Effects of landscape-scale factors on goshawk *Accipiter gentilis arrigonii* distribution in Sardinia

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Abstract – The Northern goshawk is a widespread and well-studied species, but few data concern the ecology of the corso-sardinian goshawk *Accipiter gentilis arrigonii*, which is endemic of Corsica and Sardinia. We studied the breeding habitat selection of the goshawk at landscape scale using MaxEnt, a presence-only modelling method. Working with 37 goshawk localizations, we built three single models, at 10, 30 and 50 km^2 scale, and a mixed model, combining variables at different scales. The latter results the best one (AUC=0.866). The woodland variables are the most important factors (about 2/3 of percent contribution in the model) and they seem to act at the minimum scale (10 km^2): the woodland area (>200 m from the forest edge) is the most important variable and it has a positive effect, as well as the broadleaved forest and the coniferous forest, even if the latter only if present in small amount (<0.02 km^2). At broader scales (30 and 50 km^2) the goshawk seems to be sensitive to human disturbance avoiding plains (where there is the highest level of human activity) and urban areas, including small and sparse settlements. The surface of open land <200 m from forest edge, which is a goshawk hunting habitat, has a low weight but a positive effect at scale of 50 km^2.

Key-words: northern goshawk, Sardinia, breeding ecology, breeding habitat selection, MaxEnt.

INTRODUCTION

The goshawk *Accipiter gentilis* is a holarctic species with an extensive distribution in North America, Asia, and Europe; one of its many subspecies, the corso-sardinian goshawk *A. gentilis arrigonii,* is endemic to Corsica and Sardinia (Cramp & Simmos 1980, Brichetti & Fracasso 2003).

A host of studies throughout its vast range (Kenward 2006) have resulted in broadly similar findings with regards to the ecological requirements for nesting sites: availability of large trees in mature forest, including smaller woodlands, and a preference for northern exposure (Penteriani 2002). However, if analyses are performed on a larger landscape scale, significant variability emerges (Penteriani *et al*. 2001). The only recurring element is the prevalence of woodland in the immediate surroundings of the nest (Penteriani 2002), but the adaptability of goshawks at this scale is quite high, so that in the absence of other limiting factors they regularly nest in landscapes with limited forest cover, including urban areas in some cases (Kudo *et al*. 2005, Rutz *et al*. 2006). In the Mediterranean area, the ecological needs of goshawks in terms of nesting sites are essentially the same (Mañosa 1993, Alexandrou *et al*. 2008), while the few studies that have examined the issue at the landscape scale have also found a certain degree of variability (Penteriani & Faivre 1997).

Although the goshawk is a relatively well-studied species, there is little specific knowledge on the ecology of the subspecies *arrigonii* (Palumbo & Gallo-Orsi 1999): there are few studies from either Sardinia (Murgia *et al*. 1988, Carrai *et al*. 2001) or Corsica (Thiollay 1968, Seguin *et al*. 1998), and even in the conservation plan drafted in Corsica (Thibault *et al*. 2003), ecological information is mostly descriptive in nature.

Although genetic, morphometric, and bio-acoustic data suggest that the taxonomic distinctiveness of Corsican and Sardinian goshawks versus continental ones should be treated with caution (Thibault *et al*. 2003), goshawks in Corsica do show distinct biological characteristics (Thibault *et al*. 1992). The uniqueness and conservation interest of these populations thus justifies the pursuit of improved and specific knowledge on their ecology (Palumbo & Gallo-Orsi 1999, Gustin *et al*. 2009).

This study, promoted by the Sardinian Forestry Agency (Ente Foreste della Sardegna) as part of the drafting of management plans for public forests, is aimed to: (a) evaluate how the distribution of goshawks at the landscape scale is determined by various landscape factors; and (b) highlight goshawks ecological preferences in a peculiar Mediterranean context, in light of the variability shown by the species in breeding habitat selection at a landscape level (Penteriani 2002).

STUDY AREA AND METHODS

The study area comprises the whole of Sardinia (total surface area = ~24,000 km^2).

