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Expert assessment of landscape-level conservation strategies in boreal forests for biodiversity, recreation and water quality

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ABSTRACT

Determining effects of landscape-level conservation strategies is needed, yet a challenging and costly endeavour. The aim of this study was to evaluate the effects of landscape-level conservation strategies in forests on biodiversity and provision of two ecosystem services (recreation and water quality). Specifically, we focused on the spatial allocation of unmanaged areas in production forests and different levels of "land sharing" or "land sparing". They were represented through seven scenarios constructed for a boreal managed forest landscape in central Sweden. All scenarios had the same total level of conservation effort, but they differed in the combinations of sizes of unmanaged areas and how these areas were spread in the landscape. In one scenario, this was complemented with extended rotation of production areas. Experts (researchers in relevant fields) assessed these scenarios for overall biodiversity, recreation, and water quality. We used the Delphi technique: experts filled out an online survey individually in two rounds. In the second round they were familiarized with anonymized responses of others from the previous round. There was little agreement between experts whether concentration of unmanaged areas in one part of the landscape or dispersion of them around the entire area is more beneficial, for biodiversity as well as for the two ecosystem services. The explanation of the opinions given by biodiversity experts were based on different ecological theories resulting in different conclusions (mainly habitat complementation vs. metapopulation ecology). A few large unmanaged areas were considered more beneficial for biodiversity than many small areas. The main argument was that long-term species persistence becomes higher with larger areas. For recreation and water quality, there were almost no differences in estimates between these two strategies. One "land sharing" approach, retention trees, received the lowest score. The second "land sharing" approach, extended rotation, was scored higher, especially regarding recreation. This may be because extended rotations generate features of high recreational value, such as mature, thinned forests with not so much dead wood. Conclusively, we suggest a strategy of mixed conservation measures, with considerable efforts directed towards establishing and maintaining large unmanaged areas.

1. Introduction

Intensive forest management for production of timber and bioenergy has negative impacts on biodiversity and several non-provisioning ecosystem services (Pohjanmies et al. 2017). Traditionally, negative impacts of intensive forest management have been mitigated by setting aside forest areas as reserves. For a few decades, this strategy has been combined with contributions from managed forests such as retention of trees at harvesting (Gustafsson et al. 2012) and extension of rotation lengths (Roberge et al. 2016). With increasing global reliance on timber and bioenergy, the area of intensively managed forests is predicted to continue growing (Warman 2014). This will result in a higher proportion of landscapes comprised primarily of managed forests and thus an even more pressing need for identification of strategies beneficial for biodiversity conservation and delivery of non-provisioning ecosystem services in such landscapes.

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Much ecological research has been undertaken on the effect of the spatial allocation of conservation areas on biodiversity (e.g. Schwartz 1996, Cabeza et al. 2004, Arroyo-Rodriguez et al. 2020). The SLOSS (Single Large Or Several Small) debate, which started almost 50 years ago, considered whether a few large or many small conservation areas is the best alternative for biodiversity protection (Simberloff & Abele 1982) and is still ongoing (Fahrig 2019; Volenec & Dobson 2019). More recently, "land sharing" vs "land sparing" has been debated, focusing on whether it is better to combine intensively managed land with preservation of high-quality habitat ("land sparing") or to meet both production and preservation objectives within the same area ("land sharing") (Phalan et al. 2011, Betts et al. 2021). The spatial distribution of conservation areas has also been considered, often within the framework of metapopulation theory (Hanski 2011). Despite considerable ecological research, there is still no consensus on how to evaluate and interpret available data (e.g. Hanski 2015, Fahrig 2017, Ranius et al. 2019). One reason for this is uncertainties that arise due to, for instance, complex conservation goals, involving the preservation of various organism groups and habitats at various spatio-temporal scales, and long delays before the full consequences of newly introduced conservation regimes are observed (Kuussaari et al. 2009). Climate change also effects the conditions for biodiversity conservation, adding complexity and uncertainty to decisions about biodiversity conservation (Keeley et al. 2018; Kujala et al. 2013).

Apart from having a positive effect on biodiversity, leaving forests unmanaged or extending rotations can be beneficial for delivery of non-provisioning ecosystem services (Pohjanmies et al. 2017). Unmanaged forests tend to have more irregularly spaced large trees and a higher visual diversity, which increase the recreational values (Gundersen & Frivold 2008; Edwards et al. 2012). On the other hand, messiness or feelings of being unsafe in unmanaged forests can be perceived negatively by recreationists (Gundersen & Frivold 2008). The in-between options involving some management without visible traces have been considered more appealing (Edwards et al. 2012), which suggest that land-sharing approaches may be an attractive option. Another non-provisioning service often negatively affected by forestry operations is water quality. Forest harvesting affects water quality mainly because of a decline in evapotranspiration that results in wetter soils and higher stream runoff. In return, this can cause increased export of nutrients, metals and sediments, which may affect aquatic biodiversity (Futter et al. 2016). Leaving unfelled forests as buffers between water bodies and clear-cuts can mitigate such negative effects (Gundersen et al. 2010). The spatial distribution of unmanaged forest buffers along streams and lakes is, therefore, important for water quality (Kuglerová et al. 2014).

