Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Short Communication

Urban wildlife in times of COVID-19: What can we infer from novel carnivore records in urban areas?

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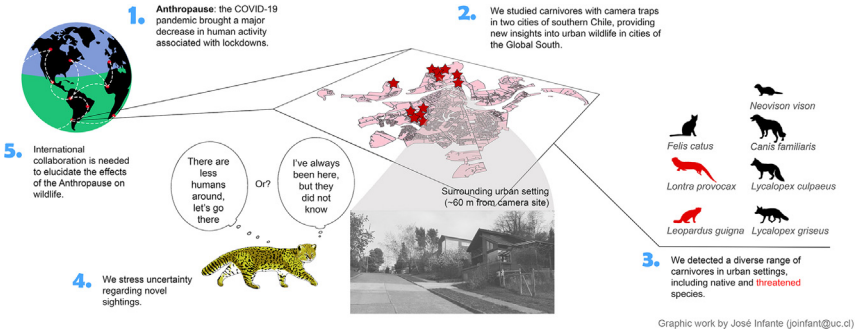
HIGHLIGHTS

- Wildlife sightings during COVID-19-lockdowns have received considerable attention.
- During partial lockdowns we recorded four native carnivores in Chilean cities.
- None of the native species detected have been previously linked to urban areas.
- It is difficult to determine if these records were influenced by partial lockdowns.

GRAPHICAL ABSTRACT



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ABSTRACT

The onset of the COVID-19 pandemic brought an unusual decrease in human activity associated with partial and total lockdowns. Simultaneously, a series of wildlife sightings—mainly in urban areas—have been brought to public attention and often attributed to lockdown measures. Here we report on a series of wild carnivore records, including threatened species, obtained through camera traps set in urban forests, campuses, suburbs, and peri-urban areas of two cities in Chile, during partial lockdown measures. Our records are novel for Chile, a country where urban carnivore ecology is mostly unknown, and include the detection of four native carnivores, including the vulnerable güiña (*Leopardus guigna*) and the endangered southern river otter (*Lontra provocax*). These records also constitute a valuable baseline collected during partial lockdown measures in two cities of the Global South. We emphasize, however, that these findings cannot be used to argue for or against an effect of lockdown measures on wildlife. More generally, we call for caution in the interpretation of seemingly novel carnivore records during periods of lockdown and stress the value of international collaboration in evaluating the effects of the Anthropause on wildlife.

1. Introduction

Human presence has a considerable impact on the distribution, abundance and behaviour of wildlife (Dirzo et al., 2014; Gaynor et al., 2018; Tucker et al., 2018). Nowhere is this more apparent than in urban areas, where extreme land-use change combined with high levels of human activity have created hostile environments for many species (McKinney, 2006; Bateman and Fleming, 2012; Santini et al., 2019). In addition to habitat loss derived from land cover change, wildlife in urban areas face major challenges such as increased human-related mortality (Loss et al., 2015). Yet, while many species avoid urban

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areas, others become urban dwellers (Fischer et al., 2015), benefitting from—but not necessarily depending on (Newsome et al., 2015)—anthropogenic food resources (e.g., Bozek et al., 2007; Castañeda et al., 2019). Species that profit from urban resources—such as some mesocarnivores—can reach higher densities in urban than in natural areas (Šálek et al., 2015) providing ecosystem services—and sometimes disservices—to society (Soulsbury and White, 2016). Despite major advances in the global understanding of urban wildlife ecology, urban areas located in the Global South, have received scant attention (Magle et al., 2012), making broad inferences on global responses to human activity and urbanization challenging.

