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Selecting surrogate species for connectivity conservation

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ABSTRACT

Habitat loss and fragmentation impede the movement of animals across landscapes causing biodiversity change. One strategy to counter these effects is to protect and restore habitat quality and connectivity for a diversity of species. How should surrogate species be selected to represent a diversity of needs from a larger species pool?

Using a recent method to prioritize multispecies habitat networks, we tested how the selection of surrogate species affects prioritization outcomes. We ran prioritization schemes using subsets of N (N = 0, 1, 3, 5, 7, 9) species selected from a 14-species reference set. Selection was based on different concepts of surrogate species: *umbrella*, *taxonomy*, *habitat diversity*, *movement diversity*, *movement and habitat diversity*. Prioritization outputs were compared to the 14-species set for their effectiveness and comprehensiveness at retaining habitat quality and connectivity criteria, and for their spatial congruence.

We show that species-based surrogates perform better than habitat-based surrogates and that a moderate number of species (5–7) might be sufficient to capture the needs of a broader species pool for one habitat type (forest). However, how species are selected matters as much as how many. The best performing approach is to select species representing a diversity of habitat and/or movement needs. Umbrella or taxonomy-based selections were less effective and comprehensive.

Our results can guide the selection of surrogate species when designing a prioritization plan for regional connectivity conservation. We recommend favoring systematic trait-based species selection over single-species, umbrella or taxonomy-based selections. When a proper species-based surrogate approach cannot be done, a habitat-based surrogate approach might still be a useful alternative.

1. Introduction

Integrating connectivity conservation and restoration with land planning is a widespread strategy for achieving biodiversity conservation targets given land-use and climate change (Heller and Zavaleta, 2009). Because the species of a given region differ widely in their resource needs, habitat requirements and movement abilities, connectivity – the degree to which a landscape allows species movement - is inherently species-specific and highly scale-dependent (Taylor et al., 1993). The challenge of connectivity conservation thus lies in simultaneously satisfying this diversity of needs (Vos et al., 2001). New methods now make it possible to design multi-species and multi-scale habitat networks, for instance by combining spatial prioritization tools and connectivity analyses (Magris et al., 2015; Albert et al., 2017). However, there remains the necessity to reduce the many dimensions of multiple species requirements to a manageable set of criteria (Wiens et al., 2008). Surrogate approaches are used in conservation planning when the number of species of concern is too high, and to compensate for incomplete knowledge of a regional pool of species and their requirements for persistence (Wiens et al., 2008). Two types of surrogates are used to define conservation objectives: the species-based (or fine-filter) approach uses one or a limited number of species as a surrogate for a larger suite of species (Caro and O'Doherty, 1999), while the indirect (or environmental, coarse-filter, 'stage') approach uses more general proxies based on land-cover types, habitat types, naturalness, or environmental conditions to serve as surrogates for the species that use or inhabit them (Anderson and Ferree, 2010). Merits of the first approach are often limits of the second and vice versa. The indirect approach is less analytically intensive and typically yields a single connectivity network and a single set of habitats with high conservation

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priority. There is no need to deal with the uncertainty arising from multiple species-specific networks (Lindenmayer et al., 2002). The species-based approach leads to networks that may be easier to interpret, to validate with field data, and more effective for engaging discussion with local stakeholders because they are targeted towards species-specific needs (Wiens et al., 2008). However, a major criticism of the species-based approach is that it seems unrealistic that the needs of a handful of species can effectively represent the needs of a broad range of species (Lindenmayer et al., 2002). This concern is particularly vivid when selecting 'umbrella' surrogate species, i.e. species with broad home ranges – such as large carnivores - whose requirements are believed to encapsulate the needs of many others (Breckheimer et al., 2014).

Recent years have seen an evolution of concepts and methods to select sets of surrogate species, each designed to address concerns about the approach (Wiens et al., 2008). For instance, 'focal species' are a suite of species selected systematically to reflect vulnerability to a diversity of threats (Lambeck, 1997). To better tailor the selection of multiple surrogate species to the conservation objectives at hand, more quantitative approaches have also been tested by grouping species from the regional pool based on shared threats and similar characteristics (e.g. trait-based multivariate dimension-reduction techniques) (Wiens et al., 2008). For instance, 'Dispersal guilds' may be built by grouping species by similar fine-scale movement behavior (inter-patch and gap-crossing distances, minimum patch area, Lechner et al., 2016). Ecological profiles (or 'ecoprofiles') were also introduced to deal with connectivity conservation and spatial planning; they classify species according to their potential vulnerability to habitat fragmentation, i.e. based on their habitat preferences, area requirements, and dispersal abilities (Vos et al., 2001; Opdam et al., 2008).

