The Alan Mitchell Memorial Lecture 2000

The Growth Rate of Taxus Baccata: An Empirically Generated Growth Curve.

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Girth measuring at Farringdon, Hampshire

Introduction

This condensed essay is a roundup of a broad study of yew tree growth rates that has been carried out between 1996 and 2000. Ageing Yews is frustrating and complicated, but I believe that these results are solid enough to share. Here is a list of the main themes discussed in this paper:

1) Growth rates of yews up to 800 years old, discovered by ring counts and known planting dates.

2) An interpretation of certain aspects of the growth patterns of very large and ancient yews that have a bearing on their growth rate.

3) Splicing different forms of data into the same graph.

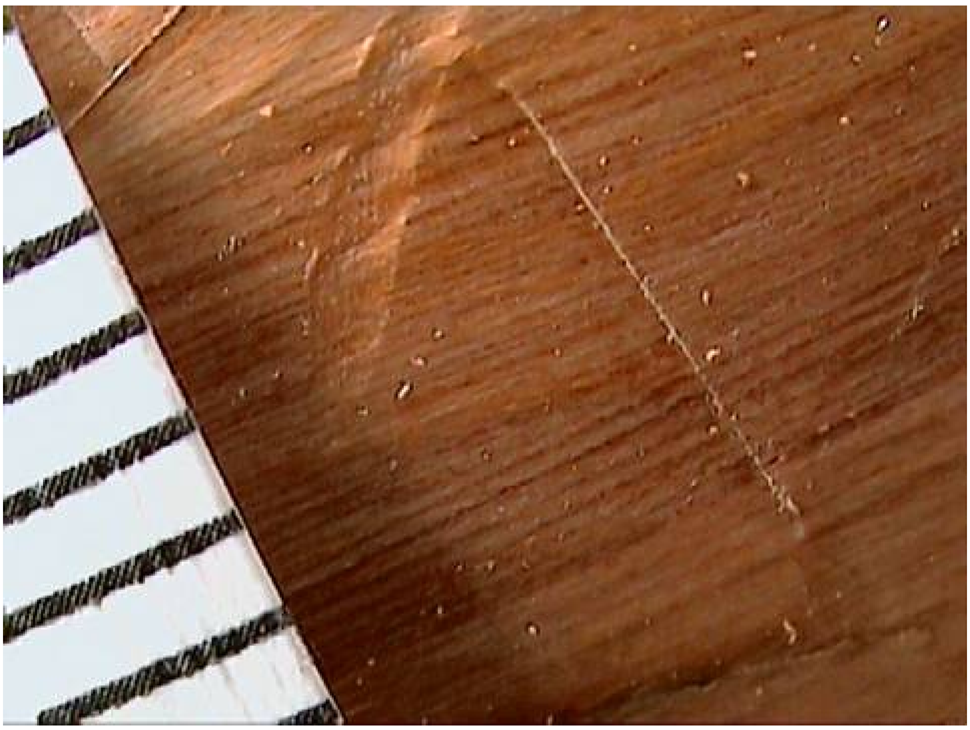
4) The graph of the growth rate of yews that is calculated from measurements of 182 specific yew trees, and which can be used to estimate minimum ages for yews of up to 10 meters in girth.

The following paper is necessary because historically there has been a lot of debate over the ages of large yew specimens. In 1998 the debate was renewed when Stephen Dennis, a tree surgeon relying on his own "complex mathematical formula" disputed David Bellamy's age for the Linton yew, suggesting that the tree was little more than 1,000 years old, rather than 4,000 (1). That there could be such a big gap between these two estimates of the age of a tree suggests that there is a need for more research.

The subject of ageing ancient yews has been in dispute on and off ever since Augustine de Candolle, writing in 1831, realised that tree rings represent annual increments. On this basis he attempted to age the yew at Fortingale, among others (in Lowe, see bibliography).