The starting data comprises 49 records of goshawks during the breeding season, distributed throughout the study area. From these, we selected and used those that were plotted with a precision of less than one kilometre; in cases in which multiple records (closer than two kilometres) may have referred to a single pair, we only selected one. A total of 37 records were deemed suitable for use, distributed nearly throughout Sardinia (Fig. 1).

On the basis of existing knowledge on the species' ecology (Penteriani 2002, Kudo *et al*. 2005), we calculated the following ten variables: (1) standard deviation of elevation (ELEV_SD) to describe the morphology (as elevation is more variable as the morphology is more uneven) and (2) amount of north-facing surface area (km^2; N_FACING), drawn from a digital land model with 50-meter cells; surface area (km^2) of (3) Cork oak *Quercus suber* woodland (WOOD_SU), (4) other deciduous woodland (WOOD_BR) and (5) coniferous woodland (WOOD_CO), drawn from the regional land use map (from official Sardinia Region website, www.sardegnageopoertale.it); (6) urban surface area (URBAN); (7) road density (ROADS); (8) climate (CLIMATE), drawn from the Italian phytoclimate map on the basis of ombrotype - an index based on precipitation data (Blasi *et al*. 2004); (9) core woodland surface area (WOOD_CORE), defined as interior woodland at least 200 meters away from the nearest margins, and (10) surface area of open habitats within 200 m of woodland margins (WOOD_MAR), which for all intents and purposes is a measurement of margins (Kudo *et al*. 2005). Both variables nine and ten have been drawn from the regional land use map.

All variables were calculated at a 10, 30, and 50 km^2 scale around each of the 37 goshawk records and about 10,000 points uniformly distributed throughout Sardinia (*background*) used as controls (*cfr*. below). The surface areas cover the range of values associated with goshawk home ranges on the basis of density data from several European (Joubert 1991, Widen 1997, Penteriani & Faivre 2001) and Italian areas (various studies reported in Gustin *et al*. 2010); there is no available data from Sardinia, while what little data exists from Corsica falls within this range (Thiollay 1968, Thibault *et al*. 2003). For the CLIMATE variable, which we drew from a less detailed map, we used point values at all scales.

For our analyses we used MaxEnt (Philllips *et al*. 2006, Phillips & Dudík 2008), an algorithm that compares environmental variables in the points where goshawks are present with the same variables in background points, and identifies maximum entropy distribution; that is, the distribution which, using environmental variables as "constrictors", mostly closely approximates a uniform distribution. MaxEnt, using presence-only data, returns the following: 1) the spatial distribution of suitability, 2) the contribution in percentage terms, and 3) the relation type for each variable. Points 2) and 3) thus make it possible to assess the significance of environmental variables and the ways in

