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Foraging patterns and spatial distribution of synanthropic mammals and their interaction with dogs

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ABSTRACT

Introduction: Synanthropic mammals benefit from food and shelter provided by green urban areas. However, they frequently interact with predators such as dogs which may modify certain behaviours and their spatial distribution, compromising their survival.

Objective: To determine the effect of feral dogs' presence on mesopredator synanthropic mammal feeding patterns by analyzing the spatial distribution of three species, opossum (*Didelphis marsupialis*), ringtails (*Bassariscus astutus*), and gray fox (*Urocyon cinereoargenteus*) in a green urban area in Mexico.

Methods: Camera traps and scent stations were used to record foraging patterns and spatial distribution. The habitat was characterized and correlated with duration and frequencies of synanthropic mammal feeding patterns and spatial distribution.

Results: Opossums were recorded more frequently inside vegetation compared to other areas of the park, while dogs were recorded in grass-covered areas, on roads, and in recreation zones. Ringtails and gray foxes were recorded inside vegetation and in open spaces. Feeding patterns were not affected by the presence or absence of dogs. However, the presence of dogs affected opossum and gray fox vigilance frequency and was associated with habitat characteristics. Ringtail vigilance was affected by dog presence and habitat characteristics.

Conclusion: The interaction between dogs and wildlife may generate species-specific behavioural responses, allowing some species to be tolerant of risk while others may show spatial and temporal segregation. Understanding the spatial distribution of dogs and their effect on wildlife inhabiting green urban areas will help to improve control-impact programs of dogs, reducing predation events and improving the welfare of mesopredator synanthropic mammals.

Key words: behaviour; camera traps; exotic predator; feeding habits; mesopredator; predation; scent stations; vigilance.

RESUMEN

Patrones de alimentación y distribución espacial de los mamíferos sinantrópicos y su interacción con los perros

Introducción: Los mamíferos sinantrópicos se benefician de la comida y el refugio que les proporcionan las áreas verdes urbanas. Con frecuencia interactúan con depredadores como los perros, que pueden modificar ciertos comportamientos y su distribución espacial, comprometiendo su supervivencia.

Objetivo: Determinar el efecto de la presencia de perros ferales en los patrones de alimentación de los mamíferos mesodepredadores sinantrópicos analizando la distribución espacial de tres especies, zarigüeya (*Didelphis marsupialis*), cacomixtle (*Bassariscus astutus*) y zorra gris (*Urocyon cinereoargenteus*) en un área verde urbana de México.

Métodos: Utilizamos cámaras trampa y estaciones de olor para registrar patrones de alimentación y distribución espacial. Caracterizamos el hábitat y lo correlacionamos con la duración y la frecuencia de los patrones de alimentación de los mamíferos sinantrópicos y la distribución espacial.

Resultados: Las zarigüeyas se registraron con mayor frecuencia dentro de la vegetación en comparación con otras áreas del parque, mientras que los perros se registraron en áreas cubiertas de pasto, en caminos y en zonas de recreación. Registramos zorras grises y cacomixtles dentro de la vegetación y en espacios abiertos. Los patrones de alimentación no se vieron afectados por la presencia o ausencia de perros. Sin embargo, la presencia de perros afectó la frecuencia de vigilancia de las zarigüeyas y zorras grises y se asoció con las características del hábitat. La vigilancia de cacomixtles se vio afectada por la presencia de perros y las características del hábitat.

Conclusión: La interacción entre perros y vida silvestre puede generar respuestas conductuales especie-específicas, lo que permite que algunas especies sean tolerantes al riesgo mientras que otras pueden mostrar segregación espacial y temporal. Comprender la distribución espacial de los perros y su efecto sobre la vida silvestre que habita en áreas urbanas verdes ayudará a mejorar los programas de control de impacto de los perros, reduciendo los eventos de depredación y mejorando el bienestar de los mamíferos mesodepredadores sinantrópicos.

Palabras clave: comportamiento; cámaras trampa; especies exóticas; hábitos alimentarios; mesodepredador; depredación; estaciones de olor; vigilancia.

INTRODUCTION

Animals inhabiting vegetation fragments in urban and peri-urban areas often must interact directly or indirectly with humans and domestic animals and may be affected either by the transmission of pathogens (Hernández et al., 2021; Lange et al., 2016) or by predation (Doherty et al., 2017; Guedes et al., 2021). In green urban areas, the main potential predators faced by synanthropic mammals are humans (Cooper et al., 2008; Ritchie et al., 2013) and their exotic pets, such as dogs (*Canis lupus familiaris* Linnaeus, 1758) and cats (Campos et al., 2007; Vanak & Gompper, 2009; Vanak et al., 2013; Wierzbowska et al., 2016). Dogs are often animals that have escaped or been abandoned by their owners in vegetation fragments in urban areas and can become feral animals (Hughes & Macdonald, 2013; Young et al., 2011). When several dogs are abandoned, packs are formed that become more dangerous for native animals (Hughes & Macdonald, 2013; Mella-Méndez, Flores-Peredo, Pérez-Torres et al., 2019). Similarly, feral dogs compete for shelter and food with other species with similar niches (Coronel-Arellano et al., 2021; Young et al., 2011).

