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Systematic Review Protocol

Title
To what extent does surrounding landscape explain stand-level occurrence of conservation-relevant species in fragmented boreal and hemi-boreal forest?

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Keywords
Biodiversity; Fragmentation; Habitat loss; Boreal forest; Landscape configuration

Background
Logging of trees for forestry and other land-use change is a leading causes of habitat loss worldwide with dire consequences for forest associated species. In addition to habitat loss per se, logging tends to fragment the remaining forest into smaller, isolated units or stands; species' response to habitat loss can be amplified, reduced, or altered by fragmentation. The boreal forest has been intensively used for forestry, causing a high level of habitat loss and fragmentation. This fragmentation has resulted in that only about 11% of boreal forest can be classified as 'intact. In addition, a substantial proportion of the remaining forest has been affected by thinning and/or small-scale harvest The most studied explanation for lower diversity in fragmented habitats is poor recruitment and reduced (functional) connectivity caused by long distances between suitable habitat patches. Despite this, the effect of landscape-level variables on recruitment and connectivity and thus on stand-level diversity remains underappreciated. We deem that here is urgent need to change this to facilitate the development of sustainable ways to manage remaining natural forests and the species they harbour.

Theory of change or causal model
A common approach in studies of the effects of fragmentation is biogeography models that effectively treat fragments as islands. However, compared to actual islands, forest stands fall along a gradient from effectively continuous populations, to functioning meta-populations with a balance of extinctions and (re)colorizations, to non-viable meta-populations where sub-populations lose connectivity and slowly disappear. The configuration, composition, and history of the surrounding landscape (or matrix) will directly affect where along this gradient a stand sits by altering the relative resistance to dispersal, and the carrying capacity for the species on landscape-level. See figure 1.

Stakeholder engagement
During the development of this protocol, a consultation meeting was held between the review authors and an advisory group consisting of representatives from several Swedish agencies. The main objectives of this meeting were to discuss the importance of considering the surrounding landscape in conservation planning and identify knowledge gaps, as well as landscape parameters

and other effect modifiers of interest for the stakeholders. This discussion included, among other things, landscape factors of interest, relevant landscape sizes to consider, species groups and forest types of particular interest. The result of this meeting directly affected how we defined our primary and secondary questions, PECO, search terms, inclusion/exclusion criteria, effect modifiers of interest, and data parameters to extract. This advisory group will be invited again to provide oral or written feedback on the content, readability, and clarity of the forthcoming review before submission.

Objectives and review question

The main objective will be answering the primary question: 'To what extent does surrounding landscape explain stand-level occurrence of conservation-relevant species in fragmented boreal and hemi-boreal forest?'. Additionally, we address the following secondary questions: What type of landscape factors have the strongest effect on stand-level diversity? Which landscape size has the strongest explanatory power? Do the surrounding landscape affect organism groups or species differently? For which organism groups do the largest knowledge gaps remain? What is the relative contribution of stand and landscape factors for stand-level diversity? Does forest type affect the answer to any of the preceding questions?

Definitions of the question components

Population: Forest within the boreal zone and the hemi-boreal transition zone in the following countries: Canada, Scotland, Iceland, Norway, Sweden, Finland, Estonia, Latvia, Lithuania, Belarus, Russia, Mongolia, Japan, and the American states Alaska, Maine, and Minnesota. Exposure: Fragmentation and habitat loss, defined as the breaking apart of larger forest tracts into smaller forest stands surrounded by a matrix directly affected by forest harvesting and/or other land-use change. Comparator: The following type of comparisons between landscapes/stands are of interest: Human vs Natural fragmentation; Amount of (old) forest in the matrix; Other matrix composition differences; Distance to/distribution of forest in the matrix; Time since fragmentation; Intensity/Extent of land use change in the matrix. Outcomes: Occurrence, defined as incidence, abundance, or composition of conservation-relevant species. Conservation-relevant is defined as rare, threatened, red-listed, indicator, keystone, flagship, or umbrella species. In addition, any deadwood-dependent species or species group will be considered conservation-relevant.

