

RESEARCH ARTICLE

Distribution Patterns and Relative Abundance of *Lycalopex Gymnocercus* Fisher, 1814 in Southern Santa Fe Province, Argentina

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Received: 25 July 2023 Accepted: 07 August 2023 Published: 30 August 2023

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Abstract

The study of species diversity has become relevant due to human activities that can modify it. In Argentina, the expansion of agriculture and population growth have altered the environments of the Pampas, affecting fauna such as the gray fox. This species has historically been persecuted by hunting and conflicts with human activities, but shows adaptability to modified environments. It is native to Argentina, but was also introduced in the Falkland Islands and Tierra del Fuego. Its distribution covers a large part of Argentina and neighboring countries. In the province of Santa Fe, studies were carried out to determine its presence, distribution and habitat preference. Traces were found in xerophytic forests, halophytic communities and farmland. Presence was higher in spring and summer. Records were found both near water bodies and roads and at significant distances from them. Xerophytic forests and halophilic communities showed a higher relative abundance than croplands. The data obtained in this study contribute to the understanding of the distribution and abundance of this species in its wide range of habitats, which is essential for its conservation and the preservation of biodiversity in the ecosystems they occupy. However, it is suggested that urbanization and other factors could be affecting the species. It is important to continue monitoring and analyzing these factors for proper management of the fox population and its habitat.

Keywords: Argentina, Ecology, Mammals, Santa Fe.

1. Introduction

Species diversity is an essential component of ecosystems and plays a fundamental role in the functioning and stability of biological communities. Community ecology and conservation biology have placed increasing emphasis on the study of species diversity due to concerns about its alteration and loss, mainly as a result of human activities [1]. In highly anthropized regions such as the Pampas region of Argentina, the expansion of agricultural and livestock production has led to significant changes in natural ecosystems, which directly impacts local fauna.

In Argentina, the growing demand for land for agricultural production, together with the effects of population growth, have been important factors in the alteration of the environments typical of the Pampas region. In terms of extension, the Pampas are the most important grassland ecosystem in this country, and cover a total of 540,000 km² [2], occupying the provinces of Buenos Aires (except for the extreme south), northeastern La Pampa and southern Córdoba, Santa Fe and Entre Ríos.

At present, the Pampean grassland biomes are those that have undergone the greatest changes due to human

Citation: Pablo Guillermo Rimoldi. Distribution Patterns and Relative Abundance of *Lycalopex Gymnocercus* Fisher, 1814 in Southern Santa Fe Province, Argentina. *Journal of Zoological Research*. 2023;5(1): 1-7.

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intervention through the development of agricultural and livestock activities [3], with natural remnants remaining in areas with serious impediments to agriculture.

Agricultural activity brings with it a series of transformations that affect practically all ecological processes, from the behavior of individuals and population dynamics to the composition and structure of communities and the flow of matter and energy.

Within the fauna, mammals present different levels of sensitivity to these alterations, depending on their space requirements, feeding needs, and behaviors in the face of changes in the landscape resulting from anthropization [4].

The gray fox is a species that is widespread throughout its distribution range. Although it has been historically persecuted due to hunting for its fur and conflicts with productive human activities, this species shows a remarkable ability to adapt to environments modified by human activity and appears to have a strong population resilience [5].

It is a native species of the continental area of Argentina, which is widely distributed in most of its provinces. However, it has also been deliberately introduced into other regions. In 1928, it was introduced in the Falkland Islands in order to diversify the local economy through potential fur exploitation and to control the population of the common cauquén (*Chloephaga picta*), a species considered a competitor for pastoral resources and a destroyer of tussock (*Poa flabellata*) formations. Currently, gray fox populations persist in the Falkland Islands and are considered pests due to their negative impacts on the island ecosystem.

Additionally, in the 1950s, gray foxes were introduced to Isla Grande de Tierra del Fuego in order to use them as biological control agents to reduce the population of exotic rabbits (*Oryctolagus cuniculus*). This measure resulted in the successful establishment of the gray fox on the island, extending its distribution almost entirely throughout Isla Grande de Tierra del Fuego and even on nearby islands such as Gable Island. It has been observed that the gray fox competes with the native Fuegian red fox (*Lycalopex culpaeus lycoides*), which raises concerns about possible impacts on the population of the native species.

Overall, the known distributions of *L. gymnocercus* and *L. griseus* cover practically the entire national territory of Argentina, with the exception of the high Andean regions and dense forested areas, such as the

Valdivian and Subantarctic Forests, the Paranaense Forest and the lower strata of the Yungas. In addition, the distribution extends northward, encompassing areas in central and eastern Bolivia, Paraguay, Uruguay and southeastern Brazil [5].

