Forestry and Bird Diversity in Ireland: A Management and Planning Guide

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First published in 2002 by COFORD, National Council for Forest Research and Development, Belfield, Dublin 4, Ireland.

ISBN 1 902696 26 3

Title: Forestry and bird diversity in Ireland: a management and planning guide
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Citation: O'Halloran, J., Walsh, P.M., Giller, P.S. and Kelly, T.C. 2002. Forestry and bird diversity in Ireland: a management and planning guide. COFORD, Dublin.

Cover photograph: Sparrowhawk on nest.
Photographs by Richard Mills.

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FOREWORD

Forest management in Ireland is increasingly concerned with the multiple use of forests. Socio-economic and environmental objectives now have equal importance with wood production and income generation.

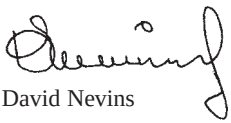
Biodiversity protection and enhancement is now part of forest management planning. It has been enshrined in the National Forest Standard, the Code of Best Forest Practice and the Forest Service Guidelines.

Much of the information used in the development of standards and guidelines has come from COFORD-funded research on the environmental interactions of forests, including a number of projects funded under our previous programme that ended in 2000. Research on the interaction of forests with biodiversity, encompassing both flora and fauna, continues in the BIOFOREST project.

This publication concentrates on bird fauna. The research on which it is based was conducted by a dedicated team of scientists at UCC. It is particularly gratifying to see this ground-breaking work, much of which has been published and disseminated in Ireland and abroad, brought to bear in the design of management and planning guidelines on how to encourage bird diversity in forests. Not only will the guidelines be of benefit to bird populations but overall biodiversity will benefit from their use in forest management.

The report is written in a direct and practical manner that will allow forest owners and managers to appreciate the importance of encouraging bird diversity. The content and style will also allow managers to cost-effectively encourage and promote bird diversity in their forests.

Dr Eugene Hendrick
Director



David Nevins
Chairman

COFORD
October 2002

ACKNOWLEDGMENTS

The input of representatives of the following organisations in the provision of comments on an earlier draft are acknowledged and appreciated:
Coillte;
Dúchas - The Heritage Service;
Department of Environmental Research Management, University College Dublin;
Forest Ecosystem Research Group, University College Dublin;
The Forest Service;
The Heritage Council;
Irish Timber Growers Association;
Irish Wildlife Trust;
National Association of Regional Game Councils;
Society of Irish Foresters;
Southwestern Forestry Services;
An Taisce;
Department, University of Limerick (Dr John Breen).

SUMMARY

With the continued expansion of commercial forestry in Ireland, influences on biodiversity (the 'variety of living things') have been the subject of much concern and debate. Interactions between forestry and breeding birds are widely seen as an important aspect of this, variously reflecting the high public profile of birds, the availability of good data on their conservation requirements and their potential value as indicators of other components of biodiversity.

This manual aims to help foresters and landowners to optimise or maximise bird diversity by suggesting ways of minimising negative effects through appropriate forest planning. We also suggest ways of maximising the benefits of forest habitat itself through appropriate management or enhancement of forest structure and composition. The focus is on managed coniferous forests and on breeding birds. Recommendations made here are based on an assessment of best current knowledge, but further research specific to Ireland is needed in some cases. Habitat features of benefit to breeding birds will, in most cases, benefit other components of forest (and wider landscape) biodiversity.

The main recommendations outlined in this guide can be summarised as follows:

- Avoid replacement of important or sensitive natural habitats, and assess avian usage of sites being considered for planting.
- Retain or protect non-forest habitat features within or bordering a planted forest for example ponds and hedgerows.
- Avoid blanket afforestation, and aim to retain some areas of open habitat, both at forest and landscape scales.
- Plant or encourage regeneration of broadleaved species, appropriate to the site and preferably in small patches or along edges, in otherwise coniferous stands.
- Plant a mix of coniferous species, e.g. pine and larch among spruce, and plant conifers such as Norway spruce, Douglas fir, Scots pine and larch on suitable sites.
- Aim to maintain a wide range of age-classes of trees, at least on a landscape level, including some sheltered areas beyond normal felling age.
- Aim for irregular stand boundaries in large plantations, to increase the ratio of edge to interior habitat, and encourage growth of broadleaved trees and scrub along both external and internal edges.
- Where possible, aim for a mix of forest patches of different sizes, e.g. many small or medium plots, with a few larger patches.
- Planning and management of an afforested area at a property or landscape scale should ideally ensure that losses and gains of early-successional and late-successional forest are as gradual and closely balanced as possible, to provide habitat for a wider range of bird species.
- If possible, concentrate intensive management and harvesting on the most productive stands and allow retention of less productive parts beyond normal felling age.
- Delay harvesting where bird species of high conservation value are known to be nesting.
- Exclude livestock from plantations, to encourage growth of herb, shrub and undergrowth layers that benefit a range of bird species.
- Thinning, resulting in increased light penetration, can provide a flush of understorey and ground vegetation growth, likely to benefit species of birds that use these layers.
- Limit, or carefully use, pesticides and herbicides.
- Consider providing artificial nest-sites (e.g. nest-boxes) to encourage particular bird species to use planted forests.

1 INTRODUCTION

1.1 PURPOSE OF THIS MANUAL

The importance of sustainable forest management (SFM), taking account of environmental and social as well as economic factors, is generally appreciated by the forest industry. As part of this process of improvement, some of the necessary basic research on interactions between forestry and biodiversity is being carried out in Ireland.

This manual is one product of a COFORD-funded study on "Forest location and enhancement strategies for biodiversity." A major part of this study has focused on birds, including fieldwork on breeding birds in relation to tree species, tree age and the size/shape of forest stands. As the project title suggests, forest management aimed (in part) at optimising or maximising biodiversity can be examined under two broad headings:

- minimising negative effects resulting from the location of new forests through strategic planning for forestry in the wider countryside;
- maximising the benefits of forest habitat in existing (and planned) forests, through appropriate management or enhancement of forest structure and composition.

The focus of the manual is on coniferous forests; optimising bird diversity, subject to overall management aims for a stand, property, forest, landscape, or region; and breeding birds.

Recommendations made here are based on an assessment of best current knowledge, but further research specific to Ireland is needed in some cases. Where necessary, relevant published information from studies in Britain, continental Europe or North America has been used, but taking into account particular circumstances relevant to Ireland. Direct reference to published work is not generally made in the text, but the list of References and further reading at the end of the report includes the sources used.

1.2 WHY BIRDS?

Although the focus here is on birds (probably the most obvious and widely appreciated component of the wildlife associated with forests), conditions of benefit to birds are likely to provide other biodiversity benefits. For example:

- birds can benefit from factors that also have a positive influence on some other biota, e.g. increased light (e.g., butterflies, ground flora), standing dead wood (e.g. fungi, insects);

- mosaics of tree species, age-classes and other habitats, on various scales, will provide diverse conditions likely to increase diversity of a range of biota, not only birds.

