DENDROCHRONOLOGY OF OAK IN NORTH WALES

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ABSTRACT

The tree-ring characteristics of material used in a 35-tree, 265-year modern oak chronology from a site in North Wales are discussed. Three methods of standardisation are compared and temporal variation in chronology statistics examined. A response function using rainfall data from a station very close to the tree site related 45% of the chronology variance to climate and 73% to climate plus prior growth.

Les caractéristiques du matérial étudié dans une chronologie de 265 ans basée sur 35 arbres actuels provenant des North Wales, sont discutées. Trois méthodes de standardisation sont comparées et la variation temporelle des statistiques chronologiques examinées. Une fonction réponse utilisant les précipitations relevées dans une station météorologique très proche des arbres, attribue au climat 45% de la variance présentée par la chronologie; 73% de cette variance sont liés au climat et à la croissance de l'année précédente.

Die dendrochronologischen Merkmale einer 35 Bäume umfassenden, 265 jährigen Eichenchronologie eines Standortes in Nord-Wales werden diskutiert. Es werden drei Verfahren der Standardisierung miteinander verglichen und die zeitasbhängige Variation der statistischen Parameter der Chronologie geprüft. Das anhand der Niederschlagswerte einer benachbarten Wetterstation berechnete Reaktionsmuster (response function) der Bäume wird zu 45% durch das Klima und zu 73% durch Klima und Vorjahreszuwachs hervorgerufen.

INTRODUCTION

In order to establish a sound basis for dendroclimatic research in a new region it is necessary to understand the tree-ring characteristics of the locally available material. In much of the hilly western flank of Great Britain the characteristic (if now fragmented) vegetation is the western oakwood. These forests are found in a region of equable climate. Rainfall is well distributed through the year, atmospheric humidity is high and extremes of temperature are rare. The dominant tree species is usually *Quercus petraea* (Mattuschka) Liebl., sessile oak, associated with *Ilex aquifolium* L., *Sorbus aucuparia* L. and *Betula* species. The western oakwoods have a characteristic epiphyte flora associated with their high atmospheric humidity and clean air. A number of such woodlands are to be found in North Wales, usually on steep slopes, on nutrient-deficient soils on the ancient acid rocks of the region. A 265-year modern chronology based on 35 sessile oaks from Maentwrog (Figure 1) in the county of Gwynedd (Lat. 52° 56' N; Long. 3° 55' W) has been set up (Leggett and others 1978). The trees grew at altitudes between 50 and 100 m O.D. on a steep south-facing slope. The site is on the north side of the Ffestiniog valley, well-known for a steep rainfall gradient of from 1000 mm/annum at the mouth of the estuary to around 2000 mm/annum 12-15 km up the valley. In this paper the tree-ring characteristics of the material from this site are discussed.

STANDARDISATION OF RING-WIDTH SERIES

Many factors influence the width of an annual ring as measured on a radius at a given height up a tree. Certain intrinsic factors such as cambial age and distance from canopy may produce effects continuous along the axis of the tree whilst others, such as branching and branch abscission, may produce more abrupt changes. These will also vary around the tree. Factors external to the tree but intrinsic to the forest stand interact with these. For example, the nature of branching, rate of growth of individual branches, and timing of their abscission will all be affected by the state of the forest canopy as a whole. This in turn will be influenced by the complex processes of tree population dynamics. Even in a uniform physical environment and with a genetically homogeneous population of trees great between-tree variations in growth rate and growth curve are to be expected, particularly in mid- and late- succession. These will be particularly apparent in annual radial increment in the lower bole of those tree species with a mainly horizontal branching system, such as sessile oak. Such between-tree variations in growth rate and growth curve are accentuated by the microsite diversity and taxonomic complexity found in real life.

