Densities of the Vulnerable marsh deer *Blastocerus dichotomus* in Bolivia's northern savannahs

BORIS RÍOS-UZEDA and GUILHERME MOURÃO

Abstract Aerial surveys have been used successfully to estimate vertebrate populations in open habitats. The marsh deer *Blastocerus dichotomus*, categorized as Vulnerable on the IUCN Red List, lives in such habitats and is suitable for aerial counting because it is conspicuous. This species, the largest South American deer, is native to Argentina, Boliva, Brazil, Paraguay and Peru but no reliable information has previously been available on its populations in Bolivia. From May to August 2007 we conducted aerial transects to survey marsh deer in three large areas of savannah. We used a modified mark–recapture method to improve the accuracy of the counts and estimated density and abundance. The corrected, estimated density of the marsh deer was 0.24 km^{-2} in the northern La Paz Department, 0.12 km^{-2} in Mamoré and 0.15 km^{-2} in Iténez. These densities are similar to the mean density of the species on other South American savannahs. This is the first large-scale survey of the marsh deer in Bolivia and the first to provide information about the density of the species in the Amazon. We recommend the creation of protected areas in these savannahs, and wildlife and domestic health programmes to conserve the marsh deer of this region.

Keywords Abundance, aerial survey, Amazon, *Blastocerus dichotomus*, Bolivia, density, marsh deer

Introduction

The marsh deer *Blastocerus dichotomus* is the largest South American deer, weighing up to 125 kg and reaching 1.2 m at the shoulder (Pinder & Grosse, 1991; Salazar-Bravo et al., 2003). Some particular anatomical characteristics of the marsh deer, such as the presence of an interdigital membrane, elongated hooves and relatively long limbs, are adaptations to marshy and flooded environments (Tomas et al., 1997).

This deer appears to be a generalist in its use of open habitats and a specialist in terms of water depth, preferring to forage in inundated areas with a depth of c. 0.7 m (Mauro et al., 1995), although it has been suggested that the selection and use of habitat by marsh deer is determined mainly by its diet (Tomas et al., 1997; Tomas & Salis, 2000). The species is restricted to humid areas, originally occuring in several types of wetland in Argentina, Bolivia, Brazil, Paraguay, Peru and Uruguay, but its distribution has been severely reduced (Pinder & Grosse, 1991; Tomas et al., 1997). Because of the reduction in its population and habitat loss the marsh deer is listed on CITES Appendix 1 and is categorized as Vulnerable on the IUCN Red List (Pinder & Grosse, 1991; Wemmer, 1998; Duarte et al., 2008; Ríos-Uzeda & Ayala, 2009). Its biology remains largely unknown (Tomas et al., 1997) and there is a lack of information about the distribution and conservation status of the species at a continental scale (Wemmer, 1998).

The Bolivian savannahs are one of the three largest flooded savannah systems in South America (Hamilton et al., 2002, 2004). The other two large wetlands are the comparatively better known Brazilian Pantanal and the Llanos of Orinoco in Venezuela. Marsh deer do not occur in northern South America (Eisenberg, 1989) but the white-tailed deer *Odoicoleus virginianus* is present in the Llanos. The Pantanal probably holds the largest marsh deer population (Mourão et al., 2000). Unlike the better known Pantanal and Orinoco savannah, the Bolivian savannahs have received little scientific attention because of difficulties of access and geographical isolation (Haase & Beck, 1989; Hanagarth, 1993; Langstroth, 1999).

Although large areas of the Bolivian savannahs do not have any detectable human activity, cattle ranching is the principal economic activity in the region (Hanagath, 1993; Langstroth, 1999). In contrast to other Neotropical floodplains, which are known to harbour marsh deer populations in areas with considerable habitat alteration, as in the floodplains of the Paraná River (Pinder, 1996; Piovezan, 2004) and the Brazilian Pantanal (Silva et al., 1999), large portions of the Bolivian savannahs are almost pristine. However, no large-scale assessment of the marsh deer

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population of Bolivia has been carried out (Tomas et al., 1997; Wemmer, 1998; Rumiz, 2002). Subsistence hunting by indigenous people in the absence of any management programme, poaching and diseases of cattle are the main threats to the marsh deer in this area (Rumiz, 2002; Ríos-Uzeda & Ayala, 2009). The aim of this study was to estimate the population size of the marsh deer in three areas of the northern Bolivian savannahs and to evaluate the importance of these areas for the conservation of the species.

