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Little Owl *Athene noctua* survey in Milan, northern Italy: distribution, habitat preferences and considerations about sampling protocol

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Abstract – We studied the Little Owl *Athene noctua* distribution in the city of Milan with a single-visit survey carried out during the 2013 breeding season. We searched for Little Owls in 82 sampling stations spread out all over the city using play-back technique. We detected 52 Little Owls in 33 sampling stations. The species appeared to be quite common in the municipality of Milan but with a greater abundance in the southern outskirts (Parco Agricolo Sud Milano). We modelled species occurrence by means of Generalized Additive Models selecting our best models with an information-theoretic approach. Little Owls' presence resulted more likely in presence of permanent crops and farmsteads. The latter represent one of the main sources of nesting sites for the species. Little Owl's detection is also more likely in relation with buildings' mean height, of about 10 meters while it appears to avoid completely the more dense urban areas present in the central and in the north-eastern side of Milan. The Little owl is finally more likely to be found in the larger urban parks. The species' distribution in the study area showed a significant spatial autocorrelation. Our best model accurately predicts 80.2% of observed data. According to model predictions 29.5% of the municipal territory has a medium or medium-high habitat suitability for the Little Owl. Field methods used in this work seemed to be easily carried out even by non-professionals. We discussed the global survey protocol for the species in light of our experience and with the desirable outlook of a large scale monitoring programme in our country: this is urgently needed to fill in the gap of knowledge on large scale distribution and population trends of the Little owl.

Key-words: General Additive Models, urban ecosystems, habitat preferences, survey protocol.

INTRODUCTION

Man has a great influence on natural environments as well as on animal species, and nowadays pristine environments not influenced by human activities are very scarce. In highly anthropized areas, ecosystems are subjected to fast and deep changes. In the 21st century the global human population underwent a rapid process of urbanization: in Italy the urban population has grown from 54.1% in 1950 to 66.7% in 2005 (United Nations 2006). The uncontrolled urban sprawl and the exploitation of natural resources by man, have lead to the alteration of natural environments with habitat loss, habitat fragmentation and waste accumulation. It is thus not surprising that urban sprawl can produce high local extinction rates for native animal and plant species (Hough 2004, McKinney 2002). Despite this critical picture several species adapted to live in urban areas in close contact with human beings; moreover a moderate human impact on natural environments could be seen, under some circumstances, as positive, because it brings to an increase in environmental heterogeneity (Rebele 1994), which in turn is known to be directly linked to species richness (McKinney 2008, Stein *et al.* 2014).

Often, fragments of natural habitats and built-up areas interpenetrate, generating an urban ecological system. Several native vertebrate species, among them birds, show a progressively adaptation to urban areas: this phenomenon has been widely investigated by analysing species distribution along urban gradients (Blair 1999, Crooks *et al.* 2004, McDonnell & Pickett 1990, Sorace & Gustin 2010).

The distribution of bird species in cities has been studied for a long time through the realization of urban atlases (Kelcey & Rheinwald 2005) and Italy is one of the European countries with the highest number of urban bird atlases (Fraissinet & Fulgione 2008).

The promotion of biodiversity in urban environments could be very important: evidence suggests that the exposure of people to residual natural elements within urban areas is a key factor in increasing citizen's sensibility towards environmental issues (Savard *et al.* 2000). On the other hand cities offer a large pool of potential participants to citizen science–based studies. The involvement of citizens in the scientific research has proved to be an effective and powerful instrument (Dickinson *et al.* 2012b) and this has been especially true with respect to urban bird studies (McCaffrey 2005). Citizen-based projects have enabled scientists to collect large amounts of data at minimal cost. They are an indispensable means of combining ecological research with environmental education and have broadened the horizon of ecologists (Dickinson *et al.* 2012b). Sometimes the quality of data collected by volunteers has been questioned: in each project it is necessary to implement methods to boost data accuracy and to account for bias, through volunteer training and testing, expert validation, and statistical modelling of systematic error among others (Kosmala *et al.* 2016).

The Little Owl *Athene noctua* is a good model species for the study of the process of "urbanization" and the possibility to engage non-professionals in authentic scientific research. The link between this species and man has always been very strong and nowadays in several parts of its actual breeding range the Little Owl breeds almost exclusively in man-made structures (Van Nieuwenhuyse *et al.* 2008). On the one hand, the Little Owl, like other owl species, is poorly studied in vast parts of its breeding range (Vrezec *et al.* 2012); but, like other owls, this is a charismatic species because of its nocturnal and predatory habits and long history of cultural value (Kovács *et al.* 2008, Movalli *et al.* 2008). Little Owls can thus entice the interest of the general public. It is also quite easy to detect and to study even by non-professional ornithologists.

This study was carried out as part of the work done for the realization of the Milan Urban Bird Atlas (Bonazzi *et al.* 2005). The aims were: a) to evaluate the general distribution of the Little Owl in Milan, a highly urbanized area; b) to preliminarily inspect environmental factors that drive species distribution in the urban environment; c) to implement simple and quick methods to survey the species, and to evaluate these methods with respect to their use in a future wide scale monitoring based on citizens.

