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Original article

How urban green management is influencing passerine birds' nesting in the Mediterranean: A case study in a Catalan city

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ABSTRACT

The vegetation within the urban system provides sheltering and food provisions to birds, influencing their nesting options. This study analyses for the first time in the Mediterranean area how different socio-ecological factors related with public urban green management can influence the nesting of the passerine bird order. It uses a case study in the city of Valls (Catalonia, Spain). First, the public urban green was quantitatively and qualitatively characterised; then the nests from the passerine birds were collected and identified, and finally, potential associations between nests and urban green-related socio-ecological factors such as vegetation type (tree, shrub, herb, liana), plant species, neighbourhood type, pruning type, fruit and seed production, and presence of insect plague were analysed. A total of 300 nests were identified and belonged, mostly, to the family of Fringillidae and Sylviidae, all from Mediterranean agroforestry areas. Passerine birds show preference for the historic centre, being this area the one with highest biodiversity of vegetation in the city, in detriment of surrounding neighbourhoods, which in turn are less biodiverse. Passerine birds do not consider four tree species (*Celtis australis*, *Laurus nobilis*, *Robinia pseudoacacia* and *Pinus pinea*) suitable for nesting whereas showing preference for two tree species of medium height and size (*Hibiscus syriacus* and *Melia azederach*). Also, passerine birds seem to preferably nest in trees that have been pruned intensively. These results suggest that, to strengthen the passerine bird diversity in cities, urban green management should promote certain species of trees of medium size and intensive pruning while supporting the overall biodiversity of the urban green. All these results contribute to inform effective urban planning and management strategies for passerine birds conservation that aim to reconcile urban development and urban biodiversity protection.

1. Introduction

The richness and diversity of bird communities in cities depends on the richness and diversity of the urban green spaces. The bioclimatic area and the type and degree of urbanisation (Clergeau et al., 2006) determine bird communities distribution in urban green spaces. However, the maximum richness and diversity of such bird communities is not necessarily achieved in less urbanised areas (Jokimäki and Suhonen, 1993; Carbó-Ramírez and Zuria, 2011). Bird communities select habitats of different degree of urbanisation accordingly to their habits. For instance, in high urbanised areas there are anthropophilic species, which take profit from the human activities, whereas in low urbanised areas bird species living in agroforestry vegetation turn up (Boada and Capdevila, 2000; Burger et al., 2004; Marzluff and Rodewald, 2008; Parker and Nilon, 2012).

Therefore, birds can find suitable habitats under optimal conditions for their living in urban green spaces, such as appropriate microclimate and refuge, large quantities of food resources, less competition between species and less predation in the nesting areas (Ortega-Álvarez and MacGregor-Fors, 2009; Camprodon and Guixé, 2012). The design and management of urban green spaces will thus affect the diversity and richness of these bird communities. Two factors play a key role in this

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Table 1
Characterisation of the ornamental vegetation in the four neighbourhood types in the study area in 2018 (Institut Cartogràfic i Geològic de Catalunya (ICGC, 2018; Institut d'Estadística de Catalunya (IDESCAT, 2018; Ajuntament de Valls, 2018).

Neighbourhood type	Inhabitants	Total area (m^2)	Density (inhab./km^2)	Public urban green spaces (m^2)[b]	% Public urban green spaces	Public urban green per inhabitant (m^2/inhab.)[c]
Single-family houses	8,360	1,056,798	7,911	74,084	7.0	8.9
Isolated houses	163	47,221	3,452	1,262	2.7	7.7
Blocks of flats	4,033	231,510	17,420	15,069	6.5	3.7
Historic centre	9,981	723,000	13,805	20,266	2.8	2.0
Total	22,537[a]	2,058,529	10,948	110,681	5.6	4.7

[a] Additionally a scattered population of 2681 inhabitants live on non-urban areas, reaching 25,218 inhabitants in total.
[b] The area of the public urban green spaces was calculated through the aerial crown occupied by each plant individual of the ornamental vegetation, so the open spaces between vegetation plant individuals are not considered urban green.
[c] The World Health Organization recommends a minimum value of 10 m^2/inhab (Rueda, 2009).

regard: the composition and the structure of the vegetation of these urban green spaces (MacGregor-Fors and Schondube, 2011). On the one hand, the composition of plant communities is intimately related to the diversity of birds (James and Wamer, 1982; Huang et al., 2015). For instance, in the city of Vinnytsia (Ukraine), researchers found significant correlations between the heterogeneity and abundance of trees with the richness and density of birds. This study also showed a positive correlation between bird diversity and plant flowering richness (Blinkova and Shupova, 2017). On the other hand, the volume and density of plants in the urban green are positively related to birds' richness and diversity (Savard et al., 2000; Mella and Loutit, 2007), so the thinning of trees and shrubs is counterproductive (Camprodon and Brotons, 2006; Yang et al., 2015). Similarly, inappropriate structure of the vegetation in green urban spaces could cause a further reduction in the diversity of birds (Ge et al., 2005; Xu et al., 2007; Yang et al., 2015).

Particularly, trees are considered as one of the most important elements to increase bird richness and diversity in urban green spaces (Palomino and Carrascal, 2006; Yang et al., 2015; Weaving et al., 2016). Tree canopies provide sheltering, nesting sites and feeding opportunities (Munyenyembe et al., 1989; Steele and Koprowski, 2001). Specially, birds use dense tree canopies, tree trunk with holes and branches that produce fruits or seeds. It is also important to consider that the presence of these resources for birds' refuge, nesting and breeding promotes the access of adjacent flora and fauna into the urban green spaces (Briz, 1999, 2004; Boada and Sànchez, 2012). To sum up, the promotion of urban green management actions leading to a suitable composition and structure of the vegetation in cities can potentially entail an improvement in the diversity and richness of birds living in there (Camprodon and Brotons, 2006; Shanahan et al., 2011).

