Assessment of production of wild edible fungi (WEF) in selected Irish forest sites, and an evaluation of the commercial potential of harvesting (FORESTFUNGI)

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A collection of ceps (*Boletus edulis*) red hedgehog fungus (*Hydnum rufescens*) and winter chanterelle (*Cantharellus tubaeformis* agg.) from Curraghchase, Co. Limerick

Excecutive summary

The FORESTFUNGI project was commissioned by The Irish National Council for Forest Research and Development (COFORD) to examine the occurrence wild edible fungi (WEF) in broadleaf and conifer forests in Ireland, and to assess their potential as non-timber forest products (NTFPs). The objectives of the project were to determine:

- What are the most productive species to be found in Irish forests?
- What volumes are produced in a typical year?
- What is the extent in year-to year variation in yield?
- What types of forest sites are the most productive?

One-hundred and fourteen forest sites were selected for survey with a geographic spread of 18 counties. These comprised 13 single-species forest types and 5 mixtures. Sitka spruce, Scots pine sessile oak, pedunculate oak, beech, hazel, Norway spruce, lodgepole pine and Japanese larch were the principal forest types. Sites were surveyed during the fruiting season for WEF (September to December) in each of the years 2007, 2008 and 2009. Production of fruit bodies of WEF was monitored in 100-m^2 permanent plots established at the sites. Fruit bodies were collected and weighed on up to 5 visits per site during each season. Comparisons were made of WEF diversity in each forest type, and estimates were made of annual WEF production in each type.

The main findings:

- Forty-four WEF species were encountered over the course of the study. Beech, Scots pine and Sitka spruce forest produced the greatest variety of species (31, 25 and 24, respectively). *Hydnum repandum*, the wood hedgehog fungus (a priority species), was the most frequently encountered edible species. The chanterelle (*Cantharellus cibarius*) the top priority species, was also relatively frequent. The frequency values were broadly mirrored by the numbers and weights of fruit bodies of each species. Winter chanterelle (*Cantharellus tubaeformis*) was most prolific in terms of numbers of fruit bodies, followed by hedgehog fungus and chanterelle. Ceps (*Boletus edulis*), probably the most

economically valuable WEF of forests, was much less common than the aforementioned species. Chanterelle (*C. cibarius*), the second most valuable species, was also the most widely distributed, being found in 10 of the 18 forest types (7 of the 10 major types).

- Winter chanterelle and wood hedgehog fungus were on average the most productive of the priority valuable species across the range of forest types sampled, although there was a great range of variation between forest types. Even though the total biomass of winter chanterelle collected over the 3 years was on average 25% higher than that of hedgehog fungus, the average productivities of each (4.7 and 4.36 kg/ha/y, respectively) were very close, because the site and visit frequencies of hedgehog fungus were over double that of winter chanterelle. Of the priority species, the highest production estimates were found for winter chanterelle in Scots pine, wood hedgehog fungus in beech, pedunculate oak and Scots pine, and cep in noble fir.

- The highest estimates for production of priority species and all species were found for Scots pine forest (47.6 kg/ha/y), followed by silver fir, beech, Sitka spruce, hazel, pedunculate oak, Norway spruce, sessile oak and birch. Larch and lodgepole pine had low production levels, especially of priority species.

- Nominal retail values (€ per kg fresh weight) were assigned to each of the edible species and the returns per hectare were calculated for each forest type based on the relative production of the species found. The highest theoretical returns were from Scots pine and beech. Estimated theoretical returns from Sitka spruce forest (€195/ha/y) were 36% of those from Scots pine. These returns are theoretical and are unlikely to cover the costs of harvesting.

1.0 Introduction

The FORESTFUNGI project was commissioned by The Irish National Council for Forest Research and Development (COFORD) to examine the occurrence wild edible fungi (WEF) in broadleaf and conifer forest throughout Ireland and to assess their potential as non-timber forest products (NTFPs). Information is needed on the potential of edible fungi as a secondary forest product. Such information is at present sparse, anecdotal and unpublished, in contrast to the situation in many other European countries, where collecting wild edible mushrooms is popular. While it is relatively straightforward to compile a list of the range of edible forest fungi to be found in Ireland, there is little or no concrete information available to answer some basic questions:

- What are the most productive species to be found in Irish forests?
- What volumes are produced in a typical year?
- What is the extent in year-to year variation in yield?
- What sort of forest sites are the most productive?
- What factors have a significant positive influence on yield?

The Forest Fungi Working Group (FFWG), was established to explore the use of WEF as a non-timber forest resource in Ireland, has highlighted the need for this information. It may be that collection of WEF is not be economic, but there may be other benefits such as fungi tourism and the encouragement of greater recreational use of forest areas. Accordingly, the aim of this project is to obtain this information, which will provide an objective basis for assessing the commercial and recreational potential of edible fungal harvesting in Irish forests. Sustainability, ongoing monitoring and site management must also be present in any programme to promote WEF as NTFPs in order for a forest to qualify for certification through the Forest Stewardship Council and similar bodies.

The objectives of FORESTFUNGI were:

1. To identify woodland and forestry sites for the monitoring of edible fungal production from a range of representative forest habitats across Ireland.

2. To obtain qualitative and quantitative information on production of fruiting bodies of WEF in these sites over a three-year period and to extrapolate production from the study sites to larger areas of similar forest in Ireland
3. To examine year-to year variation in fungal production .

Hypotheses to be tested:

1. Winter chanterelle (*Cantharellus tubaeformis* agg.) is the most common species in Irish forest based on number of fruit bodies. Wood hedgehog (*Hydnum repandum*) is likely to be the most prolific producer as measured by fruit body biomass.

2. Native and non-native forest types (i.e. pedunculate oak sessile oak, birch and beech) are more productive of priority WEF such as cep, chanterelles and hedgehog fungi.

3. Production levels are highest in deciduous forest types.

2.0 Background

2.1 Introduction

At least 1154 species of wild edible fungi (WEF) are collected worldwide for their culinary or medicinal use (Boa, 2004). Many countries such as China, Japan, Mexico, Turkey, several European countries, and major areas of central and southern Africa have long traditions of collecting WEF. In some of these countries, the collection of WEF for consumption provides significant economic returns. It is estimated that an average of 30kg of ZambezianWEF is consumed on average by each person in the region per annum (Thoen and Ba 1987). Collecting WEF is also an important if seasonal recreational activity, as well as adding variety to the diet. The Chinese collect and market many species, not only for nutrition and taste but also for their suspected healing properties. China is also the leading exporter of cultivated mushrooms. The importance of WEF as a non-wood forest product (NWFP) continues to grow. Conservation issues and logging bans in several countries has renewed interest in WEF as an alternative source of income for people previously employed in forestry. WEF have played an important role in providing new sources of income in the Pacific northwest of the U.S. and in China.

Across Europe, the most prized wild edible forest fungi are the truffles *(Tuber* species), ceps (*Boletus edulis* and related species) and chanterelle or girolle (*Cantharellus cibarius*), hedgehog fungi (*Hydnum* spp.) and saffron milkcap (*Lactarius deliciosus*), but many more species may actually be collected for consumption depending on regional preferences. France and Italy, and most Slavic and Nordic countries have strong traditions of WEF consumption. Even in in countries without such traditions, such as the Celtic countries and most of Spain, where attitudes to wild fungi have been generally negative, interest in consumption of WEF has grown steadily. Spain is the foremost example of this change. Awareness came initially from French hunters collecting in the northeast and north of Spain. At least 61 species are

now collected for consumption (de Román and Boa, 2004). While most are collected for personal consumption, there is also a growing market for chanterelles, ceps and the saffron milk-cap (*Lactarius deliciosus*). The last species is ectomycorrhizal on various species of pine, and has become a significant commercially-collected species in parts of Spain with extensive *Pinus nigra* plantations. In Andalucia, under the CUSSTA Plan a wholesale market for local pickers has been developed at Jerez de la Frontera. *Cantharellus cibarius* is also ectomycorrhizal on pine and has also become a significant commercial species in parts of Spain with extensive *Pinus nigra* plantations. Saffron milk cap has also been used to inoculate trees in New Zealand and Oregon to increase both timber yields while also providing a lucrative annual edible crop (Hall 2003; 2006). A further development in Spain is the development of black truffle (*Tuber malanosporum*) plantations using holm oak.

Studies on non-timber forest product usage in Scotland found that several species of forest fungi including chanterelle and winter chanterelle, ceps, hedgehog fungi, puffballs (*Lycoperdon* spp.), parasol mushroom (*Macrolepiota procera*), lawyer's wig (*Coprinus comatus*) and wood blewit (*Lepista nuda*) were collected for food or sale by a significant number of harvesters (Emery *et al.* 2006; Dyke *et al.* 1999).

The most dramatic expansion of a commercial and recreational WEF harvesting industry has occurred since the 1980s in the Pacific Northwest of the United States. Here, more than 20 species are collected from federal and private forests (Pilz and Molina 2002). The commercial harvest focuses on matsutake *(Tricholoma magnivelare),* morels *(Morchella* species), golden chanterelles *(Cantharellus formosus),* white chanterelles *(C. subalbidus),* hedgehog fungus *(Hydnum repandum),* Oregon white truffle *(Tuber gibbosum)* and Oregon black truffle *(Leucangium carthusianum).* Most of the matsutake harvest is exported to Japan where the estimated annual retail value of this mushroom alone is $US250M to $US500M (Hosford *et al.* 1997; Alexander *et al.* 2002; Pilz *et al.* 2001a, 2001b; Berch and Cocksedge 2003; Hall *et al.* 2003). Matsutake *(Tricholoma matsutake)* is the most valuable mushroom in the Far East. However, mismanagement of the resource, notably by picking of

immature fruit bodies and use of rakes in collecting, has led to a regional collapse of fruiting of this species (Koo and Bilek 1998).

Although the estimation of truffle production in Irish forests is not an objective of this study, mention should be made of these most valuable of WEF. Truffle is the name given to the spherical or ovoid fruit body of a number of genera and species of ectomycorrhizal fungi that associate with the roots of forest trees. Unlike other ectomycorrhizal species, truffle fruit bodies are formed underground (such fungi are referred to as *hypogeous*). This makes them difficult to find. However the ripe fruit bodies emit volatile compounds that are detected by animals, and dogs or pigs have been traditionally used to locate truffles. Truffles are important in southern European cuisine and command high prices, especially the Perigord truffle *(Tuber melanosporum)* and the rare *Tuber magnatum* (Italian white truffle), which is confined to central Italy and is probably the most expensive WEF in the world, commanding prices of up to £1,700 per kilo. Euoprean truffles are mainly associated with species of oak (*Quercus*), beech (*Fagus*) and hazel (*Corylus*). The harvest of wild truffles in Europe has steadily declined in the 20th century and much of the crop originates from planted truffle orchards or truffières. Summer or Burgundy truffle (*Tuber aestivum*) (Paolocci *et al*. 2004) is known to occur in Ireland but the extent of its distribution in Irish woodland habitats is not known.

2.2The biology, ecology and diversity of WEF

The majority of WEF belong to the fungal group known as gill fungi or basidiomycetes (Basidiomycota). Truffles, however, belong to the sac fungi or ascomycetes (Ascomycota). Only the reproductive or fruit bodies (also known as *sporocarps*), which produce spores, are collected as food if they are large enough and edible. The fungal "body" is a *mycelium* consisting of a network of microscopic filaments or hyphae, which ramifies through the substrate on which it is growing, be it soil or living or dead timber, and for the most part remains invisible until it reproduces by means of a large visible fruit body. The greatest diversity of ascomycetes and basidiomycetes, including edible species, are found in forest habitats.

Based on how they acquire their nutrition in forests, WEF can be divided into four ecological groups: decomposers of organic matter in soil or in leaf litter (*soil or litter saprotrophs*), decayers of of standing and fallen timber (*lignicolous saprotrophs*) pathogens of living trees (*lignicolous pathogens*), and *ectomycorrhizal* (EM) fungi. In the last group, the mycelium is intimately associated with the roots of forest trees and this relationship is a true symbiosis. EM fungi are very important in forest ecosystem processes, especially because they enhance the uptake of phosphorus and nitrogen by forest trees (Smith and Read 2008). The majority of forest WEF, including the most commercially valuable types (**Table 2.1**) such as truffles, ceps, chanterelles, saffron milkcap, charcoal burner and matsutake are ectomycorrhizal with a range of forest trees such as oaks, beeches, birches, hazel, pines, spruces and firs. A single tree may support many different kinds of EM fungi on its roots; unless the roots are examined, the presence of these will not be revealed until they produce their fruit bodies, which emerge above ground in autumn. Many may fruit only sporadically (i.e. on all host trees or in all years) or not all. Fruiting depends very much on weather conditions prior to and during the fruiting period and the amount of nutrition made available by the host tree to the ectomycorrhizal fungi on the roots.

From anecdotal evidence, production of fruitbodies of mycorrhizal and non-mycorrhizal fungal species appears to be very variable from year to year and these fluctuations are largely determined by weather variables. In Ireland, the principal variable that is positively correlated with production of fruitbodies appears to be average daily temperature in the period 2-4 months before fruiting (Eveling *et al.*, 1990), but other factors may also be involved, particularly soil moisture status in September and October. It also been frequently observed that productive years are followed by one or more fallow years. Because of this variability, surveys of edible fungal production need to span at least 3-4 years. The fungi themselves also have biogeographical ranges and climatic preferences; Perigord truffle (*Tuber melanosporum*) and Caesar's mushroom (*Amanita caesarea*), both southern European species, do not not occur in Irleand probably because of low summer temperatures. Not all forest trees can support EM fungi; native and introduced trees such as ash, holly, alder, yew, sycamore and lime do not support any mycorrhizal fungi (or at least any valuable edible species). Pure stands

of these trees are therefore unlikely to yield any of the most prized WEF species, but they may produce some valuable non-mycorrhizal edible types such as blewits or morels. Although the most prized WEF are ectomycorrhizal, a number of soil saprotrophs (morel, wood blewit, parasol mushroom) and pathogens (oyster mushroom, beefsteak fungus) are also highly regarded. Two of these, morel and St. George's mushroom, form fruitbodies in spring and were not targeted in this study.

Most of the highly-valued WEF found in north-western Europe are also found in Irish woods (**Table 2.1**) (Muskett and Malone 1978, 1980; Smith and Dowding 2008; Legon and Henrici 2005). The mycorrhizal types (denoted by *M* in **Table 2.1**) include truffles, ceps chanterelles and hedgehog fungus, and the most highly esteemed and commercially valuable. They cannot be cultivated in the manner of cultivated mushroom (*Agaricus bisporus*) and the commercial trade is based on harvesting from the wild (or increasingly in the case of truffles, from plantations).

2.3 WEF Research

One of the primary objectives of most applied research on WEF is to obtain estimates of WEF diversity and actual or potential fruitbody production measured as numbers and/or biomass per unit area (kg/ha). If information is available on forest types and areas, estimates of the total WEF harvest can be made by extrapolation to whole regions. Such estimates are indispensable for estimating the economic value of the WEF resource and the sustainability of harvesting efforts. Assessments have been carried out in a number of countries (**Table 2.2**). An additional objective is to assess the influence of management and environmental factors on WEF production. The most concerted of the WEF research has been carried out in the Pacific North West of the U.S. coordinated by the Pacific Northwest Research Station of the USDA Forest Service (Vogt *et al*., 1981; Liegel, 1998; Pilz *et al*., 1999; Pilz *et al*., 2004). The stimulus for this research effort has been the rapid expansion of the WEF harvest, which has raised questions about the productivity of the WEF and the actual size of the harvest, the effects of harvesting and silvicultural practices on WEF production, sustainability of the harvest, and conservation issues (Pilz and Molina, 1996). Estimates of fungal fruitbody production have been frequently made in an ecological context and usually without reference to edibility (Vogt

et al., 1992). However, one of the longest-running research projects by Straatsma *et al.* (2001) measured WEF production. This project examined fruitbody production in forests plots in Switzerland over a 25-year period.

Table 2.1 List of more common edible forest fungi known to occur in Ireland.
M =ectomycorrhizal species; P= pathogenic species; S = soil, litter or lignicolous saprotrophs.

Hedgehog fungus (*Hydnum repandum*)	*M*
Chanterelle (*Cantharellus cibarius*)	*M*
Girolle (*Cantharellus tubaeformis* and *C. aurora*)	*M*
Horn of Plenty (*Craterellus cornucopioides*	*M*
Cep (*Boletus edulis, B. reticulatus*)	*M*
Bay Bolete (*Boletus badius*)	*M*
Saffron Milk Cap (*Lactarius deliciosus*)	*M*
Blewit (*Lepista nuda*)	*S*
Cauliflower fungus (*Sparassis crispa*)	*S*
Lawyer's Wig (*Coprinus comatus*)	*S*
Parasol Mushroom (*Macrolepiota procera*)	*S*
Honey fungus (*Armillaria mellea*)	*P*
Giant Puffball (*Calvatia gigantea*)	*S*
Velvet Shank (*Flammulina velutipes*)	*S*
Chicken of the Woods (*Laetiporus sulphureus*)	*S*
St George's Mushroom (*Calocybe gambosa*)	*S*
Morel (*Morchella esculenta*)	*S*
Oyster Mushroom (*Pleurotus ostreatus*)	*P*
Summer Truffle (*Tuber aestivum*)	*M*
Beefsteak Fungus (*Fistulina hepatica*)	*P*
Slippery Jack (*Suillus luteus*)	*M*
Larch Bolete (*Suillus grevillei*)	*M*
Birch Bolete (*Leccinum scabrum*)	*M*
The Prince (*Agaricus augustus*)	*S*
Wood Mushroom (*Agaricus silvicola*)	*S*
Deceiver (*Laccaria laccata*)	*M*
Charcoal Burner) (*Russula cyanoxantha*)	*M*
Morel (*Morcella esculenta*)	*S*
St. George's Mushroom (*Calocybe gambosa*)	*S*

Nomenclature follows Legon, N.W. and Henrici, A. (2005)

Table 2.2. Studies on production of WEF.

