International Journal of Biodiversity and Conservation Vol. 1(1) pp. 011-020 May, 2009
Available online http://www.academicjournals.org/ijbc

Full Length Research Paper

Wildlife habitat selection and sustainable resources management in a Neotropical wetland

Arnaud Léonard Jean Desbiez[1,2*], Richard Ernest Bodmer[1] and Sandra Aparecida Santos[2]

[1]Durrell Institute of Conservation and Ecology, University of Kent, Canterbury, Kent, CT2 7NS, UK.
[2]Embrapa-Pantanal, Rua 21 de Setembro 1880, Bairro Nossa Senhora de Fátima, Caixa Postal 109, Corumbá 79320–900, Mato Grosso do Sul, Brazil. Tel.: 67 3233-2430.

Accepted 21 April, 2009

The identification of key habitat types for wildlife is an essential step to plan and promote sustainable land management strategies. Private cattle ranches occupy most of the Brazilian Pantanal and the recent intensification in land use practices is thought to threaten wildlife. Using encounter rates from transects, landscape use and habitat selection of the community of medium to large-sized mammals was examined to identify key wildlife habitats. Overall landscapes that had a higher proportion of forested habitats were the most used by wildlife. Within the different landscapes, forested environments can be considered key habitats for most of the native mammals considered in this study. Unfortunately, theses are also the habitats most at risk by the recent changes in land use practices. Results from this study predict that current intensifications of ranching practices will be detrimental to wildlife. In addition to deforestation, other threats such as land degradation, fire, landscape alterations such as fencing and artificial water holes may also impact landscape and habitat quality. The key to conserving biodiversity in the Pantanal is preserving the natural habitat matrix that sustains the diversity of landscapes and to continue integrating cattle ranching into the natural processes that sustain a functioning ecosystem.

Key words: Deforestation, floodplain, habitat selection, Neotropical mammals, Brazilian Pantanal.

INTRODUCTION

When considering biodiversity in sustainable management planning, it is crucial to understand how habitat changes will affect the distribution and abundance of wildlife. Rates of biodiversity loss are usually associated with a reduction in the extent of original habitat (Grelle et al., 1999; Tews et al., 2004; Sinclair and Byrom, 2006). One important step in planning and promoting sustainable land management strategies is the identification of key habitat types for wildlife (Garshelis, 2000; Morrison, 2002; Vavra, 2005; Carter et al., 2006). Management alternatives can then be planned and adapted to safeguard these important habitats.

Changes in landscapes due to the expansion of the cattle ranching industry have been a leading factor in causing deforestation in the tropics (Laurance, 1997). Extensive cattle ranching started in the Brazilian Pantanal in the mid-18th century. It is considered one of the very few examples of sustainable management of a tropical biome. Until recently this wetland was considered rather pristine (Junk, 2006; Harris et al., 2005). Private ranches whose main economic activity is beef production occupy approximately 95% of the Brazilian Pantanal (Harris et al., 2005). Under traditional management practices that consist of the seasonal movement of herds among patches of native savannas, cattle ranching are considered to have a low environmental impact (Santos et al., 2002; Santos et al., 2004).

However, this is rapidly changing. Cattle ranching is becoming increasingly competitive and many land owners are now either selling their properties or intensifying ranching practices (Seidl et al., 2001; Santos et al., 2002; Junk, 2006). Since the early 1970s, ranchers are clearing land and planting pastures of exotic grasses to increase the carrying capacity for livestock. Ranchers tend to plant pastures on the highest grounds available in their ranch since these are not subject to regular flooding and these

*Corresponding author. E-mail: adesbiez@hotmail.com.

areas are usually forested (Comastri Filho and Pott, 1996; Seidl et al., 2001).

Sustainable rural development that supports agricultural production, together with biodiversity management, is becoming widespread and integrated into agricultural policy (Firbank, 2005). Environmental services and benefits of functioning ecosystems are increasingly valued (Constanza et al., 1997; Kundhlande et al., 2000; Gustavvson et al., 2002; Torras, 2003; Turner et al., 2003). The Pantanal is recognized as a major contributor to global ecosystem services (Constanza et al., 1997; Seidl and Moraes, 2000; Junk and de Cunha, 2005). Habitats influence the distribution and interactions of animal species and their destruction can cause the disruption of key biological processes (Tews et al., 2004). It is important to understand how habitat changes affect the distribution and abundance of wildlife for biodiversity conservation and sustainable resource use planning. The objective of this paper is to analyze habitat selection patterns of the community of medium to large-sized mammals in the center of the Brazilian Pantanal to identify key habitats for wildlife. In terms of biodiversity management this means that safeguarding these key habitat types will promote wider conservation goals.

METHODS AND STUDY AREA

Study area

This study took place between October 2002 and November 2004 in the centre of the Pantanal at the Embrapa Pantanal Nhumirim ranch and its surrounding ranches (18° 59' S, 56° 39' W). The study area covered over 200 km^2. It overlapped with six traditionally managed cattle ranches, meaning that most of these ranches are comprised of native vegetation, cattle are managed extensively and human impact on the mosaic landscape characteristic of the Pantanal is low. Data was collected during a period that was considered as a prolonged and severe drought by locals (Desbiez, 2007). Further details of the study area are provided in Desbiez (2007) and Soriano et al. (1997).

Landscape and habitat availability

This study was conducted at two different spatial scales: landscapes and habitats. A habitat was characterized by a community of plants, while a landscape was defined by its habitat composition (Garshelis, 2000). The habitats recognized in the study area included: 1-) open grasslands, 2-) scrub grasslands, 3-) scrub forest, 4-) semi-deciduous forest and 5-) forest edge. All the different habitats were found in the different landscapes, but the proportions of these varied. The floodplain landscape is characterized by large expanses of seasonally flooded, open grasslands where small discontinuous islands of forest are present. The forest landscape is characterized by a high proportion of continuous semi-deciduous forest habitat and the cerrado landscape by a high proportion of scrub forest and scrub grasslands habitat. The floodplain/forest landscape is a transition between the floodplain landscape and the forest landscape and is characterized by both large expanses of flood plain, but with areas of continuous semi-deciduous forest. The forest/cerrado landscape is a transition between the cerrado and the forest landscapes and is characterized by areas of continuous forest, scrub grassland and scrub forest. Changes in land use practices and cattle management which affect these landscapes were reviewed in the literature to analyze which habitats would be most affected.