The vast majority of studies about richness and diversity of birds in urban environments focus on the breeding success, e.g. by analysing nests' depredation rates and showing that it is higher when associated with specific mammals and predatory birds (Miller et al., 1998; Matthews et al., 1999; Jokimäki and Huhta, 2000; Reale and Blair, 2005; Phillips et al., 2005; Bakermans and Rodewald, 2006; Burhans and Thompson, 2006; Smith-Castro, 2008). In the case of mediterrenean cities, nest depredation is caused mainly by the presence of cats (Stracey, 2011) and magpies (Bonnington et al., 2015), though the only magpie species present in the city (*Pica pica*) prefers the nearby rural areas instead of the urban ones (Andrén, 1992). Similarly, other works performed in peri-urban areas show that the rate of depredation of nests at low height may be higher due to the high influx of domestic animals (Miller et al., 1998) whereas those located at higher height remain better conserved (Smith-Castro, 2008). However, only few research has addressed the effects of the vegetation patterns on bird nesting in urban green spaces.

The main goal of this article is to study the effect of different socio-ecological factors related to public urban green management on the richness and diversity of nests of the passerine bird order in the Catalan Mediterranean city of Valls. First, we made inventories of the ornamental vegetation in public urban green spaces of the city of Valls and characterised its biodiversity; second, passerine nests were collected, identified and characterized in the study area; and third, the relationship between both concepts was analysed. The relationship between socio-ecological factors and the bird nesting may become a tool for urban green managers and technicians that positively consider urban biodiversity.

2. Methodology

2.1. Study area: the urban area of the city of Valls

The city of Valls is located at the northeast of the Iberian Peninsula, at an altitude of 215 m a.s.l.. The total urban area of the municipality is 2.06 km^2 (though the municipality contains up to 53.2 km^2 of non-urban spaces) and the city has a population of 22,537 inhabitants in 2018 (Ajuntament de Valls, 2018). The city has a typical Mediterranean climate characterised by soft winters and dry and warm summers. The annual precipitation is 524 mm and the average temperature is 16 °C (on average between 1993 and 2017; Centre Meteorològic de l'Alt Camp (CMAC, 2018). The urban area is divided by three water streams that structure six residential areas which cover four different neighbourhood typologies: single-family houses, blocks of flats, isolated houses and historic centre (Table 1 and Fig. 1). As expected the highest population density is found in the blocks of flats and historic centre ($>$ 10,000 inhabitants/km^2) whereas this falls significantly in the neighbourhoods of single-family houses and isolated houses ($<$ 8000 inhabitants/km^2).

2.2. Study system: ornamental vegetation of the public urban green spaces

Between 2013 and 2015 we collected qualitative and quantitative data on the total ornamental vegetation in the urban green of Valls and produced an inventory; see Table S1 for the full inventory of the ornamental vegetation. The city has an urban green area of 110,681 m^2 (5.6% of total urban area), calculated as the aerial canopy occupied by each plant individual of the ornamental vegetation (Table 1). Most of the urban green was found in the neighbourhood of single-family houses, which is also the neighbourhood type with the highest percentage of urban green spaces with respect to the total urban area. The amount of urban green area per inhabitant is 4.7 m^2, slightly smaller than Barcelona's green area (6.8 m^2/inhab Argimon, 2009).

Each plant was classified as tree, shrub, herb, liana and palm. Also the following vegetation indexes were calculated in order to characterise the habitat: species richness (S), Shannon-Weaver's diversity index (H), Simpson's diversity index (D) and Pielou's evenness index (J) (Shannon and Weaver, 1949; Simpson, 1949; Pielou, 1969).