Thus in sites such as Maentwrog, distant from extremes of cold and aridity, where between-tree interactions are an important influence on annual radial increment, growth curves of complex and variable form are to be expected. In dendroclimatic research the aim is to extract a climatic signal from the tree-ring series by separating out that variability in ring widths common to all the trees at a site and not deriving from conditions special to individual trees. This is done in two steps: (i) by removing a 'growth trend' of whatever form from the series of ring-width values for each measured radius; this is usually called standardisation, and, (ii) by averaging the indexed series from all radii at a site to produce a site chronology.

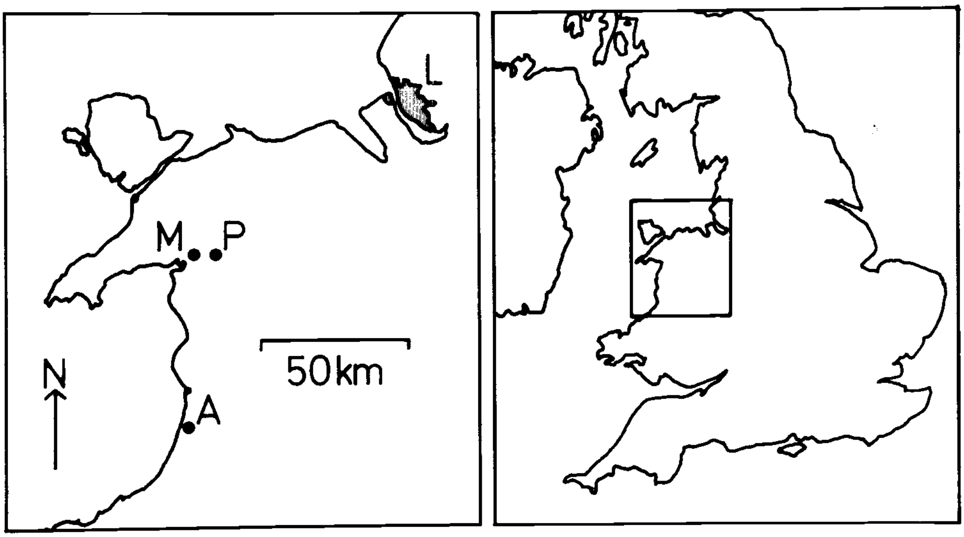

Figure 1. The tree-ring site and meteorological stations in North Wales; *M*, Maentwrog; *P*, Pont (Bont) Newydd; *A*, Aberystwyth; and *L*, Liverpool.

Three methods of removing 'growth trend' have been compared using data from Maentwrog. Chronology A was prepared by fitting either a negative exponential curve or a straight line through the ring-width series and producing an index series as the ratio of the actual and calculated values. To produce Chronology B, the polynomial curve-fit option of computer programme INDXA was used. By this means a line of more or less close fit to the actual data can be produced. The calculated curves were inspected for any consistent parallel movement. In the absence of this, the series were used in the construction of the site chronology. Chronology C was prepared by the method described by Parker and Henoch (1971). The ring-width series for each measured radius was passed through a digital filter blocking variance with wavelengths greater than eight years (LaMarche and Fritts 1972). The filtered series were then averaged to produce a site chronology.

The use of either a negative exponential curve or straight line (Chronology A) is common where stressed conifers are being examined. The polynomial curve-fit option (Chronology B) will add coefficients so long as each reduces at least a preset fraction of series variance. This may be a horizontal straight line, a sloping line or a curve whose complexity increases as the number of terms in the polynomial. This is an extremely flexible approach which allows for a situation in which each radius measured may have a different growth trend. It is possible to ensure that a minimum of low-frequency information is removed. Passing the measurements of each radius through a high-pass digital filter (Chronology C) ensures the removal of low-frequency information. It will result in a reduction of serial correlation, but cannot be used in as flexible a manner as the polynomial curve-fit.

MAENTWROG CHRONOLOGIES

Table 1 shows general statistics for the three Maentwrog chronologies. Chronology C has the lowest first-order serial correlation, and the lowest mean sensitivity. Of the two unfiltered chronologies, Chronology B has the lower first-order serial correlation. Chronologies A and B have similar mean sensitivity. Figure 2, left, shows the serial correlations for the three chronologies (ANOVA series). Chronologies A and B show a correlation structure similar to that to be expected for a first-order correlation model. Chronology C has a different structure with marked negative correlations at two and three lags. A chronology with such a complex serial correlation structure as Chronology C should be treated with caution.

