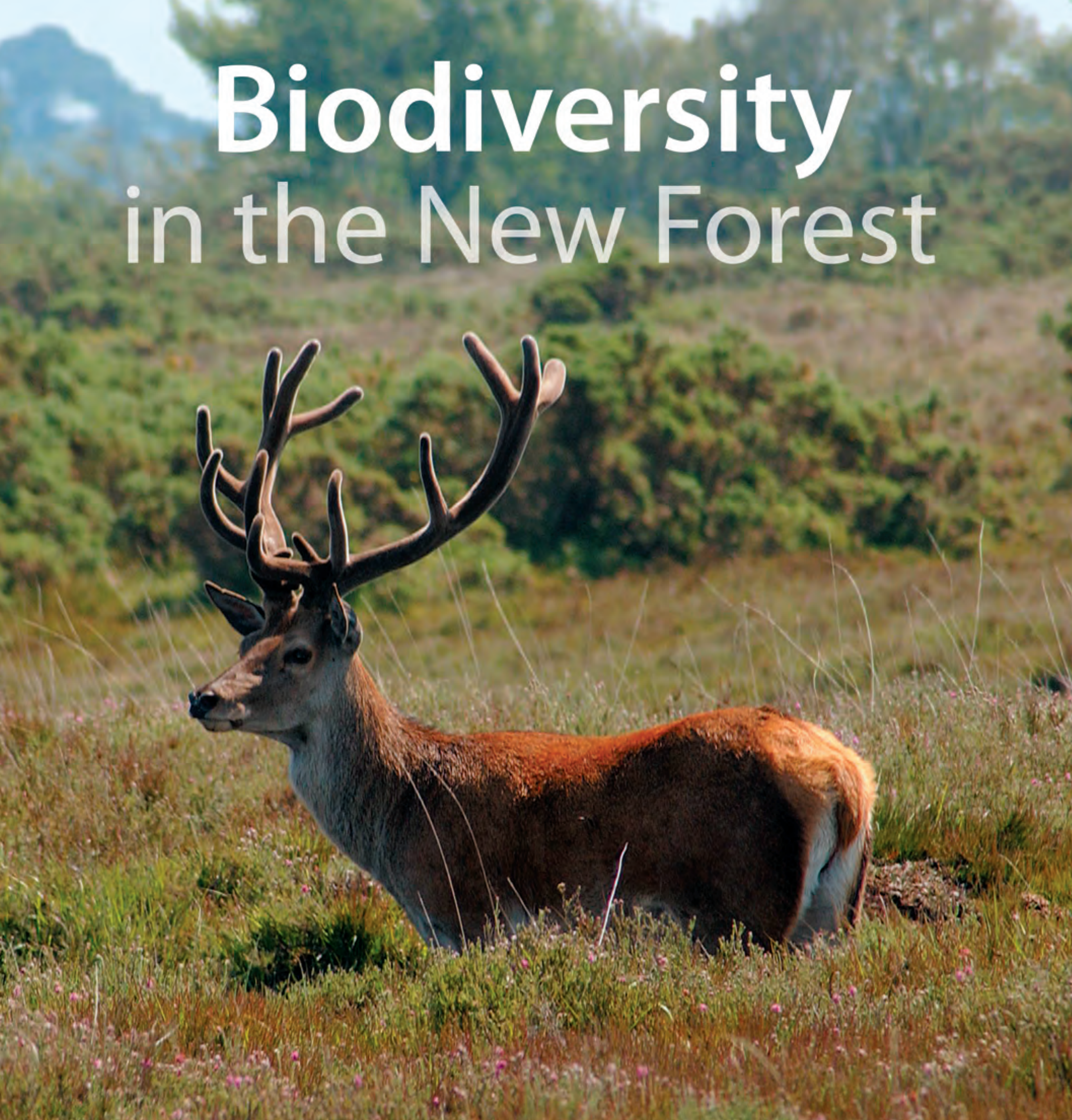
Biodiversity in the New Forest



Edited by Adrian C. Newton



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Dedicated to the memory of
Muriel Eliza Newton (1929–2009),
who loved the New Forest,
especially the donkeys.

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Back cover: Wood Crates (Adrian Newton)

The maps in this book are for illustrative purposes only, and do not represent the legal definition of National Park boundaries or any other feature

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13 The condition and dynamics of New Forest woodlands

Adrian C. Newton, Elena Cantarello, Gillian Myers, Sarah Douglas and Natalia Tejedor

Introduction

In his classic account of the New Forest, Tubbs (2001) refers to its ancient native woodlands as 'collectively the finest remnants of comparatively undisturbed deciduous forest in the lowlands of Western Europe'. This is a remarkable claim, but comes from someone who knew the woodlands intimately, and who recognised their special character and exceptional ecological value.

Tubbs' statement referred to unenclosed ancient pasture woodlands, called 'Ancient and Ornamental' (A&O) woods in the 1877 Act, of which he estimates that 3,671 ha remain. As noted by Peterken *et al.* (1996), most of the substantial A&O woods are distributed in a broad belt of near-continuous woodland centred on Lyndhurst, with additional outlying woods surviving in western and southern districts (Figure 59). This same general pattern of distribution has persisted for at least two hundred years, although during that time substantial areas of A&O woodland have been incorporated within Silvicultural Inclosures and replaced by plantations.

The A&O woodlands are dominated by beech, oak (both pedunculate and sessile), birch (both downy and silver), and holly. Typically beech and oak dominate the canopy, with birches occurring on the edges of main woodland blocks, and holly in the understorey (Peterken *et al.* 1996). Other species occurring at low density include yew, hawthorn, crab apple, rowan and whitebeam. Most of these woodlands classify as acid and oak beechwood types (National Vegetation Classification (NVC) vegetation types W10a, W10b, W11, W14–17), but other woodland types are present in limited areas, including ash-rich riverine woodland (W7), sallow and alder carrs (W4b and W5b respectively), and ash–field maple–dog's mercury woodland (W8b) on relatively base-rich soils (Peterken *et al.* 1996, Table 29). Scots pine is also widely distributed, having spread naturally following its reintroduction in the 18th century, often colonising heathland.

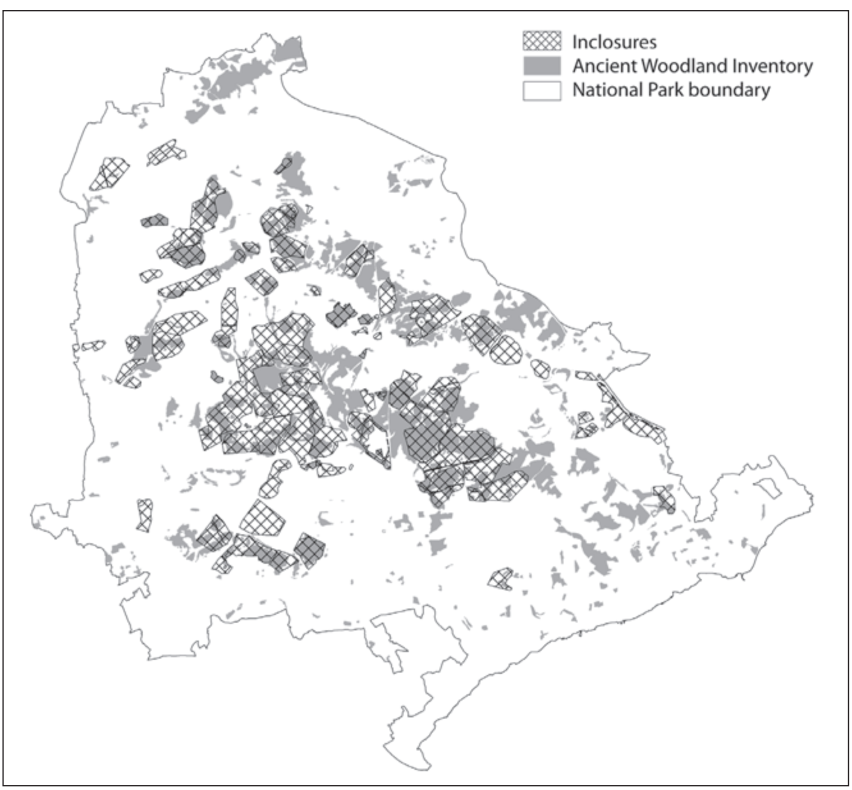

Figure 59
Map of the Inclosures and ancient woodland within the New Forest. The distribution of ancient woodland is based on the results of the national Ancient Woodland Inventory (see Goldberg *et al.* 2007 for details). For geographic context, see Figure 1.

