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Reproduction in a semi-captive herd of pampas deer *Ozotoceros bezoarticus*

Rodolfo Ungerfeld, Uruguay Tabaré González-Sierra & José Piaggio

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Information on reproductive traits of semi-captive breeding of the pampas deer *Ozotoceros bezoarticus arerunguaensis*, an endangered species, was registered during 20 years. Birth events were monitored every 1-2 days from 1981 to 2000, and birth date, mother and father identities, sex and mass of fawns were all registered. Although births occurred throughout the year, a seasonal pattern with a peak in spring was observed. Dispersion of births throughout the year increased in multiparous females that previously gave birth four times or more. The interval between two consecutive parturitions was $\sim$10 months, independently of the mother parity and of the sex of the fawn, but differed according to the timing of the previous birth. Individual variability in interbirth intervals was significantly higher in primiparous than in multiparous females. Hinds born in semi-captivity had their first birth earlier in their life than hinds that were originally captured (at $<$1 month of age) from the wild. Single fawns were observed in all but one birth, in which twins were observed. Sex ratio was not influenced by the female parity, the season, or by the father identity. Only the mother identity influenced offspring birth mass.

Key words: cervid, intercalving interval, Ozotoceros bezoarticus, Pan de Azúcar, puberty, seasonality

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The pampas deer *Ozotoceros bezoarticus* has been a widespread species for a while, originally distributed in the open grasslands (pampas) across eastern South America, within 5° - 41°S (Jackson & Langguth 1987). However, habitat fragmentation, agriculture development, competition with farmed animals (Demaría et al. 2003), unregulated hunting (Jackson & Giullieti 1988) and transmission of infectious diseases (Jungius 1975/76) confined animals to small isolated populations. Small populations have been reported in Argentina, Brazil and Uruguay (e.g. Dellafiore et al. 2003). Based on

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cytogenetic, molecular (González et al. 1998) and morphometric (González et al. 2002) data, two subspecies endemic from Uruguay, *O. b. arerunguaensis* (Salto, 31°65'S, 56°43'W) and *O. b. uruguayensis* (Rocha, 33°45'S, 54°02'W), have recently been identified. The *O. b. arerunguaensis* subspecies is considered critically endangered by the IUCN (Tavares et al. 2002). Semi-captive breeding of animals that came from a population of *O. b. arerunguaensis* started in 1981 at the Estación de Cría de Fauna Autóctona, Pan de Azúcar, Maldonado, Uruguay (ECFA). This population, the largest in the world for captive pampas deer, recently reached 100 animals.

In spite of being an endangered species, very little is known about pampas deer biology, and especially the reproductive biology of the species. The study of the pampas deer is also of great theoretical interest as, with the exception of the deer introduced to New Zealand, no cervids have been reported as far south as the pampas deer (Redford 1987). As the natural populations of pampas deer can hardly be managed, information regarding reproductive biology has been estimated by very indirect means rather than determined through direct observations. For example, the gestation length has been estimated to be slightly >7 months (Jackson 1987) from the rut-birth period interval. Likewise, a peak of fawns observed in spring suggested a seasonal reproductive pattern (Merino et al. 1997).

Considering the lack of information about reproductive biology in this endangered species, our aim was to summarise and analyse the reproductive information registered during 20 years in the semi-captive breeding of the pampas deer at the ECFA. We provide quantitative information on reproductive traits such as age at first parturition, birth seasonal pattern, interbirth interval, sex ratio and birth mass as well as on the factors that influence these traits.

Material and methods

Location and management of the population at the ECFA

Overall, the ECFA comprises 86 ha on which only native fauna is bred. At the same time, it is open as a tourist place throughout the year. It is located on Uruguay's southeastern coast (34°3'S, 55°1'W at an altitude of ~200 m a.s.l.), 6 km from the coast. During the study period (1981-2000), annual rainfall was 1,190.3 mm ± 57.5 (mean ± SEM; range: 846.0-1,657.5 mm). Monthly rainfall has been homogeneously distributed throughout the year (100.0 mm ± 4.7; range: 73.6 ± 12.1-121.6 ± 17.9 mm for December and October, respectively). Light hours range from 09:48 to 14:31, and minimum and maximum temperatures were 17.0 and 30.2°C, and 7.5 and 16.3°C for January and June, respectively.

