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Research article

# A retrospective review of causes of mortality in captive springboks (*Antidorcas marsupialis*) at the Réserve Africaine de Sigean, France from 1990 to 2015

**Benjamin Lamglait**

*Réserve Africaine de Sigean, 19 Chemin du Hameau du lac, 11130 Sigean, France. Current address: Faculty of Veterinary Medicine, Université de Montréal, 3200 Rue Sicotte, Saint-Hyacinthe J2S 2M2, Canada.*

*Correspondence: Benjamin Lamglait, e-mail: benjamin.lamglait@hotmail.fr*

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**Abstract**

Springboks (*Antidorcas marsupialis*) are medium-sized African antelopes commonly kept in captivity; nevertheless, veterinary literature on common conditions in captivity is scarce for this species. To better understand the prevalence of different causes of death in this species, the medical and zoological records of 560 springboks having died at the Réserve Africaine de Sigean (France) from 1990 to 2015 were evaluated to determine the causes of mortality. These causes were then compared between gender, age classes, month of death and location. In the neonate age class, the main cause of death was maternal neglect (57.4%; 74/129). This condition was not impacted by neonatal examination in the first few days of life. Casualties following bad weather conditions appeared to be a leading cause of death in the juvenile, subadult and adult age classes (13.2%, 15.0% and 18.1%, respectively). Trauma – mainly by conspecifics – was significantly more prevalent in males in the subadult (P=0.033) and adult (P=0.011) age classes during the reproduction period (September to January). On the other hand, females appeared significantly more affected by reproductive disorders (P=0.019). In the juvenile, subadult and adult age classes, 52.4% (226/431) of deaths took place during the coldest months (November to February). Most of the conditions pointed out may be preventable with appropriate management, such as hand rearing or provision of more shelters and retreat areas as necessary for the well-being of this small antelope species.

## Introduction

Springboks (*Antidorcas marsupialis*) are medium-sized antelopes originating from the dry grasslands, bushland and shrubland of southwestern and southern Africa (Mills and Hes 1997). Springboks have been considered as Least Concern by the International Union for the Conservation of Nature since 2008 and their wild populations seem to be increasing (IUCN SCC 2016). This species is commonly kept in captivity; nevertheless, veterinary literature on common conditions in captivity is scarce (Iverson et al. 1982; Laurent et al. 2010; Thompson et al. 2013) and is lacking in general for captive antelopes compared to other orders (Müller et al. 2009; Schenk et al. 2009; Dünner et al. 2010; Gull et al. 2010; Müller et al. 2010; Flach 2011; Soares et al. 2013, 2015; Anderson et al. 2016; Leclerc et al. 2016; Jones et al. 2018; Bartlett et al. 2019; Scaglione et al. 2019). This species has been kept at the Réserve Africaine de Sigean, a safari park in the south of France, for 27 years as multimale multifemale groups in two distinct mixed-species enclosures – 'Plaine' and 'Brousse'. 'Plaine' is an 18-hectare flat exhibit with 60–80 springboks present year-round; ostriches (*Struthio camelus*), Grevy's zebras (*Equus grevyi*) and other antelopes, including waterbucks (*Kobus defassa*) and blue wildebeest (*Connochaetes taurinus*) are also present in this mixed-species exhibit. 'Brousse', a 10-hectare hilly drive-through enclosure with forested areas, is also a mixed-species exhibit with 30–40 springboks, ostriches and other antelopes, such as southern lechwes (*Kobus leche*), blue wildebeest and Cape elands (*Taurotragus oryx*). The aim of this retrospective study on mortality in this captive springbok population held in a zoo between 1990 and 2015 was to highlight issues on which to focus. To better understand the prevalence of the different causes of death in this institution, mortality was compared between gender, age classes, month of death and location.