All other analyses presented in this paper are based on Chronology B (Figure 3). This is because the methods used to produce it can be related to what is, a priori, a realistic ecological model of annual radial increment. As a result the discarding of low-frequency climatic information should be kept to a minimum. Although Chronology B has a high serial correlation it appears to conform to a relatively simple model (Figure 2, left). The polynomial curve-fit option has also been used by Pilcher (1976) in the preparation of an oak chronology from Rostrevor, Northern Ireland. Chronology statistics for three sites are compared in Table 2. Mean ring width, serial correlation, mean sensitivity and standard deviation are similar, particularly between Maentwrog and Rostrevor. Percent variance, years x trees, that is between-tree variance, is higher at Maentwrog than at the other two sites. Percent variance, years, that is variance retained by the common chronology, is smaller at Maentwrog. In general, the statistical properties of the Maentwrog chronology are similar to those of the only two European oak chronologies similarly analysed and reported in the literature.

Table 1. General statistics for Maentwrog oaks.

	Chronology Series		
Number of trees	—	35	
Number of radii	—	70	
Mean ring width	—	1.59mm	
Method of standardisation	A Exponential or linear	B Polynomial curve-fit	C High-pass filter
Years analysed	265	265	251
Interval	1710-1974	1710-1974	1717-1967
Mean index	0.99	1.00	1.00
Serial correlation	0.62	0.58	0.08
Mean sensitivity	0.18	0.18	0.09
Standard deviation	0.25	0.23	0.09
	ANOVA Series		
Number of trees	—	14	
Number of radii	—	28	
Years analysed	—	78	
Interval	—	1875-1952	
Method of standardisation	A Exponential or linear	B Polynomial curve-fit	C High-pass filter
Mean index	0.79	0.99	1.00
Serial correlation	0.54	0.53	-0.035
Mean sensitivity	0.25	0.25	0.10
Standard deviation	0.33	0.33	0.09
Analysis of variance:			
Error Years	0.08	0.08	0.02
% variance, Years	27	26	30
% variance, Years x Trees	41	42	41
% variance, Years x Radii x Trees	32	32	29
	100	100	100

TEMPORAL VARIATION IN THE MAENTWROG CHRONOLOGY

Mean sensitivity did not change markedly during the ANOVA period (Figure 2, right) whereas mean index and correlation among trees did, usually in opposition to one another. This suggests that under limiting conditions, when rings are narrow, the general environmental effect overrides between-tree variability to produce higher correlations.

It has been suggested that the period 1875-1900 was one of greater variability than 1905-1930, the latter period having a high frequency of days with westerly winds (Lamb 1966). Table 3 shows percent variance held by the common chronology (percent variance, years) to have been slightly greater in 1875-1900 than in 1905-1930 at the expense of between-tree variance (percent variance, years x trees). This suggests that in such a period of greater climatic variability, limiting conditions more commonly occur, bringing ring-width variation between trees into unison and so increasing variance held by the common chronology.

Table 2. Comparison of general statistics for oak at three sites.

	Maentwrog	Rostrevor[1]	Schleswig[2]
Chronology Series			
Number of trees	35	18	15
Number of radii	70	36	30
Years analysed	265	226	158
Interval	1710-1974	1750-1975	1812-1969
Mean ring width	1.59 mm	1.00 mm	1.94 mm
Serial correlation	0.58	0.56	0.36
Mean sensitivity	0.18	0.22	0.19
Standard deviation	0.23	0.30	0.21
ANOVA Series	Maentwrog	Rostrevor[1]	Schleswig[2]
Number of trees	14	10	15
Number of radii	28	20	30
Years analysed	78	100	81
Interval	1875-1952	1780-1879	1880-1960
Error, Years	0.08	0.10	0.06
% variance, Years	26	42	38
% variance, Years x Trees	42	28	33
% variance, Years x Radii x Trees	32	30	29
	100	100	100

