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BIODIVERSITY IN IRISH PLANTATION FORESTS

Final Report

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

NATIONAL COUNCIL FOR FOREST RESEARCH & DEVELOPMENT
AN CHOMHAIRLE NÁISIÚNTA UM THAIGHDE AGUS FORBAIRT FORAOISE

DEPARTMENT OF THE ENVIRONMENT, HERITAGE AND LOCAL GOVERNMENT

Environmental Research Technological Development and Innovation (ERTDI) Programme 2000-2006

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Heritage and Local Government.

OUR RESPONSIBILITIES

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We license the following to ensure that their emissions do not endanger human health or harm the environment:

- waste facilities (e.g., landfills, incinerators, waste transfer stations);
- large scale industrial activities (e.g., pharmaceutical manufacturing, cement manufacturing, power plants);
- intensive agriculture;
- the contained use and controlled release of Genetically Modified Organisms (GMOs);
- large petrol storage facilities.

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- Conducting over 2,000 audits and inspections of EPA licensed facilities every year.
- Overseeing local authorities' environmental protection responsibilities in the areas of - air, noise, waste, waste-water and water quality.
- Working with local authorities and the Gardaí to stamp out illegal waste activity by co-ordinating a national enforcement network, targeting offenders, conducting investigations and overseeing remediation.
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- Independent reporting to inform decision making by national and local government.

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- Quantifying Ireland's emissions of greenhouse gases in the context of our Kyoto commitments.
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ENVIRONMENTAL RESEARCH AND DEVELOPMENT

- Co-ordinating research on environmental issues (including air and water quality, climate change, biodiversity, environmental technologies).

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- Assessing the impact of plans and programmes on the Irish environment (such as waste management and development plans).

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- Promoting waste prevention and minimisation projects through the co-ordination of the National Waste Prevention Programme, including input into the implementation of Producer Responsibility Initiatives.
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The organisation is managed by a full time Board, consisting of a Director General and four Directors.

The work of the EPA is carried out across four offices:

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- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

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Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí
a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
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RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

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- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

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- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

Environmental RTDI Programme 2000–2006

Biodiversity in Irish Plantation Forests

(BIOFOREST Project, http://bioforest.ucc.ie)

(2000-LS-3.1-M2)

Final Report

BIOFOREST

Prepared for the Environmental Protection Agency and
the National Council for Forest Research and Development

by

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BIODIVERSITY

The Biodiversity Section of the Environmental RTDI Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in this area. The reports in this series are intended as contributions to the necessary debate on biodiversity and the environment.

DECLARATION

All results presented in this report are included in a DVD which will be made publicly available one year from the publication of this report.

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Executive Summary

Introduction

The Republic of Ireland published a strategic plan for the forest sector in 1996 (DAFF, 1996) which involved increasing the forest cover dramatically. Ireland is one of the least forested countries in Europe, even though forestry plantations have increased forest cover from less than 1% of land cover to about 10% in the last century. The plan aims to increase this to 17% by 2030, mainly by planting new commercial forests at approximately 20,000 ha per year. This increase represents a huge change in land use and land cover across Ireland, and has far-reaching economic, social and ecological consequences.

The most widely planted species in these commercial forests is Sitka spruce (*Picea sitchensis*), a non-native conifer, and many forest industries are associated with this species. Having changed some funding policies in the late 1990s to promote the use of broadleaves in plantations, the planting of ash (*Fraxinus excelsior*) increased significantly and broadleaves now constitute 20% of new plantings.

In order to promote forest biodiversity and fully practice sustainable forest management (SFM), it is necessary to know what organisms are associated with the forest plantations, and what the manager should be aiming at. A multitude of questions needed to be answered, from the most basic (What organisms are living in or associated with the plantations? What are the differences between these and the flora and fauna of native/semi-natural forests?) to the more complex (Has afforestation improved the general biodiversity of the area? What effect does previous habitat type have on the diversity of the developing forest? What policies and practices support the creation and maintenance of the most diverse plantations?). Until recently very little was known about the ecology of these forests and their associated flora and fauna: ecologists were more likely to investigate natural land-cover types than these more artificial ones. Ireland's native and semi-natural woodlands are very different ecologically to most forest plantations. The former are generally dominated by a broadleaf mix and are not clear-felled at commercial maturity whereas the latter have traditionally been dominated by a non-native conifer monoculture on a clear-felling cycle of 35–55 years.

Design of the BIOFOREST Project

Against the forestry background described above, the Environmental Protection Agency (EPA) and the Council for Forest Research and Development (COFORD) arranged to jointly fund research on forest biodiversity from National Development Plan funds, in the ERTDI programme. The resulting BIOFOREST project was a large-scale project running from 2001 to 2006 with the aim of providing much-needed basic information on biodiversity in Irish plantation forests. The focus of this research was to illustrate the effects of different aspects of management on biodiversity within forests, from the planning stage through to the mature forest. The research had an applied orientation and objectives to feed directly into the updating of forest policy and practice documents.

This large-scale project (2000-LS-3.1-M2) was structured as three smaller projects, each addressing a separate aspect of forest biodiversity. These were:

- Project 3.1.1: *Biodiversity Assessment of Afforestation Sites*
- Project 3.1.2: *Assessment of Biodiversity at Different Stages of the Forest Cycle*
- Project 3.1.3: *Investigation of Experimental Methods to Enhance Biodiversity in Plantation Forests*.

The BIOFOREST research team comprised the following organisations:

- Department of Zoology, Ecology and Plant Science (ZEPS), Environment Research Institute (ERI), University College, Cork (UCC)
- Department of Botany, School of Natural Sciences, Trinity College, Dublin (TCD)
- Coillte Teoranta, The Irish Forestry Board (Coillte).

The research team was guided with input from a Steering Group that included external experts from other organisations in Ireland (e.g. Dúchas/National Parks and Wildlife Service) and abroad (Denmark, Finland, the UK). The input of other external experts was requested as necessary and supported by COFORD and the EPA.

Assessment of biodiversity in any habitat or landscape is a difficult task to achieve on a comprehensive scale, given the range of components of biodiversity (different biota) that could be measured if logistics allowed. At most, studies aimed at assessing biodiversity directly can expect to measure the occurrence and diversity of only a small proportion of biota, whether animal, plant, fungal or microbial. Choosing the appropriate groups to study raises questions of subjectivity, and different groups may respond differently to habitat and other environmental variables. Nonetheless, this project required the development of inventories, and specific groups of organisms that include taxa known to have utility as biodiversity indicators elsewhere were targeted. An additional approach was to try to identify features of the habitat or landscape that could be used to predict biodiversity, at least in relative terms, for comparisons over space or time. Indicators of biodiversity can be viewed in three categories: structural, compositional and functional.

This study included these three main indicator types. The main taxonomic groups included in the project were spiders, hoverflies, birds and plants. These were chosen on the basis that they represented a range of functional groups whose taxonomy and ecology were sufficiently well known to facilitate their use as indicators. In all three sub-projects interdisciplinarity was stressed, and wherever possible the different groups were studied in the same study sites and during the same periods. Studying different groups in this manner gives better insight into the functioning of the ecosystem, thereby shedding more light on possible management methods and best practice.

Project 3.1.1: Biodiversity Assessment of Afforestation Sites

The main objectives of this project were to:

- Assess the biodiversity of frequently afforested habitats.
- Develop methodologies for biodiversity assessment and identify indicator species in these habitats.
- Assess the efficacy of the *Forest Biodiversity Guidelines* (Forest Service, 2000) and recommend improvements.

The final technical report for the project (Smith *et al.*, 2006) includes all of these items. The work included a special report on pre-afforestation assessment practices (Gittings *et al.,* 2004), and contributed to two university theses (Bolli, 2002; Buscardo, 2005).

Project 3.1.2: Assessment of Biodiversity at Different Stages of the Forest Cycle

The main objectives of this project were to:

- Assess the range of biodiversity in representative forests at key stages of the forest cycle.
- Review possibilities for enhancement of biodiversity in plantation forests and make recommendations.
- Assess the effectiveness of the *Forest Biodiversity Guidelines* in light of the results of this study.

The final technical report for the project (Smith *et al.*, 2005) includes all of these items. This project produced two PhDs (French, 2005; Oxbrough, 2006), although parts of Oxbrough's thesis also came from Projects 3.1.1 and 3.1.3.

Project 3.1.3: Investigation of Experimental Methods to Enhance Biodiversity in Plantation Forests

The main aim of this project was to:

- Identify those forestry management practices (with the possibility of using experimental plots) which are best suited to maintaining and enhancing biodiversity in plantation forests.

This was fine-tuned during the period that the other two projects were under way, in consultation with the project's international Steering Group and other experts. The main activities outlined were:

- An extensive survey of open-space habitats (glades, rides and roadsides) within plantation forests.
- The establishment of an experiment on the manipulation of open space in the forest, focusing on roads.
- A separate study on Hen Harrier habitat requirements.

The final technical report for the project (Iremonger *et al.*, 2006) includes all of these items. This project also produced a special report on Hen Harriers (Wilson *et al.*, 2005) and a PhD (Coote, 2007).

Conclusions and Recommendations

The individual projects concluded, in general, that forestry plantations can make a significant positive contribution to biodiversity in the landscape if properly planned and managed, and can have a negative effect if not. The promotion of biodiversity in forestry needs the support of good policies and practices. Fifty-seven recommendations are made, addressing different aspects of forestry from strategic planning to localised planning and practice. The needs for future research are outlined. The recommendations are listed below; the full text gives context and rationale for these.

Strategic forest planning

1. Require all non-urban local authorities to prepare Indicative Forestry Strategies.
2. Compile specialist reports identifying biodiversity constraints outside designated sites.
3. Complete countywide habitat surveys and biodiversity action plans and establish a biological records centre.[1]
4. Survey invertebrate biodiversity in semi-natural habitats of conservation importance.
5. Establish ecological advisory units in each local authority.
6. Establish a system of professional accreditation for ecological consultants in Ireland.
7. Incorporate requirements for biodiversity assessment (in 21, below) in Environmental Impact Assessment (EIA) *Advice Notes*.
8. Develop guidelines for the choice of invertebrate taxa for EIAs.
9. Develop a more thorough classification of vegetation communities in Ireland.
10. Afforestation and agricultural improvement should be regulated in areas with Hen Harriers.
11. Develop a mosaic of different stand age classes in heavily afforested areas occupied by Hen Harriers.

Pre-afforestation site assessment

12. Develop screening criteria to identify afforestation projects requiring a sub-threshold EIA.
13. Forest Service should employ ecologists.
14. Pre-afforestation site surveys should map habitats using a standard classification and note the presence of indicators and other biodiversity features.
15. Consider site biodiversity in context of the surrounding landscape prior to afforestation.
16. Foresters submitting grant applications should have completed accredited ecological training courses or employ qualified ecologists.
17. A sample of grant applications from each self-assessment company to be inspected by a Forest Service ecologist.
18. More comprehensive consultation procedures for grant applications.
19. Local authorities to comment on conservation issues pertaining to grant applications.
20. Refer applications where biodiversity concerns have been raised to a Forest Service ecologist to determine whether a more thorough assessment is required.
21. Biodiversity assessments in afforestation Environmental Impact Statements (EISs) must conform to specified standards.
22. Biodiversity assessments contained in EISs to be reviewed by a Forest Service ecologist, or an accredited external ecologist.
23. Proposed changes in land use should be regarded as being potentially damaging to Hen Harriers if they decrease the proportion of suitable habitat to below 30%.

Forest establishment

24. Semi-natural habitats should not be afforested, unless there are mitigating circumstances.

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1. The Irish National Biodiversity Data Centre was officially opened in January 2007 on the Carriganore Campus of the Waterford Institute of Technology. The Centre's duties cover the collection of records from public bodies and private collectors, their validation, collation, classification and digitisation plus education, research and training in biodiversity.

25. Establish plantations in close proximity to semi-natural woodland.

26. Create a mosaic of stands of different age and structure at the landscape scale.

27. Include a mixture of canopy species when planting.

28. Review the adequacy of the existing requirement for 5–10% open space in the *Forest Biodiversity Guidelines.*

29. Stipulate a minimum width of 15 m for linear open-space features included in the Area for Biodiversity Enhancement (ABE).

30. Leave small unplanted areas to maintain gaps through the forest cycle.

31. Leave small areas of wet habitat and avoid drainage where possible.

32. Include open space within broadleaved component of plantation.

33. Retain scrub, hedgerows and other marginal and additional habitats and allow for adequate buffer zones.

34. Design complex edges to plantations to increase proportion of edge habitat.

35. Leave boundaries unplanted to allow development of complex edge structure.

Forest management

36. Provide guidelines to help foresters to identify potentially important habitats for ground flora, spider and hoverfly diversity.

37. Rigorously thin Sitka spruce forests to prevent canopy closure.

38. Promote broadleaved woody vegetation in young conifer plantations.

39. Ensure grazing pressure is low enough to allow broadleaved tree and shrub vegetation to develop.

40. Retain mature Sitka spruce stands, where there is no risk of damage to adjoining semi-natural habitats.

41. Retain large diameter dead wood.

Future research

42. Test and refine the indicators identified in this project.

43. Conduct a comprehensive national survey and classification of grasslands.

44. Investigate forestry and biodiversity at whole-farm and landscape scales.

45. Investigate the implications for biodiversity of different tree species mixtures.

46. Investigate the biodiversity of open spaces in plantations in agricultural lowland landscapes.

47. An investigation of the biodiversity of over-mature commercial plantations.

48. A study of the biodiversity of second-rotation forests.

49. A study of the biodiversity in forests under continuous cover management.

50. Monitor forest biodiversity in permanent plots.

51. Investigate the inclusion of native woodland elements into commercial plantations.

52. Further investigate the biodiversity of different open-space habitats within forests.

53. Determine the influence of grazing pressure on broadleaved tree and shrub vegetation in open spaces.

54. Investigate the biodiversity of other taxa found in Irish forests and afforested habitats.

55. Develop a custom-designed GIS for analysis of habitat in areas with Hen Harriers.

56. Collect more detailed habitat data from the areas with Hen Harriers.

57. Improve our understanding of Hen Harrier habitat requirements.

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1 Introduction

1.1 International Activities for Conservation of Biodiversity and Sustainable Forest Management

Currently across the globe there is unprecedented interest in the earth's biological diversity, or 'biodiversity'. The United Nations Convention on Biological Diversity (CBD) was signed by 150 countries, including Ireland, at the United Nations Conference on Environment and Development (UNCED) in 1992, and the convention came into force in 1993. The treaty was a landmark in the environment and development field, as it took for the first time a comprehensive, rather than a sectoral, approach to conservation of the Earth's biodiversity and sustainable use of biological resources. It recognised that both biodiversity and biological resources should be conserved for reasons of ethics, economic benefit and indeed human survival. It implicitly accepted the telling point that the environmental impact which future generations may most regret about our time is the loss of biological diversity, in part because most of it – for example loss of species – cannot be reversed. 'Biological diversity' was defined as "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*".

Forest ecosystems have come under special scrutiny, particularly through the activities associated with the Convention for Sustainable Development (CSD). The CSD set up an Intergovernmental Panel on Forests, which progressed internationally agreed procedures for forest planning and management. The subsequent Intergovernmental Forum on Forests worked towards implementing the procedures, particularly at the international level. Meanwhile, there have been regional initiatives working at government level towards supporting Sustainable Forest Management (SFM). The Helsinki Process applies to European countries and the Montreal Process to temperate countries outside of Europe. Other proposals exist for tropical countries (Conference of the Parties IV, 1998). Ireland is a Signatory State to the Helsinki Process, which follows ministerial conferences on the protection of forests in Europe, the first two of which were in Strasbourg (1990) and Helsinki (1993). The definition of SFM adopted by the Helsinki conference was "*the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems*".

An outcome from the Helsinki conference was Resolution H2, in which the countries endorsed guidelines to the conservation of biodiversity in European forests.

International pressure to manage forests sustainably has resulted in systems of certification for sustainably managed forests. Each country adapts certain principles to their own systems and forests are evaluated and certified as sustainably managed. The system standard for Ireland is still being revised, but is operational (Soil Association, 2004). There is pressure on forest owners to comply with these principles and guidelines.

1.2 Irish Forestry

The Republic of Ireland is one of the least forested countries in Europe, even though forestry plantations have increased forest cover from less than 1% of land cover to about 10% in the last century. Forest policy aims to increase the country's forest cover to 17% by 2030, mainly by planting new commercial forests (DAFF, 1996). By far the most widely planted species in these commercial forests is Sitka spruce (*Picea sitchensis*), a non-native conifer, and many forest industries are associated with this species (DAFF, 1996). Following international trends and agreements outlined above, the Irish forestry sector must promote forest biodiversity through abiding by the guidelines specified by the Helsinki Process. Having changed some funding policies in the late 1990s to promote the use of broadleaves in plantations, the planting of ash (*Fraxinus excelsior*) increased significantly and is now one of the most frequently planted species. The Irish Forest Service published a number of documents in 2000 to help promote best practice and good international standards (Forest Service, 2000b,c,d,e,f), including guidelines for biodiversity. These documents indicate progress towards compliance with the requirements of SFM.

In order to practise SFM and promote forest biodiversity, it is necessary to know what organisms are associated with these forests, and what the manager should be aiming at. A multitude of questions need to be answered, beginning with the most basic and progressing to the more complex, including: What organisms are living in or associated with the plantations? What are the differences between these and the flora and fauna of native/semi-natural forests? Has afforestation improved the general biodiversity of the area? What effect does previous habitat type have on the diversity of the developing forest? What policies and practices support the creation and maintenance of the most diverse plantations? Until recently very little was known about the ecology of these forests and their associated flora and fauna; ecologists were more likely to investigate natural land-cover types than these more artificial ones. Ireland's native and semi-natural forests are very different ecologically to most forestry plantations. The former are generally dominated by a broadleaf mix and are not clear-felled at commercial maturity whereas the latter have traditionally been dominated by a non-native conifer monoculture on a clear-felling cycle of 35–55 years.

1.3 BIOFOREST Project

Against the forestry background described above, the Environmental Protection Agency (EPA) and the National Council for Forest Research and Development (COFORD) arranged to jointly fund research on forestry and biodiversity in the ERTDI programme. The focus of this research was to illustrate the effects of different management methods on biodiversity within forests, from the planning stage through to the mature forest.

The BIOFOREST Project was a large-scale project running from 2001 to 2006 with the aim of providing some much-needed basic information on biodiversity in Irish plantation forests. The research had a particularly applied orientation and objectives to feed directly into the updating of forest policy and practice documents. The project was funded from the National Development Plan funds through the EPA and COFORD as part of the Environmental RTDI Programme 2000–2006. The project was launched officially at a ceremony during the COFORD conference *Opportunities for Enhancement of Biodiversity in Plantation Forests* October 2002, in Cork, by the Minster of State at the Department of the Marine and Natural Resources, Hugh Byrne.

This large-scale project (2000-LS-3.1-M2) was structured as three smaller projects, each addressing a separate aspect of forest biodiversity. These were:

- Project 3.1.1: *Biodiversity Assessment of Afforestation Sites*
- Project 3.1.2: *Assessment of Biodiversity at Different Stages of the Forest Cycle*
- Project 3.1.3: *Investigation of Experimental Methods to Enhance Biodiversity in Plantation Forests*.

The objectives were to build a picture of biodiversity in a spectrum of Irish plantation forests and how this is affected by previous land cover, land use and current management methods. They were designed to add significantly to knowledge of Irish forests and help to guide future land-use planning and forestry practices.

The BIOFOREST research team comprised the following organisations:

- Department of Zoology, Ecology and Plant Sciences (ZEPS), Environment Research Institute (ERI), University College, Cork (UCC)
- Department of Botany, School of Natural Sciences, Trinity College, Dublin (TCD)
- Coillte Teoranta, The Irish Forestry Board (Coillte).

This consortium brought together a team of researchers and partner organisations that have extensive experience in ecology, biodiversity assessment and forest biodiversity studies across a broad spectrum of botanical and zoological groups. The UCC group is involved in large-scale biodiversity studies funded by the EU, COFORD and the Heritage Council and was a partner in a large concerted action related to biodiversity indicators in forests (BEAR). The TCD group is one of the foremost forest plant ecology groups in the country and has wide experience in general botanical surveys, forest and woodland plant biodiversity studies and in production of forest biodiversity guidelines. Coillte Teoranta, the Irish Forestry Board, is the primary forest owner and manager in Ireland, and the staff on the project have specific expertise in forest ecology.