**Table 1.** Distribution of cause of death by age category in springboks (*Antidorcas marsupialis*, n=560) housed in Sigean (1990–2015). Age categories were designated as follows: neonates, 0–7 days; juveniles, 7 days–9 months; subadults, 9 months–1.5 yr; and adults, >1.5 yr of age.

| | Neonate (n=129) | Juvenile (n=106) | Subadult (n=27) | Adult (n=298) |
|---|---|---|---|---|
| Predation | 13 (10.0%) | 7 (6.6%) | 0 (0.0%) | 2 (0.7%) |
| Maternal neglect | 74 (57.4%) | 6 (5.7%) | 0 (0.0%) | 0 (0.0%) |
| Trauma | 11 (8.5%) | 12 (11.3%) | 3 (11.1%) | 50 (16.8%) |
| Digestive | 2 (1.6%) | 14 (13.2%) | 4 (14.8%) | 52 (17.4%) |
| Respiratory | 3 (2.3%) | 7 (6.6%) | 2 (7.4%) | 19 (6.4%) |
| Reproductive | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (3.4%) |
| General sepsis | 3 (2.3%) | 4 (3.8%) | 2 (7.4%) | 9 (3.0%) |
| Bad weather | 2 (1.6%) | 24 (22.6%) | 4 (14.8%) | 54 (18.1%) |
| Unknown | 7 (5.4%) | 4 (3.8%) | 4 (14.8%) | 29 (9.7%) |
| Others | 5 (3.9%) | 8 (7.5%) | 1 (3.7%) | 25 (8.4%) |
| Not necropsied | 9 (7.0%) | 20 (18.9%) | 7 (25.9%) | 48 (16.1%) |

## Materials and Methods

The deaths of 560 springboks held at the Réserve Africaine de Sigean (France) were recorded during the period 1990–2015. For all these deaths, the zoological and medical records were examined as well as necropsy reports when available. The data obtained were then tabulated by cause of death, age, gender, month of death and location ('Plaine' versus 'Brousse'). The causes of death were categorised as follow: involvement of digestive, respiratory or reproductive systems, trauma, predation, maternal neglect, general sepsis, bad weather conditions, others, unknown and not necropsied. Inanition following maternal neglect was confirmed at necropsy by a complete vacuity of the digestive tract associated with an evacuation of meconium in neonates. The prevalence of mortality within each category was determined for age and gender when known; $X^2$-squared tests were used to test for any differences in the causes of mortality between age classes, genders and location, as well as for comparison between life expectancies, average age at death and influence of neonatal examination. Data recording and statistical analyses were performed using Microsoft Excel (Microsoft, Redmond, WA 98052, USA) and SAS 9.4 (SAS Institute, Inc, Cary, NC 27513, USA). Statistical significance was determined for $\alpha$=0.05. The neonatal examination performed in the present institution consisted of a short-term manual restraint in the first few days for tag identification, gender determination, a quick physical examination and umbilical cord disinfection. The springboks studied were divided into four age classes: less than 1 week (neonate), 1 week to less than 9 months – average age at weaning (juvenile), 9 months to less than 18 months – average age at puberty (subadult) and more than 18 months (adult).

Life expectancy was calculated as previously described by Wiese and Willis (2004) with an age-based matrix approach widely used for animals, and using the number of years the animals lived.

The cause of death for each individual was determined using the medical records and necropsy reports when available. For the few cases where a conclusion was not clearly identified in the records, the clinical signs and necropsy lesions were used by the author to determine a cause of death. If several conditions could have led to the death of an animal, the most important one (clinical history prior to death, necropsy lesions) was used to classify the case as described before. For euthanised animals, the relevant conditions in their medical history were analysed for classification.

## Results

Necropsy reports were available for 416 individuals (74.3%; 416/560). The most common reason for missing reports was the state of decomposition being too advanced to perform a post-mortem examination. The zoological and medical records were also examined to determine the cause of death of other animals. The cause of death was not determined for 128 individuals (22.9%; 128/560), including 44 necropsies with inconclusive results. The prevalence of disease within the 11 categories of this study with regards to the different age classes is presented in Table 1. The distribution of the different causes of death appeared different among the age classes.

***Neonate age class (0–7 days)***

Neonatal deaths were quite prevalent as 23.0% (129/560) of individuals died before the age of 1 week. The main cause of death was maternal neglect (57.4%; 74/129). The other main causes of death in this age class were predation (10.0%; 13/129) by medium-sized carnivores (red foxes, *Vulpes vulpes*, and European badgers, *Meles meles*) and trauma (8.5%; 11/129), which mostly comprised crushing injuries inflicted by exhibit mates.