MATERIALS AND METHODS

Study area

Milan is the second largest Italian city and the total population stood at 1,262,101 inhabitants on 31st December 2012. It's located in the middle of the Po Plain, one of the most populated areas in Europe. No less than 64.7 % of Milan's territory is occupied by built up areas, and the 13.8% by urban green areas (parks, gardens and sports facilities - Fig. 1). Agriculture is mainly relegated to the southern outskirts and occupies 19.0% (16.2% arable fields and 2.8% grasslands) of the municipality surface. The city is surrounded by a system of highly congested motorways. Milan hosts two regional parks: Parco Nord Milano at the north-eastern side of the city and Parco Agricolo Sud Milano that surrounds the southern part of the city, from west to east.

Study species

The Little Owl is a small nocturnal raptor. It is territorial and monogamous and it usually lives in isolated pairs. The species has many types of vocalizations used all year round (Brichetti & Fracasso 2006). It feeds on insects, small mammals and birds, but its diet can vary considerably within its breeding range (Van Nieuwenhuyse *et al*. 2008; for Italy see Bon *et al*. 2001, Bux & Rizzi 2005; Arcidiacono *et al*. 2007). It is a secondary cavity nester, nesting in natural or anthropogenic holes (e.g. pollarded willows or mulberry trees) and in man-made structures (mainly farmsteads buildings, but also ruins and other buildings, both residential and industrial). In its global distribution range the breeding season varies with latitude: from February to April in southern regions, from March to June in central-northern regions, with annual shift in cases of cold winters and rainy springs (Mastrorilli 2005).

The native habitats of Little Owls are open landscapes with shrubby vegetation and rocks. However it has adapted to live in other secondary habitats, mainly open farmlands. It usually breeds under 1200 m a.s.l., throughout the Palearctic regions, in northern Africa and in the Arabian Peninsula (Cramp & Simmons 1980). The European breeding population is estimated at around 618,000-1,170,000 breeding pairs and it is stable, even if recent population declines have been documented in northern and central regions (Chrenková *et al.* 2017, Kitowski & Stasiak 2013, Šálek & Schröpfer 2008, Żmihorski *et al.* 2009, Šálek & Lövy 2012, Thorup *et al.* 2013, Šálek *et al.* 2016); it is listed as a 'SPEC 3' species (BirdLife International 2017).

In Italy the species is sedentary and breeds across the entire peninsula and on islands, with the exception of some Alpine interior areas and large woodlands; the estimated size of the national breeding population ranges from 40,000 to 70,000 pairs (Brichetti & Fracasso 2006). It is not listed in the national Red List of breeding birds (Peronace *et al.* 2012) and has a favourable conservation status with a general population stability and local declines or fluctuations (Gustin *et al.* 2010). The main conservation concerns for the species are habitat modification (cutting of tree lines and hedgerows, decline in grasslands extension), the intensification of agricultural practices (e.g. increase in chemical inputs), cold winters, restoration of buildings, and the increase in vehicular traffic (which leads to several casualties; Galeotti *et al*. 2001).

Sampling design

Sampling design has been based on the grid used for an existing urban atlas project (Bonazzi *et al.* 2005). The city surface has been subdivided into 207 1x1 km squares (based on the UTM grid): these have been grouped into 40 sectors containing each up to six 1x1 km squares. For each sector two squares have been selected for sampling (primary sampling units), moreover, for each peripheral sector, likely the most important areas for the species, a substitute sampling unit has also been identified in the case primary units were not accessible or sampling not feasible for some reason. We chose the 1x1 km squares with the higher availability of little disturbed and safe place. Exact sampling location within 1x1 km squares has been placed as close as possible to the square centre, taking into consideration the same logistic constraints.

Field methods

The survey has been carried out using playback method (Bibby *et al.* 2000). It relies on Little Owl reaction to a conspecific vocalization. Little Owl's vocalizations have been reproduced by means of a tape lure and the likely positions of answering individuals have been recorded on a regional map (scale 1:10,000) on the basis of calls provenance and environmental features (Fig. 2). A mean audibility range of 500 m for Little Owl song, based on field measurements, has been suggested by some authors (Centili 2001, Van Nieuwenhuyse *et al.* 2002). With a 500 m radius it is possible to cover an 80 ha surface, larger than a mean Little Owl home range size estimated in 30 ha (Finck 1993). It is thus enough to detect a song location to locate a territory (Van Nieuwenhuyse *et al.* 2002).

The survey has been carried in 2013, between March and May as in these months Little Owls showed the highest response rates (Centili 2001). Sampling started at sunset and ended approximately by 1.00 a.m. Each sampling station was visited once by at least two researchers of which at least one was a professional (or a trained researcher). Professionals and non-professionals recorded independently the presence/absence of the Little Owl and compared their observations at the end of the listening session. Professionals sightings were always considered the correct results. Disagreement in results were recorded to understand main difficulties in species detection for non-professionals.

