RESEARCH ARTICLE

Biological Corridors, a Recovery Strategy in Highly Fragmented Landscapes: Case study of Biological Corridor Rosario - Santa Fe Highway, Argentina

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ABSTRACT

The knowledge about mammals in Santa Fe has grown extensively in recent years; however, a significant portion of the territory remains poorly explored, particularly the center-south of the territory in the province. Nowadays, the landscape is a mosaic of productive systems, with a high degree of fragmentation, leaving a few natural remnants. The aim of this work is to present the results of the survey of medium and large native mammals of the Biological Corridor of the AP- 01 included within the Provincial System of Natural Protected Areas by decree N°. 1723/14. This area connects Rosario and Santa Fe, and it extends through two phytogeographic regions, the Espinal and the Pampa. The fieldwork was carried out from January to October in 2020, on a seasonal basis. The methodology was based on standardized linear transect routes in search of signs of activity (footprints, feces or excrement and / or caves) and direct methods (sightings or carcasses) along the four courses of water that cross the corridor (Aº Los Padres, Colastiné, Monje and Carcarañá river). From 363 records of presence, a specific richness of 11 species was obtained which were comprised in eight families. The results allowed us to expand the baseline proposed for the corridor up to 53.8%, establishing the first records of Puma yagouaroundi, Puma concolor, Conepatus chinga, Lontra longicaudis, Procyon cancrivorus, Hydrochoerus hydrochaeris and Myocastor coypus. The comparative analysis between the zones that served as sample made it possible to determine that the Espinal has greater wealth and relative abundance than the Pampa. In addition, the sampling areas located closer to urban centres have less biodiversity, since they negatively influence wild populations. Considering that much of southern Santa Fe has transformed into agricultural fields, combining the effects of population growth, it is of sum importance to highlight the role of biological corridors for the conservation of native mammals.

Keywords: *relative abundance, biological corridors, mastofauna, specific richness, Santa Fe*

INTRODUCTION

General characterization

Due to their extension, the pampas constitute the most important grassland ecosystem in Argentina, and total about 540,000 km^2 [1], occupying the provinces of Buenos Aires (except its southern end), northeastern La Pampa, southern Córdoba, Santa Fe and Entre Ríos. The dominant vegetation in this region was, originally, the steppe or pseudo-steppe of grasses among which the genera Stipa, Poa,

Piptochaetium and Aristida were predominant. Taking into account its vegetation, the Pampean Province can be divided into four districts: Uruguayan District, Eastern Pampean District, Western Pampean District and Southern Pampean District. The south of the Province of Santa Fe corresponds to the Uruguayense District, where the characteristic community is the flechilla meadow or "flechillar", dominated by species such as *Stipa neesiana, Stipa tenuissima, Poa lanigera* and *Eragrostis cilianensis* [2]. Different edaphic and geomorphologic limitations favored the presence of other plant communities: halophilic grasslands, with salt grass and espartillo; diverse grasslands and wooded communities restricted to ravines. The fauna of the Santa Fe pampas is characterized by numerous species of birds such as the chajá (*Chauna torquata*), partridge (*Nothura maculosa*), birds of prey and those associated with aquatic environments such as herons (*Ardea alba*) and crows (*Plegadis chihi*). Among the mammals we can mention species such as the coypu (*Myocastor coypus*), weasel (*Didelphis albiventris*), cuis (*Cavia aperea*), vizcacha (*Lagostomus maximus*), carnivores such as the puma (*Puma concolor*), wild cat (*Leopardus geoffroyi*), pampas grey fox (*Lycalopex gymnocercus*), ferret (*Galactis cuja*) and skunk (*Conepatus chinga*) [3 - 4]. Nowadays, the pampas of Santa Fe has suffered great transformations due to human intervention through the development of agricultural activities and the mastofaunistic composition has been greatly affected [4].