Search strategy

For the proposed review, we will search for peer-reviewed articles in four bibliographic databases and two search engines. Due to limitations within the review group, searches will be restricted to publications with title and abstract written in English, Swedish or Norwegian. If publications of interest written in a different language are identified based on English title and abstract, assistance with translation will be considered on a case by case basis. Supplementary searches will be done through the reference lists of related reviews. The reference processor Mendeley (Mendeley Ltd.) will be used to import, collate, and convert references to allow importation to the online evidence synthesis tool Cadima (version 2.2.3). No restrictions regarding time of publication will be used. For the bibliographic data bases Web of Science, PubMed, SCOPUS and CAB abstracts (all accessed via subscriptions to the Mid Sweden University Library) we will use the search string specified below adapted to each individual search engine syntax. All search term blocks (see 8.1) will be combined using the Boolean operator AND. Terms within each block will be combined using the Boolean operator OR unless otherwise specified. The first block defines the relevant population. To ensure the comprehensiveness of the search, the terms in this block will be searched for in all fields ('ALL=' in WoS). Block two serves to identify with a landscape component. Block three to identify studies of forest fragmentation. The fourth block defines the relevant outcomes. Block two, three, and four all target the 'topics' of the publications ('TS=' in WoS), this means that the terms are searched for in the title, the abstract, and the keywords identified by the study authors as well as by WoS.

Bibliographic databases

The following search string will be used for Bibliographic data bases (here formatted for Web of Science (WoS)). The truncation symbol * is used as a wildcard character, and denotes any number of and combination of characters. No stopping criteria will be used; all identified publications will be screened. "ALL = ((forest* OR wood* OR deadwood* OR dead-wood*) AND (boreal* OR boreonemoral OR hemiboreal OR hemi-boreal OR taiga OR Sweden OR Finland OR Fennoscandia OR Norway OR Canada OR Alaska OR Estonia OR Russia OR Scotland OR Iceland OR Mongolia OR Japan OR Siberia OR Latvia OR Lithuania OR Maine OR Minnesota OR Belarus))" AND “TS = (landscape* OR region* OR spatial OR provinc* OR "large-scale" OR surrounding OR fragment* OR matrix)” AND “TS = (fragment* OR continu* OR connectivity OR isolate* OR "habitat loss" OR woodlot* OR "forest stand*" OR metapopulation OR "habitat patch*" OR configuration OR "old-growth forest*" OR "woodland key habitat*" OR "management histor*" OR "land-use histor*" OR "land use histor*" OR "historic* land use")” AND “TS = (biodiversity OR "species richness" OR distribution OR abundan* OR occurrence OR composition OR extinction* OR diversity OR densit* OR cover OR coloni*ation* OR occupancy OR dispersal OR community OR viab* OR "population trend*" OR activity OR "species turnover" OR nesting OR incidence OR "genetic diversity" OR "genetic structur*" OR "isolation by distance" OR "isolation-by-distance")”

Web-based search engines

For google, and google scholar, two sets of simplified versions of the search string will be used and the first 200 hits from each of these four searches will be exported using the online tool Publish or Perish and further screened. The search strings used will be (1)"Boreal forest fragmentation surrounding landscape" and (2) "Boreal forest fragmentation matrix conservation"

Organisational websites

36 specialist websites will be screened for additional peer-reviewed articles and grey literature, mainly Master’s theses, PhD theses, and reports. Searches will be done using the key words "forest" AND "fragmentation" (and the Swedish and Norwegian equivalents). (Name of site with country in brackets if needed): Environment Canada (Canada; Natural Resources Canada; Parks Canada; Luke - the Natural Resources Institute of Finland; Metsohallitus - the Finnish Forest Administration; Ministry of Agriculture and Forestry in Finland; SYKE - the Finnish Environment Institute; Valto - the Finnish Ministries' publications archive; NORA - the Natural Environment Research Counsil Open Research Archive (Great Brittan); UK Environment Agency; bioRxiv - online archive for unpublished preprints in biology (International); Conservation Evidence (International); EU publications (International); European chapter of the Society for Ecological Restoration (International); European Commission Joint Research Centre (International); European Environment Agency (International); International Union for Conservation of Nature; Nordic Council of Ministers (International); Society for Ecological Restoration (International); The International Boreal Forest Research Association - IBFRA (International); United Nations Environment Programme; BioFokus (Norway); Landbruksdirektoratet - Norwegian Agricultural Agency; Miljodirektoratet - Norwegian Environment Agency; NIBIO - Norwegian Institute of Bioeconomy Research; NINA - Norwegian Institute for Nature Research; Norwegian Forest and Landscape Institute; NatureScot - Scotland's Nature Agency; DiVA Thesis database (Sweden); Jordbruksverket - Swedish Ministry of Agriculture; Lansstyrelser i Sverige - County Administrative Boards in Sweden; Naturvardsverket - Swedish Environmental Protection Agency; Skogsstyrelsen - Swedish Forest Agency; Svensk fageltaxering (Sweden); Uppsok Thesis database (Sweden) United States Environmental Protection Agency; United States Forest Service.