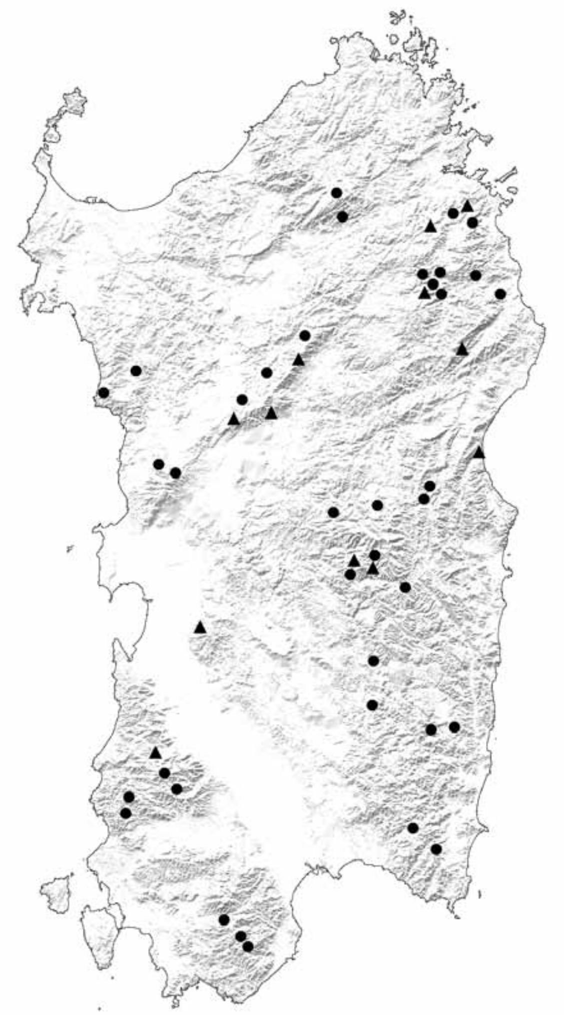

Figure 1. Goshawk localizations during the breeding period; circles indicate data with high geographical resolution, and therefore used for ecological analysis; triangles, the others.

which they determine the species' distribution. We built a model at each scale (10, 30 and 50 km^2). Under the hypothesis that the impact of environmental factors may be felt each at a different scale, we built also a model combining variables measured at different scales (Weaver *et al*. 2012), using each variable at the scale at which it was most significant, trying various combinations for those which had a similar degree of significance at more than one scale. We built an initial model using all presence data, and subsequently built another 10 models, each with a different sub-sample, in order to have a "field of variation" that makes it possible to assess the true contribution of each variable (very wide fields of variation, evidence of highly different effects in the 10 models, indicate non-decisive effects).

RESULTS AND DISCUSSION

At the three different scales (50, 30, and 10 km^2; see Tab. 1) the most important variables remain the same, i.e. WOOD_CORE and WOOD_BR, although their relative importance changes considerably, while the effect of other important variables (ELEV_SD, URBAN, WOOD_CO) changes even more. All three models have similar levels of efficiency, as indicated by AUC values. The combined model is more efficient, albeit slightly (Tab. 1), suggesting that the variables do in fact "work" at different scales. The effect of factors that work at different scales has already been shown in goshawks (Penteriani & Faivre 1997, Penteriani *et al*. 2001) and combined model, with variables at different scales, have recently been used for other species as well (Weaver *et al*. 2012).

Variables directly related to woodland areas – namely WOOD_CORE, WOOD_BR and WOOD_CO – account for over 2/3 of the total percentage (Tab. 1), showing that forested landscapes are the decisive factor explaining goshawk distribution. The effect of all three variables is greatest at the smallest (10 km^2) scale, suggesting that these characteristics are especially important in the areas closest to the nest. Indeed, among landscape factors, the presence of woodland is the only one that is always important for goshawks (Penteriani 2002, Tornberg *et al*. 2006).

The core woodland area is the most important variable, and its effect is always positive and growing (Fig. 2), indicating the need for extensive woodland, and most of all for areas that are relatively distant from forest margins. Indeed, goshawk nests are often located deep in the forest interior (an average of over 450 m from the nearest edge, Penteriani 2002), and forest areas far from edges generally remain important in spite of the species' adaptability (Rutz *et al*. 2006), especially in the fragmented landscapes (Kudo *et al*. 2005), which are typical of the Mediterranean area.

The effect of deciduous woodlands is positive overall, while the effect of coniferous woodlands is negative for large areas, but it is positive for areas smaller than 200 hectares (which comprise the vast majority of cases, Fig. 2). Broadly speaking, the effect of woodland area is positive, without any particular preferences emerging, at least at this scale; indeed, the species inhabits a great variety of woodland types (Penteriani 2002), which it selects on the

Table 1. Results of the three single models (at 50, 30 and 10 km^2 scale) and the mixed one, built with variables at different geographical scale. In all the models the variable CLIMATE is calculated at the point level. The variable WOOD_SU is not included in the composite model because it does not increase the efficiency.

