Guidelines for Forestry and Biodiversity

A report prepared for the Forest Service by

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Section A of this document contains technical details that form the basis for the operational stipulations specified in Section B.

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List of Acronyms

CBD - Convention on Biological Diversity
CCD - Convention to Combat Desertification
CIFOR - Center for International Forestry Research
CSD - United Nations Commission on Sustainable Development
FAO - Food and Agriculture Organisation of the United Nations
FCCC - Framework Convention on Climate Change
FIPS - Forest Inventory and Planning System
IFF - Intergovernmental Forum on Forests
ILO - International Labour Organisation
IPF - Intergovernmental Panel on Forests
IUFRO - International Union of Forest Research Organisations
NGO - Non-Governmental Organisation
NWS - Native Woodland Scheme
SFM - Sustainable Forest Management
UN/ECE - United Nations Economic Commission for Europe
UNCED - United Nations Conference on Environment and Development
UNEP - United Nations Environment Programme
UNGASS - United Nations General Assembly Special Session
WIS - Woodland Improvement Scheme

Botanical nomenclature in this text mainly follows Webb (1977) and Mitchell (1974).

SECTION A. Technical background to Operational Guidelines

1. Introduction

1.1 Forests and the global debate

Currently across the globe there is unprecedented interest being taken in the Earth's biological diversity. The word "biodiversity", a contraction of "biological diversity", began to be used in the 1980s, when the international conservation community intensified their thrust to raise awareness of its perilous predicament. IUCN-The World Conservation Union published the "World conservation strategy" in 1980, and since then there has been a movement that is manifested both globally and locally to create a means by which the countries of the world can all work towards stopping the progress of species extinctions and habitat loss. Over one hundred and fifty countries signed the United Nations Convention on Biological Diversity (CBD), which came into effect in 1993. Other related Conventions are the Convention on Trade in Endangered Species (CITES), the Convention on Sustainable Development (CSD), the Convention to Combat Desertification (CCD) and the Framework Convention on Climate Change (FCCC).

Forest is one ecosystem that has come under special scrutiny. The CSD set up an Intergovernmental Panel on Forests, which made headway towards internationally agreed procedures for forest planning and management. The subsequent Intergovernmental Forum on Forests is working towards implementing the procedures, particularly at the international level. Concurrent with this there are regional processes on sustainable forest management (SFM) which are refining guidelines for different regions. Individual countries that are signatories to these regional processes are obliged to work towards establishing a legal and institutional framework in which these guidelines can be put into practice. The texts of the decisions of the Fourth Meeting of the Conference of Parties to the CBD include a particular section on forest biological diversity (Conference of Parties IV, 1998). Among many other decisions, a statement supported "identification of general guidelines or methodologies to help ensure that forest plans and practices reflect biological diversity conservation consideration, as well as social, cultural and economic factors".

1.2 Drafting national guidelines

The national guidelines should be designed to cover the diverse aspects of forests and forestry and their influence on other sectors, including nature conservation, biodiversity, soil protection, forest health, archaeology, fisheries, economics and social aspects. The present study addresses the subject of biodiversity in particular, but this, in order to be appropriately applicable, must take into account the issues involved in the other subject areas. The Forest Service has to date published three sets of guidelines, on landscape, fisheries and archaeology (Forest Service, 1996 a;b;c), and there are others in preparation besides this one, concerning water and forestry (Ryan, in prep.), environmentally sound harvesting (Purser Tarleton Russell Ltd, in prep.), landscape (O'Leary and McCormack, in prep.) and archaeology.

Many countries on the European continent, including Scandinavia, and in North America have adopted a policy of multi-use forestry for plantation forests (Spellerberg and Sawyer, 1998). Forestry systems prevalent in Ireland, the UK and New Zealand have focused more on using non-native conifer trees in single- or two-species stands, as tree crop plantations. For reasons mainly elaborated upon later, there is a movement to diversify the recent Irish forest initiative and to plant more mixed-species stands. One reason for this is concern over the effects of the conifer tree crops on the Irish natural heritage (Heritage Council, 1999; McCormack *et al.*, 1999). Apart from some Scots pine forests, Ireland never evolved a rich conifer forest habitat and therefore there are very few associated species assemblages that gravitate naturally to these habitats in preference to stands of native trees. The recent proliferation of conifer plantations in Ireland has led to the spread to Ireland of some species not previously found here. These are species that have evolved in the conifer forests of continental Europe. Over time, more of these species may migrate to Ireland, but the truly rich and interesting specialist biota associated with natural conifer forests will not develop here; the species diversity in Irish conifer plantations will remain "truncated" (Speight, 1998).

Botanists and ecologists generally distinguish between native and non-native (or "alien") species, and there is a general assumption that the introduction of extensive plantations of the latter are not good for the environment. Wild forests are rare ecosystems that used to be widespread in Ireland (Mitchell and Ryan, 1997), and the species that were associated with these ecosystems do not exist in the same dynamic equilibrium in stands of non-native species of trees. The wild, natural forests were dominated by a mixture of broadleaved species, with Scots pine more abundant on upland, less rich sites. The focus on non-native tree crops has led to a dominance of these in our forest complement. Although these have not generally been used to replace native forests (some native forests are removed by "scrub clearance" activities), they have at times replaced areas of native bog, heathland or grassland that harboured associations of native species. This replacement is of particular concern because of the loss of native habitat (Ratcliffe, 1990; Hickie *et al.*, 1993).

On the basis of the recent and ongoing international processes concerning forests and forestry (Conference of Parties IV, 1998), Ireland is showing some movement away from monocultures and towards more mixed-species forests, including a proportion of broadleaves in the overall forest complement. This is driven by the Government stipulations for grant aid (see Section 5.1). The use of native species is ecologically advantageous in that they already have an associated flora and fauna existing in the country. Non-native species have no associations of this type and thus plantations of these species will inherently be of a lesser "bioquality", or value for nature conservation (see Section 1.3).

Countries which up until recently perceived their production forests as a tree crop (Maclaren, 1996) are reviewing national policies to be more in agreement with the philosophies of modern SFM, where the forest is viewed holistically and its multiple functions are taken more into account. Investment in very species-poor plantation forests can be a dubious undertaking because of:

- the vulnerability of such systems to environmental disasters, particularly if the species used are not native and if they are planted as monocultures

- a change in the market may render the entire enterprise uneconomical.

Periodic destructive events, for example fire, storm damage, pest and disease outbreaks, can wipe out these systems more easily than more diverse natural systems, which are inherently more stable, buffered against disasters by their diversity (Department of Agriculture, Food and Forestry, 1996; Farrell *et al.*, in press; Führer, 1989; Heliövara and Väisänen, 1993). However, forests of all types, both natural and plantation, are affected by these events, as outlined by Savill *et al.* (1997). Intensively managed single- or two-species plantation forests are often compared to agricultural crops to justify the planting of this type of forest over a more diverse system. However, whereas if a herbaceous crop were to succumb to an environmental disaster the recovery through re-planting and regrowth would be at most one or two years, possibly even just one growing season, the destruction of a forest can mean a great loss of time and financial investment for softwood and even more for hardwood. As almost half the total expenditure on a tree crop of 50 years' rotation is incurred during the first four years of its life (O'Carroll, 1984), the survival of the crop throughout the rest of the growth cycle is economically vital. Having to repeat this most expensive phase after ten years or so would not be financially viable. Additionally, if the market changes, an agricultural crop can be changed accordingly within a year or so, but a forest is not so easy to alter. Clearly a forest is a different enterprise to an agricultural crop, if for these reasons alone.

Plantation forests that consist mainly of conifers can have value for nature conservation. Stands retained to grow out of the pole stage towards maturity can support distinctive and valuable species assemblages of lower plants, vertebrates and invertebrates (Butterfield *et al.*, 1995). Hodge *et al.*, (1998) indicated that there were a number of sites in Britain with conifer forest that have been designated as Sites of Special Scientific Interest (SSSIs). However, none of these have been designated as SSSIs by virtue of their biodiversity, except in some old native Scots pine woods. These conifer forests that have SSSI designation are so assigned because of other features of natural interest, *e.g.* geomorphological. In some of these, the flora is the main interest, but this relates to remnant habitat which has persisted under conifers following afforestation (Stevenson, *in litt.*). Some areas of conifer forest in Britain have been important for endangered species, *e.g.*, Red Squirrel, Scottish Crossbill and Capercaillie, just as there are native species in Ireland which associate more with pine forests than with broadleaves (see Section 4.1).

Currently under development by the Forest Service is the Forest Inventory and Planning System (FIPS), a geographically-based information system that will provide a good monitoring tool for forestry in Ireland. The information contained in the system will include topography, soil suitability for forestry, tree species of each forest and the stage of development of each forest stand. Ideally it could provide a basis for the intimate linkage between site suitability and forest planning, and also be a tool for control at a broader scale by providing an accurate overall picture of what types of forest are present in Ireland, their abundance, stage of growth and productivity.

Initiatives concurrent with the drafting of these Guidelines are the development of a Biodiversity Action Plan, a Code of Best Forest Practice and a National Forestry

Standard for Ireland*. Meetings to develop the criteria and indicators for SFM in Ireland are also taking place and will feed into the Code and the Standard. These Guidelines for Biodiversity are written concurrently with these initiatives.

1.3 Forest management and biodiversity

The forest estate is an important economic resource in Ireland - in 1996 there were some 16,000 people in Ireland employed in forestry and its associated industries (Department of Agriculture, Food and Forestry, 1996). Sales from Irish sawmills in 1998 amounted to £140 million, with exports of £35 million (Department of the Marine and Natural Resources, 1998). In 1995 the contribution of sawnwood and panelboard to GDP was 0.3%. The Strategic Plan for forestry (Department of Agriculture, Food and Forestry, 1996) foresees an output of timber increasing four-fold between now and the year 2030. The current primary processing output from the raw material is based on two complementary sectors, sawmills, which produce sawn timber and board mills, which use forest thinnings and sawmill residues to produce MDF, chipboard, etc. (Department of the Marine and Natural Resources, 1998). However, along with the development of the industry, the wider importance of forests for biodiversity and other environmental services are of increasing concern to the Irish people. The challenge facing the Irish forestry sector is one which is not limited to Ireland: how to increase the non-timber value of the resource for biodiversity, landscape, recreation and the general quality of the environment without compromising wood supply targets and requirements.

Aspects of biodiversity management to be taken into account for this study are a) what range of forest types occur in Ireland, b) what are the legal and institutional instruments in place that influence forest management, c) what is the current biodiversity of Irish forests, d) what is the long-term prospect for the survival and enhancement of this biodiversity, and e) whether this can be improved by altering management practices while maintaining a sustainable and economically viable forest resource. The answers to some of these questions are only partly available currently. For a full understanding of the forest processes, functions and economics, more targeted research will be needed. We must, however, work with what we now have, and aim at a better informed forestry in the future. The Guidelines publications should be reviewed periodically for these reasons.

Forest managers need to take account of the impact on biodiversity of forest design, silvicultural systems and management options. This requires an understanding of the natural processes at work on the site: the carbon, water and nutrient cycles, species ecology and dynamics such as dispersal, competition and succession, plant-animal interactions such as herbivory and pathogenicity and natural disturbances affecting the site both as frequent and as rare events, such as high winds, floods or fire. Understanding these natural processes alone is a complex and daunting task, but additionally the forest manager is obliged to consider the social and economic elements of the forest, and how local communities may be affected by different forest management practices.

In considering the forest ecosystem in terms of biodiversity, it must be noted that greater biological diversity is not necessarily globally desirable, even in terms of ecology and

* The author of the current document was involved in the preparation of the National Forestry Standard and had access to a draft of the Code of Best Forest Practice, but not to the Biodiversity Action Plan.

conservation. More important is the issue of biological quality (or bioquality), meaning the value of the organism for nature conservation (Hughes *et al.,* 1998). A greater species complement is not necessarily a desirable quality because not all species have the same value or merit, for example, in an extreme case, a forest with only few species may have a higher bioquality than a forest with a greater species complement, if that forest is the only site for a particular rare species in the country. This means that raising the number of species in a forest tract is not necessarily automatically a good thing for forest ecology and conservation, because the species complement that forms the increase may be undesirable and of low conservation value. The introduction of *Rhododendron ponticum* into a tract of woodland will temporarily increase the biodiversity of that tract by one species, but this actually devalues the community because the species is an invasive alien and will eventually lead to the disruption of the natural systems in the woodland by preventing the regeneration of the native species (Cross, 1982).

Bioquality is also influenced by the extent to which a species is specific to particular ecosystems. Generalist species can tolerate a range of habitat types, but specialists need particular elements to be present in their surroundings. For example, many wood-degrading organisms are specialists as they can only degrade certain species of tree: indeed some of these can only live in wood that is already decayed to a certain extent, and of a particular species. Other species can live in a range of decaying wood types, and these are the generalists. Specialist species may therefore be confined, for example, to old oak woodlands, and not be capable of living in short-rotation forests of other species. Generalists are in many cases able to live in old oak woodlands as well as many other forest types. Specialist species have generally evolved over time to fit into very specialised niches, and will only exist in native habitats where they evolved. The habitats for these species become less and less as the land is altered from its natural state, and they become isolated in fragments of the native forests that remain. These are the species that are of most concern and value for nature conservation. The more generalist species are more common and of less interest, therefore of lower bioquality.

Species richness is often confused with species diversity. Species richness can be determined by enumerating the species occurring within a given sample area. However, an area with a greater number of closely related species is not as diverse as the same area with the same number of species which are not closely related. The Global Biodiversity Strategy (WRI *et al*., 1992) used the example of two islands, one with two species of bird and one species of lizard, the other with three species of bird. The former is the more species-diverse island. The complexity of the concept has led to the formulation of a number of formulae to determine diversity (Standovár, 1996).

1.4 Forest types in Ireland

Ireland has a variety of forest and woodland types, of widely differing structure and composition, from native oak high forest to mature conifer plantations and low scrub forests to young plantations. The definition of "Forest" as now internationally recognised by the FAO Forest Resources Assessment project, and as used for international reporting to them and other UN bodies on parameters associated with forests, is:

> Land with tree crown cover (or equivalent stocking level) of more than 10 percent and area of more than 0.5ha. The trees should be able to reach a minimum height of 5m at maturity *in situ*.

> May consist *either* of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground; or of open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 percent. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest.
>
> **Includes:** Forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5ha and a width of more than 20m. Rubberwood plantations and cork oak stands are included.
>
> **Excludes:** Land predominantly used for agricultural practices.

Although the level of 10% tree cover seems low compared to the general perception in Ireland of what a forest or a woodland is, this is the international definition on which Ireland is now obliged to report. For the present paper however a more traditional cover level for "forest" will be employed, but "forest" will not be distinguished from "woodland", as in some ecological classifications (*e.g.*, Mueller-Dombois and Ellenberg, 1974) in which "woodlands" are understood to have a smaller percentage tree crown cover than "forests". The types of wooded land dealt with in the present study will generally have a crown cover of more than 30%, as would both the "forests" and the "woodlands" of Mueller-Dombois and Ellenberg. The height criterion of 5m used by FAO is not used in this paper; a more flexible approach has been adopted, to include the areas of native forest dominated by such species as hazel.

The forests of Ireland covered 8.9% of the total area of the country in 1998 (Department of the Marine and Natural Resources, 1998). This represents a total of 613,806ha, of which public and private planted forest accounts for 500,317ha. The proportion of broadleaf-dominated areas to conifer-dominated areas was approximately 21% to 79% (FIPS, 1999). These data are not in a form that the areas of the different forest types as described below could be extracted.

Forests in Ireland are divided into three main ecological categories, adapting some definitions and divisions used by FAO for their global Forest Resources Assessment (1998) and Peterken (1996). These categories were drafted in association with the Environment Working Group for the national Forestry Standard, Criterion 4 (Forest Service, in prep.). The use of the terms "native", "natural", "semi-natural", "virgin", "primary", "secondary" and "ancient" in the context of Europe, particularly Britain, are discussed by Peterken (1996). As there are very different characteristics associated with each of these terms by different people, depending on sector or discipline associations, it was thought necessary to give descriptions, with example species, in this document.

Ireland's forests, as in those of much of Europe, have virtually all been influenced by the activities of people. For this reason, the forests have primarily been divided into "semi-natural" and "plantation", depending on the degree of human influence. The semi-natural forests are those which are not intensively managed for timber production, but which may have been planted. These forests have a higher degree of "naturalness" in terms of structure and species composition than do the intensively managed plantation forests. The semi-natural forests are subdivided into two main types depending on current tree species composition, thus yielding a total of three main different forest types for Ireland: (a) native semi-natural forests, (b) non-native semi-natural forests and (c) intensively managed plantations (see below).

1.4.1 Native semi-natural forests.

These are forests dominated by native tree/shrub species, and include a wide range and variety of forest types, for example, the following:

- "ancient" woodlands, *i.e.* wooded sites which research has shown to have been continuously wooded through the past (Peterken, 1981), (although the composition of these woodlands may have been altered by past management). These sites are of foremost importance for biodiversity. In Britain these generally date from the 1600s, but in Ireland it is more probable that they date from around 1720 (D.L. Kelly, pers. comm.).
- native oakwoods, most of which were planted around 200 years ago, or were managed by coppicing or pollarding.
- relatively young stands which have arisen spontaneously due to a change in landuse, e.g. birch high forest on cutaway bog, low forest with hazel or sally. Although such woodlands lack the continuity of older stands, they have no history of having been managed for timber production, and have therefore a relatively natural species complement and structure

Woodlands in this category are dominated by native tree species, and are not subjected to rigorous management practices that interfere in a major way with natural processes. These ecosystems are generally located in protected areas or private estates, but some small areas of native woodland may be found on marginal land (Neff, 1974). The latter may not be very old or large but nonetheless are valuable as habitats for native fauna and flora. The main tree species in these native semi-natural forests are: *Quercus petraea* (sessile oak), *Fraxinus excelsior* (ash), *Betula pubescens* (downy birch), *Pinus sylvestris* (Scots pine), *Alnus glutinosa* (alder), *Ilex aquifolium* (holly), *Sorbus aucuparia* (rowan), *Populus tremula* (poplar), *Salix cinerea* ssp. *oleifolia* (sally), and *Corylus avellana* (hazel). There are other common trees that may also be considered shrubs (as may the last two in the preceding list) such as *Crataegus monogyna* (hawthorn), *Viburnum opulus* (guelder rose), *Euonymus europaeus* (spindle tree), *Salix aurita* (eared willow), *Salix caprea* (goat willow) and more uncommon trees such as *Prunus padus* (bird cherry), *Prunus avium* (wild cherry), *Juniperus communis* (juniper), *Taxus baccata* (yew) and *Sorbus aria* (whitebeam). *Quercus robur* (pedunculate oak) is common, indeed dominant, in many woodlands and considered native, although it may have been introduced into Ireland in the 1600s. *Betula pendula* (silver birch) is also thought to have been introduced, and native populations of Scots pine are thought to have virtually died out, to be replaced by Scottish stock. The elm, *Ulmus glabra*, was once a common feature of Irish native forests but is now scarce because of Dutch Elm disease.

Neff (1974) listed the principal native and naturalised trees and shrubs in Ireland, and gives an account of the composition of some native forests. The potential coverage of Ireland by natural vegetation, including forests, was mapped by Cross (1998), but there is no comprehensive map of current pockets of native forest. The native forests (see below) may be categorised into different plant associations, or community types, and the following is a list recently compiled by Aileen O'Sullivan (1999):

- **Acidophilous oak forests**
  - Sessile oak forests (*Blechno-Quercetum* subass. *typicum*)
  - Sessile oak forests rich in bryophytes and lichens (*Blechno-Quercetum* subass. *scapanietosum*)
  - Mixed oak woodlands with *Hyacinthoides non-scripta* (*Blechno-Quercetum* subass. *coryletosum*)
- **Mixed pedunculate oak-ash forests** on base-rich brown earths and rendzinas (*Corylo-fraxinetum*)
  - Pedunculate oak-ash forests with *Corylus avellana, Circaea lutetiana, Brachypodium sylvaticum* and *Veronica montana* (*Corylo-fraxinetum* subass. *veronicetosum* and *typicum*)
  - Hazel-ash forests on shallow calcareous soils with *Sesleria albicans* and *Asplenium trichomanes*, rich in bryophytes (*Corylo-fraxinetum* subass. *neckeretosum*)
  - Ash-pedunculate oak-hazel woodlands with *Filipendula ulmaria* (*Corylo-fraxinetum* subass. *deschampsietosum caespitosae)*
- **Wetland woods**
  - Riparian woodland with *Salix* spp. and *Alnus glutinosa* (*Salicetum albo-fragilis*)
  - *Salix* woodland of lakeshores and stagnant carr (*Osmundo-Salicetum atrocinereae*)
  - Alder-ash woodland with *Carex remota* (*Carici remotae-Fraxinetum*)
  - Birch woodland with holly and rowan, on deep peat well drained in upper layers (*Betuletum pubescentis*)
  - Birch-willow woodland with *Sphagnum* on waterlogged peats (*Sphagnum palustre-Betula pubescens* community)

1.4.2 Non-native semi-natural forests.

These forests are similar in structure the more established examples of the above, but are dominated by non-native trees. They are the most unknown quantity in Irish forest vegetation, and include forests that have either been enrichment-planted or that have no native forest origin but are not intensively managed exclusively for short-term rotations and intensive wood production. These forests are mainly located in older privately-owned estates, and have not, until very recently, been systematically included in any government surveys. The FIPS remote-sensing survey in principle includes these, although it is not currently planned to include the semi-natural forests of Ireland in the comprehensive ground-truthing survey (A. O'Sullivan, pers. comm). The non-native semi-natural forests, however, may contain the most exciting examples of the potential forests of the future in Ireland, because they are generally of mixed species and have at some time in the fairly recent past been used for timber harvesting.

The species used in planting these forests are the introduced *Fagus sylvatica* (beech), *Acer pseudoplatanus* (sycamore), *Carpinus betulus* (hornbeam), *Tilia sylvatica* (lime), *Larix* spp. (larches), *Picea* spp. (spruces), *Pinus* spp. (pines) and *Abies* spp. (firs). The native (or accepted as such) pedunculate oak, and ash may also have been used but do not dominate. The dominance of introduced trees in the forest influences the forest ecology, which is reflected in the composition of the associated vegetation and fauna, which can differ substantially from those of a native semi-natural forest. These forests, however, support some of the most magnificent examples of mature trees, as the land used for the forest was frequently of very good quality and not poor like the soils of many of Ireland's remaining native semi-natural forests.

1.4.3 Plantation forests.

These are forests that are completely anthropogenic and were originally intended to be managed intensively for wood production, as tree crops (in a very small percentage of cases the primary purpose of the forest has changed and these have been left to grow old, past their commercial optimum). They are generally even-aged stands of one or two tree species of foreign origin (with one species dominant) that remain largely species-poor in associated flora and fauna (particularly those of high bioquality). These forests are relatively new in Ireland: the oldest areas of plantation forest would date from the early 1900s, but the actual trees on these would generally be in their second or third rotation (E.P. Farrell, pers. comm.). Since the 1940s a major programme of afforestation by the state has resulted in a massive increase in the proportions of this type of forest as compared to the other two forest types. The main tree species currently used for wood production in Ireland are *Picea sitchensis* (Sitka spruce), (covering 60% of the total forest area and accounting for 65% of current afforestation), *Picea abies* (Norway spruce), *Pinus contorta* (lodgepole pine) and *Pseudotsuga menziesii* (Douglas fir) (Department of Agriculture, Food and Forestry, 1996). To a lesser extent Scots pine, larch (*Larix decidua*, *L. kaempferi*, *L.* x *marschlinsii*) and the broadleaves oak (two species), beech, birch (two species) and ash are used to increase the diversity of the forests.

First rotation, even-aged, thicket-stage conifer plantations have low value for biodiversity because they are new ecosystems lacking structural and spatial diversity. In the UK where conifer monocultures were used to replace existing broadleaved forest, there were many recorded effects on the soil (Peterken, 1981), *e.g.,* the accumulation of organic matter as a thick mat, leading to reduced decomposition, and an increase in woodlice, millipedes, slugs and snails decrease, mites, ticks and springtails. Earthworm biomass can be 100 times less under conifers because of the acidity of the soil, so there is less aeration of the soil from their activity and a corresponding decrease in bacterial activity. First rotation forests are of lower biodiversity value than second or third rotations, which are enriched by (frequently unwanted) natural occurrences of native trees, *e.g.*, birch, rowan.

