BioOne DIGITAL LIBRARY

Population management as a tool in the recovery of the critically endangered Western Derby eland Taurotragus derbianus in Senegal, Africa

Authors: Koláčková, Karolína, Hejcmanová, Pavla, Antonínová, Markéta, and Brandl, Pavel

Source: Wildlife Biology, 17(3) : 299-310

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/10-019

The BioOne Digital Library (https://bioone.org/) provides worldwide distribution for more than 580 journals and eBooks from BioOne's community of over 150 nonprofit societies, research institutions, and university presses in the biological, ecological, and environmental sciences. The BioOne Digital Library encompasses the flagship aggregation BioOne Complete (https://bioone.org/subscribe), the BioOne Complete Archive (https://bioone.org/archive), and the BioOne eBooks program offerings ESA eBook Collection (https://bioone.org/esa-ebooks) and CSIRO Publishing BioSelect Collection (https://bioone.org/csiro-ebooks).

Your use of this PDF, the BioOne Digital Library, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Digital Library content is strictly limited to personal, educational, and non-commmercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne is an innovative nonprofit that sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Wildl. Biol. 17: 299-310 (2011)
DOI: 10.2981/10-019
© Wildlife Biology, NKV
www.wildlifebiology.com

Original article

Population management as a tool in the recovery of the critically endangered Western Derby eland *Taurotragus derbianus* in Senegal, Africa

Karolína Koláčková, Pavla Hejcmanová, Markéta Antonínová & Pavel Brandl

The critically endangered Western Derby eland *Taurotragus derbianus derbianus*, representing < 200 wild individuals, undoubtedly needs a coordinated conservation programme. To promote the survival of this subspecies, a single worldwide semi-captive population was established in Senegal in 2000, with one male and five female founders transferred from the Niokolo Koba National Park. To determine a long-term conservation strategy, we used demographic and pedigree data based on continuous monitoring of reproduction during 2000 - 2009 in breeding enclosures in the Bandia and Fathala Reserves, in conjunction with modelling software. In 2009, the semi-captive population consisted of 54 living individuals (26 males and 28 females), managed using the minimal kinship strategy. The female breeding probability was 84%, annual calf and adult mortality rates were 5.09% and 3.27%, respectively, and the annual population growth rate was 1.36. As the population grew, the animals were progressively separated into five herds within two reserves. A pedigree analysis revealed an effective population size of 6.72 and an N_e/N ratio of 0.13. The population retained 77% of the gene diversity (GD). The founder genome equivalent (FGE = 2.21) was relatively low due to the overrepresentation of one founder male. Although the mean level of inbreeding (F) reached 0.119, a significant potential GD (92%) was still retained. In this article, we predict GD development in this population in the next 100 years with the inclusion of new founders. If the whole wild population were included, we could maintain 90% of GD. As this option is not practically feasible, we present three options with the goal of maintaining 75% GD. We highly recommend capturing new founders from the remaining wild population to ensure the survival of the subspecies at least in semi-captivity, which could allow possible reinforcement of the wild population or reintroduction in the future. The semi-captive population, if appropriately constituted and genetically managed, could play a considerable role in Western Derby eland conservation.

Key words: conservation programme, demographic structure, endangered antelope, genetic management, pedigree analysis, Taurotragus derbianus, West Africa

Karolína Koláčková, Institute of Tropics and Subtropics, Czech University of Life Sciences, Kamýcká 129, 16521, Prague 6, Suchdol, Czech Republic - e-mail: kolackova@its.czu.cz
Pavla Hejcmanová, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences, Kamýcká 1176, 16521, Prague 6, Suchdol, Czech Republic - e-mail: hejcmanova@fld.czu.cz
Markéta Antonínová, Zakouma National Park, Wildlife Conservation Society, Chad - e-mail: antoninova@post.cz
Pavel Brandl, Prague Zoological Garden, U Trojského zámku 120/3, Prague 7, Troja, Czech Republic - e-mail: brandl@zoopraha.cz

Corresponding author: Pavla Hejcmanová

Received 22 February 2010, accepted 15 May 2011

Associate Editor: Paul J. Wilson

Survival of many endangered species depends upon human assistance in captive breeding programmes, particularly when the preservation of the entire natural ecosystem is unlikely to be feasible (Ebenhard 1995, Hanks 2001). Over time, captive breeding may lead to the reinforcement or reestablishment of the wild populations. However, this goal can be reached only if captive populations are managed in an appropriate genetic and demographic manner (Ballou & Foose 1996).

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Captive populations of endangered species should be managed to retain high levels of gene diversity over long periods, so that small populations avoid inbreeding and other genetic problems (Thévenon & Couvet 2002, Armstrong & Cassey 2007, Trinkel et al. 2008). When a loss of gene diversity occurs, it may reduce reproduction in the short term (Wildt et al. 1987, O'Brien et al. 1985) and diminish the capacity of populations to evolve in response to environmental changes on a long-term basis (Ralls et al. 1988, Zachos et al. 2009, Frankham et al. 2003). Thus, minimising kinship is the most appropriate and highly recommended genetic management strategy (Ryder & Fleischer 1996, Montgomery et al. 1997). Despite the genetic problems, it is possible for a species to establish a viable population even with few founding individuals, as long as appropriate management is applied to the captive breeding population. In some cases, this approach has saved species from extinction, e.g. as observed in European bison *Bison bonasus* with 12 founders (Olech 2008), Przewalski horse *Equus przewalski* with 13 founders (Bouman 1979) or Arabian oryx *Oryx leucoryx* with < 20 founders (Henderson 1974, Sausman 2007). Successful captive animal breeding programmes are usually based on the knowledge of individual animals registered in studbooks (Glatson 1986, Kůs 2000) and on pedigree analyses (Pemberton 2004, Ralls & Ballou 2004, Grueber & Jamieson 2008). For the precise origin of all wild-caught animals, careful identification of individuals, and their life histories are essential parts of the studbook system (Jarvis 1969).

The Giant eland *Taurotragus derbianus* is the largest antelope in the world and belongs among the flagship species of Central and West Africa. Its colour is ruddy fawn or chestnut, with vertical white stripes on flanks and conspicuous black and white markings on the face, ears, limbs and dewlap (Fig. 1). Males can weight up to 907 kg and both sexes have long, spiralled horns reaching up to 123 cm (Kingdon 1982). There are two subspecies of Giant eland, distinguished until now on the basis of the geographical distribution and morphological description. The Western subspecies *T. d. derbianus* (Gray 1847), the Western Derby eland, alias the Western Giant eland (Wilson & Reeder 2005) is characterised by smaller size, bright rufous ground

Figure 1. Part of a semi-captive herd of the Western Derby elands in the Bandia Reserve (Photo by P. Brandl).