variable	description	50 km^2	30 km^2	10 km^2	combined	
		perc. cont. %			scale	perc. cont. %
ELEV_SD	standard deviation of elevation	15.3	16.2	4.8	30 km^2	13.3
N_FACING	north-facing surface area	0.2	0.8	3	10 km^2	3
CLIMATE	climate (ombrotype)	5.4	1.7	3.3		1.3
WOOD_CORE	core woodland surface area	29.9	37.4	37.4	10 km^2	37.6
WOOD_MAR	woodland margins area	2.3	2.3	0.2	50 km^2	5.5
WOOD_BR	deciduous woodland	24.9	20.5	26.4	10 km^2	19.5
WOOD_CO	coniferous woodland	5	9.7	12.4	10 km^2	10.9
WOOD_SU	Cork Oak woodland	2.9	2.9	1.8		
URBAN	urban surface area	13.8	6.2	10	50 km^2	6.7
ROADS	road density	0.3	2.2	0.7	30 km^2	2.1
auc		*0.857*	*0.863*	*0.862*	*0.866*	

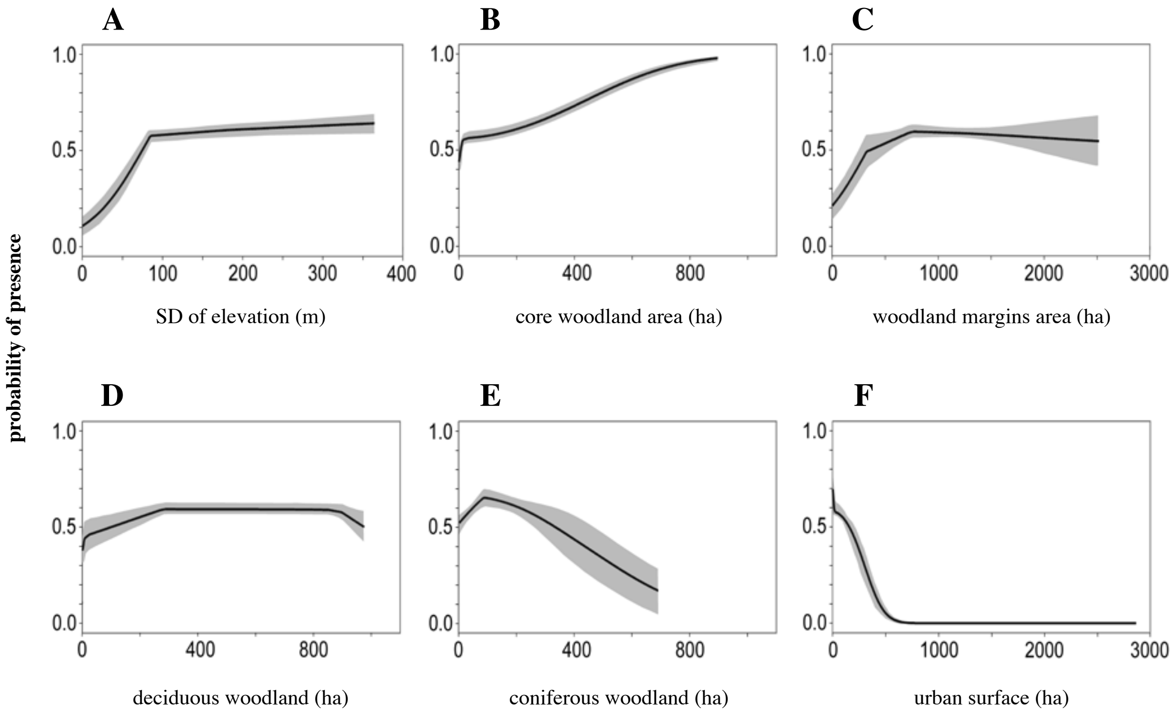

Figure 2. Relationship between the most important variables, as resulted from the mixed model, and the probability of goshwak presence; in the ordinate axis the logistic output is reported, on the abscissa axis the values of variables. The variables are: A) ELEV_SD, B) WOOD_CORE C) WOOD_MAR, D) WOOD_BR, E) WOOD_CO, F) URBAN.

basis of structure rather than composition (Greenwald *et al*. 2005). The limited data available for Corsica and Sardinia indicate that *A. g. arrigonii* also inhabits a variety of forest types (Palumbo & Gallo Orsi 1999, Thibault *et al*. 2003); most known nests are in Holm Oak *Quercus ilex*, but several instances of nesting in coniferous trees are known (Thibault *et al*. 2003), even in areas where conifers are rare (Murgia *et al*. 1988).