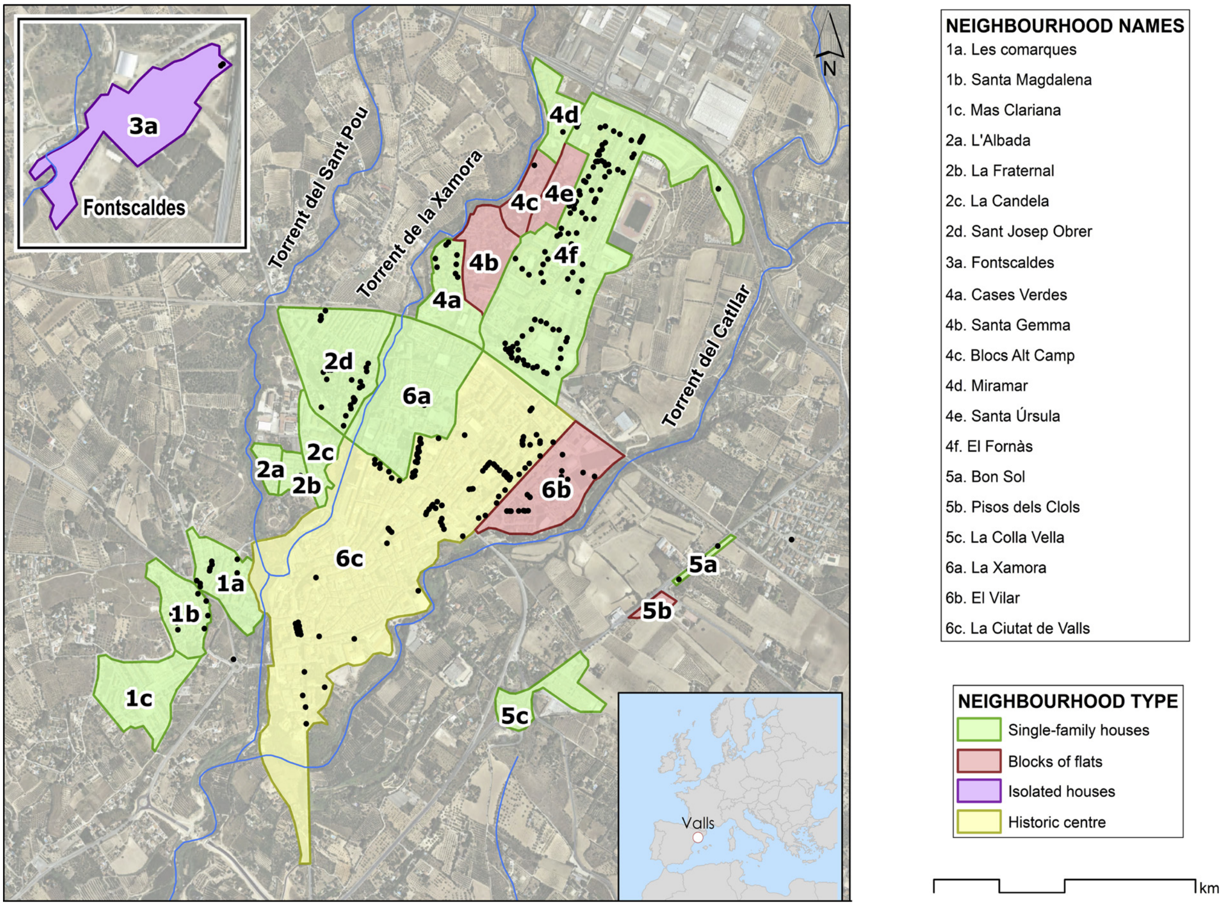

Fig. 1. Overview of the city of Valls (coordinates of longitude 41.285578 and latitude 1.249462) and its neighbourhoods with the corresponding types (coloured polygons) and the location of the collected nests (black dots) (Institut Cartogràfic i Geològic de Catalunya (ICGC, 2018). All neighbourhoods of single-family houses are formed of housing occasionally with garden except the neighbourhoods of Bon Sol, la Colla Vella and la Xamora that their houses always contain a garden. The blocks of flats of Santa Gemma, Blocs Alt Camp and Santa Úrsula are close to an industrial area.

2.3. Collection, storage, identification and characterisation of the passerine bird nests

We collected passerine bird nests in the urban green of Valls on January 2013 and produced the corresponding inventory in collaboration with the Park and Gardens Service of the city of Valls. Nests were kept in a dry and fresh place during 7 to 10 days for their identification (see identification criteria in Table 2). Then, they were introduced in plastic zip-lock bags together with a naphthalene ball to avoid organisms' proliferation (González, 2012). All nests come from six passerine birds: *Carduelis carduelis, Serinus serinus, Chloris chloris, Sylvia melanocephala, Turdus merula* and *Sylvia atricapilla*. We did not find other nests from different bird species in the studied urban green spaces of the city. Apart from the bird species name, we noted down the nest height and plant individual identifier, see Table 3.

2.4. Total vegetation, potential nesting vegetation and actual nesting vegetation

As seen, the *total vegetation* is formed of all plant individuals of trees, shrubs, herbs, lianas and palms located at Valls' urban green spaces. However, not all plant species are chosen by passerine birds for nesting purposes. So, we focused on a subgroup of the total vegetation that we called the *potential nesting vegetation* which is composed of all individuals of plant species that would be hosting at least a single nest. But in order to strengthen the robustness of the analysis, we only coded a plant species as potential nesting vegetation if any of its individuals host at least three nests. Then, each individual of the potential nesting vegetation was characterised considering the following socio-ecological factors (or categorical variables): vegetation type, plant species name, neighbourhood type where the individual was placed; fruit and seed production; presence of insect plague during bird breeding period (spring's end-summer); and pruning type (see Table 3 for more details).

Table 2
Nest identification criteria for the passerine breeding birds (Harrison, 1991; Duperat, 2005; Filella com. verb., 2015).

Bird species	Identification criteria
-*Carduelis carduelis*	- Totally lined inside and usually with feathers at the bottom of the nest.
-*Serinus serinus*	- Semi-lined inside. Can present some feathers.
-*Chloris chloris*	- Only lined in the outside. It presents a more defined cup shape and higher lateral walls than *Carduelis carduelis* and *Serinus serinus nests.*
-*Sylvia melanocephala*	-Cylindrical shape. Deeper and denser than *Sylvia atricapilla*. Usually built with vegetation from more humid areas.
-*Turdus merula*	- Very big and lined with mud at the bottom.
-*Sylvia atricapilla*	-Bigger but less dense than *Sylvia melanocephala. Built with branches from drier environments.*

Table 3
Variables used to characterise each nest and each plant individual of the potential nesting vegetation.

Variables	Value
Nest variables	
- Nest id	Number
- Plant individual id	Number
- Bird species name	Character
- Nest height	Low (< 2 m), medium (2 - 4.5 m) or high (> 4.5 m)
Socio-ecological factors	
- Plant individual id	Number
- Vegetation type	Tree, shrub, herb, liana or palm
- Plant species name	Character
- Neighbourhood type	Single-family houses, blocks of flats, isolated houses and historic centre
- Pruning type	Intensive or maintenance
- Fruit & seed production	Yes or no
- Presence of insect plague	Yes or no

Regarding pruning, the intensive one has the aim of controlling the volume of the canopy whereas maintenance is only used in old trees to keep the natural shape of the tree (Drénou, 2000). Finally, we created a subgroup of the potential nesting vegetation named the *actual nesting vegetation* that is formed of all plant individuals that actually host a single nest.

2.5. Socio-ecological factors' effects in passerine bird nesting

The statistical hypothesis of this study is the following: there is an influence of the socio-ecological factors on passerine nesting, so the vegetation pattern of such factors in the actual nesting vegetation will be different than the one of the potential nesting vegetation. This would indicate that the categorical variable that originates such pattern is an important factor in the passerine nesting. For example, if birds select a certain tree species, the proportion of this species among the actual nesting vegetation will be statistically higher than the proportion of the same species among the potential nesting vegetation.

