

## Research Letters

## Cat and dog predation on birds: The importance of indirect predation after bird-window collisions



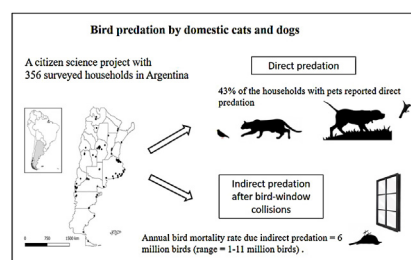
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## HIGHLIGHTS

- Domestic cats (*Felis silvestris catus*) and dogs (*Canis lupus familiaris*), affect birdlife in various ways, including predation.
- Besides direct predation, birds caught by cats and dogs after collisions with windows represents an unexplored human cause of avian mortality.
- Bird-window collisions should be incorporated into the assessment of bird predation by cats and dogs.
- Minimizing the number of cats and dogs per household and the time spent outdoors would help reduce avian mortality.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Predation of free-living birds by cats (*Felis silvestris catus*) and dogs (*Canis lupus familiaris*) is one of the main urbanization impacts on avifauna worldwide. In addition to direct predation, these pets capture birds after window collisions, an unexplored human cause of avian mortality. In this study we (1) estimated the number of cats and dogs in Argentina, (2) calculated the metrics of direct bird predation by cats and dogs, (3) analyzed factors that influence the probability of pets capturing birds, and (4) estimated annual bird mortality due to pet predation following bird-window collision events. To this end, we conducted an online survey to collect information on bird predation by cats and dogs in Argentina, both direct and indirect after bird-window collisions. We found that more than 68% of participants had at least one dog or cat, and of these, 45.3% reported having observed at least one case of bird predation by cats or dogs in their household. We estimated that the rough annual bird mortality rate due to predation following bird-window collisions could reach approximately 6 million birds in Argentina (range = 1–11 million birds). Our results show that direct bird predation by pets but also indirect predation after bird-window collisions represents a considerable source of avian mortality, which requires further attention in pursuit of solutions.

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## Introduction

The advance of urbanization over natural environments and the introduction and spread of exotic species constitute two of the main threats to biodiversity (Díaz et al., 2019; Newbold et al., 2015). An

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increase in human infrastructure and the introduction of companion animals can alter natural ecosystems and affect native species. For instance, the predation of birds by domestic animals and their collisions with man-made structures may kill millions of individuals annually (Bonacic et al., 2019; Lambertucci et al., 2015; Loss et al., 2015, 2014).

Cats (*Felis silvestris catus*, hereafter “cats”) and dogs (*Canis lupus familiaris*, hereafter “dogs”) are the most widely distributed domestic carnivores worldwide (Clout and Russell, 2007). These species have an increasingly negative impact on native fauna (Doherty et al., 2017; Loyd et al., 2013; Silva-Rodríguez and Sieving, 2012; Zapata-Ríos and Branch, 2016). The impact of cats and dogs currently threatens 430 and 145 species at risk of extinction worldwide, respectively (Doherty et al., 2016). Cats and dogs represent one of the most common causes of anthropogenic mortality for birds and mammals, and are linked to the extinction of 63 species globally (Doherty et al., 2016; Hughes and Macdonald, 2013; Loss et al., 2013). Although the impact of domestic dogs on wildlife has been less studied, they have contributed to 11 vertebrate extinctions (Doherty et al., 2016).

Globally, domestic dogs represent a potential threat to at least 78 bird species of 25 families (Doherty et al., 2017). The impact of feral cats on wildlife has been well documented on islands, and it is estimated that they pose a threat to 123 endangered bird taxa on at least 120 different islands (Medina et al., 2011). In the United States, free-ranging cats kill at least one billion birds every year (Dauphiné and Cooper, 2009), and are being considered the leading anthropogenic cause of passerine mortality in urbanized areas (Loss et al., 2015). In Canada, 5 million cats kill approximately 140 million birds and small animals each year (Brickner, 2003).