The onset of the COVID-19 pandemic in early 2020 brought about major changes to human dynamics on a global scale. Extensive areas of the world faced lockdowns with more than half of the world's population

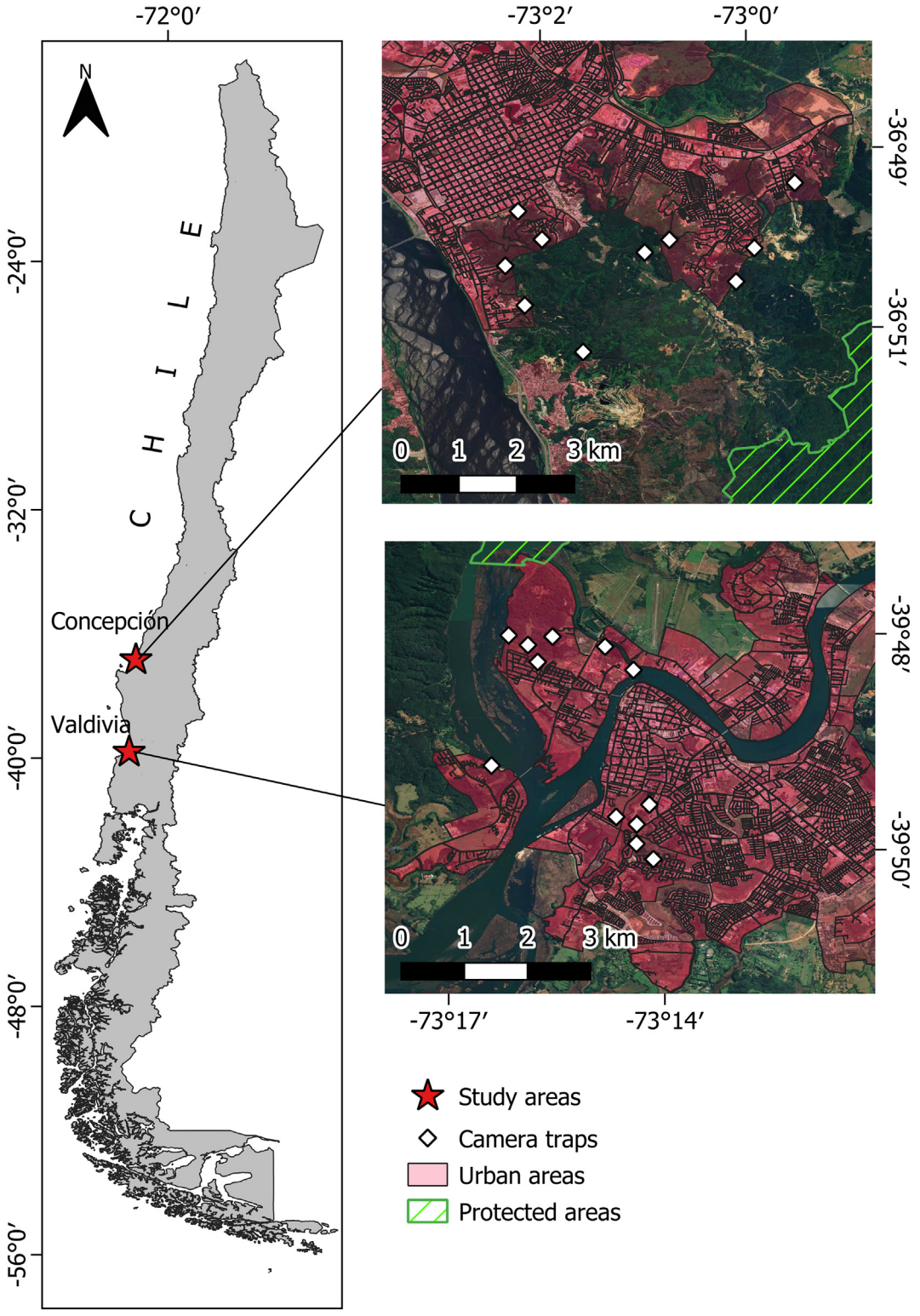

Fig. 1. Map of the study area and the distribution of camera traps in Concepción and Valdivia (Background map data: Google, Maxar Technologies). Urban area borders follow the 2017 National Census cartography (INE, 2018) and protected areas follow the official cartography (BCN, 2020).

affected (Bates et al., 2020). The global reduction in human activity, recently coined 'the Anthropause' (Rutz et al., 2020), was accompanied by a series of sightings of wildlife in cities around the world, disseminated through the press and social media, and echoed in academic publications (e.g., Paital, 2020). These sightings prompted a (renewed) interest in the response of wildlife to the reduction in human activity brought about by lockdown measures (Corlett et al., 2020; Manenti et al., 2020; Rutz et al., 2020; Zellmer et al., 2020). For example, there is evidence from Italy that lockdowns have triggered behavioral changes in both native and invasive vertebrates (Manenti et al., 2020).