However, attention should be paid to the possibility that site management or enhancement for birds might in some circumstances conflict with conservation requirements of other animal and plant groups or other heritage features.

Birds (or particular species of birds) can be seen as:

- 'umbrella' species, whose habitat-conservation benefits other species;
- 'flagship' species, with a high public profile, whose conservation is seen as a particularly high priority, e.g. birds of prey, or birds as a whole relative to more inconspicuous groups;
- economically important, e.g. game species like woodcock;
- ecologically important, e.g. for natural dispersal of seeds, or as food species for other birds;
- intrinsically important, as individual species, regardless of their perceived importance under other headings.

Maintaining or encouraging diversity of bird (or other) species may not always be the most valuable goal for biodiversity conservation. In some cases, it may be more important to retain or encourage characteristic or scarce or threatened species than to retain or encourage a wider mix of more common species. For example, it is important to avoid converting an important mix of bird species characteristic of a particular habitat (e.g. upland moorland) to a forest bird assemblage, even if this produces an increase in bird species richness or other measures of bird diversity.

1.3 BIRD DIVERSITY AND IRISH FORESTS

General issues in Ireland relevant to maintaining or improving bird diversity include:

- the importance of breeding open country species;
- the importance of the avifauna of our remaining areas of semi-natural broadleaved woodland;

but

- the general lack of large areas of natural or semi-natural woodland;
- the paucity of 'forest interior' species of birds (e.g. large woodland raptors, woodpeckers), and a greater relative importance of forest-edge species than in Britain or mainland Europe;
- the potential for colonisation or re-colonisation of planted forests by forest specialist species;
- provision by new forests of additional habitat for habitat generalists;

and

- the potential for afforestation to compensate for ongoing losses of other habitats, e.g. hedgerow and scrub ('low forest').

A summary of the likely breeding birds at various stages of the coniferous forest cycle is presented in Table 1 (page 4).

1.4 OTHER ENVIRONMENTAL GUIDELINES AND PRACTICES

In some cases, the recommendations made here may already be part of (or consistent with) existing forestry practices, even where the original aim was economic timber production. In particular, the recently revised Forest Service Guidelines for forestry and biodiversity take account of many of the points raised here. Revised guidelines relating to other aspects of the environment and heritage (e.g. freshwater) have been issued by the Forest Service, and will provide a strong basis for environmentally sustainable forestry in the years to come.

Not all recommendations will be appropriate in particular situations, or given other constraints (land-ownership, logistics or economics). However, implementation of at least some of these recommendations in any given situation is likely to have a net benefit for birds. We hope that further refinement of these recommendations, to take account of further research of Irish birds in relation to forestry, will be possible in future. This applies in particular to the expected growth in lowland afforestation, and in the proportion of broadleaved plantations, both of which may raise particular opportunities in relation to maintenance and encouragement of avian diversity.

TABLE 1: CHARACTERISTIC BREEDING BIRDS OF IRISH CONIFEROUS STANDS. SOME SPECIES LISTED ARE RARE NATIONALLY OR IN SOME REGIONS, BUT MAY RESPOND TO FOREST AVAILABILITY, WHILE SOME COMMON SPECIES MAY NOT OCCUR AT ALL ALTITUDES.

Forest Type	*Potential Bird Species Present*
Newly-established forests (0 to 5 years)	Hen Harrier, Nightjar, Skylark, Meadow Pipit, Wren, Dunnock, Stonechat, Whinchat, Grasshopper Warbler, Sedge Warbler, Whitethroat, Reed Bunting.
Young forests, including regenerated forest (5 to 15 years planted)	Hen Harrier, Pheasant, Woodcock, Nightjar, Wren, Dunnock, Robin, Stonechat, Whinchat, Blackbird, Song Thrush, Grasshopper Warbler, Sedge Warbler, Whitethroat, Blackcap, Chiffchaff, Willow Warbler, Goldcrest, Coal Tit, Siskin, Linnet, Redpoll, Reed Bunting.
Older forests (20 to 50+ years) a. General	Grey Heron, Woodcock, Woodpigeon, Wren, Dunnock, Robin, Blackbird, Song Thrush, Mistle Thrush, Goldcrest, Coal Tit, Treecreeper, Jay, Hooded Crow, Raven, Chaffinch, Siskin, Crossbill, Bullfinch
Older forests (20 to 50+ years) b. Edges and smaller stands	Sparrowhawk, Merlin, Long-eared Owl, Chiffchaff
Older forests (20 to 50+ years) c. Broadleaved edges/patches	Pheasant, Blackcap, Spotted Flycatcher, Blue Tit, Great Tit, Long-tailed Tit

2 CHOICE OF SITES FOR AFFORESTATION

2.1 FOREST LOCATION: AVOIDANCE OF SENSITIVE AREAS OR PARTICULAR HABITATS

A recent review of Irish forestry policy from an environmental viewpoint (Hickie *et al.* 1993) listed the following as "priority habitats for conservation in their present state":

- lightly grazed and undrained active blanket bogs and raised bogs;
- good quality heather moorland;
- seasonally flooded pasture and meadows;
- river banks and lake shores;
- unimproved dry grassland;
- existing native woodland;
- coastal grasslands, e.g. sand dunes and machair.

Most of these habitats will be important for birds, although the importance of a particular site may vary. Local survey data may be required for proper assessment, and consultation with Dúchas and BirdWatch Ireland is recommended where forestry development is being considered. Although some of these habitats may seem unlikely locations for forestry, some have been planted in the past. It is recommended that planting be avoided in these habitats.

Other important bird habitats that could be replaced or damaged by afforestation include:

- streams in acid-sensitive catchments (where conifer-mediated acidity may reduce breeding success of bird species like dippers).
- lowland fens and marshes, including reed beds (direct losses to tree-planting, or loss through lowering of water table as a result of pre-planting drainage or water uptake by trees).

Birds of upland and moorland habitats are probably the group most vulnerable to loss of habitat as a result of afforestation. Data on the distribution of these species have recently been reviewed by the authors, and a sample map is presented here showing areas with the highest diversity of relevant species (Figure 1). Many of these species nest and feed only in open habitats, while others are capable of nesting in young plantations (e.g. hen harrier) or along the edges of older plantations (e.g. raven, merlin) but require open habitats for foraging. Extensive afforestation, with resultant ‘fragmentation’ of open habitats into smaller, perhaps widely-separated, patches, can lead to losses of such species on local or landscape scales. Many, but not all, of the important squares identified by this study coincide with statutory Special Protection Areas, Special Areas of Conservation or Natural Heritage Areas in the Republic of Ireland. Some restrictions already exist on forestry activities within these areas, although afforestation may be permitted in some circumstances.

