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Overlooked subterranean saproxylic beetle diversity in clear-cut stumps and its implications for stump extraction ☆

Jonas Victorsson, Mats Jonsell *

Department of Ecology, Swedish University of Agricultural Sciences, Box 7044, SE-750 07 Uppsala, Sweden

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ABSTRACT

Stump extraction (which include removal of coarse roots) will reduce the available habitat for insects breeding in dead wood (saproxylic species). The root-living diversity is largely unknown which is unsatisfactory as 68% of the wood harvested at stump extraction is root wood. We compared the diversity of saproxylic beetles in Norway spruce, *Picea abies*, coarse roots with that in the above-ground part of the same stumps. Five below-ground (root) and eight above-ground (stump) samples were collected from early-decay stumps at each of twelve Swedish clear-cuts. In total 8314 saproxylic beetles of 60 species were reared from the 156 wood samples. The estimated species richness in roots (47 species) was 51% of that in stumps (93). When root and stump samples were pooled the total estimate was 116 species. The phylogenetic diversity (average taxonomic distinctness) in individual roots was only 63% of that in stumps. Species composition differed between substrate types, and only 28% of the species were common to both substrates. Most root samples were numerically dominated by *Dryocoetes autographus* (33% of the samples) or *Hylobius abietis* (10%). Most stump samples were dominated by *Crypturgus* spp. (66%) or *Rhagium inquisitor* (19%). Of the 17 most abundant species, five were associated with roots and two of those used roots exclusively. Ten species were associated with stumps. We conclude that the root-living beetles constitute an important part of the stump/root assemblage and should not be overlooked when the effects of stump harvest on biodiversity is evaluated.

1. Introduction

It is easy to overlook biodiversity in areas that are hard to reach. In all the studies on insects–plant interactions performed between 1985 and 2005 less than 2% deal with subterranean or root-feeding insects (Gange, 2005). This is not because root feeding is deemed unimportant but because root sampling is difficult. Also in studies of dead wood dependent (saproxylic) species almost all studies on species diversity concern only the above-ground part of dead trees (Stokland et al., 2012). Among 482 Swedish saproxylic beetle species only 3% are suggested to be associated with subterranean wood, i.e. the subterranean part of stumps and roots (Ehnström and Axelsson, 2002). This low figure is undoubtedly due to our lack of knowledge of root-living saproxylics.

Studies on subterranean saproxylic species have focused on economically important species, especially pine weevils of the genus *Hylobius* and bark beetles of the genus *Hylastes* (e.g. Björklund et al., 2005; Bylund et al., 2004; Nordlander et al., 2005). The larvae of these species develop in subterranean conifer wood and the newly hatched adults cause economic damage by feeding on conifer seedlings (Day et al., 2004). Our knowledge of other parts of the subterranean beetle fauna in wood is based on qualitative anecdotal data mainly provided by beetle collectors (e.g. Saalas, 1923; Palm, 1959; Ehnström and Axelsson, 2002). This is the case not only for clear-fell stumps, but for dead wood in general (Stokland et al., 2012). As far as we know, there are no quantitative comparative studies of this diversity. Except for the well known pest-species mentioned above, we do not know if the under-ground assemblage is only a subset of the above-ground assemblage or if it contain specialists.

Clear-fell stumps and their coarse roots are becoming important as a source of bioenergy due to an increasing concern for climate change. In Sweden it is estimated that stump extraction could substitute 2.5–5% of the energy currently derived from fossil fuels (Anonymous, 2011), which would be important greenhouse gas mitigation. Norway spruce is the main tree species targeted for stump harvest and therefore it was selected for this study. Current stump harvesting methods remove the above-ground part of the stump as well as coarse roots with a diameter above 5 cm (von Hofsten, 2006). This results in a harvestable stump biomass consisting of 32% above-ground wood and of 68% root wood

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* Corresponding author.
E-mail address: mats.jonsell@slu.se (M. Jonsell).

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(Hakkila, 1975; von Hofsten, 2006). We know that stump extraction is negative for species found in the above-ground part of stumps (Andersson et al., 2012; Jonsell and Schroeder, 2014; Victorsson and Jonsell, 2013a,b). If the fauna in the roots is just a subset of the above ground fauna, knowledge of the above ground fauna will be sufficient when conclusion are made on how species in roots are affected by stump harvest. If not, the subterranean fauna also needs to be considered.

Our aim was to characterize the subterranean saproxylic beetle assemblage in Norway spruce stumps. We looked for similarities or differences between below and above ground regarding diversity and species composition. We hypothesized that the underground assemblage: (1) has a lower diversity than the above-ground assemblage and (2) differ in species composition from the above-ground assemblage. In the diversity analyses, we first estimated the cumulative species richness over all samples for each substrate type. We then compared the two substrate types regarding five basic community parameters calculated for the assemblage in each stump: total abundance, species number, evenness, dominance and taxonomic distinctness. For simplicity the above ground parts are hereafter termed "stumps" and below ground parts "roots".