In this context, we present novel insights into the presence and ecology of mesocarnivores in two cities of southern Chile within the context of COVID-19-related restrictions. Although restrictions in Chilean urban areas have ranged from partial to full lockdown (with "dynamic quarantines", Cuadrado et al., 2020), a nationwide curfew (22:00 to 5:00) was enacted on 22nd March 2020. Since then, a number of carnivore sightings in Chilean urban areas have captured the public's attention (see Table S1, Supplementary Material). Although the most notable of these were a number of puma (*Puma concolor*) sightings in Santiago (mentioned in Paital, 2020; Rutz et al., 2020; see also https://youtu.be/AH292i32zxU), other cities, such as Valdivia, also recorded sightings of carnivores including a puma and even an elephant seal (*Mirounga leonina*) (Table S1, Supplementary Material). In an attempt to collect more standardised and systematic data on the detection of terrestrial wildlife in two cities, Valdivia and Concepción, we took advantage of reduction in human mobility to conduct a preliminary study to document the presence and activity of carnivores in parks, urban forests, university campuses and peri-urban areas during COVID-19 related restrictions.

2. Methods

We conducted an exploratory camera trap study between April 17th and August 10th, 2020 in the city of Valdivia and between May 5th and August 11th in Concepción, southern Chile, corresponding to Austral fall and winter. Valdivia is a medium sized city inhabited by 150,048 citizens (INE, 2019). The city is characterized by the presence of rivers, wetlands, and some forest remnants. Although there are records of nine wild carnivore species in rural areas of the region (Table S2, Supplementary Material), chilla foxes (*Lycalopex griseus*) and invasive American minks (*Neovison vison*) are the only wild terrestrial carnivores that are occasionally detected in some areas of the city (E. Silva-Rodríguez pers. obs.). The city of Concepción is a conurbation inhabited by 719.944 citizens (INE, 2019), and characterized by residential and industrial development along with satellite neighborhoods (Pauchard et al., 2006). The city is bordered in the north and south by wetlands and the Bío Bío river, respectively. Native forest remnants immersed in large non-native tree plantations, and a protected area (Nonguén Natural Reserve; 3039 ha) located 5.7 km away from the urban border, represent the major natural habitats adjacent to urban settings (Fig. 1). Six species of wild carnivores are present in surrounding rural areas (Table S2, Supplementary Material), but none are known to occur regularly in the city. During the surveys, both cities were under partial lockdown measures, including night curfew (22:00 to 5:00), closure of the University campuses, and the suspension of schools.

In Valdivia, we set up 12 camera traps (Bushnell Trophy Cam Essential, models E2 and E3) in forested areas or wetlands across three areas of the city (Fig. 1) encompassing two University campuses, two urban forests and the border of a suburb. The largest urban forest sampled was c. 150 ha, and was not connected to larger fragments. Cameras were set at short distance from houses and buildings (23–330 m, Median = 89 m) and in forested areas, behind dense vegetation and/or close to rivers and wetlands, at sites that would minimise theft and ensure a minimum distance of 350 m between locations. In Concepción, we set 10 camera traps (Bushnell Trophy Cam Essential and HC801A), although one was stolen and therefore not included in this study. Most of the cameras were installed in forests located in the urban-wildland border in the southeast section of the city (range of distances to border: 22–229 m), except for one camera that was placed 766 m from it (Fig. 1). The minimum distance between camera locations was ca. 500 m.