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

colour and up to 17 body stripes (Kingdon 1982, Antonínová et al. 2008) and the Eastern subspecies *T. d. gigas* (Heuglin 1863), alias the Eastern Giant eland has larger body size, sandy ground colour and around 12 body stripes (Kingdon 1982).

The only confirmed wild population of *T. d. derbianus* occurs in eastern Senegal, Africa (Nežerková et al. 2004), and it is estimated at < 200 individuals (Renaud et al. 2006). The presence of a viable population of this antelope in the surrounding states of Mali, Guinea and Guinea-Bissau has not been confirmed (Darroze 2004). This low population count, which is a result of overharvesting for meat and habitat destruction caused by the expansion of human and livestock populations, prompted the classification of the Western subspecies as 'critically endangered' (IUCN 2010).

Although the need to establish an *in situ* conservation programme (East 1998, Chardonnet 1999) as well as an *ex situ* captive breeding programme (Sausman 1993) was recognised as early as in the 1990s, conservation actions in Senegal were not set up until the 2000s (Nežerková et al. 2004). In 2000, we aimed at establishing an *in situ* conservation programme with a protective breeding enclosure directly in the Niokolo Koba National Park (NKNP). In the end, the project was not feasible and the Senegalese authorities recommended redirecting focus onto the semi-captive population in the Bandia Reserve (Nežerková et al. 2004). As far as we know, no other conservation action for the recovery of the Western Derby eland has been performed in the NKNP.

A semi-captive Western Derby eland population, unique in the world for the subspecies, was created in Senegal in 2000, with the main objective of conserving the subspecies and reinforcing wild populations in West Africa, in conformity with the IUCN recommendations to establish a captive breeding programme when the number of wild individuals drops below 1,000 (IUCN SSC 1987). The Society for the Protection of the Environment and Fauna in Senegal and the Directorate of National Parks of Senegal captured nine individuals (one young male, five adult females and three young females) in the NKNP in Senegal and transferred them to the Bandia Reserve in western Senegal. Before reproduction started, three adult females died in a quarantine camp (Akakpo et al. 2004), and therefore, six individuals (one male and five females) became the founders of a semi-captive breeding programme in Senegal (Nežerková et al. 2004).

The objective of our study was to assess the potential of a long-term viable strategy for conservation breeding of the endangered Western Derby eland. We first assessed the current demographic and genetic parameters within its semi-captive population using a set of parameters characterising both the structure and dynamics of the population. We then used these data to make predictions about gene diversity dynamics in the long term and to provide practical recommendations for further conservation activities.

Methods

Study area and breeding management

We studied the semi-captive population of Western Derby eland in two nature reserves in western Senegal, i.e. in the Bandia and Fathala Reserves, respectively (Fig. 2). In both reserves, we kept Western Derby eland breeding herds in special enclosures, separated from other antelope species. The Bandia Reserve is a fenced nature reserve located 65 km south of Dakar, in the Sudano-Sahelian ecosystem with an annual mean rainfall of 484 mm (Hejcmanová et al 2010a). The Fathala Reserve is a fenced nature reserve within the Delta du Saloum National Park, located in southwestern Senegal, i.e. in the Sudano-Guinean savannah (Nežerková-Hejcmanová et al. 2005). Annual mean rainfall there reached 839 mm (Banjul meteorological station; Lykke 1994).

In the Bandia Reserve, the initial 50 ha enclosure was gradually enlarged as the semi-captive population grew. As the population increased, we successively constituted three breeding herds in enclosures of 400 ha, 250 ha and 70 ha, respectively, in the Bandia Reserve, and a breeding and a bachelor herd in enclosures of approximately 70 ha and 1,000 ha in the Fathala Reserve in 2006, 2008 and 2009. The geographical separation of breeding herds was carried out for two main reasons: 1) the ecosystem of the Fathala Reserve is similar to the Western Derby eland's natural habitat (Nežerková et al. 2004); therefore, the semi-captive animals are maintained in an environment offering a natural diet; 2) separation serves as a protection against the risk of disease outbreaks in one of the locations, consistent with basic veterinary principles (Snyder et al. 1996). Before transport, all individually selected animals were immobilised using ethorphine hydrochloride in combination with xylazine (Chardonnet 2003, An-

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

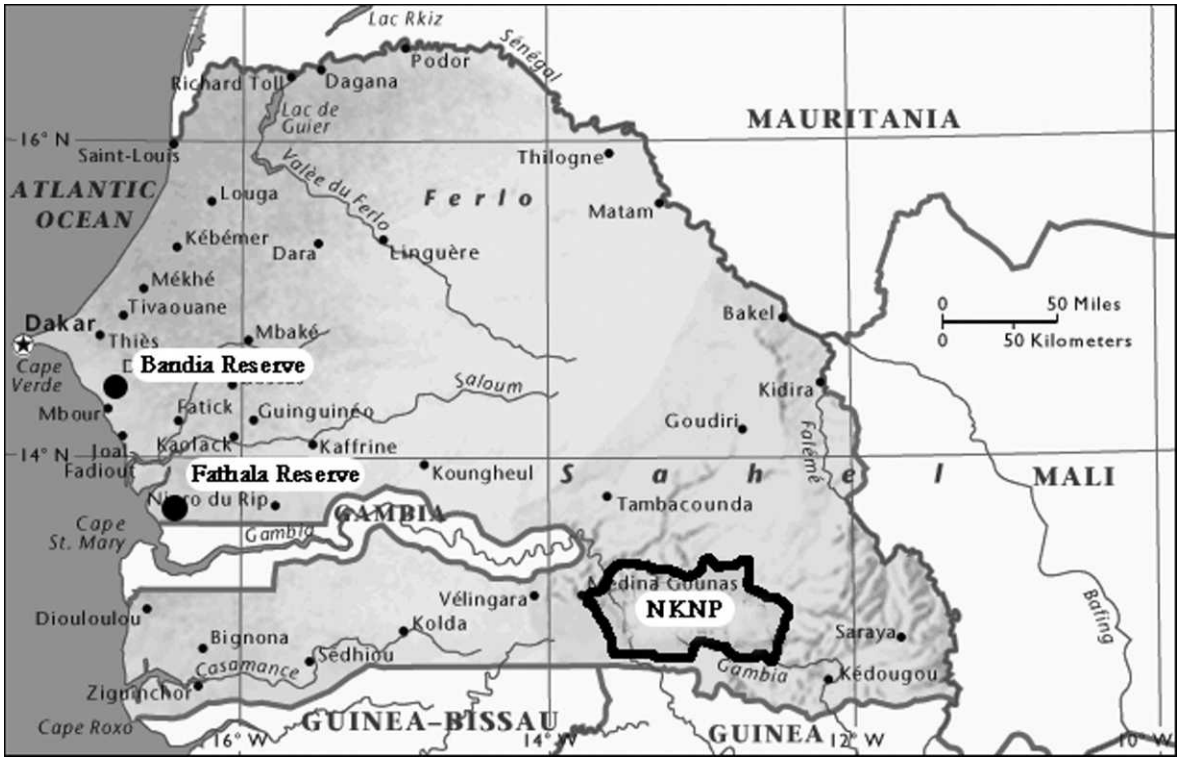

Figure 2. Distribution of the Western Derby eland and the locations of the Bandia and Fathala reserves.