Researchers broadcasted the Little Owl sound-track from Rochè (1996) that lasts 78 seconds. It is separable into 9 sequences containing three types of vocalization: alarm call, "miaou" and "ghuk" (male song).

We followed the Flemish Little Owl Project sampling protocol (Leysen *et al.* 2001 - Table 1): 1) once arrived to the broadcasting point, the observer had to spent a minute listening for spontaneous vocal activity; 2) then the call track was broadcasted three times, with each track separated by a one minute listening; 3) the observer continued listening for 5 minutes after the last sequence. Broadcasting was stopped as soon as a Little Owl was detected and the

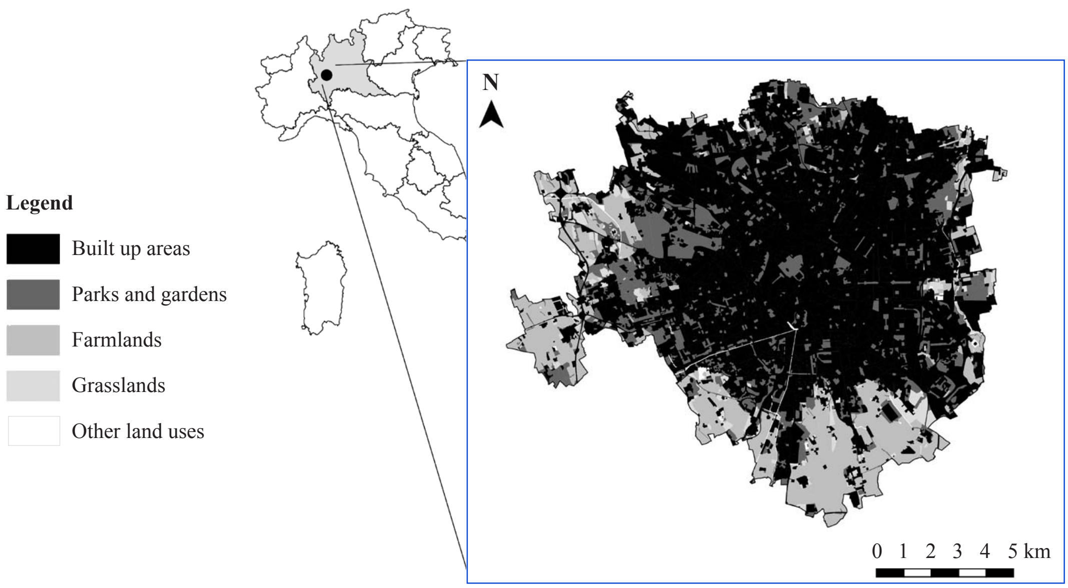

Figure 1. Study area location and land use map of the city of Milan.

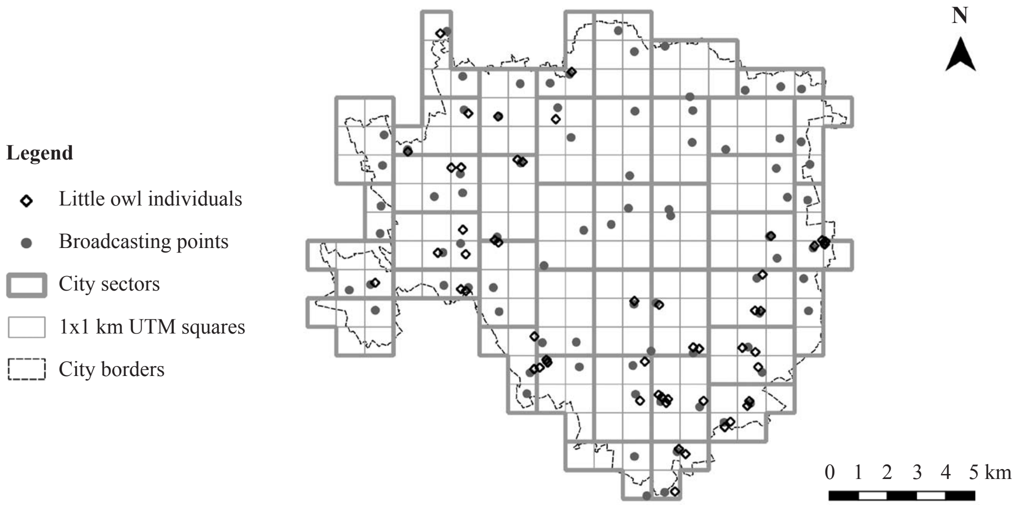

Figure 2. Map showing broadcasting points and Little Owl individuals locations.

first detection of an individual was followed by 5 minutes of listening. Broadcast vocalizations were played at volume and clarity levels consistent with that of wild owls as too high a volume can scare off Little Owls (Juillard 1984).

Environmental variables

The choice of the sampling scale is the first step in modelling species occurrence. Habitat selection in animal species could be seen as a hierarchical process that acts at different scales (Johnson 1980). Martínez and Zuberogoitia (2004) suggested a multi-scale approach with three levels to study the environmental preferences of Little Owl: landscape, home range and nest-site scale. The sampling design of this study allowed us to work only at the home range scale and that has been used for the extraction of environmental variables. The environmental variables that can potentially influence the presence of Little Owls have been derived from known literature (Van Nieuwenhuyse & Bekaert 2002, Martínez & Zuberogoitia 2004, Zabala *et al.* 2006, Żmihorski *et al.* 2009, Šálek & Lövy 2012, Šálek *et al.* 2016).

