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JZAR Research article

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Body condition scoring of white *Ceratotherium simum* and black rhinoceros *Diceros bicornis* in European zoos

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Keywords: BCS, feeding, husbandry, nutrition, Perissodactyla, reproduction

Article history:
Received: 01 Apr 2025
Accepted: 08 Jan 2026
Published online: 31 Jan 2026

Abstract

White *Ceratotherium simum* and black *Diceros bicornis* rhinoceroses differ in ecology and sociality, which is reflected in their ease of care in zoos. Zoo-housed black rhinos are susceptible to unusual diseases, like iron overload disorder and hypophosphatemia, that have hypothetically been linked to obesity. We applied published body condition scores (BCS; 1-5) to 84 adult white and 57 adult black rhinos living in 41 European zoos, established our own BCS protocol with overview scores and scores for individual body regions, based on our ability to distinguish scores on photographs, and related these to husbandry conditions. Exact body mass was available for 17 and 20 white and black rhinos, and was estimated for the rest. Scoring was conducted by one single observer, twice in a blinded manner. White rhinos were kept in larger enclosures and received a lower proportion of non-forage feeds than black rhinos. Contrary to previously published BCS protocols, the protocol presented here achieved a distinctively higher number of identical scores at repeated scoring from photographs for all evaluated body regions. BCS were generally positively correlated to body mass, but were not related to the percentage of non-forage feed in the individual diets. White rhinos had higher scores than black rhinos (e.g., BCS overview side 3.83 ±0.76 vs. 3.39 ±0.85), suggesting that obesity, if at all, is more common in white rhinos. Additionally, BCS were relatively independent of age in white rhinos but declined in black rhinos with age, supporting concepts of chronic, accumulating health problems in black rhinos. In black rhinos, BCS were lower in animals with impaired dental status compared to animals without such alterations. In both species, males tended towards lower BCS compared to females. BCS had no effect on female black rhinos breeding status, but tentative evidence suggested that non-breeding white rhinos show higher BCS. Our findings do not support concepts that associate black rhino health problems with obesity, but emphasize the relevance of strategies for maintaining long-term health. In white rhinos, the provision of ad libitum forage is considered beneficial from a behavioural point of view, but forages of sufficiently low nutritional (but appropriate) quality should be chosen to prevent overconditioning.

Introduction

Standard veterinary practice in companion animals comprises general health checks including weighing and/or evaluation of body condition score (BCS) on a regular basis (Baldwin et al. 2010; Battini et al. 2014). In zoo and wildlife medicine, regular evaluation of the physical condition of animals under human care is recommended, too (Barrows et al. 2017). Especially in non-domestic animals, preventive medicine - above all non-invasive methods - is of particular importance (Carpenter et al. 2016) to detect deviations from a healthy state at an early stage (Barrows et al. 2017). For many health problems in rhinoceroses ('rhinos'), weight loss and deterioration of body condition are among the earliest noticeable symptoms (Pilgrim and Biddle 2020). However, a common challenge in many zoological facilities with large mammals is the lack of an appropriate weighing device (Wyss et al. 2012; Schiffmann 2020). Weighing presupposes that individual animals can regularly be moved onto scales. Additionally, body mass alone does not differentiate between muscle tissue and fat deposits (Schiffmann 2020). Furthermore, there may be inter-individual variations depending on sex, age, size, reproductive status, and other factors, which have not yet been defined in every species (Heidegger et al. 2016).

BCS has proven to be a valuable tool in the care of farm animal species such as horses (Henneke et al. 1983; Dugdale et al. 2012), cattle (Ferguson et al. 1994; ; Azzaro et al. 2011; Isensee et al. 2014), donkeys (Valle et al. 2017), goats (Battini et al. 2014; Vieira et al. 2015) and sheep (Russel 1984). Additionally, protocols exist for various non-domestic mammal species whose body contours are not concealed by thick, long fur, such as elephants (Wemmer et al. 2006; Fernando et al. 2009; Morfeld et al. 2014; Wijeyamohan et al. 2014; Morfeld et al. 2016; Schiffmann et al. 2017; Schiffmann et al. 2019), cheetahs (Dierenfeld et al. 2007; Reppert et al. 2011), tapirs (Clauss et al. 2009; Perez-Flores et al. 2016), ruminant species (Ezenwa et al. 2009; Wright et al. 2009; Taylor et al. 2013; Zielke et al. 2018; Clavadetscher et al. 2021), ant-eating mammals (Clark et al. 2016), and various primates (Berman and Schwartz 1988; Clingerman and Summers 2005; Millette et al. 2015; Reamer et al. 2020; Ghassani et al. 2023). Whenever there is the possibility to compare BCS of zoo animals systematically to BCS of free-ranging specimens, one generally expects that the zoo specimens obtain scores in the higher (better and over-conditioned) range of the scale, due to a lack of resource scarceness that may occur in natural habitats. Several of the references cited above indicate such a difference (Morfeld et al. 2014; Perez-Flores et al. 2016; Clavadetscher et al. 2021).

BCS systems have been described for the three rhino species mainly kept in zoos: One for white rhinos (Keep 1971), one for black rhinos (Reuter and Adcock 1998) and one for greater one-horned rhinos (GOH) (Heidegger et al. 2016). Additionally, two recent image collections provide basis for body condition scoring in white rhinos, with images for scores from one to five (Tubbesing n.d.; Versteege and van den Houten 2011), but they lack - similar to the scoring system by Keep (1971) - detailed description of the differences in all body regions between the scores, which can make a consistent application challenging. Whether one of these scores can be applied to both African species has not been tested, to our knowledge. Both scoring systems for African rhinos were originally based on free-ranging animals, and an over-conditioned status or obesity is not mentioned in these protocols. However, obesity is a common concern nowadays in zoo animals (Bray and Edwards 2001). This was described in zoo rhinos previously (Clauss and Hatt 2006; Wyss et al. 2012), and is also part of the BCS protocol for the GOH rhino (Heidegger et al. 2016) that was based on zoo specimens. In particular, a recent theory that combines different disease symptoms observed in zoo black rhinos, including iron overload disorder (IOD) and hypophosphatemia, focuses on obesity-derived insulin resistance (Schook et al. 2015). Additionally, Edwards et al. (2015) suggested that overcondition in female black rhinos may be a contributing factor to reduced reproductive success. By contrast, Clauss and Hatt (2006) hypothesized, based on their personal experiences, that black rhinos may be less prone to obesity than the other two zoo rhino species, possibly due to their more nervous nature and, as browsers, a potentially lower probability to overeat on non-browse forages in a zoo-housed setting.