So what is new about this current offering? Firstly, it is an empirical piece of work. It does not rely upon many arboricultural theories. In this sense it is a fresh start. Secondly the age against girth graph that is produced is not mathematically modelled along the lines of an exponential curve. This allows the observation and analysis of the several oddities in the data set, and the maths used are tailored to the job of understanding the particular data that are available. Thirdly it uses a very firmly statistical methodology. The overt use of a pre-set sampling frame is one important example of the very basic steps in science that are an essential precursor to meaningful results. Scientific method is sadly lacking in the analysis of several yew tree experts, for example John Lowe, who appeared to rely entirely upon common sense, selected examples and opinion. It should be said that although Lowe's analysis may be lacking, his fieldwork was generally rather good, and a debt of gratitude is owed him for measuring so many ancient yews, and publishing his work. A list of authors from whom historic measures have been taken, and to whom a similar debt is owed, is found in the bibliography below.

The following analysis demonstrates that the ideas of Allen Meredith and Professor David Bellamy on ageing yews are broadly correct, and roughly corroborates most of the ages given in the gazetteer in The Sacred Yew (2). A yew such as the specimen at Linton is quite likely to be as much as 4,000 years old, although judging only by girth, and ignoring the state of the tree, the graph in this work gives an age of about 2,000 years. The figure of 2,000 can be regarded as an absolute minimum, or a basic figure to add to, because the Linton tree is rather complex. A limitation of this study is that it does not examine variables that may imply that a yew is older than its current girth would suggest.



Yew rings from a fallen trunk section at Borrowdale against a 1mm scale

Part 1:

Girths, Rings and References.

One example of each sort of information used to study younger yews.

There are two kinds of data used in building a picture of the early growth of ancient yews. Below are very brief examples of each. The first example given here is from Alice Holt.

Ring Counts

This researcher has been working on growth rates of yew in the forest of Alice Holt near Farnham, Surrey. It so happens that many yews were cut down in 1996, and could therefore be girthed and ring counted. The resulting data gives a very solid foundation for estimating age.

Table 1

Non-hollow felled yews at Alice Holt: Summary of a census.

Mean age, ie Mean no. of rings	Yew stumps in sample. N= 44	Mean annual rings	Mean base girth (meters)	Mean girth increase mm/year (growth rate of sample)
Over 170	1	335	3.2	10
140-169	9	148	1.86	12.8
100-139	13	130	1.65	12.5
60-99	7	72	1.0	13.7
Under 60	14	52	0.55	10.4

Some very small yews are excluded from later graph data because they were cut at the base, and the trunk was not available for measure at the usual height of 3 feet. A compensation mechanism can be used on larger trees, but is invalid on yews that are under 35 cm at 3 feet (3). The largest yew is excluded because it creates a graph point with a sample size of 1.

As you can see from the table, a yew of 3.2 meters in girth and 335 years of age was discovered, and is shown by the counts on the younger specimens to be no anomaly.

Felled 340 year old yew at Alice Holt 1996

Planting Dates

The other type of information that is of use in understanding the early growth of the yew is obtained from known planting dates, especially where we know the age of a group or avenue of yews. Documentary evidence is needed for this sort of study, backed up by fieldwork. Here is an example of the sort of reference taken to be good evidence of the age of a tree or trees:

Transactions of the Woolhope Naturalists' Field Club Herefordshire (Est. 1851)

Volume for 1933

Page xii: "James (Tomkins) became M.P. for Leominster in 1623 and traditionally is said to have planted the avenue of Scotch Firs and Yews about this time if not in commemoration of the event.

Page xiii: "The members proceeded on foot up Monnington Walk and it was noted that since their last visit in 1920 many of the fine Scotch Firs had died where they stood. The Hon. Secretary said that it was worth noting that one of the Scotch Firs was blown down in 1868, and the annual rings were found to number 240, which would bring the date of the trees to 1628, that is about the date that tradition assigns to them. In 1870 a number of the Yew trees were measured and their average girth was 5 feet 10 inches..."