Table 1. Playback protocol employed at each sampling station.

Phase	Duration (sec.)	Action
1	60	Silence and listening
2	78	Call track
3	60	Silence and listening
4	78	Call track
5	60	Silence and listening
6	78	Call track
7	300	Silence and listening
Total	**714** (sec.)	

We worked on species occurrence, i.e. presence versus (apparent) absence. To do this we had to obtain a certain number of presence and absence areas. Little Owl home range size has been considered 30 ha (Génot & Wilhem 1993, Van Nieuwenhuyse & Bekaert 2002) which corresponds to a 309 m radius circular plot. For species absence we considered each survey point in which no Little Owl has been detected and drew the plot around those points. For species presence we considered each Little Owl location (as evaluated by observers) as plot centre. In order to reduce pseudo-replication problems the plot choice have been done trying to prevent overlapping: if two or more plots overlapped for more than one-third of their surfaces we randomly chose one of them. Applying this procedure we obtained 81 plots: 36 presence plots and 45 absence plots.

For each circular plot we extracted environmental variables by means of Quantum Gis 1.7.4 vector analysis tool (QGIS Development Team 2013) using freely available land use vectorial maps (1:10,000). First of all the percentage of cover of each land use category has been obtained from regional land use map (DUSAF - www.cartografia.regione.lombardia.it). We moreover calculated the building's mean height and total volume to get indicators of urban environment structure (source: built-up areas of Provincial County Seats wms.pcn.minambiente.it/ogc?map=/ms_ogc/wfs/Edifici.map). We finally obtained these other variables: the presence of farmsteads buildings and the maximum extent of parks crossed by the plot (regional vectorial maps - www.geoportale.regione.lombardia.it/).

Some of the selected land use categories had a very small extent in the majority of plot showing a skewed distribution including several zero values. To overcome this problem we thus converted these variables into binary factors (presence=1, absence=0) keeping their interpretation simple. We arcsine-square-root transformed continuous land use variables before running the statistical analyses (Sokal & Rohlf 2009).

Data analyses

We modelled the Little Owl's environmental preferences in the study area by means of generalized additive models (GAM, Wood 2006), using the presence/absence of Little Owl as a binary dependent variable and a logit link function. GAMs are semi-parametric extensions of generalized linear models that allow non-linear relationships between response and independent variables. Moreover they correctly estimate regression coefficients in presence of spatial autocorrelation (Beale *et al.* 2010). We account for the spatial structure of our data incorporating their coordinates in GAMs as tensor product smooth terms (we referred to this part of the model as "spatial effect" in the remaining text).

Some of our continuous predictors were highly correlated (Tab. 2). In these cases we decided to retain only one of the correlated variable as predictor. The variables left out were those that showed the least significant single variable GAM model. We retained Building's mean height (% cover of built-up areas and Building's total volume removed) and Largest area of the parks crossed by the plot (% cover of gardens and parks removed).

We used an information-theoretic approach in model selection procedure (Burnham & Anderson 2002) comparing models with all possible combinations of predictors. We ran all the models and, for each of them, we calculated the Akaike's Information Criterion corrected for sample size (AICc - Hurvich & Tsai 1989). AICc represents a trade-off between explanatory power and model complexity. Models with the lowest AICc values are considered the most parsimonious models, therefore the best ones. We considered a model to be a candidate one only if it had AICc lower than the AICc of all its simpler nested models (Richards *et al.* 2011): in this way we reduce the risk of selecting too complex models (Raffalovich *et al.* 2008).

We considered best models all the most supported models, i.e. all models with a difference in AICc with the best model smaller than 2 (ΔAICc<2 - Burnham & Anderson 2002). We evaluated the importance of individual variables using the summed Akaike weights over all these best models (Burnham & Anderson 2002). The discrimination ability of the best model has been evaluated both by calculating its accuracy (percentage of correctly predicted presences and absences) and the area under the ROC curve (AUC).

We run statistical analyses with mgcv (Wood & Scheipl 2016), MuMIn (Bartoń 2016) and pROC (Robin *et al.* 2011) packages of R 2.15.1 software (R Core Team 2012). Our best model has been used to draw an occurrence probability/habitat suitability map of the whole study area. For this purpose a new geographical grid, based on 547 m side cells (30 ha surface, equivalent to the Little Owl home range), has been drawn. Fitting our model prediction for each new cell we obtained the probability to detect Little Owl, expressed as a continuous variable bounded between 0 and 1. We convert these values into 5 categories: low (probability's value between 0 and 0.2), medium-low

Table 2. Habitat variables measured at the home-range scale (30-ha plots).