In addition, N_FACING has a positive, albeit limited effect, likely due to the greatest availability of suitable nesting sites on northern slopes: actually, almost of the known goshawk nests in Corsica and Sardinia have a northerly exposure (Murgia *et al*. 1988, Thibault *et al*. 2003) as is the case elsewhere in the Mediterranean (Mañosa 1993, Penteriani & Faivre 1997, Alexandrou *et al*. 2008) and throughout the species' range, with the sole exception of the northernmost areas (Penteriani 2002).

The remaining factors act mainly on a large scale (30 or 50 km^2). The most important among them is ELEV_SD, which has positive effects across a broad range of values (Fig. 2), and which essentially indicates that goshawks avoid low-lying areas. This relationship is at least partly indirect: low-lying areas tend to have few landscape elements with positive effects (mainly those related to woodland areas) and many with negative effects (mainly those related to anthropization, *cfr*. below). URBAN plays a clearly negative role; although the relative importance of the variable is low (6.7%), its effect is very strongly negative even for small areas (Fig. 2) and applies to vast areas as well (50 km^2), so that even a modest degree of urbanization is enough to make large areas unsuitable; this effect is compounded by that of road density, albeit with a lower relative importance (2.1%). This agrees with the general ecology of the species, which largely avoids highly anthropized areas (Rutz *et al*. 2006, Tornberg *et al*. 2006). Although this negative selection may depend in part on local factors, such as the fact that urban areas are generally distant from mature woodlands (Penteriani 2002), and although goshawks do breed in some cities (Rutz *et al*. 2006), they generally avoid the most urbanized areas even within highly anthropized landscapes (Kudo *et al*. 2005).

WOOD_MAR has a positive, albeit limited (5.5%) effect (Fig. 2), in line with the findings of Kudo *et al*. (2005). At a broader scale (50 km^2), the availability of woodland margins improves habitat suitability for goshawks, which frequently use them as hunting sites (Kenward 1996, Tornberg *et al*. 2006).

Goshawks in Sardinia are rather demanding in terms

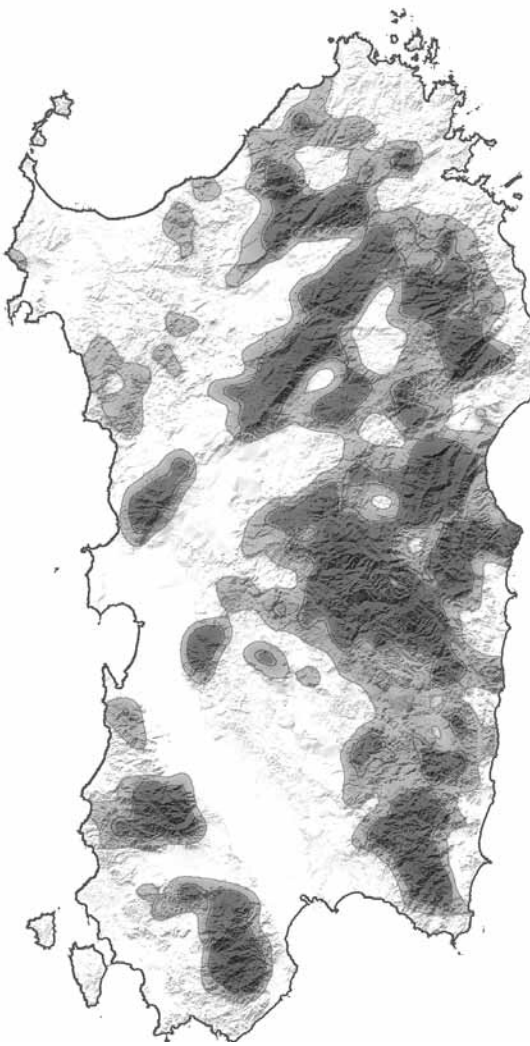

Figure 3. Goshawk suitability map in Sardinia, as resulted from the combined model: the light grey indicates medium suitability (5760 km^2, threshold "10 percentile training presence"), the dark grey indicates high suitability (5320 km^2, threshold "Maximum training sensitivity plus specificity").

