The feeding of rhinoceroses

-

reminder and update

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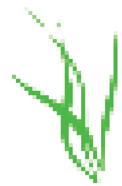
EAZA Conference Belfast 2016

University of Zurich[UZH]

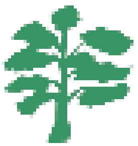
Clinic of Zoo Animals, Exotic Pets and Wildlife

Natural diets of rhinoceros



100% grass

Natural diets of rhinoceros



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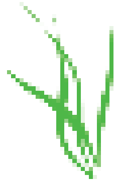

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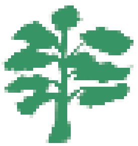
Natural diets of rhinoceros



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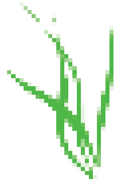

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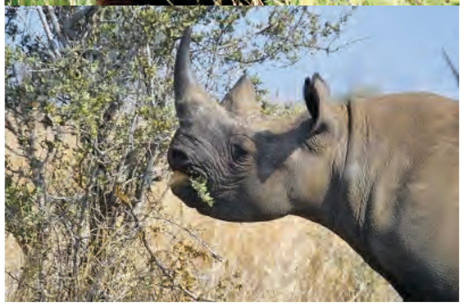
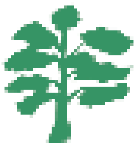
Natural diets of rhinoceros





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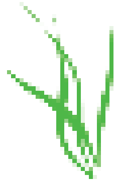

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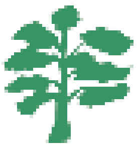
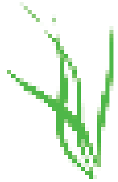
Natural diets of rhinoceros



100% browse

mix & fruits ?

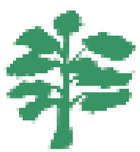


100% grass

Natural diets of rhinoceros

Trewia **fruits in the wild:**

- different from commercial fruits
- less than 3% of daily dry matter intake in peak times!



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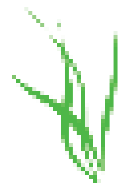
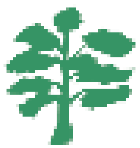
mix & fruits ?



100% grass

Zoo diets of rhinoceros



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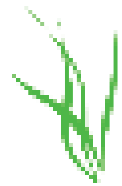

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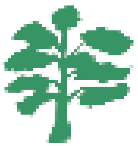
Zoo diets of rhinoceros



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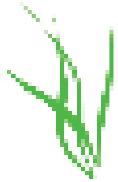
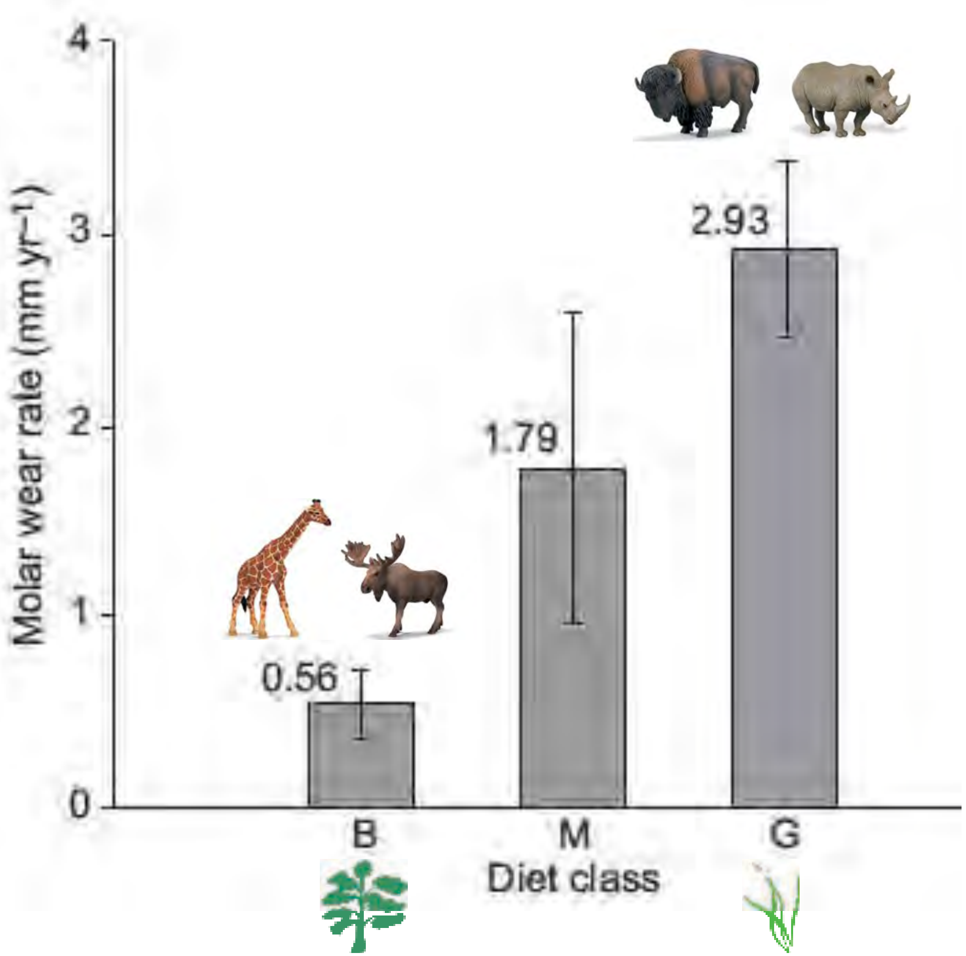


100% grass

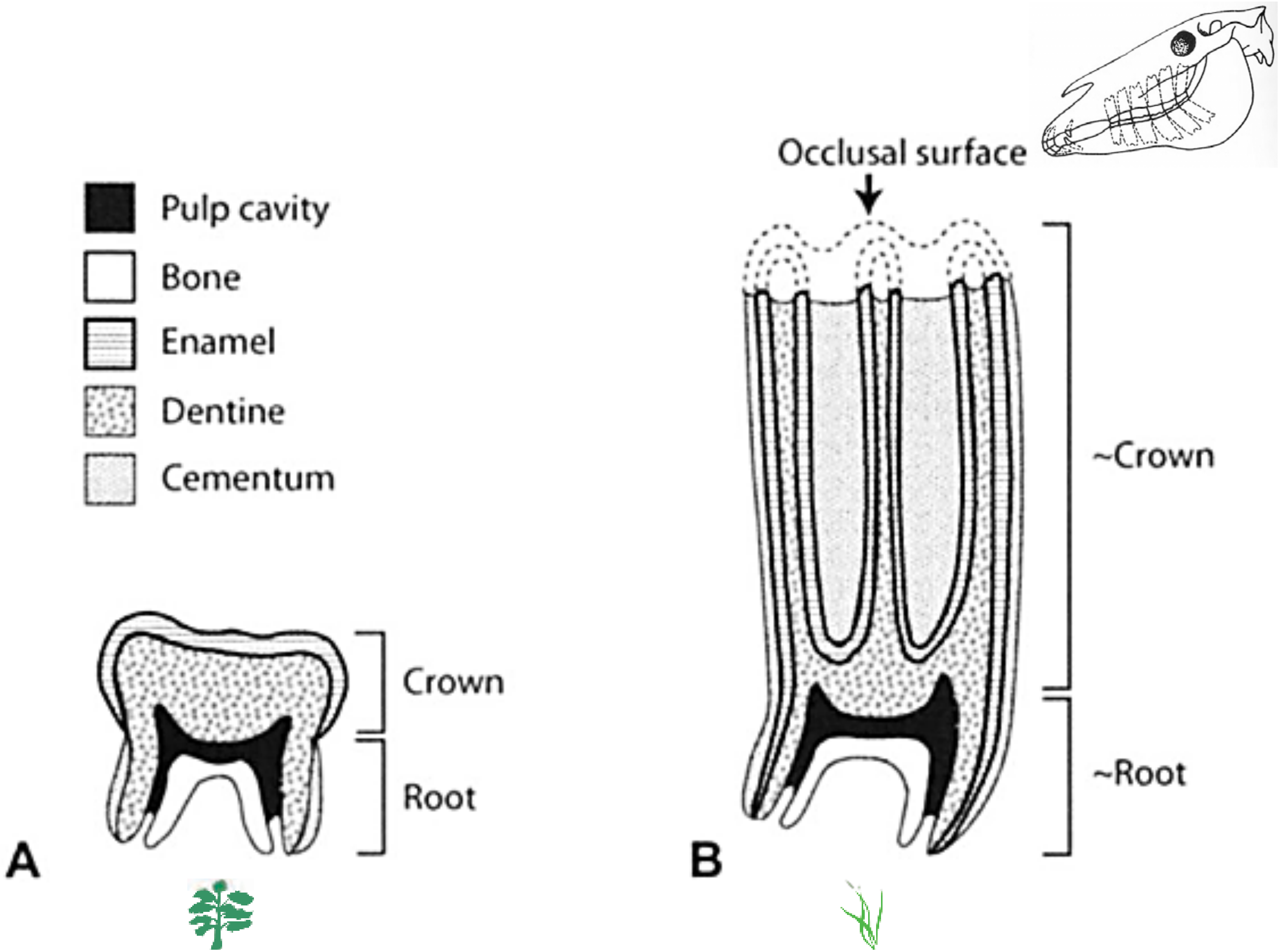
A comparison of observed molar wear rates in extant herbivorous mammals

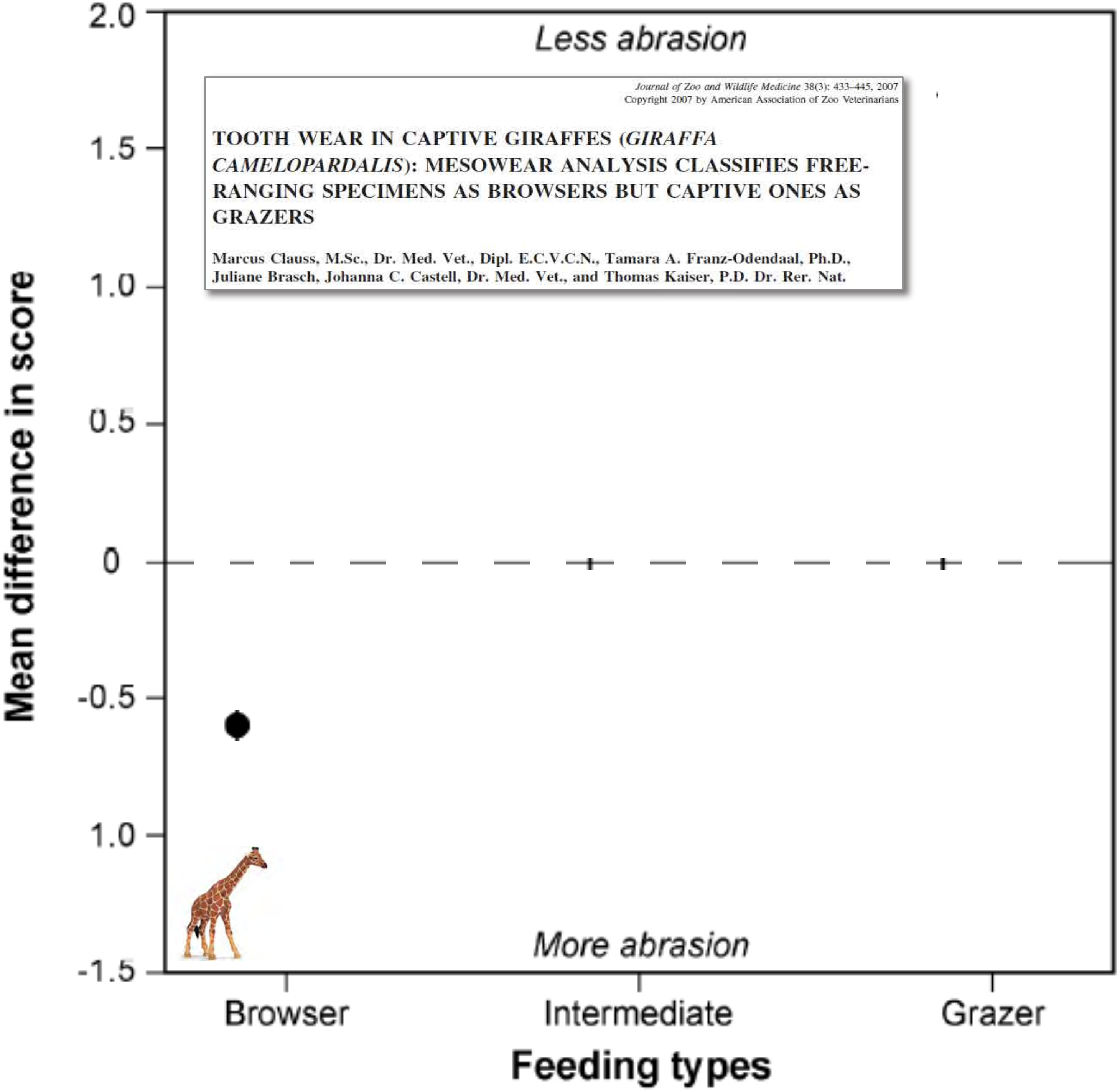
John Damuth[1] & Christine M. Janis[2]