Type	Variable	Abbrev.
Continuous	% cover of built-up areas*	built
	% cover of gardens and parks†	parks
	% cover of arable lands	arable
	% cover of permanent grasslands	grass
	Building's mean height*	build.h
	Buildings total volume*	build.v
Categorical	Largest areas of the parks crossed by the plot†	max.prk
	Presence of main roads	roads
	Presence of bare ground (quarries, construction sites, ballasts, ...)	bare
	Presence of other green urban areas	oth.gre
	Presence of permanent crops	per.cro
	Presence of small wood plots	wood
	Presence of farmsteads	farm

Continuous predictors with the same symbol are highly correlated (|r|>0.6)

(0.21-0.4), medium (0.41-0.6), medium-high (0.6-0.8) and high (0.1-1).

RESULTS

Field survey results

We detected 52 Little Owls in 33 out of 82 sampling stations. In 5 stations Little Owls were spontaneously calling at the arrival of researchers. No Little Owls were detected in the central and the north-eastern part of the city. The species showed to be uniformly distributed in the rest of the study area, with higher densities in south-eastern side.

Species occurrence modelling

Of the 67 candidate models, the most supported one included five variables plus the spatial effect (Tab. 3): the presence of permanent crops and farmsteads positively influences the probability to detect the species whereas, the presence of wood plots had a negative effect on species detection (Tab. 4). The occurrence probability of Little Owl had a roughly quadratic relationship with mean height of buildings, with a peak value at about 10 m (Fig. 3, left); Little Owl occurrence was finally positively influenced by the extent of urban parks (Fig. 3, right). This best model explained 44.5% of the total deviance and accurately predicted 80.2% of the observed data.

Five other models were well supported (ΔAICc<2 - Tab. 3): the 6 best model have a total AICc weight of 0.485. The most important variables in shaping species occurrence were presence of permanent crops and buildings height, even if this latter predictor is not significant in the best model. Spatial correlation contributed significantly to explain Little Owl presence in all best models. Other well supported predictors were the presence of farmsteads buildings and the extent of urban parks that positively influenced Little Owl presence. Finally the presence of wood plots and that of main roads were negative factors that showed little support.

Accuracy and predictions

Model predictions obtained with the single best model or averaging the six best models were highly correlated (Pearson's correlation: r=0.987, p<0.001). We thus considered the performance of the best model to draw prediction map and to illustrate single variables effects on species occurrence. The best model can accurately classify the 80.2% of observed data. The occurrence probability/habitat suitability map built with the best model is shown in Fig. 4: 44.0% of squares have a low suitability, 16.0% medium-low, 10.7% medium, 11.8 % medium-high and 17.5% high.

DISCUSSION

Species distribution and driving factors

Our results showed that Little Owls were quite common in the city of Milan, but it showed an uneven distribution, with higher densities in the suburban agricultural zone of Parco Agricolo Sud Milano and lower densities in more urbanized areas (centre and north-east). These results agree with those of other studies carried out in Mediterranean areas: Sorace (2002) found that Little Owl abundance was similar in urban parks (especially in farmland urban parks) and in the surrounding farmlands, while Sorace & Gustin (2009), analysing results of 27 ornithological urban atlases, observed that the frequency of Little Owl was lower in the centre than in other sectors of the cities. The adaptation by Little Owls to urban ecosystems is far from being a universal pattern, though. In polish cities for instance Kitowski & Grzywaczewski (2010) documented the extinction process of this species, taking place especially in the northern and southern part of the country.

In Milan the Little Owl seems to select areas with a landscape structure suitable for its hunting activities. The species is more likely to be found in presence of permanent crops, like e.g. orchards: these crops can supply suitable hunting areas with abundant food and perches. These latter

Table 3. Most supported models (ΔAICc<2) describing influence of environmental factors on Little Owl occurrence in Milan. Models are ranked according to their ΔAICc; the model with the lowest ΔAICc is the best AICc model. ΔAICc: difference between the AICc of each model and the AICc of the best model; w: AICc weight of the model. For variable abbreviation see Tab. 2. spat = spatial effect.

rank	Model description	df	AICc	Δ AICc	w
1	spat+build.h+per.cro+max.prk+farm+wood	10	87.478	0.000	0.116
2	spat+build.h+per.cro+max.prk+farm+roads	17	87.752	0.274	0.101
3	spat+build.h+per.cro+farm+wood	9	88.172	0.694	0.082
4	spat+build.h+per.cro+max.prk+roads	15	88.606	1.128	0.066
5	spat+build.h+per.cro+max.prk+wood	10	88.678	1.199	0.063
6	spat+build.h+per.cro+max.prk+farm	15	88.855	1.377	0.058

Table 4. Wald tests and relative significance of each parametric and smooth term in the most supported model (lower AICc). On the right side of the table variable importances considering the most supported models (ΔAICc<2) are showed: *Frequency* is the number of models in which each variable appeared; *Importance* is the sum of the Akaike weights over all of the models in which the predictor term appears.