The aim of this study was to apply several BCS systems to white rhinos and black rhinos kept in European zoos. This was done to evaluate the practicality of different scoring systems, to compare the two African rhino species to assess whether there was a systematic difference in the tendency towards obesity, and to assess whether there were correlations between the BCS and other recorded husbandry factors.

Material & Methods

Zoo visits

From March 2022 to March 2023, 41 zoological institutions holding African rhinos in Europe were visited by the first author. 115 (43.72) white rhinos and 82 (36.46) black rhinos were included in the study. This represented 38% and 95% of the white and black rhino population kept in Europe at this time. This corresponds to the aim to survey the black rhino population completely, with a similar number of white rhinos assessed for comparison. The selection of the holdings was not based on any defined condition, but institutions closer to the point of origin of the primary author (Germany) were preferred to keep travelling expenses low.

Each animal was observed on site for a couple of hours, if possible, from a close view at the inside enclosure as well as from distance and in motion in the outside enclosure. An overview BCS based on the general impression of the observer as well as scores for different body parts were made for each individual on site ('on-site score'; scores from 1 – very thin to 5 – obese, with increments of 0.5). The latter scoring was mainly based on the scoring system by Heidegger et al. (2016) for GOH but also considered species-specific peculiarities described elsewhere (Keep 1971, Reuter and Adcock 1998) (Table S1). The overview score did not follow a defined description, but was a subjective overall impression of the observer.

Additionally, each rhino was photographed from a lateral and a rear view. If possible, the pictures were made against a well-contrasting background and with adequate lighting conditions. All pictures were taken while the respective animals were standing still or walking slowly. In some cases, additional photographs of rhinoceros provided by keepers were included in our evaluation.

Photograph-based work

Photographs were cropped, mirrored or brightened if necessary. Based on the side and rear photographs, a second scoring of the individual body parts was made, in the same way as the on-site score (allowing 0.5-steps). This was done in a blinded manner by the same evaluator ('photo-based score old'). There were two black rhinos (1.1) of which no suitable photographs could be obtained, so they were excluded from the evaluation.

During the process of the initial scorings, we noticed that animals included in the study did not show the full range of the score, especially the lower scores for some body parts were not seen. Furthermore, we obtained the impression that some body parts were easier to score than others, and that for some parts, distinguishing between two stages was more a matter of subjective impression than a clear presence or absence of structures. We decided to test new scoring systems to assess how many stages we could actually distinguish (rather than trying to sort an impression into a pre-defined range of 1-5), and which body parts are most suitable for assessing body condition.

To cover the full range of possible conditions, representative for zoo-housed as well as free-ranging white and black rhinos, we also included older pictures from deceased individuals provided by the institutions and carried out an internet search to supplement our photo data set. Especially for the lowest scores, we added images from the internet or from organisations in Africa (white rhino: neck score 1, shoulder score 1+2, spine score 1+2, rump score 1 (both photos), overview side score 1, overview rear score 1 from Mariska Bijsterbosch, Wildlife Vets Namibia; black rhino: spine score 1, rump score 1 (lateral photo), overview side score 1 from www.agefotostock.com).

For the development of a new scoring system, we evaluated the standard body parts used so far (Keep 1971; Reuter and Adcock 1998; Heidegger et al. 2016): neck, shoulder, ribs, spine, rump, abdomen and tail base. As the previously existing scores for the neck and the ribs in rhinos included appearance as well as presence of skin folds, we applied a score based on the overall appearance and an additional score for the folds to those two areas. To do so, we focused on the prominence of certain bony points or the appearance and shape of the soft tissue, without adhering to a predefined number of scores. Instead, we looked at how many distinctions per body region could be clearly identified, as it has already been done with giraffes (Clavadetscher et al. 2021), and based on previous findings that fewer body points and scores may be easier to apply and replicate (Morfeld et al. 2016; Schiffmann et al. 2017). We developed a verbal description in combination with example photographs for each body region individually for each species. We focussed on describing the clear visibility of bone points and the shape of soft tissue, and on avoiding subdivisions such as more/less or pronounced/lightly pronounced. The aim was to create a score for the individual body parts that is as little subjective as possible and can clearly categorise every animal in a score.

Additionally, we established a total score with the usual five stages in a lateral and a rear view based on the overall appearance (overview side, overview rear). The difference to the overview scoring using the old scheme was that according to the old scheme, it did not matter from which angle you observed the animals, whereas with the new overall score, the view angle was clearly defined (side or rear). For the overview scores, we used example pictures for each score and combined this with descriptions derived from the evaluation of individual body parts.

All animals were scored twice in a blinded manner according to this new developed scoring system (‘photo-based score new’) by the same assessor, and an average of the two scoring sessions was calculated. Hence, even if for the scoring only full integers were used, the final mean scores can show 0.5 steps due to averaging. For the body parts that were assigned a different number of stages in white rhinos and black rhinos, we introduced an intermediate level for the species with the higher number at an appropriate point of the score to allow comparability between species. We did not assess how different persons applied the scores.

Additional data

Information about feeding management, husbandry, and medical records were collected during the zoo visits. Together with general information about individuals from the studbook, these data were put in relation to the BCS. According to the age classification used by Radecke-Auer et al. (2023), rhinos over five years were classified as adults, and younger animals were excluded from the correlations with other factors. If no current information about the body mass was available, an estimated weight was used (in 67 white and 37 black adult rhinos). All animals which previously produced offsprings were classified as ‘breeding’, irrespective of when the last calf was born. For the enclosure size, the biggest possible enclosure of an individual was used in the evaluation, if an animal was kept variably in different outside enclosures. The amount of non-forage feed items was calculated from our diet analyses described elsewhere (Sauspeter et al. 2025).