Habitat availability in each landscape was estimated through line-transects. Twenty-one transects ranging between 3.5 and 5 km and marked at 50 m intervals were randomly placed throughout the study area. Four transects were opened in the forest landscape, four transects in the cerrado landscape, eight in the floodplain landscape, three in transition between forest and floodplain and two in an area of transition between cerrado and forest. Transects were marked and habitat was categorized every 50 m along the transect. Habitat availability for each landscape was estimated from the total proportion of 50 m habitat segments from the transects within the landscape.

Landscape and habitat use

Use of landscape was estimated through encounter rates of animals or groups of animals sighted from transects in each landscape. Transect census began at sun rise and trails were carefully walked alone by the same observer. A total of 552 km were walked in the forest landscape, 665 km in the cerrado landscape, 410 km in the floodplain landscape, 296 km in transition between forest and floodplain, and 241 km in an area of transition between cerrado and forest. For encounters to remain independent events, sightings of groups of social animals were recorded as a single sighting. This ensures that habitat use results do not become biased due to large group sizes.

Landscapes are composed of a mosaic of exceptionally different habitats, therefore on the same line-transect, the observer may walk through a forested environment with a maximum visibility of 25 m and later find him(her)self in open grasslands, where the maximum visibility is well over 250 m.

To make sure that animals all had the same probability of being counted from each transect, regardless of habitat, encounter rates were calculated using only animals sighted within the effective strip width determined for the species through DISTANCE software analysis (Thomas et al., 2004). For species with a low number of sightings (N<60), DISTANCE could not be applied and a conservative measure was used (Table 1).

Encounter rates for each habitat in each landscape were calculated to evaluate habitat selection. Each 50 m portion of the transect was categorized in each of the five habitat categories. On each transect, the encounter rates for each species or group on each 50 m proportion of the transect was determined. The frequency of sightings took into account the number of times the section was sampled to standardize the frequency of sightings. By grouping the encounter rate of each species in each habitat category, habitat use for each species from each landscape was then determined. The association between the proportion of habitat type in each landscape and the encounter rate was tested using linear regressions.

Resource selection

Use (encounter rates for each species) and available resource units (available habitat) were censused from transects across the entire study area. Manly's standardized habitat selection index for constant resources was used to compare habitat selection in the different landscapes. This index was chosen because it does not fluctuate with inclusion or exclusion of seldom-used resources (Manly et al., 2002) and is considered more versatile than other selection-preferences indexes (Garshelis, 2000). The index is based on the selection ratio wi, which is the proportional use divided by the proportional availability of each resource.

$$w_i = o_i / \pi_i$$

Table 1. Distance from the transect used to calculate encounter rates, using DISTANCE software (D) or a conservative estimate (C).

Species	Distance from the transect (meters)
Collared peccary (*Tayassu tajacu*)	13 (D)
White-lipped peccary (*Tayassu pecari*)	17 (D)
Feral pig (*Sus scrofa*)	10 (D)
Grey brocket deer (*Mazama gouazoubira*)	15 (D)
Red brocket deer (*Mazama americana*)	15 (C)
Pampas deer (*Ozotoceros bezoarticus*)	130 (D)
Marsh deer (*Blastocerus dichotomus*)	15 (C)
Lowland tapir (*Tapirus terrestris*)	35 (C)
Agouti (*Dasyprocta azarae*)	10 (D)
Capybara (*Hydrochaeris hydrochaeris*)	150 (D)
Black howler monkey (*Allouatta caraya*)	12 (D)
Giant anteater (*Myrmecophaga tridactyla*)	10 (C)
Southern tamandua (*Tamandua teradactyla*)	10 (C)
Six banded armadillo (*Euphractus sexcinctus*)	10 (C)
Coati (*Nasua nasua*)	8 (D)
Crab-eating fox (*Cerdocyon thous*)	10 (C)
Ocelot (*Leopardus pardalis*)	10 (C)
Puma (Felis concolor)	10 (C)
Tayra (*Eira Barbara*)	10 (C)

Where:

o_i = Proportion of the sample of used resource units in category i or frequency of sightings.

π_i = Proportion of available resource units in category i or landscape/habitat area.

A w_i value larger than 1 indicates a positive selection for the resource and a value less than 1 indicates avoidance of the resource. A value around 1 indicates that the resource was used proportionally to its availability and no resource selection was noted. The preference/avoidance of each species for each resource was calculated from the selection ratio w_i and tested for each species in each habitat using a chi-square test adjusted by Bonferroni. Habitats that were selected by a species in different landscapes are considered as key habitats for that species. Selection ratios were then standardized so that they add to 1 using Manly's standardized selection ratio to compare habitat selection among species following the equation:

$$B_i = \frac{w_i}{\sum_{i=1}^{H} w_i}$$

Where

H = number of resource units.

B_i values enable direct comparison between selection ratios within each resource unit (habitat) and can be interpreted as the probability that for any selection event, an animal would choose category i resource unit over all others, assuming that all resource units are available to the animal in equal proportion (Manly et al., 2002). Habitat availability and habitat use for the entire study area was used to calculate the Manly's selectivity index (B_i) for habitat use. This conceals variations in habitat selectivity between landscapes, but facilitates comparisons of habitat selection between species. Habitats with the highest Manly's selectivity index (B_i) for habitat use were considered key habitats for the species. Calculations were made with the extension adehabitat in the statistical package R (Ihaka and Gentleman, 1996; Calenge, 2006).

RESULTS

The floodplain landscape is the simplest of the landscapes and is characterized mostly by seasonally flooded grasslands. The four other landscapes are more complex and shaped by a mosaic of different habitat types, each covering less than 50% of the area (Table 2). Loss of traditional land use and cattle management will impact all landscapes and habitats. However, a review of changes in land use practices in ranches (Table 3) shows that forested areas are usually the primary target.

