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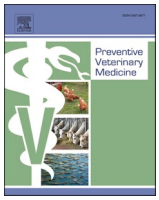

An assessment of the owned canine and feline demographics in Chile: registration, sterilization, and unsupervised roaming indicators

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ABSTRACT

The global rise in companion animal populations, particularly dogs and cats, is driven by emotional and social benefits for owners, and their population management is becoming critically important to avoid a plethora of adverse effects on themselves, humans, and wildlife. We estimated the size and density of the owned canine and feline population in Chile and evaluated the status of microchipping, registration, sterilization rates, and the proportion of owned animals that roam unsupervised. A cross-sectional household survey in 36 districts was conducted and standard inferential statistics was employed to analyze differences between cats and dogs, sexes within each species, and between rural and urban areas. Additionally, two negative binomial models with mixed effects were developed to predict the number of dogs and cats per households. Two methods were used to compare population size estimates at the country level, multiplying: (1) the estimated mean number of companion animals per household by the estimated number of households at the country level, and (2) the estimated human:dog and human:cat ratios by the total human population. The study involved 6333 respondents, of which 76% (74% urban; 83% rural) owned companion animals (dogs and/or cats). Individuals in rural multi-person households increase the probability of owning dogs and/or cats. Additionally, women exhibit a greater inclination towards cat and dog ownership compared to men, while those over 30 years old demonstrate lower rates of companion animal ownership in contrast to the 18–30 age group for both species. The overall human:dog and human:cat ratios estimated were 2.7:1, and 6.2:1, respectively. The estimated total number of owned dogs and cats in Chile ranged from 9.6 to 10.7 million, depending on the methodological approach, while national median density of companion animals was 12 dogs per km2 (ranging from 0.02 to 7232) and 5 cats per km2 (ranging from 0.01 to 3242). This nationwide study showed one of the highest percentages of households with companion animals in Latin America and relatively low registration and sterilization rates, highlighting the need to strength long-term public policies to control populations of companion animals and promote responsibility in pet ownership.

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1. Introduction

The increase in the population of companion animals, particularly dogs and cats, is a global trend observed in recent decades, promoted by numerous social and emotional benefits, even being considered as part of the family (Cleary et al., 2020; Hartwig and Signal, 2020; Jacobson and Chang, 2018; Salgado-Caxito et al., 2023). In addition, societal and economic reasons, including the use of domestic animals for hunting, herders, and pest control, drive the dog and cat population increase (Cobb et al., 2021; Crowley et al., 2019; López-Jara et al., 2021; Mahlaba et al., 2017). However, there is an increasing concern on the undesired effects of population growth of companion animals, specifically concerning the unsupervised outdoor access of dogs and cats (Silva-Rodríguez et al., 2023; Tan et al., 2021). These animals are particularly susceptible to injuries, infectious diseases, pose public health threats through bites, disease transmission such as rabies and other zoonoses (Barrios et al., 2021; Benavides et al., 2019; Stull et al., 2015), and represent a serious threat to native wildlife from predation to disease transmission (Villatoro et al., 2019). Additionally, poorly trained dogs and cats can cause disturbance to human neighbors (e.g., barking or defecating in streets) that can cause negative impacts to human well-being (Cross et al., 2009). These aspects make it necessary to assess companion animal ownership under a One Health approach, as it allows for an understanding of the relationship between people, animals, plants, and their shared environment and its effect on the health and well-being of all (Overgaauw et al., 2020).

Reliable estimates of global canine and feline populations are not available. However, it has been proposed that more than 600 million cats and 900 million dogs live closely with humans worldwide (Hosie and Hofmann-Lehmann, 2022). In particular, Latin America has more than 165 million companion animals (Pet Food Industry, 2021), although country-level estimations of these populations are limited. Local studies and official reports are available in Argentina (Dirección General de Estadística y Censos, 2023), Brazil (Baquero and Queiroz, 2019; Junqueira and Galera, 2019), Colombia (Florez and Solano, 2019), Perú (Rendón et al., 2018), and Uruguay (Ministerio de Ganadería Agricultura y Pesca, 2017), showing variability between countries and within countries. In Chile, a large number of local studies estimating the size of dogs and cats populations have been conducted since the study by Montes (1966), generating highly variable estimates. The human:dog ratios reported in Chile ranges from 10.7:1–1.1:1 (Acosta--Jamett et al., 2010; Astorga et al., 2015; Silva-Rodríguez et al., 2023; Villatoro et al., 2019), and from 4.3:1–3.2:1 for cats (Ávila Ponce, 2021; Guerrero, 2012). The contrast among studies can be explained by different methodological designs (e.g., surveys, transects, others) that influence the estimates and comparison across geographical areas, species, and human demographic characteristics (e.g., urban, and rural areas), and also by temporal changes with a decreasing human:dog ratio over time (Acosta-Jamett, 2015). Given the worldwide pattern of increase in the population size of companion animals, it is relevant to conduct a nationwide assessment of the population size of cats and dogs in Chile, plan effective campaigns of companion animals' ownership and estimate the benefits and impacts of this population.

In Chile, the Responsible Pet and Companion Animal Ownership ("Programa de Tenencia Responsable de Animales de Compañía", or PTRAC, in Spanish) started in 2014 to promote the introduction of a mandatory tag registration, promotion of spaying and neutering of companion animals, educational activities, among others. This program is directed by the Undersecretary of Regional and Administrative Development of the Ministry of the Interior and Public Security, Government of Chile ("Subsecretaría de Desarrollo Regional y Administrativo del Ministerio del Interior y Seguridad Pública", or SUBDERE, in Spanish). Before this study, the PTRAC assumed an estimated population of 3.8 million dogs and 1.2 million cats, using a human:dog ratio of 5.1:1 (Garde et al., 2022) and a human:cat ratio of 14.7:1 (personal communication). However, societal and human population changes could influence the population dynamics of companion animals, such as birth and death rates, adoption and veterinary care, migration, and abandonment, among others. Therefore, regularly obtaining up-to-date information is crucial for designing public policies to control populations and promote a proper companion animal ownership. Without a precise estimate of the number of dogs and cats in the country, the impact of campaigns is difficult to plan and interpret (Garde et al., 2022). Supported by the PTRAC, we present the results from the First National Study on Companion Animal Ownership to estimate and characterize the companion animal population in Chile. We used the results of the survey to estimate: (i) the size and density of the canine and feline population, (ii) the current percentages of registration, microchipping, and sterilizations, which are the main strategies for canine and feline population control in the country, and (iii) the proportion of owned animals with unsupervised outdoor access.

