

Bird-window collisions in a city on the Iberian Mediterranean coast during autumn migration

Raül Aymí, Yolanda González, Txiqui López & Oscar Gordo

Collision with buildings is a major threat to birds that provokes the death of millions of birds every year in built-up areas. Despite its magnitude, this phenomenon remains poorly studied in Europe. We studied bird-window collisions during postnuptial migration in the city of Tarragona (NE Spain). We surveyed a 15-m-high residential building in the city centre with a reflective façade for 189 days during postnuptial periods in 2012–2015. We found 172 dead birds belonging to 15 species, most of them migratory. Blackcaps *Sylvia atricapilla*, Reed Warblers *Acrocephalus scirpaceus* and Pied Flycatchers *Ficedula hypoleuca* were the commonest casualties, representing 72% of all recovered bird corpses. Once the uneven sampling effort between days and years was corrected for, we estimated that the total number of fatalities during the study period was 350 birds (SE = 22.2). However, this figure is probably an underestimate due to certain biases in sampling carcasses in a city including collection by pedestrians or removal by cleaning services and owners. Overall, there was a patent seasonal pattern to the collisions, with a peak around 1 October, probably reflecting the timing of migration in the species present at the site. There were no differences in either age, sex or biometrics between the birds found in Tarragona and those trapped on the same days at a ringing station in the Ebro Delta, 60 km to the south-west. This suggests that the probability of collision affected all migrants in a uniform fashion. Our study demonstrates for the first time that bird collisions with buildings are a serious threat to migrants in the Mediterranean, a key area for bird migration in Europe.

Key words: bird collision, glasses, reflectivity, migration, mortality, Tarragona, NE Spain.

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Collisions of birds with buildings, especially those with windows and balconies made of glass or other reflective materials, are one of the most serious problems for bird conservation in modern cities (Klem 1990, Evans Ogden 1996, Sabo *et al.* 2016). Some estimates of annual bird mortality due to collisions suggest alarming numbers as high as 365–988 million victims in the USA (Loss *et al.* 2014a) and 25 million in Canada (Machtans *et al.* 2013) annually. Although no

estimate is available for Europe, there is no reason to expect a more favourable situation for birds on this continent. Every year billions of birds migrate across Europe and cross highly populated European cities, where the use of glass façades is becoming increasingly popular. However, little attention has ever been paid to this conservation issue in Europe, where available evidence is limited to a few local reports (Haupt 2009, Zbyryt *et al.* 2012, Schmid *et al.* 2013,

Campedelli et al. 2014, Šumrada 2015). Haupt (2009) investigated in October 2006–November 2007 the effects on birds of the illumination of a 162.5-m-high building in Bonn (Germany). Its nocturnal illumination attracted more than 1,000 birds belonging to 29 species directly to the tower and its outbuildings and, in total, 200 birds died instantly due to collisions, while many others were injured and probably died later. Therefore, bird-window collisions also represent a serious hazard for birds in European cities.

Birds collide with façades mainly due to their reflectivity, transparency and/or to nocturnal lighting (Haupt 2009, Sheppard 2011, Schmid et al. 2013, Bahls et al. 2014). Glass panes produce a mirror effect and reflect surrounding trees or vegetation and birds perceive these images as a continuation of a suitable habitat. Transparency, on the other hand, gives a false perception that there is no obstacle as birds can see sky or a suitable habitat in the background. Birds are also attracted by lights (Evans Ogden 1996, Rich & Longcore 2006, Rodríguez et al. 2017, La Sorte et al. 2017), especially in poor weather or fog, and get confused and then collide with obstacles (Haupt 2009).

In 2012, the occurrence of bird fatalities centred on a building in the centre of the city of Tarragona (NE Spain) was detected fortuitously (Imma Martínez, pers. comm.). Subsequently, we were informed of a complaint that local people had made in 2008 regarding the number of dead birds. Thus, there was evidence to suggest that this site was a blackspot for bird mortality, presumably ever since it was built in 2000. To quantify the number of species involved and the phenology of bird casualties on this building, we carried out surveys during the postnuptial migration period in 2012–2015. As well, we compared the sample of dead birds with those trapped in a nearby ringing



Figure 1. The studied building in Plaça Imperial Tarraco, Tarragona. (Photo: Raül Aymí).
L'edifici estudiat a la Plaça Imperial Tarraco, Tarragona. (Foto: Raül Aymí).

station over the same period of time to determine whether certain species and/or individuals are especially sensitive to collisions with windows.

