Chapter (non-refereed)

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Mammals of Scottish upland woods

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1 Introduction

In this paper I discuss the distribution and status of mammals in upland woods in Scotland, with particular reference to the effects of commercial forestry.

2 Status and distribution

There is little quantitative information about the status of most Scottish upland mammals, but generalized maps and biological accounts are found in Corbet and Southern (1977). Maps compiled by the Mammal Society (Corbet 1971) and the ITE Biological Records Centre (BRC) (Arnold 1984) (Table 1) largely rely on non-systematic records from observers and relate to a 10 km grid; absence can mean 'not present' or merely 'not looked for'. The response from observers in Scotland has generally been poor. The Wildlife Branch of the Forestry Commission (FC) has conducted and published 5-yearly wildlife surveys since 1973. These surveys are compatible with those of the BRC, but are restricted to species present on FC land, and do not include those found elsewhere in the same 10 km grid squares. The survey also refers to the one point in time and does not take into account whether or not a species had been present in the recent past. Hence, grey squirrels (*Sciurus carolinensis*) have been reported in the valley of the River Dee, Aberdeenshire, by FC staff, but they do not appear in their survey results as they were not actually seen on FC property.

The Clyde Area Branch of the Scottish Wildlife Trust has produced 'atlases' of wild vertebrates present in various parts of the Clyde area, and recently there have been systematic surveys of single species such as otters (*Lutra lutra*) (Green & Green 1980), pine martens (*Martes martes*) (Verlanders 1983) and wild cats (*Felis silvestris*) (Easterbee in progress), which give a much more objective idea of distribution and status than hitherto.

In any case, there are many problems of finding mammals, let alone enumerating them, compared, for example, with birds. Birds are more obvious, visually and vocally, and are mostly diurnal; they also attract greater public interest. Reasonable estimates of abundance can be made by counting the number of singing, territorial cocks in the spring (eg Moss 1978). Mammals, on the other hand, are more secretive, frequently nocturnal, and it is only in species such as moles (*Talpa europea*) and badgers (*Meles meles*) that leave obvious signs, that the problems are lessened somewhat. One important exception is the red deer (*Cervus elaphus*) living on open hill land. It is Britain's largest land mammal and is relatively easily seen and counted in open country. Sample counts have been made by the Red Deer Commission (RDC) since 1960, and these counts suggest a rise in total numbers from 180 000 in 1965 to 270 000 in 1984 (Stewart 1979, 1985). The counting technique is described by Stewart (1976), and the one test of consistency made from a population reconstruction using mortality data (Lowe 1969) suggested a level of precision for total numbers around 2%, although errors in classifying the sexes and different age classes were larger.

Other estimates of the population size of various mammals rely on intensive studies at particular sites or in specific habitats. The densities found in these studies are then extrapolated to similar habitats elsewhere and, too often, to dissimilar ones. Although this approach gives some idea of what densities might

Table 1. Recent sources for information on the distribution and status of mammals in upland Scotland

i. General	Biological Records Centre distribution maps	Arnold 1984
	Mammal Society distribution maps	Corbet 1971
	Generalized maps of distribution and general accounts	Corbet & Southern 1977
	Forestry Commission mammal/bird damage questionnaire	eg Tee *et al.* 1985
ii. Specific	Squirrels (*Sciurus* spp.)	Shorten 1954
		Lloyd 1983
	Deer	Whitehead 1964
	Red deer (*Cervus elaphus*)	Mitchell *et al.* 1977
	Sika deer (*Cervus nippon*)	Ratcliffe 1986
	Fallow deer (*Dama dama*)	Chapman & Chapman 1980
	Feral goat (*Capra* domestic)	Whitehead 1972
	Pine martin (*Martes martes*)	Lockie 1964
		Verlanders 1982
	Wild cat (*Felis silvestris*)	Taylor 1946
		Jenkins 1962
		Easterbee in progress
	Otter (*Lutra lutra*)	Green & Green 1980
	Mink (*Mustela vison*)	Cuthbert 1973

be expected in various habitat types, it is seldom tested over a wide area or in different habitats (cf MacDonald *et al.* 1981). For example, Loudon (1980) estimated the population densities of roe deer (*Capreolus capreolus*) in several forests in the Borders. He used a variety of methods, and his suggested densities are often used by forest managers to apply to their own areas, irrespective of the degree of similarity with the Border plantations. Charles (1981) estimated the numbers of short-tailed field voles (*Microtus agrestis*) in 2 first rotation forests, also the Borders, and related them to forest structure (see below). There are, however, no reliable estimates of vole densities from other parts of the country, or in older forests or second rotation crops. Considering the importance of this species as a prey item for carnivores and raptors, this is a serious gap in our knowledge.

3 Woodland type

Most British upland mammals are naturally animals of woodland or of the woodland edge. The forest provides not only food but also cover from predators and disturbance, shelter from weather, and sites for nesting and roosting. However, most upland mammals are very adaptable and are not obligate on particular woodland types, although their densities may be affected.

Woodmice (*Apodemus sylvaticus*) thrive best in broadleaved woods and hedgerows, and densities may reach up to 200 ha^{-1} in oak (*Quercus* spp.) forests after a good acorn crop (Gurnell 1979). Venables and Venables (1971) found that woodmice became less numerous in the older parts of a conifer plantation in Wales, and Birkan (1968) reports that they were abundant in pine (*Pinus* spp.) forests in France, especially in stands 10–12 years old. Woodmice densities are thought to be less than 30 ha^{-1} in northern conifer plantations (Flowerdew 1984) and may be restricted by the availability of seeds for food in winter, when they are known to migrate to nearby scrubland or broadleaved woods until more favourable conditions return (Gurnell 1979).