Many of the A&O woods are 'ancient', in that they have been in existence for at least 400 years. Some appear to be 'primary', in that they have never been completely cleared since the arrival of humans in the area, and may therefore be considered direct descendents of the original 'wildwood' (Peterken *et al*. 1996, Rackham 2003). This continuity of woodland cover is thought to be an important factor in conferring their high value as habitat for wildlife. While the structure and composition of the woodlands has been greatly influenced by a long history of human intervention, and in particular the activities of livestock and deer, the presence of large trees and large quantities of dead wood create a structure that is believed to resemble that of wildwood (Peterken *et al*. 1996). Tubbs (2001) suggests that the riverine woodlands may be among the least disturbed of the Forest's A&O woodlands, possessing great diversity of age structure and substantial accumulations of dead wood, and may represent the only substantial examples of ancient floodplain forests remaining in England (Peterken and Hughes 1995).

According to Tubbs (2001), a further 344 ha of ancient pasture woods occur within the Silvicultural Inclosures, which with some other remnants, gives a total of approximately 4,035 ha. The Inclosures themselves primarily comprise plantations established after the Acts of 1698, 1808 and 1851, together with the results of replanting or natural regeneration, most of which originated in the 20th century as a result of harvesting of the earlier plantations (Tubbs 2001). Much of this replanting was of exotic conifer species, but the earlier plantations were mainly of oak, of which extensive areas still survive. Further areas of conifer plantation were established (in the 'Verderers' Inclosures') on open heathland in the 1950s and 1960s (Tubbs 2001). The current total area covered by the New Forest Inclosures is 8,493 ha (Forestry Commission 2007). As described by Tubbs (2001), livestock have often been excluded from Inclosures at various times in their history through the use of banks, ditches and fences, with the aim of protecting tree regeneration from herbivory, but individual Inclosures have not always been continuously enclosed. In addition, measures taken to exclude livestock have not always been completely successful.

The aim of this chapter is to provide an overview of previous ecological research and survey work that have been undertaken on New Forest woodlands, with a focus on woodland dynamics. It is widely recognised that effective conservation management of woodlands depends critically on understanding the ecological processes influencing their dynamics, but in the case of the New Forest, such processes have been the focus of some debate and uncertainty. The current condition of New Forest woodlands is then considered, in the light of available information. Survey data describing the distribution of dead wood are also summarised, to provide an indication of the current status of this important habitat resource. The potential management implications of current trends in woodland composition and structure are then briefly explored.

Table 29
Distribution of Ancient and Ornamental woodlands following a survey undertaken in 1996 (after Peterken *et al*. 1996). (Note that the estimate of total area differs slightly from that of Tubbs 2001.) The term 'emergent woods' refers to those secondary woodlands that have developed since 1850.

Compositional group	Area (ha)	% of total area
Old oak and/or beech woodlands	1,174	31
Emergent broadleaved woodlands	485	13
Ash-rich riverine woodland	157	4
Other riverine woodland	133	3
Stands of Scots pine	184	5
Area of Ancient and Ornamental Woodlands surveyed in 1996	3,684	98
Total area of Ancient and Ornamental Woodlands in 1996	3,770	100

For detailed accounts of the natural history and management history of the New Forest woodlands, the reader is referred to Tubbs (1968, 2001). Wright and Westerhoff (2001) provide a detailed ecological description of New Forest woodlands, whereas Goriup (1999) provides a useful introductory account.

Previous surveys and research

In order to illustrate how an understanding of the ecology of New Forest woodlands has developed over recent decades, a summary is provided here of the survey and research investigations that have been undertaken, listed by author and structured chronologically. This account does not claim to be comprehensive; one of the features of previous research and survey work in the area is that the results have not always been made widely available, and are often difficult to access. The emphasis here is on those investigations that have contributed to an increased understanding of woodland dynamics, rather than woodland ecology more generally.

(i) Peterken and Tubbs

The first detailed analysis of woodland structure and dynamics in the New Forest was presented by Peterken and Tubbs (1965). Analysis of the age structure of woodlands and evidence relating to the dynamics of herbivore populations suggested that phases of active tree regeneration have occurred over the past 300 years, which were related to the fluctuations in grazing and browsing pressure, and the incidence of heathland burning. Trees were divided into three age classes (old, intermediate and young, referred to as 'A', 'B' and 'C' respectively). The ages of each generation were established by counting annual growth rings from a representative sample of trees, obtained from a variety of different woods. Results indicated that generation A dates from 1649–1764, whereas generation B primarily originates from 1858–1923. In contrast, very little recruitment was recorded in the period 1765–1850.

Generation C results from a period of ‘vigorous and widespread’ regeneration that coincides roughly with the period of World War II. However, at time of writing, the authors reported that regeneration was prevented or held in check by browsing of livestock and deer in most of the unenclosed woodlands, ‘although not always in unshaded sites’ (Peterken and Tubbs 1965).

Comparison between tree age structures and herbivore numbers suggested some correlations between the two. Most notably, the B generation appeared to date from the almost complete removal of deer following the 1851 Deer Removal Act, whereas C regeneration coincided with the decline in browsing pressure during World War II. Similarly, browsing pressure was high during 1760–1850, when little regeneration took place. However, generation A appears to have arisen during a period of high browsing pressure, a result that the authors were unable to explain (Peterken and Tubbs 1965).

The survey undertaken by Peterken and Tubbs (1965) was limited in scope, as ring counts were obtained from only 141 trees in 31 woodlands (Table 30). Information on herbivore numbers must also be considered to be somewhat uncertain, particularly for relatively early dates. However, Tubbs continued to collect ring count data in subsequent years, increasing the sample size to 530. In his final account, Tubbs (2001) reiterated the existence of three principal age classes, with the A generation dating from 1660–1760, the B generation mainly during 1840–1870 and the C generation between 1900 and 1960, with least regeneration occurring between 1920 and 1935. Tubbs (2001) stated that after 1970, tree and shrub regeneration ‘petered out… over most of the Forest’. This apparently confirmed the prediction made by Peterken and Tubbs (1965), that as a result of elevated browsing pressure, ‘successful regeneration in unenclosed woods will become impossible in the next few years’. However, this observation was not supported by any quantitative survey data.

Mention should also be made of George Peterken’s research into the ecology of holly, the subject of his PhD dissertation. Peterken (1966) refers to one of the ‘outstanding problems of 19th century holly regeneration’, namely the fact that at that time holly regeneration was confined to woodland clearings and margins, ‘with the result that characteristic holly rings developed’. Yet in other woods, regeneration occurred throughout the woodland, to form the present-day closed understorey. This he attributed to an interaction between browsing pressure and light availability; although holly is a shade-tolerant species, he suggested that on relatively shaded sites, the species grows less vigorously, and is therefore more susceptible to the negative impacts of browsing on growth.

(ii) Small and Haggett

Concern about the state of A&O woodlands, and the limited extent of natural regeneration, led to a survey undertaken by Small and Haggett (1972). This was incorporated into the management plan for the New Forest for the period 1972–1981, and formed the basis for management for many years (Peterken *et al.* 1996).

Table 30
Summary of woodland surveys undertaken in the New Forest.