2. Materials and methods

2.1. Study design

Data were obtained from a national cross-section study, leading to the First National Study on Companion Animal Ownership in 2021. Details of this survey design (e.g. cross-sectional stratified two-stage random sampling) used to estimate the number of companion animals are provided in Salgado-Caxito et al. (2023). Chile is administratively divided into 16 regions, 56 provinces, and 346 districts. The number of provinces and districts varies between regions. According to the last census, human population reached 17,574,003 people (12% in rural areas) and 6,499,355 households in 2017, respectively (Instituto Nacional de Estadísticas, 2018). Assuming that 75% of households had at least one dog or cat (CADEM, 2022), an acceptable margin of error of 5%, and a desired confidence of 95%, we randomly selected 35 districts to be sampled. There were 11 districts where conducting fieldwork in rural areas proved impractical due to logistical constraints; nonetheless, these districts, characterized by a substantial urban population, remain representative. In these districts, the human:dog and human:cat ratios were substituted with the average ratios observed across all rural areas of the districts.

Surveyed districts encompassed about 14% of the human population and span a wide range of settings and livelihoods, covering rural, urban, coastal, and inland areas (Fig. 1). Districts' administrations were contacted by the PTRAC and researchers to inform and voluntarily enroll them in the field study. Data from one additional district (i.e., Puchuncaví district) was included since it was conducted following the same study approach two months after the rest of the survey had finished.

"Random Selection Within Subsets" tool was used in QGIS 3.24 to select groups of blocks (urban areas) and entities (rural areas) within each previously selected district. Then, a route transect for each location was established. Pollster's teams conducted the survey by walking their respective transects within the demarcated study block or entity. All teams were trained through two 3-hour virtual workshops covering the research problem and the study's overall goal, fieldwork details such as the number of surveys needed, and urban and rural transect locations. Additionally, a comprehensive itemization of each questionnaire module and its questions was formulated, including possible biases in the way the survey is setting out.

2.2. Questionnaire

A characterization questionnaire was employed to gather data on companion animal ownership practices, incorporating a comprehensive set of questions available in Supplementary Material 1. The questionnaire was collaboratively designed by the PTRAC and the researchers involved in the study and administered by trained pollsters using the web interface of KoBoToolbox (www.kobotoolbox.org) through mobile

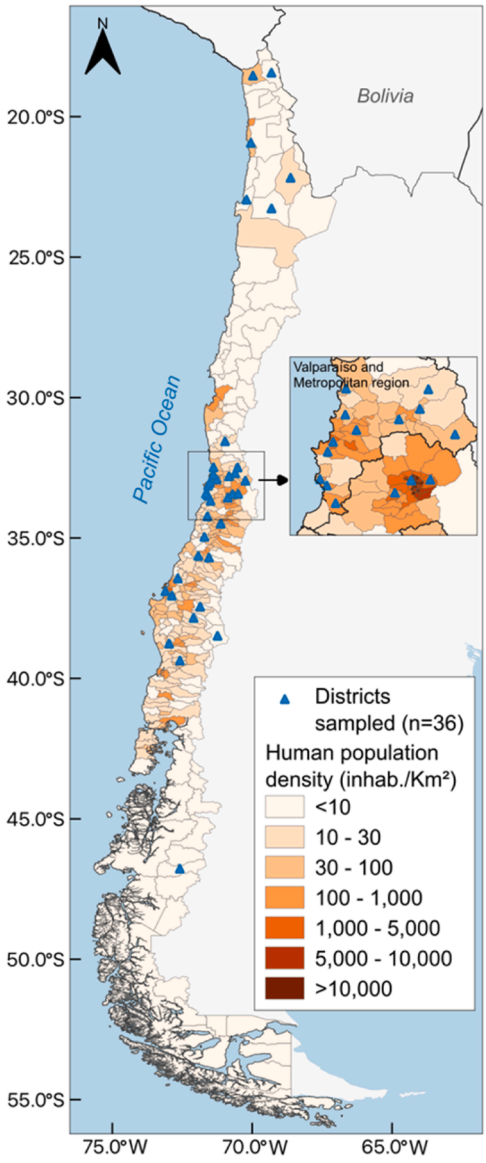

Fig. 1. Chile and the distribution of districts colored by human population density. Blue triangles refer to sampled districts in the study (n = 36).

phones. The respondents were individuals from selected rural and urban areas across the country, aged 18 years or older. Before administering the survey, participants were briefed on the research background, emphasizing the significance of studies in companion animal populations, including possible improvements in public policies and sanitary aspects, as well as on confidentiality and information protection. Subsequently, they digitally signed a consent form, confirming their understanding and acceptance of the collection, storage, and analysis of their responses.

To accommodate time restrictions, respondents provided information on a maximum of 5 dogs and 5 cats. The questionnaire covered various aspects, including demographic details of the respondents and data pertaining to their companion animals, such as sex, age, breed, and health care information, including vaccination, parasite control, and veterinary visits. Additionally, the survey aimed to explore the emotional bond between owners and their companion animals as well as the frequency of preventive veterinary care, and these specific results were analyzed by Salgado-Caxito et al. (2023).

Data confidentiality was maintained throughout the study period. Coordinates of the households were only used for data analysis, reported herein in aggregated form (i.e., by district), and not published or shared with any other parties. The information was meticulously coded and managed using spreadsheets in Excel (Microsoft Corp., Redmond, WA) and R version 4.2.2 (R Core Team, 2020) to ensure accurate and organized data processing. This study was approved by the Research Safety Ethics Committee and by the Social Sciences, Arts, and Humanities Ethics Committee of the Pontificia Universidad Católica de Chile (protocol number: 210922003).

2.3. Statistical analyses

2.3.1. Companion animal characteristics

For both dogs and cats, we estimated the percentage of animals being sterilized, microchipped, registered, and roaming unsupervised, with the corresponding 95% confidence intervals (95% CI), using the BinomCI function (Agresti-Coull method) in the "*DescTools*" package in R (Signorell, 2022). For each variable, an assessment of the significance of the observed differences in the percentages between cats and dogs, sexes within each species, and rural and urban zones, was performed with Pearson's Chi-Squared test using the "*Janitor*" package (Firke, 2023).

2.3.2. Regression modeling for companion animal ownership prediction

Poisson models were initially tested, however, overdispersion was observed. Therefore, we employed two negative binomial models with mixed effects were developed to predict the number of dogs per households (0, 1, 2, 3, 4, ≥5) and number of cats per households (0, 1, 2, 3, 4, ≥5). The included independent variables were zone (urban, rural), type of residence (apartment, other), number of inhabitants in households (numeric), gender (female, male), age (18–30, 31–60, >60 years), and whether there was another species (dog or cat) present in the households (yes, no). All numeric independent variables were scaled and centered to have a mean of 0 and a standard deviation of 1. Null and maximal models were constructed using function glmer.nb in the "*lme4*" package in R. Household and district were included as random effects to account for potential non-independence of observations among companion animals living in the same household. Final models were selected using the Akaike Information Criterion (AIC).

