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Discussion

Quantifying the need and potential of assisted migration

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ABSTRACT

Assisted migration is recognized as a possible method for species conservation under climate change. Predicted decrease in range size and emergence of new suitable areas due to climate change are the main reasons for considering assisted migration. The magnitude of such changes can be used to guide decisions on the applicability of this conservation method. However, it has not been formalized how predictions acquired, e.g., with the help of species distribution models or expert assessments, should translate into recommendations or decisions. Climate change threat indices concentrating on predicted loss of habitat are not directly applicable in this context as they do not define whether a species has the potential to expand its range compared to the area that remains suitable. Here we present a conceptual framework for identifying and quantifying situations in which predictions indicate that a species could benefit from assisted migration. We translate predicted changes in suitable area into separate metrics for migration need and migration potential on the basis of the amount of lost, remnant, and new area. These metrics can be used as part of decision-making frameworks in determining the most suitable conservation method for a specific species. They also hold potential for coarser screening of multiple species to estimate the proportion of species that could benefit from assisted migration within a given time frame and climate change scenario. Furthermore, the approach can be used to highlight time frames during which assisted migration or, alternatively, other conservation actions are the most beneficial for a certain species.

1. Introduction

Observed and potential effects of climate change on biodiversity are becoming evident (Dawson et al., 2011; Brommer et al., 2012; Urban, 2015). A concern that traditional conservation methods may not be enough to safeguard species from decline has led to proposals of new proactive methods, such as actively moving species to new areas in pace with the changing climate (Peters and Darling, 1985; Hunter, 2007; Schwartz et al., 2012). Although rarely implemented to date, this approach has been extensively discussed. It has variously been called assisted migration, assisted colonization, and managed relocation, among others, and also defined in different ways (Hällfors et al., 2014). In the strict sense, however, it is a type of conservation translocation (sensu IUCN, 2012) in which species are moved from their indigenous range to areas where they would be predicted to move as climate changes, were it not for anthropogenic dispersal barriers or lack of time (see Hällfors et al., 2014 for a thorough discussion); here we refer to the method in this sense and call it assisted migration (AM). We use 'conservation' in the broad sense, i.e., include in it all actions aimed at safeguarding biodiversity, both preserving approaches and conservation management.

To begin with, it should be noted that wide consensus on the acceptability of AM has not been reached (Hewitt et al., 2011; Maier and Simberloff, 2016; Siipi and Ahteensuu, 2016). Nevertheless, AM has already been conducted for the conifer *Torreya taxifolia* in the USA (Barlow and Martin, 2004; Marris, 2008) and for two butterfly species in the UK (Willis et al., 2009), and is being considered, e.g., for the butterfly *Euphydryas editha quino* (Marris, 2008). Hence, it is important to develop best-practice guidelines for the possible future implementation of the method even if their application, in the end, may not turn into mainstream conservation practice. Indeed, several frameworks have been presented for guiding decisions on whether and when a species needs AM, for risk evaluation, and for planning the process if deemed feasible (Hoegh-Guldberg et al., 2008; Richardson et al., 2009; McDonald-Madden et al., 2011; Pérez et al., 2012; Schwartz & Martin, 2013).

Predictions of future changes in suitable areas have repeatedly been suggested as aids in evaluating the need of AM (Chauvenet et al., 2012; Schwartz, 2012; Guisan et al., 2013; Gallagher et al., 2014). Such predictions can be derived at least through expert evaluation, mechanistic niche models, or species distribution models (SDMs). All these approaches contain uncertainties and caveats, such as biases in expert judgement, and assumptions on ecological equilibrium and local adaptation in niche models. These have been extensively discussed in the literature (Heikkinen et al., 2009; Araújo and Peterson, 2012; Martin et al.,

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2012). However, the prediction methodology is continuously developing (Morin and Thuiller, 2009; Martin et al., 2012; Braunisch et al., 2013) and holds clear potential in this context as long as predictions are interpreted in the light of the limitations of the applied methodology. Nevertheless, it has not been established how the information obtained from predictions should be translated into decisions on whether or not to apply AM.

The absence of a recognized method for utilizing the information on range change predictions means that managers wishing to evaluate the appropriateness of AM are left with a recommendation on what tool to use but with no instructions on how to use it. This lack of guidance may result in subjective decisions and thereby inconsistent policy, or even in a status quo where no decisions are made, leading to a high risk of losing biodiversity in a rapidly changing world. A formal and rigorous way of utilizing range change predictions for the specific purpose of AM evaluations and decisions is therefore needed.

