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Predation of wildlife by domestic cats in a Neotropical city: a multi-factor issue

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Abstract Domestic cats are a potential risk for native fauna in the Neotropics. Intrinsic (age, weight, sex, color) and extrinsic (nocturnal confinement, time spent outside the home, distance to green areas, etc.) factors can influence the type and quantity of prey that cats take to their homes. The study goal was to evaluate domestic cat predation in a Neotropical city. We intend to answer the following questions: (1) Which is the richness, dominance and abundance of prey captured by domestic cats? (2) Which are the extrinsic or intrinsic factors that most influence prey capture by domestic cats? We predict that: (a) cats will capture a large diversity of native wildlife and (b) extrinsic factors will have a greater effect compared intrinsic factors due to the innate predatory cat's behavior. We chose 120 cats from 44 households in the city of Xalapa, Veracruz, Mexico. We documented the richness, dominance and abundance of wildlife species captured and brought home by cats during March to August 2019 and those intrinsic and extrinsic factors that modulate their predatory behavior. The cats captured 246 prey items, 35.8% were reptiles, 23.2% invertebrates, 17.9% amphibians, 15.4% birds and 7.7% mammals. The prey items belonged to 64 taxa (17 birds, 17 invertebrates, 15 reptiles, nine mammals and six amphibians). The lizard *Sceloporus variabilis* was the most captured prey. Of the prey items, 93.5% were native and 6.5% non-native. Five intrinsic and 5 extrinsic factors contributed most to the predation events, of which cat stripe color, time spent by the cats outside of the home and nocturnal confinement were the most important. These results allow us to understand the harmful effect of cats on wildlife in a Neotropical city.

Keywords *Felis catus* · Free-ranging cats · Prey brought home · Urban wildlife

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Introduction

Domestic cats (*Felis catus*) are found all over the world, apart from Antarctica (Trouwborst et al. 2020). In 2009, there were an estimated 600 million

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domestic cats worldwide (Driscoll et al. 2009). The number of domestic cats could be markedly higher today, especially if unowned and feral cats are considered. In cities, one of the most worrying impacts of cats is predation of wildlife (Piontek et al. 2021). This predation threatens 367 species of wildlife, of which 63 have already become extinct as a result (Doherty et al. 2016; Loss and Marra 2017).

Cats are opportunistic hunters and their predatory behavior is innate, and can persist even if the individuals are sufficiently fed (Adamec 1976; Spotte 2014). Their prey commonly includes wildlife, such as birds (Dauphiné and Cooper 2009; Woods et al. 2003; Woinarski et al. 2017), mammals (Loss et al. 2013; Krauze-Gryz et al. 2017; Murphy et al. 2019), reptiles (Arnaud et al. 1993; Barratt 1998; Woinarski et al. 2018), amphibians (Woods et al. 2003; Baker et al. 2005; Woinarski et al. 2020) and invertebrates (Gillies and Clout 2003; Medina and García 2007; Woolley et al. 2020), many of which are native. However, most cat predation studies have focused on the birds and mammals (Blancher 2013; Mella-Méndez et al. 2019; Murphy et al. 2019), with little attention paid to other groups like amphibians, reptiles and invertebrates (Seymour et al. 2020; Woinarski et al. 2020). In the United Kingdom, for example, cats were found to be responsible for killing 44 species of birds, 20 species of wild mammals, 4 species of reptiles and 3 species of amphibians (Woods et al. 2003). Similarly, other studies in United Kingdom, New Zealand and Australia document a greater preference for mammals and birds versus reptiles and invertebrates (Barratt 1998; Baker et al. 2008; Hansen 2010). According to Caro (1980) and Doherty et al (2016), mammals and birds are frequently used as prey by adult cats to teach hunting techniques to their young, and are also common inhabitants of areas in proximity to human settlements where cats are abundant.

A variety of approaches have been used to quantify cat predation and diet, including kittycams (Loyd et al. 2013; Seymour et al. 2020), artificial prey (Biben 1979; Markowitz and Laforse 1987), stomach content analysis (Krauze-Gryz et al. 2012) and quantification of prey brought home (Borkenhagen 1978; Loss and Marra 2017). Despite the fact that only a minority of the prey caught by the cats are ultimately brought to the home, which thus underestimates by about 3–4.5 times the number of prey captured by excluding that consumed or abandoned away from the home (Seymour et al. 2020), it is possible to find a partial representation of the species most affected by the cats' predatory behavior (Krauze-Gryz et al. 2019; Legge et al. 2020).

Various factors of the urban environment in which cats live have been associated with their predatory effect and species captured (Lilith et al. 2006; Thomas et al. 2012; Jaroš 2021). These include extrinsic factors such as: (a) *time spent by the cats outside of the home:* "more time out = more captured prey" (McDonald et al. 2015; Hanmer et al. 2017), (b) *nocturnal confinement*: "more confinement = fewer captured prey" (Linklater et al. 2019), (c) *distance to green areas*: "nearby green areas = increased predation because these have an effect on the movement of cats" (Barratt 1998; Graham et al. 2012; McDonald et al. 2015; Woinarski et al. 2019), (d) *green area size*: "larger areas offer the opportunity to find more prey" (Dickman 1996), (e) *number of events and duration of cat-human cohabitation in the home*: "more coexistence = less predation" (Cecchetti et al. 2021), (f) *use of play towers*: "longer playing time = fewer animals caught" (Cecchetti et al. 2021) and (g) *type*, *origin and quantity of food*: "more foods of animal origin and with meat protein = less predation" (Piontek et al. 2021; Cecchetti et al. 2021). Intrinsic factors such as the age, weight, sex, color and sterilization status of the cats, have been similarly associated, although this has not been conclusive (Barratt 1998; Woods et al. 2003; Van Heezik et al. 2010; Bengsen et al. 2012; McDonald et al. 2015). Even the color of the cat could be an important trait, since large felines such as tigers use stripe color to confuse potential prey and increase capture success (Fennell et al. 2019).