Resource use

The pampas deer, capybara and the feral pig had higher encounter rates in the floodplain landscape and the crab-eating fox had higher encounter rates in the cerrado landscape (Table 4). All the other mammals had higher encounter rates in the three other landscapes. Some species had very low encounter rates or were not even sighted in the floodplain and cerrado. The association between the proportion of habitat type in each landscape (Table 2) and the frequency of sightings was tested Table

Table 2. Proportions of habitat available in each landscapes of the study area.

Habitat types	Landscapes				
	Floodplain	**Floodplain/ Forest**	**Forest**	**Forest/Cerrado**	**Cerrado**
Open grasslands	0.85	0.47	0.21	0.39	0.21
Scrub grasslands	0.04	0.03	0.16	0.27	0.23
Scrub forest	0.02	0.01	0.10	0.13	0.42
Forest	0.05	0.38	0.37	0.11	0.08
Forest edge	0.04	0.11	0.16	0.10	0.06

Table 3. Changes in land use practices in ranches [(adapted from Eaton in Chandler and Johansson (2004)].

Changes	Consequences
Division of properties	Loss of traditional low-impact cattle ranching practices
Deforestation	Loss of forest biodiversity
Selective timber harvest	Over harvest of valuable hardwood for forests
Exotic pastures	Native pastures and forest replaced by exotic grasses
Uncontrolled burning	Loss of forest habitats and native pastures
High cattle stocking rate	Over grazing, alteration of pastures and forest under story

Table 4. Encounter rates (sightings/100 km) of mammals in the different landscapes from the centre of the Pantanal between October 2002 and November 2004. Highest encounter rates are in bold.

Species	Floodplain	Floodplain/ Forest	Forest	Forest/ Cerrado	Cerrado
Collared peccary (N=70)	0.244	2.366	5.440	2.903	3.607
White-lipped peccary (N=43)	0.000	3.042	3.986	1.244	0.451
Feral pig (N=82)	6.341	2.366	0.362	1.659	1.653
Grey brocket deer (N=169)	0.732	3.380	9.602	10.369	7.815
Red brocket deer (N=9)	0.000	1.014	0.725	0.000	0.000
Pampas deer (N=276)	56.098	21.633	0.906	4.148	2.254
Marsh deer (N=4)	0.000	1.014	0.000	0.000	0.000
Lowland tapir (N=16)	0.000	0.676	1.631	0.415	0.451
Agouti (N=369)	3.415	24.675	19.567	9.125	18.335
Capybara (N=52)	2.683	2.366	0.616	0.415	0.150
Howler monkey (N=74)	3.659	6.422	2.536	1.659	2.254
Giant anteater (N=10)	0.244	0.338	0.544	0.830	0.150
Southern tamandua (N=15)	0.244	0.676	0.725	0.830	0.751
Six banded armadillo (N=34)	1.951	2.028	0.906	0.415	0.751
Coati (N=160)	3.902	9.464	8.878	4.977	3.907
Crab-eating fox (N=20)	0.488	0.338	0.725	0.830	1.202
Ocelot (N=4)	0.000	0.000	0.544	0.000	0.150
Puma (N=3)	0.000	0.338	0.181	0.000	0.150
Tayra (N=11)	0.000	0.338	0.725	1.244	0.601

5). For half the animals tested there was no significant relationship (t statistic, P>0.05), for the other half, white-lipped peccary, grey and red brocket deer, pampas deer, tapir, coati and crab-eating fox, the proportion of a habitat type within a landscape could help predict frequency of sightings (t statistic, P<0.05). For more than half these animals the forest or forest edge was the habitat type that could predict frequencies.significant relationship (t statistic, P> 0.05), for the other half, white-lipped peccary, grey and red brocket deer, pampas deer, tapir, coati and crab-eating fox, the proportion of a habitat type within a landscape could help predict frequency of sightings (t statistic, P<0.05). For more than half these animals the forest or forest edge was the habitat type that could predict frequency.

Table 5. Results from linear regressions to determine habitat type within a landscape that could help predict frequency of sightings.

Species	Habitat type	R^2 values and t statistic
White-lipped peccary (N=43)	Forest edge	R^2=0.912 P=0.011
Feral pig (N=82)	Open grasslands	R^2=0.918 P=0.010
Grey brocket deer (N=169)	Scrub grasslands	R^2=0.797 P=0.042
Red brocket deer (N=9)	Forest	R^2=0.953 P=0.004
Pampas deer (N=276)	Open grasslands	R^2=0.943 P=0.006
Lowland tapir (N=16)	Forest edge	R^2=0.882 P=0.018
Coati (N=160)	Forest	R^2=0.998 P<0.001
Crab-eating fox (N=20)	Scrub forest	R^2=0.870 P<0.001

Table 6. Habitat selection of the mammals in the five different landscapes in the centre of the Pantanal between October 2002 and November 2004. A habitat can be selected up to five times (once in each landscape). A habitat was considered selected in a landscape and marked "+" when: $w_i > 1$ and P < Bonferroni level 0.0125.

Species	Open grassland	Scrub grassland	Scrub forest	Forest	Forest edges
Collared peccary			++	++	+++
White-lipped peccary			+	+++	++
Feral pig	++	+	+	+++	+
Grey brocket deer		++	+		+++++
Red brocket deer				++	
Pampas deer	++++				
Marsh deer	+				
Lowland Tapir	+	+	+	+	
Agouti			+++	++++	+++
Capybara	+++++				
Howler monkey				++++	++
Giant anteater	+++	++	+		
Southern tamandua			+	++	+++
Six-banded armadillo	+	+	+	++	++
South American coati			+++	++++	+++
Crab-eating fox	+++	+++			+
Ocelot				+	+
Puma				+	
Tayra				+++	++

Habitat selection

Habitat selection (w_i >1 and P< Bonferroni level 0.0125) can vary between landscapes, but most species selected the same habitats in the different landscapes (Table 6). A species can select up to two habitats in a landscape or none at all. For some species, the selection ratio could not be calculated since the animal was not seen or the encounter rate was too low. For most species, the forest and forest edge were the most selected habitat within the different landscapes and can be considered key habitats for biodiversity conservation.