Bank voles (*Clethrionomys glareolus*) are also most abundant in broadleaved habitats, and in conifer plantations in France they are most numerous in stands 6–30 years old (Birkan 1968). S J Petty (pers. comm.), however, has found that both bank voles and woodmice were absent from young grassy restocked Sitka spruce (*Picea sitchensis*) sites in Northumberland and Argyll in spring and summer, and that numbers were very low in autumn. Such provisional findings are a cause for concern, and we need to know the shape, area and distribution of broadleaved woodland or scrub that may be necessary to maintain viable populations of these small rodents in conifer forests.

No British mammal depends entirely on conifers. Red squirrels (*Sciurus vulgaris*) are apparently most abundant in large Scots pine (*Pinus sylvestris*) woods (ie 80 100 ha^{-1} in Scotland (Tittensor 1970); 110 100 ha^{-1} in eastern England (Reynolds 1981); see Gurnell 1983). Red squirrels will also occupy pure broadleaved or mixed woods when available, and Purroy and Rey (1974, quoted in Gurnell 1983) give densities in Spanish woods varying from 31 100 ha^{-1} in mixed oak to 14 100 ha^{-1} in Scots pine and 3 100 ha^{-1} in beech/fir (*Fagus sylvatica/Abies* spp.) forests. The fruits and seeds of deciduous trees and shrubs are important food items for red squirrels at certain times of the year (Moller 1983). No quantitative information is available on the densities or the ecology of red squirrels in the extensive Sitka spruce forests in the Scottish uplands, although the squirrels do occur there and feed on the spruce seeds. Elsewhere in northern Europe, 'spruce woods' appear to be preferred over pine forests (Pulliainen 1973), and the seeds of spruces have a higher calorific value than those of pines (Danilov 1938). Provided that rotations are long enough to allow the trees to mature and produce good cone crops, Sitka spruce forests should make suitable habitat for red squirrels. It may be that small areas containing other tree species would enable red squirrels to survive in these plantations, if Sitka seed alone is insufficient to maintain them.

As few mammals are totally reliant on conifers for food but depend on them more for cover, it may be immaterial which species is planted. Nevertheless, Sitka spruce is clearly going to be the dominant tree in the uplands for the foreseeable future (Figure 1). Certainly, the undergrowth differs under various conifers or with different thinning or planting regimes (eg Sakura *et al.* 1985). Hill (1979), for example, found that the ground cover of vascular plants under pines and larches (*Larix* spp.) 20–60 years old was 20–30% and 25–60% respectively; under the denser canopies of Sitka spruce, cover was only 5%. One would imagine that a greater variety of insects would be found in habitats with a more diverse vegetation, but no comparative studies have been made on the insects associated with different conifer woods in the uplands (Welch 1986).

4 Effects of afforestation

The large-scale afforestation of the uplands since the 1920s has been beneficial to most mammals by starting to redress the balance between woodland and open ground habitats that has been upset since the forest clearances. On the other hand, re-creating forests must be at the expense of other habitats and those animals dependent on them.

Although planting large areas of moorland and sheepwalk has had detrimental effects on some species of wading birds and on some birds of prey (Newton 1983), the opposite appears to be true for mammals. Most mammals have profited from the increase in forest cover and the luxuriant ground vegetation found during the early forest stages due to ploughing, draining and fertilizing. Even mountain hares (*Lepus*