Dogs become a problem for wildlife because they are important predators for animals of different taxa (Doherty et al., 2017; Zamora-Nasca et al., 2021). Dogs may hunt or harass synanthropic mammals (Villatoro et al., 2019). Thus, some synanthropic mesopredator mammals may change their behaviour due to the presence of dogs (Guedes et al., 2021; Vanak & Gompper, 2010). One way to explain this interaction is the so-called the fear landscape that represents the predation risk that an individual perceives in their environment, which modifies certain behaviours, such as foraging patterns, feeding, and vigilance (Bedoya-Perez et al., 2013; Laundré et al., 2001; Sinclair & Arcese, 1995; Tolon et al., 2009; van der Merwe & Brown, 2008). The fear landscape considers the predator identity (hunting habits) (Altendorf et al., 2001) and prey (group living, vigilance, and feeding behaviours) (Altendorf et al., 2001; Stanford, 2002) both being integrated with spatial and temporal habitat characteristics, such as roost availability (Sweitzer, 1996; van der Merwe & Brown, 2008), lunar light intensity, and seasonal changes (Juliana et al., 2011; Nowak et al., 2017; Prugh & Golden, 2014) to obtain a representation of the most and least risky sites according to prey perception. Thus, it is possible to determine the decisions that individuals make in their daily lives to satisfy their needs and not die trying.

Individuals inhabiting or visiting risky areas had increased vigilance and decreased foraging times. Moose (*Alces alces*) reduce their feeding time, inhabiting-sympatry with wolves, resulting in a poor-quality diet, which might compromise their survival populations in the long term (Christianson & Creel, 2010; Creel et al., 2009; Edwards, 1983; Hernández & Laundré, 2005). Likewise, when prey avoid high-risk sites and migrate to safer sites, they also restrict their energy requirements; that is, although they forage longer and keep watch less (Altendorf et al., 2001), these are low quality food sites (Creel, 2018).

Studies on the fear landscape in synanthropic mammals are scarcely relevant when migration is not an option; that is, green urban areas (urban parks, urban vegetation fragments, municipal or state protected areas), unlike natural areas, are islands surrounded by the urban matrix, a barrier that increases exposure to synanthropic predators. Therefore, it is important to understand how synanthropic mesopredator mammals interact with predators, such as dogs, and how this interaction might be influenced by habitat, especially considering that whether synanthropic mesopredator mammals exhibit avoidance tactics against dogs has not been extensively examined (Mitchell & Banks, 2005).

Our aim was to determine the effects of dogs on synanthropic mesopredator mammal feeding patterns by analyzing their spatial distribution, feeding and vigilance behaviours, and habitat characteristics. We hypothesized that the riskiest sites, those with the highest dog presence, might be the ones most avoided by synanthropic mammals and were thus expecting the following observations at these sites: 1) fewer prey records, 2) longer vigilance than feeding times, and 3) less vegetation and protective coverage availability against predators.

MATERIALS AND METHODS

Study area: Our research was carried out in Natura Park in Xalapa City, Veracruz, Mexico (Fig. 1), which has a 103 ha extension and is surrounded by an urban matrix. The predominant vegetation is secondary vegetation consisting of cloudy and lowland forests, coffee plantations (*Coffea arabica* L.), and exotic trees (p. ej. *Spathodea campanulate, Jacaranda mimosifolia*, *Eriobotrya japonica*) (Secretaría de Medio Ambiente [SEDEMA], 2001). This green urban area is restricted to visitors with pet dogs; however, the presence of feral dogs inside the park has been recorded (Mella-Méndez, Flores-Peredo, Bolívar-Cimé et al., 2019; Mella-Méndez, Flores-Peredo, Pérez-Torres et al., 2019). Medium-size wild mammal species previously recorded in Natura Park are gray fox (*Urocyon cinereoargenteus* Schreber, 1775), long-tailed weasel (*Mustela frenata* Illiger, 1815), ringtail (*Bassariscus astutus* Lichtenstein, 1830), raccoon (*Procyon lotor* Linnaeus, 1758), nine-banded armadillo (*Dasypus novemcinctus* Linnaeus, 1758), common opossum (*Didelphis marsupialis* Linnaeus, 1758), Virginia opossum (*Didelphis virginiana* Allen, 1900), and gray four-eyed opossum (*Philander opossum* Linnaeus, 1758) (Mella-Méndez, Flores-Peredo, Bolívar-Cimé et al., 2019).