All of the yews were measured at three feet from the ground in March 1999. Table 2 is a summary of the findings, including the measures from 1870. The 1999 data is used as a single point on graph A on page 5.

Table 2

A summary of the yew data from Monnington Walk, Herefordshire.

Age	Mean girth meters	Standard deviation (girth)	Number of trees	Mean rate Mm pa	Data type
242	1.78	Not known	Not known*	7.4	Planting date and historic measures, 1870
371	3.08	0.635 meters	42	8.3	Planting date and current measures, 1999

* The 1870 data cannot be used as data, or to calculate "recent rate" (see below) because the sample is neither an overt census with specified exclusions nor a random sample.

A full report was written about the visit in spring 1999, and work was done on the data. To summarise:

1) There was no significant difference between the growth rates of male and female yews.
2) There was no significant difference in growth rate between the left and right sides of the avenue.
3) The growth rates of the individual trees plot as a good bell curve, suggesting that the yews measured at Monnington Walk were all planted together.

Sources of information for part 1.

The above illustrations show the kind of information considered solid enough to count as evidence, and to be included in the study. All measurements were made by this researcher, except for those found in The Sacred Yew, and 8 rather important yews measured by Andy McGeeney at Westbourne Churchyard, Hampshire. Andy McGeeney brought Cherkley Court to my attention, and assisted with the fieldwork. He also commented on the first draft of this essay. Thanks also to Robert Bevan-Jones, who brought the work of Williams-Freeman and the above passage about Monnington Walk to my attention.

A section of internal stem from a 5m girth felled yew at Cherkley Court, factors like the effect of internal growth on girth-age estimates remain to be studied. They are not included in this analysis.

<u>Part 2</u>

The big yews and how they grow

Growth rates in ancient yew, and how those rates are affected by particular stages of growth.

The following information has been produced by tracking down old references to yew tree girths, and re-measuring those trees, a method which has in the past been considered notoriously unreliable, its detractors including Alan Mitchell (4). However, by applying a rigorous methodology, the variables that made the whole thing seem unusable can be identified, and sense can be made of the huge differences in growth rate between yews of similar sizes. In brief, once the girth is over 5 meters, the growth rate of a yew is dictated almost an order of magnitude (ten times) more by the physical state of the tree than by its actual girth (this was checked using one-way ANOVA tests). Most yews appear to go through the same life history of states.

The yew seems to grow in distinct stages. The majority of trees go through several life events that have a bearing on the rate at which their trunk expands. We need not concern ourselves with the initial stages of growth here. Starting with a yew of say a meter in girth, we find that we have a tree a hundred or so years old, and growing fast, up to 20 mm girth increase per year, though less if it is shaded in woodland. As it grows the girth increase is reduced in accordance with John White's idea of CAI, or Constant Annual Increment (5). This reduction in rate continues for hundreds of years, until at last the tree is growing very slowly indeed. At this stage it has a very strong core of heartwood which compresses well. Crucially, the outer layers of the trunk are adapted to cope with tension, stretching forces. Eventually the tree begins to rot out, beginning with the oldest wood, the heartwood. Two things happen. Firstly, the weight of the upper part of the tree comes to rest more and more on new wood that is not designed to cope with compression. Secondly, and as a consequence, the area of trunk under undue stress begins to grow. This does not mean that the tree is producing more wood as a whole, but that the area of stress, i.e. the lower bole where we would measure the tree, is receiving the lion's share of the wood. What we see is an explosion of growth in a tree that will typically be between 4 and 6 meters in girth, a very odd phenomenon, and one which has, in the past, led researchers such as John Lowe to conclude that the yew is a fast growing tree. As the yew grows in girth, the forces of rot keep up until the tree trunk is a tall empty cone, which can no longer support itself. It begins to collapse, loosing canopy, and creating a short hollow tube with branches: a shell. With little canopy, a low habit, and no appreciable strain on the lower trunk, girth increase is very slow from this point on. There is one further change in habit which is not yet statistically proved, but which I suspect, and which does show up on graph A as a rise in rate at 9-10 meters girth. The final stage of growth is reached when the tree trunk splits and fragments and begins to form a ring of individuals. This appears to be a very fast growing phase when it first occurs, and then seems to slow and stabilise as the new growths reach a substantial girth in their own right. Excellent examples of this are found at Tandridge church in Surrey and Breamore church in Hampshire.