2. Forest policy and biodiversity

2.1 Biodiversity - international definitions

On 22 May 1992, in Nairobi, the nations of the world adopted a global Convention on Biological Diversity. On 5 June of the same year, at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, a record number of over 150 countries signed it. Approximately 18 months later, on 29 December 1993, the Convention entered into force. 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*

Biological diversity is therefore not the sum of all the ecosystems, species and genetic material, but the variability between them. It is therefore an *attribute* of life contrasting with "biological resources", which are the tangible biotic components of ecosystems, defined as follows:

"Biological resources" includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity"

Biodiversity is most conveniently described in terms of three conceptual levels (Glowka *et al.*, 1994):

Ecosystem diversity: the variety and frequency of different ecosystems[*]
Species diversity: the frequency and diversity of different species[†]
Genetic diversity: the frequency and diversity of different genes and/or genomes. In the definition of biological diversity, genetic diversity is represented by the phrase "The diversity within species". It includes the variation both within a population and between populations.
In the international context, the biological diversity of Ireland is protected by the following European laws:

> Habitats Directive (No.92/43/EEC). This set the legislation for Special Areas of Conservation (SACs), covering certain habitats in Europe and thereby conserving the species and ecosystems within them.
>
> Birds Directive (No. 79/409/EEC). This set up legislation for Special Protection Areas (SPAs) for birds.
>
> Additionally, Ireland has agreed to operate within the guidelines of the Pan-European Landscape Diversity Strategy.

Ireland has also ratified the CBD. Ireland is also a signatory to the CITES convention and is bound by it by being a member of the EU (P. Buckley, pers. comm.), although it has not yet been ratified by Ireland specifically.

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[*] A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (Glowka *et al.*, 1994)
[†] A population of organisms which are able to interbreed freely under natural conditions (Wilson, 1992)

2.2 Forest policy and the international drive towards SFM

Until very recently, the forest policy in Ireland has viewed commercial forests as being tree crops, managed for the sole purpose of timber production. This has been the case in other countries too, but over the last ten years or so there has been an increasing interest in managing forests "sustainably", in the modern sense of the word. The meaning of SFM has developed over time according to the changing needs of society. The possibility of truly sustainable development in the forest sector was discussed by Farrell (1997). Originally, sustainability in forest management was mainly considered as the sustainable yield of timber to cope with wood shortages (Third Ministerial Conference on the Protection of Forests in Europe, 1998). However, the importance of other multiple functions of forests has gradually been incorporated into forest management (Farrell, 1997). During the latter half of this century, the concern about the deterioration of forests throughout Europe led to an increasing awareness of the economic, ecological, social and cultural values of forests by the broader public. Periodically throughout history when the effects of a scarcity of forest products prevailed, even in the fourth century BC, this has happened, and resulted in regulations limiting the exploitation of forest resources (Farrell *et al.*, in press).

Modern SFM demands a more holistic approach to forest systems, taking into account the tree species used for the crop, whether it is native or non-native, whether the trees grown on a site are all of one species (a monoculture) or a mixture of species, the occurrence of other species in the forest both plant and animal, whether these in turn are native or non-native, and their relative abundances, and how they all interact with each other and the abiotic environment to compose the entire living forest system. SFM also takes into account the interactions between people and the forest: how the forest is used by the local communities as well as how the forest serves the populace on a larger scale, ultimately how it provides the population with clean air and water, directly and indirectly. The science of modern SFM is very young, but already there are sets of international guidelines available that have been drawn up following UNCED and agreed by the Intergovernmental Panel and Forum on Forests (IPF and IFF). The notion of international forest regulation had its roots in two proposals in 1990: one for a global forest convention, and the other for a forest protocol within the climate change convention. The hope of various countries that 1992 UNCED would produce an international forest convention, however, proved premature and disagreement continues over the need for such a convention and its modalities (FAO, 1999).

The IFF continues the work of the IPF, and in particular is now concerned with the implementation of the recommendations of the IPF. These are closely linked with other international initiatives promoting sustainable development, such as the CBD and the FCCC. The work programme on forest biological diversity, that has been recently adopted under the decision IV/7 of the Conference of the Parties to the Convention on Biological Diversity (Bratislava, May 1998), takes into account, as appropriate, the IPF proposals for action in regard to the areas of focus of the programme on the research, cooperation and development of technologies necessary for the conservation, sustainable use and equitable sharing of benefits arising from biological diversity of all types of forests. Element 3 of this work programme stresses the importance to contribute to ongoing work in other international and regional organisations and processes, in particular, to the implementation of the proposals for action of the IPF and to provide inputs to the IFF.

The Kyoto Protocol under the FCCC has provided a major incentive for countries to engage in the valuation of forests as carbon sinks. There is also growing recognition of the need to quantify services provided by forests in areas such as biological diversity, water and ecotourism. Research into forest systems was the subject of a special international body , the International Consultation on Research and Information Systems in Forestry (ICRIS), sponsored by Indonesia and Austria in cooperation with IUFRO, CIFOR, FAO and the IFF Secretariat.

Meanwhile, there have been regional initiatives working at government level towards supporting 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 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, which, in the light of the following sentiments, the countries endorsed the following guidelines to the conservation of biodiversity in European forests:

- Having regard to the fact that the conservation and appropriate enhancement of biological diversity in all types of forests is an essential element for their sustainable management
- Recalling the definition of biological diversity agreed upon in the Convention on Biological Diversity: *viz.* "Biological diversity means 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."
- Recalling the concept of conservation defined in the World Conservation Strategy (IUCN *et al.*, 1980) as the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations
- Considering the urgent need to show respect for the evolutionary heritage of species and forest ecosystems, in order to enable the adequate genetic adaptive capacity to be safeguarded in the interest of present and future generations
- Considering that the combination of the direct and indirect actions of man on forests can contribute to a decrease in intraspecific variability, species diversity and ecosystem variety
- Considering the objectives and measures set out in the Convention on Biological Diversity that was signed at the United Nations Conference on Environment and Development (UNCED) in June 1992 in Rio de Janeiro, and considering in particular the precautionary principle in the preamble to the Convention, which notes that "where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimise such a threat"
- Recalling that biological diversity is also the basis of genetic improvement of species and varieties of technical and economic interest
- Considering the general objectives and specific measures stated in the Convention concerning the Protection of the World Cultural and Natural Heritage (1972), the Convention on the Conservation of European Wildlife and Natural Habitat (1979), the Convention of Barcelona and its Protocol Concerning Mediterranean Specially Protected Areas (1982), the EC Directives concerning the Conservation of Wild Birds (1979) and the Conservation of Natural Habitats and Wild Fauna and Flora (1992), the Council of Europe's European Network of Biogenetic Reserves (1976), and the Council of Europe's Decision on Preservation of Natural Forests (1977)

The Third (and most recent) ministerial conference on the protection of forests in Europe was held in Lisbon in June 1998, and was attended by 36 European states, the European Community, five observer countries and 14 international organisations. The outcomes of the previous ministerial conferences were endorsed, and further to them the Lisbon conference adopted two Resolutions: L1 "People, Forests and Forestry - enhancement of the socio-economic aspects of SFM" and L2 "Pan-European criteria, indicators and operational guidelines for sustainable forest management". Additionally a "vision" for forests into the 21st century was declared, recalling the forest-related decisions and agreements of UNCED, UNGASS, the XI World Forestry Congress, the CBD, the FCCC and the CCD. Based on this vision, commitments to the promotion of SFM and its contribution to the conservation of biological diversity were declared. This was not declared on its own but as an integrated part of the role of the forest sector in rural development, employment, the enhancement of the environment, and the overall sustainable development of society. Implementation of these ideals would be through collaboration with the ministerial process "Environment for Europe", in particular their "Work-programme on the conservation and enhancement of biological diversity in forest ecosystems 1997-2000", and with the work of other organisations, in particular FAO European Forestry Commission, UN/ECE Timber Committee, UNEP, ILO, NGOs and other stakeholders. They committed to work towards the drafting of a legally binding instrument on the management, conservation and sustainable development of all types of forests within the work of the CSD/IFF.

2.3 The Helsinki guidelines

In terms of the development of SFM in Ireland and the formulation of guidelines for forests and biodiversity, the second Resolution declared from the Lisbon conference must be examined (Third Ministerial Conference on the Protection of Forests in Europe, 1998). In the second resolution, Ireland endorsed (a) the indicators associated with the six criteria in "Pan-European criteria and indicators for SFM" as a basis for international reporting, and (b) the "Pan-European operational guidelines for SFM" for practical use. The first of these is important because in undertaking to report internationally on these indicators, Ireland must set up systems by which these indicators can be monitored to collect the data for the reporting. The second is important because it is within the framework of these guidelines that Ireland must draw up its own national guidelines for SFM, and as they are "operational" guidelines, they must be practical and implementable. If the institutional support and legal framework for these operational guidelines is not optimal in Ireland, this must be altered to facilitate the implementation of the guidelines, particularly at local level. Forest managers need to get substantial support at this stage in Ireland because the whole approach of SFM is altering how they have been trained to operate in the recent past.

The fourth of the six criteria adopted in Lisbon was "Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems". The quantitative indicators that are cited for use to monitor the criterion include such parameters as:

- Changes in the area of natural and ancient semi-natural forest types, strictly protected forest reserves and forests protected by a special management regime

- Changes in the number and percentage of threatened species in relation to total number of forest species
- Changes in the proportions of stands managed for the conservation and utilisation of forest genetic resources and differentiation between indigenous and introduced species
- Changes in the proportions of mixed stands of 2-3 species and in the proportions of annual area of natural regeneration in relation to total area regenerated

In addition to these quantitative indicators there are four sets of descriptive indicators and their attendant details:

1. Existence of a legal/regulatory framework, and the extent to which it:

- Clarifies the concept of management, conservation and sustainable development of forest
- Provides for national adherence to international legal instruments
- Provides for legal instruments to protect representative, rare or vulnerable forest ecosystems
- Provides for legal instruments to protect threatened species
- Provides for legal instruments to ensure regeneration of managed forests

2. Existence and capacity of an institutional framework to:

- Maintain, conserve and appropriately enhance biological diversity at the ecosystem, species and genetic levels
- Identify the economic value in forests whose management is adjusted in favour of maintaining biological diversity
- Develop and maintain institutional capacity and distribution of responsibilities related to protected areas
- Maintain degree of implementation of confirmed national forest conservation programmes
- Develop and maintain institutional instruments to protect threatened species
- Develop and maintain institutional instruments to ensure regeneration of managed forests
- Conduct inventories on proportion of area covered by trees significantly older than the acceptable age of exploitation currently used (in production forests)

3. Existence of economic policy framework and financial instruments, and the extent to which it:

- Creates new resources and incentives to enhance the mechanisms for predicting impacts of human interventions on forests
- Supports economic value in forests whose management is adjusted in favour of maintaining biological diversity
- Supports the representativeness of protected forests in relation to ecological and regional distribution
- Supports implementation of management guidelines to take into account threatened species
- Provides for economic incentives for taking account of environmental issues in management planning (in production forests)
- Conducts inventories/assessments on bioindicators (in production forests)

4. Existence of an informational means to implement the policy framework, and the capacity to:

- Develop new inventories and impact assessments on biological diversity
- Develop tools to assess the effects of forest management on biological diversity
- Enhance measures to re-establish the endemic biological diversity in forests managed for production
- Apply measures for rehabilitation of degraded forest areas
- Construct periodically reviewed lists of threatened forest species
- Enhance the level of knowledge on threatened species / assessments, inventories or research on threatened species
- Take measures to maintain or to re-establish biological diversity in old (production) forests
- Monitor changes in the proportions of afforested or reforested areas covered by indigenous and introduced species, conifer and deciduous species

The operational guidelines (see above) drawn up by a panel of experts and adopted at the an Expert Level Preparatory Meeting (April 1998, Geneva) of the Lisbon conference form a common framework of recommendations for implementing SFM at the site management level. These recommendations follow the structure of the six Pan-European criteria that were identified as the core elements of SFM. For clarity they were divided into “Guidelines for forest management planning” and “Guidelines for forest management practices”, focusing on basic ecological, economic and social requirements for SFM within each criterion. In putting these guidelines into practice, the content should be adapted to the specific local economic, ecological, social and cultural conditions, as well as to respective forest management and administration systems already in place. In order to facilitate the implementation of the guidelines there might be a need for the promotion and equitable support of the government, society and other beneficiaries, to create and maintain a sound balance of interests including a sound economic basis for forestry. The potential users of the guidelines are:

- Forest managers and owners
- Sub-national organisations, as a reference tool for informing and advising forest owners and managers, in planning the practices and/or supervising their implementation
- National/governmental decision makers, as a reference for setting codes for forest practice and forest management planning that will be in agreement with international policy fora (*e.g.*, UNCED forest principles and Lisbon resolutions)
- International forest dialogue, as a reference for Europe in the global forest dialogue
- (Panels needing) communication tools and certification systems, as an indicative reference for the establishment of standards for certification and other quality assurance systems which would remain independent from the Pan-European Process

As above, criterion 4, "Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems" is the most applicable section to the present report. The operational guidelines for this criterion are as follows:

1. Guidelines for forest management planning (FMP)

- FMP should aim to maintain, conserve and enhance biodiversity on ecosystem, species and genetic level and, where appropriate, diversity at landscape level
- FMP and terrestrial inventory and mapping of forest resources should include ecologically important forest biotopes, taking into account protected, rare, sensitive or representative forest ecosystems such as riparian areas and wetland biotopes, areas containing endemic species and habitats of threatened species, as defined in recognised reference lists, as well as endangered or protected genetic *in situ* resources

2. Guidelines for forest management practices (FMC)

- Natural regeneration should be preferred, provided that the conditions are adequate to ensure the quantity and quality of the forests resources and that the existing provenance is of sufficient quality for the site.
- For reforestation and afforestation, origins of native species and local provenances that are well adapted to site conditions should be preferred, where appropriate. Only those introduced species, provenances or varieties should be used whose impacts on the ecosystem and on the genetic integrity of native species and local provenances have been evaluated, and if negative impacts can be avoided or minimised.
- FMC should, where appropriate, promote a diversity of both horizontal and vertical structures such as uneven-aged stands and the diversity of species such as mixed stands. Where appropriate, the practices should also aim to maintain and restore landscape diversity.
- Traditional management systems that have created valuable ecosystems, such as coppice, on appropriate sites should be supported, when economically feasible.
- Tending and harvesting operations should be conducted in a way that do not cause lasting damage to ecosystems. Wherever possible, practical measures should be taken to improve or maintain biological diversity.
- Infrastructure should be planned and constructed in a way that minimises damage to ecosystems, especially to rare, sensitive or representative ecosystems and genetic reserves, and that takes threatened or other key species - in particular their migration patterns - into consideration.
- With due regard to management objectives, measures should be taken to balance the pressure of animal populations and grazing on forest regeneration and growth as well as on biodiversity.
- Standing and fallen dead wood, hollow trees, old groves and special rare tree species should be left in quantities and distribution necessary to safeguard biological diversity, taking into account the potential health and stability of forests and on surrounding ecosystems.
- Special key biotopes in the forest such as water sources, wetlands, rocky outcrops and ravines should be protected or, where appropriate, restored when damaged by forest practices.

2.4 SFM initiatives in Britain and Ireland

Following the sentiments expressed in the European guidelines, the Signatory States to the Helsinki Process committed themselves to preparing specific national guidelines and to incorporating them into their forestry programmes for implementation. The new forest policies in Britain reflect a turn towards SFM and away from treating forests as tree crops (Forestry Authority, 1998a). In the early years the British Forestry Commission was charged with developing a strategic timber reserve. What prevented British foresters from recognising the importance of ancient woodlands was that they were brought up in the dominant tradition of forestry: high-forest plantation management. What they had been taught to see was such that to convert what is now called an ancient woodland into a conifer plantation, a common practice from the 1950s onwards, seemed nothing other than the good practice of turning a wasteland to productive use (Peterken, 1993; Tsouvalis-Gerber, 1998; Watkins, 1990).

Changing perceptions of the value of semi-natural habitats and the effect of plantations on visual amenity and biodiversity caused a significant re-appraisal in the late 1970s and early 1980s resulting in the development of a forest design and planning process by the Forestry Commission to realise multipurpose objectives in its forests. This is in line with international forest debates (see above). The Forest Stewardship Council's forest management standards for great Britain (Forest Stewardship Council, 1998) has recently been endorsed by the UK government, and adapted into the UK Woodland Assurance Scheme (Forestry Commission, 1999). It has a number of operational guidelines for semi-natural and plantation forest management. The British Forestry Commission's current Biodiversity Research Programme is an important part of the British forestry strategy, and is formulated to provide the guidance and decision support tools required by forest managers to follow an ecologically-based forest design and management planning process. This was promoted in Ireland, by Neff (1974) and Cross (1987), among others.

Ireland is actively involved in putting into place mechanisms that will feed the SFM initiative. A National Forestry Standard and a Code of Best Forest Practice are being drawn up by the Forest Service. An expert panel on SFM and certification has been convened by Just Forests, the Irish node of the Forest Stewardship Council (T. Roche, pers. comm.). Coillte, the semi-state forestry company, recently hosted a panel on topics related to SFM and the forest environment in general, and published a framework for SFM (Coillte, 1999). The certification standards proposed by different bodies have been under discussion for a number of years (*e.g.*, ISO 14000, Forest Stewardship Council). COFORD, the National Council for Forest Research and Development, was set up in 1993 to co-ordinate all forestry research in Ireland, in recognition of the importance of forest research to the Irish economy and the role it would play in the future development of the industry (COFORD, 1994).

The major current internal influences on the development of the forest sector and forest management practices in Ireland are (a) the strategic plan for the development of the forestry sector in Ireland (Department of Agriculture, Food and Forestry, 1996), (b) the current grant schemes in operation for forestry and for agriculture (Davoren, 1998), (c) the movement away from semi-state planting and towards private planting, (d) the recent establishment of The Heritage Council and their recommendations for forestry (Heritage Council, 1999) and (e) the current movement for forest certification (for SFM).

3. Ecosystem diversity

The broadest scale at which biodiversity can be measured and managed is at the ecological system level, which would range from the single habitat to the diversity of ecosystems in the landscape. The diversity of the forest ecosystem is reflected in the degree of structural heterogeneity within the forest: the relative abundance of small or large trees (trees are obviously the major structural components of a forest), whether they are deciduous or evergreen, the relative abundance of associated plants such as shrubs, herbs, climbers and epiphytes, and the distribution of all these components. Within the forest there may be areas distinct from those that are tree-dominated, for example, where a tree has fallen and produced a gap where light-demanding herbs and tree seedlings can proliferate, or there may be a patch of rock that is relatively bare, or a stream that forms a natural break in the tree stand. These are all examples of the ecosystem diversity.

3.1. Landscape scale diversity

The forest as a component of the diversity of the landscape, and the effect of landscape composition on the biodiversity of the forest is important. Forest planning should take into account the place of the forest as a component of landscape-scale ecology. In an increasingly fragmented landscape, forest patches function as ecological islands, the different surrounding land uses providing barriers to forest species. Ideally the forest land use should be planned in conjunction with land uses of other sectors to provide the optimal mosaic for environment, biodiversity and socio-economics (Lund and Iremonger, in press). Failing this the planning of the forested areas should take into account the surrounding land uses, and be planned as a component of that landscape (Hunter and Calhoun, 1995; McCormack *et al*., 1999; O'Leary and McCormack, in prep.).

Within the forested parts of the landscape, there is diversity that may be made up of different forest types growing adjacently: these may be caused by natural phenomena such as a difference in the underlying geology, or they may be the result of careful planning of forest patch plantings. Stands of differing species composition or of stand age or size class may exist beside each other, forming a mosaic pattern in the landscape that can be more natural in appearance than vast areas of single-species, even-aged trees. To a degree, the more diverse the structure of the forest area, both in terms of the single ecosystem (α diversity) and of adjacent ecosystems (β diversity) (Groombridge, 1995), the better for the forests' biodiversity value (Spellerberg, 1996).

Landscape scale forest planning can address the β diversity value of an area by creating a patchwork of different landcover variants that is sympathetic to landform and amenity value. This can be used to be ecologically beneficial (Diaz and Apostol, 1993) by including a variety of landcover types; open space as well as forested lands. Areas of different quality for biodiversity can be included at this level, creating ecologically advantageous permanent habitat networks. These can form a linked patchwork which provides a variety of habitat types for mobile species to use and, as a result, increases both the α and β diversity.

Landscape planning, where each ecological unit is evaluated for its value and capability separately and then together with other units in the area, is an inherently difficult and complex process. Where the land is all under one ownership there is a big enough task to plan a landscape, but more often the land falls under many different owners, which adds yet another dimension to the planning task. These problems are being addressed through the use of computers as planning aids. In Ireland the FIPS will be an invaluable tool for this at one level, but more detailed models may also be required, such as that being developed by the Ecological Site Classification Project and the Biodiversity Assessment Project of the British Forestry Commission (Forestry Commission, 1998). McCormack *et al.* (1999) proposed a system of landscape evaluation and design for use in Ireland. The effects of landscape design on biodiversity are not yet fully known and the involvement of ecologists or foresters with strong ecological training should be involved in the landscape planning.

Work on island biogeography has shown that in terms of planning for conservation there are a number of configurations of habitat distribution that are better than others (Diamond, 1975):

- One large woodland is generally better than many small woodlands of the same area.
- Separate woodlands should be clustered rather than evenly dispersed.
- Separate woodlands in a cluster should be equidistant from each other, *i.e.,* the cluster should be circular rather than linear in a chain.
- Separate woodlands should be linked by strips of similar habitat, *e.g.*, hedgerows, but the usefulness of hedgerows and networks of small copses as "biological corridors" is questionable in Ireland, particularly with regard to plant species (Good, 1998).
- Small woods are probably best with minimum edge to area ratio, but as size increases, the desirability of increasing the external edge increases (Good *et al.*, 1991). In Ireland, the species of native and non-native semi-natural woodland have suffered as a result of increasing edge to interior ratio (Neff, 1974).

3.2 Structural diversity

Biodiversity encompasses a range of spatial scales, and has elements associated with forest ecosystem structure (canopy, understorey layers, ground flora), composition (species, population and community diversity) and function (*e.g.*, succession, decomposition and nutrient cycling) (Ferris-Kaan, 1995; Heywood and Baste, 1995; Humphrey *et al.*, 1999). Disturbance within the forest system as a natural dynamic has been shown to lead to structural diversity, thus structural diversity has a temporal as well as a spatial component. Structural diversity provides a great range of microhabitats, which can be inhabited and used by a great variety of organisms, at different times. There have not been many studies of forest structural diversity in Ireland; the reader is referred to Iremonger (1990) and Turner and Watt (1939) as examples.

In any forest there are tree crowns, composed of the leaves and twigs that form a canopy at a height above the ground. This canopy has its own particular microclimate, in that wind speed drops once inside the canopy, and humidity can be higher than in the air above. The small branches and leaves provide shelter for many species of bird and some mammals, as well as a food source for many invertebrates. The canopy provides support for dependent higher plants such as epiphytes and climbers, as well as for vascular cryptogams. In its cycle of growth, the canopy produces dead wood and leaves, which provide other microhabitats that are required by many invertebrates and fungi. These can remain in the canopy for a period, or they may be shed through some disturbance and lie on the forest floor before being decomposed. The decomposition process provides a vital part of the renewal of the ecosystem through the recycling of the nutrients in the trees (see Section 4.5.1). The forest provides for different organisms in all its different parts - many forest floor organisms do not venture into the canopy. This process applies also to the other layers in the forest system, the understorey trees, the shrubs and the herbs.

3.3 Habitat disturbance

Disturbance of the system provides a continuously renewed set of microhabitats for each species. In natural forests the creation of gaps in the canopy cover is most important because it allows the tree species to regenerate, through allowing light penetration to the forest floor where saplings can stand in a suspended state of life until the opening of an opportunity for growth and development. In managed systems artificial disturbance can enhance the diversity of the forest, creating new microhabitats for the many different assemblages of organisms or indeed providing the space for natural regeneration to take place.

Because natural disturbance is such an essential part of a living, dynamic ecological system, from regular small-scale disturbances to larger infrequent events, natural systems are in a continuous state of change (Hunter, 1990). Destruction and renewal are an integral part of these systems. In terms of forest biodiversity, it is important to understand the natural disturbance regimes that operate to produce a diverse, stable system. All ecosystems in Ireland are now to varying extents influenced by human activities, whether directly or indirectly. In order to manage forest systems sustainably it is essential to understand what natural processes kept these systems alive before human impacts. An understanding of the natural ecosystems contributes to the knowledge base that facilitates management of less natural systems such as plantation or non-native semi-natural forests.