Ann. Zool. Fennici 51: 188–200
Helsinki 7 April 2014

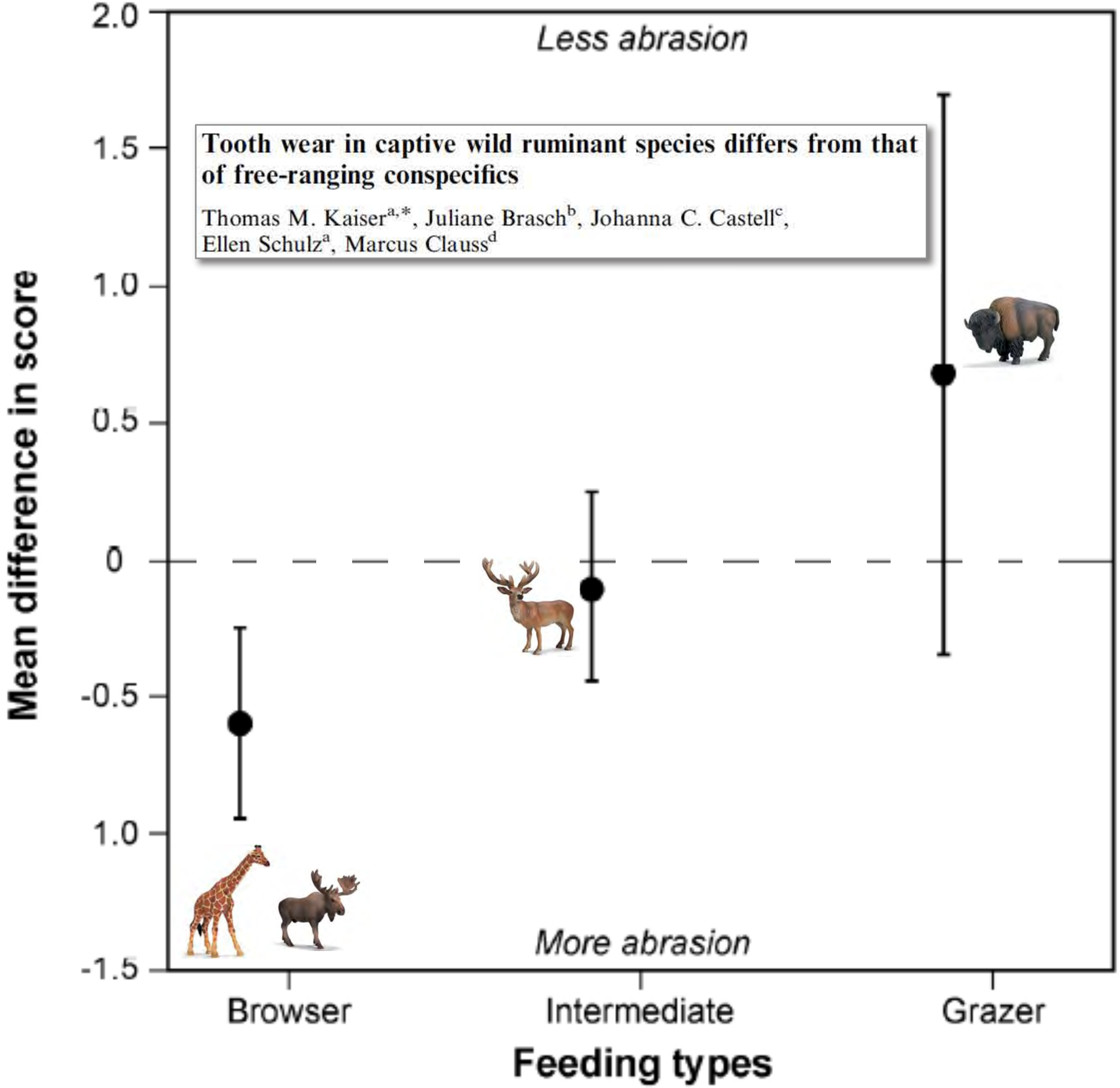


Hypsodonty


Occlusal surface
Pulp cavity
Bone
Enamel
Dentine
Cementum
Crown
Root
~Crown
~Root
A
B



Less abrasion
Journal of Zoo and Wildlife Medicine 38(3): 433–445, 2007
Copyright 2007 by American Association of Zoo Veterinarians
TOOTH WEAR IN CAPTIVE GIRAFFES (GIRAFFA CAMELOPARDALIS): MESOWEAR ANALYSIS CLASSIFIES FREE-RANGING SPECIMENS AS BROWSERS BUT CAPTIVE ONES AS GRAZERS
Marcus Clauss, M.Sc., Dr. Med. Vet., Dipl. E.C.V.C.N., Tamara A. Franz-Odendaal, Ph.D., Juliane Brasch, Johanna C. Castell, Dr. Med. Vet., and Thomas Kaiser, P.D. Dr. Rer. Nat.
More abrasion
Mean difference in score
2.0
1.5
1.0
0.5
0
-0.5
1.0
-1.5
Browser
Intermediate
Grazer
Feeding types


Less abrasion
More abrasion
Tooth wear in captive wild ruminant species differs from that of free-ranging conspecifics
Thomas M. Kaiser[a,*], Juliane Brasch[b], Johanna C. Castell[c], Ellen Schulz[a], Marcus Clauss[d]
Mean difference in score
2.0
1.5
1.0
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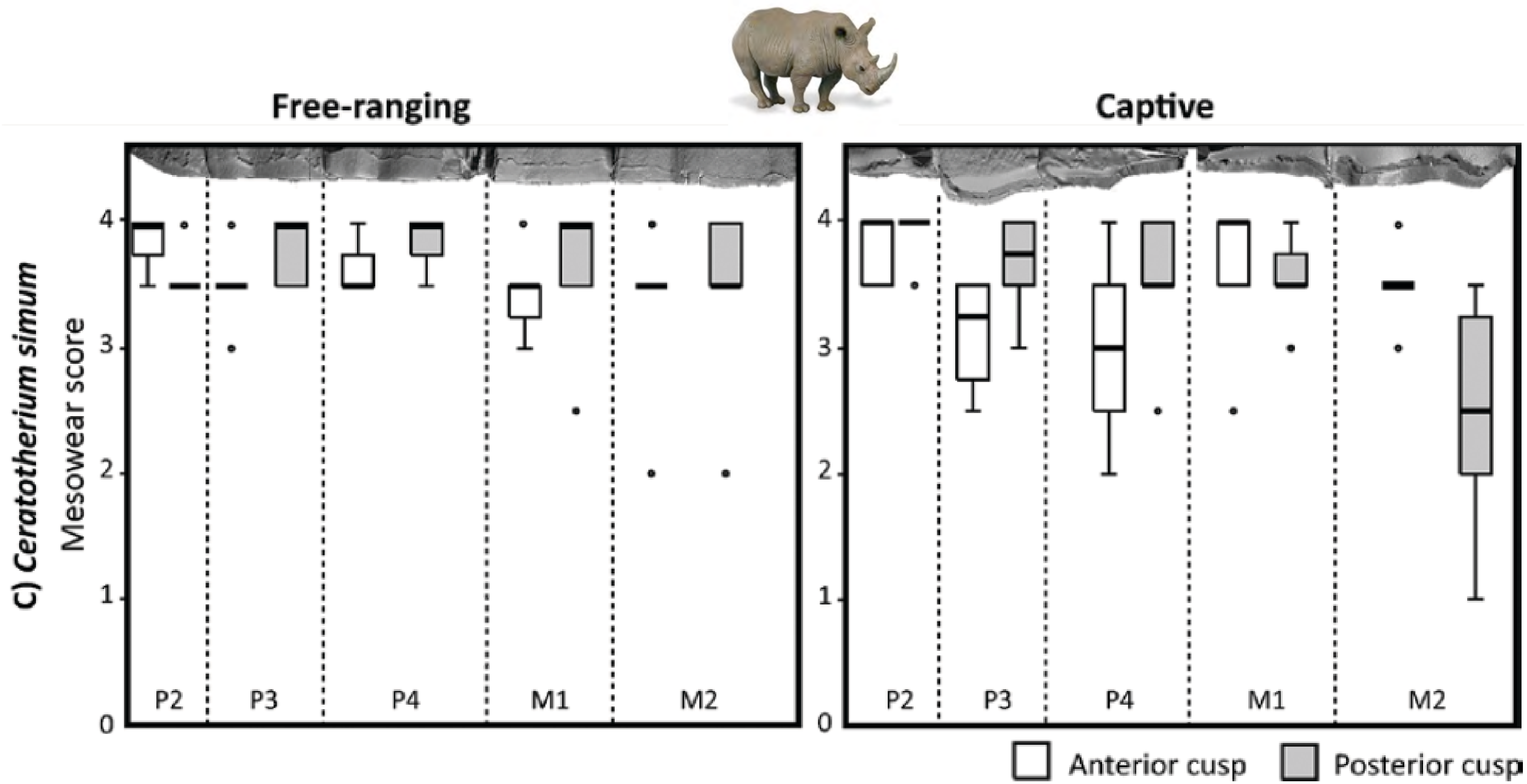
Tooth wear in rhinos

Contributions to Zoology, 83 (2) 107-117 (2014)

Tooth wear in captive rhinoceroses (*Diceros*, *Rhinoceros*, *Ceratotherium*: Perissodactyla) differs from that of free-ranging conspecifics

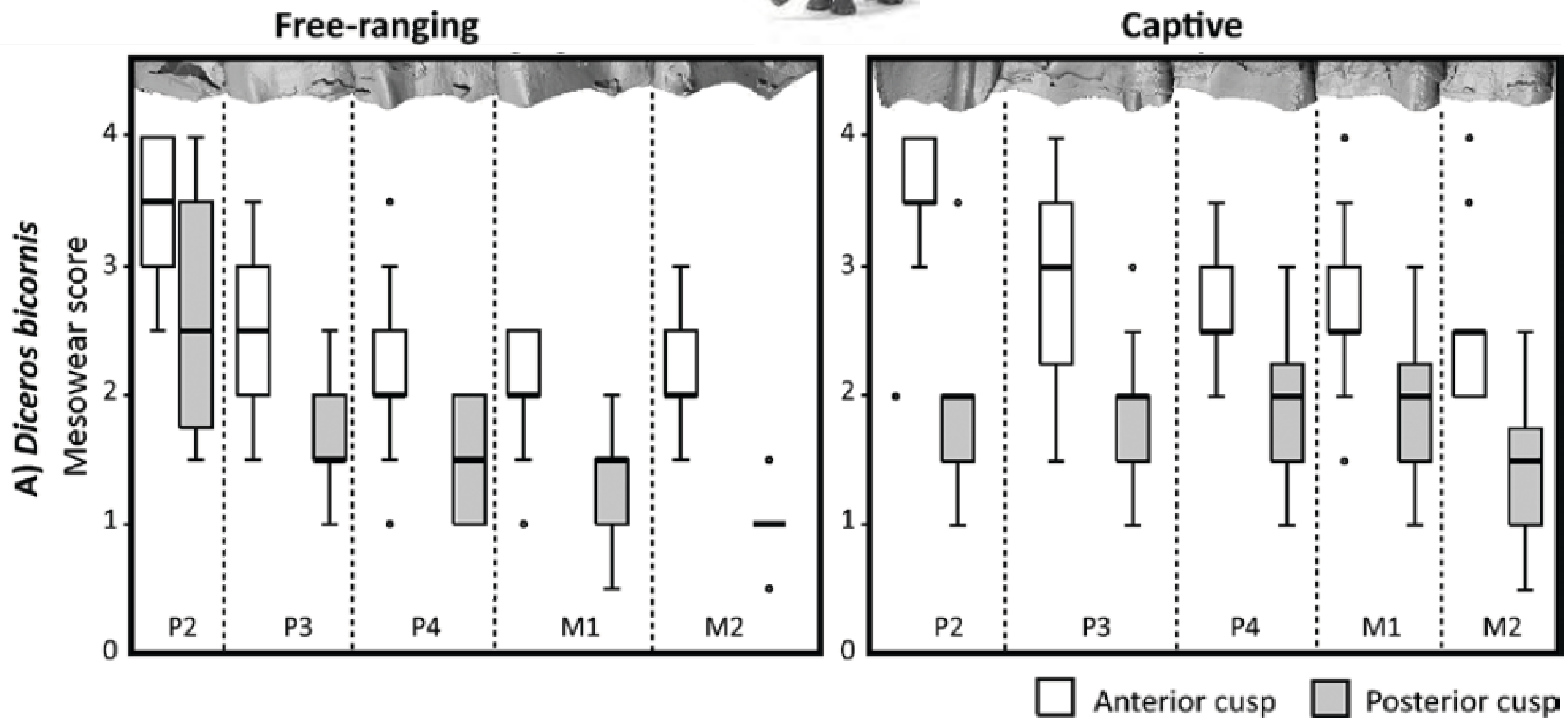
Lucy A. Taylor[1,2], Dennis W.H. Müller[3,4], Christoph Schwitzer[1], Thomas M. Kaiser[5], Daryl Codron[3,6], Ellen Schulz[5], Marcus Clauss[3,7]

Tooth wear in rhinos



from Taylor et al. (2014)

Tooth wear in rhinos



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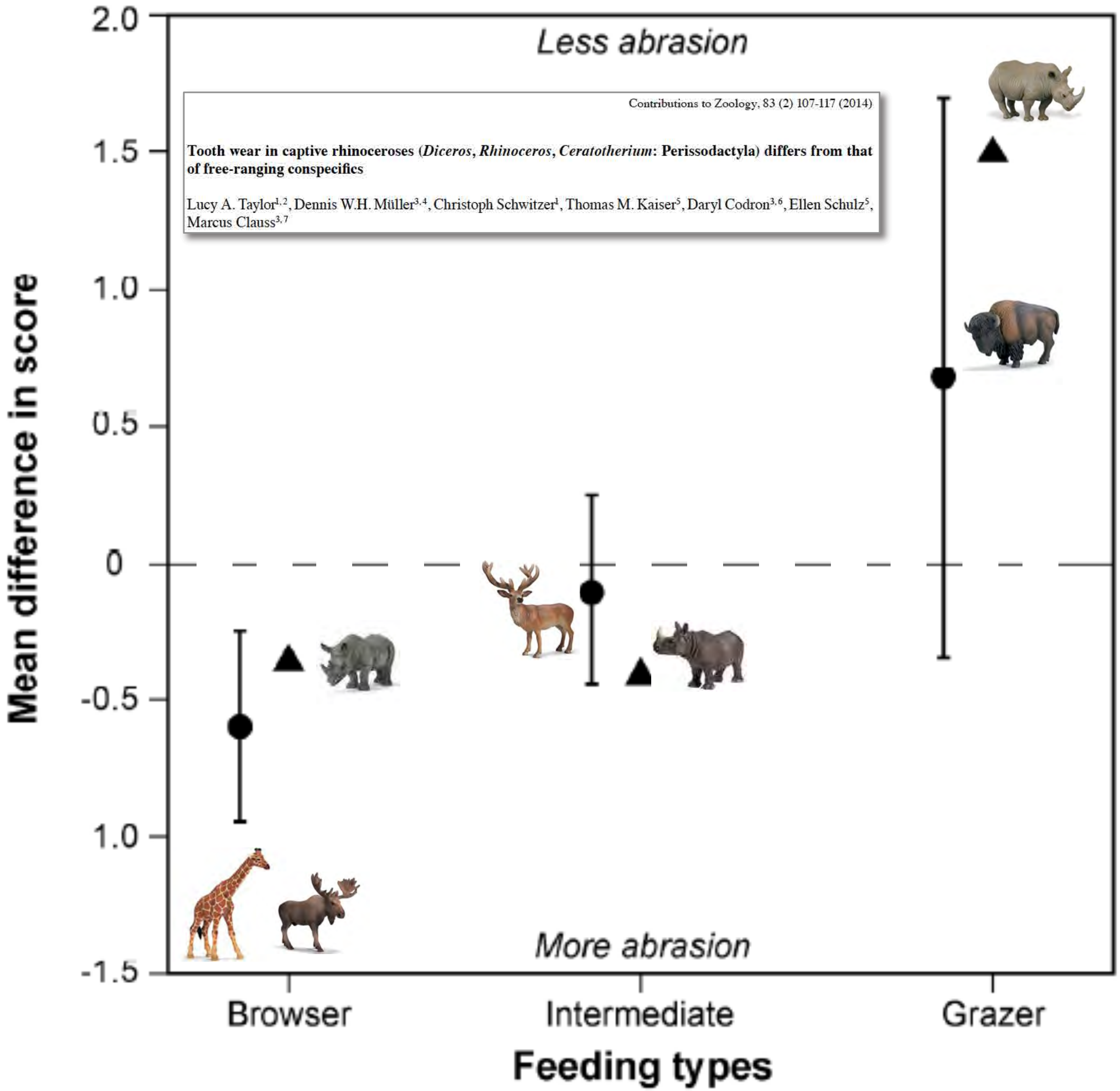
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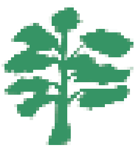
Zoo diets of rhinoceros



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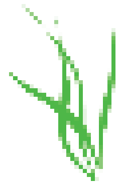
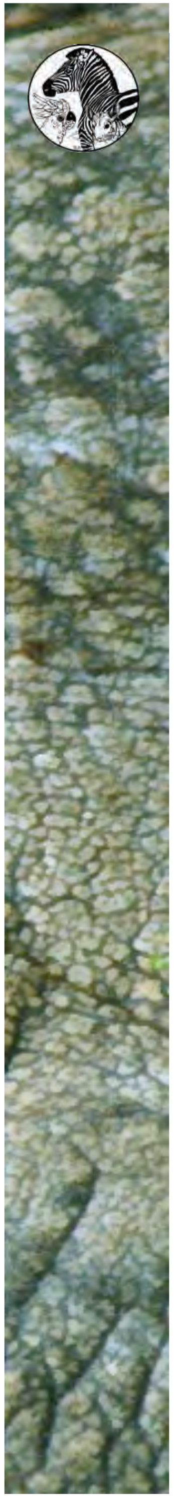


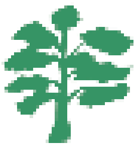
100% grass

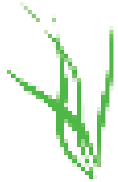
Zoo diets of rhinoceros

Crude fibre ~25%
Ingredients!