The research team was guided with input from a Steering Group that included external experts from other organisations in Ireland (e.g. Dúchas/National Parks and Wildlife Service, NPWS) and abroad (Denmark, Finland, the UK). The input of other external experts was requested as necessary and supported by COFORD and the EPA. Staff names and groupings are listed in Appendix 2.

Assessment of biodiversity in any habitat or landscape is a difficult task to achieve on a comprehensive scale, given the range of components of biodiversity (different biota) that could be measured if logistics allowed. At most, studies aimed at assessing biodiversity directly can expect to measure the occurrence and diversity of only a small proportion of biota, whether animal, plant, fungal or microbial. Choosing the appropriate groups to study raises questions of subjectivity, and different groups may respond differently to habitat and other environmental factors. Nonetheless, this project required the development of inventories, and specific groups of organisms that include taxa known to have utility as biodiversity indicators elsewhere were targeted. An additional approach was to try to identify features of the habitat or landscape that could be used to predict biodiversity, at least in relative terms, for comparisons over space or time. Larsson *et al.* (2001) identified a number of potential indicators of biodiversity which can be broadly divided into three classes:

1. Structural indicators (e.g. area of forest from national through landscape down to stand scales, field boundary connectivity between forests or other habitats on a landscape scale, or amount of dead wood on a stand scale)
2. Compositional indicators (measurements of actual components of biodiversity, e.g. number or diversity of tree species on different scales, numbers or diversity of species of particular animal groups, etc., if these are considered likely to reflect or predict overall biodiversity)
3. Functional indicators (e.g. frequency and intensity of natural or human activities, including land management).

This study developed indicators in these three classes. In assessing compositional indicators, the main taxonomic groups included in the project were spiders, hoverflies, birds and plants. These were chosen on the basis that they represented a range of functional groups whose taxonomy and ecology were sufficiently well known to facilitate their use as indicators. In all three sub-projects interdisciplinarity was stressed, and wherever possible the different groups were studied in the same study sites and during the same periods. Studying different groups in this manner gives better insight into the functioning of the ecosystem, thereby shedding more light on possible management methods and best practice.

This report is a synthesis of five technical reports produced by the BIOFOREST Project (Gittings *et al.*, 2004; Smith *et al.*, 2005, 2006; Wilson *et al.*, 2005; Iremonger *et al.*, 2006). For more information on a particular aspect of the BIOFOREST Project, the reader is referred to these more detailed reports. All project outputs (reports, papers, etc.) are listed in Appendix 1.

2 Methods

2.1 Measuring Biodiversity

Strictly speaking, biodiversity is an ecological concept and does not equate with conservation value. For example, the concept of biodiversity makes no distinction between native biodiversity and artificial diversity in the form of introduced species and altered ecosystems (Angermeier, 1994). However, the term 'biodiversity' arose in the context of concerns about the destruction of natural habitats and the extinction of species on local and global scales (Gaston, 1996b). As such, use of the term in socio–political contexts is inextricably linked with the value of the natural world. It is this wider sense of the word 'biodiversity', incorporating both the variability of the natural world and its value, that is employed in the *Forest Biodiversity Guidelines* (Forest Service, 2000c). Therefore, our use of the term in this report will mean both the variability of species and ecosystems and their conservation value, in accordance with how 'biodiversity' is used in management contexts.

The most basic method of measuring biodiversity is to report the total species richness of the taxonomic group being considered (Magurran, 1988; Gaston, 1996a). However, total species richness does not indicate anything about the identity of the species involved. Ubiquitous species generally require little effort to ensure their conservation, but rare, threatened or specialised species will probably require adoption of specific conservation measures. In fact, total species richness can be misleading, as in some habitats of biodiversity conservation value (e.g. blanket bog) total species richness can increase following anthropogenic disturbance due to the invasion of widespread generalist species, masking the effect of the loss of rare, threatened and specialised species. To address this issue, we have also analysed the species richness of various species groupings that are subsets of the total biota in each of the taxonomic groups: rarity/conservation status, forest use, and functional or behavioural groups.

A second component of species-level biodiversity is the evenness or the relative abundances of the species (Begon *et al*., 1990; Gaston, 1996b). Sites dominated by one or a small number of species are intuitively less diverse than sites where species abundances are more equably distributed. Traditionally, mathematical diversity indices, such as Simpson's or Shannon's indices, have been constructed to take into account both species richness and evenness aspects of species diversity. However, in situations where the species assemblage is comprised of a disparate group of mainly non-interacting species the ecological meaning of species evenness may be unclear. As an example, consider two hypothetical forest bird communities. One has two Nightjars and two Wood Pigeons, the other has 20 Nightjars and 100 Wood Pigeons. Because Wood Pigeons and Nightjars do not interact, their relative abundances tell us nothing of interest about the ecology of the assemblages. In fact, the second community is clearly of greater biodiversity conservation value due to its larger population of a threatened bird species, although it has lower evenness than the first community. Therefore, we have focused on species richness rather than species diversity as our main measure of biodiversity for animal groups.

2.2 Vegetation

2.2.1 Terrestrial vegetation sampling

The vegetation team sampled terrestrial vascular plants, mosses, liverworts and lichens in all three projects. Vegetation data were collected at three different scales: the habitat scale, the 100 m^2 scale and the 4 m^2 scale. In Project 3.1.1, vegetation was also collected at the site scale. The number of plots at each scale in the different sub-projects is given in Table 2.1.

At the habitat scale in Project 3.1.1, all habitats present on site were mapped according to the Heritage Council habitat classification scheme (Fossitt, 2000). Within each habitat, plant species were recorded on the DAFOR scale: D, dominant; A, abundant; F, frequent; O, occasional; R, rare. In Project 3.1.3, a complete species list was compiled for glades and for a 20 m long section of rides and roads.

At the 100 m^2 scale in Project 3.1.1, the presence of plant species was recorded. In Project 3.1.2, species cover was recorded to the nearest 5%. In all 4 m^2 plots, the cover of plant species was recorded to the nearest 5%.

Table 2.1. The number of sites and number of sampling units at three different scales (habitat, 100 m^2 plot and 4 m^2 plot) in the vegetation survey.

Project	Sites	No. sampling units		
		Habitat	100 m^2 (per site)	4 m^2 (per 100 m^2)
3.1.1	48	All habitats on site	3	2
3.1.2	42	–	3	1
3.1.3	20	5 open spaces per site	–	2+*

*Per open space.

Vegetation structure data were collected at different scales, including average height and percentage cover of vegetation in different strata, such as trees, saplings, shrubs, brambles, forbs, graminoids and bryophytes/ lichens. Precise definitions of these vegetation layers varied according to the aims of the different projects. Also recorded were the percentage cover of bare soil, leaf litter, coarse and fine woody debris and other non-vegetation categories. In Project 3.1.2, percentage cover and volume of woody debris were recorded in different size and decay classes in each 100 m^2 plot.

Environmental and management data were also collected; the nature and scale of the data collected depended on the aims of the project. Data recorded in all projects included slope, aspect, elevation, soil type and drainage, grazing intensity, and silvicultural or other land management. Soil samples were collected in all projects, and soil pH and organic content were determined. In Projects 3.1.1 and 3.1.2, concentrations of soil nutrients, such as P, N, K, Ca and Mg were determined. In Project 3.1.3, the light environment was measured using hemispherical photography (Rich, 1990).

Nomenclature followed Stace (1997) for vascular plants, Smith (2004) for mosses, Paton (1999) for liverworts and Purvis *et al.* (1992) for lichens.

2.2.2 Epiphyte sampling

In Project 3.1.3, we studied the epiphytic flora associated with forest open spaces. All epiphyte surveying took place on the north side (i.e. south-facing side) of open spaces. Epiphytes were studied on a pair of trees at each of 12 sites, one tree at the edge of an open space and one tree in the forest interior. Study plots were located on the trunk and branches at four different height zones in the tree: tree base, lower, middle and upper. Trunk plots were located on the side of the trunk facing the open space and the opposite side (referred to as south and north sides, respectively). Plots were 50 cm in height, and ranged from a maximum width of 25 cm to that required to sample a half cylinder of the trunk. The percentage cover of each epiphyte species and total percentage cover of bryophytes, lichens, vascular epiphytes, others (algae, fungi, etc.), needle litter, and total percentage bare bark were estimated.

In the middle and upper zones, a branch from the north side and a branch from the south side were removed for study on the ground. Three plots, 25 cm long by 50 cm wide, were studied on each branch. The percentage of the plot occupied by branches and needles was estimated and the percentage cover of each epiphyte species and total percentage cover of bryophytes, lichens, vascular epiphytes, others (algae, fungi, etc.), and total percentage bare bark were also estimated.

At each site, the slope and aspect of the site and the orientation of the edge at which trees were studied were recorded. Tree density and diameter at breast height (DBH) were recorded from two 10 m × 10 m forest plots, and used to calculate stand basal area. DBH, tree height, heights to first live branch and base of live crown and the distance of the tree from the open-space edge were recorded for each tree sampled. The height above ground, girth and inclination at the centre of each trunk plot were recorded. For branches, the height above ground (at insertion), inclination, total branch length and the length of branch covered by foliage were recorded, as well as the distance from the trunk and diameter of the main axis at the centre of each plot.

2.2.3 Data analysis

Several biodiversity metrics were calculated from the vegetation data in plots: species richness of plant groups, including vascular plants, bryophytes and lichens, Shannon's and Simpson's diversity indices and the Berger–Parker index of evenness (Magurran, 2004). Plant species were classified according to their woodland affinity, soil moisture and pH preferences, and native/alien status. Vascular plants were also classified as competitors, stress tolerators or ruderals, or combinations of these categories, according to Grime's CSR theory (Grime *et al*., 1988). The species richness of plants in all of these categories was calculated for each plot. To avoid pseudo-replication, biodiversity metrics, plant abundances and environmental data in smaller sample units were frequently averaged or otherwise combined for analyses focusing on larger scales. For example, species abundances in the two 4 m^2 plots in each 100 m^2 plot in Project 3.1.1 were averaged to produce a single independent estimate of vegetation cover.

2.3 Spiders

2.3.1 Spider sampling

Spiders were sampled in plots established in areas of homogenous vegetation cover representative of the site. The number of plots used varied depending on the particular objectives of the project. In Project 3.1.1, spiders were also sampled in three supplementary plots whose purpose was to sample other habitat features, such as hedgerows, thought to be important to the site's biodiversity.

Each sampling plot comprised five pitfall traps, which consisted of a plastic cup 7 cm in diameter by 9 cm depth. Each trap had several drainage slits pierced approximately 2 cm from the top of the cup and was filled with antifreeze (ethylene glycol) to a depth of 1 cm to act as a killing and preserving agent. The traps were placed in holes so that the rim was flush with the ground surface. The traps were active from May to July and were changed three times during this period, approximately once every 3 weeks. Where large numbers of traps were lost through disturbance, the sampling period was extended for another three weeks. Plots from which fewer than 12 traps were collected were excluded from analyses. Spiders were sorted from the pitfall trap debris and stored in 70% alcohol. Spiders were identified to species level, excepting juveniles, which were excluded from analyses. Nomenclature follows Roberts (1993).

The percentage cover of vegetation was recorded in a 1 m^2 quadrat surrounding each pitfall trap. The vegetation was classified into the following structural layers: ground vegetation (0–10 cm), lower field layer (>10 cm to 50 cm) and upper field layer (>50 cm to 200 cm), and cover of dead wood, leaf litter, rocks and bare soil, and depth of leaf litter, were also recorded. All cover values were estimated using the Braun–Blanquet scale (Mueller-Dombois and Ellenberg, 1974). The main vegetation species present within each plot were also recorded. Two soil samples from each plot, taken to a depth of 15 cm, were analysed for organic content. Grazing intensity was ranked from 0 to 3.

2.3.2 Data analysis

We analysed relative rather than absolute spider abundances, as the efficiency of pitfall traps may have been affected by variation in vegetation structure around the traps. Species were categorised according to the literature into the following habitat associations: general habitat preference (open habitats, forested habitats or generalists), moisture preference (wet habitats, dry habitats or generalists) and vegetation preference (ground layer, low vegetation, bushes and trees or generalists).

2.4 Hoverflies

2.4.1 Hoverfly sampling

We used Malaise traps to sample hoverflies. In Project 3.1.1, we installed two traps within 50 m of each other along linear features within each site. In Project 3.1.2, we installed two traps in each site. Where possible, these traps were at least 100 m apart and 100 m from the forest edge. In Project 3.1.3, we installed four Malaise traps in each site: two on forest roads, and two in glades. The traps were located within 10 m of the edge of the open space, so that they sampled both the open-space and the forest fauna.

The Malaise traps were operated continuously from early May to between mid-July and early September, depending on the project, on whether a sampling period was compromised by trap damage, and on whether catches in the trap were unusually low. The contents of the traps were collected approximately every 3 weeks. Where farm livestock were present, we used temporary electric fencing to protect traps. Sites where some of the Malaise traps were damaged during more than one round of sampling are excluded from analyses at the site scale, but successful traps in these sites are included in the analyses at the trap scale. All hoverflies caught in the Malaise traps were identified to species.

We used a macrohabitat classification based upon the CORINE classification (Commission of the European Communities, 1991), but with modifications to reflect habitat characteristics of importance to hoverflies (Speight *et al*., 2004). We recorded the spatial extent of each major macrohabitat supplementary habitat type in a 100 m radius around each Malaise trap. We recorded habitat structure in this area, using categories based largely on those defined by Speight (2000) and using the DAFOR scale (see Section 2.2.1). Data were collected for a selection of these categories, as appropriate to the habitats under study, in each project. In Project 3.1.1, we recorded frequency of the above parameters in discrete lengths of hedges and treelines, and in discrete patches of scrub. In unplanted sites, grazing intensity was estimated from 1 to 3. In Project 3.1.2, we also estimated canopy cover, frequency of clearings and abundance of dead wood in several different categories.

2.4.2 Data analysis

We divided the recorded species into open-habitat associated species and woody vegetation species. For Project 3.1.3, we further subdivided these groupings into forest species, open scrub species, small open-space species and large open-space species. We also used classifications, based upon microhabitat associations, to define species groups that might be associated with trees and shrubs and with wet habitat features. In each of the projects, we also identified species of particular conservation interest belonging to a selection of the following groups: anthropophobic species (unable to tolerate human activity), species associated with surface water habitats, wetland specialists, wet grassland specialists and scrub specialists.

Caution is required in interpreting abundance data from Malaise trap catches. However, we considered that it was appropriate to use abundance data when comparing open-space types within sites in Project 3.1.1. For all analyses in Projects 3.1.2 and 3.1.3, we used presence–absence data. Analyses of Project 3.1.2 data were restricted to species whose ecologies were associated with macrohabitats present within the site.

2.5 Birds

Bird data were collected from each site over the course of two visits, one in May/early June and one in June/early July. Due to timing constraints, early visits to Project 3.1.2 sites in 2001 were missed, and a round of visits from early July to August were made. All bird surveys were conducted between 07:00 h and 18:00 h, and restricted to relatively fine weather. Clusters of birds of the same species were recorded as having a maximum number of two individuals. Flying birds of species that typically forage over wide, non-territorial areas and above the forest canopy were excluded from the survey.

In all projects, bird assemblages were sampled using point counts. Between four and 12 points were situated in each site (depending on project and on site size) at a minimum of 100 m apart, to cover as wide a range of environmental variation relevant to the study as possible. Points were located in the field using a Garmin GPS 12 and aerial photographs/1930 series six-inch (scale 1:4000) OS maps. Counts were conducted for 10 min, during which time the identity and distance from the observer of all birds detected were recorded. Point counts were conducted between 07:00 h and 11:00 h and between 13:00 h and 17:00 h (GMT). Each point was visited once in the morning and once in the afternoon. The following variables were estimated for an area 50 m around the point: area of shrub cover, area of non-crop tree cover, area of brash cover, total area of open space, crop tree canopy cover and crop tree height.

Mapping surveys were conducted in unplanted Project 3.1.1 sites. During mapping surveys, all areas of a site were approached to within 50 m, and areas of shrub and tree cover to within 20 m. The species and position of all birds seen or heard were recorded on a 1:4000 map of the site. The same map was used to record the shape, size and position of any substantial areas in the following categories: hedges, treelines, semi-natural woodland, shrub cover, pre-thicket and closed canopy forest plantation, farmyards and gardens. For each hedge, all woody plant species contributing to hedge structure were identified to species or genus level. Hedges were scored in the following categories: canopy height, width and structure, number of mature and young standard trees, percentage gaps, number of connections to other hedges and woodland/forest, presence and size of hedge-bank and ditch vegetation and presence of a grass verge.

In Project 3.1.3, approximately 1 km of road was censused in each study site, between 08:00 h and 18:00 h. We recorded the species, position and distance from the observer of all birds within 10 m of the road gap edge, excluding birds flying over the forest canopy. The following variables were estimated for homogenous sections of road: shrub cover (woody vegetation 0.5–2 m high), broadleaved tree cover (broadleaved vegetation >2 m high), brash cover, crop tree height, and road gap width. Road section length was measured from aerial photographs.

2.5.1 Data analysis

Densities of birds recorded from mapping surveys in Project 3.1.1 were estimated as the mean number of birds recorded from a site, divided by the site area. Numbers of birds detected in each road section during the road survey in Project 3.1.3 were treated as relative abundances. The numbers of birds detected during point counts was affected both by distance from the observer and by environment around the point. For Projects 3.1.2 and 3.1.3, these numbers were converted to densities using the computer programme Distance 4 (Smith *et al.*, 2005; Iremonger *et al.*, 2006; Wilson *et al.*, 2006).

For Project 3.1.3, analysis of bird point count data was restricted to evaluating presence/absence data for each species. Measures of bird species richness within 50 m and 100 m were used to investigate relationships with open space at the same scales. Species richness for all bird species detected was used to investigate relationships with open space within 200 m and 300 m of the point count locations. Several bird species associated with broadleaved woodland occurred too infrequently along roads for their abundances to be evaluated separately, so for analysis of the road survey data these species were combined into a single group.

In Project 3.1.1, Arcview GIS 3.2 was used to calculate lengths of hedges and areas of non-hedge features, and to assign birds recorded during mapping surveys to hedges (areas within 12 m of mapped hedges), non-hedge features and areas of open land. Mapping data were analysed at the scale of individual hedges, and at the scale of the site. Point count data were used to compare unplanted and planted sites. In order to eliminate the effect of hedge length on bird species richness and abundance, values of these variables were standardised for length of hedge.

In Project 3.1.2, species were classified as forest specialists if more or less restricted to forest habitat, forest generalists if occurring in a wide variety of habitats with an element of tree cover, and open species if requiring areas with no forest cover.

2.6 General Data Analysis

Standard statistical techniques appropriate to ecological data were used. Prior to parametric analyses, variables were inspected for conformity to the assumptions of parametric statistics. Variables were transformed, outliers were removed and non-parametric statistics were used as needed. Univariate analyses included correlation, linear and non-linear regression for testing for relationships between continuous variables. Analysis of variance (ANOVA), *t*-tests and non-parametric equivalents were used to test for differences among treatment groups. Differences in frequency of qualitative variables, among groups were tested using likelihood ratio χ^2 tests (or G-tests in Sokal and Rohlf, 1995). Multivariate statistical analyses included ordination (e.g. non-metric multidimensional scaling (NMS) and canonical correlation analysis (CCA)), clustering (e.g. flexible-ß clustering) and multivariate comparisons tests (e.g. multivariate analysis of variance (MANOVA) and multi-response permutation procedure (MRPP)). Univariate analyses were performed with SPSS 11.0 (SPSS, 2001), and multivariate analyses were conducted using SPSS or PC-Ord (McCune and Mefford, 1997).

In Projects 3.1.1 and 3.1.2, indicators of biodiversity were developed. These indicators were designed to be used by non-specialists to identify sites of potentially high biodiversity. Structural and functional indicators were assigned if statistical analysis showed that they were significantly associated with sites that supported species-rich or otherwise important assemblages of plants or animals. Bird species compositional indicators were developed in the same way; Amber or Red-listed bird species were considered *de facto* indicators of biodiversity. Plant species compositional indicators were assigned using the indicator species analysis method of Dufrêne and Legendre (1997), which provides an indicator value score based on the constancy and fidelity of a species in a given assemblage.

3 Project 3.1.1: Biodiversity of Afforestation Sites

3.1 Introduction

The objectives of this project were to:

- Assess the biodiversity of frequently afforested habitats
- Develop methodologies for biodiversity assessment and identify indicator species in these habitats
- Assess the efficacy of the *Forest Biodiversity Guidelines* (Forest Service, 2000c) and recommend improvements.

The sections below summarise the complete technical report for this project (Smith *et al.*, 2006). All data are incorporated into the BIOFOREST Database.