3.3.1 Fire and storms

Fire and storms are two of the natural phenomena that can have a major effect on forest structure. These can have disastrous effects on a forest and cause major financial losses. Careful planning and management can mitigate the damage caused, however, and certainly in the case of fire, it can be managed to have beneficial effects. In some forest types deadwood is the principal facilitator of fires that actually rejuvenate the forest, removing accumulations of litter and releasing nutrients, thus providing opportunities for regeneration and creating spatial diversity at the landscape scale (Samuelsson *et al.*, 1994). Fire has become an important management tool in some of the world's forests, and is currently being investigated in Sweden for its use for between-rotation site preparation (Skogforsk, 1999). It has not been used extensively in Ireland, but its potential should be investigated.

3.3.2 Grazing

There have been a number of studies on the influences of disturbance in Irish forests and woodlands, *e.g.*, Bleasdale and Conaghan, 1996; Hayes *et al.*, 1991; Kelly, in press; Little *et al.*, 1996; Mitchell, 1990. Studies in other countries can contribute to the knowledge base, particularly if the systems are similar to those in Ireland. The effects of herbivory by mammals have been widely documented, and problems with over-grazing by deer and other herbivores causing a reduction in tree regeneration success can now be handled successfully by forest managers. Plantation forests in Ireland are generally profoundly different to native semi-natural forests, so disturbance regimes that foster biodiversity in native habitats may not translate directly to the non-native plantation. However, as Ireland works towards SFM the forest cover will gradually become more predominantly non-native semi-natural forest. Disturbance regimes that increase biodiversity and quality of habitat in plantation forests need to be discovered by research on these systems specifically.

Studies in Britain have found grazing by large herbivores, both domestic and wild, to be an important management tool in semi-natural forests (Kirby *et al.*, 1994). Kelly (in press) showed recently that although plant diversity in oak woodland increases initially if heavy grazing is eliminated, the long-term elimination of grazing actually causes diversity to decrease. In fenced-off plots within the woodland, holly cover increased dramatically over 10 years, forming a dense thicket that continued to expand. In the ground layer *Luzula sylvatica* (wood rush) increased dramatically. These two species represent the small number of relatively grazing-sensitive species that can, if grazing is eliminated, proliferate. In a clear-felled plot that was also fenced off there was more diversity in the regenerating tree species, with birch, oak, rowan and sally in addition to holly saplings. The birch predominated, and ivy was abundant in the ground layer, a characteristic feature of secondary stands with low grazing levels. The overall conclusion of the paper was that low-level grazing was probably the best management practice for plant diversity in the woodland.

3.4 Habitat continuity

It can be useful for nature conservation purposes to differentiate “primary” from “secondary” forest, because usually the primary forest is of higher value. This is because of the complex ecological web that has developed, including tightly interrelated inter-species dependencies and in many cases the evolution of new taxa. Distinct species assemblages are associated with the different types of forest that have developed over hundreds of years. The development of the soil and its associated biota is an integral part of this process. The total species complement that exists in ecological balance cannot be generated in a short space of time by human management techniques: nature must take its course.

Definitions of “primary” and “virgin” forest generally would not include Irish forests, even the older ones, because there is now evidence that virtually all forests in Ireland were cut down or otherwise managed for products at one stage or another. The range of native semi-natural forests in Ireland extends from very recent forests, where a land management practice has been changed from, for example, pasture, and given rise to the growth of trees, to older forests on sites that have been forested for a longer period, perhaps hundreds of years. The type and intensity of past interference greatly affect the nature of the forest and its value. Areas of forest managed for coppice products periodically over hundreds of years generally have a similar species composition to ancient high forests (Peterken, 1993). Areas of forest that were converted at one time to agricultural cropland, however, support less valuable species assemblages.

Thus the continuity of the forest over time is a very important factor in the determination of its ecological value. While the ecological balance of natural forests is developed over hundreds of years, it is also possible to see improvements in the species complements of forests over tens of years. Applying these principles to the Irish situation, it is indeed found that there are more forest species associated with later rotations in plantation forests than with newly afforested land. Management practices can nurture the forest ecology by maintaining old trees through rotations. Harvesting systems that maintain a continuous cover mean that there is less of a disruption to the forest ecology than in the case of clearfelling, where the whole system is interrupted periodically.

4. Species and genetic diversity

This section examines the diversity in different taxonomic groups and the effects of management on these, *e.g.*, mammals, birds, fish, invertebrates, trees, shrubs, herbs, ferns, mosses, lichens and microorganisms, including fungi. In terms of biodiversity of Irish forests, a review of the scientific studies on Irish woodlands and forests can produce lengthy species lists for certain sites, some with cover/abundance ratings. The more complete species lists, particularly for plants, come from native semi-natural forests: there has been little comprehensive biological inventory work done in conifer plantations, except on very specific groups of organisms. In the woodlands not only larger animals and plants have been recorded but also the less visible life, *e.g*., soil fauna, bryophytes and fungi. The largest research project carried out in Ireland with regard to biodiversity in commercial forests was the AQUAFOR project, and even in this the research was largely confined to species of bird, fish and invertebrate (Allott *et al.*, 1997; Farrell *et al*., 1997; Giller *et al*. 1997; Kelly-Quinn *et al.*, 1997).

There has been no synthesis of this information into a national list that could feed into studies on forest-occurring species, such as that currently being carried out for the Food and Agriculture Organisation of the United Nations (FAO) (WCMC, in prep.). Ireland is not the only country lacking in this information: in fact most countries would have difficulty assembling this (Kapos and Iremonger, 1998). The FAO, in putting together their Global Forest Resources Assessment 2000, has been under pressure to include more information on forest ecology, a shift from their previous emphasis on timber supplies. Increasingly, countries will be obliged to provide information of this sort to the United Nations as part of their reporting responsibilities, and this should be taken into account in developments in national forest information structures.

There has been more research carried out on British forests than on Irish ones. British ecological systems are not exactly the same as those of Ireland, not least because there are many species native to Britain that do not occur naturally in Ireland, but also because of differences in climate, geology and even history. Britain is far more densely populated and industrialised than Ireland, and this affects the demand for all the different forest resources, be they timber, non-timber product or non-extractive uses such as recreation.

Despite these differences there are many similarities between Britain and Ireland, and Irish foresters use many of the same tree species and techniques as Britain. For this reason Ireland can benefit greatly from the findings of British research teams. The percentage of forest cover in Ireland is similar to that in Britain, and in both countries this has increased dramatically in the last 50 years.

Among the published UK government literature that outline forestry issues that are of interest to Ireland in the current debate are the UK Forestry Standard (Forestry Authority, 1998a), a set of Forestry Practice Guides (Forestry Authority, 1994; 1996), their various Guidelines publications (Forestry Commission, 1990; 1991; 1993; 1994; Forestry Authority, 1995; 1998b) and a number of other booklets such as "The forestry practice guide: forest design planning. A guide to good practice" (Forestry Authority, 1998) and "Creating new native woodlands" (Rodwell and Patterson, 1994). The non-governmental publication "Forest management standards for Great Britain" (Forest Stewardship Council (FSC), 1998) outlined the standards that must be met for a forest to be certified as sustainably managed by the FSC. These were incorporated into the UK Woodland Assurance Scheme (Forestry Commission, 1999).

The massive increase in Ireland of monoculture plantations of non-native species in new forests has given rise to some concern for our natural heritage. In Scotland it was recorded that 66 common vascular plant species were substantially reduced in number as a result of the proliferation of conifer plantations, and a further 46 could be added to that list (Ratcliffe, 1986). Furthermore, 51 local vascular plant species were found to have declined nationally in the UK due to afforestation (Peterken, 1996). Twenty-two bird species were recorded as being permanently displaced, substantially reduced or at risk of decline due to afforestation. These figures need, however, to be qualified by more information about possible corresponding increases in other species. An increase in the area of land covered by forest will reduce the area of land covered by other types of habitat, and change the accompanying species mix. A decrease in non-forest species does not necessarily mean that the biodiversity value of the area has been reduced, it may be that is has just been changed. Research on this topic has been relatively recent and much more information is needed before concrete conclusions can be drawn. In the subsections below Irish species are discussed in relation to forests and forestry.

4.1 Mammal diversity

The mammals of Europe number 167 (Whilde, 1993), of which 31 are considered native to Ireland. In comparison, Britain has 54 mammal species. Three of the Irish species are endangered: two bats and the Ship rat. One species of mammal is considered to be extinct in Ireland: the Grey Wolf. In addition to these endangered or extinct species there are ten that are considered to be internationally important: the Hedgehog, five species of bat, the Irish Hare, the Pine Marten, the Badger and the Otter.

Results of studies on Brackloon wood in Co. Mayo (Little *et al.*, 1998) have shown that in this semi-natural system the management aim of increasing tree cover was seen as a positive development in terms of the wellbeing of all the mammal species resident in or adjacent to the wood. It seems that although the bats need the wooded area for resting and cover, they prefer to fly in areas without trees. More bats were recorded along the woodland edge than within woodland gaps, probably due to the higher insect densities and better flying conditions, without obstacles. Tangney and Fairley (1994), in studying bats in Connemara National Park, found that rivers and pools were the habitats most favoured by bats, while coniferous forest stands were least favoured.

The native Irish deer, the Red Deer, survives in the Killarney region. Other herds have been reintroduced. Deer use forests for shelter and food, and particularly during the summer come down from the heathlands in the mountains to feed in the warmer valleys. The recent threat to the Red Deer from the introduced Sika Deer seems to have abated somewhat with the implementation of culling of the latter in problematic areas. The Sika Deer were out-competing the Red Deer through massive population growth. Increasing densities caused the appearance of possible hybrids and the risk of the corruption of the genetic stock of the Red Deer.

The Pine Marten is considered the most threatened of the larger mammals in this country, and is considered threatened in seven of the EU countries in which it occurs (Whilde, 1993). However, it has been reported to be increasing in areas with conifer forests that have cone-producing trees (generally more than 25 years old) (Little *et al.*, 1998; Peterson *et al.*, 1997).

The Red Squirrel is considered a native species although it became very rare, if not extinct, in Ireland around the late 17th and early 18th century. The species was re-established in the latter half of the 19th century from stocks in Britain and the continent. The survival of the Red Squirrel in Ireland is currently under threat by competition from the Grey Squirrel, a North American species introduced in the early 20th century. Studies on habitat preference of these two squirrels showed that the Red Squirrel is most commonly found in wooded areas that are either predominantly conifer, with the exception of Sitka spruce, or where there are mixed stands (Reilly, 1997; 1998). In general the Red Squirrel population increases with the proportion of conifers in the stand, particularly Scots pine, lodgepole pine and Norway spruce. Densities of both Red and Grey Squirrel populations in Sitka spruce are very low, as has been found in other studies (Lurz, 1995). Grey Squirrels favour habitats dominated by oak or beech, and seem to actively avoid areas with a high proportion of Sitka spruce.

Suggestions for management in favour of the native Red Squirrels arising from these results are therefore to increase the number of mixed stands (conifer and broadleaf) in the landscape and to increase the proportion of pines used in both conifer and mixed stands. A significant number of trees of cone-bearing age (25 years+) should be components of the forest (Reilly, 1997). To avoid attracting Grey Squirrels to the forest, large-seeded broadleaves, particularly sycamore, should not be planted around the forest edge (Good *et al.*, 1991). During thinning operations the destruction of cone-bearing trees and trees containing dreys should be avoided. Forestry operations should if possible be kept to a minimum during the breeding seasons (January-April and July-September, approximately) (Lurz, 1995). Because the Grey Squirrel actively avoids areas with a high proportion of Sitka spruce, it may be recommended to increase the proportions of this in mixed conifer stands in order to give the Red Squirrel an opportunity to thrive without competition from the Grey Squirrel (Reilly, 1997). This however would have to be approached with caution if other types of biodiversity were to be taken into account as well.

Major issues associated with mammal diversity in Irish forests are habitat destruction and fragmentation, the uniformity of structure associated with current production forests, "biological corridors" between habitats (*e.g.*, hedgerows) and the effects of grazing on vegetation. Mammal species composition changes with the stage in the rotation, the smaller species in the early stages and the larger species including deer and predators using all stages. Whelan (1995) divided the mammal species using forest plantations into two groups, those that prefer the forest habitat and those that use the habitat but may feed mainly outside of it. The forest layout, tree species, forest structure and the quality of the forest edge will influence species richness and the density of individual species. In general, broadleaved stands have a better ground and shrub layer and so provide both food and shelter: broadleaves provide more food than do conifers. The presence of a shrub layer may be important in supplying food in years when there is a poor mast crop on canopy trees.

4.2 Bird diversity.

There are 141 species of regularly breeding birds in Ireland, 35 (21% of the total) of which are listed as endangered or extinct (Purcell, 1996). By comparison Great Britain has 210 species and there are 471 species recorded for Europe. Regarding the conservation status of bird species in Ireland, the following should be noted:

14 (6.5%) of species are listed as (a) having suffered at least a 50% decline in the last 25 years, (b) have suffered a historical decline, or (c) are of global conservation concern.
88 (40.9%) of species have (a) suffered a 25-49% decline in the last 25 years or (b) are rare breeders (300 or less breeding pairs).
85 (39.5%) of species have a favourable conservation status in Ireland.
8 (3.7%) of species make up at least 10% of the north west European population for that species.

Walsh *et al.* (1998a; b) suggested some strategies for forest location and enhancement for avian diversity. Factors affecting this include the availability of arthropod prey, the availability of seeds, shelter factors, the associated ground/herb/understorey cover, management techniques employed for optimisation of wood production and the altitude/geology/soil type required for good growth. Additional factors that are specific to Ireland are that there is a limited species pool, a scarcity of natural woodland and woodland or forest plots tend to be smaller than in other western European countries, which gives a greater edge to area ratio.

A brief synopsis of the effects of intensive production forestry in Munster (currently mainly conifers) on birds indicate that there is a loss of open-country habitat for species of high conservation importance, in general there is a reduced diversity of species compared with broadleaved woodland, and acidification in sensitive catchments impacts negatively upon stream birds (Walsh *et al.* (1998a). There are also gains listed: "mature plantations" (understood to be those at their commercial optimum, rather than genuinely mature (at the point of senescing) plantations) provide optimum habitat for a range of bird species, and young conifers provide habitat for additional species. Individual bird species were recorded as being affected as follows: upland or moorland species lose nesting habitat (*e.g*., Red Grouse, Golden Plover) or hunting habitat (*e.g*., Merlin), Hen Harriers can nest either on heather moorland or among newly planted conifers, but are ultimately lost from afforested land, scrubland species like Nightjar and Willow Warbler gain new habitat in young forestry and woodland species like Long-eared Owl, Goldcrest and Crossbill gain new habitat as forests mature (Walsh *et al.* 1998a). Goldcrest, a generalist species, was found to be the most abundant and widespread species in conifer plantations (O'Halloran *et al*., 1999).

In broadleaf forests there was a smaller proportion of the total bird population made up of Goldcrest, and there were higher densities and diversity of migrant species. The "hole nesting" species such as Blue Tit and Great Tit were present in the broadleaf forests but not in the conifer plantations. In intensively-managed production forests old trees are generally not present and nesting holes in the trunks and branches are lacking. The use of nesting boxes can increase the occurrence of hole-nesting species, and is therefore a laudible enterprise. It should be noted however that in terms of overall biodiversity, nestboxes are not a substitute for an old tree with holes because of the many species of microbiota that are associated with the latter. Additionally, the boxes do need to be maintained and monitored. Pine Martens have been known to use nest boxes: some nestbox schemes have been adversely affected by Pine Marten predation, and the association of nestboxes with prey by some predators (Shaw and Dowell, 1990).

In conifer plantations, the greatest number of species apparently associated with Norway spruce and Douglas fir, the least with Sitka spruce and lodgepole pine. There was no clearcut relationship between number of bird species and number of conifer species, but there was a positive relationship between bird species and number of broadleaved woody species (including shrubs and trees). More species were recorded towards the forest edge than at points more than 50m in from the edge. Early or intermediate stages of the planting cycle supported the greatest diversity of bird species, including rare species such as Hen Harrier and Nightjar, but overall bird densities were found to be highest in the latest growth stages. Overall bird diversity was highest in forests with a good mix of different age-classes of conifer. Afforestation of lowland agricultural land has a more positive effect on avian diversity than afforestation of moorland or upland areas. Upland afforestation is more likely to have a negative effect on birds in NW Ireland. Unplanted areas adjacent to upland afforestation will reduce negative impacts on avian diversity, by providing other nesting and feeding habitats.

In terms of the actual number of nesting birds recorded, there were 41 species recorded over three years during the nesting seasons. According to O'Halloran and Giller (1998), this is comparable to the numbers in deciduous woodlands and agricultural sites in Munster. Research in Brackloon Wood, Co. Mayo, found twenty-five species of bird, including six migrant species, were associated directly with the woodland habitat. Fourteen breeding species were found in a Norway spruce plantation and eight in Sitka spruce. This seems much lower than the 41 species recorded in the Munster area (O'Halloran and Giller, 1998), and for other forested areas reported by Whelan (1995).

Whelan (1995) also reported that although there was little difference between number of breeding pairs per 10ha of oakwood in Killarney and Wicklow, and conifer plantations, the species richness was much greater in the oakwood sites. Mixed conifer and broadleaf sites contained a greater number of bird species than pure conifer stands. The percentage and distribution of the deciduous trees within the stand played an important role.

The effects of the proliferation of conifer forests in the landscape on bird bioquality (as opposed to simple species abundance and diversity) is still not quite clear, particularly in the context of native species assemblages. As with other groups, the pattern of land use in the landscape and how the different components can be managed together to foster native biodiversity of high bioquality needs to be clarified.

4.3 Fish, amphibian and reptile diversity.

There is only one reptile in Ireland, the Viviparous Lizard, and this is not considered endangered (Whilde, 1993). Three amphibians have been recorded, one of which is endangered, the Natterjack Toad. The Common Frog is not endangered in Ireland but is considered of international importance. Of the 26 species of freshwater fish, nine are considered endangered or extinct (35%). These fauna are quite depauperate when compared with the corresponding numbers for Great Britain and Europe. In Great Britain there are seven species of reptile, eleven of amphibian and 55 of fish. In Europe the numbers are 85 reptiles, 45 amphibians and 215 freshwater fish.

The most important group to consider, with relevance to forests in Ireland, is the fish. The effect of the recent increase of conifer plantations in the country has been linked to problems with fish stocks in rivers and lakes. Many major river systems in Ireland now either rise in or receive drainage from catchments with plantation forest. The main concerns are increases in certain deleterious chemical ions and also of sediment from forestry operations in soil and stream water (Clenaghan *et al.*, 1998; Farrell *et al.*, 1993; Johnson *et al.*, in press; O'Halloran *et al.*, 1996). The chemical ions are deposited naturally through atmospheric input, and are mainly marine in nature: sodium, magnesium, chloride and sulphate. The deposition of these ions is increased by the passage of rainfall through the canopy of forests, thus increasing the concentrations of most in the soil waters (Giller *et al.*, 1993).

In soft water catchments such as those associated with granite bedrock in the east and west of the country, the increase in ions was found to cause the pH of the water to drop, often below pH 4. This caused a problem for salmonid and other fish stocks, which are poisoned by the high aluminium levels (>0.2mgl^{-1}) associated with these low pHs. In the south of the country the effect of the ion concentrations in the water was much less, the pH generally not falling below 5. Suggested reasons for the latter were the buffering effect of Old Red Sandstone and its associated soils, the deciduous trees and forest roads (which are augmented with limestone chippings) between the conifers and the streams, and the relatively low atmospheric pollution levels in that area Clenaghan *et al.* (1998). Peterken (1996) advocates that where there are drains within the forest they should stop well before the stream and the number of contacts between roads and watercourses should be minimised. This helps to reduce the adverse effects of soil and fertiliser runoff.

The effects of coniferous plantation forestry on salmonid species diversity in streams within a forested catchment in Kilworth, north Cork, were measured by Lehane *et al.,* (1998). The environmental variables in the streams measured were current speed, depth, stream substrate, mean width and stream morphology. The terrestrial variables were the percentage of tree overhang, bankside vegetation, percentage of each tree type present (*i.e.*, coniferous, broadleaved, shrub), the open vegetation percentage (*i.e.*, grass, ferns and moss), average tree height and average tree age. Initial results showed that there was no linear relationship between fish populations and levels of afforestation. Additionally, there was no strong evidence for detrimental effects of forestry on fish populations except at high altitudes with high catchment afforestation (Lehane *et al*., 1998). The following patterns were discovered:

- There tended to be more fish in sites with low and medium (20-50%) catchment afforestation levels than in similar sites with no forests, or high levels (>50%)
- This pattern was strongest at low (<100m) and high (>300m) altitudes
- Only in catchments with high afforestation and at high altitudes were there detrimental effects from forestry on fish stocks.
- The role of shading by trees, woody debris in the stream and other effects associated with streams within forests are not yet clear. Changes in light, chemistry and ecology of the streams resulting from felling are being investigated (O'Halloran and Giller, 1998).

In contrast, studies in Wicklow and Connemara found that coniferous plantations had negative effects on fish stocks, attributed to the acidification and increase in aluminium levels of stream water caused by runoff from conifer plantations (Allott *et al*., 1997; Kelly-Quinn *et al*., 1997). These catchments were not found to have the same buffering capacity as those in Cork, which was a major factor in the differences between the sites.

Other organisms are affected by the absence of Salmonids from water bodies, perhaps the most pertinent being the Freshwater Pearl Mussel (*Margaritifera margaritifera*). This organism, which is a protected, listed species and used as an indicator of water quality, requires salmonid fish for its successful reproduction (Moorkens, 1999). It also requires water low in nutrients, high in oxygen and low in sediment, and for this reason is found in upland nutrient-poor streams where there has been a low level of disturbance to the land. Many sites where the Mussel occurs have peaty soil that is erosive and may be on sloping ground which increases the sediment runoff. These are areas that are now used for forestry activities, and for this reason the practices employed in forests near these water bodies should minimise the sediment runoff caused by ploughing, ditching and harvesting (Moorkens, 1999). Fertilisers should only be used with the greatest of care and supervision.

4.4 Plant species diversity

Europe contains some 12,500 species of vascular plants of which 1,500 are considered threatened throughout their distributional range across the continent (Curtis and McGough, 1988; Neff, 1996). Ireland's flora may be considered an impoverished sample of the flora of northwest Europe, with only 815 undoubtedly native species (Webb, 1983), though this is a conservative estimate, and the total may be as high as 1,000 (Curtis and McGough, 1988). The total flora is 1,309 species, which includes introductions well established in the wild. In comparison, Great Britain has some 1,400 species. The main subdivisions of the vascular plant flora in Ireland show the following figures: Pteridophytes 78 species, Gymnosperms 3 species and Angiosperms 1,228 species (including naturalised species) (Neff, 1996). Threatened plants comprise about 6% of the Irish flora. Many threats are related to habitat destruction.

Ireland's uniqueness, botanically, rests not only on its species complement but rather on the ecological groupings into which these associate themselves. In particular the Burren region of Co. Clare, Connemara in west Galway and the southwest portion of the country in Cork and Kerry are renowned variously not only for the lushness of their growth, landscape ruggedness and scenic beauty, but unique associations of plant groups not seen elsewhere in Europe.

There are 759 species of Bryophyte in Ireland. Forty-six species of liverwort and 146 species of moss are considered under threat. In comparison, there are some 1,000 bryophytes recorded for Great Britain and 1,800 for Europe (Neff, 1996). Many Irish plant communities tend to have high bryophyte cover, and bryophytes often account for a high proportion of the species present.

Plant species of the forests of Ireland have not been grouped together and listed exclusively from those in other systems. The major forest-occurring tree species are outlined in Section 1.4. There have been many studies carried out on Ireland's native semi-natural forests that include inventories of plants and their ecology (*e.g.*, Iremonger, 1986; Kelly, 1981; Kelly and Iremonger, 1997; Kelly and Kirby, 1982; Mitchell, 1988; Little *et al.*, 1998). Very little has however been written about Ireland's commercial forest plantations: one study of plant diversity found that species richness was greater in an oak forest than in an adjacent mature conifer plantation and a clearfelled site (Fahy and Gormally, 1998).