of availability of woodland areas far from margins; in addition, they are quite sensitive to anthropization. These characteristics hold true in many other parts of the species' range (Penteriani 2002, Rutz *et al*. 2006), but in this context they provide some interesting food for thought.

Overall, more than 11000 km^2 (46% of the whole Sardinia) are classified as suitable for goshawk by combined model (Fig. 3), largely overlapping with species' known distribution (Murgia 1993, Brichetti & Fracasso 2003). With regards to forest habitats, recent dynamics have improved habitat suitability for goshawks, after deforestation in the 20th century had likely done the opposite (Beccu 2000). Although risk factors such as forest fires and land use remain, especially in certain types of woodland (Palumbo & Gallo-Orsi 1999), an overall positive trend can reasonably be expected to continue. The other critical factor regards anthropization: although goshawks have shown themselves to be able to live even in the presence of high levels of anthropization (Rutz *et al*. 2006), in Sardinia they appear to be particularly sensitive to presence of urbanized areas ad roads.

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REFERENCES

Alexandrou O., Vlachos C. & Bakaloudis D., 2008. goshawks *Accipiter gentilis* nest-tree and stand preference in the Dadia-Lefkimi-Soufli forest. north-eastern Greece. Avocetta 32: 5-11.

Beccu E., 2000. Tra cronaca e storia. Le vicende del patrimonio boschivo in Sardegna. Carlo Delfino Editore, Torino.

Blasi C., Ciancio O., Iovino F., Marchetti M., Michetti L., Di Marzio P., Ercole S. & Anzelotti I. 2004. Il contributo delle conoscenze fitoclimatiche e vegetazionali nella definizione della rete ecologica d'Italia. In: Blasi C., d'Antoni S., Dupré E. & La Posta A. (eds.). Atti del Convegno "La conoscenza botanica e zoologica in Italia: dagli inventari al monitoraggio" - Quaderni di Conservazione della Natura 18. INFS, Ministero dell'Ambiente pp. 161-180.

Brichetti P. & Fracasso G., 2003. Ornitologia italiana. Vol. 1 Gaviidae-Falconidae. A. Perdisa Ed., Bologna.

Carrai V., Congiu A. & Bulgarini F., 2001. Dati preliminari del censimento del Marangone dal ciuffo *Phalacrocorax aristotelis desmarestii* e dell'Astore sardo *Accipiter gentilis arrigonii*. Avocetta 25: 189.

Cramp S. & Simmons K.E.L., 1980. Birds of the Western Palearctic. Handbook of the Birds of the Europe, the Middle East and North Africa. Vol. II (Hawks to Bustards). Oxford University Press, Oxford, UK.

Greenwald D.N., Crocker-Bedford D.C., Broberg L., Suckling K.F. & Tibbits T., 2005. A Review of Northern goshawk Habitat Selection in the Home Range and Implications for Forest Management in the Western United States. Wild. Soc. Bull. 33 (1): 120-129.

Gustin M., Brambilla M. & Celada C. (eds.), 2009. Valutazione dello stato di conservazione dell'avifauna italiana. Specie in allegato I della direttiva Uccelli. Ministero dell'Ambiente e della Tutela del Territorio e del Mare, LIPU.

Gustin M., Brambilla M. & Celada C. (eds.), 2010. Valutazione dello stato di conservazione dell'avifauna italiana. Volume I. Non-Passeriformes. Ministero dell'Ambiente e della Tutela del Territorio e del Mare, LIPU.