In 1981, seven animals aged <1 month (three males and four females) were captured from the population located in Salto (i.e. *O. b. arerunguaensis*) and brought to the ECFA. In 1982, 14 animals (five males and nine females) aged <1 month were captured and brought to the ECFA. Of these 14 animals, five (two males and three females) died before reproducing.

Adult animals weigh about 30-40 kg (total body length: 110-40 cm; shoulder height: 70-75 cm). No marked sexual dimorphism exists in mass, but only males have antlers. Groups composed by one stag and 8-12 hinds and their fawns were run together throughout the year in areas of approximately 0.5 ha (i.e.18-26 deer/ha). Animals grazed over native pastures and lactating females were supplementally fed. Daily amount of food may be considered *ad libitum*, as part of the additional food usually was left over for the following day. As the amount of food was given daily during the 20 years, the nutritional status of animals did not vary much among months or years. Males were relocated in confinements in which only males were managed when they were approximately one year of age. In most cases, the males were later exchanged with national zoos.

Data recording

Each confinement area was carefully checked daily during 1981-2000, and all births were registered as well as the dates of birth, the mothers' identities and the sex and mass of fawns (all data were obtained at the time of birth or one day later). As in each confined area only one stag was present, the data about the individual father identity was also registered.

Statistical analysis

All data were analysed using the Stata Statistical Software 8.2 (2003).

Birth seasonality

The distribution of parturitions throughout the year was compared with a uniform distribution by using

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the Kolmogorov-Smirnov test. The influence of season and year on that distribution was tested using a Poisson model regression. Separated analyses were performed for each female parity to avoid the influence of the previous parturition date. The reference season considered by the Poisson model regression was summer. When significant differences occurred, the frequency of parturitions in different seasons was compared using Bonferroni adjusted tests. As primiparous females and females that just gave birth, and multiparous females with three or more parturitions were significantly different, data were pooled in those categories. The distribution of the parturitions from parity #4 onwards were overdispersed ($S = 0.32$; $P = 0.003$). Therefore, a binomial negative regression was used instead of a Poisson regression to analyse females with parity > 3. The frequency of parturitions per season according to the female parity was compared by using a Fisher exact probability test.

Interbirth interval

The effects of year, season, month, mother identity, mother parity, gender of the fawn and father identity on the interbirth interval (number of days between two parturitions, IBI), as well as the influence of these variables during the previous parturition, and the body mass of fawn at both parturitions were assessed using linear models. The Kruskal-Wallis test was used because of the heteroscedasticity of the IBI in relation to the season. Season-to-season comparisons were performed using the Mann-Whitney test. The distributions of IBIs according to female parity were compared using a Bartlett's test.

Age at first parturition

As all animals were of known age (i.e. all captured at about 15 days of age), the age at first parturition was precisely known for each female. We looked for an influence of the birth site (Salto vs ECFA) using a two-sample t-test.

Fawn sex ratio

The influences of the female parity, month of birth and father identity on the fawn sex ratio were assessed using a logistic regression. Mother identity was also included as a cluster to account for pseudoreplication (*sensu* Hurlbert 1984).

Fawn mass

The influences of year, season, month, mother identity, female parity, father identity, sex of the fawn, IBI, and the interactions between female parity and sex, between female parity and season, and between sex and season on the fawn mass were analysed using linear models.

Results

Overall, 272 births were registered throughout the study period. Single fawns were observed in all but one birth, in which twins were observed. Both twins were males (0.65 kg and 0.90 kg), which died a few days later.

Birth seasonality

Although births were observed in every month of the year, the distribution of parturitions per month was significantly different from a uniform distribution ($N = 270$, $D = 0.81$, $P < 0.001$; Fig. 1). There was no effect of year (for the different comparisons: $-0.18 \leq z \leq 0.72$; $1.05 \leq SE \leq 1.72$; $CI = -2.31$-2.99; $0.56 \leq P \leq 0.95$).