Most of the studies that have evaluated predation by cats have been conducted in temperate regions with specific taxonomic groups (*e.g.* birds, mammals) (Dickman 2009; Lazenby et al. 2021) or have addressed a particular approach (*e.g.* biological, social, ethological) (McDonald et al. 2015; Deak et al. 2019; Trouwborst et al. 2020; Jaroš 2021). Some of these have been conducted in the USA (Loss et al. 2013; Loyd et al. 2013), Canada (Flockhart et al. 2016), United Kingdom (Thomas et al. 2012), Italy (Mori et al. 2019) and Poland (Krauze-Gryz et al. 2017; Piontek et al. 2021), countries in which the ecological diversity is low. The negative effect of cats could therefore be greater in areas of high diversity such as the Neotropics (Morrone 2014). Neotropical urban areas harbor a wide variety of wildlife, since they present diverse environments, climates and biomes that provide a wide range of shelters, food and habitats (Macgregor-Fors and Ortega-Álvarez 2013; Morrone 2014). Likewise, these resources in Neotropical cities can also favor the presence of non-native species, such as cats (da Rosa et al. 2020), since confinement of pets within the home is not a common practice among the human population (Reece 2005), thus increasing the probability of exerting severe impacts on wildlife.

Given the need to increase the existing knowledge about the impact of domestic cats in Neotropical areas using different approaches, the goal of the present study was to evaluate domestic cat predation in a Neotropical city, including the ecological and ethological components. To attain our goal, we seek to answer the following questions: (1) What is the richness, dominance and abundance of prey captured by domestic cats in a Neotropical city? (2) Which extrinsic or intrinsic factors most influence prey capture by domestic cats? Based on the information presented, we hypothesize that: (1) Neotropical cities such as Xalapa are the habitat of an important native wildlife diversity which is vulnerable to predation by domestic cats, so it is predicted that cats will capture a great diversity of native fauna, particularly mammals and birds, and (2), predatory behavior in cats is innate and is exhibited despite receiving enough food and is independent of age, weight or sex (intrinsic factors), so it is predicted that extrinsic factors will have a greater influence on the frequency of capture.

Materials and methods

Study area

The study was conducted in the city of Xalapa in Veracruz, Mexico (19° 32´ 24″ N, 96° 55´ 39″ W), which has an area of 124.4 km^2 and a population of *ca.* 510,000 inhabitants (4099.6 ind./km^2). The elevation ranges from 1220 to 1557 m above sea level and the climate is temperate humid type C(fm) (García 1981). The mean annual temperature is 18 °C and mean annual precipitation is 1100–1600 mm (INEGI 2009). Xalapa is located in the Neotropical region and has a heterogeneous structure of grey areas such as buildings, residential zones, neighborhoods and suburban areas, as well as water bodies (lakes, streams) and green spaces with ecological parks, unused private properties, gardens and tree and shrub vegetation in the streets and avenues. Moreover, a high presence of domestic cats has been recorded in various parts of the city, many of which enter the green areas and exert an important pressure on the native fauna (Mella-Méndez et al. 2019).

Experimental design

Selection of participants

The homes selected for this study were those in which the hunting cat owners agreed to participate in the project voluntarily, either when they were visited in their homes by the researchers during February 2018 or by responding to an advertising campaign of one month in duration conducted on television, radio and social networks such as Facebook and Instagram (Mori et al. 2019). The homes were distributed in a scattered manner at various points in the city (Fig. 1). A total of forty-four homes wished to participate voluntarily, presenting a total of 120 cats. These households were provided with a descriptive sheet containing comprehensive information about the project (Online Resource 1), a consent form, as well as plastic bags in which to deposit the prey captured by their cats, following the methodology proposed by Churcher and Lawton (1987) and Barratt (1998).

Richness, dominance and abundance of captured prey

For six consecutive months (1st of March to the 31st of August 2018), corresponding to the reproductive and breeding periods of wild birds and small mammals (Cruz-Angón et al. 2008; Ceballos and Oliva 2005), the hunting cat owners were asked to recover any prey items brought home by their cats and to deposit these in the plastic bags (Churcher and Lawton 1987; Barratt 1998; McDonald et al. 2015), as well as to take photographs of the prey when it was not possible to recover the cadaver (Seymour et al. 2020). The records were compiled through monthly visits with the aim of keeping the owners engaged with the project. The prey items were identified by the researcher and classified as birds, mammals, amphibians, reptiles or invertebrates, attempting to identify them to the