Material and methods

The studied building is located in the centre of the city of Tarragona (n^o 2, Imperial Tarraco Square; 41° 07' 11"N 1° 14' 43"E). It is semi-circular in shape and is located in the NW of the square, on the corner of Av. Andorra and Av. Marqués de Montoliu. It has six stories (c. 15 m high) whose five upper floors have balconies constructed with 145 modules of reflecting glass (Figure 1). Although atypically Spanish, its architectural style with glass façades is becoming popular in new buildings. Opposite the building, there are two London planes (*Platanus x acerifolia*), about 10-m high, that are reflected in the balcony glass. In addition, some balconies are lushly decorated with plants that confer them a more natural aspect.

Table 1. Sampling details, showing the dates of each study period, the number of sampled days, the number of visits carried out, the total number of casualties found each year, and the number of days with victims. *Detalls del període de mostreig de cada temporada. Es mostren la data i el nombre de dies que conté el període, i el nombre de visites dutes a terme. També es detalla el nombre de dies en què es van trobar ocells i el nombre d'ocells totals trobats a cada temporada.*

Year Any	Period Període	Days Dies	Visits Visites	Birds Ocells	Days with birds Dies amb ocells
2012	1/10 - 19/11	44	75	50	23
2013	2/9 - 13/11	30	36	15	8
2014	31/8 - 24/11	51	59	32	22
2015	7/8 - 6/11	64	66	75	37

During the autumns of 2012–2015, 236 visits on 189 different days were made to the outside of the building. We walked a transect in parallel to the front of the building (Figure 1) to look for any bird that had collided with the building during its postnocturnal migration period (August–November, Table 1). In 2012, we visited the building at different times of the day (06:30–13:30) but found that the best period for sampling were the three hours around dawn (Figure 2). We even witnessed several collisions during these hours. Moreover, the dead birds found at this time of day were still warm and showed no sign of rigor mortis, thereby suggesting very recent deaths. By contrast, the number of dead birds diminished towards midday (Figure 2), probably due to the fact that the number of carcasses or injured birds removed by the inhabitants of the studied building or pedestrians is greater than the number of potential fresh collisions. If we assume that the probability of removal during the day by people is approximately constant, this pattern suggests that only a few collisions occur more than four hours after sunrise. In light of this evidence, we have sampled the area since 2013, mainly between 07.00 and 10.00. In addition, during the study period, we also conducted 20 nocturnal visits (more than 30 minutes before sunrise) to sample potential nocturnal collisions. From 2014 onwards, we also placed a collection box in the street where local people can leave the dead birds they find. The aim was to reduce the potential underestimate of the number of collisions due to the removal of birds by people before we conducted our daily sampling. The species and, whenever possible, the age and sex of all carcasses were determined. We followed the ICO's standardized ringing protocols (ICO 2003) and took the following post-mortem measurements of fresh and complete victims: wing length (maximum chord), third primary length and body mass. We measured wing and third primary lengths with a ruler to the nearest 0.5 mm; body mass was determined with a digital balance (± 0.1 g).

Since we did not sample the entire autumn migration period and did not sample every day during the migration period, we could not use our raw data as an accurate estimate of the total number of fatalities. So, to estimate this value, we calculated the total number of fatalities recorded in the period 2012–2015 in each

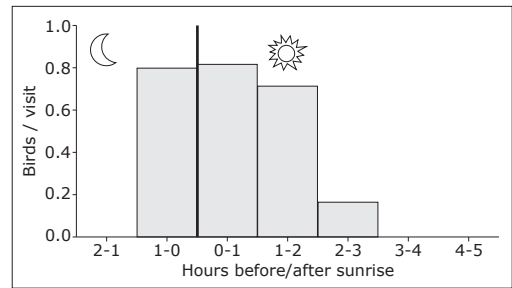


Figure 2. Number of birds found per visit at different moments of the day in 2012.

Nombre d'ocells trobats per visita a diferents hores del dia durant l'any 2012.

pentad (five-day periods, from 7 August to 24 November, $n = 22$ pentads). This was used as the response variable in a Generalized Lineal Model (GLM) with a Poisson error distribution, log-link function, and pentad and squared pentad as predictor variables. A second-order polynomial on a log scale describes a Gaussian curve, which can be assumed to represent a suitable function for modelling the seasonal distribution of fatalities during migration. The estimated coefficients of this polynomial were transformed into the more understandable parameters of a Gaussian curve – i.e. mean passage date, its standard deviation (SD) and the total number of birds involved (as the height of the curve) – by a reparametrization of the GLM (for the mathematical details, see Lindén 2011, Lindén *et al.* 2017). The standard errors (SE) of these parameters were estimated by simulating 100,000 values in a multivariate normal distribution, in which we used the covariance matrix derived from the GLM as a covariate matrix. We used the number of sampling days within each pentad during the four years of study as an offset variable to account for the sampling effort. We carried out these GLMs also for the particular data of the Reed Warbler *Acrocephalus arundinaceus* and Blackcap *Sylvia atricapilla*.