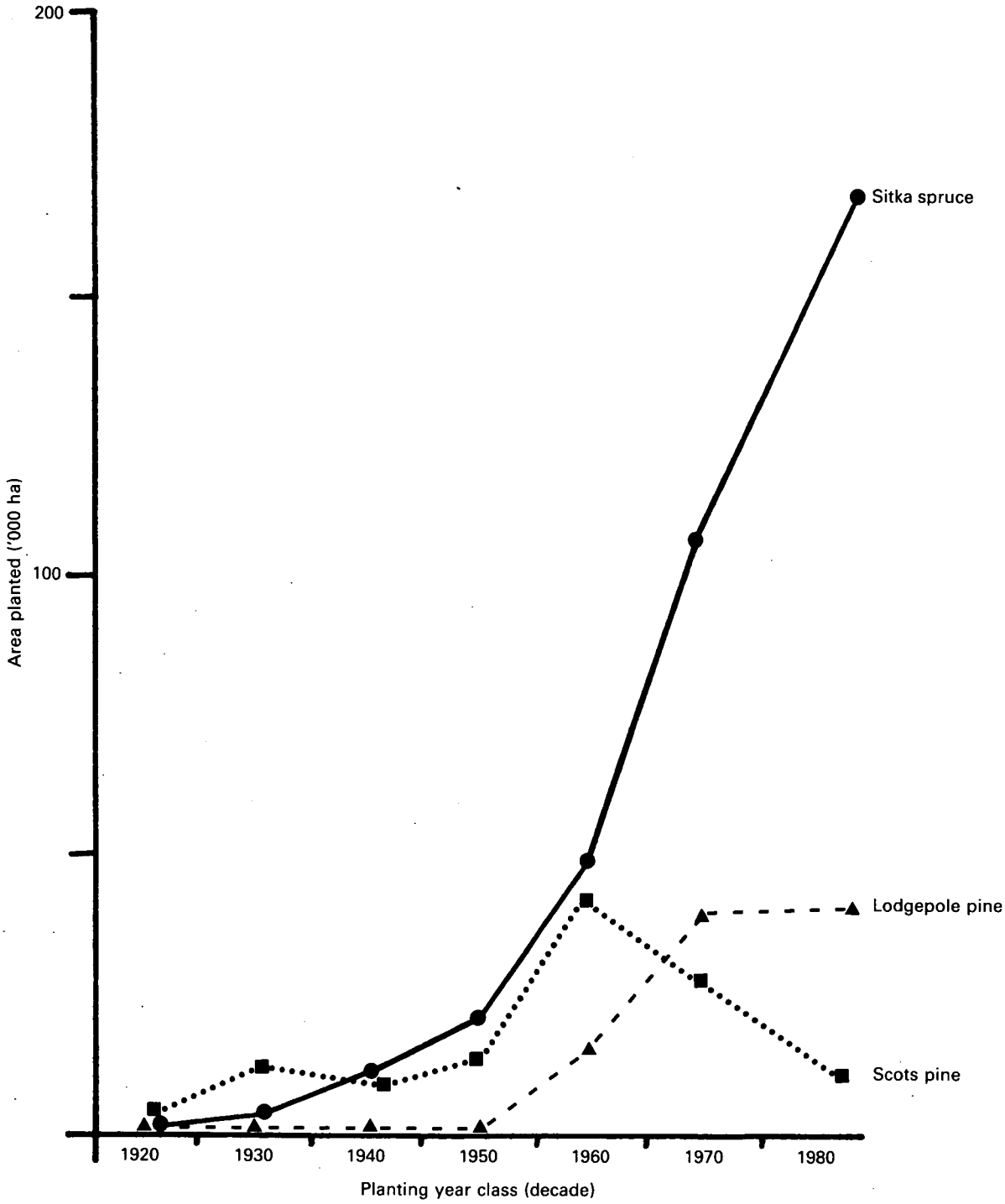

Figure 1. Area planted (kha) of Scots pine, lodgepole pine and Sitka spruce in Scotland per decade (source: Forestry Commission 1983)

timidus), which are most abundant on heather (*Calluna vulgaris*) moors in Britain, and particularly in the east and central Highlands (Watson & Hewson 1973), will use the cover of plantations and survive there, provided sufficient heather moorland is left above the tree-line. In many parts of the Highlands, a large area of moorland will be unplantable and should ensure their survival. Elsewhere in northern Europe, mountain hares are found in open woodland or scrub habitats (eg Pulliainen 1982) and not in very open country as in Britain. In fact, the FC wildlife survey (1983) shows that mountain hares are present in around half of the 10 km squares where the FC has property in Scotland, and in most of these squares in the Scottish uplands.

Most concern should be over the loss of broadleaved woodland and of coppice and scrub through felling or through under-planting with more vigorous conifers. Although few mammals are obligate on such woodlands, mixed broadleaved/conifer stands should be better habitats for most mammals in the same way as they are for birds (Newton & Moss 1981; Newton

1983), the conifers providing good cover all year round and the deciduous parts a variety of food. Mixed woods also (i) allow a better development of the herb/shrub layer than pure conifer woods, (ii) contain many broadleaved species which are preferred foods for mammalian herbivores, eg brambles (*Rubus* spp.), rowan (*Sorbus aucuparia*), (iii) give a more diverse seed crop, (iv) contain a greater variety of insects, and (v) have more suitable roosting sites for bats.

In Scotland, Parr (1981) estimated that broadleaved woodland decreased by 50% and by as much as 80% in some counties between 1945 and 1979, and that this habitat now occupied less than 1% of the land area. He regarded the amount of coppice left as being 'negligible'.

5 Plantation structure

Following afforestation, the seral stages of the forest provide various combinations of food and cover which affect mammal species differently, but the young forest stages before canopy closure are the key habitats for nearly all mammals.

During the first few years of woodland establishment, there is abundant food, cover and nesting sites for short-tailed voles. Consequently, numbers of voles are higher in these young stages than in later ones. Charles (1981) found that population densities were also influenced by soil fertility and by ground vegetation, ranging from 23 100 ha^{-1} on blanket peat with heather to 280 100 ha^{-1} on mineral soils dominated by bent (*Agrostis*) grasses. In older stands, voles were restricted to rides and clearings, and densities of 5 100 ha^{-1} were similar to those found on open hill ground. During 'plague' years, such as in the Carron Valley, Stirlingshire, in 1952–53, exceptional densities of 2000–3000 voles ha^{-1} were recorded (Charles 1956). Likewise, common shrews (*Sorex araneus*) were found to be most numerous in the younger plantations, but they would occupy older stands when there was sufficient undergrowth (Middleton 1931). By contrast, red squirrels rely on mature forests for food and for their dreys, and bats such as the noctule (*Noctula noctula*) need dead trees or old hardwoods with holes for their roosts. A lack of old or dead trees is characteristic of the truncated successions found in commercial forestry systems throughout the world (eg Leopold 1978).

Whereas some mammals are more or less dependent on one seral stage, others such as the deer and carnivores use all stages, the young for food and the older ones for cover. In fact, these 2 groups of mammals have benefited more than most from afforestation.