Domestic animals such as dogs and cats (hereafter, pets) are among the invasive alien species that seriously affect the number of globally threatened bird species (BirdLife International, 2018). Besides direct predation, birds caught by pets after collisions with windows represents another human cause of avian mortality (Loss et al., 2015). However, although scientific evidence shows that bird predation by cats and bird-window collisions represent two of the main causes of avian mortality (Klem et al., 2004; Loss et al., 2015), few studies have been carried out that reflect the combined impact of these threats. Birds that collide with windows may die instantly, or in many cases may suffer injuries that decrease their capacity for movement for a period of time. In the latter case, a pet can take advantage of the situation and prey on them. Cats in particular have been implicated as removers of bird carcasses following window collision (Hager et al., 2012), but their role as predators of injured birds that survive collisions has not yet been explored.

In South America only a few studies have focused on bird mortality due to predation by pets. In Brazil, 16.5% of dog scats and 13% of cat scats analyzed included bird items (Campos et al., 2007). In Chile, 31 of 168 dogs and 27 of 51 cats assessed brought avian prey items to their home (Schüttler et al., 2018). In Argentina, studies have yet to address the impact of pets on birds. A global market survey shows that Argentina is one of the countries with the highest percentage of pet owners in the world, particularly dogs (66% of participants said they had at least one) followed by cats (23% of respondents) (GFK, 2016). This fact, coupled with the large number of free-roaming dogs and cats without owners, poses a serious threat to birds, and should be urgently studied.

In this work, we evaluated bird predation by pets using an online survey which was distributed within Argentina through media and social networks. Our objectives were to: (1) determine the approximate number of pets in Argentina, (2) calculate direct predation on birds by pets, (3) analyze factors that influence the probability of pets capturing birds, and (4) estimate annual bird mortality due to pet predation after bird-window collisions.

## Material and methods

### Online survey

We developed an online survey using the Survio tool (<https://www.survio.com/es/>) to assess the current impact and factors influencing the predation of birds by pets in Argentina. The survey was carried out within a citizen science project called “Bird-Window Collisions in Argentina” and most of the questions were set to evaluate this issue (Rebolo-Ifrán et al., 2019). Complementarily, other questions were included with regard to pet ownership and the role of pets as predators of wild birds. The online survey was initially sent via e-mail to Argentine non-governmental organizations (NGOs) dedicated to wildlife conservation, and research centers and universities running courses related to biology and the environment, which then sent the survey to their students, staff and associates. In addition, the survey was publicized through our research group’s Facebook page (<https://www.facebook.com/GrInBIC/>), which was available to the general public. Additionally, to promote the survey at the local level, we published an article in the regional newspaper “Río Negro” of northwestern Patagonia (<https://www.rionegro.com.ar/bariloche/investigan-la-muerte-de-aves-por-colisiones-contra-las-ventanas-BF4546120>) to encourage the community to participate in the survey. The survey was anonymous and participants were asked to answer only one per household. The questionnaire focused on considering both direct predation (DP) and predation after bird-window collisions (PABWC). The responses of each participant were used to estimate: (1) the number of pets in Argentina, (2) the characteristics that may affect the probability of pets catching birds due to DP, and (3) the annual bird mortality due to PABWC. The survey was available for one year from November 23, 2017. The responses provided by participants related to household characteristics and pet behavior were used to identify characteristics that could influence the probability of pets capturing birds (Table 1).

We were also interested in knowing whether the distance from households to green areas was a driver of the probability of pets capturing birds, therefore we introduced the DistGreen variable (Table 1). The following were considered green areas: (1) squares and parks, in the case of highly urbanized areas such as cities, and (2) gardens or public spaces forming part of the surroundings of the households, in the case of less urbanized areas. For this purpose, we used a subset of surveys only from the participants who provided their complete address (i.e., street, number and town). Google Earth satellite images were then used to measure the distance from each household to the nearest green area of  $\geq 500$  square meters (DistGreen).

### Data analysis

To identify which factors influenced the probability of a participant registering the occurrence of a pet capturing a wild bird by DP, we used a Generalized Linear Mixed Model (GLMM) with a binomial distribution (with parameter  $N = 1$ , representing a Bernoulli process), and logit link function, fitted with the R glmer function, package lme4 (Bates et al., 2015). We used the binary variable Depred (which indicates whether or not an interviewee registered the occurrence of any bird predation) as a response variable. The model included the fixed effects variables: Garden, Habit, NumPets and BirdAttract (Table 1) as explanatory variables and the cities of the surveyed households (Locality) as a random effect. Considering that the time participants spent in their homes (Hours) could influence the probability of observing a bird predation event, we used a weighted regression. We assigned the weight = 1 for participants who spent more than 4 h in their homes during the day,

