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Otter (*Lutra lutra*) distribution modeling at two resolution scales suited to conservation planning in the Iberian Peninsula

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Abstract

We used the results of the Spanish Otter Survey of 1994–1996, a Geographic Information System and stepwise multiple logistic regression to model otter presence/absence data in the continental Spanish UTM 10×10-km squares. Geographic situation, indicators of human activity such as highways and major urban centers, and environmental variables related with productivity, water availability, altitude, and environmental energy were included in a logistic model that correctly classified about 73% of otter presences and absences. We extrapolated the model to the adjacent territory of Portugal, and increased the model's spatial resolution by extrapolating it to 1×1-km squares in the whole Iberian Peninsula. The model turned out to be rather flexible, predicting, for instance, the species to be very restricted to the courses of rivers in some areas, and more widespread in others. This allowed us to determine areas where otter populations may be more vulnerable to habitat changes or harmful human interventions.

Keywords: Otter distribution; Spatial modeling; GIS; Conservation; Iberian Peninsula

1. Introduction

The Eurasian otter (*Lutra lutra* L., 1758) is a semi-aquatic territorial carnivore which feeds mainly on aquatic prey and whose habitat is usually linked to the existence of relatively clean freshwater, available shelter (riparian vegetation, rocky structures and others) and abundant prey (Vega and Valladares, 1996; Ruiz-Olmo and Delibes, 1998; Trindade et al., 1998). The otter's worldwide distribution has shown a sharp decline in the last decades (Elliot, 1983; MacDonald and Mason, 1983), although a general recovery has been noted in recent years (Ruiz-Olmo and Delibes, 1998). The species' conservation status has justified its inclusion in the List of Rare and Threatened Mammals of the Council of Europe, in Appendix II of the Berne Convention, in Appendices II and IV of the Habitat Directive of the European Union, in Appendix I of the CITES and in the 2000 IUCN Red List of Threatened Species (Hilton-Taylor, 2000), where it is classified as vulnerable.

Iberian otters have some differences in comparison with the ones from the rest of Europe: They are smaller (Valladares et al., 1996; Vega and Valladares, 1996; Ruiz-Olmo et al., 1998) and, at least in some regions, have a lower mean number of cubs per litter (Ruiz-Olmo, 1994). Nevertheless, these differences do not justify that they be considered as a separate sub-species (Delibes, 1990). The otter is classified as vulnerable in the Red Book of the Vertebrates of Spain (Blanco and González, 1992) and included in Appendix II (species of special interest) of the Royal Decree 439/90, which regulates the National Catalogue of Threatened Species. In Portugal, the otter is classified as data deficient in the Red Book of the Vertebrates (S.N.P.R.C.N., 1990); however, the Portuguese otter survey of 1995 (Trindade et al., 1998) showed that its situation is very favorable, its distribution being practically generalized throughout the country. The Portuguese population of otters is presently considered one of the most viable in Europe (Trindade et al., 1998).

Traditionally, investigation on the factors that affect otter conservation in Spain has been based on small-scale studies or on local factors such as habitat features (e.g. Elliot, 1983; Nores et al., 1990, 1991; Bueno and

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Bravo, 1998). However, as Ricklefs (1987) and Levin (1992) pointed out, local populations are also likely affected by historical and environmental processes that act on a regional or continental scale. The study of regional-scale processes is, therefore, important to complement ecological studies carried out on more local scales (Vaughn and Taylor, 2000).

The large-scale modeling of species' distributions is becoming a fundamental tool for ecosystem management and biological conservation, as it provides a broader geographic perspective that works as a context for local studies. Spatial modeling underwent a great advance in the last years with the progresses in spatial statistics and the generalization of the use of Geographic Information Systems (GIS). These systems, designed to acquire, store, manipulate, transform, combine, analyze and represent geographically referenced data, allow for a greater scope and precision in forecasting the presence of species in several kinds of geographical units. With the help of GIS and large-scale distribution models, conservation programs may have more satisfactory results as the factors that affect, on a larger scale, the survival of populations are taken into account (Corsi et al., 1999).

Two nation-wide otter surveys have been previously carried out in Spain, the first one in 1984–1985 (Delibes, 1990) and the second in 1994–1996 (Ruiz-Olmo and Delibes, 1998). Barbosa et al. (2001) analyzed the results of this second survey, assessing the relative contribution of spatial, environmental and human factors on the proportion of positive sites of otter in each Spanish province, but such a study is too coarse to infer the eventual impact of the construction of a dam or a transportation infrastructure, for example, on a particular otter population. Otter surveys can, however, be used to elaborate distribution models based on presence probabilities that, when extrapolated to a finer resolution scale, allow a more detailed knowledge of the species' potential distribution. In this way, conservation planning might incorporate the identification of areas where otter populations could be more vulnerable to habitat destruction or fragmentation.

Our aims are to model the distribution of the Eurasian otter in continental Spain using the UTM 10×10-km squares as territorial units, to check the behavior of the model when extrapolated to continental Portugal, and to extrapolate it to a deductive model of otter distribution in 1×1-km squares in the whole Iberian Peninsula.

2. Methods

2.1. Study area

The Iberian Peninsula, situated at the extreme southwest of Europe, covers an area of approximately 580,000 km^2 and includes the continental territories of Spain and Portugal. Most of its main mountain ranges have a marked longitudinal component, so that the main rivers flow longitudinally to the Atlantic Ocean and to the Mediterranean Sea. The Mediterranean watershed is narrower and most of its rivers have a seasonal regimen, whereas the Atlantic watershed is wider and its rivers have a more abundant and permanent flow (Bosque and Vilà, 1989). The climate of the Peninsula is heterogeneous, with a longitudinal gradient of precipitation and a latitudinal gradient of both precipitation and temperature (Capel, 1981). It has a marked peninsular character, since the isthmus that connects it with the rest of the continent is relatively narrow (about two-fifths of its northern boundary) and is crossed by the Pyrenees, which hinders the biotic and abiotic interactions with the adjacent territories.

