# Why do Greater one-horned rhinoceroses (Rhinoceros unicornis) die? - An evaluation of necropsy reports

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# WHY DO GREATER ONE-HORNED RHINOCEROSES (*RHINOCEROS UNICORNIS*) DIE? – AN EVALUATION OF NECROPSY REPORTS

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## Summary

Many case reports about different diseases in greater one-horned rhinoceroses (*Rhinoceros unicornis*) have been published, but an overview of the prevalence of diseases and an evaluation of causes of death is lacking. Necropsy reports of 106 greater one-horned rhinoceroses from 38 zoos worldwide were evaluated. Half of them were from adult animals, a third from perinatal deaths/stillbirths and the rest from juveniles and sub adults. Cardiac problems (cardiomyopathy, myocarditis, heart infarct) and cardiovascular failure due to gastrointestinal or pulmonary disease were the most frequent causes of death in adults. Among gastrointestinal problems, gastric ulcers and impactions, often with sand, were the most frequent findings. Sixteen adult greater one-horned rhinoceroses were euthanised, mainly due to chronic disease, foot problems or uterine leiomyomas. The two latter problems are suspected to be associated with obesity, and most of the animals with these problems were reported to be in good body condition at death. Leiomyomas are additionally thought to be predisposed by repeated oestrus cycles without pregnancy. Foot problems were only noted in 6 % of the animals and are probably underestimated in this dataset. Systematic documentation of necropsy findings is desirable, including complete animal identity, anamnesis, circumstances of death (natural death, euthanasia, and stillbirth), body condition scoring and weight.

## Introduction

In the late 1940s, the first greater one-horned rhinoceroses (*Rhinoceros unicornis*) were captured and transported into zoos (VON HOUWALD, 2010). Because of the popularity and great value of individual rhinos, extensive treatment of any disease issue was usually initiated. Many case reports in rhinoceroses and treatment possibilities were published in the 1970s and 1980s, e.g. impaction (SIMONS and JENKE, 1977) or exudative dermatitis (JONES and THOMSETT, 1972; SIMONS and JENKE, 1977). In 1979, a review of diseases of captive and wild rhinoceroses was published (SILBERMAN and FULTON, 1979). Husbandry and environmental issues such as inadequate diets and sub optimal flooring have led to obesity and pododermatitis (VON HOUWALD and FLACH, 1998). These caused welfare concerns and received attention in the 1990s. Necropsies of dead animals were probably performed, but these were not reported systemically; therefore necropsy findings were still rarely published at that time. In four greater one-horned rhinoceroses from Zoo Basel, a fungal pneumonia, Farmer's lung, was diagnosed and precipitins against *Micropolysora faeni* were found (GUTZWILLER et al., 1985). In 1995, a review of necropsy reports in black and white rhinoceroses was performed (GÖLTENBOTH, 1995). The most frequent findings in black rhinoceroses (*Diceros bicornis*) were infections, among them haemolytic anaemia, septicaemia, purulent bronchopneumonia and trauma or accident. Interestingly, almost half of the white rhinoceroses (*Ceratotherium simum*) died from trauma/accident or stress during transportation, but none of them, and also none of the greater one-horned rhinoceroses, died from haemolytic anaemia (GÖLTENBOTH, 1995). The cause of that syndrome

is not known, but different causes like immune complex disease (MURRAY et al., 2000), enzymatic modulation of red blood cells, vitamin E deficiency, iron overload and leptospira are suspected (DENNIS et al., 2007). That result suggests that a generalisation of necropsy findings to all rhinoceros species is inappropriate. In this study, necropsy reports of greater one-horned rhinoceroses worldwide were reviewed.

## Material and methods

Reports were collected by the European studbook keeper (Beatrice Steck, Zoo Basel). Zoos were asked to send all pathology reports they have collected during the time of keeping Indian rhinos in their facility. From all the animals, age, gender and origin were evaluated with the help of the INTERNATIONAL STUDBOOK and categories "natural death", "euthanasia" or "stillbirth" were noted, if possible. Wild-caught animals were divided into wild-caught as juveniles (capture in the same year than estimated birth), wild-caught as sub adults (capture in the next year up to five years after estimated birth) and wild-caught as adults (capture more than five years after estimated birth). Fifteen animals could not be attributed to one of the categories because their age was unknown. Cause of death (if not euthanasia) was recorded; if there was no conclusion, the cause of death was estimated with the help of a pathologist (Dr. Nadia Robert, Dipl. ACVP) based on the different reported findings. However, this was not always possible. One to five findings were noted, including the cause of death, but also incidental findings like pododermatitis; if there were more than five, those which contributed to the death or main on-going disease were chosen. Quantitative measures are displayed as means and standard deviations.