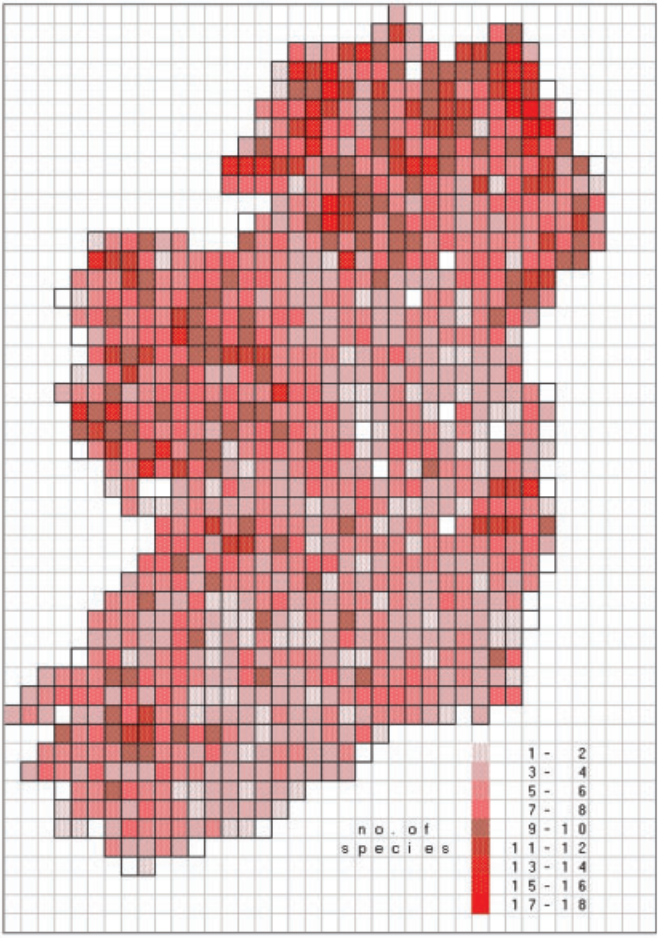


FIGURE 1: NUMBERS OF UPLAND OR FORESTRY-SENSITIVE BIRD SPECIES (BASED ON A LIST OF 21 POTENTIAL SPECIES) RECORDED DURING THE 1988-91 BREEDING ATLAS (GIBBONS *ET AL*. 1993). RECORDS INCLUDE PROBABLE/CONFIRMED BREEDING AND OTHER (SUMMERING) RECORDS.

Identification of acid-sensitive catchments, i.e. where the underlying geology provides poor 'buffering' capacity against possible acidic inputs caused by the interception of pollutants from the atmosphere by coniferous forests, is important from a fisheries viewpoint, but is also important for maintaining optimal conditions for some bird species (e.g. dipper).

In terms of conserving bird diversity, the following general recommendations can be made:

- Target less important or less sensitive habitats for planting of coniferous forests.
- Where possible, use 'degraded' (e.g. heavily grazed) or developed land for planting in preference to natural or semi-natural habitats.
- Planning of new forest locations should take published data on birds into account, to identify areas likely to be inappropriate for afforestation or where, at least, detailed pre-surveys are needed before precise forest locations are confirmed.
- For EIS (Environmental Impact Statement) purposes, where existing data are inadequate, adequate bird surveys should be commissioned at appropriate times of year (spring/summer for breeding birds, winter for some species, e.g. Greenland white-fronted goose).
- Take account of the wider implications of planting on any site, including potential influences of adjacent sensitive habitats.

Soil, topography (e.g. elevation, slope, aspect) and climate may have strong influences on general biodiversity in forests, through their influence on the length of the growing season, on energy availability/productivity and vegetation structure within a habitat and more direct effects on animals or plants themselves (e.g. temperature, humidity).

Recommendations:

- Where possible, concentrate afforestation in more productive locations as this will minimise the planted area required for a given timber yield, thus helping to reduce pressure on open habitats (especially in the uplands) that support important bird populations.

Raven nestlings in an old castle.

2.2 FRAGMENTATION OF EXISTING WOODLAND

Although the major losses of our natural or semi-natural woodland have long since occurred, further fragmentation of such woodland into smaller blocks needs to be avoided. Consolidation of existing areas into larger blocks may be required.Even the conversion of small parts of existing broadleaved woodland (including scrub) stands to coniferous plantation could have significant fragmentation effects, reducing the already limited area of semi-natural woodland available to birds and other wildlife. However, in general this practice does not occur in Ireland.

Recommendations:

- Avoid partial or complete replacement of existing broadleaved stands with conifers.
- Consolidate existing areas of natural or semi-natural woodland into larger blocks.

2.3 RETENTION OR PROTECTION OF EXISTING NON-FOREST HABITAT FEATURES

Within or immediately adjacent to a new forest, other habitats can contribute to avian diversity. On agricultural land, planted for forestry, remnants of field boundaries or even buildings, e.g. raised ditches or walls, may provide nesting habitat for birds such as blue tit and wren. Ponds or marshy areas, if left undrained and unplanted, may support additional species of bird within a forest (even at the compartment level), and also provide valuable habitat for amphibians and insects. Retention of adjacent hedgerows or scrub (low forest) will increase connectivity to the surrounding countryside. These habitats in themselves may support bird species that might otherwise only use the forest itself over part of its rotation or for foraging. Adequate unplanted zones between forests and non-forest features may also be important, e.g. to prevent excessive shading of ponds.

Young kestrel on an old wall.

Recommendations:

- Retain remnant field boundaries and buildings when afforesting ex-agricultural sites.
- Retain ponds or marshy areas.
- Retain adjacent hedgerows or scrub.
- Allow buffer zones between forested and unforested features.

2.4 AVAILABILITY OF NON-FOREST COVER

Long-eared owls at nest.

Non-forest cover is particularly important for bird species characteristic of open habitats, e.g. breeding waders in the uplands. However, some species that nest (or can nest) in coniferous plantations also require open habitats for foraging. Examples include sparrowhawk, merlin, long-eared owl and raven. Where the forest area is extensive, such species may nest only around the edges, or in individual small blocks, and forage in surrounding habitats. Open habitat will also benefit other animals and plant groups. Further research aimed at quantifying the value of open areas, at various scales, may lead to further suggestions for mandatory targets for open areas.

Recommendations:

- Avoid blanket afforestation, and aim to retain some areas of existing open habitat, the larger the better, within forests and, particularly, within landscapes as a whole.
- Within a given forest area, aim to have 5 to 10% open space and/or retained habitat.