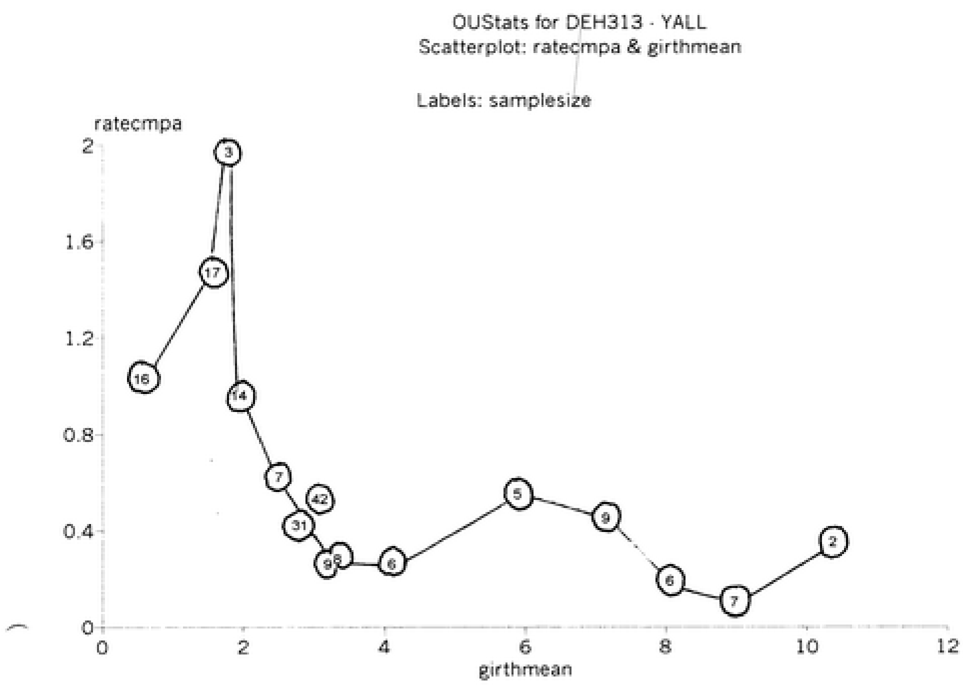
Table 3

Summary: Seven stages of yew development

Growth stage	Description of growth stage	Rate of girth increase
1. Seedling	From germination, and the first year.	Slow
2. Sapling	Until grown well beyond the reach of deer	Faster
3. Solid tree	No rot at the centre	Fast, slowing
4. Hollowing	Rot creeping in, stem still mainly intact	Slow
5. Hollow	Rotted out, able to contain a person	Fast
6. Shell	Top of trunk gone, no "roof" to the hollow	Slow
7. Ring	New young yews forming out of old shell	Fast

Stages 3, 4+5 and 6 have been shown to have significantly different growth rates using a Chi Square test: $p<0.01$. Sample: Hampshire yews over 5 meters girth.

Graph A: Rate against Girth.



a) Each point shows the number of trees that contribute data to it.
b) Rate of growth is represented on the vertical axis, and is in centimetres of girth increase per year.
c) The horizontal axis represents tree girth in meters.

How graph A is constructed.

Graph A cannot be used to read off the age of a tree, but it is a necessary explanatory stage in the calculation of graph B, which does plot age against girth, and can be used to estimate yew tree ages.