***Juvenile age class (8 days–9 months)***

Juvenile deaths were quite high, as 44.6% (250/560) of animals died before weaning (9 months). The main causes of death were secondary to bad weather conditions and represented 22.6% (24/106) of deaths. Bad weather conditions included low temperatures (less than 5°C) or cold wind for several consecutive days, snow and floods occurring in the first winter after birth. The other main causes of death in this age class were of digestive origin (13.2%; 14/106) and trauma by conspecifics or exhibit mates (11.3%; 12/106). In this age class, digestive pathology was mostly of parasitic aetiology (helminthosis, coccidiosis).

***Subadult age class (9 months–1.5 years)***

In the subadult age class, the most prevalent causes of deaths were digestive disorders (15%, 4/27), mostly infectious enteritis, and bad weather conditions (15%, 4/27).

***Adult age class (>1.5 years)***

In the adult age class, the most prevalent causes of deaths were



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**Table 2.** Life expectancy at birth and at puberty in springboks housed in Sigean, by gender and location. Superscript letters on the same line represent statistically significant differences (P<0.05) in comparison to the other category (males versus females; 'Brousse' versus 'Plaine').

| | All | Males | Females | 'Brousse' | 'Plaine' |
|---|---|---|---|---|---|
| Life expectancy at birth (years) | 6.0 | 6.0 | 6.6 | 7.2 | 5.6[a] |
| Life expectancy at puberty (years) | 4.4 | 4.4 | 4.9 | 5.4 | 4.1[a] |

bad weather conditions (18.1%, 54/298), digestive disorders (17.4%, 52/298), mostly traumatic reticuloperitonitis, chronic helminthosis and tooth disorders, and trauma (16.8%, 50/298), mostly leg fractures and intra- and inter-specific aggression by exhibit mates.

***Life expectancy and average age at death***

These two parameters were calculated to allow comparisons with previous mortality studies on captive antelopes (Tables 2 and 3); nevertheless, life expectancy is considered a better indicator of population dynamics (Wiese and Willis 2004). In this population, the life expectancy at birth was 6.0 years, slightly affected by gender and significantly different between locations (P=0.026). The life expectancy at puberty was 4.4 years for the overall population; this indicator was also slightly different between males and females, and significantly different between locations (P=0.032). The average age at death was 2.7 years for the overall population, reaching 3.5 years if neonatal deaths were excluded. This age was significantly higher for females compared to males (P=0.021). When focusing on location, springboks kept in 'Plaine' died significantly earlier when compared to those housed in 'Brousse' (P=0.043). The high percentage of neonatal mortality (13.2%; 74/560) significantly affected the dynamics of this population as shown by the significant differences between life expectancy at birth and at puberty (P=0.017), and average age at death including or excluding neonatal deaths (P=0.021).

***Gender***

The gender was indicated in the zoological records for 483 springboks (86.3%; 483/560); the causes of death sorted by gender are given in Table 4. Some categories among the causes of death were significantly affected by gender. The main cause of death for males was trauma, occurring in 16.3% (41/252) of all male deaths. Trauma was significantly more prevalent in males in the subadult (P=0.033) and adult (P=0.011) age classes, and mostly represented by leg fractures secondary to intra-specific aggression by exhibit mates. On the other hand, females appeared significantly more affected by reproductive disorders (P=0.019), mostly linked to parturition. Although the numbers were small in this age category, juvenile females also seemed to be more affected by bad weather conditions (33%, 2/6; P=0.046).

***Time of year***

The distribution of deaths was not constant year-round (Figure 1). In the juvenile, subadult and adult age classes, 52.4% (226/431) of deaths took place during the four coldest months (November to February). The other peak of deaths occurred from March to June and was correlated with neonatal mortalities. Deaths of traumatic origin were more prevalent during the reproduction period (September to January), as seen with the distribution of deaths among adult males; 62% (40/65) of deaths in this category occurred during this 5-month period, reaching 66% (21/32) in adult males. For the overall population, deaths were less prevalent from July to October.