tonínová et al. 2006). All individuals were examined and then transferred either to another enclosure in the Bandia Reserve or into the Fathala Reserve. Animals were revived after approximately 30 minutes after the first application of immobilisation drug. No animal mortality occurred during or after transport. We carried out all actions with the presence of the authorities of the Directorate of National Parks of Senegal and Society for the Protection of the Environment and Fauna in Senegal (Antonínová et al. 2006, Koláčková & Váhala 2009).

Breeding in the semi-captive Western Derby eland population started in 2002. By June 2009, the population had grown to 54 individuals. We recorded all births, mortalities, sex of offspring and calving dates during 2000 - 2009. In all years, except 2003, we recorded mother-offspring kinship based on direct observation of mother-offspring interactions. Based on the data from the Eastern subspecies, we presumed males to be sexually mature at two years of age (Shurter 1996), although the presence of a dominant bull naturally postpones breeding by the other males for many years in the natural environment (Bro-Jørgensen 1997). As the young males (up to three years of age) were regularly removed from breeding herds to avoid mating, we presumed that the dominant (or the only one) bull in the herd was the sire of all offspring. Although there are certain limits in the accuracy of mother-offspring bonding (Vaňková et al. 2001), and even with sire certainty (De Young et al. 2006), we used those data for the pedigree, as determining pedigree using microsatellites was not technically possible. We then completed the pedigree for all nine years of captive breeding, namely from June 2000 to June 2009.

Data analyses

The pedigree data for the Western Derby eland were constructed and maintained in the Single Population Animal Record Keeping System (SPARKS), compiled by the International Species Information System (ISIS 1992). Individuals alive in June 2009 and their ancestors were included in the pedigrees; individuals who died without producing any descendants were excluded from the gene-drop analysis. The unknown mother-offspring kinship for the five individuals born in the 2003 was set into the SPARKS as 'unknown mother' for every specific individual. 'Founder' means 'genetic founder', i.e.

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

wild-born individuals on top of the pedigree, presumed to be unrelated. We created a pedigree chart using Pedigraph 2.3 (Garbe & Da 2006).We calculated individual inbreeding coefficients (F) using SPARKS (ISIS 1992) and corroborated them using Population Management 2000 (PM 2000) software (Lacy & Ballou 2002, Pollak et al. 2002). SPARKS and PM 2000 used life tables and pedigrees to calculate deterministic population analyses, gene drop analysis, and the following measures of genetic variability: actual population size (N), effective population size (N_e, including correction of the unequal sex ratio), N_e/N ratio, gene diversity (GD), potential GD, percentage of known genotypes, founder genome equivalents (FGE) and mean kinship (MK).

N_e is defined as the size of an idealised population with a random union of gametes in each generation, which would have the same intergenerational variance in allele frequencies as does the studied population. GD is defined as the variance in allele frequencies at a genetic locus, equal to the heterozygosity expected in a population with random union of gametes (i.e. in a Hardy-Weinberg equilibrium), according to the equation $GD = 1 - \sum(p_i 2)$, in which p_i is the frequency of allele i, and the summation is over all alleles at that locus. Given that no founders are added, natural selection, mutation and immigration do not appear and that the population is bred randomly, the GD in the population decays according to the equation: $GD_t = GD_0 - (1-1/2N_e)^t$, in which the subscripts denote generations and N_e in each generation. The rate of decay of the GD is independent of the initial level of GD and of the allele frequencies at the loci. Hereafter, we refer to the GD as a proportional value to the baseline population from which founders come, GD_t/GD_0, where $GD_0 = 1$. FGE is the expected number of unrelated founder genomes that should contain the observed level of GD in the study population, $FGE = 0.5/(1 - GD_t/GD_0)$. MK is the average coefficient of kinship of an animal to each living, non-founder animal in a pedigree. The overall mean kinship of the population (mean MK) equals $1- GD_t/GD_0$ (Lacy 1995).

Population management and gene diversity modelling

To predict population development, we created a long-term model of population parameters and population growth using the PM 2000 software (Lacy & Ballou 2002) based on current knowledge of kinship of the animals as well as demographic and genetic parameters. The model included GD development in a 100-year period for cases of no inclusion of any new animal and under the condition of inclusion of new founders from the wild. A common goal in population management is to maintain a level of 90% of the original GD (Frankham et al. 2003). If ever this goal could not be achieved, we determined an alternate GD corresponding to the actual and feasible level of GD in the current population, with the aim of maintaining it within the given period of 100 years. In addition, GD depends on demographic and genetic parameters of the population, e.g. population growth rate or maximum allowable population size. The latter implies that a limited number of animals can be included in the *ex situ* conservation programme. Respecting the real possibilities and feasibility of the *ex situ* conservation programme, we set the maximum allowable population size at 800 individuals to retain 90% of the original GD, and at 400 individuals to retain 75% of the original GD in order to create practically applicable options for Western Derby eland conservation decision-makers.

Results

Demographic parameters

During 2000 - 2009, a total of 61 Western Derby eland offspring were born (Fig. 3 and Table 1). It is most likely that mating occurred synchronously, considering that the majority of calves were born in December (61%). Subsequently, 20% of births were recorded in January and 10% in February. The age structure was evenly distributed between the sexes (Fig. 4).