In order to determine whether the dead birds we found are a random sample of birds migrating through the study region during the postnocturnal migration or, alternatively, a particularly susceptible fraction of migrants, we compared our sample of dead birds with a sample of the same species captured on the same days at a constant-effort ringing station in the Ebro Delta, Canal Vell, 40° 44' 16"N 0° 47' 16"E (data provided by the Institut Català d'Ornitologia).

The Ebro Delta lies 60 km south-west of Tarragona, in the same direction as the main flux of songbird migration passing south-westwards in autumn along the Mediterranean coast (Bernis 1966, 1966-1971). Therefore, we can assume that our sample of birds and those trapped in the Ebro Delta belong to the same migratory population. Canal Vell, the most active ringing station in Catalonia (Baltà & Aymí 2013), is located beside a coastal lagoon whose main plant communities consist of flooded reed and reedbeds with some tamarisks, surrounded by patches of shrubby halophilic formations of *Arthrocnemum fruticosum*.

We compared the number of dead birds found in Tarragona with those trapped in Canal Vell for each species in an attempt to detect differences in the bird community composition and structure of the two samples. We used Chi-square tests to compare the distributions of species abundances at each site. We performed an annually based comparison because the heterogeneity Chi-square test (Zar 1999) showed that some annual distributions did not belong to the same frequency distributions ($\chi^2 = 429$, d.f. = 40, $p < 0.001$). This result revealed that species numbers fluctuate from year to year with a certain degree of independence, and so proportions are not necessarily constant over time (Holmes *et al.* 1986).

Although we assumed that the migratory population of birds passing through Tarragona and Canal Vell was the same, there may be differences in the phenology of collisions and captures if the collision probability is not evenly distributed amongst all individuals. To check this hypothesis, we used Chi-square tests to compare the seasonal distribution of collisions in Tarragona vs. captures at Canal Vell by grouping daily data in pentads. We also carried out Chi-square tests for each year independently given that the sampled periods differed markedly between years (Table 1).

In some of the most-trapped species, we determined whether the sex and age ratios found in our sample differed from those of the trapped birds from the reference ringing station at Canal Vell. Our objective was to investigate whether males or females are more susceptible to collisions, and whether inexperienced juveniles are more prone to die in a collision. We used 2x2 contingency tables and calculated the two-tailed

Fisher exact test whenever possible; otherwise, we calculated the Yates corrected Chi-square given the small sample size available for some sexes and ages in Tarragona (Zar 1999).

Finally, we also tested for differences in the average wing and third primary lengths, and in body mass, using several t-tests, with site as a grouping factor. As before, we aimed to determine whether or not dead birds had any particular traits that made them more susceptible to collision. Wing length and body mass are related to flight manoeuvrability in birds (Alatalo *et al.* 1984, Hedenström 1992, Lind *et al.* 1999, Burns & Ydenberg 2002) and thus we hypothesised that heavier individuals with longer and more pointed wings would be more susceptible to collision due to their poorer manoeuvrability.

All analyses were conducted with R 3.2.2 (R Core Team 2015).

Results

We found 172 dead or dazed birds (Table 2). The probability of finding at least one such bird on any sampling day ranged from 27% (in 2013) to 58% (in 2015). Such variability between years did not differ from the expected distribution of probabilities given the different sampling effort in each year ($\chi^2 = 4.58$, d.f. = 3, $p = 0.205$). The average number of birds found per day ranged from 0.5 (in 2013) to 1.2 (in 2015). In this case, we found that abundances deviated from the expected distribution ($\chi^2 = 17.31$, d.f. = 3, $p < 0.001$), suggesting that there were similar probabilities of collision but different intensities during the study years. The year 2015 had the greatest number of collisions during the study period.

We found 15 different species of dead or dazed birds (six individuals were unidentifiable; Table 2). All were migratory passerines with the exception of the Sardinian Warbler *Sylvia melanocephala*, a common breeder in the area that performs short local dispersive movements. Species frequencies were very uneven, the three commonest species (Blackcap *Sylvia atricapilla*, Reed Warbler *Acrocephalus scirpaceus* and Pied Flycatcher *Ficedula hypoleuca*) representing up to 72% of all casualties. This distribution differed markedly from that observed every year at the Canal Vell ringing station for the same set of

Table 2. Number of birds found dead or dazed due to collisions. The annual number of collisions and the total number for the study period (in bold) are shown. *Nombre d'ocells trobats morts o estabornits per col·lisió. Es mostra el nombre d'individus trobats cada temporada, així com el total durant l'estudi (en negreta).*

