

Project: Secondary woodland biodiversity value

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1. Project summary:

Woodland creation and restoration are often assumed to benefit biodiversity. However, slow habitat succession rates and time lags in species responses have resulted in a lack of empirical studies assessing the long-term value of these activities. Here, we used ancient semi-natural woodlands (250+ years old; usually regarded as high quality habitats for many taxa) as reference sites to assess how secondary woodlands planted over the last century are performing in terms of their value for biodiversity, using moths (a biologically-diverse group and indicator for forest quality and wider biodiversity) as a case study. Preliminary results indicated moderate differences in the vegetation structure of ancient vs. secondary woodlands; in general, ancient woodlands had larger trees, higher structural heterogeneity, denser understorey and canopy cover, larger proportion of native tree species and lower tree densities than secondary woodlands. Despite these habitat differences, ancient and secondary woodlands harboured similar moth abundance and species richness, suggesting that they can both be valuable habitat for moths. Future work will explore how key differences in habitat structure between ancient and secondary woodlands relate to moth species composition. These findings will provide scientific evidence to inform conservation actions and policy aimed at increasing the value of secondary woodlands for biodiversity.

2. Introduction:

Woodland is one of the most biologically diverse ecosystems on Earth and an important habitat for many wildlife species. Historically, woodland cover has been drastically reduced, with worldwide deforestation resulting in a 50% decrease in woodland cover over the last three centuries ⁽¹⁾. Over recent decades, deforestation rates have slowed down; net forest loss has halved over the last 25 years and forest extent has increased in many countries, particularly in temperate regions ⁽²⁾. These trends are mainly due to deliberate planting (often encouraged through the provision of financial incentives to landowners; e.g. agri-environment schemes), rather than to natural expansion. In the United Kingdom (UK), long-term deforestation has been so severe that woodland cover went from a post-glacial high of 70% to a low of 5% in 1900 ⁽³⁾. Woodland planting programmes over the last century have been successful in increasing woodland cover to a new high of approximately 13% ⁽³⁾. This trend is expected to continue; for instance, the Scottish Government has pledged to create 10,000 ha of new woodlands per year between 2014-2020, and has allocated £252 million to forestry grant schemes aimed at increasing woodland amount and quality ⁽⁴⁾.

It is often assumed that creating new woodlands will benefit biodiversity. However, slow habitat development rates coupled with time lags in species colonisation and capitalisation of resources in new habitat patches, have resulted in a lack of empirical studies assessing the long-term value of woodland creation. Additionally, despite an overall increase in woodland area over recent decades, many species (particularly those associated with native semi-natural woodland) continue to undergo severe population declines in several countries, including the UK ⁽⁵⁾.

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The occurrence, abundance and diversity of many woodland taxa are likely to be strongly influenced by local habitat characteristics (e.g. patch size and quality) and, to a lesser extent, by their surrounding landscape (e.g. degree of connectivity between habitat patches ⁶). Woodland age has been identified as one of the key factors determining the occurrence of many woodland-dependent species, particularly vascular plants. However, its effect on other taxonomic groups (including most animals) has been largely ignored ⁽⁶⁾. Very few invertebrate studies have assessed species responses to ecological continuity, but over 60 % of those that did found significant positive associations (e.g. for saproxylic beetles in broadleaved woodlands ⁷). Woodland age can influence the occurrence of species in two ways; firstly, older woodlands have been wooded long enough (i.e. have long ecological continuity) to allow colonisation by woodland species which are often poor dispersers; secondly, sites with long ecological continuity are often characterised by an old-growth habitat structure, such as high structural heterogeneity and large amounts of deadwood. Such characteristics influence habitat quality and are often important in determining the abundance and/or diversity of many species groups (e.g. moths ⁸). Ancient semi-natural woodlands are therefore usually regarded as higher quality habitats for many taxa than woodlands in earlier successional stages ⁽⁹⁾. As such, they can be used as reference sites (e.g. to identify the biodiversity pool with the potential to colonise secondary woodlands) to assess how secondary woodlands are performing in terms of their value for biodiversity.