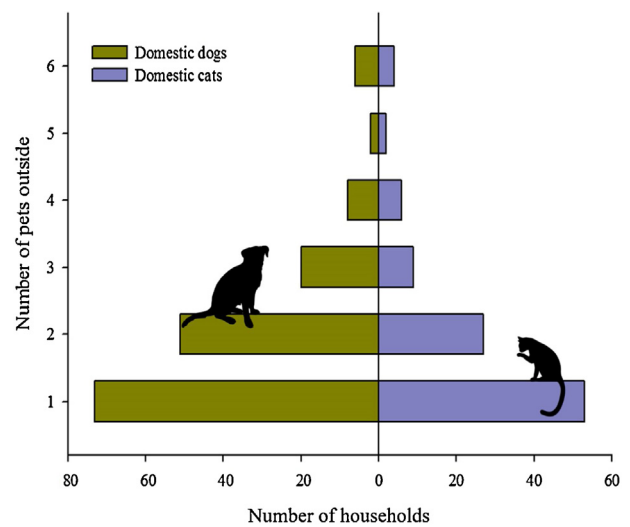
**Table 1**  
 Questions and/or description used for metric estimations and for variable compilation. The name and type of variables included in the models are reported.

Question/Definition	Variable	Type of variable	Categories
(1) Do you agree to participate in this survey?		Categorical	Yes/No
(2) How did you hear about this survey?		Categorical	Facebook/e-mail/newspaper/Twitter/WhatsApp
(3) What is your address?	Locality	Nominal	-
(4) How long do you stay at home during daylight hours?	Hours	Categorical	More/Less (than 4 h)
(5) Do you have a garden outside your household?	Garden	Categorical	Yes/No
(6) How many pets (cats and dogs) do you have?	NumPets	Numerical	-
(6a) How many of them are cats?		Numerical	-
(6b) How many of them are dogs?		Numerical	-
(7) Where do your pets (cats and/or dogs) stay for most of the day?	Habit	Categorical	Inside/Outside
(8) Do you have any artificial bird attractor outside your household? (feeders, nests, water fountains)	BirdAttract	Categorical	Yes/No
(9) Have you ever seen your pets catch a bird?	Depred	Categorical	Yes/No
(10) Which of your pet(s) did you see catch a bird?		Categorical	Cat/Dog
(11) Have you seen or heard a bird collide with windows of your building in the past year?		Categorical	Yes/No
(11a) How many birds that collided on those occasions finally died because a cat predation?		Numerical	-
(11b) How many birds that collided on those occasions finally died because a dog predation?		Numerical	-
(12) Distance to green area of ≥500 square meters nearest to the participant's home	DistGreen	Numerical	-

and weight = 0.5 for those who spent less than 4 h at home during daytime hours. We performed a GLM with a binomial distribution (Bernoulli, with parameter  $N = 1$ ) and the logit link function to evaluate the presence/absence of a predation event (Depred), depending on the variable DistGreen. For this, we only used the subset of data from participants that provided their precise household address. Each household was located with the highest degree of precision reported (province, city and neighborhood or street with and without number), which allowed us to measure the distance of each household to the nearest green area (DistGreen). We used the same weighting as in the previous model to take into account the time participants spent in their homes (Hours). We validated the models through residual diagnostics performed using DHARMA R package (Hartig, 2016). We plotted residuals versus fitted values and versus each covariate; normality of the random effects was also tested. We checked for collinearity between variables using the VIF (variance inflation factor) function of the carR package (Fox et al., 2012). In addition, we assessed whether the proximity of households to green areas (see Table 1) affected the probability of DP. All statistical analyses were performed in R (R Core Team, 2019).

The mortality rate per household due to PABWC (R) was calculated from the responses of pet owners who reported collisions with windows during the past year, and who also indicated the number of birds that had been captured by their pets after collisions. To separate post-collision mortality from mortality due to PABWC, we asked participants what had happened to birds after the collision and how they were able to differentiate between these two events.