## Results

In total, 106 necropsy reports of greater one-horned rhinoceroses were collected (1943 – 2008), mostly from Europe and North America (table 1). Around one third was from newborns/stillbirths and almost half of adults (table 2). In total 440 one-horned rhinoceroses are listed in the studbook; of those, 150 were wild-caught and 290 zoo-born. Fifty-seven percent of all animals listed in the studbook are dead (249/440). Death rate was 19 % for newborns/stillbirths (captive-born), 5.5 % for captive-born juveniles, 19.3 % for wild-caught juveniles, 4.7 % for captive-born sub adults, 16.9 % for sub adults which were wild-caught as juveniles and 6.5 % for sub adults which were wild-caught as sub adults (table 3).

*Tab. 1: Regions from where necropsy reports were received and corresponding number of animals and zoos (in brackets).*

| Region | Animals (Zoos) |
|---|---|
| North America | 48 (16) |
| Europe | 44 (16) |
| Asia | 12 (4) |
| South America | 1 (1) |
| Australia | 1 (1) |
| Total | 106 (38) |

*Tab. 2: Age categories and number of necropsy reports received in total and number of males and females.*

| Age categories | Necropsy reports (male.female) |
|---|---|
| newborns/stillbirths (0 - 1 day) | 32 (15.17) |
| juveniles (1 day -1 year) | 8 (4.4) |
| sub adults (1 - 5 years) | 9 (7.2) |
| adults (> 5 years) | 57 (34.23) |
| Total | 106 (60.46) |

*Tab. 3: Origin, number of deths for different age categories (deaths), total number of animals per age category (total), animals alive which are still in those age categories (alive) and death rates (%) according to the studbook population (VON HOUWALD, 2010).*

| died as | newborns/stillbirths | | | juveniles | | | | sub adults | | | | adults | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| origin | deaths | total | % | deaths | total | alive | % | deaths | total | alive | % | deaths | total | alive | % |
| captive-born | 55 | 290 | 19.0 | 13 | 235 | 7 | 5.5 | 10 | 215 | 29 | 4.7 | 60 | 176 | 116 | 34.1 |
| wild-caught as juveniles | | | | 17 | 88 | 0 | 19.3 | 12 | 71 | 0 | 16.9 | 33 | 59 | 59 | 55.9 |
| wild-caught as sub adultes | | | | | | | | 2 | 31 | 0 | 6.5 | 20 | 29 | 29 | 69.0 |
| wild-caught as adults | | | | | | | | | | | | 14 | 16 | 16 | 88 |

Weight measurements or estimations were performed for 52 % of the animals (55/106) (figure 1). General body condition was described in less than half of the necropsy reports. In the newborn/stillborn group, body condition scoring was performed for nine out of 32 deaths (seven as good/normal, two as poor), in the juvenile group, three out of eight animals were scored (two as good, one as poor), in the sub adult group, five out of nine animals were scored (two as good, three as poor) and in the adult group, 25 out of 57 animals were scored (13 as good, 10 as poor and two as moderate).

In the newborn/stillbirth group, 14 were abortions, six were perinatal deaths (lungs at least partially inflated), one was euthanised due to trauma, probably by the mother, three died in the first day and from eight animals the circumstances of death were unknown (lung inflation not mentioned). Fifteen of abortions/perinatal deaths were from primiparous dams with an age of 10.6 ± 5.1 years and 17 were from pluriparous dams with an age of 17.3 ± 5.9 years. The cause for the abortion was mostly unknown; only one case of umbilical torsion, one case of placentitis and one case of trauma of the mother were noted. Causes for perinatal deaths were also mostly unknown; however, three of them were diagnosed with septicaemia (alpha-haemolytic *Streptococcus* spp., *E. coli*, *Acinetobacter* spp., Staphylococci and beta-haemolytic Enterococci). The weight of animals that died in the first day was 60.8 ± 11.2 kg (n = 8).