Zoo diets of rhinoceros



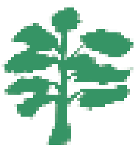




100% browse

100% grass

Zoo diets of rhinoceros



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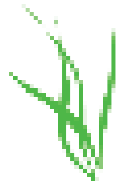
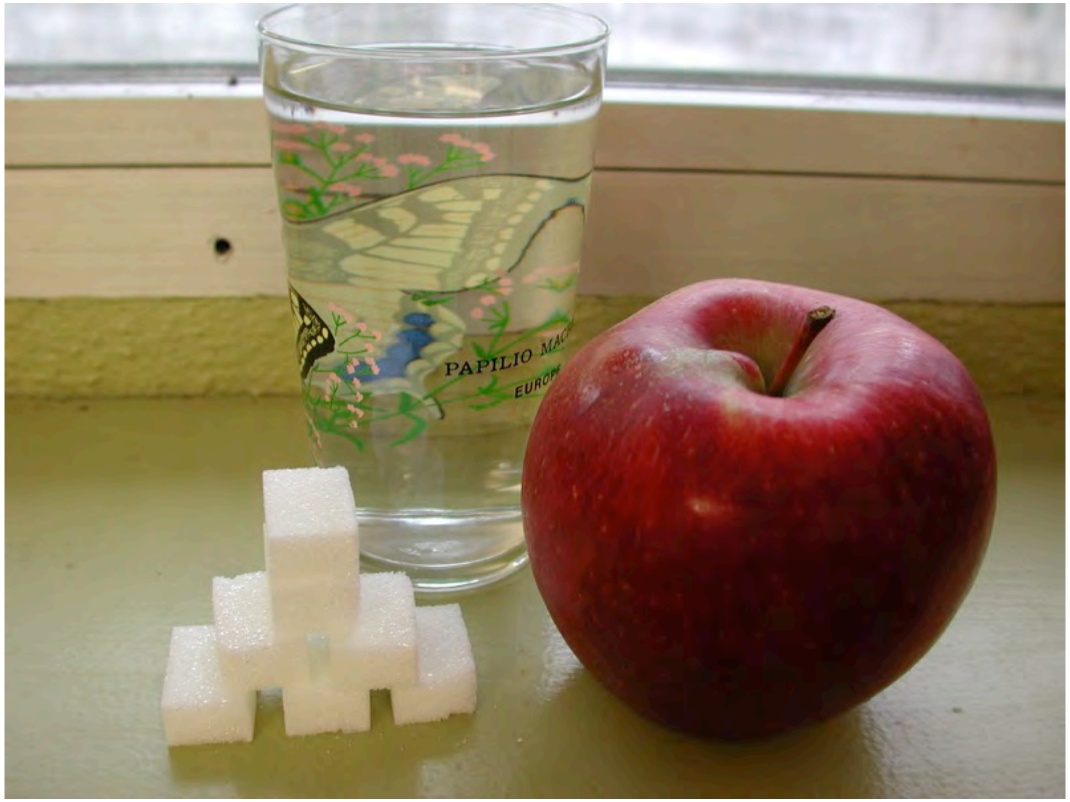


100% grass

What's in an apple ?

- **85 % water**
- **10 % sugar**



Fruits and Vegetables

Fruits

	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"		%		‰
	%	%	------------------- dry matter -------------------			
Honey	18.6	81.4	0.5	92.3	0.1	0.2
Rock melon	87.0	13.0	6.9	92.5*	0.5	1.6
Water melon	93.2	6.8	8.8	90.5*	1.5	1.6
Ananas	85.3	14.7	3.1	89.3	1.1	0.6
Grapes	81.1	18.9	3.6	85.2	1.0	1.1
Apple	85.3	14.7	2.3	84.3	0.5	0.8
Dried dates	20.2	79.8	2.3	83.1	0.8	0.7
Cherry	82.8	17.2	5.2	82.6	1.0	1.2
Banana	73.9	26.1	4.4	82.0	0.3	1.1
Grapefruit	89.0	11.0	5.5	81.4	1.6	1.5
Pear	84.3	15.7	3.0	80.6	0.6	1.0
Peach	87.5	12.5	6.1	75.5	0.6	1.8
Mango	82.0	18.0	3.3	71.1	0.7	0.7
Plum	83.7	16.3	3.7	70.0	0.9	1.1
Apricot	85.3	14.7	6.1	67.6	1.1	1.4
Gooseberry	87.3	12.7	6.3	66.9	2.3	2.4
Kiwi	83.8	16.2	6.2	66.5	2.3	1.9
Fig	80.2	19.8	6.6	65.2	2.7	1.6
Orange	85.7	14.3	7.0	64.3	2.9	1.6
Strawberry	89.5	10.5	7.8	61.4	2.5	2.8
Black currant	81.3	18.7	6.8	53.3	2.5	2.1
Red currant	84.7	15.3	7.4	48.6	1.9	1.8
Blueberry	84.6	15.4	3.9	47.8	0.6	0.8
Blackberry	84.7	15.3	7.8	46.7	2.9	2.0
Raspberry	84.5	15.5	8.4	44.6	2.6	2.8
Guava	83.5	16.5	5.5	40.6	1.0	1.9
Papaya	87.9	12.1	4.3	19.8	1.7	1.4
Avocado	68.0	32.0	5.9	1.3 (due to high fat content)	0.3	1.2

*minimum

Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

Vegetables

	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"		%		‰
	%	%	------------------- dry matter -------------------			
Sweet potato	69.2	30.8	5.3	94.0*	1.1	1.5
Manioc/Tapioca	63.1	36.9	2.7	86.9	1.0	1.0
Beetroot	88.8	11.2	13.7	76.9	2.6	4.0
Potato raw/cooked	77.8	22.2	9.2	69.4	0.4	2.3
Cucumber	96.8	3.2	18.8	64.7	4.7	7.2
Tomato	94.2	5.8	16.4	59.5	2.4	4.5
Pumpkin	91.3	8.7	12.6	54.9	2.5	5.1
Green beans	90.3	9.7	24.6	54.5	5.9	3.9
Onion	87.6	12.4	10.1	46.7	2.5	3.4
Kohlrabi	91.6	8.4	23.1	45.8	8.1	5.9
Carrot	88.2	11.8	8.3	41.8	3.5	3.0
Chicoree	94.4	5.6	23.2	41.4	4.6	4.6
Squash	88.7	11.3	12.4	40.6	2.4	3.8
Radish	94.4	5.6	18.8	39.6	6.1	4.7
Aubergine	92.6	7.4	16.8	35.9	1.8	2.9
Sweet pepper	91.0	9.0	13.0	35.7	1.2	3.2
Celery stalks	92.9	7.1	16.9	30.7	11.3	6.8
Cauliflower	91.6	8.4	29.3	30.2	2.4	6.4
Chinese cabbage	95.4	4.6	25.9	29.1	8.7	6.5
Leek	89.0	11.0	20.4	29.0	7.9	4.2
Broccoli	89.7	10.3	32.0	27.4	10.2	8.0
Zucchini	92.2	7.8	20.5	25.6	3.8	2.9
Brussels sprouts	85.0	15.0	29.7	25.1	2.1	5.6
Savoy cabbage	90.0	10.0	29.5	24.1	4.7	5.6
Lettuce	95.0	5.0	25.0	22.0	7.4	6.6
Kale/Green cabbage	86.3	13.7	31.4	21.7	15.5	6.4
Fennel	86.0	14.0	17.4	20.1	7.8	3.6
Celery root	88.6	11.4	13.6	19.7	6.0	7.0
Girasole	78.9	21.1	11.6	19.0	0.5	3.7
Artichoke	82.5	17.5	13.7	16.6	3.0	7.4
Field salad/Lamb's lettuce	93.4	6.6	27.9	10.6	5.3	7.4
Mangold	92.2	7.8	27.3	8.8	12.8	5.0
Spinach	91.6	8.4	30.0	7.3	15.0	6.5
Parsley	81.9	18.1	24.5	7.2	13.5	7.1
Endive	94.3	5.7	30.7	5.3	9.5	9.5

*minimum

Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

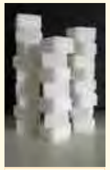
AnimalWelfareWeb.nl

Sugars and other nutrients in produce (of fruits and vegetables)

All values expressed as g/kg wet weight, unless otherwise stated.

Fruits

Banana
Musa acuminata



104 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
3.4	234	28.8	6.6	13.3	12.4	0.04	0.27	0.28	0.002	44.2	5.5	0.14

Apple
Malus domestica

86 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
2.2	143	14.6	8.6	4.3	8.3	0.04	0.17	0.04	0.001	20.8	5.5	0.1

Orange
Citrus x sinensis

56 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
2.2	130	14.3	9.2	7.8	4.9	0.35	0.22	0.1	0.001	40	5.5	0.5

Kiwi
Actinidia deliciosa

52 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
2.5	156	25.3	19.7	12.9	8.3	0.32	0.33	0.13	0.003	31.4	5.5	0.65

Papaya
Carica papaya

27 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
2.1	135	18.5	16.5	18.4	4.7	0.25	0.1	0.22	0.007	197	-	0.55

Vegetables

Carrot
Daucus caurota

45 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
1.6	115	11.2	10.2	6.8	4	0.36	0.29	0.12	0.004	9170	5.5	0.02

Sweet potato
Ipomoea batatas

32 gram sugar

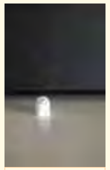
Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
3.0	197	39.4	9.7	8.3	11	0.45	0.47	0.15	0.009	3730	-	0.26

Celery
Apium graveolens

14 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
0.9	71	11.1	8.9	12.2	2.1	0.57	0.3	0.08	0.004	14.2	2	0.2

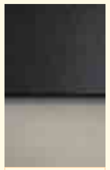
Spinach
Spinacia oleracea



1 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
1.1	83	16.7	9.7	32.1	6.6	1.29	0.41	0.26	0.05	3490	29	0.52

Endive
Cichorium endivia



0 gram sugar

Energy MJ	Dry Matter	NDF	ADF	Crude Protein	Fat	Ca	P	Mg	Fe	Vit. A RE	Vit. E α-TE	Vit. C
0.6	62	11	8.9	13	2	0.52	0.28	0.15	0.008	1030	-	0.07

Photos and design, Emile Prins, 2012.
Information used from Danish Food Composition Table and Schmidt *et al.*, (2005).

Contact: Tjalling Huisman
Email: tjalling.huisman@wur.nl
Phone: +31-(0)58-2846311

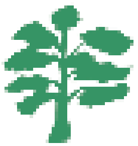
courtesy Tjalling Huisman

Zoo diets of rhinoceros

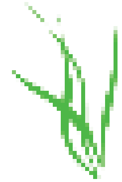
100% browse

100% grass

Zoo diets of rhinoceros



100% browse



100% grass

Key problem: obesity

from Hatt & Clauss (2006)

Key problem: obesity

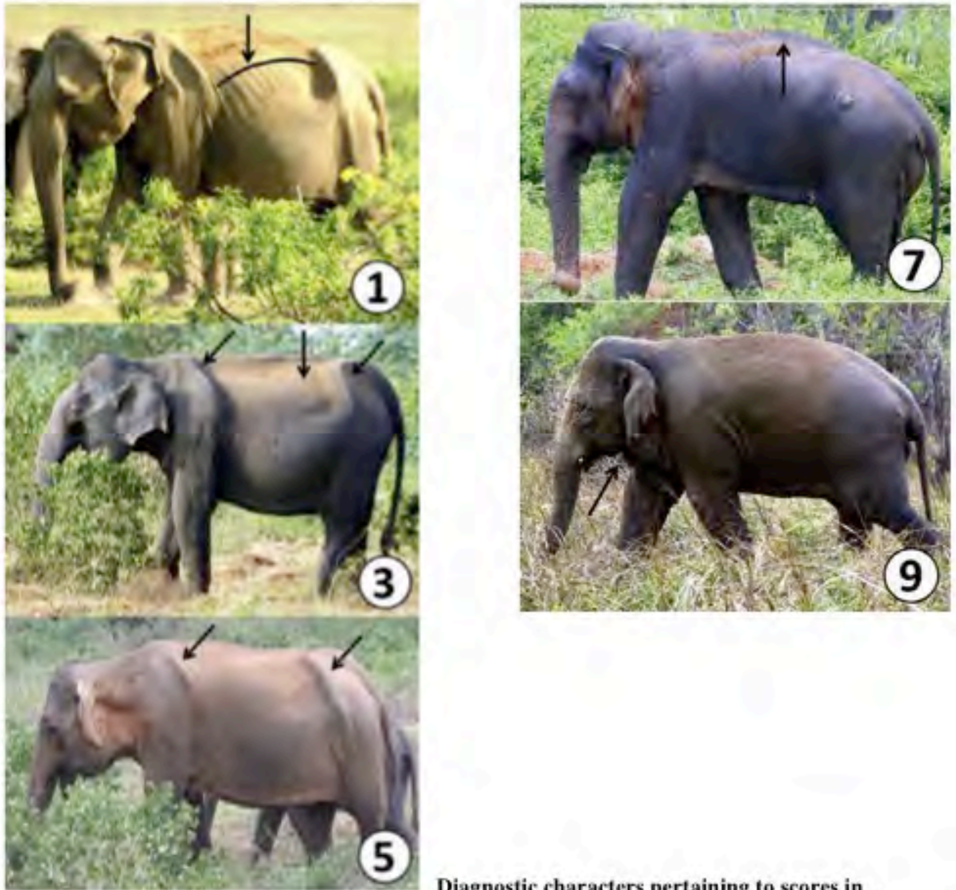
from various internet sources and own photo

Key problem: obesity

from Clauss & Hatt (2006)

