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Key features for saproxylic beetle diversity derived from rapid habitat assessment in temperate forests

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ABSTRACT

Managing and monitoring forest biodiversity is challenging and rapid habitat assessment protocols should be developed to provide us with general key features based on field data.

A rapid habitat assessment protocol was implemented over a wide forest gradient in France to analyze surrogacy patterns and performance consistency of presumed key attributes for saproxylic beetle diversity (large trees, microhabitat-bearing trees with trunk cavities, fruiting bodies of saproxylic fungi, tree crown deadwood and sap runs, large logs and snags) and of stand openness. Data compiled in this study include standardized deadwood and window-flight trapped beetle data from 313 plots in oak, lowland and highland beech, lowland pine, highland spruce–fir and mixed temperate forests throughout France.

The most structuring factors for species richness and composition of saproxylic beetles were the density of cavity- or fungus-bearing trees and of snags, as well as the degree of openness in the 1-ha surrounding the stand. These key habitat features were nevertheless inconsistent over the different types of temperate forests, and for rare species vs. all species combined. No one variable robustly explained variations in species richness in the deciduous or conifer forest types.

The influence of deadwood and "habitat trees" was affected by meso- and micro-climatic features. A significant effect of stand openness on saproxylic beetles was observed both in deciduous and in conifer forests, but only in lowlands. Effects on species richness due to an interaction between substrate availability and openness were observed in montane forests only.

Our results point toward the relevance of ecological attributes in tracking changes in saproxylic beetle biodiversity in specific forest contexts, but our study failed to identify any universal structural biodiversity indicators which could be surveyed in part with data from national forest inventories and used to track progress in sustainable forest management or in the protection of sensitive areas.

1. Introduction

1.1. Saproxylic invertebrates as indicators of sustainable forest management

As early as 1988, the Council of Europe exhorted European governments to use prioritarily saproxylic organisms, i.e. those associated to deadwood and related microhabitats, in the evaluation of forest conservation status (Recommendations R(88)10 and 11). Since the 1990s in North America, Australia and many European countries, the fate of deadwood substrates in commercial forests has become an increasing concern in conservation planning and forest management where native species conservation and ecologically sustainable resource use are valued (Grove, 2002a,b). In recent years forest managers have also become increasingly aware of the role both of trees with special characteristics ("habitat trees") and of deadwood in maintaining a declining biodiversity (Harmon, 2001). In Europe, probably the best documented part of the world, saproxylic insects have been identified as a highly threatened group (Nieto and Alexander, 2010). Saproxylic beetles are the most well-studied species group and are commonly favored as indicators of response to deadwood management (Siitonen, 2001) for logistical and ecological reasons (well-known taxonomy, inexpensive trapping, high sensitivity to changes in forest conditions, a wide range of ecological requirements). However, detailed taxonomic surveys are often prohibitively expensive and time-consuming. Therefore quick and easy direct or indirect biodiversity

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indicators to monitor saproxylic beetle biodiversity should be explored.

1.2. Rapid forest habitat assessment

Managing and directly monitoring forest biodiversity is challenging due to (i) the large number of species, (ii) the hardness of species identification and (iii) the wide variety of species habitat requirements. Using indirect structural characteristics to evaluate biodiversity levels may therefore be useful (Lindenmayer et al., 2000) to produce (i) relevant biodiversity indicators, (ii) better targets for sustainable forestry and (iii) more effective selection criteria for conservation areas. Tews et al. (2004) and Lindenmayer et al. (2006) suggested using keystone elements as targets to improve and monitor eco-friendly forest management. Quick and easy methods have been suggested to survey these key elements and shortly describe the habitat of forest organisms (Venier and Mackey, 1997). Presumed key attributes are already used in national environmental standards for forestry certification (FSC and PEFC). From the literature and some census data, we surveyed the rapid habitat assessment protocols where field data at stand level (e.g. indicators of High Conservation Value Forest, Jennings et al., 2003; European forest scorecards, Sollander, 2000) are used to provide us with general key features. In Belgian forests, based on available field data from the state forest inventory, a standardized practical methodology has been developed to monitor certain important aspects of biodiversity that are both easily measurable and susceptible to changes through silvicultural practices (Van Den Meersschaut and Vandekerkhove, 2000). The methodology retains aspects of forest structure, tree species composition and deadwood features as biodiversity indicators. High scores are given to very large trees (>80 cm dbh), large snags and large logs, which are usually associated with a wide variety of microhabitats and have been acknowledged as being important to diversity. All these standards result from negotiations rather than ecological research. Following the Belgian methodology, we constructed a list of potential key habitat attributes for saproxylic beetles in temperate forests which we felt were appropriate in monitoring the impact of management on saproxylic resources and biodiversity.

