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Commercial spruce plantations support a limited canopy fauna: Evidence from a multi taxa comparison of native and plantation forests

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ABSTRACT

Globally, the total area of plantation forest is increasing as deforestation and fragmentation of native forest continues. In some countries commercial plantations make up more than half of the total forested land. Internationally, there is growing emphasis on forestry policy for plantations to deliver biodiversity and ecosystem services. In Ireland, native forest now comprises just 1% of total land cover while non-native spruce forest makes up 60% of the plantation estate and approximately 6% of the total land cover. The majority of plantation invertebrate biodiversity assessments focus on ground-dwelling species and consequently a good understanding exists for these guilds, especially ground-active spiders and beetles. Using a technique of insecticide fogging, we examine the less well understood component of forest systems, the canopy fauna (Coleoptera, Araneae, Diptera and Hemiptera), in Irish spruce plantations (Sitka and Norway) and compare the assemblage composition, richness and abundance to that of remnant native forest (ash and oak). In addition, we examine the potential for accumulation of forest species in second rotation spruce plantations and identify indicator species for each forest type.

From 30 sampled canopies, we recorded 1155 beetles and 1340 spiders from 144 species and over 142 000 Diptera and Hemiptera from 71 families. For all taxa, canopy assemblages of native forests were significantly different from closed-canopy plantation forests. No indicators for plantation forest were identified; those identified for native forest included species from multiple feeding guilds. Plantations supported approximately half the number of beetle species and half the number of Diptera and Hemiptera families recorded in native forests. Although assemblages in Norway spruce plantations were very different to those of native forest, they had consistently higher richness than Sitka spruce plantations. No differences in richness or abundance were found between first rotation and second rotation Sitka spruce plantations. Compared to other forest types, Sitka spruce plantations contained far greater total abundance of invertebrates, due to vast numbers of aphids and midges. Under current management, Sitka spruce plantations provide limited benefit to the canopy fauna typical of native forests in either first or second rotations. The large aphid populations may provide abundant food for insectivores but may also lead to reduced crop production through defoliation. Progressive forestry management should attempt to diversify the plantation canopy fauna, which may also increase productivity and resilience to pest species.

1. Introduction

Global deforestation continues to fragment and reduce natural forest as afforestation of commercial plantations expands (FAO, 2010). Globally, over 29% of land area is forest, of which 3% is plantation and under current trends this is expected to account for 21% by 2100 (Brockerhoff et al., 2013). At present, some countries have much greater proportions of forested land comprising plantations; for example, Ireland 89%, UK 69%, India 51% and Japan 44% (FAO, 2001; Forest Europe et al., 2011). As the area of plantations increases, so does the importance of management to ensure the needs of regional biodiversity are met. Concerns are often raised about the lack of biodiversity associated with plantation forest (Hartley, 2002; Brockerhoff et al., 2008), and when compared to natural forest, plantations can lack specialist forest species (Helle, 1986; Niemela, 1993; Finch, 2005). In areas where afforestation has occurred on non-forest habitat, as is often the case in Western Europe, plantations may also have negative effects on the biodiversity of open habitats (Butterfield et al., 1995; Brockerhoff et al.,

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2008). However, recent studies have shown that in some situations plantation landscapes can provide conservation benefits for regionally important species (Berndt et al., 2008; Pawson et al., 2008; Pedley et al., 2013). To understand and optimise plantation landscapes, there is a pressing need to examine which aspects of forest biodiversity are supported in plantation habitats.

Forest canopies contain a large proportion of the total diversity of organisms on Earth (Lowman and Wittman, 1996), with a major part of this diversity attributed to invertebrate species. In fact, in the tropics it has been suggested that there are twice as many arboreal forest species than there are ground-dwelling ones (Erwin, 1982). Although the canopy in temperate forests may be less species diverse than in tropical forest, many species utilise temperate forest canopies for at least part of their life cycle (Ulyshen, 2011). Invertebrates are an important component of all forest ecosystems, where they have roles in food-webs and nutrient cycling, and as prey for other invertebrates, small mammals and birds (Askenmo et al., 1977; Wilson et al., 1999; Halaj and Wise, 2001). They are also used to monitor forest change and management (Schowalter, 1995; Ji et al., 2013). Arthropods in particular are strongly influenced by the compositional and structural dynamics of their immediate habitats and the surrounding landscape, and respond quickly to brief, sudden changes in environmental conditions (Robinson, 1981; Marc et al., 1999; Rainio and Niemela, 2003).

