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Analysis

Fine-scale conservation planning outside of reserves: Cost-effective selection of retention patches at final harvest

Karin Perhans [a,*], Dan Glöde [b], Jessica Gilbertsson [c], Anette Persson [d], Lena Gustafsson [a]

[a] Department of Ecology, Swedish University of Agricultural Sciences, P.O. Box 7044, SE-750 07 Uppsala, Sweden
[b] Mellanskog, Uppsala Science Park, P.O. Box 127, SE-751 04 Uppsala, Sweden
[c] WSP Environmental, Järnvägsgatan 13, P.O. Box 714, SE-251 07 Helsingborg, Sweden
[d] Swedish Forest Agency, Lasarettsvägen 3B, SE-668 40 Bäckefors, Sweden

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ABSTRACT

Retaining forest patches at final harvest is a key conservation measure in boreal forests, but guidelines for how to increase its cost-effectiveness are lacking. In a study in boreal Sweden, we compared the cost-effectiveness of three different approaches a forest owner may use to select patches: selection based on the conservation value of patches alone, economic cost alone or both of them combined. We also compared the cost-effectiveness of six different common types of patches. Conservation value was measured as species richness of bryophytes and lichens and as structural characteristics of patches. Compared to the selection approach in which both conservation value and cost were used, cost-effectiveness was 5–14% lower when only conservation value was used, depending on how conservation value was measured. On the contrary, using only the economic cost decreased the cost-effectiveness by only 1–2%. Among the patch types, swamp forest areas and deciduous tree groups were cost-effective types to retain. However, the patch types were complementary in their species composition and all hosted unique species. We argue that, ideally, assessments of both conservation values and economic costs of retaining patches should be made prior to harvest to enable planners to make well-informed and cost-effective decisions.

1. Introduction

Land outside of reserves comprises a vast majority of the total habitat for most species and provide essential ecosystem services (Lindenmayer and Franklin, 2002; Meir et al., 2004). Accordingly, the limitations of reserves as the only means to stem the loss of biodiversity have been increasingly acknowledged. Within forest biodiversity conservation, the focus has shifted during the last decade from a strong emphasis on traditional reserves towards conservation measures in the managed forest landscape (the "matrix"; Ricketts, 2001; Debinski, 2006; Gustafsson and Perhans, 2010). In regions with a long history of forest management and with fragmented natural forest areas, conservation and restoration measures outside of reserves may be even more crucial.

In boreal forests around the world, a cornerstone among conservation measures in the matrix is the continuous establishment of small-scale retention patches at final harvest (Simberloff, 2001; Millennium Ecosystem Assessment, 2005; Rosenvald and Lõhmus, 2008). Retention patches are groups of trees left at logging, intended to benefit forest biodiversity in three main ways (Franklin et al., 1997): (1) as "life-boats" for sensitive flora and fauna over the stand regeneration phase, (2) by increasing the structural variation in the new developing stand, both in a short- and a long-term perspective, and (3) by increasing the connectivity in the forest landscape.

In Sweden, retention patches are created on most harvested areas since a few decades ago and cover on average 3% of harvested areas (Swedish Forest Agency, 2008). According to the Swedish forestry act, retention patches or dispersed trees should always be left whenever it is judged necessary to protect sensitive species or environments (SKSFS, 1993) and forest certification standards state that at least 10 trees per hectare should always be left (e.g. Swedish Forest Stewardship Council, 2009). Compared to other countries (e.g. the US; Franklin et al., 1997) retention patches in Sweden are small (generally smaller than 0.5 ha) but, accordingly, the average size of harvested areas in Sweden is only 4.1 ha (Swedish Forest Agency, 2008).

A forest owner in Sweden is expected to make small-scale retention measures without any economic compensation for the loss in harvest revenue, and must in most cases prioritize between different potential conservation options. Despite the large combined amount of such conservation efforts, very few studies exist that evaluate their cost-effectiveness. These include studies on measures to increase the amount of dead wood (Ranius et al., 2005; Jonsson et al., 2006) and the effect of retention measures on recreation and forest fauna (Carlén et al., 1999). On the contrary, a large number of studies focus on issues of cost-effectiveness for large-scale reserve networks (e.g. Ando et al., 1998;

* Corresponding author. Present address: The Ecology Centre, School of Biological Sciences, University of Queensland, St Lucia, QLD 4072, Australia. Tel.: +61 7 3365 2450; fax: +61 7 3365 1655.
E-mail addresses: karin.perhans@ekol.slu.se (K. Perhans), lena.gustafsson@ekol.slu.se (L. Gustafsson).

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Snyder et al., 1999; Polasky et al., 2001; Messer, 2006; Strange et al., 2006). These all show that if both conservation values and economic costs of potential reserves are acknowledged, cost-effectiveness can be increased compared to when only conservation values are used, as is most often the case. Using only economic information to guide reserve selection might also in some cases be more cost-effective than using information about conservation values alone (Juutinen et al., 2004).

In the case of an individual small-scale (<50 ha) forest owner (the total land of whom comprises about 50% of all productive forestland in Sweden), the decision of which parts of the stand to leave as retention patches is made either by the forest owner or by a contractor hired for planning and logging. Although not much is known about what type of information is generally used in practice for selecting retention patches, there are indications that small-scale forest owners do include economic concerns at least to some extent when selecting areas to set aside as part of their certification commitments (Glöde et al., 2003) or when leaving retention patches (Wikberg et al., 2009). On the other hand, Ingemarsson et al. (2004) did not find that economic aspects were generally considered when professional planners selected conservation areas for forest plans of small-scale forest owners. Thus, there is most likely a large variation among individual forest owners in terms of what information is used as a basis for selection.