We have selected moths as our case study group because they are a biologically diverse taxon with many species (e.g. about two-thirds of British macromoths) occurring regularly in woodlands ⁽¹⁰⁾ and a sensitive indicator group for forest quality ⁽¹¹⁾. In addition, many moth species have undergone significant population declines over the last few decades and have gained special conservation concern status. Habitat loss and fragmentation have been identified amongst the most important factors driving moth population declines; changes in the structure, management and spatial configuration of woodlands have also been linked to declines of certain species ⁽¹²⁾. In addition, models based on habitat characteristics of recently planted woodlands have predicted these to have lower moth abundance and species richness than older, more mature semi-natural woodlands ⁽¹³⁾. Moths are also an important food source for many taxa (e.g. bats and birds).

3. Aims and objectives:

Here, we use ancient semi-natural woodlands as reference sites to assess how secondary woodlands planted over the last century are performing in terms of their value for biodiversity, using moths (a biologically-diverse group and key indicator for forest quality and wider biodiversity) as a case study. Specifically, we aim to: (1) to compare moth abundance, diversity and species composition in secondary vs. ancient woodlands to assess their degree of similarity; (2) to examine if moth abundance, diversity and species composition relate to differences in habitat structure (e.g. tree density, clutter, structural heterogeneity) between secondary vs. ancient woodlands; and (3) to produce management recommendations aimed at increasing the value of semi-natural woodlands for biodiversity.

4. Methods:

4.1 Site selection: We used 15 historic woodland creation sites which form part of the Woodland Creation & Ecological Networks project (WrEN; www.wren-project.com), a large-scale natural

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experiment designed to study the effects of long-term woodland creation on biodiversity and inform landscape-scale conservation ⁽¹⁴⁾. These secondary broadleaved woodlands are located in central Scotland (study area ca. 7,335 km²) and have been created over the past 150 years on what was previously agricultural land; sites were selected from the National Forest Inventory of Scotland (Forestry Commission dataset); OS historic maps (Edina dataset) were used to determine their approximate age. In addition, we used 15 ancient woodlands (250+ years old) of similar characteristics and located in the same study area, which were identified using Scotland's Ancient Woodland Inventory (Forestry Commission dataset).

4.2 Characterisation of woodland attributes: We conducted field surveys to characterise the vegetation structure of all woodland sites using the point-centred quarter method along an edge-to-interior transect to collect data on tree species richness, tree density, tree diameter at breast height (DBH; only trees ≥ 7 cm DBH were measured), amount of deadwood, understorey and canopy cover (%); general attributes relating to woodland management (e.g. signs of grazing) were also recorded.

4.3 Moth surveys: Surveys were conducted from 1st June to 11th September. A paired-site design (15 pairs of ancient-secondary woodland patches; moth surveys conducted simultaneously in sites within a pair) was used to minimise the effects of weather and seasonality when surveying moths in ancient and secondary woodlands, and to improve statistical power. Two portable 6 W Heath light traps powered with 12 V batteries were used in each woodland (one at the edge and one at the centre of each woodland patch). Traps were activated before sunset, switched off 4 hours after sunset (using automated timers) and checked the following morning; moths were identified and released on site. All sites were surveyed at least twice during the field season (with 15+ days between trapping sessions) to increase the probability of detecting species with different flight seasons.

4.4 Data entry, processing and analysis: All data have been entered into a master dataset and a list of species recorded in ancient and secondary woodlands has been compiled. Additionally, moth species have been categorised according to their habitat specificity (i.e. woodland specialist, woodland generalist; non-woodland species) and overwintering stage (i.e. adult, pupa, larva, egg) using published literature (Emmet [1993] and Sterling & Parsons [2012] for micromoths; Waring & Townsend [2003] for macromoths). Preliminary data analyses (i.e. Generalised Linear Models) were conducted to quantify differences in vegetation structure between ancient and secondary woodlands; summary calculations and figures have been produced to visualise differences in moth abundance and species richness between ancient and secondary woodlands (statistical analyses for moth data pending).