Data collection: QGIS (QGIS Development Team, 2020) was used to generate random camera trap stations separated by 150 m to ensure spatial independence (Ramírez-Cruz, 2020). We excluded camera trap stations located on main roads or sites that were

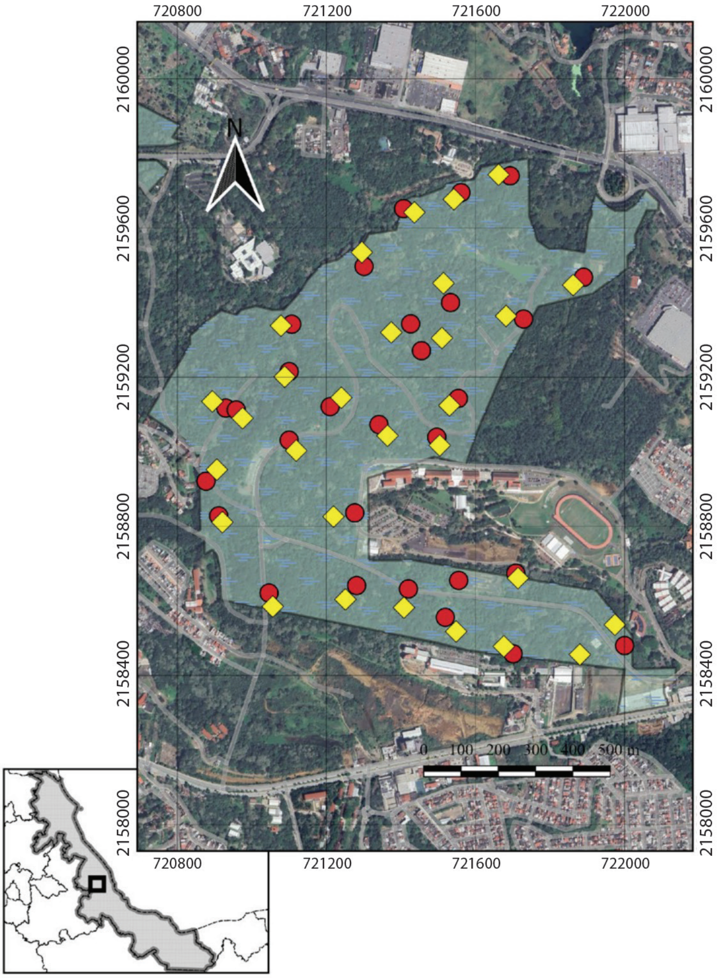

Fig. 1. Samplings design of camera traps (yellow squares) and scent stations (red points) at Natura Park (green area), Xalapa, Veracruz, México. Veracruz State is shown in shaded grey area on the small square. / **Fig. 1.** Diseño de muestreos de cámaras trampa (cuadros amarillos) y estaciones de olor (puntos rojos) en el Parque Natura (área verde), Xalapa, Veracruz, México. El estado de Veracruz se muestra en el área gris sombreada en el cuadrado pequeño.

highly exposed to avoid stolen camera traps. We sampled 27 camera trap stations from 15 March to 8 May 2021. Due to the limited number of camera traps, each station was sampled for 11 consecutive days, randomly rotating the cameras until all 27 stations were covered. The cameras were placed at a height of 50 cm above the ground and were programmed to take photographs and video recordings for 30 s. Each camera trap station had a feeding tray of 21.5 x 16.5 x 3 cm with a mix of 16 pieces of banana and two boiled eggs, impregnated with vanilla essence and covered with leaf litter to ensure foraging behaviours (Bedoya-Perez et al., 2013). The bait was placed only during the first two days of each sampling period.

We reduced the sampling bias in open sites, such as main roads and areas accessible to visitors (sports fields, playgrounds, parking areas, and guardhouses), by installing circular 1 m diameter olfactory stations baited with sardines and vanilla. We reviewed the footprints for the first two days of each sampling period. The spatial design of the scent stations was similar to that of the camera trap stations; each camera trap station had its own olfactory station. However, the olfactory stations were not placed at the same location as the camera traps, but rather on the roads or trails closest to the camera trap stations (Fig. 1). To reduce the spatial independence bias between the records obtained by camera traps and olfactory stations, the camera trap stations that were sampled differed from the olfactory stations during each sampling period.

We characterized the vegetation surrounding each camera trap station using the point-centered quadrant method (Mueller-Dombois & Ellenberg, 1976) and selected the tree where the camera trap was placed as the center. We measured the nearest shrub and tree distance (~5 cm in diameter at breast height), herbaceous cover, and vegetation cover that we considered as protection against predators. The latter was estimated using a 1 m ruler marked with black and white bands every 10 cm; the ruler was positioned 10 m from the central tree with the camera trap, and the percentage of bands not visible or covered by vegetation was estimated in each quadrant (Griffith & Youtie, 1988). The method used to characterize vegetation and cover against predators' states that four quadrants allow the variation in vegetation around the central point to be captured, rather than focusing on a single direction. We averaged all measurements to avoid pseudo-replicas and obtained a unique measurement at each camera trap station.

Synanthropic mammal and dog occupancy models: Single-species occupancy models were used to model the detection (p) and occupancy (ψ) probabilities of each synanthropic mesopredator. We used the protection cover against predators as a habitat covariate to determine if it influenced detection probability, whereas occupancy probability was modelled as a function of all habitat covariates and the presence or absence of feral dogs at each camera trap station. To determine whether the covariates represented our hypotheses, we generated null models in which the detection and occupancy probabilities were not influenced by any variable. We then compared the null models and the models that included covariates using the Akaike information criterion adjusted for small samples (AICc) (MacKenzie et al., 2006), and we selected the model that showed ΔAICc < 2. When we obtained two or more plausible models (ΔAICc < 2), we averaged them using the MuMin package (Barton, 2020).

