Environmental drivers of House Sparrow *Passer domesticus* presence and abundance in the Metropolitan Area of Barcelona: a multi-variant approach

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Despite being one of the most abundant animal species in the world, House Sparrow *Passer domesticus* numbers have declined significantly worldwide in recent decades, above all in urban areas. We studied the influence of vegetation, urban structure, human activity and predators on the presence and abundance of House Sparrows in the Metropolitan Area of Barcelona (MBA), Catalonia, Spain. We established 80 point-counts in four land categories defined by urban location (intraurban, periurban) and urbanisation density (low, high) in spring and winter in 2015 and 2016. We used random forest models to analyse how presence and abundance were related to 22 explanatory variables. Our results highlight the complex interaction between structural and anthropogenic factors and House Sparrow presence and abundance. Presence increased with proximity to allotments and in areas with mid-level tree densities and no shrub cover; conversely, abundances peaked in areas with more litter. Predators and urban land-category had little impact on either House Sparrow presence or abundance. Neither presence nor abundance showed seasonal differences. Natural and semi-natural vegetation remnants and the heterogeneity of green spaces are crucial for the presence of House Sparrows in urban landscapes. As urbanisation becomes more intensive and homogeneous, these green spaces are becoming increasingly scarce, a factor that probably contributes to the observed declines in this sparrow's populations throughout Europe. Human activity plays a critical role in its abundance, although any dependence on human-mediated resources may leave populations vulnerable in the event of changes in urban waste-disposal practices.

Key words: *Passer domesticus*, population decline, random forest, urban areas, urban debris

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Mediterranean ecosystems have long been threatened by habitat loss and, for instance, in recent decades the progressive urbanisation of natural landscapes has become a significant driver of habitat transformation (Myers *et al.* 2000). Adaptation to built-up areas requires great behavioural and physiological plasticity (González-Lagos & Quesada 2017) and prompt a wide range of responses in bird species. Birds may avoid, make use of or even thrive in urban landscapes, which can lead to local population extinctions, declines or increases, respectively (Fischer *et al.* 2015). Some species successfully exploit urban areas, where they establish new populations beyond their original ranges. In particular, the drastic simplification of natural habitats provoked by urbanisation can benefit granivorous and frugivorous bird species (Marzluff 2016). A well-known example of a geographical expansion is that of the House Sparrow *Passer domesticus*. Since the late twentieth century, this species has become one of the most widespread and abundant bird species worldwide. Originally a Middle Eastern Asia species, it has spread as a commensal with humans throughout Eurasia in recent millennia (Ravinet *et al.* 2018) and has also colonised America, parts of southern Africa and Australia (Anderson 2006).

Yet, despite being one of the most abundant animal species in the world that has lived in close association with humans for centuries (Anderson 2006, Ravinet *et al.* 2018), the House Sparrow has declined significantly in recent decades. This regression is subject of growing concern since its population has declined by about 66% in Europe since the 1980s (PECBMS 2024) and by 21% in Spain in 2008–2018 (SEO/BirdLife 2019). These declines have been especially notable in urban areas throughout the world (e.g. Newson *et al.* 2009, Yadav *et al.* 2018, Berigan *et al.* 2020) and, for instance, the House Sparrow population in the city of Barcelona decreased at an annual rate of 6.5% in 2002–2022 (Anton & Ferrer 2022).

Birds have species-specific requirements including suitable habitats that can provide nesting sites, food and protection (Martin 1988, Chalfoun & Schmidt 2012, Fuller 2012). Understanding these requirements is crucial for effective conservation, especially in the face of climate change and pressure from human development (Fuller 2012). House Sparrows have been able to satisfy these requirements in close proximity to humans and today occur exclusively in anthropomorphic habitats such a farmland and built-up areas (the exception being *Passer domesticus bactrianus*, Anderson 2006). In urban areas, House Sparrows find nesting sites in buildings and feed their young during the breeding season on a great variety of edible rubbish (Summers-Smith 1999), as well as on invertebrates (Hole *et al.* 2002, Moreno-Rueda & Soler 2002, Vincent 2005). However, the House Sparrow is a highly sedentary species whose home ranges are relatively small (Snow & Perrins 1998, Vangestel *et al.* 2010, but see Havlíček *et al.* 2022). In the breeding season, adult birds forage within 60–70 m of their nests (Vincent 2005, Peach *et al.* 2008), with the core of the home range covering as little as 39–130 m^2 (Vangestel *et al.* 2010). This sedentary lifestyle makes House Sparrows vulnerable to decreases in both favourable urban habitat and food availability, especially during the breeding period.

