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Explicit nation-wide habitat models for common Italian Piciformes

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Abstract – The aim of this paper is to assess the effect of broad scale environmental and geographical variables on the presence of Italian commonest breeding Piciformes (Wryneck, Green, Black, and Great Spotted Woodpeckers). Using the data of MITO2000 (2000-2003), logistic regression models were built, relating their presence with area occupied by Corine land-use categories, habitat diversity, morphological and elevation-range, latitude and longitude. Our analyses seem to give some basic information about large scale ecology of the species, allowing to indicate different habitat types (heterogeneus habitat for Wryneck, broadleaved woods for Green Woodpecker, woods for Great Spotted Woodpecker). Our models clearly show the importance of geographical variables to infer how species ecology changes at different latitudes: Green and Great Spotted Woodpecker for example, become commoner, and less linked to woods, northwards.

INTRODUCTION

Woodpeckers are typically considered forest species and efficient woodland biodiversity indicators, from local (Mikusinski *et al.* 2001) to continental scale (Mikusinski and Angelstam 1998). Moreover, the ecology of woodpeckers is complex: they show a different degree of specialization (Angelstam and Mikusinski 1994) and, even if they need tree-presence anyway, some species have evolved to live in non forested habitats (Gorman 2004). In Italy nine woodpecker species are regularly present: *Picus canus* and *Picoides tridactylus* have a distribution limited to the north-east part of Italy; *Dendrocopos medius* and *Dendrocopos leucotos* are concentrated in small areas in the central and southern Apennines only; *Dendrocopos minor*, even though it is widespread along continental and peninsular regions, results scarcely detected due to its low detectability (Meschini and Frugis 1993). The most widespread species are *Jynx torquilla*, *Picus viridis*, *Dryocopus martius* and *Dendrocopos major*, these species are less demanding in terms of habitat requirements, being, for example, less linked with the presence of mature stands and dead wood (Mikusinski and Angelstam 1998, Gorman 2004).

Mathematical models are useful tools to describe species ecology and they are widely used in ornithology (Osborne *et al*. 2001, Ambrosini *et al*. 2002, Seoane *et al*. 2003, Brotons *et al*. 2004a, Rushton *et al*. 2004). Although some doubts on their effectiveness still remain (Gutzwiller and Barrow 2003, Chamberlain *et al*. 2004), these techniques, if correctly applied, have proved to be valuable tools for the knowledge of the actual distribution of species and to obtain objective information on the main ecological factors affecting their presence (Guisan and Zimmerman 2000, Scott *et al*. 2002, Bustamante and Seoane 2004). Ecological models built at regional scale have resulted able to stress some features about woodpecker ecology, particularly to what concern habitat preferences (Tobalske and Tobalske 1999).

The availability of ornithological data originating from national monitoring schemes, that may be related to broad scale variables, enables to build habitat suitability models with great geographical value by means of GIS application (Scott *et al*. 2002, Brotons *et al*. 2004a, Suarez-Seoane *et al*. 2004). Due to their objectivity, these models can be used as reliable tools supporting the decisions for biodiversity conservation, allowing planners to know more on the factors affecting species distributions and projecting those beyond sampled areas (Naesset 1997, Woodhouse *et al.* 2000, Osborne 2005).

Apart from information describing their habitat (e.g. Pedrini *et al.* 2005), the ecological requirements of Italian woodpeckers are reported only for few species at local scale (e.g. Tellini Florenzano 1996, Bettiol *et al*. 2000, Rassati *et al*. 2001, Ceruti *et al*. 2003, Guerrieri and Castaldi 2003, Pirovano *et al*. 2003). The only attempt of ecological analysis at national scale concerns the definition of deterministic models for Italian vertebrates (Boitani *et al*. 2002), based on subjective evaluation by specialists.