In the juvenile group (n = 8), none of the animals died older than four months; three of them were from primiparous dams and five from pluriparous dams. There were three cases of septicaemia, two cases of death during anaesthesia (one of them due to aspiration), two cases of gastrointestinal problems (one gastric ulcer, one colon torsion), and one case whose cause of death was unknown.

In the sub adult group, four animals died due to complications because of gastrointestinal problems (two with sand impaction, one with caecum transposition and one with salmonella enteritis). One animal died due to liver rupture and peritonitis due to hepatitis, and three animals were euthanised due to gastric ulcers (including pain, pharyngeal obstipation or signs of obstructive gastrointestinal disease), due to renal failure and due to a vertebra fracture, respectively.

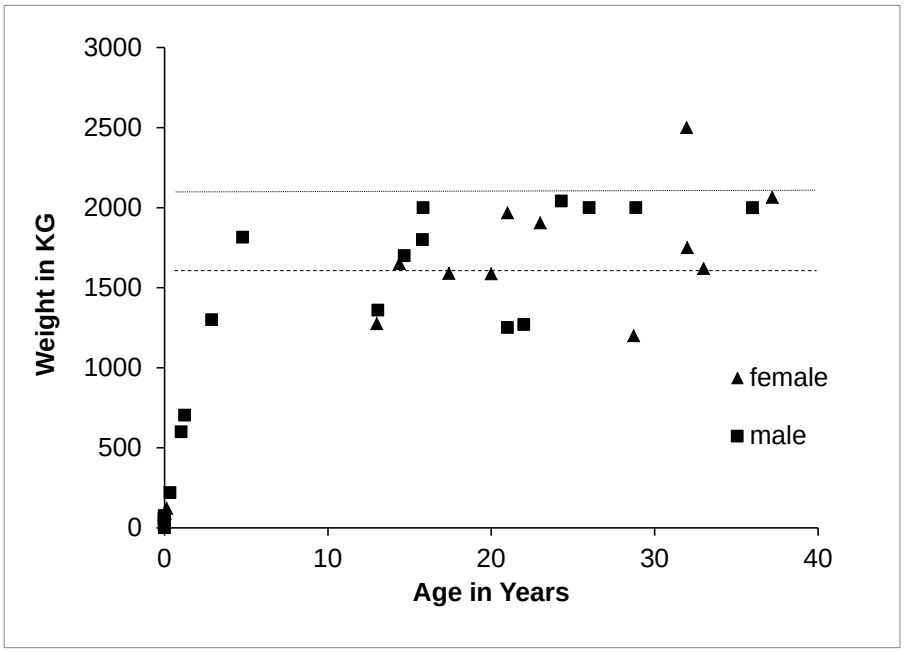


*Fig. 1: Weight development of male and female greater one-horned rhinoceroses in comparison with the mean weight in female (dashes) and male (dots) wild greater one-horned rhinoceroses (OWEN-SMITH, 1988; SILVA and DOWNING, 1995).*

Thirty-two of the adult rhinoceroses died of a natural death, 16 were euthanised and from nine, the death circumstances were unknown. Four animals were euthanised due to foot problems, five due to chronic disease (renal failure; osteoarthritis; allergic lung disease and heart insufficiency; arteriosclerosis, pancreatitis and glomerulonephritis; in one case, just chronic disease was noted), two due to leiomyomas, one with an additional rectum prolapse (both 32 years old, size of leiomyomas up to 18 cm (noted in one animal)) and five for other reasons like trauma or fracture of vertebrae. Eight animals died due to cardiovascular failure (age: 19.0 ± 9.1), eight due to the complications of gastrointestinal problems (peritonitis due to rupture of gastric ulcers, cardiovascular failure, bloating), four due to trauma (spinal cord fracture, during mating, attacked by male, strangulation), three due to a renal problem, two because of a septicaemia/toxaemia and two due to respiratory problems (one during sedation). Fourteen animals died from other or unknown causes.

Impaction as a finding was found in nine adult animals, four of them specified as sand impaction. These four animals were all from different regions worldwide, one from Europe, from Asia, from North America and Australia, respectively. Additionally, in one animal, a sand accumulation was noted, but not an impaction. Furthermore, two animals with gastric impaction and one with colonic impaction were noted in which the cause for the impaction was not specified.

Ulcers either as a cause leading to death or as an incidental finding were noted in 14 adult animals. In 93 % (13/14) of the cases, the ulcers were in the stomach and only in one case, a colonic ulcer was noted. The age of death of animals with gastric ulcers was very variable (youngest 0.1 years, oldest 32 years) and the sex ratio was almost balanced (eight males, five females).