We constructed co-occurrence occupancy models to determine whether the presence of dogs affected occupancy probability and synanthropic mammal detection using the wiqid package (Meredith, 2022). These models estimate occupation probability and species B detection (subordinate, i.e., mesopredators) based on the presence or absence of species A (dominant, i.e., dogs) (Devarajan et al., 2020; Richmond et al., 2010). We created two models, the first was an unconditional model ($\psi BA = \psi Ba$), where mesopredator occupation is not influenced by the presence/absence of dogs; while the second model was conditional ($\psi BA \neq \psi Ba$), where mesopredator occupation is influenced by the presence/absence of dogs. Subsequently, AICc was used to evaluate the models, and the model with the lowest value was selected as the best fit. We used the best model for estimating the species interaction factor (SIF), which indicates occurrence probability of both species at a site compared to what would be expected if both species occurred independently (MacKenzie et al., 2006). SIF values of 1 indicate that both species occur independently; that is, there is no relationship in the occupation of both species. SIF values > 1 indicate that the species co-occur more frequently than expected under an independence hypothesis, suggesting a positive association, whereas SIF values < 1 indicate that the species co-occur less frequently than expected under an independence hypothesis, suggesting a negative association, segregation, or evasion (MacKenzie et al., 2006).

To estimate temporal overlap between dogs and mesopredators, we used independent records, considering those records that were at least one hour apart or when two or more individuals were observed in the same photograph. Delta 1 was used as the overlap estimator because the species with the lowest number of records had fewer than 50 independent records (dogs). In addition, 95 % confidence intervals were estimated. The overlap package in R software (Meredith et al., 2024) was used.

Feeding patterns: We analyzed video records obtained by the camera traps, and the foraging duration and vigilance behaviour were quantified in: 1) foraging, the individual is observed manipulating, chewing, or consuming the food, using/or not using its front limbs, and, 2) vigilance, the individual is in a probable alert state, occasionally making lateral head movements, and 3) rapid vigilance, we only quantified the frequency, the individual briefly interrupts its foraging activities and quickly observes its surroundings. The videos were analyzed using Boris software (Friard & Gamba, 2016).

We reduced the bias in record frequency obtained from camera traps and olfactory stations (11 and 2 days, respectively) using generalized linear models with binomial distribution (presence or absence of mesopredator or feral dogs). We modelled the foraging duration and vigilance recordings using generalized linear models with a Gaussian distribution, whereas the rapid vigilance event frequency was modelled with a Poisson distribution. We incorporated two-factor interactions into all models (binomial, poisson and gaussian generalized linear model) with habitat variables and the presence/absence of dogs. Statistical analyses and occupancy models were performed using R software (R Core Team, 2017), considering a significance level of < 0.05. The significance of the variables in the generalized linear models was determined by the chi-square test.

RESULTS

Only three (opossums, ringtails, and gray foxes) of the eight previously registered species of medium-sized mammals were detected by the trap cameras. Opossums and dogs differed between camera traps and scent stations, opossums were recorded more frequently by camera traps (inside the vegetation, $X_2 = 26.16$, df = 1, $p < 0.001$), while dogs were recorded more frequently by the scent stations (outside the vegetation, $X_2 = 7.28$, df = 1, p = 0.006). No significant differences were observed for ringtails ($X_2 = 3.71$, df = 1, p = 0.05), gray foxes ($X_2 = 0.06$, df = 1, p = 0.79), or raccoons ($X_2 = 0.75$, df = 1, p = 0.38) between camera traps and scent stations.

Single species and co-occurrence occupancy models: Single species occupancy models showed that grass cover negatively affected ringtail occupancy (ψ = -0.34, CI = -1.26-0.56); however, no variable affected its detection (Table 1). Considering the gray fox, protection from predators positively affected gray fox detection (p = 0.27, CI = -0.54-1.30), while tree distance positively affected its occupancy (ψ 0.38, CI = -0.54-1.30); whereas the presence of dogs negatively affected gray fox occupation (ψ -0.72, CI = -2.64-1.19) (Table 1). Only the presence of dogs positively affected the opossum occupation probability (ψ 6.77, CI = -85.94-98.60) (Table 1). The best-fitting co-occurrence model was the unconditional model, showing no interaction between synanthropic mammals

Table 1

Single species occupancy model of synanthropic mammals. / **Tabla 1.** Modelo de ocupación de especies de mamíferos sinantrópicos.

Model	AIC	ΔAICc
Ringtail		
p (.) ψ (.)	334	0
p (.) ψ (Grass cover)	336.8	1.97
Gray fox		
p (.) ψ (.)	189.9	0
p (Protection from predators) ψ (.)	191.6	1.66
p (.) ψ (Tree distance)	191.7	1.78
p (.) ψ (Dogs)	191.9	1.96
Opossum		
p (.) ψ (.)	408.4	0
p (.) ψ (Dogs)	410.2	1.84

and dogs (Table 2). All the co-occurrence models had SIF values of 1.