Considering that the gestation period of the Eastern subspecies of the Giant eland lasts for 265 days on average (with a range of 255 - 275 days; Bro-Jørgensen 1997), the conception of our animals was assumed to take place at the beginning of March. This was later confirmed by opportunistic observations of mating in the captive population. The youngest age at conception was 16.2 months; however, on average, this age was 29.97 (± 10.46 SE) months or 31.94 (± 9.7 SE), excluding the extreme case. The female founders gave birth for the first time at an age of 35.07 (± 0.9 SE) months on average, while the youngest cow gave birth at only 25 months. Females produced one offspring per year and bred with a probability of 0.84 (breeding rate)

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

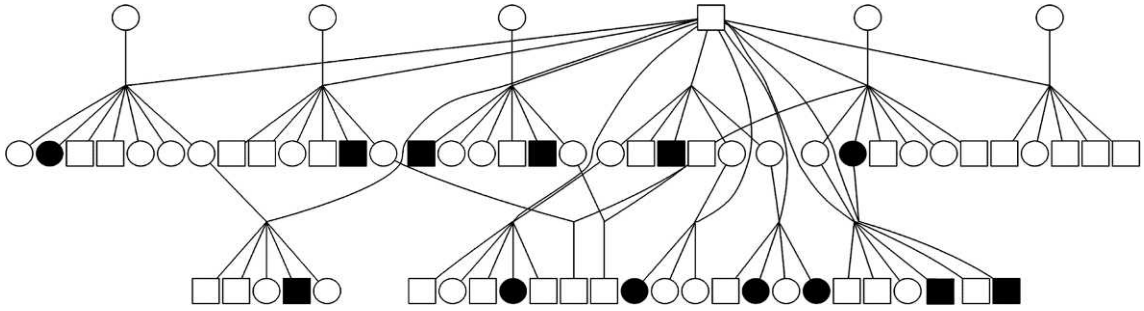

Figure 3. Pedigree of the population of Western Derby elands bred in semi-captivity (during June 2000-June 2009). The symbols represent: ■ = males; □ = females; empty symbols = living animals; black symbols = dead animals.

each year. In the Bandia Reserve, the oldest cow that gave birth was 12 years old, while the oldest male was 10 years old. These were the oldest animals in the breeding population at that time. The annual calf mortality rate was 5.09% (± 6.89 SE) and overall calf mortality was 6.56% (four out of 61 calves born); all calf mortalities were males. The annual non-calf mortality after the population stabilised (beginning in 2001) was 3.27% (± 3.72 SE) with an overall non-calf mortality of 14.3% (six females and three males out of 63 total adult individuals). Analyses of the life table of the Western Derby eland (see Table 1) indicated that the deterministic annual population growth rate was 1.36 (35.8% ± 12.9 SE).

Genetic parameters

With an actual population size of 54 individuals, the current effective population size estimated from two male and 10.5 female breeders was 6.72. The N_e/N ratio was 0.13. The animals in the pedigree had 91.7% of the known origin in the population. The population had retained 77% of GD from the founders. The overall mean level of inbreeding in the population was F = 0.119 and FGE was 2.21 (Table 2). On the other hand, a significant potential GD of 92% still remained in the population. Furthermore, the population had retained some of the original GD of the founders; this amount can be evaluated through proper management by MK (Table 3), which was at 0.226 on average.

Table 1. Demographic parameters of the semi-captive population of the Western Derby eland in Senegal during June 2000-June 2009.

Variable	♂♂	♀♀
Founders	1	5
Present number of individuals (N)	26	28
Number of adults in the population	14	13
Total births	32	29
Total deaths	7	6
Generation length*	6.12	5.86

* Generation length is defined as the average age of parents of newborn individuals in the population.

Population genetic models

For the first model, we set the maximum population size at 800 individuals. If any wild founder were added to this population, GD would decline to 69% at the end of 100 years. When we combined the current *ex situ* population with the whole free ranging population, estimated at 170 individuals (which means 170 founders), the model resulted in reaching and maintaining 90% of GD at the end of 100 years. The final population size was 735 individuals (Fig. 5A). This option, however, did not seem practically feasible. Therefore, we set the alternate goal of 75% of the GD in subsequent models,

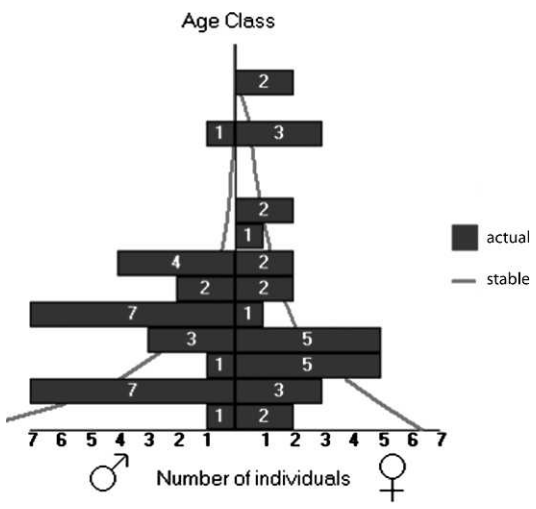

Figure 4. Male and female age structure of the living individuals of the Western Derby elands held in semi-captivity in June 2009. The wild-born proportion (founders) is indicated by empty bars and the captive-born by black bars.

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Table 2. Founder contributions for the genetic management of the pedigree in the semi-captive Western Derby eland population in Senegal.

Founder	Sex	Age	Current founder contribution	Descendants	Target founder contribution	Status of contribution
1	♂	10	0.64	48	0.17	Over
2	♀	12	0.09	10	0.17	Under
3	♀	12	0.05	5	0.16	Under
4	♀	10	0.06	5	0.17	Under
5	♀	10	0.06	6	0.17	Under
6	♀	10	0.10	12	0.17	Under

and set the maximum allowable population size at 400 individuals. If no founders were added, GD will decline to 65% at the end of 100 years. Considering the new goal, we chose three options for including new founders from the wild: only one inclusion at the beginning, two inclusions and four inclusions during the 100-year period. The first model option revealed the need for 15 founders, and a final population size of 374 animals (see Fig. 5B). The option of two inclusions revealed the need to include five founders, with a repetition after 45 years (10 founders in total). The population size needed to reach the goal was determined to be 326 animals (see Fig. 5C). The model with a repetition every 25 years counted the inclusion of two founders each time (eight founders in total), and set the necessary population size at only 301 animals (see Fig. 5D).

Discussion

When establishing a captive breeding programme of an endangered species, at least 20-30 wild-born founders are considered necessary for establishing a viable population (Lacy 1987). If practical, even more founders are preferable (Wilson et al. 2005). Once a breeding population is established, its early management can greatly influence the potential for future generations (Mace 1986). The unique semi-captive breeding programme of Western Derby elands started with only one male and five females. Despite the small number of founders, however, the population has responded well, due in part of careful monitoring of breeding history and kinship in the population. This is not always the case in pedigree analyses in endangered species conservation programmes (Zechner et al. 2002, Goyache et al. 2003).

Table 3. Mean kinship (MK) distribution in the semi-captive Western Derby eland population in Senegal in June 2009.