2.2. Distribution data

We recorded otter presence/absence data for each of the 5187 continental Spanish and 1000 continental Portuguese UTM 10×10-km squares. Data on otter distribution in Spain are the result of the national otter survey carried out in 1994–1996 (Ruiz-Olmo and Delibes, 1998) and were converted into presence/absence data in UTM squares. Data on otter distribution in Portugal are the result of the national otter survey carried out by Trindade et al. (1998) in 1995, where each UTM square was surveyed. Surveyors looked for otter signs in all kinds of aquatic habitats, including river and lake shores, narrow streams, drainage ditches, and dams, for example. The distribution data obtained are shown in Fig. 1.

2.3. Independent variables

We recorded variables related to environmental conditions, human activity and spatial situation to induce the factors that affect otter presence. Given that the processes that account for species' distribution patterns are frequently different on different scales, we only used a set of variables that hypothetically act on a 1×1-km scale as well as on a 10×10-km one. We therefore excluded variables related to habitat heterogeneity or land roughness such as the altitude range. Surface area was not considered because the deductive model was to be based on equal-area 1×1-km squares. We also cared not to include variables whose range on a 1×1-km scale significantly exceeded its range on a 10×10-km one, as was the case of mean slope. The 25 variables used and their sources are listed in Table 1.

Spatial autocorrelation, which is present in the independent variables as well as in the distribution data, can lead to loss of power of the model as it violates the assumption of most standard statistical tests that observations are

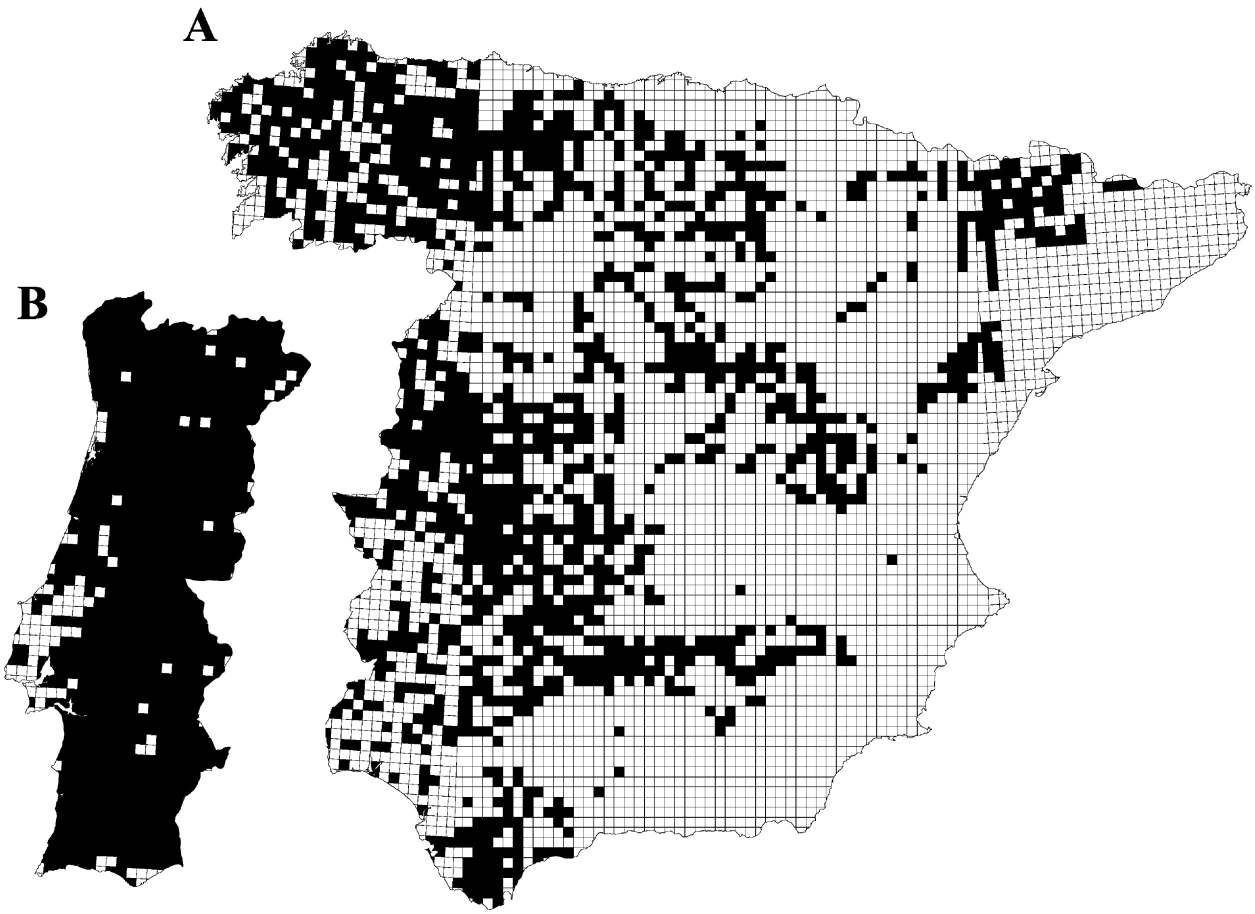

Fig. 1. Otter *Lutra lutra* distribution based on UTM 10×10-km squares in Spain (A) and in Portugal (B). Black squares represent otter presences. (A: source data taken from Ruiz-Olmo and Delibes, 1998; B: adapted from Trindade et al., 1998).

independent (Legendre and Fortin, 1989; Legendre, 1993). Some authors choose to ignore spatial autocorrelation (Romero and Real, 1996; Brito et al., 1999; Teixeira et al., 2001), while others attempt to minimize it by using subsets of non-adjacent samples within the study area (e.g. Brito et al., 1999). However, Legendre (1993) argued that spatial structuring should be included in the models as it is functional in ecosystems, and that the use of subsets leads, additionally, to a significant loss of information. In the present study, we used all the UTM 10×10-km squares in the study area and included spatial variables in the analysis to take into account the possible spatial structuring of the distribution data.