The work included two reviews:

1. *Biodiversity Assessment in Preparation for Afforestation: A Review of Existing Practice in Ireland and Best Practice Overseas,* produced as a stand-alone report (Gittings *et al.*, 2004)
2. *Review of the Biodiversity of Habitat Types Used for Afforestation in Ireland*, incorporated into the final project technical report (Smith *et al.*, 2006).

3.2 Review of Methods of Biodiversity Assessment

3.2.1 Introduction

The objective of this study was to review different pre-planting habitat biodiversity assessment methods used overseas and to highlight those that would be most suitable for integrating into the methodologies used in Ireland. The review focused on the assessment of terrestrial and wetland biodiversity (i.e. largely excluding aquatic biodiversity). There is no standardised protocol for the assessment of biodiversity in afforestation sites, but methods include assessment of species biodiversity using traditional inventory and biota analysis and landscape-scale assessment of biodiversity using remote sensing and GIS.

3.2.2 Methods

Information on existing practice in Ireland was collated from a variety of published policy documents, guidelines and reports, and by consultation with personnel in the relevant agencies. In addition, the biodiversity assessments contained in the nine afforestation Environmental Impact Statements (EISs) that had been carried out in Ireland were reviewed. Existing practice was regarded as deficient where it was considered likely to fail to identify sites of high biodiversity importance, resulting in the risk of damage to such sites.

Information on existing practice overseas was obtained by literature searches, a questionnaire survey and web searches. The United Kingdom was the only country where we found evidence of a significant body of relevant information, so we focused a more detailed information search on the United Kingdom. This included a review of a sample of Scottish afforestation environmental statements. Examples of best practice were identified as those that were most likely to identify sites of high biodiversity importance, thereby having greatest potential for prevention of damage to the site biodiversity.

3.2.3 Irish practice

The recent introduction of statutory consent procedures for all afforestation, and new procedures for Environmental Impact Assessment (EIA) of afforestation have addressed the major deficiencies that previously existed in the legislative control of afforestation in Ireland. However, with the exception of criteria relating to designated sites, the legislative procedures for screening for sub-threshold EIAs are not very specific. Local authorities, which should be equipped with strategic overviews of their constituencies, are not required to carry out strategic assessments for forestry. In the few cases where strategic assessments have been prepared, minimal attention is given to potential biodiversity constraints outside designated areas.

The personnel involved in biodiversity assessment for afforestation do not currently receive adequate training or other guidance (e.g. in the Forest Service publication the *Forest Biodiversity Guidelines*) for the identification of habitats and fauna and flora of biodiversity importance.

The employment of an ecologist by the Forest Service was a welcome development, although more than one ecologist is needed. The official guidance on conducting EIAs, published by the EPA, does not deal with issues such as scope, survey methods and evaluation in sufficient detail. None of the EISs reviewed contained adequate assessments of overall biodiversity. The main deficiencies were insufficient scoping, non-standardised habitat/vegetation classifications, reliance on incomplete lists of species with little or no information on abundance or distribution within the site, and little or no evaluation of the conservation importance of the site. The fact that six of the nine afforestation projects for which an EIS was submitted were approved indicates that assessment by the local authorities was deficient. Despite lacking in-house expertise in biodiversity assessment, the Forest Service and local authorities are responsible for assessing the biodiversity impacts of all afforestation proposals. The state nature conservation agency (NPWS) is only consulted about proposed afforestation located in or near designated areas.

In conclusion, lack of adequate strategic assessment, failure of regulations to require biodiversity assessment for the vast majority of afforestation proposals, and serious deficiencies in those biodiversity assessments that are carried out mean that sites of high biodiversity importance are currently at risk of being damaged by afforestation.

3.2.4 United Kingdom practice

The low area thresholds for an EIA of afforestation projects and the provisions for a sub-threshold EIA appear to provide an effective framework for identifying afforestation projects for which an EIA should be carried out. Local biodiversity action plans provide a coherent method of identifying priority habitats and species. Strategic assessments often include information on biodiversity constraints outside designated sites, with countywide Phase 1 habitat surveys providing a valuable resource.

The low area thresholds and provisions for the sub-threshold requirement of an EIA make this the principal method used for biodiversity assessment. Other specific procedures for biodiversity assessment have also been developed for special grant schemes and private forestry companies. Preliminary surveys and consultations during the scoping process for an EIA enable identification of those aspects of the site’s ecology that require more detailed investigation. Standardised survey methodologies are used, and the survey effort and methods are clearly stated in the environmental statement. Data are also taken from previous surveys and consultations. Where there is a significant nature conservation interest, the findings of the environmental statement are reviewed by the statutory nature conservation agency.

In conclusion, the ecological information that is available through strategic assessments, conservation designations and consultation with both statutory and non-statutory conservation organisations means that, for most forestry proposals, the Forestry Commission is able to make well-informed decisions about whether an environmental assessment is necessary and what its scope should be. Where best practice is achieved, environmental assessments are successful in identifying much of the biodiversity held by a site, either through field surveys or through reviews of existing knowledge. Generally, assessment procedures are such that the risk of new afforestation resulting in significant damage to conservation interests in the UK is low.

3.3 Habitats Review

A core principle of SFM is that forestry does not impact detrimentally on unforested habitats. Therefore, information on the biodiversity of habitats that are frequently subject to afforestation is required if Ireland’s forests are to be managed sustainably. We reviewed the biodiversity of three types of habitats that are commonly afforested in Ireland: improved grasslands, wet grasslands and peatlands, and identified potential indicators of biodiversity to be tested using field data.

The Irish habitat classification scheme developed by the Heritage Council (Fossitt, 2000) provides the most current and widely used broad classification of habitats in Ireland. This level of classification is adequate for use when studying mobile, wide-ranging taxa, such as birds. However, the broad habitat types defined by Fossitt (2000) frequently combine distinctive plant communities that differ in ecology and biodiversity. The Braun-Blanquet system of phytosociology has often been used in the past by researchers in Ireland, and provides a more fine-scale system of classification. Another advantage of this system, from our point of view, is the use of character species to define and distinguish phytosociological associations with other levels (syntaxa) in the classification hierarchy. Character species of syntaxa of high biodiversity interest are well suited to be potential indicators of biodiversity.

Climate, soils and human management determine the composition and abundance of species in grasslands. In general, the more intensive the management, the lower the biodiversity. Small pockets of semi-natural grassland are often found in a matrix of more intensive land use, and are vulnerable to loss through agricultural intensification, dereliction or conversion to a different land use, such as forestry. Various attempts have been made to estimate the cover of different grassland types in Ireland, but these are generally either inaccurate, out of date, or localised. Irish grasslands are divided into three phytosociological classes comprising lowland pastures, upland acid grasslands and dry limestone grasslands. Lowland pastures are further subdivided into a group of dry semi-natural grasslands, improved grasslands and intermediates, and a group of oligotrophic and base-rich wet grasslands. Improved grasslands are heavily grazed, frequently cut for silage, usually receive high fertiliser and herbicide applications and are often reseeded. Such grasslands are generally species-poor and are dominated by *Lolium perenne* and *Trifolium repens*, together with a limited number of agricultural weeds. With the exception of field-margin hedgerows, improved grasslands usually also support a poor bird fauna. In contrast, wet grasslands can be some of the most species-rich grassland communities in Ireland. Both oligotrophic and base-rich wet grasslands are frequently dominated by rush (*Juncus*) species and often support a diverse assemblage of broadleaved herbs. However, species-poor intermediates between improved and wet grasslands can also be dominated by rushes and superficially resemble more high biodiversity types. Wet grasslands such as the Shannon callows can be important feeding and breeding grounds for wildfowl and waders.

Peatlands in Ireland include bogs, fens and wet heaths. Of these, the peatlands that appear to be most frequently afforested in Ireland are blanket bogs and wet heaths. Wet heaths occur on shallow peats or peaty podzols and are generally dominated by dwarf shrub vegetation, especially *Calluna vulgaris* and *Erica tetralix*. Wet heaths frequently occur in intimate mosaics with blanket bog. Blanket bogs can be divided into two types: lowland blanket bog, which occurs in oceanic climates in the west at elevations below about 150 m , and upland blanket bog, which occurs in hilly or mountainous terrain throughout the country. Upland blanket bogs are characterised by an abundance of *Sphagnum* mosses, *Eriophorum* species and dwarf shrubs, including *Calluna vulgaris, Erica tetralix* and *Vaccinium myrtillus*. In contrast, lowland blanket bogs are more grassy in appearance, with *Schoenus nigricans* and *Molinia caerulea* as among the most prominent species, and lower *Sphagnum* cover than in upland blanket bogs. Lowland blanket bogs also frequently include a variety of hydrological features, such as flushes, pools, streams and swallow holes; these can also be found in upland bogs, but are much less common. Blanket bogs and wet heaths support a number of birds of conservation concern, including Red Grouse, Lapwing, Golden Plover, Curlew and Greenland White-fronted Geese. Blanket bogs and wet heaths are important Irish habitats at national and international levels. Active (i.e. peat-forming) blanket bogs are priority habitats for conservation under the EU Habitats Directive, and wet heath is also a designated, though non-priority, habitat for conservation. Ireland contains approximately 8% of the world's blanket bogs, and therefore has an important international role in conserving these habitats.

3.4 Biodiversity Survey

3.4.1 Study design and site selection

We identified three broad habitat types that are among those typically used for afforestation in Ireland: peatlands, improved grassland, and wet grassland. Ideally, the biodiversity of these habitats and the initial effects of afforestation on this biodiversity would be investigated by surveying sites before they were planted, and tracking them over the course of the forest cycle. However, for a number of reasons this approach was not practical, and instead we paired unplanted study sites of the relevant habitat type with 5-year-old, first-rotation plantations. Planted and unplanted sites were chosen to be closely matched in terms of relevant environmental conditions such as soil type, drainage, slope, altitude, and proximity of other types of habitats such as forests and rivers. Where possible, the paired sites were adjacent to each other, although three of the pairs were separated by 1–5 km. Sitka spruce (*Picea sitchensis*) was the main tree species in the planted sites.

We initially identified candidate pairs of sites from the Forest Inventory and Planning System (FIPS), and refined this selection using aerial photographs. We identified other candidate sites by making enquiries of local and regional forest managers and forestry contractors. We ground-truthed nearly 100 sites, of which we selected 24 pairs of planted and unplanted for this study (eight within each habitat type) (Fig. 3.1). We surveyed eight pairs of sites (four peatland and two each of improved and wet grassland) and the three unpaired sites in 2002. We surveyed the remaining 16 pairs of sites in 2004. In addition to these paired sites, we also surveyed an additional three unplanted sites (one improved grassland and two wet grassland) in 2002, which were afforested less than a year later.

3.4.2 Vegetation

3.4.2.1 Diversity in unforested habitats

We recorded 531 taxa of vascular plants, bryophytes and lichens in 133 habitats in the 51 sites. Vascular plant species richness was higher in unplanted wet grasslands than in unplanted improved grasslands or peatlands. Bryophyte and lichen species richness was highest in peatlands and lowest in improved grasslands. Total species richness, Simpson's diversity and Berger–Parker evenness were significantly lower in improved grasslands than in wet grasslands or peatlands.

Most of the plant species in improved grasslands preferred mesic conditions, whereas species preferring damp conditions were the most common moisture group in wet grasslands, and species preferring wet habitats were the most common group in peatlands. Typical woodland plants made up less than 2% of the flora in any group. Species often found in both wooded and unwooded habitats formed a lower proportion of the flora in improved grasslands than in wet grasslands or peatlands. Competitors comprised a relatively low proportion of peatland species, while improved grasslands supported a relatively low proportion of stress tolerators, with the majority of the species employing ruderal strategies.

Cluster analysis of the habitat data confirmed the pre-established habitat groups, and further subdivided improved grasslands and peatlands into subtypes. We also found that supplementary and marginal habitats can contribute substantially to the biodiversity of a site, through provision of habitats for species that would otherwise not occur in the main habitat matrix. Additional cluster analyses were carried out on 100 m^2 and 4 m^2 plot data. Although there was substantial variation among sampling scales in the assignment of sample units to clusters, certain patterns emerged from the data. In peatlands, the more intact lowland blanket bogs were distinguished at the larger scales from the remainder of the wet heaths and upland blanket bogs, which were on the whole more disturbed and of less biodiversity interest. Grasslands were generally divided into improved grasslands, semi-improved grasslands, oligotrophic wet grasslands and base-rich wet grasslands. The latter two groups were recognised as potentially being of high biodiversity interest, although their value will depend to a great extent on the landscape context. A given semi-natural wet grassland may be of ecological importance in

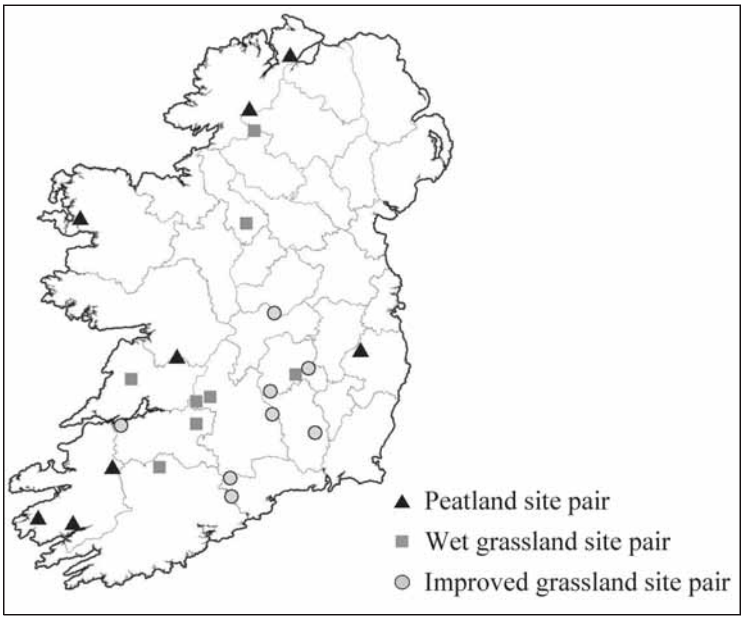

Figure 3.1. Locations of all paired sites in Project 3.1.1.

an agriculturally intensive landscape, whereas the same wet grassland may be of little particular interest in landscapes where communities of similar or higher quality are abundant. For indicators of plant diversity see Section 3.4.6.

3.4.2.2 Effects of afforestation

Vascular plant species richness at the 4 m^2 plot scale (but not larger scales) was significantly higher in unplanted sites in all habitat groups. Bryophyte and lichen species richness in 100 m^2 plots was significantly higher in planted improved grasslands and peatlands than in unplanted sites, as a result of the provision of new microhabitats by forestry drains. Simpson's diversity was lower in planted wet grassland and peatland 4 m^2 plots.

Compared with planted plots, unplanted plots contained a higher proportion of species associated with open habitats and a lower proportion of species occurring commonly in both open and wooded habitats. In peatlands and improved grasslands, a higher percentage of vascular plant species had competitor strategies in planted than in unplanted sites. In grasslands, plants with ruderal strategies comprised a higher proportion of the species in unplanted than in planted sites. Stress tolerators and species preferring wet conditions were proportionately more abundant in unplanted than in planted peatlands. Acidophilic and non-ruderal plants made up significantly more of the flora in planted than in unplanted improved grasslands.

There were significant differences in species composition and abundance between planted and unplanted sites within each of the three habitat groups. These differences were large in improved grasslands (due to substantial increases in competitive grass species, principally at the expense of *Lolium perenne*) and peatlands (where *Molinia caerulea* often becomes dominant). The difference between planted and unplanted wet grasslands was not as large, varying with wet grassland type. Tests of the 100 m^2 plot presence/absence data also detected significant differences between planted and unplanted sites within the habitat groups. Differences were more pronounced at the 4 m^2 scale than at the 100 m^2. Hedgerows, treelines and associated streams did not differ in composition between planted and unplanted sites.

3.4.3 Hoverflies

We recorded a total of 98 species of hoverflies, of which 63 are associated with open habitats and 50 are associated with woody vegetation habitats. Four of these are considered to be threatened and another five species are considered to be decreasing.

3.4.3.1 Diversity in unforested habitats

Open hoverfly assemblages in the three unplanted habitats were generally distinct from one another, in peatlands more than in the other two habitats. The number of open-habitat associated, wet grassland specialist and woody vegetation species was significantly higher in wet grassland sites than in peatland sites. However, peatland sites had the highest numbers of open-habitat associated anthropophobic species. The proportion of the Irish hoverfly fauna in different characteristic open-habitat groupings represented in the unplanted sites was never more than 50% (and often much lower), with the exception of some of the more species-poor faunal groups.

In both peatland and grassland habitats, sites where total hoverfly catches were very low (i.e. less than 100) tended to be widely scattered in ordination space, indicating insufficient sampling to characterise the hoverfly assemblages of these sites. There was no relationship between species richness (of all hoverflies, or of wetland specialist species) and wet habitat parameters. However, a small group of wet grasslands identified by cluster analysis of grassland sites was typified by species associated with surface water and/or oligotrophic habitats and had higher species richness than the other site clusters. Sites with low grazing intensity had significantly higher numbers of grazing-sensitive species, and numbers of wet grassland specialists were positively correlated with the frequency of tussocks. Numbers of woody-vegetation associated species were correlated with an index of broadleaved woody vegetation cover. The residuals from the regression of woody vegetation species richness against this index were positively correlated with occurrence of understorey vegetation.

3.4.3.2 Effects of afforestation

The ordination of the open-habitat associated species does not show any separation between the planted and unplanted peatland sites. The ordinations of the open-habitat associated and woody-vegetation associated species in the improved and wet grassland sites show a broad separation between the planted and unplanted sites. There were more woody vegetation and tree/tall shrub species in planted than in unplanted grassland sites. There were no other significant differences in species richness between the planted and unplanted sites.

In the planted grassland sites, numbers of woody-vegetation and tree/tall-shrub associated species were positively related to the length of hedges and treelines and the weighted cover of other broadleaved woody vegetation. The differences in numbers of woody-vegetation and tree/tall-shrub associated species between the paired planted and unplanted sites were correlated with the differences in the indices of woody vegetation cover. The growth stage of the planted conifers was not correlated with the species richness of these species groups. Nine species were more abundant in planted sites than in unplanted sites, and ten species showed the opposite pattern. Wetland specialists were significantly more abundant in unplanted sites, but open-habitat, surface water, woody-vegetation and tree/tall-shrub associated species did not differ significantly between planted and unplanted sites.

3.4.4 Spiders

3.4.4.1 Diversity of unforested habitats

Of 33,157 individuals caught, 3,448 were juveniles and 189 species were identified from the remainder. The majority of species sampled were typical ground-layer species, but 30 species were associated with low vegetation and six species with trees and shrubs. Across habitat types, species richness was lowest in the improved grasslands. Spider abundance in supplementary plots (see Section 2.3.1) was greater than in the main habitat type in improved grasslands and peatlands and less in wet grasslands.

More open-habitat associated species, fewer forest-associated species and more wetland-associated species were found in standard plots than in supplementary plots, especially in grassland sites. The number of open- or forested-habitat species did not differ between the habitat types. The number of ground-layer spider species was highest in improved grassland and lowest in peatland sites, but did not differ between the standard and supplementary plots. The number of low-vegetation species did not differ between habitat or plot type. Several rare or notable species were sampled within the peatland and wet grassland habitats (for further details, see Oxbrough *et al.*, 2005). No rare species were found within the improved grasslands. For indicators of spider diversity, see Section 3.4.6. (For further details, see Oxbrough *et al.*, 2007.)

NMS ordinations of grassland plots revealed much greater variation in assemblage structure among supplementary plots than among standard plots. Among peatland plots, spider species assemblages in supplementary plots differed from those in standard plots. Peatland spider species assemblages were also broadly distinguished by habitat type and, among supplementary plots, by the presence or absence of upper field-layer vegetation. Spider assemblages of upland blanket bogs, wet heaths and to a lesser extent lowland blanket bogs were distinguished from those of cutover bogs. Ground vegetation cover was associated with wet heath and upland blanket bogs, whereas lower field-layer cover was associated with cutover bogs and stream edges.

Cluster analysis revealed four main groups of spider assemblages:

1. the Peatland-Open Group comprised the majority of standard peatland plots and some standard wet grassland plots
2. the Improved Grassland-Open Group comprised most of the standard improved grassland plots
3. the Wet Grassland Group mostly comprised supplementary and standard wet grassland plots
4. the Linear Group comprised supplementary plots from all three habitat types.