Sample	Measurements	Scope	Reference
141 trees sampled in 31 woodlands	Ages estimated from ring counts, for holly, oak and beech	Unenclosed woodlands only	Peterken and Tubbs (1965)
‘All high forest and park sub-compartments visited’	Visual assessment of whether regeneration (including trees of up to 100 years old) was ‘adequate’	Unenclosed woodlands only	Small and Haggett (1972)
24 woods including oak-dominated woods important for lichens, plus representatives of four other woodland types	20 random points in each wood, used to sample point-centred quarters; four trees nearest each point measured for girth at breast height	Unenclosed woodlands only	Flower (1977)
All woodland compartments visited	Presence of oak and beech saplings (>2 m height and <0.2 m girth) noted; girths of largest trees measured	Unenclosed woods plus woods of ‘mostly similar origins’ in Statutory Inclosures	Flower and Tubbs (1982)
310 sample sites, each of 200 m^2, located by overlaying randomly orientated grids on maps of the woodland units, with 500 m spacing	Counts of seedlings (<130 cm height), saplings (>130 cm height, <5 cm diameter) and trees, size data, and visual estimates of canopy density and litter layer	Unenclosed woods	Morgan (1977, 1987a,b)
173 sample sites, including all units used for monitoring of woodland condition by Natural England; each plot 2,500 m^2	Stand structure and composition, including seedlings classified as trees <1.5 m in height, saplings as = 1.5 m in height and < 10 cm dbh, and trees as = 10 cm dbh. Also surveyed browsing damage	Unenclosed woods and Inclosures	This chapter

Analysis of historic maps indicated that woodland area increased substantially during 1867–1909, and between 1909 and 1963, largely as a result of tree regeneration on former parkland. In total, some 517 ha of woodland was estimated to have been established during the period 1867–1963, representing a gain of some 21% in the area of broadleaved native woodland in the unenclosed ('Open') Forest during this period of 96 years. The authors suggested, on the basis of map analysis supported by field observations, that in some areas regeneration has occurred between large, open-grown trees, which formerly occurred at relatively low density in areas subjected to heavy grazing pressure. This resulted in conversion of scattered trees to extensive blocks of continuous-canopy woodland, an increase in connectivity between woodland fragments, and an increase in area of some individual woods. These two phases of woodland expansion correspond roughly to the periods of low grazing pressure identified by Peterken and Tubbs (1965).

Small and Haggett (1972) visited every 'high forest and park subcompartment' (Table 30) and classified each according to the amount and extent of regeneration, defined as 'an adequate distribution throughout the stand of healthy oak or beech trees up to an estimated 100 years of age that will ensure continuity of high forest (diameter at breast height of 6.5–38.8 cm)'. According to this definition, only limited areas (17.4 ha in total) were found to be lacking regeneration, most of which were relatively homogeneous stands of beech. Approximately 901 ha were classified as areas without adequate regeneration, i.e. 26.7% of the total broadleaved woodland area. However, the assessment of regeneration was purely subjective, and no quantitative data were collected on density of juvenile trees. It is also unclear, therefore, precisely what constitutes 'adequate' regeneration according to these authors.

Small and Haggett (1972) conclude that broadleaved tree species have regenerated successfully on a wide range of site types over a long period, over much of the area of unenclosed woodlands of the New Forest. According to Peterken *et al*. (1996), these authors also noted that 'younger age classes have regenerated in small groups no more than a few square yards in extent, often arising, particularly in the case of oak, by growing through blackthorn scrub which has given protection against browsing animals'. Those areas where regeneration is lacking are typically those where 'the die back of old beech is a main feature. Under such areas 'lawns' and bracken beds develop with no regeneration'.

(iii) Flower and Tubbs

The report produced by Flower and Tubbs (1982) details a thorough study of the historical origins and use of the New Forest, and results of fieldwork undertaken during 1977–1978. This survey involved visits to woodland compartments, defined on the basis of their species composition and age structure. Girths of the largest trees were measured, to assess the age of the oldest trees present. Regeneration was assessed by noting the presence of oak or beech saplings >2 m height and <0.2 m girth. Results indicated that oak saplings were present in 182 compartments, and beech in 153 compartments, with both oak and beech present in an additional 128 compartments (giving a total of 563). The authors noted that few seedlings appeared to have survived in very recent years, most of those recorded representing recruitment in the early and mid-1970s rather than the late 1970s. However, overall, regeneration was considered to have taken place recently despite high herbivore populations, though its distribution was patchy. The authors found no evidence that beech regenerates more successfully than oak, and no correlation was found between soil type and species dominance, when data from a subset of 20 woods were analysed (Flower and Tubbs 1982).

This report built on work undertaken previously by Flower (1980a,b) towards his PhD (Flower 1977; see also Flower 1983). This involved a survey of 24 woods, involving the measurement of trees using a point-centred quarter method (Table 30), although trees <1.5 m in height were not included in the survey. Data were used to classify the plant communities using a phytosociological ordination method, enabling primary and secondary woods to be differentiated. On the basis of age profiles (derived from girth measurements), Flower (1977) concluded that 'the Forest is quite capable of perpetuating itself', and noted that the regeneration phases described by Peterken and Tubbs (1965) are clearly discernible (Flower 1980a). Analysis of historical records also enabled Flower (1980a) to identify a period of intensive felling of oak in the late 17th century, which gave rise to the oldest generation of oak now found in the unenclosed woods, and led to a marked increase in the representation of beech in many woods (Flower 1980a).

(iv) Morgan

Richard Morgan also undertook a programme of field research towards his PhD in the 1970s (Morgan 1977), at about the same time as that of Nicholas Flower, although his results were not published until many years later (Morgan 1987a,b). This research was later supplemented by further field survey work (Morgan 1991).

Unlike the surveys described above, Morgan (1977, 1987a) employed a systematic design, involving surveys of 310 sample plots located on a regular grid (Table 30), distributed throughout the unenclosed woodlands of the New Forest. Results indicated that almost 47% of stands were dominated by a single species, either oak or beech, with *Fagus* being the more frequent (27.7% of stands surveyed). When all sites were pooled together, stem diameter classes for both oak and beech displayed a similar, 'negative exponential' frequency distribution, with beech displaying generally higher frequencies in the middle size classes (35–75 cm dbh) and oak in the 15–35 cm dbh size classes (Morgan 1987a). Seedlings of both species occurred widely but were generally of low density (i.e. most often <5 seedlings per 200 m^2); oak and beech seedlings were recorded on 36.1% and 17.1% of sites, respectively, the corresponding figures for saplings being 17.4% and 13.9% (Morgan 1987a).

These data were used by Morgan (1987b) to challenge the model proposed by Peterken and Tubbs (1965) and supported by Flower (1980a), with three main phases of tree recruitment coinciding with periods of relatively low herbivore pressure. Specifically, Morgan (1987b) identified three main weaknesses in the model: (i) the evidence of three generations remains equivocal, (ii) the anomalies identified by Peterken and Tubbs (1965) themselves undermine the model (such as the occurrence of a relatively high herbivore density during recruitment of the 'A' generation), and (iii) the model does not provide an adequate explanation for the observed changes in regeneration occurrence, both temporally and spatially.

Morgan (1987b) rightly points out that Peterken and Tubbs (1965) did not adopt a formal sampling scheme in their work (Table 30), and as a result, their results may be biased. In addition, samples for ring-counts were selected to be representative of the already identified age groups, risking circularity. Coupled with the low sample sizes employed, Morgan (1987b) was surely right to state that the model has not yet been rigorously tested (despite the additional ring counts reported by Tubbs 2001). Morgan (1987b) also highlighted inconsistencies in the results of Flower (1980a) compared with those of Peterken and Tubbs (1965), as well as the limitations of the point-centred quarter method that Flower adopted. The size-frequency distributions presented by Morgan (1987a) failed to provide any evidence in support of discrete phases of recruitment, yet his data were derived from a survey that was more comprehensive than any other undertaken previously.

Morgan (1987b) went further in his critique, highlighting the probable role of timber extraction in stimulating periods of increased tree regeneration, a point also recognised by Flower (1980a). He concluded that explaining patterns of woodland structure purely in terms of changes in browsing pressure is over-simplistic, a point supported by the fact that regeneration has apparently occurred in the past at times of high browsing pressure. This he ascribes to the role of understorey shrubs, such as holly, in protecting seedlings from herbivory. This process was investigated further by Morgan (1991), by assessing regeneration in a single plot (36 m × 24 m) in a single site (Ridley Wood). The position of each seedling was recorded, together with information on a variety of environmental variables. Larger oak and beech seedlings were found to be associated with protective conditions, namely sites with young holly or fallen branches, or adjacent to canopy gaps. However, saplings of both oak and beech were absent.