Until now, the numerous attempts to assess the performance of surrogate species have revealed some general lessons (Roberge and Angelstam, 2004). First, multiple surrogate species are better than any single surrogate species, because management actions that target a single species do not necessarily benefit the conservation of all co-occurring species, especially those limited by different ecological factors (Carroll et al., 2001, Roberge and Angelstam, 2004, but see Olds et al., 2014 for an effective single-species design). Second, surrogate species from a given taxon may not necessarily confer protection to assemblages composed of other taxa (Breckheimer et al., 2014; Di Minin and Moilanen, 2014). Third, a systematic selection of a diverse set of species has proven to reflect well the needs of other species (Roberge and Angelstam, 2004; Cushman and Landguth, 2012). Watson et al. (2001) found that a landscape designed to meet the habitat requirements of a set of carefully selected bird species encompassed the requirements of all other bird species experiencing similar threats. Fourth, recent studies have also found that spatial conservation priorities for connectivity may strongly differ according to the choice of surrogates (Krosby et al., 2015; Théau et al., 2015). In practice, it remains difficult to know how to best select surrogates to accommodate the habitat and movement needs of all the species in a region.

We asked three main questions:

1) Can an indirect approach using habitat characteristics alone replace a carefully-conducted species-based approach?
2) When using a species-based approach, how many surrogate species should be selected to represent the needs of a diverse fauna?
3) When using a species-based approach, how should species be selected? Can a good selection procedure help reduce the number of required species?

To address these questions, we build on the methods and data from Albert et al. (2017). They developed a method combining graph-based connectivity analyses with a spatial prioritization tool. They used this method to identify a forest habitat network based on the habitat quality and connectivity requirements of a range of vertebrate species in southern Quebec (Canada). This dataset offers a good opportunity to test different methods for selecting surrogate species because: i) refined habitat and graph models are already available for fourteen species, and ii) species have been selected carefully to reflect the diversity of habitat requirements and movement abilities of the local forest fauna.

To test how the selection of surrogate species affects prioritization outcomes, we ran new prioritization schemes for the same case study using either an indirect approach (based on unspecified forest habitat) or a species-based approach with fewer species ($N = 1$, 3, 5, 7, or 9). Species were selected from the reference set using six different common methods: (i) each species alternately, (ii) based on their taxonomy (supposedly different traits and life-history), (iii) based on their potential as an umbrella species (large spatial requirements), or (iv) based on their diversity of habitat needs, (v) movement abilities, or (vi) both combined. These species subsets were created 'from scratch', i.e. as would be done in a new connectivity conservation project when only a list of species and some basic information about their taxonomy, body mass (proxy for area requirement), habitat requirements and movement abilities are available. The new conservation networks were compared to the 14-species network for their spatial congruence, but also to assess how well and how evenly they conserve the needs of all fourteen species (Grantham et al., 2010). We predicted that a selection of few species based on their diversity of needs should perform as well as the 14-species reference set and better than the indirect approach. We also ran an extensive sensitivity analysis to make sure our results on surrogate species selection are robust to prioritization parameterization.

2. Material and methods

2.1. Study area

The study area is the St Lawrence Lowlands around Greater Montreal, in Southern Quebec, Canada (~27,500 km^2). About half of the area is covered by agricultural land, mainly annual crops. With 10% of the area urban, the region is also the most populated in Quebec (ca. 4 million inhabitants). Remnant forests cover about a fourth of the area and are threatened by the rapid sprawl of low density urban areas. Only 1.2% of the land area is currently protected (Fig. B1), but there is strong political will and commitment from diverse stakeholders to conserve the quality and connectivity of forest habitat within and across the region (Mitchell et al., 2015).

2.2. Identification of spatial conservation priorities

Conservation priorities for habitat quality and connectivity in the study area were identified using the material produced by Albert et al. (2017) (Sections 2.2.1 & 2.2.2) and following their general method of spatial prioritization (Section 2.2.3).

2.2.1. Selection of a reference species set

A set of fourteen vertebrate surrogate species was selected in a previous study (Albert et al., 2017) to represent the regional forest (and treed-wetland) biodiversity and the vertebrate fauna's needs in terms of habitat and connectivity (Fig. 1, Fig. B2). The selection was made among the 48 mammals, 216 birds, and 32 amphibians and reptiles occurring in the region using a multivariate analysis based on traits that are known to characterize how vulnerable species are to habitat fragmentation: habitat requirements, population dynamics and movement abilities (Henle et al., 2004). Species characteristics were gathered from wildlife guidebooks.

2.2.2. Habitat quality and connectivity metrics

Maps of habitat quality were developed for each selected species, based on a literature review and using raw data from multiple sources (e.g. Quebec ministries of energy and natural resources, and forests, wildlife and parks). Baseline habitat-quality maps were obtained from a