Collared peccaries, white-lipped peccaries, red brocket deer, howler monkeys, agouti, coati, southern tamandua, ocelot, puma and tayras, always selected forested habitats within the landscape. Habitat selection varied between landscapes for the feral pig and the crab-eating fox. The difficulty of recording key habitats for the tapir and the six-banded armadillo are most likely due to the methodology and low encounter rates. Pampas deer, marsh deer and capybara selected open grasslands. The grey brocket deer selected forest and scrub grasslands as well as forest edge, while the giant anteater selected open and scrub grasslands and scrub forest. Data on the felids should be interpreted with caution since the number of sightings was low.

Habitat availability and habitat use for the entire study area was used to calculate the Manly's selectivity index (B_i) for habitat use. Key habitats for the collared peccary were any habitat with forest cover (scrub forest, forest, forest edge) while key habitats for the white-lipped peccary were the forest and forest edge (Figure 1). For the

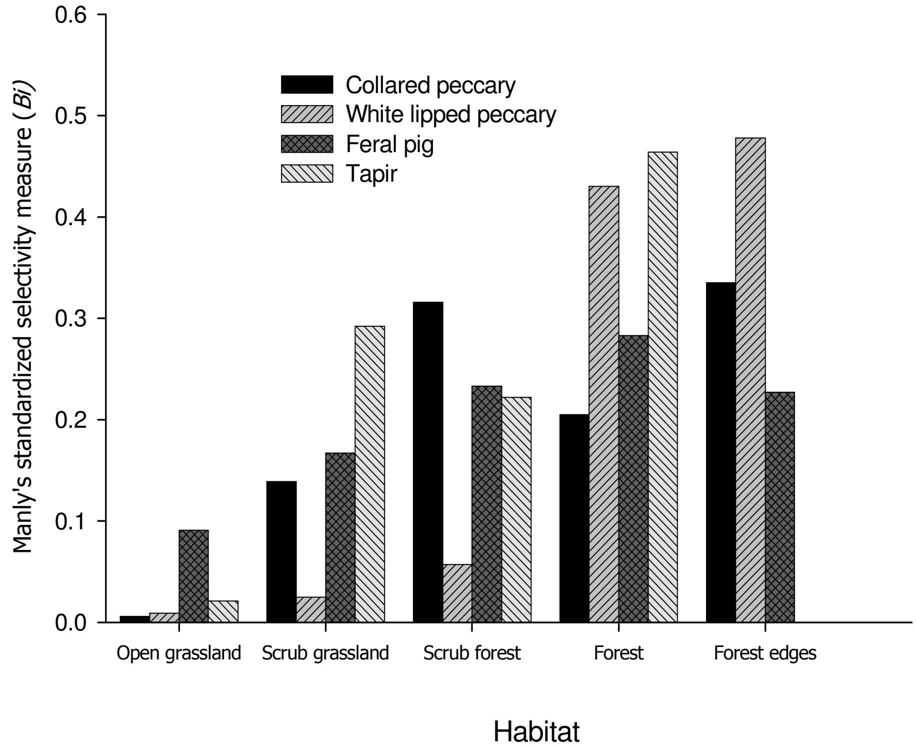

Figure 1. Probability of habitat selection in the study area as determined by Manly's standardized selectivity measure (B_i) for collared peccaries, white-lipped peccaries, feral pigs and lowland tapir, in the centre of the Pantanal between October 2002 and November 2004.

tapir it appears that forest is the key habitat. No key habitat could be determined for the feral pig. The marsh deer and pampas deer both selected open grasslands (Figure 2). The red brocket deer selected the forest and the grey brocket deer the forest edge. The giant anteater had a high selectivity index for the scrub grassland while the southern tamandua had a high index for the forest edge (Figure 3). Besides the crab-eating fox, most of the carnivores selected the forest or the forest edge (Figure 4). The agouti selected the forest habitat (B_i = 0.480) twice as frequently as the forest edge and scrub forest. The howler monkey selected the forest (B_i = 0.58), the capybara the open grassland (B_i = 0.81) and the six-banded armadillo the forest edge (B_i = 0.49) and the forest (B_i = 0.35).

DISCUSSION

Overall, landscapes that had a higher proportion of forested habitats had the highest wildlife encounter rates. In some cases, proportion of forested habitats could even help predict encounter rates for certain species. Most mammals were highly selective in their habitat selection (Collared peccaries, white-lipped peccaries, red brocket deer, howler monkeys, agouti, coati, southern tamandua, ocelot, puma, tayras, pampas deer, marsh deer and capybara), and only a few species were found to select different habitats in different landscapes (feral pig and crab-eating fox).

For many of the mammals considered in this study, forested environments (scrub forest, semi-deciduous forest, and forest edge) can be considered key habitats. Apart from the pampas deer, all of these native mammals are also found throughout their distribution in forested habitats in the Amazon or Atlantic Forest (Sowls, 1997; Eisenberg and Redford, 1999; Costa and Leite, 2000; Ron, 2000; Maffei, 2001; Rodrigues et al., 2002b; Weber and Gonzalez, 2003). Generally, habitat selection results reflected well the distribution of species throughout their range.

Forested habitats are also important to species that selected open grasslands. Capybara (Alho et al., 1987) takes refuge in the forest at night particularly during the dry season to escape strong, colder winds. Forested habitats have also been demonstrated to be important for the thermal regulation of animals (Dexter, 1998) particularly those with low metabolism such as the giant anteater (Camilo-Alves and Mourão, 2006). Forested areas become important sources of resources when forage species in the open grassland become scarce (Santos, 2001). Finally, forested areas are important refuges for all species during years of extreme flooding as they are at