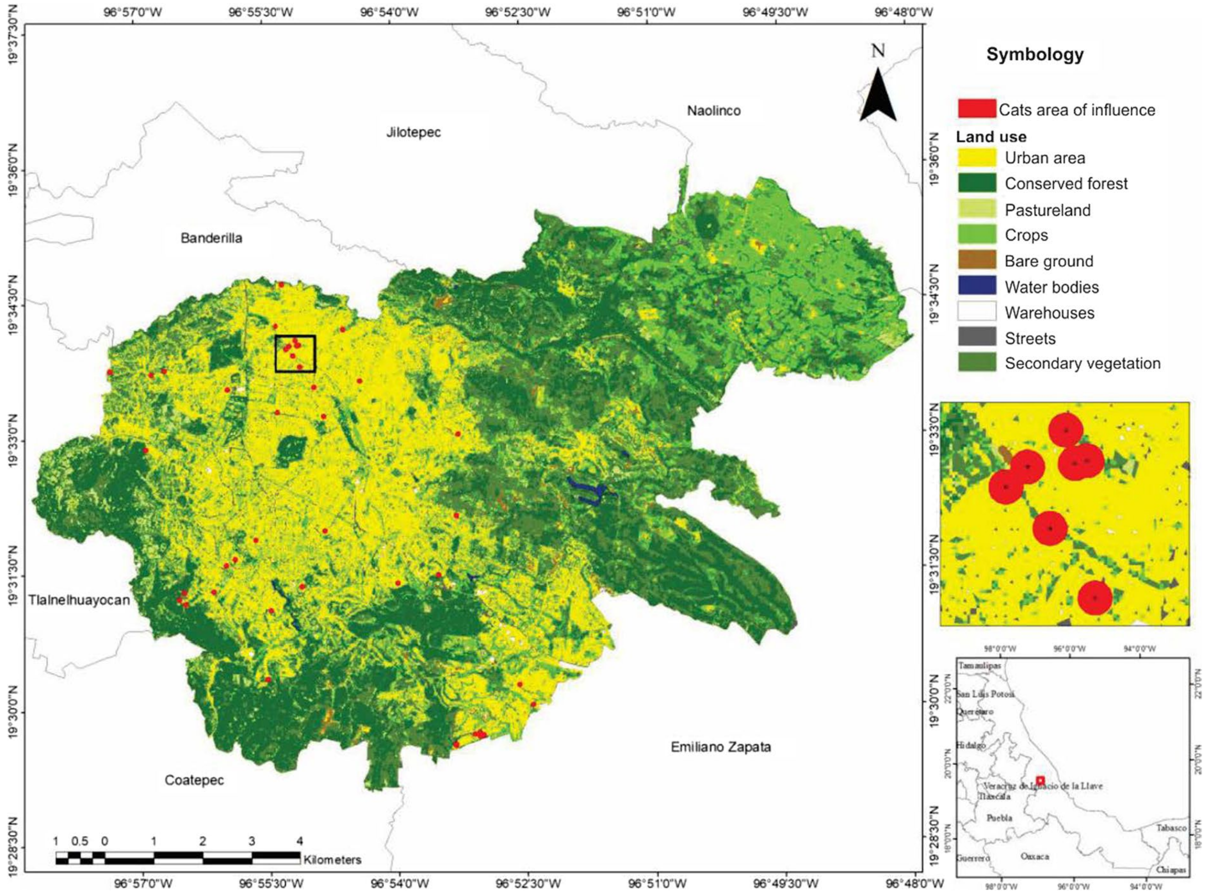

Fig. 1 Spatial location of Xalapa Veracruz, Mexico and the study´s selected households. Circles in red show the cats´ activity influence area (1 ha). The center point represents the home of each cat whose owner voluntarily decided to be an investigation participant

most accurate taxonomic level possible (generally species or genus) using guides for the identification of local fauna (Guzmán-Guzmán and Vázquez-Torres 2011; González-Christen and Ruz-Rosado 2016) as well as for the birds of Mexico and northern Central America (Howell and Webb 1995), wild mammals of Mexico (Ceballos and Oliva 2005) and invertebrates (Llorente Bousquets et al. 2004). Another classification according to origin (native or non-native) was also included (Loss et al. 2013). In the case of partially consumed prey, the remains (hair, feathers, scales, exoskeletons) were analyzed using a stereoscopic microscope in order to assign a category (generally family). In cases where identification was impossible, the remains were included in the total count of prey, but excluded from the statistical analyses (Krauze-Gryz et al. 2017).

Effect of extrinsic and intrinsic factors

To determine the extrinsic and intrinsic factors of hunting cats and associate these with their predation of wildlife, we used a survey modified from those used by Thomas et al. (2012) and McDonald et al. (2015), (Online Resource 2). In this survey, information was requested regarding time spent by the cats outside of the home, nocturnal confinement, distance to green areas, green area size, number of events and duration of cat-human cohabitation in the home, use of play towers, type, origin and quantity of food (extrinsic factors) and age, weight, sex, color and sterilization status (intrinsic factors).

A spatial analysis was conducted in order to determine the distance between the cat's home and the closest patch of vegetation (green areas). We used a satellite image obtained free of charge through Sentinel 2-A of the Copernicus Open Access Hub (https://scihub.copernicus.eu) dated May 10, 2018, with a pixel size resolution of 10 m. The supervised classification method was applied using the Algorithm Maximum Likelihood using ArcGIS® 10.5 software and the extension Patch Analyst 5.2. Eight types of cover were considered and were grouped into two categories: *natural areas* (montane cloud forest, pasture, crops, and secondary vegetation of montane cloud forest) and *gray areas* (urban area, bare soil, white roofs, streets). To evaluate the accuracy of the classification, the Kappa coefficient was used, constructing error matrices using 49 reference points taken at different points in the city of Xalapa, Veracruz, using the WGS84 system and UTM zone 14 projection. An area of influence of 10,000 m^2 (1 ha) was considered around the home of each cat, representing its approximate home range in urban zones (Kitts-Morgan et al. 2015; Hanmer et al. 2017).

Statistical analysis

To describe the richness, dominance, and abundance of prey captured by cats, the number of species and their frequencies of capture were represented in graphs of relative abundance, as well as through a histogram of the top 20 species most depredated by cats. To determine the effect of the intrinsic and extrinsic factors of the cats on the quantity of prey captured, a generalized linear mixed model (GLMM) was used (Doherty et al. 2021). First, the normality of the continuous variables was corroborated using the Shapiro Wilks test and the categorical variables were transformed to a numerical scale (Zar 2010). Subsequently, a multi-collinearity analysis was performed to verify that none of the predictor variables were correlated using the Variance Inflation Factors (VIF) from the package car (Fox and Weisberg 2019). We excluded five variables (number of events and duration of cat-human cohabitation in the home, use of play towers, type and origin of food) that presented high VIF (>3) and were less correlated to the response variables (Zuur et al. 2009). As a result, ten predictor variables were ultimately included in the model (five intrinsic and five extrinsic factors (Table 1). The models were built by relating the variables in an additive effect while the categorical variables were transformed to binary for testing. We considered homes as a random effect factor (homes with multiple hunting cats) and a Poisson distribution to represent the prey counts, using the package lme4 of R (Bates et al. 2015).