The aim of this study was to evaluate the impacts of landscape-level conservation strategies in a managed forest landscape for biodiversity conservation and the provision of two ecosystem services (recreational values and water quality). Specifically, we set out to determine which strategy is more beneficial in each of the following sets: (a) concentrated vs dispersed allocation of unmanaged forest areas; (b) a few large vs many small unmanaged forests; (c) land sharing (extended rotation and retention of trees at harvest) vs land sparing (unmanaged forest areas). To represent these strategies, we constructed seven scenarios for a managed boreal forest landscape in central Sweden (a typical landscape in a country with a large proportion of forests intensively managed) and simulated forest development for them over the next 100 years. Assessment of these scenarios' capacities for biodiversity conservation, recreation and water quality at a landscape scale is particularly challenging due to presence of much uncertainty since empirical studies are resource consuming. To overcome this challenge, we used the Delphi technique, which is a structured group expert assessment method (MacMillan & Marshall, 2006). This method is helpful in informing decision-making by synthesizing knowledge in relation to scenarios and policy (Pullin et al. 2016; Mukherjee et al. 2018). It is a structured group communication process that allows a group of experts to deal with a complex problem. Experts conduct assessments individually in a series of rounds. In round two and further, they consult group summaries from the previous round in order to decide whether to adjust their response or not. Responses are anonymized, which makes it less likely that some experts dominate the discussion and the outcomes. At the same time, through consultation of responses from previous rounds, participants are able to conduct more informed assessments (Linstone & Turoff 2002; Martin et al., 2012). The process allows for recording of divergent opinions and their reasoning (Pullin et al. 2016). The potential and usefulness of this method has been recognized in a variety of disciplines, and a few applications in ecological and conservation research already exist (Mukherjee et al. 2015).

2. Materials and methods

2.1. Studied landscape

The studied landscape is located in central Sweden (Delsbo, 62° N, 16° E, altitude: 140 – 530 m). It is owned by a single company and contains 14,935 ha of managed productive forest. The forest is typical of the Swedish boreal region; dominated by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karsten) (50 and 33% of the total standing volume respectively). Today, the landscape is mainly composed of even-aged stands and the average stand age is 45 years. About 80% of the productive forest is younger than 60 years, and 10% of the productive forest is older than 100 years. The forest owner has been certified according to the Forest Stewardship Council since the late 1990's, and thus follows the requirements to retain trees during forest operations and leave $\geq$ 5% of the productive forest land unmanaged in set asides (FSC 2010).

2.2. Scenario building

We constructed seven scenarios using the same total level of conservation effort across all of them (Table 1), i.e. leaving 16% of the area unmanaged, or in case of extended rotation its equivalent in net-present value. This level was chosen because it represents the proportion of the productive forest land not managed for timber presently, both in Sweden and in the county Gävleborg, where the landscape is located (Claesson et al. 2015). The conservation measures in the scenarios employed in this study were unmanaged areas of three different sizes (nature reserves, set asides, and groups of retention trees) and extended rotation. The first two represent entire stands left unmanaged with the main difference being that nature reserves consist of several neighboring stands and form large areas (approximately 100 ha), while the set asides are single stands ($<$ 50 ha). Groups of retention trees are the smallest unmanaged areas; they are located within stands under conventional even-aged management and left on site at final harvest. Extended rotation implies that the rotation is longer than the conventional one used in the area.

All seven scenarios shared a baseline, where 6% of the total area was taken out of timber production and split equally between the three sizes of unmanaged areas, that were distributed around the entire landscape (Fig. 1; Table 1). The difference between scenarios was regarding the dominant conservation measure which was given additional 10% of the total area. In six scenarios, the dominant conservation measure was one of the three sizes of unmanaged areas, either dispersed around the whole landscape or concentrated in a part of the landscape (namely the south-west corner). In the seventh scenario, in addition to the baseline, rotation length of managed stands was extended so that the net present value was similar to that of the forests in the other six scenarios. As a result, the minimum final felling age was set to be at least 1.5 times the lowest allowable final felling age, which varied between 45 and 90 years in the studied landscape.

Scenarios were built and simulated in Heureka, which is a Swedish forest management decision support software (Wikström et al. 2011).

Table 1
Scenarios and allocation of conservation measures. Throughout the whole landscape, 6% of the total area is assigned to "no management", of which 2% is nature reserves; 2% set asides; 2% groups of retention trees within managed stands covering the rest of the landscape*, while additional 10% is specific to each scenario.

Scenario name	Allocation of 10% of the total area or its equivalent specific to each scenario
1A: "Nature reserves dispersed"	assigned to "no management" as nature reserves and dispersed throughout the whole landscape
1B: "Nature reserves concentrated"	assigned to "no management" as nature reserves and concentrated in SW corner of the landscape
2A: "Set asides dispersed"	assigned to "no management" as set asides and dispersed throughout the whole landscape
2B: "Set asides concentrated"	assigned to "no management" as set asides and concentrated in SW corner of the landscape
3A: "Groups of retention trees dispersed"	assigned to groups of retention trees and dispersed throughout the whole landscape (10.2% of the area of each managed stand**)
3B: "Groups of retention trees concentrated"	assigned to groups of retention trees and concentrated in SW corner of the landscape (34% of the area of each managed stand in the SW corner of the landscape***)
4: "Extended rotation"	assigned to even-aged forest management with extended rotation and dispersed throughout the whole landscape

* Groups of retention trees are only assigned in managed stands and therefore areas assigned as nature reserves and set asides are excluded from the calculation. Thus, in order to reach 2% of the whole studied landscape area assigned to groups of retention trees, 2.3% of the area of each managed stand was assigned to groups of retention trees.
** Since groups of retention trees are only assigned in managed stands, an additional 10% of the total area equals 10.2% of the area of each managed stand to be assigned to groups of retention trees.
*** Concentrating the same additional retention area as in scenario 3A to the SW corner of the landscape results in a retention area of 34% for each managed stand within that corner area.

They were created by allocating each forest stand to one of five treatments: no management (for nature reserves and set asides), conventional even-aged management with groups of retention trees of one of three levels (2.3; 10.2 and 34.0% of the stand area), and even-aged management with extended rotation and with groups of retention trees (2.3 % of stand area) (Table 1). The choice of the treatment for each stand was based on their current age (i.e. at year 0), location in the landscape and area constraints that were set for each category and scenario. The oldest stands were prioritized for being selected as "no management" treatments. In the survey, outputs from Heureka in the form of maps depicting mean stand age, volume of deadwood and volume of large trees (diameter > 30 cm) per ha both at year 0 and 100 (at the end of simulation period) were presented to the experts (see Supplementary materials A for the full scenario description provided to experts).