For the medical history, written reports were looked at if available and completed with statements of keepers, curators or veterinarians. It was assessed whether or not a problem or disease was ever mentioned in the records or during the interviews. While it would have been desirable to identify the time lapsed since the last occurrence of a medical problem, this was not considered feasible on the basis of the interviews. Therefore, any associations only tested whether BCS correlated with whether an animal had ever had a certain problem. Medical issues were categorised as follows: Teeth problems included missing teeth, chewing wicks and teeth problems without further description. Diarrhoea included any mentioning of loose faeces or diarrhoea. Skin problems comprised dry skin with cracks, any kind of dermatitis or inflammation of the skin, (presumed) allergic reactions, decubitus, insect bites and skin problems without further descriptions. Lameness or nail cracks included only the clear mentioning of one of those or both. Because the severity of the respective problem could not be consistently judged from the records or interviews in a systematic manner, these were not further classified (e.g., into ‘mild’ or ‘severe’).

We specifically asked about weighing possibilities and whether the institutions monitored BCS themselves.

Comparison of body condition scores and statistical evaluation

For the scoring from the photographs, we compared the first and the second round of scoring by quantifying the number of matching and deviating scores. To test for differences between species, animal characteristics (age, body mass), husbandry indicators (enclosure size, percentage of non-forage food) and the different BCS, the nonparametric Wilcoxon test was used. In order to explore correlations between different BCS, and between BCS and age, body mass, enclosure size and the percentage of non-forage food, the nonparametric Spearman’s correlation coefficient was used. Within species, various BCS were compared by Wilcoxon test between animals of different health categories, i.e. animals for which a certain health problem was reported as absent or present. Analyses were performed in R (R Core Team 2024), with the significance level set at 0.05.

Results

At the point of our visit, regular weight checks were performed in 18 (21.4%) adult white rhinos, and for one (1.2%) individual, a BCS evaluation was present in the records. 31 (54.4%) adult black rhinos were weighed on a regular basis, and for three (5.3%) individuals, a BCS evaluation was available.

In the following, we first describe our evaluation of the individual body regions, where the old 5-stage-score was applied, and where we also assessed how many different stages we could differentiate reliably when developing the new score. Here, we also add results on the use of skin folds in the neck and thorax area. Next, we present results of the overview scores. Finally, correlations between selected scores and husbandry factors are reported as well as differences between animals of different health status.

Body parts

Neck

In both species, the neck is concave and hollowed out in front of the shoulder in thin animals (Fig. S1, S2). The nuchal ligament can be visible in thin white rhinos depending on the head position. With decline of body condition, it first becomes apparent in a head-down position, but is visible in thinner white rhinos in every head position. In black rhinos, the nuchal ligament, which should be apparent in emaciated animals according to Reuter and Adcock (1998), was only slightly visible even in thin animals. The prescapular depression, however, was clearly visible. In animals of both species with higher body condition, the nuchal ligament becomes invisible and the neck more rounded and bulging. To assess these criteria adequately, the animal should be viewed with the neck and head held straight forward, both in a heads-up and heads-down position.

Depending on the shape of the neck and the visibility of the nuchal ligament, we were able to distinguish three stages for each species. Using the old score, several stages were never assigned (Table S2; Fig. 1). The repeatability of the new (reduced) neck score was distinctively higher than of the old score (Table S3). Within species, the different neck scores showed moderate but significant correlations with each other but were not correlated to several of the other scores (Tables S4, S5). The different neck scores produced a conflicting result in the species comparison: using the old score on-site, white rhinos had significantly higher neck score than black rhinos; the opposite was true when applying the new score to photographs (Table S2).

Neck folds

In white rhinos, one can only differentiate whether a neck fold is visible in head-up position or not, leading to two stages (Fig S3). In adult animals, some kinds of folds are always visible in the head-down position. By contrast, there may be no folds in the head-down position in black rhinos (Fig. S4). A fold becomes present with increasing condition, first in head-down position, then in head-up position, and sometimes a second fold is present, which leads to three stages in black rhinos.

The repeatability of the neck fold score was high (Table S3). The neck fold score was generally not correlated to most other scores (Tables S4, S5). Black rhinos had a significantly higher neck fold score than white rhinos (Table S2, Fig. S22).

Shoulder

The gradation for the shoulder is similar in both species (Figs. S5, S6). The cranial and dorsal margins of the shoulder blade as well as the Spina scapulae are bony structures recognisable in thinner rhinos. In animals with increased condition, no bony points are visible. The shoulder must be scored with caution, as even minor changes in posture can alter the visibility of the bony structures.

We were able to distinguish four stages in both species. Using the old score, several stages were never assigned (Fig. 1). The repeatability of the new (reduced) shoulder score was distinctively higher than that of the old score (Table S3). Within species, the different shoulder scores showed significant correlations with each other and with many other scores (Tables S4, S5). White rhinos had significantly higher on-site and new photograph shoulder scores than black rhinos (Table S2).

Ribs

A classification of whether the ribs are clearly or vaguely recognisable is very subjective and cannot be based on definite characteristics. As mentioned before (Keep 1971; Heidegger et al. 2016), the skin folds can create a “ribby” appearance when assessed from a distance or in inappropriate light conditions (Fig. S11).

In both species, one can differentiate whether the ribs are visible or not, independent of the presence or absence of thoracal folds, leading to two stages (Figs. S7, S8). According to the old score, especially the lower stages were never assigned (Table S2). The rib score had a higher repeatability with the new (reduced) score compared to the old score (Table S3), but no correlation with the other scores (Tables S4, S5). White rhinos had significantly higher on-site and moderately higher old photograph rib scores compared to black rhinos, whereas the new photograph rib scores were similar for both species (Table S2).