Table 2

Co-ocurrence occupancy models between synanthropic mammals and dogs. / **Tabla 2.** Modelos de ocupación de co-ocurrencia entre mamíferos sinantrópicos y perros.

Modelo de co-ocurrencia	AIC	ΔAICc
Ringtail - Dog		
Unconditional model: ψ BA = ψ Ba	439.44	0
Conditional model: ψ BA ≠ ψ Ba	442	2.54
Gray fox - Dog		
Unconditional model: ψ BA = ψ Ba	294.58	0
Conditional model: ψ BA ≠ ψ Ba	297.40	2.81
Opossum – Dog		
Unconditional model: ψ BA = ψ Ba	513.06	0
Conditional model: ψ BA ≠ ψ Ba	515.50	2.43

Analysis of the temporal segregation of mesopredator species with dogs showed spatial segregation of the ringtail, grey fox and opossum, with overlap below 0.5 in all three cases (Fig. 2).

Feeding patterns: The foraging duration or interaction with habitation variables were not affected by the presence or absence of dogs; however, rapid vigilance frequency showed significant differences with predator protection and interaction with the presence/absence of dogs (Table 3). Foraging duration by gray foxes was not associated with habitat variables or with the presence/absence of dogs (Table 4). However, vigilance duration increased at sites with dogs and was positively associated with grass cover. In addition, there

Table 3

Feeding patterns of opossums (*Didelphis* spp.) and their interaction with habitat variables and dogs. / **Tabla 3.** Patrones de alimentación de zarigüeyas (*Didelphis* spp.) y su interacción con las variables hábitat y perros.

Habitat variables	Estimate	Standard error	P value
Duration of feeding			
Tree distance	0.21	0.88	χ_2 = 0.92, gl = 1, p = 0.70
Grass cover	-0.04	0.03	χ_2 = 3.16, gl = 1, p = 0.49
Protection from predators	0.06	0.02	χ_2 = 22.90, gl = 1, p = 0.06
Tree distance x dogs	-0.84	3.08	χ_2 = 0.03, gl = 1, p = 0.94
Grass cover x dogs	0.06	0.20	χ_2 = 5.28, gl = 1, p = 0.37
Protections from predators x dogs	-0.11	0.21	χ_2 = 1.92, gl = 1, p = 0.59
Duration of vigilance			
Tree distance	-0.84	1.30	χ_2 = 0.92, gl = 1, p = 0.20
Grass cover	0.02	0.05	χ_2 = 3.16, gl = 1, p = 0.38
Protection from predators	0.00	0.04	χ_2 = 22.90, gl = 1, p = 0.96
Tree distance x dogs	0.12	4.56	χ_2 = 0.03, gl = 1, p = 0.74
Grass cover x dogs	0.23	0.30	χ_2 = 5.28, gl = 1, p = 0.97
Protections from predators x dogs	-0.25	0.31	χ_2 = 1.92, gl = 1, p = 0.42
Frequency of fast vigilance			
Tree distance	-0.19	0.27	χ_2 = 0.78, gl = 1, p = 0.37
Grass cover	-0.00	0.01	χ_2 = 2.44, gl = 1, p = 0.11
Protection from predators	0.01	0.00	χ_2 = 2.80, gl = 1, p = 0.09
Tree distance x dogs	0.36	1.10	χ_2 = 0.1.29, gl = 1, p = 0.25
Grass cover x dogs	0.18	0.06	χ_2 = 0.48, gl = 1, p = 0.48
Protections from predators x dogs	-0.17	0.06	χ_2 = 26.16, gl = 1, p = 0.00*

*Significance less than 0.05. / *Significancia menor a 0.05.

