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Testing indicators of biodiversity for plantation forests

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ABSTRACT

In many parts of the world, plantations make up a considerable proportion of the total forest area. In such regions, the identification of high biodiversity value stands and of management practices to enhance biodiversity is essential if the goals of Sustainable Forest Management are to be achieved. Since complete biodiversity assessments are rarely possible, efforts have been increasingly focussed on the use of indicators. Of particular interest are indicators applicable to individual stands that require no specialist taxonomic or technical knowledge to assess. Candidate biodiversity indicators had been identified in a previous study using data from Irish Sitka spruce (*Picea sitchensis*) and ash (*Fraxinus excelsior*) plantations but had yet to be tested on independent data. In the present study, the provisional indicators for vascular plant, bryophyte, spider and bird diversity were tested on data from Irish Scots pine (*Pinus sylvestris*), oak (*Quercus petraea*/*Quercus robur*), Sitka spruce and lodgepole pine (*Pinus contorta*) plantations. Conifer canopy cover was confirmed as an important biodiversity indicator, due to its influence on below-canopy microclimatic and structural conditions. Bryophyte species richness was higher in relatively high canopy cover plantations on poorly drained soils, while bird species richness was higher in more open plantations with high shrub cover. Coarse woody debris was an important substrate for forest-associated bryophytes, with higher species richness at higher volumes of deadwood. Both proximity to old woodland and stand age were confirmed as positive indicators for forest-associated vascular plants. This is related to dispersal limitation in these species, with nearby woodlands acting as important seed sources and colonisation increasing with time. Stand age was also confirmed as a positive indicator for forest-associated spiders and is related to the development of suitable habitat as the plantation matures. All of the confirmed indicators can be assessed without need for specialist knowledge, are ecologically meaningful and applicable to a range of forests managed under a clearfelling system. They can be used to assess the potential value of stands for the taxonomic groups to which they apply, as well as giving insights into management practices to enhance diversity in these groups.

1. Introduction

Forests support a large proportion of the world's biodiversity (Kapos and Iremonger, 1998). In Europe, the area covered by forest stands at 45% and is increasing due to both planting and natural expansion (Forest Europe et al., 2011). While the proportion of the forest area composed of plantations (usually intensively managed forests, established artificially by planting or seeding) is on average 4% for Europe, in some countries they make up a considerably larger proportion, constituting 89% in the Republic of Ireland, 78% in Denmark and 77% in Britain (Forest Europe et al., 2011). In such countries, the identification of plantations which are potentially of high biodiversity value, and of management practices which can enhance biodiversity in plantations are essential if the goals of Sustainable Forest Management are to be met.

Since a complete assessment of biodiversity is rarely possible, other than at very small scales, there has been an increasing interest in using indicators as surrogate measures of biodiversity (Humphrey and Watts, 2004; Marchetti, 2004; Niemi and McDonald, 2004). The indicator concept is based on the principle that easily measured features that affect or derive from variation in biodiversity can be used as an index of biodiversity (Ferris and Humphrey, 1999; Landres et al., 1988). Three types of indicators can be identified – compositional (e.g. species), structural (e.g. physiognomy of forest stands and associated habitats) and functional (processes e.g. nutrient cycling) (Ferris and Humphrey, 1999; Larsson et al., 2001).

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Table 1
A summary of the stand locations and characteristics.

Stand number	Irish grid ref.	Forest type	Age (years)[a]	Soil type[b]	Annual precipitation (mm)[c]
1	S033125	Scots pine	65	Brown earth	1091
2	T144950	Scots pine	65	Podzol	1003
3	T234932	Scots pine	79	Brown podzolic	1262
4	R940330	Oak	72	Brown earth	1066
5	W442862	Sitka spruce	30	Peat	1762
6	N302111	Scots pine	71	Brown earth	979
7	T243955	Scots pine	65	Podzol	937
8	N838334	Oak	73	Brown earth	857
9	N314297	Scots pine	62	Gley	874
10	L799780	Lodgepole pine	28	Peat	1512
11	F870280	Lodgepole pine	28	Peat	1696
12	G568262	Lodgepole pine	31	Peat	1452
13	S361349	Oak	75	Brown podzolic	1132
14	S489634	Oak	151	Brown earth	939
15	T210767	Scots pine	63	Brown podzolic	966
16	R924324	Scots pine	71	Podzol	1176
17	M838042	Scots pine	60	Brown earth	971
18	Q960180	Sitka spruce	37	Peat	1762
19	S201172	Lodgepole pine	30	Podzol	1510
20	S200172	Sitka spruce	33	Brown earth	1099
21	H100898	Sitka spruce	36	Peat	1429

[a] Number of years after planting at time of study.
[b] According to the Irish Great Soil Groups (Gardiner and Radford, 1980).
[c] From Sweeney et al. (2003).