2.4. Extrapolation to population size and density

The size of the owned dog and cat population was estimated employing two methods that have been used in other countries (Acosta-Jamett et al., 2010; Baquero and Queiroz, 2019; Rinzin et al., 2016). These methods consisted of: (1) multiplying the estimated mean number of owned dogs and cats per household in our study by the number of households in the urban and rural areas reported in the last human population Census in Chile, and (2) multiplying the human:dog and human:cat ratios with the total human population. The human:dog and human:cat ratios were estimated as follows: by summing the number of people in all surveyed households for each district, divided by the sum of dogs and cats in all surveyed households for each district. Finally, the average of the sums across the 36 districts was calculated to obtain the final ratio. To eliminate outliers in the human:dog and human:cat ratio variables, the values were visualized using boxplot charts. Then, the Shapiro-Wilk test ($p > 0.05$) was performed to verify the normality of the data distribution. These analyses were performed on the R software (R Core Team, 2020) using the *stats* package. The number of households was obtained from the national census (2017) and the human population was based on the census projection for the same year of our study (2021). For each approach we obtained standard errors of estimators to construct 95% confidence intervals for means. Finally, the density of companion animals was calculated by dividing the estimated number of dogs and cats (according to the human:dog/cat ratio method) by the area (km^2) of each study district. The area corresponding to water bodies, wetlands, ice fields and national parks was subtracted from the

total area of each district because these areas are not inhabited by companion animals. Spatial analyses were conducted using Geographical Information Systems and managed using QGIS 3.24 (QGIS.org, 2023).

3. Results

3.1. Selected districts and households' characteristics

Our survey included 36 districts of the country. After excluding incomplete questionnaires, 6333 (75% urban; 24.7% rural) surveys were considered for the study (Table 1). Respondent characteristics were similar for both urban and rural areas, overall, 68% were female, with similar percentages across age groups, except for those over 60 years (~30%). Additionally, 94% of respondents were Chilean, while people from other nationalities were mainly from Venezuela, Peru, and Bolivia.

According to our survey results, 76% (95% CI 75% – 77%) of households owned dogs and/or cats (Table 2). Dogs were the most frequently reported owned species with 65% of households owning at least one dog, compared to 31% of households that owning at least one cat. The percentage of companion animal-owning households was higher in rural than in urban areas, a pattern consistent for both species. Most households have one (54%) or two dogs (27%) and, one (59%) or two cats (23%). The human:dog (3.1:1, 95% CI 2.8:1 – 3.3:1) and human:cat (6.9: 1,95% CI 6.3:1 – 7.7:1) ratios were higher in urban areas (human:dog and human:cat ratios of 2.3:1 (95% CI 2.1:1 – 2.5:1) and 5.4:1 (95% CI 4.8:1 – 6.1:1), in rural areas respectively). These results indicate a higher number of companion animals per person in rural areas compared to urban areas. In addition, human:animal ratios varied greatly across districts. Estimations for dogs varied between 1.7 and 4.8 in urban areas and between 1.1 and 3.6 in urban areas. For cats, ratios ranged from 4.4 to 11.1 in urban areas and 1.9–10.5 for rural areas. The data and results obtained for each district are given as Supplementary Material 2, including information about the district where conducting fieldwork in rural areas was not possible.

3.2. Companion animal characteristics

Data from 10,658 companion animals was obtained. Dogs were the most frequently reported owned species (68%; n = 7280) compared to cats (32%; n = 3378). Among the reported dogs, 54% were male, 61% were adults, and 35% belonged to specific breeds. For cats, 54% were female, and 64% were adults (Table 3). Parasite control, vaccination, veterinary visits, and the reasons for owning a companion animal were included in Salgado-Caxito et al. (2023).

Table 1
Characteristics of respondents.

	Urban n (%)	Rural n (%)	Overall n (%)
Number of surveys	4771 (75.3)	1562 (24.7)	6333 (100)
Gender			
Female	3211 (67.6)	1056 (67.6)	4267(67.6)
Male	1535 (32.3)	505 (32.4)	2040 (32.3)
Other	6 (0.1)	0 (0)	6 (0.1)
Age			
18 – 30	747 (15.9)	258 (17.0)	1007 (16.1)
30 – 40	782 (16.7)	250 (16.5)	1036 (16.6)
41 – 50	813 (17.3)	280 (18.5)	1100 (17.6)
51 – 60	871 (18.6)	287 (18.5)	1167 (18.7)
> 60	1475 (31.5)	440 (29.0)	1928 (30.9)
Country			
Chile	4539 (95.1)	1504 (96.3)	6043 (95.4)
Other[a]	232 (4.9)	58 (3.7)	290 (4.7)
Type of residence			
House	4622 (97.4)	1492 (95.9)	6114 (97.1)
Other[b]	121 (2.6)	63 (4.1)	184 (2.9)

[a]Other: Venezuela, Peru, Bolivia, others. [b]Other: apartment, shack, and other.

Table 2
Estimated dog and cat ownership in households in urban and rural areas of Chile.