3.4.4.2 Effects of afforestation

Total species richness did not differ between unplanted and planted peatland and wet grassland sites, but was significantly greater in planted than unplanted in the improved grassland. Across all sites, total abundance and the number of open-habitat associated and wet-habitat associated species was greater in unplanted sites, and the number of species associated with forested habitats was higher in planted sites. Numbers of ground-layer and low-vegetation species did not differ between the unplanted and planted peatlands and wet grasslands, but were significantly greater in planted than unplanted improved grasslands. In supplementary peatland plots, the number of wet habitat species was lower in planted sites than in unplanted sites. Measures of species diversity in supplementary plots did not differ between planted and unplanted grassland sites.

Grassland spider assemblages differed between unplanted and planted plots in improved grassland, but not in wet grassland. Spider assemblages from planted improved and wet grasslands are less distinct than those from unplanted improved and wet grasslands. Spider assemblages of unplanted peatland flushes were distinct from those of equivalent planted habitats in poor fen and upland blanket bog, but not in lowland blanket bog and wet heath. Upper and lower field-layer cover was greater, and ground vegetation cover less in planted than in unplanted peatland plots.

3.4.5 Birds

3.4.5.1 Diversity of unforested habitats

A total of 46 bird species were recorded during mapping surveys. Cluster analysis of hedge-plant species data identified four distinct clusters of hedges. Both within and between clusters, high bird species richness and abundance were associated with tall, wide hedges, with many mature standard trees, low percentage of gaps, high plant species richness and presence of ivy in the hedge canopy.

NMS ordination of bird density data separated sites according to two axes. Axis 1 values were strongly and positively correlated with species richness, and tended to be highest in improved grassland and lowest in peatland sites with values for wet grassland sites intermediate between these two. Axis 2 values were strongly and negatively correlated with total bird abundance, and tended to be lowest in sites with high shrub and tree cover. Cluster analysis separated sites into three grassland clusters (an improved grassland cluster, a wet grassland cluster and a mixed cluster) and two peatland clusters. Eight woodland-associated bird species were typical of the wet grassland cluster, and two open-habitat bird species were typical of the largest peatland cluster. No species were identified as being typical of the other clusters, but the absence of two open-habitat species was typical of the improved grassland cluster.

The proportions of open land, land within 12 m of large, medium and small hedges, and land under other categories of tree and shrub cover, are given in Fig. 3.2. Species richness in the grassland clusters was much higher than in the peatland clusters. Total bird abundance and densities of birds in open land were highest in the wet grassland cluster and lowest in improved grassland and peatland clusters; the latter were much lower than densities in the vicinity of hedge, tree or shrub cover. Among the grassland clusters, bird densities within 12 m of hedges were highest in the wet grassland cluster and lowest in the improved grassland cluster. Densities of birds in other tree and shrub cover were highest in the improved grassland cluster, but had little influence on bird assemblages in this cluster as it covered an average of less than 1% of sites. Measures of bird diversity were positively correlated with total length of large and medium

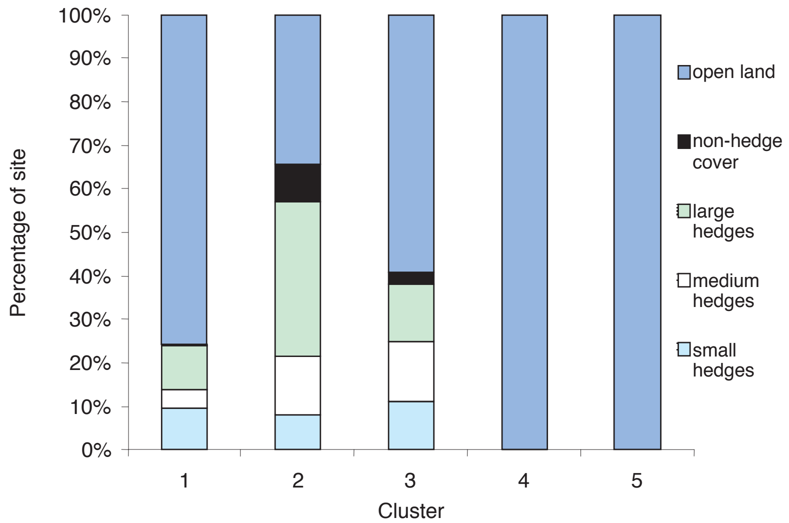

Figure 3.2. Proportions of cover types in the five bird species clusters. The values for hedge cover shown are the proportions of sites in each cluster within 10 m of each of the three hedge categories.

(but not small) hedges, area of treelines, and area of semi-natural woodland. Neither bird species richness nor abundance derived from mapping data were correlated with non-hedge shrub cover. However, several elements of shrub and tree-layer cover are positively correlated with point-count derived abundances of 14 bird species associated with woodland and scrub habitats, and negatively correlated with abundances of four species (Meadow Pipit, Redpoll, Skylark, and Stonechat) of open habitats. Abundances of 11 forest and scrub species (Blackbird, Blue Tit, Chiffchaff, Chaffinch, Coal Tit, Dunnock, Goldcrest, Robin, Song Thrush, Wren and Willow Warbler) were positively correlated with overall bird abundance and/or species richness. Abundance of skylark, an open-habitat species, was strongly negatively correlated with bird species richness.

3.4.5.2 Effects of afforestation

Estimates of species richness from point counts were consistently lower than those derived from mapping surveys, but density estimates from point-count data tended to be higher than those derived from mapping surveys. Relative to estimates of density derived from mapping surveys, estimates derived from point counts tended to be highest in improved grassland sites and lowest in peatland sites.

Total shrub cover, bird species richness, total abundance of birds, and ordination Axis 2 scores were greater in planted sites than in their unplanted pairs. Ten bird species were more abundant, in contrast with just one bird species (Skylark) that was less abundant, in afforested than in open sites. The five species that show the greatest proportional difference in abundance between planted and unplanted sites (Grasshopper Warbler, Reed Bunting, Sedge Warbler, Whitethroat and Willow Warbler) are all ground-nesting birds. The increase in abundance of these species in planted relative to unplanted sites is greater in Clusters 1 and 3 than in Cluster 2 or Clusters 4 and 5 combined. This difference between clusters appears to be related to availability of bramble cover, which tends to be low in all unplanted sites apart from those in Cluster 2, and relatively high in all planted sites apart from those in Clusters 4 and 5 (Fig. 3.2).

3.4.6 Indicators

We identified several biodiversity indicators for peatlands and grasslands. These are associated with semi-natural or natural plant communities that have experienced little human modification and the invertebrate and bird assemblages of these habitats. We have also identified several bird species of conservation concern as *de facto* indicators of biodiversity: these species are themselves of conservation interest. Many of these bird species are easy to detect and to identify, and so are therefore well suited for use in pre-afforestation biodiversity assessment. Red Data Book or legally protected plant species may also be considered *de facto* indicators of biodiversity, although we did not encounter any in our survey.

We divide the indicators into three types, compositional, structural and functional, and into two quality levels, firm and potential. Firm indicators (Table 3.1) include those that have been pre-identified or supported by previous research, and that have been tested and confirmed by the present study, and also birds of conservation concern. Firm indicators are not infallible, they simply have been independently identified by more than one source. Potential indicators (Table 3.2) are new indicators that have emerged from analysis of field data from the present study, and indicators that would otherwise qualify as firm indicators, but about which we have reservations as to their ability to discriminate between high and low biodiversity sites. Potential indicators need to be verified using independent data before their status is confirmed. Also presented are landscape-scale indicators of biodiversity for hoverflies and birds (Table 3.3). These are features that, if present within a landscape, indicate that landscape-scale biodiversity of one or more species groups is likely to be high.

Indicators should be assessed during the habitat mapping required for the site development assessment (Forest Service, 2000a), and through discussion with the landowner or inspection of existing maps and records. Plant species compositional indicators should occur frequently in order to qualify as ‘present’ for biodiversity indicator purposes. A site containing one or more landscape biodiversity indicators can be afforested without much risk if the features in question are left undisturbed and the plantation is set back an appropriate distance from them. However, caution should be exercised in the case of multiple afforestation projects over time in a single landscape.

In addition to these positive indicators, there are some *negative* indicators of biodiversity. These indicate low biodiversity (though their absence does not necessarily indicate high biodiversity), and are all associated with

Table 3.1. Firm indicators of biodiversity.

Compositional[1]	Structural	Functional
Grasslands		
Agrostis canina s.l.	Bryophyte cover >5%	Low grazing intensity[6]
Carex echinata	Forb[2] cover >25%	
Carex nigra	Graminoid cover <75%	
Carex panicea	Shrub[3] cover >5%	
Carex viridula		
Cirsium dissectum		
Danthonia decumbens		
Festuca pratensis		
Juncus conglomeratus		
Molinia caerulea		
Potentilla erecta		
Prunella vulgaris		
Pseudoscleropodium purum		
Ranunculus flammula		
Senecio aquaticus		
Succisa pratensis		
Thuidium tamariscinum		
***Locustella naevia* Grasshopper Warbler[4]**		
***Emberiza schoeniclus* Reed Bunting[4]**		
***Acrocephalus schoenobaenus* Sedge Warbler[4]**		
***Sylvia communis* Whitethroat[4]**		
***Vanellus vanellus* Lapwing[5]**		
***Tringa totanus* Redshank[5]**		
***Numenius arquata* Curlew[5]**		
***Gallinago gallinago* Snipe[4]**		
***Alauda arvensis* Skylark[4]**		
Peatlands		
***Pluvialis apricaria* Golden Plover[5]**		Extensive flushes
***Calidris alpina* Dunlin[5]**		Extensive fen habitat
***Numenius arquata* Curlew[5]**		Presence of pools
***Gallinago gallinago* Snipe[4]**		Presence of swallow holes
***Falco columbarius* Merlin[3]**		Low grazing intensity
***Circus cyaneus* Hen Harrier[4]**		Little or no peat cutting
***Lagopus lagopus* Red Grouse[5]**		Absence of erosion or fire
***Alauda arvensis* Skylark[4]**		Absence of drains
***Saxicola rubetra* Whinchat[4]**		Total P <100 mg/l

[1]High frequency (see text) of any plant species listed is a compositional indicator of biodiversity.

[2]Broadleaf herbaceous plants including ferns, but not grasses, sedges or rushes.

[3]Not including gorse.

[4]The breeding presence of any of these bird species is a potential indicator of biodiversity, but site quality and habitat availability in the surrounding landscape should also be taken into account.

[5]The breeding presence of any of these bird species indicates that a site is important for birds.

[6]Grazing intensity should be assessed over several years.

Table 3.2. New potential indicators of biodiversity.

Compositional	Structural	Functional
Grasslands		
Carex hirta	High frequency of tussocks	Total K <5,000 mg/l
Centaurea nigra	High cover of bramble	
Hypericum tetrapterum	High cover of hawthorn	
Iris pseudacorus		
Juncus bulbosus		
Lathyrus pratensis		
Leontodon autumnalis		
Mentha aquatica		
Pellia epiphylla[1]		
Stellaria graminea		
Peatlands		
Campylopus atrovirens		
Drosera rotundifolia		
Pleurozia purpurea		
Racomitrium lanuginosum		
Rhynchospora alba		
Schoenus nigricans		
Sphagnum cuspidatum		

[1]Can be easily confused with other *Pellia* species, but they are much less common, except in wet calcareous sites, and are not likely to indicate low biodiversity habitats.

Table 3.3. Landscape-scale structural indicators of biodiversity.

Salix swamp	Treelines with over-mature trees
Scrub	Surface water features (e.g. ponds, streams)
Well-developed hedgerows	Semi-natural woodland[1]

[1]Including very small pockets.

improved grassland. These include two firm negative indicators (high cover of *Lolium perenne* and recent reseeding of pasture), and five provisional negative indicators (*Poa annua, Urtica dioica, Stellaria media, Plantago major* and *Cirsium vulgare*).

3.5 Conclusions

The initial effect of afforestation on plant and animal communities is to change the relative abundances of species, rather than causing a radical shift in species compositions. These effects are largely the result of three factors: exclusion of grazing livestock, forestry drainage and changes in nutrient management. They are likely to be to the detriment of some groups of species (e.g. stress-tolerant and ruderal plants, specialist ground-dwelling spiders and open-habitat specialist birds), and benefit others (e.g. competitive plant species, generalist spiders and ground-nesting birds). However, these benefits will be temporary, not lasting beyond canopy closure except in unplanted areas of open habitat.

Forest drains may provide a temporary habitat for less competitive plant species, but the overall effect of drainage is to reduce the diversity of species dependent on wet conditions. Wet habitat features such as flushes, streams and swamps can substantially add to the plant, spider and hoverfly diversity of a site, particularly in peatland habitats. Results from all taxa indicate that other marginal and supplementary habitats, such as treelines, hedgerows, scrub, stone walls and earth banks, can also increase the biodiversity of afforestation sites, by supporting species that would not otherwise persist in the farmland matrix. Promoting broadleaved woody vegetation in young conifer plantations by retaining existing vegetation and by planting and regeneration of broadleaved trees will enhance hoverfly and bird diversity. However, all areas of retained habitat will require sufficient space if they are to remain unshaded and persist after the forest canopy closes. Also, if left ungrazed, many unplanted habitats will eventually undergo succession to scrub and native woodland and end up under a closed canopy unsuitable for open-habitat specialists. Such areas may need to have grazing continued at low intensity, in order to allow the persistence of open habitats and the species they support.

In general, afforestation sites held few species that were rare on a national or regional scale. However, biodiversity tended to be higher in wet grasslands and peatlands than in improved grasslands. Studies of all taxa agree that afforestation of semi-natural habitats would result in a net loss of biodiversity, but that the effect of afforestation on improved and semi-improved grasslands will generally be neutral or positive, particularly in landscapes that contain little semi-natural woodland habitat. The biodiversity value of semi-natural habitats, especially grassland communities, is dependent on landscape context: a particular habitat may be of significant biodiversity interest in intensive agricultural landscapes, but of less value in landscapes where similar areas of habitat are abundant.

The steps that should comprise an effective biodiversity assessment prior to afforestation are outlined in Fig. 3.3.

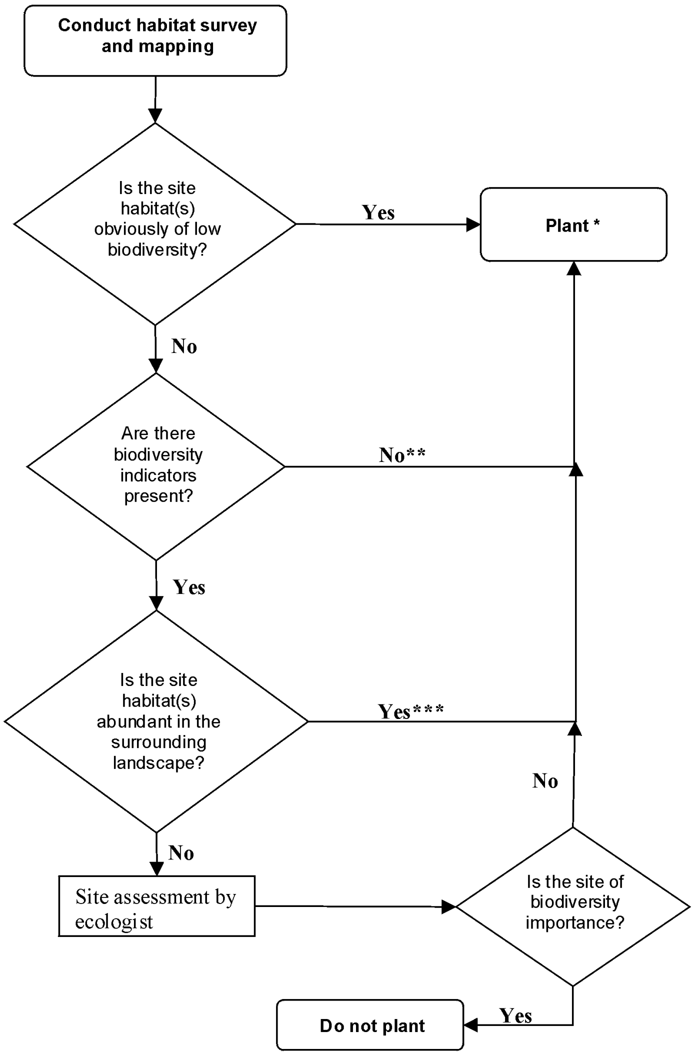

Figure 3.3. Flow chart outlining the stages in biodiversity assessment prior to afforestation.
Assuming that other criteria (e.g. landscape, water quality) have been met. **Sites with no biodiversity indicators present may still have high biodiversity and should be properly assessed before any decision to afforest is taken. ***Some habitat types (e.g. intact blanket bog) should never be planted.

Biodiversity assessment should always begin with a habitat survey, which should serve two functions: to determine whether or not a site or part of a site should be afforested on biodiversity grounds, and to identify habitats to be incorporated into the Area for Biodiversity Enhancement (ABE), as defined in the *Forest Biodiversity Guidelines* (Forest Service, 2000c). The survey should quickly reveal if the site is obviously of low biodiversity value, in which case it can be afforested with little likelihood of biodiversity loss. If the site is not clearly of low biodiversity value, then the indicators above should help decide whether or not it is of potentially high biodiversity. The indicators should be used in conjunction with each other: it would be misleading to characterise a site as having high biodiversity (or not) on the basis of just one or two indicators. We recommend as a general guideline the presence of at least four or more indicators in two or more groups (compositional, structural and functional) or four plant species indicators as a guideline for designating sites or parts of sites as potentially having high biodiversity. Unless similar habitats of comparable or higher biodiversity are abundant in the landscape, the site should not be afforested without a more detailed ecological assessment (not necessarily an EIA) and approval by a certified ecologist (Gittings *et al*., 2004). In landscapes dominated by improved grassland, tillage, commercial forestry or other intensive land uses, sites with two or more indicators present should also be referred to an ecologist for assessment prior to afforestation. The guidelines for the best number and combination of indicators in different situations should be tested by independent research using a different set of sites (see Section 6.5).

Although the biodiversity indicators we have proposed represent a tool that can be easily applied by non-specialists, they are not infallible. Furthermore, they are only applicable to peatlands, improved grasslands and wet grasslands. Further biodiversity indicators should be developed for other habitat types. If a site is suspected to be of biodiversity value, despite the absence of indicators, it should be referred to an ecologist for a more detailed assessment. If more than 15% of a site consists of semi-natural habitats, the decision of whether or not to afforest should be carefully considered in the context of the surrounding landscape matrix.

4 Project 3.1.2: Assessment of Biodiversity at Different Stages of the Forest Cycle

4.1 Introduction

The strategic plan for the forestry sector calls for 20,000 ha to be planted every year until 2030 (DAFF, 1996). To date, very little research has been carried out on the biodiversity of forest plantations and how it changes through different stages of the forest cycle. Given the proposed scale of planting, there is a need for investigation into the biodiversity supported by Sitka spruce (*Picea sitchensis*) plantations, which will account for at least 60% of the forest cover in Ireland up to 2030 (DAFF, 1996). With greater encouragement for the planting of broadleaves, research on the biodiversity of broadleaf plantations is also necessary.

This project addresses the current lack of information on biodiversity in Irish plantation forestry. The overall aim of the project was to obtain a comprehensive understanding of the biodiversity of conifer and broadleaf forest plantations at different stages of development, and to develop indicators of biodiversity as tools for monitoring and management. We evaluated current forest practices in the light of our findings, and recommended changes to these practices that could enhance the biodiversity of Ireland's plantation forests.

The main objectives of this project were to:

- Assess the range of biodiversity in representative forests at key stages of the forest cycle
- Review possibilities for enhancement of biodiversity in plantation forests and make recommendations
- Assess the effectiveness of the *Forest Biodiversity Guidelines* in light of the results of this study.

The following sections summarise the complete technical report for this project (Smith *et al.*, 2005), which is available from COFORD. All data are incorporated into the BIOFOREST Database.

4.2 Study Design and Site Selection

Recent planting trends showed that Sitka spruce was the dominant species being planted, and that ash (*Fraxinus excelsior*) was the dominant broadleaved species. In suitable sites, applications for afforestation grants on enclosed land must contain a minimum of 10% broadleaves, and the *Forest Biodiversity Guidelines* recommend that these should be planted "*in swathes and not as single stems within the canopy*". Based upon these considerations, we designed our survey around three forest types (pure Sitka spruce, pure ash and Sitka spruce–ash non-intimate mixes) and five age classes, which represent the major structural changes that take place in forest development over the course of a commercial rotation. A definition of each age class and the number of sites we surveyed in each forest type–age class combination are given in Table 4.1. Site locations are shown in Fig. 4.1.