Common name <i>Nom comú</i>	Scientific name <i>Nom científic</i>	2012	2013	2014	2015	Total
Blackcap	<i>Sylvia atricapilla</i>	24	2	16	32	74
Reed Warbler	<i>Acrocephalus scirpaceus</i>	8	4	8	20	40
Pied Flycatcher	<i>Ficedula hypoleuca</i>	1	3	1	5	10
Subalpine Warbler	<i>Sylvia cantillans</i>	1	1	1	4	7
Sardinian Warbler	<i>Sylvia melanocephala</i>	3		1	3	7
Common Chiffchaff	<i>Phylloscopus collybita</i>	4	1	1	1	7
Robin	<i>Erithacus rubecula</i>	2	1	1		4
Willow Warbler	<i>Phylloscopus trochilus</i>		1		3	4
Song Thrush	<i>Turdus philomelos</i>	1		1	1	3
Garden Warbler	<i>Sylvia borin</i>	1	1	1		3
Goldcrest	<i>Regulus regulus</i>	2			1	3
Nightingale	<i>Luscinia megarhynchos</i>		1			1
Common Whitethroat	<i>Sylvia communis</i>				1	1
Common Firecrest	<i>Regulus ignicapilla</i>			1		1
Common Starling	<i>Sturnus vulgaris</i>	1				1
Unidentified		2			4	6
Total		50	15	32	75	172

species (χ^2 ranged from 95 to 972, d.f. = 14, $p < 0.001$ in all four years). At Canal Vell, there was a marked predominance of Reed Warblers, Common Chiffchaffs *Phylloscopus collybita* and Robins *Erithacus rubecula*, which together represented 89% of all captures. However, these species represented only 31% of the collided and identified specimens in Tarragona, where the commonest species was the Blackcap. This species alone accounted for 44% of cases but was only marginal at Canal Vell (2% of captures).

The number of dead birds was markedly seasonal, with a peak on 1 October (SE=0.63; Figure 3a). This seasonal distribution differed from that observed at Canal Vell for pooled data for 2012–2015. The peak in collisions in Tarragona was earlier than the peak in captures at Canal Vell. In addition, the number of captures at Canal Vell was already high in August (average of 20.4 captures/day); by contrast, the number of collisions recorded during that month was minimal (only 11 cases in four years). The GLM predicted a total of 350 (SE=22.2) birds found dead during the autumn migrations of 2012–2015.

In the Reed Warbler, collisions and captures also showed marked differences in seasonality

(Figure 3b). Collisions peaked on 23 September (SE=0.61), while the peak in captures at Canal Vell occurred a full month earlier. By contrast, Blackcaps showed fairly similar phenological patterns at both sites (Figure 3c). The peak of fatalities according to the fitted GLM was on 16 October (SE=0.44), while the peak of captures at Canal Vell was reached around four days later. The period between the first and last fatalities and the period between the first and last captures was also very similar (Figure 3c). It is worth noting that in the Blackcap, the magnitude of the rate of captures exceeded fivefold the magnitude of fatalities, while in the Reed Warbler this scaling factor was 32. According to the fitted GLMs, the predicted total number of Reed Warblers found dead in the period 2012–2015 was 84 (SE=24.4), while the number of Blackcaps was 113 (SE=22.4; compare these values with those in Table 2).

A comparison of the age ratios in the four most-affected species in Tarragona reveals no differences with the Canal Vell captures during the same period (Blackcap: Fisher Exact test, $p = 0.422$; Reed Warbler: $\chi^2 = 0.04$, $p = 0.833$; Common Chiffchaff: $\chi^2 = 0.04$, $p = 0.832$; Subalpine Warbler *Sylvia cantillans*: Fisher Exact

test, $p = 0.289$). For a comparison of sex ratios, we only had reliable information for two species, Blackcap and Sardinian Warbler. In the latter,

we found no differences between sites (Fisher Exact test: $p = 1$); however, in Blackcaps more males than females collided in Tarragona, while females were more often trapped than males at Canal Vell (Fisher Exact test: $p = 0.046$). Finally, we found no statistically significant biometric differences in Blackcaps and Reed Warblers in the samples from Tarragona and Canal Vell ($p > 0.36$ all t -tests). Only for these two species were there enough samples in Tarragona to carry out these analyses with confidence.