Note 1: from Pilcher 1976
Note 2: from Eckstein and Schmidt 1974

CLIMATIC RESPONSE OF THE MAENTWROG CHRONOLOGY

Hughes and others (1978) have calculated response functions for three oak chronologies from the British Isles, including Maentwrog. They used the methods described by Fritts and others (1971) and Fritts (1976). A smaller percentage of chonology variance was attributable to climate in the case of Maentwrog than in either of the other chronologies. It was suggested that this might be related to the large distance between the Maentwrog site and the Aberystwyth meteorological station. Whilst temperature variation is likely to be spatially coherent, rainfall is known to be particularly variable in a segmented mountainous area such as North Wales. A new response function has been calculated for the Maentwrog chronology using Aberystwyth temperature data and rainfall data from Pont Newydd, a much closer station in the same valley as the tree-ring site (Figure 1). Unfortunately these data are available for a shorter period (1921-1966) than those originally used (1907-1967). Nevertheless, the response function based on the Pont Newydd rainfall data relates 45% of chronology variance to climate and 28% to prior growth as compared to 34% and 31% respectively when Aberystwyth rainfall data are used. The response functions are similar for temperature (Figure 4), but four precipitation elements are significant when Pont Newydd precipitation is used compared to two for Aberystwyth precipitation.

Table 3. Comparison of statistics for contrasting 25 year periods.

	1875-1900	1905-1930	1875-1952*
Mean index	0.94	1.06	0.99
Serial correlation	0.46	0.40	0.53
Mean sensitivity	0.28	0.25	0.25
Standard deviation	0.32	0.33	0.33
Analysis of variance:			
Error, Years	0.07	0.08	0.08
% variance, Years	33	27	26
% variance, Years x Trees	32	46	42
% variance, Years x Cores x Trees	35	27	32

*see Table 1 - ANOVA series, method B.