2.3. Delphi survey

From January to May 2018 we applied the Delphi technique and ran a two-round online survey. The experts were researchers who had obtained a PhD degree and had been conducting research on forest biodiversity, recreation or water quality issues in Sweden, Norway, Finland, Estonia, Latvia, or Lithuania (but not necessarily having their affiliation there) and who felt knowledgeable to provide assessments for the Swedish study landscape. Before starting the survey, we tested our questionnaire with experts with similar professional profiles who were not participating in the study, to ensure that the questions were clear and to validate the time required for responding to them.

In round 1, participants identified their area of expertise and based on that, they were assigned to one of the three panels: biodiversity, recreation, or water quality. After studying descriptions of the scenarios (Supplementary materials A), the experts were asked to assess each scenario's capacity in relation to their stated area of expertise at a landscape scale and 100 years from now (i.e. the end of the simulated period). Specifically, in round 1, experts were first to rank the scenarios from the worst to the best and then for each scenario to provide a percentage where 0 % represented the worst and 100 % the best conditions. Furthermore, they were asked about effects of a longer time span and a longer history of intensive forest management on their responses. They were also asked to record rational for their answers. Screenshots of a complete survey from round 1 are presented in Supplementary materials B.

In the second round, the survey focused on one question only, namely the percentage estimate of capacity of each scenario to provide biodiversity or one of the ecosystem services at a landscape scale and 100 years from now (i.e. the end of the simulated period) (See Q#17 on p. 17–18, Supplementary materials B). The anonymized group summaries (including explained rationales) as well as their own responses from round 1 were presented. Respondents were then asked to reconsider and revise their responses in the light of presented information should they deem it appropriate. Further rounds were not pursued, since there were no large changes in individual responses between round 1 and 2. Also we did not expect consensus among experts, and thus did not strive for converging responses.

Potential participants for the study were identified through a literature search and personal knowledge of the authors. The former was conducted in Google Scholar and Scopus using "forest" and "boreal" together with "biodiversity" and ecosystem services as keywords. Authors of articles on relevant topics were then investigated for fitting the following inclusion criteria: (i) having a PhD degree, and (ii) working with either biodiversity or recreation or water quality in the boreal region. This was done using personal and professional webpages of authors and other information on the internet. This yielded a list of 183 potential participants, to whom we sent invitations to participate in the study. Most of the invited researchers were experts on various aspects of biodiversity, since we were not able to identify more experts on the two ecosystem services, and this was also reflected in the final sample of participants. Round 1 was completed by 23 participants and round 2 by 22 participants, out of which 14 completed both rounds (Table 2). In the analysis we included participants who completed both rounds as well as only one round. Participants added in the second round were making their judgement based on group summaries from the previous round and their own expertise, thus staying within the requirements of the Delphi protocol. The outcomes from the statistical analysis were the same independent on whether these participants were added or not. The average participant had 15 years of research experience after completing their PhD (range: 4–45 years). Experts in the panel on biodiversity covered the following species groups as those they were most knowledgeable about: birds, fungi, invertebrates, bryophytes & lichens, and vascular plants, while for instance, no experts on mammals participated (see Supplementary materials C for the breakdown of experts between species groups). Our panel sizes for recreation and water quality were lower than the one for biodiversity, however they were within the rule of thumb recommendation for studies applying the Delphi technique to ensure that diverse perspectives and areas of knowledge are reflected (three to five experts per field of expertise) (Novakowski & Wellar, 2008).

2.4. Analyses

The analyses consisted of three steps: (i) individual responses and ranking among scenarios were summarized; (ii) statistical tests between sets of strategies were conducted; (iii) comments and arguments were summarized. (i) In the first step we summarized the individual responses of experts in each panel to determine if they recognized differences between scenarios in their capacity to preserve biodiversity or provide one of ecosystem services (recreation or water quality). Since experts