5. Preliminary results:

5.1 Woodland attributes: Vegetation characteristics differed to some extent between secondary and ancient woodlands. Specifically, although there were no significant differences in tree species richness, ancient woodlands had a higher proportion of native tree species than secondary woodlands (Fig. 1a); structural heterogeneity (quantified as standard deviation in tree DBH), canopy and understorey cover were all significantly higher in ancient than in secondary woodlands (Fig. 1d-f); ancient woodlands also had marginally lower tree densities than secondary woodlands and marginally larger trees (i.e. higher mean values of tree DBH)

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(Fig. 1b & c). However, the amount of variation explained by woodland age (i.e. ancient vs. secondary) for individual vegetation variables was generally low, ranging from 6 to 19%.

5.2 Moth communities: After a survey effort of 182 trap-nights, a total 5,407 moth specimens were captured. These belonged to 23 families (the most common were Noctuidae, Geometridae, Tortricidae and Crambidae) and 233 species (Fig. 2). Ancient and secondary woodlands harboured similar moth species richness and abundance. On average, 10.0 (\pm 0.8 SE) species and 28.4 (\pm 3.8) individuals were captured per trap in ancient woodlands (n = 93 trap-nights) compared to 11.4 (\pm 0.8) species and 31.4 (\pm 3.6) individuals per trap in secondary woodlands (n = 89 trap-nights) (Fig. 3). The proportion of woodland specialist species was also similar in ancient (26.3% species, 13.7% individuals) and secondary woodlands (29.0% species, 13.6% individuals). However, species composition was somewhat different; from a total of 233 species, 61.3% were present in both woodland types, whilst 17.6% were exclusively present in ancient and 21.2% in secondary woodlands.

6. Preliminary discussion:

We found moderate differences in the vegetation structure of ancient vs. secondary woodlands, with ancient woodlands having on average larger trees, higher structural heterogeneity, denser understorey and canopy cover, larger proportion of native tree species and lower tree densities than secondary woodlands. Despite these habitat differences, preliminary data analyses suggest that ancient and secondary woodlands can both be valuable habitat for moths, as they harbour similar levels of moth abundance, species richness and proportion of woodland specialists. However, species composition was somewhat different between the two woodland types, with less than two thirds of moth species present in both ancient and secondary woodlands. This is likely to be related to the observed differences woodland habitat structure and the life-history traits (e.g. larval feeding preferences, overwintering stage) of different moth species. Additionally, woodland management impacting on vegetation (e.g. reduced tree regeneration due to over-grazing) was apparent at some of our sites and we suggest this is likely to play a major role in determining the suitability of woodlands for moths.

7. Progress to date and future work:

Summary of activities supported by Sustainable Forestry SCIO: The funds requested from the SF SCIO were spent as outlined in the original project application (i.e. on recruitment and salary of a full-time field assistant to carry out moth surveys and species identification; G4:11 appointment, fixed-term for 16 weeks). The contribution of the SF SCIO was essential to carry out the work proposed in the application and the project could not have gone ahead otherwise. The timing and duration of activities have broadly adhered to those specified in the original project application. Specifically:

- We recruited a field assistant and made preparations for the field season (e.g. gathering field equipment and preparing site maps; 15th May – 1st June).
- Field surveys (i.e. moth trapping and identification sessions) were conducted during the summer (1st June – 11th September), meeting the number of sites originally planned.

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- All data have been entered into a digital database (1st June – 22nd September).
- Preliminary data analyses have been conducted (25th September – ongoing task).