We digitized the variables using the CartaLinx 1.2 software and processed them using the Idrisi GIS software. Continuous climatic variables were interpolated from isoline maps with the Idrisi32 TIN and TINSURF modules performing parabolic bridge and tunnel edge removal. We then obtained mean values of the variables for each UTM 10×10-km square, using the digital UTM grid maps obtained from the Área de Defensa Contra Incendios Forestales (DGCN, Ministerio de Medio Ambiente) (Spain) and the Laboratório de Cartografia Biológica da Universidade de Évora (Portugal).

2.4. Statistical analyses

The potential distribution area of a species relates its presence to certain conditioning factors (Bustamante, 1997). Several methods allow for the determination of potential distribution areas, some of them in terms of probability of occurrence of the species in each geographic unit (Brito et al., 1999; Teixeira et al., 2001). In the present work we used multiple logistic regression (Hosmer and Lemeshow, 1989), a technique widely used in the spatial modeling of species' distributions (e.g. Decarie et al., 1995; Romero and Real, 1996; Franco et al., 2000; Kleinschmidt et al., 2000), including the otter (Kemenes and Demeter, 1994; Madsen and Prang, 2001). It produces a probabilistic model that predicts a binary dependent variable, as is the case of presence/absence data, from a set of discrete or continuous independent variables. The logistic regression model has the form

$$P = \frac{e^y}{1 + e^y} \quad (1)$$

where P is the probability of occurrence of the species, e is the basis of the Napierian logarithm, and y is a regression equation in the form

Table 1
Variables used to model otter distribution in Spain

Code	Variable
HJN	Mean relative air humidity in January at 07:00 h (%) (1)
HJL	Mean relative air humidity in July at 07:00 h (%) (1)
HR	Annual relative air humidity range (%) (=|HJN-HJL|)
PET	Mean annual potential evapotranspiration (mm) (1)
AET	Mean annual actual evapotranspiration (mm) (=min[PET, P])
I	Mean annual insolation (h/year) (1)
SR	Mean annual solar radiation (kwh/m^2/day) (1)
TJN	Mean temperature in January (°C) (1)
TJL	Mean temperature in July (°C) (1)
T	Mean annual temperature (°C) (1)
TR	Annual temperature range (°C) (= *TJL-TJN*)
DF	Mean annual number of frost days (minimum temperature $\leqslant 0$ °C) (1)
DP	Mean annual number of days with precipitation $\geqslant 0.1$ mm (1)
P	Mean annual precipitation (mm) (1)
MP24	Maximum precipitation in 24 h (mm) (1)
RMP	Relative maximum precipitation (=MP24/P)
PI	Pluviometric irregularity (2)
RO	Mean annual run-off (mm) (3)
SP	Soil permeability (3)
A	Mean altitude (m) (4)
DH	Distance to the nearest highway (km) (5)
D100	Distance to the nearest town with more than 100,000 inhabitants (km) (5)
D500	Distance to the nearest town with more than 500,000 inhabitants (km) (5)
LA	Mean latitude (°N) (5)
LO	Mean longitude (°W) (5)

Sources: (1) Font (1983). (2) Spain: Montero de Burgos and González-Rebollar (1974). (3) Spain: I.G.M.E. (1979), Portugal: http://snig.cnig.pt/snig/framemg.htm; (4) http://www.etsimo.uniovi.es/~feli/data/datos.html(5) I.G.N. (1999). Data on the number of inhabitants of the urban centers were taken from the Instituto Nacional de Estadística (http://www.ine.es) for Spain and from the Enciclopédia Universal (http://www.universal.pt) for Portugal.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n \quad (2)$$

where β_0 is a constant and β_1, β_2, ..., β_n are the coefficients of the n independent variables x_1, x_2, ..., x_n that significantly affect the probability of occurrence of the species (Tabachnick and Fidell, 1996).

By definition, the logistic function is symmetric and its inflection point corresponds to a P value of 0.5, which is usually used as a cut-off point, or probability threshold, above which to assume the species' presence. In this way, we can classify a square as presence or absence according to the model. Misclassification can happen due to reduced sensitivity or specificity of the model, sensitivity being the ability of the model to correctly classify the species' presences, and specificity referring to the correct classification of absences (Brito et al., 1999). However, when the number of presences in the study area is different from that of absences, the logistic regression within the function's domain is not symmetrical, but rather deviates towards the extreme that presents a greater number of cases. In these situations, there is a disagreement between the logistic function and the species' response to the environmental conditions (Rojas et al., 2001). The value 0.5 is indeed the probability threshold above which the species is more likely to be present than it is to be absent, but does not necessarily correspond to the environmental threshold above which the species is more likely to be present than expected at random (i.e. than expected considering the proportion of presences in the study area).