The research described by Morgan (1991) can similarly be criticised, for being limited to a single site of limited size, and at a single point in time. In the analysis that he presents, it is also difficult to tease apart the relative role of protection and light availability in enabling tree establishment. However, the data presented do provide some evidence for tree seedling establishment of beech and oak seedlings occurring under a woodland canopy, on microsites protected from herbivores.

(v) Putman and colleagues

In the 1970s and 1980s, populations of large herbivores in the New Forest were the focus of an intensive programme of research undertaken by Rory Putman and others at the University of Southampton. This research is profiled in another chapter in this volume (see Chapter 14), as well as by a series of publications (Putman 1986, 1995, 1996; Putman *et al.* 1987, 1989) and is therefore not described here in detail.

In the context of woodland dynamics, one of the more important pieces of research was that described by Putman *et al.* (1989). Two 5.6 ha fenced exclosures were established in Denny Lodge Inclosure in 1963, one of which was kept free of all large herbivores, and the other of which was subjected to herbivory by fallow deer at a density of 1 ha^{-1}. Vegetation in both plots was surveyed after intervals of 6, 14 and 22 years. In the grazed plot, tree regeneration was completely absent; in the ungrazed plot, rapid regeneration of a range of tree species (including both beech and oak) occurred within the first six years, with sapling densities reaching 7,115 ha^{-1} after 22 years. Differences in vegetation structure were also apparent, with much of the vegetation between 10 and 70 cm above ground being composed of bracken, while a range of understorey species were recorded in the ungrazed plot. The results of this experiment therefore provide a clear demonstration of the potential impact of herbivory on tree regeneration within woods.

(vi) Vera and colleagues

In 2000, the Dutch researcher Franciscus Vera published a highly influential book, based on his PhD thesis, which examined the potential role of vertebrate herbivory in the dynamics of woodlands in the lowlands of Central and Western Europe (Vera 2000). While not without criticism (Bradshaw *et al.* 2003, Rackham 2003, Mitchell 2005, Svenning 2002), the book has stimulated a great deal of debate about the role of herbivores in woodland ecology, and has contributed to a major shift in thinking regarding the role of grazing animals in conservation management of woodlands (Hodder *et al.* 2005, Kirby 2003, 2004; see also Olff *et al.* 1999 and Vera *et al.* 2006).

Vera (2000) presented what he described as 'the theory of the cyclical turnover of vegetations' (Figure 60). This is based on the idea that the original vegetation of the lowlands of Europe was a park-like landscape, in which successional processes are determined by large herbivorous mammals and birds (such as the jay) that act as seed dispersal agents. Specialised grass eaters, such as wild cattle and wild horses, produce grassland vegetation in which thorny shrubs become established, into which species of tree may become established. These are then protected from herbivory, and develop into groves of trees, which

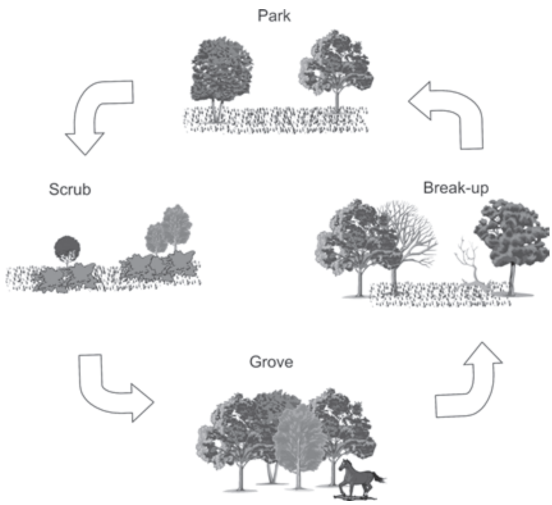

Figure 60
Schematic diagram of Vera's cyclical theory of vegetation turnover. This consists of the three phases of Open Park, Scrub and Grove, to which a fourth has been added (following Kirby 2003), 'Break-up', representing the transition from woodland back to open habitats. Following Kirby (2003), after Vera (2000), the Park phase is a largely open landscape with a thin scatter of trees left from the previous grove; vegetation is mainly grassland or heath species. In the Scrub phase, spread of thorny shrubs excludes herbivores; young trees grow up with the shrubs and eventually overtop them. In the Grove phase, which is the tree-dominated phase of the cycle, a closed tree canopy shades out the shrubs, and herbivores return, preventing regeneration. In the Break-up phase, the canopy opens out as trees die; vegetation shifts from woodland to grassland species.

advance into the grassland as the thorny shrubs advance. Regeneration of trees within the grove is prevented because of shade, and because of herbivory, as animals are able to enter the grove as it matures. As a result, the forest grove eventually degenerates into grassland, and the cycle begins again (Figure 60).

Vera (2000) considered the New Forest in detail, examining the evidence provided by the studies listed above with reference to the 'cyclical theory'. Key statements include:

- In woodland, there is little or no regeneration of trees, because of the high densities of herbivores.
- Interpretation of data presented by Flower (1980a) and Putman (1986) showed that the regeneration of trees in the New Forest occurred with densities of animals (1.4–1.5 feeding units ha^{-1}) at which Peterken and Tubbs (1965) considered regeneration was not possible.
- Both Peterken and Tubbs (1965) and Flower (1980a) failed to consider regeneration on the margins of woods in thorny scrub, instead focusing on regeneration in canopy gaps within woodlands.
- In the New Forest, 'woodlands have spread in concentric circles in an expanding ring of mainly young oak, which emerged from the advancing blackthorn scrub…', and 'throughout the New Forest this has resulted in a concentric expansion of forests in the form of successive generations of trees'.
- The regeneration of trees in thorny scrub explains how regeneration can take place, outside woodlands, even with very high densities of herbivores.

Although Vera's cyclical theory appears plausible, the account is based largely on a critical evaluation of the scientific literature, rather than on a substantive body of original data. Statements such as the spread of woodland in 'concentric circles' are not supported by any quantitative evidence presented either by Vera (2000) or any of the references he cites in support of this contention, or by the analyses of historical maps presented by Small and Haggett (1972), although concentric expansion of holly is mentioned by Peterken (1966). The question remains, therefore, whether Vera's theory accurately depicts woodland dynamics in the New Forest.

Some efforts have subsequently been made to test Vera's theory. For example, Bakker *et al.* (2004) examined the role of thorny shrubs in protecting palatable tree species across four floodplain woodlands in north-west Europe, including a site near to the Beaulieu River in the New Forest. Exclosure experiments indicated that oak grew best in grassland exclosures and on the edge of thorny shrub thickets. Field observations indicated that oak was found to be able to regenerate in the presence of large herbivores through spatial association with blackthorn. However, spatial expansion of both blackthorn and oak coincided with periods of low rabbit abundance and not with livestock density.

(vii) Mountford and colleagues

For his doctoral research, Ed Mountford examined the long-term dynamics of six lowland British woodlands, based on resurveys of permanent sample plots (Mountford 2004). One of these sites was Denny Wood in the New Forest, the results of which were presented in two publications (Mountford and Peterken 2003, Mountford *et al*. 1999). The research involved resurveys of two transects 20 m wide, established by ecologists at Southampton University in the 1950s, one of which was located within Denny Inclosure and the other in the unenclosed part of Denny Wood. The two publications present an exceptionally detailed account of the changes that have occurred in the woodland in recent decades.

Results from the unenclosed transect indicate that (Mountford and Peterken 2003):

- Woodland structure has changed markedly over the past 40 years. In 1959 the transect comprised closed beech-oak forest with abundant holly understorey. Forty years later, this had become an open oak-beech parkland with little understorey.
- Species-rich lawns and stands of bracken had spread extensively, and large herbivores had become far more numerous.
- Survival of oak was higher than that of beech, which suffered particularly from drought in 1976 and debarking by grey squirrels.

- Holly was reduced mainly by browsing and debarking by ponies and deer.
- A total of 21 established seedlings (≥40 cm height and <1.3 m) of seven tree species were recorded in 1999, mostly in clumps of protective bramble or under bracken. However, recruitment of tree species has been very limited since the 1950s.