The majority of invertebrate research comparing plantation to native forests has been carried out on the non-canopy component, predominately through pitfall trapping of ground invertebrates. Few studies have sampled both the canopy fauna of plantations and native forests in the same landscape. Those studies that have compared canopies of native and plantation forest include short rotation *Eucalyptus* plantations in Australia (Cunningham et al., 2005), tropical hardwood plantations in Thailand (Tangmitcharoen et al., 2006) and coniferous plantations in North America (Schowalter, 1995). What is lacking is an assessment of the canopy invertebrates of non-native plantations in Europe, focusing on what the closed canopy of these commercial forests provide for the regional forest biota of older native forest. It has been shown that the structurally complex canopies of old forests support more species than the relatively simple canopies of young forests (reviewed in Ulyshen, 2011). Similarly, it is likely that commercially mature plantations, which are relatively young compared with remnant old-growth forest, also support less species. However, with increased amounts of plantation forest and continued deforestation of native forest, there is a need to address the degree to which commercial forests support the canopy biodiversity of native forests (Schowalter, 1995). Identifying gaps in biodiversity protection will contribute to evidence-based conservation (Sutherland et al., 2004), helping to meet national and international objectives for conservation (EPA, 2007; EC, 2011).

In this study, we examine the canopy invertebrates (Coleoptera, Araneae, Diptera and Hemiptera) of remnant patches of native forest in Ireland and non-native spruce plantations. Native forests in Ireland, like elsewhere in Western Europe, have undergone severe reduction and fragmentation. Anthropogenic land change has severely impacted Ireland's natural biodiversity; remaining patches of native forest can now only be termed 'semi-natural' having been utilised over centuries for wood fuel and grazing (Peterken, 1996). Only 1% of the surface area of Ireland is comprised of natural forest, and most remaining patches are small (75% are less than 5 ha) and isolated in a landscape of intensive agriculture (Cross, 2012). Commercial conifer plantations form a large part of the total forested land in Ireland; approximately 10% of the surface area of Ireland has been afforested, mainly through the planting of non-native conifers. Forest expansion planned over the next two decades will see the total reach 15% (COFORD Council, 2009).

Given the extent of land that will be under plantation in the coming years, it is important to understand the biodiversity in afforested and also reforested habitat. As plantations often occur as mosaics of different aged stands, it is likely reforested stands will be colonised by species inhabiting adjacent closed-canopy habitat through metapopulation dynamics (Hanski, 1999). In addition, if permanent closed-canopy habitat is maintained within the local mosaic there is potential for accumulation of forest specialist through successive rotations. To explore the biodiversity potential of plantation forests in Ireland, two types of remnant native forest (ash and oak) were sampled as reference points with which to compare the canopy invertebrates of differing types of non-native plantation forests, first and second rotation Sitka spruce and first rotation Norway spruce. We used a technique of insecticide canopy fogging to sample invertebrates from the five forest types to answer the following questions; (1) Do plantations support canopy invertebrate assemblages similar to native forests and do patterns of species richness, abundance and composition correspond for all taxa? (2) Does the canopy fauna in second rotations plantation change and do these successive rotations support increasing numbers of forest specialists than first rotations?

2. Methods

2.1. Study sites

Thirty closed-canopy forests, comprising five types, were sampled in Ireland (Fig. 1); six ash (*Fraxinus excelsior*) dominated

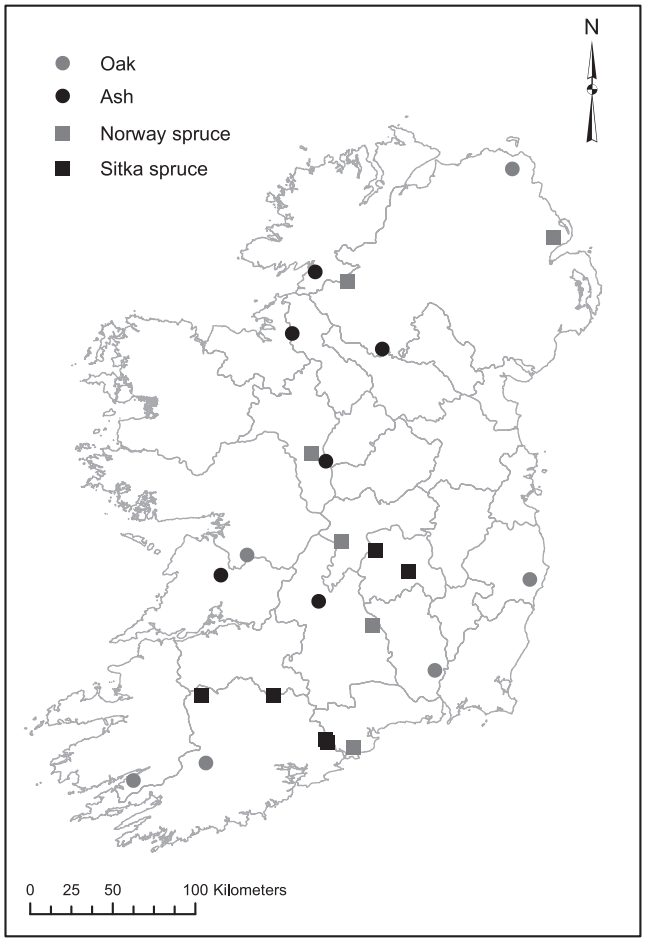

Fig. 1. The distribution of sampled forest sites across Ireland.