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HABITAT SUITABILITY MODEL FOR EUROPEAN WILD RABBIT *(ORYCTOLAGUS CUNICULUS)* WITH IMPLICATIONS FOR RESTOCKING

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ABSTRACT

The European wild rabbit, Oryctolagus cuniculus*, is a key species in the Iberian ecosystems. However, its populations are seriously depleted. Therefore, the development of habitat suitability models could be an important step towards the establishment of management and recovery plans. An habitat suitability model was developed for the rabbit in the 4,606 ha of the Peneda-Gerês National Park (northern Portugal). The framework was based on 3 steps: (1) construction of an habitat suitability model using the logistic regression of presence/absence of rabbits on habitat variables, (2) location of suitable habitat on a map, with the help of a Geographic Information System (GIS), by applying the above-obtained regression coefficients to the digitalized data of a land-cover map, and (3) delineation of the best potential sites for restocking. In June-July 2000, presence/absence of rabbits was determined by the presence/absence of pellets, warrens and individuals on 86 100-m radius random circular plots,* i.e. *3.14 ha each representing the area occupied by a family group in summer. The initial dataset was divided into 56 sampling plots to build the model and 30 sampling plots (15 with rabbits and 15 without rabbits) for cross-validation. Measured habitat variables were % cover of tall scrubland, % cover of rocks, and interspersion (an index measuring the amount of intermixture of forage and shelter patches). These variables were calculated for all pixels of a digital land-cover map, using a moving 100-m radius window approach. Plots on which wild rabbits were present had a mean 10+3.4%(SE) percentage of rocks, 16.3+3.8% percentage of tall scrubland and an interspersion index of 0.9+0.09 (*vs *1.3+0.7, 2.7+1.5 and 0.4+0.05 for “absence” plots,* P *< 0.05). The logistic model revealed an overall prediction success of 86.7%. The percentage of true correctly-predicted positives was 93.3% and the percentage of true correctly-predicted negatives was 80.0% (cut-off level at* p *= 50%). Model results showed that 34.5% of the area provided suitable rabbit habitat (*P *> 50%), distributed over 106 patches. Three clusters of suitable patches were delineated, assuming a critical threshold distance of 200 m between neigh-*

bour patches (distance equal to the mean dispersal ability of rabbits) for their inclusion into the same group. In that way, an area of 508.7 ha (11% of the study area) including the best potential site for restocking was delineated. Results suggested that management efforts should be aimed at promoting the connection between the three habitat-patch clusters. The framework presented provides a method for accurate and rapid assessment of habitats suitable for wild rabbit and could assist managers in identifying the best potential restocking sites.

I. INTRODUCTION

The European wild rabbit, *Oryctolagus cuniculus*, populations declined over the past few decades in the Iberian Peninsula, mainly as a result of habitat destruction, overhunting and diseases, namely myxomatosis and viral haemorrhagic disease (BLANCO and VILLAFUERTE, 1993). Consequently, rabbit populations were depleted and fragmented (FA *et al.*, 1999).

The rabbit is a key species in the Iberian ecosystems, since it is an important prey for predators (SORIGUER, 1983), such as the Iberian lynx, *Lynx pardinus*, and the imperial eagle, *Aquila adalberti* (DELIBES and HIRALDO, 1981; PALOMARES *et al.*, 2001). Thus, conservation of the rabbit is critical for the conservation of these threatened species and the Iberian ecosystems. In addition, the rabbit has also a great economic value, since it is an important game species (ROGERS *et al.*, 1994). Any positive effect on rabbit populations is likely to have a positive impact on human and non-human communities (PALOMARES, 2001).

In the Peneda-Gerês National Park (PGNP), northern Portugal, rabbits are scarce and the remaining populations largely depend on shelter availability, mainly tall scrubs and gaps between rocks (CARVALHO, 2001; CARVALHO and GOMES, 2004). In other regions, where there is a good interspersion between shelter and food rabbits are more abundant (ROGERS and MYERS, 1979; PALOMARES and DELIBES, 1997; VILLAFUERTE and MORENO, 1997).

