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Tolerance of focal species to forest management intensity as a guide in the development of conservation targets

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ABSTRACT

Although forest managers are trained to optimize timber production, they should be encouraged to integrate biodiversity conservation as an element of sustainable forest management. To do so, coarse-filter approaches should be complemented with an assessment of the response of carefully selected focal species to forest management intensity. Once conservation objectives have been defined, researchers should determine the shape of focal species' responses to descriptors of management intensity. Sharp transitions (thresholds) in species responses can yield insight for the development of quantitative conservation targets, with the understanding that critical resources (e.g., specific stand structures; amount of habitat in the landscape) should be maintained well above the threshold values observed. Conservation targets should be determined by land managers and policy-makers on the basis of objective, empirical evidence obtained by researchers to ensure that scientific investigation is conducted in the absence of external pressure.

1. Introduction

In 1969, Ian McHarg published the first edition of *Design with Nature*, a book promoting the integration of dynamic natural processes into landscape planning. Forty years later, it seems that McHarg has largely succeeded. Land managers across the world talk in terms of sustainable resource management, ecosystem management, or integrated resource management. The question is: have we moved beyond the rhetoric? The answer varies greatly among forest regions of the world. In this paper, we will examine how conservation ecologists and forest managers could join efforts to plan forest harvesting so that it maintains biodiversity and associated ecosystem services. The approach we propose is already being applied to various degrees in some jurisdictions, but we feel that there is a need to inject more science into the process (Villard and Jonsson, 2009a). Because biodiversity conservation in the realm of forest management requires close collaboration between researchers, policy-makers, and land managers, we will also examine the role that researchers should strive to play in such interactions.

Niche theory states that each species has ecological requirements outside of which it simply cannot persist. In forest ecosystems, those requirements include basic abiotic conditions, microhabitat features (e.g., specific types of wood substrates), and mesohabitat characteristics, such as the amount of dead wood in a stand. One could add to these requirements particular landscape structures allowing sufficient immigration of propagules into suitable habitat. The approach we advocate here is based on such basic biological/ecological principles. Yet, few jurisdictions that we are aware of have adopted forest management guidelines based on the ecological requirements of a set of species. Part of the reason for this is that it is often argued that it is impossible to meet simultaneously the requirements of thousands of species inhabiting the same forest landscape. Yet, fine-filter or meso-filter approaches (Hunter, 1990, 2005), as we will see below, offer an important contribution to forest biodiversity conservation.

Just as forest managers are trained to set targets to maintain or increase timber yields for particular landscape units, they should be encouraged to meet conservation targets, themselves based on solid empirical data on species/population requirements. In other words, the claim that a company or public agency practices sustainable forest management should be backed by concrete, measurable indicators of its ecological performance. The responsibility of conservation ecologists should be to identify appropriate indicators and to collect data that can guide decisions when setting conservation targets.

2. Can coarse-filter approaches stand alone?

Lindenmayer et al. (2006) strongly argued for a set of general principles to guide sustainable forest management. Their principles

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include the maintenance of (i) landscape connectivity; (ii) integrity of aquatic systems; (iii) stand structural complexity; (iv) landscape heterogeneity; and (v) the use of knowledge on natural disturbance regimes. Although we agree with this general framework and coarse-filter perspective, application of these guidelines still requires knowledge about their effects on the occurrence/population viability of actual species. For example, structural connectivity can be quantified (e.g., Moilanen and Nieminen, 2002), but it must be related to the dispersal ability of actual species to determine *functional* connectivity (Taylor et al., 2006), i.e. the interaction of a species' movement patterns with the landscape's physical characteristics. Another case in point: although structural components are one of the most important niche dimensions for forest species, retention levels or restoration efforts must be guided by knowledge of functional relationships between the amounts and types of, for example, dead wood needed to support local populations of focal species (Berglund et al., 2009). Natural disturbance regimes do provide a template for management, but the structures created by natural disturbances and forestry operations are widely different and an evaluation of focal species' response is still needed to increase the likelihood that natural disturbance emulation by forestry actually achieves conservation goals (Perera et al., 2004; Drapeau et al., 2009). With respect to landscape structure and heterogeneity, species may require that suitable habitat exceeds a certain fraction of the landscape to be present and to persist over the longer term (e.g., Andrén, 1994; Fahrig, 1997; Betts et al., 2007; Betts and Villard, 2009). Beyond the maintenance of landscape heterogeneity inspired from some relevant historical benchmark, we should, thus, determine the ranges of woodland habitat cover needed by actual species sensitive to landscape context.