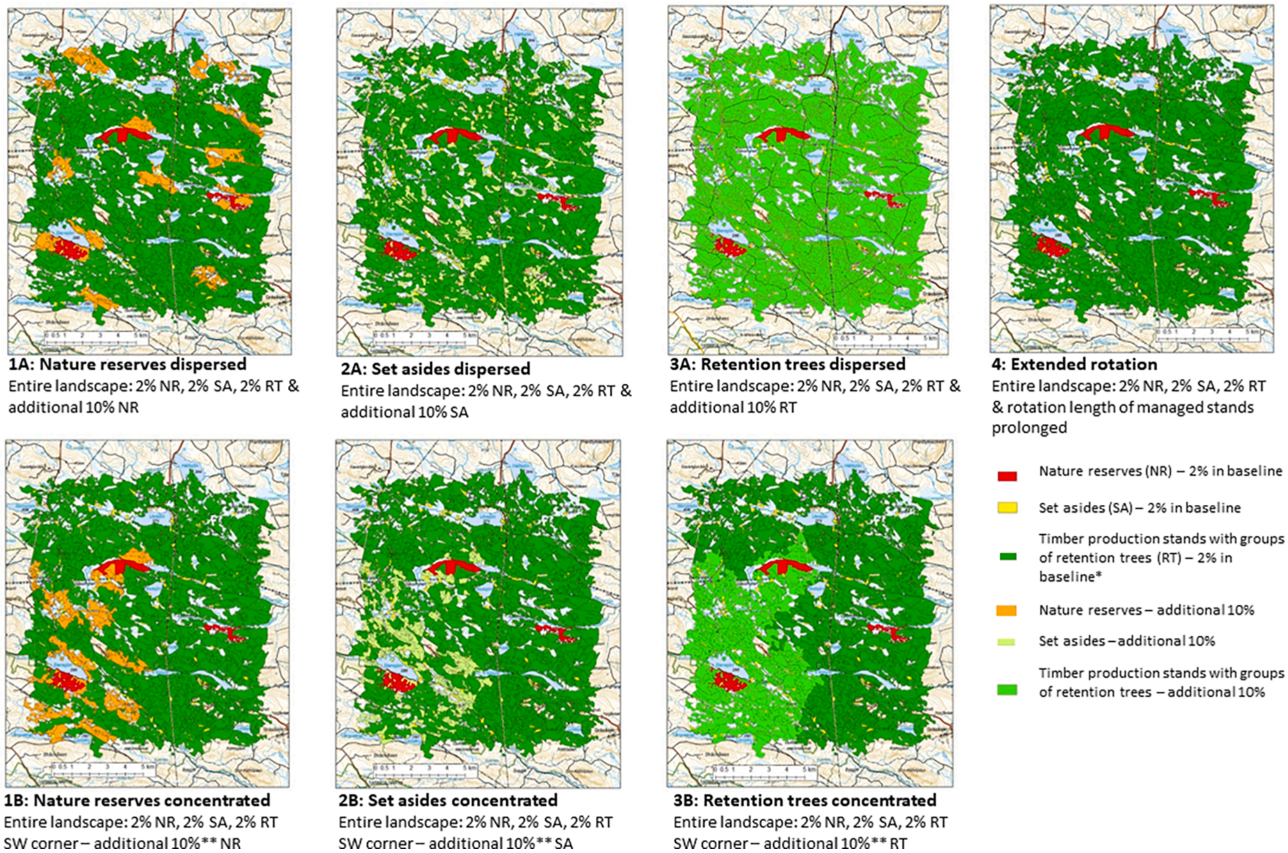

Fig. 1. The allocation of conservation measures in the landscape for each scenario. * In Scenario 4 this area is managed with an extended rotation length. **All percentages (including the additional ones in the SW corner of the landscape) are given in relation to forests in the entire landscape. Groups of retention trees are only assigned to managed stands after nature reserves and set asides are excluded from the total area, resulting in higher actual percentages of retention trees in each managed stand than 2% in baseline and additional 10% (for exact calculations for each scenario see Table 1).

Table 2
Number of experts in each panel and round.

Panel	Round 1	Round 2	Both Round 1 and 2	Used data*
1. Recreation	4	5	4	5
2. Water quality	3	1	0	4
3. Biodiversity	15	13	9	19

* In the final analysis we pooled answers from round 2 with those from round 1 who did not complete round 2.

were giving scores in percentage and could have different starting points, but overall show the same trends in relative capacity of scenarios, we converted their scores into ranking using a scale from 1 to 7. (ii) In the second step, we used the percentage scores given by experts and tested statistically whether there were differences between the scenarios in the scores given by experts. The analysis compared scenarios grouped according to two dimensions: (1) concentrated vs dispersed allocation of unmanaged areas; (2) the dominant conservation measure (i.e. nature reserves, set asides, groups of retention trees, and extended rotation). Differences between estimates for scenarios with dispersed and concentrated unmanaged areas were calculated for each respondent, as means of the scenarios of the three sizes of conservation measures (nature reserves, set-asides, and groups of retention trees). To determine a preference in either direction, a one-sample Wilcoxon rank sum test was conducted separately for each panel (biodiversity, recreation, and water quality). Differences in estimates for scenarios with different dominant conservation measures were analyzed using only dispersed scenarios to enable comparison with extended rotation and avoid pseudo-replication. The biodiversity panel data were normally distributed and thus analyzed with a pairwise *t*-test, while recreation and water quality with smaller sample sizes were analyzed with paired Wilcoxon rank sum tests. (iii) The third step of analysis involved summarizing of comments provided by experts, in order to identify arguments for and against different scenarios.

3. Results

On an individual level, experts in all three panels found scenarios to differ in their capacity for preservation of biodiversity and provision of recreation or water quality. For each expert we converted provided percentages scores (see Supplementary materials D) into rankings that reflects relative capacity of scenarios to provide biodiversity, recreational values and water quality. We found that scenarios with nature reserves as a dominant conservation measure were regarded as most beneficial for biodiversity (Fig. 2). Findings from further investigation by testing the differences between percentage scores given by experts for scenarios together with a summary of rationales they provided to support their scoring are presented below.

3.1. Concentrated vs. dispersed allocation of conservation measures in a landscape

For biodiversity and recreation, 11 and 2 experts respectively gave higher scores to concentrated allocation of unmanaged areas in the landscape while 8 and 3 experts respectively preferred dispersed allocation. For water quality, respondents were either neutral or preferred dispersed allocation. The preference for either concentrated or dispersed allocation was not statistically significant in any of the three panels