The factors driving the House Sparrow decline must inevitably be affecting their basic requirements in some way or another. However, the actual combination of factors explaining population declines may differ between and within urban areas because of the huge heterogeneity that characterises them. Some of the main factors include urban structure (e.g. old vs. recently built-up areas; Moudrá *et al.* 2018), human activity (e.g. industrial vs. agricultural; Hole *et al.* 2002), vegetation (e.g. cover and degree of naturalisation; Murgui & Macias 2010, Sánchez-Sotomayor *et al.* 2023, Bernat-Ponce *et al.* 2024), access to water and predation pressure (Bell *et al.* 2010). Other, less evident factors such as pollution (Herrera-Dueñas *et al.* 2014), changes in how urban parks are watered (Murgui & Macias 2010) and improvements in street hygiene and waste-removal policies (Bernat-Ponce *et al.* 2022, Havlíček *et al.* 2022) may all also be playing an important role .

Urban planning and management ideally require long-term population studies if the impact of urbanisation on certain species is to be fully evaluated (Jokimäki *et al.* 2021). However, bird monitoring programs have traditionally overlooked urban areas, so there is a scarcity of reliable relevant information. Alternatively, spatial analyses could be conducted to relate environmental factors to species presence and abundance, which may help identify the main drivers affecting these population parameters. The aim of our study was thus to shed light on the factors affecting the decline of the House Sparrow in an urban mosaic in the western Mediterranean, the Metropolitan Area of Barcelona (hereafter, MAB), through a multi-variant approach. Specifically, we analysed how human activity, vegetation structure, urban structure and the presence of predators affect the spatial distribution of the presence and abundance of the local House Sparrow population.

Material and methods

Study area and sampling design

Fieldwork was carried out in the MAB in spring and winter of 2015 and 2016. The MAB (lat 41.3825, long 2.176944, WGS84; c. 636 km^2) lies in the Mediterranean bioclimatic region in the north-east Iberian Peninsula (AMB 2024). It is densely populated and embraces 36 municipalities, including the city of Barcelona, with a total population of around 3.3 million. The area includes densely urbanised zones in the Barcelona Plain, agricultural landscapes in the delta of the river Llobregat, and extensive wooded areas in the surrounded hills (Rivas-Martínez 2005). The region experiences annual maximum temperatures of 21°C and minimum temperatures of 8°C, with an average annual precipitation of 466-764 mm (Ninyerola *et al.* 2005). Our study focused on the urbanised matrix of municipalities in which, due to operational constraints, we selected a subset of municipalities (Fig. 1).

We defined four urban-land categories by combining two dichotomous variables: (i) location (intraurban vs. periurban) and (ii) vegetation cover as a proxy of urbanization intensity (high vs. low). Following MacGregor-Fors (2010) and MacGregor-Fors *et al.* (2017), the periurban zone was objectively delineated using a smoothed urban boundary and its confidence interval to identify a peripheral transitional band (see MacGregor-Fors 2010 for more details). The urbanisation intensity was categorised using NDVI-based vegetation cover: areas with >60% green cover were considered low intensity urban areas, while those with <60% green cover were defined as high intensity (Garcia- Arroyo *et al.* 2025). This classification allowed us to generate four meaningful land categories (*Intraurban High*, *Intraurban Low*, *Periurban High* and *Periurban Low*) with which we compared House Sparrow distributions across a realistic urban gradient.

This classification framework captures the complexity of urban gradients and provides a more nuanced approach to assessing the effects of urbanisation on bird distribution, as has been demonstrated by previous studies (MacGregor-Fors *et al.* 2017). Rather than dividing the region into large discrete zones, the four urban-land categories can occur anywhere within the metropolitan area. Thus, intraurban areas are not always characterised by high population density and not all periurban areas are low

