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Utilisation of remnant dry-forest corridors by the native fauna in a pastural landscape in the Paraguayan Chaco

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In the agricultural landscape of the Chaco Central of Paraguay, remnant strips of primary forest separating pastures are used in cattle ranching to control erosion and to prevent the spread of disease and fire. As the cattle industry expands and the rate of land conversion, from natural forest and bushland to cattle pastures increases, the possible impact of habitat loss, fragmentation and decreased connectivity of the landscape raises concerns for the native animal populations.

I have inventoried remnant strips of forest present in the pastural landscape, cattle pastures and surrounding primary forest in an attempt to determine if the remnant vegetation also serves as wildlife corridors and partially alleviates possible impacts of fragmentation. I conducted track sampling, bird census, and drift trapping in three replicates sites, each consisting of core forest, remnant forest strips and pastural landscape components.

In all faunal groups studied (birds, small and large mammals, amphibians and reptiles), it was found that the remnant forest strips are highly utilized. Species composition and abundance ranking were remarkably similar between the three landscape elements, yet the rate of mammal observations in the corridor (remnant forest strip) was twice that of the other landscape elements. Although some degree of connectivity is provided by the pastures themselves for the majority of species in all studied faunal groups, the inclusion of remnant strips of forests in the pastural landscape appears to drastically increase movement of individuals and connectivity across pastures.

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Introduction

The Gran Chaco is one of South America's most biodiverse and unique habitats (Taber et al. 1997). It is listed by the World Wildlife Fund as a global top 200 conservation priority habitat. Despite this, the region has received almost no conservation investment or research (Redford et al. 1990). The main vegetation type is dry thorn forest. Historically, the area has been sparsely populated by nomadic hunters and gatherers practicing limited agriculture. The Chaco Central was settled by agricultural Mennonites in 1927. Since then, large portions have been converted to pastural and agricultural fields at a rapidly increasing pace. Agriculture is now responsible for 80% of the gross income in the Paraguayan Chaco. Beef and dairy production constitute 90% of agricultural activities, making the cattle industry the major economic activity of the region (Janzen pers. comm.).

Within the Chaco, there are currently still vast tracts of natural primary forests and abundant wildlife. The current legislation regarding land-use practices specify the obligation of estancia owners to leave at least a 100 m wide strip of natural vegetation to separate fields (ley 422 art. 60) and a total of 25% of the property owned in natural state (ley 422 art. 42), to prevent erosion and the spread of disease and fire. The result is a landscape mosaic of forest fragments and structural corridors within the agricultural landscape. Remnant corridors are defined as strips of natural vegetation that result from the clearing of the surrounding matrix during landscape fragmentation (Forman 1983; Saunders and Hobb 1991). The utilisation of these various landscape components by the native fauna have yet to be studied in the Gran Chaco.

Habitat loss and fragmentation is the main cause of the modern-day extinction crisis (Wilcox and Murray 1985). Evaluating the effectiveness of current land-use practices at meeting the needs of wildlife in one of the world's top conservation prioritised habitats is essential as land conversion accelerates.

Corridors are often cited as the solution to the well-known and common problems of habitat fragmentation, including genetic isolation and local extinction. Globally, millions of dollars are being invested into corridor creation projects, often without any real scientific study into the actual effectiveness or consequences of corridor implementation (Nohlgren and Gustafsson 1995; Simberloff et al 1992). Corridors have been criticized for the lack of empirical evidence of their effectiveness. Nohlgren and Gustafsson (1995) warn that the use of corridors is a biological experiment based on weak scientific evidence and must be evaluated.

It is generally accepted, based on evidence provided by population viability modelling and demographic studies that landscape connectivity enhances a population's viability (Beier and Noss, 1998; Hobbs, 1997). The debate about corridors and landscape connectivity has moved beyond 'Is landscape connectivity needed?' to 'Do corridors effectively increase landscape connectivity?' (Simberloff et al. 1992). Most studies in the literature fail to present evidence that corridors function as conduits between patches (Nohlgren and Gustafsson 1995). To show that a corridor increases connectivity, a study must not only provide a measure of plant or animal movement within corridors but also of the movement through the matrix. Beier and Noss (1998) state that few studies provide a measure of the extra-corridor movement by animals for comparison and therefore do not demonstrate that the presence of a corridor adds connectivity beyond the level which may exist had the corridor not been present. I sampled equally in the core habitat (primary dry thorn forest), matrix (pasture) and corridor (remnant primary dry thorn forest) to allow a comparison of movement and species composition within all three landscape elements.

Corridor studies on species richness and community composition and on ecosystem level are greatly lacking in the literature (Beier and Noss 1998). Beier and Noss (1998) argue that observations of the natural movement of animals in a fragmented habitat better demonstrate the influence of conservation corridors on landscape connectivity than controlled experiments.

This method allows for detection of the real life benefits of corridors in the actual landscape and on the actual community that is targeted.