	Urban (95% CI)	Rural (95% CI)	Overall (95% CI)
Pet-owning households (n)	3505	1296	4801
Pet-owning households (%)	73.5 (72.3–74.8)	83.0 (81.1–84.9)	75.8 (74.8–76.9)
Number of dogs	5134	2146	7280
Households owning dogs (%)	62.4 (61.0–63.8)	73.9 (71.8–76.2)	65.3 (64.1–66.5)
Households owning 1 dog (%)	55.4 (53.6–57.2)	51.8 (48.9–54.7)	54.2 (52.7–55.8)
Households owning 2 dogs (%)	27.4 (25.8–29)	25.8 (23.3–28.3)	27.0 (25.6–28.3)
Households owning 3 dogs (%)	9.7 (8.6–10.7)	11.9 (10.1–13.8)	10.3 (9.4–11.2)
Households owning 4 dogs (%)	4.3 (3.6–5.1)	5.8 (4.5–7.1)	4.7 (4.0–5.3)
Households owning ≥5 dogs (%)	3.2 (2.5–3.8)	4.7 (3.5–5.9)	3.5 (3.0–4.1)
Dogs owned per dog-owning household (*Mean*)	1.7 (1.7–1.8)	1.8 (1.7–1.9)	1.8 (1.7–1.8)
Dogs owned per household (*Mean*)	1.1 (1.0–1.1)	1.4 (1.3–1.4)	1.2 (1.1–1.2)
Dogs owned per household (*Mean, range*)	1 (0–5)	1 (0–5)	1 (0–5)
Human:dog ratio*	3.1:1 (2.8:1–3.3:1)	2.3:1 (2.1:1–2.5:1)	2.7:1 (2.5:1–2.9:1)
Number of cats	2484	894	3378
Households owning cats (%)	29.8 (28.5–31.1)	35.0 (32.6–37.4)	31.1 (30.0–32.2)
Households owning 1 cat (%)	58 (55.4–60.5)	62.6 (58.6–66–7)	59.3 (57.1–61.4)
Households owning 2 cats (%)	23.6 (21.4–25.8)	21.1 (17.6–24.5)	22.8 (21.0–24.7)
Households owning 3 cats (%)	8.8 (7.3–10.3)	9.3 (6.9–11.8)	8.9 (7.6–10.1)
Households owning 4 cats (%)	4.7 (3.6–5.8)	3.8 (2.2–5.5)	4.5 (3.6–5.4)
Households owning ≥5 cats (%)	4.9 (3.7–5.9)	3.1 (1.7–4.6)	4.3 (3.4–5.2)
Cats owned per cat-owning household (*Mean*)	1.7 (1.7–1.8)	1.6 (1.6–1.7)	1.7 (1.7–1.8)
Cats owned per household (*Mean*)	0.5 (0.5–0.6)	0.6 (0.5–0.6)	0.5 (0.5–0.6)
Cats owned per household (*Mean, range*)	0 (0–5)	0 (0–5)	0 (0–5)
Human:cat ratio*	6.9:1 (6.3:1–7.7:1)	5.4:1 (4.8:1–6.1:1)	6.2:1 (5.6:1–6.9:1)

* Human:dog and human:cat ratios are the means of the ratios across districts, and the overall is the sum of urban and rural ratios.

3.3. Sterilization, microchipping, registration, and unsupervised roaming

Sterilization, microchipping, registration and unsupervised roaming in the owned dog and cat population are shown in Table 4 and Fig. 2. Sterilization was higher in cats compared to dogs and varied between sexes for both species. In both dogs and cats, the percentage of females spayed was higher than males neutered. The sterilization in urban areas was also higher than in rural areas. These differences were statistically significant ($p < 0.001$) (Table 4).

The percentage of animals with both microchipped and registration were 32% for dogs and 18% for cats. Nevertheless, percentages were slightly higher for microchipping, showing that in some cases the animal is not registered in the national pet and companion animal registry.

Microchipping and registration were higher for dogs compared to cats. Microchipping in dogs was 48% for females, significantly higher than males which was 39% ($p < 0.001$) (Table 4). A similar pattern was found in cats with 27% of females and 23% of males microchipped ($p=0.004$). Registration in female dogs, was 43% compared to the 34% in males ($p < 0.001$). In cats the difference between sexes was smaller

Table 3
Number (%) of companion animals by sex, age, and breed.

Companion animals	Number (n) 10658	Percentage (%) 100
Dogs	**7335**	**68.3**
Sex		
Female	3335	45.5
Male	3964	54.0
NA*	36	0.5
Age		
<1	917	12.5
1–7	4500	61.3
>8	1642	22.4
NA	276	3.8
Breed		
Pure	2544	34.7
Mixed	4150	56.6
NA	641	8.7
Cats	**3394**	**31.7**
Sex		
Female	1847	54.4
Male	1490	43.9
NA	57	1.7
Age		
<1	761	22.4
1–7	2169	63.9
>8	357	10.5
NA	107	3.2
Breed		
Pure	93	2.7
Mixed	1224	36.1
NA	2077	61.2

* N/A: Refers to the proportion of informants that did not know or chose not to answer.

with 23% of females and 19% of males registered (p = 0.006). Microchipping and registration in urban areas was significantly higher than in rural areas.

Owned animals that were allowed to roam unsupervised was higher in cats compared to dogs. Differences between rural and urban areas were not statistically significant (Table 4). The percentage of unsupervised cats was 21% in rural areas, and 21% in urban (p=0.8), while unsupervised dogs were 14% in rural areas, and 12% in urban (p=0.09). Of the animals that roam unsupervised 37% of dogs and 52% of cats were sterilized.

3.4. Regression modeling for companion animal ownership prediction

The odds of having a higher number of dogs per household are higher in rural areas compared to urban areas (OR=1.2), in houses compared to other type of residence (OR=1.5) and increase with the number of inhabitants in households (OR=1.2). Conversely, is lower in ages >31 years compared to the 18–30 years group (OR=0.9) and when there is at least one cat present in the household compared to households with no cats (OR=0.9) (Table 5). Similarly, the odds of having a higher number of cats per household are higher in rural areas compared to urban areas (OR=1.3), in houses compared to other type of residence (OR=1.8), increase with the number of inhabitants in households (OR=1.2) and for female gender compared to male gender (OR=1.4), Additionally, is lower when there is at least one dog present in the household compared to households with no dogs (OR=0.8) and in the group aged >60 years compares to the 18–30 age group (OR=0.8) (Table 6).

3.5. Extrapolation of owned dog and cat populations at the country-level

The estimated owned companion animal population in Chile was either 9.6 or 10.7 million, depending on the employed methodological approach (Table 7). The estimation based on the number of households (Method 1) provided the largest estimate of 7252,069 (95% CI = 7005,976 - 7517,807) dogs and 3426,964 (95% CI = 3207,287 – 3634,996) cats, representing 82% and 84% of dogs and cats in urban areas, respectively. By contrast, the lowest estimation was provided by the method based on the human:dog and human:cat ratios (Method 2) that provided an estimation of 6633,873 (95% CI = 6124,302 - 7235,960) dogs and 2943,635 (95% CI = 2640,915 - 3221,420) cats. These representing 85% and 86% of dogs and cats in urban areas, respectively.

Table 4
Percentage of sterilization, microchipping, registration, and unsupervised roaming animals segregated by species and sex.