Since a national synthesis based on field observation data is missing and due to the availability of large amount of information on breeding woodpecker localizations in Italian territory that comes from the database of MITO2000 project (Fornasari *et al.* 2004), we have calculated stochastic models at the national scale for the occurrence of the four Italian commonest Piciformes (*J. torquilla*, *P. viridis*, *D. martius* and *D. maior*) assessing the effect of environmental (land use, but also ground morphology) and geographical (e.g. latitude) variables. In particular, we aimed to assess the effect of large scale environmental variables (land use and topography) and geographical ones, whose effects can be likely ascribed to changes in climatic conditions and seem to play a decisive role in explaining the distribution of the investigated species, greatly improving the validity of the models (Hawkins and Diniz-Filho 2004). These variables, largely used in the past to describe the ecogeography of birds (e.g. Voous 1960), were subsequently scarcely taken into account since their effect was considered difficult to prove (see Fasola 1985). In recent years, due to the aid of more reliable and robust statistical techniques, variables such as latitude are newly considered of capital importance to define the ecology of bird species, at least at large scale (e.g. Forsman and Mönkkönen 2003).

STUDY AREA AND METHODS

We overlapped a 2.5 x 2.5 km grid on the whole Italian territory excluding small islands. The grid mesh was empirically selected considering the structure of the available database and the ecology of the investigated species. For each grid mesh, we defined the presence or absence of each investigated species and we calculated the values of several environmental and geographical variables.

The data on bird occurrence were obtained from MITO2000 database, the Italian Bird Monitoring Scheme, that consists of randomly selected 10-min point counts (Fornasari *et al*. 2002). We took into account data collected in 2000-2003 years for the four Italian commonest Piciformes species, i.e. *J. torquilla*, *P. viridis*, *D. martius*, *D. major*.

Each species was considered present in every grid cell in which it was recorded at least one time; to what concern the absence, due to the well known problems in coping with false-absence cases (Kerr *et al.* 2000), and considering the characteristics of our sampling design, in order to limit this problem we have excluded all grid cells with only one point count, considering each species absent in every grid cell in which at least two point counts were carried out without finding it. Models have been built using logistic regression (software Statistica 7.0) because, at the time when the analyses were processed (autumn 2006), presence-only methods were not yet available.

The environmental and geographical variables used to build the models are reported in Tab. 1. Besides the classic geographical variables (e.g., longitude), we individuated some areas characterised by biogeographical specificity (i.e., river Po flood plain, Sicily, Sardinia, see Minelli *et al.* 2002) that were analysed as "dummy" variables (Waite 2000). In each 2.5 x 2.5 km mesh, we calculated the median altitude using the data obtained from a DTM (Digital Terrain Model; cell size 300 m^2). Standard deviation of altitude was used to describe the topography (as altitude is more variable as the morphology is more uneven). For the environmental variables we used the Corine Land Cover map (third level; Büttner *et al*. 1998) retrieving the surface of different land use in each 2.5 x 2.5 km mesh. As a measure of environmental diversity, we calculated the Shannon index on land-use Corine categories.

Interpolating point-abundance data (IDW method; see Fortin and Dale 2005), we defined the range of each species assuming as its boundaries the isoline that excludes less than 1% of species presence. Subsequent analyses were conducted only on the meshes included in this range. The IDW method (Inverse Distance Weighting) calculates a value for each grid cell from data points within a specified search radius, weighting closer point more than those farther away. We analysed the presence/absence data looking for the effects of first and second polynomial order for every variable and their possible interactions (Draper and Smith, 1998). To obtain the most informative models of descriptive nature (McNally 2000), they were built selecting the best combination of variables according to the AIC (*Akaike Information Criterion*, McQuarrie and Tsai 1998) value. Models with lower AIC indicate a greater degree of parsimony (greater variance explained per parameter). Then we measured the efficiency of the obtained models selecting, for each species, the most informative one based on the AUC value (*Area Under the ROC Curve*, Hosmer and Lemeshow 2000). In all cases, we included in the models only the variables, or their interactions, whose marginal contribution was significant ($p<0.05$).

Only for *J. torquilla*, *P. viridis* and *D. major*, due to the big amount of available data, we firstly built the model with a data subset, randomly chosen and corresponding to the 80% of the available ones, and then we validated it (checking for their statistical significance, $P<0.05$) using the remaining 20% (Massolo and Meriggi 1995); the definitive model was built using all available data. For each of the four investigated species, the selected model gave the probability of presence in each 2.5 x 2.5 km mesh of the species range. Thus, it was possible to spatially explicit the model on its whole Italian range.

RESULTS

The variables that are included in the selected models for each species are reported in Tab. 1 and the statistics of the models are summarized in Tabs. 2-5; the probability of species presence in their range are mapped in Figs. 1-4. The most efficient model is that for *D. martius*, in fact, even if it is the simplest, we have a AUC value of 0.752; the other models do not exceed 0.700.