In the south of the province of Santa Fe, although its presence is known, there are no studies at a low scale that allow us to generate explanatory hypotheses regarding the distribution patterns of this species in one of the most anthropized areas of the planet, as is the study area in this research.

The objective of this contribution is to present new records of presence, distribution patterns and habitat preference for the pampas gray fox *Lycalopex gymnocercus* Fisher, 1814.

2. Materials and Method

2.1 Study Area

The area corresponds to the Carcarañá river basin in the province of Santa Fe, which is bordered to the west by the province of Córdoba and to the east by the Paraná river. It covers an area of 4,575 km² and is located between 32°26' and 33°20' S and 62°04' and 60°36' W. This area is part of the Belgrano and Iriondo departments, to the north of the Carcarañá River; and Caseros, San Lorenzo and General López to the south of it. Average annual temperatures range between 14 °C and 20 °C, with most of the precipitation concentrated in spring and summer. Annual precipitation over the region averages 970 mm and is distributed by isohyets with a north-south orientation, with the maximum in the eastern region and the minimum to the west [6].

2.2 Selection of Sampling Sites

Five sampling zones were established within the basin (distant from each other by 50 km), both on the banks of the Carcarañá river and its tributaries. Each zone for this work took the name of the nearest locality as a reference. Thus, the names were established for each sampling zone as follows: 1-Oliveros Zone (ZO) (32°34'30 "S, 60°54'11 "W), 2-Berreta Zone (ZB) (32°53'48 "S, 61°16'24 "W), 3-Villa Eloísa Zone (ZVE) (33°01'54 "S, 61°42'45 "W), 4-Zona Berabevú (ZBe) (33°21'09 "S, 61°51'09 "W) and 5-Zona Montes de Oca (ZMO) (32°35'22 "S, 61°50'37 "W) (Fig. 1). These sectors were defined with the objective of obtaining a good representation of the total extension of the basin, taking into account that all the existing environmental units in the study

area are represented. Based on this, three 3 km long transects were established in each study zone, taking into account that the first one is located on the river/tributary margin, while the remaining ones are parallel

to it with a distance of 5 and 10 km respectively (Fig. 1). Thus, the methodology used was based on standardized line transects in search of signs of activity [7].

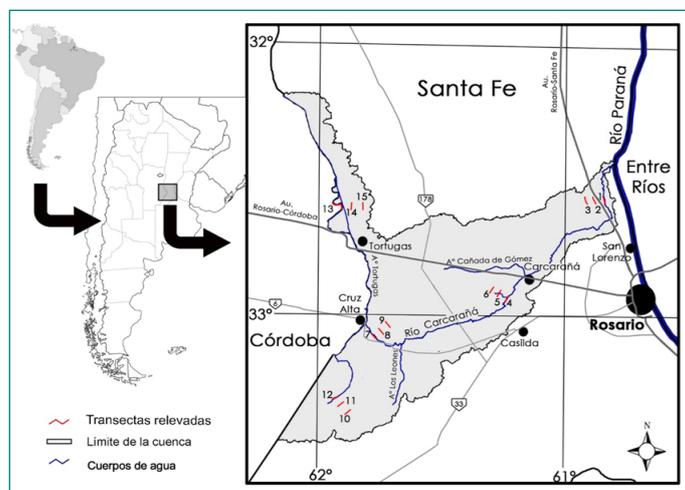


Figure 1. Detail of the Carcarañá river basin in the province of Santa Fe (Argentina). Some reference localities and transect sites are indicated: 1, Oliveros Zone ($32^{\circ} 34' 30''$ S, $60^{\circ} 54' 11''$ W); 2, Berreta Zone ($32^{\circ} 53' 48''$ S, $61^{\circ} 16' 24''$ W); 3, Villa Eloísa Zone ($33^{\circ} 01' 54''$ S, $61^{\circ} 42' 45''$ W); 4, Berabevú Zone ($33^{\circ} 21' 09''$ S, $61^{\circ} 51' 09''$ W); 5, Montes de Oca Zone (ZMO) ($32^{\circ} 35' 22''$ S, $61^{\circ} 50' 37''$ W).

2.3 Data Collection

Field work was carried out during two consecutive years (2020-2021), seasonally (autumn, winter, spring and summer), with a periodicity of two days per month. The methodology used was the survey of indirect evidence (tracks and feces) and the collection of information from direct evidence (sightings). Transect walks were conducted on foot, during daylight hours and at an average speed of one km/h, and were carried out during one day for each zone. A total of 80 days of field work and a total sampling effort of 360 km were completed in the four environmental units proposed (1- halophilic communities of the esparto type, 2- xerophytic riparian forest, 3- farmland, 4- urban and peri-urban environments). In 2021, photo-trapping was incorporated as a support method for species confirmation.