***Location***

When comparing the causes of death by location, deaths linked to bad weather conditions (28.3 and 20.2%; P=0.040), maternal neglect (20.2% and 12.7%; P=0.033), respiratory disorders (5.6% and 3.2%; P=0.046), and predation (1.6% and 5.7%; P=0.022) were significantly different between 'Plaine' and 'Brousse', respectively (Table 5).

***Influence of neonatal examination***

In the study population, a neonatal examination was performed in 58.7% (322/548) of the dead springboks born at Sigean. Neonatal death in springboks was not statistically associated with neonatal manipulation nor with gender or location at birth (P>0.05).

## Discussion

Veterinary literature for captive springboks is limited to few clinical reports (Iverson et al. 1982; Laurent et al. 2010; Thompson et al. 2013), and a retrospective analysis of causes of springbok mortality was not identified in peer-reviewed literature. The results of this retrospective study represent the first overview of springbok mortality in a captive population and highlight some age- or gender-related issues. As a retrospective study using data from a 26-year period, however, there may be several limitations associated with variations in record keeping, husbandry management and pathologic and/or medical differences. Although the number of deaths included in this retrospective study is significant, all the cases reported occurred at the same institution; as a result, the

**Table 2.** Life expectancy at birth and at puberty in springboks housed in Sigean, by gender and location. Superscript letters on the same line represent statistically significant differences (P<0.05) in comparison to the other category (males versus females; 'Brousse' versus 'Plaine').

| | All | Males | Females | 'Brousse' | 'Plaine' |
|---|---|---|---|---|---|
| Average age at death (years) | 2.7 | 2.6 | 3.4[a] | 3.1 | 2.3[b] |
| Average age at death – neonatal deaths excluded (years) | 3.5 | 3.3 | 4.1[a] | 3.7 | 3.1 |

**Table 4.** Distribution of cause of death by gender in springboks (*Antidorcas marsupialis*, n=483) housed in Sigean (1990–2015). Superscript letters on the same line represent statistically significant differences (P<0.05) between males and females.

| | Male (n=252) | Female (n=231) |
|---|---|---|
| Predation | 7 (2.8%) | 8 (3.5%) |
| Maternal neglect | 40 (15.9%) | 31 (13.4%) |
| Trauma | 41 (16.3%) | 21[a] (9.1%) |
| Digestive | 22 (8.7%) | 29 (12.6%) |
| Respiratory | 11 (4.4%) | 14 (6.1%) |
| Reproductive | 0 (0.0%) | 9[a] (3.9%) |
| General sepsis | 5 (2.0%) | 8 (3.5%) |
| Bad weather | 54 (21.4%) | 46 (19.9%) |
| Unknown | 20 (7.9%) | 16 (6.9%) |
| Others | 14 (5.5%) | 18 (7.8%) |
| Not necropsied | 38 (15.1%) | 31 (13.4%) |

**Table 5.** Distribution of cause of death by exhibit location in springboks *(Antidorcas marsupialis*, n=479) housed in Sigean (1990–2015). Superscript letters on the same line represent statistically significant differences (P<0.05) between 'Brousse' and 'Plaine'.

| | 'Brousse' (n=158) | 'Plaine' (n=321) |
|---|---|---|
| Predation | 9 (5.7%) | 5[a] (1.6 %) |
| Maternal neglect | 20 (12.7%) | 65[a] (20.2%) |
| Trauma | 13 (8.2%) | 25 (7.8%) |
| Digestive | 20 (12.7%) | 31 (9.7%) |
| Respiratory | 5 (3.2%) | 18[a] (5.6%) |
| Reproductive | 2 (1.3%) | 7 (2.2%) |
| General sepsis | 4 (2.5%) | 6 (1.9%) |
| Bad weather | 32 (20.2%) | 91[a] (28.3%) |
| Unknown | 12 (7.6%) | 13 (4.0%) |
| Others | 16 (10.1%) | 17 (5.3%) |
| Not necropsied | 25 (15.8%) | 43 (13.4%) |

conclusions drawn are representative of this institution and may not be applicable to other captive populations. Nevertheless, the goal of this study was to identify the more important causes of mortality with a view to improving husbandry and medical management of captive springbok populations.