2.5 CONNECTIVITY

The spatial arrangement of forest stands in a landscape can affect the location, movements, foraging and persistence of species, including birds. Retaining corridors such as hedgerows through surrounding countryside (in lower-altitude areas) is likely to contribute to maintenance of avian diversity, and may increase the likelihood of colonisation of forest blocks by some species (but less so than in the case of small mammals). Reduced contrast between forest patches and the surrounding habitats can increase connectivity between forest patches. For example, the transition from high forest through low forest to pasture is less abrupt transition than that from high forest to pasture.

Recommendations:

- Retain corridors such as hedgerows through surrounding countryside.
- Reduce contrast between forested and open habitats.

Sparrowhawk at nest.

2.6 SET-ASIDE OF SOME LAND AS CONSERVATION AREAS

Larger-scale owners of forest lands may consider the possibility of retaining some planted areas on a non-commercial basis, to provide longer-term habitat for birds and other forest biota. This is particularly valuable if the conserved area has features or species of particular interest. Such conserved areas would also be potentially valuable for educational and research purposes, and as sources for colonisation of new, or newly matured, stands elsewhere in the same forest or landscape.

Recommendations:

- Set-aside some forest areas for non-commercial conservation, educational and research benefits.
- Encourage growth of large trees beyond normal felling size and age.

3 FOREST DESIGN: COMPOSITION AND STRUCTURE

3.1 TREE SPECIES

Coal tit among catkins.

Work on pole-stage plantations in the south west of Ireland suggests that coniferous stands that have a higher number of broadleaved tree species present also have the highest numbers of breeding bird species. Stands dominated by Douglas fir and Norway spruce appeared to support higher species richness of breeding birds than comparable stands of Sitka spruce, Noble fir, pines and Japanese larch. Possible influences of other factors (e.g. altitude and soil quality) could not be ruled out, but there are good theoretical grounds for a relationship between tree species richness and bird species richness. No significant relationship was found between the number of coniferous species in a stand (or at a study point) and the number of bird species. Nevertheless, some species appeared to favour particular conifers: for example, goldcrests occurred most frequently at study-points dominated by spruces and firs, coal tits at points dominated by lodgepole pine and noble fir. Stands of Japanese larch and Scots pine generally had well-developed ground vegetation (reflecting increased light penetration in spring), and this favoured some bird species (e.g. wren). Long-eared owls in Co Cork showed an apparent preference for stands containing Scots pine or other pine, perhaps a reflection of the greater suitability of pines (compared with spruces) as nest locations. In winter, greenfinches in Munster showed a strong preference for stands of noble fir, reflecting the suitability of the cones for feeding.

Studies in Wales have also indicated that broadleaved trees can increase bird species richness in coniferous plantations, for example by providing suitable habitat for chiffchaffs and other warbler species. For maximum benefit, it was suggested that broadleaved trees be provided in patches, rather than single trees. However, it is important to keep in mind that coniferous trees provide an important habitat or refuge for red squirrels as well as bird species.

Many first rotation coniferous plantations in Ireland are dominated by Sitka spruce and lodgepole pine, species which were considered likely to grow well on 'virgin' sites of uncertain productivity. It is now clear that some sites are capable of supporting more demanding species (e.g. Norway spruce).

Wren with nesting material.

Recommendations:

- Plant a proportion of broadleaved species that are appropriate to the site (and preferably native to the region), preferably in small patches, rather than as isolated trees.
- Where possible, retain existing native trees as habitat features in themselves, and as sources for natural dispersal (individual trees, small patches, riparian zones or large patches).
- Allow or actively encourage regeneration of native broadleaves (aided by retention trees), at least along edges.
- Where yields from conifers are uneconomic or subject to controls (e.g. riparian zones) consider replacing with, or allowing natural regeneration of, broadleaves.
- Preferably establish a mix of coniferous species, e.g. pine and larch among spruce.
- Where possible, plant Norway spruce, Douglas fir, Scots pine or larch in preference to Sitka spruce or lodgepole pine, where suitable soil conditions exist.
- Where Sitka spruce or lodgepole pine are harvested from sites that are now known to be capable of supporting more demanding trees species, consider replanting with such species.

3.2 AGE OF TREES

Bird diversity and abundance show changes in relation to the age (or height) of a forest stand. Work done by the authors indicates that, in the very early stages of a plantation in Ireland, some open-country nesting birds are likely to be retained in the short-term, e.g. meadow pipit. As the scrub layer (young conifers and naturally regenerating broadleaves) increases, bird species diversity tends to increase, but additional open-country species are lost. The diversity of warbler species tends to be highest in the early or intermediate stages of a plantation (ca. years 5-15), with willow warbler often the most abundant breeding bird present. As canopy closure and tree height increase, scrub-nesting species are replaced by species typical of higher forest, e.g. goldcrest and chaffinch. Although bird diversity or species richness may be lower late in the forest succession (in Ireland and other parts of Europe at least), densities of birds tend to be higher (presumably reflecting greater total availability of food). Overall bird diversity or species richness in a given forest area will tend to be highest if a good mix of trees in different age-classes is available.

Habitat availability for cavity-nesting birds (notably blue and great tits) will tend to be greatest in older forests, but coniferous plantations rarely reach a stage where decay or damage provide suitable nest-holes. Retention of some trees, preferably in wind-stable patches,

beyond normal felling age, is likely to increase nest-hole availability, and is recommended.

Recommendations:

- Aim to maintain a wide range of age-classes (cohorts) at least on a landscape scale. This may require adjustment of harvesting schedules, to produce a more even range of age-classes (including trees beyond normal harvesting age). However, very small-scale mosaics of tree ages (e.g. <0.1 ha patches of young trees among older trees) may be of relatively little benefit in providing habitat for additional bird species.
- Retain some sheltered areas of trees beyond normal felling age, indefinitely if possible. Suitable areas may include stream margins, or terrain where harvesting is particularly difficult.
- Further thinning within retained patches of older trees may be beneficial since this would allow development of 'old-growth' characteristics such as large limbs which are more likely to produce nest-cavities through decay or loss.

3.3 EDGE/SHAPE OF FOREST STANDS

Although forest edges are favoured by some wildlife (e.g. game species), and may hold large numbers of some species, increases in edge habitat resulting from forestry activities can cause problems in forests where important species depend on 'interior' habitat. In Ireland, this is not generally perceived as a problem, as most of our remaining forest wildlife does not appear to depend strongly on forest interiors. In fact, increasing the amount of edge habitat is likely to have an overall positive influence on biodiversity of many animal and plant groups, notably birds.

Nevertheless, created forest edges tend to differ markedly from natural edges, by being more abrupt, by having a greater influence on adjacent forest (e.g. through wind damage resulting from clearfelled areas larger than natural gaps), by tending to cut across the landscape without regard for natural landscape features, or by their greater length. With appropriate planning and management, created forest edges can be brought to more closely resemble natural edges, with resultant likely benefits for biodiversity, particularly if retained from rotation to rotation.

