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A multi-temporal approach to model endangered species distribution in Europe. The case of the Eurasian otter in Italy

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ABSTRACT

We analyzed the relationship between changes in land cover patterns and the Eurasian otter occurrence in southern Italy over the course of approximately 20 years (1985–2006) using multi-temporal species distribution models (SDMs). The study area includes five river catchments covering most of the otter's Italian range. Land cover and topographic data were used as proxies for the ecological requirements of the otter within a 300-m buffer around river courses. We used species presence, pseudo-absence data, and environmental predictors to build past (1985) and current (2006) SDMs by applying an ensemble procedure through the BIOMOD modeling package. The performance of each model was evaluated by measuring the area under the curve (AUC) of the receiver-operating characteristic (ROC). Multi-temporal analysis of species distribution was performed by comparing the maps produced for 1985 and 2006. The ensemble procedure provided good overall modeling accuracy, revealing that elevation and slope affected the otter's distribution in the past; in contrast, land cover predictors, such as cultivations and forests, were more important in the present period. During the transition period, 20.5% of the area became suitable, with 76% of the new otter presence data being located in these newly available areas. The multi-temporal analysis suggested that the quality of otter habitat improved in the past 20 years due to the expansion of forests and to the reduction of cultivated fields in riparian belts. This evidence stresses the great potential of riverine habitat restoration and environmental management in supporting the future expansion of the otter in Italy.

1. Introduction

Habitat reduction is widely acknowledged as one of the major causes of species decline (e.g., Ewers and Didham, 2006 and reference therein), and land-use change constitutes one of the most important causes of habitat loss for wildlife (Sala et al., 2000). The understanding of how species are linked to land cover changes over time represents a sound tool for landscape planning that addresses biodiversity conservation (Torres et al., 2010; Le Lay et al., 2010). The restoration of natural habitats is one of the most efficient in situ conservation actions. This is particularly true in European countries where legal protection and environmental regulations in the past 30 years have reduced the pressure of other threats to wildlife, such as direct persecution and pollution (Schipper et al., 2008). The preservation and restoration of habitats for wildlife are explicit goals of several directives adopted by the European Community (EC), i.e., the Birds Directive (79/409/EEC, recently replaced by the 2009/147/EC), the Habitat Directive (92/43/EC), and the Water Framework Directive (WFD 2000/60/CE). These directives have defined a list of species and habitats of conservation interest and compel state members to run periodic surveys to monitor their conservation status over time. The EC has defined standard protocols for land-use mapping and updating (CORINE Land cover, http://www.eea.europa.eu), allowing an analysis of the changes over time in a common, reliable dataset (Anon, 1999). However, although presence data derived from periodic surveys and CORINE land cover maps produced in a standard, homogenous way exist throughout Europe, the relationship between land cover transformations and habitat suitability for endangered and rare species remains understudied (Holmes and Sherry, 2001; Knick and Rotenberry, 2000; Demaría et al., 2004; Clavero et al., 2010; Torres et al., 2010).

Here, we explore how multi-temporal data on both species presence and land cover can be combined to evaluate past and present distributions, habitat availability, and pressures on rare and endangered species. Using multi-temporal species distribution models

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Table 1
Environmental predictors used in the species distribution modeling, and their relation to otter ecological requirements or disturbance.

Variable name	Ecological otter requirement/disturbance factor	Source	Resolution
Topographic factors	Food availability and hunting capacity	Digital Elevation Model (Basilicata region)	20 mt resampled at 30 mt
Cultivations	Anthropogenic pressure	Landsat-TM image (1985 and 2006)	30 mt
Forests	Riparian vegetation cover	Landsat-TM image (1985 and 2006)	30 mt
Shrubs	Riparian vegetation cover	Landsat-TM image (1985 and 2006)	30 mt
Sparse vegetation	Absence of riparian vegetation cover	Landsat-TM image (1985 and 2006)	30 mt