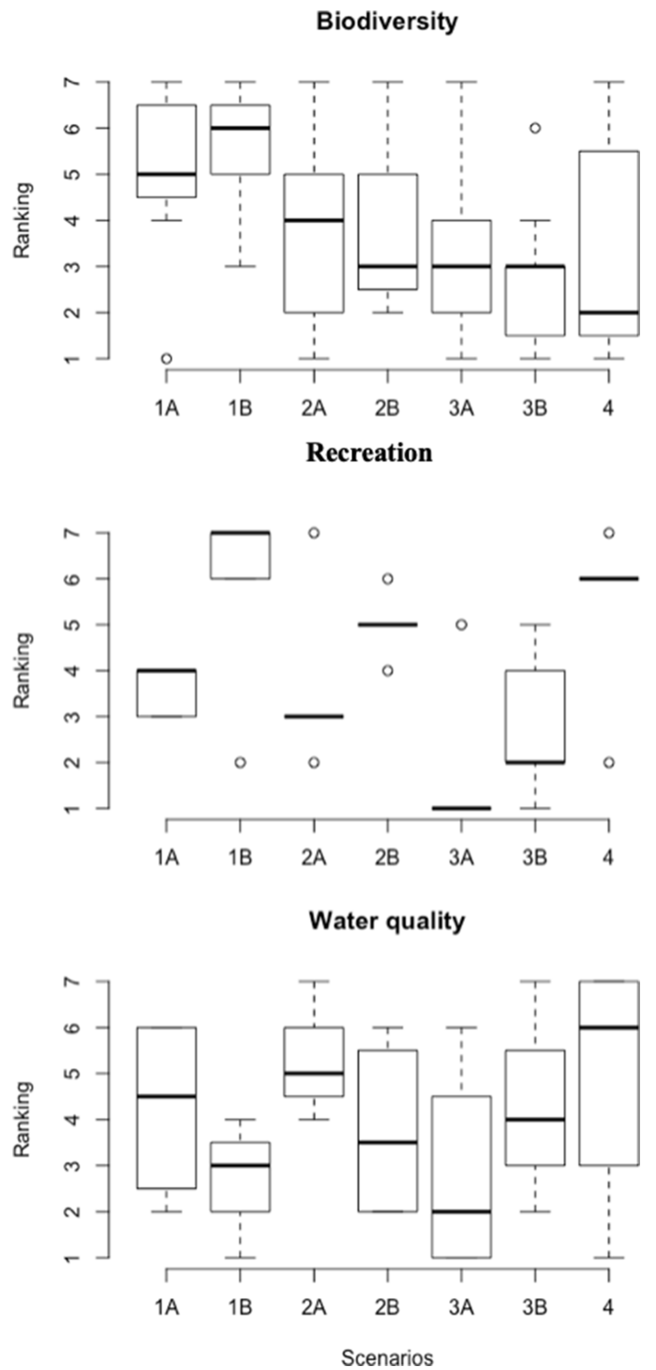

Fig. 2. Range of relative ranking provided by experts for each scenario, where "1″ is the lowest and "7" – the highest capacity of scenario in terms of biodiversity conservation or one of the two ecosystem services. Rankings have been derived based on percentage scores provided by experts (see Methods for details). Panels: biodiversity – 19 experts, recreational values – 5 experts, and water quality – 4 experts. The bold line inside the box is the median value, boarders of the box are the 1st and 3rd inter-quartile, and whiskers are the full range.

(Fig. 3; p varied between 0.37 and 0.72, one-sample Wilcoxon test based on the mean of the three sizes of unmanaged areas per respondent).

Overall, 12 experts provided some arguments for their response in relation to dispersed or concentrated allocation of unmanaged areas (9 for biodiversity, 2 for recreation, and 1 for water quality). Eleven experts in the biodiversity panel also provided references to scientific studies backing up their responses. However, no one presented comprehensive arguments for their responses. Arguments provided by experts on

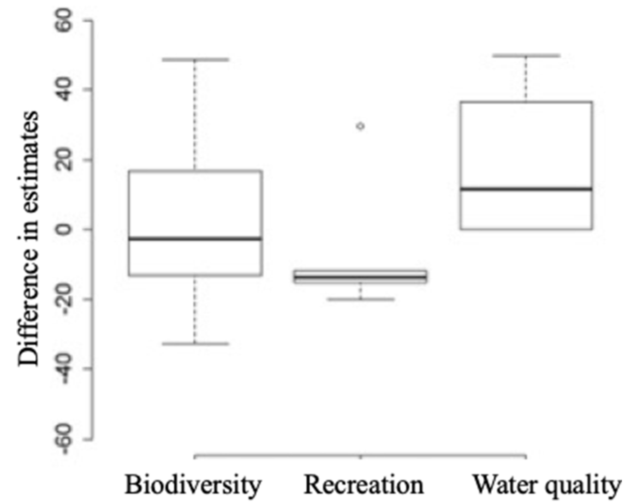

Fig. 3. The difference in estimates (scores in %) provided for dispersed and concentrated options for scenarios 1–3 (median, inter-quartile range, max and min). A positive value indicates a preference for dispersed allocation, calculated based on the mean of the three answers (being estimates between 0 and 100) from each respondent. Sample (panel) size: biodiversity – 19, recreation – 5, water quality – 4.

biodiversity revealed that the differences in answers between experts were related to how they assessed the weight of different ecological processes. The main argument for concentrated allocation provided by biodiversity experts was that larger population sizes can be reached and exceed threshold levels for population persistence within at least some areas, referring to e.g. Hanski (2011). Experts sometimes supported this argument by statements about limited dispersal propensity of certain species groups. Arguments for dispersed measures included that sites of high conservation value may be preserved irrespective of where they are in the landscape in such scenarios, and that habitat quality is generally more important than the spatial allocation. Furthermore, an expert pointed out that dispersed allocation increases the colonization probability over the whole landscape (referring to e.g. Fahrig 2017). In addition, the habitat amount hypothesis (Fahrig 2013) was mentioned. One argument among recreation experts for concentrated measures was that it generates one sub-area of higher quality providing fascination and stress relief, while some experts believed that dispersed allocation may be better for people walking over longer distances. A water expert argued for dispersed allocation, since it minimizes the area of large, continuously disturbed areas.

3.2. Size of unmanaged areas and land sharing vs. land sparing

Scenarios with the dominant conservation measure being large vs. small unmanaged areas and land sharing vs. land sparing had significantly different estimated benefit for biodiversity and recreation, but not for water quality. For biodiversity, nature reserves (i.e. large areas) were preferred by experts (Fig. 4; $p < 0.05$ in pairwise t-tests), while for recreation set-asides (i.e. small areas) and extended rotation (i.e. land sharing) were scored higher than groups of retention trees (i.e. land sharing) (Fig. 4; p (extended vs. retention) = 0.063 and p (set-asides vs. retention) = 0.058; paired Wilcoxon rank sum test). For water quality, there were no significant differences between any of these four dominant conservation measures (Fig. 4; p-values between 0.37 and 1; paired Wilcoxon rank sum test).

