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Research article

Health and health management of captive white rhinoceroses (*Ceratotherium simum*): results from an online survey

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Abstract
In 2009 an online survey was sent out to various zoos across Europe and Israel to gather information concerning the health status and management of captive white rhinoceroses (*Ceratotherium s. simum*). The goals of the online survey were to understand (1) the occurrence of disease in different organ systems, (2) the role of different management systems in disease incidents and (3) the effect of age and sex on the disease occurrence. Of 70 institutions contacted, 45 responded to the survey. The answers were analysed and baseline information concerning management and health in the various captive settings was collated. The analysis shows that some organ systems (skin, gastrointestinal tract and reproductive tract) are more affected by disease issues than others. The study also shows that veterinarians are still reluctant to sedate or anaesthetizse rhinos in order to make a diagnosis. This results in the long-term and repeated use of antibiotics and non-steroidal anti-inflammatory drugs based solely on visual examination of the animal. This approach can potentially mask disease progression and lead to a significant worsening of the initial problem and ultimately to death.

Introduction

The white rhinoceros is listed as near threatened on the IUCN (International Union for Conservation of Nature) Red List (Emslie 2011). While the overall population is increasing, poaching remains a major concern in the wild. A significant decrease in the wild population has been noted in Zimbabwe, and has been attributed to increasing demand for the horn (Miller 2003; Marshall 2011; WWF 2011).

White rhinoceroses are generally viewed as easy to maintain in captivity (Rookmaaker 1998). However, the species does not reproduce well in captivity and the captive population in the EEP (European Endangered Species Programme) is still not sustainable (Schwarzenberger et al. 1998; Hermes et al. 2006). In addition to reproductive difficulties, diseases present problems in captivity. Evaluating the underlying cause of a disease is often inherently difficult, and therefore numerous disease incidences remain unresolved. In 1992, Kock and Garnier performed the first thorough evaluation of reported diseases in captive white rhinoceroses. Their findings showed that trauma was the most common cause of death, followed by diseases of the digestive system. Infectious diseases were viewed as being very uncommon.

To get an overview of the health situation of the captive population, an online survey was initiated in September 2009. Various different types of surveys are routinely used in research today (Teel and Manfredo 2010). Some approach problems from a sociologic point of view, as is often the case in wildlife conservation issues. Others have routinely been employed to assess the health status of species, e.g. humans (Breen and Kessler 1994). A similar approach has also previously been used in captive-held species (e.g. the cheetah health survey of Munson 1993). Health surveys have proved a useful tool in captive population health management, as they provide a population-wide insight into the type and prevalence of diseases occurring within the respective population. While

they do not provide the depth and detail of an actual clinical health assessment, they incur less cost and pose no direct risk to the animals involved (Brenner et al. 2002).

The survey explored management and disease incidents in white rhinoceroses (*Ceratotherium s. simum*) within European zoos, keeping the code of good veterinary practice (GVP) in mind. The GVP specifies ethics and principles of conduct for veterinarians. Various codes of conduct co-exist; for example, the GVP of the Federation of Veterinarians of Europe, and the GVP of German veterinarians, serve as general guidelines for veterinarians in the respective legislative areas (BPT e.V. 2005; FVE 2002). These guidelines describe how veterinarians should treat animals and their owners (BPT e.V. 2005: "shall endeavor to ensure the welfare and health of the animal"), how to use medicinal products (BPT e.V.: "the medicinal products shall be used after examining the animal … in the adequate way and in the adequate amount proposed by the manufacturer") and other relevant topics in everyday veterinary life (FVE 2002: "measures taken shall comply with the approved and up-to-date veterinary science"). For zoos and aquariums there is an additional code which deals with animal health and husbandry, namely the World Association of Zoos and Aquariums' (WAZA) code of ethics and animal welfare (WAZA 2003). Amongst other things, it states that "appropriate animal husbandry practices must be in place and sound veterinary care available".

The specific aims of this study were to understand: (1) the occurrence of disease in different organ systems of white rhinoceroses, (2) the effect of age and sex on the disease occurrence and (3) the role of different management systems in disease incidents.

Methods

The online questionnaire was hosted by a commercial company specialising in constructing and implementing questionnaires (www.2ask.at). The structure and aim of the questionnaire were explained in an invitation email containing the link to the survey, which was sent out to 70 zoos in Europe and Israel housing white rhinoceroses. The survey was written in English and consisted of 38 questions in seven categories. The first part covered the general management, housing and medical monitoring of rhinoceroses. The second part covered individual disease incidents. For each individual disease incident, presenting symptoms, diagnostic measures, therapy, and/or necropsy were asked for.