It has been suggested that corridor studies should be species specific, concentrating on animals that require landscape connectivity such as mammals with large home ranges (Beier and Noss 1998). I argue that the value of approaching a corridor's affects on the entire community in which it is intended to provide connectivity to, is greater than a species per species approach. Conservationists accept that no species is protected without protection of the health and quality of the habitat on which it depends. Therefore, studies on the continued functioning of a system during times of fragmentation are essential. The holistic ecosystem approach will provide broader and more long-term conservation benefits.

The aim of this study was to assess if remnant corridors passing through pastural land areas are utilised by the native fauna and thereby increase the connectivity of the landscape and may therefore be considered as an effective tool to mitigate the effects of forest fragmentation in the Chaco Central. This was accomplished by comparing the utilisation of the corridors and the pastural fields by the species present in the core forest habitat. Track sampling, bird census and drift trap setting were the techniques used to inventory the various landscape elements.

Study site and methods

Study site

The study took place at Gran Siete (located south-west of Filadelfia), dept. Boqueron, Chaco Central, Paraguay (22° 30.851' S, 060° 35.986'W). The area is a complex of 5 cattle ranches, surrounded by unbroken primary forest. The dominant vegetation type is dry thorn forest as described by Short (1975).

Cattle grazing was established in the area during the 1970's. Since then, a total of 172 53.5 ha have been cleared for cattle grazing, mainly in 200 ha blocks. The pastures are divided by remnant strips of primary thorn forest. These strips physically connect blocks of the original, primary forest across the pastures. They have been exposed to grazing. The pastures are seeded with a combination of Gatom panic (*Panicum maximum* var. gatom panic) and Buffalo (*Pennisetum ciliare*) grasses. Grazing density is 1-1.5 cows/ha. Shrubs and weeds are removed approximately every two years, using plowing or rolling. Burning has not been used as a management tool on the studied pastures (interview with estancia owner and employees). Hunting has been banned on the main estancia since its establishment, yet a local indigenous community carries out a subsistence level of hunting (per. observation).

The study took place during the dry season, from the 20th of May 1999 to the 17th of July 1999. The mean minimum and maximum temperature was 14°C and 24°C, respectively, with a range from -1°C to +35°C. A total of 20 mm of rain fell in the area during the period of data collection.

The core forest sites studied represent various locations in one continuous forest. Vegetation characteristics are very similar among the forest replications. Dense patches of bromeliads are the dominant groundcover interspersed with ground cacti and various herbs (80% total ground cover). Algarrobo (*Prosopis spp.)* and Acacia (*Acacia spp.*) create a dense canopy at 3 m height. A top canopy at 10 m height is constituted of sparsely spread Quebracho (*Aspidosperma quebracho-blanco and Schinopsis quebracho-colorado*), Palo Santo (*Bulnesia sarmientoi*), cactus tree (*Cereus stenogonus, C. coryne*), and bottle tree (*Chorisia insignis*) individuals. The corridors are remnant strips of primary thorn forest, left during land clearing for pastures. Exposure to grazing has reduced the density of the shrub and groundcover vegetation within the corridors. Both visibility and ease of movement are increased in the corridors relative to the intact forest. On the pastures, grass height and density varied considerably between replicates (40-120 cm height, 60-90% cover). Shrub cover on the pastures range from

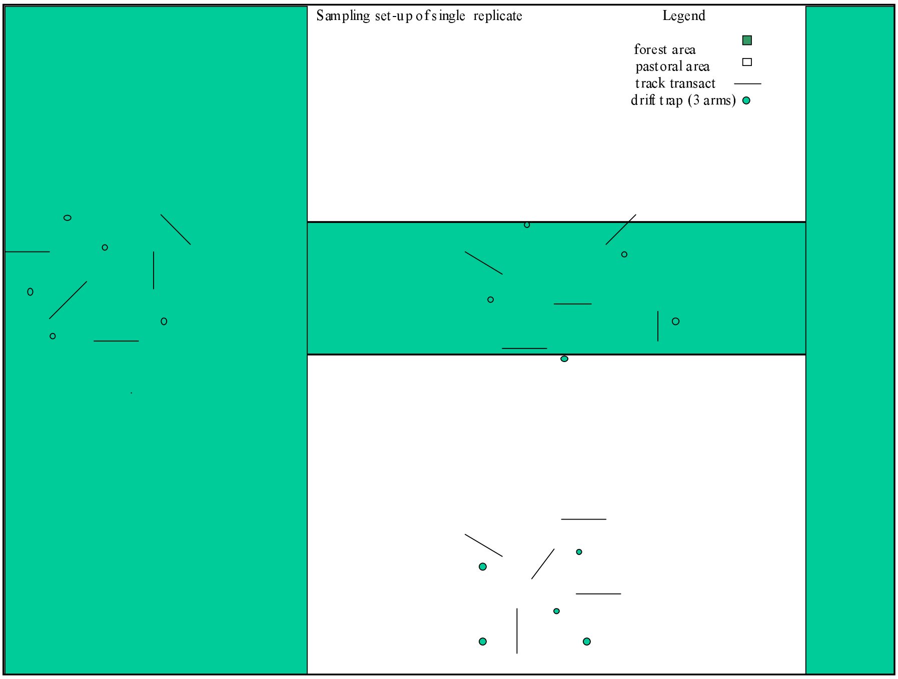

Figure 1. Sampling setup of single replicate

5-20% and a shrub height of 60-180 cm.