On the enclosed transect, results indicate that (Mountford *et al.* 1999, Mountford and Peterken 2003):

- The stand was denser than the unenclosed transect in 1959, but also comprised closed beech–oak–holly forest at that time.
- Substantial canopy gaps were created during the past forty years, primarily as a result of mortality of large oak and beech trees as a result of the 1976 drought, coupled with the effect of subsequent storms.
- Canopy gaps tended to be colonised by species-poor grassland and stands of bracken; areas of closed high forest were associated with little ground vegetation.
- Holly was much reduced, principally owing to browsing and debarking by deer and ponies. Browsing almost completely prevented tree regeneration.

Based on these results, Mountford and Peterken (2003) concluded that tree regeneration has largely been prevented in Denny Wood in recent decades as a result of heavy browsing, largely by ponies. This is despite the presence of possible protective features such as spiny shrubs, fallen trees and bracken. Coupled with the reduction in the understorey, the accelerating break-up and mortality of old-growth stands, and damage by grey squirrels, Denny Wood – and potentially the other wood pastures of the New Forest – are currently at a vulnerable point in their history, according to these authors.

The results provide some insight into Vera's hypothesis. Most importantly, populations of herbivores have largely prevented tree regeneration since 1964, despite a substantial increase in the area of canopy gaps. The recruitment that has occurred has largely been restricted to sites protected from browsing. The understorey itself, composed of holly and bramble, which could potentially protect oak and beech saplings, has itself been almost destroyed by heavy browsing. The results therefore contradict those of Morgan (1987a,b), who suggested that regeneration can occur widely within woods can because of the presence of protective cover (Mountford *et al.* 1999). According to the Vera hypothesis, such regeneration should occur primarily outside woodlands; canopy dieback of woodland groves should lead to their replacement by grassland (Vera 2000). In this respect, therefore, the results obtained for Denny Wood support Vera's cyclic regeneration model.

The study by Mountford and colleagues is of exceptional importance. As the most detailed example of long-term monitoring of permanent plots in the New Forest, it provides a unique insight into the long-term changes that have been occurring in the woodlands of the area. The level of detail and rigour of the investigation make it a model of its kind, and the results highlight the enormous value of this kind of long-term investigation. Despite this, as the authors would readily admit, the study is limited in scope, to just two plots within a single woodland. Questions remain, therefore, whether the results obtained are representative of the New Forest A&O woodlands as a whole.

(viii) Other work

Peterken *et al.* (1996) provided a review of the distribution, composition and structure of the A&O woodlands, based on a review of existing data and a resurvey of the woodlands. This involved revisiting most A&O woodlands, with the primary aim of refining the survey undertaken by Flower and Tubbs (1982). The report is appended by a series of digitised maps, largely based on the hand-drawn maps produced by Flower and Tubbs (1982), but updated in the light of the survey data. The report provides a valuable and detailed overview of the A&O woods, but provides only limited quantitative information on the structure and composition of the woodlands. However the report presents the important finding that overall, some 5% of the A&O woodlands show signs of canopy collapse, similar to that recorded for Denny Wood by Mountford *et al.* (1999).

Peterken *et al.* (1996, Annex 8) list a number of long-term ecological research studies undertaken in New Forest woodlands, including the Denny Wood transects resurveyed by Mountford (see above). Five additional transects were recorded during the project described by Peterken *et al.* (1996), three in Woodfidley Beeches (Denny Old Inclosure), and one in each of Denny Wood (northern A&O regeneration plot), and Stubbs Wood. These were accurately mapped but not permanently marked. Data from the transects were not presented in the report, although results from Woodfidley were briefly described, indicating that complete exclusion of stock and deer had led to the development of abundant beech regeneration, but very little oak regeneration was observed on this site. However, frequent regeneration of oak was observed in the Denny Wood regeneration plot (such fenced plots having been established from time to time in various woods, to encourage regeneration).

Peterken *et al.* (1996) also mention research by Prof. Henk Koop of the Instituut voor Bos- en Natuuronderzoek, Wageningen, Netherlands, which involved the creation of ten transects in unenclosed woodlands. These were mapped in detail in the early 1980s as part of a European-wide study of forest dynamics, and resurveyed several times thereafter. Some of the results obtained are presented by Drenth and Oosterbaan (1984), Koop (1989) and Siebel and Bijlsma (1998). None of these studies reported significant regeneration (Mountford *et al.* 1999). The main results reported by Koop (1989) indicate that the central parts of A&O woods that were included in the survey, including Denny Wood, Mark Ash Wood, Bratley Wood and Berry Wood, were characterised by a relatively homogeneous structure of beech with stem diameters of around 100 cm. These were interpreted as belonging to the A generation of Peterken and Tubbs (1965) (i.e. mid-17th century in origin). Koop (1989) also refers to the spread of bracken following the collapse of old beech-dominated stands, which he suggests may completely limit tree regeneration. However, it is possible that bracken could act as a protective nurse for tree species such as oak; whether this occurs in the New Forest has not yet been rigorously determined. Tubbs (2001, p. 355) notes that the ecological role of bracken is poorly understood.

Pyatt *et al.* (2003) described additional work undertaken in the New Forest Inclosures, focusing on application of the Ecological Site Classification. This is a method developed by Forestry Commission researchers to characterise the ecological characteristics of forested sites, based on an assessment of soil conditions, climate and ground vegetation. The approach is designed to assist in choice of species for timber production, and as a guide to silvicultural operations, including those in native woodland (Pyatt *et al.* 2003). Surveys of plant communities were carried out in 153 2 m × 2 m quadrats, and used in combination with preexisting soil survey data to define and map the different site types present. Key findings include the fact that the climatic factor most limiting tree growth in the New Forest is summer moisture supply; soil limitations include generally low fertility and a predominance of shallow winter water tables. The results are of value for understanding the association between different plant communities and edaphic variables, but as the analyses are restricted to the Inclosures, the report is of limited value for understanding New Forest woodlands as a whole.

Results of a recent survey

In order to assess the current structure, composition and condition of New Forest woodlands, a new survey was undertaken during 2005–2007 by the current authors. Unlike previous surveys, both Inclosures and A&O woodlands were included in the sample, to provide an overview of New Forest woodlands as a whole. The sampling approach adopted the woodland units defined by Natural England (formerly English Nature), which are used as a basis for monitoring the condition of woodlands designated as SSSIs (see Chapter 12). The habitat category is referred to by Natural England as 'Broadleaved, mixed and yew woodland – lowland', and covers all wooded areas in the New Forest including A&O woodlands, exotic and native plantations, within open forest and enclosed forest areas. In some parts of the New Forest, these units follow the compartment boundaries used by the Forestry Commission in their management plans, but in others, such as the Open Forest, unit boundaries are defined by the shape of the woodland derived from habitat maps (Wright and Westerhoff 2001). The precise boundaries of these units continue to be modified; the survey employed unit boundaries as they were defined in 2005.

A total of 173 woodland units were sampled (Figure 61), representing all units defined as this habitat type, with the exception of those that were too small to accommodate a survey plot, or were located on private land or were otherwise inaccessible. In each

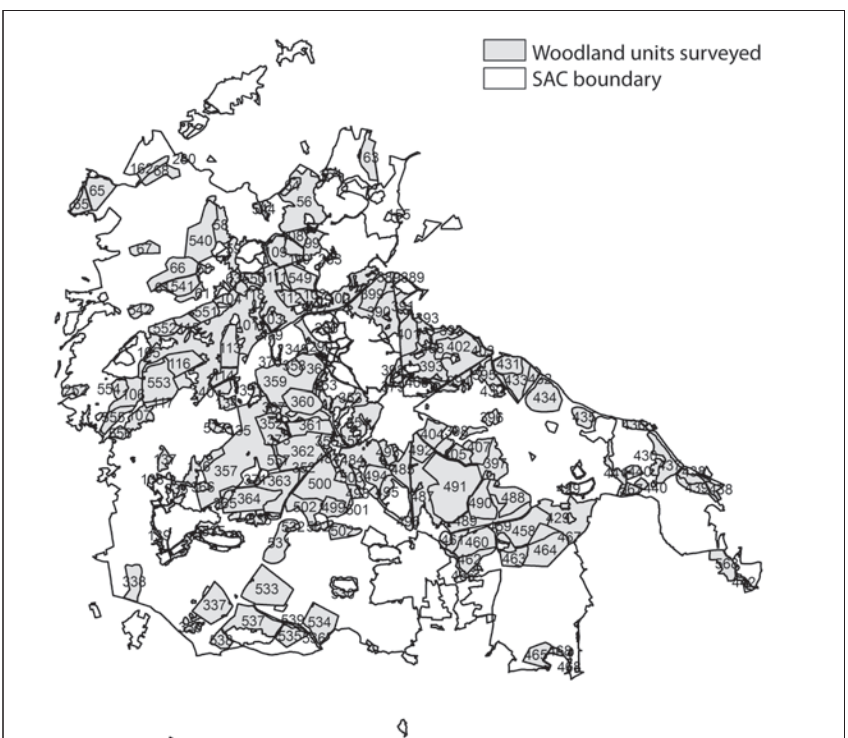

Figure 61
Map of woodland units (see text for definition) included in the woodland survey undertaken during 2005–2007. The numbers of the units refer to those employed by Natural England for monitoring the condition of SSSI units, from which the boundaries are also derived.

