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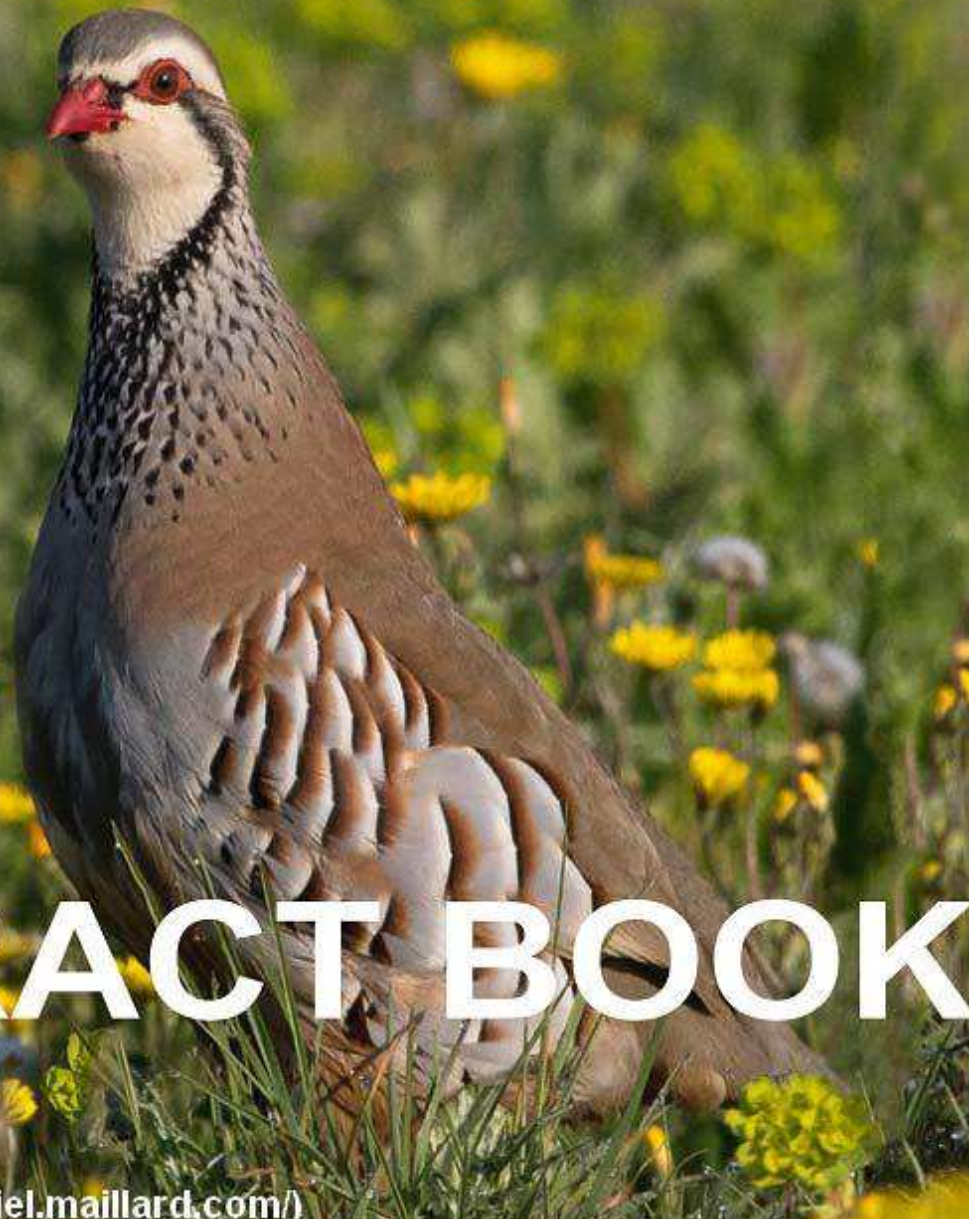
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ABSTRACT BOOK

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The golden jackal (*Canis aureus*) in Europe: predicting habitat suitability of a rapidly establishing carnivore

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The golden jackal's *Canis aureus* range in Europe is expanding rapidly and populations are increasing. Historically restricted to the Mediterranean and Black sea coastal regions [1], jackals are now reproducing in most of Southeastern European and some Central European countries [2-4]. Current population trends suggest that population expansion is far from complete. The hypothesis according to which the species expansion may be the result of a mesopredator release mediated by grey wolves *Canis lupus* [5] is gaining support. Indeed, local evidence suggest that golden jackals avoid or have disappeared from core areas recolonized by wolves, and continental distribution patterns of both species show a marked negative correlation [1]. In turn, the colonization of this new carnivore could have profound impacts on existing animal communities [6], and trigger a large-scale trophic cascade – as reported in North America for an analogous wolf-coyote system [7,8,9]. From an applied perspective, the presence of this new carnivore has been found to be a source of ecosystem services [10] and is already receiving high interest among wildlife managers and policy makers [3]. In this study, we aimed at characterizing the golden jackal realized niche, and identifying areas of high habitat suitability, which are likely to be colonized in the future.