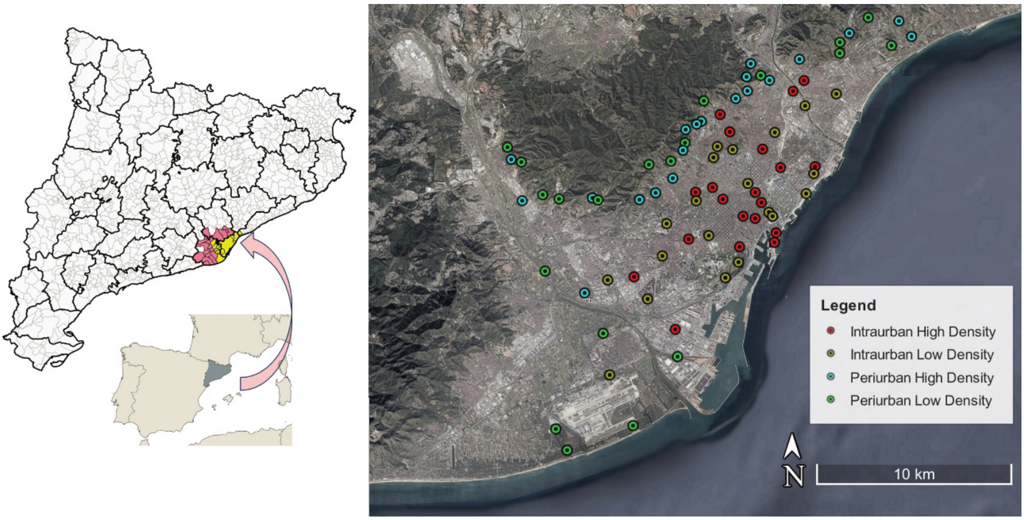

Figure 1. Point counts in 2015–2016 used in the House Sparrow study in the Metropolitan Area of Barcelona classified into four urban land-use categories. The red area corresponds to the entire Metropolitan Area of Barcelona, while the yellow area represents the sector within the MBA where the study was conducted.
Punts de comptatge del pardal comú durant els anys 2015–2016 a l'Àrea Metropolitana de Barcelona, classificats en quatre categories d'ús del sòl urbà. La zona vermella correspon a tota l'Àrea Metropolitana de Barcelona, mentre que la zona groga indica la secció dins de l'AMB on es va dur a terme l'estudi.

Table 1. Environmental variables used in this study covering the within 50-m radius of each point-count (except "Proximity to schools" and "Proximity to allotments"). Right columns: effect on presence-absence (P) and abundance (A) based on partial dependence plots: increase ↑, decrease ↓, concave ∩ and convex ∪.
Variables ambientals utilitzades a l'estudi que cobreixen el radi de 50 m de cada punt de comptatge (excepte "Proximitat a escoles" i "Proximitat a jardins"). Columna dreta: efectes sobre la presència-absència (P) i abundància (A) basats en gràfics de dependència parcial: augment ↑, disminució ↓, còncau ∩, convex ∪.

Variables	Description	P	A
Human activity			
Litter	Litter and food in the street (0 = areas without litter, 1 = areas with remains of litter, 2 = areas with abundant litter)	↑	↑
Pedestrians[1]	Number of pedestrians passing (3-minute count)	↑	↑
Cars[1]	Number of cars (3-minute count)	↓	↓
Vegetation structure			
Tree_cover (%)[2]	Land covered by tree canopies in the 50-m point-count radius	↓	↓
Tree_density	Number of trees occupied in the 50-m point-count radius	∩	↑
Tree_richness	Number of tree species occupied in the 50-m-point-count radius	↑	↑
Tree_height (m)[2]	Height of the tallest tree (dead or alive)	∪↓	↓
Shrub_cover (%)[2]	Land covered by shrubs occupied in the 50-m-point-count radius	↓	∪
Herb_height (cm)[3]	Height of the tallest herb occupied in the 50-m-point-count radius	↓	↑
Herb_cover (%)[2]	Land covered by herbaceous plants occupied in the 50-m-point-count radius	∩	↑
Ground_cover (%)[2]	Land not covered by plants occupied in the 50-m-point-count radius	↑	↑
Urban structure			
Concrete (%)[2]	Land covered by tarmac (paved area) in the 50-m-point-count radius	∩	↑
Building_cover (%)[2]	Land covered by buildings occupied in the 50-m-point-count-radius	↓	∩
Building_height (m)[4]	Height of the tallest building occupied in the 50-m-point-count radius	↓	↓
Building_age[5]	Age of five oldest buildings (mean)	↓	↑
Poles	Streetlights and utility posts	↑	↑
Terraces	Number of terraces occupied in the 50-m-point-count radius	↓	↑
Antenna	Number of antennas occupied in the 50-m-point-count radius	↓	↑
Distance_school (m)[6]	Mean distance to the three nearest schools	↑	↑
Distance_allotment (m)[6]	Distance to nearest allotment	∩	↓
Water cover (%)[2]	Land covered by rivers, ponds or swimming pools	↑	↑
Predators	Number of Eurasian Magpies *Pica pica* or cats in a 50-m radius around the point-count in the 7-min count	↓	↑

[1] See MacGregor-Fors *et al.* 2017. These variables were taken just before the 7 min bird point-counts.
[2] Percentage of cover in the 50-m radius around the point-count. Percentage of trees, shrubs and herbs, ground, concrete, building, and water cover can sum over 100%, (e.g. several understory vegetation types can be found under tree cover). Deciduous plants in winter estimated during spring (with leaves). All measurements are highly repeatable (Del Canto *et al.* 2014; Lee *et al.* 2016).
[3] Measured with a ruler (error: ± 0.5 cm)
[4] Direct estimation, assuming that a person is about 1.8 m in height and a building story about 3.5 m.
[5] Mean age of five random building occupied in the 50-m radius around the point-count. Age information was extracted from https://www.sedecatastro.gob.es/
[6] Direct measurement from https://www.google.es/maps

density. For example, some parks and residential neighbourhoods with abundant green spaces in the MAB are low-density intraurban areas, whereas certain periurban MAB municipalities near the city centre are high-density areas.

