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Common beech *Fagus sylvatica* L; survival and longevity in changing times

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Veteran trees not only have an intrinsic interest in themselves; they also provide information about climatic conditions and masting over periods equal to many human generations. This paper endeavours to highlight existing records of veteran populations of *Fagus sylvatica* L. in Europe, especially in Sweden, and also provides fresh information regarding trees in Germany and the Carpathian Mountains of the Ukraine.

For reasons of space it is not possible to list all the very many papers dealing with the influence of climatic warming on forest trees, but it is clear from those quoted here that common beech is particularly influenced by it. In general the effect has been to move the areas favourable to the species northwards in the lowlands and upwards in mountainous regions. This is very much the case in Britain where the Forest Authority no longer approves of beech planting in southern and eastern England. The use of sweet chestnut *Castanea sativa* as its replacement in broad-leaved forests is likely to result in ecosystems markedly different from those which evolved under beech. Sweet chestnut is predicted to increase in growth and productivity in the east of England as beech retreats north and west.

The English Beech Mast Survey was initiated in 1980; its recorders have in consequence observed the storm damage to beech stands, particularly in the south, during that time. The remarkable response by beech to lava flows on the presently dormant volcano of Etna, Sicily, is both described and illustrated. In many cases lava that engulfed the trees had destroyed the main trunks, but left scorched bases from which the trees had coppiced successfully.

Keywords: basal area increment (BAI); common beech *Fagus sylvatica*; climax forest; dendrochronology; old-growth forests; *urwald*; virgin forest; veteran trees; climate change; masting; lowland and mountain forests; ecosystem conservation; volcanoes and lava flow

Introduction

The influence of man in the past ten thousand years on the forests of the entire world has been so profound that the areas of natural climax forests now existing are relatively limited. Fortunately, there are a considerable number of natural forest reserves in which these ecosystems continue to grow without the intervention of man, by logging or other means. In these the flora, fauna and vital processes have persisted unchanged for many centuries. The terminology employed in describing such forests varies but, as Alfonso, Gaiser, Rubic, and Reubel (2010) point out, the terms climax forest, old-growth forest, *urwald*, and virgin forest are often used as being almost equivalent classifications applying to these ancient ecosystems which are valuable both as carbon sinks and examples of truly natural forests. Virgin forest, however, literally means a forest entirely unaffected by man;

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on this strict definition Peters (1997) states that in all his extensive studies he never encountered a truly virgin beech forest.

Common beech *Fagus sylvatica* is an extremely widespread and valuable tree; the continued health of which is in many places threatened by climate change, a subject discussed by Thomas and Packham (2007). This paper describes the distribution of veteran beech trees and outlines what appears to be the main effects of climate change on existing beech forests; effects so serious that the areas in which it will in future be planted have been radically changed.

Masting, the production of abnormally large amounts of seed in certain years, is very marked in this species and the results of the first 28 years of the English Beech Masting Survey, which began in 1980, are described in Packham, Thomas, Lageard, and Hilton (2008). During this period there were a number of gales that caused severe damage to beech stands. Beech roots tend to be rather shallow, particularly over chalk, and in England older trees are consequently liable to uprooting in severe gales; a summary is given of the main examples of this during the period of the survey. The situation in Sweden is usually rather different, due to trunk weakening caused by large parasitic fungi, and in many cases gales cause the trunks to snap well above the ground leaving standing dead hulks (Packham & Hytteborn, 2012).

Beech has been repeatedly affected by climatic changes during the Quaternary and the main implications resulting from the studies of Magri et al. (2006) in revising our views of the phylogeography of *Fagus sylvatica* in Europe are outlined. The paper ends with a discussion of the remarkable response of the tree to lava flows on Mount Etna, Sicily.