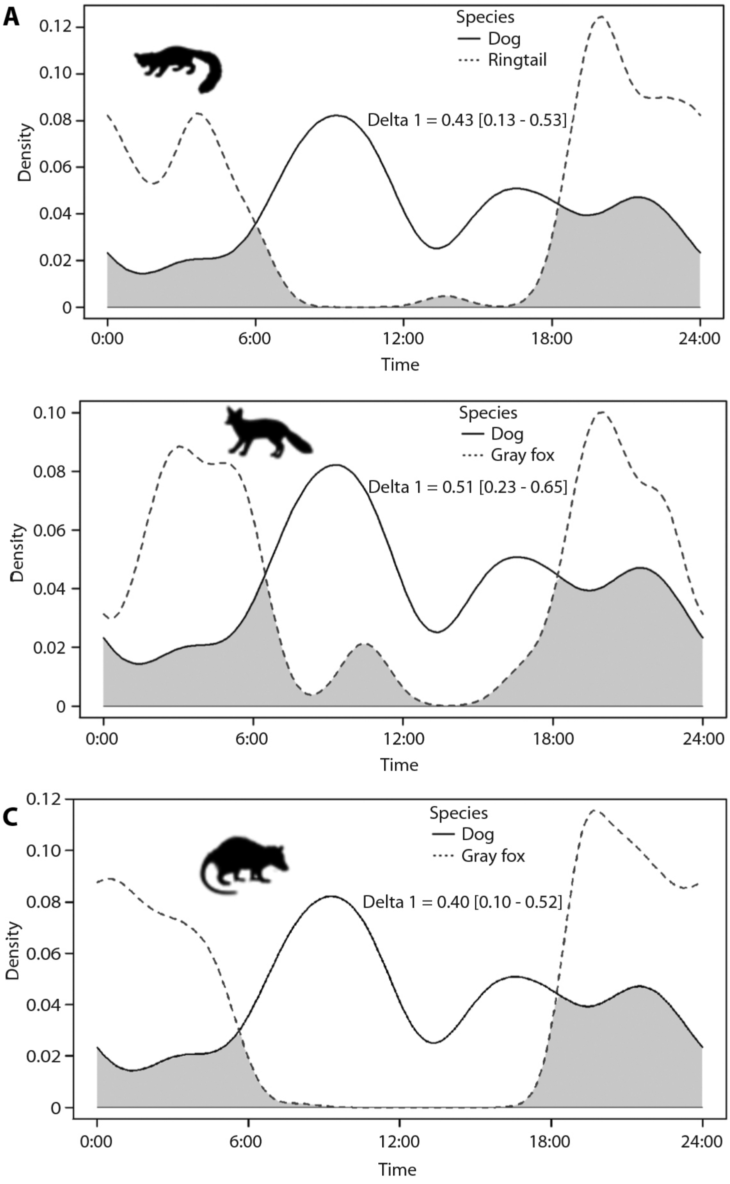

Fig. 2. Temporal segregation plots are shown for the ringtail (a), grey fox (b) and opossum (c). In all cases the overlap was less than 0.5. / **Fig. 2.** Se muestran los gráficos de segregación temporal del cacomixtle (a), zorra gris (b) y zarigüeya (c). En todos los casos el traslape fue por debajo del 0.5.

was a positive association with arboreal distance, which increased substantially at the sites where dogs were recorded. Rapid vigilance frequency increased at sites with dogs, whereas the interaction with tree distance and the presence/absence of dogs decreased when dogs were present and increased when dogs were absent. Likewise, this behaviour showed a positive association with grass cover, and although in sites with and without dogs, the positive association was maintained, it increased substantially at sites where dogs were recorded.

Table 4
Feeding patterns of gray foxes (*Urocyon cinereoargenteus*) and their interaction with habitat variables and dogs. / **Tabla 4.** Patrones de alimentación de zorras grises (*Urocyon cinereoargenteus*) y su interacción con variables de hábitat y perros.

Habitat variables	Estimate	Standard error	P value
Duration of feeding			
Tree distance	-3.85	4.05	$\chi_2 = 57.13$, gl = 1, $p = 0.34$
Grass cover	0.38	0.55	$\chi_2 = 3.45$, gl = 1, $p = 0.81$
Protection from predators	0.18	0.21	$\chi_2 = 14.78$, gl = 1, $p = 0.62$
Tree distance x dogs	-15.27	11.73	$\chi_2 = 115.94$, gl = 1, $p = 0.17$
Grass cover x dogs	-0.70	0.70	$\chi_2 = 63.30$, gl = 1, $p = 0.31$
Protections from predators x dogs	NA	NA	NA
Duration of vigilance			
Tree distance	0.57	1.17	$\chi_2 = 1.61$, gl = 1, $p = 0.58$
Grass cover	0.04	0.15	$\chi_2 = 26.28$, gl = 1, $p = 0.02$*
Protection from predators	0.09	0.06	$\chi_2 = 9.20$, gl = 1, $p = 0.19$
Tree distance x dogs	20.33	3.40	$\chi_2 = 191.73$, gl = 1, $p < 0.01$
Grass cover x dogs	0.00	20	$\chi_2 = 0.01$, gl = 1, $p = 0.96$
Protections from predators x dogs	NA	NA	NA
Frequency of fast vigilance			
Tree distance	-0.34	0.28	$\chi_2 = 15.37$, gl = 1, $p = 0.006$*
Grass cover	0.15	0.06	$\chi_2 = 19.42$, gl = 1, $p < 0.001$*
Protection from predators	0.03	0.01	$\chi_2 = 1$, gl = 1, $p = 0.48$
Tree distance x dogs	-20.44	5768.21	$\chi_2 = 45.18$, gl = 1, $p < 0.001$*
Grass cover x dogs	-0.22	7.96	$\chi_2 = 2.57$, gl = 1, $p = 0.003$*
Protections from predators x dogs	NA	NA	NA

*Significance less than 0.05. / *Significancia menor a 0.05.

Foraging duration and vigilance as well as the rapid vigilance frequency of ringtails did not show significant associations with habitat variables or their interaction with the presence or absence of dogs (Table 5).

