European Journal of Soil Biology 75 (2016) 97–106

Contents lists available at ScienceDirect

European Journal of Soil Biology

journal homepage: http://www.elsevier.com/locate/ejsobi

Original article

Microhabitat heterogeneity enhances soil macrofauna and plant species diversity in an Ash – Field Maple woodland

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ARTICLE INFO

Article history:
Received 29 December 2015
Received in revised form
26 April 2016
Accepted 28 April 2016
Available online 15 May 2016

Handling Editor: Stefan Schrader

Keywords:
Soil biodiversity
Plant biodiversity
Multivariate ordination
Small-scale heterogeneity
Woodland

ABSTRACT

The high biodiversity of soil ecosystems is often attributed to their spatial heterogeneity at multiple scales, but studies on the small-scale spatial distribution of soil macrofauna are rare. This case study of an Ash – Field Maple woodland partially converted to conifer plantation investigates differences between species assemblages of soil and litter invertebrates, and plants, using multivariate ordination and indicator species analysis for eleven microhabitats.

Microhabitats representing the main body of uniform litter were compared with more localised microhabitats including dead wood and areas of wet soil. Species accumulation curves suggest that for this site it is more efficient to sample from varied microhabitats of limited spatial scale rather than the broad habitat areas when generating a species inventory. For comparative work sampling the main body of uniform litter is more appropriate, given that microhabitats vary from woodland to woodland and would make standardisation problematic.

Vegetation showed more distinctive microhabitat-specific species assemblages than soil and leaf litter invertebrates and was strongly associated with environmental variables. Microhabitats with distinct assemblages included dead wood habitats, which had a high proportion of saproxylic species; a highly disturbed microhabitat with distinct plant and soil species characteristic of ruderal habitats and seeps with earthworm species rarely sampled in standard soil biodiversity surveys.

The leaf litter in the conifer plantation area was species poor and the biodiversity quantified was considerably enhanced by the sampling from the additional microhabitats - illustrating the importance of small-scale heterogeneity for increasing plant and soil macrofauna biodiversity at this site.

1. Introduction

Soils are among the most important sources of ecosystem services, providing goods and functions beneficial to human populations, including supporting the majority of food production, regulating water quality and supply, buffering against floods and droughts and participating in carbon and nutrient cycling [1,2]. Soils have a high level of biodiversity, representing 23% of described organism diversity [3], in some ecosystems soil biodiversity may outnumber above ground biodiversity [2,4].

Spatial and temporal heterogeneity at multiple scales is a clear influence on soil biodiversity, with well-established differences in soil fauna from contrasting mull and mor forest soils [5] and habitat types [6,7]. On a smaller spatial scale tree species diversity has been found to influence earthworm density [8] and the presence of dead wood is positively correlated with soil arthropod abundance and diversity [9].

Previous studies [6,7] sampled the main microhabitat of uniform leaf litter and the soil beneath it, avoiding major sources of micro-heterogeneity such as dead wood and wet soil. This study investigates diversity patterns of soil macrofauna and plants at a smaller spatial scale, using Winkler bag extraction of leaf litter, soil pits and plant quadrats within a single woodland to survey eleven microhabitats.

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http://dx.doi.org/10.1016/j.ejsobi.2016.04.012
1164-5563/

2. Materials and methods

2.1. Site description

The surveys were carried out in two adjoining woodlands, Timber Copse and Greatmead Copse (50°43′46.59″N, −1°15′5.10″E), on the Isle of Wight, an island off the coast of Hampshire, southern England. The island is one of the most southerly parts of the UK and has a temperate climate (Köppen-Geiger classification Cfc) [10] with an annual mean maximum temperature of 14.5 °C, and a minimum of 8.2 °C, and with a mean annual precipitation of approximately 700 mm (30 year average) [11]. The study site comprises 7.7 ha of privately owned mixed coniferous and deciduous woodland, part of a 60 ha complex of woodlands in the North East of the Island comprising the North-eastern Woods Isle of Wight Biodiversity Opportunity Area, which is also a Site of Importance for Nature Conservation [12]. The site is 20 m above sea level, bordered by deciduous woodland and pastureland with a small stream along the Western edge. The soils are fertile, seasonally waterlogged clays and loams [13] the underlying geology comprising Palaeogene clays, silts and sands of the Hamstead Beds and calcareous mudstones of the Bembridge Marls Formation [14]. The site is classified as ancient replanted woodland, defined as continuous woodland cover since at least 1600 AD but where the original native tree cover has been replaced by planting [15]. In this case the previous crop of oak (*Quercus* L.) was harvested in the 1950s with Timber Copse replanted with 3.9 ha Western Red Cedar (*Thuja plicata* Donn ex D.Don 1824) and 0.3 ha Norway Spruce (*Picea abies* (L.) H.Karst 1881) in 1964 (Forestry Commission, unpublished). Greatmead Copse was not replanted and has regenerated naturally with a community approximate to National Vegetation Classification (NVC) Woodland 8 *Fraxinus excelsior - Acer campestre - Mercurialis perennis* woodland [16].