MK range	No of individuals	% of population
< 0.0256	5	10.2
0.1776 - 0.1989	27	42.9
0.1992 - 0.2665	9	16.3
> 0.3154	13	30.6

Demographic parameters

The Western Derby elands in the Bandia Reserve have reproduced each year since the establishment of the first semi-captive herd. The reproduction delay occurred after each animal transfer, directly following captures from the wild (Akakpo et al. 2004) and after the creation and transfer of new herds to new breeding enclosures (Antonínová et al. 2008). This also led to prolonged generation length in respective females. However, the population exhibited, in general, an ability to grow continuously.

The reproductive parameters of the Western Derby eland kept in semi-captivity, such as age at first conception and giving birth, were higher than for captive breeding females of the Eastern subspecies of Giant eland in zoo facilities. For instance, first conception in Giant eland was at an age of 18.5 months (Shurter 1996), whereas 13-24 months was reported for the common eland *T. oryx* (Hayssen et al. 1993) and other related species (Rubeš et al. 2008). Our recorded breeding rate was higher in comparison with that of the Giant eland, recorded at 74%, but similar to the 83% found for undisturbed common eland populations (Bro-Jørgensen 1997). Calving periods in both related taxons of common eland and Giant eland usually peak in wet seasons when food availability is greatest (Kingdon 1982, Spinage 1986, Bro-Jørgensen 1997, Pappas 2002). In spite of this, it seems that the calving of wild Western Derby elands in the NKNP (P. Hejcmanová & M. Antonínová,

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

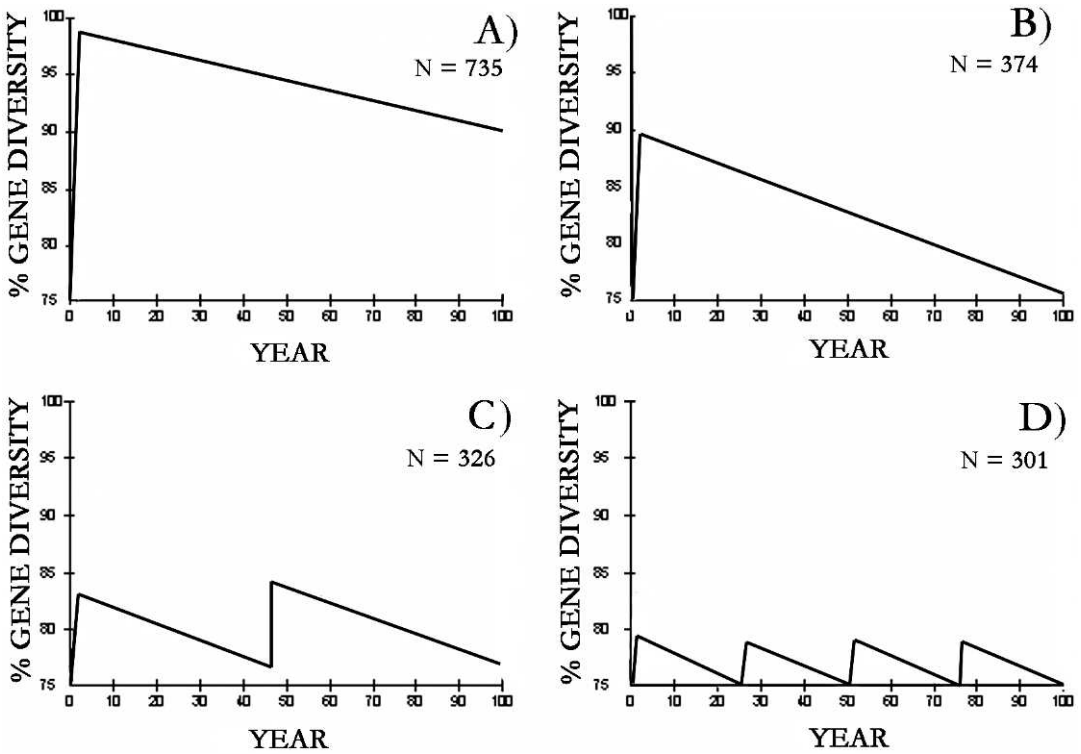

Figure 5. Predicted development of gene diversity over time in the case of inclusion of new founders from free-ranging population: A) shows inclusion of 170 individuals; B) inclusion of 15 individuals at once; C) inclusion of five individuals twice in a 100-year period; and D) inclusion of two individuals four times in a 100-year period. (N = the lowest number of individuals we have to keep within the conservation programme to meet the required GD level).

pers. obs.), as well as in the Bandia reserve, peaks at the beginning of the dry season (November-December).

Greater maternal expenditure on male offspring has been widely documented in polygynous dimorphic ungulates (Trivers & Willard 1973, Hogg et al. 1992, Bérubé et al. 1996, Zschokke et al. 1998), but in others the maternal expenditure was equal for both sexes (e.g. Kojola 1998, Mysterud et al. 2007, Ungerfeld et al. 2008). For 61 births in the semi-captive population of Western Derby elands, we determined a birth sex ratio close to 1:1. On the other hand, males suffered greater juvenile mortality, similar to that described by Bro-Jørgensen (1997) in the Eastern Giant eland. In our study, one of these four juvenile mortalities was caused by self-injury, one by the death of the mother just after parturition, and two for unknown reasons.

The wild-born founders of the semi-captive population approached the threshold age of reproduction (11 years for males and 14 years females) by the end of our study (Bro-Jørgensen 1997). However, the semi-captive Western Derby elands actually represent a young stock, with a short life history and a relatively low number of individuals. Despite this, our demographic estimates are the only data existing for the Western Derby eland worldwide.

Genetic parameters

We considered the genetic situation of the population unsatisfactory due to a low number of founders, and in particular a solitary male. N_e is almost always lower than N but can be increased by good genetic management (Folch & Jordana 1998, Wilson et al. 2005). An N_e of 6.72 as well as an N_e/N ratio of 0.13 were relatively low in comparison with common N_e/N ratios of 0.2-0.4 or 0.1-0.5 in other captive populations of endangered species (Frankham et al. 2003, Lacy 1995), or 0.3-0.5 in genetically unmanaged populations (Kleiman et al. 1996). Compared to 2008 (Antonínová et al. 2008), these parameters increased slightly due to the first reproduction of a young male in the breeding herd created in 2006 (Antonínová et al. 2006). We expect yet another

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

increase in the future, if another two young males in recently created breeding herds (2008, 2009) start to reproduce. Disproportionate reproduction by particular individuals favours the survival of genes from ancestors from differential reproduction, and increases the chance of loss of genes from other ancestors (Ryder & Fleischer 1996, Wilson et al. 2005). The distribution of the founders' contribution was heavily skewed due to the exclusive position of the breeding male, and so an overrepresentation of his genes in the subsequent generations was found. This unequal genetic contribution of founders caused the FGE to be lower than the actual number of founders, and consequently, there was a lower gene diversity (Lacy 1989). Such a situation could be improved by selecting individuals with low MK values who carry genes uncommon in the population, and breeding them more than individuals with common genes (Wilson et al. 2005).