To define the best model, the function "dredge" of the package "MuMIn" of R (Barton 2018) was used, as well as a classification of models applied based on the Akaike information criterion (AIC) with a second order correction for the reduced sample size, considering the accumulated weight of the different AICc (Burnham and Anderson 2002). The set of models grouped all of the possible combinations of these explanatory variables. To emphasize the relative power of the regression coefficients, the continuous covariables were standardized to present a mean of 0 and a standard deviation of 1 (McDonald et al. 2015). Moreover, we interpreted the relative importance of

Table 1 Set of intrinsic and extrinsic factors of the studied subjects considered in the generalized linear mixed model

Type of factor	Name of factor	Range	VIF GVIF^(1/(2*Df))
Intrinsic	Sex	Female–male	1.193
	Age	3 months up to 12 years	1.328
	Weight	1.5 kg up to 5.3 kg	1.335
	Color	White-black-grey-brown-striped	1.065
	Sterilization	Yes–no	1.148
Extrinsic	Meals per day	1 up to 7	1.102
	Distance between the home and nearest green area	2.8 m up to 94.6 m	1.011
	Size of the nearest green area	75 m^2 up to 4876 m^2	1.037
	Time spent outside home	0 up to 23 h	1.314
	Nocturnal confinement	Yes–no	1.23

the variables using their accumulated AICc weight and their confidence intervals (α < 0.05). We tested the significance of the models with respect to a null model (number of prey items ~ (1 | homes).The goodness-of-fit of the models was assessed by calculating the conditional and marginal coefficients of determination computed with the function R-squared GLMM in the MuMIn package (Barton 2018). The marginal R-squared represents the variance explained only by the fixed part of the model, while the conditional R-squared is interpreted as the variance explained by the entire model, including both fixed and random factors (Nakagawa and Schielzeth 2013). This analysis only included those cases that identified the cat responsible for the prey capture.

Results

Richness, dominance and abundance of prey captured

High variation was recorded in the amount of prey brought home by hunting cats ($\bar{x}$ = 2.02, SD = 4.39), in which some cats brought no prey items to their homes while one cat captured and brought up to 38 prey. The cats captured 246 prey items, equivalent to about 4 items/cat/year, of which 88 (35.8%) were reptiles, 57 (23.2%) invertebrates, 44 (17.9%) amphibians, 38 (15.4%) birds and 19 (7.7%) mammals (Fig. 2a, Online Resource 3). The captured species belonged to 64 taxa, of which 17 were birds, 17 were invertebrates, 15 were reptiles, nine were mammals and six were amphibians (Fig. 2b). The histogram shows that four of the ten most captured species were lizards of the genera *Sceloporus* and *Anolis* (Fig. 3). A total of 93.5% of the prey items captured (59 spp.) were native, while 6.5% were non-native (5 spp.) (Fig. 2b).

Effect of intrinsic and extrinsic factors on the capture of prey

The analysis showed that the cats that spent more time outside the home, those that were not spatially confined at night and those with striped coloration were associated with a higher number of prey items captured (Fig. 4, Online Resource 4). Equally, the relative importance of the variables showed that the highest accumulated AICc contributions were time spent outside the home (c = 1), nocturnal confinement (c = 0.99) and striped coloration (c = 0.95), while the lowest were weight (c = 0.33), distance to green areas (c = 0.32), size of green areas (c = 0.31), age (c = 0.26), sex (c = 0.26), sterilization (c = 0.09) and number of meals per day (c = 0.06).

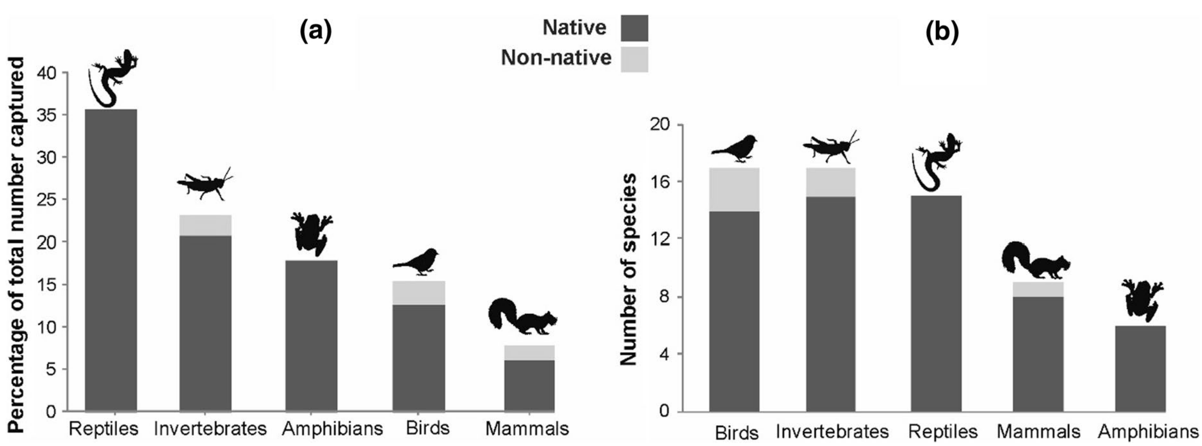

Fig. 2 Total percentage of captured specimens by taxonomic group (**a**) and number of species (**b**) captured by domestic cats in the city of Xalapa, Veracruz, Mexico