All cameras were set to take 2 or 3 images/videos per trigger, with a 3 s delay. We did not use scent lures, and placed all cameras ensuring that they would be triggered by movement occurring at ground level. Sampling effort totaled 1054 trap days (42–114 days per camera) in Valdivia and 726 trap days (41–96 days per camera) in Concepción, close to those recommended for vertebrate inventories (Rovero et al., 2013).

We analyzed the data collected calculating two simple—but widely used—metrics: the proportion of cameras that recorded each species, and the camera trapping detection rate (independent pictures/trap-days x 100). For the latter, we considered records as independent when separated by at least 60 min (Rovero and Marshall, 2009). Finally, we estimated species activity patterns, through kernel density functions, and derived a coefficient of temporal overlap (Ridout and Linkie, 2009) between the activity of chilla foxes (*Lycalopex griseus*, the only native carnivore species with enough records) and that of its main prey (rodents, Martínez et al., 1993, Silva-Rodríguez et al., 2010), an intraguild predator and interference competitor (domestic dog, Silva-Rodríguez et al., 2010) and a potential competitor (domestic cats). Activity patterns and overlap were fitted in R (R Core Team, 2020) using the package overlap (Ridout and Linkie, 2009; Meredith and Ridout, 2020). Overlap estimates may range from 0 to 1 (i.e., from no overlap to full overlap, Ridout and Linkie, 2009). As recommended for sample sizes above 75 events (all but one species analyzed), we used the estimator Dhat4 ($\widehat{\Delta}_4$) and generated bootstrap basic0 confidence intervals (Meredith and Ridout, 2020).

3. Results

Surveys in both Valdivia and Concepción recorded a total of seven carnivore species (Table 1, Fig. 2). In Valdivia, the most frequently

Table 1
Camera trapping rate (Records per 100 trap days) and proportion of camera traps that recorded carnivores in two urban areas of southern Chile during COVID-19 partial lockdowns. Species are presented according to their origin, conservation status (following IUCN, 2020), habitat characteristics of sites with detection, and minimum distance (m) to human buildings (MDHB).

Common name	Species	Origin	Status	Habitat	MDHB	Camera trapping rate		Proportion of cameras (%)	
						Concepción	Valdivia	Concepción	Valdivia
Culpeo fox	*Lycalopex culpaeus*	N	LC	F, R	155	0.0	0.3	0.0	16.7
Chilla fox	*Lycalopex griseus*	N	LC	F, W, R	23	0.0	11.9	0.0	58.3
Domestic dog	*Canis familiaris*	D		F, R	23	0.8	7.7	44.4	58.3
Güiña	*Leopardus guigna*	N	VU	F, W, R	32	2.8	0.7	55.6	41.7
Domestic cat	*Felis catus*	D		F, W, R	23	0.3	6.9	22.2	66.7
Southern river otter	*Lontra provocax*	N	EN	F, R	330	0.0	0.1	0.0	8.3
American mink	*Neovison vison*	I		F, W, R	63	0.0	0.6	0.0	41.7

Origin: Native species (N), Free-ranging domestic carnivores (D), and invasive alien species (I).
Status: Endangered (EN), Vulnerable (VU), Least Concern (LC).
Habitat: Forested areas including native forest, mixed forest and plantations (F), Wetlands (W), River borders (R). Note that a camera may be in more than one habitat category.

Fig. 2. Records of four carnivore species in Valdivia, southern Chile. (a) Southern river otter (*Lontra provocax*), (b) güiña (*Leopardus guigna*), (c) culpeo fox (*Lycalopex culpaeus*) and (d) invasive American mink (*Neovison vison*).

detected species was the chilla fox (126 records), followed by the domestic dog (*Canis familiaris,* 81 records) and the domestic cat (*Felis catus*, 73 records). We also detected the vulnerable güiña (*Leopardus guigna*, 7 records) and the invasive American mink (6 records). Finally, we detected culpeo fox (*Lycalopex culpaeus*) on three occasions and obtained a single record of the endangered southern river otter (*Lontra provocax*). Both chilla foxes and güiñas were detected at very short distances from houses (<40 m) and co-occurred with domestic dogs and cats, whereas the single river otter record was obtained a few meters away from a major river. Other species detected included invasive hares (*Lepus europaeus*), domestic horses (*Equus caballus*) and assorted bird species, the most notable being the stripe-backed bittern (*Ixobrychus involucris*) and the endemic black-throated huet-huet (*Pteroptochos tarnii*).