	Top model			Best models (Δ AICc<2)	
Predictor	**d.f**	**χ^2**	**P**	**Frequency**	**Importance**
Categorical predictors					
Presence of permanent crops	1	4.714	0.030	6	1.00
Presence of farmsteads	1	3.346	0.067	4	0.73
Presence of small wood plots	1	1.764	0.182	3	0.54
Presence of main roads	-	-	-	2	0.34
***Continuous predictors** (smoothed)*					
Buildings height (m)	2.31	6.546	0.113	6	1.00
Maximum park extent	1	2.713	0.099	5	0.83
Spatial effect	3	15.341	0.002	6	1.00
Deviance explained			44.5%		
Prediction accuracy			0.802		
AUC ROC			0.797		

are a key feature in Little Owl hunting behaviour (Tomé *et al.* 2011). Little Owl occurrence is also more likely in bigger parks, where grassy areas and tree lines or isolated trees are more abundant. This result agrees with the well know preference of Little Owl for pastures and meadows flanked by pollarded trees, that has been documented in most part of its breeding range characterized by anthropogenic areas (Van Nieuwenhuyse *et al.* 2008).

With respect to buildings, Little Owl select an intermediate mean height that characterizes residential areas. According to Kitowski & Grzywaczewski (2010) these areas provide abundant lookouts, fundamental for the preying tactics of the species. Moreover the regular mowing and trampling of lawns and other grassy areas allow Little Owl to feed on ground invertebrates, close to their nesting sites.

The presence of farmstead buildings was one of the most supported predictors in our analyses. The Little Owl, being a secondary cavity nester, nest site availability is one of the main limiting factors for the species in several parts of its range (Van Nieuwenhuyse *et al.* 2008). Farmsteads and other rural buildings are often used by the species for nesting and are actually the main nest sources in different areas (Van Nieuwenhuyse *et al.* 2008) . Farmstead can thus be considered a good proxy for nesting site availabil-

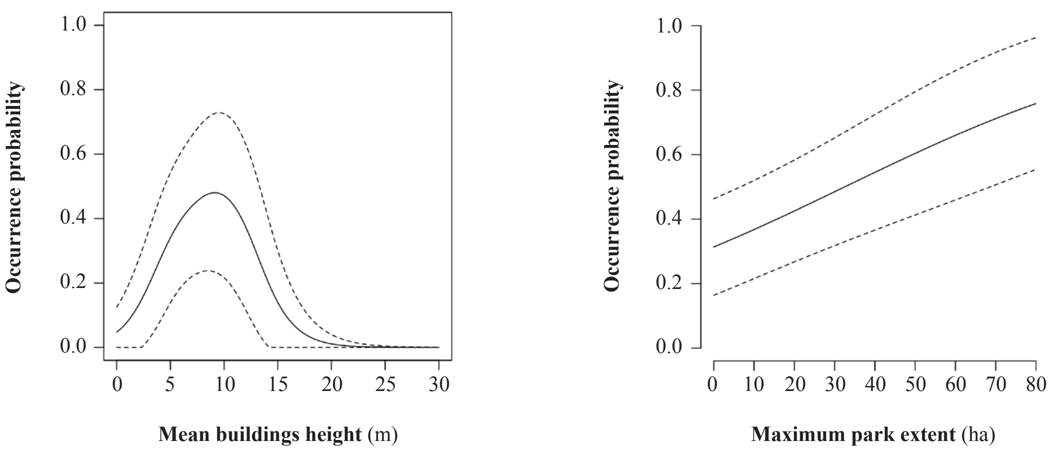

Figure 3. Relationship between Little Owl's occurrence probability and two continuous predictors. Solid line: prediction; dashed lines: prediction ± standard error). To draw the lines we set all other predictors at a certain value (For Maximum park extent plot: Mean building height = median value; permanent crops = 0; small wood plots = 0; Farmsteads=0. For Mean Building's height plot: Maximum park extent = median value; permanent crops = 0; small wood plots = 1; Farmsteads=1).

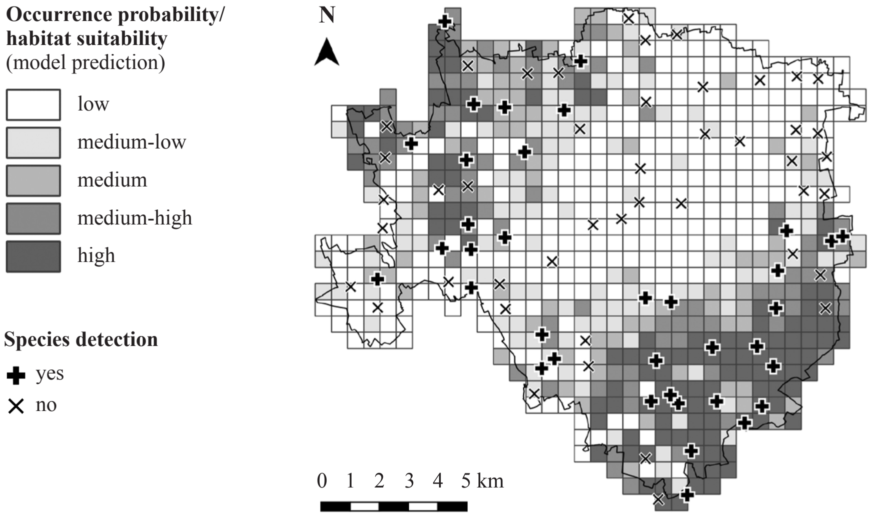

Figure 4. Model prediction for the occurrence of Little Owl in Milan. Results of field survey have been superimposed to habitat suitability map.

