Uneven-aged Silviculture in Britain

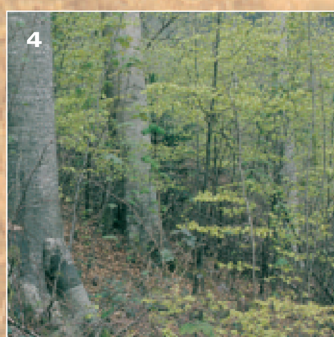
by Gary Kerr

1 Douglas fir at Longleat Estate, Wiltshire

2 Natural regeneration of oak

3 A female flower and ripe male flowers on Douglas fir

4 Beech at Ebworth Estate, Gloucestershire



Introduction

Uneven-aged silviculture has had a limited role in British forestry but this is changing as a result of demands for greater diversity, avoidance of clearfelling and increased use of natural regeneration (Forestry Commission, 1998; McIntosh, 2000; UKWAS, 2000). The use of uneven-aged silviculture requires silvicultural knowledge and observation of stand dynamic processes, but most forest managers lack the experience and confidence to put it into practice and there is limited guidance to assist them (Paterson, 1958; Reade, 1990). This article describes the results of studies on three different uneven-aged stands, gives some guidance on how uneven-aged silviculture could be used in Britain, and suggests areas for further research.

For the purposes of this account an uneven-aged woodland is one in which there are three or more age classes. Uneven-aged silviculture is therefore a sequence of stand interventions designed to perpetuate these three or more age classes; generally this will produce conditions of continuous cover.

Methods: sample stands

Three stands were selected with an uneven-aged structure. The first, at Plashetts Wood in East Sussex, has an even-aged oak canopy and dense mixed-age understorey of sycamore which developed due to the protection from browsing offered by pheasant rearing pens (Plate 1a and b). The second is a mixed stand of grand fir, Douglas fir, sycamore and ash on a sandy soil overlying chalk at Snake Wood, Thetford Forest (Plate 2a and b). This was an even-aged conifer stand until the 1970s, when windblow of some trees in the canopy and prolific natural regeneration initiated the process of stand differentiation. The third stand is Sitka spruce and Norway spruce at Knightwood Inclosure in the New Forest. The history of the stand is unknown but the structure is diverse with a range of diameters at breast height (dbh) between 7 and 91 cm (Plate 3a and b).

(a)

(b)

PLATE 1

(a) and (b) Even-aged oak canopy with dense understorey of sycamore at Plashetts Wood, East Sussex. (Forest Research Photo Library a: 42446, b: 42450)

(a)

(b)

PLATE 2

(a) and (b) Mixed stand of grand fir, Douglas fir, sycamore and ash at Snake Wood, Thetford Forest. (Forest Research Photo Library a: 42458, b: 42461)

(a)

(b)

PLATE 3

(a) and (b) Diverse structure of a stand of Sitka spruce and Norway spruce at Knightwood Inclosure in the New Forest. (Forest Research Photo Library a: 42436, b: 42441)

Stands were assessed using a variety of methods to ensure that representative species and diameter information were obtained which could be expressed on an area basis. At Knightwood three height classes of trees were identified and the total height of a sample of large diameter trees in each height class were measured. The mean height for each of the three classes was used as a top height from which to estimate form height using Table 12 in Edwards (1983). Form height is important in uneven-aged silviculture because it allows volume to be estimated directly from diameter data (volume = basal area x form height).

Methods of uneven-aged management

Reverse-J diameter distribution

A reverse-J diameter distribution describes a pattern which has been observed in some uneven-aged woodlands when the frequency of tree size has been investigated (De Liocourt, 1898). A typical reverse-J diameter distribution is shown as the 'ideal structure' in Figure 1; additional information is given in Box 1. Generally the number of trees in successive diameter classes reduces by a constant, commonly referred to as *q*, which is the ratio between the number of trees in one diameter class to the number in the next larger class. The actual structure of a woodland is determined and then compared with an appropriate 'ideal' reverse-J diameter distribution. The difference between actual and ideal is then used to decide how many trees, and of which size, should be removed.