To estimate the approximate annual mortality due to PABWC ( $M_{PABWC}$ ) in the entire country (Argentina), the total number of inhabited households in Argentina was obtained from the data provided by the latest national census (INDEC, 2010). Although the number of households may have increased by 2017, we prefer to use this official value even though it may be an underestimate. We estimated the total number of pet-owning households with bird-window collisions in a year (H) using this information, plus the percentage of households with pets, and the number of these households that experienced bird-window collisions. The annual mortality rate for the country was obtained by multiplying the estimated number of pet-owning households that reported bird-window collisions (H) by the mortality rate per household due to this cause (R), as follows:  $M_{PABWC} = H * R$ . In addition, we calculated



**Fig. 1.** Frequency distribution of the number of pets that remain outside the house during most of the daylight hours.

the range of annual mortality as  $MPABWC = H * R$  (mean ± SD). Of course, this is only a preliminary, basic estimation of a complex problem involving the interaction of several factors, some of which we may not have contemplated.

**Results**

*Pet abundances*

We collected 356 complete surveys from households in Argentina. A total of 243 (68.3%) participants reported having at least one pet in their household. Of these, 76.5% indicated that they had at least one dog (with an average of 1.85 dogs per household with dogs), whereas 51% reported having at least one cat (with an average of 1.79 cats per household with cats). Among pet owners, 81% allowed their pets to stay outside the house during most of the daylight hours. Of these, most participants had one or two pets, ranging from 1 to 12 per household (Fig. 1).

**Table 2**

Model results assessing the probability of pets catching birds according to variables related to the pets and the households they live in (on a logit scale). Statistically significant p-values are shown in bold. Random effects: Explained variance  $\pm$  SD =  $1.613^{-10} \pm 1.27e^{-05}$ . Groups (locality) = 60. N = 243.

Coefficients	Estimates	Std. Error	Z value	p-value
Intercept	-0.62	0.82	-0.76	0.45
NumbPets	0.46	0.18	2.58	<b>&lt;0.01</b>
Habit (outdoor)	11.7	0.51	2.31	<b>0.02</b>
Garden (yes)	-0.47	0.77	-0.61	0.54
BirdAttract (yes)	-0.14	0.33	-0.42	0.67

### Direct predation

Of the participants who indicated having at least one pet (n = 243), 110 (45.3%) reported that they had observed at least one DP of a bird by their pets (Fig. 2). Cats were responsible for 72 (65.5%) of these predation events, while 49 (44.5%) were carried out by dogs (Fig. 2); 11 participants indicated that their cats and dogs were both bird predators. Considering only participants who owned both pet species (67), 32 (47.8%) had observed DP involving only their cats and 8 (11.9%) had observed DP only by their dogs, while 9 participants mentioned that both pets had preyed on a bird at least once (13.4%).

### Factors influencing the probability of direct predation

The probability of observing direct predation was positively related to the number of pets in the household (Table 2, Fig. S1). Thus, a household with one pet had 36% probability of seeing its pet catch a bird, while if it had two pets the probability rose to 44%, and with four pets the probability was 60%. In addition, we found that when a pet remained most of the day inside the house, the probability of the pet capturing a wild bird was 33%, but the probability increased to 57% if the pet spent most of the day outside the house (Fig. S2). No relationship was found between the probability of a pet being observed catching a bird or the presence of a garden or bird attractors in the vicinity of the household. Finally, the proximity of households with pets to green areas (DistGreen) did not influence the probability of observing pets capturing wild birds (N = 85, Z = 0.41, p = 0.69, 95% CI = -0.001/0.002).

### Annual bird mortality after bird-window collision events

We found that bird deaths had been caused by PABWC in 13.7% of households (17 of 124) where bird collisions had been reported in the previous year (Fig. 2). The annual bird mortality rate per household due to PABWC (R) was 1.59 birds/household  $\pm$  1.23 SD. The number of inhabited households in Argentina is 11,317,507 according to the INDEC 2010 national census. Our data indicate that 68.5% of households in Argentina have pets, and that 51% of these households reported bird-window collisions during the previous year (Fig. 2). Therefore, we estimate that the number of households in Argentina with pets and annual bird-window collisions (H) could be around 3,924,911 million. Finally, the approximate annual mortality due to PABWC ( $M_{PABWC}$ ) was estimated between 1 and 11 million birds (average = 6 million).