	Dog (n = 7280)	p-value	Cat (n = 3378)	p-value
Sterilization	38.7 (37.5–39.8)		58.8 (57.2–60.5)	<0.001
Sex				
Male	21.2 (19.9–22.5)	<0.001	47.6 (45.1–50.2)	<0.001
Female	59.3 (57.6–60.9)		67.9 (65.7–69.9)	
Zone				
Rural	31.6 (29.6–33.5)	<0.001	38.7 (35.4–41.9)	<0.001
Urban	41.6 (40.2–42.9)		65.5 (63.6–67.4)	
Microchipped	43.1 (41.9–44.2)		25.3 (23.8–26.9)	<0.001
Sex				
Male	39 (37.5–40.6)	<0.001	22.7 (20.6–25)	0.004
Female	47.8 (46.1–49.6)		27.4 (25.3–29.5)	
Zone				
Rural	36.1 (34.1–38.3)	<0.001	18.5 (15.9–21.2)	<0.001
Urban	45.9 (44.5–47.3)		27.5 (25.7–29.4)	
Registered	38.1 (36.9–39.3)		21.2 (19.8–22.7)	<0.001
Sex				
Male	34.3 (32.8–35.9)	<0.001	18.8 (16.8–21)	0.006
Female	42.6 (40.8–44.4)		23.1 (21.1–25.2)	
Zone				
Rural	30.8 (28.7–32.8)	<0.001	15.6 (13.1–18.1)	<0.001
Urban	41.2 (39.8–42.7)		23.1 (21.3–24.9)	
Unsupervised roaming	12.9 (12.1–13.6)		20.9 (19.6–22.4)	
Sex				
Male	14.03 (12.9–15.1)	0.001	23.3 (21.2–25.5)	0.002
Female	11.45 (10.4–12.5)		18.9 (17.2–20.7)	
Zone				
Rural	13.9 (12.5–15.4)	0.09	20.5 (18–23.4)	0.8
Urban	12.4 (11.5–13.3)		21 (19.5–22.7)	

3.6. Density of owned dogs and cats

Median companion animal density in the country was estimated to be 12 dogs per km^2 (mean = 342), ranging from 0.02 to 7232 dogs per km^2 for the different districts and 5 cats per km^2 (mean = 153), ranging from 0.01 to 3242 cats per km^2 for the different districts. All districts

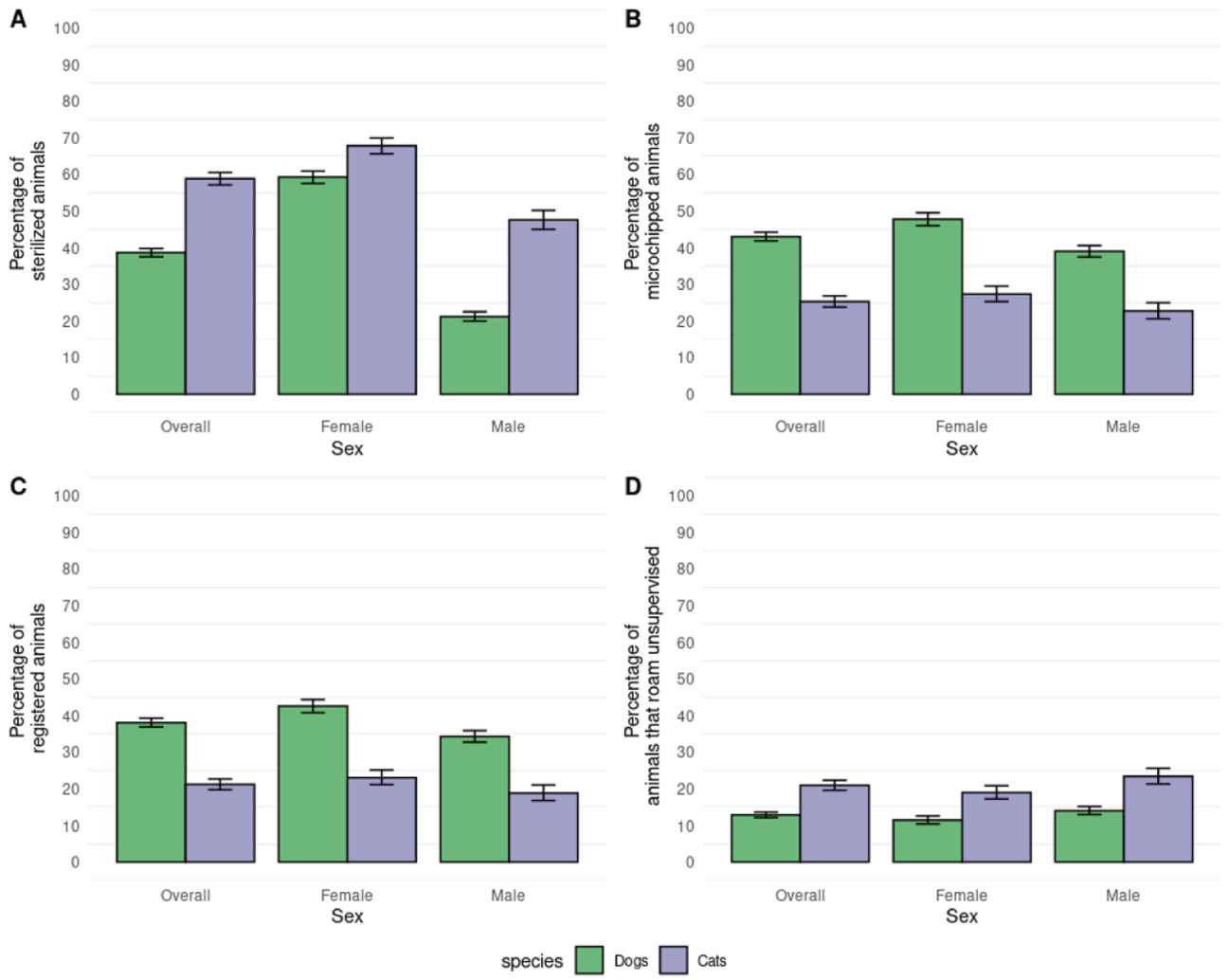

Fig. 2. A. Percentage of sterilized animals, segregated by species and sex. B. Percentage of microchipped animals, segregated by species and sex. C. Percentage of registered animals segregated by species and sex. D. Percentage of animals that roam unsupervised, segregated by species and sex. Data represent percentage ± 95% CI.

Table 5
The final negative binomial model for factors associated with dog ownership. AIC of the null model: 36812. AIC of the maximal model: 34717. AIC of the final model: 34717.