Overall, 8 experts provided arguments for their response in relation to effects of size of the unmanaged areas or land sharing vs. land sparing (7 for biodiversity and 1 for recreation). Again, none of the experts provided comprehensive reasoning for the responses. The main argument for a few reserves rather than many set-asides presented by

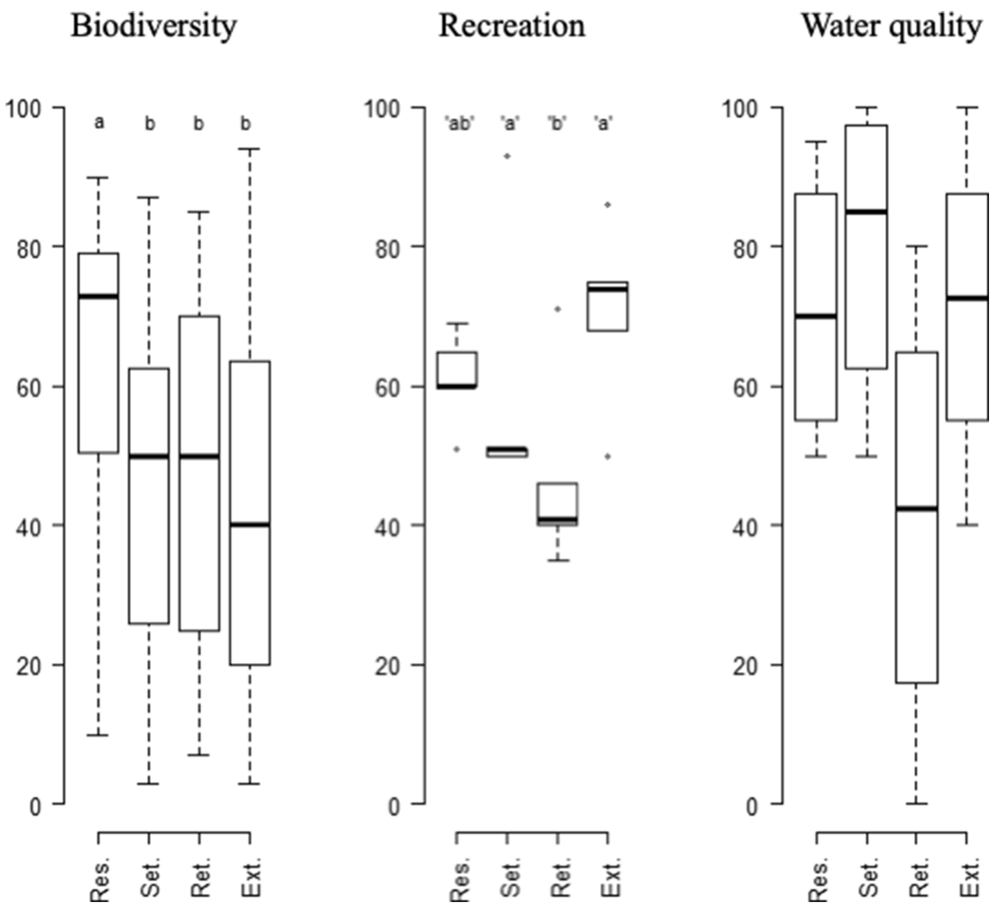

Fig. 4. Expert estimates (scores in %) for scenarios with conservation measures dominated by nature reserves (Res.), set asides (Set.), retention trees (Ret.), and extended rotations (Ext.) (median, inter-quartile range, max and min). Only scenarios with dispersed alternatives were considered. Sample (panel) size: biodiversity – 19, recreation – 5, water quality – 4. Within each panel, different letters above scenarios indicate a difference at the 0.05 level, with the case of ab not being different from either a or b, and ‘’ around letters indicating the 0.1 level, based on pairwise *t*-test for biodiversity and paired Wilcoxon rank sum test for recreation and water quality.

biodiversity experts was that larger populations have lower extinction risk. Moreover, it was pointed out that some species have large area demands. One expert argued for large reserves because the hydrology in larger undisturbed areas is better for certain moist-demanding organisms, while another expert stated that the negative edge effect for moist-demanding organisms is small even for set-asides and thus argued that these are large enough and preferred many small areas. One expert argued against set-asides because they are, for policy reasons, less long-lived environments. Experts presented two arguments against allocating measures in form of a few large reserves. First, the average distance between unmanaged areas becomes larger when protecting only a few reserves. Second, with many set-asides the diversity among the unmanaged areas becomes higher. One biodiversity expert preferred extended rotations, because they increase the time window for colonization and population growth. On the other hand, reserves and set-asides were preferred due to their habitat quality; one expert regarded managed forests with retention as a generally poor habitat and another expert assumed that the extension was not long enough to create habitats. Regarding recreation, one expert argued that larger unmanaged areas could provide better experiences for those seeking time in a natural environment. Most of water experts argued that location is more important for unmanaged forests rather than the specific conservation measure as stated in our scenarios. One expert pointed out that retention trees could decrease erosion and increase water uptake compared to clear-cuts, whereas another expert considered the significance of retention trees for water quality to be small.