Most of the production forests in Ireland have been planted in the last 50 years, and a great percentage of these are under 25 years old (Heritage Council, 1999). The non-native conifer species that have been used in these forests cast a deep shade, particularly in the earlier stages. This shade, in conjunction with the mat of needles that develops on the forest floor, inhibits the development of a shrub or herb layer that would embody the plant species diversity of the forest. Subject to research, it is reasonable to conclude that only when the forest reached an age when gaps would be formed, and some heterogeneity developed, would some plant diversity appear in the forest. In the few examples of older conifer plantation forests this can be seen happening. However it is not currently an aim of the newer forests to allow them to reach these ages: the rotation for Sitka spruce in Ireland is about 35-50 years, too young for a reasonable association of plants to develop underneath (this is assuming that there are enough plants native to Ireland that are capable of forming such an association under virtual conifer monoculture, which may not be the case).

Unless research proves otherwise, it seems that the only way to increase plant diversity in production forest stands is to increase the diversity of tree species planted, to ensure that there is a significant broadleaf component in the mix, and to use the benefits of thinning, that allow more light onto the forest floor. The mixture of species would ensure a longer life to the forest (the rotation for other species is longer than for Sitka spruce) and would encourage the development of a community of associated plants. Active management would also be required to bring propagules of forest plants to the forests. Many of the new forests have been planted on sites that were not previously covered in forest, or not for a number of centuries, and the wealth of propagules normally available in the soil of a native forest is absent. Proximity to a native semi-natural forest site would influence the amount of intervention required: if there is no forest in the vicinity the chances of seeds or other propagules of forest plants being transported by natural means to the new forest would be minimal. The benefits of thinning and its effect on the stability and quality of the timber crop, as well as on the biodiversity of the area, should be the subject of specific research.

The emphasis here must be on *forest* plants. The issue of bioquality is as important here as in other areas of the discussion of biodiversity. Increasing the plant diversity *per se* is not what is required - the object is to increase the number of *forest* species. In a study on a broadleaved wood in England, which had a well-developed forest ground flora, part of the wood was felled and part of it left with closed canopy. The number of species in the felled plot rose rapidly to about twice that in the undisturbed woodland (Kirby, 1990). However, the species that colonised the felled plot were ruderal, highly competitive plants of a different ecology to native forest plants. In terms of the value of the forest system for plant diversity it is not desirable to create conditions in which ruderal adventives predominate.

4.5 Microfauna and flora

Included in the forest microbiota are invertebrates, fungi and algae, as well as lichens. These organisms are the most diverse and numerous in the forest ecosystem, and many of them play a vital role in the survival of all the species through their constant work of decomposing organic matter and recycling the forest nutrients (Voerhof and Brussard, 1990). Exact data on numbers of these organisms in Ireland is not easy to find, except in the case of lichens. There are 1,050 taxa of lichen recorded for Ireland. In comparison, Great Britain has some 1,700 and Europe some 5,000. Certain pollution-sensitive species are represented in Ireland in greater abundance than elsewhere because of the lower levels of air pollution.

Most forest microbiota live in dead wood, soil and leaf litter, and are described below in these sections. Important also for certain groups are the open spaces in the forest: rides and glades, and also waterways and their associated buffer zones. Many spiders and butterflies are examples, as well as moths, although some of the latter can live within the forest but more species are found in spaces (Peterken, 1996). Certain communities of macroinvertebrate are associated with leaf litter in streams (Clenaghan *et al.*, 1998; Murphy *et al.*, 1998). A recent Irish study of the Syrphidae concluded that conserving certain microhabitats in forests was the most efficient conservation measure for these organisms, because they are not naturally regularly distributed throughout the ecosystem but restricted to particular microhabitats (Speight, in press). This provides concrete evidence that concentrating on components such as dead wood and leaf litter is justified.

Although these organisms play such a vital role in forest systems, and the benefits of mycorrhizae are recognised by foresters, microbiota in general are viewed with suspicion by many parties because they include pest and disease organisms. In any commercially-managed plantation a pest outbreak can mean financial losses. For this reason precautions are taken which include the use of pesticides. Few pesticides are used today that are completely selective: that is, that they would control only the pest organism and not affect any other organisms. The use of pesticides therefore can result in the killing of many beneficial organisms along with the problem species. In Irish forest plantations the main precautions taken are the dipping or spraying of saplings (transplants) on planting and the treatment of stumps with urea (not strictly a pesticide, but used as an inhibitor of Fomes). These treatments are fairly restricted in the area affected but do affect organisms other than the target species. Currently however there seems to be no reasonable commercial alternative to these treatments, although a lessening in the preponderance of conifers in the plantings would lessen the requirement for urea applications. Research into the necessity of treating all cut conifer stumps on all sites with urea needs to be carried out.

In natural forest systems there is inherently a balance maintained among the organisms present, so that only very unusually would one organism become a big problem. In artificial systems, particularly those of low species diversity, there is little buffering capacity in the ecosystem, and it is easily affected by outbreaks of pests. Following this logic, in working towards a more biodiversity-friendly forest, mixed stands of conifers and broadleaves, particularly if they are allowed to age and develop an associated flora and fauna, should be less vulnerable to outbreaks of pests or disease. Additionally, if one species of tree becomes affected by a pest (*e.g.*, Pine Weevil), the forester still has other species of tree that will be commercially viable.

In speaking of forest health, there is a tendency to focus on outbreaks of disease and pests, and defoliation due to atmospheric pollutants. The health of a forest should be viewed holistically. In a natural system, each group of organisms, each microhabitat, has its own function in the larger forest. When each of the components, which may be made up of numerous individual organisms, functions correctly, the ecosystem is healthy. In artificial systems however, all of the groups of organisms necessary to carry out the vital functions may not be present, and this must be compensated for by inputs to the system. This may be in terms of adding a nutrient to the soil, converting the elements present in the soil so they become available to the plants, or introducing a particular animal to the system to perform some link function in a vital process. In an effort to create healthier anthropogenic forests, an aim should be to ensure that they are as ecologically balanced as possible. This includes focusing on the less obvious elements of the forest system: the microbiota in the soil, the leaf litter and the dead wood.

4.5.1 Dead wood

Deadwood is important for diversity through directly providing sustenance, nutrients and shelter for numerous species of forest animals, plants and fungi. It directly increases habitat diversity and provides microhabitats that are more stable, moist and sheltered than most surrounding habitats (Hodge and Peterken, 1998). By providing a rooting medium for tree regeneration, deadwood influences stand dynamics and structure, which in turn influences biodiversity. In some forest types, most successful tree regeneration takes place on fallen logs ("nurse logs"), (Harmon *et al.*, 1986; Iremonger, 1986), either because the competitive effects of the field layer are temporarily reduced (Harmon and

Franklin, 1989), or for other reasons, *e.g.*, providing a slightly elevated and therefore drier micro-habitat in wooded wetlands. Deadwood is an important source of nutrients, acting in effect as a slow-release fertiliser (Carey, 1980).

In natural forests, the processing of dead wood is vital to the renewal of the forest through releasing the energy and nutrients required to fuel the forest system. Numerous organisms are associated with this activity, and many of them are species-specific. It is a particularly complicated process because it deals with wood, which has a complex chemistry and requires the attention of "teams" of specialised fungi, invertebrate animals and micro-organisms. These work together or sequentially to effect the "resorption" of the wood into the forest. One third of a tree's annual intake of nutrients is used in making wood. The saproxylic organisms can process up to 10 metric tonnes of dead wood per hectare per year (Speight, 1989a). The task of breaking down wood is sufficiently complex that no single saproxylic can gain access to all the energy and nutrient trapped there. The partially decomposed wood resulting from the activities of pioneer saproxylics is thus used by secondary saproxylics and then again by tertiary saproxylics. The entire process of decomposition occupies 15-50 years (Speight, 1989a). A full account of saproxylic invertebrates and their conservation is given by Speight (1989b).

Many saproxylic organisms that have evolved with the natural forest are specific to particular types of wood (Speight, 1988). Thus, the suite of organisms that are active in a conifer forest is different to those active in a deciduous woodland. The enzymes necessary to digest the wood of conifers are different from those needed to digest the wood of broadleaved species. Because of the great impact that people have had on Europe's landscape over the centuries, pockets of natural forest that remain are generally either very small and isolated fragments or have been modified to such an extent that their natural processes are no longer intact. Ensuring that dead or dying trees remain in the forest has not been a priority in forest management systems. For this reason, many saproxylic organisms disappeared from vast tracts of their previous range in Europe and became very localised where they still occurred. During the 19th century, the disappearance of saproxylic organisms accelerated due to the general introduction of "forest hygiene" into forest management practices. In Scandinavian forests it was suggested that there was an 80% drop in overall faunal species diversity associated with the conversion of natural conifer stands to commercial conifer crop (Heliövara and Väisänen, 1984). Changes to more biodiversity-friendly management practices in Scandinavia in the 1990s has probably ameliorated this situation (National Board of Forestry, 1996; Swedish Environmental Protection Agency, 1998).

Forty percent or more of saproxylic species can be recognised as under threat of extinction in Europe. Many hundreds of invertebrate animals and fungi are involved. The whole food web is affected by this. Predator invertebrates such as the Syrphidae (hoverflies) use the saproxylic organisms for food (Speight, 1988). Additionally, the saproxylics share their habitat with lichens, mosses and liverworts which are now also endangered. Tree hole-nesting birds, bats which need tree cavities for roosts and other mammals which rest, hide, feed or nest in such places, decline along with their habitats. Thus the effects of saproxylic decline are widespread among other taxonomic groups.

In Ireland, species of saproxylic associated particularly with oak and elm are very few. This has been ascribed to eradication by forest clearance rather than to other causes, such as the failure of the species to colonise Ireland after the post-glacial because of its remoteness (Speight, 1988). Because of the current spatial distribution of natural forest fragments remaining in Europe, the likelihood of natural re-colonisation of the Irish forests from there is minimal. Any increase of faunal diversity in Ireland's forests would have to be by deliberate introduction.

Smaller, less economically important trees may provide a richer diversity of saproxylic species but have not yet been fully investigated. Species associated with scrub woodland or with the understorey of higher forests such as birch, hazel, holly, eared willow, sally and goat willow tend to be more continuously present and more widely distributed in the Irish landscape than oak and elm, so their associated decomposers may also be more widespread (Speight, 1988). The sycamore, a naturalised broadleaf in Ireland, has been found to be very attractive to invertebrates because rotten pockets are frequent in its branches.

The only conifer that has, in Ireland's postglacial history, been known to dominate relatively widely in natural stands, is Scots pine. It is not certain that this species has had a continuous presence in Ireland since it colonised naturally. There is evidence that it probably became extinct before its re-introduction about 300 years ago (McCracken, 1971; Mitchell, 1976). Conifer-specific saproxylics must have declined with the pine, and those that are present must have either survived on relict pine populations or on juniper or yew, or been re-introduced along with pine or with species of larch, spruce and fir, because a number of these do exist in the Irish fauna (Speight, 1988). Host-specific saproxylics are those that are the most endangered because in the absence of their favoured species they cannot survive. These more specific fauna contribute more to the bioquality of an ecosystem (see Section 1.3) than their more generalist associates. Very few species that are associated with pine are host-specific, and those that have been introduced along with other conifers to Ireland are all generalist. In Britain it is possible to distinguish between the microfauna of indigenous pine forest and commercial pine plantations, including those of Scots pine, as well as between those of *Pinus* spp. in general and of fir, spruce, larch, etc. As in Ireland, in Britain the saproxylic species exclusive to one or another of the introduced genera of conifers are generally lacking. However, the pine-associated European saproxylics are well represented in Britain, one suite of them being virtually confined to the remaining patches of Caledonian Scots pine. The few Irish Scots pine saproxylics are among those species in Britain that characterise the native pine forests rather than those of the plantations.

Clearly the richness of biodiversity and the health of forest systems are affected at a very fundamental level by the presence or absence of dead and dying wood, and its associated organisms. Seventy-eight percent of all forests in Britain occupy ground not previously wooded, and thus possess no legacy of deadwood or associated saproxylic organisms (Hodge and Peterken, 1998). The percentage for Ireland is probably higher. The volume of dead wood in British forests varies enormously, from one to $130m^3\ ha^{-1}$ (figures for semi-natural forests and plantations, excluding broadleaved high forest after catastrophic blowdown, for which the figure is much higher) (Hodge and Peterken, 1998). Because of the nature of the saproxylic species, it is apparent that to just create deadwood is now not sufficient, we need to look into actually providing the opportunity for colonisation by the more species-specific saproxylic organisms, and for them to build up populations within the forest. This may happen naturally as forest plantations move into their fourth rotations and more, because there will have been a certain build up of dead wood over the number of rotations. This needs the clarification of further research. Forest management practices for the conservation of saproxylics are given by Speight (1989b).

The best management practice that would allow the development of a good forest saproxylic community would be to allow trees in the stand to become over-mature, and to senesce. As the tree grows old it naturally begins to shed old wood and to provide microhabitats that different species can use, from pockets that accumulate litter to holes that provide shelter or nesting places for larger species. A range of diameter classes of branch becomes available for colonisation by decomposers. Dead wood over 15cm diameter has been identified as being particularly important. This is the rarest class of dead wood in forests because often there are much smaller-diameter pieces; even in intensively-managed conifer plantations there is a certain amount of brash. Trees that develop hollow trunks are also particularly important because they support a specialist biota inside the trunk (M. Speight, pers. comm.). Cut stumps in managed forest can be used as a host for many saproxylic species, if left untreated.

Natural levels of deadwood cannot be recreated in forests from which timber is extracted. But, an effort can be made to determine a minimum quantity of deadwood that would make a useful contribution to biodiversity and ecological processes in Ireland's forests. Hodge and Peterken (1998) have suggested a minimum quantity of deadwood that should be left in British forests used for timber harvest. This is based on the minimum requirement of certain indicator species. A recommendation of at least $5m^3\ ha^{-1}$ of wood greater than 15cm diameter was made, representing between 0.25% and 1% of the standing volume in economically mature conifer stands. The ecological benefits of this would be greatest if deadwood were concentrated in locations where a continuity of supply can be assured. One system proposed was to reserve a 0.1ha patch of old forest for every 2ha of short rotation stand (5 percent of the forest area) (Hodge and Peterken, 1998). Uneven-aged permanent retentions of this extent, if no timber were extracted from them, would eventually have the potential to meet perhaps half of the $5m^3\ ha^{-1}$ recommendation for the whole forest area.

These recommendations seem rather low in view of the amount of timber generally expected to be produced in Irish plantations: $400m^3ha^{-1}$. In Sweden it has been recommended to leave 5-20 big trees ha^{-1} to mature, die and decay naturally in the forest (Nilsson, 1992). This may not be practical in Ireland, where they would surely be windthrown between rotations. Another method, more practicable in Ireland, is to cut a certain number of the forest trees a few metres above the ground and leave them as standing dead in the forest. These cut off trunks have more resistance to windthrow than whole trees because of the absence of the crown. These should not be felled during the harvest. A proportion of the late thinnings could also be ring-barked. This would increase the volume of dead wood and would also provide a proportion raised above the ground level that would be more attractive to certain species, including animals and possibly epiphytes.

In forests where native tree species are not being used, these recommendations would be best followed along with the utilisation of other European species of tree for cultivation.

Both the species of tree and the associated biota would be taxonomically closer to those of Irish ecosystems. Irish species would stand a better chance of being able to associate with these species, supporting the formation of ecologically rich semi-natural forests.

4.5.2 Soil and leaf litter

The architectural components of the forest are more noticeable than the areas underground or on the surface, which are generally teeming with life. Soil is one of the most complex living phenomena on this planet. Much of life above ground is dependent on the health and living processes of the soil. It nourishes, recycles, cleanses, anchors. It is a highly variable mixture of rock, water, air and life. The living soil, the vegetation that grows on it, the wildlife that lives in this vegetation and the people that cultivate the soil and depend on its fertility, cannot be separated. They all work as one system, each part dependent on the others. For many invertebrates and fungi the soil and litter layers of the forest are most important, and the processes here impact fundamentally on the forest ecosystem. The type and condition of the soil of the forest is most important for the growth of the trees, and so the organisms that affect the processes that take place there are vital (Blackith *et al*., 1996; Henegan and Bolger, 1997).

In Ireland, clearance of native woodlands in historical times resulted in an increase in water flux, erosion and morphological changes in soil resulting from the disruption of the equilibrium between factors of soil formation (Farrell *et al*., 1996). On nutrient-poor, acid soils in the west, deforestation has probably contributed to the spread of blanket peat. On soils of higher base status, disturbance of the hydrological balance may have led to the increased occurrence of gleyed soils. In both cases, soil productivity has diminished as a result (Farrell *et al*., 1996), and the tree species that will grow on the site are often different to those that were originally found in the area. Not only has deforestation been blamed for the changes in soil quality, but also such seemingly minor activities as the extraction of leafy twigs for use as winter fodder (Farrell *et al.,* in press). The resulting loss of soil nutrients contributes to a reduction in the acid-neutralising capacity of the soil and the acceleration of soil acidification. This in turn affects the biodiversity of the soil and associated waters (see section 4.3).

Soil communities are among the most species-rich components of terrestrial ecosystems (Giller, 1996). The volume of soil under $1m^2$ of woodland could contain over 200 species of arthropod and up to 1000 species of soil animals *in toto* (Anderson, 1975). Mature forest soils appear to have a phylogenetic diversity greater than any other habitat, other than perhaps coral reefs (Behan-Pelletier and Bisset, 1992). Bacteria are the most numerous living organisms in the soil. There can be as many as 1,000,000,000 bacteria in a single gram of soil. Fungi are a very diverse group that occupy a wide variety of micro-habitats in the soil. Saproxylic fungi are responsible for the decomposition of wood. The decomposition of organic matter and the mixing of this in the soil is very important, and soil biota are essential to this process. Important fauna associated with soil include earthworms, springtails, mites, woodlice, snails, millipedes and ants, and species of beetle and fly spend periods of their lives in the soil. Earthworms and other organisms mix organic matter into the soil, facilitating the decomposition process and the recycling of nutrients to the plants of the forest (Blackith *et al*., 1996).

In Ireland, studies on Carabid invertebrates, which have been proposed as potential indicator species for conservation potential in forests (Butterfield *et al.*, 1995), recorded 14 species in Brackloon Wood, and 25 in Camolin Wood. Camolin Wood has more fertile, base-rich soils and a different land use history: it was one of the first forests planted by the Forest Service in the early 1900s. It had agricultural activity, including cultivation, prior to afforestation. Also, it is surrounded by grazing land and has a mix of deciduous and coniferous stands. The study concluded that the differences in Carabid populations were probably related to past and current land use as well as to inherent site conditions.

A study of Carabids in Breen wood in Co. Antrim, which includes an oak wood as well as an adjacent 30-40 year old conifer plantation, showed that there was a big difference between the carabid communities of the two forest types (Day *et al*., 1993). Carabid communities did not show any significant differences between a Sitka spruce plantation and a Japanese larch plantation. There was a greater Carabid species richness in the conifer stands, probably due to the similarity of soil type between these and the surrounding natural vegetation, which was heathland. The trend contrasted with other studies, *e.g*., in Sweden 14 species of carabid were found in an oak stand as against 10 in a spruce forest.

In Ireland, broadleaf forests are generally found in areas that are more fertile and have a very different soil composition than conifer plantations. The latter have tended to be planted on upland, nutrient poor sites. As such the soil biota will be inherently different in each place from the start, and direct comparisons may not be valid. The whole area of soil quality and the effects of forestry needs further research.

4.6 Genetic diversity

Within each population of organisms there is a genetic diversity in that each individual has a different genetic makeup from the rest. If populations of the same species are separated from each other for long periods of time, each population develops similarities among itself that differentiate it from the next. Taken to the extreme, if the populations are completely cut off from each other, each may evolve genetically to such an extent that the populations are no longer the same species. Over time each population makes adaptations to its environment, so that an individual from one place may not thrive when moved to a different place, even though organisms of the same species live there. These different species populations are called ecotypes. An ecotype is an expression of a particular genetic makeup, which is called a genotype.

In terms of genetic diversity, the concern for Irish forests has been that the seed for the trees grown in Ireland largely originated outside of the country. For the species alien to Ireland this is obviously not an issue, but concerning trees native to Ireland, the native ecotype stock is being reduced and replaced by the importation and planting of trees of non-native provenance. Genetic diversity is part and parcel of biological diversity, and efforts must be made to ensure that it is nurtured along with attention given to species and ecosystems. Although the genotypes of trees in Ireland have not been examined for differences to stock from other countries, it is logical to conclude that trees of Irish origin should be ecologically more suited to the Irish environment. Genotypes and phenotypes unique to Ireland may exist due to its isolation and westerly location to mainland Europe

New thrusts to provide Irish stock to Irish forests have resulted in the development of nurseries, and there are currently 11 species of tree available in Ireland from EU certified stands (Department of the Marine and Natural Resources, 1997). Five of the EU-regulated species are native to Ireland: pedunculate and sessile oak, ash, Scots pine and poplar. However, the Irish seed stands are not necessarily of native provenance (of which the ancestor trees were native). Although according to de Brit (1995), the difficulties accessing material for planting that is of Irish origin should no longer be a sizeable problem, at least 80% of oak and about 50% of the birch planted in Ireland is currently of non-native provenance (P. Doody, *in litt*.). Reasons for this are the low production and the short viability of seed by Irish oak. As other native tree species are not highly commercial, they are not EU-regulated and their planting from non-Irish stock is not monitored.

The problems with using Irish stock for planting commercially-oriented forests is that most species have not undergone breeding programmes, and the quality of the tree for commercial purposes is unknown. This can only be remedied by establishing breeding programmes for Irish species, particularly those that are generally currently not considered commercially viable, such as hazel, holly and rowan. At present, the commercial potential of Irish native stock is only beginning to be investigated, with projects now focusing on oak and birch (COFORD, 1999). As tree breeding is not a process that gives rapid results, products from the exercise may not be available for some twenty years, or much longer.

Research has already been carried out by Teagasc into the breeding of some trees for silviculture (Douglas, 1995). This could be steered towards diversifying the stock of Irish tree species of local provenance, and the official maintenance of reserves of Irish genetic resources in the form of seed collections, stock nurseries and germplasm banks (Byrne, 1995). In many exercises for stock improvement there are vegetative techniques used that can result in the proliferation of many individuals with the same genome (Douglas, 1995; Mac an tSaoir, 1995). Although this is often the way to produce the fastest results from breeding programmes, it is very undesirable from the point of view of biological diversity and should be avoided. In addition to establishing or expanding breeding programmes, the maintenance of wild populations is absolutely necessary to maintain the rich naive gene pool.

There may be cost penalties associated with active genetic conservation. It may be necessary to forego using the fastest growing or best formed genotypes if local stock is to be preferred to selectively bred improved material (Soutar and Spencer, 1991). However, genetic conservation has wide applications in maintaining the ecological, aesthetic and economic contributions of trees to human happiness and wellbeing. Natural variation in native trees is vital to sustaining woodland ecosystems and is a source of genetic material for use in forestry and arboriculture.

5. Forest planning, law and economics

5.1 Forest planning and the law

The basis for all successful planning is information. Until very recently Ireland was lacking a fully-functional informational database on forests, their locations, sizes, ownership, forest type, age and land potential (Department of Agriculture, Food and Forestry, 1996). The most modern database was that of Coillte, but this was restricted to its own commercial holdings. A new FIPS has been set up by the Forest Service that is designed to deliver this information. The FIPS includes data from the interpretation of satellite images and aerial photographs, as well as from ground-based forest inventory. It is a state-of-the-art system that should fulfil all the needs of forest planners. It will enable the Forest Service to carry out numerous analyses, such as planting by species mix or by ownership, by geographical area or by land potential. It will also facilitate forest design in relation to landscape, and forest monitoring exercises that may follow the development of all of the forests in Ireland. A European initiative that will feed into the information system for Ireland will be the COST Action E4: Forest Reserves Research Network (European Forest Institute, 1999).