We conducted 20 point-counts in each of these land classes. Each point-count was randomly distributed within each land-class using the *Random points in layer bounds* tool from Qgis (QGIS Development Team 2013) (Fig. 1). To guarantee the independence of observations between point-counts, all were placed at least 200 m from each other (MacGregor-Fors *et al.* 2017). Point-counts were carried out from 6:30 to 9:30 am, when bird detectability is higher, always under favourable weather conditions: absence of rain, wind speed < 15 km/h, and no extreme temperatures (<0ºC; >25ºC) (Bibby *et al.* 2000). Point-counts lasted 7 minutes, during which the observer annotated the number of House Sparrows within a 50 m radius (Ralph *et al.* 1996) while avoiding double counts. Every point-count was visited four times annually in 2015 and 2016: twice during winter (1 Dec-31 Jan) and twice during spring (1 May-31 Jun). We took the maximum of each season as a proxy of its abundance (Toms *et al.* 2006, Quesada *et al.* 2010). Bird data were collected by a single observer (JO).

Environmental variables

To describe local conditions, we compiled information on 22 environmental variables that may influence the presence and abundance of House Sparrows (Table 1). Nineteen variables were compiled *in situ* within a 50-m radius around each point-count. One variable (Building age) was obtained from the Cadastral Register (Dirección General del Catastro 2018) and two others (Distance to schools and Distance to allotments) were calculated using Google Maps (Google 2018). All environmental variables were recorded by a single observer (XC) (Table 1).

These variables can be classified in four groups (see Table 1 for descriptions):

i) Human activity: although car traffic negatively affects the local occurrence of House Sparrows (MacGregor-Fors *et al.* 2017), the presence of litter, especially food scraps, is expected to have a direct influence on their abundance (Bernat-Ponce *et al.* 2022).
ii) Vegetation structure: vegetation is important as shelter and as a source of invertebrates, which are crucial during the rearing period (Vincent 2005). Additionally, exposed ground provides prized spots for dustbathing.
iii) Urban structure: House Sparrows use elements of the urban microstructure as nesting sites (particularly old tile-roofed buildings) (Bernat-Ponce *et al.* 2024), perches (e.g. antennas, utility posts) and even as feeding areas (terraces) (MacGregor-Fors *et al.* 2017). Urban planning elements may explain their distribution and abundance at a larger scale (MacGregor-Fors *et al.* 2017). Thus, two additional variables beyond the 50-m range were also measured: proximity to schools, which is related to availability of litter, and proximity to allotments, which is positively related to invertebrate availability in organic gardens (Quesada & MacGregor 2010, Kwartnik-Pruc & Droj 2023).
iv) Predators: The presence of predators is expected to have a negative impact on the presence and abundance of House Sparrows (Bell *et al.* 2010, Shaw *et al.* 2008).

Statistical analyses

We explored the influence of our large set of 22 predictors (Table 1) on two responses: House Sparrow presence-absence and abundance. We considered House Sparrows to be absent from a point only if all counts were zero.

We tested for spatial autocorrelation using Moran's I (I = 0.048, P = 0.0015) and, if significant, we incorporated spatial coordinates as predictors to control for this effect (Mascaro *et al.* 2014). Our final set of predictors also included the coordinates of the point-counts, season, and the four urban-land categories defined in our sample design (Fig. 1). As this work does not deal with variation of abundance over time, we only kept one count (the maximum) of the two annual replicates for each point and season. Hence, the final dataset consists of a count response, 22 environmental variables (Table 1), season (just one spring count and one in winter), and urban land category from 160 point-counts (80 in winter and 80 in spring). Since every point-count had one replicate per season, we set season as random effect to control for the lack of independence between the values obtained per season.

To capture the combined influence of environmental variables on the presence and abundance of House Sparrows, we implemented a machine-learning algorithm. Specifically, we fitted random forests using cross validation to optimize parameters and to avoid overfitting (Kuhn 2008, R Core Team 2025). Unlike generalised linear mixed models (GLMMs), random forests are particularly powerful when handling complex, non-linear relationships and interactions, and do not require a particular form of the relationship to be specified.

This is especially important when relationships between predictors and dependent variables are expected to reveal ecological thresholds relevant for data interpretation (e.g. Fig. 2b, 2c). We performed these analyses in the R environment (R Core Team 2025) using package *MixRF* for random forests (Wang & Chen 2016). Since we included each point-count twice (once per season), our response values were not independent and should be treated as

