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Post-Soviet land-use change effects on large mammals' habitat in European Russia

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ABSTRACT

Land-use change can strongly affect wildlife populations, typically via habitat loss and degradation where land use expands, and also via increasing potentially available habitat where land use ceases. Large mammals are particularly sensitive to land-use change, because they require large tracts of habitat and often depend on habitat outside protected areas unless protected areas are very large. Our research question was thus how land-use change around protected areas affects large mammals' habitat. Russia experienced drastic land-use change after the breakdown of the Soviet Union and – fortunately – wildlife data has been collected continuously throughout this time inside protected areas. We used long-term winter track count data for wild boar (*Sus scrofa*), moose (*Alces alces*), and wolf (*Canis lupus*) to assess habitat change inside and outside of Oksky State Nature Reserve from 1987 to 2007 using a time-calibrated species distribution model. Our results showed a constantly high share (at least 89%) of suitable habitat within the protected area's core zone for each species, yet also substantial habitat increases of up to 23% within the protected buffer zone, and similarly, up to 27% outside the protected area. Of the variables we evaluated, post-Soviet land-use change, particularly farmland abandonment, was the main driver of this expansion of potential habitat for the three species we assessed. Our study highlights that strictly protected areas have been playing an important role in preserving wildlife in European Russia since 1991, and also that their surroundings provide much suitable habitat for large mammals. Post-Soviet land-use change in the surroundings of protected areas may provide opportunities to increase and connect wildlife populations.

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1. Introduction

Globally, biodiversity is declining and land-use change is a major reason for this (Foley et al., 2005; Sala et al., 2000). Agricultural expansion is particularly worrisome because it results in habitat loss, degradation, and fragmentation (Fischer and Lindenmayer, 2007). This in turn can result in increased poaching, when new roads provide access into previously remote areas (Coffin, 2007; Laurance et al., 2006), in changing water availability (Power, 2010), and in invasive species spread (Brook et al., 2008). However, while agricultural expansion continues in many tropical regions (Phalan et al., 2013), agricultural abandonment has become a major land-use change trajectory, in tropical (Aide et al., 2013; Grau and Aide, 2008) and temperate (Navarro and Pereira, 2012; Schierhorn et al., 2013) regions. The biodiversity impacts of abandonment, however, are diverse and not well understood (Plieninger et al., 2014; Queiroz et al., 2014; Uchida and Ushimaru, 2014).

Large mammals (i.e., body mass > 20 kg; Vynne et al., 2011) are particularly challenging to maintain in human-dominated landscapes (Dirzo et al., 2014). These species are typically wide-ranging and require large and well-connected habitat networks, and are thus especially prone to land-use change. Furthermore, large mammals often conflict with people, livestock, and cropping (Behdarvand et al., 2014; Hoare, 1999), and are frequently poached for meat or trophies (Hilborn et al., 2006; Stokstad, 2014). Declining populations of large mammals are worrisome because of their importance for ecosystems as their disappearance can result in cascading impacts via altering food webs and triggering ecosystem shifts (Estes et al., 2011; Ripple et al., 2014).

Protected areas are a key conservation tool to safeguard species' populations and their habitats against the direct impacts of land use, and ideally against its indirect effects as well. Yet, many protected areas are too small to harbor viable populations of large mammals (Newmark, 1996) and these species depend on habitat surrounding protected areas. Prime examples include grizzly bears in the Greater Yellowstone Ecosystem (Carroll et al., 2004), giant armadillos and maned wolves in the Brazilian Cerrado (Vynne et al., 2011), Amur

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tiger in the Russian Far East (Carroll and Miquelle, 2006), and Asian and African elephants (Fernando et al., 2008; Galanti et al., 2006). The surroundings of protected areas thus fulfill an important role for biodiversity conservation since they are part of the so-called 'zone of interaction' (DeFries et al., 2010), which represents the landscape comprising the protected area and its surroundings, which is linked to the protected area via multiple ecological processes and often strong interactions between humans and nature. At the same time, protected areas' surroundings are often intensively used which can turn them into population sinks (Woodroffe and Ginsberg, 1998). Therefore, it is important to evaluate how land-use change in the surroundings of protected areas affects wildlife habitat.

Evaluating the effects of land-use change on wildlife often hinges on the availability of habitat use data from before and after land-use change occurred. Long time series of species' presence records are particularly valuable in this context (Boulinier et al., 1998; Bragina et al., 2015; Sauer et al., 2014). If longitudinal wildlife data are available, however, the challenge is how to analyze them given that data have been collected over many decades and while landscapes have changed. Time-calibrated niche models (Kuemmerle et al., 2012; Nogues-Bravo, 2009) offer an approach to maximize the information gain from long-term species occurrence data, since all available data can be used in one model, which can then be used to predict habitat availability in places and times for which no observations exist (Reside et al., 2010; VanDerWal et al., 2013).