In evaluating species' vulnerability to and threat from climate change, formalizations of the use of modelling outputs have been put forward (e.g., Thomas et al., 2011; Maggini et al., 2014). Although the proposed frameworks may be suitable for evaluating general threat from climate change, being vulnerable to climate change because of anticipated loss of distribution area does not necessarily mean that AM would be a suitable conservation method for the species. Instead, a combination of expected loss and gain of area is required for AM to be an appropriate response. A species that is not losing suitable habitat does not need to migrate and a species that will not have new climatically suitable area outside its current distribution area will not benefit from migration (with migration we mean the processes of dispersal, colonization, and establishment, which in the case of AM are aided by humans; Fig. 1). Hence, vulnerability assessments concentrating on species' sensitivity to climate change (see, e.g., Pacifici et al., 2015 for a review) are not sufficient to inform decisions regarding AM. Instead, both estimates on climate change exposure and on availability of new suitable area for translocations are necessary when deciding on and planning AM.

On the basis of our conceptualization of when a species would benefit from AM (Fig. 1), we present a straightforward method for converting predictions of changes in suitable area into metrics describing AM benefit. These metrics can be utilized in decision-making frameworks to answer those questions that concern range change. The predictions themselves can be constructed through a variety of methods, including not only correlative SDMs but also mechanistic models and expert evaluations, and be based on various data sources. Likely data include known species occurrences, climate variables, dispersal abilities, habitat requirements, habitat availability, and biotic interactions among species. The data needed for calculating the metrics we propose are readily obtainable from the range change predictions, provided these are quantifiable into spatial units, such as grid cells. The reliability of the results of predictions would largely depend on the degree of expert knowledge, the quality of the data, and other assumptions made in the process of obtaining the predictions. However, in this paper we do not attempt to test the usability of different prediction methods for range changes nor how different input data or modelling assumptions affect the predictions. Instead, the aim is to describe a process that can be used for supporting decisions in conservation once sufficiently reliable predictions on changes in suitable area are available (see Hällfors et al., 2016 for a real-life application of the method described here).

2. Methods

2.1. Derivation of the AM metrics

Assisted migration, i.e., human-mediated dispersal to and establishment in new areas, may be applicable as a conservation method for species that meet the following criteria:

1. Migration need: Climate change, e.g., changes in temperature and precipitation regimes, is predicted to render (part of) the species' current distribution area unsuitable.
2. Migration potential: Climate change is predicted to bring about new suitable area for the species.
3. Migration inability: The species either has poor intrinsic dispersal ability or faces anthropogenic dispersal barriers.

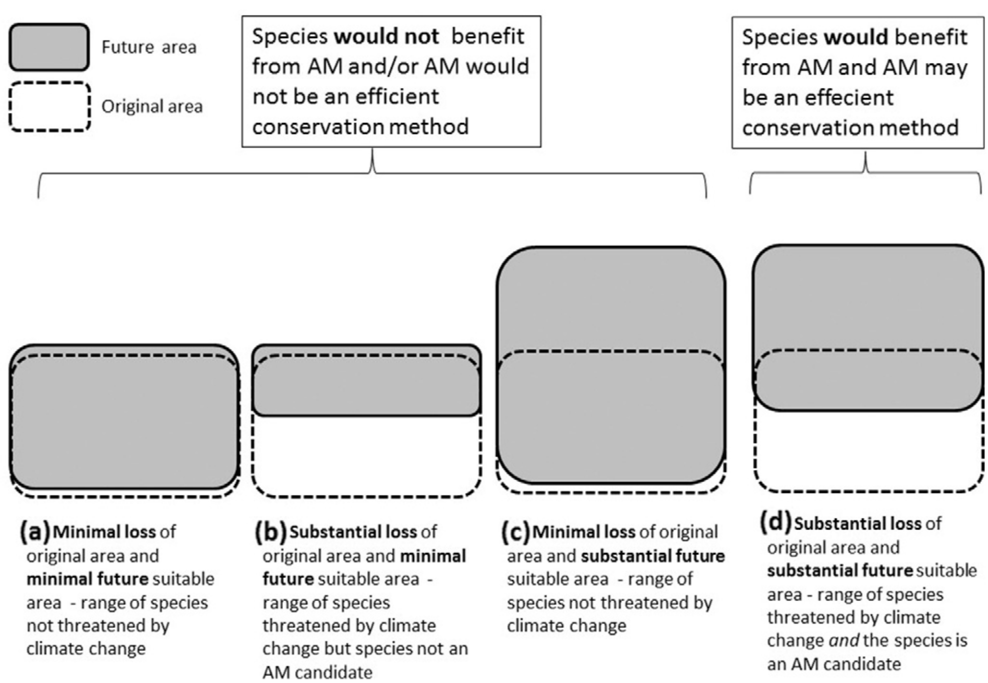

Fig. 1. Conceptualization of assisted migration (AM; sensu Hällfors et al., 2014) candidacy interpreted in the context of predictions about a species' future suitable area. If predictions suggest any of the three future scenarios (a–c), the species in question either does not need AM or does not have the potential of shifting its distribution because new area does not become available. The fourth scenario (d) suggest that AM could be an appropriate conservation method for this species.