Records of veteran trees of common beech

The Woodland Trust has done a great deal to discover and protect notable trees of all species. Verified records of 10,028 individual beech trees growing in the United Kingdom made by its Ancient Trees division up to May 2011 are as follows: 737 ancient, 6713 veteran, 2558 notable, 10 lost notable and six lost veteran. It holds detailed records of the positions of all these British beech. The Woodland Trust also holds records of ancient beech woodland sites within areas of continental Europe, and its workers have themselves visited such sites in France, Spain and Italy.

The definition of a veteran or ancient tree is as much influenced by cultural values as it is by objective scientific study. Consequently, English Nature described them as trees of biological and aesthetic interest, in the second or third stages of life with noticeable die-back characteristics including hollowing, cavities, wounds, decay fungi and large dead branches. More specific physiological features of ancient or veteran trees is that successive

Table 1. A comparison of one German and two Ukrainian forests in terms of tree height and mean dbh.

Study site	Mean dbh (cm)	Mean height (m)
140 year growth beech under selective forestry, Eberswalde, Germany, 52°48'N, 13°48'E	47.26 ± 8.81	28.75 ± 4.8
Old growth beech, Ukraine, Carpathian biosphere, Uholka-Shyrokyi Luh massif, 48°18'N, 23°41'E	47.17 ± 14.98	31.1 ± 5.11
Beech under sustainable forestry, Ukraine, Carpathian, Uholka-Shyrokyi Luh massif, 48°18'N, 23°41'E	24.7 ± 6.38	27.5 ± 5.93

annual rings of the main stem become narrower, while the crown of the tree tends to die back.

A more recent study of old beech forest in Germany and the Ukraine (Norris, Ibisch, & Hobson 2011) contrasts tree heights and diameters for old growth stands with areas of forest under commercial management (see Table 1). In the Ukrainian forests the managed and old growth stands both appear to be structurally diverse although the trees in the modified site are significantly smaller in diameter (t-test: $p = 0.014$) but not in height.

Epiphytic lichens and bryophytes on veteran beech

Countries with lower human population densities than Britain tend to have many more veteran trees and ancient woodlands, and those of Sweden are particularly interesting with regard to *Fagus sylvatica*. The studies of Fritz, Niklasson, and Churski (2009) at Biskopstorp in south-east Sweden, which demonstrated that tree age is a key factor for the conservation of epiphytic lichens and bryophytes, are impressive, as is their discussion of the relevant literature. They surveyed 37 plots bearing 571 trees, identifying 104 species of lichens and 52 species of bryophytes which are all listed together with an indication of their conservation value and growth form. Tree ages were determined using a Pressler increment borer as near to soil level as possible, and then adding the years it would have taken for the developing tree to reach that height.

The presence of many of the red-listed and indicator species, including the foliose lichen *Lobaria pulmonaria*, were strongly correlated with the tree age gradient. This very conspicuous lichen is illustrated in Packham and Hytteborn (2012). The crustose lichen *Lecanora glabrata*, the moss *Neckera pumila* and the liverwort *Metzgeria fruticulosa* are other examples of r-species associated with veteran beech trees.

In contrast Packham, Thomas, Atkinson, & Degen 2012 show only 71 species of lichen associated with *Fagus sylvatica* in the British Isles, while a survey of beech in southern England produced 45 moss and 11 liverwort species which were directly associated with this tree.

Influence of climatic warming on the growth of common beech

Changes in gas exchange and growth are key primary responses to the alterations in atmospheric CO_2 and climate change we are now experiencing. However, as Penuelas, Hunt, Ogaya, and Jump (2008) point out, the results of short-term experimental studies of plants in growth chambers, such as those of Morison (1993) and Picon, Guehl, and Aussenac (1996), may not provide a satisfactory guide to the behaviour of mature trees when subjected to change in their natural environments. The responses indicated by tree-ring studies at the southern edge of the distribution of *Fagus sylvatica* in Europe, in the Montseny Mountains some 50 km north-northwest of Barcelona, are of considerable interest and included mature trees in the higher, central and lower altitudinal forest limits. As the title of their paper indicates increasing water-use efficiency did not avoid growth decline induced by warming at lower altitudes.