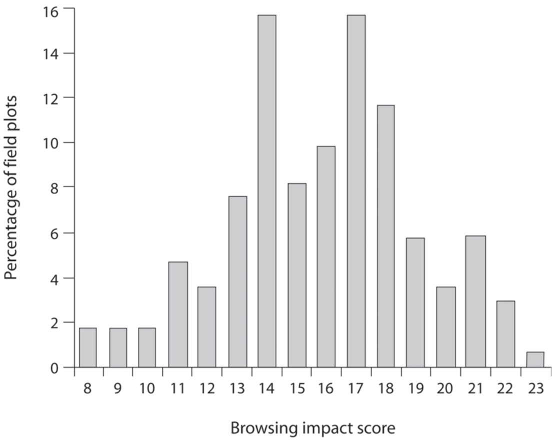

Figure 62
Results of the survey of browsing impacts, undertaken throughout New Forest woodlands (see text for details). The browsing impact score is based on the variables presented by Reimoser et al. (1999). Scores of < 10 presented here would classify as Moderate browsing pressure, 11–18 as Heavy, and ≥ 19 as Very Heavy, according to the definitions presented by Reimoser *et al*. (1999).

unit, a 50 m × 50 m plot was located randomly, and surveyed for woodland structure and composition (Table 30). In addition, a series of ten variables were assessed as indicators of browsing impact, based on Reimoser *et al.* (1999). Data from the survey of browsing impact indicated that browsing pressure does vary between woodlands; for example, a browse line was evident on 62% of plots surveyed. Overall, however, almost all of the New Forest woodlands are being browsed heavily, or very heavily (Figure 62): 5.1% of field plots (and therefore woodland units) were classified as Moderate browsing, 76.3% as Heavy, and 18.6% as Very Heavy, following the definitions presented by Reimoser *et al*. (1999).

Despite this, saplings of 41 tree species were encountered in the survey, 18 of which (44%) were non-native. Overall mean sapling density was 7.8 ha^{-1}. However, regeneration was patchy, with zero saplings recorded in 11% of sample plots. The sapling size-class was dominated by holly and hawthorn; oak saplings were relatively scarce, at a mean density of 2.7 ha^{-1}, and recorded in only 16% of plots. Corresponding figures for beech were 17.6 ha^{-1} and 25.7%. These results indicate that tree regeneration within New Forest woodlands is widespread, although patchy and often at low density. It should be noted that introduced species feature prominently in the sapling flora; for example, both Douglas fir and pine were among the ten most abundant species as saplings (Figure 63).

Current condition of New Forest woodlands

The monitoring of habitat condition of SSSIs currently carried out by Natural England (see Chapter 12) employs an approach called Common Standards Monitoring (CSM), developed by the JNCC (JNCC 2004). This involves a questionnaire survey of a range of indicators, which is completed by performing a subjective visual assessment during structured walks. The latest results of this process (see http://www.english-nature.org.uk/Special/sssi/, accessed August 2008) indicate that 113 (32% of the units area) of the New Forest woodland units are currently in favourable condition, 75 (5%) are classified as unfavourable declining, 20 (1%) as unfavourable no change, and 366 (62%) as unfavourable recovering. The reasons for unfavourable condition are not

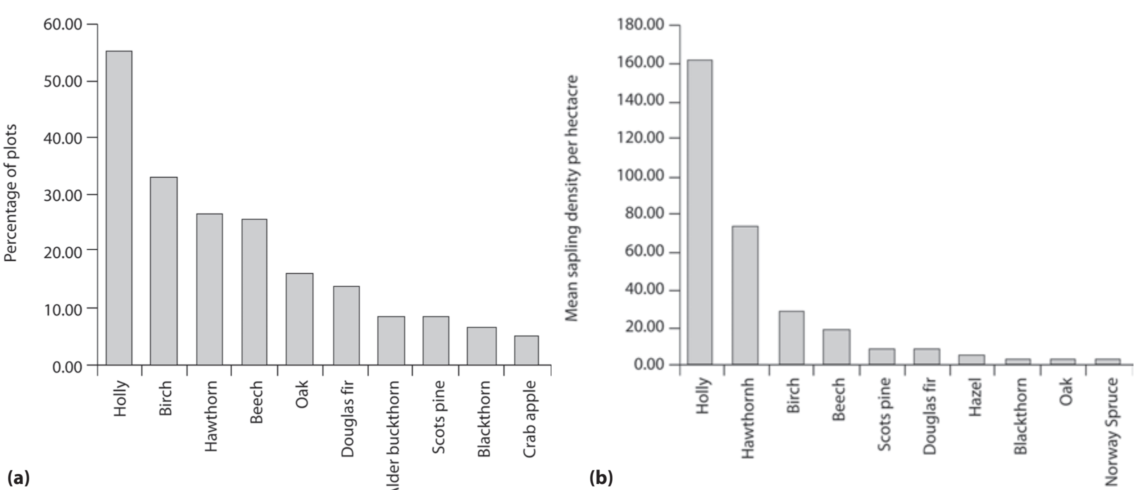

Figure 63
Regeneration of tree species in New Forest woodlands, based on a survey undertaken in 2005–2007. The data presented relate to saplings (i.e. trees = 1.5 m height and <10 cm dbh), assessed in randomly located 50 x 50 m plots. (a) percentage of plots in which saplings of different tree species were present, the ten most abundant species being illustrated; (b) mean sapling densities for the 10 species occurring at highest densities.

systematically reported in this assessment, but widely cited factors include lack of dead wood, presence of exotic species (principally conifers), presence of *Rhododendron*, poor development of ground flora, extensive areas of bare ground, lack of tree regeneration and overgrazing. Many of these problems are currently being addressed by management interventions, such as the widespread removal of conifers and the hydrological restoration undertaken in the LIFE projects (see Chapters 12 and 17). The introduction of such management interventions accounts for why such a high proportion of woodland units are currently considered to be unfavourable recovering rather than unfavourable.

Although monitoring of habitat condition is clearly an essential source of information to guide management action, the effectiveness of the CSM approach has not been widely evaluated. Concerns stem from the fact that the assessment is subjective and therefore potentially unreliable (Gaston *et al.* 2006). Another key issue relates to which indicators should be used to assess condition, referred to in the context of Natura 2000 sites (such as the New Forest Special Area of Conservation, or SAC) as 'favourable conservation status (FCS)'. The selection and testing of FCS indicators has previously received very little attention from researchers, and limited information is available regarding how FCS should be assessed. Potentially, indicators of forest biodiversity that have been developed to support assessment of sustainable forest management (SFM) (e.g. see Lindenmayer *et al.* 2000, Angelstam and Dönz-Breuss 2004, Newton 2007) could be of value in this context.