Habitat models are useful tools to help managers and researchers to predict the presence, distribution or abundance of a species (BUCKLAND and ELSTON, 1993; MORRISON *et al.*, 1998). Therefore, the development of a habitat suitability model for wild rabbit could be an important step to the establishment of management and recovery plans for the species in a given region. Additionally, since habitat suitability influences the success of restocking operations (LETTY *et al.*, 1998), the development of a model could also be a powerful tool to delineate the best locations for successful rabbit releases.

The objective of this study was to develop a framework to identify potential suitable habitat for rabbits and the best release sites for restocking operations in the PGNP. The framework is based on the: (1) construction of a habitat suitability model using logistic regression, (2) identification of suitable habitat by applying regression coefficients with a Geographic Information System (GIS) and (3) delineation of the best potential sites for restocking.

II. MATERIAL AND METHODS

II.1. STUDY AREA

The study was carried out in the PGNP located in northern Portugal, near Montalegre (41°49'N, 07°47'W). The region is situated in the transition area between the Ibero-Atlantic acidiphilous oak woodland vegetation and the Supra-Mediterranean vegetation belt (OZENDA and BOREL, 2000). This area has high land-cover/vegetation formations and a great heterogeneity. Of the total 4,606 ha of surface area, 49.2% is covered by low matorral of *Erica cinerea, Ulex* spp. and *Chamaespartium tridentatum*, 19.3% corresponds to deciduous forests of *Quercus pyrenaica and Q. robur*, 15.0% is agricultural land (pastures included), 9.3% tall scrubland of *Genista* spp. and *Cytisus* spp., 3.2% rocks and 3.6% rural villages and roads (Figure 1). An extensive plateau interrupted by small valleys, with altitudes ranging from 800 to 1,400 m, characterizes the topography of the area. Annual rainfall is 2,000 mm and annual average temperatures range between 7.5 °C and 10 °C.

II.2. DATA COLLECTION

The presence/absence of rabbits was determined on 86 random circular plots of 100 m radius (approximately the area occupied by a family group, VILLAFUERTE 1994), in June-July 2000. Presences were determined by searching for pellets, warrens and direct observation of individuals from a previous study (CARVALHO, 2001; CARVALHO and GOMES, 2004). Rabbits were considered absent when no signs were detected after an exhaustive search on each plot. Additionally, in all "absence plots" night searches were performed with a spotlight, and from hunters data were collected on the location of rabbits killed during the game season, to confirm the absence of rabbits in the sampling plots. Therefore, the potential risk of declaring an absence, when rabbits could be present at very low densities, was minimal.

Rabbits were related to three habitat structure variables that were critical for rabbits in the region (CARVALHO and GOMES, 2004): % cover of tall scrubland (> 1 m), % cover of rocks, and interspersion. Interspersion is a measure of the intermixture of foraging (pasture/fields and matorral) and shelter (tall scrubland, rocks and forest edge) patches. The interspersion index I is expressed as: $P/2(\pi A)^{1/2}$, where P is the perimeter of the edge between shelter and foraging patches, and A the area of the reference plot (3.14 ha) (LITVAITIS *et al.*, 1996: p. 261). For each circular plot, habitat variables were determined by GIS analysis, using a digital land-cover map of the area, with 16 m^2 of resolution, made after aerial orthophotomaps, and ground corrected.

This initial dataset was divided into 56 samples to build the model and 30 samples to evaluate the model.

II.3. HABITAT MODEL

With the rise of new powerful statistical techniques and Geographic Information System (GIS) tools, the development of predictive habitat models has rapidly increased in ecology (GUISAN and ZIMMERMANN, 2000). In this

Figure 1: Land-cover map of the study area, obtained by supervised classification of aerial orthophotomaps of the Peneda-Gerês National Park, northern Portugal. Top right: location of the study area in Portugal.
Figure 1 : Carte d'utilisation du sol de l'aire d'étude obtenue à partir de photographies aériennes et contrôle sur le terrain de la classification des sols. Parc National de Peneda-Gerês, nord du Portugal. Légende, de haut en bas : rocailles, forêt feuillue, matorral, broussailles hautes, terres cultivées, villages/routes/chemins, limites de l'aire d'étude. En haut à droite : localisation de l'aire d'étude au Portugal.

context, logistic regression is gaining importance as a nonparametric, non-linear alternative to parametric procedures. This technique is potentially more robust than parametric procedures to deviations from multivariate normality and equal covariation, and performed similarly, or better, than other techniques applied to presence-absence data (MORRISON *et al.*, 1998; MANEL *et al.*, 1999). Logistic regression habitat models have been used to predict distributions and to map habitat suitability within GIS, with success, and for many wildlife species (*e.g.* GLENZ *et al.*, 2001; ODOM *et al.*, 2001; WOOLF *et al.*, 2002).