In order to compare sites that differed in the relevant features (e.g. species composition and growth stage), but that were otherwise similar, we selected sites in the following clusters or pairs that were matched for geographical location, soil type, drainage and altitude:

- Four clusters, each consisting of three pure spruce sites of age classes 2–4 and a spruce–ash mix site of age class 2
- Four pairs, each consisting of a pure spruce site and a spruce–ash mix site of age class 1
- Four pairs, each consisting of a pure spruce site and a spruce–ash mix site of age class 4.

We found very few pure ash sites of suitable size and configuration for the purposes of our survey, so pure ash sites were not selected to geographically or environmentally match any of the other sites in our survey.

We initially identified potential sites from the Coillte inventory database that, as well as meeting the requirements for site type and cluster, conformed to the following additional criteria: minimum dimensions of 4 ha in area and 100 m in width, to accommodate bird point counts; first rotation on previously unforested land; and no forestry operations planned that might interfere with our surveys.

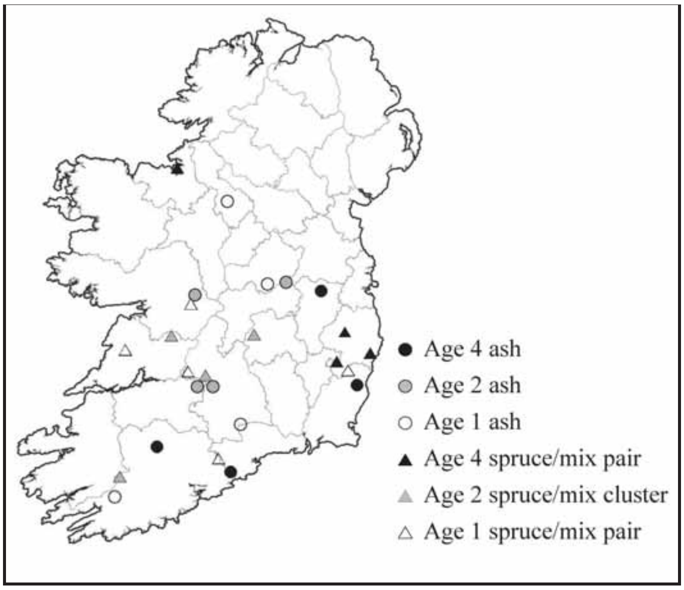

Figure 4.1. Locations of study sites for Project 3.1.2.

Table 4.1. Number of sites surveyed in each forest type–age class combination.

Age class	Age range (years)	Pure ash	Pure spruce	Spruce–ash mix
1	5	4	4	4
2	8–15	4	4	4
3	20–30	0	4	0
4	35–50	0	8	4
5	>50	4	0	0

We conducted field visits to confirm the suitability of these potential sites. On these field visits, we checked the structural development of the forest (age class 1 Sitka spruce sites with a closed canopy, Sitka spruce of age class 2 with an open canopy, and poorly developed Sitka spruce of age classes 3 and 4 were excluded), soil type and drainage, to confirm that they matched the classification in the Coillte database.

Despite our pre-survey field visits, we found that stand age was frequently not well correlated with stand structure, due to differences in site fertility and management. Therefore, cluster analysis was used to separate study sites according to their stage of structural development, using tree height, diameter, spacing and canopy cover data from the field. Spruce sites clustered into five structural types: pre-thicket, thicket, closed-maturing, reopening and mature. As Sitka spruce stands matured, canopy cover increased at first, and then decreased with the commencement of thinning operations (Table 4.2). Ash clustered into five structural types: pre-thicket, pole, closed-maturing, semi-mature and mature. Canopy cover in ash stands more or less levelled off at the closed canopy stage, but did not reach the maximum observed in Sitka spruce stands (Table 4.2). The term ‘mature’ as used here does not equate with commercial maturity. Ash plantations in the mature structural type may not be ready for harvest for several years, whereas spruce stands may reach commercial maturity by the reopening stage or earlier.

4.3 Vegetation

Species composition and diversity of the understorey flora in Sitka spruce and ash plantations were dependent on forest type and structure, as well as on site fertility and history. In pre-thicket sites, the tree crop had a negligible influence on vegetation communities and species indicative of the original habitat type remained abundant. In more mature sites, the influence of the canopy and differences between Sitka spruce and ash plantations were more apparent. Over the Sitka spruce forest cycle, vascular plant species richness initially decreased,

Table 4.2. Mean percentage canopy cover and tree height in the five structural stages in Sitka spruce and ash stands.

Sitka spruce			Ash		
Structural stage	Canopy cover (%)	Height (m)	Structural stage	Canopy cover (%)	Height (m)
Pre-thicket	29.6	2.5	Pre-thicket	12.2	3.1
Thicket	80.3	5.9	Pole	57.8	4.4
Closed-maturing	86.9	12.7	Closed-maturing	77.1	9.0
Reopening	70.8	18.8	Semi-mature	75.6	18.8
Mature	54.7	21.1	Mature	72.2	21.6

reaching a minimum in the closed-maturing stage, and subsequently increased in the reopening and mature stages. In ash forests, numbers of vascular plant species also tracked canopy cover, decreasing from a high point in the pre-thicket stage to lower numbers in the semi-mature and mature stages. Overall, ash forests supported more vascular plant species than Sitka spruce. On the other hand, bryophyte species richness increased with forest maturity in both forest types, and Sitka spruce forests supported more bryophyte species on average than ash. When total plant species richness was compared, we found no significant differences between Sitka spruce and ash forests when variation due to structural stage was removed.

Species composition differed between Sitka spruce and ash forests. The majority of ash stands were planted on brown earth and gley soils, and the flora was dominated by species that prefer a neutral substrate or are broadly tolerant. In contrast, the vegetation communities in the Sitka spruce stands were dominated by acidophilic vascular plants and bryophytes. Although differences in pre-planting soil type and chemistry certainly explain some of these differences, the acidic nature of the spruce litter and its accumulation to form a deep humus layer probably also play a part.

In both the Sitka spruce and ash forests, the numbers of species with a preference for woodland habitats increased through the structural cycle. In addition to structure, forest age was positively associated with greater numbers of woodland species. Numbers of woodland vascular plant species in plantations were also positively associated with the area and proximity of old woodland. The increased importance of woodland species in mature sites reflected a decline in species characteristic of the original unwooded habitat. The flora of more mature ash plantations was similar to but more species-poor than that of native woodlands where ash is prominent, and the flora of the more mature Sitka spruce stands had some affinities to native acidophilic oak woodlands.

4.4 Spiders

One hundred and thirty-nine species of spider were found during the study. Of these, 15 were classified as having a preference for forest habitats and 19 for open areas. NMS ordination of all sites separated pre-thicket Sitka spruce, pre-thicket ash and mixed, and pole ash sites from the more mature sites, placing approximately half of the closed maturing ash sites with the younger ash and spruce sites. Factors related to this separation included those typical of open habitat, such as cover of lower and upper field layers (which were highest in younger sites), and forest-related factors such as twig cover, dead wood, ground vegetation and litter depth (which were highest in older sites). Semi-mature and mature ash sites were also separated from closed-maturing Sitka spruce. Factors related to this separation included most of the above forest-associated factors (which were highest in ash sites), but also needle litter cover and organic content (which were highest in spruce sites).

In age class 2, the species assemblages in Sitka spruce plots were more similar to each other than the assemblages in ash plots. The overall mean species richness of spiders was slightly higher in Sitka spruce than in ash sites. In both spruce and ash stands, species richness tended to decrease with structural maturity. There were no significant differences in total species richness either between the Sitka spruce and ash components of mixed stands or between the mixed stands and matching pure Sitka spruce stands. The number of forest specialists and ground-layer species tended to increase with structural maturity, and was higher in spruce than in ash sites. The number of open-habitat specialists and low-vegetation species decreased with maturity. Lower field-layer vegetation was positively correlated with total spider species richness and open-habitat specialist species richness whereas canopy closure had a negative effect on these species variables. Forest spider species were positively correlated with litter cover, litter depth and twig cover.

4.5 Hoverflies

We recorded a total of 72 species, including 54 new county records of 34 species. We recorded ten tree/shrub specialists of which six were mainly saproxylic species (forest specialists), and we recorded 19 anthropophobic species.

The principal axis of separation generated by NMS ordination separated the hoverfly assemblages of pre-thicket sites from those of more mature sites, especially from mature ash sites. In pre-thicket sites, hoverfly assemblages appeared to be determined primarily by pre-planting habitat type. The assemblages of most of the thicket and drier mature spruce and most of the closed-maturing, reopening and wetter mature spruce sites also differed from one another. This separation was associated with a more open canopy and increased cover of tall shrubs and tussocks in the former group.

Measures of species richness were generally similar between ash and Sitka spruce sites, and between the ash and Sitka spruce components of the mixed sites. Overall hoverfly species richness and numbers of wet substrate species were highest in pre-thicket and closed-maturing sites. Species richness of forest and tree/shrub specialists and dead wood species increased between the pre-thicket and closed-maturing stages, but did not change with further structural development of the forest. Numbers of canopy tolerant, anthropophobic, foliage species and wet substrate species did not vary significantly between structural groups. Numbers of herb layer, ground debris and root zone species all showed a general trend of decrease with increasing structural development. At the level of the trap, species richness of several functional groups of hoverflies tends to be positively associated with clearing area (especially in more structurally developed sites) and negatively associated with tree height.

Species richness of wet substrate species was positively associated with diversity of wet habitats and absence of drainage ditches. The species richness of dead wood species in age classes 3 and 4 Sitka spruce was positively correlated with the frequencies of standing dead wood and fallen trees. However, within the groups of wet (where these categories of dead wood were more abundant) and dry sites, these relationships were no longer significant.

4.6 Birds

A total of 62 species were recorded, of which 15 were not used in subsequent analyses because they were classed as non-breeding over-flyers, or because they were not recorded within 50 m of the observer. Fourteen species of conservation concern were recorded, including two over-flying hirundines (Swallow and Sand Martin), and two birds of prey (Hen Harrier and Peregrine). The other species were all typical of open or scrubland habitats, with the exception of Crossbill, Redpoll and Spotted Flycatcher. Unlike the other three species groups, birds responded to forest structure at a coarser resolution, and forests were therefore classed as Older, Intermediate and Younger.

Species classified as typical forest species for the purposes of the analysis appeared to prefer more mature plantations. However, the only one of these that is a true forest specialist, requiring large areas of interior forest, is the crossbill, which was recorded in only three sites (all of which were Older pure Sitka spruce sites). Of the nine typical forest species recorded, four were species known to actively prefer a coniferous forest habitat (Goldcrest, Coal Tit, Crossbill and Siskin). Within the bird habitat subgroup of Older sites, the number of forest species we recorded did not respond to any of the measured environmental variables. This suggests that the forest species in question, beyond showing a preference for the more mature forest stands, are quite generalist in their forest habitat requirements within the stand or at the landscape scale. With the exception of Crossbill, the only true forest interior species occurring in Ireland (Redstart, Pied Flycatcher and Wood Warbler) are restricted to semi-natural oak woodlands and were absent from our sites. The paucity of bird species of conservation importance at later stages of the forest cycle can partly be attributed to the extreme rarity of true forest specialists in Ireland. However, the survey methods did not allow a thorough investigation of the importance of spruce and ash plantations for some nocturnal or poorly detectable forest species (e.g. Nightjar or Long-Eared Owl).

The growth stage of the forest was the main determinant of bird community composition and bird species richness. Younger stages of the forest cycle were characterised by the presence of a number of ground-nesting seed eaters, some of which were Red/Amber species of conservation concern. The presence of such species was probably more influenced by the original habitat of the site than by features of the young plantation. The birds of Intermediate forest stages tended to be generalists such as Robin, Wren and Dunnock. Stands of any age with high densities of these species tended to support species-rich assemblages. Older stages of the forest cycle supported more forest species as defined for the purposes of this study; however, the lack of any true forest specialist species, requiring large expanses of interior forest habitat, was marked. Such species are scarce in Ireland. Indeed, the forest species we recorded showed a preference for the forest edge and for well-developed shrub, herb and moss layers. Older stands were typified by Goldcrests, high densities of which were associated with species-poor forest stands.

The influence of species of tree on bird assemblage appeared to be negligible. However, the mature ash stands included in the study all incorporated a conifer element – pure stands could not be found for study. Additionally, these are results from Sitka spruce and ash alone so caution must be exercised in extrapolating these results to any other forest types.

4.7 Indicators

The indicators we have proposed for identifying sites of high biodiversity value for the four taxonomic groups above are shown in Tables 4.3 and 4.4. Table 4.3 gives the indicators we identified in thicket stage to mature spruce sites, and Table 4.4 does the same for pole stage to mature ash sites. Separate biodiversity indicators for pre-thicket forests were developed by Smith *et al.* (2005), but many of these have been superseded by Project 3.1.1 indicators for afforestation sites (Section 3.4.6). It should be noted that the findings of this study relate only to the taxonomic groups studied. The indicators given here will not necessarily be successful in distinguishing habitats of

Table 4.3. Biodiversity indicators for thicket through mature Sitka spruce stands. The sign of the indicator's relationship with species richness for each taxonomic group is given in brackets.

	Compositional[a]	Structural	Functional
Vascular plants and bryophytes	*Rubus fruticosus* agg. *Dryopteris dilatata* *Agrostis capillaris* *Thuidium tamariscinum* and *Plagiothecium undulatum*[b] *Hypnum jutlandicum*[b] *Dicranum scoparium*[b] *Eurhynchium praelongum*[b]	Canopy cover (–) Forb cover >20% (+) Bramble cover <30% (+) Bryophyte cover >50% (+) Needle/FWD cover (–) CWD (+)[b] Proximity to woodland (+)[c]	Thinning (+) Available P (+)[d]
Spiders		Canopy cover (–) Cover of 10–50 cm tall vegetation (+)	Thinning (+)
Hoverflies		CWD (+)	Wet habitats (+)[e]
Birds	Dunnock (+) Robin (+)[d] Blackbird (+) Wren (+)[d] Redpoll (+)[f] Chaffinch (+)[f] Willow Warbler (+)[f] Blackcap (+)[f] Long-tailed Tit (+)[f]	Distance from edge (–) Shrub cover (+) Age (–)[f]	Elevation (–)

[a]Plant species indicators should be used as the two sets shown. Bird species indicators are high abundances of the indicated species, rather than simple presence.
[b]Indicators of bryophyte diversity only.
[c]Indicator of woodland vascular plant species richness.
[d]Mature (or Old) stands only.
[e]Not including thicket stands.
[f]Intermediate stands only.

Table 4.4. Biodiversity indicators for pole through mature ash stands. The sign of the indicator's relationship with species richness for each taxonomic group is given in brackets.

	Compositional[a]	Structural	Functional
Vascular plants and bryophytes	*Agrostis stolonifera* (–) *Thamnobryum alopecurum* (+)[b] *Polystichum setiferum* (+)[b] *Hedera helix* (+)[b] *Primula vulgaris* (+)[b]	Proximity to woodland (+)[bc]	
Spiders		Cover of 10–50 cm tall vegetation (–)[b] Soil cover (–)	
Birds	Dunnock (+) Blackbird (+) Wren (+) Robin (+)[d] Redpoll (+)[e] Chaffinch (+)[e] Willow Warbler (+)[e] Blackcap (+)[e] Long-tailed Tit (+)[e]	Distance from edge (–) Shrub cover (+) Age (–)[e]	Elevation (–)

[a]Plant species indicators should be used together as one set. Bird species indicators are high abundances of the indicated species, rather than simple presence.
[b]Indicators of woodland species richness.
[c]Vascular plant species richness only.
[d]Mature (or Old) stands only.
[e]Intermediate stands only.

high biodiversity value for other groups, especially of invertebrate fauna (including spider assemblages in higher levels of the forest strata). Also, time-intensive surveys are often required to locate and identify species of special conservation value. There are no easily surveyed indicators that can be relied on to give an accurate assessment of all components of biodiversity in afforested sites. For instance, measuring only vascular species richness will distinguish between forests that are species-poor and species-rich for vascular plants. However, such an approach may overlook habitats that are important for bryophyte diversity, and possibly for other groups as well. Additionally, this approach would give equal weighting to common plants and less frequent plants of more importance for biodiversity. No one type of indicator, including species indicators, should be used in isolation when assessing the diversity of a Sitka spruce or ash stand. Although we have developed these indicators for use by non-specialists, some training will nevertheless be required to use them effectively (see Recommendation 36 below).

When assessing the biota of a site, it is recommended that the structural, environmental and management status (e.g. thinning history, previous land use, location) of the stand be studied in conjunction with species composition. We include several such factors among the indicators listed below, and others can be useful in interpreting floral and faunal survey data.

These indicators can be used to assess the effect of site management practices on biodiversity and/or to identify sites that potentially are of high biodiversity value. If indicators for particular subgroups of species, such as forest specialist spiders, are desired, see the appropriate chapter in Smith *et al.* (2005). These indicators of biodiversity should be considered as provisional indicators only, until they are verified using independent data (Noss, 1999). In addition, the context in which they have been identified, i.e. pure stands and non-intimate mixes of Sitka spruce and ash, must be taken into consideration prior to their application. Except for indicators of bird diversity, the indicators in Tables 4.3 and 4.4 should be employed at the site or stand level, rather than at the level of the whole plantation or landscape.

The various indicators should be used in conjunction; in general, it is misleading to label a stand as 'biodiverse' (or not) on the basis of just one or two indicators. We recommend the presence of at least four indicators in two or more groups (compositional, structural and functional) as a general guideline for designating sites or stands as potentially having high biodiversity. The numbers and types of indicators that should be present in order to accurately categorise the biodiversity status of forest units should be investigated during the process of indicator verification. The indicators cannot substitute for thorough floral and faunal surveys, particularly when sites of potentially major biodiversity importance are involved, but can be employed as a first step in biodiversity management assessment or identifying sites of biodiversity value. In sites where few indicators are present, management practices can be reviewed and improved. Forest stands or plantations identified as being of potentially high biodiversity can be surveyed and assessed more thoroughly and management for biodiversity can be prioritised in forest planning and operations.

4.8 Conclusions

Different forest types and stages of the forest cycle support different biota. In the early stages of the forest cycle, species from the original unwooded habitat persist. Previous and adjacent land uses are important influences on ground flora composition and diversity. Open habitats of high biodiversity value should not be afforested, as most or all of the biota associated with these habitats will not persist long beyond canopy closure.

In contrast, the later stages support a more characteristic woodland biota. The paucity of natural woodlands in Ireland means that plantations have the potential to provide important habitats for populations of some forest species that would otherwise be scarce, especially in intensively farmed landscapes. However, the rarity of true forest specialist bird species in Ireland means that the potential role of plantations for these species is currently limited. Proximity and abundance of old semi-natural woodland and scrub in the landscape increase the species richness of typical woodland plants. In particular, ash forests originating from or adjacent to old woodland or scrub had developed a flora most similar to that of old semi-natural woodland. Availability of shrub cover was also important for bird diversity. The most important habitat features for forest specialist hoverflies are wet substrates and dead wood.

Sitka spruce plantations can have a negative impact on understorey flora diversity, especially during periods of canopy closure. However, if managed appropriately, Sitka spruce forests can be more species-rich and aesthetically pleasing. Of all stages in the Sitka spruce structural cycle, the mature stands support the richest communities of both vascular plants and bryophytes. It is important to note, however, that not all spruce stands may reach the mature structural stage, which is not equivalent to commercial maturity. Sitka spruce forests are important habitats for bryophyte diversity as they support more specialist species than the ash stands.

Understorey flora diversity varies less in ash than in Sitka spruce plantations; while the early stages of the ash structural cycle support high numbers of vascular species, the semi-mature and mature stages are more favourable habitats for bryophyte diversity. At no stage in the forest cycle are the vegetation communities beneath the broadleaf canopy as species-impoverished as the communities beneath the closed-maturing Sitka spruce stands. In general, mature sites with a more open canopy (such as that provided by ash plantations) will support a greater number of spider species. Ash forests also appear to support a greater number of saproxylic hoverfly species than spruce forests.

We found no consistent effects of mixed plantations on the biodiversity of either the Sitka spruce or the ash components of these stands. However, the fact that different species assemblages are supported by ash and Sitka spruce means that adding ash to a Sitka spruce plantation is likely to increase the biodiversity of plants and spiders at the plantation scale. The same is also true for hoverflies, especially if the ash component includes grassy clearings. There was little separation between the bird assemblages of ash and Sitka spruce. However, the mature ash sites we studied all incorporated a conifer element, and the bird assemblages we encountered may be different from those supported by pure ash sites. The biodiversity of pure or mixed plantations of other species of broadleaves is worthy of further investigation.