Sampling

I selected three replicate sites, consisting of remnant thorn forest corridor, which pass through cattle pasture. Each end of the corridors connects to unbroken primary thorn forest. I inventoried the corridor, core forest and adjacent pasture in each replicate with identical methodology. The corridors have a width of 208, 155, and 100 m, with equal lengths of 2 km. The large mammal fauna was identified using track identification; bird fauna, using visual and auditory census and; small vertebrate fauna, using drift trapping. Data for each faunal group was collected simultaneously in each of the landscape elements, over consecutive days, one replication at a time. Skin contact with vegetation and soil was avoided to reduce scent trails.

I conducted the large fauna census using track identification. Five, 20 x 1 m transects were established using a blocked random approach over a 4 ha area in the central region of each landscape element. Each transect was cleared of all ground vegetation and the soil sieved and swept for optimal track identification conditions. The canopy vegetation if present, was left intact. Each transect was randomly orientated in a South to North, East to West, Northeast to Southwest, or Southeast to Northwest direction. One to two days of data collecting was carried out with no bait present prior to commencement of baiting at each replicate. Each transect was baited and checked for tracks every 24 hours over 10 consecutive days as weather permitted. Each transect was randomly baited in the centre with one of: 10 g of ground maize, 1 canned sardine, half a banana, 100 g piece of pumpkin or 1 tbsp. of peanut butter. Tracks were photographed and preserved as a plaster of Paris mould for confirmation of identification.

In the same four ha areas, using blocked random distribution, I placed five drift trap stations for the small vertebrate census. Each station consisted of four smooth-walled, plastic buckets, 25 cm deep with a 25 cm diameter, buried at ground level, in a three-arm formation.

The buckets were connected by veneer wood, 450 cm in length and 30 cm in height, to guide animals into the buckets. I emptied each trap once every 24-hour period for 12-16 days/replicate. Voucher specimens are deposited at Museo Nacional de Paraguay, Asuncion.

An avian species census was conducted for a 20 min. timed interval at one randomly chosen track transect in each landscape element, on each day, during which all avian species present within visual and auditory range were recorded.

Analysis

I compared the species richness between the three landscape elements for each of the faunal group: large mammals, small mammals, reptiles and amphibians and avian species. The Friedman Two-way analysis of Variance by Ranks test was used to examine differences in species numbers and number of observations between the landscape elements. Sørensen Similarity Values were calculated using species presence data and species frequency of mammal track observation data, as described in (Magurran 1988) $C_s = 2j/a + b$ where j = the number of species found in both landscape components and a = the number of species found in landscape component a; and b = the number of species found in landscape component b. The total number of observations between the landscape elements were compared at a species level and at a guild level, using the Friedman Two-way analysis of Variance by Ranks test.

Two sightings of a canid were determined to be Maned wolf (*Chrysocyon brachyurus*) in highest probability and were analysed as such.

A single observation was considered to have occurred each time a species was identified on a transect. As a result several individuals of the same species which stepped on the same transect on the same day were recorded as only one observation, while a single individual who stepped on more than one transect in a day's period was recorded as an observation for each imprinted transect. Despite this lack of real abundance data, frequency of species observation was still used as a measure of relative abundance for between landscape element comparisons, as I judged it most probable that individual species behaviour in this regard remained constant from landscape element to landscape element.

Results

Species richness between landscape elements

The species richness was surprisingly uniform between the three landscape elements for all faunal groups studied with the exception of the avian community (Appendix 1 to 3). The communities of birds and large mammals contribute the most to faunal species richness in all of the studied landscape elements.

Large mammals

A total of 24 mammal species were identified from the track transects during the study period. No significant difference was detected in the number of mammal species identified between the three landscape elements (The Friedman Two-way Analysis of Variance by Ranks) (Fig. 2). No mammal species was found in the forest, which was not found in either the corridor or the pasture. The armadillo *Chaetophractus sp.* and the rodent *Ctenomys sp.* were observed exclusively in the pasture.

Small mammals

A total of three species of opossum mice and four species of rodents were captured in the drift traps. All of the opossum mice species occurred

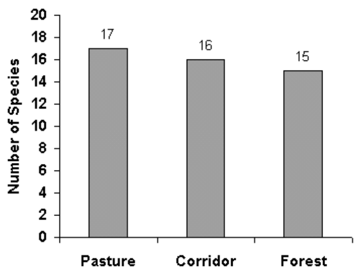

Figure 2. Total number of large mammal species identified on baited track sampling transects (1 x 20 m) in various landscape components. Pooled data from 3 replicates containing 5 transects over 10 days in each landscape component.