Splicing the data

There is an obvious problem with adding different sorts of data into the same graph: we must check that we are comparing like with like. Mixing planting dates with ring counts seems quite satisfactory, as a tree is of a certain girth and a certain age whichever method of checking the age is used. In the case of the historic measures, however, there is a serious difficulty. We cannot say what the age of the tree is, so we cannot put it on the graph. A solution needs to be found. Here the method is to use the commonalities that exist between the different sorts of data to bind them together. We have plotted a graph of girth against recent growth rate for all of the yews in the study. We can now use it to work out how long a typical yew might take to reach certain girths. These time spans give us data points that we can later apply to graph B. A summary of the working for this is in appendix 5.

An important thing to note is that direct growth rates are not used in graph A. As the growth rate of a young yew starts fast, and slows radically through the centuries it is misleading to simply measure a yew, find out when it was planted, divide girth by age and say that the rate is such-and-such. The yew will have averaged that rate over its entire life; that is its **total rate**, it is very unlikely to be its most recent rate of growth. To find out the **recent rate**, or an approximation of it, we need to subtract the growth and age of younger trees from the girth and age of the ones that we are interested in, then calculate rate using the differences. This cuts out the influence of earlier stages of growth, and allows the recent rate to be isolated.

Table 4

An example of the calculation of recent growth rate for three imaginary samples of trees 100, 200 and 400 years old respectively, contrasting total and recent rates of girth increase.

Tree data	X	Y	Z
Age (A)	100	200	400
Girth (G)	200	300	400
Total Rate (G/A)	**2**	**1.5**	**1**
Age difference (Ad)	Ax=100	Ay-Ax=100	Az-Ay=200
Girth difference (Gd)	Gx=200	Gy-Gx=100	Gz-Gy=100
Recent Rate (Gd/Ad)	**2**	**1**	**0.5**

The recent rate is the rate that the yew has been growing at since the previous check, which is the figure needed to correctly represent the growth of a tree on a graphic curve. Importantly, it is also the same kind of information that is produced by analysing growth rates of large trees over historic periods of time. Using this method, we can now compare like with like when including our three different streams of data in a graph that includes a time factor.

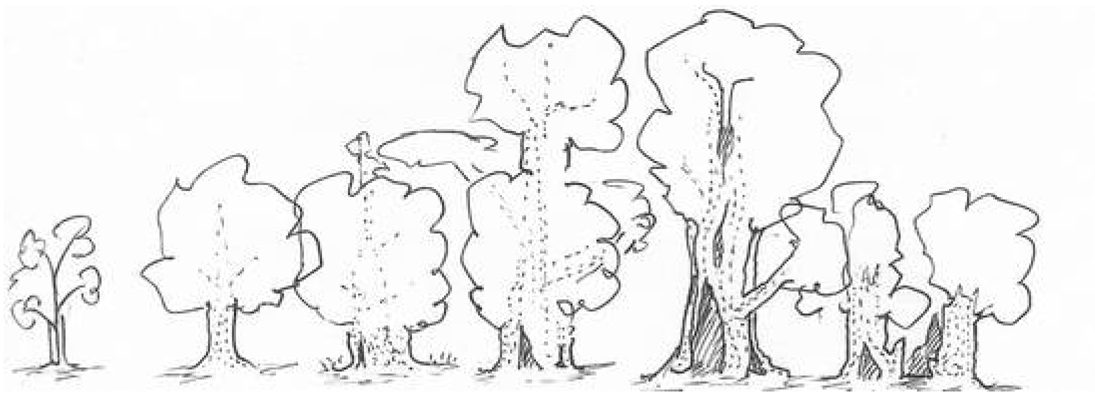
Content of graph A

Graph A, then, contains the three different sorts of information that have just been discussed. The first set of data contains ring counts, with girth measures. These are only easily obtainable for about the first 200 years, after this time intact specimens become so rare that it is very difficult to obtain a statistically useful sample. The difficulties are twofold, firstly and thankfully not very many large yews are cut down. Secondly, when they are felled they are seldom intact; the centre has generally rotted out.