Thorax skin folds

In white rhinos, folds can be visible at two locations on the torso: on the cranial thorax the breast folds, and on the caudal thorax the flank folds (Figs. S9, S11). Four stages could be distinguished in white rhinos. In black rhinos, the breast fold can be absent, and there is no distinct flank fold, so we could only differentiate three stages in black rhinos (Fig. S10). In both species, some additional folds can be visible on top of the ribs.

The repeatability for the thorax fold score was high (Table S3), but there were no correlations with other scores (Tables S4, S5). White rhinos had significantly higher new photograph scores for thorax folds (Table S2, Fig. S22).

Abdomen

No differentiation was made whether the abdomen seemed more or less filled, as this was considered to be connected with hydration and feeding status (Reuter and Adcock 1998). The abdomen can be smooth, or it can form a line when it bulges over the costal arch, which is more prominent in white rhinos but also visible in black rhinos (Figs. S12, S13, S14).

So, in both species two stages could be defined. Several stages were never assigned with the old score (Table S2, Fig. 1). The repeatability was significantly higher with the new (reduced) score compared to the old abdomen score (Table S3). The scores for the abdomen showed significant correlations with most other scores (Tables S4, S5) and white rhinos were assigned significantly higher scores for the abdomen with all three scores (on-site, old photograph, new photograph) compared to black rhinos (Table S2).

Spine

In both species, the spine shows a clear variation depending on the body condition (Figs. 3, 4). There are usually three visible parts, the withers, the lumbar spine and the sacrum (Fig. S15). In thin animals, the column is distinct over its entire length with deep hollow depressions on either side. As the condition increases, the hollowing remains only recognisable in the lumbar area, and all bony structures appear more rounded and less angular.

In white rhinos with a higher body condition, tissue can protrude on both sides next to the column and create a groove above it (Fig. S15). In black rhinos, this formation of a distinct groove was not observed. In both species, we could differentiate between five stages for the spine. According to the old score, some stages were never assigned (Table S2, Fig. 1). The new photograph score showed a higher repeatability for the spine compared to the old photograph score (Table S3). The spine score showed correlations with most of the other scores (Tables S4, S5). The on-site spine score and the new photograph spine score were significantly higher in white rhinos than in black rhinos (Table S2).

Rump

Similar to the spine, the rump can show different stages of hollowing out or rounding off (Figs. S16, S17). It should be noted that in higher-conditioned white rhinos, the rounding is more distinct than in black rhinos, so that the rump size seems larger in horizontal than vertical direction in a rear view. In both species, the Crista iliaca, the Tuber coxae, and the sacrum are bony landmarks recognizable in thinner individuals. We were able to define five stages here, too. Some stages were not present with the old score (Table S2, Fig. 1). The repeatability for the rump scores was higher with the new photograph score than with the old one (Table S3) and had correlations with most other scores (Tables S4, S5). White rhinos were assigned significantly higher on-site and old photograph rump scores than black rhinos (Table S2).

Tail base

The tail base can vary from slim and bony, with the individual vertebrae visible, to broad with wrinkles at its base (Figs. S18, S19). For the white rhino, we were able to distinguish four different stages, while in black rhinos there was an additional fifth stage, which was expressed in an extra 0.5- interval between stage 1 and 2 according to the stages for white rhino. Several stages were not present with the old score (Table S2, Fig. 1).

The repeatability was significantly higher with the new (reduced) photograph score than with the old one (Table S3). Here again, the tail base scores correlated with most of the other scores Tables S4, S5) and white rhinos had significantly higher tail base scores with all three scores (on-site, photograph old, photograph new) compared to black rhinos (Table S2).

Overview scores

The overview scores represent a subjective general impression of the animal. In order to reduce subjectivity to some extent, we defined exemplary images for each stage, with which the corresponding photos could be compared for scoring, and added verbal descriptions collated from the individual scores. For the new scoring scheme, we describe a score for the overview from a side view and from a rear view (Figs. 5, 6, S20, S21).