### Discussion

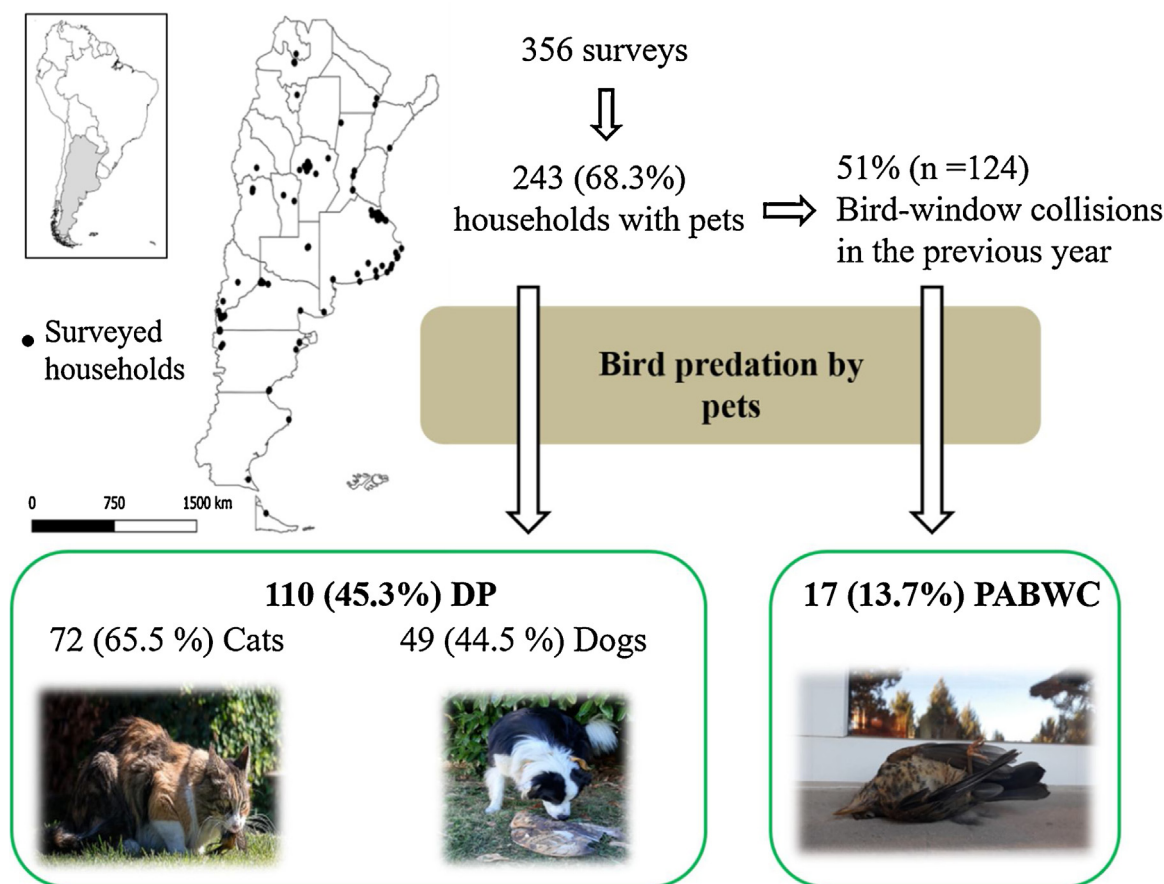
We found that the level of direct and indirect bird predation by pets in Argentina is a cause of great concern. Mortality due to captures after window collisions is a major cause of avian death, and should be considered when assessing bird predation by pets, as well as when proposing mitigation measures. Windows could potentially be more dangerous for birds in Argentina than previ-

ously thought (Rebolo-Ifrán et al., 2019). In addition to causing the instantaneous death of many of the birds that collide, windows can also increase the risk of predation by pets, which can prey on injured birds. Birds may not die instantly on impact, but may be unconscious or immobilized by injuries, thus constituting very easy prey for pets that have access to the outdoors. From our survey results, we roughly estimated that pets could kill about 6 million birds annually (range = 1–11 million birds) following bird-window collisions in Argentina. It is very likely that our method underestimates bird mortality, since not all owners are likely to have seen the moment of collision and subsequent predation by their pets (Baker et al., 2008), or owners may not remember all the events of this type that occurred during the previous year. However, the values obtained here give a first quantitative approximation of this problem, which may be useful for future comparisons and to highlight the need for more research on this subject. Moreover, the results highlight the need for implementation of mitigation measures, both for indirect (after bird-window collisions) and direct pet predation on birds.