The forest planning exercise needs to follow standards, and these need to be set, giving full consideration to all the different sectors affected by forestry or by which forestry is affected: the timber industry, national and international markets, non-wood forest products, the effects of forestry on rural communities, agriculture, fisheries, the landscape, other aspects of the environment and the national heritage, including nature. No nationally recognised or international formal standards have been implemented in Ireland in relation to forest establishment or management, except the European Communities Environmental Impact Assessment (EIA) Regulations, which provide for EIA within the context of planning permission for initial grant-assisted afforestation and for the conversion of broadleaf high forest to conifers (Department of Agriculture, Food and Forestry, 1996). Measures that will ensure good EIAs are the completion of fisheries maps and maps of sensitive river catchments, the establishment on a statutory basis of Natural Heritage Areas (NHAs) and regular review of all maps and lists of ecologically sensitive areas by the appropriate authority (Department of Agriculture, Food and Forestry, 1996). There are currently forestry plantations in some NHAs and indeed in the SACs, sites of European importance that form a subset of the NHAs. For biodiversity conservation it is important that special attention is paid to these areas, and forestry practices ceased where they are deleterious to the overall ecology of the area. Additionally, the Forest Service (now within the Department of the Marine and Natural Resources) imposes silvicultural and environmental requirements on all grant-assisted forestry projects, which effectively act as minimum standards in these areas (Department of Agriculture, Food and Forestry, 1996). Many standards and restrictions applying only to grant-aided afforestation projects should be made to apply to all afforestation projects, whether grant-aided or not.

Coillte Teoranta, the semi-state forestry company, operates its own Continuous Improvement Scheme for forest management on a self-assessment basis. Coillte is subject to the same requirements as all others insofar as grant-assisted forestry projects are concerned (see below). Although Coillte manages more forested land than the sum of all the rest of the forest owners in Ireland, it was not established with environmental concern as one of its primary objectives. Rather, its objects targeted the commercial side of forestry, citing efficient silvicultural practices, woodland industries and the enhancement of the effective and profitable operation of the company. Since Coillte's establishment, there has been a massive movement towards forest policies that are more environmentally conscious (see Section 2). In a sense the goalposts have moved, and Coillte's objectives should be re-examined to enable it to function in the new playing field (Farrell, 1997). Coillte's recent publication on SFM (Coillte, 1999) indicates that steps in this direction are underway.

Financial support for private forestry comes under two schemes, the Operational Programme for Agriculture, Rural Development and Forestry (OPARDF) and the Common Agricultural Policy (CAP). Forestry under these programmes is financed 75% by the EU and 25% by the exchequer. A number of tax incentives also apply to forestry development. These schemes and incentives are not producing the required result of an afforestation target of 25,000 ha per year (up to the year 2000) (Davoren, 1998). Figures for 1997 show a planting level of only 11,403ha, and figures for 1998 were only 12,928ha (Department of the Marine and Natural Resources, 1998). This is at least partly due to higher rates of subsidy for agricultural enterprise than for forestry. Davoren (1998) suggests a number of measures that could be taken to improve the forestry option for potential farm-foresters.

The above schemes financed the planting of many forests for which the standards allowed the planting of up to 100% Sitka spruce in any one stand. Standards now demand that each afforestation project contains a mixture of a minimum of two species, and a maximum planting of 85% of any one species (Department of Agriculture, Food and Forestry, 1996). Sitka spruce planting is now restricted to 60% of annual afforestation, and the afforestation of other diverse conifers is increased to 20% of total afforestation. Broadleaves should account for at least 20% of annual afforestation.

In view of the current movements towards SFM (see Section 2), and in particular the concern over the forest ecosystem functionality, much higher percentages of broadleaf in the mixture should be standard. This, however, needs to be carried out as a part of a comprehensive land use plan, with suitable proportions of the land allocated to each land use type (Lund and Iremonger, in press), and within the forest land, the tree species suited to the type of land. In general, the tree diversity in reforestation exercises should be increased. Results of research into biodiversity patterns (see Section 4.5.1) have indicated that tree species of European origin, if not Irish, should be favoured over those from other continents, when practicable.

The Woodlands of Ireland initiative has suggested a new grant scheme, the "Native Woodland Scheme" (NWS), whereby the development of native semi-natural forest for multifunctionality would be supported (Little, 1999). The present Woodland Improvement Scheme (WIS), although it has funded the development of some semi-natural woodlands in the past, is considered too commercially oriented, not adequately addressing the conservation requirements of these woodlands. Also, WIS payments were insufficient to revitalise woodlands with serious problems with invasive species (A. O'Sullivan, pers. comm). The Woodland Amenity Scheme was also found to be inadequate for the proposed task. Through the proposed NWS, conservation-compatible multifunctional management systems would be researched and refined, supporting the wider implementation of the principles of SFM. Not only would existing forests come under the scheme, but new forests would also be planted.

This scheme would facilitate the scenario described above with respect to other European countries and multifunctionality (see Section 1.2). Indeed the practices used under this scheme may in time actually replace the forestry systems that have been prevalent in Ireland in recent times, that use non-native and non-European tree species as intensively managed tree crops. This would be much more compatible with the conservation of biodiversity and ecosystem health, and is the type of system that is being promoted by the Heritage Council (1999). However, under the current economic system for forestry, this scheme may not be viable, and would result in the halting of afforestation in Ireland. As much of the broadleaf afforestation taking place is now due to the success of the conifer plantations, a change in the framework under which this situation pertains would possibly collapse the system altogether and even halt the broadleaf projects. It requires careful consideration to find a way that it could be implemented without losing the valuable financing for afforestation projects in Ireland.

Whether this particular NWS is implemented by the Government or not, the general aim of the scheme is one that promotes sustainable, ecologically sound afforestation and is laudable. Additionally, regulations for the maintenance of remnants of natural woodland that would not be the subject of intervention management but would be left for the specific purpose of providing continuity in native semi-natural forest habitat over time must be implemented. This will ensure that the more specific and important native old-forest species complement can develop and increase, not only the more generalist species that can survive in many different habitats, including forest (J. Good, pers. comm.; Speight, 1988; 1989b).

5.2 Irish forests and the market

When the strategic plan for forestry in Ireland was released in 1996, the European market for timber was such that the cost of importing timber supplies to Europe would probably have been high relative to the price of locally produced timber. It was estimated that Ireland was relatively well placed to supply these markets on a cost-competitive basis. With the enlargement of the EU however, there will be more timber available to the European market than was previously estimated, reducing Ireland's competitiveness (Department of Agriculture, Food and Forestry 1996). Additionally, the strategic plan forecasted the continued planting of Sitka spruce-dominated forests at a very high rate of 25,000ha per year (until the year 2000 and 20,000ha per year thereafter), a target that has not been reached for the past three years. In view of the change in attitude towards forestry towards a more environmentally sustainable industry, the shortfall in planting in the past years may be a good thing because in the new millennium it is probable that extensive conifer plantations will be discouraged. There is an opportunity now to plant the more modern mixed, multi-purpose forests of the future instead of the species-poor production forests of the past. In countries where there is a high degree of manual labour in forestry and high costs (*e.g.*, Germany), the profitability demands of forestry have promoted nature-oriented forestry (Hellström and Welp, 1996), whereas in countries with highly mechanised forestry (*e.g.*, the Nordic countries), nature-oriented forestry has been more likely to be conceived as a threat to profitability (Hellström, 1999). The latter has been the case in Ireland, but with the changing of the emphasis in Irish forestry, Ireland should evolve characteristics more similar to that of Germany, where more biodiversity-friendly systems are in operation. This will require a re-examination of the economics of Irish forestry.

The key to the changeover will be in how the economics of forestry are managed by the state Forest Service. The grants for forestry are currently the most important factor in the determination of the nature and extent of new forest establishment and the management aims of the existing forests (Clinch, in press; Davoren, 1998). The market and other benefit assumptions of the 1996 strategic plan for forestry were the subject of a rigorous economic analysis in 1998 and found to be questionable (Clinch 1998; in press). One of the principal reasons was that even before subsidies were considered, the strategic plan would not necessarily contribute to the welfare of society and therefore its implementation should be carefully examined. It was emphasised however that the net environmental benefits of the plan would be positive.

A weakness of the critical study of the strategic plan was that it was limited to assessing the efficiency of the government's existing plan and this did not show whether some other package of measures would provide a higher (or lower) rate of return and thereby be a more viable proposition (Clinch, 1999). Such measures would include reduced levels of planting, different species mixes and longer rotation periods. It is anticipated that a new more modern approach to forestry in the future will facilitate a system that is both economically beneficial and better for the environment and natural heritage. A truly integrated study of the potential for forestry and the derivation from this of an integrated plan are required. The current moves towards writing a National Forestry Standard and Code of Best Forest Practice for Ireland are steps in the right direction.

More than 95% of afforestation and private reforestation activities in Ireland are grant-aided. Reforestation activities by Coillte are not grant aided (C. O'Donovan, *in litt.*). Currently the criteria that need to be fulfilled for a grant to be given are the only rules that govern what is planted and subsequent forest management practices. For example, the stipulation that broadleaves should be included in the overall forest estate at a level of 20% applies only to forest activities that are grant-aided. In the absence of the necessity for grant aid, any planting regime at all that is favoured by the investor can be employed (Hendrick and MacAree, pers. comm.). A more desirable scenario would be to divorce the stocking and management requirements from financing and to require instead ecologically-friendly sustainable planting regime and management systems across the board. Variability in site suitability would have to be taken into account by treating each forest area individually. This will need to be done anyway for the forthcoming FIPS to be successful.

Because there is a link between the presence or absence of forests and the value of land, houses and related items, it is vital that the national agency for planning of forestry should not be financially linked to the implementation body. A study of the impact on house prices of the presence in surrounding forest of different proportions of Sitka spruce, other conifers and broadleaves showed that broadleaves increased house prices and Sitka spruce decreased prices (Garrod and Willis, 1993). The conclusion of the study was that considerable amenity value could be derived from broadleaved planting as compared with Sitka spruce and other conifers. In Ireland the planning agency is now separated from implementing agencies (Coillte and other forest developers and contractors), and this situation should be allowed to continue.

5.3 The sociological element

One of the most striking of the non-legally binding Forest Principles agreed at UNCED in Rio de Janeiro in 1992 was:

> Forest resources and forest lands shall be managed and used sustainably to fulfil social, economic, ecological, cultural and spiritual needs of present and future generations (United Nations 1993).

The practical significance of this and other principles can be debated endlessly. What is clear, however, is that the statement reflects a recognition that forests have values that transcend those of timber and other material products (Mather, 1999). At the end of the 20th century, the perceived values of forest services are arguably increasing relative to those of material goods, especially in the developed world. In the United States, for example, forests have been increasingly viewed as environments and as aesthetic resources, rather than solely sources of timber and other commodities. In Ireland there is an increasing body of opinion in the same direction (Crann, 1999; Heritage Council 1999). This fundamental change needs to be addressed at the level of planning the establishment of forests and of their management.

However, a balanced view must be taken of the reaction of people to the changes seen in their countryside. According to Kimmins (in press),

As a species, humans are highly visual. Much of our judgment about our environment is based on what we see. We also have a deeply ingrained dislike of change. The visual images we grow up with are imprinted on our psyche. We do not like to lose them or see them change.

Although Ireland was at one time an island with a very high percentage of forest cover, in the last few hundreds of years the people have become accustomed to a more open landscape. Afforestation causes a great change in the landscape which, whether it represents an improvement in the ecology of the area or not, can cause people to object.

Present-day planners and technicians quite often do poor social engineering, unassisted by the professional competence derived from sociological and anthropological knowledge (Cernea, 1991). To ensure that more people, particularly in the immediate community, support forest planning, it is important to have officials with social sciences training on the planning team. This may be done by training existing staff or by making use of specialist consultants with these skills, who could form part of an integrated and multidisciplinary team of planners. Such a system ensures more buy-in from the community from the start which protects against problems later on.

In Spain, the reforestation policy created an agency staffed predominantly by forestry engineers (García Perez, 1998). These, although well-qualified to deal with the physical aspects of reforestation, climate, soil type and infrastructure to be constructed, lacked the knowledge and experience of dealing with the socio-economic aspects of planning. The exclusion of interest groups generated resentment and distrust among the affected people.

Past trends in reforestation planning still impinge on the ability of the present forestry agency in Spain. After the take-over by the military regime in 1939, foresters trying to achieve spectacular results opted for massive reforestation with single-species conifers. This was the result of lack of technical knowledge of management of mixed plantations and the pressure exercised by powerful groups interested in the production of wood. One of the main arguments for Spanish foresters choosing fast-growing and frugal species such as *Pinus nigra* and *P. pinaster* has been that they are able to succeed in highly degraded soils. However, plantations with these species have been established indiscriminately even in areas where the soil is not degraded (Garcia Perez, 1998). Ireland is among the countries that can learn from the Spanish experience.

5.4 The role of agroforestry, wood pasture and coppice

It has been claimed that agroforestry presents greater potential to combine the dual goals of sustainable rural development and conserving biodiversity than commercial agriculture or plantation forestry in tropical countries (Pimental *et al.*, 1992; Gajaseni *et al.*, 1996). Most of these claims have been expressed in general terms of increased structural, habitat and species diversity. The ideas are supported by data from temperate hedgerow systems which demonstrate clearly the biodiversity benefits of maintaining tree cover (in hedges, windbreaks, ditches and forest fragments) within the agricultural landscape, especially for birds (Arnold, 1983; Best, 1990; Hobbs and Wallace, 1991; Lack, 1988).

Biodiversity in intercropping systems may be limited in the main to species which are adaptable to open disturbed “farm” habitats and/or which are of significant benefit to farmers and local communities. For this reason, without specific governing regulations, the species mix grown in agroforestry systems will be determined by farm economics, and is therefore inherently susceptible to market fluctuations. This means there is no guarantee for secure conservation uses in the long term. While agroforestry may allow some native species to survive and even thrive, it cannot conserve more than a subset of species, nor all the complexity of interactions associated with true forest (Hughes *et al.*, 1998). Bioquality (see Section 1.3) of agroforestry systems will always tend to be lower than adjacent forest. A more lasting effect may be that genes that are successful in farm/field habitats will be favoured and the original evolutionary equilibrium will be altered.

Agroforestry systems have not been in common usage in Ireland, but a project is being set up to research their potential (D.W. Jeffrey, pers. comm.). Evidence from other studies indicates that the greatest contribution of the agroforest will not, in general, be for its bioquality, but as a buffer or barrier which mitigates edge effects, reduces outside interference and encroachment, protects adjacent forest, and as bridges or stepping stones, links forest fragments (Hughes *et al.*, 1998). Agroforestry (intercropping), is generally more integrated into the agricultural sector than are pasture woodland or coppice management systems, which seem to fall between two stools, and are neither fostered by the agricultural sector nor the forestry sector in Ireland.

Pasture woodland and coppice are not common in Ireland, but these systems have been used in Britain for hundreds of years (Kirby *et al.*, 1995). They are important for biodiversity because they provide a structure and continuity similar to forest, which fosters woodland species (Peterken, 1993). In southern Sweden old meadows with scattered tree cover are the only habitats with long unbroken tree continuity (National Board of Forestry, 1996). A management system of coppice with standards provides both timber trees and a continuous supply of small diameter branch, as well as a field layer that can be used for grazing (Peterken, 1993). The use of coppice more extensively in Ireland would conserve areas now seen as unproductive disposable scrub, which provide habitats for species of conservation importance. In conjunction with areas of forest and hedgerow in the landscape, these can contribute to the network, providing important refuges for species requiring tree cover. A recent report has described some detailed management techniques for conservation of birds in Irish farmland, including the management of hedgerows and scrub areas (Donaghy and Murphy, 1999).

6. Forest management modification for biodiversity enhancement

Managed forests have a valuable role to play in conserving biodiversity, and the knowledge base of how forest management can be modified to optimise biodiversity conservation is expanding (Sayer and Iremonger, 1999). The crucial step in fostering biodiversity in forests is the translation of this knowledge into improved forest management and conservation practices (Kapos and Iremonger, 1998). At the level of the management unit, the retention of small refuge areas and the maintenance of riparian buffer strips are widely recognised as being effective ways of helping plant and animal species survive the periods of disruption associated with industrial logging. On a broader scale, there is now interest in distributing logged and unlogged forests in an appropriate way throughout the broader landscape in order to take account of the ecological requirements of plant and animal species. The term Forest Ecosystem Management is used to describe such landscape-scale approaches to reconciling the needs for agriculture, forest production and biodiversity conservation (Sayer and Iremonger, 1999). The need for integrated land use assessments and management has been highlighted by Lund and Iremonger (in press), where the mosaic of agriculture and forest and their planning and management should ideally function together, instead of disconnectedly. These separate sectors should be linked at the planning stage to ensure an integrated land use strategy.

At all stages during the forest cycle the ecological impacts of the management practices need to be examined and evaluated. In an area that has the potential to support forest, the first exercise that needs to be completed is to decide what sort of forest should be present in it. This requires careful planning and research, taking into account the suitability of the site for forest, its potential impact on the landscape, the species that will be successful in the area, the growth stages and their structural composition, the financial grants available and their demands, the returns expected, how the forest is to be perpetuated, and its effect on the local community.

In terms of biodiversity, a mix of tree species closest to the native forests of an area is most desirable. If this is not possible for economic or other reasons, a mix of native species that is not found in nature may be used, or failing that, a mix that includes both native and non-native species, with possibly the latter predominating. The locations of sites of special ecological importance within or even outside of the forest should be taken into account, particularly NHAs, SACs and SPAs, but also unlisted natural areas, as well as waterways. These should be worked into the forest design plan, as well as rides and other open areas, and specially set-aside nature areas (Fuller and Peterken, 1995; Good *et al*., 1991). Habitat links (*e.g.*, hedgerows, areas of scrub) to other forested areas should also be considered at this stage as these may influence the layout of the forest. Once these vital plans have been made, forest establishment can begin.

Forest establishment can be accomplished by natural means, that is, by natural regeneration, or by planting. For natural regeneration to occur, there needs to be a source of seeds *in situ*. This will be present in the soil in areas that have recently been under forest, although whether the species that are required for the new forest are present will depend on the composition of the cleared forest. Natural regeneration is hardly ever used in Ireland at present, but as the forest area expands and the sites enter their second or third rotations, there may be enough seed of a suitable nature for natural regeneration, at least in part, to take place. Also, with the movement away from large clearfells, natural regeneration should become a more viable alternative than it has been in the past. A mix of natural regeneration and planting may be used where some of the species required for the forest are present in the soil seed bank or as saplings, but others are absent.

Species may be planted in groups or interspersed. Planting in straight lines has been disapproved of for aesthetic reasons, but the convenience of this practice for management and also changes in thinning practices has made this practice more acceptable (E.P. Farrell, pers. comm.). In the past, the straight planting lines were highly visible in young forests because of the thinning system employed which involved removing up to one line in three at first thinning. Due mainly to stability problems induced by this system, practice has changed and now lines are removed but at lower intensity with selection thinning in between. Subsequent thinnings have always been carried out by selecting individual trees, masking, rather than accentuating the lines. Where there are contours the lines should follow these.

The tree species mix is of the utmost importance because the trees in a forest dictate much of the ecology of the area, as they are the principal structural components. In areas where there was no forest previously or the species used in the past was or were not those required in the new forest, the new forest will be completely planted. For biodiversity conservation and the preservation of diverse gene pools, the origin of the propagules planted is very important. Ideally if possible these should be mainly of local or otherwise national origin. A small percentage of the stock may be brought from outside of Ireland, but in preference these should be of European origin.

Having established the trees of the forest at an appropriate density (see Joyce, 1998; Rodwell and Patterson, 1994), leaving spaces for animals and plants that require open areas in addition to canopy cover, the other structural layers in the forest should be considered. In the very young stages the shrub layer may need to be kept down to allow the trees to develop, but as they reach more than four metres (more than the height of a developed shrub layer) shrubs and smaller trees should be allowed to grow. In areas where there is no stock of these in the soil seed bank, they may need to be planted within the developing forest. These associated plants are themselves a part of the biodiversity of a forest and provide structural and functional diversity necessary for associated species assemblages.

As the forest grows past the thicket stage into the pole stage, thinning should take place. This is a very important stage in the ecological development of the forest, and should be carried out with great care and attention. Fairly substantial thinning will create gaps allowing light to penetrate to the forest floor, encouraging shrub, herb and animal species. The operation should be effected with as little disturbance as possible to the remaining trees, shrubs and other organisms. Much of the wood and brash from the thinnings can be left in the forest to provide dead wood. In forests that have entered their second or more rotations, there should be standing dead trunks greater than 15cm in diameter that were left over from a previous rotation, having been cut off at a few metres height, or ring-barked. Nilsson (1992) recommended a level of 5-20 big trees ha^{-1} to be left to senesce and decay naturally.

In addition to dead wood, it has been suggested that an inoculation of the soil of the new forest, possibly indirectly through inoculating nursery soil of the developing saplings (transplants) with some soil from a semi-natural forest should increase the possibility of development of a greater range of soil biota. The soils under new plantations are mainly non-forest soils and will develop over time, but can be aided in this process. More research is needed into the area of these new forest soils and measures that can be taken to progress their ecological development.

Rotation lengths and the need for old growth have been discussed by Peterken (1996). Forest plantations, even those of mixed species, remain incomplete ecosystems if felled at the commercial optimum. The relatively rich pre-thicket stage will be well represented, but the habitats associated with old growth, such as large trees, snags, large fallen logs and a spacious well-lit structure will be missing. It is a high priority, therefore, to create mature forest structures.

For this reason, and in terms of sustainable management, the current trends are away from large scale clearfelling. Clearfelling, although the simplest for the managers from the point of view of getting the timber out of the stand, has been shown to cause soil degradation and to be deleterious to landscape and biodiversity, and generally is destructive to the continuity of the ecosystem processes. The UK Woodland Assurance Scheme stipulates that in plantations over 20ha no more than 25% should be felled in any 5-year period unless all felling and restocking is based on an adequate felling design plan (Forestry Commission, 1999). The alternative, albeit generally more expensive, to clearfelling is selective felling, and there are a number of variations within this.

Because structural diversity is so important to biological diversity, and cover is so important for forest species, the ideal forest will have a range of tree ages and species, and large clearfells will be avoided. Selective felling, however, creates smaller open areas that can simulate the gaps created in a natural forest system by tree falls. The structural diversity so created increases the biodiversity of the area. Species that require dense cover, if the patchwork of felled and standing forest is tight enough, can migrate to the closed parts from the open areas. Temporary open habitats and young stands created by selective felling systems are a significant component of the ecosystem and have been found to be important for a range of mobile open land and forest edge species. Their ecological value is enhanced by practices mentioned above such as retention of standing dead wood, encouragement of broadleaves and increasing the width and structural diversity of permanent edges (Ferris-Kaan, 1995; Patterson, 1993; Petty *et al.*, 1995;).

Much of the forested landscape of Ireland now exists in very large, even-aged stands. Using the selective felling practices described above, these landscapes should gradually be replaced by either a patchwork of small even-aged areas at different stages of development or a completely integrated forest of diverse age structure. Reforestation projects in particular should be used as opportunities to diversify the species mix and forest design used. Peterken (1996) outlined a method of replanting by "partitioning" so that patches of forest at each stage of growth can be maintained, in particular old stands that would be felled at age 100. For example, if 16.7% of the plantations were retained on a 100-year rotation and 83.3% were felled on a 40-year rotation, the mean tree age of the whole forest would still be 25 years (the same as that of a standard rotation of 50 years applied over the whole forest), yet old-growth habitats would be created and there would be no cost to the area of pre-thicket stands (also important for wildlife).

In each forest, except in those where biodiversity conservation is the primary aim and the whole forest will be allowed to senesce and regenerate naturally (probably only in protected areas), an area of the forest should be set aside for biodiversity. This area should be allowed to grow old, past the mature stage and into the senescent stage. Ideally no felling should take place in this section and the ecosystem should be permitted to operate naturally. This will encourage the build up of biodiversity particularly in the soil but also in the above-ground components of the forest. Specialist species that are confined to older forest areas will be favoured over the more common generalists. The small size of some forest holdings in Ireland make it necessary for a certain amount of planning for this on a landscape scale, and control by some responsible body. Preferably the Forest Service, with the facility of its FIPS, should act in conjunction with the Local Authority in this enterprise, enlisting the services of an ecologist. The UK Woodland Assurance Scheme standard for certification (Forestry Commission, 1999) stipulates that in forests where 75% of the area is covered by the primary tree species, an area of 10% should be allocated particularly for the development of biodiversity. Probably an area between 5% (Hodge and Peterken, 1998) and 10% would be the optimum for a commercial forest, depending on other site factors. In this document these areas are termed *nature retention areas.* This would not, in general, include open spaces, which should constitute an additional 5-10%, but should be planned in conjunction with these.

Open spaces in forests have been shown to increase forest biodiversity. A proportion of 5-10% is recommended to be specifically managed as open space, particularly in forest plantations. This should be planned in conjunction with the nature retention areas, to yield a total land within the forest of 15% that is either open or especially set aside for forest nature conservation. In forest patches less than 10ha, these should be designed in conjunction with the surrounding land and the open space requirement may be reduced. Due to the greater edge effects in small forests there is not such a great requirement for open space. The management of ridelines, buffer zones around water bodies and other open areas is described in some detail in section B of this document, and the reader is referred to this an Fuller and Peterken (1995) for more details.