Monitoring body condition

Body Condition Index Scores

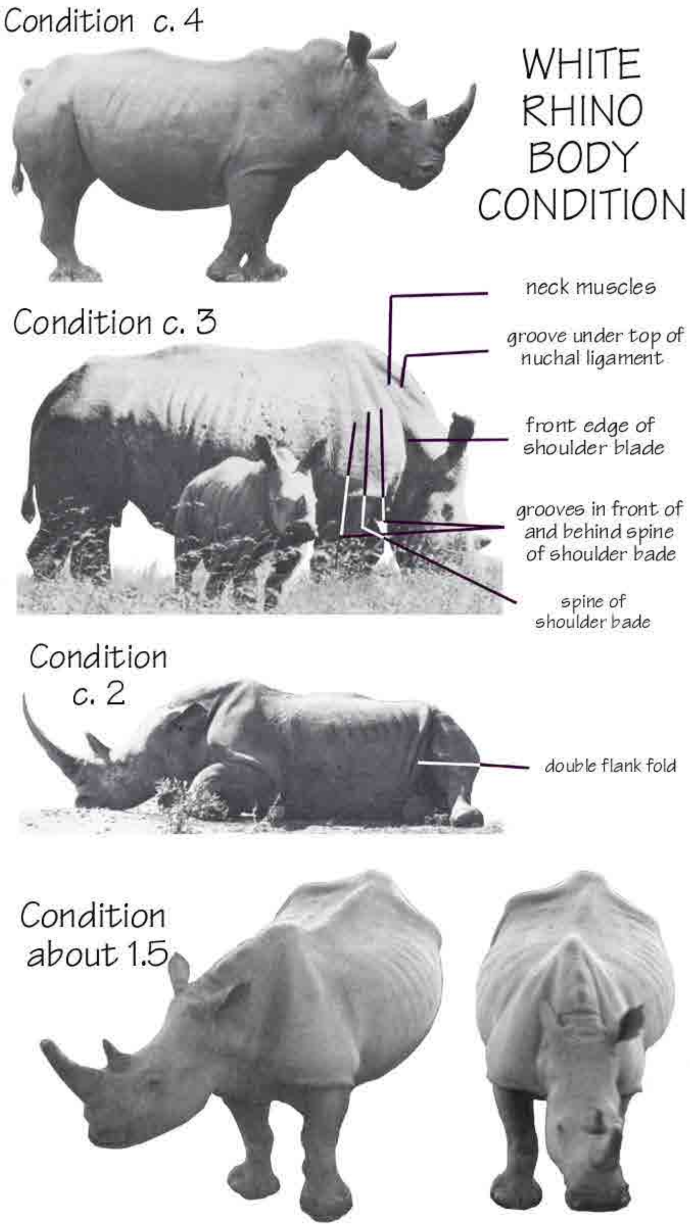


Diagnostic characters pertaining to scores in photographic scale.

1	All ribs (shoulder to pelvis) visible, some ribs prominent (spaces in between sunken in)
3	Some ribs visible (spaces in between not sunken in), shoulder and pelvic girdles prominent
5	Ribs not visible, shoulder and pelvic girdles visible
7	Backbone visible as a ridge, shoulder and pelvic girdles not visible
9	Back rounded, thick rolls of fat under neck

If it is difficult to decide between two points on the scale, as the scale is composed of odd numbers, the score represented by the intervening even number is assigned.

Monitoring body condition



from Keep (1971)

Monitoring body condition

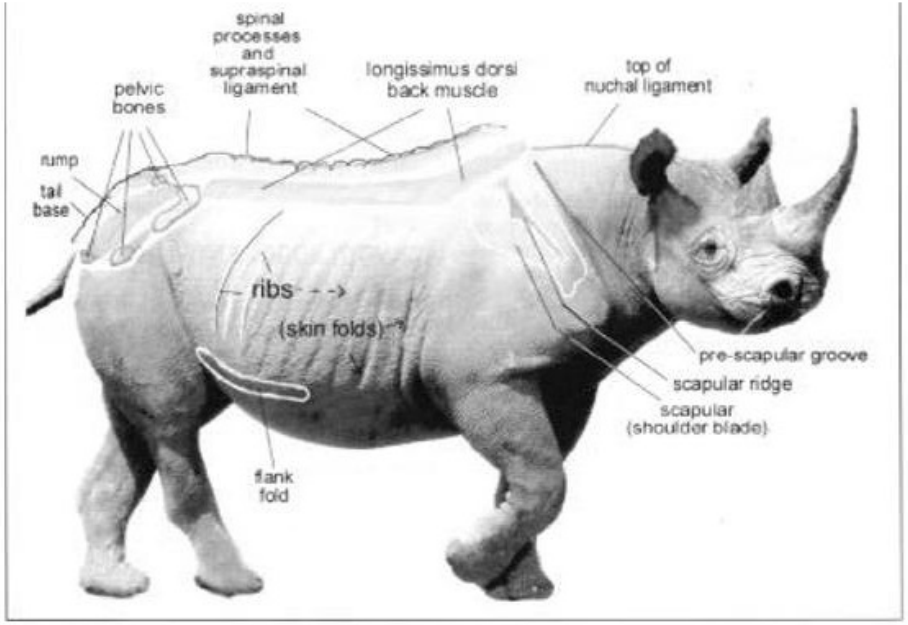
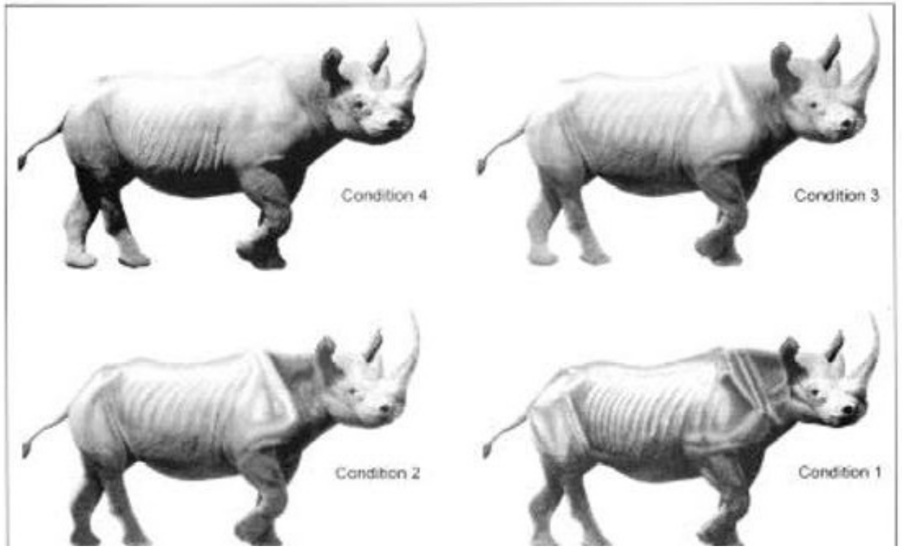
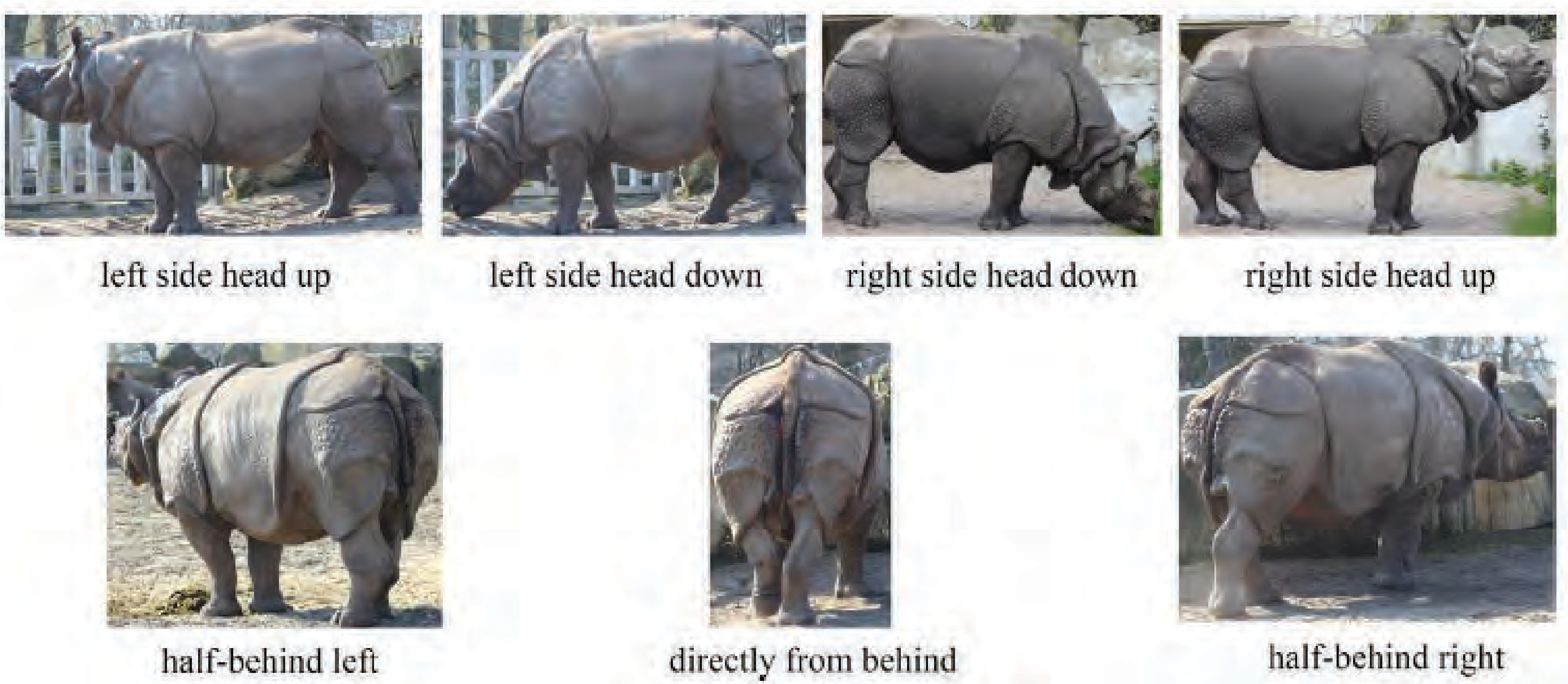


Figure 1. The body regions and specific anatomical features to be observed when assessing a rhino's condition.



from Reuter & Adcock (1998)

Monitoring body condition



from Heidegger et al. (2016)

Monitoring body condition

Zoo Biology 9999 : 1–12 (2016)

RESEARCH ARTICLE

Body Condition Scoring System for Greater One-Horned Rhino (*Rhinoceros unicornis*): Development and Application

Eva M. Heidegger,[1] Friederike von Houwald,[2] Beatrice Steck,[2] and Marcus Clauss[1]*

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Zoo Basel, Basel, Switzerland

Preventing obesity in zoo animals is increasingly recognized as an important husbandry objective. To achieve this goal, body condition scoring (BCS) systems are available for an ever-increasing number of species. Here, we present a BCS for the greater one-horned rhinoceros (*Rhinoceros unicornis*) based on an evaluation (on a scale from 1 to 5) of seven different body regions, and report resulting scores for 62 animals from 27 facilities, based on digital photographs. In animals above 4 years of age, this BCS correlated with the body mass:shoulder height ratio. Although differences between the sexes for individual regions were noted (with consistently higher scores in males for the neck and shoulder and in parous females for the abdomen), the average BCS of all regions did not differ significantly between males (4.3 ± 0.4) and females (4.1 ± 0.5). Linking the BCS to results of a questionnaire survey and studbook information, there were no differences in BCS between animals with and without foot problems or between parous and non-parous females. In a very limited sample of 11 females, those eight that had been diagnosed with leiomyoma in a previous study had a higher BCS (range 3.9–4.9) than the three that had been diagnosed as leiomyoma-free (range 3.5–3.7). The BCS was correlated to the amount of food offered as estimated from the questionnaire. Adjusting the amounts and the nutritional quality of the diet components is an evident measure to maintain animals at a target BCS (suggested as 3–3.5). Zoo Biol. XX:XX–XX, 2016.

Keywords: rhinoceros; body condition; obesity; feeding; reproduction; foot lesion

INTRODUCTION

The greater one-horned rhinoceros (*Rhinoceros unicornis*, GOH-rhino) is currently the least threatened of the three still-existing Asian rhinoceros species. It can be found in seven Indian National Parks and Wildlife Sanctuaries, as well as in two National Parks and one Wildlife Sanctuary in Nepal [von Houwald et al., 2014]. According to the International Union for Conservation of Nature and Natural Resources (IUCN), the population in the wild is classified as "vulnerable" [Talukdar et al., 2008] and with current numbers ranging around 3,400 individuals [von Houwald et al., 2014], it is still far from a "near threatened" status. In contrast, the other Asian rhino species, the Sumatran (*Dicerorhinus sumatrensis*) and the Javan rhinoceros (*Rhinoceros sondaicus*), are critically endangered [van Strien et al., 2008a,b]. Rhinos represent examples of species where improvements of the management of ex situ populations are important components of the overall preservation efforts.

Zoos and wildlife parks play an active role in conservation through establishing breeding programs and creating awareness for animal protection and welfare. The international studbook listed 207 (males.females.unknown: 105.100.2) GOH-rhinos in 73 institutions at the end of the year 2014. Currently, 24 European zoos are housing 65 individuals (31.34) and 79 animals (38.41) are living in 29 North American zoos and wildlife parks [von Houwald et al., 2014].

Conflict of interest: None.