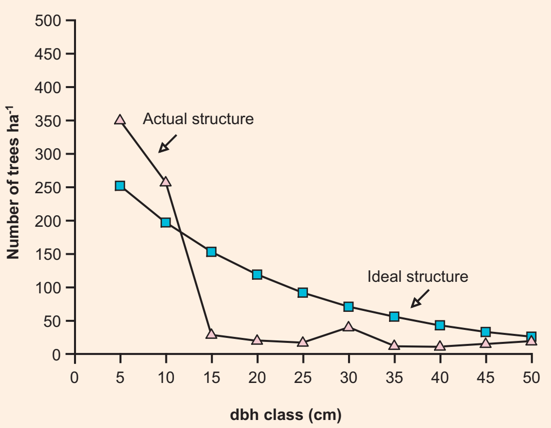


FIGURE 1

Results from comparison of the Snake Wood stand with an ideal reverse-J diameter distribution.

Box 1 Reverse-J diameter distribution

The reverse-J diameter distribution is a negative exponential function whose form can be described by the equation:

$$Y = ke^{-ax} \quad [1]$$

where Y = number of trees per unit area of a dbh class
x = mid-point of the dbh class
k and a are constants.

The constants k and a will vary with species and site. The constant k describes the stocking of saplings beyond browse height and a defines the relative frequencies of successive diameter classes. The constant a is related to q by the equation:

$$q = e^{aw} \quad [2]$$

where q = the ratio between the number of trees in one size class to the number of trees in the next larger class
w = the width of the dbh classes
a = constant (as above).

The ideal diameter distribution used in the example of Snake Wood had a = 0.05 and k = 396.3. Substituting these values in equation [1] generates the ideal diameter distribution in Figure 1 (hint: for the 5–9.9 cm class x = 7.5). The values of a and k relate to the ecological characteristics of the tree species or woodland type. For example, birch would be expected to have large values of a and k because it is a prolific seed producer and intolerant of shade, whereas beech may have a lower value of a compared with birch because it is tolerant of shade (Philip, 1994). However, in practice, the value of these constants is difficult to determine. The spreadsheet by Clarke (1995) is helpful in this respect because it allows ideal diameter distributions, and hence the values of a and k, to be determined from input of basal area, dbh of the largest tree and a value of q.

Clarke (1995) devised a spreadsheet which generates appropriate 'ideal' reverse-J diameter distributions. The spreadsheet requires the forest manager to input: (1) basal area, which for spruces and Douglas fir should be 25–35 m^2 ha^{-1} (Mason and Kerr, 2001); (2) diameter of the largest tree; this is usually set by the forest manager from a knowledge of timber markets; (3) the constant *q*, as described above. Using a modified version of this spreadsheet (Kerr, 2001) an 'ideal' diameter distribution was defined for Snake Wood using 32 m^2 ha^{-1}, maximum diameter of 50 cm and a *q* value of 1.3.

There has been little work defining reverse-J diameter distributions for woodlands in Britain and guides such as Yorke (1998) rely on data from central Europe. However, recent work (Kerr, in press) has determined a suite of reverse-J diameter distributions for coppice-with-standards woodlands in East Sussex. One of these diameter distributions has been used to examine how the stand at Plashetts Wood could be managed using uneven-aged silviculture.