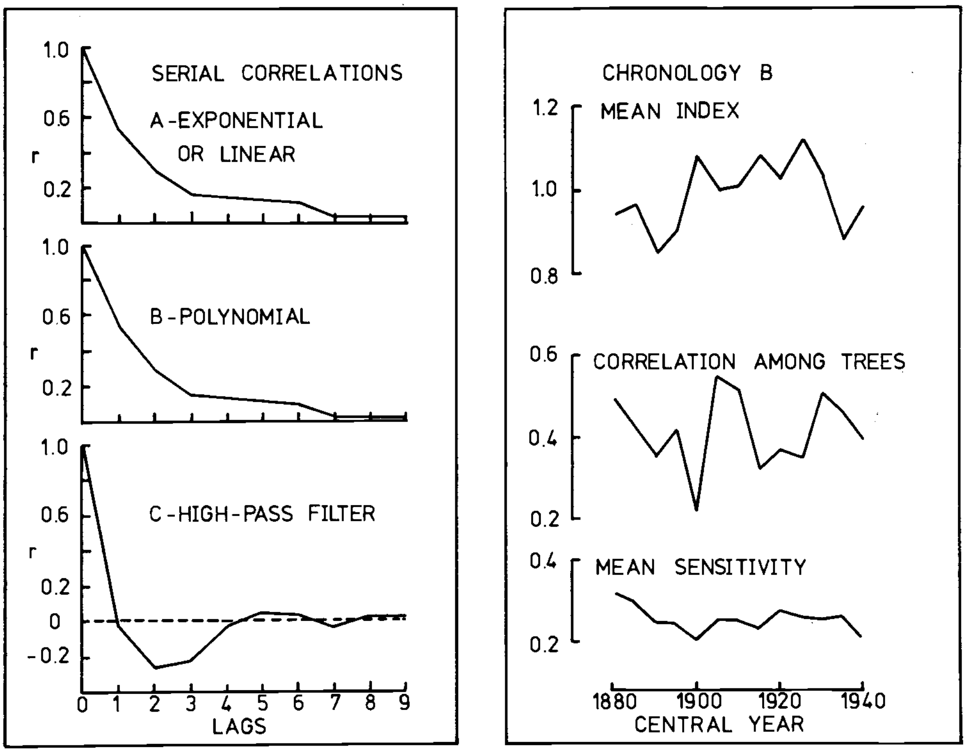

Figure 2. *Left,* Serial correlations (*r*) for the three Maentwrog chronologies up to nine lags; *Right,* Temporal change in statistics for the ANOVA period (14 trees, 28 radii) for Maentwrog chronology B. Each point is a 10-year mean, calculated at 5-year steps.

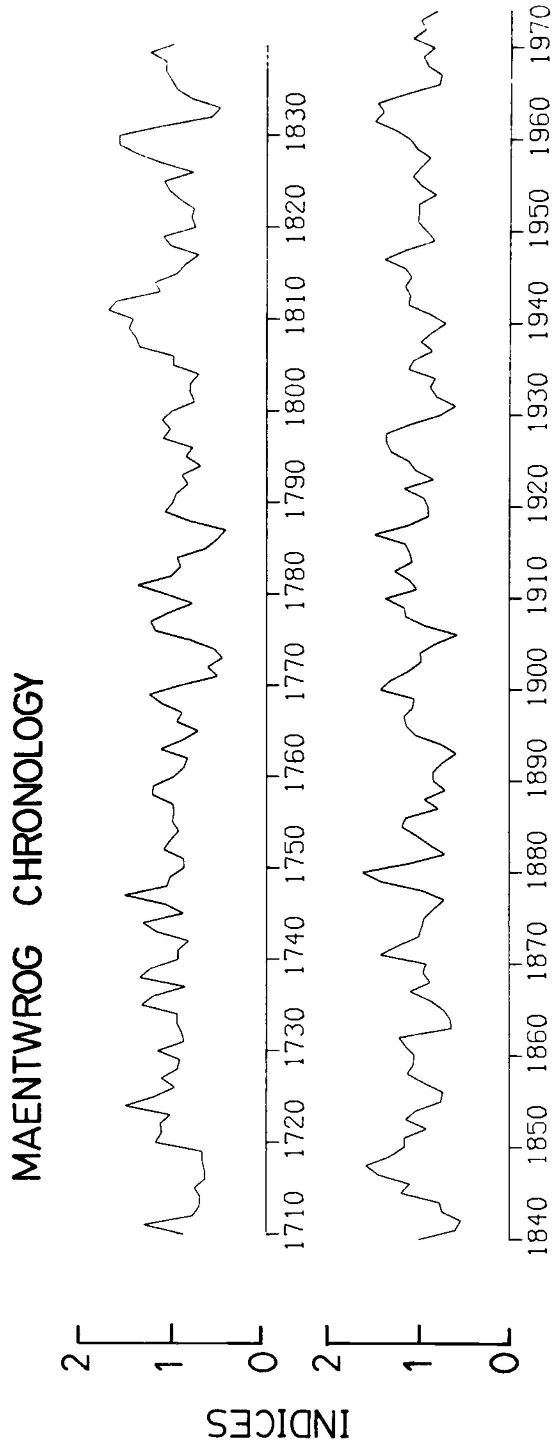

Figure 3. Maentwrog chronology B, standardised by the polynomial curve-fit option.