4. Discussion

4.1. Concentrated vs. dispersed allocation of unmanaged areas

There was little agreement among biodiversity experts regarding effects of concentrated vs. dispersed allocation of conservation measures, even though many biodiversity experts individually demonstrated clear preference for one or the other and supported their opinions with ecological theories. Several experts utilized arguments related to meta-population theory, which suggests that long-term persistence of dispersal-limited habitat-specialized species is favoured by concentrating conservation measures (Hanski 2011). This is because a threshold habitat density must be exceeded to keep the colonization rate at least at the same level as the local extinction risk, which is needed for landscape-level species persistence (Lande 1987). Empirical studies for birds and mammals suggest that many species require at least 20% of the landscape covered with habitat (Andrén 1994). Also, occurrence patterns of deadwood-dependent organisms in boreal forests, give support to concentrating conservation measures in landscapes with higher conservation value (Rubene et al. 2017; Nordén et al., 2018). On the other hand, for certain mosses and epiphytic lichens, a large proportion of the colonizations are probably due to long-distance dispersal (Lönell et al. 2014; Gjerde et al 2015), which results in small differences between concentrated and dispersed allocation for these species, both regarding genetic exchange and colonization-extinction dynamics. Ecological theory also provides several arguments for dispersed allocation. If landscapes and the species communities that inhabit them are heterogeneous (Müller & Gossner 2010), concentrated allocation implies that habitats and species that mainly occur in the subarea with a low level of conservation measures will suffer; in contrast, with dispersed allocation, conservation efforts can be undertaken at the most valuable sites everywhere, benefitting communities occurring all over the landscapes. Dispersed allocation may also promote dispersal, and thus also genetic exchange, through entire landscapes and regions, since there will be more stepping stones also in the poorest parts of the landscape. This aspect is expected to be more important during rapid climate change. This is because the resultant change in environmental conditions causes species to shift their potential distribution ranges, making it necessary for many species to migrate through less suitable areas to reach regions with improved conditions (Keeley et al. 2018). Therefore, preservation of various types of biodiversity both in short and long term probably requires a combination of concentrated and dispersed allocation.

One of the respondents referred to the habitat amount hypothesis, which suggests that the amount of habitat within a landscape of a certain scale of response is the main factor explaining species richness, while the spatial configuration of the habitat within that landscape is not important (Fahrig 2013). If this hypothesis is true and the spatial scale of biodiversity response is of the same size or larger than our study landscape, all scenarios would result in similar outcomes for biodiversity since the habitat amount was similar. However, field studies in managed boreal forest landscapes have either not supported this hypothesis, or supported it at a much smaller spatial scale (Ranius et al. 2019). On the contrary, in a larger variety of habitats, tests have given some support for the hypothesis (Martin 2018; Watling et al. 2020). Thus, the habitat amount hypothesis is indeed relevant for this question, but more empirical studies are needed before it can be used as an argument for certain conservation strategies in managed boreal forests.

Similar to the biodiversity panel, there was no consensus among experts on recreation whether concentrated or dispersed allocation of unmanaged forests in the landscape is more beneficial. One argument for concentrating unmanaged areas was that such an approach may provide higher quality sites for visitors, who are seeking to experience more natural areas located closer to one another and willing to travel longer distances to reach the site. One potential disadvantage of such an approach could be that certain areas become over-crowded (Aasetre et al. 2016). However, such risk is lower in sparsely populated areas like the one in our study. Dispersed allocation might also be more beneficial for recreational activities that take place over larger areas, such as walking. Consequently, the fact that recreation includes many different activities conducted by people with various preferences means that advantages can be identified both for concentrated and dispersed allocations.

As the hydrological effect of forest harvesting is proportional to the harvested area, some experts argued for dispersed conservation measures as a practice to minimize the extent of contiguously disturbed areas. This is in line with empirical studies from boreal forests demonstrating that if small proportions ($< 10\%$) of a catchment area are clear-cut, water quality remains largely unaffected (Schelker et al. 2014). This speaks for careful landscape planning to avoid excessively large clear-cut areas within the same 10-year period (Öhman et al. 2009). However, water quality is also affected by the spatial allocation of forest harvesting within stands. For instance, forest harvesting should be avoided in riparian areas in direct proximity to streams and lakes (Kuglerová et al. 2014). Therefore, the location of different conservation measures in relation to watercourses is important, but our scenarios did not include such information. This probably explains why there was no clear preference for either concentrated or dispersed allocation from the water experts.

Conclusively, many experts regarded the spatial allocation as important, but there are several arguments supporting both strategies. This suggests it is desirable to spread the risk by doing both, to some extent within landscapes, but also by varying the measured between different landscapes.

4.2. Size of unmanaged areas and land sharing vs. land sparing

The estimated benefit for biodiversity differed dependent on the size of the unmanaged areas. Large unmanaged areas (nature reserves of about 100 ha each) were considered most beneficial by experts. The main argument why a few large unmanaged areas are better than many small for biodiversity was that long-term species persistence becomes higher with larger areas due to lower dispersal mortality, higher population densities, and a lower risk of suitable sites being unoccupied. There seems to be only limited support for these assumptions in boreal forests (but see Öckinger & Nilsson 2010). In addition, a few large areas may be better for some vertebrate species because the individuals have large area requirements (see Roberge et al. 2018) and also for species sensitive to edge effects, since for them the forest interior (which constitutes a larger proportion of the area of larger unmanaged area) is of higher quality (Ruete et al. 2016). On the contrary, many small unmanaged areas can be more favourable than a few large ones if forest of high conservation value mainly occurs in small patches. Reserve selection could then more specifically target these areas. There is some empirical support for this (Bouget & Parmain 2016), however, whether this is an important factor is landscape specific (Ranius & Kindvall 2006) and the spatial scale of the response differs among ecological species groups (Percel et al. 2019), which affects the optimal size of the unmanaged areas. Another advantage with many small unmanaged areas is the shorter inter-patch distance, which minimized dispersal limitations.

Conclusively, in landscapes dominated by production forests, such as in our study, experts regarded larger conservation areas as more valuable than a larger number of smaller ones. This may be seen as contradictory to recent studies suggesting that small, isolated patches are important and therefore more effort needs to be dedicated to connecting and restoring them (Wintle et al. 2019). However, that is not the case since the large conservation areas (reserves) in our scenarios are about 100 ha (which is realistic in this kind of landscape), while Wintle et al. (2019) defined a small patch as $< 1,000$ ha.