Primiparous female hinds gave birth in spring more often than in other seasons ($N = 65$, $\chi^2 = 23.13$, $P < 0.01$). More births were observed in summer than in autumn ($b = -1.71 \pm 0.77$ (SE), $z = -2.22$, $P = 0.027$). There was no difference in birth frequency between autumn and winter ($\chi^2 = 0.64$, $P = 1.0$). At their second and third parturition, females gave birth in spring more often than in the other seasons (second parturition: as compared to summer: $b = 1.20 \pm 0.47$, $z = 2.59$, $P = 0.01$; as compared to autumn: $\chi^2 = 6.69$, $P = 0.03$; as compared to winter: $\chi^2 = 9.39$, $P = 0.007$; third parturition: as compared to autumn ($\chi^2 = 7.16$, $P = 0.02$), as compared

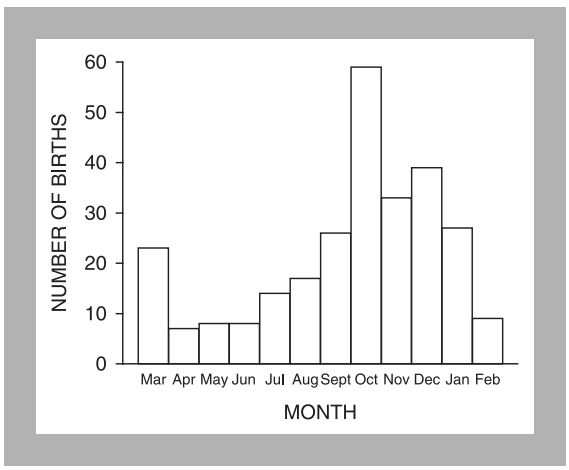


Figure 1. Monthly distribution of 272 births registered during 20 years in a herd of pampas deer.

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to summer: b = 0.92 ± 0.48, z = 1.90, P = 0.058; as compared to winter: $\chi^2 = 9.39$, P = 0.007). Multiparous females with >3 parturitions gave birth more often in spring than in summer and in autumn (as compared to summer: b = 0.90 ± 0.31, z = 2.87, P = 0.004; as compared to autumn: $\chi^2 = 18.59$, P < 0.001); and the number of parturitions in autumn tended to be lower than in summer (b = -0.64 ± 0.37, z = -1.74, P = 0.08) and winter ($\chi^2 = 5.21$, P = 0.067).

The seasonal distribution of birth differed between primiparous (N = 45) and multiparous females with >3 parturitions (N = 70; P = 0.006). Similarly, the seasonal distribution of births for females at their second parturition (N = 35) differed from that of multiparous females with >3 parturitions (P = 0.044). The seasonal distribution of births for females at their third parturition (N = 27) did not differ from that of females with higher parity (P = 0.26). There was no difference in the frequency observed in first and second parturitions (P = 0.27). As results were similar, the frequency of parturitions per season according to the hind's number of parturition is shown pooled in two categories: primiparous females and females which only gave birth once, and females with parity two or higher pooled (Fig. 2).

Interbirth interval

Considering all data, the IBI was 313 ± 46 days (median ± semi-interquartile range), with the shortest IBI being 234 days. The IBI varied significantly among years (F = 3.52, df = 14, P = 0.05), mothers (F = 4.04, df = 30, P = 0.031), seasons (F = 5.08, df = 3, P = 0.035) and months (F = 3.83, df = 10, P = 0.044) of the previous parturition. IBIs were from 251.0 ± 8.5 to 512.5 ± 266.6 days according to mother identity, and from 270 ± 28.1 (May) to 414.4 ± 102.8 (February). The timing of the previous parturition influenced IBI (df = 3, $\chi^2 = 22.10$, P < 0.001; Table 1).

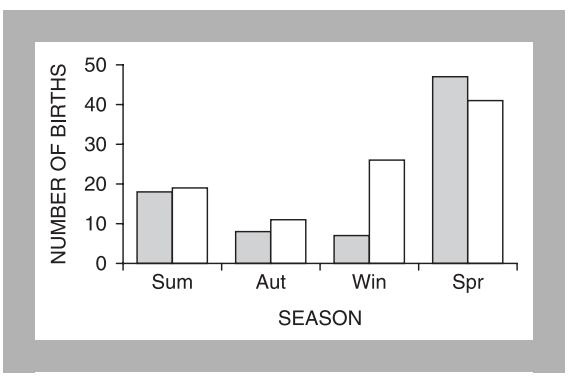


Figure 2. Number of births/season according to female parity (□ 1-2 parturitions, N = 80; ▢: ≥ 3 parturitions, N = 97).

Table 1. Influence of the previous birth season on the interbirth interval in days (mean ± SEM).

Previous season	Intercalving interval
Spring	357.5 ± 11.1
Summer	334.9 ± 31.6
Autumn	284.5 ± 18.2
Winter	331.4 ± 19.5

Spring (Sp) vs Summer (Su): z = 1.83, P = 0.07; Sp vs Autumn (A): z = -0.21, P = 0.84; Sp vs Winter (W): z = -2.6, P = 0.008; Su vs A: z = -1.81, P = 0.07; Su vs W: z = -4.33, P < 0.0001; A vs W: z = -2.04, P = 0.04.