Surrounding the Pampean region there are different forest units, which form a transition zone between it and the ecoregions of Chaco to the north and Monte to the west. This transition zone has been called the Espinal ecoregion [2] and its biodiversity has been declining in recent decades as a result of habitat destruction, overexploitation of natural resources, pollution and the introduction of exotic species. The Espinal covers an area of more than 330,000 km^2 in Argentina, being able to recognize three districts: Ñandubay District, Algarrobo District and Caldén District. Differentiate the fauna of the Espinal is not easy, because as mentioned above is a transition zone, which is why it shares many of the species found in the ecoregion of the Pampas as the puma, skunk, ferret, cuts, chajá, partridge, heron, etc. In the Santa Fe espinal can be differentiated: within the group of birds, the yellow cardinal (*Gubernatrix cristata*), chinchero chico (*Lepidocolaptes angustirostris*) and curutié blanco (*Cranioleuca pyrrhophia*); while among the characteristic mammals are the brown corzuela (*Mazama gouazoupira*), aguará guazú (*Chrysocyon brachyurus*), bush fox (*Cerdocyon thous*) and aguará popé or osito lavador (*Procyon cancrivorus*) [5]. In general, the flora of the Espinal is represented by species of the genus Prosopis and other tree species of low altitude (less than 10 meters). In the center of the province of Santa Fe is a large part of the Algarrobo District, where the forest formations are represented by *Prosopis nigra, Prosopis alba, Geoffroea decorticans* and *Celtis ehenbergiana*, among others. However, human activities have had drastic consequences on the native forests of the province, due to deforestation for the extraction of timber, fruits for food and use of soil resources for agricultural activities, leaving the forest formations very restricted to the banks of the main river and stream beds [6]. This association between natural watercourses and forest formations is of great importance because they facilitate the movement of many animal species [7].

Anthropic activities and their consequent modification of the landscape

The province of Santa Fe presents a degree of subdivision and use of the soil that has modified its original aspect, turning it into a plain where cereal and oilseed crops predominate. In general, the province can be considered as an area of agricultural production that grows to the detriment of livestock and in an overexploitation of the soil with intensive practices of double annual crops, such as wheat and soybeans [7].

Anthropogenic activities have favored the lack of "ecological communication" due to changes in land use [8], leading to fragmentation processes, which directly affect the dispersal of species. Thus, habitat loss and fragmentation are considered one of the main threats affecting biological diversity [8]. Both have profound implications for wildlife and the conservation of flora and fauna; among the main consequences are the loss of species and changes in ecological processes. Fragmentation causes each portion of forest or any other environment to acquire particular characteristics in terms of local extinction processes and changes in the composition and abundance of

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species, which implies greater environmental heterogeneity between sites and a decrease in the quality of habitats, where populations must move from one fragment to another in order to use the resources provided by each of them.

Landscape units and importance of biological corridors

The provincial territory is made up of more than 130,000 km^2, of which 26% are purely agricultural, 32.4% are suitable for livestock-agriculture, 31.5% are exclusively for livestock and the remaining 10% correspond to areas that cannot be used because they are not suitable for productive activities, the latter being the existing or potential spaces for conservation. From this perspective, the different landscape units of the province can be recognized: the predominant matrix is of anthropic origin, dominated by the extension of soybean monoculture, interrupted only by physical barriers such as rivers, railway lines, roads and buildings, among others. The patches are surfaces that differ from the rest of the landscape because they are structural spaces, functionally well defined, which show signs of self-sustainability and commonly have relatively proportional shapes (oval, rectangular, square) where the edge effect does not reach the core of the system. They are generally large depressions or flooded areas that lack the potential for agronomic exploitation; and biological corridors, which can be natural or anthropogenic, are spaces that are longer than wide, where the edge effect has a significant impact on the core of the system, but despite this, they acquire considerable importance in terms of connectivity as they are pathways for flora and fauna species that use them to move from one patch to another or between corridors, preventing reproductive isolation by facilitating gene flow between individuals of the same species [9]. Thus, the landscape of the province of Santa Fe is currently a mosaic of productive systems and scarce natural remnants, which are the only alternative for the conservation of animal and plant species, being necessary to protect them through the development of strategies and the promotion of a harmonious management of productive systems with the environment that surrounds them. Thus, in order for animal species and communities to thrive in landscapes that have been severely modified by humans, connectivity between natural habitat mosaics must be sufficient for species to be able to move around to obtain the resources they need, allowing the conservation of diverse forms of life, including those considered threatened or endangered, and ensuring the maintenance of biodiversity and ecosystemic and evolutionary processes.

Importance of the research topic

In AP-01 Brigadier Estanislao López there have never been any records of the mammals present. In order to have information about which species could be found in the area, we referred to Pautasso (2008) who worked on a district/department scale. Considering the five districts of the province covered by PA-01, he refers to: common weasel (*D. albiventris*), red weasel (*Lutreolina crassicaudata*), common mulita (*Dasypus hybridus*), large mulita (*Dasypus novemcinctus*), hairy (*Chaetophractus villosus*), bush fox (C. thous), aguará guazú (*C. brachyurus*), pampas fox or grey fox (*L. gymnocercus*), wild cat (*L. geoffroyi*), puma (*P. concolor*), common skunk (*C. chinga*), river otter (*Lontra longicaudis*), lesser ferret (*G. cuja*), aguará popé or osito lavador (*P. cancrivorus*), common cuis (*C. aperea*),capybara (*Hydrochoerus hydrochaeris*) and coypu (*M. coypus*). Many of these species still manage to survive because despite the alterations generated in the habitat by human action, a small portion of the territory remains poorly exploited, in particular the remnants of forests or grasslands that exist on the banks of rivers and streams, which are still in retreat, and small protected areas such as the biological corridor in question.