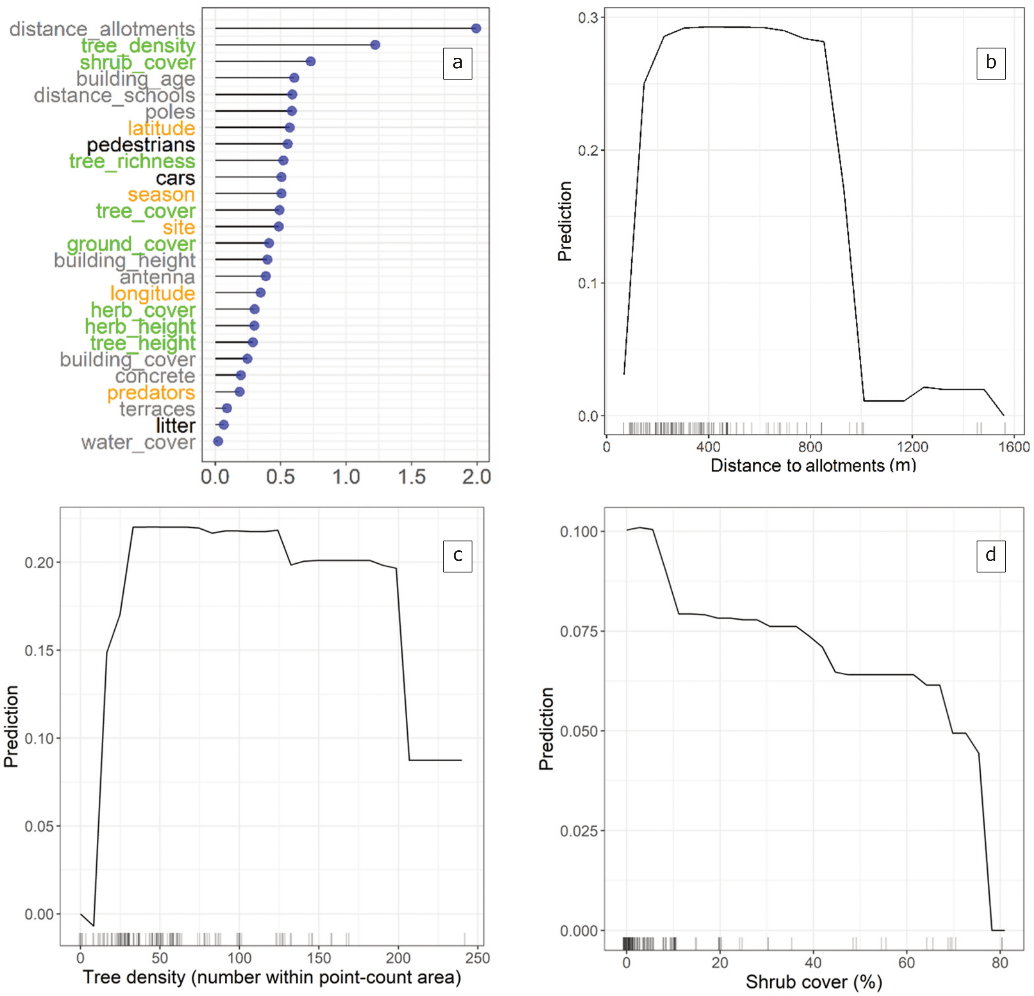

Figure 2. (a) Feature importance from the random forest analysis of House Sparrow presence-absence in the Metropolitan Area of Barcelona. The figure shows the importance of human activity (black), vegetation structure (green), urban structure (grey) and predators and other covariates (latitude, longitude, season and urban land type, in yellow) in explaining House Sparrow presence-absence. The X-axis is the average increase in mean-squared error over the trees and divided by its standard deviation, so that the absolute value does not matter as much as the relative difference between variables. (b-d) Partial dependence plots showing the only three environmental variables affecting the presence-absence of the House Sparrow. See Table 1 for more details about the variables used.

(a) Importància de les variables obtingudes de l'anàlisi de random forest sobre la presència-absència del pardal comú a l'Àrea Metropolitana de Barcelona. Es mostren les variables de vegetació (verd), estructura urbana (gris), activitat humana (negre), depredadors i d'altres covariables (latitud, longitud, temporada i tipologia de sol urbà, en groc) per explicar la presència-absència del pardal comú. L'eix X indica l'augment de l'error quadrat mitjà sobre els arbres i dividit per la seva desviació estàndard, de manera que el valor absolut no importa tant com la diferència relativa entre les variables. (b-d) Gràfics de dependència parcial que mostren les úniques tres variables ambientals amb efecte sobre la presència-absència del pardal comú. Vegeu Taula 1 per a més detalls sobre les variables utilitzades.

random effects. We trained our models by selecting a random sample consisting of 80% of the dataset (preserving the overall class distribution for the presence-absence response). Then, we tested the performance of our model using the remaining 20% of the dataset. Finally, we obtained feature importance using the permutation method or mean decrease in accuracy.