We defined five stages for both species. Again, using the old

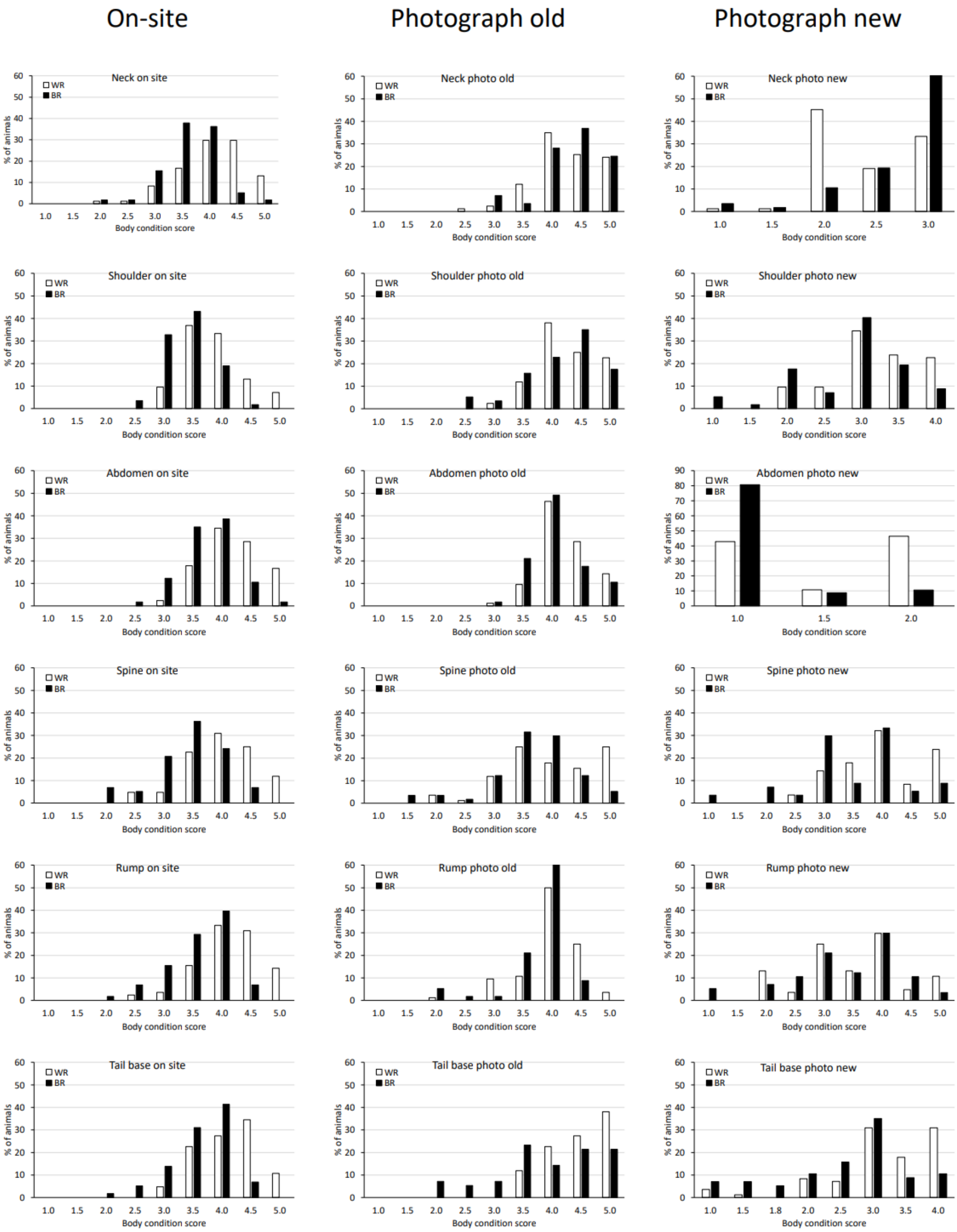


Figure 1. Distribution of different body conditions scores for evaluated body parts in 84 adult white rhinos *C. simum* and 57 adult black rhinos *D. bicornis* kept in European zoos based on on-site evaluation, photographs according to the old scoring scheme, and the new scoring scheme developed in this study.

Table 1. Comparison between the BCS of spine and overview side 84 adult for white rhinos *C. simum* and 57 adult black rhinos *D. bicornis* in visited zoos according to the new scoring scheme.

Variable	Species	Score/number of animals	Mean+SD	Mean+SD	P value
Sex	WR		Male	Female	
		n	27	57	
		Spine new	3.9±0.5	4.0±0.8	0.558
		Overview side new	3.7±0.7	3.9±0.8	0.344
	BR	n	21	36	
		Spine new	3.1±0.9	3.7±0.9	0.018
		Overview side new	3.0±1.0	3.6±0.7	0.007
Breeding status male			Breeding	Non-breeding	
	WR	n	15	12	
		Spine new	3.9±0.6	4.0±0.5	0.503
		Overview side new	3.7±0.8	3.8±0.5	0.738
	BR	n	16	5	
		Spine new	3.3±0.8	2.8±1.1	0.540
		Overview side new	3.0±0.9	3.0±1.2	0.726
Breeding status female			Breeding	Non-breeding	
	WR	n	36	21	
		Spine new	3.8±0.8	4.4±0.7	0.008
		Overview side new	3.7±0.9	4.1±0.6	0.063
	BR[1]	n	15	10	
		Spine new	3.7±0.7	3.5±1.2	0.653
		Overview side new	3.7±0.7	3.6±0.7	0.540
Diarrhoea			No diarrhoea	Diarrhoea	
	WR	n	65	19	
		Spine new	4.0±0.8	3.9±0.6	0.435
		Overview side new	3.9±0.8	3.6±0.6	0.041
	BR	n	47	10	
		Spine new	3.6±0.9	3.0±0.7	0.033
		Overview side new	3.4±0.8	3.2±1.0	0.563
Tooth problems			Healthy teeth	Tooth problems	
	WR[2]	n	43	6	
		Spine new	3.8±0.8	4.1±0.8	0.444
		Overview side new	3.7±0.8	3.7±0.8	0.963
	BR[3]	n	15	5	
		Spine new	3.3±1.1	2.3±0.8	0.091
		Overview side new	3.1±0.9	2.3±1.1	0.126

If the categories led to significant differences in age ranges, comparison was restricted to only animals of a similar age range: [1]12-28 years; [2]>16 years; [3]>23 years

score, several stages were never assigned (Table S2, Fig. 2). The repeatability of the new overall scores was similar to those for the spine or the rump (Table S3). Within species, the overview scores showed significant correlations with each other and with many other scores (Tables S4, S5). White rhinos had significantly higher on-site and photo-based overview scores than black rhinos; only in the new overview rear score was the difference not significant (Table S2).

Correlations with husbandry and animal factors

As reported elsewhere (Sauspeter et al. 2025), the proportion of non-forage feeds was lower in white rhinos (7.0±8.3 %, range 0-54.6 %) than in black rhinos (15.6±11.9 %, range 1.2-66.0 %). In neither species was there a significant correlation between the BCS and the amount of non-forage feed in the diet (Table S4, S5). Whereas there was no significant relationship between the BCS and the enclosure size in white rhinos (Table S4), there was a significant, positive correlation between enclosure size and