December temperature, June temperature, rainfall in June, July and December of the previous year all have significantly negative response function elements. October, April and May temperatures and April rainfall have significantly positive response function elements. Eckstein and Schmidt (1974) also found a positive October temperature element in Schleswig-Holstein and Holmsgaard (1955) using different methods found a similar relationship in Danish oak. All three response functions for British Isles oaks reported by Hughes and others (1978) had a significantly positive October temperature element. At Maentwrog there is a significantly negative temperature element in December, at Rostrevor (Hughes and others 1978) in December and January and at Schleswig in November (Eckstein and Schmidt 1974). It may be that some relatively consistent interactions between oak ring width and conditions the previous autumn and winter exist. Response functions for considerably more sites will be needed before this can be tested. Significantly positive temperature and rainfall elements in April are found at Maentwrog (this paper) and at Rostrevor (Hughes and others 1978), and there is a significantly positive temperature element in May at Raehills (Hughes and others 1978). These months correspond with the initiation of early wood formation and the opening of leaf buds.

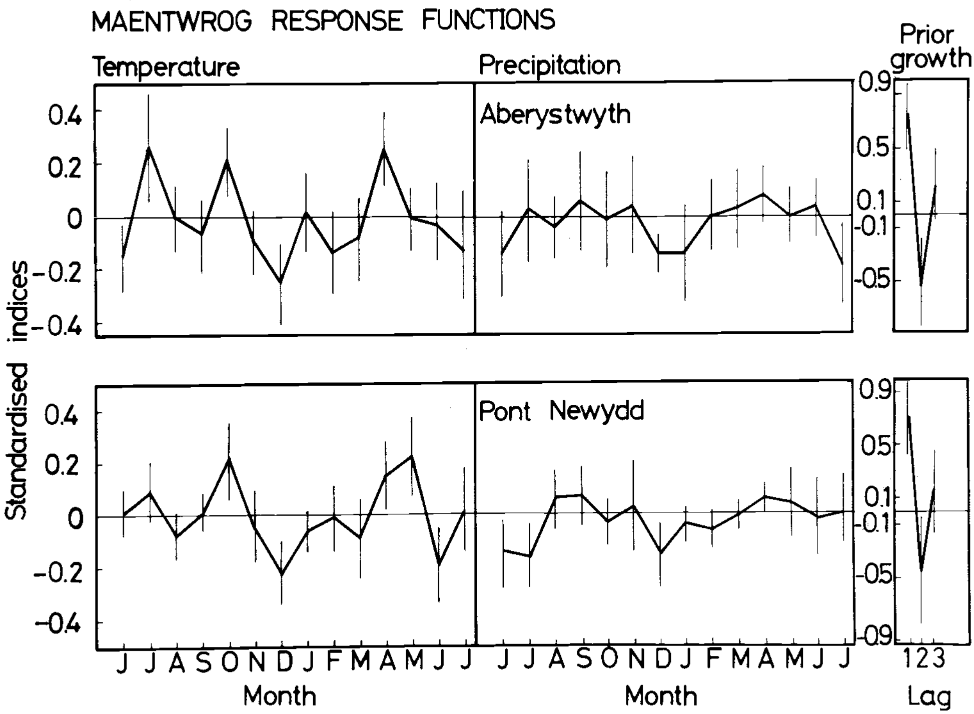

Figure 4. Maentwrog response functions. The upper response function was calculated using Aberystwyth temperature and precipitation (1907-1967). The lower response function was calculated using Aberystwyth temperature and Pont Newydd precipitation (1921-1966). The vertical lines through each response function element show 95% confidence limits. Where the lower limit is above the zero line, there is a significantly positive response function element. Where the upper limit is below the zero line, there is a significantly negative response function element. Response functions were calculated for a 14-month period starting in June of the year prior to growth.

DENDROCLIMATOLOGY IN THE WESTERN OAK WOODS

The work reported here has shown there to be a potential for dendroclimatic research on the wet western flank of Great Britain. This reinforces the findings of Pilcher (1976) and Hughes and others (1978). This was to be expected as crossdating has been established between the Maentwrog chronology and the Rostrevor chronology (Pilcher 1976) from Northern Ireland. It is intended that the Maentwrog chronology will form part of a multisite network to be used in the reconstruction of mesoscale climatic variation for the last 250 years. Ring-width data for two radii from each of the 35 trees used in the chronology are lodged in the International Tree-Ring Data Bank.

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