An interesting feature of the results is the large number of deaths in the neonate age class, representing 23.0% of deaths in the study population. High mortality rates in neonates have already been reported in several captive antelope species (Besselmann et al. 2008; Müller et al. 2009; Schenk et al. 2009; Dünner et al. 2010; Gull et al. 2010; Flach 2011; Wolfe 2014; Leclerc et al. 2016; Rduch and Sliwa 2017; Jones et al. 2018; Hizem et al. 2019). Failure to thrive and maternal neglect – identified at necropsy by a complete vacuity of the digestive tract associated with an evacuation of meconium – represent the major causes of neonatal death in this captive population. Maternal neglect is a common occurrence in non-domestic ruminants and has been previously reported as one of the major causes of death in a few retrospective reviews of mortality in captive gazelles (Wolfe 2014; Soares et al. 2015; Anderson et al. 2016; Rduch and Sliwa 2017; Jones et al. 2018; Hizem et al. 2019). Death following maternal neglect is the consequence of starvation, hypoglycemia and hypothermia secondary to the absence of nursing. Dams reported as inexperienced, ill, housed in unnatural social or environmental conditions, or stressed by human presence are reported as the most likely to reject a neonate (Wolfe and Lamberski 2012; Wolfe 2014; Soares et al. 2015). Human interference with and handling of the newborn while administering neonatal treatment had been proven to negatively impact the survival of newborns in some gazelle species (Meier et al. 2009; Wolfe 2014; Soares et al. 2015). Neonatal examination and tag identification of young animals in the first few days of life, however, did not influence neonatal mortality in the present captive population. This difference may be due to the different nature of the maternal–infant interactions between the species or differences between institutions in the duration or procedures realised during the neonatal examination. Life expectancy at puberty was lower in 'Plaine', thus the proportion of young – and nulliparous, inexperienced – dams may be more important in this enclosure. This could explain the higher incidence of neonatal death following maternal neglect in this enclosure. Inadequate social or environmental situations may also influence the prevalence of maternal neglect; both enclosures are mixed-species exhibits, but the species vary. Cape elands could potentially play a role as a dominant species and may inflict trauma to other species including springboks. This species was also dominant at feeding areas. 'Brousse' offers a more diverse environment with more retreat areas and could be more