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Monitoring body condition

BCS 5

BCS 4

BCS 3

BCS 2

BCS 1

from Heidegger et al. (2016)

Monitoring body condition

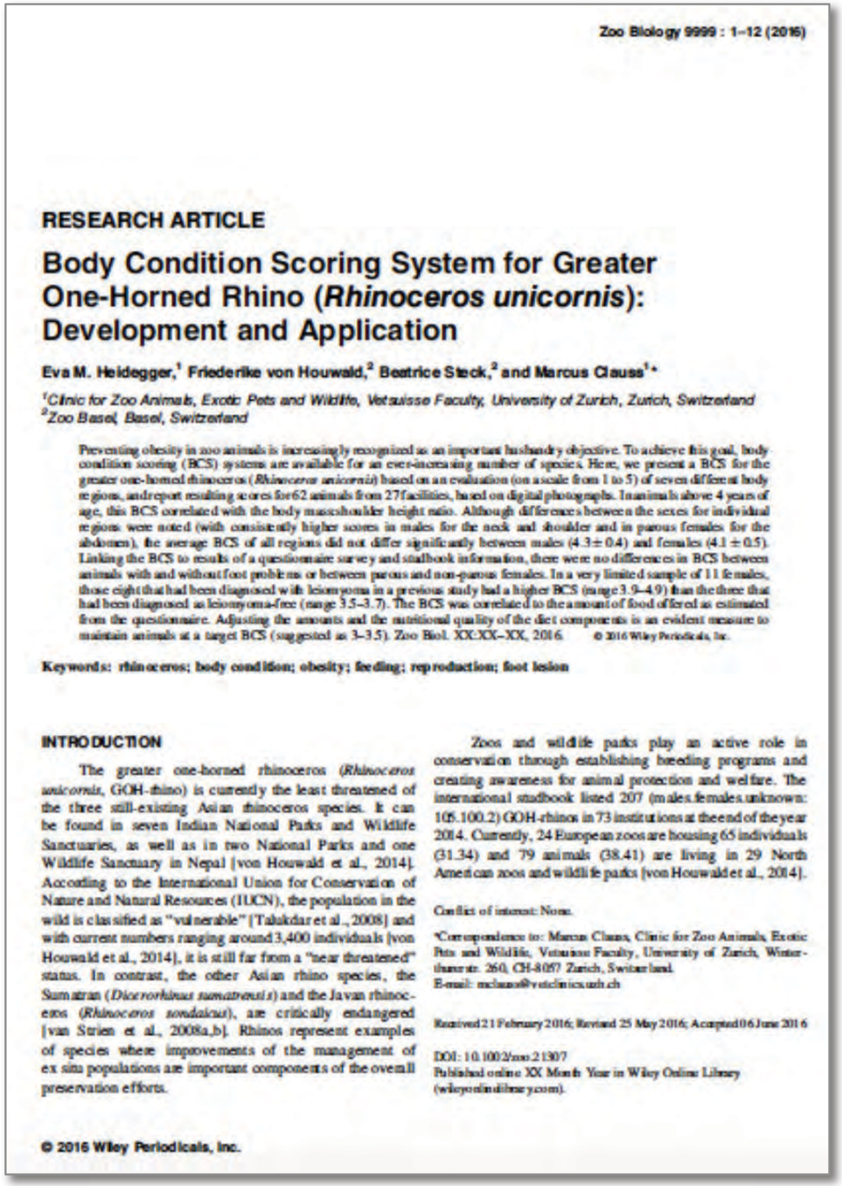
Irregular ovarian activity, body condition and behavioural differences are associated with reproductive success in female eastern black rhinoceros (*Diceros bicornis michaeli*)

Katie L. Edwards[a,b,*], Susanne Shultz[c], Mark Pilgrim[b], Susan L. Walker[b]

General and Comparative Endocrinology 214 (2015) 186–194

Body condition scores (BCS) ranged from 3.0 to 4.5, and there were no differences in BCS according to age (Mann Whitney $U = 92.500$, $P = 0.157$). However, among reproductive-age females, nulliparous females had higher BCS than parous females (Mann Whitney $U = 52.500$, $P = 0.004$),

Monitoring body condition



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RESEARCH ARTICLE

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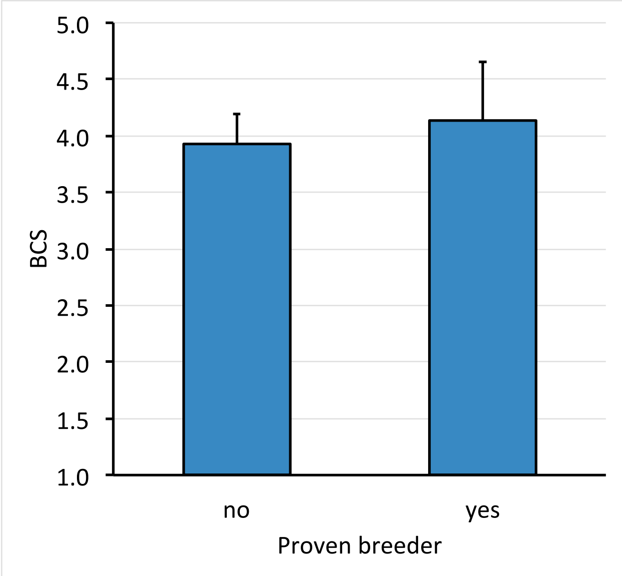
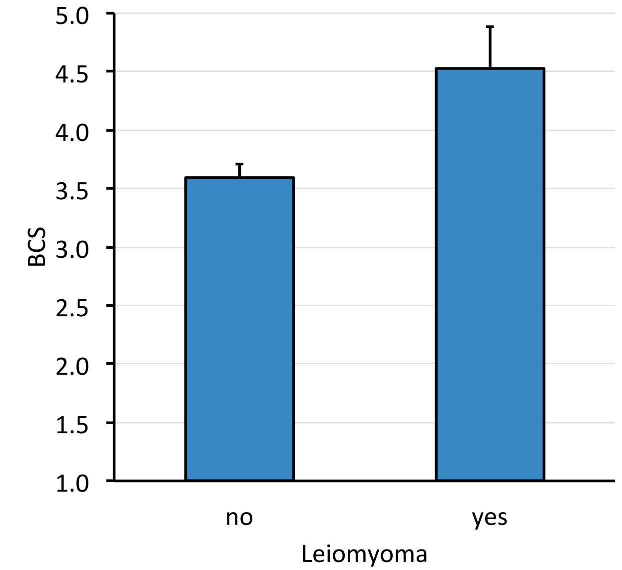


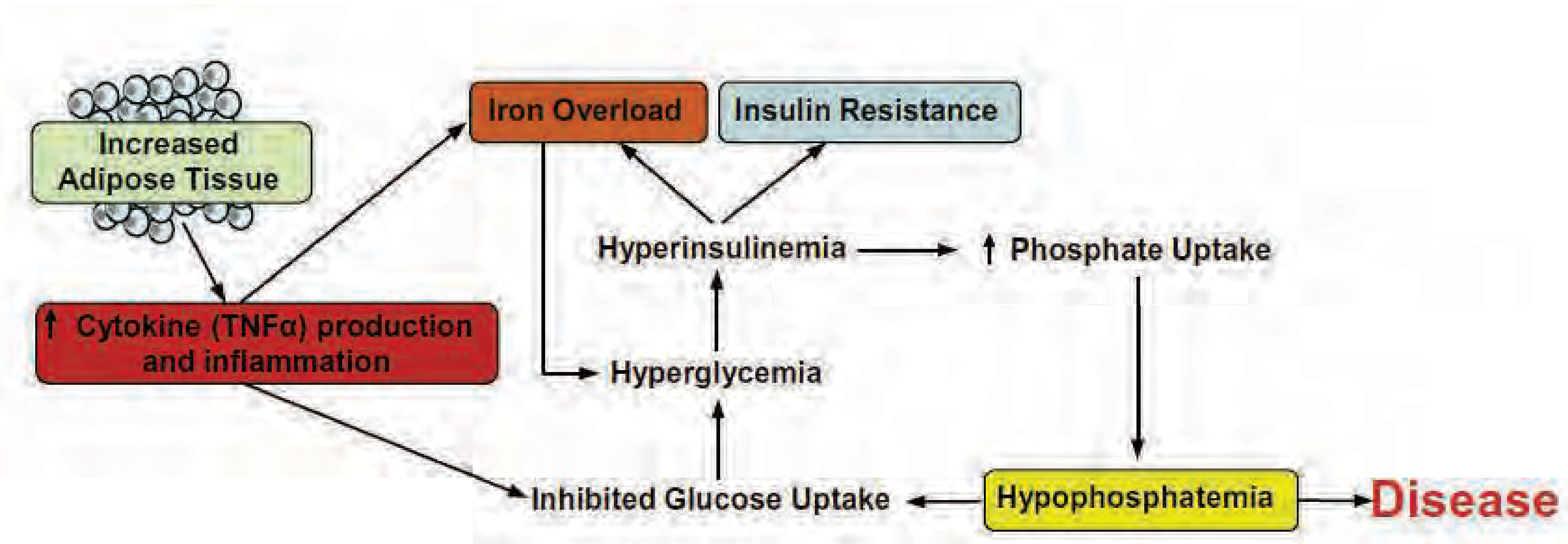


Monitoring body condition

Increased inflammation and decreased insulin sensitivity indicate metabolic disturbances in zoo-managed compared to free-ranging black rhinoceros (*Diceros bicornis*)

Mandi W. Schook[a,b,c,*], David E. Wildt[a], Mary Ann Raghanti[c,d], Barbara A. Wolfe[b,e,f], Patricia M. Dennis[c,f]

General and Comparative Endocrinology 217–218 (2015) 10–19



Monitoring body condition

from Collen et al. (2011)

from Taylor et al. (2013)

Ways to generate obesity

(too little exercise)

High-energy feeds

Birthday cakes

Birthday cakes

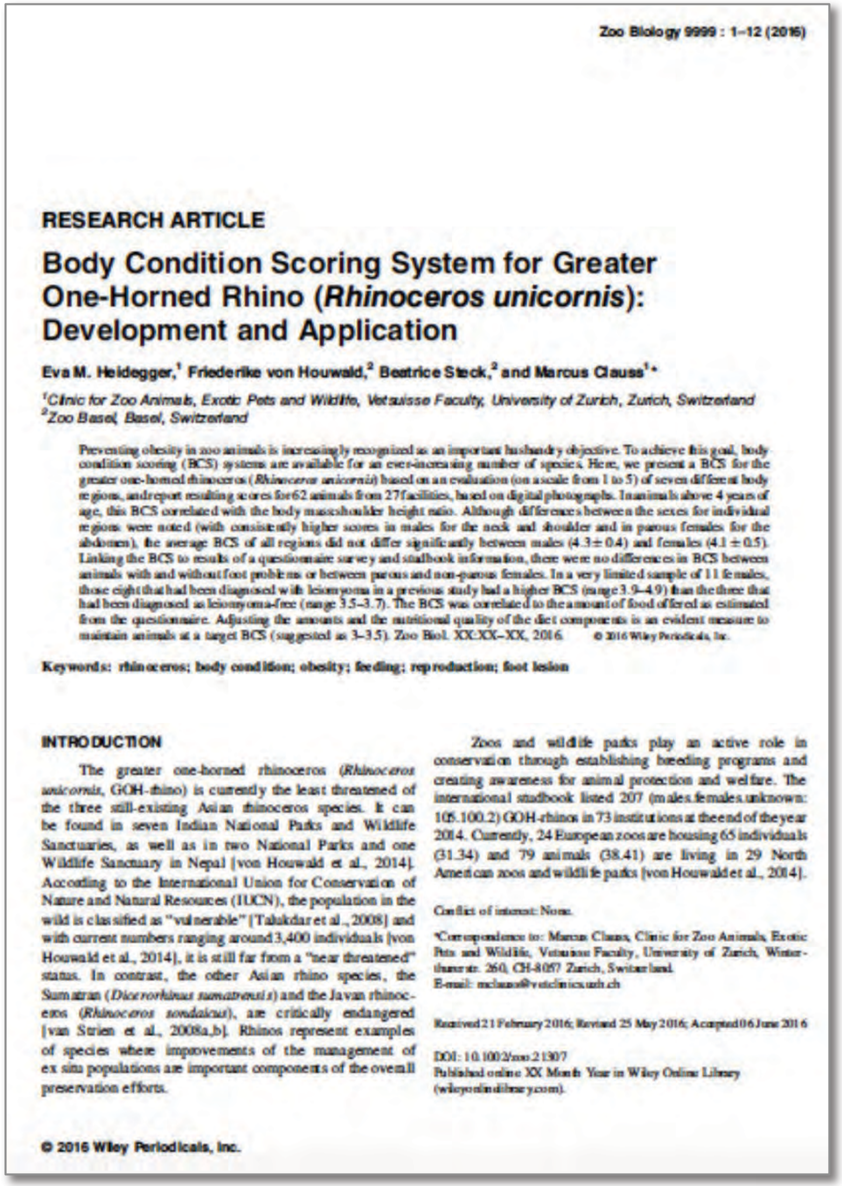
Ways to generate obesity

(too little exercise)

High-energy feeds

Too much of medium-energy feeds

Monitoring body condition



Zoo Biology 9999 : 1–12 (2016)

RESEARCH ARTICLE

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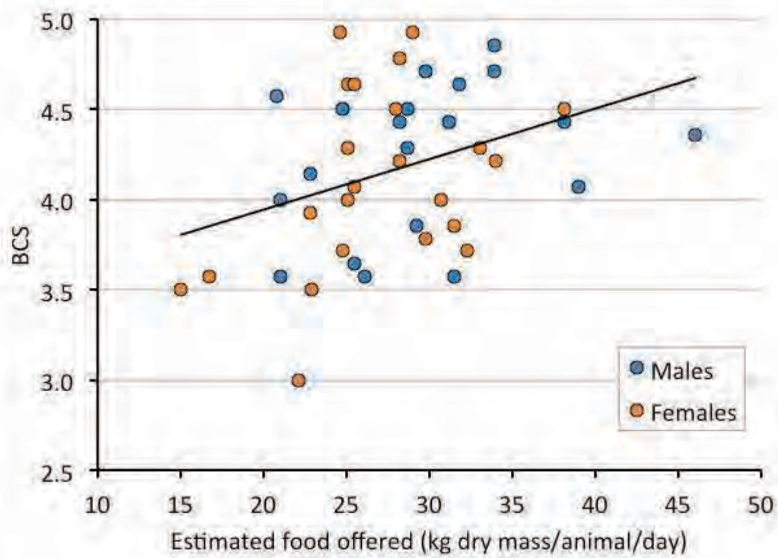

Ways to generate obesity

(too little exercise)

High-energy feeds

Too much of medium-energy feeds

Journal of Zoo and Wildlife Medicine 43(3): S108–S113, 2012

IOD IN RHINOS—NUTRITION GROUP REPORT: REPORT FROM THE NUTRITION WORKING GROUP OF THE INTERNATIONAL WORKSHOP ON IRON OVERLOAD DISORDER IN BROWSING RHINOCEROS (FEBRUARY 2011)

Marcus Clauss, Ph.D., D.V.M., Ellen Dierenfeld, Ph.D., M.S., Jesse Goff, D.V.M., Ph.D., Kirk Klasing, Ph.D., Liz Koutsos, Ph.D., M.S., Shana Lavin, Ph.D., M.S., Shannon Livingston, M.S., Brian Nielson, Ph.D., Michael Schlegel, Ph.D., P.A.S., Kathleen Sullivan, M.S., Eduardo Valdes, Ph.D., and Ann Ward, M.S.

Table 1. Sample diets for browser rhinos.[a]

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Ingredient					
Produce (%)	5.00	5.00	5.00	5.92	16.60
Herbivore pellet (%)[b]	20.00	20.00	20.00	20.14	10.00
Alfalfa hay (%)	35.00	30.00	30.00	0.00	0.00
Coastal hay (%)	40.00	25.00	10.00	0.00	0.00
Bermuda hay (%)	0.00	0.00	0.00	12.68	36.70
Timothy hay (%)	0.00	0.00	0.00	28.64	0.00
Sudangrass hay (%)	0.00	0.00	0.00	0.00	36.70
Browse (%)[c]	0.00	0.00	0.00	32.61	0.00
Triple Crown Safe Starch (%)[d]	0.00	20.00	35.00	0.00	0.00
Total (%)	100.00	100.00	100.00	100.00	100.00
Nutrient (dry matter basis)					
Crude protein (%)	17.88	17.06	16.66	12.18	12.03
Acid Detergent Fiber, ADF (%)	28.85	28.63	28.32	33.97	32.54
Neutral Detergent Fiber, NDF (%)	49.25	46.49	43.03	55.75	58.72
Starch (%)	nr	nr	nr	2.87	nr
Ethanol-soluble carbohydrates (%)	nr	nr	nr	2.41	nr
Water-soluble carbohydrates (%)	nr	nr	nr	3.06	nr
Crude fat (%)	2.61	3.34	3.92	2.58	2.14
Iron (ppm)	300	302	310	207	237
Calcium (%)	1.07	1.11	1.18	0.75	0.58
Phosphorus (%)	0.32	0.34	0.36	0.32	0.29
Magnesium (%)	0.29	0.34	0.38	0.23	0.29
Potassium (%)	1.89	1.99	2.14	1.49	2.00
Sodium (%)	0.26	0.33	0.40	0.22	0.21
Iron (ppm)	300	302	310	135	237
Zinc (ppm)	53	72	87	89	69
Copper (ppm)	15	19	23	15	17
Manganese (ppm)	64	74	80	81	67
Selenium (ppm)	0.21	0.21	0.21	0.17	0.27
Vitamin A (IU/kg)	4,232	6,034	7,436	4,320	8,983
Vitamin D3 (IU/kg)	269	703	1040	280	481
Vitamin E (IU/kg)	90	139	177	240	113
Thiamin (ppm)	2.27	2.31	2.35	nr	9.50
Riboflavin (ppm)	3.41	3.48	3.54	nr	4.00
Pantothenic acid (ppm)	4.60	4.69	4.76	nr	10.00
Niacin (ppm)	9.25	9.44	9.59	nr	23.00
Choline (ppm)	273	279	283	nr	456
Biotin (ppm)	0.04	0.11	0.16	nr	0.04

[a] nr = Not reported.
[b] Herbivore pellet varies in iron (Fe) content: Diets 1–3 contain 345 ppm Fe dry matter basis (DMB); diet 4 = 106 ppm Fe DMB; diet 5 = 342 ppm DMB.
[c] See Table 2.
[d] Wayzata, Minnesota.