2.4 Spatial Analysis

To establish associations between *Lycalopex gymnocercus* presence records and the environmental variables studied (distance to roads and fence edges, land cover, etc.), a geographic information system was generated to integrate information from different sources. Landsat TM 5 satellite images of March 28, 2020 were used to generate the maps and the approach scale was 1:100,000. The satellite images were obtained from the Data Distribution Center of the Instituto Nacional de Pesquisas Espaciais. The

Gauss-Krüger coordinate reference system (Belt 5) defined by POSGAR WGS84 was used. The image was geometrically corrected with a first degree polynomial and 40 control points. The RMS (root mean square error) of the geometric correction process was 0.7 pixels. The programs used for spatial analysis were ArcGis 10.0 (ESRI, Redlands, CA, USA), IDRISI Selva GIS (Clark University, Worcester, MA, USA), Quantum GIS 1.7.4 and gvSIG 1.11.0.

2.5 Land Cover Map Generation

For the identification of vegetation units, an unsupervised classification with 15 classes was performed. Subsequently, each of the classes generated was assigned to the different vegetation and environment units based on the spectral characteristics of the image. For the correct assignment, we used our own field information and high-resolution images available from Google Earth. These classes were then regrouped based on the data collected in the field. In this process, the different spectral classes could be reassigned to some of the different environmental units according to the existing bibliography for the south of the province of Santa Fe (croplands, xerophytic forests, halophytic communities and urban environments). For validation, 100 points were randomly drawn and these were corroborated by field information and sources of higher spatial resolution, obtaining an accuracy in the cover map of 90%.

2.6 Principal Component Analysis (PCA)

The multivariate technique of principal components was applied prior to the transformation of the original variables with logarithms. Principal Component Analysis (PCA) was carried out to evaluate the significance of the environmental variables in the analysis of the presence of the species. This analysis allows visualizing the weight of each of the variables considered and the linear combination of these variables that express a percentage of the general variation of the data. The technique allows us to know the most important variables and to infer species-environment relationships from presence data and associated environmental variables in a given area, in this case, in the distribution of the gray fox in the basin. The PCA was performed with the Statgraphics program.

3. Results

In total, 74 records of *Lycalopex gymnocercus* presence were obtained (Fig. 2), during the years 2020 - 2021, finding traces in all seasons, eleven (14.86%) in winter, thirteen (17.57%) in autumn, nineteen (25.68%) in spring and 31 (41.89%) in summer. Significant differences were found in the presence of traces of the species between seasons (Chi-square = 13.13, $gl = 1$, P-Value = 0.000289) since the goodness-of-fit test to a uniform distribution yields P-Value less than 0.01, thus the hypothesis of fit to a discrete uniform distribution can be rejected with a confidence level of 99%.



Figure 2. Detail of direct records, feces, footprints and camera traps.

L. gymnocercus was recorded in three of the four environmental units sampled, xerophytic forest, halophytic communities and croplands. The data obtained in halophilic communities are presented separately, taking into account the subdivision of this unit into esparto grasslands and salt meadows. Thus, 46 (62.16%) evidences were found in xerophytic forest (20 in summer, 11 in spring, 8 in autumn and seven in winter), nineteen (25.68%) in croplands (three in autumn, one in winter, seven in spring and eight in summer), three (4.05) in halophilous communities of the esparto grassland type (presenting all records in winter) and six (8, 11%) in halophilic communities of the sparse or impoverished salt meadow type (two in autumn, one in spring and three in summer), registering significant differences in the comparison between seasons and environment (Chi-Square = 21.43, $gl = 9$, $p < 0.0109$). In relation to this, the analysis by environmental unit allowed us to establish that xerophytic forest and farmland showed significant differences between seasons for this species (chi-

square, $p < 0.05$), with a greater number of records of presence in spring-summer.

The total sampling effort for croplands was 240 km traveled, 48 km for xerophytic forest, 24 km for halophilic communities of the Espartillar type and 24 km for halophilic communities of the sparse or impoverished salt meadow type, which results in a relative abundance of *L. gymnocercus* of 1 trace of *L. gymnocercus* in each season. *L. gymnocercus* of 1 traces/Km for xerophytic forest, 0.12 traces/Km for halophilic communities of the Espartillar type, 0.25 traces/Km for halophilic communities of the salt meadow type and 0.07 traces/Km for croplands. The records of *L. gymnocercus*, from the point of view of spatial analysis, were very heterogeneous, however, it is noteworthy that 66.21% of the records were less than 130m from the nearest watercourse. The average distance was 90m (RQ=248.869).