Results

Presence-absence

The random forest model explained a moderate amount of the presence-absence variability (R^2=31.4%). Distance to allotments was the most influential environmental factor explaining House Sparrow presence-absence (Fig. 2b), followed by tree density and shrub cover (Fig. 2c, d). House Sparrow presence steeply increased up to 200 m from the nearest allotment, then decreased at a distance of 800 m, and was negligible at 1,000 m (Fig. 2b). House Sparrow presence steeply increased at tree densities of up to 40 trees per point-count area, levelled out at 180 trees and then dropped (Fig. 2c). House Sparrow presence was greatest where shrubs were absent but then slowly decreased and plummeted to 64% shrub presence (Fig. 2d).

Abundance

The random forest model also explained a moderate amount of the abundance variability (R^2= 43.3%). House Sparrow abundance was lowest in areas with no litter (Fig. 3a, b) but rapidly reached a maximum in areas with small amounts of litter. Using a non-parametric ANCOVA, we found that the relationship between abundance and all environmental variables did not vary between seasons, i.e. the interaction

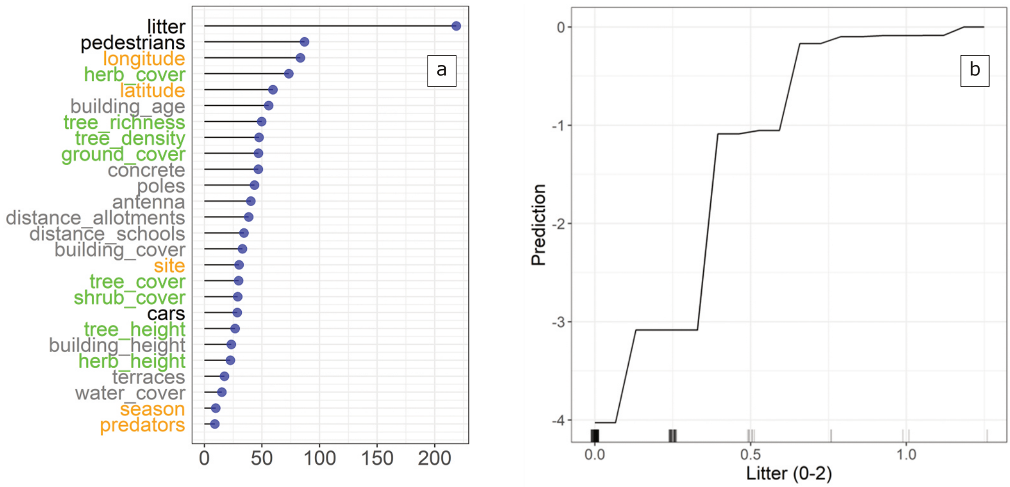

Figure 3. (a) Feature importance from the random forest analysis on House Sparrow abundance in the Metropolitan Area of Barcelona. The figure shows the importance of human activity (black), vegetation structure (green), urban structure (grey), predators and other covariates (latitude, longitude, season and urban land type, in yellow) in explaining House Sparrow abundance. The X-axis is the average increase in mean-squared error over the trees and divided by its standard deviation, so that the absolute value does not matter as much as the relative difference among variables. (b) Partial dependence plot showing the only environmental variable clearly affecting the abundance of the House Sparrow. See Table 1 for more details about the variables used.
(a) Importància de les variables obtingudes de l'anàlisi de random forest sobre l'abundància del pardal comú a l'Àrea Metropolitana de Barcelona. Es mostren les variables de vegetació (verd), estructura urbana (gris), activitat humana (negre), depredadors i d'altres covariables (latitud, longitud, temporada i tipologia de sol urbà, en groc) per explicar l'abundància del pardal comú. L'eix X indica l'augment de l'error quadrat mitjà sobre els arbres i dividit per la seva desviació estàndard, de manera que el valor absolut no importa tant com la diferència relativa entre les variables. (b) Gràfics de dependència parcial que mostren l'única variable ambiental que afecta clarament l'abundància del pardal domèstic a l'AMB. Vegeu Taula 1 per a més detalls sobre les variables utilitzades.

term in the ANCOVA abundance ~ season*variable was $P > 0.05$. This suggests that House Sparrows do not make movements to fine-tune their adaptation to changing seasonal requirements (e.g. increasing protein needs for reproduction in spring). Predators and urban land-category had low or no impacts on either the presence or abundance of House Sparrows. We found no seasonal differences in either the presence or the abundance of House Sparrows.

Discussion

Our results show that the presence and abundance of House Sparrows in the MAB are not driven by the same factors. Their presence largely depends on structural factors such as distance to allotments, tree density and shrub cover since they occur, above all, near gardens and avoid high tree densities (but also avoid treeless areas) and areas with a high shrub cover. On the other hand, abundance is mainly affected by human activity, largely by the amount of available litter. This dichotomy highlights how different factors affect species occurrence and population size in urban environments and provides insight into the complex picture of urban biodiversity loss.