Study area

Bolivia's northern savannahs (Fig. 1) are known as the Llanos de Moxos, a series of floodplains in the Amazon lowland basin of Bolivia comprising mainly open, wet savannah (Langstroth, 1999), drained by the headwaters of the Madeira River (Hamilton et al., 2002). The area of these savannahs is c. 150,000 km^2 and the core area is bordered by the Beni, Mamoré and Iténez rivers. Mean annual rainfall is 1,300–2,000 mm, falling mostly in December–March (Hamilton et al., 2004). Mean annual temperature is 25.9 °C in northern La Paz, 26.8 °C in northern Beni (Haase & Beck, 1989) and 27 °C in central Beni (Hanagarth, 1993). The mean altitude is c. 150–160 m, ranging from 135 m in the north-east to 210 m in southern Chapare (Langstroth, 1999). The three survey areas were the northern La Paz savannahs in the western Beni region, the Mamoré savannahs in the central Beni region, and the Iténez savannahs in the Baures sub-region in the eastern Beni region (Fig. 1).

Methods

We conducted aerial surveys during the dry season of 2007 (May–August): in the northern La Paz savannahs during 7–12 May, the Mamoré savannahs during 23–24 June, and the Iténez savannahs during 1–4 August. We counted marsh deer from a Cessna 206 aeroplane flying at 200 km h^{-1} and 60 m above the ground. The team for each survey consisted of the pilot, a navigator and four observers, two on each side of the aeroplane. We counted the deer in 200-m wide transects delimited by a pair of rods fixed on the wing struts (Bayliss & Yeomans, 1989; Mourão et al., 2000).

A total of 101 transects of unequal sizes were systematically distributed 5 or 10 km apart in 11 blocks with areas of 1,550–3,511 km^2: five blocks in the La Paz region, two in the Mamoré region and four in the Iténez region (Table 1). All except one block were surveyed in the morning. Sampling intensity was defined as the ratio of the area sampled (i.e. the sum of the areas of the strip transects) and the total area surveyed (Table 1). Counts were tallied at the end of each unit of 1 minute of flight (3.3 km of transect).

Because aerial counts are known to be negatively biased (Caughley, 1977) we used the double-count method to improve the accuracy of counts on both sides of the

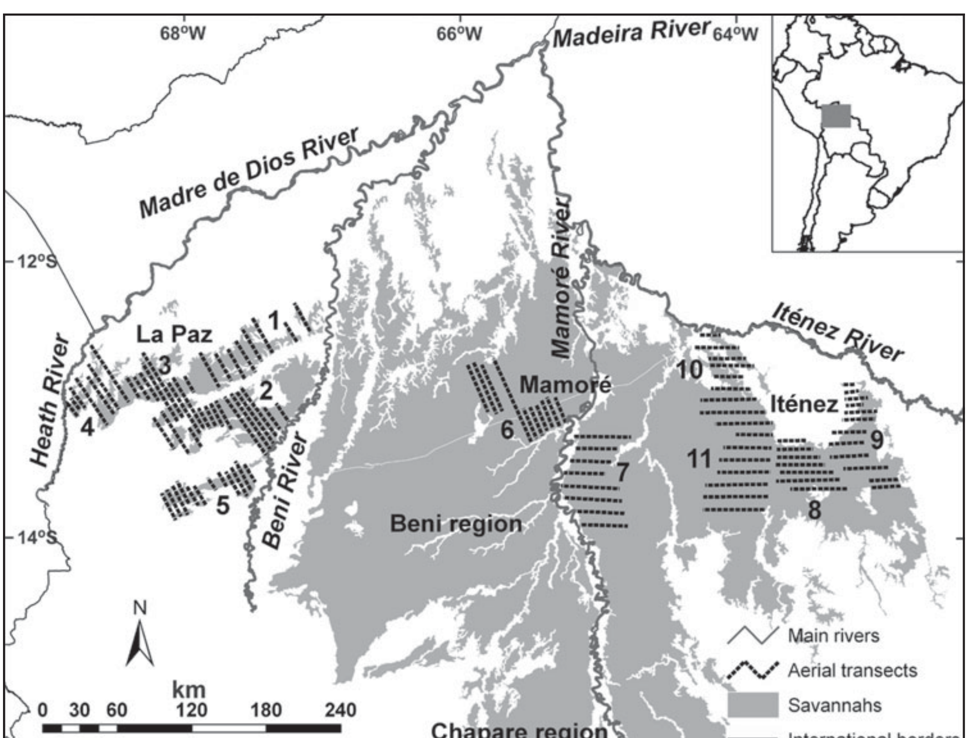

Fig. 1 The savannahs of northern Bolivia, indicating the locations of the three sites (northern La Paz, Mamoré and Iténez) surveyed for the marsh deer *Blastocerus dichotomus*. The numbers indicate the 11 survey blocks (see Table 1 for further details). The shaded rectangle on the inset indicates the location of the main map in northern Bolivia.

