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Review

Reviewing the strength of evidence of biodiversity indicators for forest ecosystems in Europe

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ABSTRACT

With a growing number of forest biodiversity indicators being applied in forest policy documents and even more being suggested by the scientific community, there is a need to evaluate, review and critically assess the strength of evidence for individual indicators, their interrelationships and potential overlaps and gaps. Biodiversity indicators proposed for forest ecosystems in Europe were reviewed with the overarching aim of providing advice on strategic selection and combination of indictors. The objectives were to (1) establish interrelationships between indicators and their indicandum (i.e. the indicated aspect of biodiversity); (2) assess the strength of scientific evidence for individual indicators; and (3) identify a set of indicators with confirmed validity for further scientific testing and inclusion in long-term reporting and decision-making regarding forest biodiversity. Ten indicator groups and 83 individual indicators were identified with application from stand scale up to landscape scale in 142 eligible scientific papers. In 62 of the 142 studies no statistical correlations between indicator(s) and indicandum were performed and 42 (out of the 62) did not even present a clear indicandum. In the remaining 80 studies, 412 correlations between indicator and indicandum were identified. However, only six correlations were assessed as being supported by strong evidence, i.e. three or more studies found statistical correlation between the indicator and indicandum, and no studies reported contradictory results. For the species richness relationships, there was strong evidence for positive correlations between deadwood volume and wood-living fungal species richness; deadwood volume and saproxylic beetle species richness; deadwood diversity and saproxylic beetle species richness; age of canopy trees and epiphytic lichen species richness. There was strong evidence for a negative correlation between tree canopy cover and spider species richness. Concerning species composition-related correlation, there was strong evidence that the species composition of epiphytic lichens changed with the age of canopy trees. These results imply that the validity of most indicators on which monitoring and conservation planning are based are weakly scientifically supported and that further validation of current biodiversity indicators for forest ecosystems is needed.

Contents

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1. Introduction

Just 25 years ago, biodiversity was considered a minor issue in environmental policy; too broad and vague a concept to be applied to real-world regulatory and management problems (Noss, 1990). Today, biodiversity conservation has become a key issue in policy and management of all natural resources, not least forest ecosystems which is the focus of this review (Gao et al., 2014; Mace et al., 2012). As foreseen by Noss (1990), the development of measurable biodiversity indicators has been instrumental in this change.

Since the Rio Earth Summit in 1992, a large number of biodiversity indicators for forests and other ecosystems, and changes in these ecosystems over time, have been proposed in individual studies or by large programmes, such as the Convention on Biological Diversity (CBD) (Biodiversity Indicators Partnership, 2010), Forest Europe (2010), the Montréal Process (Process, 2009), Streamlining European Biodiversity Indicators (SEBI) (EEA, 2012), etc. Despite the large number of studies conducted to date, recent policy documents and guidelines have concluded that very few indicators with good Europe-wide coverage are available for assessing trends in these (EEA, 2012). Moreover, several countries have reported efforts to implement biodiversity conservation in working towards sustainable forest management in practice, but none has quantified forest biodiversity targets related directly to specific biodiversity indicators (Barbati et al., 2014). This could be due to the complexity of biodiversity, meaning that there is no easy answer on how to illustrate status, changes and trends in selected components of biological diversity, including loss of biodiversity (EEA, 2012).

Ferris and Humphrey (1999) conducted a review of forest biodiversity indicators and concluded that it is important to understand clearly the interrelationships between indicator species/groups, their habitat requirements and the species groups they are intended to indicate. The dichotomy is that the indicators need to have verified quality, so they do not show or indicate something that is untrue, while at the same time being easy to communicate and understandable to policy makers. As a result, pan-European policy reports on forest biodiversity mention only a few indicators related to biodiversity and forestry. For example, SEBI (EEA, 2012) has only three indicators directly or indirectly connected to biodiversity: forest growing stock, increment and fellings, and the occurrence of deadwood.

Measurable indicators have undoubtedly supported operationalisation of the biodiversity concept. However, we are now at a point where agencies are having difficulties in identifying and choosing between the large number of indicators proposed. This again hinders the same agencies from composing a set of complementary indicators with supplementary properties. A critical review of the strength of evidence for existing indicators and assessment of their interrelationships (overlaps and gaps) is thus important for continued development and refinement of indicators as policy and management tools for biodiversity conservation. This need is illustrated by the initiative undertaken recently by COST Action E43 to harmonise indicators included in national forest inventories for biodiversity assessment across European countries (e.g. Chirici et al., 2012).

Three primary attributes of biodiversity are widely recognised as providing a framework for research on forest biodiversity (Spanos et al., 2006; Larsson et al., 2001a,b; Noss, 1990; Franklin, 1988). These are: (1) Species/composition; identity and variety of elements, including species lists and measures of species diversity; (2) structure; physiognomy of forest as measured within a stand to variation at forest scale and on to the pattern of forest patches at a landscape scale; and (3) function; ecological and evolutionary processes, including gene flow, disturbances and nutrient cycling. The focus on forest biodiversity indicators in the present review is restricted to species/compositional indicators and structural indicators, because they are more amenable to measurement by forest researchers (Ferris and Humphrey, 1999). In addition, species/compositional and structural elements may act as surrogate functional indicators, e.g. forest stand structures may reflect natural and human disturbance, while deadwood decay stage (a structural indicator) may be a good indicator of decomposition processes.

Simberloff (1997) distinguished two main uses of biodiversity indicators that are still valid today: (i) the presence and fluctuations of the indicator are able to reflect those of other species/taxa in the community; and (ii) the presence and fluctuations of the indicator are able to reflect chemical/physical changes in the environment. Actually, the latter could appropriately be called “environmental indicators” (McGeoch, 1998) or “environmental health indicators” (Caro and O’Doherty, 1999). In the present review, we focused on the first type of biodiversity indicators, i.e. indicators which can be used as a surrogate measure of other components of forest biodiversity (the *indicandum*) and thus provide a short-cut in surveys or monitoring programmes.

The overarching aim of this review was to provide advice on strategic selection and combination of complementary biodiversity indicators, by compiling and assessing species/composition and structural biodiversity indicators suggested for use in European forest ecosystems. Specific objectives were to:

(1) Establish and review suggested indicators and interrelationships between indicators and their indicandum (i.e. the aspect of biodiversity indicated).
(2) Assess the strength of scientific evidence for individual indicators.