ity in our study area as well as in other areas (Šálek *et al.* 2016). Spatial effect turned out to be very important in our data, suggesting that accounting for spatial autocorrelation is of pivotal importance in modelling Little Owl distribution. The sources of spatial autocorrelation could be both biological and statistical (Dormann *et al.* 2007). Within biological causes, Little Owl's short-scale dispersal (Schaub *et al.* 2006, Spina & Volponi 2008) could be the main cause of a spatial pattern observed. According to Thorup *et al.* (2010) spatial dependence of observations could also arise from conspecific attraction or social system. From a statistical point of view, spatial autocorrelation of residuals may originate if non-linear relationships between species and environment are modelled as linear or if the statistical model fails to account for important spatially structured predictors (Dormann *et al.* 2007). Using GAM we prevented the first type of statistical problem but we can't rule out the possibility of a missing predictor in our model. This is a common issue in species distribution modelling because not all relevant predictors are always available as GIS layers (Brambilla *et al.* 2009) or easily collectable in the field.

Our best model correctly classified the 80.2% of data, showing thus a good accuracy, comparable to or better than that of other European studies (Van Nieuwenhuyse & Bekaert 2002, Martínez & Zuberogoitia 2004, Zabala *et al.* 2006). The model predictions showed that the 29.5% of the municipal territory has a medium or high suitability for the species but it should be noted that these areas are mainly relegated to the peripheral parts of Milan. Environmental suitability map followed quite accurately the survey results deviating from them especially in the eastern and north-western sectors of the city where there are potentially suitable green areas but where the species has not been detected.

This could be due to the presence of other important factors in determining the distribution of the species that we did not account for. One of this could be the presence of bigger owls, like e.g. Tawny Owl *Strix aluco* and Long-eared Owl *Asio otus* which are known to attack the Little Owl (Mikkola 1976, Zuberogoitia *et al.* 2005) and thus displace it. The places where our model predictions most deviate from observed data are characterized by the presence of wooded plots that can host some forest owl species (Tawny Owl has been actually detected during Little Owl census in two woodland urban parks in the north-western side of the city).

Detectability issues

The non-detection of Little Owl in certain areas where its occurrence has been predicted by the best model should not necessary mean that the species is actually absent. The lack of species detection could be linked to its low detectability. The Little Owl is known to lower its vocal activity in presence of larger owl species (Zuberogoitia *et al.* 2008). Moreover in deeply urbanized areas, the effectiveness of the survey method and the detectability of the species can be deeply conditioned by urban noise (Simons *et al.* 2007) or by the structure of the urban pattern: vertical elements, like buildings and trees in parks, all of which could interfere with the propagation of sound. In order to account for these sources of variability the collection of additional information on ambient noise should be incorporated into routine sampling protocol. Ambient noise could be directly recorded by researchers with an empirical categorical scale (e.g. low, medium, high): this method proved to work when adopted during a woodpeckers survey in the same geographic area (Muzio 2016). The description of habitat structure could be hardly feasible in field. Recent development of LiDAR technology is very promising (Davies & Asner 2014): its use in ecological studies is fast growing and it will likely became the routine method to decribe habitat sctructure (Tattoni *et al*. 2012, Ficetola *et al*. 2014). The discussion about these sources of variability in species detectability emphasize one of the main drawbacks of our study: the single visit within the breeding period. It prevented us to jointly model the two aspects that determine the output of a field survey: true occupancy and detectability (MacKenzie *et al.* 2002). The detection probability issue has been considered by Johnson *et al.* (2009) who wrote a general survey protocol for the species. These authors stated that a single visit approach could be used in general distribution surveys aimed at showing the general distribution of owls and, at the same time, useful to highlight areas for future works. The same authors suggested a minimum of four visits for demographic and density studies: this number of visits is considered necessary to detect 95% of the breeding population.

Considerations on sampling protocol

The protocol suggested by Johnson *et al.* (2009) is very demanding not only for the number of visit but also with respect to the survey methods: it considers 4 km² squared survey units (2 x 2 km) divided into sixteen squares of 25 ha. In our experience this survey unit is hardly feasible in a single night. Moreover this sampling strategy is very demanding for non-professionals and we believe a spot-calling approach would be much better: it allows to increase the survey area with the same sampling effort. For this reason it has been successfully adopted in several large scale studies (Martínez & Zuberogoitia 2004, Zabala *et al.* 2006, Šálek & Schröpfer 2008, Habel *et al.* 2015, Šálek *et al.* 2016, Chrenková *et al.* 2017). In order to avoid the oversampling of only suitable areas, it could be necessary to apply a stratified sampling design so as to homogeneously sample the different environments present in a study area.
The monitoring of owls is a difficult and demanding task, due to the nocturnal activity that may discourage volunteers, as well as some health and safety issues involved. It is therefore crucial to define effective methods finding the best trade-off between scientific outputs and sampling effort. In Spain Zuberogoitia *et al.* (2011) confirmed the need of 4 visits to detect the 95% of breeding pairs but they also suggested to evaluate response rates of Little Owls in each study area because the species detectability could have substantial geographical variations. Moreover the same authors assumed a constant detectability over the breeding season and this could not be the case. Probably, monitoring the species during the peak of detectability could allow to detect the 95% of breeding pairs with less than 4 visits.