Many of the larger Scottish Carnivora have increased their range since the turn of the century, eg pine martens (Lockie 1964; Verlanders 1983), wild cats (Jenkins 1962; Corbet 1971) and foxes (Lloyd 1981), and more than one factor has been involved. Langley and Yalden (1977) reviewed the possible reasons for the decline of the rarer carnivores during the 19th century and for their subsequent recovery. They concluded that the revival was due mainly to less persecution because it coincided with a decrease in the number of gamekeepers (particularly during and immediately after the First World War) and occurred before large-scale afforestation from the 1920s. Hewson and Kolb (1974), on the other hand, associated the rise in the number of foxes (*Vulpes vulpes*) killed at Eskdalemuir forest with the increase in forestry there (Figure 2). They thought that the supply of field voles was more important than the protection from man given by thick plantations, for fox control was vigorous at Eskdalemuir. Although nowadays there is less persecution than formerly because there are fewer gamekeepers, there would seem little doubt that commercial forestry will favour most carnivores through the added protection afforded and the increased food supply from voles. Current restrictions on methods of control will also encourage carnivores throughout upland Scotland and elsewhere.

Less is known about the smaller mustelids such as stoat (*Mustela erminea*) and weasel (*M. nivalis*) in upland plantations. The increase in voles should assist both species, provided that they can hunt effectively in commercial forests where there has been much disturbance to the forest floor. This hypothesis also assumes that stoats, like foxes (Hewson & Leitch 1983), will be able to change from their dependence on rabbits for food. Both mustelids could, therefore, increase their range, especially in north and west Scotland where they are less common at present than in the south and east.

All 3 main deer species in the uplands, red, roe and sika (*Cervus nippon*), naturally live in open woodland or woodland edge and all have increased their range considerably with the advent of widespread afforestation.

Roe deer became extinct in the Scottish lowlands and in England and Wales by the end of the 17th century (Bewick 1800; Ritchie 1920), and were restricted to the 'highland fastnesses of Ross, Inverness, Argyll and Perth' (Ritchie 1920). They began to increase again following the planting of woodlands in the late 18th and early 19th centuries, and are now the most widespread deer species in Britain. They are even found in suitable habitats in suburban areas such as in and around the city of Aberdeen. Roe reach their highest densities in young plantations or in the early stages of restocked forests (Loudon 1980; Staines & Welch 1984) and may reach 25 100 ha^{-1} in spruce forests 5–15 years old. Population densities drop to around 10 100 ha^{-1} once the canopy has closed.

Red deer are no longer restricted to open hill ground, but have colonized most large coniferous plantations in

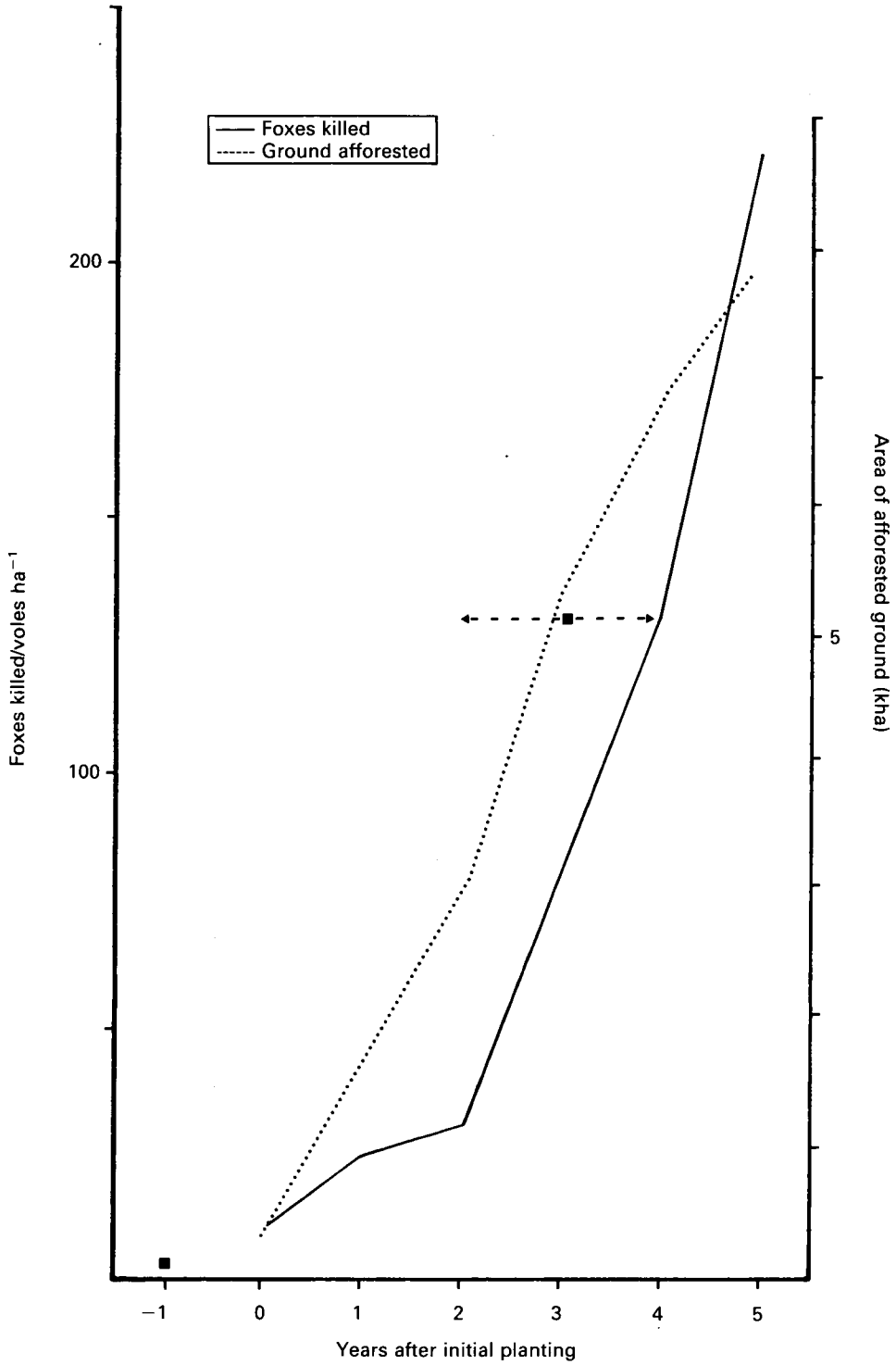

Figure 2. Relationship between the number of foxes killed and ground afforested at Eskdalemuir, with densities of voles (■) (source: Hewson & Kolb 1974; Charles 1981)