Variable	OR (CI 95%)	p-value
Zone		
Urban	-	-
Rural	1.24 (1.15–1.33)	<0.001
Type of residence		
Other	-	-
House	1.54 (1.28–1.86)	<0.001
Inhabitants in households (n)	1.15 (1.12–1.18)	<0.001
Cat ownership		
No	-	-
Yes	0.86 (0.83–0.89)	<0.001
Age		
18–30 years	-	-
31–60 years	0.93 (0.86–0.99)	0.033
60+ years	0.84 (0.78–0.91)	<0.001
Gender		
Male	-	-
Female	1.05 (0.99–1.10)	0.12

Table 6
The final negative binomial model for factors associated with cat ownership. AIC of the null model: 26145. AIC of the maximal model: 24647. AIC of the final model: 24647.

Variable	OR (CI 95%)	p-value
Zone		
Urban	-	-
Rural	1.30 (1.11–1.53)	0.002
Type of residence		
Other	-	-
House	1.75 (1.18–2.59)	0.005
Inhabitants in households (n)	1.15 (1.09–1.22)	<0.001
Dog ownership		
No	-	-
Yes	0.84 (0.80–0.87)	<0.001
Age		
18–30 years	-	-
31–60 years	0.90 (0.77–1.05)	0.18
60+ years	0.76 (0.64–0.90)	0.001
Gender		
Male	-	-
Female	1.36 (1.21–1.54)	<0.001

Table 7
Estimated number of owned dogs and cats in Chile based on two methods.

National Statistics	Urban (n)	(95% CI)	Rural (n)	(95% CI)	Overall[c] (n)	(95% CI)
Number of households[a]	5,523,639		962,894		6,486,533	
Human population[b]	17,430,714		2,247,649		19,678,363	
Estimated owned dog population						
Method 1	5,933,484	5,744,585–6,131,239	1,318,585	1,261,391–1,386,567	7,252,069	7,005,976–7,517,806
Method 2	5,645,347	5,209,284–6,161,085	988,526	915,019–1,074,876	6,633,873	6,124,302–7,235,960
Estimated owned cat population						
Method 1	2,875,858	2,706,583–3,038,001	551,106	500,705–596,994	3,426,964	3,207,287–3,634,996
Method 2	2,530,865	2,269,845–2,756,392	412,770	371,070–465,029	2,943,635	2,640,915–3,221,420
Estimated owned cat and dog population						
Method 1	8,809,342	8,451,168–9,169,241	1,869,691	1,762,096–1,983,562	10,679,033	10,213,264–11,152,802
Method 2	8,176,212	7,463,520–8,917,476	1,401,296	1,286,089–1,539,904	9,577,508	8,749,609–10,457,381

[a] Obtained from the national census (2017). [b] Obtained from human population projection in 2021. [c] Overall is the sum of urban and rural areas estimations. Method 1: multiply the estimated mean number of owned dogs and cats per household in our study by the number of households in the urban and rural areas reported in the last human population Census. Method 2: multiply the human:dog and human:cat ratios with the total human population.

with over 1000 dogs or cats per km^2 (n = 30 and n = 20, respectively) belonged to the Metropolitan region while lowest densities for both dogs and cats were observed in the districts of southern regions (Aysén and Magallanes) (Fig. 3).

4. Discussion

Estimations of dog and cat populations at the national level are crucial for managing companion animal populations, preventing adverse effects for themselves, humans, and wildlife. We report the first study providing a large spatial scale and up-to-date rigorous analysis on the size and density of the canine and feline populations in Chile. We also assessed the status of companion animal registration, microchipping, sterilization rates and roaming. Our results provide important insights into the scale of companion animal ownership in the country, supporting the development of evidence-based strategies to control companion animal populations and strengthen educational programs.

The results of our survey suggest that Chile has one of the highest percentages of households owning companion animals (76%) including Brazil (44%), Mexico (56%), and Uruguay (72%) (Baquero and Queiroz, 2019; Junqueira and Galera, 2019; Ministerio de Ganadería Agricultura y Pesca, 2017). Dogs were the most common species in Chile (65%) compared to cats (31%). For dogs, estimates for householders were similar to Uruguay (67%) and Perú (62%), lower than Costa Rica (76%), and higher than Brazil (44%), and Mexico (49%) (Baquero and Queiroz, 2019; Flockhart et al., 2022; Ministerio de Ganadería Agricultura y Pesca, 2017; Peña-Corona et al., 2022; Rendón et al., 2018). The proportion of households owning cats was similar to Uruguay (28%), but higher than Mexico (7.5%) and Brazil (18%) (Junqueira and Galera, 2019; Ministerio de Ganadería Agricultura y Pesca, 2017; Peña-Corona et al., 2022). Compared to high-income countries in the Northern Hemisphere, the percentages of companion animal ownership are lower than in Chile for dogs and close for cats. In the U.S. is higher for dogs (45%) than for cats (26%), whereas in European countries, the proportions for dogs (25%) and cats (26%) are similar (American Veterinary Medical Association, 2022; European Pet Food Industry Federation, 2023).

The high percentage of companion animals in Chilean households could be due to different reasons, including human population growth, the reduction of birth rate, and the increase in living costs (Acosta-Jamett, 2015; Guo et al., 2021; Wu et al., 2018). Several studies have identified factors associated with companion animal ownership. Individuals residing in rural households are more likely to own dogs and/or cats, possibly due to the less restrictive outdoor space limitations, and also in multi-person households, consistent with reports in similar studies (Downes et al., 2009; Flockhart et al., 2022). Conversely, women may be more likely to own cats compared with men, and individuals over 30 years of age are less likely to own dogs, while those over 60 years of age are less likely to own cats when compared to the 18–30 age group. Our results reflect the fact that companion animal ownership is a socio-cultural aspect, which should be considered in the design and implementation of intervention strategies with a more comprehensive territorial perspective, including animal welfare, veterinary services, and companion animal-related industries.

Our study identified spatial heterogeneities in the human:dog and human:cat ratios between districts and rural and urban areas, similar to studies conducted in other Latin American countries. For instance, Junqueira and Galera (2019) demonstrated wide contrasts across the 26 states of Brazil, between species (human:dog 3.8:1; human:cat 9.1:1) and between rural and urban areas. Peña-Corona et al. (2022) reported a human:cat ratio that varied from 11:1–31.4:1, but slightly differences in the human:dog ratios across 32 states in Mexico. Additionally, several studies conducted in different sectors of Lima (Peru) reported human:dog ratios ranging from 1:3.9–1:7 (Arauco et al., 2015; Rendón et al., 2018; Soriano et al., 2017). In Chile, Silva-Rodríguez et al. (2023) reported a human:dog ratio of 1.3 in rural areas and 2.9 in urban areas in the Los Rios region (Southern Chile). Ávila Ponce (2021) estimated a human:dog ratio of 1.5:1 and a human:cat ratio of 3.2:1 in Coya, a small urban area in O'Higgins region. Other past studies reported similar variations, Astorga et al. (2022) estimated a human:dog ratio of 1.5:1 (0.1:1–8:1) in 2012 in twelve localities of Paine (Metropolitan region, central Chile), Villatoro et al. (2016) in 2013–2014 reported a human:dog ratio of 1.3 in Los Rios region, and Acosta-Jamett et al. (2010) reported a human:dog ratio from 5.2 to 6.2 in cities and 1.1–5.3 in towns and rural areas in Coquimbo region (northern Chile). These studies indicate that the human:animal ratio is increasingly close to 1:1, especially in dogs, which would mean that the human and animal populations are growing similarly over time, as suggested by (Acosta-Jamett, 2015). Nevertheless, deriving global conclusions from studies conducted in different periods can introduce biases attributed to economic and social factors. Therefore, the simultaneity of our study reduces this bias by performing all estimates in the same period.