In Concepción, the only native carnivore detected was the güiña. This species was detected at five of the nine camera locations and at a minimum distance of 34 m from the closest house and sidewalk. In contrast, domestic dogs and cats were detected in four and two cameras, respectively (Table 1). Similarly to Valdivia, all three species were found to co-occur at camera locations. Other species recorded in Concepción included both canopy and understory birds, such as the Austral thrush (*Turdus falcklandii*), the black-throated huet-huet and the chucao tapaculo (*Scelorchilus rubecula*).

The chilla fox in Valdivia was the only native carnivore with enough records to perform further analysis ($n = 126$). Temporal activity was concentrated during nighttime, although diurnal activity was also recorded (Fig. 3a). Chilla foxes showed very high activity overlap with rodents ($\hat{\Delta}_4 = 0.85$, bootstrap CI [basic0]: 0.79–0.90, Fig. 3b) and relatively low activity pattern overlap with domestic dogs ($\hat{\Delta}_4 = 0.31$, 0.21–0.42, Fig. 3c). Lastly, chilla foxes had high activity pattern overlap with domestic cats ($\hat{\Delta}_4 = 0.74$, 0.63–0.85, Fig. 3d).

4. Discussion

Chile is undergoing rapid urbanization (Pauchard et al., 2006; Dobbs et al., 2019), a process that has come at a heavy cost for native wildlife (Silva et al., 2016). In this context, the finding that threatened species —like the güiña—can occur in urban forests and periurban areas at short distances from human infrastructure in both urban areas represents a positive sign that cities might be able to accommodate some wildlife species. Notably, the güiña was the only native carnivore detected in Concepción, the largest city surveyed. In contrast, in Valdivia we detected most of the terrestrial carnivores known to be present in the region (7 out of 11 species, including domestic and invasive species, see Table S2, Supplementary Material) and the presence of puma was also recorded (P. Villagra, pers. comm., Table S1, Supplementary Material). Our results are therefore surprising, considering that the presence and ecology of carnivores in urban areas of Chile is—as in many other countries of the Global South—mostly unknown (Magle et al., 2012). In fact, after searching the Web of Science Core Collection (http://apps.webofknowledge.com/, search terms: Urban and carnivore* and Chile, Search Date 2 July 2020), we found no published report on the occurrence of urban terrestrial carnivores in Chile. This is a major barrier to understanding seemingly novel, but anecdotal, records of wildlife, and particularly within the context of COVID-19 related restrictions.

Despite their novelty, some of the most notable records we obtained may not be related to the partial lockdown. For example, the southern river otter is known to be present in the Carlos Anwandter Nature Sanctuary (Franco et al., 2013), a Ramsar site located close to the urban limit of Valdivia, in the same river and at short distance of the site we detected it (Fig. 1). Although its presence in urban areas has not been documented in the scientific literature, its presence near the civic center of the city has been anecdotally reported before (A. Valenzuela-Sánchez