The logistic regression model was based on the function (DOBSON, 2001: p. 111):

$$\text{logit}(P) = ß_0 + ß_1x_1 + ß_2x_2 + ... + ß_nx_n, \text{ and}$$
$$\text{logit}(P) = \log[P/(1\text{-}P)] \text{ resulting in}$$
$$P = 1/[1+ \exp(ß_0 + ß_1x_1 + ß_2x_2 + ... + ß_nx_n)].$$

where $ß_0$ is a constant, x_n are habitat variables selected to enter the model, $ß_n$ are regression coefficients adjusted to each variable and P is the probability of occurrence of an event (in the case of rabbit presence).

II.4. MODEL EVALUATION

Thirty plots were used to evaluate the model (15 presences and 15 absences, randomly selected from the original dataset). Evaluation of model performance required the derivation of one matrix of confusion that identified true positive, false positive, false negative and true negative cases predicted by the model. From the values in the matrix of confusion four performance measures were calculated (MANEL *et al.*, 2001): overall prediction success (percentage of all cases corrected predicted), sensitivity (percentage of true positives correctly predicted), specificity (percentage of true negatives correctly predicted) and Cohen's kappa (proportion of all possible cases of presence or absence that are correctly predicted after accounting for chance effects). Kappa values derived at $p = 0.5$ provided a robust indicator of model performance when compared to a more sophisticated receiver-operating characteristic procedure and are unaffected by the prevalence of the target organism (MANEL *et al.*, 2001).

II.5. LOCATING SUITABLE HABITAT

The digital land cover map was used to made three maps representing the percentage of tall scrubland, the percentage of rocks, and interspersion, by a moving window (100 m radius) approach. Values were calculated using all the cells in the window, to be stored in the central cell. This method was applied for all pixels of the entire area like in RITTERS *et al.* (1997). The resulting maps were combined with the help of the logistic regression equation to create a final map, on which the probability of rabbit presence was depicted. This procedure was conducted with MFworks 3.0 (Keigan Systems, Inc.).

The predictions from the model may be used to measure the suitability of sites for the species (BUCKLAND and ELSTON, 1993) and, therefore, the probabilities were reclassified into categories of habitat suitability. Although suitability is a continuum between 0 (totally unsuitable) and 100% (optimum), in a practical sense a site may be considered "suitable" when the probability of rabbit presence is equal or superior to the probability of rabbit absence ($P > 50\%$), and "unsuitable" when the probability of rabbit presence is inferior to the probability of rabbit absence ($P < 50\%$).

It is important to note that each pixel identified as "suitable" represents the centre of a circular area of 3.14 ha (window with 100-m radius) where rabbits may find suitable conditions of tall scrubland, rocks and interspersion. This approach allows to determine the exclusive location of the sites that, at least temporarily, have conditions to support a rabbit nucleus.

Spatial distribution is also a critical aspect to wildlife. As distances between patches of suitable habitat increase, the probability of recolonization / utilization by dispersing individuals decreases. Therefore, we tried to delineate discontinuous clusters of suitable habitat patches with an inter-patch distance that allows recolonization / utilization with some degree of facility by dispersing rabbits. Two patches were considered to belong to the same cluster when the distance between them was < 200 m, *i.e.* the natural dispersal range of the species according to COWAN (1991).

II.6. DELINEATING THE BEST SITES FOR RESTOCKING

In order to maximize chances of survival and establishment, release sites should be surrounded by suitable habitat to comprise movements of rabbits after their release. In a translocation operation carried out in France, the rabbits settled down, on average, at about 200 m from their release warrens (LETTY *et al.*, 2002).

Based on this information, a map depicting the percentage of suitable habitat in a radius of 200 m around each pixel was made. A gradient from 0 (absence of a suitable habitat within a radius of 200 m from the pixel in the centre) to 100% (presence of a continuous area of suitable habitat within a radius of 200 m from the pixel in the centre) resulted from this procedure. The final map was reclassified into 4 classes deemed to represent the potentiality for restocking: very poor, 0-25%; poor, 26-50%; moderate, 51-75%; high, 76-100%. These procedures were performed through GIS overlay facilities using Mfworks 3.0 (Keigan Systems Inc.).