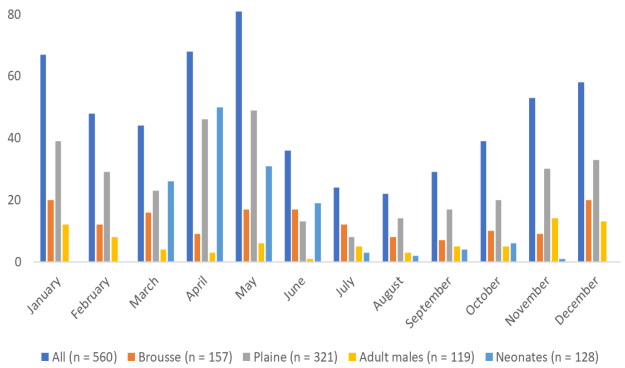


**Figure 1.** Annual distribution of death in springboks (*Antidorcas marsupialis*) housed in Sigean (1990–2015).

suitable for a small antelope species in a mixed-species exhibit. Increased inbreeding in some captive populations has also been reported as a cause of newborn mortality (Hizem et al. 2019). A lower genetic fitness and an increased incidence of congenital or hereditary malformations may be suggested. In the present captive springbok population, inbreeding may have influenced neonatal mortalities. The genetic parentage of this population is not possible to determine, however, as this species is presented in multimale multifemale groups in the zoo exhibit. It is also important to note that neonatal malformations were rare in this species during the study period. As neonate springboks are not weighted routinely, the influence of birth weight on survival has not been evaluated in this study; nonetheless, this parameter may have contributed to the high proportion of neonatal deaths in this captive population, as previously demonstrated in captive Thomson's gazelles (*Eudorcas thomsonii*) (Browne et al. 2011) and Cyprus mouflons (*Ovis orientalis laristanica*) (Deiss et al. 2010). Several actions could be taken to reduce mortality in newborns in this springbok population. As maternal neglect was the most important cause of neonatal death in this population, artificial hand-rearing could be developed. Although scarce in the peer-reviewed literature in springboks, hand-rearing of young exotic bovids has been previously reported (Ŝpála and Váhala 1989; Greene and Stringfield 2008; Wolfe and Lamberski 2012; Petzinger et al. 2014). During the last 3 years of the period under review, some females were successfully hand-reared with artificial milk powder formulated for kids and lambs. Following the same considerations described in other exotic bovid species, the frequency of meals was reduced during growth with a gradual introduction of fodder. Some of these hand-reared individuals reached adulthood and raised offspring themselves and became well integrated into the herd. Young hand-reared individuals were kept in pairs to limit impregnation. To limit aggressive behaviour towards humans, artificial breeding of young males was not carried out in this collection over the period considered, as previously recommended (Ŝpála and Váhala 1989; Greene and Stringfield 2008). The success of hand-rearing of young exotic bovids also depends on the early recognition of neonates suffering from maternal neglect. Thus, nursing behaviour and maternal–infant interactions are important elements to document for early identification of maternal neglect, as previously described in several antelope species (Murdock et al. 1983; Ralls et al. 1986; Mooring and Rubin 1991). Zookeepers' experiences are also a major asset for the early detection of this condition. Further studies on nursing behaviour and maternal–infant interactions in springboks would also allow better early identification of maternal neglect and thus improve the success of hand-rearing. On the other hand, all actions carried out that could increase the survival of reproductive females could reduce the incidence of neonatal mortalities linked to maternal neglect, since the proportion of multiparous, and therefore possibly more experienced, females would be greater. Other significant conditions affecting neonates were predation (10.0%, 13/129) and trauma (8.5%, 11/129). Predation was significantly more prevalent in 'Brousse' and correlated with the more frequent observations of red foxes and European badgers in this enclosure compared to 'Plaine'. Traps have been installed for several years to capture these two species, particularly in 'Brousse'. However, the impact of these traps is difficult to assess as predation was variable between years. Traumatic conditions were mainly crushing injuries inflicted by other species, such as blue wildebeest and Cape elands, while neonates were hidden in forage distribution areas. Provision of forage distribution or padded areas with a restricted access to large exhibit mates have been considered to reduce the incidence of this cause of death. Protected areas with branches were added to 'Plaine' and 'Brousse' but did not seem to be occupied by young springboks that preferred to lie down in depressions in flat areas or in forage. Other measures to consider are the introduction of other types of protected areas for young springboks or a change in the species composition of the enclosures.

Deaths related to bad weather conditions also represented a significant cause of mortality in this study. The bad weather conditions reported in the records consisted of heavy rain, cold temperatures (less than 5°C) or cold winds for several consecutive days, snow or floods. The Réserve Africaine de Sigean has indeed experienced several episodes of major floods, mainly located in the part of the zoo which holds 'Plaine'. This partly explains the significantly higher number of deaths due to bad weather conditions in this enclosure compared to 'Brousse'. A greater susceptibility of springboks to climatic conditions in 'Plaine' compared to 'Brousse' could also reside in the topography of the first enclosure. Although plant windbreaks are available in both enclosures, 'Brousse' – a hilly exhibit with forest areas – offers more shelter than the flat, treeless 'Plaine'. Additional heated shelters were added to the enclosures during the last 5 years of the study period; however, the necessary hindsight was not significant enough at the end of this study to assess the impact of these new buildings on the death rate in this species in relation to bad climatic conditions. It is, however, important to mention that the addition of these shelters may have had a smaller impact than expected because springboks rarely enter buildings, even if semi-open or when the weather conditions are bad. The addition of windbreaks or forest areas seem to offer more suitable shelter for this species. To limit the mortalities linked to recurrent floods, some measures have been undertaken during the last 15 years of the study, such as the construction of dikes, the channeling of water in certain parts of the enclosures, the construction of elevated areas and shelters within the enclosures, and the creation of traps in fences to facilitate the passage of water. These measures reduced mortalities during the last floods; however, during major floods, some mortalities still occurred. The zoo is still working with local communities to allow the construction of dikes upstream of the park to limit the recurrence of floods in the zoo. More deaths due to bad weather conditions were recorded between November and February, the four coldest months of the temperate climate; this observation has been reported previously in some captive gazelle populations (Gull et al. 2010; Anderson et al. 2016; Hizem et al. 2019; Scaglione et al. 2019). Respiratory disorders were not a leading pathology in the present population, in contrary to the results of several previous studies on mortality in antelopes under human care (Schenk et al. 2009; Müller et al. 2010; Soares et al. 2013, 2015; Leclerc et al. 2016; Jones et al. 2018; Scaglione et al. 2019). The deaths related to these conditions were also mainly concentrated between November to February, thus suggesting that the pneumonia encountered during this period may be related to bad weather conditions. The significantly higher prevalence of respiratory disorders in 'Plaine' than in 'Brousse' during the period considered also supports this hypothesis. As previously reported for livestock, respiratory infections are multifactorial diseases and climatic conditions are likely to increase the occurrence, distribution and prevalence of respiratory diseases; farming practices and land use, zoological and environmental factors, the establishment of new microenvironments and microclimates, and the interaction of these factors may also be involved in the pathogenesis of respiratory diseases in captive ruminants (Gale et al. 2019).