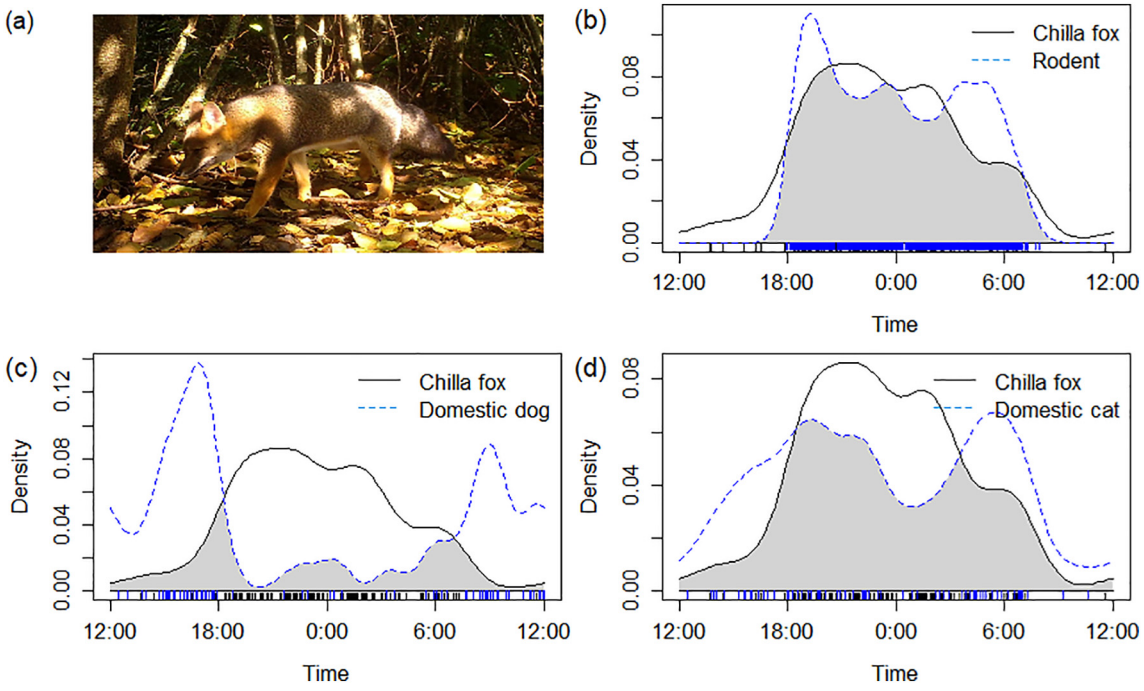

Fig. 3. (a) Daytime record of a chilla fox (*Lycalopex griseus*) in Valdivia, Chile. Activity pattern of chilla foxes ($n = 126$) and its overlap with that of (b) rodents ($n = 778$), (c) domestic dogs ($n = 81$) and (d) domestic cats ($n = 73$) in Valdivia. The time zone corresponds to UTC -4.

pers. comm.) and other otter species utilize urban areas in other areas of the world (e.g., Khoo and Lee, 2020). In contrast, our study noted the presence of the güiña at multiple urban and periurban locations across both cities. These observations are in line with the findings of recent studies highlighting the ability of this species to tolerate higher levels of fragmentation and human-related disturbances in mosaic landscapes than previously thought (see Gálvez et al., 2018). Recent records reported on social media have also documented the presence of güiñas in other urban areas of central Chile in close proximity to people's homes during partial lockdown (see Table S1, Supplementary Material). The presence of güiñas in urban areas could have two alternative explanations. Partial lockdown could have enabled individuals (either adults or dispersing juveniles) to explore urban habitats from nearby rural areas. Alternatively, they could be urban dwellers or visitors that have gone undetected until now. Finally, invasive American mink was detected infrequently, but in several cameras in Valdivia. This mustelid is not considered an urban species (Santini et al., 2019) and it is less frequent in urban areas than in rural areas (Brzeziński et al., 2018). However, its presence in urban and periurban areas of Chile has been previously documented (Sepúlveda et al., 2011; Díaz, 2015). As invasive alien species, mink, along with domestic cats and dogs, represent an important threat to native wildlife occurring in urban (and rural) areas. Our study thus highlights the potential for urban areas to act as an interface between the conservation and management of native and invasive wildlife, respectively.