In summary, general guidelines inspired from a coarse-filter approach may provide a good starting point but they should be complemented with quantitative analyses and models at the species level to ensure that this strategy meets the requirements of carefully selected focal species.

3. Conservation targets

One of the first conservation targets to be widely considered across the world was the 10% target for protected areas established at the 1992 Convention on Biological Diversity. Because the goal was not based on science and did not require performance indicators other than total area under protection, it led some countries to designate vast, relatively unproductive areas as reserves. Ecologists have proposed concepts akin to conservation targets, namely minimum viable population (Shaffer, 1981) or metapopulation (Hanski et al., 1996). These concepts later led to the development of population viability analysis (PVA – Beissinger and McCullough, 2002), which can provide guidance for land managers in charge of protecting focal species while planning resource extraction. However, PVA models are mainly being developed for species at risk, owing to the data requirements (and costs) associated with this procedure. Ironically, it is especially challenging to obtain reliable demographic or even ecological parameters to develop such models for rare species. Furthermore, some parameters (e.g., natal dispersal distances) are technically difficult to obtain for many species.

Here, we propose an approach that can yield insight into the ecological requirements of individual species or the response of particular species guilds. As pointed out by Lindenmayer et al. (2006), species-specific requirements may lack generality, which is the major drawback of fine- or even meso-filter approaches. Nonetheless, forest managers should ultimately be able to demonstrate that harvest strategies maintain specific elements of biodiversity, beyond the structures and processes upon which they are associated. Since not all species were created equal, some may provide more insight than others about the state of the ecosystem (Roberge and Angelstam, 2009). A special category of focal species are those with an official status, such as red-listed species, species targeted by conservation programmes, or species included in international conventions. For better or worse, the viability of their populations represents a conservation objective. This includes for instance species listed in the European species and habitat directive, for which EU member countries are required to achieve "favourable conservation status" (Anonymous, 2007). That being said, the use of focal taxa must always be based on a thorough knowledge of the system at hand and should be the object of scrutiny because surrogates for biodiversity have not always proven to be efficient (Rodrigues and Brooks, 2007).

The search for "fragmentation thresholds" has led to interesting debates, and it remains highly controversial (Fahrig, 2003; Lindenmayer et al., 2005; Ranius and Fahrig, 2006; Koper et al., 2007; Betts and Villard, 2009). Our goal is not to review this debate and take a stand. Rather, we want to point out that, when taken for what they are, i.e. sharp transitions in species/assemblage response to an ecological gradient, threshold responses to the amount of specific resources may yield insight for eventual conservation target setting. When such thresholds are present, they represent an important tool for target setting. Blind adherence to such thresholds is dangerous because their detection is sensitive to various sources of bias (Guénette and Villard, 2004; Lindenmayer et al., 2006; Villard, 2009) and threshold values tend to vary among species considered (Guénette and Villard, 2005; Ranius and Fahrig, 2006). However, the fact that they are sometimes missing, require specific analytical methods, and are often species-specific should not be used as arguments to toss out the approach. This would leave the field open to blind guesses on what are appropriate levels to maintain for critical habitat and landscape variables. The fact that some species are much more sensitive to the loss of certain ecosystem structures may make them efficient umbrellas for other, less demanding ones. Indeed, demonstrating umbrella or "surrogacy" effects remains a critical task for conservation biologists (Roberge and Angelstam, 2004; Rodrigues and Brooks, 2007).

4. Statistical considerations in threshold detection

To investigate potentially insightful species responses to stand/landscape alteration by forestry, we can start by identifying features at risk. In many industrial forests, those features are chiefly represented by old stand attributes, such as dead wood in all its forms, large-diameter trees, non-commercial tree species, natural regeneration, mixedwood stands, large blocks of mature/old forest, or landscape mosaics with a high degree of functional connectivity, even for species with low vagility.