A large amount of work has been undertaken in developing indicators at national and international scales, such as the pan-European indicators for Sustainable Forest Management (MCPFE Liaison Unit Vienna, 2003). However, indicators that can be used by forest managers at the stand scale are also important (Ferris and Humphrey, 1999). In order to be of practical use to forest managers, these indicators need to be easy to assess, repeatable, cost-effective and ecologically meaningful (Ferris and Humphrey, 1999). Despite the popularity of the indicator concept, few indicators have been adequately tested or validated (Niemi and McDonald, 2004; Noss, 1999). Following an extensive study as part of the BIOFOREST project (Iremonger et al., 2007), Smith et al. (2008) developed a set of indicators of biodiversity for plantation forest stands in Ireland, but likely to be applicable over a wider area with similar climates. These stand- and landscape-scale compositional, structural and functional indicators of biodiversity covered five taxonomic groups – bryophytes, vascular plants, spiders, hoverflies and birds – and used data from 44 Sitka spruce (*Picea sitchensis*) and ash (*Fraxinus excelsior*) plantation forests. However, they remained provisional until tested on independent data and their applicability to plantations of other tree species was unknown. The aim of the present study was to test these indicators in plantations of a range of tree species of various ages in order to assess their broad applicability.

2. Materials and methods

2.1. Site selection

A total of 21 stands of four different plantation forest types were selected across the Republic of Ireland: nine were plantations of Scots pine (*Pinus sylvestris*), a conifer species of disputed native status (Roche et al., 2009); four were plantations of oak (*Quercus petraea*/*Quercus robur*), both native broadleaved species; four plantations were dominated by Sitka spruce (*P. sitchensis*) and a further four were plantations of lodgepole pine (*Pinus contorta*), both non-native conifer species and the most common and second most common forest types in the Republic of Ireland respectively (Forest Service, 2007; Table 1). All were first rotation (newly established) plantations, although some were established on sites of former woodland. Stands were all greater than five hectares in area and included a range of plantation ages, soil types and climatic conditions (Table 1). One lodgepole pine and three Sitka spruce stands were surveyed in 2010, with the remainder of the stands surveyed in 2011.

These plantations are generally managed using a clear-felling/clearcutting and replanting system (Forest Service, 2000), with Sitka spruce and lodgepole pine plantations managed on short rotations of 35–45 years (Anon., 2005c), while the rotation length is generally 70–80 years for Scots pine (Anon., 2005b), and 130–160 years for oak (COFORD, 2002). Thinning is usually carried out at regular intervals, other than on unstable sites; lodgepole pine stands often remain unthinned for this reason (Anon., 2005a). Line and selection thinning is the most commonly used method, where lines of trees, normally following the original planting rows, and suppressed and sub-dominant trees are removed, with groups of dominants and co-dominants broken up to create an even distribution of the final crop of trees (Forest Service, 2000).

2.2. Data collection

Data on the species richness and abundance of vascular plants, bryophytes, spiders and birds were collected, along with several structural and functional variables, in order to test the indicators developed by Smith et al. (2008) (Table 2). Data on hoverflies were not collected.

Bryophytes and vascular plants were surveyed in three representative 10 m × 10 m plots, located at least 50 m apart, in each stand. The percentage cover of each species was estimated to the nearest 5%. The structural data collected within each plot were the percentage cover of the canopy (planted trees), shrub layer (woody species <2 m tall, including *Rubus*), field layer (non-woody species) and conifer litter, and the total volume of coarse woody debris (CWD; >10 cm diameter). Five soil samples were collected from the corners and centre of each plot to a depth of 10 cm (excluding litter and fermentation layers) and bulked for analysis. Soils were then air dried and sieved and available P was extracted using Morgan's reagent and quantified by a colorimetric method (Allen et al., 1986).

Active ground-dwelling spiders were sampled using three transects located at least 50 m apart, and adjacent to the vegetation plots where possible, each containing five pitfall traps (Curtis, 1980). Pitfall traps, which were plastic cups, approximately 7 cm in diameter and 9 cm high, filled with 3 cm of ethylene glycol, were