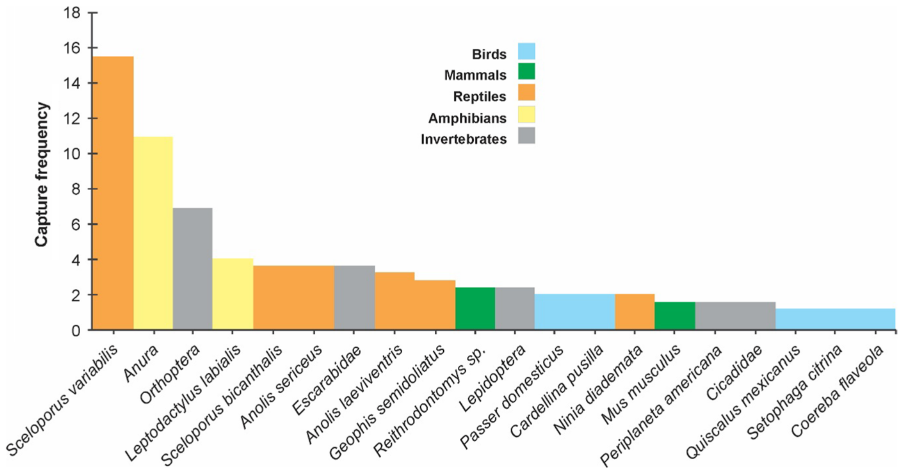

Fig. 3 Capture frequency of the twenty species most captured by domestic cats in the city of Xalapa, in Veracruz, Mexico

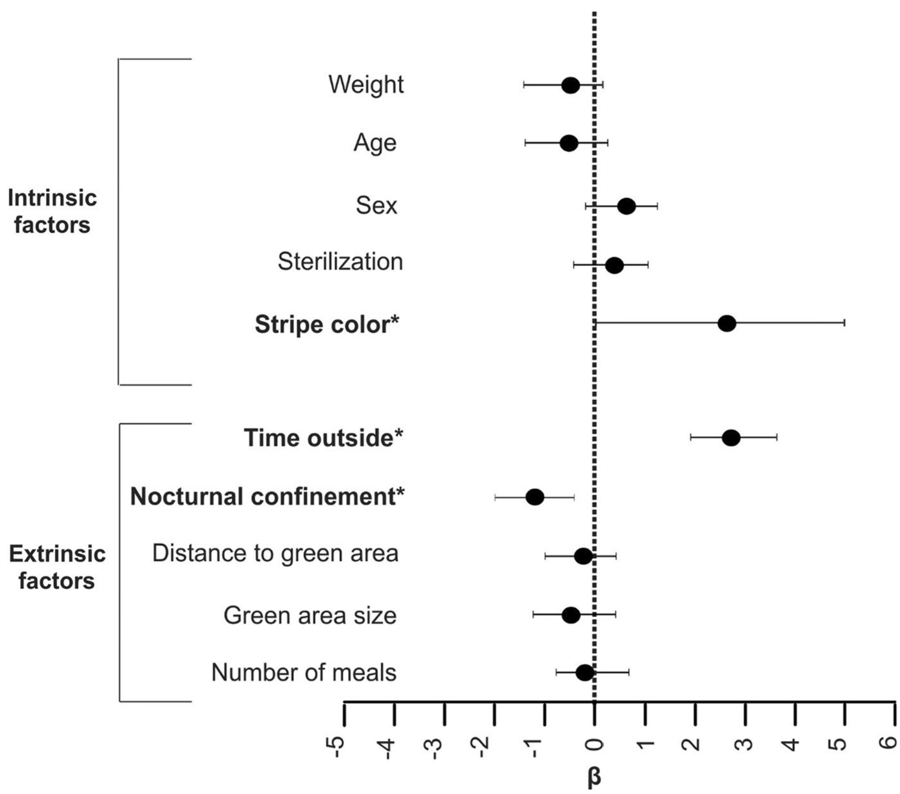

Fig. 4 Mean β values ($\pm IC$ 95%) that indicate the direction and size of the effects of the intrinsic and extrinsic variables that contribute to explaining the quantity of prey. Asterisk denotes the factors with the highest AICc weight in the model combinations

Discussion

Richness, dominance and abundance of prey captured

Our hypothesis that Neotropical cities are habitat to an important diversity of native wildlife vulnerable to predation by domestic cats was partially supported, since 64 taxa were affected, which means a higher number compared to other studies carried out in temperate environments where there was a larger sample size and more days of monitoring (Baker et al. 2005; Krauze-Gryz et al. 2012, 2017; Thomas et al. 2012). However, the average number of prey captured by hunting domestic cats was appreciably smaller than that reported in most previous studies. For example, Legge et al. (2020) reported an average of 38.9 items/cat/year from a compilation of 47 studies conducted across the globe using different techniques to those used in this study, including kitticams and analysis of stomach contents and excreta. This could be due to the fact that predation estimates based solely on the count of prey brought home tend to greatly underestimate the actual predation quantity, since the cats can return with only 23% (Loyd et al. 2013), 18% (Seymour et al. 2020) or 10% (Krauze-Gryz et al. 2019) of the captured prey, while other prey items are consumed or left at the capture site. In addition, 61 cats in our sample spent less than an hour per day away from home. Moreover, the patterns observed with respect to the prey items captured do not necessarily reflect their abundance, but rather could be the result of the anti-predation responses exhibited by each species, as well as their habits of displacement in the urban environment, and thus their ease of capture (Spencer et al. 2017). This is because cats can capture prey depending on their availability, ease of capture and abundance, for which reason the assemblage of their prey could be the result of a combination of inter-related variables that is likely to differ among regions and local species (Coman and Brunner 1972; Fitzgerald and Turner 2000).