Once features at risk have been identified, one can plot the probability of presence of focal species (Fig. 1a), their abundance (Fig. 1b), or species richness (Fig. 1c) against a gradient in forest management intensity. Species richness can be applied to a particular guild, e.g., woodland specialists (Bennett and Radford, 2009), susceptible to respond to a generic definition of forest cover/structure. Thresholds, if present, can be detected using rigorous statistical procedures. When using a binary response variable, such as presence–absence of a species or event (e.g., successful reproduction), ROC analysis (Zweig and Campbell, 1993; Guénette and Villard, 2005; Berglund et al., 2009) or segmented logistic regression (Betts and Villard, 2009) can be used. With a continuous response variable such as abundance or species richness, piecewise regression (Toms and Lesperance, 2003) can be applied. Occupancy modeling is developing fast (MacKenzie et al., 2006) and has a strong influence on current wildlife research (Burnham and Anderson, 2002). When data are available, modeling could also address nesting, reproduction, regeneration or other performance parameters and thus move closer to population viability analysis.

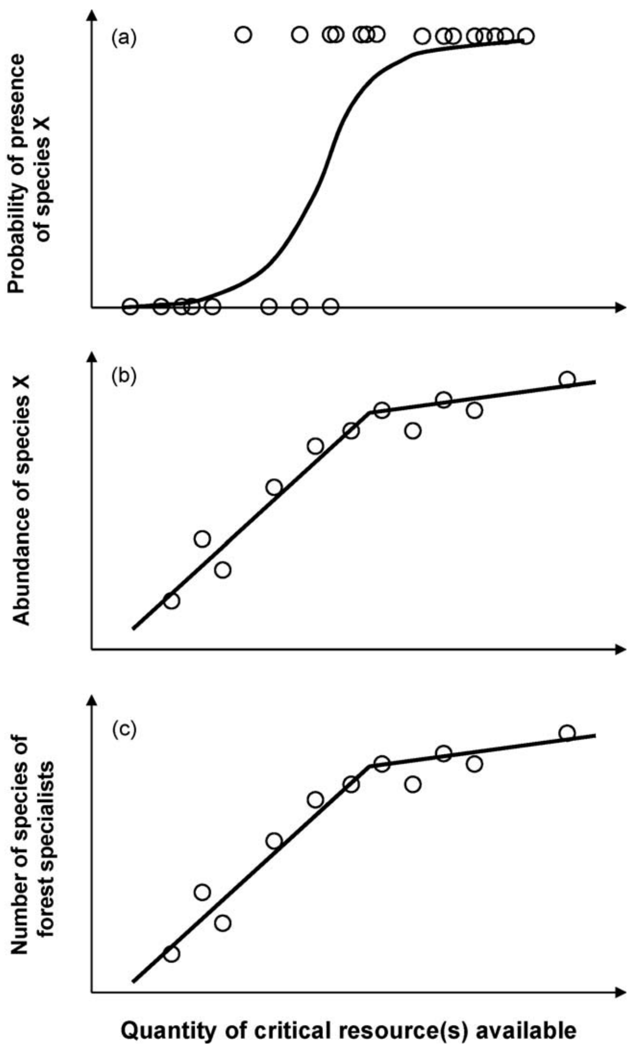

Fig. 1. Response of hypothetical species to gradients in critical habitat characteristics expressed in terms of presence–absence (a), an abundance index (b), or species richness (c). Thresholds in species response can be detected using ROC analysis (a) or piecewise regression (b and c). See text for details.

A critical point to note is that even well-defined, statistically robust thresholds should not be directly translated into conservation targets. For example, Bennett and Radford (2009) observed that species richness of woodland specialist birds declined precipitously below 10% woodland cover within landscape blocks. Applying a 10% cover rule for conservation planning in this system would likely lead to disaster, since many species would then be allowed to decline to the brink of regional extirpation. Guénette and Villard (2005) evaluated quantitative targets set by the New Brunswick Department of Natural Resources for large-diameter tree densities in old forest habitat. Instead of using the threshold value of a single focal species, they plotted thresholds observed in the presence–absence of 10 forest bird species responding positively to this variable. Targets based on the response of a broader set of species in different stand types are expected to be more robust. Then, further research should document species response in terms of fitness parameters, possibly narrowing the scope to the species deemed most sensitive to habitat alteration by forestry based on simple presence–absence data. For example, Poulin et al. (2008) compared the presence–absence threshold found by Guénette and Villard (2005) for the Brown Creeper (*Certhia americana*) to a threshold in the presence or absence of a nest in apparently suitable habitat. The probability of presence of a nest corresponded to a threshold nearly twice as high as the threshold for mere presence.