The variance in IBI varied in relation to female parity (df = 7, $\chi^2 = 35.40$, P < 0.001). The IBIs of primiparous females were significantly more dispersed than the IBIs of multiparous females (SD: 132.6 for primiparous vs 59.8 at parity 2, 71.0 at parity 3, 52.7 at parity 4 and 78.0 days at parity 5; P < 0.001).

Age at first parturition

First parturition occurred when hinds were 693.6 ± 28.1 days old. Hinds born at ECFA had their first birth earlier in their life (N = 35; 642.5 ± 28.4 days) than hinds that originally came from Salto (N = 10; 872.6 ± 46.4 days, t = -4.23, P < 0.001).

Fawn sex ratio

Three fawns were not sexed so that 140 females and 129 males were registered. The father identity did not influence sex ratio (for the different individuals (N = 18): $-1.23 \le z \le 0.89$, $0.30 \le SE \le 3.65$, CI = 0.20-32.91, $0.22 \le P \le 0.88$). Likewise, the female parity had no influence on the sex ratio (for the different comparisons: $-1.54 \le z \le 1.36$, $0.24 \le SE \le 3.81$, CI = 0.06-26.94, $0.13 \le P \le 0.84$), nor the season (for the different comparisons: $-0.31 \le z \le 0.84$, $0.51 \le SE \le 1.31$, CI = 0.25-7.42, $0.40 \le P \le 0.76$).

Fawn mass

Birth mass was 1.86 kg ± 0.03 for males and 1.86 kg ± 0.04 for females, and so did not differ between the sexes (df = 1, F = 3.12, P = 0.11). The only studied factor that influenced birth mass was the mother identity (df = 33, F = 2.90, P = 0.047). There were no significant effects of year (df = 14, F = 1.44, P = 0.29), season (df = 3, F = 1.09, P = 0.4) month (df = 11, F = 2.22, P = 0.12), mother parity (df = 7, F = 1.02, P = 0.48), father identity (df = 11,

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Table 2. Fawn mass (in kg) according to age (in days) of the fawns (N = 7; five males and two females).

Age	Mass
0	1.59 ± 0.12
7	2.44 ± 0.15
14	3.31 ± 0.18
21	4.10 ± 0.20
28	4.73 ± 0.23
30	5.03 ± 0.23

$F = 1.67$, $P = 0.23$) or IBI (df = 1, $F = 1.77$, $P = 0.22$), nor of any interaction tested (all $P > 0.125$). The data from seven fawns that were weighed at 0, 7, 14, 21, 28 and 30 days are presented in Table 2.

Discussion

According to our knowledge, this is the first report presenting and summarising an overall view of the reproductive biology of the pampas deer. As data were obtained under semi-captive conditions, the information cannot be extrapolated to natural environments, where deer might for instance differ in social structure, space, feeding and predation pressure (Price 2002). However, the improvement of knowledge of pampas deer biology may be useful when developing conservation strategies and new captive breeding experiences.

Births were observed in every month, but the observed distribution throughout the year suggests the existence of a moderately seasonal reproductive pattern, which complements the observations of an annual cycle in testosterone faecal concentrations (Pereira et al. 2005) and antlers (Tomás 1995) in pampas deer males. As previously reported for most ungulates studied so far, pampas deer show seasonal reproductive patterns, with parturition mostly occurring in spring-summer (e.g: mule deer *Odocoileus hemionus*: Bowyer 1991; Eld's deer *Cervus eldi thamin*: Monfort et al. 1993; musk deer *Moschus chrysogaster*: XiuXiang et al. 2003; Pere David's deer *Elaphurus davidianus*: Brinklow & Loudon 1993; red deer *Cervus elaphus*: Clutton-Brock et al. 1982; roe deer *Capreolus capreolus*: Gaillard et al. 1993). In wild ungulates, seasonal reproductive patterns may be influenced by photoperiod (Bunnell 1980), population density (Langvatn et al. 2004), short (Cameron et al. 1993) or long-term (Bowyer et al. 1998) effects of climate, physical condition during the rut period (Adams & Dale 1998), or plant phenology (Loe et al. 2005). In agreement with our observations, and although no direct data are presented, the occurrence of a peak of births in spring (September-November) was reported in wild populations of pampas deer located in similar latitudes (Argentina, San Luis, 34°S and Uruguay, 31° and 33°S; Jackson & Langguth 1987). After pooling data from four locations in Argentina (34-57°S), the same authors observed newborn fawns in all months of the year, with a peak of 67.0% between August and December (recalculated data). In the Emas Park (Brazil, 18°S) Redford (1987) reported that 62% of births took place between September and November. In the ECFA population, in which food supply is homogeneous throughout the year, the seasonal pattern seems to be less strict than in the wild populations, suggesting that food availability has a direct influence on cyclic activity. Taking into consideration all this information, the pampas deer seems to be a seasonal breeder, with most parturitions occurring during spring, but with a breeding activity throughout the year.