Country	Edible Species	Production (kg/ha/y)	Reference
Scotland	Scot pine –all fungi		
Scotland	(a)Birch – All edible spp.. (b) Scots pine- All edible spp. (c) Sitka spruce-All edible spp.	(a)187 (b) 138 (c) 26	de Roman *et al*. 2004
Spain	(a) Scots pine –*Boletus edulis* (b) Scots pine -*Lactarius deliciosus* (c) Scots pine- *C. cibarius*	(a) 3-69 (b) 0 -29 (c) 0.03 -2.9	Martinez-Peña *et al.* 2011
Spain (Pyrenees)	Scots pine- *Lactarius deliciosus*	1.36	Bonet *et al.* 2004
Russian Federation (Central Siberia)	"Most popular (edible) mushrooms"	65–170	Vladyshevskiy *et al.* 2000
Russian Federation (Arkhangelsk)	(a) *Lactarius torminosus*, (b) *Russula* sp.	(a) 2–14 (b) 9	Chibisov and Demidova 1998
Finland(Sotkamo)	All edible mushrooms (a) 1976 and (b) 1977	(a) 30(b) 85	Koistinen, 1978
Finland	*Gyromitra esculenta*	50–100	Jalkanen and Jalkanen, 1978
Estonia	All WEF (1978 to 81)	124-499	Kalamees and Silver 1988
Estonia	(a) *Suillus variegatus* (b) *Lactarius rufus*	a) 41 (b) 405	Kalamees and Silver 1988
Mexico	All edible species	85	Lopez *et al.* 1992
Mexico (Veracruz)	All edible species, two sites (a) and (b) for 1983 and 1985 respectively	(a) 234 -1759 (b) 180 -747	Villarreal and Guzmán, 1985; 1986
Mexico (Veracruz)	(a) *Suillus granulatus*; (b) *Cantharellus cibarius* (c) *Amanita caesarea*; (d) *Boletus edulis* (For 2 years)	(a) 75-246; (b) 4 – 8 (c) nd -38 (d) 9-150;	Villarreal and Guzmán, 1985; 1986
United States (Pacific northwest)	(a) *Tricholoma magnivelare* (b) *Morchella* spp. (c) *Cantharellus* spp.	(a) 3–15 (b) 1– 6 (c) 0 – 2	Pilz and Molina 2002

2.3.1 Sampling designs and survey methodologies

Estimating with accuracy the production of WEF in forest stand presents a number of difficulties. Fruitbodies of most WEF show clumped distributions, and many (especially ectomycorrhizal [EM] species) show extreme spatial patchiness; the sampling methodology must be able to take account of this. The emergence of fruitbodies may be very patchy within a fruiting season, and virtually all WEF show marked variation in production from year to year; estimates of yearly production therefore include large statistical confidence intervals, and monitoring for a period of at least ten years is regarded by some authors as a minimum for obtaining valid estimates of production. Fruitbodies do not persist for long (3 weeks maximum), so sampling must be frequent enough to capture all emerging fruitbodies and avoid double counting. Fruitbodies may be eaten by animals and collected by humans, introducing a statistical bias into production estimates. Underground fruitbodies of truffles are by their nature time-consuming and difficult to survey. Because of these difficulties, estimates of WEF production in individual sample plots are generally underestimates.

Sampling designs and methodologies depend on the aims of the inventory. For example, if the prime aim is assessment of diversity of forest fungi, the survey method must be able to detect rare species; if however the prime aim is to estimate production of species that are generally common, then the survey must involve frequent sampling in defined areas with sufficient replication between sampling units, in this case forest stands (Mueller *et al.*, 2005). Sampling designs may be stratified, random, or systematic (Kerns *et al*., 2002). Pure random sampling would not be considered cost-effective in that it is generally time-consuming and can leave large areas unsampled or undersampled (Barbour *et al*., 1999). Vogt *et al.* (1992) give an overview of sampling designs and methods used in studies of fruitbody production. For estimating production of WEF (a prime aim of this proposal), many studies use stratified designs where the strata may be vegetation or soil type or other habitat factors such as management. Straatsma *et al.* (2001) used 5 replicate 300m^2 plots, and Eveling *et al*. (1990) used a single transect. In inventories of matsutake in the PNW-US (Pilz *et al*., 1999), golden chanterelle (Liegel, 1998), and morels (Pilz *et al*., 2004), the sampling methodology has involved the use of

replicate 2m x 50m or 2 x 100m permanent strip plots as sampling units, either randomly or non-randomly aligned. Similarly-sized and shaped plots were used by Ohenoja (1984) in Finland. Strip plots have the advantage of minimising the effects of trampling which is likely with frequent sampling in large square or circular plots, and has been shown to cause more damage than picking of fruit bodies in long-term studies of WEF (Pilz and Molina 2002; Peter *et al.* 2001). Long, narrow strip plots also have practical advantages over circular or square plots, especially in brushy terrain. A disadvantage of strip plots is that they may not be large enough to sample fruitbodies in a year of poor production, and too large in a good year. Adaptive sampling has been proposed as a solution to this problem (Thompson and Seber, 1996) but it is time-consuming. Permanent strip-plots plots are required for WEF inventories because they allow for repeat sampling of the same site from year to year to assess the influence of temporal variation. If permanent plots are chosen as representative of the forest type, extrapolation is possible to a larger area.

Plot size is highly significant for species richness data but not so critical for estimating total mushroom production: this was the conclusion after a five year study of fungi in north-eastern Spain (Bonet *et al.* 2004; Martinez de Aragon *et al.* 2007). Many small sample plots at many well-separated sites are considered to be more useful for this kind of work than exhaustive sampling of a few large plots (Palmer and White, 1994; Nekola and White 1999; O'Brien *et al.* 2005). A smaller plot size is considered appropriate if the aim is fruit body production, rather than estimating species richness or biodiversity (O'Brien *et al.* 2005; Ohenoja 1993; Vogt *et al.* 1992).

Although other types of sampling units such as line and belt transects, and plotless (distance) methods such nearest individual, point-quarter, nearest neighbour methods and timed transects have been mentioned in the context of WEF productivity estimates (Kerns *et al*., 2002), they do not seem to have been employed or their use explored to any extent. They are often more technically demanding and time-consuming, especially for less experienced surveyors.

Frequency of sampling and the duration of the monitoring study are important issues in sampling designs for assessing WEFF production. Fungal yields are not reliably estimated in just three years, but over decades of study, as fruit body production varies greatly both spatially and temporally (Ohenoja, 1993; Yamada and Katsuya, 2001). The sampling frequency depends on the persistence of fruitbodies, and since most fruitbodies are transient (days –three weeks), the optimum frequency is daily monitoring. However, since this is rarely practical, most studies have sampled with a frequency of 1-3 weeks. For estimates of production of commercially valuable species, the shorter frequency interval is the more desirable (Vogt *et al*., 1992). Duration of monitoring, particularly for commercially valuable species, should also be greater than one year or harvest season (Vogt *et al*., 1992), and in regions with considerable yearly variations in summer weather like Ireland, three years is the minimum monitoring period.

2.4 Irish forests: the context for WEF in forests

Responsibility for managing the publicly owned forest estate, which comprises 445,315 ha or 7% of the land area, is vested with Coillte, a private limited company, the shares of which are held by the Minister for Agriculture, Fisheries and Food and the Minister for Finance on behalf of the Irish State. Planting policy has focussed in Ireland as elsewhere, on non-native conifers from the Pacific Northwest such as Sitka spruce. Occasionally, beech woods were established on the sites of existing oak woodlands that were cleared or underplanted for the purpose *e.g.* Powerscourt Deerpark, Co. Wicklow and at Union Wood, Co. Sligo.

Irish forests, including broadleaved woodland and conifer plantations, have extended in area from approximately 1% of Ireland at the beginning of the 20th century to almost 10% at present. The Forest Service has undertaken to expand this area to 17% by the year 2030 (Department of Agriculture & Food, 2008). *Picea sitchensis* (Sitka spruce), a non-native species first introduced from the Pacific Northwest, now constitutes 60% of all forest cover (Joyce & O'Carroll, 2002), followed by another Pacific Northwest species *Pinus contorta* (lodgepole pine), then *Picea abies* (Norway Spruce), Japanese larch (*Larix kaempferi*), *Pseudotsuga menziesii* (Douglas Fir) and *Pinus sylvestris* (Scot's pine). These species are ectomycorrhizal and are known to harbour a wide diversity of fungi in their native ranges and in the UK (Humphrey *et al.* 2000). A contemporaneous study of diversity

of macrofungi in Irish forests (O'Hanlon 2011; O'Hanlon and Harrington 2011) found that macrofungal diversity in Sitka spruce and Scot pine sites were comparable to native sessile oak forests. Many of these forests were planted in dense blocks and have been intensively managed as fast-growing crops. Deciduous semi-natural oak forests have not been components of forest expansion; overall deciduous cover is currently at 3%, including hedgerows which make up approximately half of this figure.

A recent inventory of the country for National Parks and Wildlife Service (Perrin *et al.*, 2008) showed that ash (*Fraxinus excelsior*) woods are the most common deciduous woods in Ireland and there has been a big increase in ash plantations. Because ash is non-mycorrhizal, ectomycorrhizal WEF are absent. There is little information about the occurrence of saprotrophic WEF in ash forests, but O'Hanlon's study (2011) indicate that ash forests in Ireland, and plantations in particular, are relatively poor in macrofungi, including saprotrophic WEF. The same applies to stands of non-native sycamore. Beech (*Fagus sylvatica*), a commonly planted non-native tree, is a versatile EM host; macrofungal diversity and diversity of priority WEF is high in continental beechwoods and relatively high diversity is to be expected here. Native sessile and pedunculate oaks, hazel, and birch are all hosts to a wide range of fungi including most of the priority WEF in the case of the oaks (Watling 1984).

2.5 WEF in Ireland

Approximately 55-60 species of forest fungi known to occur in Ireland could be considered edible (Muskett and Malone 1978; 1980; Phillips 2006). Many more are considered not worthwhile, of unknown edibility, hallucinogenic, emetic or poisonous. One specific study on WEF in Ireland is a B.A. thesis (Smith, 2001) that studied the potential value of wild fungi from the culinary viewpoint. Anecdotal evidence suggests that hedgehog fungus *(Hydnum repandum)* is the most common edible species by weight to be found in Irish broadleaved woods, followed by winter chanterelles *(Cantharellus tubaefomis* agg. and C. *aurora*). The only estimates of any WEF production in Ireland concern the golden chanterelle (*Cantharellus aurora* [=*Craterellus lutescens*]), which grows in association with mountain avens in the Burren in a heathland habitat (Harrington 2003; Harrington and Mitchell 2005).

Harvesting of WEF in Irish forests was traditionally rather insignificant, but interest in collecting for culinary use has increased greatly in recent years. This is linked with the increase in demand for organic and fresh local produce, a demand that is strongly backed by groups such as the Slow Food movement. This indicates that there is room for import substitution with our own native wild edible forest mushrooms. There is a demand from restaurants and hotels for organic native wild forest mushrooms that cannot be supplied at present. There is, however, some indication that native produce could satisfy this demand, but the extent of this has yet to be quantified (Smith 2006). Approximately €600,000 worth of fresh or chilled wild mushrooms (excluding truffles and *Agaricus*) and €800,000 worth of frozen wild mushrooms was imported into Ireland in 2005 (Smith, 2006). Most of these were destined for the hotel and restaurant trade, but a significant and increasing proportion is making their way to private consumers. The market for WEF and the volume of imports are likely to increase significantly in the future. Irish consumers are now purchasing species such as oyster mushroom (*Pleurotus ostreatus*) and shiitake (*Lentinula edodes*) at supermarkets for home use, though at relatively high prices.

Up to now, knowledge about native WEF in Ireland was confined to a small group of people or people of mainland Euopean descent, where collecting of WEF is traditional. There is anecdotal evidence that significant numbers of recent eastern European immigrants in Ireland are actively harvesting wild forest mushrooms, and that some are supplying restaurants. They could provide a nucleus of knowledge to promote more widespread harvesting of wild fungi. In comparison with mainland Europe and Scandinavia, the Irish are generally unaware of the culinary and commercial opportunities of forest fungi. In Sweden for example, 13 million kg of edible mushrooms were gathered each year between 1974 and 1977 (Salo, 1995). As well as an enjoyable pursuit, fungi are bartered and sold, supplementing local rural economies. Across Scandinavia the *Everyman's Law* for collecting berries and non-hypogeous fungi applies. This means that one can walk anywhere to collect mushrooms for personal use.

Irish foresters have not been trained study the potential of forest fungi as symbiotic partners advantageous to tree health and timber yields, nor have they considered the potential of Irish forests as sources of WEF. Publications deal almost exclusively with pathogenic fungi such as *Heterobasidion annosum, Armillaria*

mellea and others (McAree, 1975; Joyce & O'Carroll, 2002). (*Armillaria mellea* agg. is considered by some to be edible when young, if well cooked, so it has been included in this study as an edible species.)

3.0 Methods

3.1 Site selection

The hypothesis guiding site selection was that forest type is the principal variable habitat influencing WEF production. In August 2007, a list of potential sites was compiled with reference to several GIS datasets: Forestry Inventory Planning System (FIPS), Geological Survey of Ireland data, Teagasc Soil Map, and National Inventory of Native Woods for the National Parks and Forest Service (Phases I, II and III). Additional data was received from Coillte on forest stands. *A priori* data was gathered on geology, soil, tree type, stand age (where available), aspect, altitude and location. Sites were chosen primarily on the basis of dominant tree type. Sites chosen comprised mature, single-species stands. Thirteen single-species forest types were selected (**Table 3.**1). The numbers of sites dedicated to each forest type were chosen to broadly reflect the relative areas of these forest types in Ireland. In addition to these, a number of sites of mixed stands were also selected: oak mixed 3; beech mixed 3; larch mixed 1; Norway spruce mixed 2. One-hundred and fourteen sites in total were identified, with a geographic spread of 18 counties (**Table 3.2**). Only 76 of these sites were sampled in 2007 due to logistical constraints, the full list was sampled in 2008 and 2009; except for sites that were deleted because of clear-felling, disturbance or accessibility issues.

Table 3.1 Dominant tree species used for designating forest types

Forest type	Dominant tree type	Status	Number of sites
Sitka spruce	(*Picea sitchensis*)	Introduced	19
Scots pine	(*Pinus sylvestris*)	Introduced	17
Beech	(*Fagus sylvatica*)	Introduced	15
Sessile oak	(*Quercus petraea*)	Native	15
Norway spruce	(*Picea abies*)	Introduced	8
Birch	(*Betula pubescens*)	Native	7
Lodgepole pine	(*Pinus contorta*)	Introduced	7
Pedunculate oak	(*Quercus robur*)	Native/Introduced	6
Hazel	(*Corylus avellana*)	Native	3
Japanese larch	(*Larix kaempferi*)	Introduced	3
Silver fir	(*Abies alba*)	Introduced	2
Noble fir	(*Abies nobilis*)	Introduced	1
Western hemlock	(*Tsuga heterophylla*)	Introduced	1
Douglas fir	(*Pseudotsuga menziesii*)	Introduced	1

Forest types which were omitted from the survey include single-species ash (*Fraxinus excelsior*), willow (*Salix* spp.), alder (*Alnus glutinosa*) and sycamore (*Acer pseudoplatanus*) forest types. This is because ash and sycamore are non mycorrhizal; i.e. they do not support ectomycorrhizal fungi on the root system, Similarly, alder and willow support a limited range of ectomycorrhizal fungi that does not include any of the priority edible species (chanterelles, ceps, hedgehog fungus etc.). Strong anecdotal evidence suggests that these forest types are largely bereft of priority WEF.

Table 3.2. Sites sampled in FORESTFUNGI survey. A single plot of a forest type was sampled at each location, exceptions are given in brackets.

Site No.	Forest type	Location	County
1	Beech	Ards	Donegal
2	Beech	Avondale	Wicklow
3	Beech	Bansha	Tipperary
4	Beech	Coole Park	Clare
5	Beech	Cratloe	Clare
6	Beech	Curraghchase (2)	Limerick
7	Beech	Dereen	Kerry
8	Beech	Glenosheen	Limerick
9	Beech	JFK Park	Wexford
10	Beech	Knockman	Tipperary
11	Beech	Lauragh (2)	Kerry
12	Beech	Lismore	Waterford
13	Beech	Mooghaun (2)	Clare
14	Beech	Old Head Wood	Mayo
15	Beech	Powerscourt Deerpark	Wicklow
16	Beech (Mixed)	Derrycarne	Leitrim
17	Beech (Mixed)	Kinnity	Offaly
18	Beech (Mixed)	Union Wood	Sligo
19	Birch	Brackloon (2)	Galway
20	Birch	Cloonee	Kerry
21	Birch	Chevy Chase	Clare
22	Birch	Glendalough	Wicklow
23	Birch	Howth	Dublin
24	Birch	JFK Park	Wexford
25	Birch	Stonepark	Roscommon
26	Douglas Fir	Avondale	Wicklow
27	Hazel	Falsowart	Leitrim
28	Hazel	Lough Eske	Donegal
29	Hazel	Stonepark	Roscommon
30	Larch	Avondale	Wicklow
31	Larch	Glendalough	Wicklow
32	Larch	Union Wood	Sligo
33	Larch (Mixed)	Portumna	Galway
34	Lodgepole Pine	Barnesmore/Killeter	Donegal
35	Lodgepole Pine	Bellacorick	Mayo
36	Lodgepole Pine	Djouce	Wicklow
37	Lodgepole Pine	Dun a Ri	Cavan

Table 3.2
continued

38	Lodgepole Pine	Nephin	Mayo
39	Lodgepole Pine	Quitrent	Cork
40	Lodgepole Pine	Rossacroonaloo	Kerry
41	Noble Fir	Glendine	Laois
42	Norway Spruce	Bansha (2)	Tipperary
43	Norway Spruce	Coole Park	Galway
44	Norway Spruce	Djouce	Wicklow
45	Norway Spruce	Dun a Ri	Cavan
46	Norway Spruce	Glenosheen	Limerick
47	Norway Spruce	Lauragh	Kerry
48	Norway Spruce	Mooghaun	Clare
49	Norway Spruce	Mote park	Roscommon
50	Norway Spruce (Mixed)	Dun a Ri	Cavan
51	Norway Spruce (Mixed)	JFK Park	Wexford
52	Pedunculate Oak	Charleville	Offaly
53	Pedunculate Oak	Garadice Lough	Leitrim
54	Pedunculate Oak	JFK Park	Wexford
55	Pedunculate Oak	Lismore	Waterford
56	Pedunculate Oak	St. John's Wood	Roscommon
57	Pedunculate Oak	Union Wood	Sligo
58	Sessile Oak	Ards	Donegal
59	Sessile Oak	Brackloon	Galway
60	Sessile Oak	Cratloe	Clare
61	Sessile Oak	Cloonee	Kerry
62	Sessile Oak	Derrycunnihy (2)	Kerry
63	Sessile Oak	Devil's Glen	Wicklow
64	Sessile Oak	Glen of the Downs	Wicklow
65	Sessile Oak	Glendalough	Wicklow
66	Sessile Oak	Lauragh	Kerry
67	Sessile Oak	Killarney Muckross	Kerry
68	Sessile Oak	Raheen	Clare
69	Sessile Oak	Rossacroonaloo (2)	Kerry
70	Sessile Oak	Rosturra	Galway
71	Sessile Oak	Tomies (2)	Kerry
72	Sessile Oak	Union Wood (2)	Sligo
73	Oak (Mixed)	Avondale	Wicklow
74	Oak (Mixed)	Glendalough	Wicklow
75	Oak (Mixed)	Old Head Wood	Mayo
76	Scot's Pine	Ards	Donegal
77	Scot's Pine	Avondale	Cork
78	Scot's Pine	Ballyhoura	Tipperary
79	Scot's Pine	Bansha (3)	Tipperary
80	Scot's Pine	Charleville	Offaly
81	Scot's Pine	Cratloe	Clare
82	Scot's Pine	Curraghchase	Limerick
83	Scot's Pine	Djouce	Wicklow
84	Scot's Pine	Dun a Ri	Cavan
85	Scot's Pine	Glen of the Downs	Wicklow
86	Scot's Pine	Glendalough	Wicklow
87	Scot's Pine	JFK Park	Wexford
88	Scot's Pine	Killarney Muckross	Kerry

Table 3.2 continued

89	Scot's Pine	Lauragh	Kerry
90	Scot's Pine	Mooghaun (2)	Clare
91	Scot's Pine	Portumna	Galway
92	Scot's Pine	Slish Wood	Sligo
93	Silver Fir	Dun a Ri	Cavan
94	Silver Fir	JFK Park	Wexford
95	Sitka Spruce	Ards	Donegal
96	Sitka Spruce	Avondale	Wicklow
97	Sitka Spruce	Ballyhoura	Cork
98	Sitka Spruce	Barnesmore/Killeter	Donegal
99	Sitka Spruce	Barnesmore-Killeter (2)	Donegal
100	Sitka Spruce	Chevy Chase	Clare
101	Sitka Spruce	Cratloe	Clare
102	Sitka Spruce	Devil's Glen	Wicklow
103	Sitka Spruce	Djouce	Wicklow
104	Sitka Spruce	Glendine	Laois
105	Sitka Spruce	Glenfarne	Laois
106	Sitka Spruce	Glenosheen	Limerick
107	Sitka Spruce	Lauragh (2)	Kerry
108	Sitka Spruce	Lough Eske	Donegal
109	Sitka Spruce	Mooghaun (2)	Clare
110	Sitka Spruce	Nephin	Mayo
111	Sitka Spruce	Quitrent (2)	Cork
112	Sitka Spruce	Rossacroonaloo	Kerry
113	Sitka Spruce	Union Wood	Sligo
114	Western Hemlock	Ards	Donegal

3.2 Sampling

A number of sampling strategies were considered at the start of the project in August 2007, eventually focussing on the use of permanent plots and a modified version of the plotless point-quarter sampling method (Cottam and Curtis 1956; Worthen and McGuire 1990). The latter method was trialled in a number of sites in the 2007 survey. However, the method was not found to be practical in the field because of the relatively small size of stands, time constraints and the the generally clumped distributions of fruitbodies, which led to extreme overestimation of fruitbody population densities using this method.