III. RESULTS

III.1. MODEL RESULT AND EVALUATION

Rabbit presence was detected in 44.6% of the 56 sampling plots (rabbit absence = 55.4%). The three variables were significantly associated with rabbit presence when comparing occupied and unoccupied sites (Table I).

The logistic regression model was significant (χ^2 = 31.277; df = 3, $P < 0.0001$; R^2 = 48.5). The % of tall scrubland contributed significantly to the predictive capability of the logistic model ($P < 0.05$) and the % of rocks and interspersion approached significance (Table II). Therefore, we opted for the inclusion of the three variables into the model to retain as much biological meaning as possible.

Applying the model to the 30 plots kept for evaluation, we found that the model correctly classified 93.3% (n = 15) of the plots with rabbit presence (*i.e.* sensitivity) and 80.0% (n = 15) of the plots without rabbit presence (*i.e.* specificity), for a threshold probability for positive classification of 0.5 (cut-off level at p = 50%). Correct classifications were 86.7% and Cohen's Kappa value derived at p = 0.5 was 0.73.

TABLE I
Comparisons of values of three habitat variables at circular plots of 100-m radius where wild rabbits, *Oryctolagus cuniculus*, were absent (n = 31 plots) and present (n = 25 plots), in the Peneda-Gerês National Park, northern Portugal, in June-July 2000. $I = P/2(\pi A)^{1/2}$, where P is the perimeter of the edges between shelter and foraging patches, and A the area of the plot (3.14 ha). Mann-Whitney test.
TABLEAU I
Comparaisons des valeurs prises par trois variables de l'habitat (interspersion I, % du couvert en rocailles, % du couvert en broussailles hautes) sur des placettes circulaires de 100 m de rayon où les lapins, *Oryctolagus cuniculus*, étaient présents (n = 31 placettes) et où ils ne l'étaient pas (n = 25 placettes) dans le Parc National de Peneda-Gerês au nord du Portugal en juin-juillet 2000. $I = P/2(\pi A)^{1/2}$, où P est le périmètre des bordures entre les secteurs fournissant un couvert de protection et ceux founissant de la nourriture, et A la surface de la placette (3,14 ha). Test de Mann-Whitney.

Habitat variable	Absence of rabbits (n = 31 plots)		Presence of rabbits (n = 25 plots)		U	P
	Mean	SE	Mean	SE		
Interspersion (I)	0.382	0.050	0.887	0.089	129	< 0.001
Rocks (%)	1.3	0.7	9.9	3.4	279	< 0.05
Tall scrubland (%)	2.7	1.5	16.3	3.8	197	< 0.01

TABLE II
Habitat variables with regression coefficient estimates ($ß_i$) obtained by logistic regression analysis of wild rabbit, *Oryctolagus cuniculus*, occurrence data at 56 circular plots of 100-m radius, in the Peneda-Gerês National Park, northern Portugal, in June-July 2000.
TABLEAU II
Estimations des coefficients de régressions ($ß_i$) obtenues à l'aide d'une analyse logistique de régression des occurrences de lapin, *Oryctolagus cuniculus*, en fonction de trois variables de l'habitat (interspersion, % du couvert en rocailles, % du couvert en broussailles hautes) mesurées sur 56 placettes circulaires de 100 m de rayon dans le Parc National de Peneda-Gerês au nord du Portugal en juin-juillet 2000.

Habitat variable	Estimates ($ß_i$)	Standard deviation	t ratio	P
Constant ($ß_0$)	-2.649	0.772	-3.434	< 0.05
Interspersion	2.234	1.279	1.747	0.087
Rocks (%)	11.390	5.949	1.914	0.061
Tall scrubland (%)	8.215	3.312	2.481	< 0.05

III.2. LOCATING SUITABLE HABITAT

The logistic model was used to draw an illustrative map of the probability of rabbit presence. Probabilities were reclassified into categories of habitat suitability (Figure 2). Of the total study area, 34.5% provided suitable rabbit habitat ($P > 50\%$), distributed over 106 patches.