We represented the correct classification rates (CCR) for presences and for absences at all possible cut-off points between 0 and 1 with intervals of 0.1, so obtaining two graphics that cross at the threshold where the same proportion of presences and absences are correctly classified. We could also represent the CCR for all the squares, regardless of whether they are presences or absences, and choose the probability threshold where this percentage is highest (Brito et al., 1999; Franco et al., 2000). However, the total CCR of a model is more affected by the CCR of the predominant class, in this case absences, and this does not take into account that sensitivity should be given more importance than specificity, since presences have been confirmed while absences can be due to incomplete or ineffective sampling. We opted for representing the average between sensitivity and specificity and choosing, as the probability threshold, its highest value among the ones that correctly classify at least as much presences as absences (Rojas et al., 2001). We also evaluated the validity of the model in Portugal by checking its sensitivity and specificity in this country at this probability threshold.

The regression equation was then introduced in the Idrisi *Image Calculator* and used to create an image representing otter presence probability for the whole Iberian Peninsula in 1×1-km squares, since the independent variables were represented with approximately this spatial resolution.

3. Results and discussion

3.1. Fit of the model to the observed distribution

Otter presence probability values in each continental Spanish UTM 10×10-km square, according to the logistic function obtained (Fig. 2), are represented in Fig. 3. As can be seen by comparing Figs. 1 and 3, the predictions of the model closely match the distribution data available for Spain, since neither high probabilities were predicted in large areas where otters are absent from nor low probabilities appear in areas with conspicuous otter presence. The sensitivity and specificity of the classifications at each cut-off point are presented in Fig. 4. The best cut-off point corresponds to the *P* value 0.29, where approximately 73% of the presences and absences are correctly classified.

When extrapolated to Portugal (Fig. 5), the Spanish model has, at the 0.29 probability threshold, a high sensitivity (approximately 98%) and a low specificity (ca. 8%; Fig. 6), i.e. otters are predicted to be present in the vast majority of the continental Portuguese UTM 10×10-km squares. Consequently, otter absences in Portugal are probably due to non-analyzed factors such as water pollution or food availability.

3.2. The selected factors

For an effective conservation strategy, it is essential to determine which factors may be affecting the present populations of otters on a broad scale (MacDonald and Mason, 1983; Antúnez and Mendoza, 1992). The model obtained seems to hold a high predictive potential, which probably indicates that most of the important factors are taken into account. However, as this is a statistical model that was not designed to select between alternative explanatory hypotheses of otter distribution, some of the included variables (Table 2) might act as surrogates of other important factors not explicit in the logistic function. Factors such as water pollution or food availability, for example, were not available on UTM 10×10-km squares, but the effects of distance to main cities or water availability could be partially explained by them.

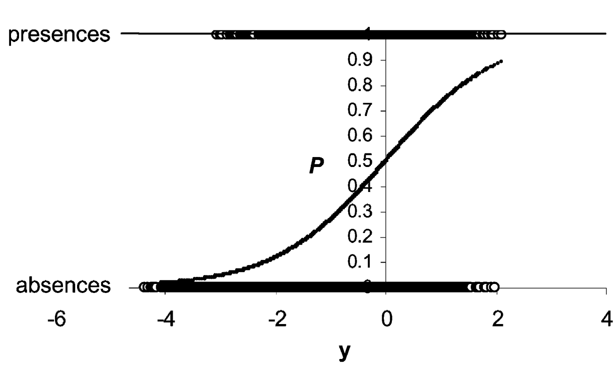

Fig. 2. Logistic function resulting from stepwise regression of otter presence/absence data in the UTM 10×10-km squares of continental Spain on the variables listed in Table 1. *P*: otter presence probability; *y*: regression equation whose variables and coefficients are shown in Table 2.

Spatial autocorrelation seems to be important in the distribution of the otter in the Spanish UTM 10×10-km squares, since geographic longitude is the first variable to enter the model, with the highest partial correlation coefficient with otter presence, and latitude is also included (Table 2). The longitudinal gradient in the distribution of the otter in Spain was noted by Elliot (1983) and by Delibes and Rodríguez (1990), who found that otters are more common in the western than in the eastern half of the country. This trend continues towards Portugal, where otter presence was confirmed in nearly 90% of the UTM 10×10 km squares (Trindade et al., 1998; Fig. 1).

Spatial autocorrelation in the distribution of a species may result from the influence of environmental and human factors that are also spatially autocorrelated (Legendre and Fortin, 1989; Borcard et al., 1992), or from processes that are inherent to its own population dynamics (e.g. contagious biotic processes such as reproduction, migration, and mortality) (Legendre, 1993). Barbosa et al. (2001) found that 45.6% of the variation in the proportion of positive sites of otter in the Spanish provinces was explained by geographic longitude, and attributed 18% of this variation to pure longitudinal structuring related to otter population dynamics. According to this interpretation, an otter population can only expand to its surrounding area, whereas areas with adequate conditions for the species will not be naturally colonized if there are no otter populations nearby (Ruiz-Olmo and Delibes, 1998), thus producing a purely spatial structuring in otter distribution. The mainly longitudinal character of this spatial structure may be due to the fact that most of the main Iberian rivers flow westward.

The increase of otter presence probability with the distance to major urban centers and to highways points to the negative influence of these indicators of human activity on this species. The proximity to major towns is often suggested as harmful for otters, especially due to the water contamination they generate downstream (Delibes and Rodríguez, 1990; Ruiz-Olmo and Delibes, 1998). This urban contamination included PCBs, which are industrially-used organochlorine compounds (Jeff-