Since complete and accurate pedigrees are such important tools, the correction of inaccurate information and the filling-in of missing information are worthwhile (Ryder & Fleischer 1996). In our study, data were missing concerning mother-offspring kinship in the five births of early 2003 in the Western Derby eland pedigree, and thus, in the analysis, these were evaluated as more inbred (higher F) than other individuals of the same consanguinity. This fact negatively affected the overall parameters of the population. With the knowledge of all the other individuals, we managed them in the end as a distinct lineage, male with females born in the same year, along with their descendants, according to a minimising kinship strategy (Ballou & Lacy 1995). Management of the population would benefit from the future confirmation of the pedigrees and estimates of genetic diversity and inbreeding based on microsatellite data.

Conservation and management implications

Although proper genetic management may slightly increase the GD, the potential GD can never be reached without new founders brought into the population (Lacy & Ballou 2002). If both wild and semi-captive Western Derby elands could be integrated and managed as one population, we could accomplish the goal of maintaining 90% GD at the end of 100 years. However, this option is only theoretical and is not applicable in practice within the framework of rational conservation efforts. On the other hand, the alternate goal of 75% GD at the end of 100 years was shown to be feasible for all three proposed options. Based on our 10 years of experience in the management of semi-captive population of Western Derby elands, namely with foraging behaviour, supplementary feeding (Hejcmanová et al. 2010b, P. Hejcmanová, unpubl. data) and with animal transfers (Antonínová et al. 2006, Koláčková & Váhala 2009), we expect that the mortality of the Western Derby elands after the captures from the wild will be significantly reduced from that observed during the initial wild captures. From an economical and behavioural point of view, the best option would be to capture 15 individuals at once, preferably five males and 10 females. This male:female ratio was determined considering breeding behaviour. Males can breed with more females; therefore, females limit the reproduction rate within the population. First and foremost, this would bring a definite long-term improvement for the Western Derby eland semi-captive population. Furthermore, it would require the organisation of only one capture operation, which is generally very costly and logistically demanding. At once, it assumes the close cooperation and agreement of all Senegalese authorities and international organisations, as well as an agreement with local communities, which consider the Western Derby elands to be their cultural and traditional property. Other options seem to be easier in the short term, however, the need for repetitive captures presents a higher risk for the future. Indeed, the survival of the Western Derby elands in the NKNP appears very uncertain and the development of this situation in the coming years is unpredictable. Therefore, the semi-captive Western Derby eland population, if appropriately constituted and genetically managed, could play a considerable role as a potential source of individuals for reinforcing the wild population or for possible reintroductions. Therefore, we emphasise the importance of involving new founders from the wild population of Western Derby elands in the NKNP into the current semi-captive population, while simultaneously monitoring the wild population and starting an *in situ* programme for the subspecies. We encourage premeditated and well-coordinated conservation actions by the respective authorities.

Acknowledgements - we are deeply grateful to the Society for the Protection of Environment and Fauna in Senegal and its directors Georges Rezk, Christian Dering, Lucien Haddad, Souhel Fourzoli and Jacques Rezk for their help, and particularly for the conservation of the Western Derby

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

eland in Senegal. A special acknowledgement is due to the representative of the Ministry of the Environment and Protection of Nature of Senegal, Souleye Ndiaye, and the Director of the National Parks of Senegal, Mame Balla Gueye. We conducted the management plans and conservation actions within the Czech Aid Development Cooperation RP10/2007. Our research was supported by the Academy of Sciences of the Czech Republic, grant N° IAA 609 3404 'Species diversity and ecology of selected vertebrates in West Africa'.

References

Akakpo, A.J., Al Ogoumrabe, N., Bakou, S., Bada-Alambedji, R. & Ndiaye, S. 2004: Essai d'élevage de l'eland de Derby (*Taurotragus derbianus derbianus*) à la Réserve de faunede Bandia: prélude à une opération de sauvegarde de cette espèce au Sénégal. - Révue Africain de Santé et Production Animale 2: 257-261. (In French).

Antonínová, M., Hejcmanová, P., Koláčková, K. & Verner, P.H. 2008: African Studbook: Western Giant Eland (*Taurotragus derbianus derbianus* (Gray, 1847)). 1st edition. - Czech University of Life Sciences, Prague, Czech Republic, 91 pp.

Antonínová, M., Hejcmanová, P., Váhala, J., Mojžíšová, L., Akakpo, A.J.B. & Verner, P.H. 2006: Immobilization and transport of Western Giant Eland (*Taurotragus derbianus derbianus*) from the Bandia Reserve to the Fathala Reserve in Senegal. - Gazella 33: 75-98.

Armstrong, D.P. & Cassey, P. 2007: Estimating the effect of inbreeding on survival. - Animal Conservation 10: 487-492.

Ballou, J.D. & Foose, T.J. 1996: Demographic and genetic management of captive populations. - In: Kleiman, D.G., Lumpkin, S., Allen, M., Harris, H. & Thompson, K. (Eds.); Wild mammals in captivity. Chicago, University of Chicago Press, USA, pp. 263-283.

Ballou, J.D. & Lacy, R.C. 1995: Identifying genetically important individuals for management of genetic variation in pedigreed populations. - In: Ballou, J.D., Gilpin, N. & Foose, T.J. (Eds.); Population management for survival and recovery. New York, Columbia University Press, USA, pp. 273-294.

Bérubé, C.H., Festa-Bianchet, M. & Jorgensen, J.T. 1996: Reproductive costs of sons and daughters in Rocky Mountain Bighorn Sheep. - Behavioural Ecology 7: 60-68.

Bouman, J.G. 1979: Breeding Przewalski horses in captivity, a short introduction. - In: de Boer, L.E.M., Bouman, J. & Bouman, I. (Eds.); Genetics and hereditary diseases of the Przewalski horse. Proceedings of the Arnhem study conference organized by the Foundation for the preservation and protection of the Przewalski horse, 176 pp.

Bro-Jørgensen, J. 1997: The ecology and behaviour of the Giant Eland (*Tragelaphus derbianus*, Gray 1847) in the wild. - Unpublished M.Sc. thesis, University of Copenhagen, Denmark, 106 pp.

Chardonnet, P. 1999: Survol écologique de 3 zones du sud-ouest du Mali en vue du dénombrement des élands de Derby et des autres grands mammifères. - Final report. IUCN Mali, DNCN, 24 pp. (In French).