http://doi/org/10.19227/jzar.v14i1.941

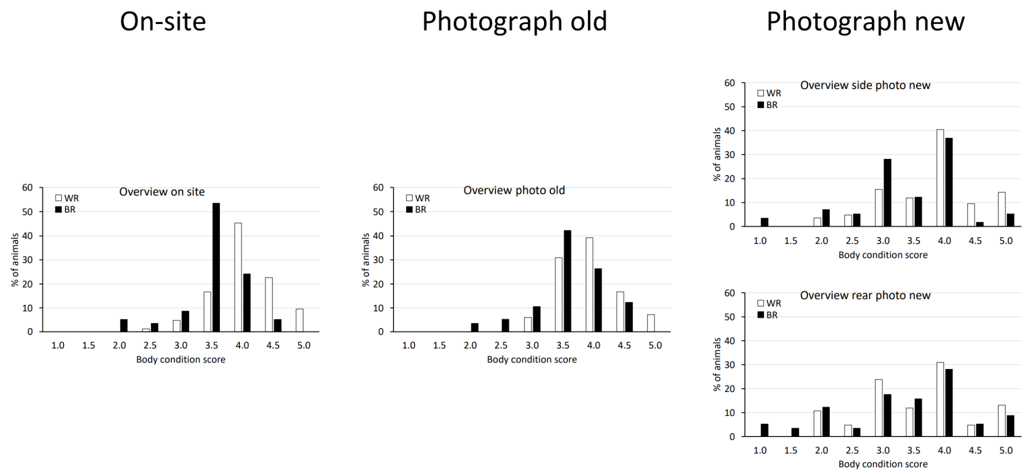


Figure 2. Distribution of different overview body conditions scores in 84 adult white rhinos *C. simum* and 57 adult black rhinos *D. bicornis* kept in European zoos based on on-site evaluation, photographs according to the old scoring scheme, and the new scoring scheme developed in this study

several BCS in black rhinos (Table S5, Fig. S23). In black rhinos, there was a negative relationship between the enclosure size and the proportion of non-forage feeds in the diet (Table S5); by contrast, this relationship was positive in white rhinos (Table S4).

For both species there were significant, positive correlations with body mass for many BCS (Table S4, S5, Fig. S23). Furthermore, there were significant, negative correlations with age; this occurred more frequently in the black than in the white rhino BCS (Table S4, S5; Fig. S24).

At no significant difference in age (males: 17.4±7.6 y, females: 20.9±9.6 y, P=0.147), male white rhinos had a significantly higher body mass (2162±196 kg) than females (1918±172 kg, P<0.001), but there was generally no significant difference in BCS between the sexes (Table 1). Similarly, there was no significant age difference between the sexes in black rhinos (males: 17.4±9.3 y, females: 19.6±8.3 y, P=0.320), and males were significantly heavier (1266±61 kg) than females (1190±95 kg, P=0.033); in black rhinos, however, males generally had significantly lower BCS than females (Table 1). There was no difference in BCS between males that had and had not bred in either species, nor in female black rhinos (Table 1). By contrast, female white rhinos that had not bred had higher BCS (Table 1).

Animals for which past periods of diarrhoea had been reported had some significantly lower BCS than animals for which this had not been reported (Table 1). With respect to reported dental disorders, affected animals were significantly older both in white rhinos (18.4±7.3 vs. 37.5±12.7 years; P=0.001) and in black rhinos (17.9±8.4 vs. 27.8±5.2 years; P=0.018). When comparing only similar age ranges, there was no effect on BCS in white rhinos, whereas black rhinos known for dental problems had lower BCS than animals without such issues, with the difference approaching significance for some BCS (Table 1).

Discussion

In the present study, we applied a variety of BCS systems to zoo-managed white and black rhinos. Apart from providing some insight into how different body parts of rhinos may or may not reasonably contribute to an overall BCS, our study indicates that if a comparable score is applied to white and black rhinos in European zoos, it is the white and not the black rhino population that seems to be more prone to obesity, despite an adequate feeding regime and no excessive amount of non-forage feed items in the white rhino population (Sauspeter et al. 2025), corresponding to a similar result based on a global comparison of the body mass of free-ranging and zoo-managed specimens of white and black rhinos (Garand et al. 2025). The absence of an evident correlation of BCS with the proportion of non-forage feed, which was, on average, actually low for both species, does not suggest that overfeeding with non-forage components is a general, critical factor in the husbandry of either species. Before discussing some of the findings in more detail, major limitations of the present study need to be addressed.

In the absence of systematic additional morphological or physiological measures, such as a measure of body height or length (to calculate a body condition index, e.g. Stirling et al. 2008; Heidegger et al. 2016; Clavadetscher et al. 2021), ultrasonographic documentation of subcutaneous fat layer thickness (Treiber et al. 2012; Morfeld et al. 2014) or other methods to estimate body composition (Chusyd et al. 2019), BCS systems inadvertently remain subjective. While corresponding studies would be beneficial, practical considerations make applications without such physiological grounding nevertheless valuable. In the present study, positive correlations between BCS of different body regions support the notion that a somewhat consistent approach can be derived in this subjective manner. These explorative correlations among different BCS help identify some body regions that might best be ignored for an overall scoring – in the present study, this applied especially to the ribs and thorax folds in white rhinos, and the neck, the neck folds, and the abdomen in black rhinos. As a consequence, these regions are not included in the verbal descriptions of our proposed overview scores (Figs. 5, 6, S20, S21). Additionally, the positive correlation between the available (actual and estimated) body mass data (Fig. S23) supports the concept that the BCS, especially those for the shoulder, spine, rump, tail base and overall approaches may be a viable method to monitor body condition.

Another aspect of BCS is the repeatability of scores between different observers. For the present study, the approach of having