Joubert B., 1991. Questions sur la chronologie de l'Autor des Palombes en Haute-Loire. Nos Oiseaux 41: 39-54.

Kenward R.E., 1996. Goshawk adaptation to deforestation: does Europe differ from North America? In: Bird D.M., Varland D.E. & Negro J.J. (eds.). Raptors in human landscapes. Aca-

demic Press, The Raptor Research Foundation, London, pp. 233-243.
Kenward R.E., 2006. Putting studies of Norh America Goshawk in context. Stud. Avian Biol. 31: 1-4.
Kudo T., Ozaki K., Takao G., Sakai T., Yonekawa H. & Ikeda K., 2005. Landscape analysis of Northern Goshawk breeding home range in northern Japan. J. Wild. Manage. 69 (3): 1229-1239.
Mañosa S., 1993. Selección de hábitat de nidificación en el azor (*Accipiter gentilis*). Recomendaciones para su gestión. Alytes 6: 125-136.
Murgia C., 1993. Guida ai rapaci della Sardegna. Regione Autonoma della Sardegna, Assessorato Difesa Ambiente.
Murgia C., Monni A. & Marras G., 1988. Primi dati sulla riproduzione dell'Astore (*Accipiter gentilis arrigonii*) in Sardegna, con note sulla sua distribuzione e consistenza in provincia di Cagliari. Riv. ital. Orn. 58: 1-7.
Palumbo G. & Gallo-Orsi U., 1999. Management Statement for Corso-sardinian Goshawk *Accipiter gentilis arrigonii*. Bird Life International, Final Draft, December 1999, 6 pp.
Penteriani V. & Faivre B., 1997. Breeding density and nest site selection in a Goshawk *Accipiter gentilis* population in the Central Apennines (Abruzzo, Italy). Bird Study 44: 136-145.
Penteriani V. & Faivre B., 2001. Effects of harvesting timber stands on Goshawk nesting in two European areas. Biol. Cons. 101: 211-216.
Penteriani V., 2002. Goshawk nesting habitat in Europe e North America: a review. Ornis Fennica 79: 149-163.
Penteriani V., Faivre B. & Frochot B., 2001. An approach to identify factors and levels of nesting habitat selection: a cross-scale analysis of Goshawks preferences. Ornis Fennica 78: 159-167.
Phillips S.J. & Dudìk M., 2008. Modelling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 30: 727-736.
Phillips S.J., Anderson R.P. & Schapire R.E., 2006. Maximum entropy modelling of species geographic distribution. Ecological Modelling 190: 231-259.
Rutz C., Bijlsma R.G., Marqiss M. & Kenward R.E., 2006. Population limitation in the Northern Goshawk in Europe: a Review. Stud. Avian Biol. 31: 158-197.
Seguin J-F. & Vidall P., 1998. Données préliminaires sur la repartition et l'effectif de l'Autor des palombes (*Accipiter gentilis*) en Corse. Trav. Sc. Parc nat. rég. & Rég. nat. Corse 58: 105-112.
Thibault J-C., Patrimonio O. & Torre J., 1992. Does the diurnal raptor community of Corsica (Western Mediterranean) show insular characteristics? J. Biogeogr. 19 (4): 363-373.
Thibault J-C., Seguin J-F. & Torre J., 2003. Plan de restauration de l'Autor des palombes cyrno-sarde en Corse. Parc naturel régional de Corse.
Thiollay J-M., 1968. Notes sur les rapaces diurnes de Corse. Oiseau Rev. Fr. Orn. 38: 187-208.
Tornberg R., Koppimäki E. & Byholm P., 2006. Ecology of the Northern Goshawk in Fennoscandia. Stud. Avian Biol. 31: 147-157.
Weaver J.E., Conway T.M. & Fortin M-J., 2012. An invasive species' relationship with environmental variables changes across mulptiple spatial scales. Landscape Ecol. 27: 1351-1362.
Widen P., 1997. How, and why, is the Goshawk (*Accipiter gentilis*) affected by modern forest management in Fennoscandia? J. Raptor Res. 31 (2): 107-113.

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