Comprehensiveness of the search

The search terms for the proposed review were identified through a combination of reviewing relevant publications, brainstorming within the team, discussion during the stakeholder meeting,

and searches in synonym databases. We initially identified 26 benchmark publications which were used to refine and test the comprehensiveness of the search string. As long as not all benchmark publications were found, the search terms were adapted accordingly. Web of Science (WoS) was used during this process. When a search string that detected all 26 publications had been identified, 17 additional (total 43) publications were added to the benchmark list to confirm the comprehensiveness of the search string and reduce risk of bias. The benchmark publications were identified through a combination of being already known to the research group, searches through reference lists of known publications, and independent searches through Google Scholar. The latter served to ensure that the benchmark publications had a widespread both geographically and in terms of focal species. Only publications indexed in WoS were included on the list. After the extension of the list of benchmark publications, only minor changes were done before the final search string was identified. The final search string found all 43 benchmark publications.

Search update

An annual search update will be performed until the review is published.

Screening strategy

The online tool Cadima will be used for screening identified articles for relevance. This screening will be conducted as a two-step process; for step one, screening will be based on title and abstract, for step two, screening will be based on the full text. In both steps, the reviewer will evaluate each publication by answering yes/no/unsure to whether the study/studies 1) took place in boreal or hemi-boreal forest, 2) quantified diversity, 3) examined diversity on stand-level, 4) related diversity to the surrounding landscape, 5) looked at conservation-relevant species, 6) included primary data, 7) related to human caused forest fragmentation (see details on inclusion criteria below). Based on the answers, each publication will be labelled as ‘include’, ‘exclude’, or ‘unsure’. During the screening of title and abstract, all publications labelled include or unsure will make it to full text screening and reviewers will tend towards inclusion. All publications labelled unsure after full text screening will be checked by two other reviewers, and if uncertainty remains, the publications will be discussed by the full review team. Reviewers will not evaluate publications on which they are listed as co-authors.

Eligibility criteria

Relevant population is forest in boreal zone or the hemi-boreal transition zone in: Canada, Scotland, Iceland, Norway, Sweden, Finland, Estonia, Latvia, Lithuania, Belarus, Russia, Mongolia, Japan, and the American states Alaska, Maine, and Minnesota. We use FAO’s definition of forest. The studied forest stands can be managed or unmanaged forest of any age (including clear-cuts). Relevant exposure is fragmentation through direct human impact (logging for forestry or land use change). The measurement of fragmentation-level can be qualitative (such as ‘more’ or ‘less’) or quantitative. Relevant comparators are stands in landscapes that differ in terms of landscape context, composition, configuration, and/or historic change; any factor describing the matrix surrounding the stand is considered a landscape factor. We will not define any maximum or minimum size of the stand, matrix, or landscape. We will include studies of landscapes before and after exposure (BA studies), an exposed landscape to a control (CE studies), landscapes along a gradient (G studies) or multiple levels of fragmentation (M studies). Studies must have examined effects of fragmentation at landscape scale on the occurrence of conservation-relevant species on stand level. Only primary studies will be included. Relevant outcomes are incidence, cover, abundance, density, richness, and composition of conservation-relevant species of all organism groups. Conservation-relevance includes, threatened, declining, red-listed, rare, indicator, flagship, umbrella, and key-stone species as described by the study authors, as well as all deadwood-dependent species. Invasive or pest species will not be considered conservation-relevant. Studies of any life stage of the species will be included.

Consistency checking
Before the start of each screening step, the built-in consistency check tool in Cadima will be used. Before step one, consistency check will include 100 titles and abstracts which will be screened by four members of the review team. Cadima then automatically provides a kappa value. Any kappa vlaue below 0.6 will result in discussion in the entire group around the inconsistecies to streamline the interpretation of the criteria as well as the abstracts. The consitecy check will then be reitterated until a kappa value above 0.6 is reached. Once this is reached, Cadima will be set to 5% overlap, meaning that the first 5% of titles and abstracts are screened by two authors. Any inconsistencies during this screening will be discussed in the entire group to futher refine interpretation of critera. If agreement can not be reached, authors will err on the side of caution and include such publications to the full-text step. Once all titles and abstracts are screened, the same consistecy procedure till be used for full text, but 10% of the publications will be used.