Although not a substitute for thorough ecological surveys, the presence of certain easily identified species or the measurement of certain structural characteristics of a forest may give an insight into the species richness of a plantation.

5 Project 3.1.3: Investigation of Experimental Methods to Enhance Biodiversity in Plantation Forests

5.1 Introduction

The objective of Project 3.1.3, as stated in the COFORD/EPA scoping document, was:

To identify those forestry management practices (with the possibility of using experimental plots) which are best suited to maintaining and enhancing biodiversity in plantation forests.

The first task for the Research Group was to carry out a review of methodologies used to enhance biodiversity in plantation forests, to inform the further design of the field phase of the project. The different options open to the Group were discussed at a special session during the conference *Opportunities for Enhancement of Biodiversity in Plantation Forests*, 24 October 2002, Vienna Woods Hotel, Cork. Contributors included members of the BIOFOREST Steering Group and individuals from forest-related institutions both inside and outside of Ireland. A decision was made that this project should focus on the use of open space in forests for biodiversity enhancement. As there were only resources available to study one forest type in this project, and for reasons laid out by Smith *et al.* (2005), forests dominated by Sitka spruce (*Picea sitchensis*) were chosen as the subject.

This project comprised three main elements:

1. An extensive survey of forests with different configurations of open space

2. The establishment of an experiment on the manipulation of open space in the forest, focusing on roads

3. A separate study on Hen Harrier habitat requirements.

The following sections summarise the technical report for this project (Iremonger *et al.* (2006)), which is available from COFORD. All data are incorporated into the BIOFOREST Database.

5.2 Extensive Survey

5.2.1 Introduction

Natural forests almost always contain some open, treeless areas within them. These may be temporary canopy gaps of varying sizes caused by disturbance agents, such as windthrow, fire or insect attack. More or less permanent open spaces can also be found in forests in places that are not favourable to tree growth because of waterlogged soils, rock outcrops or herbivory. Open spaces within forests provide suitable sites for plant species that cannot tolerate the shaded conditions of the forest interior (Peterken and Francis, 1999). The additional habitats and species supported within open spaces serve to increase the biodiversity of the forest as a whole.

The value of open spaces for forest biodiversity is recognised by the Forest Service, which requires 5–10% of open space to be created or maintained as part of the Area for Biodiversity Enhancement (ABE) within new forestry plantations in order to qualify for afforestation grant aid (Forest Service, 2000c). Such open spaces can include ridelines, firebreaks, forest roads and turning bays, unplantable areas, areas left unplanted to facilitate ESB power lines or other utilities, and buffer zones for aquatic habitats and archaeological features. In essence, these open space types can be simplified into three: linear open spaces, non-linear open spaces (or glades) and roads. Although roads are also linear features, their management (e.g. surfacing with gravel) and the different roadside habitats (e.g. road cutting banks, roadside drains) provided make them qualitatively different from other linear open spaces. A key aim of maintaining open spaces as part of the ABE within plantation forests is to "*conserve and enhance the biodiversity value throughout the entire forest*" (Forest Service, 2000c). A secondary benefit is the provision of semi-natural open habitats that may be rare in intensively managed landscapes.

The objectives of this sub-project were:

- To assess the biodiversity of plants, spiders, hoverflies and birds in open spaces in plantation forests
- To investigate the major environmental and management factors influencing biodiversity at the plantation scale between open spaces and within the open space
- To recommend measures that can enhance the biodiversity of plantation forests through planning and management of open space.

5.2.2 General methods

5.2.2.1 Study sites

We selected 12 sites in two geographic clusters referred to as Cork (in Counties Cork, Kerry and Limerick) and Wicklow (Counties Wicklow and Dublin) (Fig. 5.1). We selected sites that had a wide range of configurations of open spaces from a GIS forest inventory database. Within each cluster, we standardised, as far as possible, soil type and habitat/vegetation types of the open spaces. All sites were plantation forests comprised primarily of Sitka spruce, ranging in age from 26 to 47 years old, and at least 80 ha in size. The sites in the Wicklow cluster were on podsols with rock outcrops and with dry–humid acid grassland/dry heath vegetation (as defined by Fossitt (2000)) in the unplanted open spaces. The sites in the Cork cluster were on deep blanket peats and peaty podsols with modified blanket bog vegetation in the unplanted open spaces.

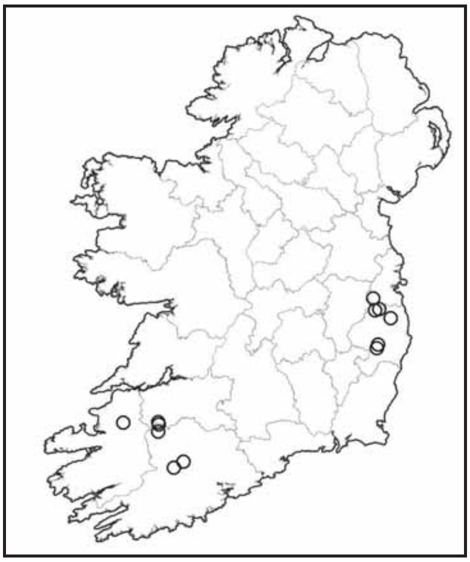

Figure 5.1. Locations of study sites for the extensive survey of open spaces in Project 3.1.3.

5.2.2.2 Plantation-scale open-space metrics

We calculated the amount of habitat in each of nine categories: broadleaf scrub, road, undeveloped plantation, windthrow, clear-fell, young forestry, unplanted open space within the plantation, external open space, and the length of rides. The area in each of these categories was calculated for within 50 m, 100 m, 200 m and 500 m of each central vegetation plot; for within 50 m, 100 m, 200 m and 500 m of each tree sampled for epiphytes; for within 100 m, 200 m and 300 m of each spider plot; for within 100 m, 200 m and 300 m of each Malaise trap; and for within 300 m of each bird point-count location. The habitat categories were mapped using aerial photographs, and the amounts of habitats within a specified distance (radius) of an open-space centre were calculated using ArcView GIS.

5.2.3 Terrestrial vegetation

5.2.3.1 Diversity at plantation scale

A total of 229 terrestrial plant species were recorded. The mean site vascular plant species richness of 4 m^2 plots ranged from 5.4 to 10.7. There were no significant relationships between biodiversity metrics calculated at the open-space scale and the amount of non-forest habitat in the nine categories referred to in Section 5.2.2.2 at any of the four scales we investigated.

5.2.3.2 Diversity between open spaces

Combining both geographical clusters, rides had lower vascular plant species richness and higher bryophyte species richness than glades and roads. Roads had higher vascular plant species richness, numbers of species associated with open habitats and Simpson's diversity than the other two open-space types. In roads, pH was positively associated with vascular plant species richness, Simpson's diversity and vegetation evenness. Road-verge plots adjacent to forest roads surfaced with limestone gravel had higher vascular plant species richness than roads surfaced with local sandstone or mica-schist.

5.2.3.3 Diversity within open spaces

Total vascular plant species richness and open species richness (including vascular, bryophyte and lichen, see Section 2.2.3) were higher in roadside plots located on the road verge or ditch than in plots on banks or road setback.

In glades, centre plots had significantly lower bryophyte and lichen species richness, Simpson's diversity index and vegetation evenness than edge plots. There were no significant differences in open species richness between plot locations in glades. Total vascular plant species richness and open species richness in the ride centre plot were significantly higher than in ride edge plots. Vascular plant species richness in 4 m^2 plots was positively associated with transmitted direct and diffuse solar radiation. In contrast, bryophyte species richness, vegetation evenness and Simpson's diversity index were generally lower in plots receiving more sunlight.

Vascular plant species richness was positively correlated with ride width. There was a weak negative association between bryophyte and lichen species richness and ride width. Open species richness, Simpson's diversity index and Berger–Parker evenness index were not well predicted by ride width. The ratio of ride width to tree height was no better predictor of biodiversity metrics than ride width alone. Vascular and non-vascular plant species richness were positively associated with glade area. There was no clear relationship between glade area and open species richness, Simpson's diversity index or Berger–Parker evenness. There were no meaningful relationships between biodiversity metrics and any measures of light intensity or road width in road plots.

Transmitted solar radiation at the centre of open spaces was well predicted by width of linear open spaces, but less well predicted by either the ratio of road/ride width, or by the area of non-linear open spaces. However, tree height explained a significant amount of the residual variation from a regression of transmitted diffuse light on road/ride width.

5.2.3.4 Vegetation structure

Cluster analysis produced five coherent groups of plots that differed primarily in cover of Sitka spruce, graminoids and bryophytes. Vascular plant species richness was significantly lower in the group with highest Sitka spruce cover, which was dominated by plots in rides, and plots at the edges of open spaces. Bryophyte and lichen species richness were lowest in the graminoid-dominated group, which was dominated by plots in glades and plots in the centre of open spaces. Simpson's diversity index was lower in groups dominated either by mosses or graminoids than when neither was dominant. There were no significant differences in open species richness between groups.

5.2.4 Epiphytes

A total of 68 species of epiphytes were found on the 24 trees surveyed – 28 bryophyte, 39 lichen and one vascular plant species. Two of the bryophyte species recorded are likely to appear on the Irish Red Data List for bryophytes, which is in the process of being compiled. Only 16 species occurred in more than 5% of plots. Mean species richness was 22.6 at the site level, and 16.3 at the level of the individual tree. Bryophyte species richness was significantly lower in the Wicklow sites than in Cork. Bryophyte species richness was positively associated with tree density and negatively associated with mean diameter of trees in the immediate area; density and diameter were also negatively correlated. Site elevation was negatively associated with bryophyte species richness in Wicklow sites and negatively associated with lichen species richness in Cork sites. Species richness was not significantly associated with age of the plantation, site aspect, width of the open space, glade area or canopy openness at the centre of the open space. Amount of open space 50–500 m from the sampled trees had no apparent effects on epiphyte biodiversity.

There were no significant differences between edge and interior trees from each site in terms of Simpson's diversity, Berger–Parker evenness, epiphyte cover, or total bryophyte and lichen species richness. Average DBH and basal area were significantly greater in the edge plots than the interior plots.

Bryophyte species richness decreased with height on the tree while lichen species richness increased. Edge trees showed more variation in species richness between trunk plots than did interior trees. In particular, there was more variation in species richness between north-facing and south-facing plots at the same height. Bryophyte cover was significantly higher on the south side of the edge trees than on the south side of interior trees, and on the south side of the edge trees compared to the north side of the same trees.

5.2.5 Spiders

A total of 11,872 individual spiders (including 2,690 juveniles) were captured in 13 families and 122 species. Twenty-four species were classified as being associated with open habitats and 14 with forested habitats.

5.2.5.1 Trends along the open to forest transect

Across the transect from open-space centre to forest interior, mean species richness and abundance decreased. Richness and abundance of open-habitat associated species were significantly greater in the open space compared to the other points, whereas richness and abundance of forest-associated species were significantly lower. Fifty-two species in the centre of the open space did not occur 5 m into the forest, whereas only six species occurred in the forest but not in the centre of the open space. Spider assemblages found at the edge of the open space represent a transition of assemblages in the centre of the open space to those within the forest. Variability in species composition of spider assemblages at the forest boundary and within the forest is relatively low compared to those in the open-space centre and edge. Spider assemblages appeared to be closely associated with vegetation structure: high cover of field-layer vegetation in the open space, cover of ground-layer vegetation at the open-space edge and needle litter and twig cover within the forest.

5.2.5.2 Influence of open-space type and size

Species richness and abundance of all spiders and of open-habitat associated species were significantly greater in glades than in rides or roads. Abundance (but not species richness) of forest-associated species was significantly lower in glades than in roads.

Roads and rides had similar spider assemblages. Ride/road-verge width was positively related to abundance of all spiders and open-habitat associated spiders and to open-habitat associated species richness, and negatively related to abundance of forest-associated spiders. Glade area was positively related to abundance of open-habitat associated species. Cluster analysis separates roads and rides that are less than 15 m wide from those that are wider than 15 m. The assemblages of narrow roads and rides (<15 m wide) with cover of vegetation 10–50 cm tall were distinct from those of wider rides with similar vegetation structures. These represented a transition between forest interior and open habitats with high lower (10–50 cm) field-layer cover.

5.2.5.3 Large-scale influence of open space

The total number of species and individuals, as well as the number of open-habitat associated species, were positively correlated with the area of unplanted open space within 200 m, and negatively correlated with ride length. Forest-associated species abundance, however, showed the opposite trend. However, it is likely that ride area indirectly represents the amount of forested area within 200 m of the sampling points, i.e. the greater the amount of planted forest, the greater potential for more rides. There were no significant relationships between the species variables and the following open-space types: road, outside, undeveloped, windthrow, clear-fell, broadleaf, total unforested and total open space. Plots which had >10% unplanted open space within 200 m were significantly greater in mean species richness than those with <5%. There was no significant difference between forest-associated species richness or species abundance and proportion of unplanted open space, or between the other open-space categories and the species variables.

5.2.6 Hoverflies

We recorded a total of 75 species, of which 65 are associated with closed canopy spruce forest, small open spaces, large open spaces or scrub habitats, and five are associated with miscellaneous macrohabitats that occurred in, or adjacent to, particular sites. Therefore, only five species were recorded whose occurrence could not be related to macrohabitats in, or adjacent to, the trapping locations. We recorded three species that are listed as threatened. The majority (nearly 80%) of the recorded species are associated with open-space habitats rather than closed-canopy forest. Overall, more of the recorded species are associated with large open spaces than with small open spaces, but the mean species richness per site was similar in these two categories. The most common habitat association of the recorded species was with humid grassland habitats, but there were more anthropophobic species associated with moorland and surface water habitats. In fact, most (73%) of the anthropophobic species associated with humid grassland and moorland are also associated with surface water habitats. While the total and mean per-site species richness of scrub-associated species was relatively high, very few of these species are anthropophobic.

Assemblage structure was significantly different between forest roads and glades. At Malaise traps in forest roads, the numbers of species associated with small and large open spaces were positively correlated with the average road width. There were no significant relationships between the richness of these species groups with forest road width at the trap location, or between the richness of other species groups and forest road width. There were no significant relationships between any of the measures of open-space area within 100–300 m of the traps and the numbers of hoverfly species.

The numbers of tree/tall-shrub foliage species (including anthropophilic and conifer-associated species) were negatively correlated with a gradient from broadleaved trees and shrubs to coniferous shrubs. The numbers of species associated with submerged sediment, water-saturated ground and surface water habitats were positively correlated with a gradient of increasing influence of most wet habitat features, except drainage ditches.

5.2.7 Birds

5.2.7.1 Roads

A total of 31 bird species were recorded during road transects. Mean bird species richness along roads was slightly higher in Cork sites than in Wicklow sites. Sections of Cork road had higher levels of shrub cover and broadleaf cover. Bird species richness was positively correlated with shrub cover and with broadleaved tree cover. There was no significant relationship between species richness along roads and road gap width, crop height or brash cover. Shrub cover and broadleaf cover were positively correlated with relative abundances of species associated with broadleaved woodland. Road sections of 15 m or wider had significantly higher cover of shrubs and broadleaved trees than narrower road sections.

5.2.7.2 Point counts

A total of 38 bird species were recorded during point counts. The mean number of bird species detected during point counts in Cork sites was not significantly different from that in Wicklow sites. However, the areas around Cork points had significantly higher cover of shrubs and broadleaved trees than the areas around Wicklow points. Bird species richness within 50 m was positively correlated with shrub cover and broadleaved tree cover. Species richness was not significantly correlated with brash cover, crop tree canopy cover or total area of open space. Of the open-space/forest-area variables estimated from aerial photographs, broadleaved woodland area was positively correlated with bird species richness at every scale we investigated. Bird species richness was also positively correlated with road area at a 50 m scale, and with clear-fell area and total area of open space at the 300 m scale. No other open-space variables measured on aerial photographs were significantly correlated with bird species richness at any scale.

More bird species were detected in the three sites with an element of broadleaved woodland area than in the nine other sites. Within the three sites that had a woodland element, more bird species were detected from points that had greater than 0.5 ha of woodland within 200 m than from other points. In all sites, woodland area within 300 m was positively related to the occurrence of several species associated with broadleaved tree cover. Areas outside the forest and total open space within 300 m were positively related to occurrence of Meadow Pipits and Skylarks.

5.2.8 Conclusions

A large component of Irish biodiversity is associated with forest habitats, and much of this biodiversity is dependent upon areas of closed-canopy tree cover. However, another important component of biodiversity in forest plantations is the flora and fauna associated with open-space habitats within forests. Many coniferous plantation forests in Ireland are generally darker than the natural broadleaf forests and have been found to lack elements of biodiversity associated with open spaces and less dense canopies in natural forest. Many of the characteristic forest species remaining in Ireland are, strictly speaking, species of forest edges and glades, rather than forest interior species. In intensively farmed landscapes, open spaces within forests may provide a suitable habitat for species characteristic of semi-natural open habitats, which no longer occur within the surrounding landscape.

Glades, rides and roads in Irish plantation forests can support reasonably diverse communities of plants and animals. The main factors influencing epiphyte biodiversity in this study were elevation and tree density. The positive association of tree density with bryophyte species richness highlights the adaptation of bryophytes to low light levels and their low tolerance to desiccation. The main effect of open spaces on epiphyte diversity was related to the presence of live branches on edge trees, which appeared to shade the trunk and increase humidity levels. The results of this study suggest that stand management in relation to tree density may be more important for epiphyte diversity than open spaces within the forestry plantation.

In contrast, although the primary causes of variation in terrestrial vegetation composition and diversity were soil and climate factors, light regime was also important, and the vegetation of glades and wide rides was distinct from that of narrow, more shaded rides. In general, vascular plant species richness increased and bryophyte and lichen species richness decreased with increasing solar radiation. Measures of vegetation diversity were highest in the forest open-space ecotone at the edges of glades, and tended to be lower both in well-lit, grass-dominated situations and in heavily shaded, bryophyte-dominated conditions.

Invertebrate diversity was also positively affected by open space. Fifty-two of the spider species we found were restricted to open spaces, in contrast to just six species that were only present in closed canopy areas, and average spider species richness per plot was significantly higher in open spaces than in forest plots. Nearly 80% of the hoverfly fauna that we recorded was associated with open-space habitats, and around one-third of these are mainly associated with semi-natural habitats. However, other invertebrate groups (including spiders and hoverflies associated with higher vegetation layers than were sampled during this study) might respond very differently to open space in forests.

The absence of any relationship between open space at the plantation scale and diversity of plants or hoverflies, suggests that plantation-scale processes such as dispersal have relatively little influence on the diversity of these groups in open spaces. In contrast, the overall amount of unplanted open space within a plantation was positively related to both species richness and abundance of spiders. The absence of a similar relationship at a smaller scale suggests that, at the scale of the plantation, increasing the availability of open space encourages the movement of spiders between open spaces.

This study suggests that to benefit terrestrial flora or spider fauna typical of open habitats, rides and roads should be an absolute minimum of 15 m in width and, in many cases, should be wider in order to support well-developed open-space habitat in mature spruce forests. For non-linear open space, a stratified sampling approach that varies glade area may reveal a similar 'threshold' size, above which open species are supported. Our results suggest that, depending on local conditions, glade areas of 625–900 m^2 should be sufficient to have at least part of the glade well lit.

The bird fauna does not follow the patterns described above. Typical open-space specialists that are widespread in habitats just outside the plantation are largely absent from open spaces within forest plantations. However, open spaces provide the main opportunity for the development of broadleaved tree and shrub cover within conifer plantations, and such vegetation is associated with higher bird biodiversity. This is largely due to a suite of relatively uncommon species that rely on these elements of open-space vegetation for foraging and/or nesting habitat.

Open-space habitats containing broadleaved trees and shrubs can also be extremely valuable for hoverflies, as can some wet habitat features, including small-scale features such as wet flushes and temporary streams. In general, selection of areas for open-space retention should focus on areas of high biodiversity or environmental heterogeneity. There is a need to examine the biodiversity value of a range of habitat types that could potentially be selected as retained habitat, specifically with regard to whether the unique and rare species associated with pre-planting habitat persist after afforestation.

Where deer numbers are high, overgrazing of forest open space is likely to have a negative impact on biodiversity. Control of deer populations in these areas will be a necessary precursor to the development of broadleaves and shrubs within forest open spaces.

5.3 Experimental Manipulation

Strips of open spaces adjacent to forest roads can make a significant contribution to the biodiversity of forestry plantations. The extent of this contribution is partly dependent on the width of these unplanted strips. The possibility of using these strips as a focus for an experimental manipulation to be set up during this project was decided in consultation with the project Steering Group (see Section 5.1).