Table 2. Potential varieties of browse consumed by browser rhinos.

Scientific name	Common name	Iron (Fe; ppm dry matter basis [DMB])	Comments	Reference
Acacia spp.	Acacia	100		Graffam et al., 1997
Acacia adsurgens		49		Disney's Animal Kingdom (DAK), unpubl. data
Acacia auriculiformis	Ear-leafed acacia	41–86		DAK, unpubl. data
Acacia catechu	Mimosa catechu			
Acacia dealbata	Silver wattle	81		DAK, unpubl. data
Acacia farnesiana	Needlebush, huisache	126–553		Graffam et al., 1997, Ward et al., 2001, DAK, unpubl. data
Acacia holosericea	Soapbush wattle	44–137		DAK, unpubl. data
Acacia longifolia	Golden wattle	24–52		DAK, unpubl. data
Acacia podalyriifolia	Pearl acacia	59		DAK, unpubl. data
Acacia roemeriana	Catclaw acacia			Graffam et al., 1997
Acacia saligna	Blue-leaf wattle	27–76		DAK, unpubl. data
Acer negundo	Box elder	57–383		Nijboer and Dierenfeld, 1996, Fitzpatrick et al., 1998, Ward et al., 2001
Acer saccharinum	Silver maple	50–711	Fe depends on part	Nijboer and Dierenfeld, 1996, Fitzpatrick et al., 1998
Acer saccharum	Sugar maple	70–358	Fe depends on part	Nijboer and Dierenfeld, 1996, Fitzpatrick et al., 1998
Arundo spp.	Cane	43–92		DAK, unpubl. data
Baccharis halimifolia	Groundsel tree			
Bauhinia purpurea	Butterfly tree			
Bucida buceras	Black olive			
Celtis spp.	Hackberry	65–275	Fe depends on part	Nijboer and Dierenfeld, 1996, Fitzpatrick et al., 1998, Ward et al., 2001
Elaeocarpus spp.	Quandong	56–102	Winter only	DAK, unpubl. data
Elaeagnus spp.	Silverberry	71		DAK, unpubl. data
Elaeagnus angustifolia	Elliagnus	187		Ward et al., 2001
Elaeagnus pungens	Thorny olive	26–34		DAK, unpubl. data
Ficus spp.	Fig	64		DAK, unpubl. data
Ficus benjamina	Ficus	37–87		DAK, unpubl. data
Helianthus annuus	Sunflower	44–46		DAK, unpubl. data
Hevea brasiliensis	Rubber tree	35–41		DAK, unpubl. data
Hibiscus acetosella	Hibiscus	12–53		DAK, unpubl. data
Hibiscus rosa-sinensis	Hibiscus			
Hibiscus sabdariffa	Hibiscus	12–41		DAK, unpubl. data
Ipomoea batatas	Sweet potato	17–51		DAK, unpubl. data
Laurus nobilis	Bay laurel, sweet bay			
Ligustrum japonicum, *L. vulgare*	Japanese privet	114		Ward et al., 2001
Liquidambar styraciflua	Sweetgum	55–269	Fe depends on part	Nijboer and Dierenfeld, 1996, Fitzpatrick et al., 1998, DAK, unpubl. data
Liriodendron tulipifera	Tulip tree			
Lonicera spp.	Honeysuckle			
Manihot esculenta	Cassava	194		DAK, unpubl. data
Malus spp.	Crabapple			
Morus spp.	Mulberry	52–256	Fe depends on part	Nijboer and Dierenfeld, 1996, Fitzpatrick et al., 1998, Ward et al., 2001
Morus alba	White mulberry	123		DAK, unpubl. data
Musa acuminata	Banana	110	Spring and summer	DAK, unpubl. data

Zoo diets of rhinoceros

100% browse

100% grass

2010 Workshop IOD in browsing rhinos

Journal of Zoo and Wildlife Medicine 43(3): S92–S104, 2012

REVIEW OF LABORATORY AND NECROPSY EVIDENCE FOR IRON STORAGE DISEASE ACQUIRED BY BROWSER RHINOCEROSES

Donald E. Paglia, M.D., and I-Hsien Tsu, M.S.

Abstract: Necropsies of two browser rhinoceroses, African black (*Diceros bicornis*) and Sumatran (*Dicerorhinus sumatrensis*), often reveal extensive iron-pigment deposition in various tissues. This condition (hemosiderosis) has not been observed in species that are natural grazers, African white (*Ceratotherium simum*) and Asian greater one-horned (Indian; *Rhinoceros unicornis*), nor in any species free ranging in the wild. The causes, clinical significance, and consequences of captivity-acquired hemosiderosis have remained controversial despite two decades of compelling evidence that iron tends to accumulate logarithmically in *all* members of affected species in proportion to periods of expatriation; total-body iron loads can reach 10-fold in less than 3 yr and eventually exceed reference ranges by two to three orders of magnitude; iron overburdens are accompanied by laboratory and histopathologic evidence of cellular injury, necrosis and other clinical consequences characteristic of chronic pathologic iron storage disorders (ISD) in humans and other species (hemochromatosis); and that ISD develops in many other exotic wildlife species displaced from their natural habitats. The historical evolution of evidence establishing the development of pathologic ISD in browser (but not in grazer) rhinoceroses and the possible relevance of ISD to other conditions affecting these two species will be reviewed. Evidence reviewed includes new as well as published data derived from quantitative measurements of iron analytes in sera and necropsy tissues and histopathologic evaluations of current and past necropsies of captive and free-ranging rhinoceroses of all four available species. The evolutionary, husbandry, and conservation implications of ISD in rhinoceroses are relevant to understanding ISD acquired by many other species of exotic wildlife when displaced from their natural environments.

Key words: Ferritin, hemochromatosis, hemosiderosis, iron, rhinoceros species.

INTRODUCTION

Progressive loss of wilderness by human intrusion has forced numerous wildlife species to the brink of extinction and beyond. Some have been further decimated by avaricious poaching for the perceived medicinal, cultural (and actual black-market) value of their various body parts. In response to these threats, concerned conservationists have translocated animals from the wild into various sanctuaries for protection, for captive breeding programs, and for potential reintroduction into their original habitats. This has allowed closer scrutiny of otherwise reclusive animals, revealing disorders that have rarely, if ever, been observed in the wild.

Over the past several decades, four of the five extant species of rhinoceroses have been well studied in captivity, and each appears to be susceptible to characteristic sets of clinical conditions. African black rhinoceroses (*Diceros bicornis*) in particular have been affected by a number of disorders of high morbidity and mortality.[11,20,29] Episodes of acute intravascular hemolysis and chronic necrolytic dermatopathy (mucocutaneous ulcerative disease) became recognized as the two most common causes of death.[16,17,18] Additional conditions included high susceptibilities to common and exotic microorganisms, such as *Aspergillus*, *Leptospira*, *Mycobacteria*, and *Salmonella*; scattered cases of leukoencephalomalacia, an apparently congenital, central nervous system (CNS) degenerative disorder; primary idiopathic or toxic hepatopathies; idiopathic hemorrhagic vasculopathy, possibly an autoimmune disorder targeting microvasculature; nonhemolytic anemia, sometimes with cachexia, resembling the anemia of chronic or inflammatory disease; stress-related sudden death, and generalized hemosiderosis. Virtually none of these conditions has been observed in African white (*Ceratotherium simum*), Asian greater one-horned (Indian; *Rhinoceros unicornis*), or Sumatran (*Dicerorhinus sumatrensis*) rhinoceroses, with the pertinent and important exception of extensive hemosiderosis and susceptibility to infections in the latter.

The prevalence of so many severe and clinically disparate disorders in any individual species suggested that some might share common etiologic or pathogenetic factors.[47] That possibility

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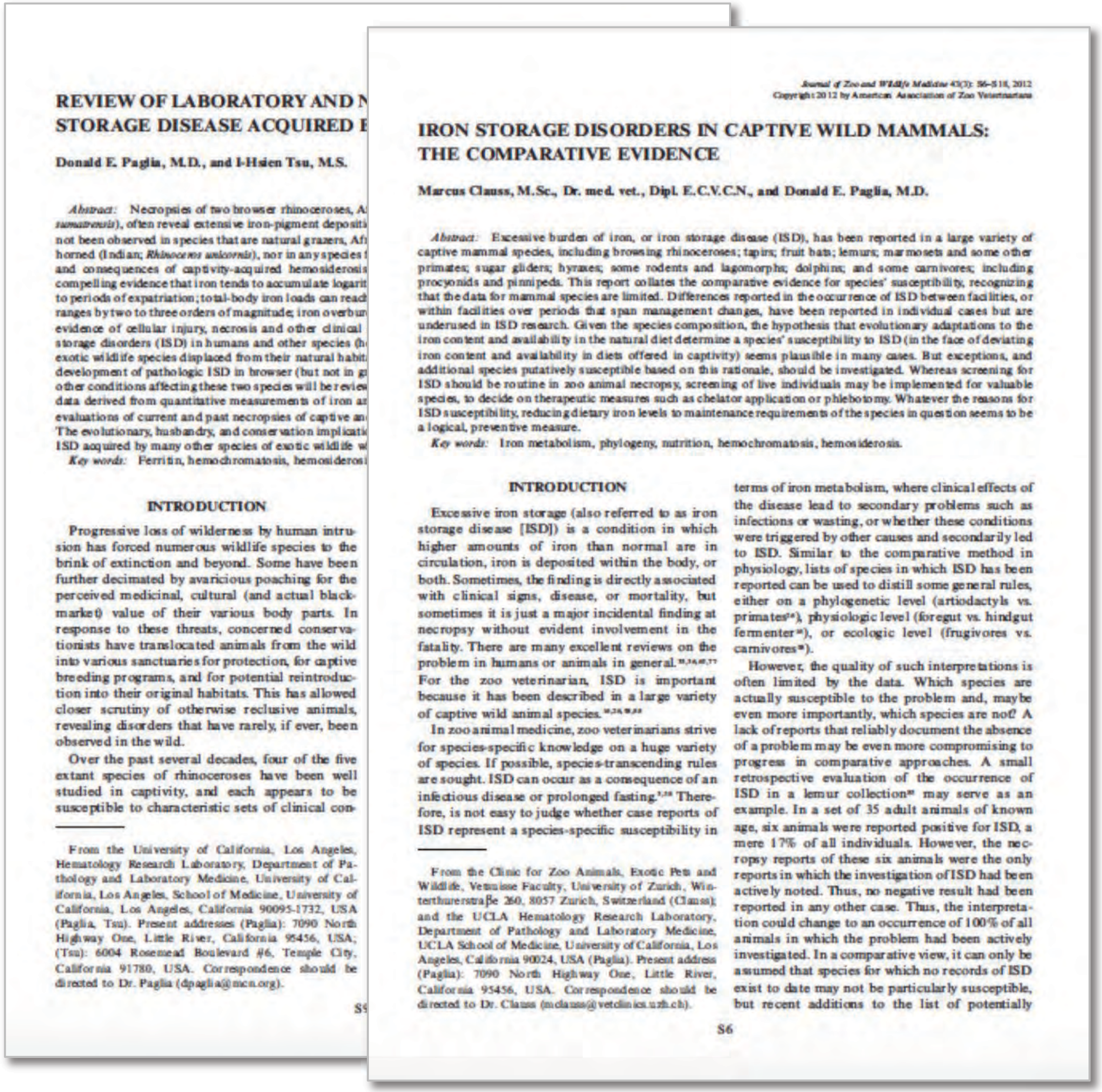
2010 Workshop IOD in browsing rhinos



REVIEW OF LABORATORY AND N
STORAGE DISEASE ACQUIRED I

Donald E. Paglia, M.D., and I-Hsien Tsu, M.S.

Abstract: Necropsies of two browser rhinoceroses, A
sumatrensis), often reveal extensive iron-pigment depositi
not been observed in species that are natural grazers, Afr
horned (Indian; *Rhinoceros unicornis*), nor in any species f
and consequences of captivity-acquired hemosiderosis
compelling evidence that iron tends to accumulate logarit
to periods of expatriation; total-body iron loads can reach
ranges by two to three orders of magnitude; iron overbur
evidence of cellular injury, necrosis and other clinical
storage disorders (ISD) in humans and other species (h
exotic wildlife species displaced from their natural habit
development of pathologic ISD in browser (but not in g
other conditions affecting these two species will be review
data derived from quantitative measurements of iron ar
evaluations of current and past necropsies of captive an
The evolutionary, husbandry, and conservation implicati
ISD acquired by many other species of exotic wildlife w
Key words: Ferritin, hemochromatosis, hemosideros

INTRODUCTION

Progressive loss of wilderness by human intrusion has forced numerous wildlife species to the brink of extinction and beyond. Some have been further decimated by avaricious poaching for the perceived medicinal, cultural (and actual black-market) value of their various body parts. In response to these threats, concerned conservationists have translocated animals from the wild into various sanctuaries for protection, for captive breeding programs, and for potential reintroduction into their original habitats. This has allowed closer scrutiny of otherwise reclusive animals, revealing disorders that have rarely, if ever, been observed in the wild.

Over the past several decades, four of the five extant species of rhinoceroses have been well studied in captivity, and each appears to be susceptible to characteristic sets of clinical con-

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Journal of Zoo and Wildlife Medicine 43(3): S6–S18, 2012

IRON STORAGE DISORDERS IN CAPTIVE WILD MAMMALS: THE COMPARATIVE EVIDENCE

Marcus Clauss, M.Sc., Dr. med. vet., Dipl. E.C.V.C.N., and Donald E. Paglia, M.D.