Contingency tables were created to study the effect of the different socio-ecological factors to passerine bird nesting, in other words the comparison of the vegetation patterns between the actual nesting vegetation and the potential nesting vegetation. The relationship between these two categorical variables was assessed using the Person's chi square statistical test ($\chi 2$) ($p < 0.01$) or the Fisher's exact test ($p < 0.01$) when the number of observations was inferior to 5 in any of the groups. All the descriptive and inferential statistical calculations were carried out using R statistical software (The R Projecte for Statistical Computing, 2018).

3. Results and discussion

3.1. Characterization of ornamental vegetation biodiversity in Valls' urban green

Our inventory show that the city of Valls presents 81 different plant families, 152 genera and 239 different species (species richness, S). For the sake of a better understanding, the biodiversity of Valls is compared to Barcelona's. Though remarkable, Barcelona reaches a higher number of vegetation species, up to 1172. All species living in the city of Valls can be found as well in the city of Barcelona. Some of the most common species from both cities coincide in the ranking of most populated species, 7 of the 15 firsts species of trees and 8 of the first 15 species of shrubs in Barcelona coincide with those of the city of Valls. Both Valls and Barcelona show a great diversity of species from all over the world, mainly from Asia, America, Africa, Oceania and as well from the rest of Europe (Argimon, 2009). So, the estimated Shannon-Weaver's diversity index (H) for Valls is 3.36 and 2.96 for Barcelona (Burriel et al., 2006). This index usually varies from 1.5 (low diversity) to 3.5 (high diversity) (MacDonald, 2003). In line with this index, the Simpson's diversity index (D) for Valls is as well high with a value of 0.88. Regarding species evenness, the Pielou's index (J) for Valls is 0.61 and for Barcelona 0.06 (Burriel et al., 2006) indicating that Valls presents more equity and a more homogenous representation for each species than Barcelona (Table 4).

When exclusively referring to trees, the number of individuals and different species is 6376 and 103 in Valls, respectively, whereas in Barcelona are found 235,000 individuals and 200 different species (Argimon, 2009). In Valls, though, they only represent the 12.1% of the plant individuals and 42% of the total different species, they occupy up to 77.5% of the total urban green area. The number of trees per inhabitant in Valls reaches a value of 0.28 whereas Barcelona shows a value of 0.15 trees/inhabitants.

The value of the Shannon-Weaver's index (H) for trees and shrubs in Valls is the highest among vegetation types, both values are above 3 and indicate a high biodiversity. However, the value for the herbs, lianas and palm species is lower than 2.0 indicating the contrary, low biodiversity in those types. Lianas and herbs species differ from trees and shrubs in the fact that they have a higher number of individuals (high richness) but they have less number of species (low diversity) (Table 4).

3.2. Characterization of nests in the urban green of Valls

We found six passerine bird species that nest in the urban green spaces of the city, which belong to three bird families, i.e., Fringilidae, Silvidae and Turdidae. These are representative of the forest ecosystems

Table 4
Characterisation of the vegetation in urban green spaces of the city of Valls.

Vegetation type	Number of indiv. (%)	Public urban **green** area, m^2 (%)	Number of genera	S[a]	H[c]	D[d]	J[e]
Trees	6,376 (12.1)	85,730.9 (77.5)	64	103	3.34	0.94	0.72
Shrubs	17,301 (32.7)	11,605.3 (10.5)	82	112	3.42	0.94	0.73
Herbs	11,186 (21.2)	7,970.7 (7.2)	19	22	1.88	0.74	0.61
Lianas	17,668 (33.4)	2,281.5 (2.1)	8	9	0.25	0.11	0.11
Palms	338 (0.6)	3,092.6 (2.7)	7	9	1.56	0.26	0.71
Total	59,869 (100)	110,681.0 (100)	156[b]	239[b]	3.36	0.88	0.61

[a] Species richness (S).
[b] 16 plant species are present with different vegetation types like those that are present as tree and shrub *(Celtis australis, Cupressus sempervirens, Eriobotrya japonica, Eugenia myrtifolia newp.albero, Hibiscus syriacus, Laurus nobilis, Ligustrum japonicum, Picea abies, Pittosporum tobira, Prunus cerasifera, Prunus laurocerasus, Broussonetia papyrifera and Thuja occidentalis),* shrub and liana (*Bougainvillea spectabilis, Rosa sp. (another))* and liana and herb *(Hedera helix)*, thus the total number of different species or number of different genera does not coincide with the sum by vegetation type.
[c] Diversity Shannon-Weaver's index (H).
[d] Diversity Simpson's index (D).
[e] Evenness Pielou's index (J).

Table 5
Characterisation of the six passerine breeding bird species in the city of Valls[a,b].

Bird species name	Ecosystems	Other passerine birds of the natural environment that do not nest in the urban green spaces of the city of Valls
Turdus merula, Sylvia melanocephala	Forests of Quercus ilex, forests of Pinus halepensis, Maquis of Quercus coccifera and Agricultural areas	*Troglodytes troglodytes, Parus major, Cyanistes caeruleus, Linaria cannabina*
Sylvia atricapilla	Riparian forests	*Motacilla alba, Motacilla cinerea, Erithacus rubecula*
Chloris chloris, Serinus serinus, Carduelis carduelis	Agroforestry areas	*Turdus viscivorus, Pica pica, Phoenicurus ochruros* and *Sturnus* sp., *Passer domesticus*

Svensson, 2014; Ornitho, 2015; BDBC, 2015.
[b] Notice that all identified birds are autochthonous in the Mediterranean climate region.