2.2. Sampling regime

The study site comprises two broad habitats, 4.2 ha of coniferous plantation (with some regrowth of deciduous species) (*con*) in Timber Copse and 3.5 ha of deciduous woodland (*dec*) in Greatmead Copse. An initial survey identified 12 *microhabitats* which covered a sufficient area for a sample size of six 1 m^2 quadrats, one of which (*streamside*) had no macrofauna, the 11 sampled are described in Table 1.

Microhabitats were classified into *standard* or *additional*. *Standard* microhabitats comprised the main body of uniform leaf litter and the soil beneath; *additional* microhabitats were those of small spatial extent – representing sources of micro-heterogeneity.

2.3. Sampling methods

Sampling was carried out during May 2013 over four sampling periods, each a week apart, with 6–7 replicate samples from each microhabitat. Each replicate consisted of a 1 m^2 quadrat, which for the deadwood microhabitats included a stump or log. All the stumps sampled were from trees felled in the 1950s so were of uniform size and decay stage, logs were in decay class III [17] and were selected on the basis of similar size (0.5–1.0 m length). Every effort was made to stratify sampling spatially and temporally to minimise variability due to weather differences and temporal effects.

Environmental variables and a vegetation survey were carried out in each 1 m^2 quadrat and macrofauna were sampled using two methods: hand sorting of soil pits and Winkler bag extraction of leaf litter. Pitfall trapping was not used since that sampling method is strongly biased towards groups which actively move on the surface [18] and is therefore unsuitable for a small spatial scale project, as it is likely to record arthropods originating from outside the microhabitat.

2.3.1. Vegetation survey

This was carried out in the same 1 m^2 quadrat used for the macrofauna surveys; the presence or absence of plant species was recorded at ground level, the understory (up to 2 m height) and canopy (above 2 m height), assuming a three dimensional 1 m^2 quadrat extended up into the canopy. Species level identifications, including grasses, sedges and conspicuous mosses, were possible for most quadrats.

2.3.2. Environmental variables

Soil moisture was measured using a Delta-T Moisture meter with an attached SM200 moisture sensor (Delta-T Devices, Cambridge, England) recorded as % moisture filled space. Soil temperature was measured with a dial soil thermometer (Electronic Temperature Instruments Ltd., Worthing, England) and pH using an analogue Westminster Deluxe Soil pH Meter (West Meters Ltd., Manchester, England). Measurements were made at 10 cm depth with the probe placed in the centre of each 1 m^2 quadrat, or in the case of logs and stumps as close to the wood as possible. Nearly half the soil temperature and pH measurements were not made due to equipment failure; values generated by random *k*-nearest-neighbour imputation were substituted in those cases using the *MissingDataGUI* 0.2–0 package [19] in R 3.1.0 [20].

Table 1
Descriptions of microhabitats surveyed.[s] 'standard' microhabitats, all others are 'additional' microhabitats.

Microhabitat	Code	Description
Mixed litter[s]	conmixlit	Mixed litter from under plantation of 50 year old plantation of *Thuja plicata* and/or *Picea abies* interspersed with regrowth of mixed broadleaf species
Logs	conlog	Leaf litter from under and periphery of logs within plantation
Moss	conmoss	Near continuous ground bryophyte layer, dominated by dominated by *Thuidium tamariscinum* (Hedw.) Schimp. 1852 and *Kindbergia praelonga* (Hedw.) Ochyra 1982
Path	conpath	3 m wide, 350 m long path through Timber Copse. Diverse and variable ground flora but little understory. *Fraxinus excelsior* L. and *Acer campestre* L. dominant in canopy.
Seeps (coniferous)	conseep	Very small, shallow water bodies flowing through conifer plantation
Stumps (coniferous)	constump	*Quercus* L. sp. stumps under conifer plantation
Bluebell woodland[s]	decblue	Woodland with *Hyacinthoides non-scripta* (L.) Chouard ex Rothm. 1944 dominant ground flora
Ivy woodland[s]	decivy	Woodland with *Hedera helix* L. dominant ground flora
Power line	decpower	0.01 ha area of deciduous woodland coppiced every 2–3 years due to presence of power line
Seeps	decseep	Very small, shallow water bodies flowing through deciduous woodland
Stumps	decstump	*Quercus* L. sp. stumps in deciduous woodland