Different types of retention patches may be established with regard to tree species composition, ground conditions, and location on the harvested area. Common types in boreal Sweden are buffer zones to streams, lakes or mires, forest on rock outcrops, swamp forest areas, and free-standing groups of trees. In some cases the choice of which types of patches to retain might be constrained by the need to focus retention towards specific features in the stand, such as a stream, but in most cases there are multiple potential areas for the planner to choose between. Retained unproductive areas within a harvested stand (areas, larger than 0.1ha, producing less than 1 m^3 of wood per hectare and year may not be harvested according to the Swedish forestry act) are generally not seen as retention patches. The effectiveness of retention patches from an ecological perspective has been increasingly evaluated (reviewed by Rosenvald and Lõhmus, 2008; Gustafsson et al., 2010) but differences between patch types have not been addressed. In order to design guidelines for cost-effective selection of patches, it is important to know how conservation values as well as costs of retaining patches vary across different types of patches.

In this study, we investigated the potential to influence the cost-effectiveness when establishing retention patches. The study was carried out from the perspective of a small-scale forest owner, selecting patches on individual harvested areas. We used two different measures of conservation value: species richness of bryophytes and lichens of conservation concern and biodiversity potential scores based on structural characteristics of patches. Specifically, we aimed to (1) compare the cost-effectiveness of three different approaches to select retention patches: selection based on conservation values alone, economic costs alone or both of them combined; and (2) investigate how the conservation value, economic cost, and cost-effectiveness differ between different types of retention patches.

2. Methods

2.1. Study Area

The study was carried out in the provinces of Medelpad and Ångermanland in middle boreal Sweden (central position of study area was 62°30′N, 17°15′E). The forests in this region have been used for commercial harvesting for more than a century and consist mostly of even-aged stands in different rotation phases (Esseen et al., 1997). The dominating tree species are Norway spruce *Picea abies* (L.) H. Karst and Scots pine *Pinus sylvestris* L. with varying components of deciduous trees, mainly birch *Betula* spp. and aspen *Populus tremula* L.

2.2. Retention Patches

In the year 2000, all newly established retention patches on harvested areas within a region of approximately 80×70 km in five forest management districts of a forest owners' association (Norrskog) were selected. The patches were all on land owned and managed by small-scale (non-industrial) private forest owners and had a tree-density of at least 650 trees (>8 cm in diameter) per hectare. In total, 74 patches were included in the study, distributed over 37 harvested areas with an average size of 10.8 ha. The patches were of six different types with regard to their forest composition, site characteristics and location on the harvested area: buffer zones to open mire (forest bogs or swamps), buffer zones to water (stream or lake), rock outcrop patches with a predominantly thin soil layer, free-standing tree groups dominated by coniferous trees, free-standing tree groups dominated by deciduous trees, and moist-wet (paludified) swamp forest patches. The average patch size differed between the types, from 0.06 ha (swamp forest areas) to 0.16 ha (buffer zones to water) (Table 1). On harvested areas with more than one retention patch, these were generally of different type, size, and situated on different parts of the harvested area.

2.3. Data Collection

2.3.1. Conservation Value

We surveyed bryophytes and lichens, as they are important species groups in boreal forests both in terms of species diversity and ecological function (Longton, 1992), and occur abundantly in all six types of retention patches studied here. Many species of bryophytes and lichens are also considered sensitive to forestry and are used as indicators for guiding conservation effort (Esseen et al., 1997). In each retention patch, bryophytes and lichens of conservation concern were surveyed in 2000 and 2001, respectively. We define species of conservation concern as red-listed species (Gärdenfors, 2000, 2005) and indicator species (Nitare, 2000). Red-listed species are classified as threatened or nearly threatened and are in many cases disfavoured by forest management, while the term indicator species refers to a set of species selected by the Swedish Forest Agency to indicate areas of high conservation value (woodland key habitats; Timonen et al., 2010). The entire retention patches were surveyed for species, using 5 m wide parallel belt transects, and the presence of species in each patch was recorded. Both species groups were recorded on all substrates up to a height of 2 m. In total, the data set included 60 species, of which 19 (8 red-listed) were bryophytes and 41 (18 red-listed) were lichens (for details regarding the species survey, see Perhans et al., 2009).

We also assigned to each patch a “biodiversity potential score” according to a methodology developed by Drakenberg and Lindhe (1999). The assessment was based on forest structures, dynamics, and other site factors indifferent to patch area (e.g. diameter of trees, seasonal flooding regime, degree of sun-exposure, and diversity of tree ages). In total, 50 patch characteristics were evaluated, and each given either zero or one point. The points were then summed up to get the biodiversity potential score for each patch. The method has been used extensively by Swedish

Table 1
Mean size, total area, and tree species composition of the different types of retention patches.

Type of retention patch (total number within parenthesis)	Mean size (ha)	Total area (ha)	Tree species composition[a]		
			Spruce (%)	Pine (%)	Deciduous trees (%)
Coniferous group (10)	0.11	1.1	35 ± 6.1	39 ± 9.8	26 ± 6.1
Rock outcrop (11)	0.15	1.7	35 ± 8.3	48 ± 10.9	17 ± 6.5
Deciduous group (9)	0.07	0.7	19 ± 6.0	7 ± 5.5	74 ± 7.3
Swamp forest (8)	0.06	0.5	29 ± 6.5	23 ± 8.1	48 ± 12.1
Buffer to mire (22)	0.14	3.0	38 ± 3.7	38 ± 5.1	24 ± 3.2
Buffer to water (14)	0.16	2.2	53 ± 6.3	14 ± 3.3	33 ± 6.1

[a] Volume (m^3/ha). Mean ± SE.