With respect to the distance to localities, all the records were more than 1050m from the nearest

locality. Fifty percent were recorded more than 3070.24m (RQ=1902.05m) from the nearest locality. With respect to the distance to roads, this ranged from 0 to 7870.81m, with 50% of the data recorded below 1030m (RQ=84.853). Fifty percent of the records were presented at an altitude of 62m above sea level (RQ=42), while the average slope grade was 1.08% (SD=0.64).

Principal component analysis was applied to the 5 environmental variables. The first two components explain 66.07% of the variance of the five variables considered. Within component 1, which is responsible for 45.15% of the variance, is the effect of distance to water and altitude. In component two, which is responsible for 20.92% of the variation, the slope was associated with a high value and, to a lesser extent, the distance to localities.

4. Discussion and Conclusion

The species *Lycalopex gymnocercus*, commonly known as gray fox or pampas fox, has a wide geographic distribution that encompasses diverse biogeographic regions. However, due to the variability of the environments and ecological conditions in these areas, population density estimates have presented notorious discrepancies in different studies.

Among the studies conducted, Crespo [8] has reported densities of approximately 1.04 individuals per square kilometer (ind/km²) in the province of La Pampa, while Luengos Vidal [9] has reported higher values of 1.1-1.5 ind/km² in a protected area in the province of Buenos Aires. However, Bustamante [10], in his estimates for the same province between 2008-2009, found a wider range, ranging from 0 to 1.5 ind/km², suggesting the existence of significant variations over time and in different localities.

In addition, studies in the province of Entre Ríos have provided average densities of 0.6 ind/km², with maximum values reaching 1.4 ind/km² [11]. Likewise, in the Paraguayan and Bolivian Chaco, densities of 0.64 ind/km² and 1.8 ind/km², respectively, have been documented [12] [13]. These disparities in estimates may be influenced by various factors, such as the quality and availability of food resources, interaction with other species, and human activity in each study area.

On the other hand, *Lycalopex gymnocercus*, known as the gray fox, also exhibits a wide range of population densities in different geographic areas. Studies in Chile have recorded densities ranging from 0.43 ind/

km² in the central-northern zone to 1.3 ind/km² in the southern region of the country [14].

In the south of the province of Buenos Aires, characterized by agricultural-livestock landscapes with fragments of natural environments such as grasslands and woodlands, García & Kittlein [15] and Caruso [16] have identified *Lycalopex gymnocercus* as the most abundant or frequent carnivore. The presence of disturbed environments and its ability to adapt to the proximity of human activities could be contributing to its success in these areas.

It is important to note that population density estimates for both species of foxes are subject to constantly changing ecological dynamics, and that future studies should continue to monitor and analyze these factors to gain a more complete understanding of the distribution and abundance of these canids in their wide range of habitats. The information generated from these studies is not only crucial for the conservation and management of fox populations, but also for the preservation of biological diversity in the ecosystems that these species occupy.

For the province of Santa Fe Pautasso [17] reports it for all the eco-regions of the province. In the Pampas eco-region, it is found in very modified sites such as soybean and corn pastures, grassy slopes and abandoned houses or factories in the fields.

In this research, records were obtained in three of the four environmental units proposed (xerophytic forest, halophytic communities and croplands), showing great amplitude in relation to the environmental variables studied. Their records were presented on roads and on the banks of water bodies, but also at distances that exceeded 8,000 m from any of these variables. From 40 m.a.s.l. to the upper altitude limit of the region (130 m.a.s.l.) there was evidence of their activity.

With respect to the records of presence, a higher value of occurrence was observed in spring and summer, both in xerophytic forest and in cultivated land, which is consistent with the time of the year with the greatest amount of resources. Some authors [18] [19] argue that this species could be increasing its area of occupancy in Argentina, since it takes advantage of many of the natural areas that have been or are being converted to agriculture. In this regard, the results obtained in terms of relative abundance per environmental unit positioned croplands with the lowest index, well below that obtained for xerophytic forests and

halophytic communities. These two environmental units presented similar results to those proposed for a protected area in the Pampean region [9].

This shows that, although it is a species that avoids forests [18], in purely agricultural areas such as this one, forested areas are of great importance as a refuge, a fact already observed for the species in the province of Buenos Aires [9]. Furthermore, there are data for this region that suggest that there is a limit to its capacity to adapt to human alterations and that the combined effect of the destruction of natural habitats and hunting can lead to local extinctions [5] [10]. With respect to this, another fact to highlight is that in the present investigation the records of *L. gymnocercus* were obtained far from urban centers, which could indicate that this species is being affected by urbanization and all that this entails (hunting, dogs, etc.).

Acknowledgments

None.

Conflicts of Interest

The author declares there is no conflict of interest.

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