We found that more than 68% of households surveyed owned at least one pet. This is in line with previous studies that place Argentina among the countries with the highest percentages of pet owners, which also include Brazil, Mexico (GFK, 2016; Zamora-Nasca unpublished data) and Chile (Escobar-aguirre et al., 2019). We also found that pet owners had a preference for dogs (76.5%) over cats (51%), which agrees with previous research on our study population (GFK, 2016; Voices, 2020) and other Latin American countries (Escobar-aguirre et al., 2019; GFK, 2016). We found an average of 1.85 dogs per dog-owning household and 1.79 cats per cat-owning household in our study, a slightly lower value for cats than reported in a recent study in Chile (2.2 cats per household, Escobar-aguirre et al., 2019). Although our data could be biased because the survey might not cover a random group of participants, the results are consistent with other studies, allowing for rough comparisons of the number of cats and dogs in Argentina. Considering that only owned pets were included in this study, we believe that the impact on wildlife could be much greater if the predation of unowned, free-roaming pets is considered. This is particularly important in countries such as Argentina and in most Latin American cities, where free roaming pets are very common (Cadena García, 2013; Campos et al., 2007; De la Reta et al., 2018; Hughes and Macdonald, 2013; Ibarra et al., 2010; Mella-Méndez et al., 2019; Zamora-Nasca et al., 2021).

Around half of the participants surveyed indicated that they had observed their pets preying on birds at least once. Even though this is a high percentage, this result could be greatly underestimated. Previous studies show that only up to 30% of prey were brought into the home by cats (Kays and Dewan, 2004; Loyd et al., 2013) and that 68% of dog predation on wildlife was perpetrated when the dogs were not under human supervision (Home et al., 2017). Therefore, many of the trapped birds may remain at the capture sites. Moreover, killings also happen in the absence of the owners. Considering that most of the households surveyed in Argentina have at least one pet and that most pet owners allow their pets to stay outside the house, the impact they have through predation on birds in Argentina is widespread and of great concern.

Scientific research has mainly focused on assessing the effect of wildlife predation by cats (Brickner, 2003; Dauphine and Cooper, 2009; Mori et al., 2019) or dogs (Doherty et al., 2017; Hughes and Macdonald, 2013; Lessa et al., 2016), but little attention has been paid to the additive predation pressure that these two pets have on wildlife (Campos et al., 2007). In this study we assessed the risk posed to wild birds by both pet species, and our results showed that both represent a significant cause of mortality for wild birds. However, according to data from participants who owned both



**Fig. 2.** Conceptual scheme showing the two ways birds were preyed on in the households surveyed: Direct predation (DP) and predation of a live bird following window collision (PABWC). Photos: Roberto Gonzalez and Natalia Reboló.

pet species, cats appear to pose a greater risk to birds than dogs, probably due to their high hunting efficiency (Scherk, 2001).

We also show that number of pets per household may be a good predictor of the probability of wild bird predation. Studies on the effect of having more than one pet per household on predation behavior are scarce and inconclusive. Some studies found no relation between the number of pets per household and the number of animals preyed on (Bruce et al., 2019), while other studies observed that the relationship of cats living together had an influence on predation behavior (Adamec et al., 1980). From our survey we found that a household with four pets (including cats and dogs) had a 60% probability that pets being observed killing wild birds, representing an additional 24% risk than households with only one pet.

As expected, we also show that the risk to wild birds from pets that commonly spend time outside is greater than from pets that remain most of the day inside the home. The negative effects on wildlife of pets with outdoor access have been documented by several studies (Dauphiné and Cooper, 2009; Doherty et al., 2017; Lessa et al., 2016; Mori et al., 2019). For example, in the United States bird deaths from cat predation alone are estimated at billions per year (Dauphiné and Cooper, 2009). The number of hours cats spent outside was positively correlated with the number of prey items they killed (Mori et al., 2019). Worryingly, we found that more than 80% of the respondents in this study reported that they allowed their pets to remain outside the home for most of the day, indicating that the risk that pets pose to birds is very high in Argentina.