In terms of frequency, reptiles (mainly Lacertilia) were the most captured group, followed by invertebrates, especially of the order Orthoptera. This contrasts with the prediction raised and the findings of other studies in which birds and mammals were found to be the main prey (Barratt 1998; Baker et al. 2008; Hansen 2010). Nevertheless, reptiles are often abundant in urban environments and have been reported as prey of domestic cats (Hernandez et al. 2018; Woinarski et al. 2020). In particular, the lizard *Sceloporus*, which was the most captured species, is a generalist species in the urban environment, with limited locomotion at low temperatures on rocks and soil that makes them easily captured prey (Webster et al. 2018).

Birds and invertebrates were the groups that presented the highest number of species depredated by hunting domestic cats, a finding that coincided with those of similar studies, in which birds are also reported as one of the groups most affected by cats (van Heezik et al. 2010; Thomas et al. 2012; Woinarski et al. 2017). At global level, birds constitute the group with the highest number of threatened and extinct species as a result of this predator (Doherty et al. 2016). This may be related to the fact that the number of bird species that are generalist or tolerant to urbanization is usually greater than that of other vertebrates such as mammals, reptiles or amphibians (Cornelis and Hermy 2004; Shochat et al. 2010). This is particularly evident in the city of Xalapa, where the richness of birds is around 341 species (González-García et al. 2016), a number that is higher than the local richness of other groups of vertebrates such as reptiles, amphibians or mammals (López-Moreno 1993; GEV 2001).

Many studies that have evaluated the prey of cats do not consider the invertebrates (Medina et al. 2011; Loss et al. 2013; Krauze-Gryz et al. 2017). We recorded a considerable number of depredated species of the orders Orthoptera, Hemiptera, Lepidoptera and Coleoptera, as has been reported in other studies (Medina and García 2007; Woolley et al. 2020). In Xalapa, as with other studies, there is a high richness of invertebrates (Jones and Leather 2012; MacGregor-Fors et al. 2015) and the auditory and visual stimuli they produce are very perceptible by hunting domestic cats, for which reason, if we add other characteristics such as their small size and few anti-predation strategies, they are easily caught prey (Ferreira et al. 2014; Hernandez et al. 2018).

One finding of note in our study is that the native species were subject to greater predation than the non-native species. This information, while novel for Neotropical cities, is very similar to that reported by other authors in temperate regions of the USA, in which it is documented that 67% of the bird species captured by cats are native (Loss et al. 2013). However, this pattern can vary according to the type of landscape, since non-native mammals are commonly recorded in the diet of cats in urban areas, while wild shrews, squirrels, rabbits and mice are more common in suburban and rural areas (Spotte 2014). It is therefore highly likely that Neotropical cities are attractive areas for native species, since there is a presence of food sources in the form of urban waste and vegetation, as well as different refuges and nesting sites (Shochat et al. 2010; Pauchard et al. 2013). However, urban areas could also act as ecological traps, since these organisms can be exposed to pressures unique to the urban areas such as those exerted by domestic cats (Vlaschenko et al. 2019).

Effect of intrinsic and extrinsic factors on the capture of prey

The results support the prediction that extrinsic factors such as the time spent by the cats outside of the home and nocturnal confinement are related to the quantity of prey captured. This coincides with that reported by other authors, who state that the more time a cat spends outside of the home, the greater the probability that it will hunt (Robertson 1998). For this reason, confinement or curfew has been a strategy implemented with good results in sites in Australia, by reducing the probability of interactions between cats and wildlife (Denny and Dickman 2010). However, nocturnal confinement of cats is not appropriate in sites where the majority of native species are diurnal (e.g. birds) and the nocturnal species are non-native (e.g. rats) (Gordon et al. 2010). If we consider the fact that the main prey of cats in our study were birds and reptiles with diurnal habits, it would be of great interest to expand this type of research into other Neotropical cities in order to evaluate the prey and their activity patterns using methodologies such as the use of kittycams (Loyd et al. 2013; Seymour et al. 2020) and possibly to recommend schedules of confinement (Doherty et al. 2015).

With the exception of the cat coloration, we found no association between intrinsic factors and the quantity of prey captured, although other studies present different evidence. For example, some studies show that female cats could capture more prey than males, through demonstrating hunting techniques to their young from the fourth week of age (Crowell-Davis et al. 2004). Equally, younger cats of lower weight could be more agile and thus able to catch more prey (McDonald et al. 2015), non-sterilized individuals could roam to a greater extent (Turner and Mertens 1986) and poorly fed cats could present a tendency to catch more prey (Silva-Rodríguez and Sieving 2011). However, these intrinsic variables themselves have had no effect in other studies (Robertson 1998; Brickner-Braun et al. 2007; Flux 2007; Loyd et al. 2013), possibly because predatory behavior is innate and can occur independently of any intrinsic trait of the cat (Polsky 1975; Adamec 1976; Spotte 2014).

Cat coloration is the only intrinsic factor that has not been considered as an explanatory variable in other studies and that showed an effect in our model, since it apparently does not modulate the cat´s agility or motivation to hunt, but rather the striped fur favors its camouflage against potential prey. This strategy is similar to that of other wild felines such as tigers, the stalking behavior of which benefits from cryptic coloration, increasing their success in terms of prey capture (Rubio-Gutiérrez and Guevara-Chumacero 2017; Fennell et al. 2019). More experimental studies are required with various combinations of immediate background and with different prey (mammals, birds, reptiles, amphibians) to test the capacity for individual reaction under controlled conditions.

Conclusions

In summary, our data suggest that, although we did not record an abundance of prey as high as that reported in other studies, a high richness of affected species was documented, especially native species of great ecological importance due to their ecosystem functions, coupled with the fact that a species of reptile (*Sceloporus variabilis*) was recorded as the most frequently captured. The duration of time spent by the cats outside of the home and nocturnal confinement constitute significant extrinsic factors associated with the capture of prey. Likewise, cat coloration was the intrinsic factor that had an effect, by improving the camouflage of the cats against their immediate background. These findings are of utility to the construction of a more complete understanding of the predatory behavior of cats in towns and cities, highlighting the importance of an integral evaluation that includes ecological and ethological aspects, particularly in a region as diverse and with such growth in urbanization as the Neotropics.