The objective of any protected area should be to help conserve and ensure the continuity of ecological and evolutionary processes, as well as the complex process of interactions between organisms and their environment. But a major problem of the current areas within the province is that in many cases they do not have adequate infrastructure or control. Many of them do not have park rangers, and official control is limited to isolated and sporadic visits. Consequently, many species of medium and large mammals are susceptible to hunting by hunters or producers in nearby areas, who persecute them because they consider them pests for their crops and domestic animals, thus threatening their productive activity [3]. This is also the case of the AP-01 Biological Corridor, which lacks park rangers and regular controls; however, it is worth mentioning

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the abundant presence of road police, who have no direct relationship or obligation to care for the biological corridor, but their presence could help control it indirectly, since, for example, they regulate vehicular traffic, which represents a threat to the native mammals of the corridor, which on numerous occasions are run over on the side of the asphalt.

In addition, it should not be forgotten that the study area is located in a purely agricultural zone, where productive activities have severely modified the landscape and continue to do so. Agricultural and livestock use produces major changes in natural ecosystems, where areas originally covered by forests and natural grasslands are replaced by crops. The practices applied deteriorate the soil and generate the displacementof numerous species of mammals to small natural relicts that may remain unexploited. In this sense, mammals that are not yet designated as threatened species could be considered potentially vulnerable forthe province in the near future. The objective of this work is to establish the diversity of medium and largenative mammals present in the Biological Corridor of the Rosario-Santa Fe highway, which could be used to ponder the importance of biological corridors in the conservation of biological diversity in regions with a high level of simplification, such as the dominant agroecosystem in its environment.

MATERIALS AND METHOD

Study area

Historically in the province of Santa Fe, there has been a growing tendency for private actors and municipalities to use the ditches to grow crops and make profits at the expense of the intrusion of public space. In this context and taking into account that in the province there are few areas for the conservation of native ecosystems and their biological diversity, the Secretariat of Environment, since 2008, has sought to promote the recovery of these public spaces and initiate the necessary actions to form a Reticulated System for the Conservation of Biological Diversity. Thus, in 2011, by means of Provincial Resolution No. 0136/11, the use of the roadside areas for specific conservation purposes is regulated, preventing any productive practice on them. In the south of the province, a biological corridor associated with the road concession of the AP-01 Brigadier Estanislao López between the cities of Rosario (32°53'06"S -60°42'38"W) and Santa Fe (22°5'47.3"S -65°35'46.5"W), which was later formalized within the Provincial System of Natural Protected Areas, by Decree No. 1723/14 by which it is designated under the category of Protected Landscape management, calling it "Biological Corridor of the AP-01 Rosario-Santa Fe" [9]. It is under provincial jurisdiction and crosses the departments of Rosario, San Lorenzo, Iriondo, San Jerónimo and La Capital.

The biological corridor covers a continuous strip of variable width delimited on one side by the asphalt line and on the other by the limits of private properties, wire fences, collector roads, front lines, etc. The lengthof the AP-01 and therefore of the biological corridor is approximately 156 km and due to its geographical position it extends through two ecoregions: the southern portion (from Km 0 to Km 95) crosses the Humid Pampa and the northern portion (from Km 95 to Km 156) the Espinal.

It has a north-south orientation and its trajectory intersects numerous lotic watersheds, which, due to the topography of the landscape, move mostly in a west-east direction, flowing into the Paraná River [9].

Due to the extensive length of the corridor, four of these intersections were selected to determine the areas to be sampled:

-Carcarañá River (32°38'38"S -60°49'33"W), elevation 25/26 meters above sea level.

-Arroyo Monje (32°23'33"S -60°56'28"W), elevation 17/18 meters above sea level.

-Arroyo Colastiné (32°1'05"S -60°59'25"W), elevation 18 meters above sea level.

-Arroyo Los Padres (31°47'43"S -60°52'03"W), elevation 15 meters above sea level.