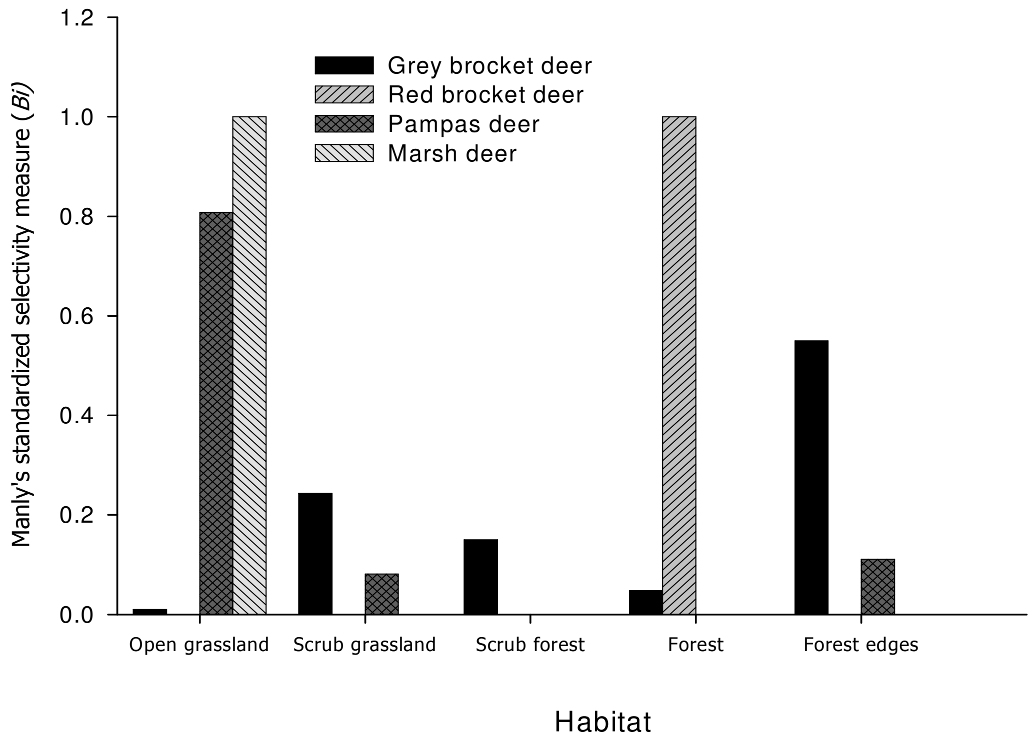

Figure 2. Probability of habitat selection in the study area as determined by Manly's standardized selectivity measure (B_i) for pampas deer, grey brocket deer, red brocket deer, pampas deer and marsh deer, in the centre of the Pantanal between October 2002 and November 2004

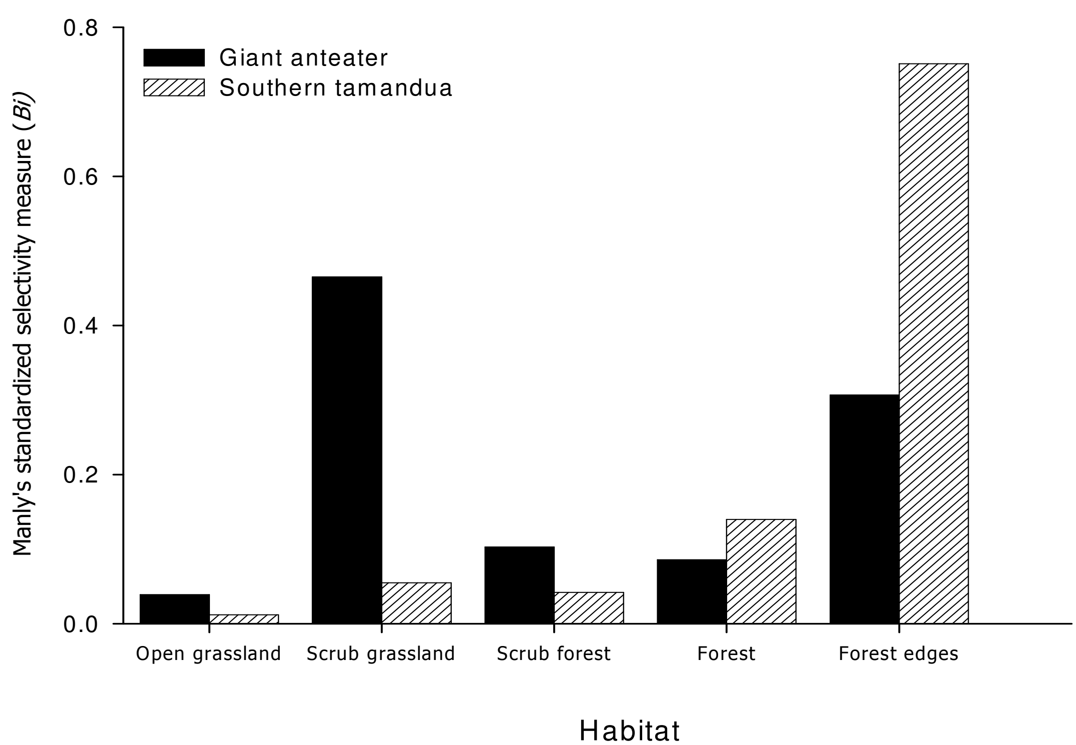

Figure 3. Probability of habitat selection in the study area as determined by Manly's standardized selectivity measure (B_i) for giant anteater and southern tamandua, in the centre of the Pantanal between October 2002 and November 2004