All the models result quite complex, including a high number of variables, except for *D. martius*. The most important variables seem to be those of geographical type: Wald statistics show that the latitude is the most important parameter, either used alone or considering the cumulative effect produced by the interaction with other variables. In the *D. martius* model, for example, we registered an important positive effect of the latitude-longitude interaction stressing that the presence probability rises with the growth of both of them. Maps in Fig. 1-4 clearly show the high value of geographical variables. Central regions for example, represent areas associated with high levels of presence probability for *J. torquilla* and even more for *P. viridis* (the relations include both first- and second-order terms, thus showing a distribution peak at intermediate values). The model for *J. torquilla* shows, as areas with the highest values of presence probability, Tuscany and Piedmont hills, and the Trentino valley bottom, areas where this species is actually common (Mingozzi *et al.* 1988, Tellini Forenzano 1996, Tellini Florenzano *et al.* 1997, Pedrini *et al.* 2005). A similar pattern is showed by *P. viridis* model distribution. The distribution of these two species seems to become more concentrated moving southwards, as stressed by other authors (Meschini and Frugis 1993).

Also *D. major* seems to be more common in the Northern regions (the relationship with latitude includes second-

Table 1. List of the variables considered to build the habitat models. For each variable, the abbreviation used in the Tables 2-5 is reported. With ‘X’ are indicated the variables entered in each species model.

variables		***Jynx torquilla***	***Picus viridis***	***Dryocopus martius***	***Dendrocopos major***
LAT	latitude	**X**	**X**	**X**	**X**
LON	longitude			**X**	
PAD	river Po flood plain				
SAR	Sardegna				
SIC	Sicilia				
ALT_MDN	altitude	**X**	**X**	**X**	**X**
ALT_DS	altitude standard deviation		**X**		**X**
URBAN	urban areas		**X**		
CROP	crops	**X**			
PERM_CROP	permanent crops	**X**			
PASTURE	grassland and pastures	**X**			
HETER_CROP	heterogeneous crops	**X**			**X**
B_WOODLAND	broadleaved forest		**X**		**X**
C_WOODLAND	coniferous forest	**X**	**X**		**X**
M_WOODLAND	mixed forest				
WOODLAND	woodland (all types)				
SHRUB	shrubland				
BEACH	beaches				
ROCK	rocks and cliffs				
WETLAND	wetland		**X**		
WATER	water				
D_SHANNON	Corine Land-use Shannon index	**X**	**X**		

Table 2. List of the variables entered in the *Jinx torquilla* model; for each of them the Wald statistic and the p value are reported. N indicates the number of positive cases. * means that there is an interaction between two different variables (e.g. LAT*ALT_MDN, interaction between latitude and the median value of altitude).

Wryneck (*Jynx torquilla*)		**N = 689**
Variables	*wald*	*p*
LAT*ALT_MDN (-)	32.83	0.000
ALT_MDN*PERM_CROP (+)	19.06	0.000
HETER_CROP (+)	18.92	0.000
LAT (+)	18.90	0.000
LAT^2 (-)	17.62	0.000
ALT_MDN*PASTURE (+)	17.33	0.000
PERM_CROP (-)	14.80	0.000
D_SHANNON (+)	13.18	0.000
LAT*PERM_CROP (+)	11.42	0.001
PASTURE*D_SHANNON (-)	10.29	0.001
C_WOODLAND (+)	9.55	0.002
ALT_MDN*CROP (+)	8.09	0.004
D_SHANNON^2 (-)	4.09	0.043
Area Under ROC Curve	**0.694**	

Table 3. List of the variables entered in the *Picus viridis* model; for each of them the Wald statistic and the p value are reported. N indicates the number of positive cases. * means that there is an interaction between two different variables (e.g. LAT*B_WOODLAND, interaction between latitude and broadleaved forest).