These watercourses were selected because they are the ones with the greatest flow and importance that cross the corridor. In addition, two of them, the Carcarañá river and the Monje stream, are located within the Pampa Húmeda region, while the Colastiné and Los Padres streams are located

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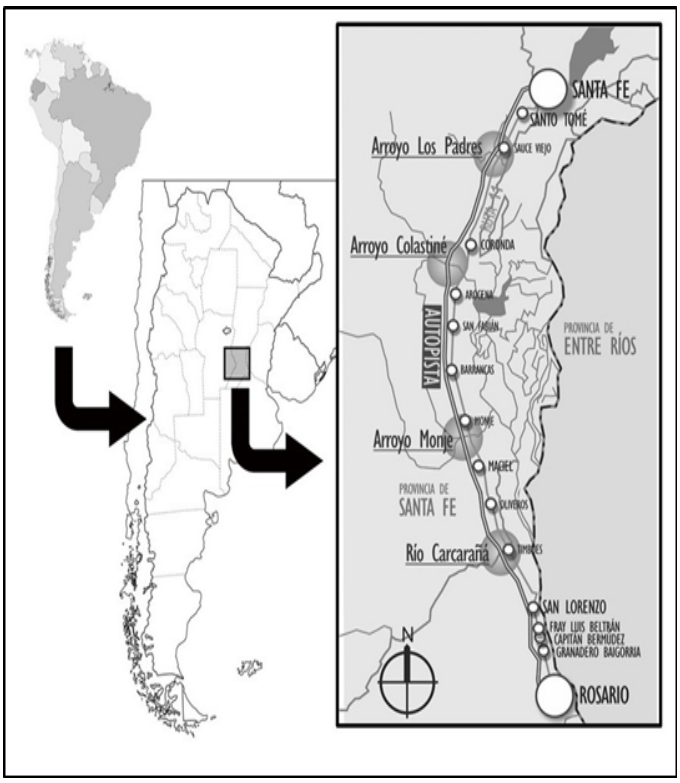
within the Espinal region, which allowed a comparison between both ecoregions.

Although the total surface of the corridors is relatively small and does not affect the economic productivity of the area, they are of great importance for the conservation of biological diversity, mainly for mammals, since their dynamics in the ecosystem is strongly affected by the different anthropic processes.



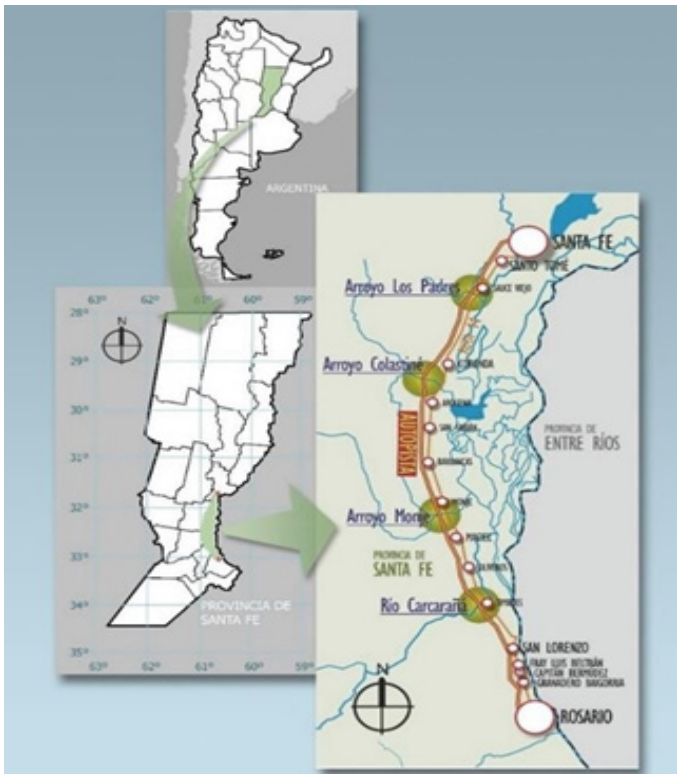


Figure 1: Location of the study area in the province of Santa Fe, Argentina.

Methodology

Medium and large mammal species vary greatly in terms of their physical, ecological and ethological characteristics, so the application of a single survey method is not appropriate for all taxa [4]. To conduct this study, a combination of methods was used to ensure that the totality of medium and large species could be recorded, considering them generally ≤1000 grams. Eight samplings were carried out in the year 2020 taking into account two per season (autumn - winter - spring - summer).

In the sampling areas already described, 200 meters were surveyed in each field trip, which were formed from four transects. Each of them was determined from the intersection of the AP-01 and the selected watercourse; each was 50 meters long (north-south) and variable width (east-west) up to the limit distanceof the corridor determined by a planting line or a fence that implied the beginning of a private property, which never exceeded 25 meters. The routes were carried out during the day at an average speed of 0.5 km/h.

