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THE APENNINE HARE *LEPUS CORSICANUS* IN LATIUM, CENTRAL ITALY: A HABITAT SUITABILITY MODEL AND COMPARISON WITH ITS CURRENT RANGE

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RIASSUNTO - ***La lepre appenninica* Lepus corsicanus *nel Lazio, Italia centrale: un modello di idoneità ambientale a confronto con la distribuzione attuale***. La lepre appenninica (*Lepus corsicanus*) è un endemismo italiano distribuito in Italia centro-meridionale, in Sicilia e in Corsica. Nel Lazio esistono piccole popolazioni, spesso isolate tra loro. Scopo di questo lavoro è la realizzazione di un modello di idoneità ambientale per questa specie. L'areale sinora conosciuto nel Lazio dimostra che il *taxon* è adattabile a diverse tipologie ambientali e a varie altitudini s.l.m. Il modello è stato elaborato su piattaforma GIS, attribuendo al tipo di uso del suolo (secondo la classificazione del progetto CLC) e alla quota (categorie DTM) un punteggio conforme alle preferenze ecologiche della specie. Il modello ottenuto è stato comparato con uno proposto precedentemente e confrontato con la distribuzione attuale della specie ottenuta a partire dai dati di presenza raccolti dal 1990 al 2009. Anche considerando la maggior mole di dati utilizzata nel presente studio, la differenza più evidente tra i due modelli è l'estensione maggiore delle aree ad alta idoneità ambientale da noi ottenuta. L'85,7% delle localizzazioni ricade nella classe di idoneità più elevata, suggerendo che il modello riflette le preferenze ecologiche della specie e può rappresentare un utile strumento gestionale.

Parole chiave: Lepus corsicanus, idoneità ambientale, preferenze ecologiche, Italia

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The Apennine hare was originally described by De Winton (1898) as a species (*Lepus corsicanus*) from specimens found in Corsica. Later the taxon was downgraded as a subspecies of the European hare, i.e. *L. europaeus corsicanus*, and considered in this way for a long time, by several authors (e.g.: Miller, 1912; Ellerman and Morrison-Scott, 1951; Toschi, 1965; Corbet, 1978). Palacios *et al*. (1989) and Palacios (1996) highlighted relevant morphometric differences between *L. e. corsicanus* and *L. e. meridiei* by analysing cranial biometry, hair structure, and dental characteristics of museum specimens originally collected during the 19th century and during the first decades of the 20th century, when restocking with hares for hunting purposes had not yet begun. According to these authorities, *L. europaeus* and *L. corsicanus* are distinct species with no evidence of hybrid specimens, as confirmed by Angelici and Luiselli (1998). More recently, mitochondrial DNA analyses have

fully confirmed the specific status of *L. corsicanus* (Pierpaoli *et al*., 1999; Riga *et al*., 2003).

The current distribution of *Lepus corsicanus* includes central and Southern Italy from Umbria and Southern Tuscany to Calabria (Angelici and Spagnesi, 2009). The species is also present in Sicily.

While hare distribution in this island seems quite uniform, in the Italian peninsula distribution is fragmented, with several isolated populations (Angelici and Spagnesi, 2009).

Since the mid 1980s, we have been compiling and constantly updating the distribution of *Lepus corsicanus* in Latium (17227 Km^2, Tab. 1). Summarizing, in this region *L. corsicanus* is present in some zones as the Mediterranean Tolfa mountains and surrounding areas, some reserves along the coast, and some pre-Apennine and Apennine areas, altitudinal range being from 0 to 1700 m a.s.l. (Angelici and Spagnesi, 2009).

Knowledge on the distribution pattern of endangered species is crucial to identify limiting factors (Roman Muñoz *et al*., 2005) and improve conservation strategies (Donatian *et al*., 1993; Robertson *et al*., 2003; Rushton *et al*., 2004).

Habitat suitability models integrate and synthesize species-environment relations and thus represent valuable support to projects involved in wildlife conservation and land management.