1.3. Presumed key factors for saproxylic biodiversity

Our inventory of potentially relevant habitat attributes was based on their potential surrogacy value as shown in previously published environment-biodiversity studies. The deadwood components which are particularly at stake in managed forests were included. Some studies point out that the decline in deadwood quantity due to the negative impact of commercial forestry is stronger for some deadwood types, such as snags and large logs, than for the deadwood as a whole. From Sippola et al. (1998) for instance, snag density and large log density in managed stands in Finland were respectively only 7% and 5% of their normal levels in old-growth forests. Similarly, the density of microhabitat-bearing trees, sometimes called "wildlife trees" (Hodge and Peterken, 1998) or "habitat-trees" (Bäuerle and Nothdurft, 2011), is altered by forestry (Winter and Möller, 2008), in particular for certain microhabitat types such as cavities, cracks and lignicolous fungi (Larrieu et al., 2012).

In addition, several studies have demonstrated the importance for saproxylic beetles of large logs (Økland et al., 1996; Sverdrup-Thygeson, 2001), snags, microhabitat-bearing trees (e.g. Nilsson and Baranowski, 1994), very large trees (e.g. Grove, 2002a,b) and more general forest features such as canopy closure in the immediate substrate surroundings (Stokland et al., 2012). However, the consistency of these key features had not yet been studied over

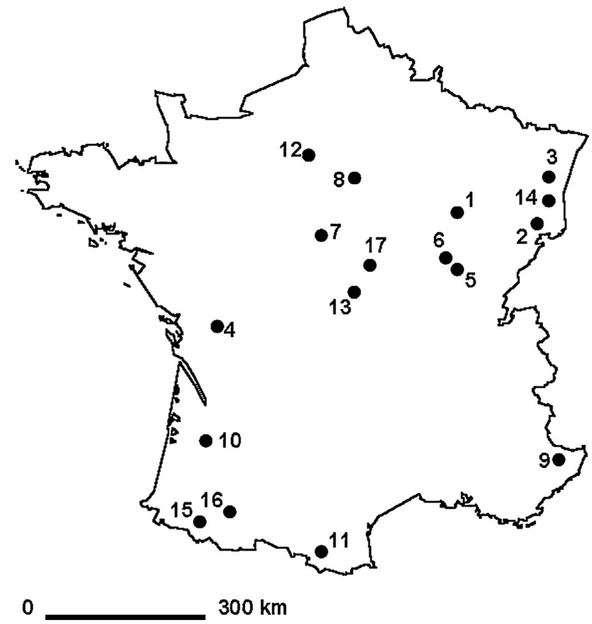

Fig. 1. Map of the 17 study forest regions in France (313 plots, 581 traps). The plots (point numbers) were part of the following datasets (between brackets is the number of plots): 1: Auberive (24), 2: Ballons-Comtois (16), 3: TaillisA (6), 4: Chize (24), 5: Citeaux (12), 6: Combe Lavaux (8), 7: Orleans (33), 8: Fontainebleau (25), 9: Mercantour (12), 10: Landes (19), 11: Orlu and Aston (18), 12: Rambouillet (60), 13: Troncais (34), 14: Ventron (8), 15: VFP (27), 16: Rebisclou (5), 17: TaillisB (20).

a wide range of forest types (conifer vs. deciduous, lowland vs. montane...).

We used a rapid habitat assessment protocol to measure the density of large trees, microhabitat-bearing trees and large logs and snags, as well as stand openness, over a wide forest gradient in France. Analyzing the relationships between these environmental data and saproxylic beetle diversity (species richness and composition), we hoped to better understand surrogacy patterns of the presumed key attributes. From lowlands and highlands and in deciduous, coniferous and mixed forests in France, we tested the following set of questions:

1. With rapid habitat assessment, are selected key habitat features for saproxylic beetles consistent over temperate forests according to the dominant tree species?
2. Is the influence of deadwood and 'habitat trees' on biodiversity affected by meso-climatic (altitudinal level for beech) and micro-climatic features (stand openness)?
3. Are there critical thresholds at the stand scale in richness–environment relationships?
4. Are key habitat features consistent between rare species and all species combined?

2. Materials and methods

2.1. Study areas, sampling design and stand characteristics

This study is based on extensive data compiled from 17 ecological projects conducted by two French laboratories: the National Research Institute of Science and Technology for Environment and Agriculture (Irstea) and the Purpan Engineering School in a variety of French forests. We sampled 313 plots in 17 forest regions, i.e. large forests or groups of closed forests (Fig. 1). The forests in hilly regions and in plains were designated as "lowland forests" (<1000 m) and the montane and subalpine forests as "highland forests" (altitude variable). We distinguished six forest types based