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Transboundary ecological networks as an adaptation strategy to climate change: The example of the Dutch – German border

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Abstract

Establishing ecological networks across national boundaries is essential for species to adapt to shifts in future suitable climate zones. This paper presents a method to assess whether the existing ecological network in the Dutch – German border region is "climate proof". Using distribution data and climate envelope models for 846 species in Europe (mammals, birds, reptiles, amphibians and butterflies) we identified 216 species with climate-induced range shifts in the border region. A range expansion is predicted for 99 species and the ranges of 117 species are predicted to contract. The spatial cohesion of the ecological network was analysed for selected species that vary in habitat requirements and colonisation ability (forest species: *Brenthis daphne*, *Dendrocopos medius*; wetland species: *Maculinea teleius*, *Lutra lutra*). The assessment shows that optimising transboundary networks and developing corridors seems a suitable adaptation strategy for the forest species and for *L. lutra*. For the immobile butterfly *M. teleius*, the present habitat network is too weak and translocation into future suitable climate space seems to be a more appropriate adaptation measure. Our results underline that due to climate change landscape planning and management should not only focus on areas where target species occur today. The presented method can identify strongholds and bottlenecks in transboundary ecological networks and incorporate demands of climate adaptation into spatial planning which forms the basis for taking measures at a more detailed level.

Zusammenfassung

Der Biotopverbund gilt als eine zentrale Anpassungsstrategie des Naturschutzes an die Folgen des Klimawandels. In der vorliegenden Arbeit wurde untersucht, welchen Beitrag Biotopverbundsysteme zwischen Deutschland und den Niederlanden zur Anpassung von klimawandelbedingten Arealverschiebungen von Arten leisten können. Durch eine vergleichende Analyse von Verbreitungsdaten und Klimahüllen-Modellen von 846 Tierarten (Säugetiere, Vögel, Reptilien, Amphibien und Tagfalter) wurden 216 Arten identifiziert, die in Zukunft potenziell grenzüberschreitende Arealverschiebungen aufgrund von Gewinnen (99 Arten) oder Verlusten (117 Arten) von klimatisch geeigneten Gebieten erfahren werden. Für ausgewählte Arten der Wälder (*Brenthis daphne, Dendrocopos medius*) sowie der Gewässer- und Feuchtlebensräume (*Maculinea teleius, Lutra lutra*) wurde die funktionale Kohärenz der vorhandenen Biotopverbundsysteme modelliert und vor dem Hintergrund der Arealverschiebungen bewertet. Dadurch, dass Wanderungskorridore und Kernlebensräume erhalten, entwickelt und neu geschaffen werden, können die Arten der Wälder und *Lutra lutra* potenziell bei der Realisierung der Arealverschiebungen unterstützt werden. Die für

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den Biotopverbund relevanten Bereiche wurden grenzüberschreitend räumlich dargestellt. Für die wenig mobile Tagfalterart *Maculinea teleius* ist die Kohärenz des Netzwerkes vermutlich zu gering, so dass eine Umsiedlung in klimatisch geeignete Lebensräume als Anpassungsmaßnahme vorgeschlagen wird. Die Ergebnisse verdeutlichen, dass sich Biotopverbundplanungen in Zeiten des Klimawandels nicht nur auf die Gebiete konzentrieren sollten, in denen Zielarten bereits heute vorkommen. Mit der vorgestellten Methode können die potenziellen Auswirkungen von Klimaänderungen mit Relevanz für den grenzüberschreitenden Biotopverbund ermittelt werden, so dass eine Grundlage für Maßnahmenkonzepte auf regionaler und lokaler Ebene zur Verfügung steht.

Keywords: Range shift; Climate envelope; Habitat network; Spatial cohesion; Connectivity; Spatial planning; Marbled fritillary; Middle spotted woodpecker; Scarce large blue; European otter

Introduction

It is widely recognised that climate change is an important factor driving shifts in species geographical distributions (Root et al. 2003; Gaston 2006). Range shifts occur when a species range contracts or a species goes extinct at the range boundary where the climate is no longer suitable. These shifts also occur as species expand towards the poles and towards higher elevations where climatic conditions have recently become suitable (Opdam & Wascher 2004). Such climate-induced shifts have already been documented for many species groups, for example, plants, butterflies and birds (*e.g.* Parmesan et al. 1999; Hickling, Roy, Hill, Fox, & Thomas 2006; Lenoir, Gégout, Marquet, Ruffray, & Brisse 2008) and shifts in species ranges are expected to continue in the coming centuries (Hughes 2000). A common method for predicting future ranges of species in response to global warming are climate envelope models (Berry, Jones, Nicholls, & Vos 2007). These models forecast shifts in distribution ranges of hundreds of kilometres for many species (*e.g.* Araújo, Thuiller, & Pearson 2006; Settele et al. 2008). Whether species will be able to migrate into suitable climate zones depends on both species characteristics and landscape patterns (Wilson, Davies, & Thomas 2010). Species with low dispersal capacity and reproductive potential will require more time to expand their range (Clobert, Ims, & Rousset 2004). Habitat generalists might adapt their distribution pattern and range along climate gradients more easily than habitat specialists (Warren et al. 2001). Habitat loss and fragmentation affect the migration of species and might hamper colonisation of a habitat that has become suitable because of climate change (Anderson et al. 2009). When the range expansion of species is blocked or too slow to adapt to the rate of changing habitat suitability, species may go extinct (Thomas, Franco, & Hill 2006).

Ecological networks are proclaimed to be an adaptation strategy to help species and ecosystems adjust to climate change (Heller & Zavaleta 2009), facilitating range expansions (Vos et al. 2008). However, most existing ecological networks in Europe aim to create spatial cohesion on a regional or national level within the present distribution (Haaren & Reich 2006). There is an increased interest in transboundary cooperation and management of ecological networks (Leibenath, Blum, & Stutzriemer 2010), but large-scale shifts in species distribution ranges caused by climate change have rarely been taken into account (Hole et al. 2009). Although some natural links between national networks already exist, for instance, through river basins as parts of the NATURA 2000 European wide network of protected areas, it is unknown whether these links are sufficient to facilitate predicted range expansions of species of different habitats and colonisation ability. Thus comprehensive methods for the assessment of international connectivity under climate change are required (Beier, Spencer, Baldwin, & McRae 2011).

In this paper we present an approach to assess whether the ecological network in the Dutch – German border region is "climate proof". First we explore the extend of the problem by identifying which fraction of species have predicted range shifts in the border region, using climate envelope data for a variety of taxa. Next, we analyse the spatial cohesion of the ecological network for selected species that vary in their habitat requirements and colonisation ability. This assessment identifies strongholds and bottlenecks in the transboundary ecological networks on regional level and identifies locations where adaptive measures should be developed on local level.

Materials and methods

Study area

The study area covers the Netherlands and the federal states of Schleswig-Holstein, Lower Saxony and North Rhine-Westphalia in the north-west of Germany. The whole region stretches over an area of 133,000 km^2. Agriculture is the dominating land use (49% arable land, 20% pastures and meadows). Forests cover about 17% of the study area, predominantly in the central part of the Netherlands and in the southern and eastern parts of the German border region. Water bodies, coastal mudflats and swamps account for 3% of the study area. Artificial surfaces, such as urban areas, cover 11%.