Traditionally, mastofaunal inventories have been constituted by organic remains of animals, which implied the sacrifice of individuals to obtain the material. Unlike small mammals, in the case of medium and large species, several individuals cannot be collected without affecting the local population [10]. For this reason, nowadays different methods are used to identify the species without being captured, based on the characteristic traces left by the animals and the recognition of local inhabitants [4].

Among the methods are direct and indirect methods. The direct methods are characterized by the capture,marking and release of individuals, camera traps, direct observation, collection of carcasses, etc. While the indirect ones make reference to the counting of traces such as scats, footprints, burrows, moulting remains, food remains, nests, feeding places, etc. The latter have certain advantages: they are easy to apply compared to direct methods; observations can be made independently of the time of activity of the species, since tracks, for example, remain for long periods of time; they can be implemented in different study areas and at any time of the year; they are useful when the species to be studied

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are nocturnal, crepuscular, sensitive to human presence or difficult to capture; they are usually cheaper than other procedures and sometimes they are the only alternative for the study of certain vertebrates that are not very accessible [10 - 4].

Methods for measuring diversity

Total diversity was estimated following Halffter and Moreno (2005), who define it as the number of species in the set of sites or communities that integrate the landscape, in this case, the number of species recorded in the different sampling zones established for the biological corridor Rosario-Santa Fe highway. The alphadiversity was estimated as the number of species [12 - 13], by directly counting the species recorded for each sampling area.

The degree of uniformity or numerical superiority of the sampled species was determined by the index of relative abundance (IAR) [13] in this case will be calculated as the number of traces per species found, divided by the unit of effort [10].

RESULTS

For the presentation of the results, the first step was to refer to the richness of the biological corridor as a whole. Subsequently, the results were ordered according to ecoregions, sampling zones and seasonality, discriminating in each of them the specific richness, relative abundance, diversity andcorresponding indices.

Biological Corridor Of The Ap-01

From 363 presence records/traces (see Annex 3), we obtained a specific richness (S) for the biological corridor of AP-01 of 11 species of medium and large native mammals, belonging to three orders, eight families and ten genera (Table 1), from direct and indirect traces.

Results obtained by Ecoregion:

As mentioned above, the biological corridor of the AP-01 extends through two different ecoregions. Los Padres stream and Colastiné stream belong to the Espinal ecoregion, while Monjestream and Carcarañá river belong to the Pampa ecoregion.

Specific wealth

For each ecoregion, the presence of medium and large mammals was recorded, yielding the results shown in Table 2:

Espinal Ecoregion: eleven species in eight families and three orders. All the species surveyed for the corridor can be found.

Pampa Ecoregion: nine species in seven families and three orders. It was possible to find 82% of the total number of species found in the corridor, excluding *P. concolor* and *P. cancrivorus.*

Relative abundance

For each ecoregion, represented by two sampling zones each, transects were walked and relative abundance was calculated based on the number of records found over the distance travelled in metres, which for each ecoregion was 3200 m, giving the following results which can be seen in Table 3:

Espinal Ecoregion: 228 presence records were obtained for a total of 11 species of medium and large native mammals. Of these, 51 (22.37%; 0.016 traces/m) corresponded to the species *L. geoffroyi*, 46 (20.18%; 0.014 traces/m) to *L. gymnocercus*, 40 (17.54%; 0.013 traces/m) to *L. longicaudis*, 29 (12.72%; 0.009 traces/m) to *D. albiventris*, 14 (6.14%; 0.004 traces/m) to *M. coypus*, 13 (5.70%; 0.004 traces/m) to *H. hydrochaeris*, 9 (3.95%; 0.003 traces/m) to *G. cuja*, 8(3.51%; 0.003 traces/m) to *P. concolor*, *C. chinga* and *P. cancrivorus* and 2 (0.88%; 0.001 traces/m) to *P. yagouaroundi*.

Pampas Ecoregion: 135 records of the presence of a total of 9 species of medium and large native mammals were obtained. Of these, 32 (23.70%; 0.010 traces/m) corresponded to the species *L. geoffroyi*, 27 (20%; 0.009 traces/m) to *D. albiventris,* 19 (14.07%; 0.006 traces/m) to *L. gymnocercus* and *M. coypus,* 15 (11.11%; 0.005 traces/m) to L. *gymnocercus* and *M. coypus,* 15 (11.11%; 0.005 traces/m) to *H. hydrochaeris,* 14 (10.37%; 0.004 traces/m) to *L. longicaudis*, 4 (2.96%; 0.001 traces/m) to *P. yagouaroundi,* 3 (2.22%; 0.001 traces/m) to *C. chinga*, and 2 (1.48%; 0.001 traces/m) to *G. cuja*.

