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How reserve selection is affected by preferences in Swedish boreal forests☆

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ABSTRACT

It is important to consider the preferences of the various stakeholders involved when evaluating effective reserve selection, since it is largely their preferences that determine which of a given set of potential reserve networks that actually is "the best". We interviewed eight conservation planners working at the county administrative boards in each of the eight administrative counties covering boreal Sweden to establish weightings for different structural biodiversity indicators by using the Analytic Hierarchy Process (AHP). The subjective weightings were applied in a reserve selection model based on a goal programming (GP) approach. The structural indicators were derived from the Swedish National Forest Inventory (NFI) and used as proxy for biodiversity potential. A biodiversity indicator score, based on the values of those indicators, was maximized. The model adjusted this score ensuring that all indicators were represented in the selection, and further also adjusted the influence of the indicators based on the subjective weightings. We evaluated the GP approach by comparing it to a simple linear programming (LP) formulation, only maximizing the indicator richness. In all cases the model was limited either by a budget or an area. The biodiversity potential in young forests are often neglected within present conservation policies, however, the proportion of selected forest under 15 years was relatively high in all our cost-effective cases, varying between 32% and 60% using the individual planners subjective weightings, compared to 80% when using a simple LP model. The proportion of selected forest over 100 years varied between 69% and 85% in the area-effective cases using the subjective weightings, compared to 80% when using a simple LP model. Middle-aged forest was not favored in any of the selections, although they make up a substantial part of the total area. We conclude that there are differences in how conservation planners prioritize the indicators, and depending on how specific biodiversity indicators are weighted the age distribution of the selected reserves differs. This demonstrates the importance of considering how to establish appropriate weightings. It is also important to consider the, at least in our case, substantial difference in how common the different indicators are to ensure that the weightings get their intended impact on the selections.

1. Introduction

The destruction, fragmentation and homogenization of natural landscapes have dramatically decreased biodiversity worldwide. Consequently, there is an urgent need to identify ways of mitigating diversity losses (Butchart et al., 2010). One common method of protecting and restoring biodiversity is to set aside areas for the maintenance and preservation of natural functions and processes in order to preserve viable populations of indigenous species (Schmitt et al., 2009).

A systematic approach to the process of finding and designing reserves has been introduced, known as systematic conservation planning (Margules and Pressey, 2000). Since the resources available for conservation do not cover all species in need of protection, effective prioritization is essential. To this end, various quantitative methods for designing optimal reserve networks have been developed over the last thirty years (Sarkar et al., 2006; Strager and Rosenberger, 2007; Williams et al., 2004). These site selection methods are generally based on the concepts of complementarity (Vane-Wright et al., 1991), irreplaceability (Pressey et al., 1994), and more recently, vulnerability (Wilson et al., 2005). If one assumes that there is spatial variation in (monetary) land values, the cost of achieving a given conservation goal by establishing a conservation area on a given area of land can be reduced by integrating the value of the selected land. Alternatively, by adopting an analogous approach, it may be possible to increase the level of biodiversity protection without affecting the cost incurred (Naidoo et al., 2006).

In addition, when designing and establishing reserves, it is essential to consider the preferences of the various stakeholders whose interests may be affected (Lahdelma et al., 2000; Moffett and Sarkar, 2006). Indeed, it is

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largely the preferences of the stakeholders that determine which of a given set of potential reserve networks is actually "the best". There is a need for tools that can both predict the impact of the different designs on specific biodiversity targets and also account for the subjective preferences of decision makers (Regan et al., 2007). It is not generally straightforward to determine how much weight should be assigned to specific factors in situations of this sort where there are numerous variables that affect the outcome of the process. Thus the development and evaluation of weighting systems is an important research question (Polasky et al., 2001). Methods of this sort have been used to assign different weights to the protection of different species when designing conservation areas, as described by Arponen et al. (2005). The importance of considering different opinions during reserve selection has been emphasized in previous studies. Notably, Strager and Rosenberger (2006) investigated the spatial variation in the value assigned to specific priority areas by different stakeholders, while Regan et al. (2007) used input from a group of conservation specialists to identify factors that are important in assigning value to different aspects of biodiversity and in weighting these different factors. However, we are not aware of any studies on how the weighting of specific aspects of biodiversity affects the age composition of cost-effective forest reserve selections.