The recommended between-trunk clearance across the forest roads is currently 15 m, with approximately 5 m being the road surface and the other 10 m being divided between the two sides of the road, leaving an average of 5 m on each side (Ryan *et al.*, 2004). On average, branches directly shade at least half of this area. Taking into account the shade from the maturing trees, there is little undisturbed open space in road gaps that is unshaded. The Research Group proposed to investigate the effect of doubling the clearance on the biodiversity of the area.

It is intended that this experiment will be maintained beyond the life of the BIOFOREST Project and that the sites will be re-surveyed periodically. As such, the ownership of the sites was important, and therefore the project was restricted to using sites owned by Coillte. Study sites were chosen from several that were scheduled to undergo re-establishment (planting after harvesting) in 2004/2005 (Fig. 5.2). Plantations dominated by Sitka spruce were the focus of the experiment. In sections of forest road within these plantations two treatments were established: in the normal treatment, trees were planted on either side of the road with a 15 m clearance across the road between trunks; in the wide treatment, trees were planted with double clearance, i.e. 30 m between trunks (Fig. 5.3).

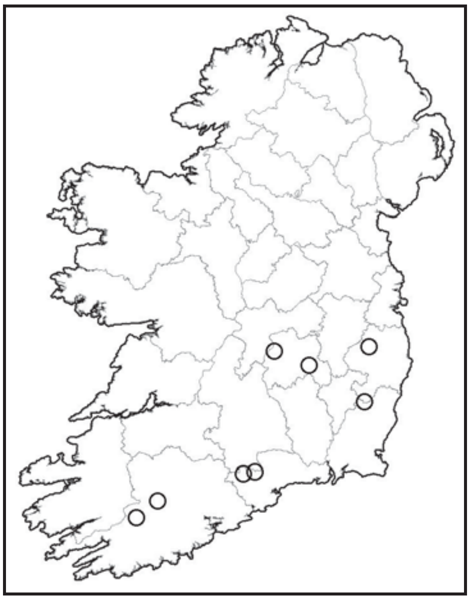

Figure 5.2. Study site locations for the road width experimental manipulation in Project 3.1.3.

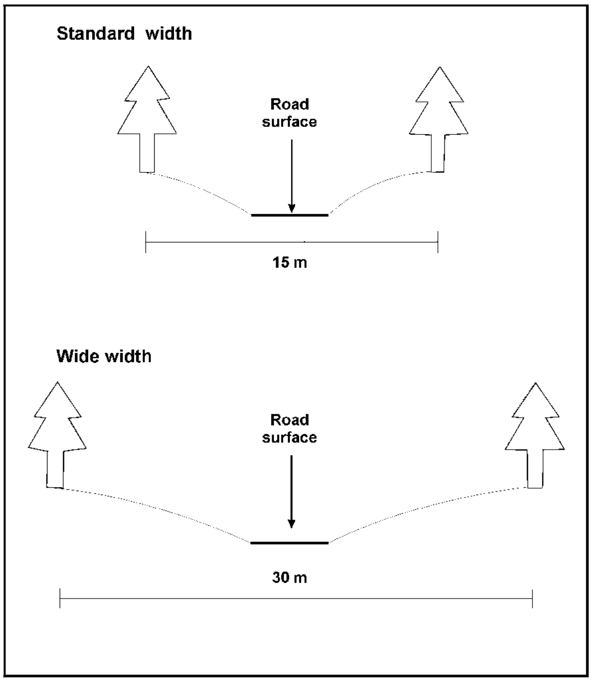

Figure 5.3. Diagram of standard and wide road width experimental treatment.

Baseline surveys were carried out during the summer of 2005 on vegetation, spiders, birds and hoverflies. Sorting and identification of specimens ensued, and the baseline data are included in the BIOFOREST Database. See Iremonger *et al*. (2006) for more detail on surveys.

5.4 Special Report on Hen Harriers

Hen Harriers *(Circus cyaneus)* are a protected bird species under European law, and one of the birds of greatest conservation concern in Ireland. In recent decades, large tracts of Hen Harrier habitat in the Irish uplands have been afforested. Hen Harriers nest and forage in young plantations, but closed canopy forests are not used extensively by this species. The suitability of Irish plantation forests for Hen Harriers therefore depends on their age structure.

Using the results of a recent national survey, the NPWS has outlined ten Indicative Areas (IAs) for Hen Harriers. These cover 3.4% of the area of the Republic of Ireland, and at the time of the survey supported roughly 75% of the Irish Hen Harrier population. In order to ensure that these areas remain suitable for Hen Harriers, land-use policy and practice within them need to be informed by the habitat requirements of this species, even if these are not fully understood at present.

This study had two aims:

1. To determine whether areas within the IAs with breeding Hen Harriers could be distinguished from areas where they did not occur, using a threshold level of habitat cover suitable for Hen Harrier hunting and nesting, and

2. To predict how changes in age structure of the forests within the IAs will affect the suitability of IAs for Hen Harriers by 2015.

It was found that areas with breeding Hen Harriers can be distinguished on the basis of percentage cover of suitable habitat: Hen Harriers were ten times less likely to occupy ranges in the IAs with less than 30% suitable habitat cover (within 1 km of their nest sites), than they were to occupy areas with more than 30% suitable habitat cover. Canopy closure in upland forests reduces the level of suitable habitat available to Hen Harriers. According to the 30% habitat threshold identified, the proportion of the IAs that is unsuitable for Hen Harriers will increase from about 30% (at the time of the Hen Harrier survey in 2002) to about 50% by 2015. Further afforestation and agricultural improvement in the uplands will have to be carefully regulated if it is not to exacerbate this process. The persistence of Hen Harriers in some areas may depend critically on the value of young second-rotation forests, relative to young first-rotation forests and open habitats such as bog and heath. This is something about which, at present, we know very little. When assessing the impact of a proposed land-use change, it is important to take into account changes in the value to Hen Harriers of habitats in the affected area and in the surrounding landscape, especially in areas with high levels of forest cover.

The results of this special study on Hen Harriers were submitted to COFORD and the EPA as a stand-alone report (Wilson *et al*., 2005). This report was also incorporated into the final technical report for the project (Iremonger *et al*., 2006).

6 Recommendations for Policy and Practice

Forests tend to be rich in biodiversity because they are the most structurally complex of ecosystems. However, even-aged single-species plantations are highly simplified ecosystems compared to natural forests, and their biodiversity is in general reduced. In particular, the closed-canopy phase in the forest cycle under Sitka spruce and other heavily shading conifers is associated with an extremely impoverished ground flora. Greater diversity in tree species enhances diversity in other plant and animal groups; this was demonstrated in our study by the contribution of ash stands to overall diversity within Sitka spruce dominated plantations.

As the forest stand matures, it acquires an increasing component of woodland specialist species (as opposed to generalist species that occur widely in both woodland and non-woodland habitats). Older forest stands favour increased diversity because of (i) greater length of time for colonisation, (ii) increased light penetration to lower strata, (iii) increased epiphyte biomass and diversity (with 'knock-on' increases in mass and diversity of other biota), and (iv) increased amounts of standing and fallen dead wood. Dead wood forms a major component of the decomposer food chain, and its presence is vital for saproxylic invertebrates and fungi, also for many bryophyte and lichen species. Retention of old stands is therefore a vital element in promoting diversity within the forest as a whole.

Gaps and open areas within forests provide a haven for light-demanding species, and may contain a major component of the overall biodiversity within a forest area. Appropriate management of open spaces is vital. For instance, we found a clear positive relationship between bird diversity along forest roads and the abundance of shrubs and self-sown native tree species. The resulting scrubby fringe provides enhanced diversity in the forest's provision of fruits and seeds, nesting sites, epiphytes, and invertebrate fauna.

Table 6.1 contains a summary of the management recommendations that we have identified, lists the taxonomic groups (where applicable) that each recommendation arises from, and indicates whether modifications to official documentation are required. Recommendations specifically requiring action from one or more areas of the forest sector are distinguished from those with a more general remit that apply not only to forestry, but also to other sectors, in particular to local and national government, and to universities and others engaged in biodiversity research. Although a given recommendation may originate from the results of a particular taxonomic group, implementation of the recommendation will often benefit the biodiversity of other groups. Recommendations are divided into five categories: (i) those dealing with strategic forest planning, (ii) those dealing with biodiversity assessments of areas for which proposals have been made to plant new forests, (iii) those dealing with planning, planting and establishment of new forests, (iv) those dealing with management in existing forests, and (v) those which suggest future areas of research.

For practical management purposes, and for ease of ensuring regulatory compliance it is desirable to have simple criteria, such as requirements for fixed percentages of open space. However, in the application of ecological management principles, there will always be exceptions to simple rules. Where our recommendations include specific criteria, these should be interpreted as general principles, and provision should be made for exceptions. In particular, priority should usually be given to existing features of biodiversity importance.

We make the following recommendations subject to the limitations of this project. Like any biodiversity study we had to be selective about the taxonomic groups that we studied. Other taxa, including arboreal spiders, host-specific phytophagous invertebrates and fungi, could show other effects of forest type and management. The plantations we studied were composed of a limited range of tree species and environmental situations. Caution should be applied when extrapolating our results and recommendations to other forest and habitat types. Our study of open space focused on sections of forest roads and rides that were predominantly orientated east–west, so the precise quantitative form of the relationships we found may not apply to sections of forest roads and rides that are orientated generally north–south. Some of the forest planning recommendations may apply to

Table 6.1. Summary of management recommendations. Recommendations are further explained in Sections 6.1–6.5. The source and, where applicable, the number of each recommendation in the source report is given as follows: R, recommendation from review of pre-afforestation biodiversity assessment procedure (Gittings *et al*., 2004); O, objective from review of pre-afforestation biodiversity assessment procedure (Gittings *et al*., 2004); A, biodiversity assessment of afforestation sites (Smith *et al*., 2006); B, assessment of biodiversity at different stages of the forest cycle (Smith *et al*., 2005); C, investigation of experimental methods to enhance biodiversity (Iremonger *et al*., 2006); and H, the distribution of Hen Harriers in Ireland in relation to land-use cover (Wilson *et al*., 2005). Where applicable, the taxa on which each recommendation is based are given as V, vegetation; S, spiders; H, hoverflies; and B, birds. The remit of each recommendation is classed as applying principally to the forest industry (F) or more generally, including to governmental or other non-forestry groups (G). Recommendations requiring modification to specific documentation are indicated as follows: E, EIA *Advice Notes*; F, *Forest Biodiversity Guidelines*.

	Recommendation	Source	Taxa	Remit	Modify
Strategic forest planning					
1	Require all non-urban local authorities to prepare Indicative Forestry Strategies	R2		G	
2	Compile specialist reports identifying biodiversity constraints outside designated sites	R3		G	
3	Complete countywide habitat surveys and biodiversity action plans and establish a biological records centre	O1		G	
4	Survey invertebrate biodiversity in semi-natural habitats of conservation importance	O2		G	
5	Establish ecological advisory units in each local authority	O3		G	
6	Establish a system of professional accreditation for ecological consultants in Ireland	O4		G	
7	Incorporate requirements for biodiversity assessment (in 21, below) in Environmental Impact Assessment (EIA) *Advice Notes*	O5		G	E
8	Develop guidelines for the choice of invertebrate taxa for EIAs	O6		G	E
9	Develop a more thorough classification of vegetation communities in Ireland	O7		G	
10	Afforestation and agricultural improvement should be regulated in areas with Hen Harriers	H1	B	F, G	
11	Develop a mosaic of different stand age classes in heavily afforested areas occupied by Hen Harriers	H3	B	F	
Pre-afforestation site assessment					
12	Develop screening criteria to identify afforestation projects requiring a sub-threshold EIA	R1		F	F
13	Forest Service should employ ecologists	R4		F	
14	Pre-afforestation site surveys should map habitats using a standard classification and note the presence of indicators and other biodiversity features	R5, A1, A3		F	F
15	Consider site biodiversity in context of the surrounding landscape prior to afforestation	A3		F	F
16	Foresters submitting grant applications should have completed accredited ecological training courses or employ qualified ecologists	R6		F	F
17	A sample of grant applications from each self-assessment company to be inspected by a Forest Service ecologist	R7		F	F
18	More comprehensive consultation procedures for grant applications	R8		G	F
19	Local authorities to comment on conservation issues pertaining to grant applications	R9		G	F
20	Refer applications where biodiversity concerns have been raised to a Forest Service ecologist to determine whether a more thorough assessment is required	R10		F	F
21	Biodiversity assessments in afforestation Environmental Impact Statement (EISs) must conform to specified standards	R11		F	E
22	Biodiversity assessments contained in EISs to be reviewed by a Forest Service ecologist, or an accredited external ecologist	R12		F	E
23	Proposed changes in land use should be regarded as being potentially damaging to Hen Harriers if they decrease the proportion of suitable habitat to below 30%	H2, H4	B	G	

Table 6.1. *Contd.*

Recommendation	Source	Taxa	Remit	Modify
Forest establishment				
24 Semi-natural habitats should not be afforested, unless there are mitigating circumstances	B1, A2, A3	V, H, B	F	F
25 Establish plantations in close proximity to semi-natural woodland	B2	V	F	F
26 Create a mosaic of stands of different age and structure at the landscape scale	B3	V, S, H, B	F	
27 Include a mixture of canopy species when planting	B4	V, S, H	F	
28 Review the adequacy of the existing requirement for 5–10% open space in the *Forest Biodiversity Guidelines*	C	S	F	F
29 Stipulate a minimum width of 15 m for linear open-space features included in the ABE	C, A4, A6	V, H	F	F
30 Leave small unplanted areas to maintain gaps through the forest cycle	B5	V, S, H, B	F	F
31 Leave small areas of wet habitat and avoid drainage where possible	B6, A4, C	H	F	F
32 Include open space within broadleaved component of plantation	B7	H	F	F
33 Retain scrub, hedgerows and other marginal and additional habitats and allow for adequate buffer zones	B8, A4	B	F	
34 Design complex edges to plantations to increase proportion of edge habitat	B9	B	F	F
35 Leave boundaries unplanted to allow development of complex edge structure	B10	B	F	F
Forest management				
36 Provide guidelines to help foresters to identify potentially important habitats for ground flora, spider and hoverfly diversity	B11	V, S, H	F	F
37 Rigorously thin Sitka spruce forests to prevent canopy closure	B12	V, S, H	F	F
38 Promote broadleaved woody vegetation in young conifer plantations	B13, A5, C	H, B	F	F
39 Ensure grazing pressure is low enough to allow broadleaved tree and shrub vegetation to develop	C	V, H, B	F	
40 Retain mature Sitka spruce stands, where there is no risk of damage to adjoining semi-natural habitats	B14	V, S	F	F
41 Retain large diameter dead wood	B15	V, H	F	F
Future research				
42 Test and refine the indicators identified in this project	A7, B16		G	
43 Conduct a comprehensive national survey and classification of grasslands	A8, B17		G	
44 Investigate forestry and biodiversity at whole-farm and landscape scales	A9		G	
45 Investigate the implications for biodiversity of different tree species mixtures	B18, C		G	
46 Investigate the biodiversity of open spaces in plantations in agricultural lowland landscapes	C		G	
47 An investigation of the biodiversity of over-mature commercial plantations	B19		G	
48 A study of the biodiversity of second-rotation forests	B20		G	
49 A study of the biodiversity in forests under continuous cover management	B21		G	
50 Monitor forest biodiversity in permanent plots	B22		G	
51 Investigate the inclusion of native woodland elements into commercial plantations	B23		G	
52 Further investigate the biodiversity of different open-space habitats within forests	C		G	
53 Determine the influence of grazing pressure on broadleaved tree and shrub vegetation in open spaces	C		G	
54 Investigate the biodiversity of other taxa found in Irish forests and afforested habitats	C		G	
55 Develop a custom-designed GIS for analysis of habitat in areas with Hen Harriers	H6	B	G	
56 Collect more detailed habitat data from the areas with Hen Harriers	H7	B	G	
57 Improve our understanding of Hen Harrier habitat requirements	H8	B	G	

reforestation projects as well as afforestation, but it should be recognised that these recommendations are based exclusively on data from first-rotation forests.

For the remainder of this chapter, the term '*Guidelines*' refers to the *Forest Biodiversity Guidelines* (Forest Service, 2000c).

6.1 Strategic Forest Planning

1. **Require all non-urban local authorities to prepare Indicative Forestry Strategies.** See below.

2. **Compile specialist reports identifying biodiversity constraints outside designated sites** as part of the preparation of Indicative Forestry Strategies. See below.

3. **Complete countywide habitat surveys and biodiversity action plans and establish a biological records centre.**[1] See below.

The above three recommendations are aimed at improving the background information on biodiversity available to people assessing whether or not a site should be planted. There are currently almost no data available for evaluation of biodiversity importance outside of designated sites. For most sites with semi-natural habitat, these recommendations would mean that some evaluation of their biodiversity importance would be possible.

4. **Survey invertebrate biodiversity in semi-natural habitats of conservation importance.** The current lack of information on Ireland's invertebrate fauna makes it hard to decide what taxa should be focussed on by any pre-afforestation assessment, and almost impossible to interpret the findings of many such assessments, in terms of a site's biodiversity value, especially at regional and local scales.

5. **Establish ecological advisory units in each local authority.** So far, Heritage Officers with ecological experience have been appointed to some local authorities. However, many other local authorities remain without any in-house ecological expertise. At present, local authorities are not encouraged to comment on afforestation grant applications, but in the event that this changes (see Recommendation 19, below), such expertise will enable local authorities to make invaluable contributions during the consultation phase of assessments.

6. **Establish a system of professional accreditation for ecological consultants in Ireland**, with the ecological components of all Environmental Impact Assessments carried out only by professionally accredited consultants.

7. **Incorporate requirements for biodiversity assessment contained (in 21, below) in Environmental Impact Assessment (EIA) *Advice Notes.*** See Recommendation 21, below.

8. **Develop guidelines for the choice of invertebrate taxa for EIAs.** At present, choice of taxa for pre-afforestation assessments is made almost solely on the basis of logistical considerations such as timescale, costs and available expertise. However, only taxa that are able to distinguish sites of high biodiversity importance should be considered suitable for such assessments. As such, appropriate taxa may well depend on the habitat type of the proposed afforestation site. Variation in species assemblages within and between habitats is poorly known for most invertebrate taxa in Ireland, so the development of guidelines may need to be preceded by thorough, habitat-stratified surveys.

9. **Develop a more thorough classification of vegetation communities in Ireland,** perhaps along the same lines as the UK National Vegetation Classification.

10. **Afforestation and agricultural improvement should be regulated in areas with Hen Harriers,** to minimise further decreases in their carrying capacity for this species. Wherever possible, afforestation in these areas should target improved agricultural land, rather than areas of bog and rough pasture, which are used by Hen Harriers for foraging. The level of afforestation which is acceptable from a Hen Harrier point of view depends on the value to Hen Harriers of the remaining unforested habitat and, critically, on the value of young second-rotation forests (see

1. The Irish National Biodiversity Data Centre was officially opened in January 2007 on the Carriganore Campus of the Waterford Institute of Technology. The Centre's duties cover the collection of records from public bodies and private collectors, their validation, collation, classification and digitisation plus education, research and training in biodiversity.

Recommendation 57, below).

11. **Develop a mosaic of different stand age classes in heavily afforested areas occupied by Hen Harriers.** Though more research is needed to confirm this, current indications are that young second-rotation forests can provide valuable nesting and foraging habitat. If this is the case, then minimising the proportion of forest that is under closed canopy at any one time will maximise the long-term carrying capacity of an area for Hen Harriers, by avoiding 'bottleneck' periods during which availability of young second-rotation forest is particularly low.

6.2 Pre-Afforestation Site Assessment

12. **Develop specific screening criteria to identify afforestation projects requiring a sub-threshold EIA.** The general absence of background information on biodiversity in Ireland, and the relatively high threshold for EIA, mean that it is imperative that afforestation projects in sites of potentially high biodiversity importance are flagged for more detailed scrutiny.

13. **Forest Service should employ ecologists.** The recent employment of an ecologist by the Forest Service was a welcome development. However, more than one ecologist would be needed to adequately cope with the remit of Recommendations 17, 20 and 22, below.

14. **Pre-afforestation site surveys should map habitats using a standard classification and note the presence of indicators and other biodiversity features.** The *Guidelines* should be revised to contain precise definitions, based upon the Heritage Council classification (Fossitt, 2000), of the habitats which are required to be mapped. However, as this classification scheme does not discriminate well between some habitat sub-types that differ in biodiversity, the development of an in-house modification of the classification for use by foresters should be considered. Also, the total extent of these habitats within a site should be mapped (not just the 15% ABE), and the fauna necessary to record should also be specified.