Chardonnet, P. 2003: Capture d'élands de Derby et pose de colliers émetteurs en République Centrafricaine. - Fondation International pour al Sauvegarde de la Faune, Paris, France, 19 pp. Available at: http://www.wildlife-conservation.org/fr/rapports-publications/rapports-techniques-et-scientifiques/%28page%29/9 (Last accessed on 9 July 2011).

Darroze, S. 2004: Western Giant Eland (*Tragelaphus derbianus derbianus*) presence confirmed in Mali and Guinea. - In: Chardonnet, B. & Chardonnet, P. (Eds.); Antelope Survey Update 9. SSC Report, Paris, France IUCN, 81 pp.

De Young, R.W., Demarais, S., Honeycutt, R.L., Gee, K.L. & Gonzalez, R.A. 2006: Social dominance and male breeding success in captive white-tailed deer. - Wildlife Society Bulletin 34: 131-136.

East, R. 1998: African antelope database 1998. - IUCN, Gland, Switzerland, 454 pp.

Ebenhard, T. 1995: Conservation breeding as a tool for saving animal species from extinction. - Trends in Ecology and Evolution 10: 438-443.

Folch, P. & Jordana, J. 1998: Demographic characterization, inbreeding and maintenance of genetic diversity in the endangered Catalonian donkey breed. - Genetics Selection Evolution 30: 195-201.

Frankham, R., Ballou, J.D. & Briscoe, D.A. 2003: Introduction to conservation genetics. - Cambridge University Press, UK, 617 pp.

Garbe, J.R. & Da, Y. 2006: Pedigraph version 2.3. - University of Minnesota, USA, Available at: http://animalgene.umn.edu/pedigraph/ (Last accessed on 11 July 2011).

Glatson, A.R. 1986: Studbooks: the basis of breeding programmes. - International Zoo Yearbook 24/25: 162-167.

Goyache, F., Gutiérez, P., Fernández, I., Gomez, E., Alvarez, I., Díez, J. & Royo, L.J. 2003: Using pedigree information to monitor genetic variability of endangered populations: the Xalda sheep breed of Asturias as an example. - Journal of Animal Breeding and Genetics 120: 95-105.

Grueber, C.E. & Jamieson, I.G. 2008: Quantifying and managing the loss of genetic variation in a free-ranging population of takahe through the use of pedigrees. - Conservation Genetics 9: 645-651.

Hanks, J. 2001: Conservation strategy for Africa's large mammals. - Reproduction, Fertility and Development 13: 459-468.

Hayssen, V., van Tienhoven, A. & van Tienhoven, A. 1993: Asdell's patterns of mammalian reproduction. A compendium of species-specific data. - London, Comstock

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Publishing Associates, Cornell University Press, UK, 1023 pp.

Hejcmanová, P., Hejcman, M., Camara, A.A. & Antonínová, M. 2010a: Exclusion of livestock grazing and wood collection in dryland savanna: an effect on long-term vegetation succession. - African Journal of Ecology 48: 408-417.

Hejcmanová, P., Homolka, M., Antonínová, M., Hejcman, M. & Podhájecká, V. 2010b: Diet composition of Western Derby eland (*Taurotragus derbianus derbianus*) in a natural and a managed habitat in Senegal using faeces analyses. - South African Journal of Wildlife Research 40: 27-34.

Henderson, D.S. 1974: Were they the last Arabian oryx? - Oryx 12: 347-350.

Hogg, J.T., Hass, C.C. & Jenni, D.A. 1992: Sex-biased maternal expenditure in Rocky Mountain Bighorn Sheep. - Behavioural Ecology and Sociobiology 31: 243-251.

ISIS (International Species Information System) 1992: SPARKS: single population animal keeping system version 1.54. - Apple Valey/Eagan, Minnesota, USA. Available at: http://www2.isis.org/Documents/SPARKS_Order_Form.pdf (Last accessed on 11 July 2011).

IUCN 2010: IUCN Red List of Threatened Species. Version 2010.2. - IUCN, Gland, Switzerland. Available at: http://www.iucnredlist.org/ (Last accessed on 30 June 2010).

IUCN SSC 1987: Prise de Position de l'UICN sur l'elevage en captivite. - Rapport de 22e reunion du Conseil de l'UICN, SSC/IUCN, Gland, Switzerland, 10 pp. (In French).

Jarvis, C. 1969: Studying wild mammals in captivity: stranded life histories with an appendix on zoo records. - International Zoo Yearbook 9: 316-328.

Kingdon, J. 1982: East African mammals. Vol. III. Part C and D (Bovids). - London, New York, Academic Press, 746 pp.

Kleiman, D.G., Allen, M.E., Thompson, K.V. & Lumpkin, S. (Eds.) 1996: Wild mammals in captivity. Principles and techniques. - The University of Chicago Press, Chicago, USA, 548 pp.

Kojola, I. 1998: Sex ratio and maternal investment in ungulates. - Oikos 83: 567-573.

Koláčková, K. & Váhala, J. 2009: Immobilisation et transfer de l'Eland de Derby de la Réserve de Bandia a la Réserve de Fathala. - Rapport de l'opération, du 15 Février au 7 Mars 2009, 9 pp. (In French).

Kůs, E. 2000: International symposium for conservation of Przewalski Horse, Prague Zoo. - Gazella 27: 9-14.

Lacy, R.C. 1987: Loss of genetic diversity from managed populations: interacting effect of drift, mutation, immigration, selection and population subdivision. - Conservation Biology 1: 143-158.

Lacy, R.C. 1989: Analysis of founder representation in pedigree: founder equivalents and founder genome equivalents. - Zoo Biology 8: 111-124.

Lacy, R.C. 1995: Clarification of genetic terms and their use in management of captive populations. - Zoo Biology 14: 565-578.

Lacy, R.C. & Ballou, J.D. 2002: Population Management 2000 user's manual. - Brookfield, Illinois, Chicago Zoological Society, USA, 36 pp.

Lykke, A.M. 1994: The vegetation of Delta du Saloum National Park, Senegal. - University of Aarhus, Denmark, AAU Reports no 33, 88 pp.

Mace, G.M. 1986: Genetic management of small populations. - International Zoo Yearbook 24/25: 167-174.

Montgomery, M.E., Ballou, J.D., Nurthen, R.K., England, P.R., Briscoe, D.A. & Frankham, R. 1997: Minimizing kinship in captive breeding programs. - Zoo Biology 16: 377-389.