Typical forest edge bordering farmland.

Forest edges commonly fall into three basic types:

- recent edge (well developed canopy but little understorey, e.g. after adjacent clearfelling);
- closed edge (following growth of shrubs and adventitious limbs along the edge);
- embedded edge (following tree growth in a clearfell area, there may be a discontinuity between tree species or tree age-classes rather than an abrupt edge).

Edges between two habitats may support birds that are specific to the edge (e.g. those requiring dense ground-cover), species that require both habitats, species primarily associated with one of the habitats, a well as habitat generalists. Bird diversity and abundance may thus be higher along the edge than in either adjacent habitat. If an edge is too abrupt, birds specific to the edge (requiring the 'ecotone' or gradation between two habitats) may be absent.

Forest edges contribute to bird diversity by:

- providing additional habitat, e.g. through the influence of increased light (influencing insect availability, and plant growth), shelter, increased availability of fruit-bearing plants, and increased likelihood of colonisation by scrub or naturally regenerating tree species;
- providing ready access to non-forest habitat required by some forest-nesting birds.

Potential negative effects include:

- Nest-predation rates may increase along forest edges compared with forest interiors. Effects are likely to be highest at farmland/forest edges, e.g. predation by corvids such as hooded crows.
- Edges are generally less sheltered during adverse weather conditions, and this may reduce numbers of some birds in winter (though this may be compensated for by other species feeding predominantly along the edge).
- General disturbance by outside factors, e.g. grazing livestock, will tend to be higher where the amount of edge is greater.

The influence of edge on a forest block will tend to be highest in small stands, where a higher proportion of the forest stand will be within any defined distance of the edge (the 'edge zone'). Stands with a complex shape will also have a higher ratio of edge to interior habitat. Thus, small blocks, or larger blocks with relatively long edges, are likely to show the most marked benefits of edge in terms of numbers of bird species present. Species requiring larger areas of interior habitat, however, are likely to occur disproportionately in larger or more regularly-shaped stands (this is an important consideration in North America where management for conservation generally aims to reduce rather than encourage edge effects). In Ireland, edge effects (including colonisation by 'non-forest-specialists') can generally be seen as positive, at least in the case of coniferous plantations.

Recommendations:

- Encourage the growth of broadleaved trees and scrub along forest edges, preferably in broad irregular bands of mixed species.
- Aim for irregular, rather than straight, stand boundaries, to increase the ratio of edge to interior habitat.
- Internal edges, e.g. existing roads and fire-breaks, can also be valuable for birds, particularly if broadleaved trees and scrub are encouraged.

3.4 PATCH SIZE

As noted above, smaller blocks of forest will have higher proportions of edge zone than larger blocks of the same shape, and this may increase bird diversity per given area. This may be of particular importance in Ireland where a high proportion of our 'woodland' bird species could be considered 'woodland edge' specialists. However, it is possible that mortality may be higher or nesting success lower in smaller patches, and that there may be less long-term persistence of species in smaller patches. A mix of forest patches of different sizes is likely to be optimal for overall bird diversity in a landscape, forest or property.

Recommendation:

- Where possible, the aim should be to achieve a mix of forest patches of different sizes, subject to other constraints (e.g. landownership, economics and logistics).

3.5 DEAD AND DYING TREES, AND 'PATCH RETENTION'

Avian usage of dead wood mainly involves 'snags' (standing dead trees or tall remnants), rather than 'logs' (fallen trees), in the North American terminology. In Ireland, dead trees, or old, partly decayed trees, provide structural complexity, particularly by providing nest cavities for birds like blue and great tit, and treecreeper. Ireland lacks woodpeckers, which are 'primary cavity-nesting' birds capable of excavating their own nest-holes (which may also provide nest sites for other, 'secondary cavity-nesting' birds like tits). Most cavities thus become available through fungal and insect damage. Fungal damage to living trees (following branch death) can also provide cavities. North American work indicates that snag or dead limbs less than 10 cm in diameter tend to be of little or no use as nest-sites for cavity-nesting birds. Old forests typically have large amounts of dead

wood, or living trees with cavities, but there is much less in managed coniferous plantations.

When a forest stand is harvested, retention of patches of living trees or standing dead wood, or even individual trees, can provide valuable habitat for some birds that might otherwise be lost during the early regrowth stage of the next generation of trees. However, retention of dead wood after clearfelling (particularly dead standing trees, intact or otherwise) is somewhat controversial in Ireland because of the risk of bark beetles in the dead wood damaging other trees.

Recommendations:

- Aim to retain some trees and standing dead wood in clearfells: one recommendation is patches of at least 25 m^2, another for five intact trees per ha of clearfell. However, green trees alone are not as good as dead trees for cavity-nesters.
- Retain patches or individual trees of broadleaved species in particular.

In some situations, a decision may be taken not to harvest conifers in the immediate riparian zone (planted before more modern guidelines on forest placement in relation to streams), in order to avoid impacts on stream ecology. Assuming the windthrow risk is low, such linear patches may contribute to avian diversity by providing trees older than the normal felling age and, ultimately, cavities suitable for hole-nesting species.

3.6 HETEROGENEITY

The importance of heterogeniety cannot be over emphasised, as the diversity of birds and of other organisms can, in broad terms, be seen as a reflection of the range of habitats available. This applies over a landscape as a whole (involving forest and non-forest habitats), and within an individual forest, and encompasses many of the points already made.

Recommendations:

- If possible, maintain a broad range of age-classes, including trees beyond normal felling age, to mimic the age-class distribution expected from natural disturbances in forest landscapes.
- Keep patches of different sizes, including large patches.
- Include patches of different habitat types (including non-forest habitats, and different tree species) within or at the margins of forests.

4 HARVESTING

4.1 HARVESTING INFLUENCES ON BIRD POPULATIONS, AND 'RESTRUCTURING' OF FORESTS

The harvesting of large blocks of planted forest is often perceived negatively by the general public, not only from an aesthetic point of view but also because woodland habitat and supporting wildlife is being removed or displaced. However, if planted forests are viewed and managed on a large enough scale, and a sufficient range of tree age-classes is present, such losses can, in part, be balanced by other areas of forest maturing and, in the longer term, by regeneration.