Figure 3. Total number of small mammal species captured in drift traps in various landscape components of the pastoral landscape of the Chaco Central of Paraguay.

in each of the studied landscape elements. All of the rodents species were represented in the corridor, while the pasture lacked representation of one species and only a single species was captured in the forest (Fig. 3). Species determination is still in progress at Museo Nacional de Paraguay. Morpho-species groups were used for the analysis.

Reptiles and Amphibians

A total of sixteen species of amphibians and five species of reptiles were captured in the drift traps. The corridor and pasture contained an equal number of twelve species captured, while only five of the species were captured in the forest (Fig. 4). Species determination is still in progress at Museum Nacional de Paraguay for some species (Appendix 3). Morpho-species groups were used for the analysis.

Figure 4. Total number of amphibian and reptile species captured in drift traps in various landscape components of the pastoral landscape of the Chaco Central of Paraguay.

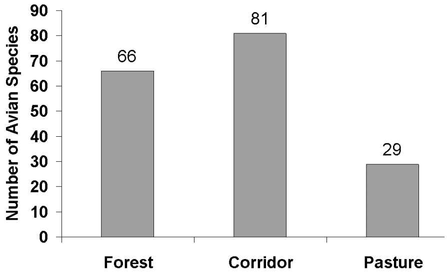

Figure 5. Number of avian species censused in various landscape elements

Avian Species

A total of 100 bird species were recorded during the timed avian species census. 80 of the species occurred in the corridor, 67 species in the forest and 29 species in the pasture (Fig. 5). The number of species in the pasture was significantly lower than the forest or corridor (The Friedman Two-way Analysis of Variance by Ranks, $X_r^2 = 6$, $p = 0.028$).

Frequency of observations

A total of 687 observations of track prints were identified. No significant difference was found between the total number of track observations per replicate between the three landscape elements (Table 1. Friedman Two-way Analysis of Variance by Ranks, $X_r^2 = 4.67$, $p = 0.194$). 46.6% of all track observations occurred in the corridor. Of all track observations encountered outside the

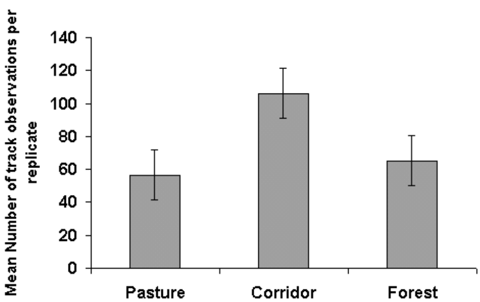

Figure 6. Mean total number of track observations of mammals per replicate (SD) in various landscape elements. One observation = one or more footprints of a species/transect/day.

Table 1. Friedman two-way analysis of variance for the number of track observations between landscape elements for large mammal guilds.

Guild	Significance		p =
Armadillos *Chaetophractus sp.* *Dasypus novemcinctus, Euphractus sexcinctus, Tolypeutes matacus*	Significant preference of pastures	6	0.028
Top Predators *Chrysocyon brachyurus, Oncifelis geoffroyi, Leopardus pardalis, Herpailurus yaguarondi, Panthera onca, Puma concolor*	Nonsignificant	4.67	0.194
Smaller Predators *Cerdocyon thous, Pseudalopex gymnocerus,Conepatus chinga, Galictis cuja,Galictis vittata, Procyon cancrivorus*	Nonsignificant	2.67	0.361
Herbivores *Catagonus wagneri,Ctenomys dorsalis Dolichotis salinicola, Mazama gouazoubira, Mazama rufina, Sylvilagus brasiliensis,Tapirus terrestris*	Significant preference of corridors	6	0.028

core forest habitat, 65.6% occurred inside the corridor, i.e. corridor passage occurred with nearly twice the frequency as did extra-corridor passage (Fig. 6). Both the species richness and the rates of capture of small mammals and reptiles and amphibians were higher in the corridor and pasture than in the forest (Table 2).

The number of track observations of the guilds armadillos, top predators, small predators and herbivores were also tested for significance between the landscape elements (Friedman two-way analysis of variance by ranks test). Armadillo tracks were significantly more often observed in pasture. Herbivore tracks were significantly more often observed in corridor. There was no significant difference in the number of observations of top nor smaller predator tracks between the landscape elements.

Table 2. The rates of capture of faunal groups between various landscape elements in drift traps (Captures/board/night).

Faunal group	Forest	Corridor	Pasture
Opossum mice	0.018	0.015	0.054
Rodents	0.002	0.021	0.034
Reptiles	0.002	0.008	0.021
Amphibians	0.015	0.1236	0.055

Community structure

I calculated Sørensen Similarity Values for each faunal group between the three landscape elements. The landscape elements are quite similar based on species presence (Table 3). The Sørenson Values describe even greater similarity when, the frequency of observation values are added as a measure of abundance (Table 4).