Detailed investigations by Piovesan, Biondi, Di Filippo, Alessandrini, and Maugeris (2008) of drought-driven growth reduction in old *Fagus sylvatica* forests of the central Apennines, Italy, suggested that long-term drought has reduced productivity here as it has in other Mediterranean mountains. Productivity of dominant trees in the two beech stands investigated was measured by dendrochronological studies measuring tree-ring widths to calculate average stem basal increment (BAI). Both stands belonged to the old-growth stage but they differed in altitude, soil parent material, mean tree age and stand structure. The Monte Cimino site on volcanic parent material at 1000 m a.s.l., was less than 200 years old. The last timber logging in the area occurred in 1947–1949. The Valle Cervara site was on calcareous parent material at 1750 m a.s.l., and many of the trees growing in an uneven aged forest here were 300 years old. One was more than 500 years old, the oldest specimen of *Fagus sylvatica* known in the northern hemisphere. In both sites BAI and water availability during the growing season (May to September) increased from 1950 to 1970 but decreased afterwards. Beech forest productivity in central Europe, on the other hand, has actually increased on recent years (Dhote & Herve, 2000; Boisvenue & Running, 2006).

Wunder et al. (2008) studied the growth-mortality relationships of nine species of forest trees in unmanaged forest reserves of the Polish forest of Bialowieza and in Switzerland. *Fagus sylvatica*, a shade-tolerant species, showed only intermediate survival probabilities on the criteria employed. It was concluded that its lower stress tolerance when compared to *Taxus baccata* and *Tilia cordata* was the cause of its relatively low lifespan which they quote as up to 350 years. In fact Piovesan, Di Filippo, Alessandrini, Biondi, and Schirone (2005) found a common beech more than 500 years old at Valle Cervara, Italy. In contrast, the life span of yew can exceed a thousand years and that of small-leaved lime can be up to a thousand years.

Beech survival during the Quaternary

The studies of Magri and her co-workers (2006) were extremely important in revising our views of the phylogeography of *Fagus sylvatica* in Europe, establishing a different and more complex series of events than the former commonly held view that the southern Iberian, Italian and Balkan peninsulas were the main source areas for trees in central and northern Europe after the last ice age. Palaeobotanical and genetic data are used to ascertain the genetic consequences of long-term survival in refuge areas and post-glacial spread. Data sets include fossil-pollen sites, plant macro-fossil sites, and in many studies of modern beech, chloroplast and nuclear markers. It was concluded that beech survived the last glacial period in multiple refuge areas, that the central European refugia were separated from those of the Mediterranean, and that the latter did not contribute to the final colonisation of central and northern Europe. While some beech populations have expanded considerably in the post-glacial period, others have made only a limited expansion. Mountain chains facilitated the diffusion of beech rather than acting as geographical barriers. Finally it was concluded that the modern genetic diversity of European beech populations has been shaped over a number of glacial-interglacial cycles.

The role of masting in enabling beech to survive heavy losses

Masting, the periodic synchronous production of large seed crops, is well developed in beech whose nuts are technically fruits. The production of so many seeds means that a great number will survive, the animals that consume them, including the larvae of *Cydia fagiglandana* Z. which attack the nuts even before they fall, having been satiated (Packham & Hilton, 2002). Fungally infected and dying trees of various species sometimes produce enormous amounts of seed at the very end of their lives. This was true in the case of Tree D in the Patcham Place site, Brighton, which had to be felled on 4 September 2002 as its trunk had become hollow due to fungal infection (Packham, 2003). In the same autumn there was an enormous crop of damsons on a tree in the first author's garden in Bridgnorth, and its roots were so rotten that it could be easily pulled over. On a broader canvas, Hilton and Packham (2003) give an account of variation in the masting of common beech in northern Europe over two centuries. The English Beech Masting Survey still continues year on year; the most up-to-date published account is that of Packham, Thomas, Lageard, and Hilton (2008) which deals with the period1980–2007.