the uplands except, so far, some in the Borders. These deer are not seasonal intruders but are resident in the woods throughout the year. Population densities of woodland red deer are similar to those found on open hill ground (see Stewart 1985) and generally range between 5 and 15 100 ha^{-1}, with up to 40 100 ha^{-1} recorded in better habitats (Ratcliffe 1984). Like roe, they are found mostly in parts of the forest where food and cover are mixed, but red deer tend to prefer older thickets for cover, especially when these are checked and with an understorey of heather (Staines & Welch 1984). Body weights and reproductive rates are frequently higher in woodland populations (compare Mitchell *et al.* 1977 with Mitchell *et al.* 1981 and with Ratcliffe 1984). In woods, puberty in red deer is usually earlier than on the open hill and adult females breed every year, resulting in a very high population turnover.

Sika deer were introduced into the British Isles from 1860. They are now feral and widespread throughout

much of north and west Scotland, and are particularly abundant in the Great Glen, in Knapdale (Argyll), and in parts of Sutherland, Inverness-shire and Peeblesshire. Their origins and current status are reviewed by Ratcliffe (1986), who estimates their current rate of spread at between 3–5 km yr^{-1}. Sika deer were present in 89 10 km squares in the FC 1983 survey, compared with only 36 squares a decade earlier. Little is known of their habitat preferences in conifer forests, but these are likely to be similar to those of red deer. In addition to the damage that sika deer do to forestry, they hybridize with red deer and cause concern for the genetic integrity of the native species.

6 Second rotation forests

Most studies of mammals in commercial forests have been done in first rotation crops. As a result, many of the findings already described have been from plantations of different planting age (eg Loudon 1980). In second and subsequent rotations, however, plantations will be structurally more diverse, the extent of this diversity depending on such factors as the size of felling coup, on problems of restocking and achieving silviculturally acceptable densities, on differential growth rates and on windthrow. There will be a greater amount of forest edge habitats and, more importantly, a greater area of young forest, because the proportion of a plantation before the canopy closes is related to the length of the rotation (König & Gossow 1979; Ratcliffe *et al.* 1986). The short rotations of 45–55 years predicted for many spruce forests in Scotland (Ratcliffe & Petty 1986) will result in about 40% of the forest being in these younger stages; in a wood with a 100-year rotation, as is common in continental Europe, this proportion drops to about 10%. British upland forests should, therefore, continue to provide good habitats for most mammals.

However, this conclusion assumes that the relationships between animal abundance and habitat types will be similar in the later rotations to those in the first. Few studies have been made in restocked forests and more knowledge is needed about the habitat preferences of mammals in this important habitat type. For example, supposing that vole numbers in restocked areas are similar to those found in afforested sites of similar age, will mammalian or avian predators still be able to hunt as effectively with the large amount of brash, other debris and ground disturbance caused by felling and extraction? The relationships between prey abundance and predator density are likely to be different.

7 Impact

Perpetuating high densities of mammals will lead to problems of management as many conflict with other land use interests. These conflicts have been reviewed by Staines (1980, 1983a) and for deer specifically by Mitchell *et al.* (1977), Staines & Welch (1981) and Staines (1983b). Briefly, carnivores can, or are thought to, influence game and farming interests and herbivores can damage woodlands by affecting the establishment, growth, and composition of woods and by competing with livestock.

It is impractical to construct a 'hit list' of wild mammalian pests for the UK because these vary regionally and seasonally, but it is worth noting that more is spent on forest protection from sheep than from any wild herbivore. Also, some species may be a pest in one area and an asset in another (eg red squirrels), or both an asset and a pest in the same area (eg deer). Voles, rabbits and feral goats may be locally important, but foxes and deer cause the most widespread concern in the uplands. All these wild mammals are encouraged by modern forestry practices, so the management problems will continue. In addition, conservation measures aimed at habitat improvement may also further the pest species.

The control of carnivores in woodlands is usually done as part of a 'good neighbour' policy towards game and farming interests, and not specifically for the management of the woodland or for the conservation of species living there.

Herbivores, on the other hand, can have very marked effects on woodlands throughout the forest cycle. Seed eating by squirrels and woodmice is not generally thought to be of great significance in preventing woodland regeneration in broadleaved woods in the lowlands. Indeed, caching is thought to be beneficial through dispersing and burying seed (Mellanby 1968; Gurnell 1981). Miles and Kinnaird (1979a), however, found losses of up to 100% of experimentally sown Scots pine seeds in Glenfeshie, Inverness-shire. They also reported heavy grazing by small rodents and slugs on Scots pine seedlings, although Edwards (1980) thought that slugs were the most important predator of regenerating trees in the native pinewood at Glen Tanar, Aberdeenshire. Field voles can also have serious effects on both commercial and natural woodlands, especially during 'plague' years (eg Charles 1956; Miles & Kinnaird 1979b). However, these plagues are usually short-lived, and excessive damage is frequently localized.