Although we expected the presence of green spaces such as gardens to increase bird density, and thus the risk of predation, we did not find any association of this variable with avian predation. This could be explained by the high degree of variability in the composi-

tion of the gardens evaluated. Some participants had small gardens with plants, whereas others had large spaces, and these could differ in terms of plant composition. This great variability could dilute the potential effect of this variable. In addition, although we expected that the distance to green areas would affect the probability of predation, we found no such relationship. This association may be valid for free-roaming cats and dogs with no owners (Mori et al., 2019); as they have larger home ranges and present foraging behavior (Hansen, 2010), they are more likely to encounter prey (Morgan et al., 2009). In contrast, pets with owners as in the case of this study are opportunistic predators. Previous studies observed that owned cats with free outdoor access spent most of their time around their house and garden, and that 80% of predation events occurred in the garden or on the edges of green areas (Kays and Dewan, 2004).

We also found no evidence that avian predation is affected by the presence of bird attractors (e.g., bird feeders). Bird feeders have the potential to increase bird density, but their presence has not necessarily been associated with an increased rate of cat predation (Dunn and Tessaglia, 1994; Lepczyk et al., 2003; Woods et al., 2003). This lack of association may be explained by the fact that increased bird density at the food source could lead to increased vigilance (Dunn and Tessaglia, 1994). In the presence of cats, birds either take longer to approach a new food source than they would in non-cat households (Tryjanowski et al., 2015), or they do not make an approach even when food is available (Freeberg et al., 2015).

The objective of this study was not to assess the composition of bird species threatened by predation. However, given the data obtained, we consider that this should be a conservation issue to address in the future. It is likely that many of the species preyed on in cities are categorized as Least concern. These species, in principle

more abundant, are those that fulfill essential ecosystem functions, such as pest control, pollination and disease control, among others (Whelan et al., 2015, 2008); reducing threats to common species is therefore an effective ecosystem conservation strategy.

## Conclusions and recommendations

It is well known that direct bird predation by pets is an important conservation problem. However, we show here that indirect predation after bird–window collisions also represents a source of considerable avian mortality, and deserves further attention. This suggests that bird–window collisions should be incorporated into the assessment of pet bird predation and mitigation measures. Our results also highlight that minimizing the number of pets per household would be one of the best strategies to reduce avian mortality caused by pets.

The percentages of direct predation found here indicate that cats pose a higher risk than dogs. For cats, indoor environmental enrichment can provide a suitable habitat in which they can exhibit natural behaviors such as scratching, chewing and playing (Herron and Buffington, 2010) and thus reduce the time they spend outdoors. In addition, there are tools that can help prevent direct cat predation, such as belled collars (Gordon et al., 2010), collars with sonic devices (Nelson et al., 2005), the Birdsbesafe, <https://www.birdsbesafe.com/> (Pemberton and Ruxton, 2020) and CatBibs (<https://www.catbib.com.au/>) anti-predation collars (Hall et al., 2016, 2015). Since cats with outdoor access can easily move between the yards and gardens of neighboring households (Kays and Dewan, 2004), leading to their owners having limited control over their behavior (Downes et al., 2009), these tools could be very useful as they do not depend on the presence of the pet owner. However, their effectiveness could vary (Ruxton et al., 2002; Woods et al., 2003) and some of them are still being tested (Mori et al., 2019). Dogs, on the other hand, can be trained not to hunt wildlife, and this could be a viable strategy for dogs that are allowed to remain outdoors. Environmental enrichment and collared walks may also discharge anxiety and prevent dogs from chasing wild birds.

Mitigation measures to reduce avian predation after bird–window collisions should focus on modifying window glass to make it visible to birds. Among the proposed measures are the placement of different-shaped decals, cords or the reduction of reflected vegetation (Hans Schmid, 2008; Ribeiro and Piratelli, 2020; Rössler et al., 2015). Another strategy is bird-friendly glass (AviProtek®), which has engraved patterns that make it visible to birds. These actions would help to reduce the indirect impact of pets on birds. Responsible ownership and the use of mitigating measures for the environmental threats that pets may cause are the key to reduce pet–wildlife conflict, so that people can continue to enjoy the benefits of pet ownership together with the presence of birds.

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Competing interests

The authors declare no competing interests.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.pecon.2021.05.003>.

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