Discussion

Good numbers of several bird species died regularly during autumn migration due to collision with the studied building. Our study for the first time in the Mediterranean region quantified this anthropogenic hazard for bird populations and demonstrates that some species could be seriously affected by the risk of collision with windows. Most birds found dead were nocturnal migrants that stopover in the city at dawn, possibly attracted by the water in the pond in the square and its surrounding trees, the street lighting, or by the whistles and songs of the Common Starlings *Sturnus vulgaris* roosting in the trees near the building. Birds gather in the square near sunrise and begin to move through the trees (authors' pers. obs.). Mortality during the night (at darkness) cannot be ruled out. This fact may explain the occurrence of a notable proportion of a very uncommon species in urban areas, namely the Reed Warbler. However, we found no collided birds in our visits to the building at 1–2 hours before sunrise ($n=14$), and only three fatalities in visits at one hour and 30 min before sunrise ($n=6$). Although not allowing for

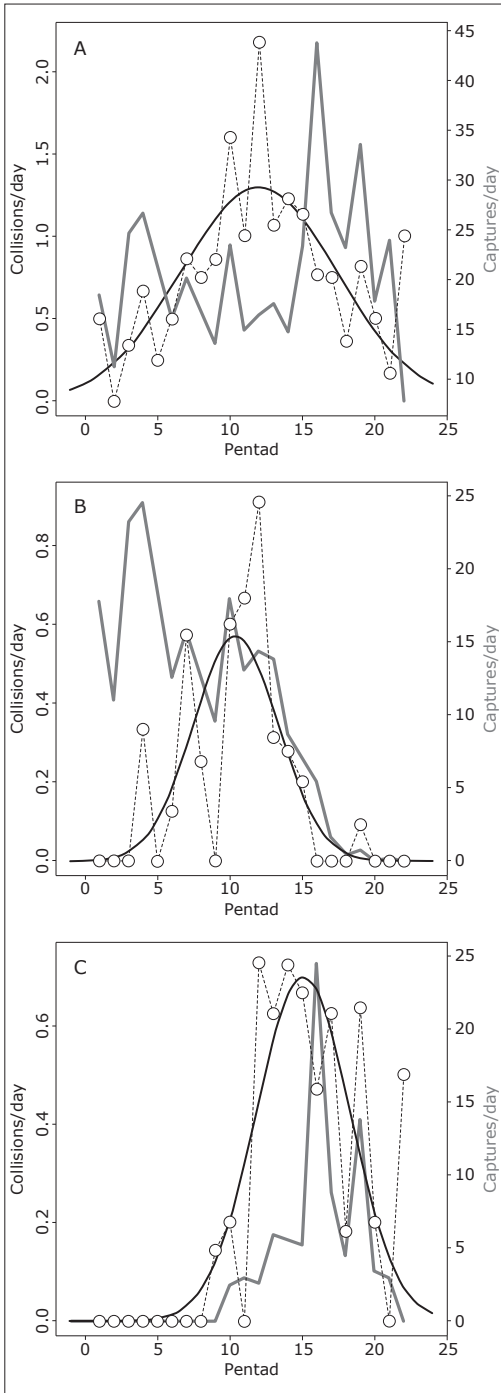


Figure 3. Collision (black) and captures (grey) rates in Tarragona and at Canal Vell, respectively, for every five-day period (pentad) during autumn migration in 2012–2015 for A) all birds; B) the *Boscarla de canyar*; and C) Blackcap. Points and dashed line show records, while the solid black line shows the best fitted GLM.

Taxa de col·lisions (negre) i captures (gris) a Tarragona i Canal Vell, respectivament, per a cada període de cinc dies (pentada) durant la migració de tardor del període 2012–2015 per a A) tots els ocells; B) la Boscarla de canyar; i C) el Tallarol de casquet. Els cercles units per la línia puntejada representen les dades registrades, mentre que la línia negra mostra el GLM amb el millor ajust a les dades.

a comprehensive analysis of collision timing, our data and surveys prior to sunrise seem to suggest that nocturnal mortality is low. Therefore, we believe that birds die mainly around dawn, when most migrants descend to seek a stopover site. In this situation, birds may mistake the reflection of the trees for the real trees opposite the building and collide with the windows. This process has previously been described and is one of the main causes of collision-related mortality in birds (Hager *et al.* 2008, Gleb & Delacretaz 2009, Borden *et al.* 2010, Bayne *et al.* 2012, Machtans *et al.* 2013, Hager & Craig 2014, Loss *et al.* 2014, Cusa *et al.* 2015).

A comparison with a nearby reference ringing station reveals notable differences in the relative abundance of the collided species. For instance, the species with the highest number of fatalities was the Blackcap, which was only captured in low numbers on the same days at the ringing station. By contrast, some commonly trapped species in the Ebro Delta, including the Robin and *Phylloscopus* warblers, only suffered sporadic casualties in Tarragona. These differences suggest that some species are especially vulnerable to suffer collisions with human infrastructures (Loss *et al.* 2014a). Nevertheless, differences between the sample of collided and ringed birds are strongly influenced by the marked differences in habitat between the study sites. Tarragona is an urban area, while Canal Vell is a coastal wetland with flooded reed and reedmace beds. For this reason, the dominant species at Canal Vell is the Reed Warbler, a typical reed bed specialist. However, the Reed Warbler was also found dead in surprisingly high numbers in the urban area, suggesting both a massive passage of European populations along the Mediterranean coastline of the Iberian Peninsula (e.g. one collided bird had been ringed in Poland) and an underestimate of the use of urban habitats by this species (Garcia 2012). Therefore, collisions may seriously affect even bird species that are less closely linked to built-up environments (Witting 2016). By contrast, the Blackcap, the species with the highest mortality due to collision, migrates across a wide front and uses many different habitats on migration (but with strong preference for habitats with berry-bearing bushes) (Jordano 1981, Shirihai *et al.* 2001). This species occurs at lower densities in reed beds than in parks and gardens in urban