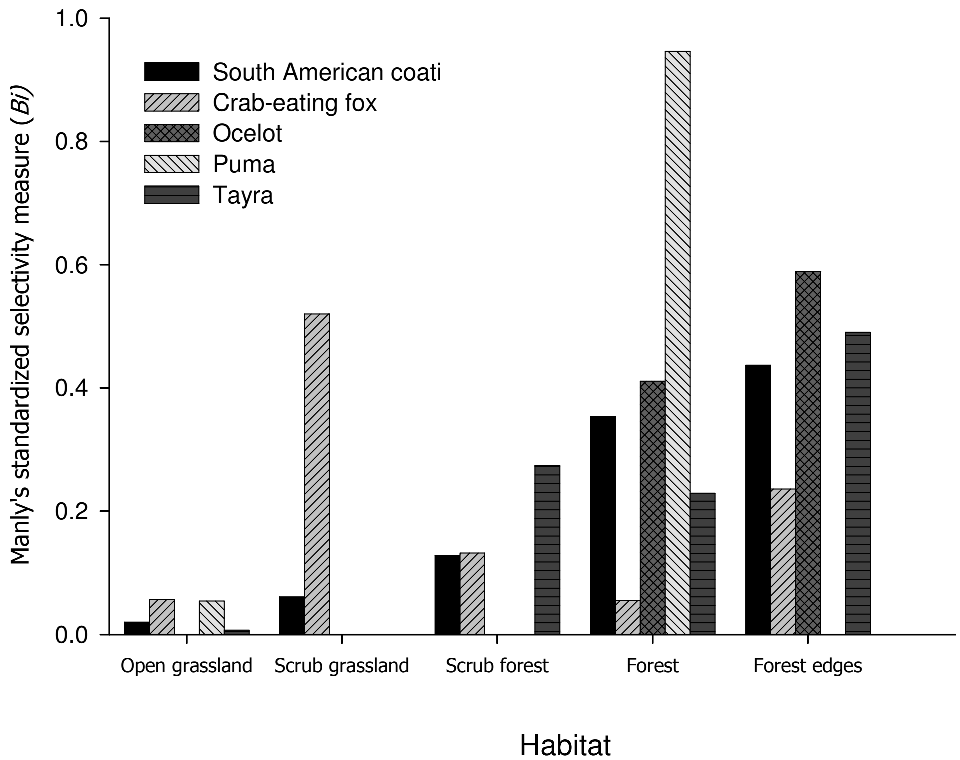

Figure 4. Probability of habitat selection in the study area as determined by Manly's standardized selectivity measure (*Bi*) for South American coati, crab-eating fox, ocelot, puma and tayra, in the centre of the Pantanal between October 2002 and November 2004

slightly higher elevations.

Regional land use trends indicate that the area of land in cultivated pastures is increasing and the amount and proportion of land in natural pastures is decreasing (Seidl et al., 2001). Deforestation in the Pantanal is on the increase, more than 40% of the forests and savanna habitats have already been altered for cattle ranching through the introduction of exotic grass species (Padovani et al., 2004). Forested landscapes were found to have the highest selectivity index for most native mammals, but they have the lowest carrying capacity for cattle (Santos, 2001). For this reason, they are the primary targets for deforestation. Results from this study predict that current intensifications and changes in land use practices will be detrimental to wildlife.

Forested habitats are important to other wildlife species not considered by the study. Caiman crocodilus yacare hide and construct their nests in forested areas (Campos, 1993). Forest habitats shelter 28.2% of the endangered bird species listed in the Pantanal (Tomas et al., 2004).

Conservation efforts for wildlife in the Pantanal should be closely linked to protection of forested areas within privately owned ranches. During the past few decades, expanding agricultural frontiers along with economic and political changes have brought the Pantanal to the forefront of developmental planning and discussion. Currently, the major threats to the Pantanal region are the planed or recently constructed hydroelectric power plants and plans to rectify and deepen the Paraguay River to facilitate ship transport through the Pantanal (hidrovia project) which will radically affect the hydrology of the entire Pantanal with far reaching negative consequences for fauna, flora and the local human population (Junk, 2006). However at the local scale, deforestation occurring in individual ranches is one of the most important threats to wildlife in the Pantanal. In addition, other changes in ranching practices are also affecting landscapes and habitat quality.

Land degradation due to an increase in stocking rate is a threat to all landscapes and habitats. Cumming and Cumming (2003) studied the scaling relationships between body mass, shoulder height, hoof area, stride length and daily ranging distance in African ungulates and found that the estimated area trampled was greater in communities dominated by larger mammals. In the Pantanal, the introduced cows, horses and buffaloes have a higher body mass, shoulder height, hoof area and stride length than any of the native ungulates and may be increasing landscape degradation. This is particularly visible near water sources during the dry season, near salt licks or inside the forest islands in the floodplain. In some areas dominated by the palm Attalea phalerata, the whole understory has been destroyed by cattle (AD personal observation). In the forests, trampling affects the regeneration of plants through the destruction of seedlings. In a ranch in the central region of the Pantanal, Johnson et al. (1997) found that after five years of cattle exclusion, seedling establishment of Sterculia apetala had improved most likely due to a lack of trampling and grazing by cattle. An increase in cattle density will increase forest degradation.

Other changes in land management may impact habitat selection and use by wildlife. Fire is a natural component of savanna ecosystems and a traditional management practice for native pastures. However, uncontrolled fires can be extremely destructive to both the native fauna and flora through habitat destruction and direct death through burning (Rodrigues et al., 2002a). The placement of artificial water holes within the driest areas of the ranch may affect the community dynamics of native fauna by favoring some species. In various parks of Africa, artificial waterholes differed substantially from the natural water regimes of the region and, in the longer term, they had complex and unwanted ecosystem effects (Harrington et al., 1999; De Leeuw et al., 2001; Sinclair and Byrom, 2006). Traditional fencing in the Pantanal was done with four strands of stretched wire enabling larger native mammals to easily cross them. Unfortunately, as properties are being sold, new owners from other parts of the country and unfamiliar with the region are placing fences with five to six strands that are preventing some native mammals from crossing the barriers (Comastri Filho and Santos, 2004). Finally, changes in the landscape and habitat availability may impact the health of wild animals. The transmission of infectious diseases between native wildlife and livestock has been documented (Hudson et al., 2002). There is further evidence that habitat fragmentation and destruction can lead to an increase or the emergence of disease in wild mammals (Daszk et al., 2001). For example, loss of marsh area and habitat shrinkage was blamed for higher tick infestation levels in marsh deer (Szabo et al., 2003).

While tropical wetlands are being destroyed, in highly industrialized countries billions of dollars are being spent to recover parts of wetlands to benefit from their associated ecosystem services that are now highly appreciated (Kuijpers, 1995; Hodge and McNally, 2000; Mitsch, 2005; Hoffmann and Baattrup-Pedersen, 2007). Although the concept of traditional agricultural landscape is sup-ported in principle at the international policy level, this does not translate at the national level. While competitive market forces render traditional practices economically unsustainable there is no coherent framework of protection or specific public policies to encourage them. Traditional low intensity cattle ranching has proven to be a sustainable management approach that maintains ecosystem function, biodiversity and dynamics of the land-scape mosaic.

Current research and practices in the Pantanal should continue to focus on viable sustainable management alternatives for the Pantanal biome that consider the native flora and fauna, livestock, the natural limitations of the biome (Santos et al., 2002; Santos and Costa, 2002; Junk and De Cunha, 2005). Research on management of native pastures, improvement of cattle management procedures, fire management, income from ecological tourism, and studies on the fauna and flora are necessary to guide management strategies. The key to conserving biodiversity in the Pantanal is preserving the natural habitat matrix that sustains the diversity of landscapes and to continue integrating cattle into the natural processes that sustain a functioning ecosystem.