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TABLE 1 Estimates of density and abundance of marsh deer *Blastocerus dichotomus* in 11 sampling blocks in three regions: northern La Paz, Mamoré and Iténez (Fig. 1).

Block (by region)	Area (km^2)	Corrected density ± SE	Corrected abundance ± SE	Sampling intensity (%)
La Paz				
1	2,197	0.17 ± 0.05	382 ± 105	5
2	2,367	0.18 ± 0.04	423 ± 103	6
3	2,956	0.11 ± 0.06	338 ± 166	3
4	1,560	0.41 ± 0.11	640 ± 173	6
5	1,550	0.38 ± 0.11	592 ± 175	6
Subtotal	10,630	0.24 ± 0.03	2,590 ± 392	5
Mamoré				
6	2,335	0.06 ± 0.02	143 ± 49	6
7	3,415	0.19 ± 0.05	664 ± 187	4
Subtotal	5,750	0.12 ± 0.03	720 ± 183	5
Iténez				
8	2,557	0.28 ± 0.10	716 ± 265	4
9	3,511	0.13 ± 0.04	475 ± 143	4
10	3,298	0.09 ± 0.03	301 ± 91	4
11	1,934	0.09 ± 0.04	175 ± 74	6
Subtotal	11,300	0.15 ± 0.03	1,670 ± 358	4
Total	27,680	0.18 ± 0.02	5,089 ± 585	5

aeroplane (Caughley & Grice, 1982; Bayliss & Yeomans, 1989; Graham & Bell, 1989; Sinclair et al., 2006). The two observers on the same side of the aeroplane independently counted the animals in the same transect. Thus, by assessing the number of animals sighted by observer 1 and missed by observer 2 (S_1), the number of animals sighted by observer 2 and missed by observer 1 (S_2), and the number of animals sighted by both observers (B), it is possible to estimate the probability (P) of observers sighting an animal in a transect as follows:

$$P = (B+1)(S_1+S_2+B)/(S_1+B+1)(S_2+B+1) - (B+1) \quad (1)$$

and the multiplicative correction factor (CF) applied to the number of animals sighted by the observers is:

$$CF = 1/P \quad (2)$$

As in most studies using this method (e.g. Caughley & Grice, 1982; Bayliss & Yeomans, 1989; Mourão et al., 2000) we used the counting unit to define whether an animal was seen by one or both observers. We then compared the corrected counts between the two teams of observers (i.e. the two sides of the aeroplane) by transects and the three surveyed regions using an ANOVA with repeated measures (using *SYSTAT v. 11*; Systat, Chicago, USA). If the corrected counts by regions did not differ between sides of the aeroplane and the corrected counts by side did not interact with regions we then pooled the corrected counts of both sides of the aeroplane to estimate marsh deer abundance, density and standard errors for blocks, regions and total area. We estimated these parameters using the equations provided by Sinclair et al. (2006) for sample units of different sizes and without replication, and used a one-factor ANOVA to examine differences in densities between the three surveyed areas.

In addition, we estimated the abundance and associated standard errors for the entire survey area, and how many years of monitoring would be required to obtain sufficient power to detect decreases in numbers over the entire area (Gerrodette, 1987, 1993). For these analyses we assumed that the marsh deer follows an exponential growth model and that the coefficient of variation is proportional to the inverse of the square root of the estimate, which is expected when the samples are strip transects (Marsh, 1995).

Results

We counted a total of 159 marsh deer, 86 in the La Paz region, 31 in Mamoré and 42 in Iténez. We were only able to determine the sex and age of deer in < 10% of observations, mostly solitary animals. Only 23 observations (19%) consisted of groups of two or more animals. The observers on the right side of the aeroplane missed fewer animals than those on the left side, although both sides consistently missed more animals in the Iténez region than in La Paz, and more in La Paz than in Mamoré. The probabilities of observers sighting marsh deer were sufficiently large (i.e. > 0.45) to provide valid estimates (Potvin et al., 2004; Potvin & Breton, 2005) and therefore we applied the double-count method to improve the accuracy of the counts. The resulting correction factors were 1.03–1.94. The corrected counts by transects did not differ between sides of the aeroplane ($F_{1,98} = 0.204$, P = 0.653) nor did they interact with the blocks ($F_{2,98} = 1.275$, P = 0.284). We therefore pooled the corrected counts from both sides of the aeroplane to estimate the density of the marsh deer.