In a previous study, Lundström et al. (2011) sought to identify a cost-effective age composition for protected forest areas in boreal Sweden. Structural indicators that are considered important for many forest species, e.g. dead wood and large-diameter trees (Nilsson and Hedin, 2001; Stokland et al., 2012) were used as proxies for the biodiversity potential, and the character of the selected reserves were identified using a goal programming (GP) approach. A biodiversity indicator score, based on the measured values of these indicators was maximized. The design of the reserve selection model also adjusted this score ensuring that all of the indicators contributed to the resulting optimized solutions. The results indicated that the most cost-effective approach was to protect a large proportion of young forests, since they are relatively cheap but still contain the important structures. However, the model used by Lundström et al. (2011) did not account for the possibility that the variables considered might be of different relative importance. By incorporating the relative importance of each indicator for biodiversity in boreal forests based on the opinions of conservation planners we argue that the model would come closer to finding "the best" reserve network. Policy makers could then use the outcome when evaluating the character of future reserve network.

The main aim of the study described in this paper was to identify how the nature of the "optimal" conservation area network in any given situation varies depending on the relative importance assigned to different aspects of biodiversity. We focused on the age distribution since present conservation policy target almost only old-growth forests, which leads to a neglect of young forest biodiversity protection potential. Interviews were conducted with eight experts who work in practical reserve establishment to obtain information on their opinions regarding the relative importance of different aspects of biodiversity. The analytic hierarchy process (AHP) was applied to assign appropriate weightings to the different indicators used by Lundström et al. (2011). AHP is a well-known method that is used in multiple criteria decision analysis (MCDA) to handle the complex task of accounting for individual and collective preferences during processes such as systematic conservation planning (Ananda and Herath, 2009; Moffett and Sarkar, 2006). The classical way of solving reserve selection problems of this type is to use simple linear programming (LP) (Williams et al., 2004), with the goal of maximizing indicator richness. However, this approach does not account for the fact that there can be large differences between the indicators in terms of their commonality risking that a common indicator dominate and controls the selection just because it is common, and a rare indicator might not be selected at all. Neglecting this inequality could prevent the weights from having their intended impact, since if the common indicators will rule the selection the weights will not have any effect. We therefore wanted to investigate the implications of this neglect by comparing a GP model to a simple LP model.

2. Methods

2.1. Study area & data

The extended model was applied to the whole of boreal Sweden (Ahti et al., 1968). The boreal forest is relatively homogenous due to its low tree species diversity (Esseen et al., 1997); it is dominated by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.), with the main deciduous trees being the birches (*Betula pendula*

Table 1
List of biodiversity indicators, criteria for assigning points, and the normalization factors used in Case 12.

Indicator	100 points	50 points	0 points	Normfact[5]
Uneven age[1]	Uneven-aged	Fairly even-aged	Completely even-aged	19
Stand character[2]	Pristine		Normal	827
Tree layer[3]	Fully layered/several layers	Two layers	One layer/no layer	21
Ground structure[4]	Very uneven/fairly uneven	Fairly even	Very even	27
Large pine	>40 cm dbh	>30 cm dbh	Not present	79
Large spruce	>40 cm dbh	>30 cm dbh	Not present	118
Large birch	>40 cm dbh	>30 cm dbh	Not present	790
Large aspen	>40 cm dbh	>30 cm dbh	Not present	1890
Large deciduous tree (not birch or aspen)	>40 cm dbh	>30 cm dbh	Not present	3309
Dead conifer tree lying	Tree > 20 cm dbh		Not present	85
Dead deciduous tree lying	Tree > 20 cm dbh		Not present	340
Dead conifer tree standing	Tree > 20 cm dbh		Not present	160
Dead deciduous tree standing	Tree > 20 cm dbh		Not present	575
Presence of rowan	Present		Not present	32
Affected by water (moving water/spring/temporarily flooded)	Yes		No	606
Volume of dead wood	>20 m^3/ha	≤20 m3/ha[6]		0.03

[1] Completely even-aged: >95% of the volume within an age interval of 5 years, fairly even-aged: >80% of the volume within an age interval of 20 years. Remaining stands classed as uneven aged.
[2] Pristine character: presence of coarse (>25 cm diameter) dead wood and no trace of management actions during the last 25 years.
[3] Tree layer: group of trees amongst which the height is approximately the same, but their mean height differs from other layers. Fully layered: all diameter classes represented, the biggest tree > 20 cm in diameter, the number of stems increasing with increasing diameter class, and the volume density (relationship between the actual volume in the stand and the potential volume) > 0.5.
[4] Ground structure: Classification based on height and frequency of irregularities (rocks, small hills and holes) on the ground.
[5] Normalization factor based on the mean point over all areas.
[6] Normalized point according to the volume of dead wood/ha, from 0 to 100.