Based on this experience and considerations already discussed (see 2.2.1), plot sampling was selected as the basis of a sampling methodology. A single permanent plot was established at the centre of each stand that represented the selected forest type in a site. Plots were rectangular, 50m x 2m and marked by tannelised timber pegs. Each plot was divided into five 2m x 10m subplots. In conifer plantations, plots were orientated across tree rows and across slope to capture data

from the full range of microhabitats (**Fig. 3.1**). A single plot was established in each site, but in some cases (see **Table 3.2**) where stands of a particular forest type were fragmented or discontinuous within the site or where the forest type was extensive (e.g. Derrycunnihy, Tomies, Union Wood), two plots were established within that site. Where possible, a number of sites were located within the same forest or contiguous forests (e.g. Ards Forest, Avondale) in order to minimize travel times and sampling effort. GPS coordinates were obtained for the northernmost corner of each plot using Garmin 3 and GPS72 devices.

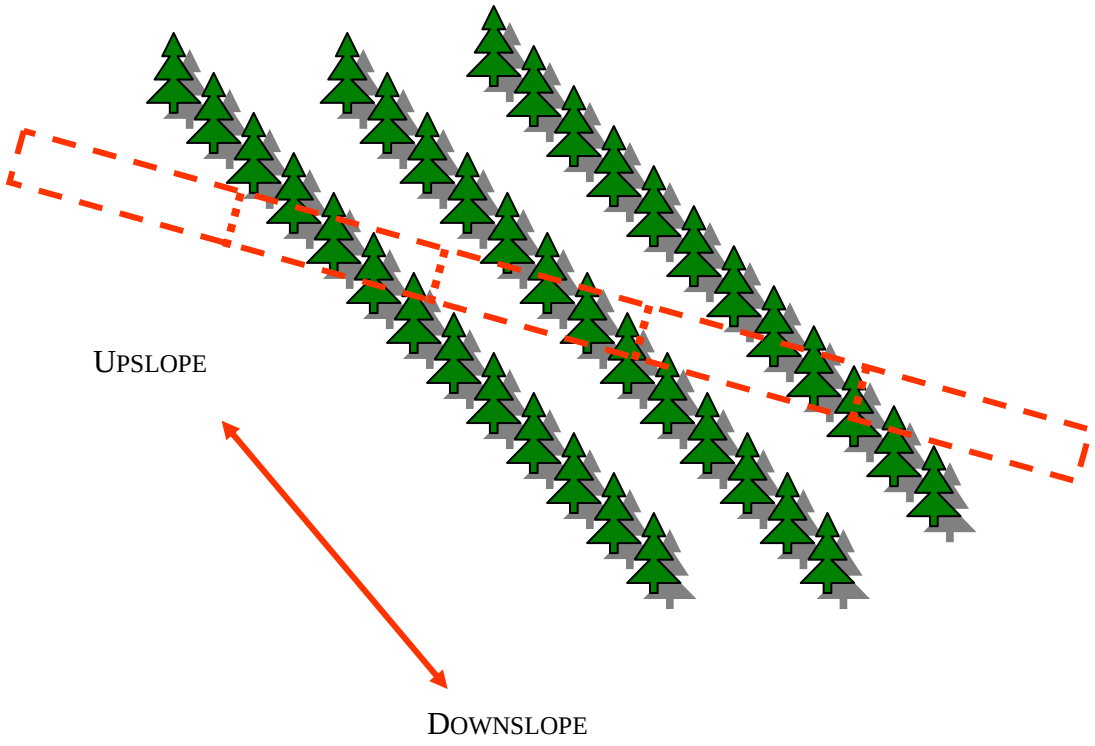

Fig. 3.1. Typical orientation of a 50-m x 2-m strip-plot in conifer plantation

Sampling commenced in September 2007. Sampling was carried out by three surveyors in 2007 and five in 2008 and 2009. Each plot was visited up to five times at approximately two-week intervals, between mid September and mid October in each year of the survey. Fruit bodies of edible were identified with the aid of standard reference works (Phillips,1981, 2007; Bon, 1987; Breitenbach & Kränzlin, 1984-2005; Boertmann, 1995, Heilmann-Clausen, 1998). Nomenclature (common and

scientific names) follows Phillips (2006). Sixteen species were classified as priority species (**Table 4.1**) or those of excellent culinary quality.

The numbers of fruitbodies of each edible fungal species were counted in each subplot of each plot. Fruit bodies were removed to avoid duplicate counting on a subsequent visit. Collected fruit bodies of each species were weighed. Where no WEF were found in plot, a search of the surrounding area, up to 50m from the centre of the plot, was made. Any edible species encountered in this area was noted as a single fruit body (irrespective of abundance or otherwise outside the plot) and the fruit body weight was also recorded. Data was stored on Excel spreadsheets.

3.2.1 Environmental data

Vegetation and soil data were collected once from each plot. Vegetation data included % cover of vascular plant species and bryophytes in plot; basal area of understory/canopy trees overshadowing plot. A subsample of soil was collected by trowel from the A horizon of each of the five subplots in the plot. The samples were bulked to provide a single soil sample from each plot. Samples were air-dried at ambient temperature and sieved. Organic carbon was determined by loss on ignition at 500°C. Soil pH was determined using a glass electrode. Total nitrogen was determined by Kjeldahl (French *et al*. 2008).

3.3 Data analysis

The following parameters were calculated.

3.3.1 Site frequency (%) and visit frequency (%)

were calculated for each species each year:

$\left(S_x/N\right)\times 100 = Sf$; $\left(S_x/V\right)\times 100 = Vf$ Where S_x = number of occurrences of species$_x$; N = total number of sites; V = total number of visits. Average site (Av % *Sf*) and visit frequencies (Av % *Vf*) were calculated as the mean of the three yearly measurements.

3.3.2 Productive sites/plots.

A productive site/plot is one which produces at least one edible species.

3.3.3 Average number of WEF species per plot .

The average number of edible species per plot were calculated as:

$$\left[\sum_{i=1}^{n} S_i\right] \Big/ n$$

Where S_i = total number of fruit bodies in plot$_i$; n= number of plots in a forest type.

3.3.4 Fruitbody totals and averages

(i) Total and average number of fruit bodies per forest type;

$$\sum_{i=1}^{n} F_i \; ; \; \left[\sum_{i=1}^{m} F_i\right] \Big/ m$$

(ii) Total and average weight of fruit bodies per forest type:

$$\sum_{i=1}^{n} W_i \; ; \left[\sum_{i=1}^{m} W_i\right] \Big/ m$$

Where F_i = total number of fruit bodies in plot$_i$; W_i = total number of fruit bodies in plot$_i$; ; m= total number of plots sampled 2007-2009 in a forest type.

3.3.5 Production estimates of individual species

(i) Total number of fruitbodies of species$_x$ per forest type

$$= \sum_{i=1}^{m} f_{xi}$$

(ii) Total fresh weight (g) of fruitbodies of species$_x$ per forest type:

$$= \sum_{i=1}^{m} w_{xi}$$

(iii) Estimated fresh weight production (kg/h/y) of fruitbodies of species$_x$ per forest type:

$$= \left[\sum_{i=1}^{m} w_{xi}\right] \Big/ (m)10$$

Where f_{xi} = number of fruit bodies of species$_x$ in plot$_i$; w_{xi} = weight of fruit bodies of species$_x$ in plot$_i$; m= total number of plots sampled 2007-2009 in a forest type.

3.3.6 Priority and non-priority WEF: production estimates

Estimates were made of production of priority species, non-priority species and all species for each forest type; standard deviations and 95% confidence limits were calculated for the mean productivity (kg/ha/y) of all the plots in each forest type.

(i) Estimated fresh weight production (kg/ha/y) of fruitbodies of priority WEF per forest type :

$$= \left[\sum_{i=1}^{m} P_i \right] \Big/ (m)10$$

(ii) Estimated fresh weight production (kg/ha/y) of fruitbodies of non-priority WEF per forest type

$$= \left[\sum_{i=1}^{m} NP_i \right] \Big/ (m)10$$

(iii) Estimated fresh weight production (kg/ha/y) of fruitbodies of all WEF per forest type:

$$= \left[\sum_{i=1}^{m} A_i \right] \Big/ (m)10$$

Where P_i = weights of all priority species in plot$_i$; NP_i = weights of all non-priority species in plot$_i$; A_i = weights of all species in plot$_i$; ; m= total number of plots sampled 2007-2009 in a forest type

4.0 Results

4.1 WEF found: general patterns

Forty-four WEF species were encountered over the course of the study (**Table 4.1**). Species that might have been expected, but were not encountered include: oak bolete (*Boletus appendiculatus*), summer bolete (*B. reticulatus*), larch bolete (*Suillus grevillei*), giant puffball (*Calvatia gigantea*), parasol mushroom (*Macrolepiota procera*), morel (*Morchella esculenta*), St. George's mushroom (*Calocybe gambosa*), chicken of the woods (*Laetiporus sulphureus*), branching oyster (*Pleurotus cornucopiae*), cauliflower fungus (*Sparassis crispa*) and summer truffle (*Tuber aestivum*). Morels and St. George's mushroom emerge in springtime and although some limited sampling was carried out at this time, these species were not found. Summer truffles are hypogeous fungi and were not systematically searched for in any of the sites because of limited time and resources. Sixteen species were designated as *priority species* based on their superior culinary value (marked "P" in **Table 4.2**)

Table 4.1. List of WEF species found in the survey 2007-2009. M = ectomycorrhizal species; P = priority species (excellent culinary quality); ? = edible but adverse effect reported in some consumers. Nomenclature follows Phillips (2006).

The Prince	*Agaricus augustus*		P
Wood Mushroom	*Agaricus sylvaticus*		P
Tawny Grisette	*Amanita fulva*	M	
The Blusher	*Amanita rubescens*	M	
Honey Fungus	*Armillaria mellea*		
Jew's Ear Fungus	*Auricularia auricula-judae*		
Bay Bolete	*Boletus badius*	M	P
Cep	*Boletus edulis*		P
Suede Bolete	*Boletus subtomentosus*	M	?
Trumpet or Winter Chanterelle	*Cantharellus tubaeformis* agg.	M	P
Chanterelle (or Girolle)	*Cantharellus cibarius*	M	P
Golden Chanterelle	*Cantherellus aurora*	M	P
Monkshead	*Clitocybe geotropa*		
Common Inkcap	*Coprinus atramentarius*		
Lawyer's Wig	*Coprinus comatus*		
Horn of Plenty (or Trompette des Morts)	*Craterellus cornucopioides*	M	P
Beefsteak Fungus	*Fistulina hepatica*		P
Velvet Shank	*Flammulina velutipes*		
Hen of the Woods	*Grifola frondosa*		
Wood Hedgehog Fungus	*Hydnum repandum*	M	P
Red Hedgehog Fungus	*Hydnum rufescens*	M	P

Table 4.1 continued…

Meadow Waxcap	*Hygrocybe pratensis*		
Amethyst Deceiver	*Laccaria amethystina*	M	
Bicoloured Deceiver	*Laccaria bicolor*	M	
Deceiver	*Laccaria laccata*	M	
Scurfy Deceiver	*Laccaria proxima*	M	
Saffron Milk Cap	*Lactarius deliciosus*	M	P
False Saffron Milkcap	*Lactarius deterrimus*	M	P
Slate Bolete	*Leccinum duriusculum*	M	
Birch Bolete	*Leccinum scabrum*	M	
Orange Birch Bolete	*Leccinum versipelle*	M	
Tawny Funnel	*Lepista flaccida*		?
Wood Blewit	*Lepista nuda*		P
Common Puffball	*Lycoperdon perlatum*		
Stump Puffball	*Lycoperdon pyriforme*		
Shaggy Parasol	*Macrolepiota rhacodes*		
Porcelain Fungus	*Oudemansiella mucida*		
Oyster Mushroom	*Pleurotus ostreatus*		P
The Goblet	*Pseudoclitocybe cyathiformis*		
Charcoal Burner	*Russula cyanoxantha*	M	P
Ochre Brittlegill	*Russula ochroleuca*	M	
Scarlet Elfcup	*Sarcoscypha aurantia*		
Bovine Bolete	*Suillus bovinus*	M	
Slippery Jack	*Suillus luteus*	M	

Hydnum repandum, the wood hedgehog fungus (a priority species), was the most frequently encountered species (**Table 4.2**). It was found in 24.3% of the forest sites and on 15.4% on average of the visits over the 3-year sampling period. Chanterelle (*Cantharellus cibarius*) the top priority species, was also relatively frequent; it was found in 22% of the sites and on 10% of the visits on average over the 3-year period. The frequency values were also broadly mirrored by the numbers and weights of fruit bodies of each species (**Table 4.3**). Winter chanterelle (*Cantharellus tubaeformis*) was most prolific in terms of numbers of fruit bodies, followed by hedgehog fungus and chanterelle (*Cantharellus cibarius*). Winter chanterelle and hedgehog fungus were also the most productive in weight terms; honey fungus replaced chanterelle as the third most productive species in weight terms because of its larger and heavier fruit bodies.

Table 4.2. Site frequency (% of sites in which a species was found) and visit frequency (% of sampling visits on which a species was found) of the principal WEF species in each of the years 2007-2009, and yearly average (3-Y). Only those species with a site frequency equal or greater than 2% are shown (for full list see Table 1-A in Appendix).

Species	Site frequency %				Visit frequency %			
	2007	**2008**	**2009**	**3-Y**	**2007**	**2008**	**2009**	**3-Y**
Hydnum repandum	28.4	23.9	20.6	24.3	21.9	14.9	9.4	15.4
Laccaria laccata	18.9	21.4	26.5	22.3	11.2	8.9	11.0	10.4
Laccaria amethystina	13.5	18.8	24.5	18.9	7.5	8.2	9.6	8.4
Cantharellus cibarius	10.8	13.7	15.7	13.4	5.3	6.8	7.9	6.7
Cantharellus tubaeformis agg.	9.5	14.5	13.7	12.6	7.0	7.7	7.4	7.4
Armillaria mellea	10.8	6.8	19.6	12.4	4.8	2.6	6.5	4.6
Russula cyanoxantha	13.5	6.8	14.7	11.7	5.9	2.1	5.5	4.5
Russula ochroleuca	1.4	3.4	16.7	7.1	1.1	2.3	10.3	4.6
Boletus badius	10.8	4.3	2.9	6.0	5.3	1.4	0.7	2.5
Lycoperdon perlatum	5.4	4.3	7.8	5.8	2.7	1.9	2.9	2.5
Lactarius deliciosus	6.8	5.1	3.9	5.3	2.7	1.9	1.2	1.9
Amanita rubescens	2.7	0.9	11.8	5.1	1.1	0.2	3.1	1.5
Boletus edulis	8.1	3.4	2.9	4.8	5.3	0.9	0.7	2.3
Hydnum rufescens	1.4	5.1	7.8	4.8	0.5	1.9	4.6	2.3
Lactarius deterrimus	5.4	3.4	3.9	4.2	2.1	0.9	1.4	1.5
Lepista flaccida	4.1	2.6	3.9	3.5	2.7	0.9	1.2	1.6
Suillus bovinus	2.7	2.6	3.9	3.1	1.1	0.7	1.2	1.0
Lepista nuda	4.1	1.7	2.9	2.9	1.6	0.5	1.4	1.2
Laccaria proxima	2.7	2.6	2.9	2.7	1.1	0.7	0.7	0.8
Sarcoscypha aurantia	0.0	0	7.8	2.6	0.0	0	3.6	1.2
Lycoperdon pyriforme	2.7	0	4.9	2.5	1.1	0	2.2	1.1
Oudemansiella mucida	0.0	2.6	4.9	2.5	0.0	0.9	1.7	0.9

Table 4.3. Numbers and weights (g) of fruit bodies of the principal WEF species in each of the years 2007-2009, and yearly average (3-Y). Only those species with a with a 3-year average of 10 or more fruitbodies are shown are shown (for full list see Table 2-A in Appendix).