To examine the use of such indicators in the New Forest, Cantarello and Newton (2008) selected a suite of indicators on the basis of a literature review, relating to forest structure and composition, dead wood volume, tree regeneration and ground flora composition. Thirty units used by Natural England for monitoring condition were randomly selected for survey. Two different methods, namely (i) sample plots and (ii) a point-transect method, were used to assess the conservation status of the units by using 17 indicators in the sample plots and 6 in the point-transect method (Table 31). Results were compared with a third approach, namely a visual assessment method based on CSM, as employed in the formal monitoring undertaken in the New Forest to assess FCS. Results suggested that mean values of indicators did not differ between the plot and the point-transect based methods ($P > 0.05$; paired t-test and Wilcoxon signed rank test). However, values obtained from these methods were poorly correlated with those obtained from the subjective CSM approach (Cantarello and Newton 2008). In addition, a significant association was recorded between sampling method and assessment of condition ($P < 0.001$, correlation test). These results raise doubts about the reliability of the CSM approach, which is currently used for assessing woodland condition in the New Forest.

Results from this random sample of 30 units can also be compared with the results of the intensive survey of Denny Wood undertaken by Mountford *et al.* (1999). This provides some insight into how representative Denny Wood is of New Forest woodlands in general. Results indicate that in terms of stem density (number of trees), tree species diversity (Shannon-Wiener index for native trees) and % big trees (>80 cm dbh), values from Denny Wood are similar to those obtained from the larger sample. However, indicators such as mean sapling density, tree basal area and stem diameter were substantially higher for the sample of 30 woodlands than for Denny Wood (Table 31). This raises the question of what constitutes a reasonable target or reference value for woodland condition. Remarkably

Table 31
Characteristics of 30 randomly selected New Forest woodlands, surveyed by using sample plot and point-transect methods. For comparison, values provided by Mountford *et al.* (1999) for the enclosed transect at Denny Wood are also presented. Adapted from Cantarello and Newton (2008).

	Plot			Point-transect			Denny Wood
	$\bar{x}$	x_{min}	x_{max}	$\bar{x}$	x_{min}	x_{max}	
Number of trees (no. ha^{-1})	256	72.0	536	251	67	602	222
Shannon–Wiener index for native trees	0.90	0.00	1.58	0.98	0.00	1.66	0.87
Basal area (m^2 ha^{-1})	33.8	13.5	49.1	31.2	10.3	76.3	23
Mean diameter of trees (cm)	43.4	25.9	80.5	43.5	27.3	75.1	32
% of big trees (i.e. dbh >80 cm)	7.25	0.00	47.4	7.3	0.00	36.2	7
Number of total saplings (no. ha^{-1})	356	0.00	1924	–	–	–	91
Number of saplings of native tree species (no. ha^{-1})	351	0.00	1924	–	–	–	91
Volume of downed dead wood (m^3 ha^{-1})	12.0	0.00	37.6	–	–	–	26
Volume of snags (m^3 ha^{-1})	5.40	0.00	25.0	–	–	–	16
Total number of tree seedlings (no. ha^{-1})	21,397	100	295,300	–	–	–	63,219
Number of native seedlings (ha^{-1})	21,143	100	295,300	–	–	–	63,219
Shannon–Wiener index for native seedlings	0.53	0.00	1.27	–	–	–	0.89
Number of ground vegetation species	4.00	0.00	13.0	–	–	–	33

Abbreviations: $\bar{x}$ = mean value, x_{min} = minimum value, x_{max} = maximum value.
For further details, see Cantarello and Newton (2008).

Table 32
Measurements of dead wood length and volume for selected New Forest woodlands. Adapted from Kirby *et al.* (1998). (SE refers to standard error of volume measurements.)

Woodland name	Site details	Length m/ha	Volume m^3/ha	SE volume
Red Shoot	Largely mature oak–holly wood pasture	3,078	62	36
Tantany	Old beech, oak, holly, with occasional blowdowns	4,649	65	20
Stubbs	Old beech, oak–holly wood pasture	3,204	35	8
Frame	Old beech, oak–holly wood pasture	4,335	76	20
Mark Ash	Old beech, oak–holly wood pasture	2,576	58	24
Denny	Open old beech–oak pasture woodland. Close to car park	816	14	7
Lyndhurst	Oak, beech, holly high forest, largely closed canopy	816	13	4
Wood Crates	Patches of old oak, beech interspersed with young birch	1,068	9	4

little research has been undertaken on this issue. There is an urgent need to define such reference values for European forests, as described by Keddy and Drummond (1996) for North America. This issue is considered further below, in relation to dead wood volume.

Dead wood

Volume of dead wood (also referred to as Coarse Woody Debris) is widely recognised as an important indicator of woodland condition, reflecting its importance as habitat for organisms such as insects and other invertebrates, fungi, lichens and bryophytes. A number of surveys of dead wood in New Forest woodlands have been carried out, including visual assessments made as part of the condition monitoring of SSSI units, performed by Natural England (see above). Overall, lack of dead wood was cited for seven woodlands as a reason for failing to meet favourable condition status in the latest assessment of SSSI units (http://www.english-nature.org.uk/Special/sssi/; accessed October 2008).

Kirby *et al.* (1998) presented an overview of dead wood estimates for a range of woodlands (87 stands on

Plate 5
Denny Wood, in the permanent transect surveyed by Mountford *et al*. (1999) (see text). This stand of beech has undergone canopy collapse, resulting in conversion to grassland, perhaps illustrating part of the cyclical dynamics described by Vera (2000) (see text).

Plate 6
Cathedral Beeches in Denny Wood, another stand of beech that has undergone canopy collapse (see text), and also an important habitat for lichens.

Table 33
Sites of primary importance for dead wood, according to the survey by Wilson (1986). The results are based on a survey of 56 A&O (unenclosed) woodlands.

Name of woodland	Species	E. White's assessment [1]
Red Shoot Wood	Oak	Good
Mark Ash	Beech	Poor/good
Burley Old Inclosure	Oak, beech	–
Little Huntley Bank	Beech	Poor
Great Huntley Bank	Beech	Good
Camel Green	Beech, oak	Good
Wood Crates	Beech	Intermediate
The Knowles	Beech	Intermediate
Spaniard's Hole	Beech, oak	Intermediate
Stubbs Wood	Oak	Good/Intermediate
Eyeworth Wood	Beech, oak	Intermediate
Great Wood	Oak, beech	Intermediate
Bramshaw Wood	Oak	Good
South Ocknell Wood	Oak, ash	–
Stubby Hat	Beech	Good

1 Refers to subjective visual assessment by White 1975

63 sites) throughout Britain. Events such as the drought of 1976 and the great storm of 1987 were found to have had a major impact on the amount of fallen dead wood in many areas. On the basis of their survey results, these authors proposed provisional benchmarks for the amount of dead wood in British broadleaved forests, with values of <20 $m^3 ha^{-1}$ considered as low, 20–40 $m^3 ha^{-1}$ as medium, and >40 $m^3 ha^{-1}$ as high. Old-growth forests in eastern North America and in continental Europe typically have values in the range 50–150 $m^3 ha^{-1}$ (Kirby *et al.* 1998). Eight stands were assessed in the New Forest (Table 32), indicating dead wood volume values in the range 9–76 $m^3 ha^{-1}$. On the basis of the benchmarks defined by Kirby *et al.* (1998), three of these woodlands would classify as low, one as medium and four as high in terms of the volume of dead wood present. The sites assessed by Cantarello and Newton (2008), which can be considered as a random (and therefore arguably representative) sample of New Forest woodlands, indicated that on average, dead wood volumes in New Forest woodlands are relatively low. A mean value of 12.0 ± 9.99 $m^3 ha^{-1}$ was reported from the 30 randomly selected woodlands units that they surveyed in detail, with values ranging from 0–37.6 $m^3 ha^{-1}$ (Table 31).

The most extensive dead wood survey in the New Forest is probably that undertaken by Wilson (1986), who identified 15 woods as of particular importance for dead wood (Table 33). Individual woodlands were thoroughly surveyed and each dead wood feature was noted (including fallen trees, standing dead trees, stumps, dead limbs, etc.), to provide total numbers of each type of feature. A total of 56 A&O woodlands were included in the survey. This was preceded by an earlier survey of 43 unenclosed woodlands by White (1975). Unfortunately, because no estimates of dead wood volume were provided by either Wilson (1986) or White (1975), it is difficult to compare these data with those obtained by more recent surveys. The two surveys also employed different survey methods, further hindering comparative analysis. However, Wilson (1986) concluded that there had been only local changes in the dead wood habitat in the Forest over the previous decade. Areas that had apparently deteriorated badly included Denny Wood, whereas in others (such as Wood Crates) the amount of dead wood had increased since the 1976 drought. Wilson (1986) noted that removal of dead wood from New Forest woodlands had 'drastically escalated… in recent years', such that many woods were 'completely bare of fallen wood'. Areas particularly badly affected included areas to the north of Lyndhurst, including Brockis Hill, Hazel Hill, Shave Wood and Denny Wood. This was attributed to the relatively easy vehicular access to these woods, enabling collection of fuelwood.