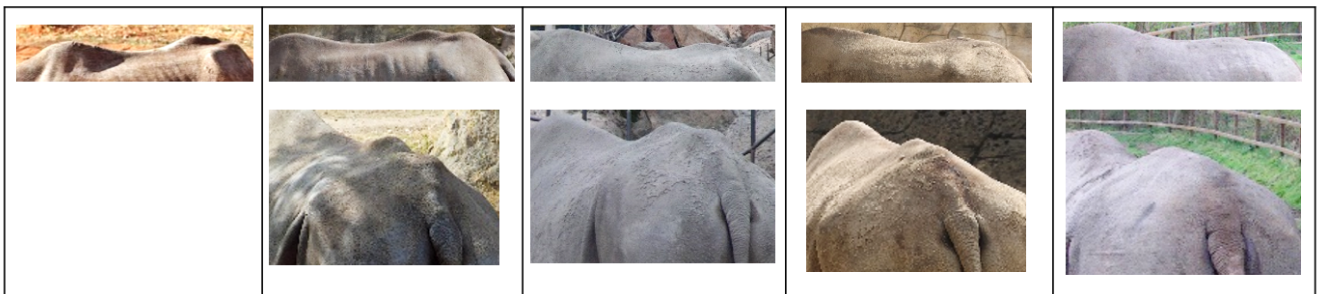
Score 1	Score 2	Score 3	Score 4	Score 5
significant depression alongside spine clearly visible over entire length; spinous processes clearly protruding over the entire spine length	depression alongside spine over entire length; depression less distinct in the thoracic spine area; spinous processes protruding in entire spine length	slight depression alongside spine only in the region of caudal thoracic and lumbar spine area; spinous processes visible, but only clearly protruding in caudal thoracic and lumbar area	no depression alongside spine; spinous processes visible but not protruding; in rear view angular shape or slightly convex	no depression alongside spine; spinous processes at some points slightly visible; in rear view convex shape; bulging possible on both sides above the medial thoracic spine

Figure 3. BCS for the spine in white rhino *C. simum.*

a single person scoring all animals in a blinded manner seemed most appropriate for consistency. In the future, workshops on body condition scoring with exercises performed by a larger number of participants (e.g., Schiffmann et al. 2017) could increase the reliability of BCS for many zoo animal species, including rhinos.

A typical problem met by persons that intend to apply a given BCS is that a gradation, especially when described in words (but even in the case of photos) cannot be easily translated into the visual impression actually gained by these persons. In this respect, reducing the number of scores for individual body parts naturally makes a system less prone to variation in scoring (Table S3), and hence adjusting the number of score steps to what can be easily differentiated is a logical approach to scoring individual body parts. However, this makes the use of several body regions challenging if their number of easily distinguishable scores differs. In giraffes, for example, this has led to the suggestion that only the hip area of the animals should be used for regular assessment of BCS (Clavadetscher et al. 2021). Rather than construing a matrix where the different scores of different body regions are weighted with respect to their score ranges, we therefore chose a verbal description for overview scores that reflects the lower differentiating potential of different body regions.

Similar to a finding in giraffes where skin folds did not seem good indicators of body condition, the detailed evaluation of the skin folds in the present study lead to the recommendation to disregard these structures when assessing body condition. Nevertheless, for experienced observers, visibilities of the ribs can serve as a clear additional indicator of poor body conditions



Score 1	Score 2	Score 3	Score 4	Score 5
significant depression alongside spine over entire length; spinous processes clearly protruding over the entire spine length	depression alongside spine over entire length; depression less distinct in the thoracic spine area; spinous processes clearly protruding in entire spine length	slight depression alongside spine only in the region of caudal thoracic and lumbar spine; spinous processes visible, but only clearly protruding in caudal area	no depression alongside spine; spinous processes visible but not protruding; in rear view angular shape	no depression alongside spine; spinous processes at some points slightly visible; in rear view convex shape

Figure 4. BCS for the spine in black rhino *D. bicornis.*

Score 1	Score 2	Score 3
		
overall appearance skinny; prominent bony structures of scapula, hip region and spine in its entire length; deep depression cranial to the scapula, alongside the spine as well as to the iliac crest	overall appearance thin. bony structures of scapula, hip region and entire spine clearly visible; depression cranial to the scapula, alongside the spine and cranial as well as caudal to the iliac crest	overall appearance ideal; bony structures of scapula, entire spine and hip region visible; slight depression cranial to the scapula, alongside the caudal spine and cranial to the iliac crest; region caudal to the iliac crest flattened

Score 4	Score 5
	
overall appearance rounded; bony structures only recognisable in the sacral part of the spine and the hip region; no depression cranial to the scapula, alongside the spine and cranial nor caudal to the iliac crest	overall appearance obese; no bony visible, except the spinous processes of the sacral spine; tissue bulging cranial to the scapula. Alongside the spine and cranial as well as caudal to the iliac crest

Figure 5. Overview BCS for the general appearance in white rhino *C. simum* from a lateral view.

Score 1	Score 2	Score 3
		
overall appearance very thin; clear bony outline of shoulder blade with spine of scapula, entire spine and hip; distinct hollowing out in front of the shoulder, alongside the spine and in hip area	overall appearance thin; bony outline of shoulder blade, spine and hip region; hollowing out alongside the spine, in front of the shoulder and in hip area	overall appearance in good condition; some bony points visible at the shoulder blade, spine and in hip area. hollowing out alongside the caudal part of the spine; hip area slightly hollowed out to flattened

Score 4	Score 5
	
overall appearance heavily built; few bony structures recognizable at the caudal part of the spine and hip area. shoulder rounded; hip area flattened	overall appearance overweight; no bony points except the sacrum; shoulder, spine and hip area rounded

Figure 6. Overview BCS for the general appearance in black rhino *D. bicornis* from a lateral view.

(Figs. 5,6). Due to the poor correlation of the neck and abdomen scores with other approaches, we suggest these regions should not receive attention during scoring, either. Thus, for our overview approach, we focus on the shoulder, spine, rump and tail base. This selection aligns with body regions previously determined most relevant in several wildlife species (Schiffmann et al. 2017).

Our results do not support the concept that the European black rhino zoo population, as a species-specific characteristic, is particularly obese. Rather, under the untested assumption that the BCS suggested here is somewhat comparable between the two African species, the results provide limited evidence that it is rather the white rhino population in which obesity is more frequent. This result parallels a recent, independent finding that globally, female white rhinos kept in zoos appear to have systematically higher body masses than reported for free-ranging specimens, whereas the body mass of black rhinos kept in zoos of either sex are within the range reported for free-ranging conspecifics (Garand et al. 2025). Additionally, necropsy reports of black rhinos kept in European zoos did not state a high number of obese individuals, but evidently this is rarely expected at point of death; yet, iron overload disorder (IOD) was basically ubiquitous in this population (Radeke-Auer et al. 2023). Even if these observations may not yield conclusive evidence that obesity is not an issue in zoo-managed black rhinos, they indicate that obesity may not be among the priority concerns in this species, and also not among the main suspected etiological factors of the extremely widespread phenomenon of IOD, as suggested by Schook et al. (2015).