Tree gap formation and the gap dynamics theory

Tree gaps in forests occur when trees die, are either blown over and uprooted, or snap, usually after being weakened by insect or fungal attack of which an interesting case in beech was reported by Packham (2003). The Giant Polypore *Meripilus giganteus* is a virulent parasite of beech and often continues to grow as a saprophyte after it has killed the tree; it is pictured in Packham, Thomas, Lageard, and Hilton (2008). Scientific interest in forest gaps and their formation has elicited reports for well over a century but the earliest papers of real significance in the context of this paper are those of Watt (1925, 1947) dealing primarily with beech, and Sernander (1936) who studied the ancient Swedish forests of Fiby urskog and Granskar following the great storms of 1931 and 1932. As a result of his studies of these two boreal forests, in which the majority of the trees were of common spruce *Picea abies*, Sernander produced his gap dynamics theory of forest regeneration in which the importance of dwarf trees, whose existence had been noted by Cnattingius (1888) many years before, is a prominent feature. This theory that is in many respects applicable to forests of other species has recently been reviewed by Hytteborn and Verwijst (2011).

Shade-tolerant dwarf spruce commonly occur growing very slowly beneath dense shade. When the gales create forest gaps, such previously shaded dwarf trees receive abundant light and grow rapidly. This release is shown clearly by the much wider annual rings which develop in the years after the gale. Sernander found release dates related to a number of gales, including the great gale of 1795.

Sernander's gap dynamics theory applies also to beech; he concluded that although spruce was the conifer most sensitive to gales, before leaf fall deciduous trees may be even more at risk. Our records showing the vulnerability of *Fagus sylvatica* to gale felling in Great Britain confirm this view. Packham and Hilton (2002) provide an illustration

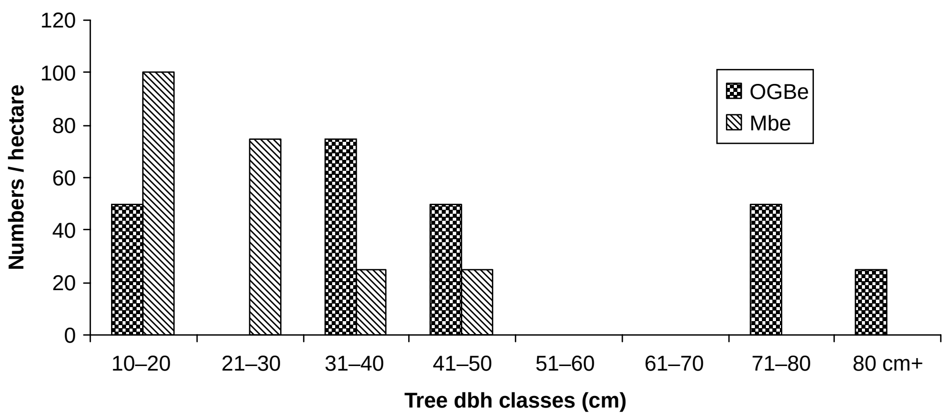

Figure 1. Stand structure in two contrasting beech forests, old growth (OGBe) and managed (MBe), Carpathians, Ukraine. As is Figure 2 all trees measured were beech.

showing how the storm of 16 October 1987 utterly devastated the hanger beechwood adjacent to the playing field by Patcham Place, Brighton, uprooting many trees.

Old beech woods that have been left to themselves for long periods come to consist of trees of every age as a result of repeated gap formation, a process described by Packham and Hytteborn (2012) who consider Swedish beech forests and how the storm gap theory applies to them.

Influence of management on cohort structure in Carpathian beech forests

Even sensitive management disrupts the cohort structure of old growth forests in this region. Larger trees are usually absent, having been extracted for timber, and the number of tree hulks is low. In the Ukraine, a shift towards younger and more uniform stands is evident in managed areas of beech forest (Figure 1).