Abstract: Excessive burden of iron, or iron storage disease (ISD), has been reported in a large variety of captive mammal species, including browsing rhinoceroses; tapirs; fruit bats; lemurs; marmosets and some other primates; sugar gliders; hyraxes; some rodents and lagomorphs; dolphins; and some carnivores; including procyonids and pinnipeds. This report collates the comparative evidence for species' susceptibility, recognizing that the data for mammal species are limited. Differences reported in the occurrence of ISD between facilities, or within facilities over periods that span management changes, have been reported in individual cases but are underused in ISD research. Given the species composition, the hypothesis that evolutionary adaptations to the iron content and availability in the natural diet determine a species' susceptibility to ISD (in the face of deviating iron content and availability in diets offered in captivity) seems plausible in many cases. But exceptions, and additional species putatively susceptible based on this rationale, should be investigated. Whereas screening for ISD should be routine in zoo animal necropsy, screening of live individuals may be implemented for valuable species, to decide on therapeutic measures such as chelator application or phlebotomy. Whatever the reasons for ISD susceptibility, reducing dietary iron levels to maintenance requirements of the species in question seems to be a logical, preventive measure.
Key words: Iron metabolism, phylogeny, nutrition, hemochromatosis, hemosiderosis.

INTRODUCTION

Excessive iron storage (also referred to as iron storage disease [ISD]) is a condition in which higher amounts of iron than normal are in circulation, iron is deposited within the body, or both. Sometimes, the finding is directly associated with clinical signs, disease, or mortality, but sometimes it is just a major incidental finding at necropsy without evident involvement in the fatality. There are many excellent reviews on the problem in humans or animals in general.[11,16,65,77] For the zoo veterinarian, ISD is important because it has been described in a large variety of captive wild animal species.[19,28,38,48]

In zoo animal medicine, zoo veterinarians strive for species-specific knowledge on a huge variety of species. If possible, species-transcending rules are sought. ISD can occur as a consequence of an infectious disease or prolonged fasting.[7,18] Therefore, is not easy to judge whether case reports of ISD represent a species-specific susceptibility in terms of iron metabolism, where clinical effects of the disease lead to secondary problems such as infections or wasting, or whether these conditions were triggered by other causes and secondarily led to ISD. Similar to the comparative method in physiology, lists of species in which ISD has been reported can be used to distill some general rules, either on a phylogenetic level (artiodactyls vs. primates[14]), physiologic level (foregut vs. hindgut fermenter[30]), or ecologic level (frugivores vs. carnivores[8]).

However, the quality of such interpretations is often limited by the data. Which species are actually susceptible to the problem and, maybe even more importantly, which species are not? A lack of reports that reliably document the absence of a problem may be even more compromising to progress in comparative approaches. A small retrospective evaluation of the occurrence of ISD in a lemur collection[38] may serve as an example. In a set of 35 adult animals of known age, six animals were reported positive for ISD, a mere 17% of all individuals. However, the necropsy reports of these six animals were the only reports in which the investigation of ISD had been actively noted. Thus, no negative result had been reported in any other case. Thus, the interpretation could change to an occurrence of 100% of all animals in which the problem had been actively investigated. In a comparative view, it can only be assumed that species for which no records of ISD exist to date may not be particularly susceptible, but recent additions to the list of potentially

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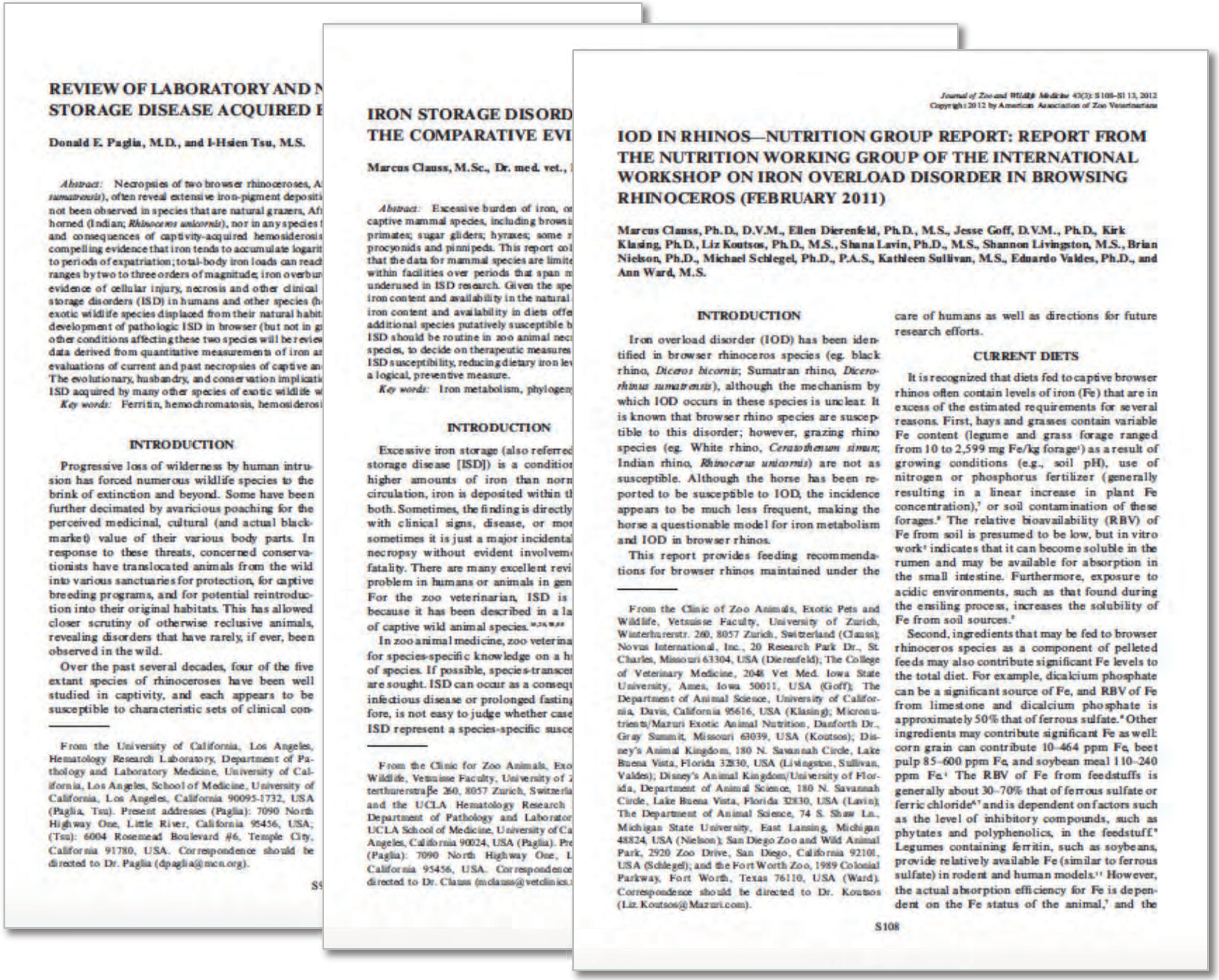

REVIEW OF LABORATORY AND N…
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THE COMPARATIVE EVI…

Marcus Clauss, M.Sc., Dr. med. vet., …

Journal of Zoo and Wildlife Medicine 43(3): S108–S113, 2012
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IOD IN RHINOS—NUTRITION GROUP REPORT: REPORT FROM THE NUTRITION WORKING GROUP OF THE INTERNATIONAL WORKSHOP ON IRON OVERLOAD DISORDER IN BROWSING RHINOCEROS (FEBRUARY 2011)

Marcus Clauss, Ph.D., D.V.M., Ellen Dierenfeld, Ph.D., M.S., Jesse Goff, D.V.M., Ph.D., Kirk Klasing, Ph.D., Liz Koutsos, Ph.D., M.S., Shana Lavin, Ph.D., M.S., Shannon Livingston, M.S., Brian Nielson, Ph.D., Michael Schlegel, Ph.D., P.A.S., Kathleen Sullivan, M.S., Eduardo Valdes, Ph.D., and Ann Ward, M.S.

INTRODUCTION

Iron overload disorder (IOD) has been identified in browser rhinoceros species (eg. black rhino, *Diceros bicornis*; Sumatran rhino, *Dicerorhinus sumatrensis*), although the mechanism by which IOD occurs in these species is unclear. It is known that browser rhino species are susceptible to this disorder; however, grazing rhino species (eg. White rhino, *Ceratotherium simum*; Indian rhino, *Rhinocerus unicornis*) are not as susceptible. Although the horse has been reported to be susceptible to IOD, the incidence appears to be much less frequent, making the horse a questionable model for iron metabolism and IOD in browser rhinos.

This report provides feeding recommendations for browser rhinos maintained under the care of humans as well as directions for future research efforts.

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CURRENT DIETS

It is recognized that diets fed to captive browser rhinos often contain levels of iron (Fe) that are in excess of the estimated requirements for several reasons. First, hays and grasses contain variable Fe content (legume and grass forage ranged from 10 to 2,599 mg Fe/kg forage[1]) as a result of growing conditions (e.g., soil pH), use of nitrogen or phosphorus fertilizer (generally resulting in a linear increase in plant Fe concentration),[7] or soil contamination of these forages.[3] The relative bioavailability (RBV) of Fe from soil is presumed to be low, but in vitro work[3] indicates that it can become soluble in the rumen and may be available for absorption in the small intestine. Furthermore, exposure to acidic environments, such as that found during the ensiling process, increases the solubility of Fe from soil sources.[3]

Second, ingredients that may be fed to browser rhinoceros species as a component of pelleted feeds may also contribute significant Fe levels to the total diet. For example, dicalcium phosphate can be a significant source of Fe, and RBV of Fe from limestone and dicalcium phosphate is approximately 50% that of ferrous sulfate.[4] Other ingredients may contribute significant Fe as well: corn grain can contribute 10–464 ppm Fe, beet pulp 85–600 ppm Fe, and soybean meal 110–240 ppm Fe.[1] The RBV of Fe from feedstuffs is generally about 30–70% that of ferrous sulfate or ferric chloride[6,7] and is dependent on factors such as the level of inhibitory compounds, such as phytates and polyphenolics, in the feedstuff.[9] Legumes containing ferritin, such as soybeans, provide relatively available Fe (similar to ferrous sulfate) in rodent and human models.[11] However, the actual absorption efficiency for Fe is dependent on the Fe status of the animal,[7] and the

S108

2010 Workshop IOD in browsing rhinos

REVIEW OF LABORATORY AND N…
STORAGE DISEASE ACQUIRED I…

Donald E. Paglia, M.D., and I-Hsien Tsu, M.S.

IRON STORAGE DISORD…
THE COMPARATIVE EVI…

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IOD IN RHINOS—NUTRITIO…
THE NUTRITION WORKING…
WORKSHOP ON IRON OVEI…
RHINOCEROS (FEBRUARY 2…

Journal of Zoo and Wildlife Medicine 43(3): S83–S91, 2012

MANAGEMENT STRATEGIES OF IRON ACCUMULATION IN A CAPTIVE POPULATION OF BLACK RHINOCEROSES (*DICEROS BICORNIS MINOR*)

Natalie D. Mylniczenko, M.S., D.V.M., Dipl. A.C.Z.M., Kathleen E. Sullivan, M.S., Michelle E. Corcoran, Gregory J. Fleming, D.V.M., Dipl A.C.Z.M., and Eduardo V. Valdes, Ing. Agr., M.Sc., Ph.D.

Abstract: During routine health screens for black rhinoceroses (*Diceros bicornis minor*) in a captive setting, serum iron and ferritin were analyzed as well as total iron binding capacity and total iron saturation. Trends for ferritin and percent iron saturation showed steady increases since 2003 in four of four animals (three males; one female) with two animals (one male; one female) consistently showing higher elevations over conspecifics. The historical diet had been comprised of a commercial or in-house complete pelleted feed; several species of fresh browse, Bermuda grass, alfalfa and timothy hays, as well as enrichment and training items (apples, carrots, sweet potatoes, and a small amount of leafy greens and vegetables). In 2009, one of the three male rhinoceroses showed a threefold increase in ferritin and concurrently exhibited clinical signs of lethargy, decreased appetite, and disinterest in training. The lone female showed a twofold increase; she also became reproductively acyclic in the prior year. The male was immobilized for examination and phlebotomy. During the same time period, a new version of the complete pelleted feed, with a reduced amount of iron, was introduced. Subsequent to the diet change, the male's ferritin levels have consistently declined, and the female started cycling again. Even with these corrective steps to reduce iron levels, levels of iron saturation remained high, and ferritin levels were still above 1,500 ng/ml. Therapeutic phlebotomy was instituted via a rigorous training program that allowed phlebotomies over a 30-min time frame. This was possible because of a long-term training program for the animals, consistent training personnel, routine collection of samples on a monthly basis, and general comfort level of the animals in the restraint chute. The results of this integrated approach showed some significant improvements and an overall positive impact on the animals.

Key words: Black rhinoceros, iron storage disorder, hemosiderosis, *Diceros bicornis minor*, nutrition, therapeutic phlebotomy.

INTRODUCTION

Iron accumulation (overload) in captive black rhinoceroses (*Diceros bicornis minor*) has been a consistent finding in both serologic and pathologic evaluation.[3,11,13,21] The clinical relevance of these findings has been a topic of much discussion as death has largely been due to other causes (Miller, Black Rhinoceros Species Survival Plan, pers. comm.). Additionally, for rhinoceros, hemochromatosis has not typically been the final diagnosis but rather hemosiderosis. Regardless, it is widely accepted in the veterinary community that it is still a significant disease issue of captive rhinoceroses. Accumulation of excess iron has been linked to many of the classic rhinoceros diseases, including hemolytic anemia, mucocutaneous ulcer disorder, and leukoencephalomalacia;[17,18] as well as a few lesser-known cases such as cardiotoxicity to doxorubricin.[20] It is also known that captive black rhinoceroses, including semicaptive black rhinoceroses in Africa, have excessive amounts of iron and iron metabolites, more than that of their free-ranging counterparts.[9] Etiology of iron overload in captive black rhinoceroses continues to remain a point of debate.

CASE REPORTS

In a collection of four captive-born black rhinoceroses (three males, one female), voluntary biannual blood collection was performed for routine health assessment. Starting in 2002, iron panels consisting of ferritin, serum iron, total iron binding capacity (TIBC), haptoglobin, ceruloplasmin, and transferrin saturation (serum iron divided by TIBC) were submitted biannually on all animals (Kansas State University Diagnostic Laboratory, Manhattan, Kansas 66506, USA). All the animals, classified as male 1 (11 yr old), male 2 (10 yr old), male 3 (15 yr old), and female (17 yr old), were observed to have elevated serum

From the Department of Animal Health, Disney's Animals, Science and the Environment, Bay Lake, Florida 32830, USA (Mylniczenko, Sullivan, Corcoran, Fleming, Valdes); the Department of Animal Sciences, University of Florida, Gainesville, Florida 32611, USA (Valdes); the University of Guelph, Ontario, N1G2W1 Canada; and University of Central Florida, Orlando, Florida 32826, USA (Valdes). Correspondence should be directed to Dr. Mylniczenko (Natalie.Mylniczenko@Disney.com).

Exasperation

Journal of Zoo and Wildlife Medicine 43(3): S92–S104, 2012

REVIEW OF LABORATORY AND NECROPSY EVIDENCE FOR IRON STORAGE DISEASE ACQUIRED BY BROWSER RHINOCEROSES

Donald E. Paglia, M.D., and I-Hsien Tsu, M.S.