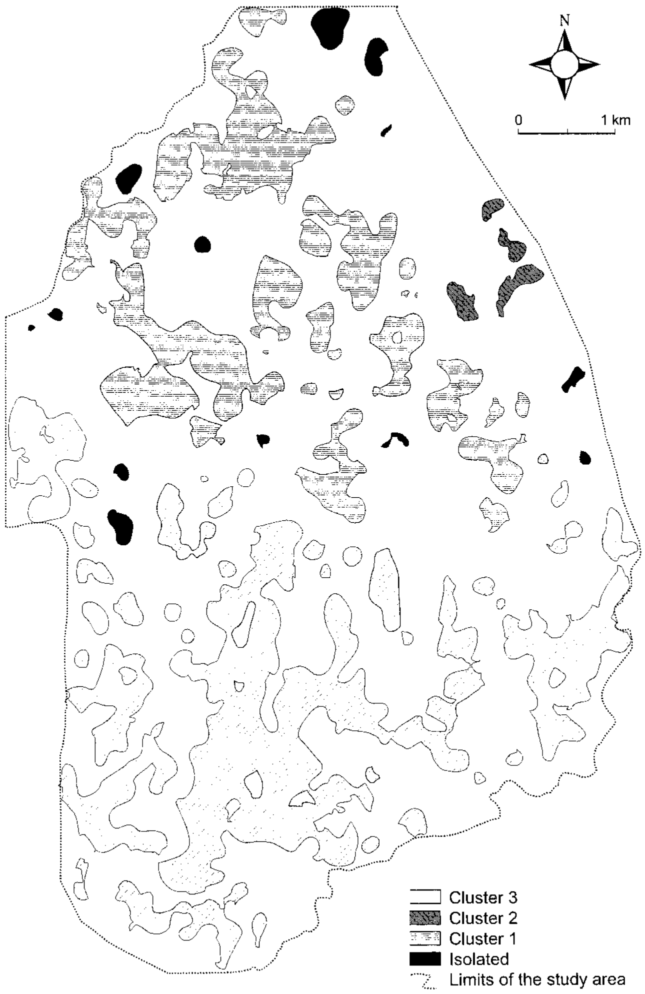

Figure 2: Location of patches with a habitat suitable for the wild rabbit, *Oryctolagus cuniculus*, in the Peneda-Gerês National Park, northern Portugal, by the analysis of the logistic regression of the presence/absence of rabbits in June-July 2000 at 56 circular plots of 100-m radius, on habitat variables. Patches were considered to belong to a same discontinuous cluster when the distance between them was < 200 m.

Figure 2 : Repérage des secteurs où l'habitat est favorable au lapin, *Oryctolagus cuniculus*, dans le Parc National de Peneda-Gerês au nord du Portugal, effectué à l'aide d'une analyse de régression logistique de la présence/absence de lapins en juin-juillet 2000 sur 56 placettes circulaires de 100 m de rayon, en fonction de variables de l'habitat. Les secteurs ont été affectés à un même groupe discontinu (cluster) lorsque la distance les séparant était < 200 m. Légende, de haut en bas : groupe 3, groupe 2, groupe 1, isolé (secteur), limites de l'aire d'étude.

Suitable habitat patches were grouped into 3 clusters, assuming a critical threshold distance of 200 m to include two patches in the same cluster (Table III). These 3 groups comprised most suitable habitat patches (81%, n = 106). Only 20 patches were considered to be isolated, *i.e.* distance to the nearest neighbour > 200 m. The area of suitable habitat varied widely among the 3 clusters, cluster II area being almost insignificant in comparison with the areas of the two others. Clusters I and III comprised a high number of habitat patches representing 545 ha and 925 ha respectively.

TABLE III
Structure of three discontinuous clusters of patches with a habitat suitable for the wild rabbit, *Oryctolagus cuniculus*, in the Peneda-Gerês National Park, northern Portugal. Patches were considered to belong to the same cluster when the distance between them was < 200 m. Suitable habitat was located by applying logistic regression coefficients to the digital data of a land cover map of the area.
TABLEAU III
Structure [nombre de secteurs, surface (ha) d'un secteur (moyenne et écart type), surface totale (ha) de l'habitat favorable] de trois groupes discontinus de secteurs ayant un habitat favorable au lapin, *Oryctolagus cuniculus*, dans le Parc National de Peneda-Gerês au nord du Portugal. Les secteurs ont été affectés à un même groupe lorsque la distance les séparant était < 200 m. L'habitat favorable a été localisé en appliquant les coefficients d'une analyse logistique de régression aux données digitalisées d'une carte d'utilisation du sol de l'aire d'étude.