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Table 1: List of species recorded in the biological corridor AP-01.

Order	Family	Genre	Scientific name	Name vulgar
Didelphiomorphia	Didelphidae	*Didelphis*	*Didelphis albiventris*	Weasel common
Carnivora	Canidae	*Lycalopex*	*Lycalopex gymnocercus*	Grey fox, pampeano
	Felidae	*Leopardus*	*Leopardus geoffroyi*	Gato montes
		Puma	*Puma yagouaroundi*	Yaguarundi
			Puma concolor	Puma
	Mephitidae	*Conepatus*	*Conepatus chinga*	Common skunk
	Mustelidae	*Lontra*	*Lontra longicaudis*	Giant otter
		Galictis	*Galictis cuja*	Ferret
	Procyonidae	*Procyon*	*Procyon cancrivorus*	Aguará popé
Rodentia	Hydrochoeridae	*Hydrochoerus*	*Hydrochoerus hydrochaeris*	Capybara
	Myocastoridae	*Myocastor*	*Myocastor coypus*	Coipo

Table 2: List of mammal species by ecoregion. References: x = presence 0= absence

Species	Ecoregion	
	Espinal	Pampa
Didelphis albiventris	x	x
Lycalopex gymnocercus	x	x
Leopardus geoffroyi	x	x
Puma yagouaroundi	x	x
Puma concolor	x	0
Conepatus chinga	x	x
Lontra longicaudis	x	x
Galictis cuja	x	x
Procyon cancrivorus	x	0
Hydrochoerus hydrochaeris	x	x
Myocastor coypus	x	x

Shannon - Wiener Diversity

The results obtained from the Shannon - Wiener index show that diversity is higher in the Espinal ecoregion, with a value of H'= 0.345, while the value obtained for the Pampas region is H'= 0.215.

DISCUSSION

This work is one of the first contributions on richness and abundance of medium and large native mammals in southern Santa Fe, and the first study carried out in the biological corridor of the AP-01, which extends in a highly modified area and of which much of its native fauna is still unknown. From this study, it was possible to determinethe presence of 11 species for the area of the biological corridor of the AP-01, providing 363 records of the presence of medium and large native mammals.

Although previous research (Pautasso, 2008) has established records of medium and large native mammals for the south of the province, they are isolated, historical and asystemic, as they were not surveyed with a common methodology. Although these records refer to the presence of certain species in the south of Santa Fe, they correspond to the total area of the different districts; there are no specific records for the corridor area. Records of 17 species are established for the departments where AP-01 extends (Rosario, San Lorenzo, Iriondo, San Jerónimo and La Capital), many of which present only one or a few occurrence data, such as *P. concolor, C. chinga, G. cuja* and *P. cancrivorus*, none of which belonged to the corridor area. In addition to the presence data presented by Pautasso (2008), this study found 11 records of *G. cuja and C. chinga*, eight of *P. concolor* and *P. cancrivorus* and six of *P. yagouaroundi*, a species that the author had not recorded for any of the five departments through which the highway extends.

Considering the specific richness, the research allowed to expand by 53.8% the baseline proposed by Biasatti et al., (2015), who indicates the presence of six species of medium and large native mammals in it. It also establishes the first records *of P. yagouaroundi, P. concolor, C. chinga, L. longicaudis, P. cancrivorus, H. hydrochaeris* and *M. coypus* for the corridor.

As mentioned above, the biological corridor of the AP-01 extends through the ecoregion of the Pampa and the Espinal. According to the conservation status established by the World

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Table 3: Index of relative abundance of mammals by ecoregion

Species	Ecoregion			
	Espinal		Pampa	
	Number of traces	Relative abundance	Number of traces	Relative abundance
Didelphis albiventris	29	0,009	27	0,008
Lycalopex gymnocercus	46	0,014	19	0,006
Leopardus geoffroyi	51	0,016	32	0,01
Puma yagouaroundi	2	0,001	4	0,001
Puma concolor	8	0,003	0	0
Conepatus chinga	8	0,003	3	0,001
Lontra longicaudis	40	0,013	14	0,004
Galictis cuja	9	0,003	2	0,001
Procyon cancrivorus	8	0,003	0	0
Hydrochoerus hydrochaeris	13	0,004	15	0,005
Myocastor coypus	14	0,004	19	0,006
TOTAL	228	-	135	-