The total number of track observations per species when expressed as an abundance ranking does not differ markedly between landscape element versus total number of track observations per species for the complete landscape (fig. 7). Exceptions to this are *Dolichotis salinicola*, which was exclusive to the corridor with the exception of one track observation in the forest (fifth most

Table 3. Sørensen Similarity Values for species richness of faunal taxon groups between landscape elements, (value closer to 1 denotes greater similarity).

	Large mammal	Small mammal	Reptiles & Amphibians	Avian
Forest-corridor	0.581	0.615	0.580	0.767
Corridor-pasture	0.545	0.920	0.583	0.407
Pasture-forest	0.750	0.800	0.580	0.333

commonly observed track in the landscape, yet second most commonly observed track in the corridor) and *Sylvilagus brasiliensis* (fourth most commonly observed track, yet never encountered in the pasture).

Discussion

Community structure

The species composition and species richness for mammals are very similar between the three studied landscape elements. Natural grasslands occur in the dry thorn forest of the Chaco and the fauna appears to be quite savannah adapted behaviorly. Historically, the natural grassland has been the most desirable for conversion to agricultural land. As a result, large portions of the natural grasslands have disappeared in congruence with the appearance of grazing pastures. My results indicate that the native fauna has been able to adapt to this land conversion. It is highly probable that the populations are continuous across the various studied landscape elements.

An exception to this is the mara (*Dolichotis salinicola*), which seems to reside nearly exclusively at forest edges and open patches within forest. Furthermore, although common in both the forest and corridor, the forest rabbit (*Sylvilagus brasiliensis*) was also never encountered in the pasture habitat. These two important prey species likely have a greater dependency on the presence of corridors for movement than other species.

Table 4. Sørensen Quantitative Similarity Values for species diversity of large mammals between landscape elements based on frequency of observation values (value closer to 1 denotes greater similarity).

	Forest	Corridor
Forest	-	-
Corridor	0.6988	-
Pasture	0.8361	0.6270

My abundance ranking analysis as well as the Sørensen Similarity Values indicated that the community structure is extremely similar both in species composition and in relative species abundance. The greater frequency of track observations in the corridor as compared to the core forest and the pasture matrix is of interest. It is apparent that the corridor holds a special function in the landscape, as activity was more concentrated within the corridor.

My results on amphibian presence differed drastically from those of Stevens and Husband (1998) in Brazilian Atlantic forest fragments. They had zero captures in the matrix agricultural land and a very impoverished species diversity in edge areas, where as experienced highest rates of capture in the matrix and edge areas. Drift trap rates of capture were extremely low (0.12 captures/board/night), as may be expected during the dry winter season. 83% of amphibian captures coincided with precipitation. As little as 1 mm of rain was sufficient to initiate amphibian movement. A possible explanation to the differing rates of capture between the landscape elements may be the difference in precipitation reaching ground level as the denser canopy vegetation of the forest may prevent the saturation of the soil.

Landscape Connectivity

The high level of species richness in the corridor indicates that it is indeed highly used by mammals and birds. Although this study did not

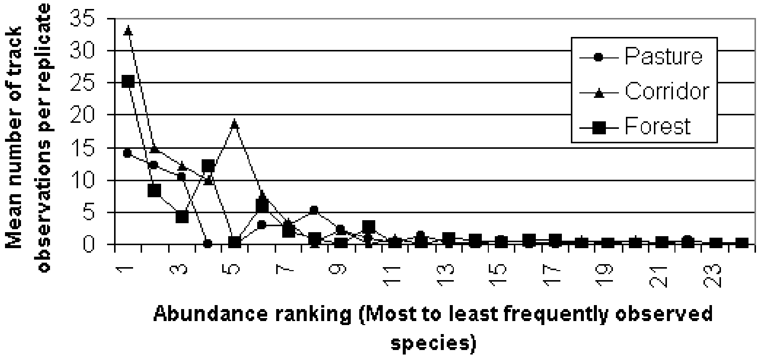

Figure 7. Mean number of track observations per species in various landscape elements vs. abundance ranking for mammalian fauna. Pooled data from 3 replicates containing 5 transects over 10 days in each landscape component. One observation = one or more footprints of a species/transect/day.

focus on the function of the corridor for each species, the patchiness in time of observations of several species (especially *Galictis cuja*, *Eira barbara, Puma concolor, Panthera onca, Myrmecophaga tridactyla,Tamandua tetradactyla*) suggests that the corridor is used on occasion to expand their territorial range. On several occasions *Herpailurus yaguarondi* tracks were observed leaving the pasture and entering the corridor or forest while dragging prey.

The repeated observation of species such as armadillos, mara, rabbit, and foxes day after day, suggests that they are residing within the corridor. The occurrence of such a resident population within a corridor suggests that the corridor will facilitate movement between habitat patches (Beier and Noss 1998). With this assumption, the repeated presence of a species in a corridor or in the matrix indicates that the population of that species is continuous from forest segment to forest segment.

Haas (1995) showed that although her studied avian species were capable of dispersing over matrix to unconnected patches, they showed a strong preference to disperse over connected habitat. My study made no observations of forest bird's movement over the matrix, where as nearly all species of forest birds were observed in the corridors.