At an early stage in the life of a planted forest (say, the first 30 years), there may be little balance, particularly if whole compartments or properties are felled at the same time. If, however, felling is staggered, so that different parts are felled at, say, five-year intervals, in time the forest area will include all of the age-classes required by particular bird species. Habitat losses in a given year will also be reduced, affecting a smaller proportion of bird populations and increasing the likelihood that some of the birds displaced will find suitable habitat elsewhere. On a wider (landscape) scale, the 'balance' achieved may be even better, and in theory some of the birds displaced by felling from one area of forest can colonise other areas of pole-stage forest (or other suitable habitat). Even the maturing of young plantations may lead to the virtual loss of some bird species within a period of several years, unless replaced (at least in part) by new areas of young plantation (or regeneration after harvesting).

The population implications of the displacement of birds as planted areas are harvested are not fully understood. Woodland birds (especially the smaller passerines) are mainly short-lived species, and opportunities for colonisation of new breeding habitat, and successful breeding there, will always be limited in the short-term. What seems likely is that:

- felling activities in a particular year (even without direct mortality of adults, eggs or nestlings) will produce a short-term net loss in populations of birds dependent on late-successional forest, as alternative areas of suitable habitat will be limited in availability (and may already be fully occupied by the same species);
- populations of other bird species will gradually, especially within five to ten years, benefit from the availability of early-successional habitat after regeneration;
- late-successional bird species will show a partial, gradual recovery as other forest areas mature (and their 'carrying capacity' for late-successional birds increases);

- both early-successional and late-successional bird species supported by coniferous plantations will show population increases in the long-term as the total area of plantation increases.

The important point here is that planning and management of an afforested area at a property or landscape scale should ideally ensure that losses and gains of early-successional and late-successional forest are as gradual and closely balanced as possible, to minimise short-term losses and maximise habitat availability for birds dependent on different growth stages of the forest.

For existing areas of planted forest, it may be possible to 'restructure' the forest to make available a greater range of age-classes at any one time. In essence, such restructuring involves delaying, or staggering, harvesting of some forest areas. Further background on restructuring of plantations is given by Hibberd (1985), based on work in Northumberland.

Recommendation:

- Within a given area of forest, concentrating intensive management and harvesting on the most productive stands may allow retention of less productive parts beyond normal felling age, with likely benefits to birds.

4.2. CLEARFELL SIZE

Large areas of clearfell, with replanted or regenerating trees, are more likely to be colonised by some species of birds (e.g. nightjar) than smaller areas. However, this needs to be balanced against landscape constraints, and against the importance of heterogeneity of age-classes within a landscape, forest or property.

Recommendations:

- For birds, optimum clearfell size in Ireland would probably be in the range of 5 to 20 ha, but the upper range (or larger regenerated areas) should preferably be achieved through staggered clearfelling (e.g. at five-year intervals rather than in a single year).
- Larger areas of clearfell may nevertheless benefit some bird species once regenerated, e.g. breeding nightjar and hunting hen harriers, but preferably should be located within a mosaic including large areas of other age-classes of trees.

4.3 TIMING OF HARVESTING ACTIVITIES

In the short-term, forestry activities can have effects on birds of adjacent habitats, and birds of the forest stand itself, through disturbance, disruption of nesting activities and losses of eggs or nestlings. Although the wood in planted forests is a crop, the forest provides habitat for many generations of birds (and other organisms) over a period of decades. The direct effects of clearfelling (and to a lesser extent thinning) activities on birds that nest in the later growth stages of a forest, should thus be considered, particularly in relation to timing of activities. Where possible, minimise tree felling during the period from April to June, which is the nesting season for the widest range of bird species. However, this may not be feasible in normal circumstances, as felling is normally carried out during periods with dry ground conditions. (Note also that crossbill, raven, grey heron and long-eared owl may begin nesting even earlier in spring or late winter.)

Recommendations:

- Delay harvesting until species of high conservation value that are known to be present (e.g. hen harrier in nearby young plantations or buzzard in harvest-age trees) have completed breeding.
- Where possible, minimise harvesting in potentially sensitive habitats from April to June.
- Timing of activities should also be considered in relation to the general Forest Service guidelines for forestry and biodiversity.

5 OTHER ASPECTS OF FOREST MANAGEMENT

5.1 GRAZING

In addition to damaging young trees, stock such as sheep can reduce the amount of ground cover and undergrowth. Such habitat is important for a range of bird species. In small, unfenced stands among pasture, cattle may present problems by churning up the soil and preventing growth of ground and shrub layers of vegetation.

Recommendation:

- Exclude livestock from plantations, using suitable fencing, to encourage growth of herb, shrub and undergrowth layers that benefit a range of bird species. This may be particularly important for forest patches in agricultural landscapes.

5.2 THINNING AND LIGHT

Canopy closure can have negative consequences for bird species that make use of undergrowth or lower vegetation layers for foraging or nesting. Thinning of trees can provide some compensation.

Recommendation:

- Thinning, resulting in increased light penetration can provide a flush of understorey and ground vegetation growth, if the area thinned is sufficient (e.g. line thinning). This increased vegetation is likely to benefit species of bird that use understorey or ground layers for feeding or nesting.

5.3 PESTICIDES

Little evidence is available about the likely effects of pesticide applications in forests on birds, but a precautionary view should be taken where possible. Birds feeding on invertebrates that have consumed pesticide could accumulate the pesticide within their own tissues. In turn, this could increase direct mortality and the rate of nest failure of birds (including predatory species such as sparrowhawk at the top of the food-chain).

Recommendation:

- Use biodegradable pesticides that will remain active in the forest environment over a shorter period, reducing the likelihood of accumulation up the food chain.

5.4 HERBICIDES

Recommendation:

- Leaving areas of natural vegetation untreated by herbicides like glyphosate can benefit birds, e.g. in clearfelled areas and along forest edges and tracks. For example, selective 'spot or band' spraying in young forests can allow development of patches of natural vegetation.

5.5 WINDTHROW

Windthrow can be a significant problem for forest managers in Ireland, and severe storms may fell patches several hectares in extent. However, windthrow of individual trees, or small patches, can have some benefits for biodiversity, by increasing light penetration and thus the growth of ground and understorey layers of vegetation. For birds, sites with large areas of windthrow are best managed by removing the trees and replanting the entire area or leaving it partly unplanted. In either case, early-successional birds (or birds favouring dense ground-cover or undergrowth) can benefit. For example, colonisation of larger windthrow gaps by willows can benefit willow warblers and other ‘scrub’ species that might otherwise be absent from a forest stand.

Recommendation:

- If fallen trees are removed from windthrown areas, this should ideally be done before regeneration of ground and scrub vegetation likely to be used by nesting birds.

5.6 PUBLIC ACCESS

The public has good access to state forests and this should continue for a wide range of socio-economic reasons.

Recommendations:

- Marked walkways and interpretative signs will encourage public appreciation of the biodiversity value of forests.
- Activities that are inappropriate to a forest setting, and likely to cause excessive disturbance to birds, e.g. clay-pigeon shooting, should be limited.
- Hunting during the appropriate season, e.g. for woodcock, may be worth encouraging, as it may stimulate appreciation of habitat quality (including ground vegetation) in commercial forests and of the value of these forests for game species.