Human activity

House Sparrow abundance was predominantly influenced by human-related variables, particularly litter availability. This finding highlights this species' adaptive behaviour (e.g. Shelley 2005, Quesada *et al.* 2022) since they have long been known to exploit urban resources including human food waste (MacGregor-Fors *et al.* 2020). It also reinforces the importance of human debris in explaining their abundance in Mediterranean cities (Bernat-Ponce *et al.* 2018, 2022). The direct relationship between litter and House Sparrow counts underscores the critical role of human activities in shaping urban bird populations (Gavett & Wakeley 1986, MacGregor-Fors *et al.* 2022), which may also be the case in the MAB.

Litter, often linked to tourism and bars (Bernat-Ponce *et al.* 2018), serves as an important food source for urban sparrows (Bernat-Ponce *et al.* 2018, this study). However, Barcelona's efficient waste management system (WASTE IN TIC 2020; Agut-Ruiz 2021) results in fewer food scraps and less debris, which potentially limits food availability. This reduction in accessible resources could further contribute to this species' decline in the MAB. Reliance on human-mediated resources may leave these populations vulnerable to changes in urban sanitation practices. Previous studies have shown that House Sparrow populations decline following improvements in waste management (Bernat-Ponce *et al.* 2022), which could be a key factor influencing their populations in Barcelona.

Vegetation and urban structure

Our findings are consistent with recent studies that highlight the importance of natural and semi-natural vegetation remnants as strongholds for House Sparrows in urban landscapes (Vincent 2005, Shaw *et al.* 2008, Vangestel *et al.* 2010, Havlíček *et al.* 2022). The complex mosaic of built-up and vegetation remnants is likely to vary within but also between cities (e.g. MacGregor-Fors *et al.* 2017). The same probably applies to the intensity of human activity and habits. Thus, if environmental and anthropogenic factors vary between urban areas, why have House Sparrows declined consistently in urban areas throughout their geographical range? Local House Sparrow populations may be negatively affected by a shortage of nesting sites and nest-building materials (Summers-Smith 2003, Radhamany *et al.* 2016, Moudrá *et al.* 2018), high predation risks (MacLeod *et al.* 2006, Bell *et al.* 2010) and even competition with other species (Moudrá *et al.* 2018). However, these factors currently do not seem to play a key role in House Sparrow presence and abundance in the MAB or anywhere else in its geographical range (Vangestel *et al.* 2010, Shaw *et al.* 2011, Moudrá *et al.* 2018).

Our results support the view that the fragmentation and complexity of urban green spaces in the MAB has created microhabitats that can either favour or deter the House Sparrow population. Urban parks, allotments and semi-natural areas provide crucial refugia in built-up environments (e.g., Quesada & MacGregor-Fors 2010, Moudrà *et al.* 2018, Havlíček *et al.* 2022, Sánchez-Sotomayor *et al.* 2023). However, as urbanisation intensifies and homogenises, these green spaces are becoming increasingly scarce, a process that has contributed to the sparrow declines observed throughout Europe (Chamberlain *et al.* 2007, Vangestel *et al.* 2010, MacGregor-Fors *et al.* 2017). Hence, the deterioration of life conditions along gradients of urbanisation may affect sparrow reproductive success (Peach *et al.* 2008, 2015) and survival (Liker *et al.* 2008), ultimately leading to the extinction of local colonies (Hole *et al.* 2002).

Predators, seasonality and urban land categories

Predators play a minor role in determining the presence and abundance of House Sparrows in the MAB. From a conservation point of view, season has more important implications. The absence of significant seasonal variation in both presence and abundance suggests that House Sparrows in this area do not undertake substantial seasonal movements. This sedentary behaviour may increase their vulnerability to localised changes in food availability and habitat structure, particularly during the breeding season when invertebrates are essential for chick-rearing. This agrees with previous studies that underscore the importance for maintaining stable urban bird populations of continuous food availability close to breeding sites throughout the year (Peach *et al.* 2008, Havlíček *et al.* 2022). Finally, land class does not seem to be determinant in either the presence or abundance of House Sparrows, possibly due to two reasons: i) the differences in abundance between point-counts was small (range = 0-14) and ii) the complexity of the MBA, in which even high-density intraurban sites offer food and even suitable nesting habitat.

House Sparrow populations have suffered significant declines in recent decades. A common approach to studying these declines is to analyse the spatial distribution and abundance of the species in relation to the variables that explain this spatial variation. This method is particularly useful when long-term trend data are unavailable (Blüthgen *et al.* 2022), especially in built-up areas that are traditionally neglected in monitoring schemes (Herrando *et al.* 2017). Furthermore, the factors contributing to past declines may differ from those influencing the species' current distribution. Therefore, longitudinal analyses are essential when attempting to fully understand whether the drivers of spatial variation are representative of the drivers observed in temporal studies.