The second set of data in the graph extends our knowledge to yews of up to about 800 years, and consists of trees of known planting date and girth. This stream also runs out because documents get scarce as one goes back in history. About half of the data of this kind used here comes from "The Sacred Yew" (2).

This is the end of the data where we know the age of the tree, and the growth rate is calculated. We now move on to the opposite situation, with historic measurement data we know the growth rates, but must calculate the mean age of the sample. See the age column in appendix 4.

The problem of how to find the ages of really big yews, older than 800 years, is as we have seen, solved by studying their historic growth rates. The material in our third set of data has been rejected in the past because the evidence it produced always seemed to be contradictory. It is now possible to use most of the information, however, as the study of growth patterns (outlined above) has provided an explanation of the source of much of the confusing variability, and the sample size is thought to be larger than any collected previously. The calculated portions of the age against girth graph B, below, are produced using this historic girth measure information. See appendices 2, 4 and 5.

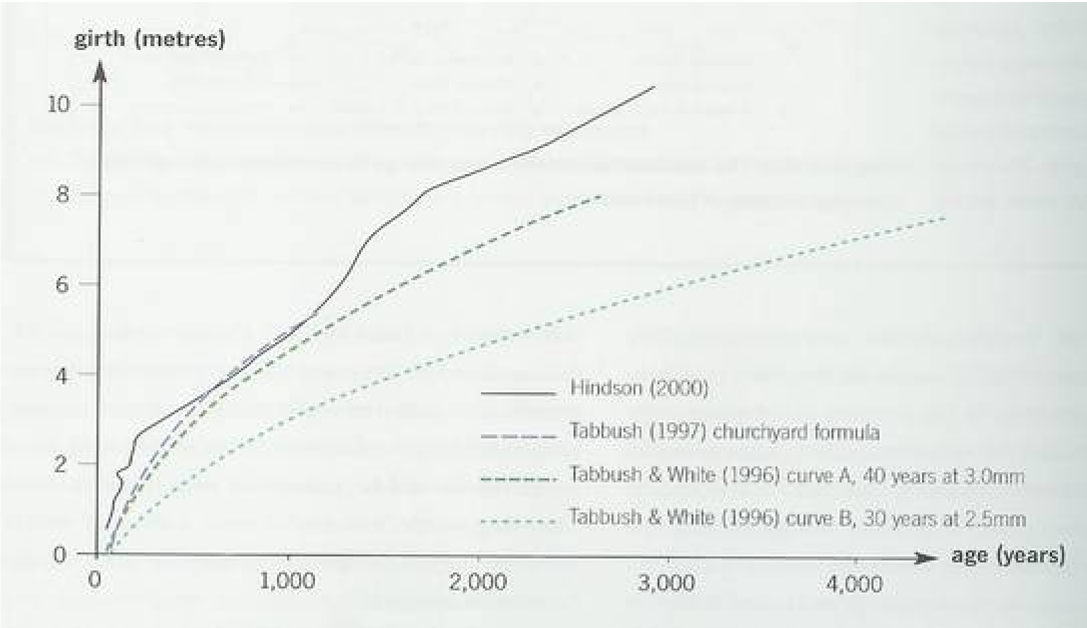


The first six stages of yew growth

Graph B

Image taken from Hageneder, F (2007), *Yew A History* because helpful relationships to other research are also graphically represented. (6)

An empirically generated age against girth graph created using the data from this study.



Allen Meredith's data.

There is a good deal of useful data in the appendices of "The Sacred Yew" which was gathered by Allen Meredith. The Sacred Yew data has been treated in the same way as the data gathered by this researcher, and used as a check. It fits the curve very well, and adds to it. It has therefore been left in. Data summaries are to be found in appendices 2 and 4.