6 FOREST MANAGEMENT FOR PARTICULAR BIRD SPECIES

6.1 ARTIFICIAL NEST-SITES FOR SMALL PASSERINES

Provision of artificial nest-sites may benefit some species that may otherwise be less likely to breed in a given stand or property, or at least may benefit research on such species (if human access to natural nest-sites is difficult). Blue tits and great tits, in particular, are uncommon nesting species in coniferous plantations, given the general lack of availability of natural nest-holes. As shown by research in Co Cork, these species will occupy nest-boxes and colonise previously unoccupied coniferous forest. A small proportion of local coal tits which nest abundantly in conifers, e.g. under the roots even in the absence of obvious nest-holes, will also use the boxes. Boxes along forest edges or rides are most likely to be colonised, and are easiest to locate and check during follow-up studies. In general, however, relatively low proportions of small nest-boxes in coniferous plantations are occupied by small passerines compared with boxes in broadleaved woodland.

Apart from entrance hole sizes, dimensions are not critical for most boxes, according to Du'Feu (1993) who uses the broad categories (Table 2) to describe the size of boxes and height of mounting.

TABLE 2: RECOMMENDED SIZES AND MOUNTING HEIGHTS OF NEST BOXES (DU'FEU 1993).

Size	*Base (mm x mm)*	*Height (mm)*	*Mounting Height*	
Very small	80 x 80	80	Low	About waist to head
Small	100 x 100	150		height
Medium	130 x 130	200	Medium	Chest height to about 5 m
Large	200 x 200	450		
Very large	250 x 600	600	High	Around 5 m and above

Barn owl nest box.

Du'Feu (1993) notes that wood is the best material for making nestboxes, but can be expensive. He recommends that the dimensions of nestboxes are generally not critical and it is easier, cheaper and more effective to make boxes according to wood available rather than to adhere slavishly to precise dimensions.

Recommendation:

- Small nest-boxes with an access hole about 30 mm wide, erected 1.5 to 2 m above ground, are suitable for tit species. Detailed specifications are available (Du'Feu 1993).

6.2 ARTIFICIAL NEST-SITES FOR OWLS AND OTHER BIRDS OF PREY

Barn owls typically nest in cavities in old buildings or hollow trees, but suitable sites may be scarce. The species will readily use artificial sites, including boxes or barrels erected along mature forest edges, if there is access to suitable feeding habitat (open country or stands of young trees) nearby. Although barn owls are not woodland birds, nest-boxes along forest edges may contribute to conservation of this endangered species in Ireland. Note also that bank voles (widely considered a pest in young plantations) are a favoured prey of barn owls in south west Ireland. Long-eared owls typically use crow or magpie nests, but also use artificial platforms.

Recommendations:

- Plastic drums (80 litre ideally), erected vertically, and triangular wooden boxes, both attached by rope 4 to 6 m above the ground, have successfully been used for barn owls - specifications are available (Shaw and Dowell 1991, Dewar and Shawyer 1996).
- Wicker baskets can provide suitable nest-platforms for long-eared owls (perhaps especially in younger trees) (Scott 1991, Dewar and Shawyer 1996).

Barn owl chicks in nest box.

Artificial nest-platforms can also be provided for tree-nesting merlins, but British experience suggests that such platforms are usually unnecessary, given the natural availability of crow and magpie nests. More ambitiously, provision of artificial nest bases for ospreys in old conifers (e.g. lakeside Scots pines) may play a role in the hoped-for colonisation of Ireland from Scotland

6.3 HEN HARRIERS

Hen harriers favour new, young plantations for nesting, perhaps because of the associated abundant, sheltered 'tussocky' cover. Further research on this species might reveal forest management techniques that would increase the suitability of regenerated plantations as nesting habitat (such habitat is generally used for hunting only). On rare occasions, the species will nest in mature coniferous plantations, particularly where the top of a tree has been lost, but breeding success is generally poor.

Hen harriers at nest.

Recommendation:

- Long-term availability of young regenerated forest (maintained through staggered felling and replanting on a landscape scale in the order of 200 ha) is likely to be value to harriers for hunting, provided that adequate areas of ungrazed, unafforested moorland are available as nesting habitat nearby.

6.4 WOODCOCK

Recommendations:

- Provision of areas of both young and old trees, with open rides, is likely to benefit nesting of woodcock in coniferous plantations.
- Ensuring good groundcover of brambles and other vegetation will benefit the species, and provide shelter for winter migrants.

Woodcock at nest.

6.5 NIGHTJARS

Recommendations:

- Large areas of clearfell and young restocked conifers, adjacent to areas of older trees, will provided suitable nesting and feeding habitat for this rare summer migrant.
- Potential use of herbicides on a limited basis in regenerated areas of young conifers, to maintain some patches of relatively bare ground attractive to nightjars for nesting, has been suggested as a possible conservation management technique.

Nightjar.

REFERENCES AND FURTHER READING

Adams, M.W. and Edington, J.M. 1973. A comparison of song-bird populations in mature coniferous and broadleaved woods. *Forestry* 46, 191-202.

Anon. 1996. Growing for the future. *A strategic plan for the development of the forestry sector in Ireland*. The Stationery Office, Dublin.

Anon. 1998. *Special Protection Areas*. Proposed candidate Special Areas of Conservation and proposed Natural Heritage Areas overlayed with Wildlife Regions [map]. The Heritage Service, Dublin.

Avery, M. and Leslie, R. *Birds and forestry*. T. and A.D. Poyser, London.

Batten, L.A. 1976. Bird communities of some Killarney woodlands. *Proc. R.. Ir. Acad. B.* 76, 285-313.

Bellamy, P.E., Hinsley, S.A. and Newton, I. 1996. Factors influencing bird species numbers in small woods in south-east England. *J. Appl. Ecol*. 33, 249-262.

Bibby, C.J., Aston, N. and Bellamy, P.E. 1989. Effects of broadleaved trees on birds of upland coniferous plantations in north Wales. *Biol. Cons*. 49, 17-29.

Bibby, C.J., Phillips, B.N. and Seddon, A.J.E. 1985. Birds of restocked coniferous plantations in Wales. *J. Appl. Ecol*. 22, 619-633.

Cannell, M.G.R., Malcolm, D.C. and Robertson, P.A. 1992. *The ecology of mixed-species stands of trees*. British Ecological Society Special Publication No. 11. Blackwell Scientific Publications, London.

Cieslak, M. 1985. Influence of forest size and other factors on breeding bird species number. *Ekol. Polska* 33, 103-121.