ACKNOWLEDGMENTS

This work was collaboration between the Durrell Institute of Conservation and Ecology (DICE) and EMBRAPA-Pantanal. This study was part of a PhD dissertation for A.L.J.D. which received funding from the European Union INCO PECARI Project. The last year of field work was funded by the Royal Zoological Society of Scotland (RZSS). We are very grateful to the owners of Porto Alegre, Dom Valdir, Campo Dora, Ipanema and Alegria ranches for allowing research on their properties and the people living on the EMBRAPA-Pantanal Nhumirim Ranch for their constant help and support. We thank Paulo Lima Borges for his assistance walking trails in the floodplain.

REFERENCES

Alho CJR, Campos ZMS ,Goncalves HC (1987). Ecologia De Capivara (Hydrochaeris hydrochaeris, Rodentia) Do Pantanal: Actividade, Sazonalidade, Uso Do Espaco E Manejo. Rev. Bras. Biol. 47: 99-110.

Calenge C (2006). The Package “Adehabitat” for the R Software: A Tool for the analysis of space and habitat use by animals. Ecol. Model. 197:516-519.

Camilo-Alves CSP and Mourão G (2006). Responses of A Specialized insectivorous mammal (Myrmecophaga Tridactyla) to variation in ambient temperature. Biotropica 38: 52-56.

Campos ZMS (1993). Effect of habitat on survival of eggs and sex ratio of hatchlings of Caiman (Crocodilus Yacare) In the Pantanal. Braz. J. Herp. 27:127-132.

Carter GM, Stolen ED, Breininger DR (2006). A rapid approach to modeling species-habitat relationships. Biol. Conserv. 127: 237-234.

Chandler M, Johansson P (2004). Pantanal Conservation Research Initiative. Annual Report 2004. Earthwatch, p. 124.

Comastri Filho JA, Pott A (1996). Introdução E Avaliação De Forrageiras Em "Cordilheira" Desmatada Na Sub-Região Dos Paiaguás, Pantanal Mato-Grossense. In. Boletim De Pesquisa E Desenvolvimento, 05 Embrapa Pantanal., Corumbá, MS.

Comastri Filho JA , Santos SA (2004). Cercas Ecológicas. In. Artigo De Divulgação Na Mídia 57. Embrapa Pantanal. Corumbá, MS.

Constanza RD Arge R, De Groots R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P , Van Den Belt M (1997). The value of the world's ecosystem services and natural capital. Nature. 387: 253-260.

Costa LP, Leite YLR (2000). Biogeography of South American Forest Mammals: endemism and diversity in the Atlantic Forest. Biotropica. 32: 872-881.

Cumming DHM, Cumming GS (2003). Ungulate community structure and ecological processes: Body size, hoof area and trampling in African Savannas. Oecologia. 134: 560-568.

aszk P, Cunningham AA, Hyatt AD (2001). Anthropogenic environmental change and the emergence of infectious diseases in wildlife. Acta. Trop. 78: 103-116.