Interpretation of the graphs

It is well known that there is a lot of variability in yew growth, however, graph B does give an average age for yew trees of given girths up to 10 meters. Preliminary statistical work suggests that 2/3 of yews are within 20% either side of this figure, less than 1/6 being even younger, and over 1/6 being older than 20% of the norm. The data set includes events in the lives of large yews such as the occasional loss of small portions of bole, but does not include destruction of the tree and subsequent re-growth, such as may be happening at Aldworth. The Aldworth tree is now about 13 feet in girth after storm damage in the 1970s. It was previously 28 feet. With larger and more complicated yews we can really have no idea how often major destruction may have occurred in their lives, a fragmented old yew can thus be almost any age, but seldom significantly less than the age shown on graph B above.

Future work

As was stated in the introduction, this study does not attempt to account for the variables that allow a yew to be much older than its girth would suggest. These variables include the existence of massive internal stems, evidence of death or destruction followed by regeneration, evidence of prolonged periods of very slow or non-existent growth, and layering. All of these are under examination and will be the subject of future works.

Appendices

Appendix 1

Historic Measure data: Criteria for inclusion decided in advance of the study.

1) *The sampling frame is ancient Hampshire yews i.e. those of 5 meters or more in girth.*
2) *The tree should have a previous measure taken no less than 30 years before the second measure.*
3) *The previous measure should be at known height above ground level.*
4) *All known trees with a suitable measure should be included in the data list, and any excluded yews should be listed.*
5) *The Sacred Yew data should conform to items 2 & 3 above.*

Appendix 2

Selected and adapted from "The Sacred Yew" and re-measured where possible.

Site	Time span	Girth, latest	At. Ht	Increase	Rate Ins.	Rate mm
Crowhurst Sy*	1650-1999	31'2"	5'	1'6"	0.05	1.3
Crowhurst Sx	1680-1982	28'0"	4'	1'	0.04	1
Darley Dale	1792-1933	33'0"	4'	1'	0.09	2.3
Aldworth	1644-1972	28'	4'	1'	0.04	1
Totteridge	1677-1991	26'	3'	0"	0.00	0
Church Preen	1833-1983	23'1"	4'	1'1"	0.09	2.3
Much Marcle	1882-1989	29'0"	5'	6"	0.06	1.5
Eastling	1874-1982	30'4"	4'	4"	0.04	1
Cudham*	1890-2000	28'9"	3'	5"	0.04	1.1

* Denotes a tree that has been re-measured since Allen Meredith's work

Example of method: Data organised for graph A

Sample	N = 9	Mean girth (m)	Mean Rate mm
>6.5m	1	7.04	2.3
>7.5m	1	7.92	0
>8.5m	6	8.90	1.2
>10m	1	10.06	2.3

In the graphs this data is combined with the material in appendix 3.

Appendix 3

List of all Hampshire yews with known girth measures

Site	Type, See part 2	1999 girth, m	at ht. feet	Period	Years	Growth mm, girth	Mm/pa girth inc	cert	Data y/n
Bedhampton (East)	4	6.53	3	1897 – 1999	102	330	3	1	Y
Bedhampton (South)	4	6.30	3	1897 – 1999	102	200	2	2	Y
Boarhunt	6	8.28	3	1915 – 1999	84	50	1	2	Y
Breamore	7	10.69	1	1962 – 1999	37	180	5	0	Y
Brockenhurst	5	6.32	3	1793 – 1999	206	1750	8	3	Y
Corhampton	5	7.14	0	1897-1999	102	430	3	3	Y
Corhampton	4	7.42	3	1897 – 1999	102	100	1	3	Y
Durley	5	7.36	5	1963 – 1999	36	230	6	3	Y
Farringdon	6	9.44	5	1781 – 1999	218	250	1	2	Y
Hambledon	6	5.92	3	1897 – 1999	102	430	4	2	Y
Hayling	5	10.50	3	1897 – 1999	102	760	7	0	N
Itchen Abbas	X	7.57	5	1960 – 1999	39	100	3	2	Y
Lockerley	4	8.46	5	1888 – 1999	111	1350	12	0	N
Long Sutton (North)	6	8.25	0	1897 – 1999	102	150	1	3	Y
Long Sutton (West)	5	5.66	0	1897 – 1999	102	960	9	1	Y
Merdon Castle (gate)	3	7.47	0	1915 – 1999	84	530	6	2	Y
Merdon Castle (seat)	5	5.26	3	1915 – 1999	84	460	5	3	Y
Priors Dean	5	7.82	5	1961 – 1999	38	280	7	2	Y
Selborne	4	7.87	3	1823 – 1981	158	660	4	*	Y
Steep	5	6.88	3	1895 – 1999	104	890	9	2	Y
Warblington	3	8.20	3	1836 – 1999	163	280	2	3	Y
West Tisted	5	6.93	3	1915 – 1999	84	610	7	3	Y