(*Quercus ilex* and *Pinus halepensis*), maquis (*Quercus coccifera*), as well as agricultural, riparian and agroforestry habitats of the Mediterranean climate regions (see Table 5 for more details) (Svensson, L., 2014; Ornitho, 2015) and therefore belong to the list of possible breeding birds (Ornitho, 2015; Svensson, 2014; Filella com. verb., 2015). All of these bird families can be found in the Iberian Peninsula all year long and are well adapted to the urban system (Boada and Capdevila, 2000; Burger et al., 2004; Parker and Nilon, 2012). There are other passerine breeding birds from the abovementioned ecosystems that do not nest in the vegetation of the urban green spaces but in holes or just migrate during the breeding season (see last column of Table 4), consequently these birds are not included in the study.

In total, 300 nests were collected with a population distribution clearly dominated by nests from the Fringilidae family (90.3%) followed by Silviidae family (6.4%), see Table 6. More than 70% of nests come from two bird species, *Carduelis carduelis* (126 nests) and *Serinus serinus* (91 nests). It was not possible to identify the species of six nests but in all cases they belonged to one of the already identified families of passerine birds. In the case of *Carduelis carduelis,* most of the nests (75.0%) were found in the neighbourhoods (3a, 5a, 5b and 5c in Fig. 1) close to the adjacent agroforestry area. Most of nests have been found in street trees (80.0%) followed by the nests found in public parks (20.0%). Indeed, according to, the streets with trees connecting urban green spaces positively influence the bird species richness, contributing with feeding and nesting sites (Fernández-Juricic, 2001).

3.3. Characterization of the potential nesting vegetation and the actual nesting vegetation

Among the 239 different species and 52,869 individuals of the total vegetation our data show that only 40 different species (7798 individuals) host at least a single nest. These species would form the potential nesting vegetation. Such vegetation is still composed of trees (30 species), shrubs (8 species) and even 2 species of liana. However, if one considers the plant species that host at least three nests then the number of species that form the potential nesting vegetation is limited to 12 different species and 2323 individuals, all of them trees (see Tables 7 and 8 for the full list of the tree species that form the potential nesting vegetation). Therefore, the difference between the total vegetation and the potential nesting vegetation is remarkable, since the potential nesting vegetation represents only a fraction (4.4%) of the total vegetation individuals and only trees are selected for nesting by passerine birds. These findings can be explained by the fact that trees are one of the main vegetation elements used to increase bird species richness in urban green spaces (Palomino and Carrascal, 2006; Yang et al., 2015) as tree canopies can provide sites for sheltering, breeding and feeding (Munyenyembe et al., 1989; Steele and Koprowski, 2001). In turn, the actual nesting vegetation, composed of all plant individuals of the potential nesting vegetation that host a nest, includes 267 plant individuals and their corresponding nests. Therefore, our results show that only the 11.5% of the potential nesting vegetation is used by passerine birds. All vegetation individuals that form the potential nesting vegetation and the actual nesting vegetation are listed in Table S2.

It is also remarkable that some common tree species (> 100 individuals) of the total vegetation do not host any single nest, which would indicate that these plant species are perceived as non-adequate for nesting purposes by passerine birds, such as *Celtis australis*, *Laurus nobilis*, *Robinia pseudoacacia* and *Pinus pinea*, see Table 8.

3.4. Plant species affecting nesting

Among the potential nesting vegetation, passerine birds prefer some trees over the others. The 267 nests of the actual nesting vegetation are distributed as follows: 32.8% in *Melia azedarach*, 16.3% in *Acer negundo*, 15.5% in *Platanus hispanica*, 7.8% in *Morus alba*, 6.6% in *Hibiscus syriacus* and 6.1 in *Ulmus minor* and 5.5% in *Sophora japonica* and 14.9% in other species. However, the pattern for the potential nesting vegetation presents a slightly different distribution: 40.1% in *Melia azedarach*, 16.1% in *Acer negundo*, 7.5% in *Platanus hispanica*, 6.0% in *Mourus alba,* 17.6% in *Hibiscus syracus* and 1.5 in *Ulmus minor* and 4.5% in *Sophora japonica* and 6.7% in other species. Indeed, the Fisher's exact test states that the differences between both distributions are statistically significant (p-value = 0.0005). Therefore, birds show preference for *Hibiscus syriacus* (+11.0%) followed by *Melia azedarach* (+7.3%) and birds do not select *Platanus hispanica* (−8.0%) and *Ulmus minor*

Table 6
Number of nests by species name and family.

Family	Bird species	Initial number of nests	%	Number of nests in the actual nesting vegetation[a]
Fringilidae	*Serinus serinus*	126	42.0	113
	Carduelis carduelis	91	30.3	79
	Chloris chloris	54	18.0	49
Silvidae	*Sylvia atricapilla*	14	4.7	13
	Sylvia melanocephala	5	1.7	5
Turdidae	*Turdus merula*	4	1.3	3
Undetermined[b]	–	6	2.0	5
Total		300	100.0 %	267

[a] Only included individuals which take part of the potential nesting vegetation (Plant species that host more than two nests). Only these nests are used for statistical purposes.
[b] Six nests were not possible to be classified though they come from any of the six passerine birds already found in the study.

Table 7
Number of individuals (number of different species) of the total vegetation, potential nesting vegetation and actual nesting vegetation.

Vegetation type	Total vegetation[a]	Potential nesting vegetation (at least 1 nest)	Potential nesting vegetation (> 2 nests)	Actual nesting vegetation[b]
Trees	6,376 (103)	3,684 (30)	2,323 (12)	267 (12)
Shrubs	17,301 (112)	4,099 (8)	–	–
Herbs	11,186 (22)	–	–	–
Lianas	17,668 (9)	15 (2)	–	–
Palms	338 (9)	–	–	–
Total	59,869 (239)	7,798 (40)	2,323 (12)	267 (12)

[a] Either autochthonous or allochthonous vegetation species are included in the total vegetation inventory.
[b] The total number of nests is 300 but notice that 33 nests were located in plant species that host less than three nests and therefore excluded from the actual nesting vegetation.