Green Woodpecker (*Picus viridis*)		**N = 1683**
Variables	*wald*	*p*
B_WOODLAND (+)	83.88	0.000
LAT*B_WOODLAND (-)	57.96	0.000
LAT (+)	48.85	0.000
LAT^2 (-)	33.91	0.000
ALT_MDN^2 (-)	28.90	0.000
D_SHANNON (+)	20.80	0.000
ALT_MDN (+)	14.56	0.000
C_WOODLAND (+)	14.09	0.000
ALT_DS^2 (-)	13.50	0.000
URBAN (-)	13.04	0.000
LAT*C_WOODLAND (-)	11.80	0.001
ALT_MDN*WOODLAND (-)	11.35	0.001
WETLAND (-)	8.54	0.003
LAT*URBAN (+)	6.79	0.009
URBAN*D_SHANNON (+)	5.32	0.021
Area Under ROC Curve	**0.698**	

order term only, and is negative), while the model for *D. martius* shows higher probabilities in the north-east part of the country with a positive relationship between latitude and longitude. In Italy *D. martius* seems to be really more common in the Estern Alps than in the West ones (Mingozzi *et al.* 1988; Brichetti and Fasola 1990; Pedrini *et al.* 1995). This species is also present along the Apennines with small populations (Meschini and Frugis 1993). Owing to the almost complete lack of MITO2000 data in these areas, we have not considered this part of species' range in model building.

Considering the 'true' environmental variables, these often enter in the models in combination with other variables and their contribution to the model is not always clear to explain, even if it is possible to evidentiate, for each species, some interesting ecological feature.

The *J. torquilla* model shows a preference for heterogeneous landscapes, as indicated by the positive relationships with permanent crops, heterogeneous agricultural landscapes and the Shannon diversity index; the negative effects of the altitude stresses well the preference of this species for lower-altitude areas. These indications well correspond with the known ecology of this species (Gorman 2004) and already described by other authors for similar studies carried on in Central Europe (Tobalske and Tobalske 1999).

The model for *P. viridis* indicates a strong positive relationship with broadleaved woods, stronger than that, though still positive, with conifers; also in this case, our results seems to be in accordance with the known ecology of the specie (Gorman 2004). However, the most interesting feature of this model is the negative relationship with the interaction between woodland and latitude: the preference for woodland decreases moving northwards and *P. viridis* could be considered a strictly forest species only in the southern part of its Italian range. Fig. 2 in fact, shows that the most suitable areas are, in southern regions, patchily distributed and localized within extensive forest systems. Moving northwards, high-suitability values become more and more widespread, interesting not only woodlands, but also heterogeneous landscapes, as also shown by the positive relationship with the Shannon index. Many authors describe similar ecological behaviours for central and northern European landscapes (Tobalske and Tobalske 1998, Rolstad *et al.* 2000), where the species has been recorded also in open lands characterised by the presence of trees and hedges (Gorman 2004); similar evidences are known also for some Italian regions (e.g. Pedrini *et al.* 2005).

Taking into account the *D. major* model, as we have found for the previous one, there is a strong positive effect of woodland (positive relationship with both broadleaf and

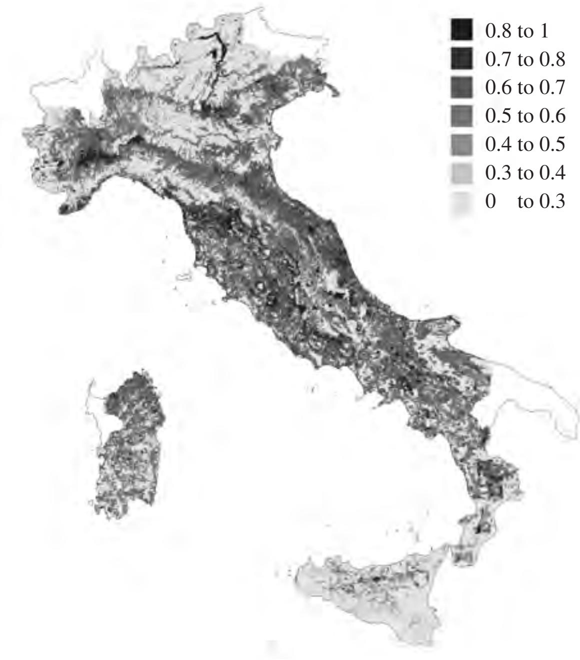

Figure 1. Map showing the result of projecting the *Jynx torquilla* habitat model (see Tab. 2) on the whole Italian territory. Values refer to presence probability.