Type refers to the number of the growth stage shown in table 3 on page 8.
Cert is the degree of certainty that all of the measures on each tree are accurate 0=certainly not, 3= confidence.
Data y/n is whether or not the data from a particular tree has been used in this study.

Corhampton yields two measures on different parts of the same tree. Both are included because the state of the tree is different at each measure site.
Selborne* cert: Note that the tree was not measured by this researcher.
Lockerley Has grown branch material over the old measure site. This measure is not suitable data as it no longer refers to bole increase alone. Exclude.
Hayling Island Continues to split apart. The girth increase due to growth is confounded with the girth increase due to splitting. Exclude.
Trees at Selbourne and Farringdon are excluded from The Sacred Yew data because they are included here, being Hampshire yews.

Bibliography

Of historic measures data sources

Lowe, J. (1897) Yew Trees of Great Britain and Ireland
Mitchell, A.F. (1972) Conifers in the British Isles
Allen Meredith in Chetan, A. and Brueton, D. (1994) The Sacred Yew
Williams-Freeman (1915) Field Archaeology as Illustrated by Hampshire
Anon (1933) Transactions of the Woolhope Naturalists' Field Club Herefordshire

Appendix 4

All data as used in graphs A and B

Age, mean (years)		Girth, mean (meters)	Recent Rate mm pa	Sample size N= 182	Data source and type
Known	Calculated				
53		0.55	10.4	16	Alice Holt, rings
121		1.56	14.8	17	Alice Holt, rings
160		1.94	9.7	14	Alice Holt, Cherkley Court, rings
370		3.08	5.4	42	Monnington Walk, planting date
455		3.33	2.9	8	Westbourne, planting date
92		1.98	19.8	3	Sacred Yew, planting dates
193		2.5	6.3	7	Sacred Yew, planting dates
262		2.8	4.3	31	Sacred Yew, planting dates
419		3.2	2.7	9	Sacred Yew, planting dates
754		4.1	2.7	6	Sacred Yew, planting dates
	1180	5.9	5.6	5	Hants data, historic measures
	1427	7.1	4.6	9	Hants & Sacred Yew, historic
	1703	8.1	2.0	6	Hants & Sacred Yew, historic
	2278	9	1.1	7	Hants & Sacred Yew, historic
	2882	10.4	3.6	2	Hants & Sacred Yew, historic

Appendix 5

Showing how the ages for graph B were calculated from the rate and girth figures from graph A

Mean Girths	Difference between mean girths, mm	Mean of corresponding rates, mm pa	Girth/Rate = age Increase in years	Total age: Running total
4.1 – 5.89	1790	4.2	426	1180
5.89 – 7.15	1260	5.1	247	1427
7.15 – 8.06	910	3.3	276	1703
8.06 – 8.98	920	1.6	575	2278
8.98 – 10.37	1390	2.3	604	2882

References

1 Anon (23/11/98) *Barking up the wrong historical tree*, Birmingham Post
2 Chetan, A. and Brueton, D. (1994) *The Sacred Yew*
3 Hindson, T. (1997) Unpublished Check on yew girth variability between base and 3 feet at Alice Holt.
4 Mitchell, A.F. (1972) *Conifers in the British Isles*
5 White, J. (1994) Forestry Authority Research Information Note 250
6 Hageneder, F. (2007) *Yew a History*, Sutton.