The average age at death, as well as the expected life expectancy at puberty, were significantly higher for females compared to males. This is consistent with previous reports of female gazelles under captive management living sometimes twice as long as males (Kohler et al. 2006; Anderson et al. 2016; Rduch and Sliwa 2017; Bartlett et al. 2019). This could be explained by specific causes of death for males. In other captive ruminant species with

a polygynous mating system, life expectancy of males is lower than for females, and probably not only caused by intensive intra-specific competition between the males, but also by their reproductive physiology per se (Müller et al. 2011; Rduch and Sliwa 2017). Trauma appeared as the most prevalent cause of death among adult male springboks in the present study and was mainly due to conspecific aggression during the breeding season. Traumatic conditions, either caused by intra-specific aggression, running into fences or capture procedures, have already been reported as frequent causes of mortality in several captive antelope collections (Knottenbelt 1990; Müller et al. 2009; Schenk et al. 2009; Deiss et al. 2010; Dünner et al. 2010; Müller et al. 2010; Flach 2011; Soares et al. 2013; Wolfe 2014; Soares et al. 2015; Anderson et al. 2016; Leclerc et al. 2016; Rduch and Sliwa 2017; Jones et al. 2018; Scaglione et al. 2019). Ethological considerations in mixed-species enclosures, special attention during the breeding period of this species and the presence of visual barriers close to the fences are all preventive measures that could be implemented.

The results of 44 necropsies were inconclusive in the present study, highlighting the fact that efforts remain to be made to better understand the causes of death in this captive springbok population. Moreover, necropsy was not performed for 15.0% of animals; the most common reason was a too-advanced state of decomposition to perform a post-mortem examination. Another explanation for the quite high proportion of animals with an unknown cause of death is the retrospective aspect of this study; poorly filled or misclassified necropsy reports may have affected the number of inconclusive necropsies. As a result, the cause of death was not established for about 23% of the studied population. This proportion remains quite high, but is close to what has been reported in previous studies in captive antelopes, with proportions ranging from 5 to 28% (Müller et al. 2009; Schenk et al. 2009; Dünner et al. 2010; Müller et al. 2010; Soares et al. 2015; Leclerc et al. 2016; Scaglione et al. 2019). Systematic necropsies and more frequent histological and bacteriological analyses could reduce the amount of undetermined causes of death in this population.

The conclusions of the present study will direct actions in the management of captive springboks. This retrospective study emphasises that springboks in Sigean seem to be quite sensitive to bad weather conditions. Many of the problems may be preventable with appropriate management, such as successful hand-rearing for a few years to decrease neonatal mortality. More shelters and retreat areas seem to be necessary for the well-being of this small antelope and to reduce the number of deaths attributable to bad weather conditions. Although the number of deaths included in this retrospective study is significant, all the cases reported occurred at the same institution; as a result, the conclusions drawn are representative of this institution and may not be applicable to other captive populations. It would be interesting to carry out a similar study in a few years to determine the impact of the various zootechnical measures implemented on the causes of mortality in this population. A similar study at a larger scale, implicating several zoos, would also be interesting to get a wider idea of the causes of mortality in captive springboks. Finally, ethological – inter- and intra-specific – studies are necessary to highlight other potential stressors in this species in mixed-species exhibits.

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