areas. Interestingly, Robins have similar habitat preferences but we found few collided individuals belonging to this species. Thus, differences related to habitat selection during migration were a major driver of the sample composition but are almost certainly not the only cause of the different patterns in the abundances of mortalities in Tarragona and captures at Canal Vell. It is likely that species' flocking behaviour, the type of flight between perches, and microhabitat selection (e.g. ground vs. canopy) play a key role in determining collision propensity. For instance, Blackcaps usually prefer treetops and make fast and impetuous flights, while Robins tend to spend more time on the ground and move by jumping or short flights. Thus, the Blackcap's typical behaviour is more dangerous in a habitat replete with hard-to-detect glass façades and this may provoke higher mortality rates.

We found some differences between the phenology of collisions in Tarragona and captures in Canal Vell, which can be attributed to the marked differences in the relative abundance of the study species and their status at each site. For instance, the presence of an abundant breeding population of Reed Warblers in the Ebro Delta gives rise to an abundance of captures in August, when migrants from more northern populations start to arrive at this lower latitude, as collision seasonality demonstrates. On the other hand, some late migratory species such as the Common Chiffchaff (*Phylloscopus collybita*) are trapped in massive numbers in the Ebro Delta but only suffer a few casualties in Tarragona. For this reason, the autumn peak of captures occurs in the second half of October, date by which collisions have decreased notably (see Figure 3a). The dominance of Blackcaps in the sample of dead birds ensured that the peak in total deaths was around the beginning of October.

Although we did not systematically collect information on the mortality on this building during spring migration, we did find a dead Western Bonelli's Warbler *Phylloscopus bonelli* and a dead Sardinian Warbler in April and May 2015, respectively. Apparently, the incidence of fatal collisions in spring is lower than in autumn, as reported at other sites (Haupt 2009, Loss *et al.* 2014a). Autumn migration involves more birds, many of which are inexperienced juveniles and, indeed, overall most victims were juveniles (see Table 3). Moreover, the trees (London planes) in

Table 3. Age, sex and biometry of the five most abundant *Sylvidae* species in this study. Individuals were classified according to age as young (Y) or adults (A), and as males (M) or females (F). The arithmetic mean and its standard deviation are shown for all measures. The length of the wing and the third primary feather (PR3) are given in mm and body mass in g; fat and muscle are unitless scores (see methods for details). In all cases, the available sample size (n) is shown below.

Edat, sexe i biometria de les cinc espècies més abundants de sílvids en aquest estudi. Els individus han estat classificats segons l'edat en joves (Y) i adults (A), i segons el sexe en mascles (M) i femelles (F). Es dona la mitjana aritmètica i la desviació estàndard de totes les variables. La longitud de l'ala i de la tercera ploma primària (PR3) estan mesurades en mm, la massa corporal en g, i el greix i el múscul són variables categòriques. En tots els casos s'indica a sota la mida de la mostra (n).

Common name Nom comú	N	Age Edat		Sex Sexe		Wing length Longitud de l'ala	PR3 PR3	Body mass Massa corporal	Fat Greix	Muscle Múscul
		Y	A	M	F					
Blackcap	37	22	3	22	15	73.13 ± 1.47 (n=20)	55.35 ± 1.51 (n=20)	18.59 ± 2.28 (n=27)	3.92 ± 1.26 (n=13)	2.08 ± 0.49 (n=13)
Reed Warbler	21	20	1	-	-	64.83 ± 1.81 (n=12)	49.58 ± 1.53 (n=12)	12.76 ± 2.14 (n=18)	4.75 ± 1.42 (n=12)	2.25 ± 0.45 (n=12)
Common Chiffchaff	4	4	0	-	-	54.00 ± 1.41 (n=2)	41.00 ± 1.41 (n=2)	6.68 ± 1.02 (n=4)	2.50 ± 2.12 (n=2)	2.50 ± 0.71 (n=2)
Sardinian Warbler	5	4	0	2	2	57.75 ± 0.35 (n=2)	42.50 ± 0.71 (n=2)	10.50 ± 0.71 (n=2)	2.00 ± 1.41 (n=2)	2.00 ± 0.00 (n=2)
Subalpine Warbler	6	3	3	2	1	58.67 ± 1.53 (n=3)	43.50 ± 2.29 (n=3)	10.43 ± 0.65 (n=3)	4.67 ± 0.58 (n=3)	2.00 ± 0.00 (n=3)

front of the studied building only begin to leaf in late April and do not attain a full canopy until May; these trees without leaves probably attract fewer birds in spring than in autumn.