All management practices in the forest should be monitored so that the causes of any changes in forest characteristics can be identified. This enables the forester to improve methods in the future so that only the most beneficial and successful techniques are used. In addition to monitoring the more silvicultural aspects of the forest, biodiversity should be monitored. There is a European project developing a system of indicators of forest biodiversity for use in Europe (BEAR, 1999). The objective of this project is to provide forest managers with a means by which to monitor the ecological integrity of their forests.

6.1 Some conclusions and recommendations

Section A of this report attempts to describe the status of forestry and biodiversity in Ireland, present some national and international research results that have bearing on the subject and touch on the major issues involved at a policy and planning level. From this study a number of guidelines for forest managers have been drawn up, and are presented in Section B. There are however a number of issues that affect the fostering of biodiversity in forests that are outside of the control of the forest manager, and need to be highlighted here.

6.1.1 Forestry expansion

Recent and current forestry expansion in Ireland does not re-create or simulate the cover of natural forests that once were a very widespread and prominent feature of the landscape. The new forests are, by and large, effectively single-species tree crops that are have low biological diversity value and in many cases have replaced natural or semi-natural habitats. The practice of felling the whole crop at commercial maturity, and not allowing for old trees and dead wood to occur, prevents biodiversity development. Policies that effected this situation will need to be re-examined and altered to encourage a more environmentally and socially acceptable forestry industry in Ireland, following the Helsinki Criterion 4 guidelines for forest practice and planning.

6.1.2 Policy and economic factors

There is currently minimal legal control over the planning and management of forests with regard to issues that affect biodiversity. For grant-aided forests some restrictions and stipulations apply, but these are not applicable to self-financed forestry. Grant aid now demands, for example, at least two species in the mix, and there are requirements for at least 20% of overall afforestation to be broadleaf. These requirements are not sufficient for the enhancement of the biodiversity in the forest, as shown in this report.

Requirements should be expanded to include more biodiversity-enhancing considerations, and they should apply to all forests, not just those that are grant-aided.

In addition to expanding the legal control to non-grant-aided forests and to include more requirements for the ecological enhancement of the forest, the prevailing grant aid needs to be re-examined in the light of its competition with agricultural schemes. Ideally the forestry grant-aid should provide an economically acceptable alternative to agriculture. It should provide a means by which sustainable, biodiversity-friendly forestry can expand and be productive. The environmental services of afforestation should be emphasised, as should multi-purpose forestry. This does not preclude the growing of economically successful species such as Sitka spruce, but that these should not be grown almost exclusively, as has been done in the past.

In order that owners of forests or potential forest land should not suffer financial losses due to their implementing these guidelines for biodiversity, there should be certain flexibilities built into the system of grant aid. Suggestions for this are (a) that the areas of land left unplanted or retained for purposes of fostering biodiversity (recommended 15%) should be included in the grant package, and (b) areas of land that are harvested but are either financially unproductive in terms of forest product generation or that are found to be of conservation value, should be excluded from the requirement to replant with trees, with no financial loss to the owner.

6.1.3 Provenance and genetic health

There are five native species that are governed by the requirements for EU seed certification: sessile and pedunculate oak, ash , Scots pine and poplar. Of these, there are registered seed stands for the oaks and ash in Ireland, but it is not certain that the parent trees are of native origin (J. Fennessy, *in litt*.). Even if some are truly native (the ancestors of the parent trees were native), there is currently not enough seed from these Irish sources to supply the greatly increased demand of recent years brought on by the policy of extensive planting. Eighty percent of oak planting stock that has been used recently is of non-native origin (P. Doody, *in litt*). Reasons given for this are (a) that Irish trees are not prolific seed producers, (b) that oaks only produce seed once every five years or less frequently, and (c) some seed, particularly oak, can only be stored for very short periods (J. Fennessy, *in litt*). For other species that do not require registration there is not enough information available to indicate whether native provenance seed stocks are available or not.

Clearly there is a pressing need, in view of current rigorous planting schedules, to (a) determine which and how many seed stands there are currently in Ireland that are of native provenance, (b) conserve these, and where the species is listed for EU regulation, seek certification for the stand, (c) identify other sites that have native trees of a suitable quality, (d) establish reserve nurseries that can take all the seed in good years, plant it and keep the saplings (plants) until they are needed, thus minimising the need for seed storage, and (e) foster the genetic diversity of Irish trees by ensuring the conservation of an adequate representation of each tree species population across the country. This should not be limited to the five species regulated by the EU but should include other native species such as the birches, wild cherry, holly, rowan, hazel, alder and others. In view of the fact that much of the recent broadleaf planting has been carried out using seed of non-native stock, rigorous records should be kept which forests are now composed of truly native stock and which are from imported stock.

6.1.4 Protected habitats and species

Some places in Ireland are protected under European law as SACs. There are many other nationally important areas in Ireland that are not included in these and that have to date no formal protection: the potential NHAs. These are however coming closer to legal protection with the publication of the Planning and Development Bill (1999). With regard to afforestation, this will restrict the disturbance of these sites without special permission, whereas before, there was no formal restriction on activities in these sites. All bird species and many mammal species are protected under the Wildlife Act and European law, and there is now an expanded list of plant species that are protected (see Appendix B). Afforestation projects, certainly those that are grant-aided, should be properly planned to take these new developments into account. Additionally, there are sites of regional or local importance for biodiversity that are not included in the proposed NHA network. These have been found on sites that have been afforested and on sites that are likely to become afforested or reforested. These sites should be assessed and if necessary protected. This does not necessarily mean that the whole site should not be forested, but more likely that a small area (or “key biotope”) within the planned forest area should be set aside, according to a plan of integrated environmentally friendly management. Ecological specialists or foresters with ecology training and expertise should be involved in a pre-planting survey and the drafting of a suitable plan for the site before any operations start.

6.1.5 Planning

There has recently been some controversy regarding the impact of the Strategic Plan for Forestry (Department of Agriculture, Food and Forestry, 1996) on the Irish national heritage. Arguments against the Plan concern mainly the changes that afforestation projects have brought to bear on Irish landscape and the predominance of virtual monocultures of non-native conifers. Some objections are generated from a genuine, deeply felt, societal sentiment of resistance to change in a landscape that has been predominantly open for generations. Others arise from concerns over loss of quality of the environment, including deterioration of water and soil quality, loss of natural habitats and biodiversity. There is a feeling of powerlessness on the part of some local or regional authorities, which have a perception that the planning and use of the lands in their jurisdiction is outside of their control. The Forest Service may address this by involving the Local Authorities more in the planning stages of forests.

This is the most crucial phase of the forest, and great care should be taken to account for site suitability, species selection and effects on the landscape. Ideally this should be carried out with the aid of the national planning tool, the FIPS, which should show the soil type, catchment area, water bodies and topography, and the state of the surrounding land use. Information of this type extracted from the FIPS could be used by the Local or Regional Authority to aid the potential forester to plan the forest. A comprehensive survey of the site should be carried out to make a plan of work, including maps and timescales, integrating the economic factors with ecological, social and landscape aspects. For both reforestation and afforestation projects this should be carried out, and individuals trained in biodiversity conservation or ecological considerations should be involved. The current Forest Service requirements for plans do not include an ecological site assessment, unless the site is over 70ha, and this is not adequate for biodiversity considerations.

The complex interactions between the forest, the soil and the surrounding habitats and water bodies are not yet fully understood. In particular the new forests planted recently have not had time to show the full effects that they will have on their environment, and only study over a number of rotations will show truly meaningful results. There is, however, enough information on certain parameters that definite recommendations can be made for sustainability- and biodiversity-enhancing planning and management. These are stated in this document. The gap between reading the recommendations and implementing them on the ground must also be bridged effectively, and for this there will need to be a definite effort made for training and demonstration.

6.1.6 Training and demonstration

Theory and practical training in forest management for biodiversity should be given to all officials who will be called upon to give advice to individual forest owners and managers, to ensure that the recommendations are properly effected (see Section 2.3). The individuals to be trained should include forest developers and contractors, as well as individual forest owners who are involved in the active management of their forests. The current training schemes, which are relatively extensive in the type of training and the number of forest owners and managers involved (Curtin Dorgan Associates, 1997), do not cover the biodiversity issue adequately. It is recommended here that courses be established and demonstration forests be set up throughout the country, to show the effects of different management practices. One-day workshops should be held in each demonstration forest periodically as needed, showing not only the effects of good management but also those of bad management practices.

As the FIPS will be the most powerful planning tool for afforestation in the country, it should be made available to Local or Regional Authorities for their use in assessment of planning applications for forest development, and to aid the planning and design of new forests. Training in the use of the FIPS should be given as needed.

6.1.7 Research and development

The main areas where research is needed to integrate biodiversity into forest management in Ireland are:

The economics of putting into practice the recommendations for biodiversity enhancement in Ireland should be investigated. In particular, taking into account the long-term nature of the forest investment, the economic soundness of diversifying the newly planted (or reforested) areas. A re-examination of forests on older estates that have a more diverse species mix should provide some insights. The fostering of forests of this nature through schemes such as the Native Woodland Scheme is recommended. Additionally, the use of the forest as an amenity in terms of the effect of this on economics should be investigated.

The current support of forest research should be continued and expanded, particularly into methods to enhance the biodiversity of forest plantations as a part of the landscape mosaic. Interactions between the different land uses in the landscape and how these can operate synergistically to benefit forest biodiversity should be examined.

The FIPS should include a modelling facility whereby a potential forest's effect on the landscape and ecosystem β diversity should be fully shown. This should be a 3-dimensional graphical system that can show how the landscape and habitat patterns will change over time, given particular forest design parameters.

Native tree species that are not currently considered of commercial value should be investigated for their potential, and their non-timber contributions to multi-purpose forestry. In forest plantations these may be useful in buffer zones around forest edges or at the sides of rides, maximising their potential contribution to plantation forest biodiversity.

It is possible that adverse perceptions of the forest in the landscape would be different if the forests were more diverse, or if the public understood better the underlying reasons for afforestation with particular species, or species mixes. An outreach programme using demonstrations is suggested, where measures to promote biodiversity in forests are demonstrated.

Among other suggested areas for research are:

Forest soils - particularly how new forests behave on different soil types, and how the soil develops under these forests. The use of a component of semi-natural forest soils in nurseries should be examined, so that when the plants are transferred to a site for afforestation they may carry with them an inoculum of important microbiota

Plant biodiversity - methods to enhance plant biodiversity in new forests.

Methods to reduce the necessity for Urea application in forest plantations.

The strengthening of information about quality trees of native provenance, and their availability.

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SECTION B. Operational guidelines for forestry and biodiversity

Background

Forestry in Ireland is undergoing a re-examination of priorities and ideals to keep it in line with international agreements and movements towards sustainable forest management (SFM). This involves a re-evaluation of the policies on planting, management and financing of forestry. Sustainable forestry, as a concept, has progressed from the provision of a sustainable timber harvest to a more holistic view that encompasses the forest as an ecosystem with multiple purposes, not least of which is the maintenance and enhancement of biodiversity. The biodiversity of a forest not only includes the mammals and birds most commonly understood by the word "wildlife", but also the trees, shrubs, herbs, bryophytes, lichens, insects, molluscs and other organisms that are often ignored. Forest management for biodiversity must include all of the latter, for these constitute most of the diversity within the forest system. The direct financial rewards from multiple-purpose forest management are not as immediate, or possibly ever as high as those from forests managed solely for financial gain from wood production. However, a primary aim of a multiple-use forest could still be timber production, and the increase in environmental quality adds to the overall economic benefits. The information on forests and how to manage them sustainably and for biodiversity is far from complete. It is recommended that the guidelines stipulated in this document be revised periodically, to keep abreast of new findings. For more complete information on issues surrounding biodiversity in Irish forests, the reader is referred to the technical part of this document (Section A).

Biodiversity is most conveniently described in terms of three conceptual levels:

- **Ecosystem diversity:** the variety and frequency of different ecosystems
- **Species diversity:** the frequency and diversity of different species
- **Genetic diversity:** the frequency and diversity of different genes and/or genomes. In the definition of biological diversity, genetic diversity is represented by the phrase "The diversity within species". It includes the variation both within a population and between populations.

The issues surrounding forest biodiversity are mainly concerned with bioquality (value for the conservation of nature). Higher biodiversity value does not merely mean that there are more species in a given place - the species present must have a certain value for nature conservation. For example, in the Irish situation, the addition of Sika Deer or rhododendron to the species complement of a forest will not raise the biodiversity value, it will actually lessen it because these are non-native species that can actually damage native ecology. Replacement of agricultural cropland by forest plantation generally increases the biodiversity value of the area, whereas replacement of natural habitats such as heathland or natural grassland decreases it.

The utilisation of forest plantations for recreation has risen in recent years, and has become an item to consider when planning a forest, particularly on State owned properties. People visiting a forest like to see abundant wildlife: generally focusing on birds and mammals. This should not be confused with the forest biodiversity. While these visible and sometimes charismatic species make the forest more attractive and interesting for visitors, they do not indicate that the forest is high in biodiversity value. Sometimes the species that visitors enjoy are not even native. While a plantation with certain attractive animal species makes for an enjoyable walk by the visitor, how much more does a native forest offer in terms of biodiversity, with its wealth of associated plants and microbiota as well as birds and mammals.

In essence, the most favourable systems for biodiversity value are natural ones. The closer the resemblance between planted forests and natural forests, the better for biodiversity. However, in most cases planted forests are managed for commercial gain, and this often means the use of non-native species and mixtures of trees not found in nature. These forests, if managed correctly, can have value for biodiversity and enhance the ecology of the landscape.

Documents other than the current one deal with some of the issues surrounding forestry in Ireland today, and the reader is referred to the National Forestry Standard (Forest Service, in prep.) the Code of Best Forest Practice (Forest Service, in prep.) and other Guidelines publications (Forest Service, 1996 a;b;c; Purser Tarlton Russell, in prep.; Ryan, in prep.). A Biodiversity Action Plan for Ireland is being prepared by Dúchas The Heritage Service, and will impact forest-related issues. The present report of necessity must be limited to the subject of forest biodiversity.

Within the current national and EU legal and economic framework, the most important timber species in Ireland are non-native conifers, and these are what will predominate at least in the plantings of the next generation, or until the economics and legalities change (see full technical text of this report, and also Clinch, 1999). This is not necessarily the best framework for biodiversity in Irish forests, so these Guidelines in parts may not indicate the most commercially optimal practices. However, even some small changes in management may mean a much better opportunity for biodiversity enhancement.

Legal instruments and other agreements

Currently across the globe there is unprecedented interest being taken in the Earth's biological diversity, in an effort to stop the progress of species extinctions and habitat loss. Ireland ratified the United Nations Convention on Biological Diversity (United Nations 1993) in 1996. This is a far-reaching agreement that covers the protection of habitats, species and genetic resources, using all different methodologies available, and commits to the sustainable use of the components of biodiversity. A special emphasis was put on forest biodiversity through the establishment of the Intergovernmental Panel on Forests by the United Nations Commission for Sustainable Development, which made headway towards internationally agreed procedures for sustainable forest planning and management. The subsequent Intergovernmental Forum on Forests is working towards implementing the procedures, particularly at the international level.

Concurrent with this there are regional processes on SFM. The process for Europe, by which Ireland is bound, has defined criteria and indicators of SFM, and gives operational guidelines presented in Appendix A. Individual countries that are signatories to these regional processes are obliged to define more country-specific guidelines and work towards establishing a legal and institutional framework in which these guidelines can be put into practice. There is now market pressure for these to be finalised, as a growing number of outlets for forest products demand that the products come from sustainably managed sources. This has given rise to a number of certification agencies that can certify a forest as being sustainably managed, and impacts the market for the wood and other forest products.

The use of the land for forestry is affected by a number of EU and national laws. With regard to forestry and biodiversity, there are two European Directives, the Habitats Directive, that conserves Special Areas of Conservation (SACs), and the Birds Directive, that designates Special Protection Areas (SPAs) for birds. Ireland has also agreed to operate within the guidelines of the Pan-European Landscape Diversity Strategy. National laws that are important for forestry are the Wildlife Act and the Forestry Act. Natural Heritage Areas (NHAs) will be provided for in the next amendment to the Wildlife Act, that is currently in the form of a bill. Many potential NHAs have already been identified by Dúchas, and if a forest is planned in an NHA permission must be sought during the planning stage. The surveys to identify NHAs are, however, not complete, and there are still ecologically important sites without any potential NHA designation. The Forest Service consults Dúchas also if a forest is planned within the vicinity of an NHA. The European SACs form a subset of the NHAs, and forestry activities within these are prohibited.

The list of plants protected under the Flora Protection Order of the Wildlife Act has been expanded and now includes 68 species of vascular plant, 14 species of moss, four species of liverwort, one lichen and two stoneworts (see Appendix B). It is an offence to damage these species or to interfere with their habitats. All species of wild animal are protected and it is an offence to knowingly damage these or their nests or other dwellings. Of special interest are birds of prey (Buzzard, Eagle, Falcon, Harrier, Hawk, Kite, Osprey, Owl) and the mammals Badger, Bat species, Red Deer, Hare species, Hedgehog, Otter, Pine Marten, and Red Squirrel. In a planned forest area, or before undertaking operations that might damage an animal or its dwelling, the area must be inspected to ensure that this will not occur. In the event of the presence of, for example, Badger setts, Dúchas can provide assistance to implement measures to encourage the badgers to move on before the forestry operation takes place.

The destruction of vegetation on any land not under cultivation is prohibited during the nesting season, from 1st April to 31st August. This includes hedgerows and other scrub areas that wildlife use for shelter or as habitat. If the vegetation is a safety hazard there is an exemption to this regulation. Grant-aided afforestation and reforestation projects are subject to some restrictions with regard to species used and planning approval required. Grants available for nature-sensitive selective planting of semi-natural forests currently come under the Woodland Improvement Scheme, but these are not seen to be as financially beneficial as grants for more commercial plantations.

Ireland's forests

Ireland's forests, as those of much of Europe, have virtually all been influenced by the activities of people. For this reason, the forests have primarily been divided into Semi-natural and Plantation, depending on the degree of human influence. The semi-natural forests are those which are not intensively managed for timber production, but which may have been planted. These forests have a higher degree of "naturalness" in terms of structure and species composition than do the intensively managed plantation forests.

They are subdivided into two main types depending on current tree species composition: whether native or non-native species of tree dominate. Thus, three main forest types are defined for Ireland: (a) Native semi-natural forests, (b) Non-native semi-natural forests and (c) Plantation forests.

Native semi-natural forests

Trees found in native semi-natural forests include sessile and pedunculate* oak, ash, elm*, downy and silver* birch, alder, holly, rowan, sally, poplar*, wild cherry, Scots pine, juniper and yew. Other trees that may be considered shrubs or non-forest woody species are hazel, hawthorn, guelder rose and spindle tree, eared willow, goat willow, arbutus and whitebeam. There are many other associated woody and non-woody species, depending on the ecology and geographical location of the area, for example if it is a base-rich well-drained site in the south east of the country or a more acid and poorly drained site in the south west. The complement of native biodiversity that is associated with these forests will have been built up over the number of years during which the site has not suffered major interference. These include associated forest species: herbs, ferns, mosses, liverworts, lichens and fungi, as well as all of the forest animal species, including the invertebrates (beetles, worms, spiders, ants, mites, flies, wasps, moths, butterflies and dragonflies, to name a small selection) as well as the vertebrates (amphibians, fish, birds and mammals). These interact in a complex way to create the functioning ecosystem that presents itself as a native semi-natural forest.

Non-native semi-natural forest

The non-native semi-natural forest has a resemblance to the native semi-natural forest, but is dominated by non-native trees. The greater the proportion of native species and the longer it has been standing without major interference, the greater the resemblance, and the greater the value for biodiversity. Many of the old estates maintained a forest of this nature and used it for timber production. The trees occurring in these forests are generally a mixture of native and non-native trees with timber potential, but by definition the non-native species dominate. Some examples of tree species are: the broadleaves pedunculate oak, ash, birch, beech, lime and hornbeam, sycamore and horse chestnut, and the needleleaves pine, larches, spruces and firs.

Plantation forest

Plantation forests are those that are managed intensively for timber production, as tree crops, almost invariably until the last few years, composed of non-native conifer tree species. The main species used are Sitka spruce, Norway spruce, lodgepole pine and Douglas fir. To a much lesser extent Scots pine and larch, and the broadleaves beech, birch and ash are used. Until now these forests have been managed as even-aged and often single-species stands that have a very low level of associated flora and fauna, in comparison to semi-natural forests. Many species that have evolved along with native

* Pedunculate oak, silver birch and poplar are generally accepted as native, although there is some debate. The elm is rare due to its decline caused by Dutch elm disease.

Irish forests are "specialist" species, not "generalist", meaning that they form a particular group of species that are ecologically and functionally linked, and will thrive only in the environment where they have developed. It is these species that are most interesting from a biodiversity point of view, because the more generalist species are more common and have less of a specialised role in the environment. The specialist species will generally not live in a plantation of non-native trees because it is a completely different ecological system to the native forests. Specialist species are of a higher *bioquality*, or value for nature conservation, and from this point of view are more important in considering biodiversity than the more common generalists.

Planning and management

The most important step in the management of forests for biodiversity is that of planning. The forester is required to refer to the forthcoming Code of Best Forest Practice and National Forestry Standard for the most recent recommended practices and legalities, as well as the Guidelines publications and certification criteria, where required. For semi-natural forests the reader is also referred to the UK Forestry Authority's Forestry Practice Guides (Forestry Authority, 1994). For biodiversity in particular there are a number of items to consider, all of which are influenced by the type of forest planned. The forest may already be in existence, and the required plan may be one that will render it more sustainable or biodiversity-friendly. The forest may be a new forest that will change the land use practice of an area from, for example, permanent pasture. The good planning of a forest, taking into account all of its environmental aspects and encompassing biodiversity and sustainability issues, is an exceptionally complex matter. It is now a requirement for all afforestation projects to have prior approval by the Forest Service of a plan that has been drafted by an accepted forester or company. For ensuring maintenance and enhancement of biodiversity in the forest plan, however, the specific input of a specialist trained in forest ecology or biodiversity conservation is necessary.

The Forest Inventory and Planning System (FIPS) that is being built by the Forest Service will aid planning at many levels (see "Landscape-level considerations", below). The forest plan should include maps of the site and follow the stages of the planned forest through to maturity and harvesting. This will ensure that as the forest grows, its effects on the ecological, cultural and landscape qualities of the area will be fully considered. As the FIPS is a geographically-based information system with time-referenced data, it should be able to support the drafting of such plans.

All management practices in the forest should be monitored so that the causes of any changes in forest characteristics can be identified. This enables the forester to improve methods in the future so that only the most beneficial and successful techniques are used. In addition to monitoring the more silvicultural aspects of the forest, biodiversity should be monitored. There is a European project developing a system of indicators of forest biodiversity for use in Europe (BEAR, 1999). The objective of this project is to provide forest managers with a means by which to monitor the ecological integrity of their forests.

Landscape-level considerations

These include the effects that the forest will have on the landscape, including such features as the visual impact and the ecology of the area. There are cultural factors associated with the visual impacts, but the present paper is more concerned with the ecological implications of adding a forest to the mosaic of land use. The forest design can be planned initially at the landscape level so that diverse aspects of design can be taken into account, such as the location of planned open spaces and roads. The proximity of the planned forest to any other forested area, and therefore the degree of isolation from the propagules of forest plant species, or from a source of forest fauna, is important. The different types of forest adjacent must also be considered: whether young or old, whether native or not. Generally a diversity of tree species creates a more aesthetically pleasing landscape, and this is also better for biodiversity. The choice of tree species in the mix should be suited to the site and take the objectives of the forest management into account. If the objective is to create a new semi-natural woodland, the reader is strongly urged to read literature from the UK Forestry Authority, because of the paucity of information on this type of forest in Ireland (Forestry Authority 1994; Rodwell and Patterson, 1994). However, some trees that are native to Britain are non-native in Ireland, and this should be taken into consideration.