Once saplings reach the height of the surrounding vegetation, and in the case of commercial trees this often means soon after being planted, they become susceptible to browsing by deer and other larger herbivores. This browsing is the most widespread form of damage. It is well established that large numbers of red deer can inhibit the establishment of certain herbaceous species and the regeneration of the native Caledonian pine forest; they can also severely damage commercial crops (Mitchell *et al.* 1977; Staines & Welch 1981). In simple terms, in natural woodlands the ratio of seedlings : deer needs to be increased, either by decreasing the deer population or by increasing the density of seedlings, as well as by fencing or other protection (for fuller discussions,

see Mitchell *et al.* 1977; Miles & Kinnaird 1979b; Staines 1983b; Booth 1984).

Although the growth of Norway spruce (*Picea abies*) is often retarded by heavy browsing, Sitka spruce on fertile sites may be little affected. However, browsing on Sitka spruce can cause multiple stemming which reduces timber value (Welch *et al.* 1983; Staines & Welch 1984). There is no quantitative information on the long-term effects of browsing on the growth of other commercially grown conifers in this country, but many other conifer and broadleaved species are more susceptible and less resilient to browsing than Sitka spruce. It will be difficult, therefore, to have the diversity of tree species which is desirable from both silvicultural and conservation viewpoints, without adequate protection from the large deer populations.

In addition to the damage done by browsing, red and sika deer also eat the bark of many trees. The incidence and the effects of bark-stripping vary with the species of tree, but it is most prevalent on willows (*Salix* spp.) and aspen (*Populus tremula*) amongst hardwoods, and on Norway spruce and lodgepole pine (*Pinus contorta*) amongst the conifers (Mitchell *et al.* 1977). Bark-stripping is perhaps more of a problem in commercial than in natural forests, and damage can be extensive. If the trunk is completely girdled, the tree will die, but there is little evidence so far that the removal of smaller areas of bark has any appreciable effect on growth rates. However, such wounding means that the tree is more susceptible to attack from fungi and other pathogens, and the timber can be further degraded through staining and resin inclusion. Sitka spruce appears to be more resilient to this form of damage than other species, such as Norway spruce, but the long-term effects of bark-stripping are not yet adequately known.

Because of the good habitat provided by plantations and the difficulty of controlling deer there, deer populations will increase and the conflicts with other land uses will continue. More quantitative studies are needed on the long-term impact of deer and other herbivores on natural and commercial woodlands and, more importantly, specifically on the ways to resolve these land use problems.

8 Conclusions

Most upland mammals are increasing in Scotland and present-day systems of commercial forestry encourage them. Whereas no species of mammal is threatened by afforestation, more diverse habitats created through planting mixtures of trees will benefit most wildlife; more diverse habitats also have landscaping and amenity value and are silviculturally desirable. However, we need to know more about the extent, shape, distribution and size of hardwood 'islands' to encourage particular species of mammals, and about the consequences of these habitat improvements on others, including pests.

Most studies of the ecology of woodland mammals have been done either in broadleaved woods in the lowlands or in first rotation conifer crops in the Borders. There is a need for more studies which relate specifically to the major forest types in northern Britain and to the second rotation crops which will be the predominant woodland habitats in Britain in the future.

9 Summary

The status, distribution and impact of mammals are discussed, with particular reference to upland conifer plantations.

Most British mammals are naturally woodland dwellers, but few depend entirely on either broadleaved or coniferous woods. Plantation structure is regarded as having a more important effect on the numbers and distribution of most mammals than woodland type.

Overall, most mammals have benefited from the afforestation of open hill land, but concern is expressed over the loss of broadleaved woodlands.

Second rotation forests will be structurally more diverse and, because of short rotations, will have a large proportion of young, open canopy forest. These forests should make ideal habitats for most mammals, including pests.

More research is needed on the ecology of mammals in northern Scotland, and specifically in second rotation crops as these will become the predominant forest types in the future.

10 References

Arnold, H.R., ed. 1984. *Distribution of the mammals of the British Isles. (Provisional.)* Abbots Ripton: Institute of Terrestrial Ecology.

Bewick, T. 1800. *A general history of quadrupeds.* Newcastle-on-Tyne.

Birkan, M. 1968. Repartition écologique et dynamique des populations d'*Apodemus sylvaticus* et *Clethrionomys glareolus* en pinnède à Rambouillet. *Terre Vie,* **3,** 231–273.

Booth, T.C. 1984. Natural regeneration in the native pinewoods of Scotland. A review of principles and practice. *Scott. For.,* **38,** 33–42.

Chapman, N.G. & Chapman, D.I. 1980. The distribution of fallow deer: a world wide review. *Mammal Rev.,* **10,** 61–138.

Charles, W.N. 1956. The effect of a vole plague in the Carron Valley, Stirlingshire. *Scott. For.,* **33,** 280–288.

Charles, W.N. 1981. Abundance of field voles (*Microtus agrestis*) in conifer plantations. In: *Forest and woodland ecology,* edited by F.T. Last & A.S. Gardiner, 135–137. Cambridge: Institute of Terrestrial Ecology.

Corbet, G.B. 1971. Provisional distribution maps of British mammals. *Mammal Rev.,* **1,** 95–142.

Corbet, G.B. & Southern, H.N. 1977. *Handbook of British mammals.* 2nd ed. Oxford: Blackwell Scientific.