Species	Total Number of Fruitbodies				Total Weight (g) of Fruitbodies			
	2007	**2008**	**2009**	**3-Y**	**2007**	**2008**	**2009**	**3-Y**
Cantharellus tubaeformis agg.	1199	2805	1471	1825.0	5861.2	16180	3023	8354.7
Hydnum repandum	536	842	141	506.3	8657.9	9816	1694	6722.6
Cantharellus cibarius	57	630	760	482.3	527.3	2558	2350	1811.8
Armillaria mellea	437	69	508.0	338.0	3215.1	605	4107	2642.4
Laccaria amethystina	111	658	230	333.0	291.0	2016	292.6	866.5
Laccaria laccata	152	355	183	230.0	639.0	1344	222.2	735.1
Hydnum rufescens	3	98	318	139.7	15.0	654	1461	710.0
Russula ochroleuca	14	111	281	135.3	190.0	2705	1355	1416.7
Lepista flaccida	50	247	29	108.7	535.0	1378	338	750.3
Oudemansiella mucida	0	21	157	59.3	0.0	103	152	85.0
Suillus bovinus	112	5	55	57.3	810.0	81	1007	632.7
Cantharellus aurora	0	0	31	10.3	0.0	0	37	12.3
Lycoperdon perlatum	10	81	48	46.3	40.0	560	166	255.3
Russula cyanoxantha	17	13	57	29.0	435.4	360	414	403.1
Lycoperdon pyriforme	8	0	76	28.0	44.0	0	50	31.3
Craterellus cornucopioides	61	9	0	23.3	595.0	70	0	221.7
Lepista nuda	22	9	36	22.3	347.0	137	29	171.0
Lactarius deliciosus	16	19	17	17.3	392.3	413	447	417.4
Hygrocybe pratensis	0	7	35	14.0	0.0	39	76	38.3
Auricularia auricula-judae	4	0	36.0	13.3	8.0	0	84	30.7
Boletus edulis	21	12	5.0	12.7	917.8	1400	323	880.3
Boletus badius	13	14	5.0	10.7	649.1	435	254	446.0
Sarcoscypha aurantia	0	0	30	10.0	0.0	0	160	53.3

4.2 WEF profile of the different forest types

One hundred and fourteen sites were visited over the course of the 3-year survey (see Table 3.1). These comprised 14 different forest types with a single dominant species in each and 4 mixed types. Sitka spruce was most represented of the forest types (19 sites) followed Scot's pine (17), sessile oak and beech (15 sites each). Not all sites were visited in each year of the survey; 74 sites were visited in 2007, 116 in 2008 and 102 in 2009. A total of 187 site visits were made in 2007 (average 2.5 per site), 427 in 2008 (3.7 per site) and 417 in 2009 (4.1 per site) (**Table 4.4**). The mean numbers of visits per plot were 2.4 in 2007, 3.7 in 2008 and 4.1 in 2009. The percentage of

Table 4.4. Site and visit data for different forest sites.

	Year	Beech	Beech (Mixed)	Birch	Douglas Fir	Hazel	Larch	Larch-Scots Pine	Lodgepole Pine	Noble Fir	Norway Sp (Mixed)	Norway Spruce	Oak (Pedunculate)	Oak (Sessile)	Oak (Mixed)	Scots Pine	Silver Fir	Sitka Spruce	W. Hemlock	Total
Number of sites	2007	9	2	9	1	2	2	-	4	-	2	3	3	13	1	9	1	12	1	74
Number of sites	2008	14	2	7	1	2	3	1	6	1	2	9	5	16	3	18	2	22	1	116
Number of sites	2009	12	3	7	-	3	3	1	6	-	2	4	3	15	3	14	2	23	1	102
Number of visits	2007	22	3	20	3	3	7	-	13	-	7	3	10	27	3	26	4	31	5	187
Number of visits	2008	50	11	28	3	9	12	6	20	6	6	32	31	50	8	58	6	87	4	427
Number of visits	2009	53	12	28	-	6	12	4	24	-	8	17	12	60	12	61	8	96	4	417
Number of productive sites	2007	9	2	8	1	2	2	-	3	-	2	3	2	10	1	8	1	10	0	64
Number of productive sites	2008	13	1	6	0	2	2	0	0	1	0	7	4	10	2	15	1	14	1	79
Number of productive sites	2009	10	3	7	-	3	2	1	1	-	1	4	1	13	3	14	2	20	1	86
Productive sites %	2007	100	100	89	100	100	100	-	75	-	100	100	67	77	100	100	83	89	0	86
Productive sites %	2008	87	50	86	0	100	67	0	0	100	0	85	80	63	67	83	50	64	100	68
Productive sites %	2009	83	100	100	-	100	67	100	17	-	50	100	33	87	100	100	100	87	100	84

productive sites, where productive is defined as yielding at least one edible species, was highest in Scots pine and was also relatively high in Sitka spruce and Norway spruce (althought the volumes were low in the last) (**Table 4.4**). Beech, Scots pine and Sitka spruce forest produced the greatest variety of edible species in total, and of priority species (**Table 4.5**).

Table 4.5. Diversity of priority WEF and total WEF in the different forest types

Forest type	Total Species	Priority Species
Beech	31	12
Scot pine	25	11
Sitka spruce	24	11
Sessile oak	19	10
Norway spruce	18	9
Birch	14	6
Silver fir	12	4
Oak (Mix)	10	5
Beech (Mix)	9	3
Hazel	8	3
Pedunculate oak	7	3
Lodgepole pine	6	1
Larch	5	1
Norway spruce (Mix)	5	2
W. Hemlock	3	1
Douglas fir	1	0

The relative proportions by weight of WEF found in each of the major forest types are shown in **Tables 4.6-4.15.**

4.2.1 Beech forest

The most diverse range of fungi (31 species over the 3 years) was found in beech forest, including 12 of the 16 priority species (**Table 4.6**). Wood hedgehog fungus (*H. repandum*), winter chanterelle (*C. tubaeformis*), chanterelle (*C. cibarius*), charcoal burner (*Russula cyanoxantha*), red hedgehog fungus and the deceivers (*Laccaria laccata* and *L. amethystina*) were the most abundant edible types by weight in beech forest. Wood hedgehog fungus contributed the bulk of WEF biomass in 2008 and 2009, but was less important in 2009. The uncommon trompette des morts (*Craterellus cornucopioides*) and hen of the woods (*Grifola frondosa*) were confined to this forest type.

4.2.2 Sessile and pedunculate oak forest

A smaller range of WEF was found in sessile oak (19 species) and pedunculate oak (7 species) over the 3-year sampling period compared to beech forest (**Table 4.7** and **Table 4.8**). The comparatively small number of species recorded in the pedunculate oak forest type is probably related to the smaller number of sites (3 vs. 13) sampled in this forest type. Ten priority species were recorded in sessile oak forest. Ceps (*Boletus edulis*) were the most abundant by weight in sessile oak forest but not by numbers because of their large individual fruit body size. Honey fungus (*Armillaria mellea*) and the priority species chanterelle and wood hedgehog fungus were the most abundant species in terms of fruit body numbers, site frequency and visit frequency in this forest type. In pedunculate oak forest, the most abundant species by weight and numbers was wood hedgehog fungus, which was one of only 3 priority species recorded in this forest type.

Table 4.6. WEF species found in beech forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1)	(2)	(3)	(4)	(5)	(6)
	2007	2008	2009	Av.% Wt	Av % Sf	Av % Vf
Hydnum repandum	62.2	40.9	10.2	37.8	11.5	16.9
Cantharellus tubaeformis agg.	-	19.8	22.4	14.1	5.2	5.2
Cantharellus cibarius	6.0	7.9	8.1	7.3	5.4	6.0
Armillaria mellea	-	0.8	16.9	5.9	3.0	3.4
Grifola frondosa	8.4	6.8	-	5.1	2.0	3.5
Hydnum rufescens	0.3	3.5	9.3	4.3	5.7	5.1
Russula cyanoxantha	3.1	3.3	6.4	4.3	11.6	9.6
Craterellus cornucopioides	9.8	1.4	-	3.7	2.0	1.7
Laccaria amethystina	0.6	4.9	4.5	3.4	11.8	12.1
Boletus badius	2.9	-	4.6	2.5	3.5	3.3
Lepista nuda	3.6	1.7	-	1.8	3.8	2.9
Boletus edulis	-	3.9	0.6	1.5	1.6	1.2
Laccaria laccata	1.5	2.3	0.5	1.5	8.8	8.4
Russula ochroleuca	-	-	3.6	1.2	2.0	2.3
Agaricus sylvaticus	-	-	2.6	0.9	0.7	1.0
Lactarius deterrimus	-	0.4	2.1	0.8	1.6	1.5
Oudemansiella mucida	-	1.2	1.2	0.8	3.9	3.9
Clitocybe geotropa	1.1	1.0	-	0.7	2.0	1.7
Lactarius deliciosus	-	-	2.0	0.7	1.6	1.2
Suillus bovinus	-	-	2.0	0.7	1.4	0.7
Amanita fulva	-	-	1.0	0.3	0.7	0.3

Lycoperdon pyriforme	0.2	-	0.4	0.2	1.8	1.9
Suillus luteus	-	-	0.5	0.2	0.7	0.3
Lycoperdon perlatum	0.1	-	0.3	0.1	1.8	1.2
Sarcoscypha aurantia	-	-	0.4	0.1	0.7	0.7
Auricularia auricular-judae	0.1	-	0.2	0.1	1.8	1.5
Lepista flaccida	-	0.2	-	0.1	1.0	0.9
Amanita rubescens	-	-	0.1	0.05	0.7	0.3
Hygrocybe pratensis	-	-	0.1	0.03	0.7	0.3
Pseudoclitocybe cyathiformis	0.05	-	-	0.02	1.1	0.9
Leccinum duriusculum	-	-	-	-	-	-

Table 4.7. WEF species found in sessile oak forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) **2007**	**(2)** **2008**	**(3)** **2009**	**(4)** **Av. % Wt.**	**(5)** **Av. % Sf**	**(6)** **Av. % Vf**
Boletus edulis	27.4	35.5	15.0	26.0	17.1	11.1
Armillaria mellea	20.8	4.3	26.1	17.0	15.8	6.3
Cantharellus cibarius	9.1	12.0	20.5	13.8	33.3	16.3
Hydnum repandum	9.1	14.5	7.4	10.3	34.3	23.6
Cantharellus tubaeformis agg.	6.5	3.8	8.3	6.2	17.7	7.3
Laccaria laccata	-	12.3	0.2	4.2	8.5	3.1
Laccaria amethystina	5.9	4.5	0.9	3.8	24.9	9.6
Lepista nuda	10.1	-	-	3.4	2.6	1.2
Hydnum rufescens	-	2.8	6.0	2.9	6.5	3.0
Russula cyanoxantha	5.8	0.9	0.6	2.4	9.1	4.9
Russula ochroleuca	-	3.7	3.1	2.3	6.5	3.4
Fistulina hepatica	-	-	6.0	2.0	2.2	0.6
Suillus bovinus	4.5	-	-	1.5	2.6	1.2
Boletus badius	-	3.9	-	1.3	2.1	0.7
Leccinum versipelle	-	-	3.2	1.1	2.2	0.6
Leccinum scabrum	-	-	2.1	0.7	2.2	0.6
Laccaria proxima	0.4	1.2	-	0.5	6.7	2.6
Suillus luteus	-	-	0.7	0.2	2.2	0.6
Lactarius deliciosus	0.6	-	-	0.2	2.6	1.2

Table 4.8. WEF species found in pedunculate oak forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Clitocybe geotropa	-	-	100.0	33.3	11.1	2.8
Fistulina hepatica	11.8	-	-	3.9	11.1	6.7
Hydnum repandum	88.2	88.7	-	59.0	17.8	24.1
Hydnum rufescens	-	1.1	-	0.4	6.7	1.1
Laccaria amethystina	-	6.9	-	2.3	6.7	5.4
Laccaria laccata	-	2.7	-	0.9	13.3	3.2
Lycoperdon perlatum	-	0.6	-	0.2	6.7	2.2

4.2.3 Birch forest

Fourteen edible species, including six priority species were recorded in total from birch forest over the sampling period. Honey fungus was the most abundant species by weight and fruitbody numbers, followed by the priority species, wood hedgehog fungus, winter chanterelle, chanterelle and red hedgehog fungus (*H. rufescens*) (**Table 4.9**).

Table 4.9. WEF species found in birch forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Armillaria mellea	84.2	11.0	40.9	26.0	17.1	11.1
Hydnum repandum	2.8	12.5	0.6	17.0	15.8	6.3
Cantharellus tubaeformis agg.	-	40.4	-	13.8	33.3	16.3
Cantharellus cibarius	7.9	12.5	11.7	10.3	34.3	23.6
Laccaria laccata	0.9	23.5	17.5	6.2	17.7	7.3
Hydnum rufescens	-	-	7.8	4.2	8.5	3.1
Leccinum duriusculum	0.5	-	1.9	3.8	24.9	9.6
Sarcoscypha aurantia	-	-	6.5	3.4	2.6	1.2
Amanita rubescens	-	-	1.9	2.9	6.5	3.0
Laccaria bicolor	1.4	-	1.3	2.4	9.1	4.9
Russula cyanoxantha	0.5	-	-	2.3	6.5	3.4
Craterellus cornucopioides	0.5	-	-	2.0	2.2	0.6
Laccaria proxima	1.4	-	-	1.5	2.6	1.2
Auricularia auricula-judae	-	-	9.7	1.3	2.1	0.7

4.2.4 Scots pine forest

This forest type was the second-most diverse in edible fungal species after beech forest, yielding 25 different species in total over the sampling period, including 11 priority species (**Table 4.10**). Winter chanterelle (*C. tubaeformis* agg.) dominated the edible fungal assemblage; on average per year, this species constituted 66% of the total fruit body numbers and 54% of the total fruitbody weight in this forest type. It was also found on almost 55% of visits to Scots pine sites on average per year. Wood hedgehog fungus and chanterelle were next in importance by weight; hedgehog fungus was more widely distributed among the Scots pine sites than chanterelles however.

Table 4.10. Edible fungal species found in Scots pine forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Cantharellus tubaeformis agg.	66.0	74.0	23.1	54.4	26.2	54.5
Hydnum repandum	25.8	12.5	-	12.8	32.1	15.7
Cantharellus cibarius	-	6.1	26.0	10.7	12.9	16.1
Suillus bovinus	-	0.4	15.6	5.3	9.0	7.0
Lactarius deliciosus	2.6	1.7	6.3	3.5	15.1	8.6
Hydnum rufescens	-	0.9	7.3	2.7	2.4	3.6
Clitocybe geotropa	-	-	7.5	2.5	0.5	3.2
Laccaria amethystina	1.8	3.6	0.9	2.1	19.2	13.8
Armillaria mellea	-	-	3.1	1.0	2.7	7.7
Amanita rubescens	-	-	2.7	0.9	1.6	7.5
Laccaria laccata	1.8	0.7	0.1	0.9	12.2	5.5
Russula cyanoxantha	0.5	0.2	1.6	0.8	9.9	7.5
Oudemansiella mucida	-	-	1.8	0.6	1.1	2.6
Russula ochroleuca	-	-	1.6	0.5	4.4	10.1
Auricularia auricula-judae	-	-	0.6	0.2	0.5	2.5
Cantharellus aurora	-	-	0.6	0.2	1.1	5.0
Boletus badius	0.6	-	-	0.2	3.7	0.1
Suillus luteus	0.4	-	0.2	0.2	0.5	2.5
Lycoperdon perlatum	0.3	-	0.1	0.1	4.8	4.9
Amanita fulva	-	-	0.3	0.1	0.5	2.4
Lactarius deterrimus	0.1	-	0.1	0.1	4.3	2.4
Fistulina hepatica	-	-	0.1	0.04	0.5	2.4
Laccaria proxima	-	-	0.1	0.04	0.5	2.4
Sarcoscypha aurantia	-	-	0.1	0.04	1.1	2.4
Boletus edulis	-	-	0.05	0.02	0.5	2.4

Saffron milkcap (*Lactarius deliciosus*), false saffron milkcap (*L. deterrimus*) and bovine bolete (*Suillus bovinus*) all associates of conifers, particularly pines, were found much more frequently in this forest type than elsewhere. Golden chanterelle (*C. aurora*), which is much less common the related chanterelle species, was found only in this forest type, in a single site.

4.2.5 Sitka spruce

Similar levels of diversity were found in Sitka spruce forest. Twenty-four WEF species were recorded over the sampling period and 11 of these were priority species. Four species, honey fungus, ochre brittlegill (*Russula ochroleuca*), winter chanterelle and wood hedgehog fungus dominated the WEF assemblage (**Table 4.11**). Ceps and chanterelles were found, but at low site frequency (1 and 3 Sitka sites respectively). Both of these mycorrhizal species are likely to have associated solely with Sitka spruce in these sites. Deceivers (*Laccaria laccata* and *L. amethystina*) were common in this forest type, although they contributed little to the overall fruitbody biomass. False saffron milkcap occurred in five Sitka sites, but at low biomass, and saffron milkcap was found in one site, probably in association with a Scots pine near the plot in that site.

Table 4.11. WEF species found in Sitka spruce forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) **2007**	**(2)** **2008**	**(3)** **2009**	**(4)** **Av. % Wt.**	**(5)** **Av. % Sf**	**(6)** **Av. % Vf**
Armillaria mellea	34.2	-	18.5	26.3	8.5	2.8
Russula ochroleuca	-	24.4	16.8	20.6	13.2	9.2
Cantharellus tubaeformis agg.	7.1	37.0	16.9	20.3	8.5	7.6
Hydnum repandum	28.8	9.1	22.9	20.3	13.1	6.1
Hydnum rufescens	-	-	8.4	8.4	1.4	1.4
Boletus edulis	7.8	-	-	7.8	2.8	2.2
Amanita rubescens	1.5	-	5.1	3.3	10.0	3.2
Boletus badius	4.9	2.5	2.3	3.3	12.8	4.3
Laccaria amethystina	0.4	7.1	1.4	3.0	17.3	7.9
Lycoperdon perlatum	0.2	6.7	0.6	2.5	11.5	5.4
Laccaria laccata	1.3	4.1	1.4	2.2	27.6	9.7
Cantharellus cibarius	-	3.6	0.5	2.1	4.5	2.3
Lactarius deliciosus	-	2.0	-	2.0	1.5	0.4
Lactarius deterrimus	0.9	2.4	1.9	1.7	10.0	3.6

Table 4.11 continued…

Lepista flaccida	1.9	0.9	-	1.4	7.1	3.6
Russula cyanoxantha	0.3	-	1.7	1.0	7.1	2.1
Sarcoscypha aurantia	-	-	1.0	1.0	1.4	0.7
Lycoperdon pyriforme	-	-	0.4	0.4	1.4	0.7
Pseudoclitocybe cyathiformis	-	-	0.3	0.3	1.4	0.3
Agaricus sylvaticus	0.1	-	-	0.1	2.8	1.1
Laccaria proxima	-	-	0.02	0.02	1.4	0.3
Macrolepiota rhacodes	-	-	-	0.01	2.3	0.6
Pleurotus ostreatus	-	-	-	0.01	1.4	0.3
Suillus luteus	-	-	-	0.01	2.8	1.1

4.2.6 Norway spruce

Eighteen WEF species in total were recording from the nine Norway spruce forest sites, including 10 priority species. By weight, winter chanterelle was the most abundant species on average per year over the sampling period, followed by honey fungus and wood and red hedgehog fungus (**Table 4.12**). Ochre brittlegill and deceiver were also important in this forest type. Chanterelle occurred in small numbers in two sites in 2007 and 2008, and cep was found in one site in 2008. Wood hedgehog was the most widely distributed edible species in this forest type, occurring in 25% to 40% of sites depending on year. It was also the most frequently encountered, being found on 18% to 33% of visits depending on year.

4.2.7 Larch

Only five WEF species were recorded in total over the three years from the three pure larch forest sites. The tree pathogen honey fungus (*Armillaria mellea*) and the ectomycorrhizal species, deceiver (*L. laccata*) were themost abundant by weight in this forest type (**Table 4.13**). Bay bolete (*Boletus badius*) a priority species, was found in two of the three years.