We employed mixed effect logistic regression models to assess the influence of age and sex (and their interaction) on the probability of disease occurrence in each organ system. Sample size was 2970 (each year of age of each animal is one case), with 172 rhinos, ranging from one to 46 years of age, from 45 zoos and 93 disease incidences in total. Individual and zoo were modelled as random effects with the former nested in the latter. Statistical analysis was performed using the Program R 2.12.2 x64 (R Development Core Team 2011).

In order to evaluate and compare different models, Akaike's Information Criterion (AICc) corrected for small sample sizes was used (Burnham and Anderson 2002). In all cases there was not one single best model, so a method of model averaging and multi-model inference to obtain sound results was used (Burnham and Anderson 2002). These methods allow inference over all models considered, but this inference is weighted according to model support by the data. Additionally, these methods do not only estimate standard errors and p-values unconditionally to a single model, they also provide the probability of single variables being in the unknown "best" model (so-called "relative variable importance"). Unlike variable selection based on p-values of single models this technique has a sound mathematical basis and is increasingly recommended (Mazerolle 2006; Brix et al. 2009; Lukacs et al. 2010; White et al. 2010; Symonds and Moussalli 2011). For these calculations the R package MuMIn (Barton 2013) was employed. In order to estimate the effect of different management systems (zoos) an aggregated dataset was created, in which each individual is a case and the zoo, the number of disease incidents, the sex and the average of the age is reported. Then, a basic model with the number of disease incidents as the dependent variable, age, sex and their interaction as fixed and independent variables and zoo as a random factor was estimated. This was compared with a model without zoo based on AICc difference. The magnitude of the "zoo" effect is given by the standard deviation of the random effect in comparison to the intercept of the model. It was not possible to estimate the influence of the zoos as a fixed effect due to limited sample size (rhinos per zoo).

Results

Of 70 zoos, 45 (64%) completed the questionnaire. In total the disease histories of 172 (109 females, 63 males) rhinos were reviewed. In 159 cases the questionnaire was fully completed.

General management and housing

Inside and outside enclosures were present in 34 institutions, while nine had only outside enclosures (two did not answer this question). The flooring in the outside enclosures consisted predominantly of sand or grass. In the inside enclosure mostly plain concrete is used. The animals are kept in varying group-structures that range from herds to female groups and multi-species groups including zebra, antelopes, giraffe, ostrich, camel, bush-pig. The animals were usually fed once a day with a mixture of pellets, fruits and vegetables, and high quality hay ad libitum.

Medical monitoring and prophylactic measures

In 29 (64%) institutions there is some form of ongoing reproductive monitoring. The most common reasons for not monitoring included: no interest; animals too old to reproduce; and no medical training. The most common method of reproductive monitoring is collecting and analysing faecal samples from female animals. Of the 45 institutions, 31 (69%) reported taking various biological samples on a regular basis for monitoring and baseline health status evaluation (9 do not sample, 5 did not answer). The most common samples taken are faecal samples, followed by a combination of faeces and blood samples. Check-ups for parasites are performed in 32 institutions on a regular basis (10 do not sample, 3 no answer). Of the institutions that do perform a regular faecal screen for parasites, 15 did not report the species of parasites found or, in some cases, even whether parasites were found. In 17 institutions a variety of parasites (e.g. *Strongyloides* spp*., Gasterophilus* sp., *Nematodes* sp., *Ascarida* sp., *Oxyuris equii*) were identified. In 3 out of these 17 institutions animals were not treated with anthelmintics, although they were found to be positive in the faecal examination. Most of the positive animals reported are housed in mixed-species exhibits.

Regular anti-parasitic treatment is performed in 23 institutions (mostly once or twice a year), using varying agents of the avermectin and/or benzimidazole groups. Out of these 23, seven apply these agents, without prior faecal diagnosis. Only two institutions vaccinate their rhinos regularly (rabies and tetanus toxoid respectively).

Diagnosis and therapy

The use of diagnostic tools and measures was low. In 47 out of 93 individual disease incidents no diagnostic tools, except a visual examination, were employed. Nevertheless, in 24 out of these 47 cases, veterinarians applied antibiotics, non-steroidal anti-

inflammatories (NSAID), or steroids, alone or in combination. When diagnostic tests were performed, blood tests were most common, or alternatively a combination of blood tests and faecal analysis. Unfortunately it was not asked if the sampling was performed under sedation/anaesthesia or if the animals were trained for these purposes. Specific tests were performed for herpesvirus, poxvirus, apthovirus and rotavirus, as well as tuberculosis serology, and various kinds of skin scrapings. Causative agents were proposed in 25 cases. Infectious causes were assumed in five of these (*Herpesvirus*, *Pasteurella* spp., *Leptospira* spp., *Streptococcus* spp. and *Staphylococcus* spp.) and 20 non-infectious (e.g. trauma, neoplasms and intestinal rupture).