Land sharing approaches were less preferred than land sparing ones among biodiversity experts. Still, many studies show that tree retention (a land sharing approach) improves the conditions for local biodiversity (see Fedrowitz et al. 2014 for a review). On the other hand, based on metapopulation modelling, it has been questioned whether tree retention is an efficient way to promote landscape-level population persistence for wood-dependent species, even though many species may use the retained areas as habitat (Ranius & Roberge 2011). One reason for this is that for long-term persistence, threatened species often require a density of structures higher than obtained by retention (Penttilä et al. 2004). Moreover, retention trees are, for many taxa, a different habitat in comparison to forest interior trees (e.g. for deadwood-dependent beetles: Sverdrup-Thygeson & Ims 2002). This means that retention trees add new habitats in comparison with a landscape with no retention forestry, which are the good news, but it is a disadvantage that retention can only compensate to a limited extent for insufficient intact old forest. In contrast, prolonged rotation of managed stands creates a habitat which is more similar to unmanaged forest, but the lack of long-term continuity of various tree habitats may make it of lower value than permanent reserves (Ranius et al. 2016). This may explain why it was considered to have comparatively low value by the biodiversity experts, even though it has been shown to improve the conditions for biodiversity (Lassauce et al., 2012). To sum up, a combination of land sharing and land sparing approaches is favourable for biodiversity (Mönkkönen et al. 2014), but more focus on land sparing was preferred by the experts.

For recreation, land sharing approaches were both the most and least preferred (extended rotations and retention trees, respectively). Extended rotations generate forest characteristics with high recreational values, such as mature, thinned forests with not so much dead wood (Gundersen & Frivold 2008). With almost all forest units being under even-aged management however, one potential disadvantage could be the lack of visual diversity between them (Edwards et al. 2012). While retention trees are generally regarded positively (Gundersen & Frivold 2008), large unmanaged forests have been scored higher for recreation by experts, suggesting that they could cater better to the interests of those seeking to be in a natural environment.

For water quality, the scoring provided by experts was relatively similar for large and small unmanaged areas and extended rotations. One reason for lack of large differences pointed out by one expert was that for water quality the location of the unmanaged areas (for example, proximity to water bodies) is more important than whether it is dispersed across the entire landscape or concentrated in one area. Extended rotations imply that harmful harvesting operations take place less often (Roberge et al. 2016). Although this will probably have minimal local effect on water quality when harvesting is taking place (Schelker et al. 2012), it will have positive effects at the landscape scale as extended rotation periods result in fewer clear-cut areas (Futter et al. 2016). Even though experts pointed out the erosion-decreasing capacity of retention trees, this measure received the lowest ranking, with one of the experts stating that they have small significance for water quality.

4.3. Methodological considerations

The classical Delphi technique aims to achieve an expert consensus based on the assumption that experts are rational people who, after sharing and discussing arguments, eventually agree on the most probable and reasonably accurate estimate (Linstone & Turoff 2002). This is attained by removing the psychological bias of group behaviour by applying an anonymous process and sharing knowledge on the topic. However, this assumption has been criticized for being unrealistic or undesirable, as experts often disagree about the outcome of events and people usually do not change their mind as often as they should, giving too much weight to their own opinion and too little to the views of others (Bolger & Wright 2011). Another well-established Delphi approach, the policy Delphi, is based on the notion of dissensus, and aims to explore the variety of views of an issue (Linstone & Turoff 2002). In this study we combined the consensus and dissensus approaches (cf. Rikkonen et al. 2019), since we were interested in identifying the most preferred scenarios, and the arguments supporting both the common views and the relevant counter-arguments overshadowing them. Thus, we conducted statistical analysis to identify preferred scenarios, as well as reported the diversity of views in a qualitative manner.

Overall, we found the Delphi technique to have been useful in this study when identifying and synthesizing the range of different relevant considerations among experts, since it minimized the risk that important aspects are forgotten due to authors' bias. However, we have encountered several difficulties often reported by other studies employing Delphi technique, such as poor response and high drop-out rates (Mukherjee et al. 2018). Moreover, the experts did not give any comprehensive explanation for their estimates. Consequently, it is impossible to be certain whether every expert took the time to consider all important aspects in their responses. Hence, adding face-to-face or online deliberation session to the classic Delphi technique set-up (for example, as suggested in Hanea et al., 2018) may give rise to a more engaged and deep discussion, while also mitigating time constraints of experts.

5. Concluding remarks

The three aspects considered in this study – biodiversity, water quality, and recreation – are all favoured by a less intensive forestry. However, in terms of how and where to leave forests unmanaged, these aspects differed widely in how experts ranked various options. For biodiversity, a few large unmanaged areas received the highest scores and prolonged rotations the lowest, while for both recreation and water quality, prolonged rotations were given high scores. Thus, environmental concern should not only focus on one aspect, but if several aspects are important, they all have to be considered in policy-making and management.

Given the findings of this study, we suggest that in Sweden and other countries where most of the forest land is managed intensively for wood production, a strategy of mixed conservation measures should be applied also in the future, with a considerable part of the efforts being directed towards establishing and maintaining large unmanaged areas. Such a diversified conservation strategy is probably more cost efficient than focusing on a single measure (Mönkkönen et al. 2014) and beneficial when mitigating negative effects of climate change (Robillard et al., 2015).

We have studied a landscape where a great majority of the forest land is used for a forestry practice which is intensive, but that is still mostly utilizing native tree species and with some conservation concern taken into account in every production stand. Such areas are frequent in Sweden, Finland and other regions in Northern Europe and Northern America. In other parts of the world, a much larger proportion of the forests are still unmanaged. Where more forests have never been affected by intensive forestry, it may be more attractive to focus on protecting these forests, rather than on conservation measures in the production stands, especially if the production stands are dominated by plantations of exotic tree species (Ranius & Kindvall 2006). Another factor which may affect the choice of conservation strategy is the natural disturbance regimes, since inhabiting forest species are adapted to them. For instance, in temperate forests the spatial and temporal continuity of forest habitats may be more important for biodiversity than in boreal forest, since there the natural disturbances tend to be generally more small-scaled (Bengtsson et al. 2000). For recreation, the outcome of strategies is affected by the cultural context, since it includes many different activities with different demands, and the interests for performing different activities probably differ among countries.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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