Cuthbert, J.H. 1973. The origins and distribution of feral mink in Scotland. *Mammal Rev.,* **3,** 97–103.

Danilov, D.N. 1938. The calorific value of main food-stuffs of the squirrel. *Zool. Zh.,* **17,** 734–738.

Edwards, I.D. 1980. *The conservation of the Glen Tanar native pinewood near Aboyne, Aberdeenshire.* PhD thesis, University of Aberdeen.

Flowerdew, J. 1984. *Woodmice.* Oswestry: Anthony Nelson.

Forestry Commission. 1983. *Census of woodlands and trees 1979–1982.* Edinburgh: FC.

Green, J. & Green, R. 1980. *Otter survey of Scotland 1977–79.* London: Vincent Wildlife Trust.

Gurnell, J. 1979. *Woodland mice.* (Forestry Commission forest record no. 118.) London: HMSO.

Gurnell, J. 1981. Woodland rodents and tree seed supplies. In: *Proc. Conf. Worldwide Furbearers,* edited by J.A. Chapman & D. Pursley, 1091–1124. Falls Chard: R.R. Donelly & Sons Co.

Gurnell, J. 1983. Squirrel numbers and the abundance of tree seeds. *Mammal Rev.,* **13,** 133–148.

Hewson, R. & Kolb, H. 1974. The control of foxes in Scottish forests. *Scott. For.,* **28,** 272–282.

Hewson, R. & Leitch, A.F. 1983. The food of foxes in forests and on the open hill. *Scott. For.,* **37,** 39–50.

Hill, M.O. 1979. The development of a flora in even-aged plantations. In: *The ecology of even-aged forest plantations,* edited by E.D. Ford, D.C. Malcolm & J. Atterson, 175–192. Cambridge: Institute of Terrestrial Ecology.

Jenkins, D. 1962. The present status of the wild cat *Felis silvestris* in Scotland. *Scott. Nat.,* **70,** 126–138.

König, E. & Gossow, H. 1979. Even-aged stands as habitat for deer in central Europe. In: *The ecology of even-aged forest plantations,* edited by E.D. Ford, D.C. Malcolm & J. Atterson, 429–451. Cambridge: Institute of Terrestrial Ecology.

Langley, P.J.W. & Yalden, D.W. 1977. The decline of the rarer carnivores in Great Britain during the nineteenth century. *Mammal Rev.,* **7,** 95–116.

Leopold, A.S. 1978. Wildlife and forest practice. In: *Wildlife and America,* edited by H.P. Brokaw, 108–120. U.S. Forestry & Wildlife Service. Forestry Service.

Lloyd, H.G. 1981. *The red fox.* London: Batsford.

Lloyd, H.G. 1983. Past and present distribution of red and grey squirrels. *Mammal Rev.,* **13,** 69–80.

Lockie, J.D. 1964. Distribution and fluctuations of the pine marten *Martes martes* (L.) in Scotland. *J. Anim. Ecol.,* **33,** 349–356.

Loudon, A.S. 1980. *The biology and management of roe deer in commercial forests.* University of Edinburgh.

Lowe, V.P.W. 1969. Population dynamics of red deer (*Cervus elaphus* L.) on Rhum. *J. Anim. Ecol.,* **38,** 425–457.

MacDonald, D.W., Bunce, R.G.H. & Bacon, P.J. 1981. Fox populations, habitat characterization and rabies control. *J. Biogeogr.,* **8,** 145–151.

Mellanby, K. 1968. The effects of some mammals and birds on the regeneration of oak. *J. appl. Ecol.,* **5,** 359–366.

Middleton, A.D. 1931. A contribution to the biology of the common shrew *Sorex araneus* Linnaeus. *Trans. zool. Soc. Lond.,* **133,** 133–143.

Miles, J. & Kinnaird, J.W. 1979a. The establishment and regeneration of birch, juniper and Scots pine in the Scottish Highlands. *Scott. For.,* **33,** 102–119.

Miles, J. & Kinnaird, J.W. 1979b. Grazing: with particular reference to birch, juniper and Scots pine in the Scottish Highlands. *Scott. For.,* **33,** 280–288.

Mitchell, B., Staines, B. W. & Welch, D. 1977. *Ecology of red deer: a research review relevant to their management in Scotland.* Cambridge: Institute of Terrestrial Ecology.

Mitchell, B., Grant, W. & Cubby, J. 1981. Notes on the performance of red deer *Cervus elaphus* in a woodland habitat. *J. Zool.,* **194,** 279–284.

Moller, H. 1983. Foods and foraging behaviour of red (*Sciurus vulgaris*) and grey (*Sciurus carolinensis*) squirrels. *Mammal Rev.,* **13,** 81–98.

Moss, D. 1978. Diversity of woodland song-bird populations. *J. Anim. Ecol.,* **47,** 521–527.

Newton, I. 1983. Birds and forestry. In: *Forestry and conservation,* edited by E.H.M. Harris, 21–36. Tring: Royal Forestry Society.

Newton, I. & Moss, D. 1981. Factors affecting the breeding of sparrowhawks and the occurrence of their song-bird prey in woodlands. In: *Forest and woodland ecology,* edited by F.T. Last & A.S.Gardiner, 125–131. (ITE symposium no. 8.) Cambridge: Institute of Terrestrial Ecology.

Parr, T. 1981. Scottish deciduous woodlands: a cause for concern? In: *Forest and woodland ecology,* edited by F.T. Last & A.S. Gardiner, 12–15. (ITE symposium no. 8.) Cambridge: Institute of Terrestrial Ecology.