4.2.8. Lodgepole pine

Only six WEF species were recorded from the six lodgepole pine forest sites, including one priority species, bay bolete (**Table 4.14**). Tawny funnel cap (*Lepista flaccida*), an edible species of mediocre quality, was the most abundant species by weight, on average. Fruiting was very sporadic in lodgepole compared to other forest types; no edible species were recorded from any of the lodgepole sites in 2008, and only one in 2009, for example.

Table 4.12. WEF species found in Norway spruce forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Cantharellus tubaeformis agg.	75.4	34.6	-	36.7	14.4	13.2
Armillaria mellea	-	-	65.1	21.7	8.3	2.0
Hydnum repandum	22.5	28.4	-	17.0	32.8	25.2
Hydnum rufescens	-	13.8	11.6	8.5	3.3	1.0
Russula ochroleuca	-	-	13.9	4.6	8.3	5.9
Russula cyanoxantha	-	9.0	-	3.0	6.7	2.1
Laccaria amethystina	-	8.7	-	2.9	10.0	3.1
Agaricus augustus	-	-	4.7	1.6	3.3	2.1
Agaricus sylvaticus	-	4.2	-	1.4	8.3	2.0
Coprinus atramentarius	-	-	2.4	0.8	8.3	2.0
Cantharellus cibarius	2.1	-	-	0.7	14.4	12.2
Sarcoscypha aurantia	-	-	0.7	0.2	8.3	3.9
Lepista flaccida	-	-	0.6	0.2	8.3	2.0
Amanita rubescens	-	-	0.4	0.1	8.3	2.0
Lactarius deterrimus	-	-	0.4	0.1	8.3	3.0
Lycoperdon pyriforme	-	-	0.2	0.1	8.3	2.0
Laccaria laccata	-	-	0.1	0.0	16.7	3.9
Boletus edulis	-	-	0.0	0.0	3.3	1.0

Table 4.13. WEF species found in larch forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Armillaria mellea	6.5	60.2	33.9	33.5	38.9	10.3
Laccaria laccata	42.1	10.2	20.1	24.1	50.0	18.7
Boletus badius	37.4	29.6	-	22.3	27.8	12.3
Leccinum scabrum	-	-	26.6	8.9	22.2	5.6
Laccaria bicolor	14.0	-	1.0	5.0	27.8	7.5

Table 4.14. WEF species found in lodgepole pine forest sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Lepista flaccida	-	-	100.0	33.3	8.3	4.2
Russula ochroleuca	42.2	-	-	14.1	12.5	7.7
Amanita rubescens	31.1	-	-	10.4	12.5	3.8
Boletus badius	12.0	-	-	4.0	12.5	3.8
Boletus subtomentosus	7.8	-	-	2.6	12.5	3.8
Lycoperdon pyriforme	6.9	-	-	2.3	12.5	3.8

4.2.9 Hazel

Eight WEF species were recorded in total from the three hazel sites, including chanterelle, wood hedgehog fungus and charcoal burner (**Table 4.15**). Deceiver was the most abundant edible species in terms of fruit body weight.

Table 4.15. Edible fungal species found in hazel sites in each year of survey. Figures are percentages of the total weight of fruit bodies per year contributed by each species (cols 1-3); average % weight 2007-2009 (4); average site frequency 2007-2009 (5); average visit frequency 2007-2009 (6).

	(1) 2007	(2) 2008	(3) 2009	(4) Av. % Wt.	(5) Av. % Sf	(6) Av. % Vf
Laccaria laccata	87.6	15.7	4.0	48.2	35.8	55.6
Cantharellus cibarius	-	63.1	-	19.4	21.0	16.7
Lepista flaccida	-	-	88.4	14.9	29.5	11.1
Laccaria amethystina	-	4.4	1.8	7.6	2.1	27.8
Hydnum repandum	12.4	16.2	-	6.9	9.5	33.3
Laccaria proxima	-	0.7	-	1.3	0.2	27.8
Leccinum scabrum	-	-	4.3	0.9	1.4	11.1
Russula cyanoxantha	-	-	1.4	0.9	0.5	11.1

4.3 Species distributions among forest types

Deceiver (*Laccaria laccata*), a WEF species of mediocre quality, was the most ubiquitous species because it was found in all but one (lodgepole pine forest) of the 11 major forest types. It was also found consistently across all three years in all forest types except pedunculate oak and Norway spruce, where it was present on only one year. The priority edible species wood hedgehog fungus and chanterelle were also

ubiquitous in the major forest types; both were present in 8 major forest types and both were absent from larch and lodgepole pine. Honey fungus (*Armillaria mellea*) was also common in all forest types, because it is a pathogen that attacks a wide range of tree types. Most of the priority species showed no marked preference for forest types (**Table 4.16**). Principal components analysis (PCA) was carried out using reduced species list composed of species that occurred more than once during sampling. PCA did not detect any significant differentitation between the forest types in respect of the distribution of these species (**Fig. 4.1**).

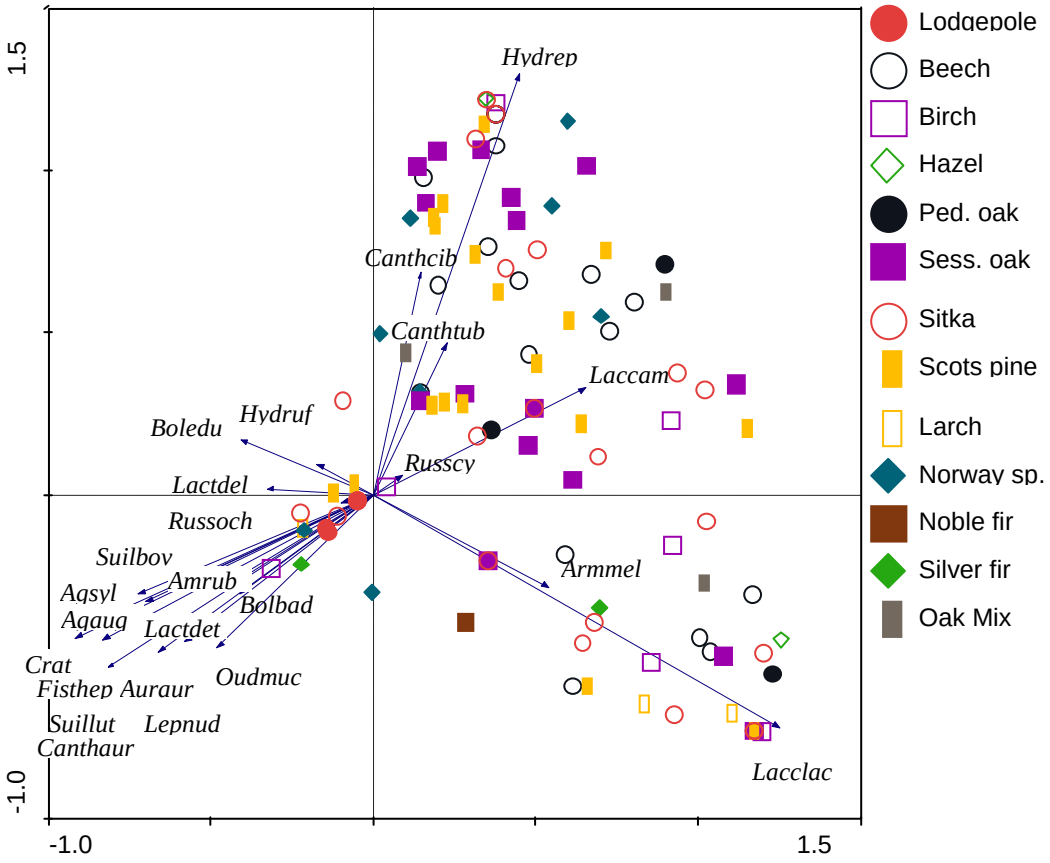

Fig. 4.1. Principal components ordination of forest types and WEF species.

Table 4.16. Occurrence of fruitbodies of WEF species in each of the forest types; figures refer to presence in each year of the survey, 2007-2009: 3 –in all three years; 2- in two years; 1 in one year only. Total refers to the number of forest types in which the species was represented (max 16).

	Beech	**Beech (Mix)**	**Birch**	**Douglas fir**	**Hazel**	**Larch**	**Lodgepole pine**	**Norway (Mix)**	**Norway spruce**	**Pedunculate oak**	**Sessile oak**	**Oak (Mix)**	**Silver fir**	**Sitka spruce**	**Scot pine**	**W. hemlock**	Total
Laccaria laccata	3	1	3	1	3	3	-	-	1	1	2	3	3	3	3	-	13
Armillaria mellea	2	1	3	-	-	3	-	2	1	-	3	2	-	2	1	1	11
Hydnum repandum	3	2	3	-	2	-	-	-	3	2	3	1	-	3	3	-	10
Cantharellus cibarius	3	-	3	-	1	-	-	-	2	-	3	1	1	2	2	-	9
Laccaria amethystina	3	1	-	-	2	-	-	-	1	1	3	3	-	3	3	-	9
Russula cyanoxantha	3	1	1	-	1	-	-	-	1	-	3	2	-	2	3	-	9
Cantharellus tubaeformis agg.	2	-	1	-	-	-	-	1	2	-	3	1	-	3	3	-	8
Hydnum rufescens	3	-	1	-	-	-	-	-	1	1	2	-	-	1	2	1	8
Amanita rubescens	1	-	1	-	-	-	1	-	1	-	-	-	-	2	1	-	6
Boletus badius	2	-	-	-	-	2	1	-	-	-	1	-	-	3	1	-	6
Lactarius deliciosus	2	1	-	-	-	-	-	-	-	-	1	-	2	1	3	-	6
Lepista flaccida	1	-	-	-	1	-	1	-	1	-	-	-	3	2	-	-	6
Lycoperdon perlatum	2	1	-	-	-	-	-	-	-	1	-	-	2	3	2	-	6
Lycoperdon pyriforme	2	-	-	-	-	-	1	1	1	-	-	-	1	1	-	-	6
Russula ochroleuca	1	-	-	-	-	-	1	-	1	-	2	-	-	2	1	-	6
Sarcoscypha aurantia	1	-	1	-	-	-	-	-	1	-	-	-	1	1	1	-	6
Boletus edulis	2	-	-	-	-	-	-	-	1	-	3	-	-	1	1	-	5
Laccaria proxima	-	-	1	-	2	-	-	-	-	-	2	-	-	1	1	-	5
Lactarius deterrimus	2	-	-	-	-	-	-	-	1	-	-	-	1	3	2	-	5
Suillus luteus	1	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-	5
Auricularia auricula-judae	2	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	4
Lepista nuda	3	-	-	-	-	-	-	1	-	-	1	-	2	-	-	-	4
Oudemansiella mucida	2	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-	4
Suillus bovinus	1	-	-	-	-	-	-	-	-	-	1	1	-	-	3	-	4
Clitocybe geotropa	2	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	3
Fistulina hepatica	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	3
Laccaria bicolor	-	-	2	-	-	2	-	-	-	-	-	-	1	-	-	-	3
Leccinum scabrum	-	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	3
Agaricus augustus	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2
Agaricus sylvaticus	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	2
Amanita fulva	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
Cantharellus aurora	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	2
Craterellus cornucopioides	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Hygrocybe pratensis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Leccinum duriusculum	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Pseudoclitocybe cyathiformis	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
Boletus subtomentosus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Coprinus atramentarius	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Coprinus comatus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Flammulina velutipes	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Grifola frondosa	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Leccinum versipelle	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Macrolepiota rhacodes	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1

Table 4.16 continued….

Pleurotus ostreatus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
# Species total	31	9	14	1	8	5	6	5	18	7	19	10	12	24	25	3	
# species prioity	12	3	6	0	3	1	1	2	9	3	10	5	4	11	11	1	

4.4 Productivity of WEF in the different forest types

The percentage of sites that were productive (defined as production of at least one WEF species) varied between 68% in 2008 to 86% in 2007 (**Table 4.4**). Scots pine sites were the most productive on average (94.4%) of the sites judged on this basis. Taking all sites of a given forest type in account, the number of WEF recorded over the 3 years was on average highest in beech forest (average =19.0), followed by Sitka spruce (14.7) and Scot's pine (14.3) (**Table 4.17**). The numbers of WEF species found in individual plots were obviously much fewer. In productive sites, the average number of edible species harvested per plot was highest in the single noble fir (*Abies procera*) and the two silver fir (*A. alba*) sites (6 and 5 species per site respectively). In the mainstream forest types, the average number of edible species per productive plot was greatest in beech (3.6 species per productive plot), followed by mixed oak forest (2.8), Scot's pine (2.6) and sessile oak (2.6).

The total and mean number of fruitbodies recorded per plot over the three years was greatest in Scots pine plots. This is due to the abundance and gregarious distribution of fruitbodies of winter chanterelle (*Cantharellus tubaeformis* agg.) in many of the Scot's pine plots. On average, 132 edible fruitbodies were found per Scots pine plot per year of survey compared to 90 for silver fir, 69 for noble fir, 60 for pedunculate oak and 48 for beech. The mean number of fruitbodies found per sampling visit was also highest in Scot's pine sites (40.7) (**Table 4.17**).

(* Higher values were found for the single noble fir site in Glendine, Co. Laois and the two silver fir sites in JFK and Dun an Rí).

Table 4.17. Numbers of WEF species per pforest typeand per productive plot, and the numbers of fruit bodies per plot, per forest types and per visit, 2007-2009

	Year	Beech	Beech (Mixed)	Birch	Douglas Fir	Hazel	Larch	Larch (Mix)	Lodgepole Pine	Noble Fir	Norway Spruce	Norway spruce (Mix)	Pedunculate oak	Sessile oak	Oak (Mix)	Scots pine	Silver Fir	Sitka Spruce	W. Hemlock
Number of WEF per forest type	2007	15	4	9	1	2	4	n/s	5	n/s	3	2	2	11	2	10	5	14	0
	2008	17	3	5	0	5	3	0	0	6	8	0	5	12	5	9	5	12	1
	2009	25	3	10	n/s	6	4	1	1	n/s	11	4	1	14	9	24	9	18	3
	3-Y	19	3.33	8	0.5	4.3	3.7	1	2	6	7.3	2	2.67	12	5.3	14.3	6.33	14.7	1.3
Mean number of WEF per productive plot	2007	3.4	2.0	1.6	1.0	1.0	2.0	n/s	1.7	n/s	1.0	1.0	1.0	2.1	2.0	2.0	5.0	2.4	0.0
	2008	2.3	3.0	2.0	0.0	2.5	1.5	0.0		6.0	2.0	0.0	1.5	2.6	3.0	2.1	5.0	1.8	1.0
	2009	4.9	1.0	2.6		2.3	3.0	1.0	1.0	n/s	3.0	4.0	1.0	3.2	3.3	3.8	5.0	2.3	3.0
	3-Y	3.56	2	2.1	0.5	1.9	2.2	1	1	6	2	1.7	1.17	2.6	2.8	2.64	5	2.16	1.3
Total number of fruitbodies per forest type	2007	334	10	215	12	41	18	n/s	25	n/s	139	8	52	244	6	1207	56	517	0
	2008	550	17	136	0	165	12	0	0	69	274	0	815	342	43	2593	267	757	7
	2009	853	17	154	n/s	38	43	1	6	n/s	236	17	1	425	14	1629	158	959	43
	3-Y	579	14.7	168	6	81	24	1	10	69	216	8.3	289	337	21	1810	160	744	17
Mean number of fruitbodies per plot	2007	37.1	5.0	23.9	12.0	20.5	9.0	n/s	6.3	n/s	46.3	4.0	17.3	18.8	6.0	134.1	56.0	43.1	0.0
	2008	36.7	8.5	19.4	0.0	82.5	4.0	0.0	0.0	69.0	27.4	0.0	163.0	21.4	14.3	144.1	133.5	34.4	7.0
	2009	71.1	5.7	22.0		12.7	14.3	1.0	1.0	n/s	59.0	8.5	0.3	28.3	4.7	116.4	79.0	41.7	43.0
	3-Y	48.3	6.39	22	6	39	9.1	1	2	69	44	4.2	60.2	23	8.3	132	89.5	39.7	17
Mean number of fruitbodies per visit	2007	15.2	3.3	10.8	4.0	13.7	2.6	n/s	1.9	n/s	46.3	1.1	5.2	9.0	2.0	46.4	14.0	16.7	0.0
	2008	12.2	1.5	4.9	0.0	18.3	1.0	0.0	0.0	11.5	10.1	0.0	26.3	6.8	3.9	48.9	44.5	8.7	1.8
	2009	16.1	1.4	5.5		6.3	3.6	0.3	0.3	n/s	13.9	2.1	0.1	7.1	1.2	26.7	19.8	10.0	10.8
	3-Y	14.5	2.1	7	2	13	2.4	0	1	12	23	1.1	10.5	7.7	2.3	40.7	26.1	11.8	4.2

The species were ranked according to their culinary and commercial value (see **Table 4.1**). The first 16, the ”priority species”, are those that are generally regarded as excellent edible species; chanterelle (*Cantharellus cibarius*), cep (*Boletus edulis*) and wood hedgehog fungus (*Hydnum repandum*) are the top three species in this ranking. Chanterelle (*C. cibarius*) was found in 10 of the 18 forest types (7 of the 10 major types). Almost 65% of the total number of fruitbodies were harvested from Scots pine sites, followed by sessile oak (13.4%), hazel (6.6%) and beech (5.3%) (**Table 4.18**).

Table 4.18. Production of chanterelle (*Cantharellus cibarius*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	5	76	1030.8	5.3	18.9	0.6	20.2	2.02
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	2	52	184.5	3.6	3.4	0.7	7.7	0.77
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	1	96	565.0	6.6	10.4	5.3	94.2	9.42
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	2	22	66.0	1.5	0.0	0.5	1.8	0.18
Norway spruce (Mix)	2	18	1	2	6.0	0.1	0.1	0.0	1.0	0.10
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	8	194	852.0	13.4	15.6	1.4	13.5	1.35
Oak (Mix)	3	33	2	11	4.0	0.8	0.1	0.3	0.4	0.04
Scots pine	21	140	5	931	2556.0	64.3	46.9	6.7	40.6	4.06
Silver fir	2	18	1	12	12.0	0.8	0.2	0.7	2.0	0.20
Sitka spruce	22	223	3	53	237.0	3.7	4.4	0.2	3.6	0.36
Western hemlock	1	13	-	-	-	-	-	-	-	-

On a fruitbody weight basis, the contribution of beech sites to total production of chanterelles was proportionately higher at 19% of total weight, and the Scots pine contribution was proportionately lower at 47% of total weight. This is because chanterelle fruitbodies were smaller than average in the Scots pine sites and larger than average in the beech sites at time of harvesting. Three of the 23 Sitka spruce sites produced chanterelles, contributing approximately 4% to the total harvest over the three years. Although Scots pine sites were the biggest producer, chanterelles were

not widely distributed in this forest type; only five of the 21 Scots pine sites produced chanterelles. In contrast, they were more widely distributed in sessile oak forest where they were found in 8 of the 19 sites. The estimated yearly production of chanterelle fruit bodies by weight (kg/ha/y) in was greatest in hazel (9.4 kg/ ha/y) followed by Scots pine (4.1 kg/ha/y), beech, and sessile oak. Despite the more common occurrence of chanterelles in the sessile oak sites, production values were comparatively low.