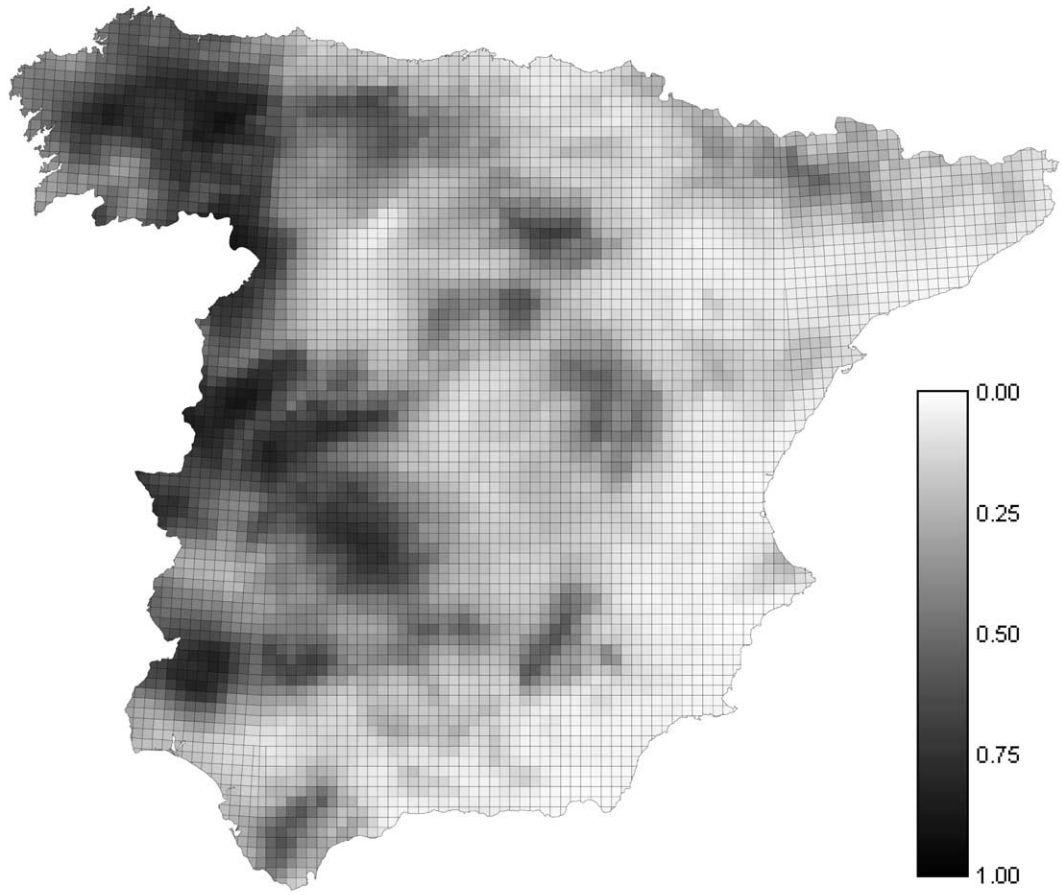

Fig. 3. Otter presence probability in each UTM 10×10-km square of continental Spain, according to the logistic regression model obtained.

eries and Hanson, 2002) and have been reported to contribute to the otter decline in Spain (Ruiz-Olmo and Delibes, 1998; Ruiz-Olmo et al., 2002).

The use of organochlorine pesticides in agriculture has also been reported as a major cause of the decline in otter populations (Gutleb, 2002; Jefferies and Hanson, 2002; Ruiz-Olmo and Delibes, 1998; Ruiz-Olmo et al.,

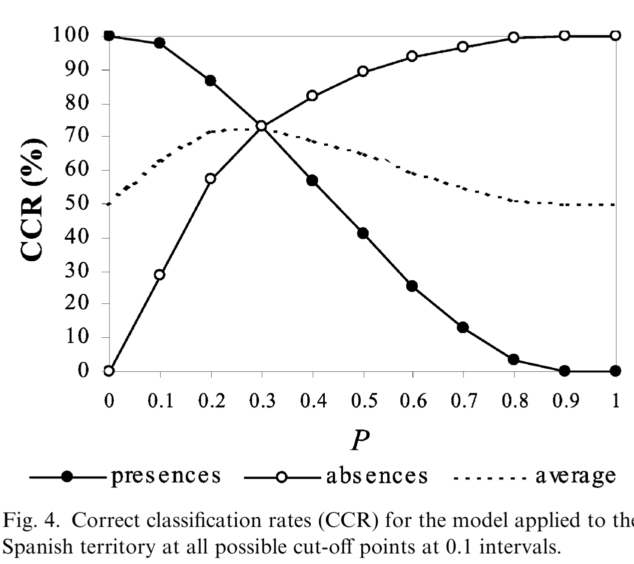

Fig. 4. Correct classification rates (CCR) for the model applied to the Spanish territory at all possible cut-off points at 0.1 intervals.

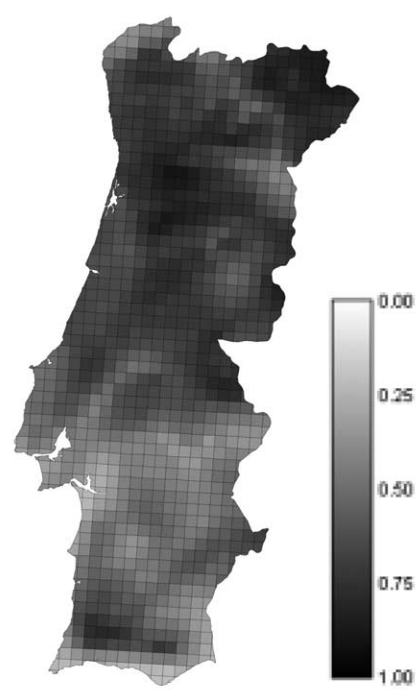

Fig. 5. Otter presence probability in UTM 10×10-km squares of continental Portugal, according to the logistic regression model obtained for Spain.