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Author contributions IM-M Conceptualization, AJM Formal analysis, IM-M and RF-P Methodology, RF-P Project administration, RF-P Resources, BSB-C Software, MCMSG, BSB-C, AJM and JDA-E Validation, IM-M and RF-P Writing original draft, MCMSG, BSB-C, AJM and JDA-E Writing review and editing. All authors have read and agreed to the published version of the manuscript.

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Availability of data and material The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

Consent to participate Participants agreed to participate voluntarily.

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Supplementary Information

Predation of wildlife by domestic cats in a Neotropical city: a multi-factor issue

Biological Invasions

Isac Mella-Méndez [1,2], Rafael Flores-Peredo [2,*], Juan David Amaya-Espinel [3], Beatriz Bolívar-Cimé [2], M. Cristina Mac Swiney G. [4] and Armando Jesús Martínez [1]

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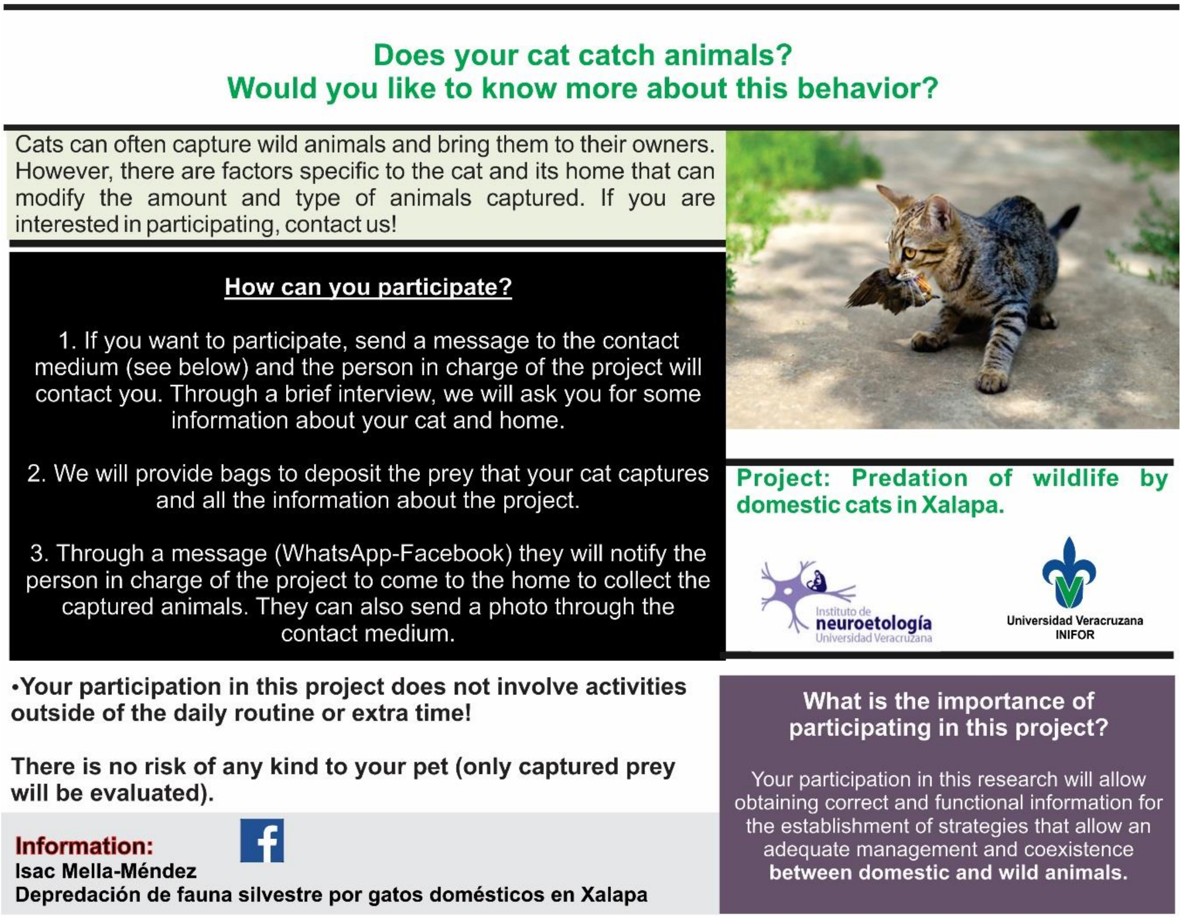
Online Resource 1. Research project descriptive brochure provided to the study participants.



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Online Resource 2. Questionnaire structure presented to cats´ owners to obtain intrinsic and extrinsic factors of the studied animals.

PROJECT: Predation of wildlife by domestic cats (*Felis catus*) in urban areas of the center of the State of Veracruz, Mexico

Maestría en Neuroetología, Instituto de Neuroetología
Universidad Veracruzana

№ of control:

This survey has a duration of 8 minutes approx. You do not have to answer questions you do not want. We can stop our conversation at any time you want for any reason. This survey does not offer any financial benefit or expense to you. All the information obtained will be treated with strict confidentiality and will not generate future inconveniences, risks or damages to you or your pet. Your answers and name will never be revealed or used for purposes other than the objective of this investigation. Your collaboration will help lay the groundwork for improving domestic animal management strategies and wildlife conservation.