Ceps (*Boletus edulis*) were found in relatively low numbers and in few sites over the course of the survey. They were most widely distributed in oak sites. A significant number of fruitbodies were, however, found in one Sitka spruce site (Bohatch, Co. Clare) and in one noble fir site (**Table 4.19**). The latter site was sampled only in 2008 because it was clear-felled in 2009. In deciduous forest, production was greatest in sessile oak (2.6 kg/ha/y).

Table 4.19. Production of cep (*Boletus edulis*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	2	3	220.0	7.9	8.3	0.0	4.3	0.43
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	-	-	-	-	-	-	-	-
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	1	2	250.0	5.3	9.5	0.3	83.3	8.33
Norway spruce	12	48	1	1	0.0	2.6	0.0	0.0	0.0	0.00
Norway spruce (Mix)	2	18	-	-	-	-	-	-	-	-
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	5	25	1618.0	44.7	25.3	0.1	25.7	2.57
Oak (Mix)	3	33	1	-	-	-	-	-	-	-
Scots pine	21	140	1	1	3.0	2.6	0.1	0.0	0.0	0.00
Silver fir	2	18	-	-	-	-	-	-	-	-
Sitka spruce	22	223	1	6	549.0	15.8	20.8	0.0	8.3	0.83
Western hemlock	1	13	-	-	-	-	-	-	-	-

Winter chanterelle (*Cantharellus tubaeformi*s agg.) is a variable species with some forms approaching *C. aurora* in appearance. Over the three years of the survey, this species was the most abundant in terms of fruit body numbers and weight. It was also the most widely distributed, being found in significant numbers in seven of the forest types (**Table 4.20**). Scots pine plots were the most prolific producers of winter chanterelles, contributing 66% of fruitbody numbers and 74% of fruitbody weight. Almost half of the Scots pine sites were productive. One Sitka spruce plot (Ards Forest, Co. Donegal) also produced significant numbers (18% of fruit bodies) of winter chanterelles in each of the survey years. One other Sitka site produced small numbers of fruitbodies, but the species was not found in any of the other Sitka sites. The estimated yearly production of winter chanterelle fruit bodies by weight (kg/ha/y) was greatest in Scots pine (29.4 kg/ ha) followed by sitka spruce (5.2 kg/ha/y- mostly one site) and beech (3.5 kg/ha/y. Production rates of winter chanterelles in the sessile oak sites were comparatively low.

Table 4.20. Production of winter chanterelle (*Cantharellus tubaeformis* agg.) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	4	443	1779.0	8.1	7.1	3.3	34.9	3.49
Beech (Mix)	5	25	1	15	110.0	0.3	0.4	0.6	7.3	0.73
Birch	8	76	2	55	255.0	1.0	1.0	0.7	10.6	1.06
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	1	245	716.0	4.5	2.8	5.1	19.9	1.99
Norway spruce (Mix)	2	18	1	5	28.0	0.1	0.1	0.3	4.7	0.47
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	5	132	354.0	2.4	1.4	1.0	5.6	0.56
Oak (Mix)	3	33	1	1	1.0	0.0	0.0	0.0	0.1	0.01
Scots pine	21	140	10	3601	18527.0	65.8	73.6	25.7	294.1	29.41
Silver fir	2	18	-	-	-	-	-	-	-	-
Sitka spruce	22	223	2	978	3404.2	17.9	13.5	4.4	51.6	5.16
Western hemlock	1	13	-	-	-	-	-	-	-	-

The closely related but much rarer golden chanterelle (*C. aurora*), which is of superior quality to winter chanterelle, was found, albeit in large numbers, in only one Scots pine site (Ards Co. Donegal), in 2009 only.

Horn of plenty (also known as trompette des morts, *Craterellus cornucopioides*) was found in one beech plot (Ards Forest, Co. Donegal) in 2007 and 2008, and in one birch plot (Stonepark, Co. Roscommon) in 2007 (**Table 4.20**). This unusual edible species is known to occurr sporadically in some numbers in St. John's Wood, Co. Roscommon, where it is probably ectomycorrhizal on pedunculate oak.

Table 4.21. Production of horn of plenty (*Craterellus cornucopioides*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	1	69	650	98.57143	98	0.51	12.7	1.27
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	1	1	15	1.428571	2.3	0.01	0.6	0.06
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	-	-	-	-	-	-	-	-
Norway spruce (Mix)	2	18	-	-	-	-	-	-	-	-
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	-	-	-	-	-	-	-	-
Oak (Mix)	3	33	-	-	-	-	-	-	-	-
Scots pine	21	140	-	-	-	-	-	-	-	-
Silver fir	2	18	-	-	-	-	-	-	-	-
Sitka spruce	22	223	-	-	-	-	-	-	-	-
Western hemlock	1	13	-	-	-	-	-	-	-	-

Hedgehog fungus (*Hydnum repandum*) was the second most prolific edible fungus found during the survey after winter chanterelle. It was also more evenly distributed among nine of the forest types; it was found in approximately 50% of the beech, Scots pine, sessile oak and Norway spruce plots, and in 1/3 of the Sitka spruce plots. A single pedunculate oak plot produced 17% of the total fruit bodies, but beech was the

most productive forest type on a weight basis, producing 35% of fruit body biomass. Estimated productivity (12.0 kg/ha/y) was greatest in beech plots (**Table 4.22**), followed by pedunculate oak, Scots pine, Sitka spruce, Norway spruce, birch and sessile oak. Even though wood hedgehog fungus was widely distributed in sessile oak sites (9 of 21 were productive), productivity was low. There were marked difference in average fruit body weight between the different forest types: the largest fruit bodies were found in beech, Scots pine and Sitka spruce plots, while the smallest on average were found in sessile oak, birch and Norway spruce plots.

Table 4.22. Production of wood hedgehog fungus (*Hydnum repandum*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	11	309	6105.1	26.2	35.4	2.3	119.7	11.97
Beech (Mix)	5	25	-	-	-	-	-	-		
Birch	8	76	2	35	390.5	3.0	2.3	0.5	16.3	1.63
Douglas fir	1	6	-	-	-	-	-	-		
Hazel	2	18	1	28	168.0	2.4	1.0	1.6	28.0	2.80
Larch	4	31	-	-	-	-	-	-		
Larch (Mix)	1	10	-	-	-	-	-	-		
Lodgepole pine	6	57	-	-	-	-	-	-		
Noble fir	1	6	-	-	-	-	-	-		
Norway spruce	12	48	4	91	784.6	7.7	4.5	1.9	21.8	2.18
Norway spruce (Mix)	2	18	-	-	-	-	-	-		
Pedunculate oak	5	63	1	200	1791.0	16.9	10.4	8.6	119.4	11.94
Sessile oak	21	134	9	62	631.2	5.3	3.7	0.5	10.0	1.00
Oak (Mix)	3	33	2	32	15.0	2.7	0.1	1.0	1.7	0.17
Scots pine	21	140	9	285	4462.9	24.2	25.8	2.0	70.8	7.08
Silver fir	2	18	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Sitka spruce	22	223	7	138	2917.0	11.7	16.9	0.6	44.2	4.42
Western hemlock	1	13	-	-	-	-	-	-		

Red hedgehog fungus was found in a similar range of forest types as the wood hedgehog fungus, but was not nearly as common. Beech contributed 50% of the fruit bodies, but on a weight basis, a single Sitka spruce site was the most prolific, producing 45% of total fruitbody mass. Estimated productivity (0.22 kg/ha/y) was

greatest in beech plots, although much lower than for wood hedgehog fungus (**Table 4.22**).

Table 4.23. Production of red hedgehog fungus (*Hydnum rufescens*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	4	213	539	50.8	25	1.59	10.6	1.06
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	1	1	8	0.2	0.4	0.01	0.3	0.03
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	1	28	200	6.7	9.4	0.58	5.6	0.56
Norway spruce (Mix)	2	18	-	-	-	-	-	-	-	-
Pedunculate oak	5	63	1	7	50	1.7	2.3	0.11	3.3	0.33
Sessile oak	21	134	2	55	222	13.1	10	0.41	3.5	0.35
Oak (Mix)	3	33	-	-	-	-	-	-	-	-
Scots pine	21	140	2	27	152	6.4	7.1	0.19	2.4	0.24
Silver fir	2	18	-	-	-	-	-	-	-	-
Sitka spruce	22	223	1	87	956	20.8	45	0.39	14.5	1.45
Western hemlock	1	13	1	1	3	0.2	0.1	0.08	1.0	0.10

Charcoal burner (*Russula cyanoxantha*) was a widely distributed species, being found in beech, sessile oak, hazel, birch, Scots pine, Sitka spruce, Norway spruce sites, but predominantly in beech sites (46% of total fruit bodies, **Table 4.23**) where it was found in 50% of the plots. The density of fruit bodies was low resulting in low productivity; the highest estimated productivity was in beech forest (1.3 kg/ha/y). Anecdotal evidence suggests that this species can be very common in beech stands in some years. There is a likelihood that it tends to be overlooked by casual collectors because of its similarity to other *Russula* species, of which there is a great variety in woodlands, including mainly non-edible species and at least two poisonous species. Moreover, *C. cyanoxantha* can be very variable in appearance, even though it is easy to identify if the correct characters are looked for.

Table 4.23. Production of charcoal burner (*Russula cyanoxantha*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	9	40	667	45.98	55.2	0.30	13.1	1.31
Beech (Mix)	5	25	-	-	-		-	-	-	-
Birch	8	76	1	1	16.1	1.149	1.3	0.01	0.7	0.07
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	1	1	4	1.149	0.3	0.06	0.7	0.07
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	1	2	130	2.299	10.8	0.04	3.6	0.36
Norway spruce (Mix)	2	18	-	-	-	-	-	-	-	-
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	3	14	115.3	16.09	9.5	0.10	1.8	0.18
Oak (Mix)	3	33	2	2	18	2.299	1.5	0.06	2.0	0.20
Scots pine	21	140	5	15	164	17.24	13.6	0.11	2.6	0.26
Silver fir	2	18	-	-	-	-	-	-	-	-
Sitka spruce	22	223	4	12	93	13.79	7.7	0.05	1.4	0.14
Western hemlock	1	13	-	-	-	-	-	-	-	-

The saffron milkcap (*Lactarius deliciosus*) is an ectomycorrhizal associate of pines, so not surprisingly, almost 80% of fruitbodies were found in Scots pine plots (**Table 4.24**). It was found in 25% of the Scots pine sites at low density of fruit bodies. Productivity (1.4 kg/ha/y) was relatively low as a result. Saffron milkcap was also found sporadically in other forest sites. It is possible that these occurrences may be due to the presence of occasional pine trees in these sites or misidentification with the closely related false saffron milkcap.

False saffron milkcap (*Lactarius deterrimus*) was less common than saffron milkcap and was mainly found in five of the 23 Sitka spruce plots (**Table 4.25**) . Productivity of this species was highest in Sitka spruce sites, but was considerably less than for saffron milkcap.

Table 4.24. Production of saffron milkcap (*Lactarius deliciosus*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	3	7	96.4	13.46	8.8	0.05	1.9	0.19
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	-	-	-	-	-	-	-	-
Douglas fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	-	-	-	-	-	-	-	-
Norway spruce (Mix)	2	18	-	-	-	-	-	-	-	-
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	-	-	-	-	-	-	-	-
Oak (Mix)	3	33	1	1	8	1.923	0.7	0.03	0.9	0.09
Scots pine	21	140	5	35	853.9	67.31	77.6	0.25	13.6	1.36
Silver fir	2	18	1	6	22	11.54	2.0	0.33	3.7	0.37
Sitka spruce	22	223	1	3	120	5.769	10.9	0.01	1.8	0.18
Western hemlock	1	13	-	-	-	-	-	-	-	-

Wood blewit (*Lepista nuda*) appears late in the season in November, December or even January. This may have contributed to the relatively small number of fruitbodies harvested over the three years (**Table 4.26**). Anecdotal evidence suggests that this species is more abundant than its ranking in this survey would suggest. Most fruit bodies were found in the two silver fir sites, but it was also found in three of the beech sites and one each of the sessile oak and mixed Norway spruce sites. The largest fruit bodies were found in beech plots. The estimated productivity of wood blewits was greatest in silver fir sites (1.2 kg/ha/y). In more widely distributed woodland types however, wood blewits are most likely to be encountered in beech or oak sites.

Table 4.25. Production of false saffron milkcap (*Lactarius deterrimus*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	2	3	90	15	22.4	0.02	1.8	0.18
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	-	-	-	-	-	-	-	-
Douglas Fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	1	1	10	5	2.5	0.02	0.3	0.03
Norway spruce (Mix)	2	18	-	-	-	-	-	-	-	-
Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	-	-	-	-	-	-	-	-
Oak (Mix)	3	33	-	-	-	-	-	-	-	-
Scots pine	21	140	2	2	15	10	3.7	0.01	0.2	0.02
Silver fir	2	18	1	1	1	5	0.2	0.06	0.2	0.02
Sitka spruce	22	223	5	13	285	65	71.1	0.06	4.3	0.43
Western hemlock	1	13	-	-	-	-	-	-	-	-

Table 4.26. Production of wood blewit (*Lepista nuda*) in the forest plots.

	Number of Plots	Number of visits	productive sites 07-9	Total frbs 2007-2009	Total Frb Wt (g) 07-9	% of Total Frbs	%Total Frb Wt.	Mean frbs per visit	Mean wt. (g)/plot/y	Est. frb wt. (kg) /ha/y
Beech	17	134	3	15	300.3	22.4	59	0.11	5.9	0.59
Beech (Mix)	5	25	-	-	-	-	-	-	-	-
Birch	8	76	-	-	-	-	-	-	-	-
Douglas Fir	1	6	-	-	-	-	-	-	-	-
Hazel	2	18	-	-	-	-	-	-	-	-
Larch	4	31	-	-	-	-	-	-	-	-
Larch (Mix)	1	10	-	-	-	-	-	-	-	-
Lodgepole pine	6	57	-	-	-	-	-	-	-	-
Noble fir	1	6	-	-	-	-	-	-	-	-
Norway spruce	12	48	-	-	-	-	-	-	-	-
Norway spruce (Mix)	2	18	1	10	6	14.93	1.1697	0.56	1.0	0.10

Table 4.26 continued..

Pedunculate oak	5	63	-	-	-	-	-	-	-	-
Sessile oak	21	134	1	12	135.667	17.91	26.447	0.09	2.2	0.22
Oak (Mix)	3	33	-	-	-	-	-	-	-	-
Scots pine	21	140	-	-	-	-	-	-	-	-
Silver fir	2	18	2	30	71	44.78	13.841	1.67	11.8	1.18
Sitka spruce	22	223	-	-	-	-	-	-	-	-
Western hemlock	1	13	-	-	-	-	-	-	-	-

The remaining priority edible species occurred in low frequency. The beefsteak fungus (*Fistulina hepatica*), a wood decay species was recorded outside the plots on large dead boles in a pedunculate oak site, a sessile oak site, and a Scots pine site. The oyster fungus (*Pleurotus ostreatus*) was found once in a Sitka spruce site in Ards Forest, Co. Donegal. The wood mushroom (*Agaricus sylvaticus*) and the Prince (*A. augustus*) were also found only sporadically; the former as one or two fruitbodies in a single site each of larch Norway spruce and Sitka spruce; the latter in one site each of beech and Norway spruce.

Overall productivity estimates for each of the WEF species in the different forest types are given in **Table 4.27**. Winter chanterelle and wood hedgehog fungus were on average the most productive species across the range of forest types sampled. Even though the total biomass of winter chanterelle collected over the 3 years was on average 25% higher than that of hedgehog fungus, the average productivities of each (4.7 and 4.4 kg/ha/y, respectively) were very close; this is because the site and visit frequencies of hedgehog fungus were over double that of winter chanterelle. The 95% confidence limits of the production estimates of winter chanterelle are much wider than for hedgehog fungus (**Table 4.27**). Of the priority species, the highest production estimates were found for winter chanterelle in Scots pine, wood hedgehog fungus in beech, pedunculate oak and Scots pine, and cep in noble fir. Among the non-priority species, high production levels were found for ochre brittlegill (*Russula ochroleuca*) in a single noble fir site and and funnel cap (*Lepista flaccida*) in the two silver fir sites. Most other non-priority species had low production estimates.

Table 4.27. Estimated productivity (kg/ha/y) for WEF species in different forest types. Priority WEF are in bold. Mean values for individual species and 95% confidence limits (CL) are included.