Since jackals are highly mobile and opportunist animals, dispersers can temporarily occupy nearly all types of habitats, far from population sources [11]. To prevent overestimation of the species' environmental niche, we focused on the sampling of established territorial jackal groups by means of a strict bioacoustic stimulation protocol [12]. We characterized the jackal environmental niche using snow cover duration [13] and ten land-cover variables extracted from Corine Land Cover, as well as grey wolf presence [14], treated as a trophic dependency covariate [15]. We modeled jackal probability of occurrence by fitting both a generalized linear

model (GLM) and a generalized additive model (GAM) to our acoustic stimulation dataset. We evaluated the model predictive performance by means of a repeated split plot. The final model was achieved through an ensemble model procedure [16] and projected across the continent at a 4km resolution, coherent with both jackal territory size and error associated with howling surveys [13].

We performed acoustic stimulations at a total of 7,832 locations in twelve countries across the European range of the species. Among these, we recorded the presence of established jackal groups at 1,734 localities. For both model types, snow cover duration accounted for the highest variable contribution (mean = 37.2%), followed by wolf presence (mean = 20.8%). Proportion of forest and agricultural land cover, as well as distance from settlements and hydrological features were also selected in the best models. Jackal habitat probability of occurrence was highest in areas with short snow cover duration, heterogeneous land cover and outside the core of the wolf range. Average jackal probability of presence ranged from 0.21 in areas of permanent wolf presence to 0.73 in areas of wolf absence. Although snow cover duration was the most influential variable to predict jackal distribution, the model predictive ability was significantly improved by including the wolf presence covariate. Both model types performed very well ($AUC_{GLM} = 0.87$ and $AUC_{GAM} = 0.89$).

Besides the clear avoidance of snowy areas, our findings imply that the species favors mosaic landscapes and avoid areas with permanent grey wolf presence, which are coherent with recent findings [1,17]. Furthermore, our modelling results suggest that large parts of Western and Southern Europe, especially in France and in the Iberian and Apennine peninsulas, may be suitable for golden jackals (Figure 1). Although our modelling framework did not explicitly account for heterogeneous availability of anthropogenic food source – a factor known to affect distribution and densities of golden jackals – we can expect further expansion of this species in the future. Altogether, these results provide managers with relevant information to prepare for the jackal's future colonization of areas where the expansion is most likely.

Figure 1: Ensemble model predictions of golden jackal's relative probability of presence in Europe. The current range of the species is pictured in the black polygons (source: Trouwborst et al. 2015).
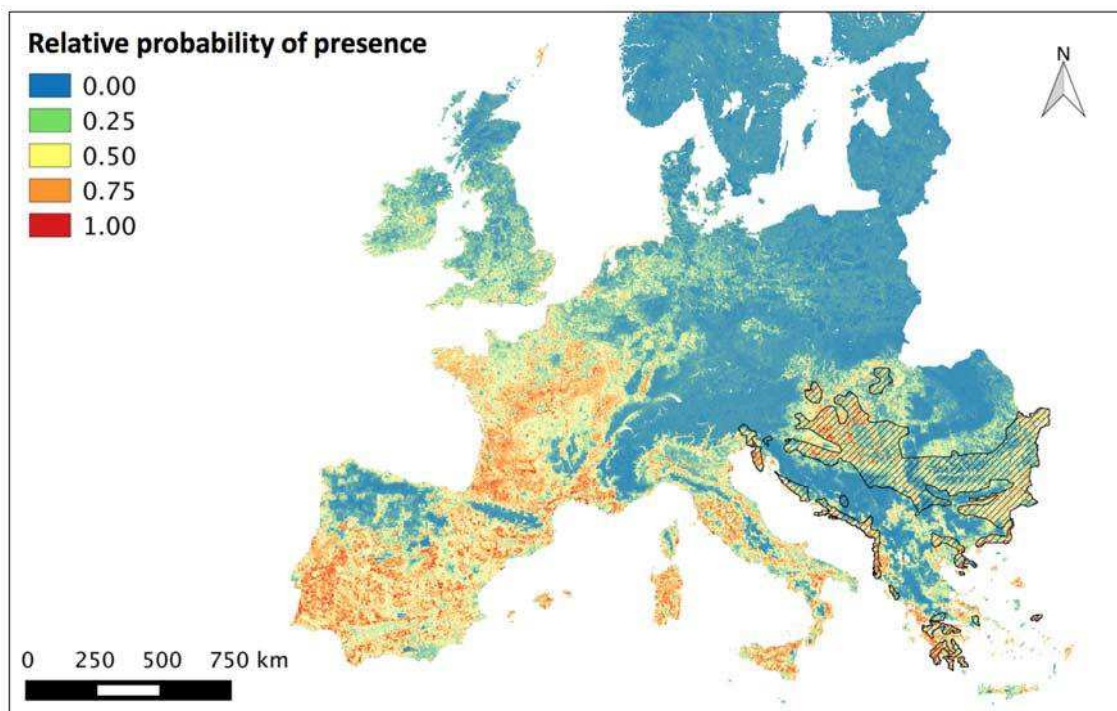
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