(−4.6) (Table 9). Interestingly, in the case of *Hibiscus syriacus,* if the birds nested randomly only 6.6% of nests would be found in this species but significantly the propensity to nest in this species is three times higher, up to 17.6%. On the contrary, *Platanus hispanica* represents 15.5% of the urban green trees, but only 7.5% of nests are found in this tree species (Table 9). These results confirm that bird nesting and diversity significantly relates with plant communities in the urban green (James and Wamer, 1982; Huang, et al., 2015). The different pattern of the actual nesting vegetation and the potential nesting vegetation according to the selected tree species can also be visualised in Fig. 2.

Among the most common nesting birds we found in Valls' urban green, only *Serinus serinus* (Fisher's test, p-value = 0.0005) shows a specific preference for some tree species whereas *Carduelis carduelis* (p-value = 0.02) and *Chloris chloris* (p-value = 0.02) show no significant differences between the actual nesting vegetation and the potential nesting vegetation, though in both cases we observed the same tendency as that seen for *Serinus serinus*. So, *Serinus serinus* tend to select *Hibiscus syriacus* (+11.0%) and *Melia azederach* (+6.0%) whereas avoids *Platanus hispanica* (-8.8%). The selected trees are medium size trees except for *Hibiscus syriacus*, which has a small size. *Melia azedarach* generally presents medium height and size (Table 10).

3.5. Preferences according to neighbourhood types

Neighbourhood types defining different urban green areas affect significantly the preferences of passerine birds nesting (Fisher's test, p-value = 0.002). The differences between the pattern of the actual nesting vegetation and that of the potential nesting vegetation by neighbourhood type (Table 11 and Fig. 3) show that birds preferably nest within the historic centre (+9.4%), and avoid the neighbourhoods with single-family houses (−5.1%) or neighbourhoods with blocks of flats (-3.4%). The preference for the historic center can be attributed, among other factors, to the higher canopy size and leaves' density of its trees compared to those in the surrounding area (Savard et al., 2000; Mella and Loutit, 2007). Also, it could be due to a lower predator pressure in the city center (Boada and Capdevila, 2000; Boada and Gómez, 2008; Parker and Nilon, 2008; Boada and Sánchez, 2012) than in peri-urban areas where the predation rates are higher (Miller et al., 1998; Smith-Castro, 2008; Marzluff and Rodewald, 2008). The vegetation in the river banks that divide the neighbourhoods, the gardens in the neighbourhoods with single-family houses and the crop lands surrounding the isolated houses need to be considered when analysing the results because they can interfere the nesting results.

The nesting preference for the historic centre might be also related to the higher biodiversity of the neighbourhood type compared to the other ones. Table 12 lists the calculation of the biodiversity indices at the level of the neighbourhood types and indeed finds a correlation between the biodiversity and the nesting tendency. The higher the biodiversity the higher the nesting tendency with the exception of isolated houses. The historic centre shows a Shannon-Weaver's index of 3.59 which is significantly higher than that of single family houses, 2.54. This relationship has already observed elsewhere (Blinkova and Shupova, 2017).

3.6. Tree structure and characteristics that influence nesting

Height is an important factor in the moment of nesting. 84.3% of nests were found at medium height (2–4.5 m), 10.3% at high height

Table 8
Classification of the plant species between non nesting and potential nesting species. The number in parentheses indicate the number of nests.

Vegetation types	Non nesting species	Intermediate situation	Potential nesting species
	Plant species that are common (> 100 individuals) but do not host any nest	Plant species that host less than three nests.	Plant species that host more than two nests
Trees	*Celtis australis, Laurus nobilis, Robinia pseudoacacia, Pinus pinea*	*Albizia julibrissin* (2), *Lagerstroemia indica* (2), *Morus nigra* (2), *Pinus halepensis* (2), *Schinus molle* (2), *Tilia cordata* (2), *Acer pseudoplatanus* (1), *Cedrus deodara* (1), *Cedrus sp.* (another) (1), *Cupressus sempervirens* (1), *Ligustrum japonicum* (1), *Magnolia grandiflora* (1), *Populus alba* (1), *Prunus cerasifera* (1), *Pyrus calleryana* (1), *Tilia platyphyllos* (1).	*Melia azederach* (107), *Hibiscus syriacus* (47), *Acer negundo* (42), *Platanus hispanica* (20), *Morus alba* (16), *Sophora japonica* (12), *Pittosporum tobira* (5), *Jacaranda mimosifolia* (4), *Ulmus minor* (4), *Catalpa bignoinoides* (3), *Populus nigra* (3), *Tilia tomentosa* (3).[a]
Shrubs	21 species[b]	*Tamarix sp.* (2), *Teucrium fruticans* (2), *Pittosporum tobira* (2), *Euonymus japonicus* (1), *Pleioblastus sp.* (1), *Pyracantha coccinea* (1).	
Lianas	*Hedera helix, Vinca major*	*Bougainvillea spectabilis* (1), *Wisteria sinensis* (1).	

[a] None of these 12 plant species is considered as an invasive and exotic species according to Spanish regulations (Royal Decree-Law 630/2013).
[b] *Abelia grandiflora, Abelia grandiflora prostrata, Aloe sp., Atriplex halimus, Berberis thunbergii, Cotoneaster horizontalis, Cotoneaster lactea, Cupressus sempervirens, Euonymus fortunei, Juniperus horizontalis, Lavandula angustifolia, Ligustrum japonicum, Ligustrum ovalifolium, Lonicera pileata, Nerium oleander, Photinia Red Robin, Pistacia lentiscus, Pittosporum tobira, Prunus laurocerasus, Rosa grandiflora, Rosa hybrida, Rosmarinus officinalis, Spartium junceum, Viburnum lucidum, Viburnum tinus, Westringea fruticosa*.

Table 9
Contingency table by plant species name without differentiating bird species (Fisher's test, p-value = 0.0005).