Genital tract tumours occurred in more than half of the females older than 15 years (only 16 reports of females older than 15 years). Genital tract pathologies (tumours or cysts) were the most frequent; they were noted in 15 animals either as the reason for euthanasia or as an incidental finding. Twelve of those females had already given birth at least once and only three were non-reproductive. Dams with genital tumours were all older than 20 years. Leiomyomas and fibroleiomyomas were the most frequent among tumours. Furthermore, in one animal a carcinoma was found and in two animals genital masses were noted. In one animal with a leiomyoma, ovarian cysts were additionally found; ovarian cysts were also found in four other animals without any other genital tract pathology.

Foot problems (mostly noted as proliferation with ulcerations) were noted in six adult animals (five males/one female), which died in the years 1987, 1995 (two animals), 1997, 2001 and 2003. Three animals were from the USA, two from Europe and one from South America. Four of these animals were euthanised due to foot problems with ages between 15.8 and 36 years. In two animals, foot problems were found as an incidental finding; these animals were six and 22.5 years old.

## Discussion

Necropsy reports were often incomplete and the cause of death was not obvious in many cases. Cardiac problems (cardiomyopathy, myocarditis, heart infarct) and cardiovascular failure due to gastrointestinal or pulmonary disease were the most frequent causes of death in adults. Around one third of the deaths in adult animals was due to euthanasia, often because of foot problems or chronic disease. For abortions or perinatal death, a cause could be found very rarely. A complete analysis of all necropsy reports was difficult, because their different quality. The identity of the necropsied animal was often missing, but this could be solved with the help of the international studbook. Often it was not clear whether an animal died or was euthanised. Even though we tried to find out the most likely cause(s) of death, this was not possible in 34 cases. Therefore, calculated percentages of findings are only approximate, and conclusions may remain tentative for most findings.

The death rate for newborns/stillbirths is relatively high with every fifth animal dying. Perinatal deaths and stillbirths are often suspected to be a problem of primiparous dams but so far there has been no

evidence for this. In our dataset primiparous dams had even less perinatal deaths and stillbirths than pluriparous dams.

There is a big difference in death rates of juveniles and sub adults between captive-born animals and those which were wild-caught as juveniles. The latter died almost four times as often as the captive-born (5.5 % and 19.3 %, respectively). Animals wild-caught as juveniles also died much more often as sub adults than captive-born or animals wild-caught as sub adults (16.9 %, 4.7 %, 6.5 %, respectively). This finding suggests that greater one-horned rhinoceros captured at less than one year of age experience stress, e.g. due to losing contact to their mother, and are probably in a more worse condition than captive-born juveniles. Animals which were captured as sub adults showed similar death rates as captive-born sub adults, leading to the suggestion that they experience less stress and are in a better condition than those captured earlier.

Weight measurements or at least estimations were only performed in 52 % of the animals. It is understandable that weighing adult rhinoceroses is not always possible, but also a lot of newborn/stillborn or juvenile animals were not weighed. Especially in newborns and stillbirths, it would be important to evaluate the maturity of the animal. For adult rhinoceroses, at least weight estimation should be performed, even more so if the animals already had to be estimated to apply medication prior to death. The age-related weight development of females and males that results from the reports is shown in figure 1, but has to be interpreted with caution, because some animals died of a chronic disease with a poor body condition. In our study, only females were heavier than their free-ranging counterparts and sex weight difference was smaller than expected from the wild (DINERSTEIN, 1991). The case of one female (figure 1) whose body mass was nearly 1000 kg above the norm for free-ranging females should sensitise for the problem of overweight in captivity. This is confirmed by the three animals currently kept at Zoo Basel: both females weigh between 1860 to 2050 kg and the male weighs around 2000 kg, which is, according to the data from wildlife, a bit too heavy for the females but normal for males. In the wild, mean weight of greater one-horned rhinoceros is 1600 kg for females and 2100 kg for males.