The number of companion animals estimated based on the number of households was 10.7 million, while the estimate based on the human:dog and human:cat ratios was 9.6 million. This is much higher than the latest update of animals registered in the National Pet Register and Companion Animals, which was 2.3 million (Subsecretaría de Desarrollo Regional y Administrativo., 2023). The former estimate may have been influenced by the 2017 housing figures, whereas the human:dog and human:cat ratios were estimated based on population projections for the same study year. Therefore, utilizing figures based on human:dog/cat ratios to estimate the companion animal population may offer a more dependable approach. Our results indicate that Central Chile exhibits the highest densities of dogs and cats in the country, aligning with the observations made by Astorga et al. (2015). The concentration of companion animals in densely populated urban areas of Chile is largely attributed to the high number of households(Acosta-Jamett et al., 2010; Astorga et al., 2015), a trend similar to that observed in Great Britain

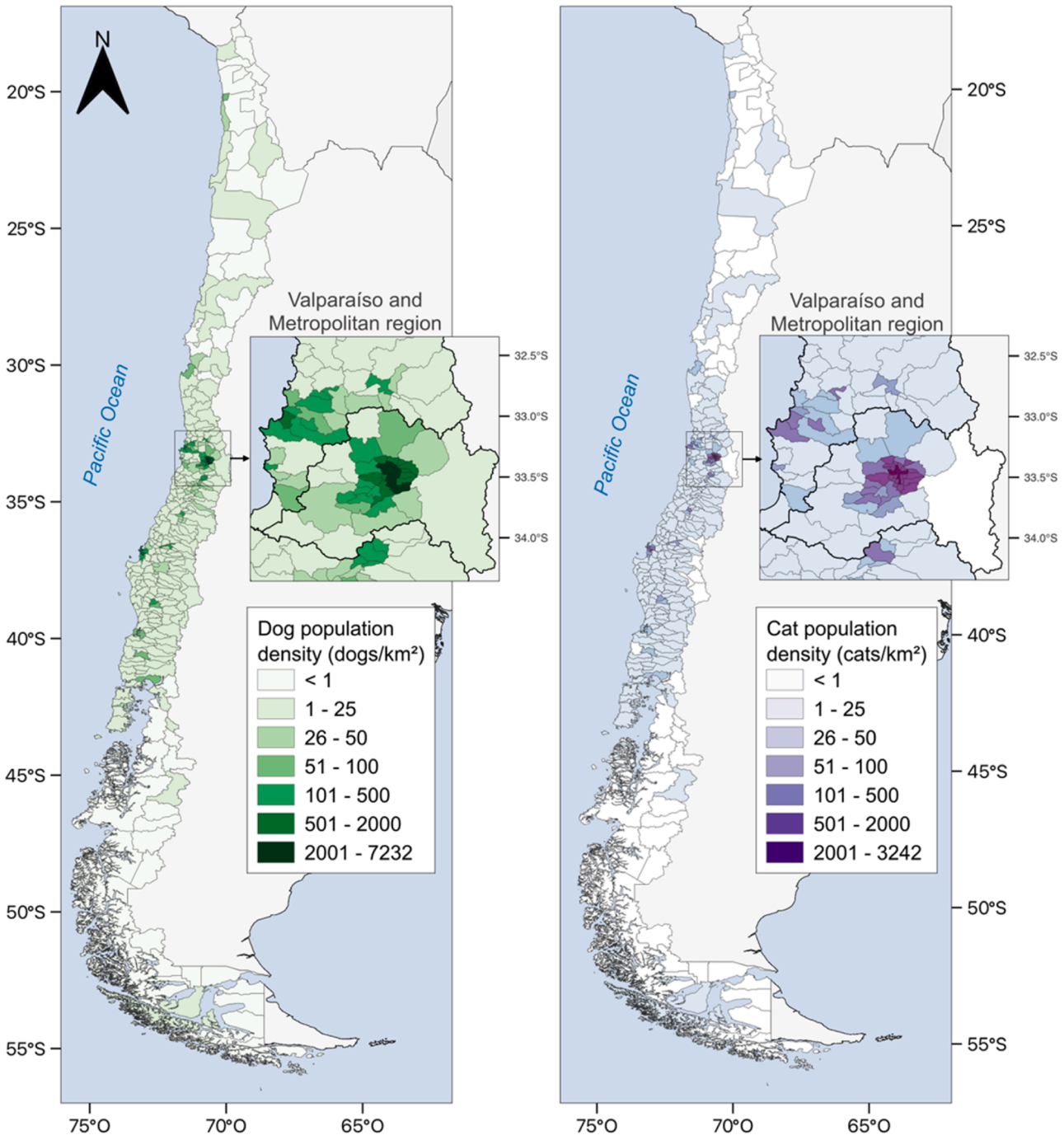

Fig. 3. Estimated density of owned dogs and cats in Chile.

(Aegerter et al., 2017).

The high rate of companion animal ownership in our study could be explained by the strong bonds between people and their companion animals in Chile (> 93% of companion animals were reported as family members) (Salgado-Caxito et al., 2023). Similar results have been reported in studies in New Zealand and the United Kingdom (Bouma et al., 2021; Gates et al., 2019), and is one of the key areas of One Health regarding companion animal, according to the World Small Animal Veterinary Association One Health Committee. Additionally, the COVID-19 pandemic's social isolation measures may have played a role in the surge of adoptions and purchases of companion animals, as people sought companionship during challenging times, leading to an increase in the number of households with companion animals and a strengthening of emotional bonds with their companion animals (Ho et al., 2021; Kogan et al., 2021; Packer et al., 2021).