INFORMATION ABOUT THE CAT

Questions	**Posible Answers**
Is the cat sterilized?	Yes / No
Which is the cat´s sex?	Male / Female
Which is the cat´s age?	> 3 months
Which is the cat´s weight?	> 1.5 kg
Which is the estimated time of activity (hours) of the cat outside the home per day?	0 / 24 hours
Does the cat wear a collar with bells?	Yes / No
Is the cat inside the home all night?	Yes / No
How many times per day do you feed your cat?	1 / Undefined
Is there a game tower in the cat's home?	Yes / No
Which is the origin of its food?	Commercial / Home
What is the texture of the cat's food?	Dry / Wet
How many hours do you coexist with your cat?	0 / Undefined
How many times per day do you coexist with your cat?	0 / Undefined

Supplementary Information

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Online Resource 3. Taxa and percentages of frequency observed in prey captured by domestic cats (n = 120) in the city of Xalapa, Veracruz, Mexico.

Taxonomic group	**Species**	***n***	**Percentage**
Amphibians	*Anura*	27	11.0
	Leptodactylus labialis	10	4.1
	Bolitoglossa platydactyla	2	0.8
	Craugastor rhodopis	2	0.8
	Craugastor laticeps	2	0.8
	Eleutherodactylus cystignathoides	1	0.4
Birds	*Passer domesticus*	5	2.0
	Cardellina pusilla	5	2.0
	Quiscalus mexicanus	3	1.2
	Setophaga citrina	3	1.2
	Coereba flaveola	3	1.2
	Troglodytes aedon	2	0.8
	Setophaga magnolia	2	0.8
	Campylopterus curvipennis	2	0.8
	Columbina inca	2	0.8
	Eugenes fulgens	2	0.8
	Empidonax affinis	2	0.8
	Icteria virens	2	0.8
	Icterus galbula	1	0.4
	Geothlypis trichas	1	0.4
	Gallus gallus domesticus	1	0.4
	Columba livia	1	0.4
	Glaucidium brasilianum	1	0.4
Mammals	*Reithrodontomys sp.*	6	2.4

	Mus musculus	4	1.6
	Muridae	3	1.2
	Didelphis marsupialis	1	0.4
	Pteronotus sp.	1	0.4
	Artibeus lituratus	1	0.4
	Cryptotis mexicana	1	0.4
	Sylvilagus floridanus	1	0.4
	Didelphis virginiana	1	0.4
Reptiles	*Sceloporus variabilis*	38	15.4
	Sceloporus bicanthalis	9	3.7
	Anolis sericeus	9	3.7
	Anolis laeviventris	8	3.3
	Geophis semidoliatus	7	2.8
	Ninia diademata	5	2.0
	Anolis rodriguezii	3	1.2
	Pliocercus elapoides	2	0.8
	Barissia imbricata	1	0.4
	Coniophanes fissidens proterops	1	0.4
	Lampropeltis triangulum	1	0.4
	Rhadinella decorata	1	0.4
	Plestidon lynxe	1	0.4
	Thamnophis proximus rutiloris	1	0.4
	Phrynosoma orbiculare	1	0.4
Invertebrates	*Orthoptera*	17	6.9
	Escarabidae	9	3.7
	Lepidoptera	6	2.4
	Periplaneta americana	4	1.6
	Cicadidae	4	1.6
	Apis mellifera	2	0.8

	Taeniopoda auricornis	2	0.8
	Blatella germanica	2	0.8
	Papilo sp.	2	0.8
	Odonata	2	0.8
	Bipalium kewense	1	0.4
	Argiope aurantia	1	0.4
	Diaethria anna	1	0.4
	Stenopelmatus sp.	1	0.4
	Syrphidae	1	0.4
	Phasmatodea	1	0.4
	Thomisidae	1	0.4
Total		**246**	**100**

Supplementary Information

Predation of wildlife by domestic cats in a Neotropical city: a multi-factor issue

Biological Invasions

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Online Resource 4. Set of candidate models (GLMM) obtained using the Akaike information criteria with delta-AIC <2 which explain the effect of the intrinsic and extrinsic factors on the number of preys captured by domestic cats. Models are ordered as an optimum value function that explains the variation. Variables included the follow information: time spent outside of the home, nocturnal confinement, cat coloration, distance between the home and the patch of vegetation (green areas), vegetation patch size, cats´ weight, cats´ age and sex. The goodness-of-fit of the models was assessed by calculating the conditional and marginal (in parentheses) coefficients of determination for GLMM.

Model	**df**	**logLik**	**AICc**	**Δ AIC**	**AIC weight**	**R^2c (R^2m)**
Time + Confinement + Color	6	-319.2	652.12	0	0.212	0.687 (0.526)
Time + Confinement + Distance + Weight	10	-318.7	654.36	0.21	0.093	0.525 (0.476)
Time + Confinement + Color + Distance	11	-315.2	654.66	0.63	0.081	0.544 (0.483)
Time + Confinement + Color + Distance + Weight	12	-312.4	654.82	0.85	0.079	0.430 (0.373)
Time + Confinement + Color + Distance + Age	12	-313	654.87	0.98	0.074	0.404 (0.394)
Time + Confinement + Distance	5	-322.9	654.91	1.02	0.068	0.412 (0.312)
Time + Confinement + Distance + Weight + Size	7	-320.6	654.97	1.12	0.055	0.518 (0.429)
Time + Confinement + Color + Weight	11	-315.5	655.1	1.15	0.052	0.413 (0.312)
Time + Confinement + Color + Sex	11	-316.1	655.21	1.22	0.045	0.454 (0.321)
Time + Confinement + Color + Size	11	-316.7	655.29	1.31	0.042	0.472 (0.308)
Time + Confinement + Color + Age	11	-315.1	655.36	1.39	0.039	0.413 (319)
Time + Confinement + Distance + Age	6	-323.8	655.39	1.49	0.030	0.520 (0.436)
Null model	118	-387.5	659.66	3.21	0.012	0.105 (0.000)