Aspects of the forest that should be taken into account at the landscape scale are: structure, continuity, tree species, open areas, nature conservation areas and the water catchment area. The FIPS, being a geographically-based information system, will ideally be able to provide a model of the landscape as it is currently being used and show how the changes brought about by the planned forest will fit. The soil, terrain and catchment information contained in it will enable it to show suitability of the site and any areas of land downstream that may be affected. The system should be able to show the planned forest in relation to other forested areas, in terms of their maturity, tree species composition and design, and the locations of any natural areas. This information will aid the planning, design and management of the new forest.

Site suitability

The suitability of the site for the planting of a new forest or the re-planting of an old forest must be determined before any operations take place. Afforestation in SACs is not generally permitted. The site should be examined for its relations to NHA and SPA-designated areas and for the presence of protected species. The suitability of the site for forestry should be determined, not only in terms of its potential to support timber trees but also very importantly with regard to its acceptability in the community and its impact on the landscape. The guidelines for forestry and archaeology must be followed for sites that may have archaeological interest.

Sites that are within NHAs will need approval for afforestation or reforestation by Dúchas. The Forest Service also generally refers to Dúchas before approving forestry activities in the vicinity of (not only inside of) these legally designated areas. Because the NHAs do not include many sites that are of local or regional importance, but concentrate on those of national importance, an examination of the site should always be carried out by an ecologist or forester suitably trained in ecology and biodiversity. Although an Environmental Impact Assessment is only currently legally required for afforestation of areas greater than 70ha, this is not adequate for biodiversity conservation. The examination should include the noting of species of wild animal or protected wild plant (see Appendix B) that would be disturbed by planting activities, and appropriate action taken. An estimate of the importance of the area for the local or regional natural heritage quality should be made. The plan for the forest should include the "non-commercial areas of the forest" described below. Pockets of biodiversity interest can be maintained in these throughout the life of the forest. If there is any doubt about the effects of planting, advice should be sought from Dúchas.

Tree species choice

The properties of the site must be matched with the potential tree species mixes. Species should be selected not only for their potential for financial success but also for their ecological value. Some indicators of soil suitability for species are given in the Code of Best Forest Practice and by Joyce (1998). For biodiversity in the forest, the choice of tree species is of paramount importance. Trees form the main structural components of the forest ecosystem and as such dominate the nature of all the associated fauna and flora. The presence of many interesting native animals and plants will be precluded by a choice of non-native tree species. Native species suitable for the site may be deduced from nearby native semi-natural woodlands or on similar site types.

Forests that are grant-aided must conform to a number of stipulations as regards the use of different tree species, according to the Strategic Plan. There is no such control on forests that are not grant-aided (see "Legal instruments and other agreements"). Some species-related stipulations for grant-aided afforestation are:

- each conifer-afforestation project must contain a minimum of at least two species, and a maximum planting of 85% of any one species.
- Sitka spruce will be reduced to 60% of annual afforestation
- The afforestation by diverse conifers will be increased to 20% of annual afforestation
- The target for annual broadleaf afforestation will continue at 20% of total annual afforestation
- The target for oak will be 20% of broadleaf afforestation.

Only the first of these stipulations applies to an individual site: the others refer to the country taken as a whole, which is more difficult to monitor. For the promotion of forest biodiversity, these stipulations must be enhanced to encourage a greater use of broadleaves, as the native timber trees are for the most part broadleaves. Additionally, an area representing 15% of the total should be kept as "Non-commercial areas within the forest" (see below). Information for the growing of semi-natural forests is minimal in Ireland. For biodiversity, however, these forests have much more potential than intensively-managed two-species crops that have been planted in Ireland in the recent past, and the reader is strongly encouraged to refer to the British Guides (Forestry Authority, 1994). Most semi-natural forests are a mosaic of small patches of different tree species. This type of mosaic is good for biodiversity and should not be changed in the new planting plan.

Sitka spruce has been the principal commercial tree species used in Ireland this century. The reasons for this are:

- it has been shown to be a producer of good quality timber, pulp and wood-based panelboards
- it can grow well on a variety of infertile sites
- it withstands exposed sites extremely well
- it is easy to handle and transplant
- it is almost pest-free in Ireland
- it regenerates naturally.

In its native British Columbia, the Sitka spruce forest is extremely biodiverse, with its own distinct assemblages of other native species, including rare ones. These are completely natural systems in which many trees grow old, reaching up to 800 years (Peterson *et al*. 1997). The Sitka spruce forests of Ireland are entirely different, being completely artificial systems and having no naturally occurring associated species. They are also only rarely left to grow over 50 years. The combined factors of age and associated biota render the Irish plantations low in biodiversity value. The use of mixes of tree species, particularly native species, can relieve this situation, but also very importantly, a proportion of the trees in the forest should be left beyond their commercial optimum.

Certain tree species attract particular elements of native wildlife. Broadleaves are across the board more attractive to most associated native forest plants and animals, including soil biota. Known exceptions to this are the Pine Martens and Red Squirrels, which are attracted to mixed broadleaf-conifer stands, or conifer stands with Scots pine (a native species), lodgepole pine and Norway spruce, but not Sitka spruce. Not only are the species of conifer important, but they should be of cone-bearing age (25 yrs+ for Sitka spruce). For birds, there is some evidence to show that more species associate with Norway spruce and Douglas fir than with lodgepole pine and Sitka spruce. Goldcrest is the most abundant and widespread bird species in conifer plantations. Bird species diversity is greater in broadleaf or mixed broadleaf-conifer forests than in pure conifer forests. As some birds mainly use the forest edge, the use of broadleaves around the edges of the forest can help to increase the bird diversity of the forest. Where broadleaves cannot be used, larches may provide an element of light penetration, encouraging undergrowth and ground-dwelling animals.

Seed / sapling (transplant) provenance

The provenance or genetic origins of the planting stock are of great importance, and for five Irish native species must currently come from an EU-certified source. These are: Scots pine, pedunculate oak, sessile oak, ash and poplar. Species available from certified sources in Ireland should not be brought in from elsewhere. Native species should always be cultivated from native stock (where the ancestors of the trees were also native), and if possible, from ecotypes of the species that have developed in similar sites to the planting area. Where a native tree species that is not registered (not certified) is to be used (*e.g.*, birch), great care should be taken to ascertain the provenance of the plants, and only Irish trees should be used. This will also concern trees of minor timber (but significant ecological) value, that would be used principally for diversifying the forest, such as holly or rowan.

Where possible, natural regeneration should be allowed to take place. This needs careful monitoring of the species represented in the seedling populations to ensure that appropriate tree species are present and in adequate quantities. Natural regeneration is easier to manage over smaller areas. As the practice of large scale clearfells declines and the practices of selective felling become more prevalent, natural regeneration will become a more practical alternative than it currently is.

Structure, age and continuity

The pattern of different tree ages both between adjacent stands and within individual stands is important. In general, the more structural diversity there is within the forest, the better for biodiversity. However, careful planning is needed because age structure affects harvesting practices and replanting strategies. A very varied age structure may be good for the biodiversity of a forest but this must be weighed against the other purposes of the forest, such as timber extraction for financial gain. Using the currently prevalent techniques, a more even age structure is more manageable for harvesting. The middle ground is to have parts of the forest designated for biodiversity conservation purposes, and to use the most ecologically friendly harvesting techniques available, including small coupe sizes. A mosaic of small patches in which each patch is even-aged is easier to manage than a plan in which all age classes are interspersed, and it is also good for biodiversity.

An examination of how bird species are affected by the different structural habitats provided by conifer afforestation shows that some species react positively while others are adversely affected. While mature plantations provide optimum habitat for a range of bird species, young conifers provide habitat for additional species. Individual bird species were recorded as being affected as follows: upland or moorland species lose nesting habitat (*e.g.*, Red Grouse, Golden Plover) or hunting habitat (*e.g.*, Merlin), Hen Harriers can nest either on heather moorland or among newly planted conifers, but are ultimately lost from afforested land, scrubland species like Nightjar and Willow Warbler gain new habitat in young forestry and woodland species like Long-eared Owl, Goldcrest and Crossbill gain new habitat as forests mature (Walsh *et al.* 1998a).

Forest structure is dominated by the canopy trees, and concerns for example the canopy height and density, the nature of the understorey layers and the ground flora. Even-aged plantations have a low structural diversity when compared to those that have been planted at time intervals, or to natural forests, in which a whole range of ages is represented, from the seedling and sapling to the mature and senescent tree. Structural diversity provides a great range of microhabitats, which can be inhabited and used by a great diversity of organisms. Structure is also affected by the diversity of tree species occurring in the forest. Each species has its own associated architecture, for example crown density and shape, leaf type and arrangement, proportion of large to smaller branches and bark texture, which will in turn attract different sets of biota.

In natural forests, a dynamic process of growth and renewal creates structural diversity. In plantations it is important to bring about structural diversity through management techniques. Letting more light onto the forest floor by planting trees with wider espacement or through a substantial thinning regime, will create a more friendly environment in the shrub and herb layers of the forest for the growth and development of diverse plant species. The structural and plant species diversity so encouraged will in turn attract diverse animal species. Shrubs provide shelter for animals that would not be attracted to a forest without a shrub layer.

The continuity of forest on a site is important for the development and perpetuation of a complement of more specialist forest species. Most important of these are the species that cannot move onto another site when the current site is radically changed, for example the plant species of the forest floor and many organisms in the soil. Soil is one of the most complex living phenomena on this planet: much of life above ground is dependent on the health and living processes of the soil. In native forests a great proportion of the biodiversity is in the soil, and this gets perpetuated through the continuous renewal of the habitat and regeneration of its tree species. In forest plantations of non-native tree species this is not so true because species of microbiota associated with the trees in their native habitats do not occur in Ireland. A compromise measure that is recommended is that a proportion of the forest is reserved, or set aside, for biodiversity. Within this area native forest species should be encouraged, and the area should not be disturbed during harvesting operations, but left to provide a continued natural habitat for soil biota and other forest biodiversity (see "nature retention areas", below).

Continuity on a site can also refer to the replacement of one forest by another, as in forest rotations. There is evidence to suggest that later forest rotations are more biodiverse than the earlier ones, because the forest cover has already attracted certain forest species to the site (E.P. Farrell, pers. comm.). This may be seen in the growth of native, unplanted tree species within later rotations, such as birch or hazel. These tree species and others associated with scrub woodland or with the understorey of higher forests such as holly, hazel, rowan and goat willow have tended to be more continuously present and more widely distributed in the Irish landscape, than the timber trees oak and elm. For this reason their associated species may also be more widespread. The growth of these tree species within or around forestry plantations will attract their associated species, thereby increasing the biodiversity of the forest significantly. Where possible these native trees should be encouraged in the forest plantation for biodiversity and for diverse uses of the forest.

Dead trees

The presence of dead wood and senescent trees are two of the most important elements for biological diversity in a forest plantation. If there were more trees left to grow old in forest plantations, as in nature, the species diversity of the forest would be much greater. For this reason it is recommended that in afforestation practices individual old trees on the site be left as part of the plantation. Not only is the dead wood itself of great importance for many organisms, the senescent tree provides holes, wounds and snags that are habitats for the less obvious microflora and fauna (*e.g.* fungi and insects) as well as birds and mammals. Experiments with nesting boxes show that the use of these can attract hole-nesting birds in the absence of natural holes in tree trunks. While this increases the incidence of these particular birds, it is hardly a substitute for providing senescent trees. Old trees have a great number of associated species, many of which are not directly visible or even attractive, but are just as worthy members of the biodiversity of the forest as the hole-nesting birds.

As well as the structural considerations described above, there is the question of the provision of dead wood for the saproxylic, or wood-eating, organisms. These are the microfauna and flora such as beetles and fungi. They play a vital role in the circulation of nutrients in the forests ecosystem, returning to the soil nutrients that have been bound up in the trees. These will in turn nourish the next generation of trees and other plants. Some of the most interesting forest biota are members of this set of organisms, which can be specific to certain species or genera of trees. These organisms have evolved along with the trees in the forest ecosystem, and will for example be associated with special microhabitats like hollow boles. Non-native species of tree will not have their own specific set of saproxylics because the trees have not evolved as part of the native forest ecosystems. Leaving the wood of non-native species in the forest will provide some of the more generalist species with a habitat, but to encourage the more specific native sets of saproxylics, the dead wood of native tree species must be provided. For this reason, plantations of non-native species should have, associated with them, areas with native trees which should be allowed to grow old (see "Structure, age and continuity" for the importance of certain broadleaves).

An exception to the above generalisations on native and non-native species of tree is the sycamore. This tree has naturalised very successfully and is very common in hedgerows and in semi-natural forests. Although not native, it is very rich in associated microbiota, and as such is a welcome addition to the non-native semi-natural or plantation forest, in terms of adding biodiversity value. It is, however very attractive to the troublesome species the Grey Squirrel, so in areas where this animal is prevalent it is probably best not to encourage sycamore.

In commercially managed plantations it is recommended to leave at least $5m^3ha^{-1}$ of deadwood exceeding 15cm in diameter (Hodge and Peterken, 1998). This amount is quite low, considering that:

- the recorded volume of dead wood in British forests varies enormously, from one to $130m^3$ ha^{-1}
- the living forest will support in the region of $400m^3ha^{-1}$ of timber when ready for felling.

Thinnings will generally not qualify for this category of dead wood, for diameter reasons. Thinnings and other sources of brash are however very important and as much as practicable must be left in the forest. In addition to leaving dead wood on the ground, the provision of standing dead trees will increase the presence of microhabitats for other species. In short-rotation commercially managed forests in Ireland, standing individual trees, if left to grow old and senescent during two or three rotation lengths, will suffer windthrow. However, trees cut at a few metres height, or ring-barked, will not, although large side branches may need to be cut from ring-barked trees. A proportion of 0.25-1% of the forest trees should be left for dead wood, or 5-20 big trees ha^{-1}. This practice should be carried out in each forest, and dead trees should be left standing from one rotation to another.

Each forest will thus have some standing dead within the plantation, an amount of dead wood of varying sizes on the ground and area(s) set aside for conservation that will provide continuity within the system (see below).

Non-commercial areas within the forest

Each forest should have at least 15% of its area reserved for natural ecosystem development and for biodiversity enhancement. These are non-commercial areas that are left unplanted and in which no commercial operations take place. The 15% should include 5-10% of open space and 5-10% managed as a forested *nature retention area*. The exact percentage of each depends on the ecology of the site: some places may naturally favour the open space designation (*e.g*., areas with expanses of marshy ground that are unsuitable for the commercial forest) while others may favour the forested nature retention area (*e.g*., sites encompassing a native woodland copse). The locations of the non-commercial areas within the forest may be steered by the presence f such a "key biotope", which may also be a stretch of unimproved grassland, a peaty hollow, patches of hazel scrub, and old hedgerow or wall, or an old tree.

Recommendations for the management of these areas are specified in three categories, below, emphasising open spaces, nature retention areas or water bodies and their surroundings. In intensively-managed commercial forests these three may be formed from distinct patches, whereas in semi-natural forests the 15% may not need to be especially set aside: it may be present already as an integral part of the forest system. A special survey would be required to determine this. The links with the rural landscape outside the forest are important in providing habitat continuity, and some useful management techniques for bird biodiversity in particular are given by Donaghy and Murphy (1999).

Open space and edges

The provision of open spaces in a forest increases the overall diversity by encouraging the presence of organisms that will not inhabit a completely closed environment. This is particularly true and important in large conifer plantations, where rides and glades provide variety and light. Bats and birds are attracted to open spaces for feeding activities, although they need the trees in the forest for shelter and nesting. Shrub and herb species that are intolerant to dense shade can flourish in the open spaces within a forest. Even in the relatively small holdings that are now mainly being afforested, 7-10ha, open spaces can be provided for diversity. For biodiversity between 5 and 10% of the forest should be left as open space, designed in conjunction with nature retention areas (below). The open space and nature retention areas should total at least 15% of the forest. In forests less than 10ha the open space requirement may be reduced because, due to edge effects, there is not such a great need for open areas in small forests. Open areas should in any case be designed taking into account the neighbouring land cover.

Well-managed rides and glades can provide vital habitats for scarce grassland plants and large numbers of grassland and scrub invertebrates. These open habitats are important for providing a large range of flower resources (nectar and pollen) for insects and can serve as population sources from which new rotations can be colonised. There should be a good network of rides and glades in the forest that can act as links between patches of forest of different ages, and as essential refuges for many species. In well-managed rides and glades, shading should be kept to a minimum because the majority of species dependent on these spaces demand warm, sunny conditions. Three factors influence the shading of rides: ride width, height of adjacent tree and orientation of the ride. As a general rule, rides should be 1.5 times the height of the bordering crop trees, so that where trees reach 20m, rides should be at least 30m wide. The ride should be managed in different parallel zones, to provide diversity within the open space. For example, the 5-10m area closest to the forest on either side should be managed as scrub that is cut every 10-20 years, preferably in patches. One side should be cut at a different time to the other side. The remaining centre area of the ride can be treated as one management zone and cut every year, or it may be treated as two distinct zones, an inside one and an outside one, with the inside one being cut three times a year and the peripheral area, near to the taller shrubs, cut every 1-4 years (Fuller and Peterken, 1995).

Rides aligned east-west receive more sunlight than those aligned north-south, so the latter ideally need to be wider than the former. Curving edges to the rides not only have a better visual effect than straight ones, especially if they are related to topography and landscape, they also increase the variability of aspect and reduce wind tunnel effects, both of which are generally advantageous to wildlife. Ride widening should proceed with caution as simultaneous removal of all shrubs from a ride would be very deleterious to biodiversity. Felling should be out of step on the two sides of the ride. Glades can be created at the junctions of rides, or in the form of scallops at intervals along the rides. Attention should also be given to any sunny banks that occur within the forest. These should be maintained and kept free of vegetation if that is their natural state. They can be important for solitary bees and wasps, and other invertebrates.

The edge of the forest is an extremely important habitat for a number of birds and mammals, and every effort should be made to render the forest edge as hospitable as possible for these. In conifer plantations, an edge of broadleaf can be most important for the encouragement of diverse native birds. These broadleaf trees may not be considered part of the potential timber-producing resource of the forest, but a provision for enhancing the environment. For this reason, trees such as rowan, birch, alder, sally or goat willow may be planted here, preferably giving way to a band of scrub (not an abrupt edge), and linking with hedgerows. In areas where broadleaves are not found to grow well, larches may be used as they are deciduous and provide more light than other conifers, but they are not as attractive for biodiversity as the native broadleaves.

Nature retention areas

These are areas within the forest that are specially set aside for nature conservation. They are not the same as the NHAs referred to in the legal section. It is recommended that the nature retention areas should comprise 5-10% of the forest area, and native forest species should be encouraged in these areas. The exact percentage should be determined in conjunction with the requirement for open areas (see above). Nature retention areas are parts of the forest that are not subjected to the same forestry operations as the rest of the forest area and are managed specifically for the fostering of forest biodiversity. They may not be necessary in semi-natural forests, as “key biotopes” (see below) may already be protected by the existing forest design. At least 10% of the canopy trees in these forests, however, should be allowed to grow old, in the absence of a designated nature retention area. Additionally, any new planning for the forest must involve a new detailed survey and must allow for the continuity of the nature retention areas or old trees.

In forests where native tree species are not likely to naturally colonise these areas (usually due to the absence of a seed source), they should be planted there. Tree species that are suited to the ecology of the area should be chosen, and these may be of (currently) non-commercial tree species such as rowan, holly, wild cherry, downy birch, alder, sally, goat willow, hazel, spindle tree, guelder rose and whitebeam. The point of having the nature retention areas in the forest is to provide an area where the trees are allowed to grow old and a forest ecosystem develop, like that of a natural forest.

The management of these nature retention areas is critical to their success. They should not be logged or subjected to other forestry operations, but left to build their own natural dynamics. In particular the trees should be allowed to grow old and die, and the dead wood left to decay on the forest floor. Non-native trees should be phased out, or in the case of rhododendron and cherry laurel, extracted. Saplings of non-native species in these areas should be uprooted, and pesticides should not be used. Grazing by livestock and over-grazing by deer and other herbivores should not be permitted. Access by people should be limited, and the collection of fruits and other plant parts should be restricted.

These areas become island habitats for forest biodiversity, and as such will not be as successful at nurturing a complete forest ecosystem with all of its complexity of function. Particularly in cases of plantations of non-native tree species, the forest around the nature retention area will provide a barrier to the movement of species from the nature retention area to either another nature retention area or to a more biodiversity-friendly semi-natural forest. However, the nature retention areas will protect and encourage many species that would otherwise be excluded from the whole forest. If biodiversity-friendly practices are implemented throughout the forest some of the native species from the nature retention area will also use other parts of the forest, and the populations should increase.

Water bodies

Rivers and other water bodies that are within the forest must come under special consideration, and indeed the reader is referred to the Forestry and Water Quality Guidelines for more detail. For biodiversity, the more natural the area around the water, the better. This is termed the buffer zone, and should not be subjected to normal forestry operations. It may be included as part of the 15% “Non-commercial areas within the forest”. In natural forests, water bodies are generally surrounded by an assortment of vegetation, including herbs, shrubs and trees. Where the habitat allows there will be areas with plants emerging from the water, and other aquatic vegetation submerged in the water. The diversity of microhabitat within the water body, for example a shaded area or a sunny one, a rocky area with rapid flow or a stagnant pool, will attract different species.

Overhanging trees will provide shade, and a proportion of 50% shaded to 50% sunny is recommended. Trees will also increase the twig and leaf litter in the water. This provides a nutrient input into the water, as well as forming structural barriers in some places to water flow. In a broadleaf forest, a moderate amount of litter is the safest middle ground to aim at, while ongoing research will yield some more specific pointers for conifer plantations. Meanwhile, conifer plantations have been shown to have deleterious effects on water courses, particularly because of the acidification of soils and leaching into the water. This happens most significantly in areas with granitic bedrock and poorly buffered soils.

Current guidelines for planting stipulate that conifer trees should not be planted within 10m of sensitive and 5m of non-sensitive aquatic areas, and broadleaves should not be planted within 5m. The efficacy of these guidelines has not yet been fully shown. If the trees are native and form part of a forest set aside for nature conservation, they can possibly grow right on the water's edge with no ill effect to the water or the organisms in the water. These areas should not be subjected to harvesting or machine-planting disturbance. Each forest presents its own particular set of environmental variables, and these must be given due consideration both when the initial forest plan is being drafted and in the management practices during the life of the forest. For example, where there are drains within the forest they should stop well before the stream and the number of contacts between roads and watercourses should be minimised. This helps to reduce the adverse effects of soil and fertiliser runoff.

The design of the unplanted area around the water body can affect biodiversity as well as the aesthetic value of the area. A mixture of structural and taxonomic elements should be encouraged; different shaped shrubs and a variety of herbs. The forest edge should optimally not appear suddenly to change to open ground but to gradually give way to this, and straight lines in any design should be avoided. This area in the forest is very important for biodiversity as it provides a number of microhabitats in close proximity, thus leading to a very diverse area. Flying species will use the area as a passageway and a feeding ground. Ground animals will benefit from the structural diversity that will provide shelter, food and water. The special habitat of a forest water body will have its own fish and other animal, particularly invertebrate species.

At a landscape level the catchment area that will be affected by the forest must be considered. Effects of the forest plantation on water flowing through or nearby the forest can be significant, affecting the biodiversity of the water downstream. In particular any protected habitats occurring downstream must be taken into account, and areas valuable for fish stocks.

Troublesome species

There are some particularly troublesome non-native species that warrant a mention in these Guidelines, because they can severely impact the biodiversity of the forest. Species of particular note are the rhododendron, the cherry laurel, the Sika Deer and the Grey Squirrel. The rhododendron forms tall dense thickets that shade out the native species of tree and other plant species, that cannot regenerate underneath. It also acidifies the soil through its leaf litter, which becomes unfavourable for the growth of some native species. The dense undergrowth can provide shelter for the Sika Deer. In these situations it has been found difficult to control the populations of the Deer, which cause problems for the native Red Deer by competition. The cherry laurel outcompetes native shrub and tree species and in some areas has meant a great deterioration in the biodiversity quality of a natural habitat. The Grey Squirrel has become a problem, implicated in the decline of the populations of native Red Squirrel, with which it competes for food and shelter. If any of these species are associated with a forest or potential forest area, specialist advice should be sought as to how to deal with them, as they can have very deleterious effects on the native biodiversity of the area.

As a general rule, cherry laurel and rhododendron should be eradicated from every site. Any remaining bushes will act as a seed source and facilitate re-invasion of cleared areas. The best strategy for eradication of these tenacious species is to fell and remove all trunks, and apply glyphosate to the cut stumps. Re-spraying may also be required, in which case care is needed to ensure that the chemical does not fall on any other living vegetation.