Beier and Noss (1998) state that few studies provide a measure of the extra-corridor movement by animals for comparison and therefore do not demonstrate that the presence of a corridor adds connectivity beyond the level which, may exist had the corridor not been present. I found that nearly all species found in the core forest are also using the pasture, with the exception of avian species. The landscape connectivity in this landscape is high even across the matrix as the rates of encouter for most mammals and small vertebrates were not lower in the matrix pasture than in the core forest. Yet, it is clear by the high rate of animal encouters that the presence of the corridor are increasing movement in the landscape greatly. Beier (1993) simulated population dynamics of cougar (*Puma concolor*) in California over 100 years and found that even minimal immigration (1-4 ind.) increased the probability of population survival in fragmented areas markedly. Such a minimal level of immigration is likely facilitated by the matrix pastures in my study area.

Movement is important not only for genetic, demographic and population reasons but also for allowing access to the full range of resources needed by an individual through-out its life history (Merriam, 1991). For this reason, corridors may be of greater importance in the Chaco Central in the winter season when drought may pose greater need for passage to fresh water sources.

It is possible that the presence of the corridors are extending the ability of animals to enter the pasture matrix by providing a sense of safety and nearness to shelter and in so doing are expanding the real available habitat for some species. Yet it is too be remembered that as Rosenberg et al (1997) state, corridors do not fully compensate for habitat loss.

Conservation Implications

The study was performed on a property with a low level of human activity. The effectiveness of a corridor may vary with the level of human activity and disturbance in the area (Reijnen et al. 1997). Even the level of animal activity across the matrix may decrease with increased disturbance. In this situation it can be speculated that the importance of the corridor increases as disturbance to the area increases. A wider corridor breadth may be necessary in more disturbed areas.

Animal populations are at a greater risk to hunting by people in the corridor. This is of special concern as my frequency of observation data indicate the native fauna seem to be attracted to the corridors. Preliminary work on nest predation (Eriksson, manuscript), reveals high rates of predation in the corridor. The community dynamics and demographic consequences of the presence of the corridor in the landscape need serious attention from conservationists, wildlife managers and researchers. The high level of animal activity occurring in the corridor suggests it may be a sink in the meta-populations.

Future research should be performed to measure actual rates of migration and to determine how high the level of connectivity is and most importantly on the demographic and species interaction effects of the presence of the corridor. Further research comparing natural grasslands and pastures, and on the landscape processes such as succession and disturbance are needed to gain a better understanding of the changes occurring in the Chaco and their implications on animal populations.

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Appendix 1. Mammal Species Observed on track transects in various landscape elements in Central Paraguayan Chaco [+ denotes species identified on the track transect in that habitat during the course of the study, (+) denotes species found present in that habitat outside of the studied transects, - denotes species not found by the author in that habitat during the time of the study]

Scientific name	Common Name English	Common Name Paraguay	Forest	Corridor	Pasture
Chaetophractus sp.	Hairy armadillo	Peludo armadillo	–	–	+
Dasypus novemcinctus	9-banded armadillo	Tatu' hu'	+	–	+
Tolypeutes matacus	3-banded armadillo	Tatu' bolita	+	+	+
Euphractus sexcinctus	6-banded armadillo	Gualacate, tatu' poju'	+	+	+
Myrmecophaga tridactyla	Giant anteater	Oso hormiguero, jurumi'	+	+	–
Tamandua tetradactyla	Collared Anteater, Lessor Anteater	Kaguare'	–	+	+
Chrysocyon brachyurus	Maned Wolf	Aguara Guazu', zorro de crin	–	+	+
Cerdocyon thous,	Crab-eating fox	zorro de monte, aguara-I'	+	+	+
Pseudalopex gymnocercus	Azara's fox	zorro de pampa, aguara-I'	+	+	+
Herpailurus yaguarondi	Jaguarundi	Jaguarundi', Gato Eyra	(+)	+	+
Leopardus pardalis	Ocelot	Gato onza	+	–	+
Oncifelis geoffroyi	Geoffroy's cat	Gato montes	+	+	+
Puma concolor	Puma	Leon americano	+	(+)	+
Panthera onca	Jaguar	Tigre, jaguarete'	(+)	+	–
Conepatus chinga,	Skunk	zorrino comon, jaguane'	+	+	+
Eira barbara	Tayra	Eira'	–	+	–
Galictis cuja	Lessor grison	Eira'	+	(+)	+
Procyon cancrivorus	Crab-eating Raccoon	Osito lavador, mapache, aguara' pope'	–	+	–
Tapirus terrestris	Brazilian tapir	Tapir, mborevi'	(+)	+	–
Catagonus wagneri	Giant peccary, Chacoan peccary	Tagua'	+	–	+
Tayassu tajacu	Collared peccary	Kurei'	(+)		
Tayassu pecari	White-lipped peccary	Tanikati'	(+)	(+)	(+)
Mazama gouazoupira	Grey Brocket deer	Guasuvira'	+	(+)	+
Mazama rufina	Red brocket Deer	Guasu'-pyta'	(+)		
Dolichotis salinicola	Mara	Tapiti' boli'	+	+	–
Ctenomy dorsalis	Tuco Tuco	Tuco tuco	–	–	+
Sylvilagus brasiliensis	Forest Rabbit	Tapiti	+	+	–