Pulliainen, E. 1973. Winter ecology of the red squirrel (*Sciurus vulgaris* L.) in northeastern Lapland. *Ann. zool. fenn.,* **10,** 487–494.

Pulliainen, E. 1982. Habitat selection and fluctuations in numbers in a population of the arctic hare (*Lepus timidus*) on a subarctic fell in Finnish Forest Lapland. *Z. Säugetierk.,* **47,** 168–174.

Purroy, F.J. & Rey, J.M. 1974. Estudio ecologico y systematico de l'ardilla (*Sciurus vulgaris*) en navarra distribicion, densidad de poblaciones, alimentacion actividad diana y anual. *Bul. Estac. Cent. Ecol.,* **3,** 71–82.

Ratcliffe, P.R. 1984. Population dynamics of red deer (*Cervus elaphus* L.) in Scottish commercial forests. *Proc. R. Soc. Edinb.,* **82B,** 291–302.

Ratcliffe, P.R. 1986. The distribution and current status of sika deer, *Cervus nippon,* in Great Britain. *Mammal Rev.* In press.

Ratcliffe, P.R. & Petty, S.J. 1986. The management of commercial forests for wildlife. In: *Trees and wildlife in the Scottish uplands,* edited by D. Jenkins, 177–187. (ITE symposium no. 17.) Abbots Ripton: Institute of Terrestrial Ecology.

Ratcliffe, P.R., Hall, J. & Allen, J. 1986. Computer predictions of sequential growth changes in commercial forests as an aid to wildlife management, with reference to red deer. *Scott. For.* In press.

Reynolds, J.C. 1981. *The interaction of red and grey squirrels.* PhD thesis, University of East Anglia.

Ritchie, J. 1920. *The influence of man on animal life in Scotland: a study of faunal evolution.* Cambridge: Cambridge University Press.

Sakura, T., Gimingham, C.H. & Millar, C.S. 1985. Effect of tree density on ground vegetation in a Japanese larch population. *Scott For.,* **39,** 191–198.

Shorten, M. 1954. *Squirrels.* (New naturalist no. M12.) London: Collins.

Staines, B.W. 1980. The management of mammals in forestry plantations and research strategies. In: *Research strategy for silviculture,* edited by D.C. Malcolm, 100–105. Edinburgh: Institute of Foresters of Great Britain.

Staines, B.W. 1983a. The conservation and management of mammals in commercial plantations with special reference to the uplands. In: *Forestry and conservation,* edited by E.H.M. Harris, 38–55. Tring: Royal Forestry Society.

Staines, B.W. 1983b. Studies of growth, reproduction and food of red deer and their relevance to management. In: *Some research on deer and its relevance to management,* 25–30. Warminster: British Deer Society.

Staines, B.W. & Welch, D. 1981. Deer and their woodland habitats. In: *Forest and woodland ecology,* edited by F.T. Last & A.S. Gardiner, 138–142. (ITE symposium no. 8.) Cambridge: Institute of Terrestrial Ecology.

Staines, B.W. & Welch, D. 1984. Habitat selection and impact of red (*Cervus elaphus* L.) and roe (*Capreolus capreolus* L.) deer in a Sitka spruce plantation. *Proc. R. Soc. Edinb.,* **82B,** 303–319.

Stewart, L.K. 1976. The Scottish red deer census. *Deer,* **3,** 529–532.

Stewart, L.K. 1979. The present position: the red deer population. In: *The next twenty years,* 4–5. Inverness: Red Deer Commission.

Stewart, L.K. 1985. Red deer. In: *Vegetation management in northern Britain,* edited by R.B. Murray, 45–50. Croydon: British Crop Protection Council.

Taylor, W.L. 1946. The wild cat (*Felis silvestris*) in Great Britain. *J. Anim. Ecol.*, **15,** 130–133.

Tee, L.A., Rowe, J.J. & Pepper, H.W. 1985. *Mammal/bird damage questionnaire 1983.* (Research and development paper no. 137.) Edinburgh: Forestry Commission.

Tittensor, A.M. 1970. *The red squirrel* (Sciurus vulgaris *L.) in relation to its food resource.* PhD thesis, University of Edinburgh.

Venables, L.S.V. & Venables, U.M. 1971. Mammal population changes in a young conifer plantation 1960–1970. Newborough Warren, Anglesey. *Nature Wales,* **12,** 159–163.

Verlanders, K.A. 1983. *Pine marten survey of Scotland, England and Wales.* London: Vincent Wildlife Trust.

Watson, A. & Hewson, R. 1973. Population densities of mountain hares (*Lepus timidus*) on western Scottish and Irish moors and on Scottish hills. *J. Zool.*, **170,** 151–159.

Welch, D., Staines, B.W., Scott, D. & Catt, D.C. 1983. Browsing damage done by red deer to young stands of Sitka spruce. *Annu. Rep. Inst. terr. Ecol. 1982,* 10–12.

Welch, R.C. 1986. What do we know about insects in Scottish woods? In: *Trees and wildlife in the Scottish uplands,* edited by D. Jenkins, 95–100. (ITE symposium no. 17.) Abbots Ripton: Institute of Terrestrial Ecology.

Whitehead, G.K.W. 1964. *The deer of Great Britain and Ireland.* London: Routledge & Kegan Paul.

Whitehead, G.K.W. 1972. *The wild goats of Great Britain and Ireland.* Newton Abbot: David & Charles.