Cross, J. 1987. Status and value of native broadleaved woodland. *Irish Forestry* 44, 81-88.

Currie, F.A. and Bamford, R. 1982a. The value to birdlife of retaining small coniferous stands beyond normal felling age within forests. *Q. J. of Forestry* 76, 153-160.

Currie, F.A. and Bamford, R. 1982b. Songbird nestbox studies in forests in north Wales. *Q. J. of Forestry 76*, 250-255.

Dewar, S.M. and Shawyer, C.R. 1996. *Boxes, baskets and platforms*. Artificial nest sites for owls and other birds of prey. The Hawk and Owl Trust, London.

Du'Feu, C. 1993. *Nestboxes: BTO Guide 23*. British Trust for Ornithology, Tring.

Ferris-Kaan, R. (Ed) 1991. Edge management in woodlands. Proceedings of a symposium held at Alice Holt lodge on 17 October 1989. *Forestry Commission Occasional Paper* 28.

Ferris-Kaan, R. (Ed.) 1995. *The ecology of woodland creation*. John Wiley and Sons, Chichester.

Forestry Commission. 1990. Forest nature conservation guidelines. HMSO, London.

Forest Service. 1999. *Draft Republic of Ireland code of best forest practice*. Forest Sevice, Department of the Marine and Natural Resources, Dublin.

Forest Service. 2000. *Guidelines for forestry and biodiversity*. Forest Service, Department of the Marine and Natural Resources, Dublin.

Foss, P.J. and O'Connell, C.A. 1996. *Irish peatland conservation plan 2000*. Irish Peatland Conservation Council, Dublin.

Fuller, R.J. 1991, Effects of woodland edges on songbirds. In: Ferris-Kaan, R. (Ed.) 1995. *The ecology of woodland creation*. John Wiley and Sons, Chichester. p 31-34.

Fuller, R.J. 1995. *Birdlife of woodland and forest*. Cambridge University Press, Cambridge.

Gibbons, D.W., Reid, J.B. and Chapman, R.A. 1993. *The new atlas of breeding birds in Britain and Ireland: 1988 -1991*. T. and A.D. Poyser, London.

Harris, E. and Harris, J. 1992. *Wildlife conservation in managed woodlands and forests*. 2nd edition. Research Studies Press, Taunton, Somerset.

Heritage Council, The. 1997. *Review of forestry policy in Ireland*. Issues paper. The Heritage Council, Kilkenny.

Hibberd, B.G. 1985. Restructuring of plantations in Kielder forest district. *Forestry* 58, 119-129.

Hickie, D., Turner, R., Mellon, C. and Coveney, J. 1993. *Ireland's forested future. A plan for forestry and the environment*. The Royal Society for the Protection of Birds, Belfast.

Hunter, M.L. 1990. *Wildlife, forests and forestry*. Principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs, New Jersey.

Hunter, M.L. (Ed.) 1999. *Managing biodiversity in forest ecosystem*s. Cambridge University Press, Cambridge.

Iremonger, S. 1999. *Guidelines for forestry and diversity*: draft. Forest Service, Department of the Marine and Natural Resources, Dublin.

Jardine, D.C. (Ed.) 1988. *Wildlife management in forests*. Edinburgh, Institute of Chartered Foresters.

Kavanagh, B. 1990. Bird communities of two short rotation forestry plantations on cutover peatland. *Irish Birds* 4, 169-180.

Lack, D. and Venables, L.S.V. 1939. The habitat distribution of British woodland birds. *J. Anim. Ecol*. 8, 39-71.

Mollan, C. and Maloney, M. (Eds.) 1991. *The right trees in the right places*. Royal Dublin Society Seminar Proceedings number 4. Royal Dublin Society, Dublin.

Morris, A., Burges, D., Fuller, R.J., Evans, A.D. and Smith, K.W. 1994. The status and distribution of nightjars *Caprimulgus europaeus* in Britain in 1992. A report to the British Trust for Ornithology. *Bird Study* 41, 181-191.

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

Moss, D. 1978b. Song-bird populations in forestry plantations. *Q. J. of Forestry* 72, 4-14.

Nairn, R.G.W. and Farrelly, P. 1991. Breeding bird communities of broadleaved woodland in the Glen of the Downs, Co Wicklow. *Irish Birds* 4, 377-392.

Nature Conservancy Council. 1986. *Nature conservation and afforestation in Britain*. Nature Conservancy Council, Peterborough.

O'Flynn, W.J. 1983. Population changes of the hen harrier in Ireland. *Irish Birds* 2, 337-343.

Ormerod, S.J., O'Halloran, J. Gribbin, S.D. and Tyler, S. J. 1991. The ecology of dippers *Cinclus cinclus* in relation to stream acidity in upland Wales; breeding performance, calcium physiology and nestling growth. *J. Appl. Ecol*. 28: 419-433.

O'Halloran, J., Walsh, P.M., Giller, P.S., Kelly, T.C. and Duffy, B.L. 1998. An assessment of avian biodiversity and opportunities for enhancement in Ireland's forests: preliminary results. *Irish Forestry* 55, 2-14.

Orchel, J. 1992. *Forest merlins in Scotland. Their requirements and management.* The Hawk and Owl Trust, London.

Peterken, G.F. 1993. *Woodland conservation and management*. 2nd edition. Chapman and Hall, London.

Peterken, G.F., Ausherman, D., Buchenau, M. and Forman, R.T.T. 1992. Old growth conservation within British upland coniferous plantations. *Forestry 65*, 127-144.

Petty, S.J. 1995. *Merlins and forestry*. Forestry Commission Research Information Note, 254.

Petty, S.J. and Avery, M.I. 1990. *Forest bird communities*. Forestry Commission Occasional Paper 26. Forestry Commission, Edinburgh.

Petty, S.J., Shaw, G. and Anderson, D.I.K. 1994. Value of nest boxes for population studies and conservation of owls in coniferous forests in Britain. *Journal of Raptor Research* 28, 134-142.

Pilcher, J.R. and Mac an tSaoir, S. 1995. *Wood, trees and forests in Ireland*. Proceedings of a seminar held on 22 and 23 February 1994. Royal Irish Academy, Dublin.

Scott, D. 1991. Long-eared owls and artificial nests. *BTO Owl Study Group Newsletter*, spring 1991, p 1-3.

Shaw, G. and Dowell, A. 1989. Barn owl conservation in forests. *For. Comm. Bull*. 90.

Walsh, P.M., O'Halloran, J., Giller, P.S. and Kelly, T.C. 1999. Greenfinches *Carduelis chloris* and other bird species feeding on cones of Noble Fir *Abies procera*. *Bird Study* 46.

Warren, M.S. and Fuller, R.J. 1990. *Woodland rides and glades: their management for wildlife*. Nature Conservancy Council, Peterborough.