Table 2
Variables included in the model and their coefficients (β), standard errors (S.E.), partial correlation coefficients (R), Wald test values (Wald, 1943) and significance (P). The variables are ranked according to their order of entrance in the model. Variable codes as in Table 1

Variable	β	S.E.	R	*Wald*	P
LO	−0.2705	0.0191	−0.1780	200.7216	0.0000
D100	0.0034	0.0014	0.0241	5.6296	0.0177
AET	0.0039	0.0004	0.1261	101.7620	0.0000
TJN	−0.1637	0.0503	−0.0370	10.5924	0.0011
DH	0.0112	0.0018	0.0757	37.9469	0.0000
A	−0.0010	0.0002	−0.0455	14.9769	0.0001
SR	0.0170	0.0023	0.0908	53.7026	0.0000
LA	0.2664	0.0588	0.0544	20.5307	0.0000
D500	0.0031	0.0008	0.0489	16.9962	0.0000
P	0.0006	0.0002	0.0422	13.1742	0.0003
SP	−00.1353	0.0489	−0.0300	7.6473	0.0057
HJL	0.0267	0.0065	0.0484	16.7091	0.0000
TJL	0.1483	0.0364	0.0482	16.5676	0.0000
T	−0.1301	0.0599	−0.0208	4.7109	0.0300
Constant	−25.5063	3.6186	–	49.6849	0.0000

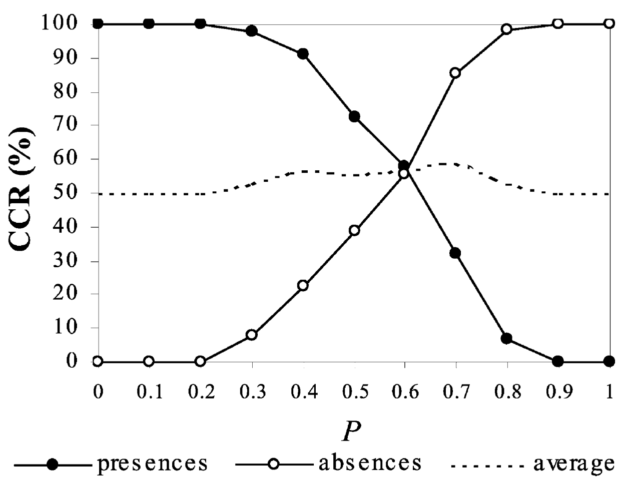

Fig. 6. Correct classification rates (CCR) for the Spanish model applied to continental Portugal at all possible cut-off points at 0.1 intervals.

2002). The inclusion of variables more directly related to this factor, such as arable land and density of livestock, would perhaps be desirable. However, such variables are not available at a national scale neither in 10×10-km nor in 1×1-km squares. In any case, Barbosa et al. (2001), using administrative provinces as territorial units, included cropland area and pasture area in a stepwise regression procedure that did not select any of these among a set of human-related variables. This could indicate that in Spain industrial rather than agricultural contamination affects otter distribution, which is in accordance with the findings of López-Martín and Ruiz-Olmo (1996) that the mainly industrially-used PCBs reach higher concentration levels in Spanish otter tissues than other agriculturally used organochlorines.

The negative association with highways can be due not only to road casualties suffered by the species, but also to indirect effects such as air and water pollution, noise, habitat destruction and fragmentation, and artificial lighting, for example (see Spellerberg, 1998). Barbosa et al. (2001) found that highway density explained 28.1% of the variance in the proportion of positive sites of otter in the Spanish provinces.

Actual evapotranspiration indicates simultaneous availability of water and energy, thus being a good predictor of productivity (Major, 1963; Rosenzweig, 1968; Wright, 1983), which seems to have a positive influence on otter distribution. July temperature may also be related to this factor, since high values of temperature in ecosystems with high water availability during summer, such as those in the Atlantic watershed, allow a greater productivity (Rosenzweig, 1968), which usually leads to greater food availability. On the other hand, in Mediterranean environments, where most rivers usually dry up in summer leaving only spaced pools, relatively high temperatures lead to a moderate eutrophy allowing a relative abundance of crayfish, amphibians, insects, and some species of cyprinids that can temporarily provide food for the otter (Jiménez and Delibes, 1990; Ruiz-Olmo and Delibes, 1998). Guégan et al. (1998) found that net primary productivity strongly influences global-scale species richness of riverine fish, the otter's main prey item.

The positive relation of otter presence with mean January temperature indicates that, once we have taken into account the factors previously included in the model, otter presence probability is higher in areas with cold winters. January temperature may be a surrogate for other factors that have a more direct influence on otter distribution: low January temperatures usually correspond to regions with snowy winters; snow can work as a natural regulator of streams, as the defrosting assures water availability when temperature increases, even in the absence of precipitation. The positive influence of annual precipitation and July air humidity and the negative influence of soil permeability on otter presence probability also point to the importance of water availability for this species. Both precipitation and permeability were previously related by other authors with otter distribution in Spain: Delibes and Rodríguez (1990), analyzing the results of the Spanish otter survey of 1984–1985, suggested a relationship between otter distribution and mean annual precipitation; Nores et al. (1991) in the province of Asturias (Northern Spain) and Barbosa et al. (2001) found that the proportion of otter presences was significantly higher in areas located on impermeable than on permeable substrate, which they attributed to the difference in superficial freshwater availability. The abundance of water does not only mean better habitat conditions or greater food availability. Pollutant concentrations in water, and hence their detrimental effect on otter populations, also depend on the amount of water available. PCBs were considered not to have been major causal agents in the otter decline in Britain (Jefferies and Hanson, 2001), where the climate is wet, but they were reported to have had strong negative effects on otter distribution in eastern Spain (Ruiz-Olmo and Delibes, 1998; Ruiz-Olmo et al., 2002), where water is scarce especially during summer.

The negative relation of otter presence probability with altitude can be due to the lack of prey in the oligotrophic high mountain waters, as Ruiz-Olmo and Delibes (1998) suggested.