It is also interesting that the distribution of births was less synchronised in primiparous than in multiparous females. As it happens in many wild mammals (Sadleir 1969, Sæther & Heim 1993, Hewison 1996, Garel et al. 2005), the age at first mating (primiparous females) may be determined by a body mass threshold, while mass might be less limiting for multiparous females (see Gaillard et al. 1992 for similar results on roe deer). Therefore, as it is the case for roe deer (Gaillard et al. 1992), red deer (Bertouille & de Crombrugghe 2002), Alaskan moose *Alces gigas* (Bowyer et al. 1998) and Alaskan caribou *Rangifer tarandus* (Adams & Dale 1998), growth may be a major determinant of primiparity in pampas deer as females need to reach a threshold body mass to become pregnant.

The IBI length was shorter than one year, but differed according to female parity. On the contrary to what has been reported for other ruminants (e.g. cattle: Yavas & Walton 2000), the IBI of primiparous females was not significantly longer, although it showed larger dispersion. It is interesting that the shortest and the longest IBI lengths were observed after autumn and spring births, respectively, which suggests that the postpartum interval for cyclic activity resumption is influenced by the season. Therefore, not only spontaneous cyclic activity but also gestation and/or postpartum anoestrous length may influence the seasonal reproductive pattern. Even though we do not have reliable data regarding

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gestation length, considering that we observed IBIs <8 months, gestation length may be <7 months (Jackson 1987).

Mean age at first parturition in hinds born in the ECFA was approximately 21 months. If we consider that gestation length is probably not >7 months, the first fertile oestrous of hinds born at the ECFA should be at an age of no more than 14 months. Probably as a consequence of the stress of capture, weaning and transportation (Hanlon et al. 1994, Waas et al. 1999), we observed a delay in the onset of reproductive activity of the hinds that came from the wild. Moreover, better food availability during lactation would allow better conditions for females breeding in captivity than for females born in Salto, and could explain differences in reproductive phenology.

Our observations showed that sex ratio at birth is close to 1:1 in pampas deer. However, the same authors observed sex ratios from 1:1.1 to 1:2 in adults. On the contrary to Clutton-Brock et al. (1984)'s observations on red deer, we did not observe any relationship between female parity and offspring sex ratio. We also did not observe any relationship between the date of parturition and the sex ratio, contrary to what Clutton-Brock et al. (1982) reported for red deer. Sex ratio patterns of pampas deer might thus be closer to roe deer than to red deer, because Gaillard et al. (1993) did not report any difference in birth date between sexes in roe deer. The absence of a sex difference in birth mass supports Gaillard et al. (1993)'s statement that differences in birth timing should only occur in highly dimorphic and polygynous species.

Similarly to previous observations in the wild (Redford 1987), hinds virtually always bear a single fawn. Possibility of twins was previously reported only once: one female in Emas Park (Brazil) was observed with two similar-sized young (Redford 1987). Previous data about birth mass ranged within 1.45 kg (Nogueira Neto 1973, cited by Merino 1997) - 2.1 kg (Redford & Eisenberg 1992); weekly growth was similar to our observations (800 g/week; Nogueira Neto 1973, cited by Merino 1997).

The lack of an influence of a seasonal effect on birth mass should be considered carefully. In bighorn *Ovis canadensis* (Hogg et al. 1992) and Dall's sheep *O. dalli* (Bunnell 1980), late conception during the rut is associated with an increase in ewe and lamb mortality, which may be related with the smaller size of late-born calves (Gaillard et al. 2000). In our conditions, we may not have detected differences that are present in the wild because supplemental food was provided throughout the year.

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