Appendix 2. List of avian species present in various landscape elements of Gran Siete, Chaco Central, Paraguay [+ denotes species identified on the track transect in that habitat during the course of the study, (+) denotes species found present in that habitat outside of the studied transects, - denotes species not found by the author in that habitat during the time of the study]

Scientific name	English name	Forest	Corridor	Pasture
Rhea americana	Greater Rhea	–	+	+
Nothoprocta cinerascens	Brushland Tinamo	–	+	–
Crypturellus tataupa	Tataupa Tinamou	–	+	–
Eudromia formosa	Quebracho crested tinamo	–	+	–
Syrigma sibilatrix	Whistling Heron	–	+	–
Theristicus caudatus	Buff-necked Ibis	–	+	–
Coragyps atratus	Black Vulture	+	+	+
Cathartes aura	Turkey Vulture	+	+	+
Elanus leucurus	White-tailed kite	–	–	+
Accipiter erythronemius	Rufous-thighed Hawk	–	+	–
Heterospizias meridionalis	Savannah Hawk	–	(+)	(+)
Geranoaetus melanoleucus	Black-chested Buzzard-eagle	–	–	(+)
Harpyhaliaetus solitarius	Crowned Eagle	–	–	(+)
Buteo magnirostris	Road-side Hawk	+	+	+
Buteo albicaudatus	White-tailed Hawk	–	–	+
Polyborus plancus	Crested Caracara	(+)	+	+
Herpetotheres cachinnans	Laughing Falcon	–	+	–
Micrastur ruficollis	Barred Forest falcon	+	+	–
Falco sparverius	American Kestrel	–	–	+
Falco femoralis	Aplomado Falcon	–	+	+
Ortalis canicollis	Chaco Chachalaca	+	+	–
Cariama cristata	Red-legged Seriema	+	(+)	(+)
Chunga burmeisteri	Black-legged Seriema	+	+	–
Columbina picui	Picui Ground-Dove	+	+	+
Columba picazuro	Picazuro Pigeon	+	+	+
Zenaida auriculata	Eared Dove	+	+	+
Leptotila verreauxi	White-tipped Dove	–	+	–
Nandayus nenday	Black-hooded Parakeet	+	+	+
Aratinga acuticaudata	Blue-crowned Parakeet	+	+	+
Amazona aestiva	Turquoise-fronted Parrot	+	+	+
Myiopsitta monachus	Monk Parakeet	+	+	+
Guira guira	Guira Cuckoo	–	+	+
Tapera naevia	Striped Cuckoo	–	–	(+)
Tyto alba	Barn Owl	–	(+)	–
Strix rufipes	Rufous-legged Owl	–	(+)	–
Glaucidium brasilianum	Ferruginous Pygmy-Owl	+	–	–
Caprimulgus parvulus	Little Nightjar	+	–	–
Hydropsalis brasiliana	Scissor-tailed Nightjar	+	–	–
Chlorostilbon aureoventris	Glittering-bellied Emerald	+	+	–
Nystalus maculatus	Spot-backed Puffbird	+	+	–
Picumnus cirratus	White-barred Piculet	+	+	–
Melanerpes candidus	White Woodpecker	–	+	–
Melanerpes cactorum	White-fronted Woodpecker	+	+	–
Picoides (Dendrocopos) mixtus	Checkered Woodpecker	+	+	–