	Beech	**Beech (Mix)**	**Birch**	**DF**	**Hazel**	**Larch**	**Larch (Mix)**	**Lodgepole pine**	**Noble fir**	**Norway spruce (Mix)**	**Norway spruce**	**Pedunculate oak**	**Sessile oak**	**Oak (Mix)**	**Scots pine**	**Silver fir**	**Sitka spruce**	**Western hemlock**	**Mean**	**Lower 95% CL**	**Upper 95% CL**
Cantharellus tubaeformis agg.	3.49	0.73	1.06	-	-	-	-	-	-	0.47	1.99	-	0.56	0.01	29.41	-	5.16	-	4.76	0.00	10.90
Hydnum repandum	11.97	0.44	1.63	-	2.80	-	-	-	-	-	2.18	11.94	1.00	0.17	7.08	-	4.42	-	4.36	1.58	7.15
Boletus edulis	0.43	-	-	-	-	-	-	-	8.33	-	-	-	2.57	-	0.01	-	0.83	-	2.43	0.00	5.45
Cantharellus cibarius	2.02	-	0.77	-	9.42	-	-	-	-	1.10	0.02	-	1.35	0.04	4.06	0.20	0.36	-	1.93	0.14	3.73
Boletus badius	0.64	-	-	-	-	0.58	0.97	0.30	4.00	-	-	-	0.17	-	0.07	-	0.90	-	0.95	0.07	1.83
Craterellus cornucopioides	1.27	-	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67	0.00	1.86
Hydnum rufescens	1.06	-	0.03	-	-	-	-	-	-	-	0.56	0.33	0.35	-	0.24	-	1.45	0.10	0.52	0.17	0.86
Lepista nuda	0.59	-	-	-	-	-	-	-	-	-	0.02	-	0.22	-	-	1.18	-	-	0.50	0.00	1.00
Lactarius deliciosus	0.19		-	-	-	-	-	-	-	-	-	-	0.01	-	1.36	0.37	0.18	-	0.42	0.00	0.89
Russula cyanoxantha	1.31		0.07	-	0.07	-	-	-	-	-	0.36	-	0.18	0.20	0.26	-	0.14	-	0.32	0.04	0.61
Fistulina hepatica	-	-	-	-	-	-	-	-	-	-	-	0.53	0.19	-	0.01	-	-	-	0.25	0.00	0.54
Agaricus sylvaticus	-	-	-	-	-	-	0.17	-	-	-	0.35	-	-	-	-	-	0.01	-	0.17	0.00	0.37
Agaricus augustus	0.17	-	-	-	-	-	-	-	-	-	0.17	-	-	-	-	-	-	-	0.17	0.16	0.18
Lactarius deterrimus	0.18	-	-	-	-	-	-	-	-	-	0.03	-	-	-	0.02	0.02	0.43	-	0.14	0.00	0.29
Cantharellus aurora	0.15	-	-	-	-	-	-	-	-	-	-	-	0.32	0.01	0.06	-	-	-	0.13	0.00	0.27
Pleurotus ostreatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	0.05	0.05	0.05
Russula ochroleuca	0.24	-	-	-	-	-	-	1.06	38.30	-	1.03	-	0.26	-	0.15	-	3.27	-	6.33	0.00	16.80
Lepista flaccida	0.02	-	-	-	4.08	-	-	0.29	-	-	0.04	-	-	-	-	22.80	0.28	-	4.59	0.00	11.84
Armillaria mellea	1.20	0.60	3.23	-	-	0.92	1.97	-	-	2.38	4.82	-	1.45	1.49	0.29	-	4.80	-	2.10	1.18	3.03
Grifola frondosa	1.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.67	1.67	1.67
Laccaria laccata	0.45	0.14	0.75	2.13	5.25	0.68	0.33	-	1.00	-	0.01	0.81	0.53	0.57	0.41	1.97	0.59	-	1.04	0.38	1.70
Laccaria amethystina	0.87	0.07	0.08	-	0.73	-	-	-	-	-	0.35	2.10	0.35	1.47	1.24	-	0.78	-	0.80	0.40	1.21

Table 4.27 continued…

Lycoperdon perlatum	0.04	0.20	0.25	-	-	-	-	-	4.17	-	-	0.17	-	-	0.04	0.70	0.67	-	0.78	0.00	1.74
Suillus bovinus	0.13	-	-	-	-	-	-	-	-	-	-	-	0.10	0.22	1.59	-	1.14	-	0.63	0.03	1.24
Clitocybe geotropa	0.23	-	-	-	-	-	-	-	-	-	-	0.33	-	-	0.71	-	-	-	0.42	0.13	0.71
Amanita rubescens	0.01	-	0.20	-	-	-	-	0.78	1.17	-	0.03	-	-	-	0.25	-	0.48	-	0.42	0.10	0.73
Leccinum duriusculum	-	-	0.50	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.26	0.00	0.73
Boletus subtomentosus	-	-	-	-	-	-	-	0.19	-	-	-	-	-	-	-	-	-	-	0.19	0.19	0.19
Leccinum scabrum	-	-	-	-	0.20	0.29	-	-	-	-	-	-	0.07	-	-	-	-	-	0.18	0.06	0.31
Coprinus atramentarius	-	-	-	-	-	-	-	-	-	-	0.18	-	-	-	-	-	-	-	0.18	0.18	0.18
Oudemansiella mucida	0.20	0.29	-	-	-	-	-	-	-	-	-	-	-	-	0.17	0.02	-	-	0.17	0.06	0.28
Coprinus comatus	-	0.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.17	0.17	0.17
Auricularia auricula-judae	0.03	-	-	-	-	0.20	-	-	-	0.28	-	-	-	-	0.06	-	-	-	0.14	0.02	0.26
Leccinum versipelle	-	-	-	-	-	-	-	-	-	-	-	-	0.10	-	-	-	-	-	0.10	0.10	0.10
Sarcoscypha aurantia	0.03	-	0.32	-	-	-	-	-	-	-	0.05	-	-	-	0.01	0.08	0.06	-	0.09	0.00	0.18
Lycoperdon pyriforme	0.05	-	-	-	-	-	-	0.17	-	0.03	0.01	-	-	-	-	0.22	0.02	-	0.09	0.02	0.15
Flammulina velutipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	0.08	0.08	0.08
Laccaria bicolor	-	-	0.08	-	-	0.14	-	-	-	-	-	-	-	-	-	0.02	-	-	0.08	0.01	0.15
Macrolepiota rhacodes	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	-	0.06	0.06	0.06
Amanita fulva	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	0.05	0.02	0.08
Laccaria proxima	-	-	0.06	-	0.10	-	-	-	-	-	-	-	0.06	-	0.01	-	0.00	-	0.05	0.01	0.08
Pseudoclitocybe cyathiformis	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	0.01	0.00	0.02
Hygrocybe pratensis	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.01	0.01
Suillus luteus	0.04	-	-	-	-	-	-	-	-	-	-	-	0.02	0.01	0.07	-	-	-	0.03	0.01	0.06

4.5 Collective yearly production estimates of forest types

The yearly estimates with 95% confidence limits for collective fruit body production for priority species, non-priority species and all species in the different forest types are given in **Table 4.28**. The highest overall productivity was recorded for the single noble fir site, mainly due to the abundance of two species, cep and ochre brittlegill. Since this consisted of only one site sampled in one year, confidence limits could not be calculated for this site and it is not included in **Table 4.28**. It would not be warranted to draw any conclusions about the productivity of larger areas of noble fir forest based on this single site. Of the major forest types, Scots pine was the most productive (especially in respect of winter chanterelle), followed by beech, pedunculate oak, hazel, sessile oak and Sitka spruce.

The highest estimates for production of priority species were found for Scots pine forest (42.6 kg/ha/y), followed by beech, pedunculate oak, Sitka spruce, hazel, sessile oak, Norway spruce, and birch. When the proportion of total production contributed by priority species is considered, Scots pine was foremost (89% of total production is priority species –principally winter chanterelle) followed by pedunculate oak, beech, sessile oak, hazel, Sitka spruce, Norway spruce and birch. Larch and lodgepole pine had low production values especially of priority species.

Confidence limits were very large for most forest types. Beech and sessile oak forest demonstrated the narrowest confidence limits; based on the mean production estimates per plot, there was 95% probability of harvesting a minimum of 3.2 and 2.7 kg/ha/y, respectively, from these forest types.

Table 4.28. Estimated yearly production (kg/ha/y) of fruitbodies of priority WEF, non-priority WEF and all WEF in the different forest types. ± Standard deviation (, lower 95% confidence level, upper 95% confidence level)

	Estimated production (kg/ha/y)		
	Priority	**Non-Priority**	**All**
Beech	23.2 ±42.1 (3.2, 43.2)	5.3 ±8.1 (1.4, 9.1)	28.5 ±43.2 (8.0, 49.0)
Beech (Mix)	1.3 ±2.6 (0, 3.6)	1.5 ±2.3 (0, 3.5)	2.7 ±2.7 (0.3, 5.1)
Birch	3.6 ±8.4 (0, 9.5)	5.5 ±6.8 (0.7, 10.2)	9.1 ±10.3 (2.0, 16.2)
Hazel	12.3 ±17.2 (0, 36.1)	10.4 ±3.1 (0, 14.7)	22.7 ±14.1 (0, 42.2)
Larch	0.6 ±1.1 (0, 1.7)	2.2 ±1.6 (0.6, 3.8)	2.8 ±2.1 (0.8, 4.9)
Lodgepole Pine	0.3 ±0.7 (0, 0.9)	2.5 ±3.5 (0, 5.3)	2.8 ±3.5 (0, 5.6)
Norway Spruce	5.7 ±10.0 (0, 11.3)	7.0. ±20.1 (0, 18.4)	12.6 ±28.7 (0 29.0)
Pedunculate oak	16.6 ±30.5 (0, 43.4)	2.9 ±4.3 (0, 6.7)	19.5 ±30.7 (0, 46.5)
Sessile oak	6.9 ±9.9 (2.8, 11.2	3.0 ±4.7(0.9, 5.0)	10.0 ±11.9 (4.9, 15.1)
Oak (Mix)	0.12 ±0.2 (0, 0.3)	3.5 ±2.4 (0.9, 6.2	3.6 ±2.5 (0.8, 6.4)
Scots pine	42.6 ±131.0 (0, 98.7)	5.1 ±7.7 (1.8, 8.3)	47.6 ±133.0 (0, 104.6)
Silver fir	4.3 ±6.1 (0, 12.7)	30.5 ±43.2 (0, 90.3)	34.8 ±49.2 (0, 103.0)
Sitka spruce	13.8 ±32.2 (0.4, 27.3)	12.1 ±19.8 (3.9, 20.4)	26.0 ±41.2 (8.7, 43.2)
Western hemlock	0.1 ±0.1 (0.1, 0.1)	3.7 ±0.1 -	3.8

Nominal retail values (€ per kg fresh weight) bassed on mainland European retail values (de Roman and Boa 2004) were assigned to each of the edible species (**Table 4.29**) and the returns per hectare per year were calculated for each forest type based on the relative production of the species found (**Table 4.29**). The highest theoretical returns were from Scots pine and beech (**Table 4.30**).

Table 4.29. Nominal retail values of WEF from Irish forests

Priority WEF	Retail value €
Boletus edulis	25
Cantharellus cibarius	25
Lactarius deliciosus	15
Hydnum repandum	15
Craterellus cornucopioides	15
Hydnum rufescens	15
Cantharellus aurora	10
Cantharellus tubaeformis agg.	10
Boletus badius	10
Lepista nuda	10
Russula cyanoxantha	10
Fistulina hepatica	10
Agaricus sylvaticus	10
Agaricus augustus	10
Lactarius deterrimus	10
Pleurotus ostreatus	10
Others	2

Table 4.30. Estimated returns (€/ha/y) from collection of WEF in different Irish forest types (retail values).

Forest Type	Retail Yield € /ha /y
Scots pine	539
Beech	349
Noble fir	338
Hazel	299
Pedunculate oak	204
Sitka spruce	195
Sessile oak	139
Norway spruce	81
Silver fir	74
Birch	67
Norway spruce (Mix)	38
Beech (Mix)	17
Larch (Mix)	16
Oak (Mix)	13
Larch	10
Lodgepole pine	8
Douglas fir	4
Western hemlock	1

4.6 Variation between years

There was considerable variation in the biomass and numbers of WEF fruit bodies between years (**Table 4.31**). Total harvest was greatest in 2008 and least in 2009. When account is taken of the difference in numbers of sites sampled per year, average yields per plot were also highest in 2008 and least in 2009. Yields from individual forest types also followed a similar pattern, with the exception of Sitka spruce plots, where yields per plot were highest in 2007. This pattern is also reflected in the yields of most individual WEF species but there were exceptions,; honey fungus, horn of plenty and wood blewit were more abundant in 2007 than 2008 (see **Table 4.3**). Even though yields were highest in 2008 the total number of WEF species was least in that year (28) compared to 2007 (32) and 2009 (39).

Table 4.31. Proportion (%) of the total weight of WEF fruit bodies found in each different forest types in each of the three years of the survey.

	Total wt. (g) of frbs			Mean wt. (g) frbs/plot			% of Total		
	2007	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
Beech	5924	5218	3385	658	373	282	41	36	23
Beech (Mix)	203	144	63	102	72	21	50	35	15
Birch	798	708	676	89	101	97	37	32	31
Douglas fir	64	0		64	0		100	0	0
Hazel	186	896	277	93	448	92	14	66	20
Larch	107	98	130	54	33	43	32	29	39
Larch (Mix)		98	5		98	5	0	95	5
Lodgepole pine	450	0	52	113	0	9	90	0	10
Noble fir		1710			1710		0	100	0
Norway spruce (Mix)	48	0	148	24	0	74	24	0	76
Norway spruce	287	1445	2663	96	145	666	7	33	61
Oak (Mix)	34	288	55	34	96	18	9	76	15
Pedunculate oak	680	4539	50	227	908	17	13	86	1
Sessile oak	1348	2875	1999	104	180	133	22	46	32
Scots pine	7625	16356	6024	847	909	430	25	55	20
Silver fir	603	1485	118	603	743	59	27	67	5
Sitka spruce	7010	5962	4183	584	271	182	41	35	24
Western hemlock	0	39	76	0	39	76	0	34	66
Total	25367	41861	19903	335	428	248			

5.0 Discussion

5.1 Edible species diversity

Forty-four edible species were recorded from 16 forest types over the three years of the study. This number was subject to considerable year-year variation, and also varied between forest types. For example 32 species were found in 2007, 28 in 2008, and 39 in 2009. Twenty-three of the recorded species are ectomycorrhizal and most of these (exceptions; *Lactarius deliciosus, Suillus grevillei*) have broad host ranges. Beech forest supported the largest number of edible species on average over the three years of the survey, and beech is known to support large numbers of different ectomycrrhizal fungi (Smith and read 2008). Eleven edible species were not encountered; two of these were spring fruiting (St. George's mushroom, *Calocybe gambosum*, and morel *Morchella* spp.) and were not deliberately sampled for. St. George's mushroom is known from anecdotal evidence to be reasonably common in "woodland habitats", while morels are much less common. Summer truffle (*Tuber aestivum*), an underground species, was not targeted in this survey and was not encountered. The absence of the other species listed on page 29, accords with the general consensus that these species are uncommon in Irish woodland habitats.

The diversity of WEF was greatest in beech forest >Scots pine>Sitka spruce> sessile oak> Norway spruce> birch. The priority species followed a similar sequence. This pattern is likely to have been strongly influenced by sampling effort; i.e. diversity is likely to be greater in forest types represented by large numbers of plots (e.g. Sitka spruce) than in less well-represented forest types. It is likely for example that birch woods would yield greater numbers of edible species with increased sampling given that birch supports ectomycorrhizal fungi and is known to have relatively large numbers of fungal associates in birch woods in the UK and mainland Europe (Watling 1984). That beech forest produced the largest number of edible species and priority edible species is not surprising given that beech supports a wide variety of ectomycorrhizal fungi. Morevoer, beech forests produce a fibrous leaf litter that supports many saprotrophic fungi such as wood blewit (*Lepista nuda*). The coniferous forests, Scots pine, Sitka spruce and Norway spruce, were not as diverse in respect of the total number of WEF species, but did produce a similar range of priority species. Comparable figures for edible fungal diversity from studies of forests in other countries are hard to come by, because of scarcity of studies, differences in

methodologies, range of forests sampled, numbers of samples, and duration of studies. Nonetheless, studies in the UK have shown that these plantation forests are habitats for a wide variety of fungi of different functional groups and that diversity in these plantations is comparable to native oak forest (Humphrey *et al*. 2000). A contemporaneous study of macrofungal diversity Irish woodland types as part of the COFORD-funded FUNCTIONALBIO project (2009-2010), showed that Sitka spruce sites produced the greatest number of macrofungal species (144), followed by oak (113), Scot's pine (89) and ash (56) (O'Hanlon 2011). To compensate for the difference in sampling effort in this study and to compare species richness of the different sites and forest types at a similar sampling intensity, sample-based rarefaction curves with 95% confidence intervals were calculated. Based on a sampling effort of 23 plots, Sitka spruce produced 76 species, Scot's pine 74 and oak 71. Sitka spruce sites produced 9 edible species (all priority species, including *B. edulis, C. cibarius* and *H. repandum*) Scots pine 13 (4 priority) and oak 10 (3 priority). In a 3-year study of 36 100-m^2 plots in Scots pine plantations in the Spanish Pyrenees, Bonet *et al.* (2004) recorded 47 species broadly classified as edible, and 16 species classified as "edible marketable". Thirteen species were in common with the FORESTFUNGI study, and included *Cantharellus cibarius, C. aurora, Hydnum repandum, H. rufescens* and *Boletus badius.* A later study of 18 Scots pine plots in north-eastern Spain (Martinez-Peña *et al.* 2011), also had a similar range of 13 species in common with this study.

Some forest types that were represented by relatively few sampling sites, for example hazel and silver fir, produced disproportionately greater numbers of edible species and in significant amounts. Increased sampling effort in these forest types would probably have yielded greater numbers of species, particularly in the case of hazel, which has extensive tracts in some parts of the country. Others forest types, such as Japanese larch and especially lodgepole pine, produced proportionately fewer than average numbers of edible species in proportion to sampling effort. Moreover, priority species were generally absent from these forest types. It is unlikely that increased sampling effort would have produced any significant increase in the numbers of edible species recorded from pure stands of these forest types.

5.2 Productivity of edible fungal species

The five most common species in terms of their frequency of occurrence in sites and on sampling visits, were in order of importance: hedgehog fungus, deceiver, amethyst deceiver, chanterelle and winter chanterelle. The overall site frequency of occurrence was low, not exceeding 25% on average, and visit frequency did not exceed 16% on average. In terms of total fresh weight biomass collected over the 3-year period, winter chanterelle was the most productive species, followed by wood hedgehog fungus, chanterelle, honey fungus and amethyst deceiver. The total weight of fruit bodies of winter chanterelle, collected over the three years of the study, exceeded that of the next most important species, wood hedgehog fungus, by almost 25%, and the numbers of its fruit bodies were almost 3½ times greater. This is because the fruit bodies of winter chanterelle show (like many ectomycorrhizal fungi) a markedly clumped distribution and tend to occur in aggregations that may contain hundreds of fruit bodies.

The highest average production estimates were found for the winter chanterelle (*Cantharellus tubaeformis* agg.), ranging from 0.56 kg/ha/y in sessile oak forest to 29.4 kg/ha/y in Scots pine forest. This species was more widely distributed than expected from anecdotal evidence, occurring not only with Scots pine (on which it mycorrhizal) but also beech, birch and Norway spruce. It was the most productive species in Sitka spruce plots where significant amounts were produced (5.2 kg/ha/y on average). Winter chanterelle is a variable species, and some forms approach the more marketable golden chanterelle (*C. aurora*), while other are duller in appearance. Golden chanterelle was found in fewer forest types and had much lower fruitbody production. Both of these species produce small fruit bodies that can be overlooked in dense forest floor vegetation.

This survey confirms the anecdotal belief that wood hedgehog fungus (*Hydnum repandum*) is the most widespread and productive of the marketable and valuable WEF species across a range of Irish forest types. This is an excellent edible species and is commonly sold in European markets. Average fruitbody production estimates ranged from 1.0 kg/ha/y in sessile oak forest to 12 kg/ha/y in beech forest. It was the most widely distributed species being found in 10 forest types including the plantation forests Sitka spruce and Scots pine where production estimates were relatively high (4.4 and 7.1 kg/ha/y, respectively). The results also show that the wood hedgehog fungus (*H. repandum*) was much more common in Irish forests than

the closely related red or terracotta hedgehog fungus (*H. rufescens*), which produces smaller, orange fruitbodies and is less marketable.

Chanterelle or girolle (*C. cibarius*) was not as productive in Irish forests as the aforementioned species, but was as widely distributed as wood hedgehog fungus and was found in the same forest types. This is regarded as an excellent edible species, and is collected and marketed on a large scale in mainland Europe and Scandinavia. Hazel, Scots pine, beech and sessile oak were the most productive forest types. Small amounts were found in some Sitka spruce sites.