The corrected, estimated density of marsh deer was 0.24 ± SE 0.03 km^{-2} in northern La Paz, 0.12 km^{-2} ± SE 0.03 in the Mamoré region and 0.15 km^{-2} ± SE 0.03 in the Iténez region. These estimates did not differ significantly between regions ($F_{2,8} = 1.27$, P = 0.33). Block 4 in La Paz had the highest density of marsh deer and Block 6 in the Mamoré region the lowest (Table 1).

Corrected, estimated total abundance was c. 5,000 marsh deer for the three areas combined (Table 1). The power analyses suggested that maintaining the overall sampling intensity at 5% we would need eight or five surveys (i.e. years) to detect a decrease of 5 or 10%, respectively, in corrected marsh deer abundance but that a decrease of 30% could be detected by just two surveys.

Discussion

Aerial surveys

Only one aerial survey of marsh deer had been carried out previously in Bolivia, in a 820-km^2 area in the northern La Paz Department in May 2004 (H. Gomez & B. Ríos-Uzeda, pers. obs). Other data on marsh deer in Bolivia are restricted to presence/absence data (Tarifa, 1996; Townsend, 1996; Anderson, 1997), without ecological information (Tarifa, 1996; Rumiz, 2002). Bolivia's northern savannahs are the north-western limit of the marsh deer's range (Pinder & Grosse, 1991; Tomas et al., 1997). Our estimated densities were lower than those reported for the wet savannahs in the centre of the species' historical range but higher than those from its southern geographical limit. In the Brazilian Pantanal estimates range from 0.09 km^{-2} (Mauro, 1993) to 0.98 km^{-2} (Mourão et al., 2000). Tomas et al. (2001) found that local density changed little across seasons, from 0.382 km^{-2} during the dry season to 0.395 km^{-2} during the wet season, but that floods strongly affected marsh deer distribution. Three independent surveys carried out in the same floodplain area of the Paraná River reported similar densities (0.51 km^{-2}, Mourão & Campos, 1995; 0.48–0.53 km^{-2}, Pinder, 1996; 0.49 km^{-2}, Andriolo et al., 2005), despite using different methods to correct for visibility bias, including line transects (Pinder, 1996; Andriolo et al., 2005) and the double-count method (Mourão & Campos, 1995; Pinder, 1996). A relatively low density of 0.09 km^{-2} was found in the Natural Reserve of Iberá, Argentina, near the southern limit of the species' range (Beccaceci, 1994).

The highest density of marsh deer that we recorded was in the northern La Paz Department, the extreme north-west limit of the species in South America. This relatively high density may be explained by the low human population density in this area (Haase & Beck, 1989; Hanagarth, 1993) and because the savannah in this area is relatively well conserved and has a higher percentage of open humid savannah than the Mamoré and Iténez regions. Overall, the survey blocks with the lowest densities were drier or have large extensions of woody savannah. The marsh deer has a similar distribution pattern in the Brazilian Pantanal (Mauro, 1993).

The estimated abundance of marsh deer in the three surveyed areas, totalling 27,700 km^2, was c. 5,000. Although the accuracy of the counts was corrected this is still a conservative estimate. Because we used units of 1 minute of flight to determine whether both observers counted the same individuals it is possible that different deer might have been assigned as the same and we may thus have under-estimated the correction factor (Mourão et al., 2000; Sinclair et al., 2006). We have not attempted to extrapolate our estimates to the whole area covered by Bolivia's northern savannahs because the areas we surveyed may be those most suitable for the marsh deer.

Management implications

The northern savannahs of Bolivia are remote, difficult to access and generally still pristine, although we observed moderate cattle-raising activities. The population of marsh deer in this region is of considerable importance, in particular because the main known refuge of the marsh deer, the Brazilian Pantanal, is threatened by large-scale deforestation and human alterations of the flood pulse. It has been estimated that >40% of the forest and savannah habitats of the Pantanal have been altered for cattle ranching through the introduction of exotic grasses (Harris et al., 2005), and > 100 small hydroelectric dams are being constructed or are planned. Besides their importance for marsh deer conservation the enclaves of savannah in the Bolivian Amazon need to be conserved to protect landscape diversity. We recommend the creation of protected areas in these savannahs, wildlife and domestic health programmes to assess the potential transmission of diseases, and a participative management programme, involving indigenous and other local people, to ensure that marsh deer harvests are sustainable.

The results of this study provide baseline estimates of density and abundance of the marsh deer in the areas surveyed, and demonstrate that an annual monitoring programme for the species is feasible. The next step will be to work with national and local authorities to establish a management programme for the marsh deer in the Bolivian savannahs.

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Biographical sketches

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