Reporting screening outcomes
A record stating the reason for exclusion will be kept for articles excluded during the full text screening and this record will be provided as an additional file to the review. In addition, the standardised flowchart template from ROSES will be used to record the number of publications/studies that pass each step as a record of the sensitivity and specificity of the search and screening. This flowchart will also be provided in the published review.

Study validity assessment
All articles remaining after full text screening will be subject to study validity assessment. This assessment will categorise the studies as being of low, medium, or high risk of bias based on ten questions which have been chosen based on previous review protocols, on the CEE Critical Appraisal Tool, and a pilot assessment utilising seven of the benchmark publications. These questions relate to the matching of compared stand and landscapes; the accounting for effect modifiers; the method of site selection; the quantification and reporting of variables, the number of replicates in relation to the variance; the accounting for pseudo replication; suitability of outcome parameter, sampling method, and analyses; and lastly the reporting of the outcome. Additional criteria and further specification may be developed in an iterative way as the reviewing process precedes. The overall outcome of the assessment of a study will equal its highest scores for any individual question, regardless of the remaining question. If sufficient information is not provided to evaluate a question, this automatically qualifies as high risk of bias. The outcomes of the study validity assessment will be provided as an additional file to the review. This file will include the categorization for each study as well as the reason for all studies deemed as being of high or medium risk of bias. A high risk of bias will not lead to exclusion of a study from the narrative review or meta-analyses but will lead to a more cautious discussion of the results.

Consistency checking
To ensure consistency, each study will be evaluated by two reviewers, neither of which will be a co-author of the study. When the categorization differs between the two reviewers, these studies will be discussed by the full review team, and if agreement still cannot be reached, the most cautious (highest risk) evaluation will stand.

Data extraction strategy
All studies passing full text screening and going through the validity assessment will go through data extraction. Data and meta-data will be extracted in two steps, based on predefined questions. In step one, all publications will be subject to meta-data extraction for narrative review. During this step, studies from which sufficient data can be extracted, will be labelled as suitable for meta-analyses. If enough studies are found suitable for meta-analyses and comparable to each other to make a biologically meaningful analysis, these will proceed to step two in which effect size and variance will

be extracted. In some instances, when relevant data is missing, study authors will be contacted to request raw data on species level. Information may be extracted from the text, figure, tables, and supplementary material. The image analysing online tool WebPlotDigitizer (version 4.5) will be used when needed to extract numerical values from figures and graphs. When only raw data is provided, the review team will calculate summary statistics. If accurate numbers cannot be extracted from text, figures, or tables, the corresponding study author will be contacted to request original data. When only averages and no quantification of variance is provided (STD, SEM, confidence intervals, etc.), studies will be excluded from the meta-analyses unless raw data can be acquired. Where data are presented from multiple years, these will be combined into a single effect size unless the study authors have stated a clear reason for not doing so.

Meta-data extraction and coding strategy

The parameters for data extraction originate from the stakeholder meeting, the primary and secondary questions to address, as well as the effect modifiers identified, and were refined using a pilot extraction from seven benchmark publications. A list of all data parameters will be attached to the protocol but include: publication details (title, authors, year, university); location and other effect modifiers (country, location, altitude etc); study design details such as study type (BA, CE, M, G), comparator type (more forest, closer to forest, spatial distribution of forest, reduction in forest over time, or time since fragmentation), and comparator details (the span of the gradient, time span of historical data etc); and landscape details (time of fragmentation, amount and type of forest etc). The composition of the landscape will be broken down into stands and matrix; for both details on size, forest age, forest composition, vegetation type, productivity, history, naturalness, and configuration will be extracted. In terms of location, the review authors will extract the coordinates and simultaneously ensure that the study has been conducted within the boreal or hemi-boreal zone. Information will also be extracted on the study subjects (species name, species group, species mobility, and species substrate) and their conservation-relevance (red listed, threatened, indicator species, etc.), and the outcome such as type (occurrence, abundance), the effect size, variance, and direction of the outcome, as well as how this compares to effects of stand-level factors, and the statistical method used. Data will be extracted into and stored in a relational database.

Consistency checking

Due to resource limitations, data extraction will mainly by one of the review authors, but this will be preceded by a consistency check where 10% of publications and studies are extracted by more than one author. In addition, the data extraction sheet will be designed and approved by all review authors.