Cep (*Boletus edulis*) is probably the most commercially valuable wild species because of the large size of its fruit bodies and its excellent flavour, which is retained on drying. Ceps were relatively unproductive in the forests investigated in this study, despite being recorded from five of the main forest types. Of interest is the finding of large numbers of ceps in a single young noble fir site in 2008. Unfortunately, this site was clear felled before the 2009 season so longer-term monitoring of the production potential of this site was not possible. Noble fir was not included initially as plantation forest of interest, but an examination of other noble fir sites is warranted in light of this finding.

Saffron milkcap (*Lactarius deliciosus*), an ectomycorrhizal associate of pines and an important edible species in Spain (de Román and Boa 2004), eastern Europe and Scandinavia, was most common in Scots pine forest, but production rates were comparable to those recorded for this species in monitored Scots pine plots in Spain (Bonet *et al.* 2004; Martinez-Peña *et al.* 2011). High yields of this species have been produced in black pine (*Pinus nigra*) plantations of inoculated trees in New Zealand (Wang *et al.* 2004; EFFNZ;http://www.effnz.co.nz/options.htm). False saffron milkcap (*Lactarius deterrimus*), a look-alike of poorer quality that is primarily a mycorrhizal associate of spruce, was less common than saffron milkcap and was mainly found in Sitka spruce forest at low production rates

Of the non-priority species, deceiver (*Laccaria laccata*), amethyst deceiver (*L. amethystina*), common puffball (*Lycoperdon perlatum*), ochre brittlegill (*Russula ochroleuca*) and honey fungus (*Armillaria mellea*) were the most widely distributed and most frequently encountered in the different forest types. Honey fungus (also known as bootlace fungus) is a serious forest pathogen, the fruit bodies of which are edible when young. It was most productive in Sitka and Norway spruce forest but not in Scots pine. Ochre brittlegill (*Russula ochroleuca*) and funnel cap (*Lepista*

flaccida) produced large numbers of fruit bodies in noble fir and silver fir sites, but production levels were low in most forest types.

It should be emphasised that the estimates of WEF productivities are likely to be under-estimates. This because it was not logistically possible to monitor plots on a continuous basis throughout the whole of the fruiting season in each year, so fruitbodies of some WEF species in some sites at least, are likely to have been missed. The extent of the under-estimate is difficult to calculate and would probably differ for different WEF species. Data from a plot in St John's Wood, which was sampled with twice the frequency of others in that site, suggests that the underestimate could be up to 30% in that site.

For reasons mentioned earlier, comparisons of wild edible fungal production are difficult to compare between studies in different countries. **Table 2.2** summarizes the results of a number of studies of wild edible fungal production in different countries. The estimates for Irish forests are generally lower than estimates from other countries particularly Russia, Baltic and Scandinavia countries, and from Scotland. Given the differences in plot sizes, sample size, survey duration and sampling methodologies, such comparisons are probably not very meaningful

Marked year-to-year variation in the the numbers and biomass of WEF fruit bodies is a characteristic of all forest types in all countries (Eveling *et al*. 1990; Straatsma *et al*. 2001). 2008 was the most productive year and 209 the least. There is no other baseline data from Ireland with which to campare the yields in these years, but from personal communication with a number of regular harvesters and field mycologists, the impression is gained that these years were average and unexceptional.

5.3 Comparative productivities of forest types

Forest of non-native species such as beech, Scots pine and Sitka spruce were found to more productive on average of WEF than native forests types such as pedunculate oak, sessile oak, hazel or birch. When production of priority species is considered and allowance is made for relative market value of these and other less valuable species, the differences are somewhat less marked; for example the putative monetary returns from production in pedunculate oak forest and hazel is ahead of Sitka spruce (**Table**

4.30). This is because priority species such as chanterelle and wood hedgehog fungus are on average more frequently encountered in the former forest types.

Nothwithstanding the likelihood that estimated productivities for individual plots are underestimates, these returns (up to €539 per hectare per year in the case of Scots pine) are unlikely to be realized for a number of reasons:

- Achievable returns from collection of WEF are impossible to calculate in Ireland because no market system exists here as yet such as is found in Scotland (Dyke and Newton 1999).
- Estimates of returns are based on retail values of WEF; wholesale returns are likely to be 50% or less.
- For individual forest stands, the estimates have low predictive evalue. This is because the estimates are means and the associated 95% confidence limits are very wide due to the inconsistent spatial and temporal patterns of fungal occurrence in plots. In this regard, the deciduous forest types, beech and sessile oak exhibited more consistent production patterns than other forest types and consequently have narrower confidence limits for production. The estimates are not based on the time/effort required to harvest a given volume of WEF. In this regard it likely that the deciduous forest types and Scots pine are considerably ahead of the coniferous forest sites, for example Sitka spruce, where the ratio of productive to unproductive sites is lower.

Because Sitka spruce is the most extensive forest type in Ireland, the production of WEF in Sitka forest is of particular importance. Twenty-four WEF species including 11 priority species were found in Sitka spruce forest. The majority of Sitka spruce sites were "productive" in the sense of producing at least one edible species. However, less desirable species, such as honey fungus and ochre brittlegill, were the most common members of WEF assemblage, and the frequency of occurrence (% site frequency and % visit frequency; see **Table 4.11**) of priority species was comparatively less. The most common priority species in Sitka spruce sites, wood hedgehog fungus and winter chanterelle, occurred at significantly lower site and visit frequencies here than in Scots pine, beech sessile oak or Norway spruce sites (See Tables 4.8-4.12). The findings indicate that, while highly-regarded WEF such as chanterelle, cep and hedgehog fungus can be found in in Sitka spruce forest sites, their

occurrence is less consistent and reliable than in other forest types. Sitka spruce harbors a diversity of ectomycorrhizas on its roots (Heslin 1992; O'Hanlon 2011) and these species are likely to be ectomycorrhizal on Sitka spruce. The relative scarcity of their fruit bodies is possibly because their mycorrhizas occur at lower and less evenly-distributed population densities, or alternatively, fruiting is reduced by envioronmental factors. Further research is needed to elucidate the real status of these important WEF in Irish Sitka spruce stands.

The findings of this project indicate that plantation forest of Sitka spruce, Scots pine and Norway spruce are significant reservoirs of native forest WEF containing similar species of WEF and in harvestable amounts. Recreational harvesting of this resource is likely to increase in the future. In the author's opinion, it is unlikely that commercial harvesting is an ecomomical proposition, on the scale, for example, currently pertaining in Scottish forests, because the theoretical returns are unlikely to cover the costs of harvesting (Dyke and Newton 1999). Further research is needed specifically on Sitka spruce, Norway spruce and larch plantations to identify factors and management measures that could amplify the WEF harvest in these forests.

As recreational use will inevitably increase, education and the safe use of the resource are important issues that need to be addressed. More information by way of education needs to be made available to the public and foresters on the range of WEF occurring in forests, safe protocols for collecting, and the dangers of toxic species. Death cap (*Amanita phalloides*), destroying angel (*Amanita virosa*) and deadly webcap (*Cortinarius rubellus* [= C. *speciosissimus*]) are relatively common woodland species that are potentially fatal if ingested (Phillips 2006; Sweeney 2008). *C. rubellus* was first reported in Ireland in 1994 (Harrington 1994) and now appears to be common in Sitka spruce plantations and plantations of other conifer species (O'Hanlon 2011).

6.0 Implications for policy and practice

The findings of this project indicate that plantation forest of Sitka spruce, Scots pine and Norway spruce are significant reservoirs of native forest WEF. It is likely therefore that these forest areas will be harvested by recreational or possibly commercial collectors in the future. Anecdotal evidence suggests that this is already happening. Currently there is no policy on the use of public forests for such activities and this should be formulated.

Increased use of forests for WEF collection by inexperienced collectors especially may have safety implications. For example, deadly webcap (*Cortinarius rubellus*) a potential lethal toxic species is common in Sitka spruce and other conifer plantations (O'Hanlon 2011) and can be mistaken for chanterelle, while deathcap (*Amanita phalloides*) is common in beech and other broafleaf forests. This may necessitate education initiative to make people aware of dangerous in popular forest locations.

It is the policy of the Forest Service and Coillte to use a range of conifer and broadleaf tree species to achieve the requirements of the draft national FSC Standards for Ireland, and to extend species diversification to reforestation sites in a manner which is silviculturally and ecologically sound. Choice of broadleaves is critical for WEF; plantings of beech oak or birch will increase diversity and yield. In future plantings therefore, consideration should be given to planting of tree species that will act as a host for WEF.

7. Conclusions and recommendations

Conclusions:

- Forty-four edible fungal species were encountered over the course of the study. Beech, Scots pine and Sitka spruce forest produced the greatest variety of edible species (31, 25 and 24, respectively).
- *Hydnum repandum*, the wood hedgehog fungus (a priority species), was the most frequently encountered edible species.
- The chanterelle (*Cantharellus cibarius*) the top priority species, was also relatively frequent, being found in ,10 of the 18 forest types (7 of the 10 major types).
- Winter chanterelle and wood hedgehog fungus were on average the most productive species across the range of forest types sampled, although there was a great range of variation between forest types. Of the priority species, the highest production estimates were found for winter chanterelle in Scots pine, wood hedgehog fungus in beech, pedunculate oak and Scots pine, and cep in noble fir.
- Even though the total biomass of winter chanterelle collected over the 3 years was on average 25% higher than that of hedgehog fungus, the average productivities of each (4.7 and 4.4 kg/ha/y, respectively) were very close; because the site and visit frequencies of hedgehog fungus were over double that of winter chanterelle.

- The highest estimates for production of priority species and all species were found for Scots pine forest (47.6 kg/ha/y), followed by silver fir, beech, Sitka spruce, hazel, pedunculate oak, Norway spruce, sessile oak and birch. Larch and lodgepole pine had low production values especially of priority species.

- Nominal retail values (€ per kg fresh weight) were assigned to each of the edible species and the returns per ha were calculated for each forest type based on the relative production of the species found. The highest theoretical returns were from Scots pine and beech. Estimated returns from Sitka spruce forest (€195/ha/y) were 36% of those from Scots pine.

Recommendations

1. A policy need to be formulated regarding the public harvesting of WEF in state forests

2. More information by way of education needs to be made available to the public and foresters on the range of WEF occurring in forests, safe protocols for collecting, and the dangers of toxic species.

3. Further research is need specifically on Sitka spruce, Norway spruce and larch plantations to identify factors and management measures that could amplify the WEF harvest in these forests.

4. Monitoring should be continued on selected sites over a longer timescale to better assess year to year variation in WEF production.

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APPENDIX

Table 1-A. Site frequency (% of sites in which a species was found) and visit frequency (% of sampling visits on which a species was found) of the principal WEF species in each of the years 2007-2009, and yearly average (3-Y).

	Site frequency %					Visit frequency %			
	2007	**2008**	**2009**	**3-Y**		**2007**	**2008**	**2009**	**3-Y**
Hydnum repandum	28.4	23.9	20.6	24.3		21.9	14.9	9.4	15.4
Laccaria laccata	18.9	21.4	26.5	22.3		11.2	8.9	11.0	10.4
Laccaria amethystina	13.5	18.8	24.5	18.9		7.5	8.2	9.6	8.4
Cantharellus cibarius	10.8	13.7	15.7	13.4		5.3	6.8	7.9	6.7
Cantharellus tubaeformis agg.	9.5	14.5	13.7	12.6		7.0	7.7	7.4	7.4
Armillaria mellea	10.8	6.8	19.6	12.4		4.8	2.6	6.5	4.6
Russula cyanoxantha	13.5	6.8	14.7	11.7		5.9	2.1	5.5	4.5
Russula ochroleuca	1.4	3.4	16.7	7.1		1.1	2.3	10.3	4.6
Boletus badius	10.8	4.3	2.9	6.0		5.3	1.4	0.7	2.5
Lycoperdon perlatum	5.4	4.3	7.8	5.8		2.7	1.9	2.9	2.5
Lactarius deliciosus	6.8	5.1	3.9	5.3		2.7	1.9	1.2	1.9
Amanita rubescens	2.7	0.9	11.8	5.1		1.1	0.2	3.1	1.5
Boletus edulis	8.1	3.4	2.9	4.8		5.3	0.9	0.7	2.3
Hydnum rufescens	1.4	5.1	7.8	4.8		0.5	1.9	4.6	2.3
Lactarius deterrimus	5.4	3.4	3.9	4.2		2.1	0.9	1.4	1.5
Lepista flaccida	4.1	2.6	3.9	3.5		2.7	0.9	1.2	1.6
Suillus bovinus	2.7	2.6	3.9	3.1		1.1	0.7	1.2	1.0
Lepista nuda	4.1	1.7	2.9	2.9		1.6	0.5	1.4	1.2
Laccaria proxima	2.7	2.6	2.9	2.7		1.1	0.7	0.7	0.8
Sarcoscypha aurantia	0.0	0	7.8	2.6		0.0	0	3.6	1.2
Lycoperdon pyriforme	2.7	0	4.9	2.5		1.1	0	2.2	1.1
Oudemansiella mucida	0.0	2.6	4.9	2.5		0.0	0.9	1.7	0.9
Laccaria bicolor	2.70	0.00	2.94	1.88		1.07	0.00	0.72	0.60
Auricularia auricular-judae	1.35	0.00	3.92	1.76		0.53	0.00	1.20	0.58
Suillus luteus	1.35	0.00	3.92	1.76		0.53	0.00	0.96	0.50
Cantharellus aurora	0.00	1.70	2.94	1.55		0.00	0.50	0.72	0.41
Leccinum duriusculum	1.35	0.90	1.96	1.40		0.53	0.24	0.72	0.50
Clitocybe geotropa	1.35	0.85	1.96	1.39		0.53	0.23	0.48	0.42
Leccinum scabrum	0.00	0.00	3.92	1.31		0.00	0.00	0.96	0.32
Craterellus cornucopioides	2.70	0.85	0.00	1.19		1.07	0.23	0.00	0.43
Fistulina hepatica	1.35	0.00	1.96	1.10		1.07	0.00	0.48	0.52
Agaricus sylvaticus	1.35	0.00	1.96	1.10		0.53	0.00	0.48	0.34
Hygrocybe pratensis	0.00	0.85	1.96	0.94		0.00	0.23	1.20	0.48
Pseudoclitocybe cyathiformis	1.35	0.00	0.98	0.78		0.53	0.00	0.24	0.26
Grifola frondosa	1.35	0.85	0.00	0.74		1.07	0.47	0.00	0.51
Amanita fulva	0.00	0.00	1.96	0.65		0.00	0.00	0.48	0.16
Agaricus augustus	0.00	0.85	0.98	0.61		0.00	0.47	0.72	0.40
Macrolepiota rhacodes	0.00	1.71	0.01	0.57		0.00	0.47	0.01	0.16
Boletus subtomentosus	1.35	0.00	0.00	0.45		0.53	0.00	0.00	0.18
Coprinus comatus	1.35	0.00	0.00	0.45		0.53	0.00	0.00	0.18
Coprinus atramentarius	0.00	0.00	0.98	0.33		0.00	0.00	0.24	0.08
Flammulina velutipes	0.00	0.00	0.98	0.33		0.00	0.00	0.24	0.08
Pleurotus ostreatus	0.00	0.00	0.98	0.33		0.00	0.00	0.24	0.08
Leccinum versipelle	0.00	0.00	0.98	0.33		0.00	0.00	0.24	0.08

Table 2-A. Numbers and weights (g) of fruit bodies of the principal edible species in each of the years 2007-2009, and yearly average (3-Y).

Species	Total Number of Fruitbodies					Total Weight (g) of Fruitbodies			
	2007	**2008**	**2009**	**3-Y**		**2007**	**2008**	**2009**	**3-Y**
Cantharellus tubaeformis agg.	1199	2805	1471	1825.0		5861.2	16180	3023	8354.7
Hydnum repandum	536	842	141	506.3		8657.9	9816	1694	6722.6
Cantharellus cibarius	57	630	760	482.3		527.3	2558	2350	1811.8
Armillaria mellea	437	69	508.0	338.0		3215.1	605	4107	2642.4
Laccaria amethystina	111	658	230	333.0		291.0	2016	292.6	866.5
Laccaria laccata	152	355	183	230.0		639.0	1344	222.2	735.1
Hydnum rufescens	3	98	318	139.7		15.0	654	1461	710.0
Russula ochroleuca	14	111	281	135.3		190.0	2705	1355	1416.7
Lepista flaccida	50	247	29	108.7		535.0	1378	338	750.3
Oudemansiella mucida	0	21	157	59.3		0.0	103	152	85.0
Suillus bovinus	112	5	55	57.3		810.0	81	1007	632.7
Cantharellus aurora	0	110	31	47.0		0.0	275	37	104.0
Lycoperdon perlatum	10	81	48	46.3		40.0	560	166	255.3
Russula cyanoxantha	17	13	57	29.0		435.4	360	414	403.1
Lycoperdon pyriforme	8	0	76	28.0		44.0	0	50	31.3
Craterellus cornucopioides	61	9	0	23.3		595.0	70	0	221.7
Lepista nuda	22	9	36	22.3		347.0	137	29	171.0
Lactarius deliciosus	16	19	17	17.3		392.3	413	447	417.4
Hygrocybe pratensis	0	7	35	14.0		0.0	39	76	38.3
Auricularia auricular-judae	4	0	36.0	13.3		8.0	0	84	30.7
Boletus edulis	21	12	5.0	12.7		917.8	1400	323	880.3
Boletus badius	13	14	5.0	10.7		649.1	435	254	446.0
Sarcoscypha aurantia	0	0	30	10.0		0.0	0	160	53.3
Laccaria proxima	4	13	7	8.0		20.0	39	9	22.7
Amanita rubescens	7	2	14.0	7.7		246.8	35	433.5	238.4
Clitocybe geotropa	6	10	6	7.3		65.0	50	500	205.0
Lactarius deterrimus	7	6	7	6.7		105.0	165	165	145.0
Coprinus atramentarius	0	0	12	4.0		0.0	0	63	21.0
Laccaria bicolor	7	0	4	3.7		35.0	0	2.3	12.4
Agaricus augustus	0	7	3	3.3		0.0	60	89	49.7
Suillus luteus	1	0	5	2.0		30.0	0	44	24.7
Leccinum duriusculum	1	1	3	1.7		45.0	13	75	44.3
Fistulina hepatica	2	0	3	1.7		80.0	0	128	69.3
Pseudoclitocybe cyathiformis	1	0	4	1.7		2.8	0	12	4.9
Grifola frondosa	2	2	0	1.3		500.0	350	0	283.3
Agaricus sylvaticus	1	0	3.0	1.3		7.0	0	130	45.7
Flammulina velutipes	0	0	4	1.3		0.0	0	5	1.7
Leccinum scabrum	0	0	4	1.3		0.0	0	88.5	29.5
Pleurotus ostreatus	0	0	3	1.0		0.0	0	0	0.0
Amanita fulva	0	0	2.0	0.7		0.0	0	53	17.7
Macrolepiota rhacodes	0	2	0	0.7		0.0	20	0.0	6.7
Boletus subtomentosus	1	0	0	0.3		35.0	0	0	11.7
Coprinus comatus	1	0	0	0.3		25.0	0	0	8.3
Leccinum versipelle	0	0	1	0.3		0.0	0	64	21.3