Feature	Cluster of suitable habitat		
	Cluster I	Cluster II	Cluster III
Number of patches	31.0	8.0	47.0
Mean patch area (ha)	17.6	2.9	19.7
SD	31.6	3.4	68.8
Total suitable habitat area (ha)	545.0	23.1	924.6

III.3. DELINEATING THE BEST SITES FOR RESTOCKING

The percentage of suitable habitat within a buffer distance of 200 m around each pixel was calculated and reclassified into categories of potentiality for restocking (Figure 3). Of the total surface area, 508.7 ha was classified as having high potential for restocking, which corresponded to 11% of the area.

IV. DISCUSSION

IV.1. METHODOLOGICAL APPROACH

The current status of rabbits in the PGNP may be the result of factors other than poor habitat conditions, such as hunting management and diseases. Therefore, the relationship between the presence of rabbits and the habitat

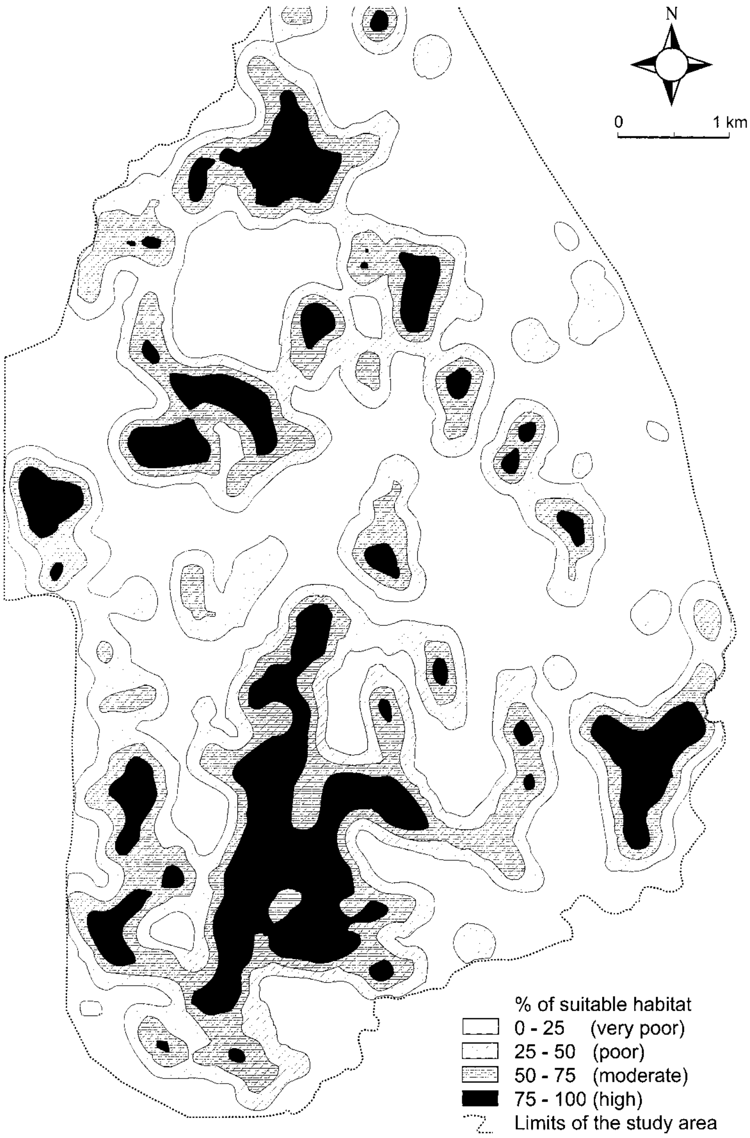

Figure 3: Location of the habitat favourable for the restocking of wild rabbits, *Oryctolagus cuniculus*, in the Peneda-Gerês National Park, northern Portugal, according to habitat potentialities for restocking, *i.e.* percentage of suitable habitat present in a radius of 200 m around each pixel centre of a map of habitats suitable for rabbits. Suitable habitat was located by logistic regression analysis of the presence/absence of wild rabbits in June-July 2000 at 56 circular plots of 100-m radius, on habitat variables.
Figure 3 : Repérage de l'habitat favorable au repeuplement en lapins, *Oryctolagus cuniculus*, dans le Parc National de Peneda-Gerês au nord du Portugal, en fonction des potentialités de l'habitat (très mauvaise, mauvaise, modérée, haute), c'est-à-dire en fonction du pourcentage d'habitat favorable présent dans un rayon de 200 m autour du centre de chacun des pixels d'une carte d'habitat favorable aux lapins. L'habitat favorable a été repéré grâce à une analyse de régression logistique de la présence/absence des lapins en juin-juillet 2000 sur 56 placettes circulaires de 100 m de rayon en fonction de variables du milieu.

types may be distorted by this bias. But the use of qualitative data (presence/absence of rabbits) minimizes this source of bias. Otherwise, that approach introduces another limitation: "good habitats" (*i.e* with high densities of rabbits) cannot be identified but only "acceptable habitats" (*i.e.* with the presence of rabbits).

In the modelling process the distance of 200 m was assumed to be the dispersing capability of rabbits. This is a conservative approach since other studies indicate that rabbits are capable of dispersing over longer distances (CALVETE *et al.*, 1997).

We chose to model habitat suitability at the pixel level, considering the habitat characteristics in an area of 100-m radius around each cell. Therefore, it must be emphasized that each pixel (16 m^2) identified as suitable represents, in fact, the centre of a 3.14-ha circle. This approach allowed to eliminate all sites too small to support even a small rabbit nucleus.