Potential effect modifiers/reasons for heterogeneity

A major potential effect modifier is that the distribution of old and relatively untouched boreal forest is not random. In Sweden and Finland, for instance, there is a clear East-West gradient that also coincide with altitude as well as a coast-to-inland gradients. Additional potential effect modifiers we deem needs to be considered are listed below. This list is based on previous reviews and expert knowledge. However, additional effect modifiers may be identified during the screening and data extraction processes, a final list of modifiers will be provided in an additional file to the review. List of effect modifiers: Ecological processes: Within and between seasonal variation, i.e., year and timing of study. Landscape factors and Matrix type: Forest cover, age and density; Historic land use; Landscape difference(s) studied; Landscape country/location and altitude; Landscape size; Extent, intensity, and timing of land-use change and forestry. Stand characteristics: Distance to nearest other stand; Stand forest density; Forest type; Productivity; Stand size; Stand age. Methodology/Study design: Extent of difference among compared landscapes; Indirect effects of fragmentation such as edge effects; Organism group/species studied; Reason for conservation relevance; Outcome type evaluated; Plot size surveyed within stand; Survey method.

Type of synthesis
The type of synthesis planned is narrative and quantitative, with the caveat that quantitative will only be performed if enough studies with comparable outcomes are identified.

Narrative synthesis methods
All publications going through data and meta-data extraction will be part of a narrative review. The aim of the narrative review will be to describe the findings and the quality of the studies, including a summary of the critical appraisal. A narrative synthesis table will be provided in the review and/or as an additional file. So-called vote counting, where the actual number of studies with a certain effect direction is given higher emphasis in the interpretation of the results, will be avoided when summarizing outcomes. During the extraction for the narrative review, individual studies will be deemed as suitable or not for meta-analyses. If extraction of effect size and variance is possible from studies for which outcomes can be combined in a biologically meaningful way, all efforts will be made to complement the narrative review with quantitative meta-analyses. The feasibility of this will be evaluated after narrative data extraction and be based on how many studies have explored comparable effect modifiers, organism groups, and outcomes, as well as on the variance found in the studies, and any interactions between, for instance, organism group and landscape size studied.

Quantitative synthesis methods
Based on benchmark publications and the pilot extraction, differences in landscape variable studied, outcome types reported, and description of the stands and matrix will be the greatest obstacles for successful and meaningful meta-analysis. However, if meta-analysis is possible, effect sizes will be standardised and weighted appropriately. Standardised mean difference and random effect models will be used when possible. Based on pilot extraction, many relevant studies will also have investigated landscapes along one or several gradients rather than being of a CE, or BA study design. If these gradients can be standardised, and heterogeneity accounted for, they will be combined using meta-regression. If possible, overall analyses will be complemented with separate analyses of individual organism groups, different sizes of landscapes, different forest types, and different outcome types. Species level data will be analysed separately from index data. The results of the critical appraisal and the plot size surveyed will be used as factors in all analyses. Forest plots will then be produced to visualise the effect size and confidence interval for each included study. The strength of evidence for the answers to the primary and secondary questions will be discussed in the light of the number of studies identified, their study validity assessments, and the consistency in direction and size of observed outcomes. Analyses will be conducted in R with the help of the metaphor package, but details around the quantitative analyses will only be known once publications have been screened and data from all studies extracted.

Qualitative synthesis methods
N/A

Other synthesis methods
N/A

Assessment of risk of publication bias
Risk of publication bias will be assessed visually using funnel plots and with an associated Eggers regression. Based on the critical appraisal, the risk of bias will be evaluated through a sensitivity analysis.

Knowledge gap identification strategy
An important aim of the review will be to identify knowledge gaps or underrepresented areas, both in terms of landscape factors, organism groups, and landscape size. A number of heat maps cross-

tabulating, for instance, landscape size and study species group will be used to identify such gaps.

Demonstrating procedural independence
Two of the review authors (MU and AA) are new to the group and have no previous publications together with the remaining ca-authors. This makes it easy to conduct screening, study validity assessment, and data-extraction with appropriate consistency checking even of papers co-authored by one or more review author.

Competing interests
The review authors have no competing interests to declare.

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Author's contributions
All authors contributed to the idea and conceptualisation of this review protocol. MU wrote the first draft, and lead the revision. All authors contributed substantially to the revision of this draft. All authors approved the submitted version.

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