Not all therapeutic measures employed ultimately proved successful. Dermal cases in particular often became chronic and the probability of recurrence was high in some of the disease incidents such as lameness-events. Overall, 19 fatalities were reported. The most common causes of death were gastrointestinal problems (including poor dental condition) (36%), followed by various neoplasms (21%) and infectious diseases (15%). The remaining 28% consisted of singular disease incidents.

Occurrence of disease in different organ systems

On the 93 reported disease incidents, 51% were reported in male animals, 49% in females. The most affected organs were the skin (*n*=26), the gastrointestinal system (*n*=16) and the reproductive tract (*n*=11) (Fig. 1).

Dermatological cases

The dermal cases included several skin wounds subsequent to trauma from conspecifics (*n*=3), as well as diverse forms of neoplasm (*n*=5; e.g. squamous cell carcinoma, neurofibrosarcoma). In 15 cases the skin problem was not characterised further; it was simply stated that the animal had “skin problems” or “dry skin”. In half of the cases no diagnostics were performed. In some cases infectious pathogens (e.g. *Pasteurella*, *Streptococcus canis*) were cultured from skin scrapings or biopsies and it was postulated that these were causative agents. Similarly neoplasms were diagnosed from either skin scrapings or biopsies.

Gastrointestinal cases

Colics (*n*=8) and enteritis (*n*=6) were the most common gastrointestinal problems reported. Major intestinal problems, such as torsions, stomach and intestinal rupture, and including one diaphragmatic hernia, were reported on four occasions. In two cases poor dental condition leading to esophageal impaction and ultimately death was reported. Two additional cases affecting the gastrointestinal tract were described without further details.

Reproductive tract cases

The 11 reproductive tract disease incidents were not described in detail and therefore are difficult to attribute to specific causes. Several female rhinos suffered from unspecified vaginal discharge. In two cases neoplasms of the ovary and uterus were described. Abortions were reported for two animals, one apparently due to a herpes virus infection. One rhino suffered from dystocia due to a very large calf, and died post partum.

Effect of age and sex

Age was found to be positively related to the occurrence of diseases in the gastrointestinal-tract, respiratory tract, the eye, as well as in foot problems and lameness events. Furthermore age had a negative effect on the occurrence of fractures in male animals, and a positive effect in females (Table 1).

Sex and the interaction of sex and age did not have any effect on disease occurrence (see Appendix). The results for the different diseases should be interpreted separately. The unconditional beta-values of age in the averaged models were positive for all diseases. The high values of relative variable importance (RVI) show that increasing age is a high risk factor for many diseases reported in the survey.

Table 1. Reported disease incidents in which age has an effect with a relative variable importance (RVI) bigger than 0.5, or p-value <0.1.

	RVI	p-value
Gastrointestinal tract	0.99	0.007
Respiratory tract	1	<0.001
Eye	0.55	0.008
Foot problems	0.72	0.112
Lameness	0.98	0.038
Cardiovascular	0.59	0.915
Fracture	0.93	0.03

Role of different management systems

A model including the zoo as random factor had an AICc about 15 points smaller than a model without zoo (full model, AICc difference is 15.0; best model (with age only), AICc difference is 14.2), which constitutes a clear difference. The standard deviation of zoo as random effect is 0.026 for both models and the intercept -0.092 and -0.091 for the full and the best model, respectively. This is almost the same magnitude of the absolute values and means the variation between the zoos is not negligible.

Discussion

This survey provides an overview of the health and health management of captive white rhinoceroses in European zoos. The relatively low response rate (64%) could in part be due to language barriers in the multi-language European landscape.