Despite the limitations of the methodology, this study has provided detailed data on rabbit distribution, that could serve as a useful baseline for future surveys, and to implement management actions in the region.

IV.2. MODEL RESULT AND EVALUATION

Our model revealed a high overall prediction success and high values of specificity and sensitivity, suggesting that it is useful to predict the occurrence of rabbits within the study area. The kappa value was 0.73 indicating a good model performance (MANEL *et al.*, 2001).

Results confirmed the adequacy of 3 variables to predict suitable habitat for rabbits in the region. CARVALHO and GOMES (2004) suggested that the distribution pattern of wild rabbits in the PGNP seemed to be determined by shelter availability and interspersion of shelter/openfield. This could be interpreted as an anti-predator strategy (JAKSIC and SORIGUER, 1981; VILLAFUERTE, 1994; VILLAFUERTE and MORENO, 1997; MARTINS and BORRALHO, 1998; BANKS *et al.*, 1999).

IV.3. LOCATING SUITABLE HABITAT

Model results show that nearly one third of the total surface area was suitable for rabbits, but its distribution was patchy. The size of the patches is a critical factor that determines patch occupancy by lagomorph species (*e.g.* LITVAITIS and VILLAFUERTE, 1996; FORYS and HUMPHREY, 1999). In the PGNP the majority of patches are small. Hence, the small suitable patches could support, at least temporarily, a small rabbit nucleus and during dispersal could act as stepping-stones between bigger patches (MORRISON *et al.*, 1998). Additionally, many of the suitable smaller sites were found in close proximity to each other (< 200 m) and when taken together they represent a considerable amount of suitable habitat. In this context, three habitat-patch clusters were delineated, observing a critical distance of 200 m between patches for inclusion in the same group. These clusters should be taken as functional groups that ensure a reasonable chance of survival for rabbits dispersing between patches. Management efforts should be aimed at promoting the connection among these clusters. This could be achieved through habitat restoration by favouring the growth of small-scattered patches of natural tall shrubs and the establishment of new ones. Controlled fires or other types of selective clearing focused on short shrubs, while avoiding tall shrubs may be beneficial to rabbits when applied to regenerate herbaceous vegetation and increase the interspersion between shelter and food (MORENO and VILLAFUERTE, 1995; PALOMARES, 2001).

IV.4. IMPLICATIONS FOR RESTOCKING

The rabbit populations in the PGNP are depleted. Therefore, the introduction of individuals by restocking could be a powerful tool to restore effective population size. To maximize chances of survival and the establishment of rabbit colonies, restocking efforts should be directed to the delineated sites.