Solar radiation is an indicator of energy availability. Its positive relation with otter presence probability might indicate that otter populations are favored in areas with high values of environmental energy, where it might be easier to satisfy their physiological requirements (see Hutchinson, 1959; Brown, 1981; Wright, 1983). The negative relation of mean annual temperature with otter presence probability may indicate a marginal influence of climatic stress on this species, which may act as a counterbalance for the positive effect of energy availability.

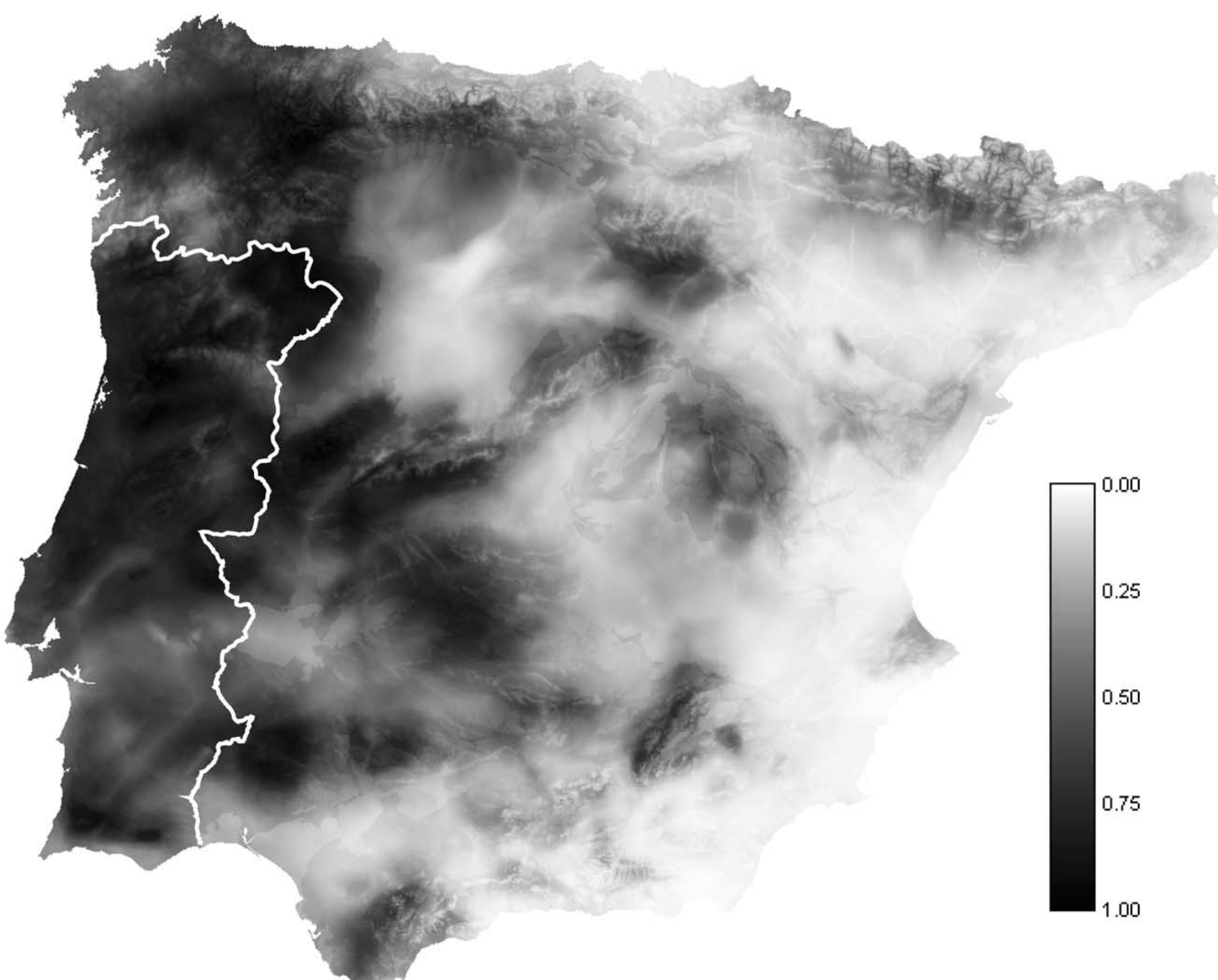

Fig. 7. Otter presence probability in 1×1-km squares in the Iberian Peninsula, according to the model obtained for continental Spain.

3.3. Extrapolation to a 1×1-km resolution

The extrapolation of the model to 1×1-km squares provided a much higher spatial resolution in the predictions about otter distribution (Fig. 7). In Fig. 8 we represent, with more detail, four different regions of the Peninsula. As can be seen in Fig. 8A, which represents the northern Iberian plateau (mean elevation >700 m) and its surroundings, otter presence probability increases in mountainous areas regardless of whether they are more (as in Spain) or less elevated (as in Portugal) than the plateau. This could be due, among other causes, to the usual increase in precipitation and scarcity of human activity in mountainous environments. In some mountain ranges the probability map reproduces the courses of rivers, i.e. the model predicts higher occurrence probabilities along them than in their surroundings. In Figs. 8B and C we represent the regions corresponding to the central Pyrenees (northeast) and the mountains of Ronda (S Spain), where the probability along rivers stands out against that of their adjacent areas. The same model predicts, on the other hand, that in the northwestern section of the Peninsula (Fig. 8D) otters are more widespread, apparently not being limited to the courses of the main rivers. During the Spanish otter survey of 1994–1996, this region had, in fact, the most widespread distribution of positive sites of otter (see Ruiz-Olmo and Delibes, 1998). This can be due to the abundance of superficial freshwater in this part of the Peninsula, where small streams are common all over the territory.