While white rhinoceroses are viewed as being rather easy to maintain in captivity, a surprising number of health problems were reported in this survey. The reasons for these varied health problems are potentially many and include amongst others: an aging population in the EEP, poor housing conditions, poor prophylactic measures and poor health management. In comparison to the black rhinoceros (*Diceros bicornis*) surprisingly few case reports of disease incidents are available in the literature: a literature search generated only 48 for white rhinoceroses and 82 for black rhinoceroses. The case reports concerning the white rhinoceroses covered mostly parasitic infections (Knapp et al. 1997; Sommanustweechai et al. 2010) and reproductive issues (Hermes et al. 2004, 2006). This discrepancy in the perceived occurrence of disease in the white and black rhinoceros is clearly demonstrated by the results of the questionnaire, which show that dermal problems actually occur quite often in white rhinoceroses although this is rarely reported in the literature. It would be interesting to look into these dermal incidents in more detail, since 15 cases were only superficially described as “skin problems”. This lack of detail is reflected in the literature, where most of the dermal case descriptions were retrieved from the grey literature using bibliographies, proceedings, the Rhino Resource Center, or via personal communication (Miller 1983; van der Westhuizen 1994; Rookmaaker 2014).

The second most common organ system affected was the gastrointestinal tract. Several forms of enteritis, and even volvuli were reported. Compared to the literature, again there is a great

discrepancy. Most reports covered parasitic infestation and in one case a volvulus in a white rhinoceros was described (de Vos 1975). It appears that dental problems are often the cause of digestive tract issues, leading to, for example, oesophageal impactions. These dental problems reflect the aging population, and while the authors acknowledge a slightly higher risk of anaesthesia in older animals it should be highlighted that only routine health checks and timely interventions can detect emerging issues, and prevent severe disease progression. This fact is particularly evident in the recorded cases of oesophageal and GI tract impactation, protracted intervention invariably leads to severe metabolic shifts with a markedly increased anaesthetic risk. Furthermore non-intervention is a welfare issue as it leads to unnecessary extended pain and suffering in the individual.

Health problems concerning the reproductive tract in this species have previously been intensively investigated. The F1 captive population does not reproduce well (Schwarzenberger et al. 1998; Swaisgood et al. 2006). A lot of work and effort has been put into research to find an answer to these specific problems and several hypotheses exist (Hermes et al. 2004, 2006; Tubbs et al. 2012). Unfortunately the reproductive disorders reported in this survey were insufficiently described. However, as the subject is a well-published problem and several groups are actively working on this subject, no more details were requested.

The use of prophylactic measures reported in this survey is scarce. Only two institutions vaccinate their animals (one against tetanus, the other against rabies). Of the 45 institutions, 32 check for parasites and provide anti-parasitic treatment on a regular basis. Surprisingly seven institutions treat their animals without prior diagnostic effort. While this may appear time and cost efficient in the short term, it certainly does not conform to GVP and is problematic in light of the global anti-parasitic drug resistance crisis. As for antibiotics, the non-targeted use of anti-parasitic agents will cause resistance and influence the gastrointestinal microflora, and consequently should only be applied when clearly indicated. The efforts made to gather baseline information vary between institutions and the reasons stated for this were diverse. In 29 institutions (64%) there is ongoing reproductive monitoring. Participants were asked why they do not use any kind of monitoring. Several reasons were given. The participants were able to choose between: 1) no interest, 2) interest, but not feasible because: 3) very old animal, 4) other. Surprisingly, several institutions replied "no interest", which is remarkable as reproductive success and the general wellbeing of an animal would be expected to be in a zoo's interest.

Various rhino-specific husbandry guidelines exist and these are generally useful in respect to husbandry, but most do not address health issues. The guidelines for the husbandry of rhinoceroses from the Association of Zoos and Aquariums (AZA) Rhinoceros Taxon Advisory Group offer some help in managing the animal, although not much is said about the diseases of white rhinoceroses (Fouraker and Wagener 1996). The "Recommended routine health protocol for rhinoceros" aims to increase baseline information about this species (Miller and Miller 2007) and provides support for managing rhinoceroses in general and also, very importantly, when they are diseased. However, it is important to note that most, if not all, aspects of good veterinary health management (diagnostics, therapy and prognosis) are also included in GVP guidelines. Adherence to GVP is difficult to assess and this survey can only infer trends from the most obvious non-adherence cases reported. It must also be noted that the GVP guidelines are geared towards domestic animals and practice, and therefore when dealing with wildlife and captive zoo species are certainly harder to follow.

Recording the history is one of the most important tools in everyday veterinary work, since this information is the basis for all further diagnostic and therapeutic steps (Baumgartner 2009). Acquiring additional and more invasive diagnostic information, e.g. biological samples, body temperature and heart rate is certainly challenging in these animals and more often than not requires a thorough knowledge of sedation and anaesthesia. This study showed that in 47 out of 93 cases no diagnostic tools were used. There are several reasons why this might be the case: lack of knowledge and concerns with respect to the administration of sedation and anaesthesia, cost of the measures, enclosure design, training status of the animals, and possibly non-veterinarians making the final medical decision. Several cases were reported in this study where anaesthesia and diagnostic measures were evidently performed too late, leading to severe consequences and even death. Delaying diagnostic and therapeutic measures is contrary to the most fundamental requirements of GVP. This approach will often lead to a worsening of the initial problem, and engender additional ones. Again, we are aware of the inherent risks of anaesthesia, but well tested protocols are available (Fouraker and Wagener 1996; Kock and Garnier 1993; Kulow 1990; Milliken et al. 2009; Radcliffe and Morkel 2014) and in some cases medical training could be of great help.