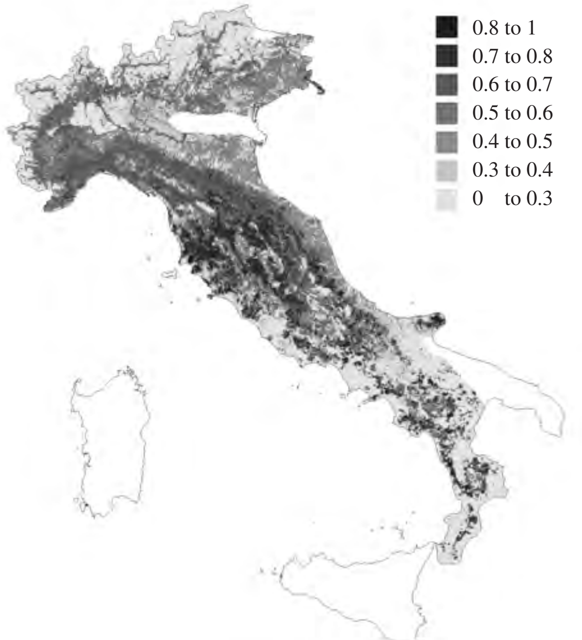

Figure 2. Map showing the result of projecting the *Picus viridis* model habitat model (see Tab. 3) on the whole Italian territory. Values refer to presence probability.

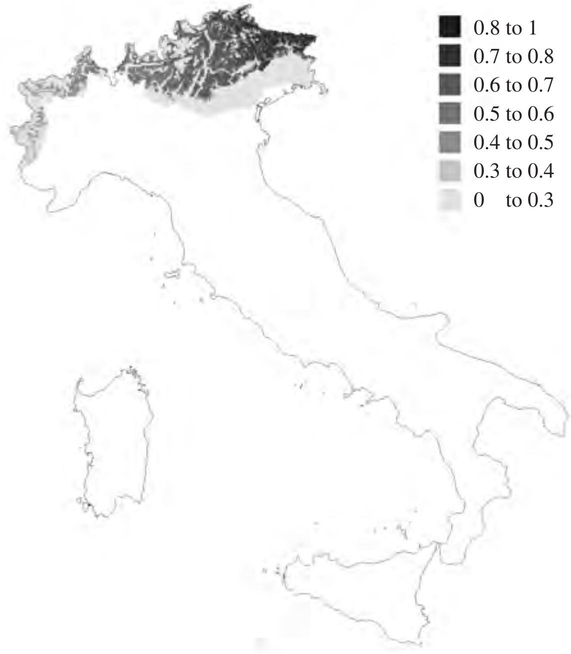

Figure 3. Map showing the result of projecting the *Dryocopus martius* habitat model (see Tab. 4) on the whole Italian territory. Values refer to presence probability.

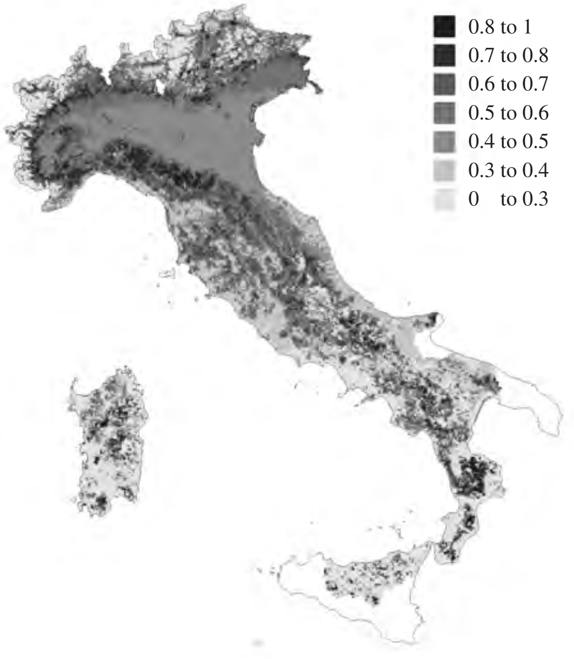

Figure 4. Map showing the result of projecting the *Dendrocopos major* habitat model (see Tab. 5) on the whole Italian territory. Values refer to presence probability.

Table 4. List of the variables entered in the the *Dryocopus martius* model; for each of them the Wald statistic and the p value are reported. N indicates the number of positive cases. * means that there is an interaction between two different variables (e.g. LON*LAT, interaction between longitude and latitude).