Wildlife Foundation (WWF), the Pampas region is categorized as an "Endangered" area, and is assigned the highest level of conservation priority, due to its great biological diversity, high degree of alteration and scarce existence of protected natural areas [14]. Only 0.2% of the original surface of the Espinal region is protected and legally declared. The Espinal ecoregion, as well as the Pampeana, showed and show a tendency to decrease the original landscape, being one of the most degraded and fragmented areas due to anthropic activities, which causes habitat destruction, overexploitation, pollution and introduction of invasive exotic species that, due to their abundance, rapid dispersion and establishment, represent a threat to biodiversity and ecosystem processes, and may cause the decline or extinction of native species. Fragmentation also affects the microclimatic conditions of the remnants, the formation of detritus, the mineralization of humus, and the movement of water and nutrients. Thus species, as well as biological interactions with the environment, can be drastically affected by the shape, size and connection between natural fragments or remnants that are the result of human activities [15]. Despite this, Pautasso (2008) determines the southern region of the province within the lowest categories in terms of protection for not possessing species of high conservation value. This data is erroneous and is a product of the lack of information concerning the mastozoological diversity of this region. Rimoldi (2014) carried out the first systematized survey for the Carcarañá river basin, establishing new data on species not recorded for the area. The review of the work of thisauthor, showed the presence of 12 species of medium and large native mammals, of which nine were recorded inthe study area of the biological corridor. The present work allows us to add the contribution of the first data on the presence of L. *longicaudis* and *P. cancrivorus*. However, it was not possible to corroborate the presence of *Lutreolina crassicaudata, Leopardus colocolo* and *Chaetophractus villosus* in the study area. This can be attributed to the fact that *L. crassicaudata* and *L. colocolo*, were surveyed by Rimoldi (2014) in the northwest ofthe Carcarañá river basin at the border with the province of Córdoba; this author did not find traces of them in the eastern region of the aforementioned basin, which is close to our study area. Although the species *C. villosus* is widely distributed in the Pampean region, it has not been recorded in the present research. This species is probably favored by the new agricultural practices that would improve the balance between quantity, quality and access tofood sources, adapting easily to the crop fields and feeding on seeds recently disseminated at sowing time and grains and/or pastures in the silos, which are present inside the surrounding agricultural fields [4]. In addition, thespecies is mainly associated with areas far from bodies of water or flooded areas, possibly due to its semi-fossorialhabits [3]; this could be the reason why this species was not recorded in the present work, since all the samplingareas were adjacent to watercourses.

Berduc et al. (2010), who worked in a protected natural area of the Espinal ecoregion in the

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province of Entre Ríos, made a list of medium and large native mammals, which corresponds almost entirely to the species found in the present work, reflecting that the species found are those expected for this ecoregion. Despite this, in the biological corridor of the AP-01 Puma concolor was recorded, while in the General San Martín Park (Entre Ríos) traces of brown brocket deer (Mazama gouazoubira), bush fox (*Cerdocyon thous*) and mulita (*Dasypus sp*.) were found. The absence of traces of these species in the study area can be attributed to the distribution of the species themselves, which according to Pautasso (2008) do not reach the southern end of the province of Santa Fe.

The contribution of this work not only adds data to those already reported for each ecoregion, but also allows to generate links between the two ecoregions never worked in the area by any of the authors mentioned.

From the analysis of the richness and abundance of medium and large native mammals in both ecoregions, it was concluded that there are differences between them. The ecoregion with the highest richness was the Espinal, presenting all the species surveyed for the corridor, while the Pampa presented 82% of the total species recorded,excluding *P. cancrivorus* and *P. concolor*. The last decade has seen a notable increase in records of the latter species in partially anthropized environments, such as the Argentine pampas, where a few decades ago it had become extinct. Chimento and De Lucca (2014), indicate a process of recovery of territory by the species in the center and east of the pampas ecoregion, deduced from the increasing number of reports since 2000. Despite this,the present study did not find evidence of the presence of *P. concolor* in the Pampa ecoregion, which could indicate that puma populations in the Santa Fe pampas are not yet in the same state as in other areas of the ecoregion, and that recolonization in this province could be slower than in the others.

In terms of relative abundance, the Espinal ecoregion is the most abundant, with 228 records of presence, while in the Pampa 135 were collected. These results are consistent with those obtained with the Shannon Index, wherethe ecoregion with the greatest biodiversity was the Espinal, and these results may be attributed to the disturbances caused by agricultural activities in the Pampean region, which has land with high productive potential. This regionhas been drastically affected in the use of the soil, extending crops to all areas of land susceptible to receive a crop, thus advancing not only on private properties, but also on roadsides, railways, potentially floodable areas, etc. [9]. [9]. All the mammal species surveyed were more abundant in the Espinal ecoregion, excluding *P. yagouaroundi, H. hydrochaeris* and *M. coypus*, which had a greater number of records of presence in the Pampa.This may be a consequence of the distribution of these species, which mainly occupy the central-northern regionof the province, without extending to the southern region, where the Espinal ecoregion is located [3].