DDe Leeuw J, Waweru MN, Okello OO, Maloba M, Nguru P, Said MY, Aligula HM, Heitkonig IMA , Reid RS (2001). Distribution and diversity of wildlife in Northern Kenya in relation to livestock and permanent water points. Biol. Conserv. 100: 297-306.
Desbiez ALJ (2007). Wildlife Conservation in the Pantanal: Habitat alteration, invasive species and bush meat hunting. In. PhD Thesis. Durrell Institute of Conservation And Ecology (DICE), University Of Kent, Canterbury.
Dexter N (1998). The influence of pasture distribution and temperature on habitat selection by feral pigs in a semi-arid environment. Wildl. Res. 25: 547-559.
Eisenberg JF, Redford KH (1999). Mammals of the neotropics. The Central Neotropics, Ecuador, Peru, Bolivia, Brazil. The University Of Chicago Press, Chicago.
Firbank LG (2005). Striking A New Balance Between Agricultural Production And Biodiversity. Ann. Appl. Biol. 146: 163-175.
Garshelis DL (2000). Delusions In Habitat Evaluation: Measuring Use, Selection, And Importance. In: Research Techniques In Animal Ecology: Controversies And Consequences (Eds. Boitani L & Fuller TK), Pp. 111-164. Columbia University Press, New York.
Grelle CEV, Fonseca GAB, Fonseca MT, Costa LP (1999). The question of scale in threat analysis: A case Study with Brazilian mammals. Anim. Conserv. 2: 149-152.
Gustavvson K, Lonergan SC, Ruitenbeek J (2002). Measuring contributions to economic production - use of an index of captured ecosystem value. Ecol. Econ. 41: 479-490.
Harrington RN, Owen-Smith N, Viljoen P, Biggs H , Manson D (1999). Establishing the causes of the roan antelope decline in the Kruger National Park, South Africa. Biol. Conserv. 90: 69-78.
Harris MB, Tomás WM, Mourão G, Da Silva CJ, Guimarães E, Sonoda F, Fachim E (2005). Safeguarding The Pantanal Wetlands: Threats And Conservation Initiatives. Conserv. Biol. 19: 714-720.
Hodge I, Mcnally S (2000). Wetland restoration, collective action and the role of water management institutions. Ecol. Econ. 35: 107-118.
Hoffmann CC, Baattrup-Pedersen (2007). Re-establishing freshwater wetlands in Denmark. Ecol. Eng. 30: 157-166.
Hudson P, Rizzoli A, Grenfell BT, Heesterbeek H, Dobson AP (2002). The ecology of wildlife diseases. Oxford University Press, Oxford.
Ihaka R, Gentleman R (1996). R: A language for data analysis and graphics. J. Compt. Graph. Stat. 5: 299-314.
Junk WJ , De Cunha CN (2005). Pantanal: A large South American wetland at a crossroads. Ecol. Eng. 24: 391-401.
Junk WJ, De Cunha CN, Wantzen KM, Petermann P, Strussmann C , Marques MI , Adis J (2006). Biodiversity and Its Conservation in the Pantanal of Mato Grosso, Brazil. Aquat. Sci. 68: 278-309
Kuijpers JWM (1995). Ecological Restoration of The Rhine/Maas Estuary. Water. Sci. Technol. 31: 187-195.
Kundhlande G, Adamowicz WL, Mapaure I (2000). Special Section: Land Use Options In Dry Tropical Woodland Ecosystems In Zimbabwe. Ecol. Econ. 33: 401-412.
Laurance WF (1997). The Scale And Economics Of Tropical Deforestation. In: Tropical Forest Remanants (Eds. Laurance WF & Bierregaard RO). University Of Chicago Press, Chicago. Maffei L (2001). Estructura De Edades De La Urina (Mazama Gouazoubira) En El Chaco Boliviano. Mastol. Neotrop. 8: 149-155.
Manly BFJ, Mcdonald LL, Thomas DL, Mcdonald TL. , Erickson WP (2002). Resource Selection By Animals, Statistical Design And Analysis For Field Studies. Second Edn. Kluwer Academic Publishers, Dordrecht, the Netherlands.
Mitsch WJ (2005). Wetland Creation, Restoration and Conservation: A Wetland Invitational at the Olentangy River Wetland Research Park. Ecol. Engi. 24: 243-251.
Morrison ML (2002). Wildlife Restoration: Techniques for Habitat Analysis and Animal Monitoring. Island Press, Washington.
Padovani CR, Cruz MLL, Padovani SLAG (2004). Desmatamento Do Pantanal Brasileiro Para O Ano 2000. In: IV Simposio Sobre Recursos Naturais E Socio-Economicos Do Pantanal, Embrapa Pantanal. Corumba, Brasil.
Rodrigues CAG, Crispim SMA , Comastri Filho JA (2002a). Queima Controlada No Pantanal. In. Documentos, 35 Embrapa Pantanal, Corumbá, MS.
Rodrigues FHG, Medri IM, Tomás WM , Mourão GM (2002b). Revisão Do Conhecimento Sobre Ocorrência E Distribuição De Mamíferos Do Pantanal. In. Embrapa Pantanal, Corumba.
Ron SR (2000). Biogeographic Area Relationships of Lowland Neotropical Rainforest Based On Raw Distributions of Vertebrate Groups. Biol. J. Linn. Soci. 71: 379-402.
Santos SA (2001). Caraterizacao Dos Recursos Forrageiros Nativos Da Sub-Regiao Da Nhecolandia, Pantanal, Mato-Grosso Do Sul, Brazil. In, p. 199. Universidade Estadual Paulista Faculdade De Medicina Veterinaria E Zootecnia, Campus De Botucatu, Botucatu.
Santos SA, Cardoso EL, Aguilar R and Pellegrin AO (2002). Princípios Básicos Para A Produção Sustentável De Bovinos De Corte No Pantanal. In, Documentos 37. Embrapa Pantanal. Corumbá, MS.
Santos SA , Costa C (2002). Manejo Sustentável Das Pastagens Nativas Do Pantanal: Produzir Mais Sem Afetar O Meio Ambiente. In. Artigo De Divulgação Na Mídia 24. Embrapa Pantanal. Corumbá, MS.
Santos SA, Crispim SMA, Comastri Filho JA , Cardoso EL (2004). Princípios De Agroecologia No Manejo Das Pastagens Nativas Do Pantanal. In, Documentos 63. Embrapa Pantanal. Corumbá, MS.
Seidl AF, Moraes AS (2000). Global Valuation of Ecosystem Services: Application To The Pantanal De Nhecolandia, Brazil. Ecol. Econ. 33: 1-6.
Seidl AF, Vila De Silva JS , Moraes AS (2001). Cattle Ranching and Deforestation In The Brazilian Pantanal. Ecol. Econ. 36: 413-425.
Sinclair ARE, Byrom AE (2006). Understanding Ecosystem Dynamics For Conservation Of Biota. J. Anim. Ecol. 75: 64-79.
Soriano BMA, Oliveira HD, Catto JB, Comastri Filho JA, Galdino S, Salis SMD (1997). Plano De Utilização Da Fazenda Nhumirim. In. Documentos, 2, Embrapa Pantanal, Corumbá, MS.
Sowls LK (1997). Javelinas and Other Peccaries: Their Biology, Management And Use. 2nd Edition. Texas A & M University Press, College Station.
Szabo MPJ, Labruna MB, Pereira MC , Duarte JMB (2003). Ticks (Acari: Ixodidae) On Wild Marsh-Deer (Blastocerus Dichotomus) From Southeast Brazil: Infestations Before And After Habitat Loss. J. Med. Entom. 40: 268-274.
Tews J, Brose U, Grimm V, Tielborger K, Wichmann MC, Schwager M , Jeltsch F (2004) Animal Species Diversity Driven By Habitat Heterogeneity/Diversity: The Importance Of Keystone Structures. J. Biogeogr. 31: 79-92.
Thomas L, Laake JL, Strindberg S, Marques FFC, Buckland ST, Borchers DL, Anderson DR, Burnham KP, Hedley SL, Pollard JH And Bishop JRB (2004) Distance 4.1. Release 2. In. University Of St. Andrews, UK. Http://Www.Ruwpa.St-And.Ac.Uk/Distance/
Tomás WM, Souza Lld , Tubelis DP (2004) Espécies De Aves Ameaçadas Que Ocorrem No Pantanal. In: IV Simposio Sobre Recursos Naturais E Socio-Economicos Do Pantanal, Embrapa Pantanal. Corumbá, Brasil.
Torras M. (2003). An Ecological Footprint Approach To External Debt Relief. World Development. 31: 2161-2171.
Turner RK, Paavola J, Cooper PC, Farber S, Jessamy V And Georgiou S (2003). Valuing Nature: Lessons Learned And Future Research Directions. Ecol. Eco. 46: 493-510.
Vavra M (2005). Livestock Grazing and Wildlife: Developing Compatibilities. Rangeland Ecol. Manage. 58: 128-134.
Weber M, Gonzalez S (2003). Latin American Deer Diversity and Conservation: A Review of Status And Distribution. Ecoscience, 10: 443-454.