Tree selection	*Hibiscus syriacus*	*Melia azederach*	*Platanus hispanica*	*Ulmus minor*
Potential nesting vegetation	6.6	32.8	15.5	6.1
Actual nesting vegetation	17.6	40.1	7.5	1.5
Difference	+11.0	+7.3	−8.0	−4.6

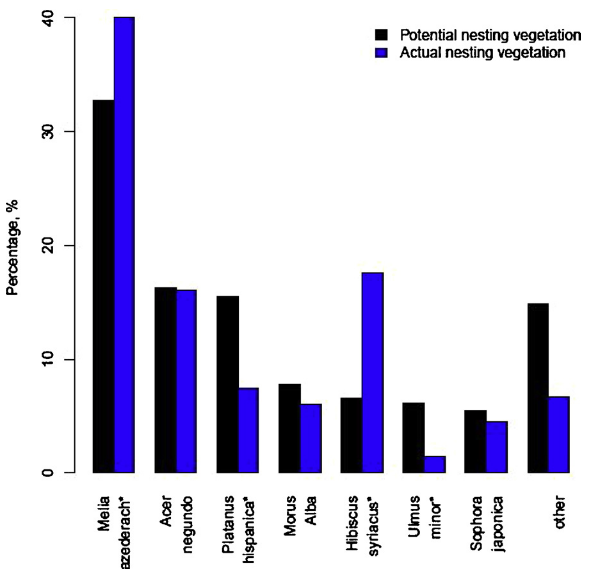

Fig. 2. The vegetation pattern of the potential nesting vegetation and the actual nesting vegetation according to the plant species. A graphical representation of Table 9. The 32.8% of the potential nesting vegetation is composed of *Melia azederach* but up to 40.1% of nests are found in this tree species indicating a clear preference for this tree species by passerine birds.

(> 4.5 m) and only 5.4% at low height (< 2 m). On the one hand, the species *Melia azedarach* provides such adequate height since it is a medium sized tree and consequently is selected intensively by birds. Contrarily, the high size of the *Platanus hispanica* prevents birds for nesting as seen in previous sections. On the other hand, this preference towards medium sized trees and not bushes is due to the human and feral domestic animals' presence (Matthews et al., 1999; Jokimäki and Huhta, 2000). At the same time, bird species that tend to nest at high height in the wild decrease the nesting height in the cities due to the lack of predators (Boada and Capdevila, 2000; Boada and Gómez, 2008; Parker and Nilon, 2008; Boada and Sánchez, 2012).

68.5% of nests of the actual nesting vegetation were found in trees that are pruned intensively, which contrasts with the fact that only 50.0% of potential nesting vegetation was pruned intensively. Therefore, birds select significantly trees with intensive pruning (Chi squared, p-value = 0.001) compared to the maintenance ones (see

Table 11
Contingency table by neighbourhood type, numbers (%) (Fisher's test, p-value = 0.002).

Neighbourhood type	Single-family Houses	Blocks of Flats	Isolated houses	Historic Centre
Potential nesting vegetation	1508 (65.0)	193 (8.3)	37 (1.6)	585 (25.2)
Actual nesting vegetation	157 (59.9)	13 (4.9)	2 (0.7)	95 (35.6)
Difference / Nesting tendency	(-5.1)	(-3.4)	(-0.9)	(+ 9.4)

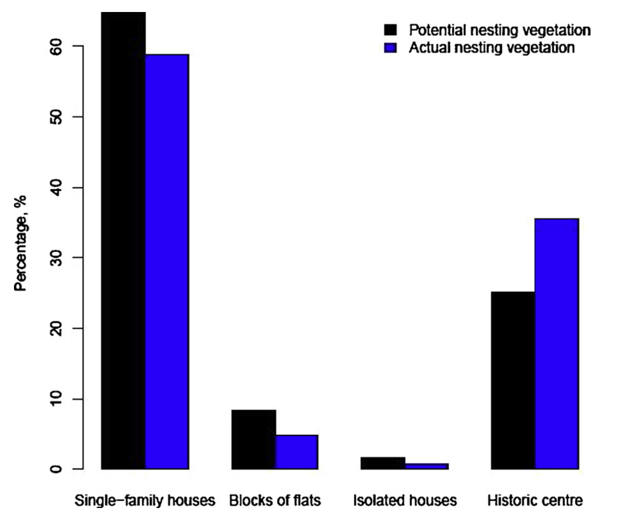

Fig. 3. The vegetation pattern of the potential nesting vegetation and the actual nesting vegetation according to neighbourhood type. A graphical representation of Table 11.

Fig. 4). Nevertheless, they only show preference for the *Melia azedarach* (chi squared p-value = 0.0008) and *Acer negundo* (chi squared, p-value = 2.5E-5) that have been lopped and do not show preference for other species with intensive pruning such as *Hibiscus syriacus* (chi squared p-value = 0.37) or *Morus alba* (chi squared p-value = 0.37). In the case of *Melia azedarach* and *Acer negundo*, it was visually observed that nests found in intensive pruned trees are located in the middle of the annual twigs. These great numbers of twigs of *Melia azedarach* and *Acer negundo* are located where the tree was pruned in winter and also generate a large foliar mass in spring. It has already proven that there is

Table 10
Contingency table by plant species name for each bird species name.

Birds	*Carduelis carduelis*[a]			*Chloris chloris*[a]		
	Hibiscus syriacus	*Platanus hispanica*	*Melia azederah*	*Hibiscus syriacus*	*Acer negundo*	*Morus alba*
Potential nesting vegetation	7.8	18.3	38.8	10.4	25.7	12.3
Actual nesting vegetation	18.7	10.7	45.3	26.2	19.0	7.1
Difference	10.9	−7.6	6.5	15.8	−6.6	−5.2
Birds	*Serinus serinus*[b]					
	Hibiscus syriacus	*Platanus hispanica*	*Melia azederach*			
Potential nesting vegetation	7.3	17.1	36.2			
Actual nesting vegetation	18.3	8.3	42.2			
Difference	11.0	−8.8	6.0			

[a] Statistically non-significant differences.
[b] Statistically significant differences.