Future work: **Statistical analyses** will be conducted to explore how key differences in habitat structure between ancient and secondary woodlands relate to woodland moth communities. Specifically, Generalised Linear Mixed Models will be used to compare moth abundance and species richness between ancient and secondary woodlands. Multivariate analyses (e.g. Structural Equation Models) will be used to assess how moth species composition relates to the vegetation structure of the two woodland types. We will also explore how moth species with differing life-history traits (e.g. habitat specificity and overwintering stage) are influenced by habitat attributes of ancient vs. secondary woodlands. Other woodland attributes (e.g. patch size and shape, proximity to other woodlands) likely to influence moth communities will be incorporated as covariates in statistical analyses. We will prepare a manuscript for submission to **publication** in a peer-reviewed journal (likely to be mid 2018) and present results at an international **conference** (an abstract has been submitted to give a talk at the European Congress of Conservation Biology 2018, in Finland). **Impact:** our results will be discussed in the context of providing scientific evidence to inform conservation actions and agri-environmental policy aimed at increasing the value of secondary woodlands for biodiversity. Existing links with government organisations directly involved in conservation, environmental management and policy making (e.g. WrEN partnership) will facilitate the translation of our findings into practical guidance (e.g. as advisory documents for woodland creation and management schemes).

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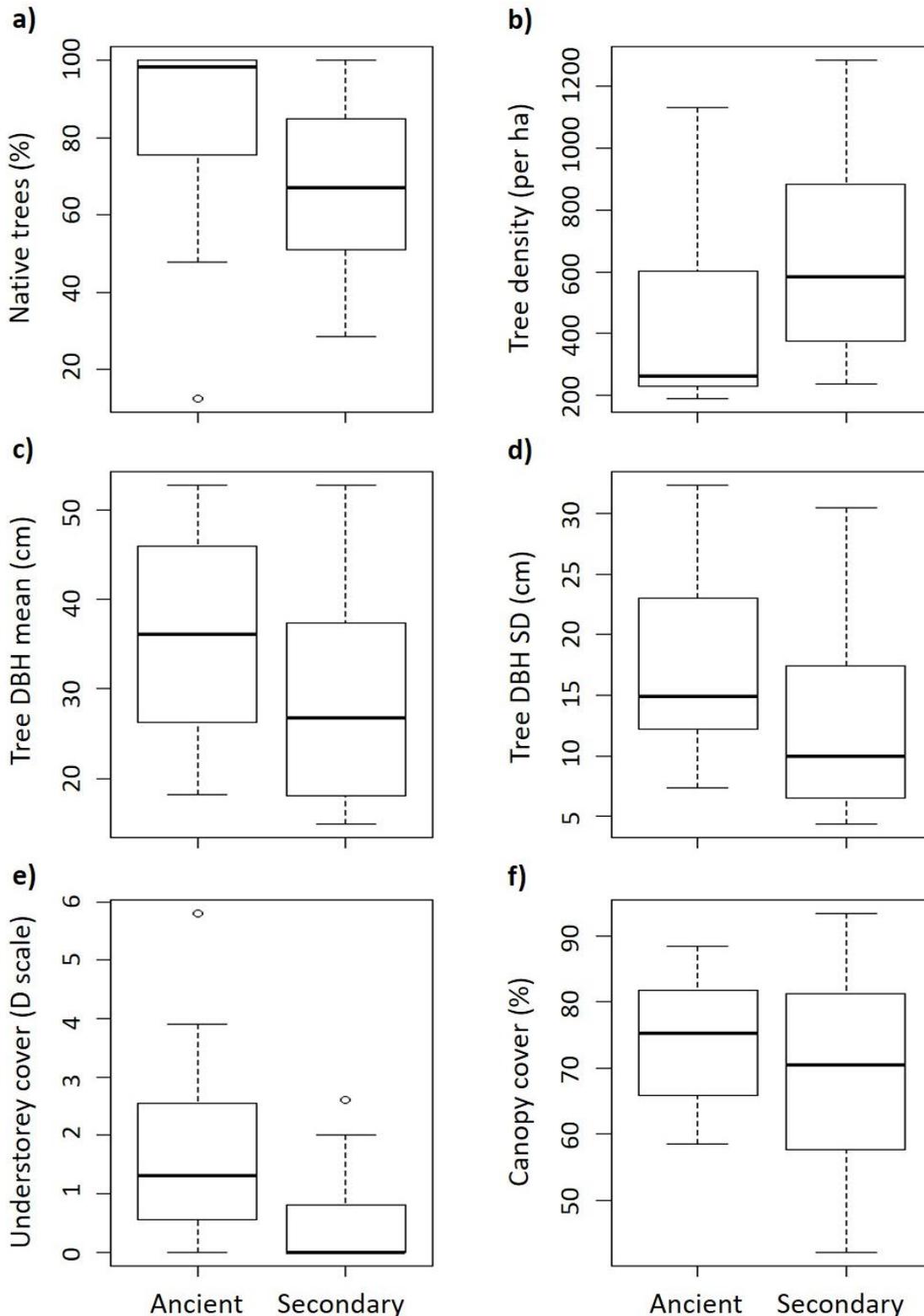