DISCUSSION

Predation risk in a fear landscape includes the individual environmental perception by the prey, as well as predator identification, which interferes with prey vigilance, feeding behaviours, and environmental use. Differences observed in the probability of opossums occurring between camera traps and olfactory stations may indicate spatial segregation associated with dogs. In urban reserves, opossums are a frequent prey for dogs (Mella-Méndez, Flores-Peredo, Bolívar-Cimé et al., 2019) because of their reduced mobility (Arcangeli, 2014; Campos et al., 2007; Carrasco-Román et al., 2021). During fieldwork, dogs and their traces (tracks and droppings) were recorded on trails and main roads, as well as a dead *D. virginiana* individual that had multiple bites caused by dogs, an event that appears to be frequent at Natura Park (Mella-Méndez, Flores-Peredo, Bolívar-Cimé et al., 2019), in this case, this interaction may be more of a competition, as there was no real predation.. The low occurrence of opossums in open areas suggests that they avoid dogs because this marsupial does not have efficient escape routes such as nearby trees or holes, thus representing easy prey for dogs. However, during night tours, we observed some opossums using roads and open spaces, which suggests that these sites necessarily represent connection zones between vegetation patches within Natura Park.

Table 5

Feeding patterns of gray ringtails (*Bassariscus astutus*) and their interaction with habitat variables and dogs. / **Tabla 5.** Patrones de alimentación del cacomixtle (*Bassariscus astutus*) y su interacción con variables de hábitat y perros.

Habitat variables	Estimate	Standard error	P value
Duration of feeding			
Tree distance	-1.33	1.82	$\chi_2 = 10.00$, gl = 1, $p = 0.54$
Grass cover	-0.03	0.07	$\chi_2 = 12.88$, gl = 1, $p = 0.49$
Protection from predators	0.04	0.06	$\chi_2 = 6.50$, gl = 1, $p = 0.62$
Tree distance x dogs	-1.56	7.21	$\chi_2 = 0.23$, gl = 1, $p = 0.92$
Grass cover x dogs	-0.11	0.44	$\chi_2 = 17.20$, gl = 1, $p = 0.42$
Protections from predators x dogs	-0.01	0.44	$\chi_2 = 0.03$, gl = 1, $p = 0.97$
Duration of vigilance			
Tree distance	0.68	0.63	$\chi_2 = 0.19$, gl = 1, $p = 0.80$
Grass cover	0.01	0.02	$\chi_2 = 2.10$, gl = 1, $p = 0.42$
Protection from predators	0.02	0.02	$\chi_2 = 1.78$, gl = 1, $p = 0.46$
Tree distance x dogs	0.03	2.51	$\chi_2 = 1.73$, gl = 1, $p = 0.46$
Grass cover x dogs	0.09	0.15	$\chi_2 = 5.05$, gl = 1, $p = 0.21$
Protections from predators x dogs	-0.15	0.15	$\chi_2 = 3.42$, gl = 1, $p = 0.30$
Frequency of fast vigilance			
Tree distance	0.32	0.27	$\chi_2 = 0.45$, gl = 1, $p = 0.50$
Grass cover	0.00	0.01	$\chi_2 = 0.17$, gl = 1, $p = 0.67$
Protection from predators	0.01	0.01	$\chi_2 = 0.16$, gl = 1, $p = 0.68$
Tree distance x dogs	-1.12	1.15	$\chi_2 = 0.19$, gl = 1, $p = 0.66$
Grass cover x dogs	0.06	0.06	$\chi_2 = 2.57$, gl = 1, $p = 0.10$
Protections from predators x dogs	-0.10	0.07	$\chi_2 = 2.19$, gl = 1, $p = 0.13$

*Significance less than 0.05. / *Significancia menor a 0.05.

The absence of differences observed in the ringtail and gray fox occurrences between trap cameras and scent stations might reflect similar ecological preferences because they usually use open spaces. Carnivores in urban reserves use vegetation and urban structures for resting and feeding (Castellanos & List, 2005; Castellanos-Morales et al., 2008; Castellanos-Morales et al., 2009; Ramírez-Cruz, 2020). Furthermore, ringtails and gray foxes use road edges to make their latrines (Barja & List, 2006; Ramírez-Cruz, 2020) and feed on anthropogenic waste in garbage dumps (Castellanos & List, 2005; Castellanos-Morales et al., 2009). Even during fieldwork, we observed both carnivores walking on the park main roads and trails on several occasions. We also recorded their feces on the roadsides, which has been documented in other studies (Ramírez-Cruz, 2020). Thus, the presence of both carnivores in the scent stations might reflect the frequent use of these open spaces, despite them being spaces with a predation risk.

The greater occurrence probability of dogs observed at scent stations associated with roads and ways has been reported in other studies on the habitat preferences of this canid (Manjarrés-Rodríguez, 2010; Reatiga-Parish, 2015; Torres & Prado, 2010). For example, the presence of roads was positively associated with canid detectability in the Alerce Costero National Park and Valdivian Coastal Reserve in South America (Silva-Rodríguez & Sieving, 2012). Similarly, the distance from trails to scent stations was one of the variables that explained the potential distribution of dogs in the upper basin of the Otún River, Colombia (Manjarrés-Rodríguez, 2010), whereas in reserves in Brazil, a higher frequency of dogs was documented outside secondary forest patches (Torres & Prado, 2010).

Interaction between synanthropic mammals and dogs: We hypothesized that synanthropic mammals would show a positive association with vegetation, providing protection from predators (Bonnot et al., 2013; Creel et al., 2005; Donadio & Buskirk, 2016). Similarly, we expected spatial segregation in dogs, which has been documented (Silva-Rodríguez & Sieving, 2012; Silva-Rodríguez et al., 2010; Vanak & Gompper, 2010); however, this only occurred in opossums, suggesting species-specific responses.