According to Rozzatti and Mosso (1997), cited by Pautasso (2008), the province of Santa Fe has 19 protected areas, which conserve 0.68% of the area occupied by the Humid Chaco in the province; 0.68% of the Paraná River Valley; 0.0012% of the Espinal; 0.07% of the Pampa; and there are no protected areas in the Dry Chaco. Inrecent decades there has been an increase in the number of protected areas, which have reached a total of 22, including Strict Nature Reserves, Managed Nature Reserves, Defense Nature Reserves, Ecological Reserves, Municipal Reserves, Private Reserves for multiple uses, Water Reserves, a Provincial Park and a National Park [9]. In spite of this, it can be observed that both the Espinal and the Pampa are among the least protected ecoregions.

Although an important part (72.7%) of the mastofauna surveyed is considered not threatened at the global level according to the International Union for Conservation of Nature (IUCN), in the country the situation is different since many of the species considered in the category of Least Concern at the global level, are found in the categories Potentially Vulnerable, Vulnerable, Near Threatened or Endangered in the country. For example: *P. yagouaroundi, P. concolor, G. cuja, C. chinga* and *L. geoffroyi* (Potentially Vulnerable); *P. cancrivorus* (Vulnerable); *H. hydrochaeris* (Near Threatened) and *L. longicaudis* (Endangered) [3]. For this reason, the importance of the biological corridor of the AP-01 Brigadier Estanislao López Highway as aprotected landscape is emphasized, because although the total area is relatively small, its potential lies in its importance for flora and fauna species. This corridor allows

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species to have the possibility of moving to meet their needs for habitat, food and reproductive activities between different natural relicts that may still exist within the territory without being exploited by anthropogenic action, thus achieving a landscape with greater connectivity. Conforming what Biasatti et al., (2013) call "Reticulated System for the Conservation of Biological Diversity", which they define as a system consisting of a network of interconnected biological corridors that are linked to other reservoirs and Natural Protected Areas. From the recovery of the bank spaces for the formation of the corridor, the advance of the secondary succession and the reestablishment of the physiognomy of the landscape was allowed, with an increase in complexity and a tendency towards stability, which is reflected in the presence of "k" type strategist species [18].

Endorsing what García Quiroga and Abad Soria (2014) mentioned, habitat loss mostly responds to meet territorial demands for urban growth, agricultural and livestock expansion and productive or industrial activities, which makes it difficult to solve, since in order to achieve a conservation area, for example, the needs that society demands and that today are increasingly greater should be left aside. On the other hand, the problem of connectivity could have a simpler and more viable solution, since it does not imply great demands of surface but continuity and territorial coherence, which does not affect to a great extent the economic productivity of the area, being able to have a greater acceptance on the part of the people who exploit these territories.

To conserve the biodiversity of the south of our province, we can say that one of the main strategies should focus on the analysis of the mosaic that is present in our area, and try to maintain and restore adequate areas to promote the diversity of native species and connectivity between them. It is necessary to manage and control not only the protected areas, but also the agricultural or industrial areas surrounding them, in order to maintain acceptable levels of conservation, thus ensuring the viability of native species.

CONCLUSIONS

In the biological corridor of the AP-01 highway, in the province of Santa Fe, the presence of 11 medium and large native mammals, belonging to eight families and three orders, was confirmed.

The first records of the presence of *P. yagouaroundi, P. concolor, C. chinga, L. longicaudis, P. cancrivorus, H. hydrochaeris* and *M. coypus* were established for the corridor, allowing for a 53.8% increase in the proposed database for the corridor.

Specific richness and relative abundance in the Espinal ecoregion were higher than those obtained in the Pampa.

The biological corridor is home to species that, although they are considered to be in the category of Least Concern worldwide, in the country they are found in one of the following categories of threat, which underscores its importance as a protected landscape.

The creation and incorporation of the biological corridor associated with the AP-01 Brigadier

Estanislao López to the Provincial System of Protected Natural Areas, allowed the protection of the last natural relics present in the area, with the aim of ensuring the viability of native species. Because it is located in a mosaic purely agricultural, it is relevant to highlight the importance of the corridor, since it enables the native mammals meet their habitat, nutritional and reproductive needs.

Consent And Ethical Approval

As per university standard guideline, participant consent and ethical approval have been collected and preserved by the authors.

Competing interests

Authors have declared that no competing interests exist.

Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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