Equilibrium growing stock

The question of defining equilibrium growing stock for uneven-aged woodlands has been well researched in Switzerland (Schütz, 1997). A stand which is in equilibrium is in a theoretical state where sustainable timber increment is generated from a size-class frequency distribution which remains broadly constant and where there is sufficient recruitment of young trees. At the stand level this equilibrium or 'target' structure is formulated for a given species composition and site in terms of the growing stock in m^3 ha^{-1} and the distribution of volume across broad dbh size categories. An equilibrium structure which has stood the test of time for European silver fir–Norway spruce–beech forests in Switzerland has a growing stock between 250 and 400 m^3 ha^{-1}, depending on site fertility, with 20% as trees 17.5–32.5 cm dbh, 30% as trees 32.5–52.5 cm dbh and 50% as trees >52.5 cm (Poore, 2001). To apply this to the stand of Sitka spruce at Knightwood it has been assumed that an equilibrium growing stock of 350 m^3 ha^{-1} is appropriate with a slight change to the size class categories of <30 cm dbh, between 30 and 50 cm dbh and ≥50 cm dbh.

Results

Snake Wood

Results from the comparison of the Snake Wood stand with the 'ideal' diameter distribution defined by Clarke's (1995) spreadsheet are shown in Figure 1. The actual stand basal area of 23.9 m^2 ha^{-1} (74% conifers, 26% broadleaves) is low for shade tolerant conifers (Mason and Kerr, 2001). In comparison to the ideal, the smaller trees (<15 cm dbh) are in surplus and all sizes above this are in deficit. This analysis suggests there is no immediate need for intervention but that within a 10-year period it may be necessary to reduce the number of smaller trees and possibly remove some large trees. Any decision to remove larger trees can only be taken after full consideration of the dynamics of the woodland. For example, if evidence suggested that tree seedlings are being heavily browsed and not developing into saplings, reducing the number of the most productive seed trees is unlikely to improve the chances of future natural regeneration. In this situation it would be best to be cautious about removing the seed trees until there was experience of developing at least one new cohort of regeneration. In the case of Snake Wood it would also be sensible to remove the grand fir first and keep the Douglas fir to increase the chances of regeneration of the more valuable species.

Plashetts Wood

Table 1 compares the structure of the stand at Plashetts Wood with a local reverse-J diameter distribution determined by Kerr (in press). This shows that there is a surplus of trees <15 cm dbh and >45 cm dbh. In Table 1, 15 cm diameter classes have been used because in the field it is difficult to differentiate between very small diameter

Table 1 Calculation of a marking guide for Plashetts Wood.

Diameter classes (cm)	Stand Trees ha^{-1}	Ideal structure Trees ha^{-1}	Difference Trees ha^{-1}	Trees to be removed (%)	Marking guide
<15	1326	671	655	49	1 in 2
15–29	125	230	<0	0	0
30–44	22	79	<0	0	0
45–59	48	27	21	44	3 in 7*
$\geq$60	21	12	9	43	3 in 7*
Totals	1542	1019	685		

* If natural regeneration of oak is required this should be delayed as these trees are the main seed source.

classes. Table 1 suggests a possible silvicultural treatment of removing half the trees < 15 cm dbh, these would be mainly sycamore, and up to 3 in 7 of the larger trees, mainly oak. However, as with Snake Wood, any decision to remove large trees can only be made after careful consideration of the effects on the woodland, particularly with oak which only produces large amounts of seed periodically. It is important to emphasise that the figures in Table 1 are a guide to management and not a prescription.

Knightwood

This woodland has a relatively high basal area (45.4 m^2 ha^{-1}) and volume (500 m^3 ha^{-1}), with a large proportion of the volume (64.3%) in trees $\geq$ 50 cm dbh (Table 2). As an example, an appropriate equilibrium growing stock has been assumed to be 350 m^3 ha^{-1} divided 20:30:50 between the size classes. Comparison of this equilibrium growing stock with the actual structure of the woodland shows that the medium and small trees are close to that required but trees in the largest size class are in surplus (see darker shaded columns in Table 2). Observation of stand data showed that the area contained 37 trees ha^{-1} which are >70 cm dbh and if these were removed the target volume for the area would be achieved. If this is done in November to April, to coincide with Sitka spruce seed dispersal, this would also increase potential for establishing a new cohort of young seedlings in appropriately sized gaps.

Table 2 Comparison of Knightwood with an assumed equilibrium growing stock.