(SDMs), we analyzed the relationship between land cover patterns and species occurrence over time. We specifically focused on changes in the distribution of the Eurasian otter (*Lutra lutra* L., Carnivora, Mustelidae) that occurred over the past 20 years in southern Italy. The Eurasian otter is an endangered, semi-aquatic, medium-sized carnivore inhabiting many freshwater habitats throughout Europe and Asia; the species is included in appendices II and IV of the 92/43/EC Directive. The decline of otter populations throughout Europe during the 1980s and the 1990s has been attributed to pollution, direct persecution, and habitat degradation (Conroy and Chanin, 2000; Kruuk, 2006; Macdonald and Mason, 1994; Mason and Macdonald, 1986). Following legal protection and the adoption of a strict legislation on water pollution, the otter started to recover in many European countries, and the species was downgraded from Vulnerable to Near Threatened in the IUCN red list (Ruiz-Olmo et al., 2008). Nevertheless, the current distribution in Europe is still marked by a large vacant corridor from Central Denmark to Central Italy (Ruiz-Olmo et al., 2008), indicating that other factors are still acting in preventing or slowing otter recovery. These factors may include riverine vegetation cover, food resources, water captions, and anthropogenic alterations of rivers. Compared with other populations in Europe, the otter in Italy is recovering rather slowly and is listed as endangered on the Italian Red List (Prigioni et al., 2007; Loy et al., 2010; Panzacchi et al., 2011). At present, the otter's Italian range is confined to residual populations located in the southern sectors of the Italian peninsula. The small population sizes, geographic isolation, and genetic differentiation from other European populations prevent any re-stocking or re-introduction measures (Prigioni et al., 2006a,b; Randi et al., 2003; Panzacchi et al., 2011; Rondinini et al., 2013). Thus, to support the natural recovery of the otter in Italy, it is necessary to correctly identify rivers that can potentially host the species in proximity to the actual areas of presence and to identify territory through which the species could disperse (Loy et al., 2010; Carranza et al., 2012). A number of species distribution models (SDMs; Guisan and Thuiller, 2005) predicting the distribution of the otter at different spatial scales have been proposed in recent decades. These models were either based on expert knowledge (Boitani et al., 2002; Loy et al., 2009) or on inferential statistical analyses (Cianfrani et al., 2010, 2011, 2013; Prenda and Granado-Lorencio, 1996). A multi-temporal approach was used by Cianfrani et al. (2010) to explore the power of SDMs to predict areas newly colonized by otters at the border of its Italian range; the authors implemented SDMs from CORINE Land Cover maps relative to a single dataset (2006). However, the matching of concomitant changes in species occurrence and land-use patterns has not been well explored to date. In this study, we used, for the first time, field data on Eurasian otter occurrence between 1985 and 2006 and coeval land-use maps to fit SDMs. By using an ensemble niche modeling approach (BIOMOD, Thuiller, 2009), we modeled the distribution of otters from the contraction period in the 1980s to the recent expansion phase in 2006, thereby accounting for the changes that have occurred over a 20-year period (Loy et al., 2009). We chose this approach because insights into the environmental predictors driving past and current species distribution would be likely to identify differential factors determining otter survival over time. Understanding the response of this threatened species to changing environmental conditions could be useful in directing environmental management planning in a more sound and efficient manner.

2. Methods

2.1. Study area

The study area includes five river catchments covering most of the southern Italian otter range (i.e., Sinni, Agri, Basento, Bradano and Cavone; Fig. 1). This area played a crucial role in the survival of the remnant otter population during the period of 1970–1990 (Loy and Racana, 1986) and still represents the most consistent part of the otter's southern range (Loy et al., 2010). In the late 1980s, Italian otters were confined to a few southern river basins, mostly found in the Basilicata region (Cassola, 1986). Specifically, otters occurred in three river courses of the region (Sinni, Agri, and Basento; see Fig. 1; Loy and Racana, 1986). Starting from the 1990s the species underwent a new expanding phase, slowly recovering northward and southward (Loy et al., 2009). Beginning in the 1990s, the species underwent a new expansion phase, slowly recovering northward and southward (Loy et al., 2009). In the Basilicata region, otters have presently expanded to all five of the analyzed basins (Loy et al., 2009, 2010; Panzacchi et al., 2011). Because otters are rarely found far from water (Beja, 1992; Chanin, 2003; Kruuk, 2006), the model was implemented using a 300-m buffer area along the main river stretches and lakes of the study area.

2.2. Species data

We used multi-temporal species occurrence data derived from published maps of otter surveys performed in the study area in the years 1985 (Loy and Racana, 1986) and 2004–2006 (Panzacchi et al., 2011). The 1985 survey was conducted in 70 sites, 14 of which (20%) were found positive for the presence of otters (Loy and Racana, 1986); the 2002–2006 survey included 86 sites, 62 of which were found positive (72%) for otter presence (Fusillo et al., 2004; Prigioni et al., 2006a,b, 2007; Fig. 2).

Both surveys were based on the same standard methodology described by Macdonald and Mason (1983), and further implemented by Reuther et al. (2000). Therefore the presence absence data are consistent and comparable.

2.3. Environmental data

Following previous studies (Prenda and Granado-Lorencio, 1996; Loy et al., 2009; Cianfrani et al., 2010, 2011), land cover and topographic data (elevation, slope, and aspect) were used as proxies of the ecological requirements of otters within a 300-m buffer around river courses (Table 1). Land cover maps referring to the two survey periods were derived from a supervised classification of high-resolution satellite data (sensor Landsat-TM) (time acquisition for the Images 10/08/1985 and 19/07/2006). Four land cover categories were considered: forests, shrubs, sparse vegetation, and cultivated areas.

The land cover classes were transformed in a GIS environment (Arc-view 9.3; ESRI, Redlands, USA) into frequency maps computed on a moving circular window with a 300-m radius around the focal