Captive rhinoceroses are often fed with restricted amount of concentrates and an *ad libitum* amount of roughage. Even with a roughage-only diet ad libitum, the daily energy intake may still be higher in individual cases than the estimated maintenance requirement (CLAUSS et al., 2005). High energy intake leads to obesity which may be linked to two frequent problems in captive greater one-horned rhinoceroses, foot problems and leiomyomas (CLAUSS et al., 2005), although predisposition for leiomyomas also occurs due to repeated oestrus cycles without pregnancy (HERMES and HILDEBRANDT, 2011). Leiomyomas and other genital tumors were found in more than half of the female rhinoceroses older than 15 years. In one animal, ovarian cysts were found as well. Leiomyomas are a common finding in large mammals and are associated with increased weight (CLAUSS et al., 2005; MONTALI et al., 1982). Captive non-reproducing white rhinoceros females exhibit approximately 310 oestrous cycles in their life, compared with around 90 in reproducing females, and their reproductive organs are exposed to prolonged periods of sex steroid fluctuations from continuous ovarian cycle activity. It is therefore suspected that non-reproductivity is also a predisposing factor for genital pathologies (HERMES and HILDEBRANDT, 2011). Although most females with leiomyomas had reproduced in this dataset, repeated non-reproductive cycles cannot be excluded even in these animals. From the eight animals having leiomyomas and whose body condition was scored, six were scored as good, which supports the hypothesis of a predisposition to develop leiomyomas in non-lean animals.

In addition to weight measurements, a scoring of the body condition should be performed at necropsy. It might be helpful to look at the scoring system used for black rhinos to get an idea of what one needs consider (REUTER and ADCOCK, 1998). Unfortunately, less than half of the pathology reports contained this easy way to describe the condition of the animal. Animals dying from complications of gastrointestinal disease were mostly scored as good, very good or normal (n = 5), and only one was scored as poor. This reflects the acute onset of disease, e.g. an impaction or a ruptured gastric ulcer.

On the other hand, three of the four scored animals that were euthanised because of chronic disease were scored as poor.
Perinatal deaths and stillbirths are often suspected to be a problem of primiparous dams but so far there has been no evidence for this. In our dataset primiparous dams had even less perinatal deaths and stillbirths than pluriparous dams.
The most frequent findings in general (cause of death and incidental findings) were gastrointestinal problems, among them mostly impactions and gastric ulcers. Gastric ulcers occur in horses due to high level of HCl, pepsin and possibly bile acid leading to a lower stomach-pH, which is neutralised by bicarbonate in the saliva. Horses fed with grain and pelleted food had a higher incidence of gastric ulcers than horses fed with hay. This is most probably due to a lower amount of saliva in the stomach content due to reduced chewing of the grain and pelleted food (MURRAY, 1999). In swine, when ration particle size was decreased, the incidence of gastric ulcers increased (MAHAN et al., 1966). It could be possible that rhinoceros with gastric ulcers are fed with a high amount of pelleted food, chew less, have a lower amount of saliva in stomach content which results in a higher pH and therefore develop gastric ulcers. Another possibility is stress-induction as known from humans (SPIRT, 2004).
Foot problems were not noticed in some wild animals which were caught for translocation (ATKINSON et al., 2004), and the prevalence of varying degrees of foot problems during a 17 years period was around 25 %, and higher in males than females, based on the inspection of live animals and feet recovered from individual necropsies (VON HOUWALD, 2001). In our dataset (necropsy reports from 1943 to 2008), prevalence of foot problems was only 6 % (6 animals/106 reports). We suspect this to be an underestimation and claim that feet may often not be examined at necropsy. The youngest animal noted with foot problems in our study was six years old, and of the six affected animals, five are males and only one is a female. These findings correspond to the comprehensive study about foot problems in greater one-horned rhinoceroses (VON HOUWALD, 2001). Unnecessary concentrate feeding leading to obesity and laminitic lesions, like in horses, is suspected to predispose for pododermatitis (GÖLTENBOTH, 1995). The last animal in which pododermatitis was found died in 2003. We hope that more detailed knowledge about the problem and a subsequent improvement of husbandry led to this putative decrease of the problem.
In the future, pathologic examinations should be performed more systematically, especially when performed by a zoo veterinarian not used to do necropsies. A model necropsy report for greater one-horned rhinoceroses is available from the husbandry manual for the species (TRUPKIEWICZ, 2002). A proper identification of the animal (including age, gender, origin, and name) and anamnesis (including death circumstances e.g. natural death, euthanasia) should be noted and a general body condition scoring should be performed. Weighing of the animals is desirable and especially important in perinatal deaths and stillbirths. All organs should be examined, and also the absence of pathologic findings should be noted.

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