Urban planning must prioritise the preservation and creation of green spaces that are both aesthetically pleasing and ecologically functional for wildlife. Initiatives such as bird-friendly urban gardens, green roofs, and green-walls (Chiquet *et al.* 2013), as well as the preservation of allotments and other semi-natural habitats, provide critical resources for urban sparrows and other species (Wolch *et al.* 2014; Peach *et al.* 2014, 2015, LPO 2019). Such strategies will help mitigate the effects of habitat loss and provide the structural complexity needed to support diverse urban bird communities (Fernández-Canero *et al.* 2010, Chiquet *et al.* 2013, Wolch *et al.* 2014). In addition, efforts to reduce the negative impacts of human activities such as managing litter in a way that still supports sparrow populations but without negatively affecting urban hygiene may prove beneficial. Thus, public education campaigns could help raise awareness concerning the importance of urban biodiversity and encourage policies such as the creation of small-scale habitats in private gardens, balconies and public spaces aimed at boosting local bird populations.

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Resum

Factors ambientals que influeixen en la presència i abundància del pardal comú *Passer domesticus* a l'Àrea Metropolitana de Barcelona: un enfocament multivariant

Tot i ser una de les espècies animals més abundants a escala mundial, el pardal comú *Passer domesticus* ha experimentat un declivi significatiu en les últimes dècades, especialment a les zones urbanes. Vam analitzar la influència de la vegetació, l'estructura urbana, l'activitat humana i els depredadors en la presència i

abundància del pardal comú a l'Àrea Metropolitana de Barcelona (AMB), Catalunya, Espanya. Es van realitzat 80 punts de cens en quatre tipus de paisatge urbà, definits segons la ubicació urbana (intraurbà, periurbà) i la densitat d'urbanització (baixa, alta) durant la primavera i l'hivern de 2015 i 2016. Mitjançant random forests, hem examinat la relació entre 22 variables explicatives i la distribució dels pardals. Els nostres resultats posen en relleu la interacció complexa entre factors estructurals i antropogènics en la presència i abundància del pardal comú. La presència augmentava en zones properes a horts, amb densitats mitjanes d'arbres i sense coberta arbustiva, mentre que l'abundància era més elevada en zones amb més acumulació de deixalles. Els depredadors i la categoria de sòl urbà van tenir un impacte molt reduït en la presència i abundància de pardals. No es van trobar diferències estacionals significatives. Els fragments de vegetació natural i seminatural, així com la heterogeneïtat dels espais verds, són essencials per a la presència del pardal comú en paisatges urbans. A mesura que la urbanització s'intensifica i s'homogeneïtza, aquests espais verds es tornen més escassos, fet que contribueix al seu declivi arreu d'Europa. L'activitat humana també és clau per a l'abundància dels pardals, però la seva dependència de recursos mediats per humans pot fer-los vulnerables als canvis en les polítiques de gestió de residus urbans.
Paraules clau: àrees urbanes, deixalles urbanes, declivi poblacional, *Passer domesticus*, random forest.

Resumen

Factores ambientales que influyen en la presencia y abundancia del gorrión común *Passer domesticus* en el Área Metropolitana de Barcelona: un enfoque multivariante

A pesar de ser una de las especies animales más abundantes a nivel mundial, el gorrión común *Passer domesticus* ha experimentado un declive significativo en las últimas décadas, especialmente en entornos urbanos. En este estudio, analizamos la influencia de la vegetación, la estructura urbana, la actividad humana y los depredadores en la presencia y abundancia del gorrión común en el Área Metropolitana de Barcelona (AMB), Cataluña, España. Realizamos 80 puntos de muestreo en cuatro tipos de paisaje urbano, definidos según la ubicación (intraurbano, periurbano) y la densidad de urbanización (baja, alta) durante la primavera y el invierno de 2015 y 2016. Mediante random forests, evaluamos la relación entre 22 variables explicativas y la abundancia y presencia del gorrión común. Nuestros resultados destacan la compleja interacción entre los factores estructurales y antropogénicos en la presencia y abundancia del gorrión común. Su presencia aumentó en áreas cercanas a huertos, con densidades medias de árboles y sin cobertura arbustiva, mientras que su abundancia fue mayor en zonas con mayor acumulación de residuos. Los depredadores y la categoría de suelo urbano tuvieron un impacto muy reducido en la presencia y abundancia de gorriones. No se observaron diferencias significativas entre estaciones. Los fragmentos de vegetación natural y seminatural, así como la heterogeneidad de los espacios verdes, son fundamentales para la presencia del gorrión común en paisajes urbanos. A medida que la urbanización se intensifica y se homogeneiza, estos espacios verdes se vuelven más escasos, contribuyendo a su declive en Europa. La actividad humana también desempeña un papel clave en la abundancia de los gorriones, pero su dependencia de recursos antropogénicos puede hacerlos vulnerables a cambios en las políticas de gestión de residuos urbanos.
Palabras clave: áreas urbanas, declive poblacional, *Passer domesticus*, random forest, residuos urbanos.

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