Figure 1. Boxplots showing upper whisker (maximum data point, excluding outliers), interquartile range box (IQR; top line = 75% of the data \leq this value; middle line = median; lower line = 25% of the data \leq this value), lower whisker (minimum data point, excluding outliers) and outliers (shown if data points are outside 1.5 x IQR above the upper quartile or below the lower quartile) for vegetation attributes of ancient and secondary woodlands.

a)



b)



c)



Figure 2. Examples of moth species recorded during field surveys in ancient and secondary woodlands in central Scotland: a) *Xanthia togata* (woodland specialist), b) *Noctua fimbriata* (woodland generalist), c) *Nudaria mundana* (ubiquitous species). Photos by Philip Sansum.

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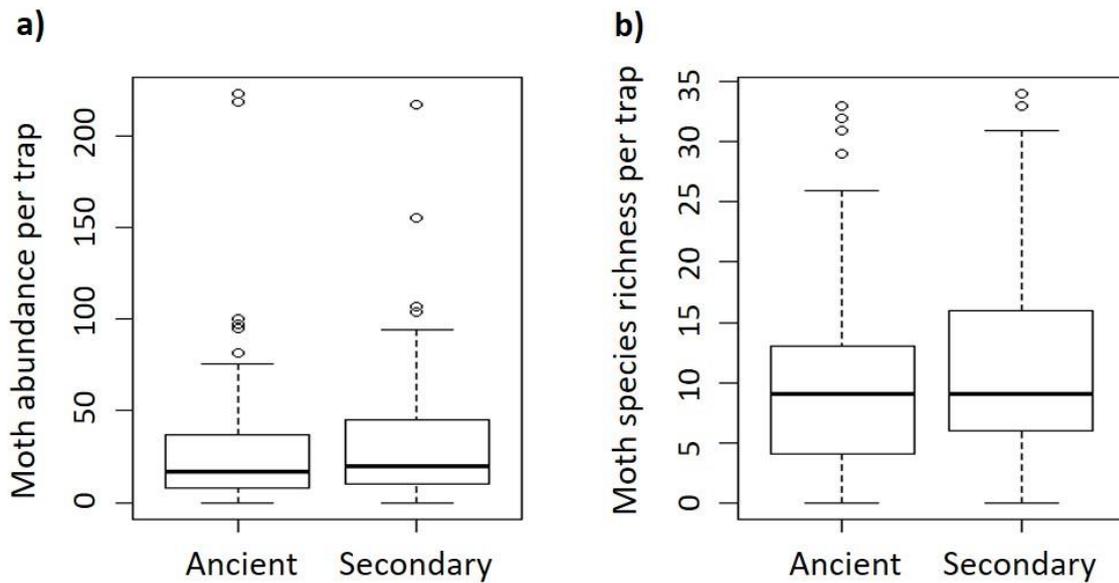


Figure 3. Boxplots showing upper whisker (maximum data point, excluding outliers), interquartile range box (IQR; top line = 75% of the data \leq this value; middle line = median; lower line = 25% of the data \leq this value), lower whisker (minimum data point, excluding outliers) and outliers (shown if data points are outside 1.5 x IQR above the upper quartile or below the lower quartile) for a) moth abundance and b) moth species richness in ancient and secondary woodlands.