In heavily shaded areas beneath dense beech the ground is bare. As a little more light enters, wood-sorrel *Oxalis acetosella* provides a field layer, while bramble takes over as the amount of light increases still more. This sequence is repeated many times in these Ukrainian forests. Thus the process of cyclic change occurs here in the same way that Watt (1925, 1947) described in southern England.

The managed beech forests in the Ukraine appear to mimic the patterns of canopy gap succession but with some noticeable differences. Many field layer plant assemblages in the modified stands include species that tolerate disturbance, especially *Rubus fruticosus, Rubus idaeus* and *Galium aparine*. Also where beech had been thinned the resultant loss of canopy shade allowed less shade-tolerant trees, in this case sycamore *Acer pseudoplatanus*, to become more prevalent (Figure 2). Human-induced disturbance in old growth beech has not only changed forest structure by removing tree hulks but has also caused shifts in vegetation function which are best considered in terms of the CSR theory (Grime, 1974; Grime, Hodgson, & Hunt, 2007). This postulates three primary ecological strategies, those of the competitors (which include herbs, shrubs and trees), stress-tolerators, and ruderals (Table 2). Ruderals are short-lived herbs or bryophytes that tend to

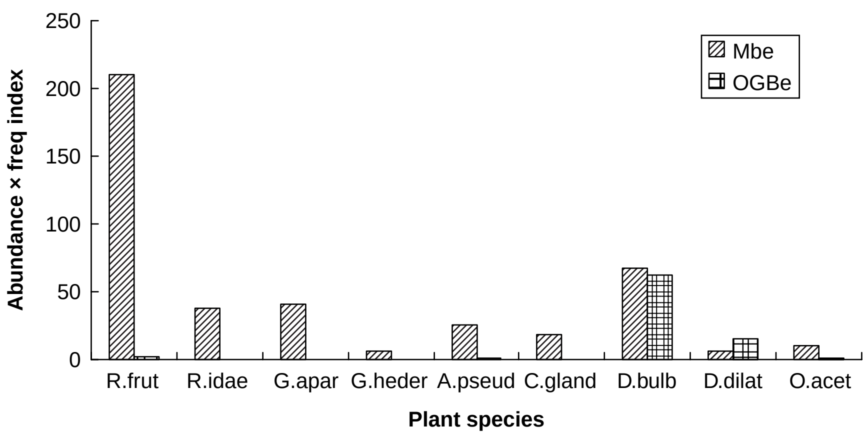

Figure 2. Plant species presence in two contrasting stands of beech, old growth (OGBe) and managed beech (MBe), Carpathians, Ukraine. *R.frut – Rubus fruticosus; R.idae – Rubus idaeus; G.apar – Galium aparine; G.heder – Glechoma hederacea; A.pseud – Acer pseudoplantus; C.gland – Cardamine glandulifera; C.bulb – Cardamine bulbifera; D.dilat – Dryopteris dilatata; O.acet – Oxalis acetosella.*

Table 2. Measures of vegetation function based on Grime's C-S-R model (1974) C – competitor; S – stress-tolerant; R - ruderal.

Forest sites	C	S	R	C x S / R
Old growth beech, Ukraine, Carpathian biosphere, Uholka-Shyrokyi Luh massif, 48°18'N, 23°41'E	1.78	4.22	1.3	5.78
Beech under sustainable forestry, Ukraine, Carpathians, Uholka-Shyrokyi Luh massif, 48°18'N, 23°41'E	2.45	2.79	2.15	3.18

grow under conditions of frequent and severe disturbance. The CSR model describes attributes of plant community processes which are crucial for ecosystem function and can allow for the comparison of functional complexity between forest stands. Coralroot bittercress *Cardamine bulbifera*, which has small bulbils at the bases of most upper leaves, is a typical woodland species often found beneath beech. Its distribution extends from southern England to S.E. Russia and the Caucasus Mountains, unlike that of *Cardamine glandulifera* which is found in Eastern Europe. The values given for C, S and R were derived for each stand using MAVIS software (Centre for Ecology & Hydrology, 2009). As C and S species are characteristic of field layers under heavy shade it follows that high values in the last column (C x S/R) of Table 2 are indicative of just that.