Mysterud, A., Barton, K.A., Jędrzejewska, B., Krasiński, Z.A., Niedziałkowska, M., Kamler, J.F., Yoccoz, N.G. & Stenseth, N.C. 2007: Population ecology and conservation of endangered megafauna: the case of European bison in Białoweża Primeval Forest, Poland. - Animal Conservation 10: 77-87.

Nežerková, P., Verner, P.H. & Antonínová, M. 2004: The conservation programme of the Western Giant Eland (*Taurotragus derbianus derbianus*) in Senegal. Czech Aid Development Project. - Gazella 31: 87-182.

Nežerková-Hejcmanová, P., Hejcman, M., Camara, A.A., Antonínová, M., Pavlů, V., Černý, T. & Bâ, A.T. 2005: Analysis of herbaceous undergrowth in woody savanna in Fathala Reserve, Delta du Saloum National Park, Senegal. - Belgian Journal of Botany 138: 19-128.

O'Brien, S.J., Roelke, M.E., Marker, L., Newman, A., Winkler, C.A., Meltzer, D., Colly, L., Evermann, J.F., Bush, M. & Wildt, D.E. 1985: Genetic basis for species vulnerability in the cheetah. - Science 227: 1428-1434.

Olech, W. 2008: *Bison bonasus* in IUCN 2010. - IUCN Red List of threatened species. Version 2010.2. Available at: http://www.iucnredlist.org/ (Last accessed on 31 July 2010).

Pappas, L.A. 2002: *Taurotragus oryx*. - Mammalian Species 689: 1-5.

Pemberton, J. 2004: Measuring inbreeding depression in the wild: the old ways are the best. - Trends in Ecology and Evolution 19: 613-615.

Pollak, J.P., Lacy, R.C. & Ballou, J.D. 2002: PM2000 (Population Management 2000). - Brookfield, Illinois, Chicago Zoological Society, USA. Available at: http://www.vortex9.org/pm2000.html (Last accessed on 11 July 2011).

Ralls, K. & Ballou, J.D. 2004: Genetic status and management of California condors. - The Condor 106: 215-228.

Ralls, K., Ballou, J.D. & Templeton, A.R. 1988: Estimates of lethal equivalents and the cost of inbreeding in mammals. - Conservation Biology 2: 185-193.

Renaud, P.C., Gueye, M.B., Hejcmanová, P., Antonínová, M. & Samb, M. 2006: Inventaire aérien et terrestre de la faune et relevé des pressions au Parc National du

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Niokolo Koba. - Plan of Urgence, Report Annex A, August 2006. Dakar, APF, DPNS, Senegal, 74 pp. (In French).

Rubeš, J., Kubíčková, S., Pajacova, E., Černohorská, H., Di Berardino, D., Antonínová, M., Váhala, J. & Robinson, T.J. 2008: Phylogenomic study of spiral-horned antelope by cross-species chromosome painting. - Chromosome Research 16: 935-947.

Ryder, O.A. & Fleischer, R.C. 1996: Genetic research and its application in zoos. - In: Kleiman, D.G., Lumpkin, S., Allen, M., Harris, H. & Thompson, K. (Eds.); Wild mammals in captivity. University of Chicago Press, Chicago, USA, pp. 255-262.

Sausman, K.A. 1993: Conservation assessment and management plan for antelope. - International Zoo Yearbook 32: 117-124.

Sausman, K. 2007: International studbook - Arabian oryx (*Oryx leucoryx*) in ISIS (2009) Studbook library. - Version 2006/2007/2008, CD-ROM.

Shurter, S. 1996: Giant Eland population management plan. - White Oak Conservation Centre, USA, 40 pp.

Snyder, N.F.R., Derrickson, S.R., Beissinger, S.R., Wiley, J.W., Smith, T.B., Toone, W.D. & Miller, B. 1996: Limitations of captive breeding in endangered species recovery. - Conservation Biology 10: 338-348.

Spinage, C.A. 1986: The natural history of antelopes. - Croom Helm, London, UK, 203 pp.

Thévenon, S. & Couvet, D. 2002: The impact of inbreeding depression on population survival depending on demographic parameters. - Animal Conservation 5: 53-60.

Trinkel, M., Ferguson, N., Reid, A., Reid, C., Somers, M., Turelli, L., Graf, J., Szykman, M., Cooper, D., Haverman, P., Kastberger, G., Packer, C. & Slotow, R. 2008: Translocating lions into an inbred lion population in the Hluhluwe-iMfolozi Park, South Africa. - Animal Conservation 11: 138-143.

Trivers, R.L. & Willard, D.E. 1973: Natural selection on parental ability to vary the sex ratio of offspring. - Science 179: 90-92.

Ungerfeld, R., González-Sierra, U.T. & Piaggio, J. 2008: Reproduction in a semi-captive herd of pampas deer *Ozotoceros bezoarticus*. - Wildlife Biology 14(3): 250-257.

Vaňková, D., Bartoš, L., Čížová-Schroffelová, D., Nešpor, F. & Jandurová, O. 2001: Mother-offspring bonding in farmed red deer: accuracy of visual observation verified by DNA analysis. - Applied Animal Behaviour Science 73: 157-165.

Wildt, D.E., Bush, M., Goodrowe, K.L., Packer, C., Pusey, A.E., Brown, J.L., Joslin, P. & O'Brien, S.J. 1987: Reproductive and genetic consequences of founding isolated lion populations. - Nature 329: 328-31.

Wilson, G.A., Nishi, J.S., Elkin, B.T. & Strobeck, C. 2005: Effects of a recent founding event and intrinsic population dynamics on genetic diversity in an ungulate population. - Conservation Genetics 6: 905-916.

Wilson, D.E. & Reeder, D.A.M. (Eds.) 2005: Mammal Species of the World. A Taxonomic and Geographic Reference. 3rd edition - Johns Hopkins University Press, USA, 142 pp.

Zachos, F.E., Hajji, G.M., Hmwe, S.S., Hartl, G.B., Lorenzini, R. & Mattioli, S. 2009: Population viability analysis and genetic diversity of the endangered red deer *Cervus elaphus* population from Mesola, Italy. - Wildlife Biology 15(2): 175-186.

Zechner, P., Sölkner, J., Bodo, I., Druml, T., Baumung, R., Achmann, R., Marti, E., Habe, F. & Brem, G. 2002: Analysis of diversity and population structure in the Lipizzan horse breed based on pedigree information. - Livestock Production Science 77: 137-146.

Zschokke, S., Studer, P. & Baur, B. 1998: Past and future breeding of the Indian rhinoceros in captivity. - International Zoo News 45: 261-276.

Downloaded From: https://complete.bioone.org/journals/Wildlife-Biology on 28 May 2025
Terms of Use: https://complete.bioone.org/terms-of-use