Diameter class (cm)	Trees ha^{-1}	Basal area (m^2 ha^{-1})	Estimated form height	Volume (m^3 ha^{-1})	Equilibrium growing stock (m^3 ha^{-1})	Difference (m^3 ha^{-1})
7–29	518	12.3	6.80	83.6	70	13.6
30–49	62	8.4	11.25	94.5	105	n/a
50+	78	24.7	13.03	321.8	175	146.8
Total	658	45.4		500	350	

Discussion and conclusions

One of the main hurdles to the wider adoption of uneven-aged silviculture in Britain is to overcome the concern of forest managers that the systems are too fussy and require intensive assessments. In all three examples the main data requirement was for information on species and diameter and there is no reason why collection of this data, with appropriate sampling, should be prohibitively expensive. In each of the examples guidance was produced which must be interpreted within the stand, depending on species and the spatial and size distribution of trees. This does require silvicultural knowledge and observation of stand dynamic processes.

This article has demonstrated two methods for managing an uneven-aged woodland but has also raised many questions concerning the approaches adopted. For example, how appropriate is the reverse-J diameter distribution as a management tool in Britain? Kerr and O'Hara (2000) argue that the lack of experience with uneven-aged silviculture in Britain has led to a tendency to regard the reverse-J diameter distribution as the only way to manage uneven-aged stands. This is clearly not the case. However, it is relatively easy to understand and implement, and the work of Clarke (1995) and Kerr (2001) enables 'ideal' diameter distributions to be generated with a minimum of information. Further research is required to obtain a better understanding of what constitutes an 'ideal' diameter distribution for any particular set of circumstances, and guide forest managers on how to select appropriate values of the constant *q*.

One possible alternative to the reverse-J diameter distribution is the concept of equilibrium growing stock. However, the figures used as an equilibrium growing stock for Knightwood were a combination of information from Switzerland and estimates based on experience by the author. We currently have no information on equilibrium growing stock in terms of volume per hectare or the distribution of volumes between different components of the crop for any important forest tree in Britain. What is certain is that sites and species are very different between Britain and Switzerland, and within Britain, and there are inherent dangers in just copying a system developed elsewhere. Another area of uncertainty is the estimation of form height. All the information in Edwards (1983) originates from even-aged stands. Many conifer species in the more open upper canopy of an uneven-aged stand are capable of carrying more volume than is suggested by the form heights used in this study.

A subject not covered in this article but of great importance is to be more specific about where, and with which species combinations, success with uneven-aged silviculture is most likely. For example, is uneven-aged silviculture appropriate to an oak woodland on a surface water gley soil or to a stand of Sitka spruce and Norway spruce in the New Forest? Two estates which have had a pioneering role in adopting uneven-aged silviculture have been Longleat and Stourhead (Western) Estates in Wiltshire. Both estates have concentrated their efforts on soils derived from greensand which is favourable for natural regeneration compared with more base-rich sites or soils with heavier textures. In addition, both estates have a mixture of conifer and broadleaved species with differing degrees of shade tolerance. Success has been most marked with species which have seedlings which are moderate to very shade tolerant: Douglas fir, ash, beech, western hemlock, Norway spruce. This experience confirms that forest managers commencing uneven-aged silviculture, or transforming even-aged to uneven-aged woodland (Mason and Kerr, 2001), should concentrate on shade tolerant species on sites where natural regeneration is reasonably reliable.

This article has examined two methods for managing uneven-aged woodland but it is important to recognise there are many more (Brasnett, 1953; O'Hara, 1996; O'Hara and Valappil, 1999). Much time and effort can be expended in researching these different systems for different combinations of species and sites. However, the immediate priority is to be able to provide simple advice and decision rules to forest managers which will allow them to achieve the objectives of uneven-aged silviculture at an acceptable cost. Our research aims to provide this advice and develop a greater understanding of the potential of uneven-aged silviculture in Britain.

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