Our survey highlighted a disparity in sterilization rates between cats (57%) and dogs (38%), with females in both species being sterilized more frequently than males. Sterilization rates in Chile, recently classified as a high-income country, are notably lower than equally classified countries such as New Zealand (97% in cats and 87% in dogs) and the United States (82% for cats and 64% for dogs) (Forrest et al., 2023; Trevejo et al., 2011). This indicates a pressing need for bolstering sterilization efforts and educational programs to address this imbalance. Our survey did not inquire about the reasons for sterilizing their animals, however, previous studies have shed light on factors influencing companion animal owners' enabling attitudes towards spaying or

neutering, including the desire to control unwanted behaviors (e.g., fighting), and reproduction control. Alternatively, disabling perceptions in the decision to neuter or spay involve concerns about animal health, sociodemographic aspects such as socioeconomic level, and rural residency related to costs and access to veterinary care (Downes et al., 2015; Forrest et al., 2023; McKay et al., 2009). In fact, in Chile the cost of sterilization can vary greatly, for instance, for male dogs rages from ~$24 USD to ~$330 USD, and for male cats from ~$17 USD to ~$280 USD (Servicio Nacional del Consumidor., 2022). These differences in costs could explain the higher sterilization rates of cats compared to dogs, and these costs may differ based on the sex and location. Additionally, it is worth noting that the impact of the COVID-19 pandemic has led to a decrease in sterilization procedures due to a delay in elective spay-neutered surgeries, reaching −80% in the US and −28% in the UK and the Republic of Ireland (Guerios et al., 2022; Owczarczak-Garstecka et al., 2022). In Chile, the provision of all veterinary and educational services provided by the PTRAC were initially suspended due to the COVID-19 pandemic and subsequently carried out with preventive measures. These extensive lags could jeopardize the effectiveness of these programs which are critically important as a large fraction of the population depends on them.

Regarding microchipped and registered companion animals, only 32% of dogs and 18% of cats' owners obey both criteria, nevertheless, the number of microchipped animals was higher than registered for both species (40% of dogs and 23% of cats microchipped; 34% of dogs and 19% of cats registered), a low number considering that it is mandated by the Law 21,020. This practice could occur because some owners do not complete the web registration process (or make mistakes that they do not correct), or because they do not have access or knowledge to perform the web registration. Also, it is important to mention the possibility that owners may confuse the official registry with private or municipal registries (e.g., Pet Civil Registration, Zoodata, etc.). There is a notable lack of knowledge among owners regarding the responsibilities mandated by the law, as evidenced in other studies (Forrest et al., 2023; Keogh et al., 2022).

The proportion of unsupervised roam cats was higher than dogs, probably associated with their common use for rodent control (López-Jara et al., 2021). However, this may pose serious threats to wildlife, as also observed for dogs (Hughes and Macdonald, 2013; Villatoro et al., 2019). Previous studies have estimated free roaming proportion using different definitions, thus results are not comparable to our study, such as the 92% reported by Sepulveda et al. (2014), the 87% reported by Villatoro et al. (2019), the 62% by Silva-Rodríguez et al. (2023) in rural areas of the country, or the 37% by Astorga et al. (2022). However, it is important to consider that regarding this type of question, it is possible that dog or cat owners provide responses according to what is "expected", an inherent bias in face-to-face interviews, therefore our result may be underestimated.

It is crucial to consider the interactions between owned and unowned animal populations, both are susceptible to injuries, and disease transmission and pose public health threats through bites (Barrios et al., 2021; Benavides et al., 2019). Unsupervised roaming, particularly in unsterilized animals, may be an important source of free-roaming animals (Makenov and Bekova, 2016). Owning dogs and allowing them to roam (Astorga et al., 2015; Silva-Rodríguez et al., 2023), and abandoning owned animals (Mota-Rojas et al., 2021; Santos Baquero et al., 2016), trigger by aggressiveness, sickness, behavioral problems, moving to another home, lack of space, among others, could be among the most important factors explaining free-roaming dog abundance. Therefore, preventing roaming and abandonment might be the best strategy to reduce the unowned-animal population size (Baquero et al., 2020; Smith et al., 2022). Our results suggest that roaming in owned animals was more frequent in males for both species, precisely in the sex with lower sterilization rates. As in Silva-Rodríguez et al. (2023) and Baquero et al. (2020), we suggest that strategies should focus on companion animal owners, especially in sterilization, education, and enforcement of Law 21,020 about keeping companion animals inside properties.

The extensive and representative sample size of our study, encompassing various regions throughout the country, enhances the reliability and robustness of the results. Additionally, the simultaneous data collection across different sectors helped to minimize variations due to external factors such as changes in economic conditions, weather, or societal events, contributing to a more comprehensive and accurate assessment of the companion animal population dynamics in Chile. However, our study encountered some limitations that need to be considered when interpreting the results. Firstly, the data was solely available for urban areas in some districts, as data collection in rural areas was not feasible giving logistical constraints. Secondly, due to time constraints and practical considerations, respondents were limited to providing information on a maximum of 5 dogs and 5 cats. This limitation may have led owners to prioritize reporting their companion animals based on the level of care and attention they received. Nevertheless, our data suggest that the potential impact of this bias on our overall findings may be relatively minor, as the mean and median number of companion animals per household is close to 1 for both species. Addressing this bias is crucial in future studies, either considering all animals per household or randomizing and applying the survey to one or a certain number of animals. Furthermore, social isolation measures imposed during the COVID-19 pandemic could have led to increased interest in companion animal adoptions, as well as a decrease in veterinary care.

5. Conclusions

This study represents a significant milestone in estimating the nationwide companion animal population in Chile, providing valuable insights for policymakers and stakeholders. The collaborative effort among academia, the public sector, and district authorities highlights the importance of interdisciplinary and multisectoral approaches to tackle complex issues like companion animal population management. We strongly advocate for the regular conduction of such estimations on a periodic basis, either as standalone studies or by incorporating key animal companion ownership questions into the Census of Population and Household, the Socioeconomic Characterization Survey, or the National Health Survey. This would facilitate continuous monitoring and enable data-driven decision-making for effective companion animal population management strategies. Our results would improve ongoing policies by defining practical implications for the design and implementation of intervention strategies with a more comprehensive territorial perspective, particularly for sterilization and microchipping and registration, for example, by emphasizing the need to enhance male sterilization rates in both cats and dogs. Therefore, investing in further research and data collection efforts will be essential in evaluating and planning the long-term impact of such programs effectively.

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Declaration of Competing Interest

The authors report no declarations of interest.

Data Availability

The raw data presented in this study are available on request from the SUBDERE via the Transparency Portal of the Chilean Government (http://www.portaltransparencia.cl/).

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2024.106185.

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