5. Who should determine conservation targets?

There is considerable confusion around the notions of conservation goals, objectives, targets and ecological thresholds. Although goals and objectives are relative terms, we submit that *targets* should be used refer to specific quantitative values that are set for conservation/management purposes (Villard and Jonsson, 2009a). In turn, *thresholds* should be used to refer to empirical relationships such as those schematized in Fig. 1. Targets may be inspired from thresholds, but they should rarely coincide because thresholds correspond, by definition, to ranges of (here, habitat) values where an ecological response may shift suddenly. Hence, conservation targets should always err on the side of safety.

As we pursued our thinking on conservation targets, we also came to the conclusion that the respective domains of research and decision-making should be clarified. The all too familiar question "how much is enough?" is often addressed to researchers by forest managers or policy-makers. This question is rather vague unless it is accompanied by clearly stated conservation objectives. If not, socio-economic or political considerations may well become entangled into the target setting process, compromising the scientific objectivity of the anticipated answer. We strongly believe that the role of the researcher should be to provide the most scientifically rigorous information possible to managers and policy-makers so that they can make sound decisions, but this rests on our ability to clearly distinguish the development of conservation policy (objectives) from that of concrete targets (see Villard and Jonsson, 2009b). Simple graphs such as those presented in Fig. 1 represent insightful tools for decision-makers, who can express the risk of a certain management plan in terms of probability of occurrence/abundance/species richness of focal species/taxa as a function of amounts of critical resources maintained in stands or landscape blocks. Of course, these are rather blunt tools that should be followed by more detailed analyses using fitness parameters such as the probability of reproduction as a function of habitat amount (e.g., Angelstam, 2004; Poulin et al., 2008).

6. Conclusion

1. Species should be an important focus of conservation and management strategies.

There is no escape from, and no excuse for not including species in modeling (either habitat suitability or dynamic population models) when developing conservation targets. Although the choice of particular species is surrounded with pitfalls (Andelman and Fagan, 2000; Lindenmayer et al., 2002), the alternative – not to include species in conservation strategies – results in target setting in the void, without clear approaches to evaluate the outcome of the management plans selected with respect to the compositional aspect of biodiversity.

2. Landscape issues must be addressed by both managers and researchers.

By definition, a landscape sampling unit is large for most focal taxa, but variability among landscapes should still be considered and controlled, and replicated experimental studies should be performed at that scale. Most landscape studies to date have either focused on theoretical landscapes (e.g., Hanski, 2000) or they have compared different landscapes with contrasting histories (e.g., Penttilä et al., 2006). Given the uncertainties surrounding biodiversity and the trade-offs between multiple goals, it is likely that some heterogeneity in the management should be advocated. This is also suggested by theoretical studies. Controlled experiments at the landscape scale, allowing large-scale manipulative strategies to be compared, would also foster increased collaboration between researchers and forest managers.

3. Application of quantitative approaches requires training.

A non-trivial condition for a more quantitative approach to biodiversity conservation in forest management is the presence of well-trained people. This calls for a much stronger involvement of quantitative scientists, willing to share knowledge and to learn about the other aspects of sustainable forest management. That this is possible is shown by the economic side of forestry, where sophisticated models to guide financially optimal land use and management schemes have been developed. If conservation planning could catch up with forest economy (e.g., Baskent, 2009; Mönkkönen et al., 2009), we would stand a better chance of maintaining not only productive forests, but also the rich biodiversity that is essential to ensure long-term ecosystem function.

4. Researchers should play their intended role.

Forest ecologists tend to be heavily involved in the development of conservation/management targets, because a passion for conservation is what led them to this profession, in many cases. Because forest management plans are the product of a variety of trade-offs and biodiversity is only one of the elements considered, we submit that researchers involved in forest ecology should focus on developing the best possible tools and let managers manage and decision-makers decide. Of course, this does not prevent them to play their role as citizens, but the distinction between their role as scientists and their actions as citizens should be made clear to all parties concerned.

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