Table 12
Characterisation of the biodiversity of the neighbourhood types of the city of Valls.

Neighbourhood types	Number of individuals	S[a]	H[b]	D[c]	J[d]	Nesting tendency[e]
Single-family houses	37824	163	2.54	0.72	0.50	−5.1
Blocks of flats	8360	143	3.43	0.93	0.69	−3.4
Isolated houses	206	19	1.98	0.76	0.67	−0.9
Historic centre	6490	143	3.59	0.94	0.72	+9.4
Total	59869	239	3.36	0.88	0.61	–

[a] Species richness (S).
[b] Diversity Shannon-Weaver's index (H).
[c] Diversity Simpson's index (D).
[d] Evenness Pielou's index (J).
[e] From Table 11.

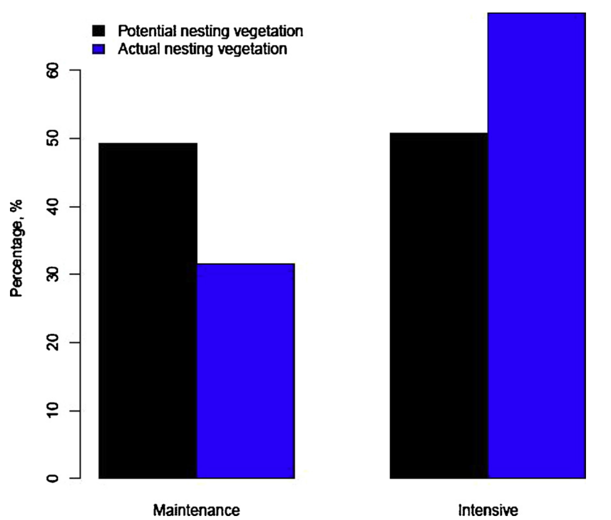

Fig. 4. The vegetation pattern of the potential nesting vegetation and the actual nesting vegetation originated by the pruning type.

a positive relationship between bird diversity and richness and the volume of the tree canopies (Savard et al., 2000; Mella and Loutit, 2007) and, on the contrary, low density of canopies during the breeding season reduces bird diversity and richness (Camprodon and Brotons, 2006; Yang et al., 2015). In fact, fauna finds shelter in large trees and in dense vegetation (Fernández-Juricic, 2001). It is also important to remark that the relationship with the intensive pruning is only found for two species, *Melia azedarach* and *Acer negundo*, whereas no effect is observed for the rest of potential nesting species, such as *Hibiscus syriacus*, *Platanus hispanica*, *Sophora japonica* and *Morus alba.* Therefore, intensive pruning cannot be considered a general recommendation for promoting passerine nesting.

86.9% of nests of the actual nesting vegetation were found in 9 plant species that produce edible fruits and the other 13.1% of nests are in 3 fruitless or non-edible fruit plant species whereas the potential nesting vegetation only shows a 78.2% of plant species that produce edible fruits. Though the statistical effect size is not so big there is a significant relationship between the presence of fruits and bird nesting and consequently birds tend to select plants with edible fruits when nesting (Chi-squared p-value = 0.001). However, the similar relationship does not hold for the presence of insect plagues (chi-squared p-value = 0.109) and birds do not tend to select plant species that suffer from louse (insect plague) during spring or summer. Thus, passerine birds do not tend to nest in feeding areas, taking into account, first, that passerine birds are granivorous and insectivorous but not frugivorous and, second, that passerine birds feed almost entirely from insects during nesting period because insects are richer in proteins and consequently more appropriate for nourish their chicks (Svensson, 2014; Ornitho, Institut Català d'Ornitologia (ICO), 2015; Huang et al., 2015).

4. Conclusions

In this article we investigated the relationship between several socio-ecological factors linked with public urban green management and their effects on the nesting of the passerine bird order in the Mediterranean city of Valls. Findings show that urban green biodiversity indices (Shannon-Weaver and Simpson) of the city of Valls fall within common range for a standard Mediterranean city. While the biodiversity results for trees and bushes were above the average, herbs and lianas were below.

Passerine birds select historic centre of the city in detriment of the other type of neighbourhoods probably due to a reduced presence of predators and higher number of trees with denser canopies. Also, the historic centre hosts the highest plant biodiversity in the city according to the Shannon-Weaver's diversity index (H), which seems to favour passerine birds nesting. Most nests have been found on streets with old trees and mostly are from *Serinus serinus*, *Carduelis carduelis*, *Chloris chloris* and *Sylvia atricapilla*, which are present usually at Mediterranean agroforestry areas. Fringillidae family birds select mainly *Melia azedarach* and *Hibiscus syriacus*, which are medium-size trees. Regarding at the pruning type, birds prefer nesting on *Melia azedarach* pruned intensively. Moreover, the identified birds nest in those trees that develop edible fruits but do not show preference for those that are attacked by insects that turn into plagues, which implies that passerine birds feed outside the nesting areas since these birds are especially insectivorous in the breeding period.

To sum up, in order to increase birds' biodiversity in Valls, and other similar Mediterranean cities, biodiversity management plans should take into account that : (1) the increment of the biodiversity of the urban green attracts also passerine birds as seen in the case of the historic center, (2) the presence of medium-sized trees in the streets like *Melia azedarach* and *Hibiscus syriacus* favour passerine bird nesting and (3) the intensive pruning *of Melia azedarach* and *Acer negundo* also foster their nesting though no effect is found for other tree species such as *Hibiscus syriacus* or *Platanus hispanica*. Despite the study is not focused on the breeding success of the identified nests, results are a useful contribution for the knowledge of urban bird biodiversity. Moreover, the results could improve the management of public urban green areas in order to promote passerine nesting.

Conflict of interest

None.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ufug.2019.03.012.

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