In native semi-natural forests, the introduced species beech and sycamore can also pose a threat through out-competing native trees and shrubs. If the management objective of the forest is to preserve the native woodland character, these trees should be removed wherever they are seen to be regenerating and posing a threat to the native species.

Special considerations for reforestation activities

Reforestation projects should not simply copy the practices and policies of previous forest crops, but must consider the new stipulations for SFM (see Appendix A). The same amount of planning, site appraisal, consideration of species choice and effects on the environment must take place as for afforestation projects. When the time comes for reforestation this gives an opportunity to modernise the planning and management of the land. Of primary importance is an examination for areas of nature conservation interest. The area may have been included in the new NHAs or SACs (see legal section), or there may be one of these sites nearby, or in the same catchment area so that it should have special consideration with regard to the forest-related activities. The area should be examined for small areas of conservation interest ("key biotopes"), that should be conserved in the new management plan. In planning the new plantation, the tree species used should be completely reconsidered in the light of the recent promotion of the use of broadleaves on suitable sites, and the promotion of species mixes. The relationship of the forest to other lands in the landscape should be re-examined and the design of the forest altered in consideration of aesthetic and biodiversity-related themes. The relation of the forest to water courses should be re-examined in the light of the new Forestry and Water Quality Guidelines, and open space and nature retention areas should be provided for as recommended for new afforestation projects (above).

Forestry operations

Establishment

This involves the planting of saplings (transplants) or the nurturing of saplings already on the site from natural regeneration. Planting mix patterns and densities recommended for semi-natural woodland are preferable for biodiversity than those for intensively-managed plantations (see Forestry Authority, 1994, for recommended guidelines). The suppression of the ground and shrub flora is necessary around the saplings at this stage. This should ideally be carried out manually, as the use of herbicide will influence the natural development of the native plants in the forest. In areas near water bodies important for salmonid fish or associated species such as the Freshwater Pearl Mussel, particularly in upland sites, care should be taken to minimise sedimentation caused by disturbance of the ground and any fertiliser application should take place only with great care and close supervision. The Forestry and Water Quality Guidelines should be closely adhered to.

Pest and disease management

Irish conifer plantations are currently relatively pest and disease free forests. This may be attributed, at least in part, to the fact that since non-native tree species are used, the pests and diseases that have evolved along with the trees in their native lands are not naturally present in Ireland. Ireland's island situation means that the sea provides a natural barrier to colonisation even by many European mainland species. The use of certified seed and saplings (transplants) for planting reduces the chances of the introduction of disease through this avenue. The prevalent practice in Irish forestry of planting entire forests with one main tree species is however risky from the point of view of the effects of pest outbreaks. These forests are very artificial systems created just as agricultural crops, to produce a commercially valuable product. They therefore do not possess any of the resistance that a balanced, healthy ecosystem would have to the outbreak of a disease or infestation. In ecosystems with diverse species, the outbreak will only be potentially damaging to certain species populations, leaving the rest of the ecosystem to function healthily, or in the case of a diverse commercial forest, the unaffected trees to yield a financial return. Some pests and diseases attack more than one species, but are limited to either broadleaves or conifers. For this reason, when diversifying the mix of trees in a forest it is safest to plant broadleaves in addition to conifers. This will certainly also be beneficial to the biodiversity of the area.

Control of Pine Weevil is generally effected by dipping or spraying the saplings (transplants) before planting. Spot control of this type is much less deleterious to the other organisms in the forest than is subsequent spraying with insecticides or fungicides. The practice of treating all conifer stumps with the urea solution recommended for the control of Fomes is deleterious to other fungi in the forest, as well as excluding colonisation of the stump by saproxylic (decay) animals, but may be necessary in the absence of an effective alternative. In more mixed species stands the Fomes may not be able to spread as easily, reducing the need for urea application.

Grazing within a forest can affect species diversity by decreasing the plants that are subject to damage and by giving the undamaged species a competitive advantage. Very intense levels of grazing in an oak forest have been found to decrease biodiversity, as has the elimination of all grazing. Although this needs to be tested in more types of forest, low-level grazing may be the optimum for biodiversity. Fencing is generally used to exclude mammals from forests. This will exclude sheep and cattle, but is not usually designed to interfere with the movement of deer. The forest trees are at most risk in the first few years after planting. To increase the use of the forest by diverse species of wild mammal, the forest manager should allow a possibly somewhat limited access by making gaps in the fencing when the most vulnerable period has passed.

Thinning and Harvesting

The process of thinning a commercial forest can have beneficial effects on the biodiversity, mainly through allowing more light to reach the forest floor. This encourages the growth of the associated plants of the forest, shrubs, herbs and tree saplings, which in turn attract certain birds and mammals through offering them shelter. As the trees of the forest in many cases will not be native in origin, the proliferation of the associated plants and animals increases the complement of native species in the forest. However, the planning of thinning and harvesting operations should take heed that the main nesting period is April to August. If there are nests, setts etc. present, the forest manager should take advice on how the impact on these can be minimised during operations. In some cases the animals may be successfully coaxed to another location.

As dead wood is so important for diversity, some material from the thinning process should be left lying on the ground. Care must be taken not to damage trees left standing. If the thinning or harvesting operation has resulted in the stemming of flow in watercourses through the presence of leaf and woody litter, these must be cleared away. The use of bridges, arches or culverts to cross watercourses is encouraged, but care must be taken to remove these structures after the harvesting operation unless they are designed specifically to be beneficial for the movement of wildlife. Any structures that prevent the free movement of the fish and other aquatic life along the waterway should not be used. Areas set aside for nature conservation should not be impacted by thinning or harvesting practices. Trees that have been cut at a few metres above the ground to provide standing dead timber should be left standing by the harvesting operation and carried over into the next rotation.

Harvesting is the most disturbing event in the life of a forest. In conifer plantations the practice of clearfelling has almost exclusively been used, but large clearfells are now discouraged, not only because of their adverse effect on biodiversity but also on the landscape. The use of irregular instead of geometric shapes for coupes is now encouraged, and shapes that are in harmony with the contours and other features of the landscape.

For biodiversity, the effect of felling is to change the whole system of the forest and render the land inhospitable for any forest species that might have been attracted during the life of the forest. The issue of continuity of tree cover is of great importance for the development of the forest as an ecosystem. In nature small gaps are created when a tree falls, and these form an integral part of the forest habitat mosaic.

Biodiversity-friendly harvesting operations should use continuous cover systems, including shelterwood, group selection and single tree selection systems, and if necessary, small coupes. Selective felling of individual trees is an expensive venture, but is the best for biodiversity. The use of small coupes is much better than large clearfells because the more mobile forest species at least are able to move into the adjacent forested areas. At present there is not enough information available to set a definite limit to coupe size, but indications are that it should be no greater than 5ha, and possibly very much smaller than that.

Many of the conifer plantations planted in the past were planted over very large areas, all at one time. The trees in these areas will be at their commercial optimum simultaneously, and the forest owners will want to harvest them with large clearfells. Working towards more environmentally friendly forest practices, there should be a division of the areas into smaller parts, and adjacent parts should be felled at intervals of at least 5 years, or more ideally, 10% of the life of the plantation. The replanting plan should then stagger the planting of these smaller areas, producing a forest area that is more structurally diverse and that can be harvested in stages. In this way large clearfells will no longer be a part of practices used in Irish forestry (see Purser Tarlton Russell, 1999), and a more diverse forest structure will be created for the future. This has been shown to some degree in the experimental management practices used in Kielder forest since the 1920s (Petty *et al*. 1995).

Harvesting and extraction can adversely affect the soil condition through compacting and disturbance leading to erosion. This will affect soil biodiversity and the ability of certain plants to grow, as well as the health of aquatic organisms in nearby watercourses (see "Establishment", above). The use of brash along machine trails is very important to reduce these effects. Additionally, a good harvesting plan should minimise the amount of movement of the machines within the forest. The employment of horse-drawn harvesting techniques are generally less disturbing to the site than the more mechanical methods.

Summary action points

Management Issues and Planning

Landscape

- The forest should be designed to form an aesthetically inoffensive if not pleasing part of the landscape.
- Tree species mixtures are better than single-species cultures for the appearance of the landscape as well as for the ecology and biodiversity of the area, and broadleaves should be included.
- Non-commercial areas of the forest (see below) should be planned taking the surrounding land uses into account. Forest roads and rides should ideally follow contours and avoid straight lines.
- The existence of hedgerows, copses of natural woodland and scrub should be used to form woody linkages between forest patches.
- Where possible areas of native semi-natural forest (including scrub) should be left in their natural state and not disturbed.
- The FIPS of the Forest Service should be used to support the design planning.

Site suitability

- A detailed plan of the site should be prepared. This should address the nature of the site (terrain, soil, slope, water courses) and outline in map and text form the proposed forest. The examinations of the site necessary for a plan of this level of detail will determine the site suitability.
- NHAs, SACs and SPAs in the vicinity should be included in the plan, and Dúchas The Heritage Service should be consulted for advice on how best to plan considering these areas.
- Areas of local conservation interest (additional to the officially designated areas above) should be identified and incorporated into the plan, probably as "Non-commercial areas within the forest" and for this reason an ecologist or specialist forester with ecological training should be included on the survey team.
- Water courses and patches with cultural heritage value should be planned according to the recommendations below and in the other Guidelines publications.

Species

- For biodiversity, a choice to plant native species is the best.
- Native and non-native species may be planted in mixture, and these may be conifer or broadleaf.
- Refer to the British Forestry Authority Guides for the management of semi-natural woodlands.
- Where not possible to plant commercially with native species, use diverse non-natives. If non-native species are used there should be at least two species in the mix, preferably at a ratio of greater than 85:15%. Broadleaf should be used at least around the edges of the forest, if not throughout.

- Pine Martens and Red Squirrels are attracted to conifer-dominated stands, or at least where conifers form part of the mix. In particular the native Scots pine should be used to attract these, or the non-native Norway spruce, which is also attractive to some bird species.

Provenance

- Where possible use natural regeneration on the site, with enrichment planting where necessary.
- For species that are EU-regulated, use only seed from certified Irish sources (unless natural regeneration is being used).
- Use seed from trees whose parent trees were Irish, and preferably grown in soil and microclimatic conditions similar to those on the site.
- Only where the above is simply not available should seed of non-native provenance be used. Non-native varieties of native species should never be used because they can corrupt the gene pool.
- Where planting non-native tree species, use seed from trees grown in Ireland, and preferably where the parent trees of these were also grown in Ireland.

Structure/age

- Encourage as diverse an age and size structure in the forest as possible. This may have to be done over time in areas with even-aged forests and in areas that are not currently forested.
- In areas where an intimate mixture of young and old trees (the natural state) is not possible, create a mosaic of small patches within the forest of different size and age groups.
- Different tree species have different structural architectures, so a mix of species will create a more structurally diverse forest.
- Old trees are of utmost importance for biodiversity: some trees in the forest should be allowed to grow old. Preferably these will be scattered throughout the forest, but in particular these should be present in the nature retention areas recommended for intensively managed plantations.
- The forest should be thinned rigorously to enable light to reach the forest floor. This encourages the development of native species in the shrub and ground layers.
- If felling in coupes, the coupes should be kept as small as possible and under 5ha, to create a mosaic structure of different age size patches (see “Thinning and harvesting”).

Dead trees

- Dead trees are a very important resource for biodiversity, and a lack of dead wood will eliminate a great percentage of the potential biodiversity of the forest. In particular wood of sizes greater than 15cm diameter should be left, at a rate no less than $5m^3ha^{-1}$, or between 5-20 big trees ha^{-1}.
- Some standing dead trees (>15cm diameter) should be left in the forest through the felling rotations. To conform with this stipulation in a forest where this has not previously been the practice the trees may need to be ring-barked. In areas with risk

of windthrow the side limbs may be lopped off, or the trees cut off at a few metres height.

- Some wood from thinnings should be left on the forest floor to decompose. Decomposing logs provide a habitat for numerous species of plant and animal, which otherwise would be absent from the species complement of the forest.
- The treatment of stumps with urea inhibits the development of numerous forest organisms which would otherwise inhabit the stump. Where possible, particularly in forests with a good species mix, avoid the treatment of stumps (see “Pest management”).

Non-commercial areas within the forest

- All forests must manage at least 15% of the land to encourage development of native habitat and biodiversity. In semi-natural forests this is usually taken care of throughout the forest by its nature: native species in the mix, diverse age and size structure, old trees, gaps. In intensively managed plantations, however, the 15% needs to be considered separately to the main stocked area, and may be composed of buffer areas around rivers, wide and well-managed ridelines, glades and “key biotopes”. Ideally these should, in combination, comprise some open areas and some closed native semi-natural forest.

Open space

- Between 5 and 10% of the forest should be composed of open space. In sites less than 10ha this should be designed in conjunction with neighbouring land use and may be reduced.
- Ridelines should be at least 1.5 times as wide as the height of the bordering trees. Curving ridelines are better than straight ones, and site characteristics should be taken into account when creating rides. The management of the vegetation in the rideline should follow the guidelines set out above.
- Key biotope areas may provide an opportunity for open space, as tree growth may be curtailed. These areas should be managed with minimal intervention.
- Open space will also be created by watercourses and their surrounding areas (see below).

Nature retention areas

- In intensively managed plantations, areas of forest with preferably native trees should be designated, occupying between 5-10% of the forest area, as nature retention areas, where the trees are allowed to grow old and die and native flora and fauna are permitted to flourish. When added to the area of open space (see above) the sum of the areas should comprise about 15% of the forest.
- In forests with “key biotopes” (see above), the nature retention area should be designed so that the biotope is included in the area.
- Native tree species should be encouraged. Where there is no seed source nearby for native trees, these may be pit-planted from a source of native, and preferably local, provenance.
- No commercial operations should take place in the nature retention area.

Water

- Some forests have bodies of water. The zones surrounding these may be included in the above 15% stipulation for open space or nature retention area.
- At the borders of rivers and pools within the forest, commercial planting should not take place within at least 10m of the forest edge.
- Only native trees and shrubs should be encouraged in the riparian buffer zone.
- Structural and species diversity should be encouraged with in the zone: different sizes and shapes of tree, shrub and herb.
- The water body should, for aquatic biodiversity, be about 50% shaded, 50% sunny.
- A moderate amount of leaf litter may be permitted to fall in the water body.
- Modifications made to the water body to facilitate harvesting should be removed afterwards.
- Drains within the forest should stop well before the river.
- The number of contacts between roads and watercourses should be minimised.

Troublesome species

- In all forests the troublesome tree species rhododendron and cherry laurel should be eradicated from the land. No live specimens should be left in the vicinity if at all possible as these act as seed sources for re-infestation of the forest.
- Sika Deer populations should be kept at levels that allow natural tree regeneration to occur. In areas where Red Deer are also present, Sika Deer should be controlled to an extent that there is no risk of hybridisation between species.
- Forests in the south and east of the country are at risk from invasion by the Grey Squirrel, which damages the populations of native Red Squirrel. Grey Squirrel is encouraged by trees with large nuts or seeds. Tree species planted around the edges of forests should not be of the large-fruited type in areas at risk from Grey Squirrel.

Reforestation

- In general the principles outlined above for afforestation projects apply also to reforestation projects. Reforestation provides an opportunity for the site to be re-assessed and re-planned according to the Biodiversity Guidelines.
- Areas in or adjacent to NHAs, SACs or SPAs must take the conservation area into account in the new design plan.
- The site should be re-surveyed to ensure the identification of “key biotopes” or other areas that should have special consideration for nature conservation. Many of these are of local significance but are not included within the formal national designated conservation areas (above). The new forest design should use these sites in its plan for non-commercial areas within the forest.
- Large forests should be divided into patches for the purposes of management. Adjacent patches should be planted at different time intervals to encourage structural diversity in the forest as a whole, and/or different dominant species should be used in adjacent patches.
- Dead trees left from the last rotation should be maintained in the reforestation plan.
- Particularly in forest plantations that were managed intensively in the past the provisions described above for 15% of non-commercial areas within the forest should be followed.

Operations

Establishment

- Saplings (transplants) should be planted at the recommended intervals.
- If pest control for the saplings is required, it is better to dip the saplings prior to planting than to spray them after planting.
- Troublesome undergrowth should if possible be removed manually. The use of herbicides should be minimised or eliminated.

Pest management

- Pests are always related to other organisms that are not troublesome and which form a natural component of the nation's biodiversity. In selecting a method to control pests, the most species-specific pest control is the most desirable. The principle here is that the pest will be eliminated or reduced without damage to other organisms. In the absence of a species-specific control, applications of pesticide should be minimised. Unfortunately very few pesticides are species-specific.
- In terms of biodiversity, prevention is better than cure, so the forest should be managed in a way that reduces the risk of pest outbreak. This includes the use of diverse tree species, and seed only from certified or hygienic sources.
- The regular treatment of conifer stumps with urea should not be necessary if the conifers are grown in a mix with a good percentage of broadleaves.
- If pesticide must be used, abide by all the control regulations. In particular apply the pesticide only directly to the pest organism, if possible.
- The exclusion of grazing animals from the forest at the initial stages should not need to be extended throughout the more established stages, except where domestic livestock are a threat. Moderate grazing by wild animals has been shown to be good for biodiversity.

Thinning and harvesting

- The forest should be thinned to allow light onto the forest floor. A dense shade caused by very dense forest growth should be avoided, as is the condition in many intensively-managed conifer plantations at the thicket stage.
- Some of the thinnings should be left on the ground both for the provision of habitats for decomposer organisms and as brash to protect the soil from damage by machinery.
- Care should be taken in the thinning operation not to damage trees that are to be left standing.
- The use of horses to thin and to harvest is encouraged, as these facilitate biodiversity-friendly practices such as selective felling and should not cause as much soil damage as machinery.
- Operations conducted during the main nesting period (April to August) should be carried out with care. Where wildlife would be disturbed, it may be possible to move animals to a safer location in the forest before operations start.
- Ensure that water bodies are not clogged up by woody debris.
- Remove all temporary crossings after the operation.

- Leave old and dead trees in the forest according to “Dead trees” above.
- Do not carry out operations in the non-commercial areas within the forest.
- Where selective felling is not economically viable the use of small coupes is advised. Clearfells larger than 5ha should not be used.
- Movements of heavy forestry machinery should be minimised by good harvesting plans.

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Appendix A: Guidelines for sustainable forest management planning and practice (The Helsinki Guidelines)

Guidelines for forest management planning (FMP)

- FMP should aim to maintain, conserve and enhance biodiversity on ecosystem, species and genetic level and, where appropriate, diversity at landscape level
- FMP and terrestrial inventory and mapping of forest resources should include ecologically important forest biotopes, taking into account protected, rare, sensitive or representative forest ecosystems such as riparian areas and wetland biotopes, areas containing endemic species and habitats of threatened species, as defined in recognised reference lists, as well as endangered or protected genetic *in situ* resources

Guidelines for forest management practices (FMC)

- Natural regeneration should be preferred, provided that the conditions are adequate to ensure the quantity and quality of the forests resources and that the existing provenance is of sufficient quality for the site.
- For reforestation and afforestation, origins of native species and local provenances that are well adapted to site conditions should be preferred, where appropriate. Only those introduced species, provenances or varieties should be used whose impacts on the ecosystem and on the genetic integrity of native species and local provenances have been evaluated, and if negative impacts can be avoided or minimised.
- FMC should, where appropriate, promote a diversity of both horizontal and vertical structures such as uneven-aged stands and the diversity of species such as mixed stands. Where appropriate, the practices should also aim to maintain and restore landscape diversity.
- Traditional management systems that have created valuable ecosystems, such as coppice, on appropriate sites should be supported, when economically feasible.
- Tending and harvesting operations should be conducted in a way that do not cause lasting damage to ecosystems. Wherever possible, practical measures should be taken to improve or maintain biological diversity.
- Infrastructure should be planned and constructed in a way that minimises damage to ecosystems, especially to rare, sensitive or representative ecosystems and genetic reserves, and that takes threatened or other key species - in particular their migration patterns - into consideration.
- With due regard to management objectives, measures should be taken to balance the pressure of animal populations and grazing on forest regeneration and growth as well as on biodiversity.
- Standing and fallen dead wood, hollow trees, old groves and special rare tree species should be left in quantities and distribution necessary to safeguard biological diversity, taking into account the potential health and stability of forests and on surrounding ecosystems.
- Special key biotopes in the forest such as water sources, wetlands, rocky outcrops and ravines should be protected or, where appropriate, restored when damaged by forest practices.

Appendix B:
List of protected plant species under the Flora Protection Order, 1999.

Vascular plants	
Scientific name	Common name
Acinos arvensis	Basil thyme
Allium schoenoprasum	Chives
Alopecurus aequalis	Orange foxtail
Arenaria ciliata	Fringed sandwort
Arthrocnemum perenne	Perennial glasswort
Asparagus officinalis	Wild asparagus
Asplenium obovatum ssp. *lanceolatum*	Lanceolate spleenwort
Asplenium septentrionale	Forked spleenwort
Astralagus danicus	Purple milk vetch
Calamagrostis epigejos	Wood small-reed
Callitriche truncata	Short-leaved water starwort
Cardamine impatiens	Narrow-leaved bitter-cress
Cardaminopsis petraea	Northern rockcress
Carex depauperata	Starved wood-sedge
Carex divisa	Divided sedge
Centaurium pulchellum	Lesser centaury
Cephalanthera longifolia	Narrow-leaved helleborine
Colchicum autumnale	Autumn crocus
Cryptogamma crispa	Parsley fern
Deschampsia setacea	Bog hair grass
Epilobium alsinifolium	Chickweed willow herb
Equisetum x *moorei*	Moore's horsetail
Eriophorum gracile	Slender cotton grass
Galeopsis angustifolia	Red hemp nettle
Groenlandia densa	Opposite-leaved pondweed
Gymnocarpium robertianum	Limestone fern
Hammarbya paludosa	Bog orchid
Helianthemum nummularium	Common rockrose
Hordeum secalinum	Meadow barley
Hydrilla verticillata	Irish hydrilla
Hypericum canadense	Canadian St. John's wort
Hypericum hirsutum	Hairy St. John's wort
Inula salicina	Irish fleabane
Lathyrus japonicus	Sea pea
Limosella aquatica	Mudwort
Logfia minima	Slender cudweed
Lotus subbiflorus	Hairy birdsfoot trefoil
Lycopodiella inundata	Marsh clubmoss
Mentha pulegium	Penny royal
Mertensia maritima	Oyster plant
Minuartia recurva	Recurved sandwort
Misopates orontium	Lesser snapdragon
Najas flexilis	Slender naiad
Omalotheca sylvatica	Wood cudweed
Otanthus maritimus	Cottonweed
Papaver hybridum	Round prickly-headed poppy
Pilularia globulifera	Pillwort
Polygonum viviparum	Alpine bistort
Pseudorchis albida	Small-white orchid
Puccinellia fasciculata	Tufted salt-marsh grass
Pyrola rotundifolia ssp. *maritima*	Round-leaved wintergreen
Sanguisorba officinalis	Great burnet
Saxifraga granulata	Meadow saxifrage

Saxifraga hartii	Hart's saxifrage
Saxifraga hirculus	Yellow marsh saxifrage
Saxifraga nivalis	Alpine saxifrage
Scirpus triqueter	Triangular club-rush
Scleranthus annuus	Annual knawel
Simethis planifolia	Kerry lily
Spiranthes romanozoffiana	Drooping lady's tresses
Stachys officinalis	Betony
Trichomanes speciosum	Killarney fern
Trifolium glomeratum	Clustered clover
Trifolium subterraneum	Subterranean clover
Trollius europeus	Globe flower
Vicia orobus	Bitter vetch
Viola hirta	Hairy violet
Viola lactea	Pale heath violet

Mosses
Scientific name
Bryum calophyllum
Bryum marratii
Catoscopium nigritum
Drepanocladus vernicosus
Leptobarbula berica
Orthrotrichum pallens
Orthrotricum sprucei
Orthrotrichum stramineum
Paludella squarrosa
Pottia wilsonii
Tetraplodon angustatus
Tortella inclinata
Weissia longifolia
Weissia rostellata

Liverworts	
Scientific name	Common name
Leiocolea gillmanii	
Leiocolea rutheana	Fen flapwort
Petalophyllum ralfsii	
Plagiochila atlantica	

Lichens
Scientific name
Fulgensia fulgens

Stoneworts	
Scientific name	Common name
Lamprothamnium papulosum	Foxtail stonewort
Nitella gracilis	Slender stonewort