By contrast, these findings support the previously stated assumption that the white rhino, as a 'more lethargic grazing species', is more prone to obesity than 'the nervous black rhino' (Clauss and Hatt 2006). Under this concept, for which admittedly any further scientific evidence is lacking, it is the susceptibility to stress that is linked to the predominance of BCS that do not indicate obesity. To our knowledge, objective measurements of 'nervousness' or 'stress susceptibility' for rhinos are lacking that would corroborate a species difference, while this difference may nevertheless be intuitive for people that have taken care of both species in zoos (Pilgrim and Biddle 2020). Radeke-Auer et al. (2023) tentatively suggested that an increased stress susceptibility can be related to several health problems in black rhinos, and might be a contributing factor to IOD, based on several reports from experiments with rats in which the iron metabolism was disturbed by stress exposure in a way seemingly compatible with IOD. In the present study, the finding that black rhinos in larger enclosures had BCS closer to the optimum, although receiving a lower proportion of non-forage food in their diet, could represent another piece of circumstantial evidence: in larger enclosures, black rhinos might be able to keep more distance from visitors, which might contribute to lower stress levels in this species (Carlstead and Brown 2005). While it appears self-evident that experimental work on different degrees of stress in black rhinos will not be performed, prioritizing measures to reduce stress under current husbandry conditions probably represents a reasonable approach to enhance the health of this species in zoos.

Findings on the decline of body mass with age (only significant in the present dataset for black rhinos) as well as BCS with age (with more significant correlations in black than in white rhinos; Tables S4 and S5) might indicate that black rhinos are more susceptible to poor nutritional status than white rhinos. Among the various diseases black rhinos are susceptible to (Dennis et al. 2007, Radeke-Auer et al. 2023), IOD appears to be unrelated to body condition at death (Radeke-Auer et al. 2023). Based on museum specimens, it has been suggested that black rhinos in zoos experience more unnatural tooth wear than white rhinos (Taylor et al. 2014). Observations during necropsies also suggest that black rhinos are affected by premature tooth wear (Radeke-Auer et al. 2023), and a comparison of faecal silica levels suggest that in zoos, black rhinos ingest distinctively more abrasive silica than animals in the wild (Sauspeter et al. 2025). While this evidently does not mean that white rhinos are not affected by tooth problems, the relevance of dental status might be particularly high in black rhino husbandry.

The fact that in black rhino males had significantly lower BCS compared to females has been reported in other species such as elephants (Morfeld et al. 2016) or chimpanzees (Reamer et al. 2020). One previously discussed explanation is that males of some species showed a lower proportion of fat mass compared to females (Chusyd et al. 2019; Stirling et al. 2008). The same may apply to rhinos, as also indicated in a seemingly higher propensity for female white rhinos compared to males for overweight (Garand et al. 2025).

A correlation between BCS and impaired breeding success has been previously found in various species, for example in male African lions *Panthera leo* and donkeys *Equus africanus asinus* (Masoud et al. 2021; Lueders et al. 2024) or female African elephants *Loxodonta africana* and guinea pigs *Cavia porcellus* (Freeman et al. 2009; Michel and Bonnet 2012). A higher BCS was listed as a predisposing factor for birth problems in female elephants (Hermes et al. 2008) and for stillbirths in Asian elephants (Kurt and Mar 1996). For greater one-horned rhinos, an association between a high BCS and female reproductive tract disease has been suggested (Heidegger et al. 2016), and for a sample of 32 female black rhinos of reproductive age, Edwards et al. (2015) reported a lower BCS in proven breeders, whereas the majority of nulliparous animals had a BCS of 4.5. Our results do not corroborate this correlation for female black rhinos. We can only speculate whether age presents a relevant variable in this relationship. Therefore, we encourage further investigations on the effect of age on reproductive success and BCS in rhinos. In contrast, non-breeding female white rhinos showed significantly higher BCS than similar-aged breeding females. This finding is in accord with a report on female Asian elephants in European zoos (Schiffmann et al. 2019). Nonetheless, it is not possible to determine whether this reflects a consistent depletion of body stores by gestation and lactation, or whether this indicates an inhibiting effect of overconditioning on conception. Evidently, other factors (breeding recommendations, specific conditions of the institution, correctly recognising the appropriate breeding time, idiosyncratic aversion and character/behaviour of individual animals) can affect the chances for a successful mating. For white rhinos, Berkeley and Linklater (2007) suggested that elevated glucose plasma levels due to overfeeding and overweight lead to a higher chance of early embryo loss. Clearly, body condition is unlikely to be the main influence factor for rhinoceros reproductive success, which depends on a variety of factors (Carlstead et al. 1999; Hermes et al. 2005; Metrione et al. 2007; Edwards 2013). Nevertheless, maintaining animals designated for breeding in a moderate body condition (corresponding to a score of 3-4) may be considered a rational approach.

Body mass and BCS monitoring by the institutions was carried out more frequently in black rhinos than in white rhinos. This might be explained by the increased number of health issues found in black rhinos that make close monitoring essential. However, for both species the percentage of institutions that actually use regular body condition scoring is surprisingly low. Training rhino staff in body condition scoring and applying this regularly would be a clear measure to improve rhino husbandry skill, and has the potential for a sensitive early warning system. Even though applying a BCS is subjective, the ease of photographic documentation of the appearance of an animal should make picture archives together with regular BCS assessment a routine tool that could potentially be offered by a Taxon Advisory Group. For elephants, such a service is being provided to the European zoo community (Schiffmann 2020). Establishing this for the few valuable specimens of the zoo rhino population appears as a logical next step in cross-zoo rhinoceros husbandry.

Acknowledgments

We thank Mariska Bijsterbosch from Wildlife Vets Namibia for contributing photographs to our data set.

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