Information on habitat availability is important for large mammals' conservation, and in the case of large carnivores, additional information on biotic interaction is required, for example, the occurrence of prey species (Hebblewhite et al., 2014). Identifying suitable prey habitat is thus essential for maintaining and restoring carnivore populations and that may also help to minimize human-wildlife conflicts. So far, only a few studies addressed biotic interaction in species distribution models, such as including food resources (Bateman et al., 2012; Kuemmerle et al., 2012) or prey habitat as predictor for carnivore habitat models (Giannini et al., 2013; Hebblewhite et al., 2014). Generally, including biotic factors improves the predictive power of species distribution models (Wisz et al., 2013), yet applications that incorporate prey habitat distributions for assessing the habitat of predator species remain scarce.

Russia provides unique opportunities to understand the effects of land-use change on wildlife habitats within and outside of protected areas. The collapse of the Soviet Union in 1991 triggered drastic changes in socio-economic and institutional conditions, which in turn resulted in widespread land-use change including agricultural abandonment (Prishchepov et al., 2012) and changes in forest harvesting (Baumann et al., 2012). Agricultural abandonment was especially widespread throughout European Russia and led to the expansion of transitional grassland and early successional forests. These changes in land cover have potentially substantial effects on wildlife by providing new habitats and connecting existing ones, at least in part contributing to the recent rebounding of large mammal populations in European Russia (Bragina et al., 2015). However, the post-Soviet upheaval also caused considerable economic hardships (Klugman and Braithwaite, 1998), lessened support for nature conservation (Wells and Williams, 1998), and resulted in drastic population declines of many large mammal species in Russia, except for wolves during the 1990s (Bragina et al., 2015).

Fortunately, Russia's protected areas were the focus of truly exceptional long-term biodiversity monitoring. Most of the 103 strictly protected state nature reserves ('zapovedniks', IUCN category Ia; IUCN and UNEP, 2014) have permanent scientific staff who collected a broad range of biodiversity and ecosystem variables for decades, using standard survey protocols, and published these in the so-called Chronicles of Nature (Летопись природы) every year (Spetich et al., 2009). An important element of the protected areas' biodiversity monitoring are winter track counts (WTCs, Зимние маршрутные учёты) that provide species' occurrence maps and estimate large mammal population sizes (Bragina et al., 2015; Carroll and Miquelle, 2006; Stephens et al., 2006). In some protected areas, WTCs have been collected since the 1960s (Lomanov, 2007), thus providing a baseline from Soviet times and covering the entire transition period of rapid socio-economic and land-use change after 1991.

Understanding how land-use change affects wildlife habitat and how these land-use changes may affect the zone of interaction surrounding protected areas is important for identifying effective strategies to protect large mammals, which can rarely survive inside protected areas alone. European Russia provides unique opportunities to learn more about these issues in general, because land-use change there has been drastic in response to the socio-economic and institutional shocks of the breakdown of the Soviet Union, and because longitudinal wildlife data have been collected in a standardized manner for decades, including the period of rapid land-use change. Our overarching goal thus was to evaluate how post-Soviet land-use change affected the distribution of potential habitat for large-mammals both inside protected areas and in their surroundings. To explore this question, we analyzed a long-term dataset of annual winter track counts for three large mammals, wild boar (*Sus scrofa*), moose (*Alces alces*), and wolf (*Canis lupus*), from Oksky State Nature Reserve, in the temperate zone of European Russia. The three species represent the largest and most wide-ranging mammals in our study region and have different habitat requirements since they are omnivore, herbivore, and carnivore species, respectively. We related the wildlife data to land-use change information derived from Landsat satellite images in order to map the availability of potential habitat inside and outside the protected area using a time-calibrated species distribution model. We furthermore assessed the impact of including information on prey habitats to model potential habitat of a large carnivore species. Our a priori hypothesis was that land-use change has led to an increasing availability of potential habitat for our target species — both inside and outside the protected area. We also assumed that the inclusion of prey variables will improve the prediction of large-carnivore habitat. Specifically, our objectives were:

1) To model habitat selection of wild boar, moose, and wolf using a time-calibrated species distribution model and to predict habitat distribution for different time periods,
2) To assess changes in habitat availability of the three targeted large mammal species within Oksky State Nature Reserve and its immediate surroundings from 1987 to 2007 due to post-Soviet land-use change, and
3) To explore the relative importance of including prey habitat distributions for analyzing predator habitats.

2. Material and methods

2.1. Study area

Our study area is located in temperate European Russia in Ryazan Oblast and includes Oksky State Nature Reserve and its surroundings (Fig. 1 and Fig. A1 in the Supporting Information). The study area covers about 800,000 ha and falls within the Sarmatic mixed forest ecoregion (Olson et al., 2001) with mainly coniferous and mixed forests, dominated by spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), and pedunculate oak (*Quercus robur*) on glacial, sandy soils. Its southern and eastern boundary is the floodplain area of the Oka River with extensive riverine grasslands. The study area is characterized by flat terrain ranging from 76 m to 172 m. The climate is moderate, with the highest mean temperature in July (20 °C) and lowest in February (−12 °C), and an annual precipitation of about 534 mm (Priklonsky and Tichomirov, 1989).

About 10% of the study area is managed by the Oksky State Nature Reserve. This federal strictly protected area was established in 1935, originally to protect the Russian desman (*Desmana moschata*) and the wetland around the Pra River, a tributary of the Oka River. In 1978, Oksky State Nature Reserve became a biosphere reserve and in 1989, a

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