Interestingly, we found no differences in the age ratios of the two samples (deaths and captures). This fact suggests that inexperienced birds are not more prone to collide with a building. This was unexpected and contradicts certain previous results (Veltri & Klem 2005, Hager *et al.* 2013) but not others (Hüppop *et al.* 2016). The high proportion of young birds found dead in Tarragona was thus simply a consequence of their abundance in migratory populations in autumn. Similarly, we found no differences between males and females; nevertheless, our sample was small and more sexed individuals of more species would be necessary to draw any sound conclusions regarding the potential effect of sex on the probability of collision. Finally, the biometry and body condition of collided birds was similar to that of the birds ringed at Canal Vell. This suggests that collided birds are as manoeuvrable as other birds despite greater fat deposits or less rounded wings. Thus, accidents seem to affect the whole migrant population evenly, as has been found in other surveys (Hüppop *et al.* 2016).

Many factors make it difficult to accurately detect or quantify bird-window collisions (Hager

et al. 2012, Bracey *et al.* 2016). Our estimate of c. 90 deaths per autumn migration on the studied building is probably an underestimate. Several reasons make us believe that we did not collect all collided birds. 1) Despite asking owners of the businesses on the ground floor of the studied building to collect dead birds, some did not, preferring instead to remove dead birds as soon as possible from the pavement in front of their premises. 2) The municipal cleaning services removed carcasses routinely during their work, which negatively affected our counts when they did so before we finished our sampling. 3) After colliding, some birds fell into the balconies and terraces where we were unable to sample. 4) Stunned birds were often collected and looked after by pedestrians and we were unable to count most of these individuals. 5) The presence of scavengers that feed on carcasses may have reduced the number of dead birds detected (Klem *et al.* 2004, Hager *et al.* 2012, Kummer *et al.* 2016b). However, this factor was probably of negligible relevance since potential scavengers such as Magpies *Pica pica*, cats and dogs are not common at the study site. Finally, given that we did not sample every day during the autumn migratory period, the estimated death rates could be greater if we missed the most intense days of passage.

The main migratory routes of European migrants cross highly populated areas, where there is a great potential for collisions. Nevertheless, unlike in North America, few studies tackling the subject of bird-building collisions have ever been conducted in Europe (e.g. Seewagen & Sheppard 2017, Haupt 2009, Zbyryt *et al.* 2012, Campedelli *et al.* 2014, Šumrada 2015). This lack of scientific research prevents us from knowing whether bird-building collision is a real conservation threat to European birds too. Here, we show that a single modest building may be responsible for a large number of casualties per year due to the reflective materials used in the construction of its façade and to its geographical position (Bahls *et al.* 2014). Unfortunately, the impact of bird collisions has not been studied in nearby urban areas (e.g. Barcelona), where large frontages with reflecting windows are a common architectural style in modern buildings. Due to the large numbers of birds involved in the migration over the Mediterranean area every year, it is reasonable to assume that collisions with buildings are causing important losses in bird populations. In comparison with summer and winter, migration periods seem to be most critical as it is when most collisions occur (Ogden 1996, O'Connell 2001, Gelb & Delacretaz 2009, Arnold & Zink 2011), except at sites with bird feeders (Klem 1989, Dunn 1993).

Corrective measures *a posteriori* to prevent bird-window collisions are very often difficult to implement, especially in large buildings. Some solutions including the use of raptor silhouettes are increasingly being used but are, nonetheless, largely ineffective (Schmid *et al.* 2013, Håstad & Ödeen 2014). The best corrective measures are those that focus on prevention via, for instance, the construction of bird-friendly buildings (Brown & Caputo 2007, Sheppard 2011, Loss *et al.* 2014a) and a reduction in night lighting (Evans Ogden 2002). Aside from buildings, other infrastructures such as noise barriers on motorways or transparent fences in which reflective glass is sometimes used, can also be a potential threat to birds (e.g. Erickson *et al.* 2005, Zbyryt *et al.* 2012, Campedelli *et al.* 2014, Loss *et al.* 2014b). The impact of these structures on birds needs to be reevaluated and the problem should be taken into account in the design of future structures.

Finally, we recommend gathering more information on buildings where bird collisions take

place regularly in order to apply management measures to mitigate bird mortality in these blackspots (Klem 2009a, 2009b; Klem *et al.* 2009). This task is perfect as a citizen-science project, as occurs in Canada (Kummer *et al.* 2016a). Once the most dangerous buildings have been identified, windows and reflecting panels can be highlighted using plastic films with markings or large stickers. Some of these solutions are relatively cheap and quick, although unfortunately they are not always welcome (Rössler *et al.* 2015). Any such measure aimed at solving this problem should always be supervised by experts and analysed to evaluate its efficiency (Klem & Saenger 2013).