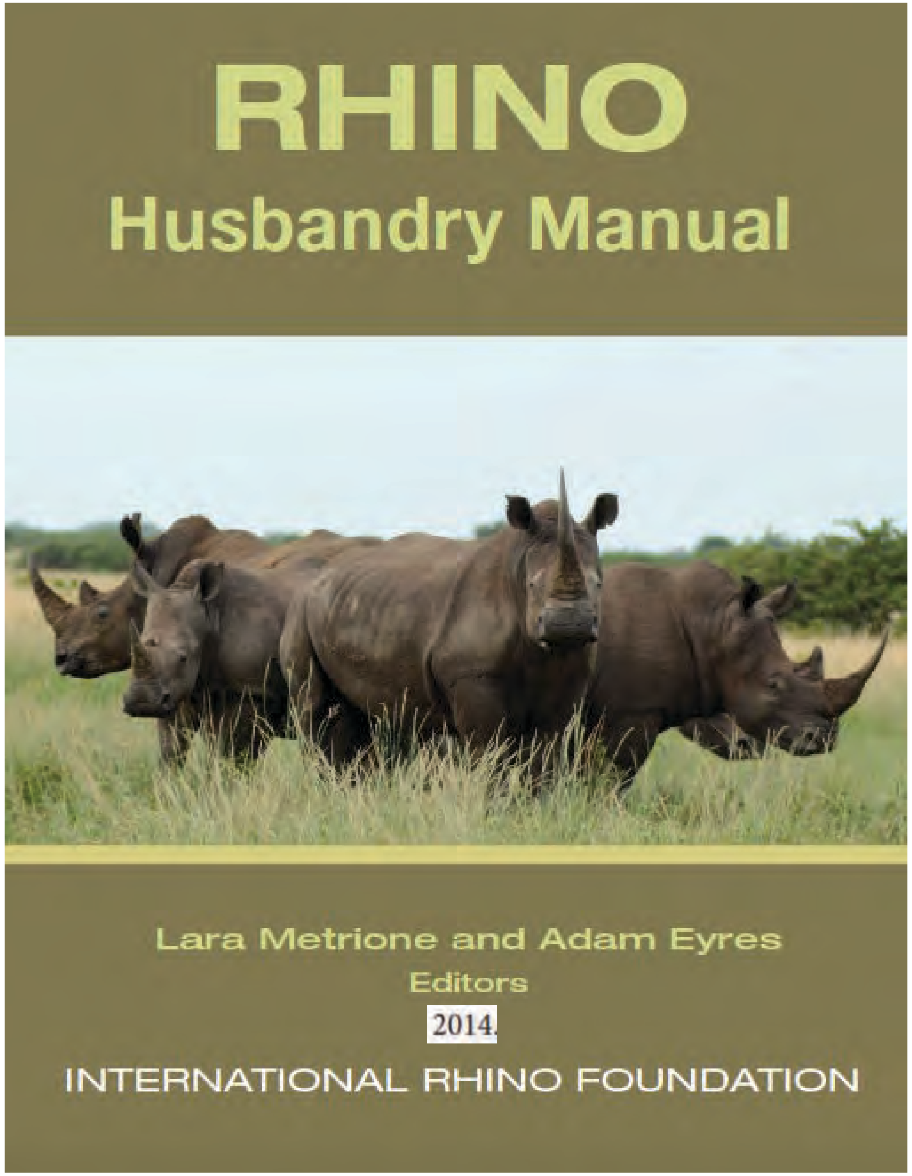
Perhaps such inertia is merely an example of Max Planck's observation that "*A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather its opponents eventually die, and a new generation grows up that is familiar with it.*"[85]

Policy

Hemosiderosis/Hemochromatosis (Iron Overload Syndrome)

Serum iron and ferritin levels in captive black rhinoceros are significantly higher than those measured in wild or recently captured animals (Miller et al., 2012). Levels appear to increase with time in captivity. In contrast, values for ferritin and tissue iron do not appear to be elevated in captive white or greater Asian one-horned rhinos (Smith et al., 1995; Paglia et al., 2001). Although hemolytic anemia, vitamin E deficiency, and hereditary disorders have all been proposed as potential causes, it is now believed to be related to dietary factors in the captive browser species. Hemosiderosis (tissue iron accumulation) is a common finding in multiple organs in black rhinoceros, although inflammation and lesions associated with these changes may also be observed (hemochromatosis). It has been suggested that high iron load may play a role in some of the black rhino disease syndromes, although evidence is limited. A fatality in a captive Sumatran rhino was associated with multi-organ hemochromatosis. Recommendations to minimize accumulation and reduce iron load include low iron diets, provision of browse, therapeutic phlebotomy (regular large-volume blood collection) and treatment with iron chelating agents in those individuals with suspected clinical disease. Recent success with large-volume phlebotomy and low iron diets have shown promising results in lowering elevated ferritin levels in captive black rhinos (Mylniczenko et al., 2012). Captive browsing rhinoceroses may be best managed in native habitat that can offer appropriate nutrition; for instance, Sumatran rhinos appear to have fewer problems with iron overload syndrome when managed in captive situations in range countries (D. Candra, pers. comm.).

Policy

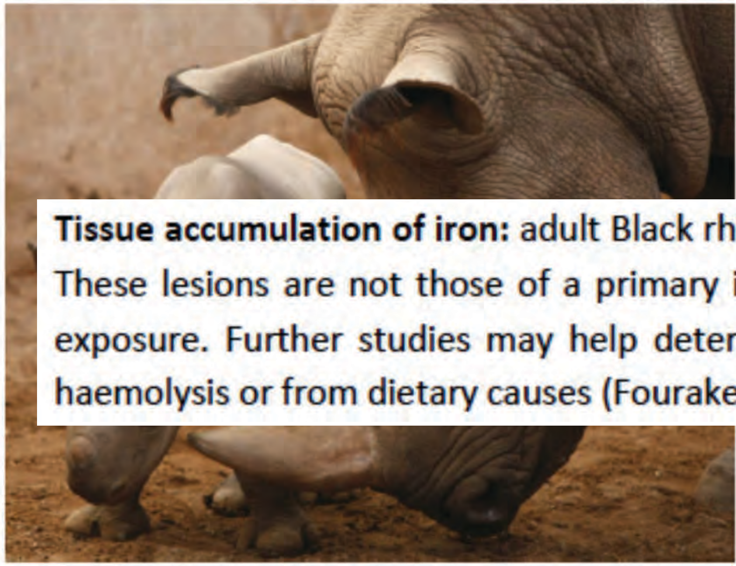


3 of the ISD 2010 workshop references (published 2012) included

Policy

EAZA Best Practice Guidelines

Black rhinoceros (*Diceros bicornis*)



Picture: Black rhino at Chester Zoo

Tissue accumulation of iron: adult Black rhinos appear to accumulate iron, particularly in their livers. These lesions are not those of a primary iron-storage disease, but similar to those of chronic iron exposure. Further studies may help determine whether the iron results from chronic sub clinical haemolysis or from dietary causes (Fouraker and Wagener, 1996).

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Name of TAG: Rhinoceros TAG

TAG Chair: Dr. Friederike von Houwald

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EAZA

CHESTER ZOO

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none of the ISD 2010 workshop references (published 2012) included!

Edwards, K. L., 2013. Investigating population performance and factors that influence reproductive success in the eastern black rhinoceros (*Diceros bicornis michaeli*). Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy.

Policy

Could ISD be mainly a North American problem?

Policy

Journal of Zoo and Wildlife Medicine 43(3): S6–S18, 2012

IRON STORAGE DISORDERS IN CAPTIVE WILD MAMMALS: THE COMPARATIVE EVIDENCE

Marcus Clauss, M.Sc., Dr. med. vet., Dipl. E.C.V.C.N., and Donald E. Paglia, M.D.

Table 1. Reports of excessive iron storage in nondomestic perissodactyls (tapirs and rhinos).

Species	Individual case[a,b]	Case series[a,b]	Epidemiologic survey[a,b]	Age dep.[a,b]	Comparison free-range[a,b]
Tapirs					
Malayan tapir (*Tapirus indicus*)		(+) histo[2]	(+) blood[73]	(+) blood[73]	
Mountain tapir (*Tapirus pinchaque*)			(+) blood[73]	(+) blood[73]	
Baird's tapir (*Tapirus bairdii*)		(+) histo[2]	(+) blood[73]	(+) blood[73]	(+) blood[45,73]
Brazilian tapir (*Tapirus terrestris*)	(+) histo[2,53]	(+) histo, blood[76]			
Rhinos					
Sumatran rhinoceros (*Dicerorhinus sumatrensis*)		(+) histo[58]	(+) blood, tissue[22,71]		
Asian one-horned rhinoceros (*Rhinoceros unicornis*)			(–) blood, tissue[22,71]		
White rhinoceros (*Ceratotherium simum*)			(–) blood, tissue[22,71,88]	(–) tissue[88]	(–) blood[22]
Black rhinoceros (*Diceros bicornis*)	(+) blood[43]	(+) histo[80]	(+) histo, tissue, blood[22,71,72,88]	(+) blood, tissue[22,88]	(+) histo, blood, tissue[22,56,64,71,72]

[a] (+), positive for excessive iron storage; (–), negative for excessive iron storage.
[b] histo, diagnosed by histology; blood, diagnosed by blood parameters; tissue, diagnosed by liver tissue iron content; age dep., age dependence.

Black rhino ISD in Europe

Journal of Zoo and Wildlife Medicine 23(2): 230–234, 1992

HEMOSIDEROSIS IN THE BLACK RHINOCEROS (*DICEROS BICORNIS*): A COMPARISON OF FREE-RANGING AND RECENTLY CAPTURED WITH TRANSLOCATED AND CAPTIVE ANIMALS

Nancy Kock, D.V.M., M.S., Chris Foggin, B.V.Sc., Ph.D., Michael D. Kock, B.Vet.Med., M.P.V.M., and Richard Kock, M.A., Vet.M.B.

Formalin-fixed and paraffin-embedded tissues from three captive black rhinoceroses from Whipsnade Zoological Gardens, U.K.,

ID no.	Category[a]	Age	Sex[b]	Time[c]	Hemosiderosis: Spleen	Hemosiderosis: Other tissues[d]
26	C	3 yr	F	3 yr[i]	+	L, Ly, I
27	C	6 yr	M	6 yr[i]	+	L, I
28	C	8 yr	M	8 yr[i]	+	L, Lu, K, I, A

Black rhino ISD in Europe

High serum concentrations of iron, transferrin saturation and gamma glutamyl transferase in captive black rhinoceroses (*Diceros bicornis*)

F. M. Molenaar, A. W. Sainsbury, M. Waters, R. Amin

Veterinary Record (2008) 162, 716-721

Serum samples were obtained from 17 captive animals. Nine of them had been captive-bred in European zoos, six were originally wild-caught in Africa but had lived at Port Lympne Wild Animal Park for over 25 years, and two were of unknown origin.

TABLE 1: Reference ranges for serum biochemistry derived from 27 free-ranging eastern black rhinoceroses (*Diceros bicornis michaeli*) calculated as the median (95 per cent confidence interval [CI] of the median) except where otherwise indicated

Parameter	Median	95% CI
Transferrin saturation (%)	42·6*	9·6†-75·6

TABLE 2: Reference ranges for serum biochemistry derived from 17 captive eastern black rhinoceroses (*Diceros bicornis michaeli*), calculated as the median (95 per cent confidence interval [CI] of the median) except where otherwise indicated

Measurement	Median	95% CI
Transferrin saturation (%)‡§	70·5	55·9-77·5

Black rhino ISD in Europe

HAEMOCHROMATOSIS IN THE BLACK RHINOCEROS (*DICEROS BICORNIS MICHAELI*): AQUIRED OR CONGENITAL?

M. Ruetten[*], H.W. Steinmetz[†], M. Clauss[†] and A. Pospischil[*]

ESVP/ECVP Proceedings 2009

Materials and Methods: Four African black rhinos aged 23 – 39 years from the Zürich Zoo were subject to necropsy examination

Conclusions: The distribution of histological lesions together with the clinical data suggests an enteric origin of excess iron, rather than recurring haemolytic anaemia or hereditary haemochromatosis.

Black rhino ISD in Europe

Iron Overload Syndrome in the Black Rhinoceros (*Diceros bicornis*): Microscopical Lesions and Comparison with Other Rhinoceros Species

J. Comp. Path. 2012, Vol. 147, 542–549

P. Olias*, L. Mundhenk*, M. Bothe*, A. Ochs†, A. D. Gruber* and R. Klopfleisch*

All rhinoceroses from the Berlin Zoological Garden submitted for necropsy examination to the Department of Veterinary Pathology at the Freie Universität Berlin during the past 30 years were included in this study. These included five African black rhinoceroses (*D. bicornis*; animals 1–5)

Level of iron storage in affected organs

Number	*Small intestine*	*Liver*	*Pancreas*	*Lymph node*	*Spleen*	*Bone marrow*	*Heart*	*Lung*	*Kidney*	*Skin*	*Adrenal/thyroid*
1	+++	+++	++	+	+++	+	NT	+++	+	–	++
2	+	++	NT	+	++	NT	NT	–	–	NT	+
3	+++	+++	++	+	++	NT	NT	++	–	–	–
4	+++	++	–	–	+++	NT	+	+++	+	–	+
5	+++	++	–	+	++	+++	+	+++	–	–	++

Conclusion

Could ISD be mainly a North American problem?

No. There is no indication that the problem is limited to North American facilities.
Rather, evidence suggests that the problem occured in 3 different European countries.

To my knowledge, these were the only countries in which the problem was investigated.

There is no rational argument for the assumption that this is not a general problem.

Preventative measures exist

RECOMMENDED PHLEBOTOMY GUIDELINES FOR PREVENTION AND THERAPY OF CAPTIVITY-INDUCED IRON-STORAGE DISEASE IN RHINOCEROSES, TAPIRS AND OTHER EXOTIC WILDLIFE

Donald E. Paglia, MD

2004 PROCEEDINGS AAZV, AAWV, WDA JOINT CONFERENCE

Journal of Zoo and Wildlife Medicine 43(3): S83–S91, 2012

MANAGEMENT STRATEGIES OF IRON ACCUMULATION IN A CAPTIVE POPULATION OF BLACK RHINOCEROSES (*DICEROS BICORNIS MINOR*)

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photos courtesy Micki Corcoran DAK

... but consider:

... black rhinos in captivity are susceptible to a range of unusual health problems such as

- hemolytic anaemia
- rhabdomyelosis
- ulcerative skin disease
- hepatopathy
- hemosiderosis ('iron storage disease')
- decreased insulin sensitivity
- increased inflammation markers
- hypophosphataemia.

The only way reasonable progress will be made on these conditions is by access to blood samples of live animals.

Conclusion

... no matter what the reasons, evolutionary causes, mechanisms, genetics, nutritional contributing factors to iron storage disease or any other diseases in black rhino ...

How can a management system not aimed at facilitating regular blood sampling or phlebotomy via training be considered responsible?

Summary

- no grain/starch (based) products/pellets
- no fruit/ vegetables (but green leafy); browse 
- someone must be knowledgable in roughage quality (high hygienic/ low nutritional quality)
- add low-energy bulk via straw  or branches 
- choose pellets based on ingredients and fibre content
- keep animal in slim/moderate body condition (best by using BCS monitoring)

- choose pellets with low iron content
- have iron storage disease management concept
- ensure easy access to blood