3.4. Applications for conservation

Presence probability values can be used to define favorable or unfavorable areas for a species, which could be taken into account when implementing specific conservation programs. For example, areas where the

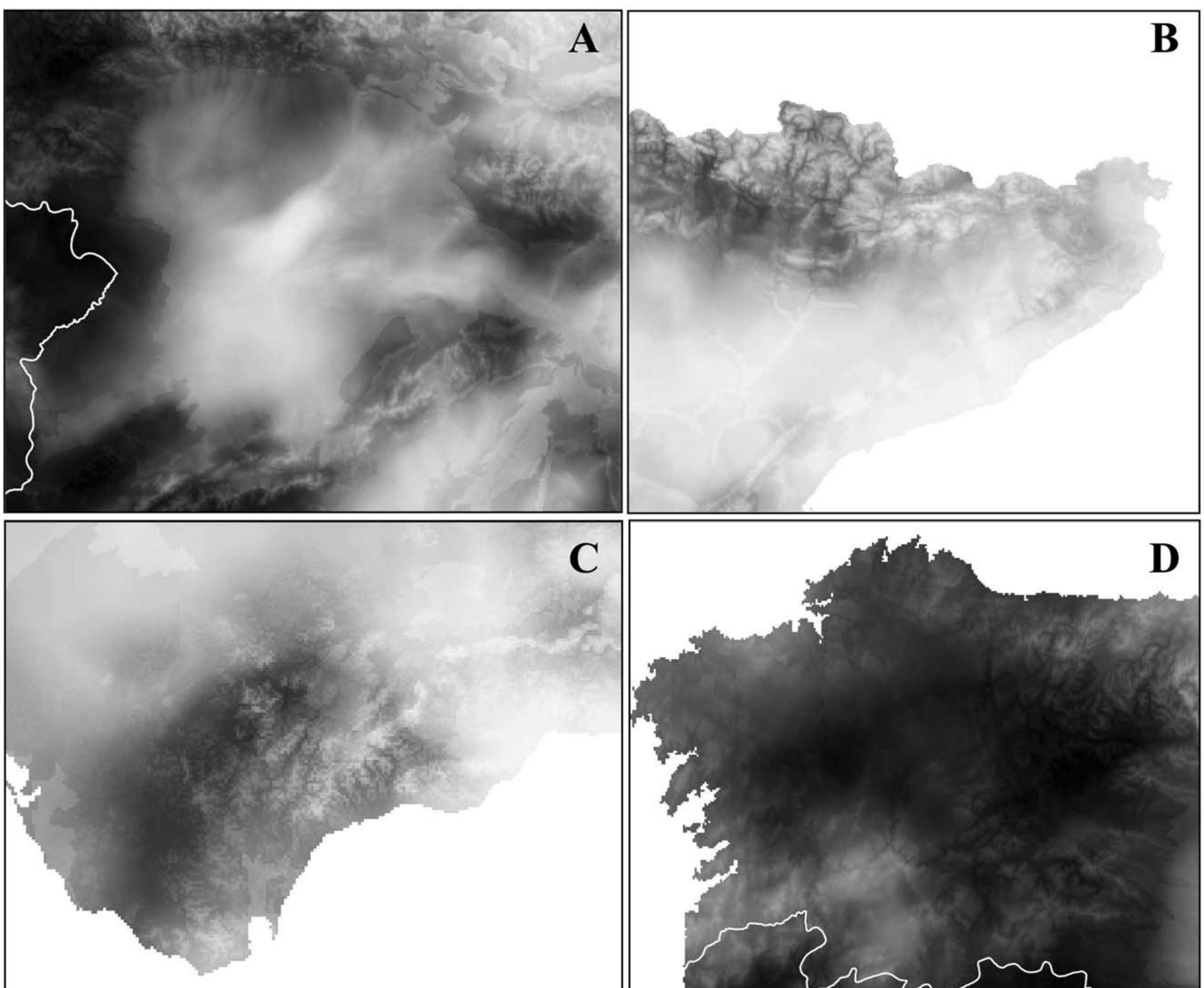

Fig. 8. Otter presence probability in 1×1-km squares in four different regions of the Peninsula. A: Northern Iberian plateau and its surroundings; B: Central Pyrenees; C: Mountains of Ronda; D: Northwest of the Peninsula.

probability of presence is four times higher than that of absence could be considered as environmentally favorable and areas where the probability of absence is four times higher than that of presence could be considered as environmentally unfavorable for a species. Determining a cut-off point above which the species is more likely to be present than expected at random can be useful to correct the probability thresholds defining these favorable or unfavorable areas (Rojas et al., 2001). The fact that the cut-off point for the otter is lower than 0.5 indicates that it is probably necessary to lower the probability values considered for determining favorable or unfavorable areas for this species in Spain.

The use of GIS for the modeling of otter distribution on a 1×1-km resolution starting from presence/absence data on 10×10-km squares allowed for a substantial increase in detail in the knowledge on this species' potential distribution. This has implications in the management of ecosystems and the planning of the construction of infrastructures potentially harmful for otter populations, such as industrial, urban or tourist settlements, transportation infrastructures, and dams, for example. Since otters are territorial, an otter population needs a considerable longitude of suitable habitat to keep a number of individuals large enough to maintain its viability. In areas where otter presence is restricted to the main course of a river and there is no connection with a nearby suitable territory, any intervention in the river is more likely bound to fragment the local otter population and could make it become non-viable. On the other hand, in regions where otter presence probability is also high outside the main courses of rivers, otters are predicted to have a greater mobility along the territory. An obstacle in the river would, therefore, cause less damage to the local population, as the individuals would still be able to keep in contact and dislodged individuals would have a better chance of getting to another suitable habitat.

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