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Resum

Col·lisions d'ocells contra finestres en una ciutat de la costa mediterrània ibèrica durant la migració de tardor

La col·lisió d'ocells contra edificis és una amenaça important per als ocells, ja que provoca anualment milions de morts a les ciutats. Tot i la magnitud d'aquesta mortaldat, Europa destaca per la manca d'estudis que hagin avaluat aquest fenomen. Aquí es proporcionen els resultats d'un estudi dut a terme a Tarragona durant el període de migració postnupcial entre els anys 2012-2015. En aquest període es van fer visites durant 189 dies a un edifici residencial de

15 m d'alçada del centre de la ciutat que té la façana de vidre, fet que li confereix un efecte mirall. Es van trobar 172 ocells morts o estabornits de 15 espècies, majoritàriament migradores. Les espècies més comunes van ser el Tallarol de casquet *Sylvia atricapilla*, la Boscarla de canyar *Acrocephalus scirpaceus* i el Mastegatatzes *Ficedula hypoleuca*, que representaren el 72% dels casos. Un cop corregit el diferent esforç de mostreig dut a terme entre dies i anys, es va estimar que el total d'ocells morts per impacte amb l'edifici durant el període d'estudi va ser de 350 individus (Error Estàndard=22.2). No obstant això, aquesta xifra segurament està subestimada a causa dels diversos biaixos que impliquen el mostreig d'ocells a la ciutat, com ara els recol·lectats pels vianants, o els eliminats pels serveis de neteja o els propietaris dels comerços del mateix edifici. El nombre total de col·lisions va mostrar un marcat patró estacional, amb un pic al voltant de l'1 d'octubre, el qual probablement reflecteix la fenologia de pas al lloc d'estudi de les espècies implicades en les col·lisions. No es van trobar diferències en l'edat, el sexe i la biometria dels ocells col·lisionats en comparació amb els capturats els mateixos dies a l'estació d'anellament de Canal Vell, Delta de l'Ebre, i que està a 60 km al SO. Aquest fet suggereix que la probabilitat d'estimar-se contra l'edifici va ser igual per a tots els individus. Aquest estudi demostra per primera vegada que les col·lisions d'ocells amb edificis són també una amenaça important per als ocells migratoris a l'àrea mediterrània, una àrea clau per a la migració a Europa.

Resumen

Colisiones de aves contra ventanas en una ciudad de la costa mediterránea ibérica durante la migración de otoño

La colisión contra edificios es una amenaza importante para las aves, ya que causa millones de muertes en las ciudades. A pesar de la magnitud de esta mortandad, existen pocos estudios en Europa que hayan evaluado este fenómeno. Aquí se proporcionan los resultados de un estudio llevado a cabo en Tarragona durante el período de migración posnupcial entre los años 2012-2015. Durante este período se hicieron visitas durante 189 días a un edificio residencial de 15 m de altura en el centro de la ciudad que tiene una fachada acristalada, característica que le confiere un efecto espejo. Se encontraron 172 aves muertas o aturdidas de 15 especies, mayoritariamente migratorias. Las especies más comunes fueron la Curruca capirotada *Sylvia atricapilla*, el Carricero común *Acrocephalus scirpaceus* y el Papamoscas cerrojillo *Ficedula hypoleuca*, que representaron el 72% de la mortandad. Una vez corregido el diferente esfuerzo de muestreo realizado entre días y años, se estimó que el total de aves

colisionadas contra el edificio en todo el periodo de estudio ascendió a 350 (Error Estándar = 22.2). No obstante, esta cifra posiblemente esté subestimada a causa de los sesgos que supone el muestreo de aves en ciudad, como el hecho de que algunos ejemplares sean recogidos por los transeúntes o que otros sean eliminados por los servicios municipales de limpieza y los propietarios de los comercios del mismo edificio. El número total de colisiones mostró un marcado patrón estacional, con un pico en torno al uno de octubre, reflejando probablemente la fenología de paso en la localidad de estudio de las especies implicadas en las colisiones. No se encontraron diferencias en la edad, el sexo y la biometría de las aves colisionadas y las capturadas en la estación de anillamiento de Canal Vell, Delta del Ebro, a 60 km al SO. Este resultado sugiere que la probabilidad de estrellarse contra el edificio fue igual para todos los individuos. Este estudio demuestra por primera vez que las colisiones de aves contra edificios también son una amenaza importante para las aves migratorias en el área mediterránea, una zona clave para la migración en Europa.

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