The most striking, and most concerning, result of this study however, was the absence of diagnostic measures and the long-term and repeated use of antibiotics, NSAIDs and steroids in some individuals. While the short-term and one-off "diagnostic use" of these drugs is certainly warranted in some cases, the repeated use of these drugs in the absence of any alleviation of the recorded symptoms clearly appears contrary to GVP. Antibiotic resistance poses a major threat not only in veterinary medicine, but also in the public health domain. Action plans are in place to combat antimicrobial resistance (Centers for Disease Control and Prevention 2011; Österreichische Agentur für Gesundheit und Ernährungssicherheit (AGES) and Bundesministerium für Gesundheit (BMG) 2011). Undoubtedly, the unnecessary widespread use of antibiotics in human and in veterinary medicine over the years is one of the major causes of increasing bacterial resistance (Fridkin et al. 1999; Goossens et al. 2005). Our results show that in 24 out of 47 cases (51%), no diagnostic tests were performed but antibiotics were given on a mid to long-term basis nevertheless. The same results were seen in the use of corticosteroids, which were often applied without a clear indication – one animal in the study was reported to show "low energy" as a symptom, and was subsequently given a combination of antibiotics and corticosteroids for an extended period of time without any further diagnosis or follow-up. Bearing these results in mind, one must question why this is the case.

Zoo and wildlife medicine, as witnessed by the wealth of information available to the veterinarian and curator, has clearly progressed from its founding "Daktari image" years. However, this study shows that in some cases the animals in our care are not receiving adequate, evidence-based care as demanded by present-day standards. Unfortunately this study, due to its structure, could not explain the discrepancy between accepted GVP and some procedures in zoological medicine. It would be interesting to repeat this study in the North American SSP to determine if this is solely a European issue. Furthermore, in our opinion it appears necessary for EAZA, EAZWV and EBVS to further education in wildlife medicine, guide zoological institutions in the employment of veterinarians and possibly adopt and implement appropriate guidelines.

Conclusion

This study shows that problems concerning the skin, the gastrointestinal tract and the reproductive tract occur more often than problems with other organ systems in captive white rhinos.

Age plays a role in the occurrence of disease (older animals are at higher risk) while sex has no effect. The use of medicinal products and diagnostic measures is perceived as problematic in numerous cases and often not in keeping with GVP. An annual rhino EEP health status report that includes a detailed morbidity and mortality review would appear to be a good method to further the veterinary care of this species and enhance exchange between institutions.

Declaration of conflicting interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix. All disease incidents screened in the questionnaire. The table gives the p-value, the relative variable importance (RVI) and the estimate, for the models with age, gender (SexF), and the interaction of age and gender (Age:SexF).

	Estimate	p-value	RVI
Gastro intestinal tract			
Intercept	-7.552	<0.001	
Age	0.077	0.007	0.990
SexF	0.055	0.920	0.370
Age:SexF	0.003	0.870	0.110
Respiratory tract			
Intercept	-27.227	<0.001	
Age	0.437	<0.001	1.000
SexF	-1.812	0.706	0.380
Age:SexF	0.004	0.984	0.100
Cardiovascular system			
Intercept	-7.253	<0.001	
Age	-0.014	0.915	0.590
SexF	-7.021	0.437	0.500
Age:SexF	0.402	0.134	0.300
Foot			
Intercept	-7.122	<0.001	
Age	0.062	0.112	0.720
SexF	0.090	0.942	0.340
Age:SexF	0.044	0.545	0.080
Fracture			
Intercept	-12.793	<0.001	
Age	-0.841	0.030	0.930
SexF	-16.208	<0.001	0.860
Age:SexF	1.415	<0.001	0.810
Lameness			
Intercept	-20.534	0.002	
Age	0.027	0.038	0.980
SexF	-0.313	0.800	0.440
Age:SexF	-0.012	0.821	0.150
Eye			
Intercept	-10.420	<0.001	
Age	0.026	0.008	0.550
SexF	-0.118	0.934	0.450
Age:SexF	-0.015	0.737	0.040