Deductive models are based on expert knowledge and/or on bibliographical references, while inductive models use information derived from species field-records (Corsi *et al.*, 1999).

Both models have been applied for the conservation, reintroduction, restocking and management of lagomorphs (e.g. Carvalho and Gomes, 2003; Raymond and Carreker, 1985; Fulgione *et al*., 2009).

A first model of habitat suitability for the Apennine hare was drafted by the Latium Regional Agency (ARP) and University of Rome "La Sapienza" in 2004 (Boitani *et al*., 2007).

In 2007, to include previously unconsidered records of the species, we developed a further habitat suitability model with the aim of producing a constantly evolving tool for the management and conservation of the Apennine hare. Some preliminary versions of

Table 1 - Land use in Latium according to CORINE Land Cover categories.

CORINE Land Cover classes		%
1.1	Urban areas	4.85
1.2	Industrial and commercial areas	1.78
1.3	Mineral dump and construction sites	0.48
1.4	Artificial non agricultural vegetated areas	0.54
2.1	Arable land	32.82
2.2	Permanent crops	12.19
2.3	Pastures	2.99
2.4	Heterogeneous agricultural areas	2.23
3.1	Forest	28.64
3.2	Scrub and/or herbaceous vegetation associations.	9.81
3.3	Open spaces with little or no vegetation	2.08
4.1	Inland wetlands	0.01
4.2	Maritime wetlands	0.01
5.1	Inland waters	1.49
5.2	Marine waters	0.08

Table 2 - Scores attributed to CORINE Land Cover categories according to the ecological requirements of the Apennine hare; 0 = unsuitable; 1 = low suitability; 2 = medium suitability; 3= highly suitability.

CORINE Land Cover categories		Score
1.1.1	Continuous urban areas	0
1.1.2	Discontinuous urban areas	0
1.2.1	Industrial and commercial units	0
1.2.2	Road and rail networks and associated land	0
1.2.3	Harbours	0
1.2.4	Airports	0
1.3.1	Mineral extraction sites	0
1.3.2	Dump sites	0
1.3.3	Construction sites	0
1.4.1	Green urban areas	1
1.4.2	Sport and leisure facilities	0
2.1.1	Non-irrigated arable land	1
2.2.1	Vineyards	1
2.2.2	Fruit trees and berry plantations	1
2.2.3	Olive groves	2
2.3.1	Pastures	2
2.4.1	Annual crops associated with permanent crops	1
2.4.2	Complex cultivation patterns	2
2.4.3	Agricultural areas with areas of natural vegetation	3
2.4.4	Agro-forestry areas	3
3.1.1	Broad- leaved forest	2
3.1.2	Coniferous forest	0
3.1.3	Mixed forest	2
3.2.1	Natural grasslands	3
3.2.2	Moors and heathland	3
3.2.3	Sclerophyllous vegetation	2
3.2.4	Transition woodland- shrub	3
3.3.1	Beaches, dunes, sand plains	0
3.3.2	Bare rock	0
3.3.3	Sparsely vegetated areas	2
3.3.4	Burnt areas	0
4.1.1	Inland marshes	0
4.2.2	Salines	0
5.1.1	Water courses	0
5.1.2	Water bodies	0

the model have been presented and discussed in some scientific meetings (Angelici *et al.,* 2007a, b).

We used GIS ARCVIEW 3.2 software (ESRI Italia) to elaborate data and develop the model. Based on the known ecological requirements of the species, scores were attributed to CORINE land cover (European Commission, 1997; European Environment Agency, 2002) and altitude DTM categories (Tab. 2, 3). The same land cover categories used for the previous model (Boi-

Table 3 - Scores attributed to altitude DTM categories; 0 = unsuitable; 1 = sub-optimal; 2 = optimal.

Altitude (m a.s.l.)	Score
0-20	1
20-400	2
400-900	2
900-1200	2
1200-1700	1
1700-5000	0

tani *et al*., 2007) were adopted to allow sound comparisons. We overlapped class scores for both habitat and altitude and obtained a final suitability score, ranging from 0 (unsuitable) to 3 (highly suitable), which allowed us to identify the areas of the region potentially suitable for Apennine hares (Fig. 1).