2. Methods

2.1. Study sites

The study was performed on twelve clear-cuts in the Boreo-nemoral and Southern boreal vegetation zones of central and southern Sweden (Gustafsson and Ahlén, 1996) (Fig. 1A). Around the study sites, approximately 70% of the land is forest and the second most common land type is agricultural land. Almost all forested land is subjected to modern forestry following standard Swedish practices, including clear-cutting and thinning. The dominating tree species are the two conifers Norway spruce, *Picea abies* (L.) Karst., and Scots pine, *Pinus sylvestris* L. Deciduous tree species were mainly birch, *Betula pendula* Roth and *B. pubescens* Ehrh., but also aspen *Populus tremula* L., black alder *Alnus glutinosa* (L.) Gaertner, pedunculate oak, *Quercus robur* L. and a few others occur as admixture.

Clear-cuts, where 80% or more of the stumps were Norway spruce, were selected among available stands in the stand-databases from forest companies active in the area (Sveaskog and Södra). The clear-cuts varied in size from 3.3 to 30.8 ha. At the time of sampling, in May 2012, eight of the clear-cuts were two years old, two clear-cuts were two and a half years old, and two were one year old. The stumps originating from final felling were therefore in decay class one following the classification in Esseen et al. (1997). The samples were collected on sites used also for another project related to stump harvest (in prep.), where half of the clear-cuts were stump extracted and the other half was ordinary clear-cuts, in a paired design.

2.2. Sampling and rearing

The samples were taken between May 2 and May 17 2012. On each clear-cut we established eight 100 m^2 sampling plots situated regularly in a quadratic grid with 50–100 m between plots (larger distance on larger clear-cuts) (Fig. 1B). In each plot we collected wood samples from one spruce stump; the one closest to the central point of the plot. The stump had to fulfil the following criteria: (1) Norway spruce stump created at final felling; (2) no visible damage from forestry machines, (3) at least 85% of the bark remaining; (4) diameter at least 22 cm (=the lower limit for commercial interest in harvest). The sampled stumps had a diameter of 45 ± 11 cm (mean ± SD) (range: 28–95 cm) and a height of 29 ± 8 cm (range: 18–67 cm). The above-ground part of the stump (from here on stump) was sampled by removing a wedge-shaped wood sample using a chainsaw (Fig. 2A). The upper part of the sample was the cut surface and these samples had a standardized bark area of 0.10 m^2. From five of the eight stumps on each clear-cut, a wood sample was collected from one of the coarse roots (from here on root) connected to the stump. These samples were taken at a distance of 30 cm from the lowest part of the stump sample as measured along the bark surface (Fig. 2B). The minimum diameter at the thinnest end of the root was 5 cm since roots smaller than that mostly remain in the soil at stump harvesting. The maximum length of a root sample was 56 cm and most of the samples were actually that long but some root sections that tapered off rapidly were shorter. The distance between the root and the soil surface was usually 20–30 cm and never less than 6 cm. Soil and dirt was removed from the root samples before rearing started. The bark of the samples was secured with strips.

The wood samples were placed individually in rearing boxes within three days of collection (Fig. 2C). Rearing boxes were kept in a greenhouse with temperatures ranging between 15 and 24 °C with occasional peaks on 29 °C during hot days. The rearing was terminated on July 16. At this point beetle emergence had slowed down markedly which agree with previous evaluations of the method (Jonsell and Hansson, 2007; Wikars et al., 2005). We then debarked the wood samples and beetle adults and larvae found

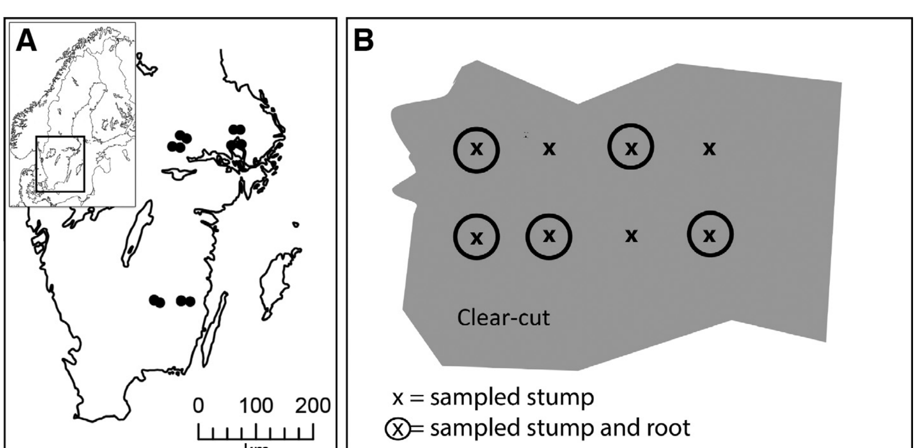

Fig. 1. Study sites. (A) Map of Sweden with the twelve sampled clear-cuts. (B) Sampled stumps and roots in one clear-cut. Stump samples were taken from all eight stumps whereas root samples were taken from five of the stumps.