We must emphasize that, when applying this framework to restocking operations, it is advisable to model different distances to comprise individual variation (*e.g.* CALVETE *et al.*, 1997). It is also important to stress that, whatever the quality of the model output, those sites identified as suitable must always be investigated in the field, so that particular characteristics of the sites may be identified and evaluated.

By applying the presented framework, managers may assess habitat suitability and potential release sites, while enhancing the probability of success in restocking. Future work should be directed to test this framework in the field.

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UN MODÈLE D'HABITAT FAVORABLE AU LAPIN (*ORYCTOLAGUS CUNICULUS*) ET SON UTILISATION POUR LE REPEUPLEMENT

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MOTS-CLÉS : Lapin, *Oryctolagus cuniculus*, système d'information géographique, modèle d'habitat, régression logistique, repeuplement, Portugal.

RÉSUMÉ

Le lapin, Oryctolagus cuniculus*, est une espèce-clé dans les écosystèmes ibériques. Cependant ses populations sont en sérieux déclin. C'est pourquoi la mise au point de modèles d'habitat favorable au lapin constitue une étape importante pour faire des plans destinés à l'aménagement et à la reconstitution des populations. Un tel modèle a été mis au point pour le lapin dans les 4 606 ha du Parc National de Peneda-Gerês dans le nord du Portugal. La démarche a consisté en 3 étapes : (1) construction d'un modèle en utilisant la régression logistique de la présence/absence de lapins sur des variables de l'habitat, (2) localisation sur un plan, à l'aide d'un système d'information géographique (GIS), de l'habitat favorable par application des coefficients de régression trouvés au cours de l'étape 1 aux données digitalisées d'une carte d'utilisation du sol, et (3) délimitation des meilleurs sites aptes au repeuplement. La présence/absence des lapins a été déterminée en juin-juillet 2000 par la présence/absence de crottes, terriers ou individus sur 86 placettes circulaires de 100 m de rayon choisies au hasard (soit 3,14 ha par placette, correspondant à la surface occupée par un groupe familial en été). Elles ont été réparties en 56 placettes destinées à la construction du modèle et 30 placettes (15 avec présence de lapins et 15 sans lapins) à la validation croisée du modèle. Les variables de l'habitat mesurées ont été : le pourcentage de couvert en broussailles hautes, le pourcentage de couvert en rocailles et l'interspersion (un indice mesurant le degré d'interpénétration des zones fournissant de la nourriture et de celles fournissant un couvert protecteur). Ces variables ont été calculées pour tous les pixels d'une carte paysagère digitalisée en utilisant une fenêtre amovible de 100 m de rayon. Les placettes où le lapin était présent avaient en moyenne 10 + 3,4 % (erreur type) du couvert en rocailles, 16,3 ± 3,8 % de couvert en broussailles hautes, et un indice d'interspersion de 0,9 ± 0,09 (contre 1,3 ± 0,7 % ; 2,7 ± 1,5 % et 0,4 ± 0,05 pour les placettes sans lapins,* P *< 0,05). La réussite prédictive globale du modèle logistique a été de 86,7 %. Le pourcentage de prédiction correcte de la présence a été de 93,3 % et celui de l'absence de 80,0 % (avec un seuil de probabilité limite* p *= 50 %). En appliquant le modèle à l'aire d'étude nous avons trouvé que 34,5 % de la surface étaient constitués d'habitat favorable au lapin (*P *> 50%) réparti en 106 secteurs. Les secteurs ont été regroupés en 3 groupes de secteurs. Le regroupement de deux secteurs dans un même groupe a été fait lorsqu'ils étaient distants de moins de 200 m l'un de l'autre (distance corres-*

pondant à la capacité moyenne de dispersion des lapins). Une surface de 508,7 ha (11 % de l'aire d'étude) renfermant les meilleurs sites favorables au repeuplement a ainsi pu être délimitée. Ces résultats impliquent que les espaces situés entre les 3 groupes de secteurs fassent l'objet d'aménagements. La démarche ici présentée est une méthode permettant la mise en évidence rapide et précise de l'habitat favorable au lapin. Elle permet aussi de venir en aide aux aménageurs pour l'identification des meilleurs sites destinés au repeuplement.

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