Although our study design does not allow us to test for an effect of COVID-19-related restrictions, it is nevertheless interesting to consider how such measures could have influenced the behaviour of some of the species detected in this study. For example, one of the chilla fox's main threats is interference competition and intraguild predation by domestic dogs (Silva-Rodríguez et al., 2010), which are particularly abundant in urban areas of Chile (Ibarra et al., 2006). However, despite being common, dogs were detected less often than foxes in Valdivia (Fig. 1), whereas under normal conditions dogs are expected to be the most frequently sighted carnivore in the urban settings considered here. This pattern may have been partially influenced by campus and park closures, which could have led to a decrease in the abundance of stray dogs due to their associations with people and the food they provide, intentionally or otherwise. For example, one of the study areas (a university campus) is used by up to 40 stray dogs–plus those that are brought by the educational community– and nearly 60% of the c. 10,000 members of the university community admit to feeding these dogs (Rivera, 2015). During campus closure, the number of stray dogs has noticeably dropped. It would appear, therefore, that COVID-related closures have resulted in a substantial reduction in food provisioning for these dogs and their displacement from some areas. This, coupled with the reduction in human activity, could have favored the detection of foxes within campus and during daytime (Fig. 2a). The observation that chilla fox activity was higher when prey was active and lower when dog-related risk was higher is no surprise. Indeed, it is in keeping with the nocturnal patterns recorded for the same species in rural areas in the absence of lockdown measures (e.g., Silva-Rodríguez et al., 2010) and closely resembles patterns of activity overlap reported for urban red foxes (*Vulpes vulpes*), domestic carnivores and mammalian prey in Australia (Gil-Fernández et al., 2020). This combination of novel and recurrent ecological insights, and the lack of suitable baseline or control treatments, highlights the difficulty of attributing changes in behaviour based on anecdotal sightings recorded during lockdown periods, something that we argue can apply to all "unusual" urban wildlife sightings reported during the pandemic.

We therefore finish with a word of caution. Many of the mammal records that have been brought to public attention around the world—such as pumas, coyotes and deer (see Paital, 2020), are already recognized as urban dwellers or visitors (Santini et al., 2019), therefore their occasional presence in urban areas during lockdowns may not be as novel as may seem. Others—such as the species we report here—are not currently associated with urban areas, and their finding could cause surprise. However, in reality, it is difficult to determine whether these records were influenced by COVID-19-related restrictions. For instance, the abundance of mesocarnivores in surrounding wildlands and the contrast between urban and adjacent habitats may favor their presence in both cities (Lidicker, 1999; Clergeau et al., 2006), independent of the potential lockdown effects. Thus, the combination of our increasing ability to observe hard to detect wildlife with the aid of camera traps, the extra time spent at home due to lockdowns, and the ease of publication of rare sightings on social media (e.g., Table S1, Supplementary

Material), is likely to increase unusual records of carnivores in urban areas during this period (Zellmer et al., 2020). This is especially the case in regions like South America that have received much less attention in the urban wildlife ecology literature (Magle et al., 2012). Therefore, what we can really infer from novel carnivore records in urban areas, is that there may be many more urban visitors and dwellers than currently known (as acknowledged by Santini et al., 2019). The COVID-19 pandemic and urban wildlife sightings have evidenced the fact that we know very little about urban carnivores in cities of the Global South.

In order to better understand the effects of this Anthropause on wildlife, we encourage researchers to take advantage of ongoing camera trapping and other species-specific ecological studies in urban-wildland gradients prior to lockdowns (Rutz et al., 2020). In particular, by sampling across multiple cities and implementing an automated detection approach through the use of camera traps, our study fits into the framework recently proposed by Zellmer et al. (2020) for studying changes in urban wildlife in times of COVID-19. Even without a before-after design, studies, such as the one presented here, provide valuable baseline data with which to evaluate trends post COVID-related restrictions. In this, citizen science can also play an important role by providing a cost-effective and engaging way of collecting data across multiple locations during and after lockdown measures. Finally, enhancing international collaborations to include data from multiple sites and regions across the world—as suggested by Rutz et al. (2020)— will ultimately facilitate scaling up from local to global patterns in order to better understand the response of wildlife to the Anthropause.

CRediT authorship contribution statement

Eduardo A. Silva-Rodríguez: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Nicolás Gálvez:** Conceptualization, Methodology, Writing - review & editing, Visualization. **George J.F. Swan:** Conceptualization, Writing - review & editing. **Jeremy J. Cusack:** Conceptualization, Methodology, Writing - review & editing. **Darío Moreira-Arce:** Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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