303	191	282	250	215	268	1	2	2	2	2	2	2	2	2	2
-	242	240	293	251	255	224	190	235	277	230	2	2	2	2	2	2	3	3	3	3
-	187	165	191	153	161	134	212	211	199	215	3	3	3	3	3	3	3	3	3	3
-	193	226	158	158	198	200	204	152	150	154	3	3	3	3	3	3	3	3	3	3
-	119	120	136	68	112	132	109	87	112	124	3	3	3	3	3	3	3	3	3	3
51	146	131	110	153	136	146	133	170	183	145	3	3	3	3	3	3	3	3	3	2
61	86	91	106	126	112	124	152				2	2	2	2	1	1	1			