According to our model, areas with the highest score cover 7991.6 km^2, while areas attributed to class 2, 1 and 0 cover, respectively, 7471.3 km^2, 68.96 km^2 and 1476.3 km^2. Highly suitable areas include a few Mediterranean coastal areas and, most of all, internal mountain areas (Fig. 1). The highest score was totalled by Mediterranean maquis with wide glades and ecotonal areas, pastures, grasslands and heaths near bush and wood (see also Angelici and Spagnesi, 2009). On the whole, suitable areas (classes 3 and 2) cover about 90% of the region, in agreement with the fact that Latium is completely included in the historical and current range of the species (Angelici and Spagnesi, 2009).

With respect to the habitat suitability model proposed by Boitani *et al*. (2007), our model includes more highly suitable areas (class 3: 46.39% *vs*. 21.90%, $\chi^2 = 4.039$; $P < 0.05$), while the other classes do not differ significantly (class 2: 43.37% *vs*. 68.61%; class 1: 0.40% *vs*. 2.42%; class 0: 8.57% *vs*. 5.76%, respectively).

In order to validate our habitat suitability model in Latium, we overlapped all hare locations recorded between 1990 and 2009 (N = 42), including sightings, accidental harvesting during the hunting season and individuals found dead (Fig. 1). Hare records were not randomly distributed among suitability classes ($\chi^2 = 45.18$; $P < 0.01$; d.f. = 3), i.e. the observed frequency of hare records in each suitability class was significantly different from the expected one (if records were

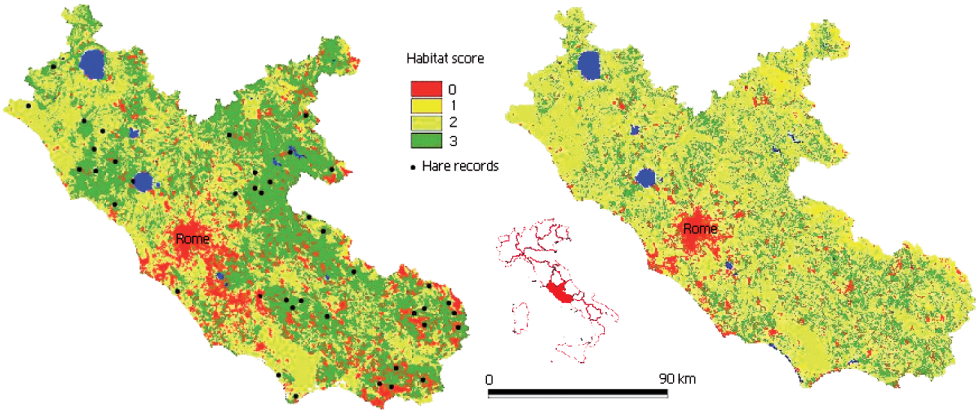

Figure 1 - Habitat suitability model for *L. corsicanus* in Latium, central Italy, including records (black spots) in 1990-2009 (left); *L. corsicanus* habitat suitability model in Latium according to Boitani *et al*., 2007 (right).

distributed in proportion to the overall area of each class). On the whole, 85.7% of all hare locations occurred in the highly suitable class, suggesting that the model reflects the habitat preferences of the Apennine hare and may represent an effective tool for the management of these lagomorphs, provided that it is continuously implemented and updated with new available data about the species' ecology and changes in land use.

Anyway, future programmes for both the conservation of extant populations and reintroductions should also consider that the Apennine hare suffers from competition (*sensu* Ricklefs, 1980) with introduced *L. europaeus*, which is larger, probably more aggressive, more adaptable and has a higher reproductive rate than *L. corsicanus*. In fact, when the two species occur in sympatry, *L. corsicanus* is found at higher altitudes than *L. europaeus*, whilst in allopatry both species occur in the same altitudinal range (Angelici and Luiselli 1998, 2007; Angelici and Spagnesi, 2009).

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