15. **Consider site biodiversity in context of the surrounding landscape prior to afforestation.** In general, areas of semi-natural habitats in areas of intensive agriculture, forestry or other highly altered landscapes should not be afforested. On the other hand, where a particular semi-natural habitat is abundant, afforestation of this habitat will not generally have significant negative impacts on local biodiversity. However, foresters and forestry inspectors should be aware of the cumulative effects of individual afforestation projects on landscape biodiversity.

16. **Foresters submitting grant applications should have completed accredited ecological training courses** or qualified ecologists should complete the relevant sections of the applications. This would greatly increase the quality of information submitted to the Forest Service by the Competent Foresters who collect this information, addressing one of the main deficiencies in biodiversity assessment for afforestation projects in Ireland.

17. **A sample of grant applications from each self-assessment company to be inspected by a Forest Service ecologist.** Self-assessment could be a very effective way for the Forest Service to save on limited time and human resources, while ensuring a high standard of ecological assessment. However, in order for this to be the case, self-assessment companies must be monitored to ensure that the quality of their ecological assessments is acceptable.

18. **More comprehensive consultation procedures for grant applications.** Some biodiversity features such as rare plants or invertebrates will not easily be picked up by initial site surveys. Many sites containing such features will already be known to members of the public, to NGOs and to locally based branches of statutory bodies. Consultation procedures for grant applications should be amended to include posting of fuller details of applications on the Forest Service website, circulation of weekly lists of applications to local authorities, NPWS and any other bodies on request, and availability of full details of each application for inspection in the local Forest Service office.

19. **Local authorities to comment on conservation issues pertaining to grant applications.** In the past, local authorities have not had in-house technical expertise available, but the appointments

of Heritage Officers have begun to remedy this deficiency. In conjunction with the previous recommendation, and Recommendation 5, above, this recommendation will help to close the consultation gap that currently exists in relation to non-designated sites.

20. **Refer applications where biodiversity concerns have been raised to a Forest Service ecologist to determine whether a more thorough assessment is required.** Only 15% of afforestation sites are designated as ABEs, so the decision as to whether or not to afforest a site where more than 15% consists of habitats of high biodiversity value should be carefully considered in the context of the habitat(s) involved, and the surrounding landscape matrix. Regardless of how abundant it is in the landscape, certain habitat types should never be afforested, such as priority habitats listed in the EU Habitats Directive

21. **Biodiversity assessments in afforestation Environmental Impact Statement (EISs) must conform to specified standards.** Surveys should include adequate scoping and description of the scoping process. All available background information should be used, and advice sought from a wide range of consultees. Surveys should be focused on taxa relevant to biodiversity issues associated with afforestation, and consideration given to the trade-off between completeness of species list and assessment of abundances. Standard habitat classifications and survey methodologies should be used, and full documentation of methodologies and effort included in ecological reports.

22. **Biodiversity assessments contained in EISs to be reviewed by a Forest Service ecologist, or an accredited external ecologist.** Even for someone with a high level of ecological knowledge, it can be hard to accurately assess the standard of a biodiversity assessment from a report. For someone with a non-ecological background, it is unreasonable to expect that they will be able to discriminate between assessments that will be successful in identifying sites of high biodiversity, and those that will not.

23. **Proposed changes in land use should be regarded as being potentially damaging to Hen Harriers if they decrease the proportion of suitable habitat in areas with Hen Harriers to below 30%.** The results of our study suggest that 3 km^2 may be an appropriate scale at which to evaluate habitat composition within these areas. Until our understanding of the value of second-rotation forests for foraging and nesting is improved, a combined limit of substantially less than 70% should apply to improved agricultural land and plantation forestry in areas with Hen Harriers.

6.3 Forest Establishment

24. **Semi-natural habitats should not be afforested, unless there are mitigating circumstances.** The *Guidelines* recommend that "*local biodiversity factors (including habitats and species of particular interest)*" should be identified and incorporated into the site development plan, but do not explicitly consider the choice of sites for afforestation. Therefore, the *Guidelines* should recommend that, where possible, improved grassland or arable land should be used for afforestation instead of semi-natural habitats, particularly in landscapes dominated by intensive farming. Priority habitats listed in the EU Habitats Directive (European Commission, 1999) should not be afforested, regardless of whether they are part of a designated site, or how common they are in the surrounding landscape.

25. **Establish plantations in close proximity to semi-natural woodland.** We recommend that plantations be established in close proximity to semi-natural woodland, in order to facilitate the establishment in plantations of woodland plants and other taxonomic groups with poor dispersal abilities. New plantations close to semi-natural woodland should preferably be established and managed under the *Native Woodland Scheme* (Forest Service, 2001) or be comprised of species already occurring in the existing woodland. Plantations comprised of tree species that are potentially invasive in semi-natural woodland should not be located near one.

26. **Create a mosaic of stands of different age and structure at the landscape scale**. The recommendation in the *Guidelines* to promote age and structural diversity at the landscape scale is supported by the results from all taxonomic groups.

A diverse forest structure should be implemented at the planning stage of afforestation. Planning a mosaic of stands of different ages and structural stages may be difficult in some landscapes where forest parcels have several different owners.

27. **Include a mixture of canopy species when planting.** The recommendation in the *Guidelines* for diversity of canopy species within a forest is supported by the results of this research. Only non-intimately mixed forests (i.e. adjacent single-species blocks) were studied, however, and therefore we can make no conclusions or recommendations on intimate mixtures of tree species (see Recommendation 45 below).

28. **Review the adequacy of the existing requirement for 5–10% open space in the *Forest Biodiversity Guidelines.*** Plantations are required to contain 5–10% open space, except in plantations of less than 10 ha in size. In some plantations, larger amounts of open space should be considered. However, the contribution of the open-space habitat within forest plantations to biodiversity at the landscape level must be considered, and a universal prescription for total amount of open space at the plantation scale may not be appropriate.

29. **Stipulate a minimum width of 15 m for linear open-space features included in the Area for Biodiversity Enhancement.** The typical width of forest ridelines is only 6 m (Forest Service, 2003) and forest drains are normally associated with little or no increase in tree spacing. Such gaps are too narrow to be treated as open space from a biodiversity perspective. Forest road widths of greater than 15 m would enhance biodiversity for some groups (e.g. flora and invertebrates) but such widths are generally avoided because wide verges are difficult for machinery to cross during harvesting. A compromise could be to develop forest roads with wide scallops, i.e. alternating sections of road of standard and wide widths. This could also benefit biodiversity by reducing wind-tunnel effects and by increasing the length of forest edge habitat.

30. **Leave small unplanted areas to maintain gaps through the forest cycle.** Although there is no minimum size for ABEs, in practice this requirement is interpreted through the retention of one or a few discrete patches of habitat that, for ease of mapping, are usually a minimum of 0.16 ha. However, even very small areas of open space (e.g. less than 400 m^2) may promote biodiversity, especially at the thicket stage. Such open spaces should be widely scattered through the forest and should be incorporated into plantations less than 10 ha in size.

31. **Leave small areas of wet habitat unplanted and avoid drainage where possible.** Small, wet habitat features can support hoverflies as well as other invertebrate and plant species. Ground preparation and other types of drainage should be avoided in or near small wet areas. Planting should be set back so that these habitats are not shaded out by the trees as they mature. If the biota they support is not dependent on open conditions, wet habitat features may be planted (without ground preparation) with suitable native tree species to create a wet woodland.

32. **Include open space within broadleaved component of plantation.** Where ash is the 10% broadleaved component of a conifer plantation, the inclusion of an area of open space large enough to allow the development of grassy clearings can provide habitat for some hoverfly species that do not normally occur in conifer plantations. Therefore, the *Guidelines* should recommend that at least some of the open space and broadleaf components be placed together, where possible.

33. **Retain scrub, hedgerows and other marginal and additional habitats and allow for adequate buffer zones.** Our research has demonstrated the biodiversity value at the site and landscape scales of marginal and additional habitats, such as hedgerows, scrub, streams, ponds, stone walls, earthbanks and others. These and other semi-natural habitats described in Fossitt (2000) should also be given specific mention in the *Guidelines*. Scrub should not be removed or planted and should be included as a retained habitat in ABEs. Planting should be set back so that these habitats are not shaded out by the trees as they mature. Where the area of marginal and additional habitats plus buffers exceeds the required 15% ABE area, the decision of whether or not to plant should be carefully reconsidered.

34. **Design complex edges to plantations to increase proportion of edge habitat.** See below.

35. **Leave boundaries unplanted to allow development of complex edge structure.** See below.

The quantity and quality of edge habitat for birds would be improved by establishing irregular external and internal forest edges (e.g. along roads and rides), encouraging heterogeneity of structure and species composition and leaving a wide, unplanted margin between the forest edge and the forest boundary or fence. These recommendations are also included in the *Forestry and Bird Diversity in Ireland* guide (O'Halloran *et al*., 2002), and are in broad agreement with existing recommendations of the *Forestry and the Landscape Guidelines* (Forest Service, 2000d).

6.4 Forest Management

36. **Provide guidelines to help foresters to identify potentially important habitats for ground flora, spider and hoverfly diversity.** At present, the *Guidelines* only contain guidance on identifying important habitats at the pre-planting stage, and even this guidance is problematic (Gittings *et al*., 2004). For SFM, it is important for foresters to be able to identify potentially important habitats and indicators within established forests that need special consideration. In order to able to do this, foresters should be given adequate guidance and, where necessary, training.

37. **Rigorous thinning of Sitka spruce forests to prevent canopy closure**. Early and frequent thinning of Sitka spruce forests to prevent complete canopy closure would promote ground flora diversity and create a habitat for spiders and hoverflies. However, this is contrary to what is considered to be silvicultural best practice. Such a thinning regime may be applied to parts of larger forests or to the whole of particular forests, such as those with good biodiversity potential or those receiving significant amenity use, and avoided in areas with significant windthrow risk.

38. **Promote broadleaved woody vegetation in young conifer plantations.** Broadleaved shrubs and trees make important contributions to forest biodiversity. The *Guidelines* should include more specific guidelines on how to encourage shrub and non-crop tree patches/stands in plantations. Pre-existing shrubs (including bramble) and saplings should be retained within conifer plantations, and natural regeneration should be encouraged, providing open spaces nearby existing broadleaved seed sources. Clearance or damage of scrub along roadsides and during thinning should be avoided where possible, in which case mechanical clearance methods should be used in preference to herbicides.

39. **Ensure grazing pressure is low enough to allow broadleaved tree and shrub vegetation to develop.** Our study was not designed to investigate the effect of grazing on forest biodiversity. However, levels of grazing differed markedly among our study sites, and may have been responsible for some of the differences we observed in the plant species assemblages, vegetation structure and hoverfly and bird diversity. More research needs to be done to determine the optimal grazing regimes for biodiversity in forest open spaces.

40. **Retain mature Sitka spruce stands, where there is no risk of damage to adjoining semi-natural habitats.** Structurally mature plantations are particularly important for vascular plants, bryophytes and spiders with strong woodland affinities. The *Guidelines* should encourage the retention of some mature stands or even small groups of trees beyond the normal felling age, except where there is a risk of exotic tree regeneration in adjacent semi-natural habitats such as woodlands, bogs and heathlands. Ideally, plantations selected for retention should have indicators associated with high botanical and spider biodiversity, and should harbour large diameter dead wood.

41. **Retain large diameter dead wood.** Although the *Guidelines* recognise the importance of retaining dead wood, they do not specify the type(s) of dead wood that should be retained. Our results indicate that, in Sitka spruce stands, large diameter dead wood supports more and rarer species of saproxylic hoverfly and bryophytes than small diameter dead wood. The *Guidelines* should require that the specified volumes of dead wood retained after thinning and felling be comprised of trees and branches greater than 7 cm diameter and preferably greater than 20 cm diameter.

6.5 Further Research

42. **Test and refine the indicators identified in this**

project. Further trials using independent data are needed to determine how many indicators in which categories best discriminate between high and low biodiversity sites. More indicators are needed for ecological situations not included in this study, such as in open habitats like dry-humid acid grassland and dry heath, in forests composed of species other than Sitka spruce and ash, and in second-rotation forests.

43. **Conduct a comprehensive national survey and classification of grasslands.** The classification of grasslands in the Irish scheme (Fossitt, 2000) is inadequate to describe the biodiversity of semi-natural grasslands, making it hard or impossible to identify grasslands of conservation value that should not be subject to afforestation. We therefore recommend that a comprehensive national survey, analysis and classification of semi-natural grasslands be undertaken, and that indicators be developed to enable non-specialists to identify grasslands of potential conservation value.

44. **Investigate forestry and biodiversity at whole-farm and landscape scales.** Important research questions include but are not limited to the following. What are the effects of afforestation in landscapes of varying forest cover? What are the effects of different age and species compositions of forest on biodiversity at the farm and landscape scales? Can forests act as corridors between habitats of conservation importance? What factors influence the immigration of species into plantations from the wider landscape?

45. **Investigate the implications for biodiversity of different tree species mixtures.** In this study, we were constrained by time and resources to investigate only non-intimate mixtures of Sitka spruce and ash. The biodiversity of mixed stands may be different, especially with regard to canopy cover. We recommend that a study on the biodiversity of popular conifer species mixes and conifer–broadleaf mixes be researched. Comparison should be made between single-species stands, intimate mixtures and intermediate situations.

46. **Investigate the biodiversity of open spaces in plantations in agricultural lowland landscapes.** Our study was restricted to plantations in upland landscapes, but a large proportion of future afforestation is likely to take place in more-or-less intensively farmed lowland landscapes. We should therefore conduct research to generate management guidelines to realise the potential of such forests. Such research should take into account the open habitats present in the landscape outside the forest boundary and differing agricultural management regimes (e.g. REPS and non-REPS farms).

47. **An investigation of the biodiversity of over-mature commercial plantations.** The biodiversity of over-mature commercial forests should be investigated, in order to determine how long such stands should be left to enhance the biodiversity value of the forest. The role of over-mature plantations as a species source for colonisation of adjacent reforestation areas should also be studied.

48. **A study of the biodiversity of second-rotation forests.** Though many commercial forests in Ireland are now in their second rotation, we know almost nothing about how the biodiversity of second-rotation forests compares to that of first-rotation forests. It is vital to know how biodiversity changes with each felling cycle, and how it is affected by aspects of second-rotation management such as ground preparation, brash management, dead wood retention and proximity to retained first-rotation stands.

49. **A study of the biodiversity in forests under continuous cover management.** Clear-fell represents the predominant management type in Irish forestry. Some research on silvicultural aspects of continuous cover systems is being carried out in Ireland, but the biodiversity implications of such management are not known. Research on the biodiversity of forests under different continuous cover systems should be carried out, perhaps using silvicultural forest plots already in existence if these are suitable.

50. **Monitor forest biodiversity in permanent plots.** This study examined biodiversity over the forest cycle by substituting sites in different stages of maturity for time. However, a more powerful study would investigate how forest biodiversity changes over the life cycle of a particular forest. State-owned biodiversity monitoring sites should be established to this end, incorporating a representative range of climate conditions, soil types and canopy species.

Appropriate project management and funding structures should be put in place to ensure long-term continuity of this research.

51. **Investigate the inclusion of native woodland elements into commercial plantations.** One method of enhancing the native biodiversity of commercial forestry plantations could be the planting of small areas of native woodland for long-term retention within the plantation. These could support woodland species that may not otherwise be able to exist in plantations of non-native species. The effects on forest biodiversity of distance from sources of woodland species and location of copses within a plantation should be studied.

52. **Further investigate the biodiversity of different open-space habitats within forests.** The focus of our project was on identifying relationships between biodiversity and open-space amounts and configuration. Therefore, to achieve adequate replication, and to avoid confounding factors, we focused on widespread and mundane open-space habitats. Research into the biodiversity of more interesting open-space habitats would help develop guidelines for the management of important retained habitats.

53. **Determine the influence of grazing pressure on broadleaved tree and shrub vegetation in open spaces.** See Recommendation 39, above.

54. **Investigate the biodiversity of other taxa found in Irish forests and afforested habitats.** Research on the biodiversity of other taxonomic and functional groups that are likely to have different ecological responses to the aspects of forest management addressed by this project would be useful. These could include: epiphytes on broadleaved trees and shrubs, fungi, spider fauna in shrubs and trees, moths and ground beetles. Moths and ground beetles have already been extracted from our Malaise trap and pitfall trap samples and could, therefore, be investigated relatively easily.

The following three measures address two main aims regarding future research on Hen Harriers – to generate information needed to implement the management prescriptions we have recommended, and to improve our understanding of Hen Harrier habitat requirements, particularly with respect to second-rotation forest. The latter aim can be achieved both directly, through increases in our understanding of Hen Harrier ecology, through the provision of data that can be used to test and refine the predictions of the Hen Harrier habitat requirement models.

55. **Develop a custom-designed GIS for analysis of habitat in areas with Hen Harriers.** This would allow the effects of a proposed change in land use on the proportion of existing and future suitable habitat cover in the surrounding area to be easily evaluated in the context of existing land uses.

56. **Collect more detailed habitat data from areas with Hen Harriers.** This should include an inventory of all forests with planting species, planting year and projected felling year, and more detailed and accurate information on unplanted habitats than were available for this study.

57. **Improve our understanding of Hen Harrier habitat requirements.** This could be done through a combined satellite- or radio-tracking study of foraging adults, and monitoring of the fledging success of Hen Harrier nests in different habitat configurations.

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Appendix 1 Project Outputs

The three sub-projects described above generated a huge amount of data, for which an interactive, GIS-based database was custom-built. This will be restricted to use by EPA- and COFORD-approved researchers for a year from submission: after this time has expired it will be made available to the general public through the EPA.

During the project a variety of outputs was generated. Apart from the six-monthly Technical Reports required to fulfil the contractual obligations, outputs were many in the form of oral and written communications. These are listed below under different category headings. In addition to these the BIOFOREST Website was created and maintained at http://bioforest.ucc.ie, and many of the listed outputs are available on that.

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Appendix 2 List of Staff

Individuals involved in the BIOFOREST Project met periodically to plan and review. The following were the main groups that met.

Research Group:

Department of Zoology, Ecology and Plant Science, University College, Cork (UCC): Prof. Paul Giller, Prof. John O'Halloran, Dr Tom Kelly, Dr Tom Gittings, Dr Mark Wilson, Dr Josephine Pithon, Dr Anne Oxbrough

Botany Department, Trinity College, Dublin (TCD): Dr Daniel Kelly, Dr Fraser Mitchell, Dr Paul Dowding, Dr George Smith, Dr Laura French, Dr Linda Coote, Dr Susan Iremonger, Dr Anne-Marie McKee and Ms Saoirse O'Donoghue

Coillte Teoranta: Dr Aileen O'Sullivan, Mr Pat Neville, Dr Alistair Pfeifer

Others joined this Research Group at different stages of the project, in particular:

Coastal and Marine Resources Centre, University College, Cork: Ms Vicki O'Donnell, Ms Valerie Cummins

Temporary research students and associates:

Ms Erika Buscardo, Ms Jacqueline Bolli, Ms Julianna O'Callaghan

Management Group:

COFORD: Joe O'Carroll, Dr Eugene Hendrick

EPA: Dr Helen Walsh, Dr Conor Clenaghan, Dr Garret Kilroy, Dr Karl Richards

UCC: Prof. Paul Giller, Prof. John O'Halloran, Dr Tom Gittings

TCD: Dr Daniel Kelly, Dr George Smith

Coillte: Dr Aileen O'Sullivan

Project manager: Dr Susan Iremonger

Steering Group:

This group was composed of the other two groups, plus:

National Parks and Wildlife Service: Dr John Cross

Forest Service: Noel Foley

Forestry Commission (UK): Dr Jonathan Humphrey

University of Helsinki (Finland): Dr Jari Niemelä

European Environment Agency (Denmark): Dr Tor-Björn Larsson

Centre for Ecology and Hydrology (UK): Dr Allan Watt

National Development Plan 2007 - 2013

Environmental Research Technological Development and Innovation (ERTDI) Programme 2000-2006

The Environmental Research Technological Development and Innovation Programme was allocated €32 million by the Irish Government under the National Development Plan 2000-2006. This funding is being invested in the following research areas:

- Environmentally Sustainable Resource Management
- Sustainable Development
- Cleaner Production
- National Environmental Research Centre of Excellence

The Environmental Protection Agency is implementing this programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

NATIONAL COUNCIL FOR FOREST RESEARCH & DEVELOPMENT
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