Appendix 2. continued

Scientific name	English name	Forest	Corridor	Pasture
Piculus chrysochlorus	Golden-green Woodpecker	+	+	–
Dryocopus schulzi	Black-bodied Woodpecker	+	–	–
Campehpilus (Phloeoceastes) leucopogon	Cream-backed Woodpecker	+	–	–
Campylorhamphus trochilirostris	Red-billed Scythebill	+	–	–
Sittasomus griseicapillus	Olivaceous Woodcreeper	+	+	–
Drymornis bridgesii	Scimitar-billed Woodcreeper	+	+	–
Xiphocolaptes major	Great Rufous Woodcreeper	+	+	–
Lepidocolaptes angustirostris	Narrow-billed Woodcreeper	+	+	–
dummy	Site-billed woodcreeper	+	+	–
Upucerthia certhiodes	Chaco Earthcreeper	+	–	–
Furnarius cristatus	Crested Hornero	+	+	–
Furnarius rufus	Rufous Hornero	+	+	–
Furnarius cristatus	Crested Hornero	+	+	–
Cranioleuca pyrrhophia	Stripe-crowned Spinetail	+	+	–
Synallaxis albescens	Pale-breasted spinetail	+	–	–
Schoeniophylax phryganophila	Chotoy Spinetail	–	+	+
Pseudoseisura lophotes	Brown Cacholote	+	–	–
Phacellodomus sibilatrix	Little Thornbird	+	+	–
Phacellodomus ruber	Greater thornbird	–	+	–
Coryphistera alaudina	Lark-like Brush-runner	+	+	+
Taraba major	Great Antshrike	+	+	–
Thamnophilus doliatus	Barred Antshrike	–	+	–
Thamnophilus caerulescens	Variable Antshrike	+	+	–
Thamnophilus punctatus	Slaty Antshrike	+	+	–
Mymorchilus strigilatus	Stripe-backed Antbird	+	+	–
Rhinocrypta lanceolata	Crested Gallito	+	+	–
Melanopareia maximiliani	Olive-crowned crescent-chest	–	–	+
Suiriri suiriri	Suiriri Flycatcher	+	+	–
Elaenia sp.	Elaenia sp.	+	+	–
Camptostoma obsoletum	Southern Beardless Tyrannulet	+	+	–
Sublegatus modestus	Scrub Flycatcher	+	–	–
Griseotyrannus aurantioatrocristatus	Crowned-slaty flycatcher	–	+	–
Stigmatura budytoides	Greater Wagtail-Tyrant	+	+	–
Hemitricus margaritaceiventer	Pearly-vented Tody-Tyrant	+	+	–
Pyrocephalus rubinus	Vermilion Flycatcher	–	–	(+)
Myiophobus fasciatus	Bran-coloured flycatcher	+	+	–
Xolmis irupero	White Monjita	–	–	(+)
Kniplegus striaticeps	Cinereous Tyrant	+	+	–
Myiarchus tyrannulus	Brown-crested Flycatcher	+	+	–
Pitangus sulphuratus	Great Kiskadee	–	+	–
Machetornis rixosus	Cattle Tyrant	–	–	(+)
Casiornis rufa	Rufous Casiornis	+	–	–
Cyanocorax chrysops	Plush-crested Jay	+	+	–
Polioptila dumicola	Masked Gnatcatcher	+	+	–
Troglodytes aedon	House Wren	+	+	+
Mimus triurus	White-banded Mockingbird	+	+	+
Cychlariss gujanensis	Rufous-browed Peppershrike	+	+	–

Appendix 2. continued

Scientific name	English name	Forest	Corridor	Pasture
Parula pitiayumi	Tropical Parula	+	+	–
Piranga flava	Hepatic Tanager	+	+	–
Paroaria coronata	Red-crested Cardinal	–	+	–
Coryphospingus cucullatus	Red-crested Finch	+	+	+
Saltator aurantiirostris	Golden-billed Saltator	+	+	–
Saltatricula multicolor	Many-coloured Chaco-Finch	–	+	+
Sicalis luteola	Grassland Yellow-Finch	–	+	(+)
Poospiza torquata	Ringed warbling finch	–	+	–
Poospiza cinerea	Black-capped Warbling-Finch	+	+	+
Lophospingus pusillus	Black-crested Finch	–	(+)	–
Myiospiza humeralis	Grassland sparrow	–	+	+
Zonotrichia capensis	Rufous-collared sparrow	+	+	+
Molothrus bonariensis	Shiny Cowbird	–	+	–
Molothrus badius	Bay-winged Cowbird	–	+	(+)
Cacicus solitarius	Solitary Black Cacique	+	+	–
Syurnellas superciliaris	White-browed Blackbird	–	–	+

Appendix 3. Amphibian and reptile species observed in various landscape elements in Gran Siete, Chaco Central, Paraguay. [+ denotes species identified on the track transect in that habitat during the course of the study, (+) denotes species found present in that habitat outside of the studied transects, - denotes species not found by the author in that habitat during the time of the study]

Scientific Name	English Name	Paraguayan Name	Forest	Corridor	Pasture
Leptodactylus bufonius	Shovel-nosed chamber frog	Rana hocico de pala	–	+	–
Leptodactylus chaquensis	Chaco frog	Rana chaqueña	–	–	+
Physalaemus biligonigerus	False-eyed frog	Jui vaca ra'y	+	+	+
Bufo granulosus	Granulated toad	Kururu, sapo	+	+	+
Bufo paracnemis	Rococo toad	Kururu, sapo	–	+	–
Phyllomedusa sauvagei	Chaco leaf frog		+	+	+
Physalaemus albonotatus	Frog		+	+	+
Dermatonotus muelleri	Mueller's narrow-mouthed frog		–	+	+
Elachistocleis ovalis	Orange thigh		–	+	–
Elachistocleis sp.	Blue		–	–	+
Homonota horrida	Chacoan straight-toed gecko		+	+	+
Tropidurus sp.	Spine lizard		–	+	–
Proctotretus doellojuradoi			–	+	–
Mabuya frenata	Bridled skink	Ambere'	–	+	+
Mabuya sp. guaporicola?	Brindled skink		–	–	+
Leptotyphlops melanotermus	Blind snake		–	–	+
Leptotyphlops sp.	Blind snake		–	–	+