Natural gap formation in mature or old growth beech forests signals the dieback or fall of trees, in some cases very large veteran trees. Studies of Ukrainian mountain beech forests, and of German beech forests, suggest that there is considerable variability in the size and quantity of dead wood generated in old stands which must reflect on the unpredictability of the random events leading to death (see Figure 3). The high proportion of small diameter logs and branch wood is likely to be the result of self-thinning because of the high mortality rate amongst young trees under a mature forest canopy.

Survival after damage by lava flows

In May 2010 Dr. D.J.L. Harding was climbing the Etna volcano, Sicily, which was dormant at the time, and where the altitudinal limit of *Fagus sylvatica*, here at its

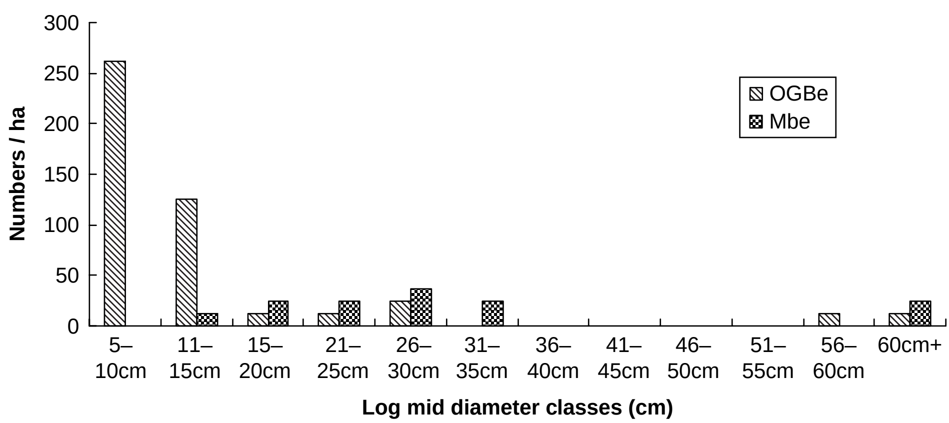

Figure 3. Size class distribution of logs and fallen trees in contrasting beech forest, old growth (OGBe) and managed (MBe), Carpathians, Ukraine. In the managed forest a high proportion of the downed wood was made up of felled and abandoned stems.

Figure 4. Coppiced beech; a number of vigorous new shoots have arisen from each engulfed original tree whose bases remained alive when the original trunks were destroyed at some time in the twentieth century.

Figure 5. The dark area on the left was engulfed by the last lava flow, that of 27 October 2002. The white outlines adjacent to it are the remains of beech that were killed by the extremely high temperatures and unusual atmospheres generated by the eruption.

southernmost point in Europe, is 1950 m. Lava flows on various occasions had engulfed many beech trees, sometimes destroying the main trunks but leaving scorched bases from which the trees had coppiced successfully. He saw illustrations of the strong eruption of 27 October 2002 which destroyed many trees and swept away dwellings and a hotel built high on the slopes of Mount Etna. In the very high temperatures of eruptions previous to 2002 some of the trees were killed but not burnt. Two of the series of photographs he took to illustrate the situation are shown in Figures 4 and 5.

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Peter Hobson is Principal Lecturer at Writtle College and Co-Director for the Centre for Economics and Ecosystem Management. For many years he has taught conservation management to postgraduate students in the UK and more recently in Germany, and directed research in forest biodiversity and adaptive conservation management.

Catherine Norris is a PhD student at Writtle College, researching thermodynamic principles in relation to ecosystem resilience and global change. Part of the research has focused on beech forests in Germany and the Ukrainian Carpathians.

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