Mountford and Peterken (2003) recorded volumes of fallen dead wood in Denny Wood of 26 and 201 $m^3 ha^{-1}$ in the unenclosed and enclosed transects respectively. The latter value is exceptionally high (see above), and reflects the canopy collapse that has occurred there as a result of the 1976 drought and subsequent storms.

Conclusions and management implications

Despite their undoubted conservation importance, the New Forest woodlands have attracted surprisingly little attention from ecological researchers. As a result, the current understanding of their dynamics is still limited. As documented by Tubbs (2001), the New Forest woodlands have been subjected to numerous management interventions over the past 150 years, many of which with hindsight appear to have been inappropriate or misjudged. The conservation value of the woods must have declined significantly over this period, as their habitat condition has deteriorated, but such trends are difficult to identify with precision because of the lack of systematic, long-term monitoring. As highlighted by Tubbs (2001), it is the loss of some old-growth stands of trees that is likely to have been most damaging in this context. Inappropriate interventions have resulted from a lack of appreciation of particular woodland characteristics, such as the habitat value of large, old trees, as well as a lack of understanding about woodland dynamics. This is exemplified by the oft-cited concerns about the perceived lack of regeneration in many woodlands. Yet it is only relatively recently that regeneration has been systematically and quantitatively surveyed throughout the New Forest woodlands.

The debate surrounding the impact of large herbivores on woodland regeneration is symptomatic of our current lack of understanding. Vera's model has undoubtedly stimulated much interest in the role of herbivory in woodland ecology, but it still awaits rigorous testing. The only way of achieving this would be through the long-term monitoring of appropriate permanent sample plots, to test (for example) whether seedlings apparently protected by spiny shrubs successfully survive into adulthood. The detailed results obtained by Mountford and colleagues (Mountford and Peterken 2003, Mountford *et al.* 1999) illustrate the value of this kind of investigation. However, the situation in Denny Wood as documented by these authors may not be typical of the New Forest A&O woodlands as a whole. At this location, beech has undergone canopy collapse as a result of the effects of drought and storm damage. The phenomenon of canopy collapse itself deserves greater research attention; while apparently widespread in the New Forest (Peterken *et al.* 1996), the characteristics of those locations where it has occurred have not been analysed in detail. Is it possible, for example, that collapse of beech has occurred on sites that are marginal for this species, such as the waterlogged, gleyed soils of Denny Wood?

The conversion of old-growth beech stands to grassland, as recorded in Denny Wood, is an interesting phenomenon that provides some support for Vera's model. Does this occur on only particular site types, or under especially high browsing pressure?

Plate 7
Young stand of regenerating beech in Mark Ash Wood, apparently establishing without the protection of spiny shrubs as hypothesised by Vera (2000). Photo: Arthur Newton

The influence of soil type on woodland succession under conditions of high browsing pressure has not so far been investigated. Other issues not addressed by Vera (2000) relate to the rate at which the processes of woodland dynamics occur, and the fact that tree species differ in their regeneration ecology. It has been documented that species such as pine and birch, for example, can colonise heathland under intense herbivory without protection from spiny shrubs (Putman 1986).

Potential limitations of the Vera model are highlighted by the work of Morgan (1991), who suggested that the thorny shrub protection process can occur within woodlands and is not limited to the margins; other areas important for tree establishment within woodlands include fallen trees and dead wood accumulations (Morgan 1991). It is notable that the only two studies that have systematically and quantitatively examined regeneration in large numbers of New Forest woodlands, namely Morgan (1987a,b) and the 2005–2007 survey reported here, both suggest that tree regeneration occurs at low density but is widespread. This is despite the fact that browsing pressure is almost uniformly heavy or very heavy. This suggests that within woodlands, some young trees (at least of relatively shade-tolerant species such as beech) are successfully able to establish themselves, in contradiction to the Vera model. If this is true, then this also casts doubt on the close linkage between herbivore pressure and tree regeneration proposed by Peterken and Tubbs (1965).

Whether Vera's model is correct or not has major implications for how the New Forest should be managed. This is explicitly recognised in the New Forest SAC management plan, which states (Wright and Westerhoff 2001):

'This theory based on vegetation dynamics at the ecosystem scale is hugely appealing and is highly significant for ecologists and foresters alike. It is ***highly consistent*** *with what happens in the New Forest'* (our emphasis).

Such a statement may be considered premature, given that the theory has not been adequately tested. The problem is exemplified by the current management practice of clearing scrub at woodland margins. If the Vera model is correct, it is precisely in such scrub that tree regeneration is expected to occur. Maintenance of scrub may therefore be critical to the long-term dynamics of woodland within the New Forest, particularly with respect to oak. Scrub clearance is undertaken to provide increased grazing opportunities for livestock, but as noted by Tubbs (2001), as the impacts of this management intervention are not systematically monitored, it is unclear whether it actually provides the benefits that are intended. This again highlights the importance of adequate monitoring to support management.

Uncertainty about the ecological dynamics of the New Forest woodlands leads to uncertainty about how their condition should be monitored. The lack of correspondence recorded between the subjective (CSM) approach currently used as a basis for condition monitoring, and data derived from more rigorous, quantitative methods (Cantarello and Newton 2008), raises further doubts about the adequacy of current monitoring approaches. As a result, managers arguably do not have access to adequate information to ascertain whether their current management interventions are being effective. This can only be resolved by investment in an adequate and robust monitoring system, supported by a programme of appropriate research.

A critical evaluation of current management approaches is beyond the scope of this chapter. Spencer (2002) provides a valuable overview of current approaches, which are further detailed in current management plans (Wright and Westerhoff 2001, Forestry Commission 2007). Examples of recent management interventions include restoration of hydrological features, clearance of exotic species such as *Rhododendron* and conifers, reintroduction of pollarding and grazing to some woodlands, pollarding of holly to improve habitat quality for rare lichens and to provide winter fodder for ponies, and restoration of bog woodland (Spencer 2002). With respect to dead wood management, the most recent management plan (Forestry Commission 2007) refers to the recent introduction of stricter controls on collection of firewood, while noting the need to maintain access along tracks within the A&O woodlands. Dead wood can be removed from such areas according to a strict set of criteria, but aside from lawns or tracks no dead wood can now be removed or sold for firewood from within A&O woodland unless it is part of an agreed management programme and in a suitable area for removal (Forestry Commission 2007). Such initiatives should undoubtedly have a positive impact on the condition of New Forest woodlands and their associated biodiversity in years to come. However, a number of problems still require attention; for example, illicit removal of dead wood was reported from some woodlands in the latest SSSI condition assessment (see earlier).

Peterken *et al.* (1996) note that the New Forest A&O woodlands occur in a complex mosaic, which 'must be managed as a unified whole'. We propose that this unified approach to management should be extended to include the Inclosure woodlands as well, given the need to manage woodlands and their associated biodiversity at the landscape scale (Lindenmayer and Franklin 2002). It is striking that the field survey described here is apparently the first systematic, quantitative ecological assessment of both A&O and Inclosure woodlands ever to have been undertaken (Table 30). The recently collected field survey data are currently being used to parameterise a spatially explicit model of woodland dynamics (LANDIS II), which can be used to explore the potential impacts of different forms of disturbance, including herbivory, on woodland structure and composition across the entire New Forest. Using this approach, future research work will examine the dynamics of woodlands at the landscape scale, with the aim of identifying the potential impacts of management interventions and other forms of environmental change. Ultimately, use of such approaches might also enable the historical development of the New Forest to be examined, following the suggestion made by Bradshaw *et al.* (2003). Our hope is that this will help reduce the current uncertainty regarding the ecological dynamics of New Forest woodlands, and help support their improved management in future.

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