The low spatial segregation between ringtails and dogs in our study may be because we recorded dogs during the day, while we recorded ringtails at night, at twilight, and only one recording during the day. This difference in activity period has also been documented in other urban reserves. In the Pedregal San Ángel Ecological Reserve, Mexico City, Ramírez-Cruz (2020) suggested that dogs accompanied by their owners did not affect ringtail spatial distribution, although they frequently occurred in the same places because of the daytime and nocturnal activities of dogs and ringtails, respectively. Likewise, the negative association of ringtails with herbaceous cover has already been registered previously, which responds to their preference for open spaces or conspicuous sites, which are used for depositing their feces and for communication between conspecifics (Ramírez-Cruz, 2020).

The spatial segregation observed between gray foxes and dogs is consistent with other studies that found that dogs displace smaller canids (Vanak et al., 2013; Vanak & Gompper, 2009; Vanak & Gompper, 2010). Gray foxes are prey that occasionally appear in the dog's diet (Carrasco-Román et al., 2021), thus safer area use, in addition to vegetation structure, given the positive association with protection against predators, are factors that reduce predation risk. Protection against predators represents the interaction between herbaceous, shrubby, and tree cover, which together comprise the sites with the greatest amount of vegetation that are frequently used by gray foxes in natural and urban ecosystems (Castellanos-Morales et al., 2009; Servín et al., 2014), both for shelter and food. The positive association with tree distance may reflect the use of open sites, such as roads, grasslands, and some buildings within the park. In urban reserves, foxes sometimes tend to use open spaces more than expected (Castellanos-Morales et al., 2008; Castellanos-Morales et al., 2009; Rountree, 2004), which may be because of the benefits in bringing them closer to human activity, even when observed in the periphery of some buildings (Rountree, 2004).

Opossums are synanthropic mammals with the highest mortality associated with dogs within urban reserves; therefore, we expected a greater occupation of sites with vegetation cover, which was not recorded in our study. Similar results were observed in *D. virginiana* inhabiting urbanized landscapes in the Chicago, Illinois, U.S.A. metropolitan area, because this marsupial did not show a specific association with vegetation cover (Fidino et al., 2016), which may be due to its ability to occupy a wide variety of habitats (Cruz-Salazar et al., 2016). We believe that the positive association between opossum occupation and the presence of dogs does not correspond to direct interaction; instead, it might reflect the use of open spaces by opossums and dogs, mainly because of high food supply availability at those sites.

Feeding habits: We expected that vigilance times would be greater at sites where dogs were present, and feeding would be reduced, which was not observed with the opossum. Our results coincide with those of some studies that have quantified the foraging and vigilance times of marsupials living in sympatry with dogs, in which no effects were observed on either behaviour (Cortés-Alfonso et al., 2021; López-Barragan & Sánchez, 2017; Rodríguez-Matla, 2016). It has been suggested that dogs do not represent a potential threat to these marsupials (Cortés-Alfonso et al., 2021); however, based on the spatial segregation observed between camera traps and scent stations, it would be convenient to explore foraging and vigilance behaviours in open spaces such as roads and trails, which are sites with a higher frequency of dogs, because we only observed these behaviours within vegetation patches using camera traps.

The positive association between the fast vigilance frequency and arboreal distance observed in opossums represents a behaviour that does not compromise daily energy requirements while reducing predation risk in open spaces. We believe that rapid vigilance events, in addition to reducing predation risk within vegetation patches, also help reduce encounters with other mesopredators at foraging stations. Foraging was the main behaviour in which opossums spent most of their time at the stations, a behaviour mostly recorded in our study area in previous research (Rodríguez-Matla, 2016). One aspect to highlight is that opossums were also vigilant during feeding states; that is, both behaviours were not temporarily excluded, which allowed them to obtain the maximum nutritional benefit inside the vegetation patch while reducing predation risk.

Regarding ringtail and gray fox foraging patterns, Rodríguez-Matla (2016) documented in sites impregnated with dog urine, a decrease in feeding times and increase in ringtail deterrence, whereas our study did not show any association with dogs and vegetation structure. When prey detect clues left by their predators, such as feces or urine, they may modify their foraging patterns (Kats & Dill, 1998; Rosell & Czech, 2000) or even remain unchanged (Rosell & Czech, 2000). A plausible explanation for our results could be the low territorial marking frequency of dogs during their walking through the feeding stations, which could be true because in the video recordings, we scarcely observed individuals marking the site. Furthermore, most of the individuals spent very little time at the feeding stations, suggesting that vegetation usage might correspond to transit areas.

The interaction between dogs and wildlife may generate species-specific behavioural responses, allowing some species to be tolerant to risk while others may show spatial and temporal segregation. Our study analyses aspects of feral dogs and synantropic mammals and we suggest that in Natura Park it is necessary to implement protocols with implementing a specific action to control feral fauna considering that this is a protected area.

Ethical statement: The authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

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