Professionals and volunteers showed no differences in species detection, apart from some confusion with the call of the female Tawny Owl recorded by non-professionals. The Little Owl is very easy to detect, also for non-expert personnel, and the training of new researchers appears to be quite straight forward.

Little owl monitoring in Italy and Europe

In Italy, despite the existence of a certain number of local studies on species distribution (e.g. Chiatante & Todisco 2012, Colaone *et al.* 2012, Mastrorilli 1997, Vendramin & Marchesi 2003), there are few or no large scale data about the Little Owl or any of the other owls in general. This is a serious lack of knowledge for bird conservation policies in our Country. Many species of owls are of conservation concern at regional, national and/or continental scale. The missing information about their demographic trends can compromise the right evaluation of their conservation status (Gustin *et al.* 2010).

The Little Owl is the most common species of owl in Italy (Brichetti & Fracasso 2006) and, at present, the only available population trend assessment for the species (moderate decline) comes from the common breeding bird monitoring programme (MITO2000 – Campedelli *et al.* 2012), a project with methodologies not targeted on nocturnal species (Fornasari *et al.* 2002).

Derlink *et al.* (2018) recently reviewed raptors and owls monitoring in Europe, gathering data from 37 countries, as part of the EURAPMON project (EURAPMON 2012). They showed that owls are significantly less monitored than diurnal raptors and that the coverage of breeding populations is poor in southern Europe. The Little Owl is one of the most studied owls in Europe by a number of active schemes (16) and number of involved countries (9). But, when monitoring effort is related to breeding range it turns out that the Little Owl is not monitored in vast parts of its European range. If we compare EURAPMON results with the published bibliography on the species (e.g. Żmihorski *et al.* 2009, Zuberogoitia *et al.* 2011, Šálek *et al.* 2016, Chrenková *et al.* 2017, Hámori *et al.* 2017), it is evident that EURAPMON failed in collecting information from all existing schemes: the reasons of this failure are the constraints of survey approach and inventory design, well explained by Derlink *et al.* (2018). Yet, despite this, the author's findings turned out to be correct. At present the majority of European countries lack population trend estimates and, as a consequence, there is no reliable trend estimation for Little Owl at a continental scale. This lack of information lowers our ability to correctly evaluate the species conservation status at a continental scale (BirdLife International 2017). The Little Owl is now classified as SPEC 3: its global population is not concentrated in Europe but it is a species of European conservation concern because its range has contracted locally in many parts of Europe (BirdLife International 2019).

Towards a large scale monitoring

The majority of raptors' monitoring schemes are run by civil or non-governmental organizations and mainly rely on volunteer effort (Derlink *et al.* 2018). Here, the Little Owl can be an ideal species in developing the first large scale monitoring programme of an owl species in Italy, with the chance to successively extend it to other owl species. Like other nocturnal raptors, the Little Owl is a captivating species for the lay person that can therefore be easily involved in monitoring and conservation actions, as it is already happening in some European Countries (Van Nieuwenhuyse *et al.* 2001). The species is easy to detect and this makes the training of volunteers undemanding. Anyway, even if entirely based on volunteer effort, a large scale monitoring is not feasible without funding. Johnson *et al.* (2009) estimated that larger demographic study areas will employ a Project Manager for 5–6 months, and Field Surveyors of 3–4 personnel for 5 months, for a total of some 26 staff-months. The possibility to involve the general public in Little Owl monitoring could increase the number of possible sponsors. With this respect it is crucial to consider and to present citizen based species monitoring not only as a research activity but also as a public good. Participation in scientific research creates authentic learning experiences, and, because of its participatory nature, citizen science can elevate public understanding of and support for science and the environment (Dickinson *et al.* 2012a).

The sampling effort needed for the monitoring is a crucial issue. Derlink *et al.* (2018) stressed the need to take into account the geographical context into which new programmes intend to operate. Volunteer-based projects are less spread in Southern Europe for several reasons: attitude to conservation, past culture of interest in nature, leisure time available and so on. In a similar context it is not feasible to start a long term research project based on intensive sampling (Johnson *et al.* 2009). It is thus crucial to find the best trade-off between sampling effort and output quality. To do this it could be useful that a preparatory study on species detectability patterns in order to set the best and more parsimonious sampling design is setup (Mackenzie & Royle 2005).

Surveys based on effective methods and strong theoretical basis are of pivotal importance in order to obtain the most accurate information about environmental preferences of the species and, ultimately, about their population trends. This is the only way to plan the needed effective conservation policies for animal species.

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