Black Woodpecker (*Dryocopus martius*)		**N = 97**
Variables	*wald*	*p*
ALT_MDN (+)	26.82	0.000
ALT_MDN^2 (-)	22.63	0.000
LON*LAT (+)	5.40	0.020
Area Under ROC Curve	**0.752**	

Table 5. List of the variables entered in the *Dendrocopos major* model; for each of them the Wald statistic and the p value are reported. N indicates the number of positive cases. * means that there i san interaction between two different variables (e.g. ALT_MDN*HETER_CROP, interaction between the median value of altitude and heterogenous crops).

Great Spotted Woodpecker (*Dendrocopos major*)		**N = 1341**
Variables	*wald*	*p*
LAT^2 (+)	51.84	0.000
ALT_MDN*HETER_CROP (+)	49.39	0.000
C_WOODLAND (+)	21.68	0.000
B_WOODLAND (+)	19.77	0.000
ALT_DS (-)	17.76	0.000
LAT*C_WOODLAND (-)	14.54	0.000
ALT_MDN^2 (-)	6.89	0.009
LAT*B_WOODLAND (-)	4.75	0.029
ALT_MDN (+)	4.36	0.037
Area Under ROC Curve	**0.669**	

conifer ones) that is more evident in the southern part of the country (Fig. 4). According to what we have described for *P. viridis*, also in this case we find a positive relationship with heterogeneous landscapes, here specifically with farmland, above all for those located at high altitude (interaction between agricultural heterogeneous lands and altitude); this confirms the well known ability of this species to live also in non-wooded habitats (Gorman 2004). The only difference existing between the *D. major* model and the *P. viridis* one is that for the first species we did not register any difference in preferences for the two type of woodland (broadleaf and conifer), according to what described by other authors (Gorman 2004).

The validation of the *J. torquilla*, *P. viridis* and *D. major* models have confirmed, in all cases, the significance of the originally selected variables.

Considering the last species, *D. martius*, the only non-geographical variable entered in the model is the altitude, with a positive effect of both quadratic and linear term, that describe a preference peak, reported, for example, in the Eastern Alps by Pedrini *et al.* (2005) around 1500 m. The lack of other environmental variables, like woodland coverage or similar, seems to be a result of the combination of the effects of altitude and of the interaction between latitude and longitude; these variables in fact individuate themselves areas characterised by great woodland-cover levels.

DISCUSSION AND CONCLUSION

The results of analysis show some interesting results, although the effectiveness of the models is quite low. This could be related with the large geographical scale which we worked at; in fact some ecological features probably need to be studied at finest scales, considering some variables such as the presence of big and dead trees or forest structure, that could be very important for these species (Gorman 2004), but that are impossible to take into account at national scale. Studies carried on with similar methodologies and at comparable scale confirm these problems, including the exception of *D. martius*, for which it has been possible to build up more efficient models (Tobalske and Tobalske 1999).

Geographical variables, whose effects can be likely linked to climatic gradients, play a decisive role in explaining distribution and ecology of the woodpeckers. This kind of variables, once frequently used to study and describe bird ecogeography (e.g. Voous 1960), were subsequently scarcely taken into account since their effect was considered difficult to prove (see Fasola 1985). In recent years, due to the aid of more reliable and robust statistical techniques, variables such as latitude are newly considered of capital importance to define the ecology of bird species, at least at large scale (e.g. Forsman and Mönkkönen 2003).

By contrast, the ‘true’ environmental variables, taken *per se*, even if with some interesting exceptions, have a minor role than the geographical ones in describing the ecology of these species, at least at wide geographical scale. As we have just stressed before, this result could be releted with the lack of fine-grained environmental information, for instance about the woodland structure, that are known to be of great importance for these species, but that at this scale are not available.

Very interesting is the use of the combination of the two variables type: for instance, variables like latitude, if used in association (e.g. interaction) with other variables, for instance the woodland, has allowed us to stress different ecological features existing in different parts of the range of the same species. For what we have just stressed, we believe that, at least for woodpeckers, we can not exclude geographical variables in building up suitable habitat models at the national scale (Hawkins and Diniz-Filho 2004, Suarez-Seoane *et al.* 2004).

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